

= Croton Dam ( Michigan ) =

Croton Dam ( or Croton Hydroelectric Plant ) is an earth @-@ filled embankment dam and powerplant complex on the Muskegon River in Croton Township , Newaygo County , Michigan . It was built in 1907 under the direction of William D. Fargo by the Grand Rapids - Muskegon Power Company , a predecessor of Consumers Energy . The 40 @-@ foot @-@ high ( 12 m ) dam impounds 7 @. @ 2 billion U.S. gallons ( 6 billion imp. gal / 27 billion L ) of water in its 1 @, @ 209 @-@ acre ( 489 ha ) reservoir and is capable of producing 8 @, @ 850 kilowatts at peak outflow . It was listed on the National Register of Historic Places in 1979 .

= = History = =

The history of the Croton dam is intertwined with the history of William A. Foote ( 1854 ? 1915 ) and James B. Foote ( 1867 @-@ 1924 ) , brothers from Adrian , Michigan , with a burgeoning electric power empire , along with William G. Fargo , a Jackson @-@ based civil engineer who designed similar hydroelectric plants throughout the Midwest .

William A. Foote was a 30 @-@ year @-@ old grist mill operator in Adrian , Michigan , in 1884 when , in what was then a common occurrence , he provided space and shaft power from his mill wheel to Thomson - Houston , a local electric utility startup , to light 12 streetlights . Fascinated by the potential , within a year he enlisted his then 17 @-@ year @-@ old brother James and moved to Jackson , Michigan , and in 1886 they jointly founded Jackson Electric Light Works ( a predecessor company to Consumers Energy ) , which began by lighting downtown Jackson electrically . The Foote brothers set up similar city specific companies in Battle Creek and Adrian within a few years . In many cases dams already built for grist mills , sawmills and the like were refit for electric generators , but in some cases , new dams were constructed . As the familiarity with the technology , and the technology itself , improved , the scope of projects became more ambitious .

= = = Predecessor projects = = =

The Foote brothers ' first projects in Jackson , Battle Creek and Adrian , like most pre @-@ 1900 electric power projects , were created for street lighting , with some limited residential and business lighting . Since transmission of electricity over long distances was not well understood , they were situated near the cities they served . But the demand for power was growing , driven by among other things , the advent of the streetcar and increased industrial use of electricity , outstripping the capacity of smaller rivers and existing dams . So larger rivers were sought . In 1898 the Foote brothers , working with engineering partner Fargo , constructed the Trowbridge Dam across the Kalamazoo River in order to supply the city of Kalamazoo . The dam was located near Allegan , about 25 miles ( 40 km ) away from the city , an unheard of distance at the time , and was the first major hydroelectric project in Western Michigan . Initially beset by power loss during transmission and other problems , the Trowbridge dam successfully provided power to a larger area than previous dams , after the Foote brothers advanced the state of the art in insulators and electric transmission equipment .

= = = Damming the Muskegon = = =

Grand Rapids was a large power market to which the Footes next turned their attention . Fargo advised the Foote brothers about possible hydropower locations on the Muskegon River , which has the second largest outflow of an inland ( non Great Lakes connecting ) river of Michigan after the Grand River ( which has a larger basin and the largest outflow of Michigan 's inland rivers ) . Unlike the Grand , the Muskegon is not navigable , so dams would not cause difficulty with river traffic . Through a subsidiary of their holding company , Commonwealth Power , the Grand Rapids ? Muskegon Power Company , in 1904 they commissioned the construction of Rogers Dam and Croton Dam on the Muskegon , as well as Webber Dam on the Grand River . Rogers , upstream of

the Croton , was finished first , in 1906 , but Croton , located where the Little Muskegon joins from the east , was a more ambitious project . One third of the village of Croton would be submerged by the impoundment lake as it began filling in August 1907 . William D. Fargo was dispatched to oversee construction and served as the Chief Engineer .

= = = Construction = = =

Fargo developed new methods for construction of earth embankment dams on foundations of soft soils , which made use of hydraulic sluicing . The dam was built during the summer , between 25 June and 3 September 1907 . The powerhouse and spillway sections of the dam were completed first , and used conventional contemporary engineering designs .

Fargo then built a pumping plant employing seven electric powered rotary pumps , to move river water up a 10 @-@ inch ( 250 mm ) pipeline to a bluff about 110 feet ( 34 m ) above the Muskegon River . A diameter reduction to 4 inches ( 100 mm ) increased the pressure to about 80 PSI , and the water was fed into nozzles via flexible rubber hoses . The high pressure streams of water carried away a soil water mix into iron troughs which routed the material about 800 feet ( 240 m ) at a slight downgrade back to the dam site . As the material was deposited it was layered , and the water allowed to drain off , compacting it . During this phase , the river was allowed to run through the powerhouse raceways and out the spillway .

The Croton Dam is one of the earliest examples of the use of this technique east of the Mississippi River . The chief advantage of the hydraulic sluicing method was its cost . The total cost of constructing the 370 @-@ foot @-@ long ( 110 m ) embankment , which contained 104 @,@ 000 cubic yards ( 80 @,@ 000 m<sup>3</sup> ) of material , was only \$ 7 @,@ 076 , or about 7 cents per cubic yard of material moved . Fargo also used this method to construct a fill of 20 @,@ 000 cubic yards ( 15 @,@ 000 m<sup>3</sup> ) for a highway bridge crossing the Muskegon River immediately downstream from the dam . The fill Fargo built for the highway bridge approach cost roughly the same .

The Croton powerhouse has two adjoining asymmetrically connected buildings : the generator building on the west and the turbine building to the east arranged in an L shape . About 3 @,@ 000 oak timber pilings support a concrete foundation , with the perimeter walls supported on sheet steel pilings , which also prevent water from undercutting the foundation . The two buildings are about 60 feet ( 18 m ) in height , with Warren trusses supporting the roofs , and extend about 150 by 80 feet ( 46 by 24 m ) .

Two reinforced concrete retaining walls extend 40 feet ( 12 m ) upstream from the northeast and northwest corners of the generator building , forming a triangle and serve as an anchor for a floating trash boom which keeps refuse out of the turbine pits . A similar triangle is formed by two reinforced concrete retaining walls extending 50 feet ( 15 m ) downriver from the south side of the generator building . A concrete retaining wall extends an additional 140 feet ( 43 m ) south from the tip of this triangle .

When the generator building first went into operation , it housed two Westinghouse horizontal generators originally rated at 6 @,@ 600 volts , operating at 225 rpm and producing 3 phase 60 cycle AC . They were driven by turbines . The voltage was stepped up to 100 @,@ 000 volts using three delta @-@ connected oil @-@ cooled transformers of 3 @,@ 000 kilowatt capacity . These were regulated with oil switches , and the transformers and switch gear were housed in the south end of the generator building .

The Croton Dam and hydro plant were completed in 1907 , and a grand opening was held on September 7 , 1907 in the village ( named after Croton @-@ on @-@ Hudson , New York ) . Contemporary accounts report that " Grand Rapids Mayor George Ellis and a large contingent of city and business officials journeyed north to the village of Croton on a special train . After touring the big dam , they adjourned to a nearby field for a fine dinner , followed by cigars and a friendly baseball game . "

In order to achieve efficient power transmission over 50 miles ( 80 km ) to Grand Rapids , a 100 @,@ 000 @-@ volt high voltage line was built , then the highest @-@ voltage transmission line in the world . Dr. Charles Steinmetz , the " wizard " of General Electric , visited the site and conducted

tests on the transmission lines in 1908 . The line voltage was increased to 110 @, @ 000 volts in early 1909 .

#### = = = Modifications = = =

A significant revamping and expansion of generating capacity was carried out in 1915 . Additional turbines and generators were added , blurring the distinction between the buildings . The generator building got pairs of Allis @-@ Chalmers quadruplex horizontal turbines to drive the Westinghouse horizontal generators . Each pair of turbines is rated at 4 @, @ 000 horsepower when operated at 225 RPM with a hydraulic head of 39 feet ( 12 m ) . The operating voltage of the two original Westinghouse horizontal generators was raised to 7 @, @ 500 volts , with a corresponding increase in the line voltage from 110 @, @ 000 to 115 @, @ 000 volts .

The turbine building was modified to take more equipment , resulting in a rearrangement of the walls to enlarge it and addition of a gable to it , similar in appearance to that on the generator building . It has a much higher floor than the generator building and received a pair of vertical turbine / generator sets .

The transformers and switching equipment were removed from the generator building in 1930 , when a separate switchyard / substation went into service to the west of the spillway . Shortly thereafter , in 1931 , Croton and Rogers dams were joined by the Hardy Dam , situated between them . The Hardy was the last major hydroelectric project constructed in Michigan by Consumers Energy . Once completed , the 40 @-@ foot ( 12 m ) -high dam would later impound 7 @. @ 2 billion U.S. gallons ( 6 billion imp. gal / 27 billion L ) of water in its 1 @, @ 209 @-@ acre ( 489 ha ) reservoir and is capable of producing 8850 kilowatts at peak outflow .

#### = = = Legacy = = =

A historical marker sign was placed at the Croton Dam , after its completion . It read :

The Grand Rapids - Muskegon Power Company ( a predecessor to today 's Consumers Energy Company ) built the Croton Hydroelectric Plant in 1906 - 1907 . The plant and its 110 @, @ 000 @-@ volt transmission line ( the highest voltage in use at that time ) attracted international attention . Curious spectators rode excursion trains to the site , where they received a tour of the dam and powerhouse , as well as a grand dinner . When the plant went into full service in September 1907 it represented the latest advances in electric power generation and transmission . Engineers from Russia , England , France , Italy , Japan , and India came to tour the plant when it opened . The facility is listed in the National Register of Historic Places .

The Croton Hydroelectric Plant was listed with the Michigan State Register and was awarded a Michigan Historical Marker ( site S0684 ) . The marker was replaced with a new one in 2005 . The site was then listed with the National Register of Historic Places in 1979 as structure ID # 79001165 .

#### = = Impact and controversy = =

While Croton advanced the state of the art in hydroelectric engineering , it also submerged significant sections of scenic and fast @-@ flowing stretches of the Muskegon and Little Muskegon rivers . Some conservationists believe that Croton Dam and the other dams on the Muskegon divide the 219 @-@ mile ( 352 km ) long river into shorter , ecologically dysfunctional units . It blocks passage of fish from one river section to the next . It allegedly causes potentially harmful changes in water temperature and oxygen levels in a stretch of the river downstream of the dam , according to company data .

The dam was threatened by rainfall during the flood of September 1986 . The Croton and Hardy nearly failed during the peak of the flood , caused by a storm that dumped 14 inches ( 36 cm ) of rain on West Michigan in 48 hours . Consumers Energy officials stated that " had the Hardy Dam failed , the Croton Dam would have been washed away and every community from Croton to

Muskegon would have been submerged under several feet of water " .

Subsequently , in 1989 , Michigan state fisheries director John Robertson characterized hydroelectric dams as " concrete and steel monsters " and suggested 11 Consumers Energy dams be removed from the Muskegon , Manistee and AuSable rivers . Local officials then gathered petition signatures from 14 @, @ 000 people who supported keeping the dams . The federal government has relicensed the dams through 2034 , but has required operating changes reducing their harmful effects on the Muskegon River .

= = Current status = =

The Croton Dam and hydroelectric plant is owned and operated by Consumers Energy , an electric power company headquartered in Jackson , Michigan . Croton generated 44 million kilowatt hours of electricity in 2006 , which would satisfy the annual electric consumption of about 6 @, @ 000 residential customers .

The three dams , Rogers , Hardy , and Croton ( all owned and operated by Consumers Energy ) , are operated in different modes but in concert give a net run of river effect on water flow . The Rogers itself has little or no impoundment and runs in run of river mode , passing through as much water as it receives . The Croton and Hardy work in concert . The Hardy , which has a larger capacity reservoir , larger turbines , and is upstream of the Croton , runs in full peaking mode , meaning that the river flow is impounded and used to generate electricity during peak demand periods . This causes wide fluctuations in water flows and reservoir levels , typically with low outflow during the night when power demand is lowest . Full peaking was once very common but because of the outflow fluctuations , is now less common . However , with the Croton immediately downstream , and with no river segment ( the Croton impoundment stretches back to the Hardy outlet ) , it can be run in re @-@ regulation mode , allowing a natural flow rate to exit . The Croton reservoir level fluctuates inversely with the Hardy , rising during the day and lowering at night . Since the Hardy reservoir is so large , its reservoir level fluctuates about 4 inches ( 10 cm ) in total , while the Croton reservoir fluctuates about 9 inches ( 23 cm ) . During the winter and spring runoff , the Hardy is allowed to fluctuate much more . It can be drawn down up to 12 feet ( 4 m ) to meet winter power demand but is required to return to normal levels by the end of April each spring .

Together , the three dams ( Rogers , Hardy and Croton ) can generate about 45 @, @ 500 kilowatts , with about 30 @, @ 000 of that from the Hardy .