Modernization of the Boulder Canyon Hydroelectric Project

Documentation of Historically Significant Features and Equipment

City of Boulder

September 14th, 2011

URS


Historical
Narrative

INTRODUCTION

The Boulder Canyon Hydroelectric (BCH) is a power-generating system located between Boulder and Nederland, Colorado along Colorado Highway 119 and Boulder and Middle Boulder Creeks. BCH, which consists of Barker Dam and Reservoir, the Barker gravity line, Kossler Dams and Reservoir, the Boulder Canyon Penstock, and the Boulder Canyon power plant, is recorded as Site 5BL752. The Boulder Canyon power plant and associated structures, which are the focus of t study, have been recorded as Site 5BL754. The power plant site is surrounded by steep, forested hills and includes a hydroelectric generating power plant (built 1909-1910), two transformer yards (Feature 5 completed in 1909 and Feature 6 completed in the late 1940s), a seven-bay vehicle garage (1937), four storage buildings (circa 1940 to 1950), and a contemporary switching building (1992). Detailed construction plans were found for the seven-bay garage, dated 1937, but a similar structure appears on a 1932 sketch map of the site. The majority of the power generating and switching equipment inside the power plant was installed during the 1930s when the plant was substantially rebuilt. The piping, gates, and other fixtures used to direct the flow of the water used for power generation are almost all original, dating to 1909-1910.

The water that is used for generating electricity is obtained from Barker Reservoir and Middle Boulder Creek, and is transported in a gravity pipeline (approximately 11.7 miles in length) from Barker Dam (located on the eastern edge of Nederland, Colorado) to Kossler Reservoir (located southwest of the power plant). From Kossler Reservoir, the water runs down a steep hill through a steel pressure line or penstock to the power plant. Kossler Reservoir is 1,800 feet higher in elevation than BCH, and penstock water pressure reaches approximately 840 pounds per square inch (psi) at the power plant. When constructed in 1909-1910, the primary water source for BCH was Barker Reservoir. In the years since, the primary use of the reservoir has shifted to that of municipal water storage for the City of Boulder (City). BCH now operates primarily on stream flow diverted from Middle Boulder Creek and directed to BCH through the gravity pipeline and penstock. Following generation, the water is discharged back to Boulder Creek at the power plant to meet in-stream flow requirements or downstream senior water rights. The City's Barker Reservoir/Middle Boulder Creek water supply is also transported by the gravity line, Kossler Reservoir, and the penstock, but it by-passes the hydroelectric plant upstream of the turbines and is transported to the Betasso Water Treatment Plant north of BCH for treatment and distribution within the City.

The City is currently undertaking replacement of one of two turbine/generators that are located in the 1909-1910 hydroelectric generating building. Two turbines/generators, each capable of producing 5 megawatts (MW) of power, were originally installed in the building. In the mid-1930s, upgrades to the generators increased the capacities to 10 MW each, for a total plant capacity of 20 MW. One generator (Unit A) failed in 2000 and was not repaired. The other unit (Unit B) has continued to supply power and will be replaced by a new 5-MW unit, which is the appropriate capacity for the water now available for generation at BCH. The City will leave the existing Unit A turbine/generator in place, but it will be inoperable. The City is also planning to replace transformers (c. 1940), install enhanced lightning protection, upgrade the wiring, remove and replace an old storage tank, and install a state-of-the-art turbine isolation valve and remote monitoring and operation equipment. In conjunction with new equipment installation, much of the large cast-iron piping within the power plant building (c. 1909) that directs water to the

turbines, and several small pumps and controllers will be replaced (City of Boulder, Department of Public Works 2009a:3)

The writing of this context has presented certain factual challenges untangling the identities of the corporate entities that planned, constructed, and operated the Boulder Canyon Hydroelectric system. The system was proposed by the Denver-Eureka Power Company (DEPC), construction was started by the Eastern Colorado Power Company (ECPC) and continued under the auspices of the Central Colorado Power Company (CCPC), which operated the plant from 1910 until 1913. In April of 1913, the Colorado Power Company (CPC) was formed to acquire the assets of several companies, including the CCPC. In 1924, CPC merged with Public Service Company of Colorado (PSCo). In 2000, PSCo merged with Northern States Power and Southwestern Public Service to form Xcel Energy, Inc. (Xcel). In 2001, Xcel sold BCH to the City, which continues to operate the plant today. The City sells the electricity generated at the BCH power plant to Xcel.

Several sources have been used to compile this context. The most comprehensive history of BCH, and one that has been the foundation of most subsequent work, was written by W. Clinton DuVall, a professor of electrical engineering at the University of Colorado, who taught there from 1919 until 1957. DuVall briefly worked for CCPC after completing college (University of Colorado College of Engineering 2011). DuVall produced his history of the site at some unknown date, in the form of an article that appeared in the *Boulder Daily Camera* (BDC). This piece, which detailed the development and construction of the plant, was reprinted in the BDC on July 14, 1960 to mark the 50th anniversary of the site. The exact date of the original article is unknown. The reprinted article notes only that, "It was written for the *Camera* many years ago by W. Clint [sic] DuVall…" (DuVall 1960).

Other histories of the plant have been produced, including several published by PSCo (1959, 1960a, 1960b, 1976, McAdams and Volstad 1982) and accounts written by Barbara Kossler (1960), Manuel Weiss (1980), Andrew Ferguson (2008), and Kris Kranzush (2010a). One of the underlying goals for this context was to analyze and attempt to reconcile conflicting statements that appeared in these various histories and to develop a comprehensive summary of the planning, construction, and operation of the plant. With the exception of a report by Curtis and Hine (1906), primary documents from the involved corporations relating to the period of construction are not present in the library archives examined for this study. Some primary documents apparently exist at PSCo/Xcel (see the article by McAdams and Volstad 1982). Xcel has not responded to requests for information. Newspaper articles published during the period of construction and throughout the operation of BCH, and photographs from the construction period provide the best historical documentation of BCH.

REGULATORY HISTORY

The use of water for hydroelectric power generation is regulated by the federal government. Early federal stream legislation had to do chiefly with preventing or removing obstructions to navigation. The Federal Water Power Act of 1901, however, empowered the Secretary of the Interior to permit rights-of-way through public lands and forest reservations "for electrical plants, poles, and lines for the generation and distribution of electric power" (Pinchot 1946), and the original filing for BCH with the U.S. Department of the Interior may have occurred in compliance with the 1901 Act.

The Federal Water Power Act of 1920 firmly established the principle of federal regulation of water power projects, limited licenses to not more than 50 years, and provided for government recapture of the power at the end of the franchise. The Act of 1920 provided for the administration of the Act by a commission of three – the Secretaries of War, U.S. Department of the Interior, and U.S. Department of Agriculture. The 1930 Reorganization Act provided for an independent commission of five full-time members authorized to employ a staff of its own (Pinchot 1946).

The Federal Power Act of 1935 authorized the Commission established under the 1930 Reorganization Act to regulate the interstate transmission and sale of electric energy. Federal control of water power continues today under the 1935 Act and its many subsequent amendments.

The Secretary of the Interior is authorized by 43 United States Code §1714 to make, modify, extend, or revoke withdrawals of land from the public domain. Withdrawals prevent an area of federal land from settlement, sale, location, or entry under some or all of the general land laws (e.g., those pertaining to homesteading or mining) for the purposes of limiting activities under those laws. Withdrawal maintains other public values in the area or reserves the area for a particular public purpose. Withdrawal also occurs by the transfer of jurisdiction over an area of federal land from one federal agency to another (USLegal.com 2011). A common means of withdrawal is by Executive Order.

There is a federal power withdrawal overlaying portions of the Barker Gravity Pipeline and Penstock that were not already private property when BCH began, reserving these areas for use in power production. The date of this withdrawal is not known, and documentation of this withdrawal was not examined in conjunction with this study. It presumably could be obtained from the Bureau of Land Management.

The last license for the hydroelectric project was issued by the Federal Energy Regulatory Commission (FERC) in 1979 and expired in 2009. The City applied to FERC in March of 2009 to convert the existing license for BCH to a conduit exemption from licensing. The exemption was granted in November 2010.

CORPORATE HISTORY

The earliest recorded proposal for a Boulder Canyon Hydroelectric plant was made by DEPC. DEPC filed an application in June 1903 with the U.S. Department of the Interior to construct a dam to take water from Boulder Creek by Tungsten (located east of Nederland) through a gravity line to the present location of Kossler Reservoir, then down the mountain slope to a hydroelectric plant located near the present-day site of BCH (DuVall 1960). The water rights for the project were appropriated on December 18, 1906 and reviewed and adjudicated on October 18, 1928 (Kranzush 2010b:3). DuVall (1960) reported that the equity of the DEPC was purchased by the CCPC from W. Hollingsworth McLeod.

The CCPC was incorporated on November 13, 1906, to promote the ideas of Leonard E. Curtis and Henry Hine to use the Colorado River (then called the Grand River) for hydropower. Curtis and Hine were electrical and hydraulic engineers in Colorado Springs who had been studying the Colorado River for several years and proposed constructing power plants at Shoshone (near Glenwood Springs) and at Gore Canyon (near Kremmling), with a storage reservoir at Williams Fork (Curtis and Hine 1906; Stone 1918:317, 318).

The CCPC was founded with a capital investment of $22.5 million (Stone 1918:317). According to DuVall (1960), the Chairman of the Board was Myron T. Herrick of Cleveland, Ohio; the President was J.R. McKee; and Leonard Curtis, Henry Hine, S.Z. Mitchell, and Copley Amory were Vice Presidents. Additional people on the Board of Directors were David H. Moffat, J.A. Hayes, Irving W. Bonbright, Geo. L. Peabody, Orland B. Wilcox, and Horace G. Lunt. Stone (1918:317) lists the above people as "incorporators and first directors," and excludes S.Z. Mitchell, I.W. Bonbright, and G.L. Peabody. Stone includes four names not listed by DuVall: Charles A. McNeill, George B. Tripp, George B. Bucknan, and T.P. Hanson.

Herrick, a former governor of Ohio, was a wealthy businessman who helped start The National Carbon Company that later became the Eveready Battery Company (Ohio Historical Society 2009). Along with many mine and railroad holdings throughout the state, Moffat is significant to Colorado history for his development of the 6.3-mile long Moffat Tunnel through the Continental Divide, allowing intercontinental railroad traffic to go over the Rocky Mountains. Moffat's work with the transportation industry helped to make Denver the railroad hub for the West, and as such established Colorado as a nationally important commercial and industrial center (State of Colorado 2011).

The corporate history of the CCPC was more complex than that presented by Stone and DuVall. An article in the BDC on March 6, 1910 entitled, "Herrick In Control of Central Power," states that Curtis and Hine retired from CCPC, and "F.C.Wolcott, G.H. Walbridge, and Myron T. Herrick, representing the General Electric Co. and eastern financial interests, were elected to the board. S.Z. Mitchell, another representative of the electrical corporation, is on the board" (Boulder Daily Camera 1910a). One can only guess at the reasons Curtis and Hine "retired" from the company, or were forced out. A BDC article published on January 4, 1908, however, states that the company "…is headed by ex-Governor Myron T. Herrick of Cleveland, Ohio. G.H. Walbridge of Colorado Springs is General Manager of the company, Albert Carr, Engineer of Construction, and J.W.E. Taylor, Superintendent. All of the above are men of affairs and have been identified with the construction of some of the greatest industrial projects of modern times."

According to Stone (1918:318), "Messrs. Curtis and Hine undertook the construction of a finely planned system at Shoshone, on the Grand River (now the Colorado River), "…its construction was progressing so satisfactorily that a second company was formed on May 13, 1907, and known as the Eastern Colorado Power Company, with Horace G. Lunt, John T. Adams, and Henry Hine as incorporators. The purpose of this was to build a dam at Nederland in Boulder County, with a complete plant on Middle Boulder Creek."

Construction of the plant that is today known as BCH by the ECPC began on April 10, 1907 (Boulder Daily Camera 1908). A BDC article on July 11, 1907 reported, "Many Men Wanted – Hydraulic Company needs men and will pay good wages." "The power house of the Eastern Colorado Power Co. at Four Mile wants for probably 20 months, men in numbers, and wages…" (Boulder Daily Camera 1907a)[1]

[1]The article went on to state, "This is a free notice copied from a circular issued by the company and because it is regarded as being of interest to men who are seeking work:

Needed: 350 Pick & Shovel men, at $2.50/day
150 Hammermen " " and up/day
30 2-Horse Skinners " "
10 4-Horse Skinners " $3.00/day

On July 26, 1907, the BDC reported, "Hundreds Laid Off", "Payroll of Eastern Hydraulic Co. cut down by sweeping order laying the men off for 10 days or more," and, "Several hundred men laid off by Eastern Hydraulic Co., nothing doing until Aug 15 on the huge works in Boulder County save at the Nederland Dam site at Sulphide. General Superintendent Taylor -- "Reason is work is ahead of machinery" (Boulder Daily Camera 1907b)

By January 1908, the ECPC was described as a subsidiary of the CCPC (Boulder Daily Camera 1908). According to histories published by PSCo, construction was halted by the economic depression of 1907, and the ECPC, "having had financial difficulties, was taken over by the CCPC" (Public Service Company of Colorado 1960a). The PSCo brochure produced for the 50th anniversary of the hydroelectric plant, with the text also printed in the BDC (Public Service Company of Colorado 1960b), states that construction did not resume until 1909, "this time under the auspices of the CCPC, which had combined assets with the ECPC."

Whatever the precise corporate relationship of the ECPC and the CPCC was, plans with both ECPC and CCPC labels were produced for the project through 1909. The ECPC continued to be mentioned in newspaper articles (Boulder Daily Camera 1909, 1910b) at the same time the CCPC was referred to in other articles about the BCH.

A BDC article dated February 18, 1911 titled, "Manufacturer Wants Pay from Power Co.," discussed the lawsuit the I.P. Morris Co. filed against the ECPC for payment of $79,038.80 for manufacturing and installing two impulse water wheels with necessary accessories in June 1907.[2] The original contract for the water wheels was with the Electric and Hydraulic Co., which later disposed of its interest in the property to ECPC. Other defendants named were the "Central Colorado Power Co., of which the Eastern Colorado Power Co. is a subsidiary, Knickerbocker Trust Co. –which holds a deed of trust from Central Colorado Power, & the McArthur Bros. Co. & Reinforced Concrete Pipe Co. (which have filed liens on Power Co.'s property). I.P. Morris Co. seeks decree of first lien."

The "Electric and Hydraulic Co." named in the above article does not appear in any other source. It is unknown if the "Eastern Hydraulic Co." named in the July 26, 1907 BDC article quoted above is the same company, a misnomer, or some sort of subsidiary of the ECPC (Boulder Daily Camera 1907b).

It thus appears that ECPC did become a subsidiary of CCPC, as both companies were operating during construction of the project. ECPC is named as a "subsidiary concern" of CCPC as late as November 1912 (Boulder Daily Camera 1912).

DuVall's history (1960) makes no mention of the ECPC, and his assertion that the "Boulder Canyon Project is a part of the original plan of the CCPC to develop hydro-electric power in Colorado" is incorrect. The CCPC's original plan was for projects at Shoshone, Gore Canyon, and Williams Fork. The BCH was conceived later, and put into play by the ECPC. The two

---

50 Tracklayers " $2.50/day
50 Hoist & Tram Men " " "
Board - $5.25/week
Hospital Fee - $1.00/month
Pay Day on the 12th of every month."

[2]If power house construction indeed began on April 10, 1907 as reported in the BDC on January 4, 1908, construction would have proceeded at an incredible rate to allow turbine installation in June 1907. One of these dates may be incorrect.

companies shared leadership, in particular Henry Hine and Horace G. Lunt, were incorporators of both companies, but the companies were originally separate corporations. The statements in PSCo histories indicate that the ECPC started construction on BCH in 1906 and are clearly incorrect, since the ECPC wasn't formed until 1907.

The assertions by the PSCo histories (1960a, 1960b, 1976), and repeated by Weiss (1980), that construction was halted by the economic depression of 1907 and not resumed until 1909 are incorrect, as are the statements that the Barker Dam site wasn't chosen until 1909. The depression did affect construction, resulting in a large reduction in manpower. The BDC article published on January 4, 1908 states that, "During the fall, previous to the failure of the Knickerbocker Trust Company, between 600 and 700 men were employed at the various camps… The original plans, which provided for the construction of the Sulphide dam first, were changed and work was shifted to the Barker meadows, where winter quarters were built and arrangements made to push the construction through… A steam shovel is now at work below the dam site… ….about 50 men are now employed at the Barker dam and this will be increased as fast as weather conditions permit the working of a larger force. It is expected that by the first of May, 300 men will be employed at Barker meadows, when the work will go forward night and day."

The original plans for BCH included two dams, two power plants, and a storage reservoir in Boulder Valley. The location chosen for one of the dams (Sulphide Flats, to create "Nederland Reservoir") was found to be unsuitable, and as described above, work was switched to the second dam site in Barker Meadows on land owned by Hannah Barker, who refused to sell the land to the power company. The land was acquired through condemnation proceedings, with a legal fight for valuation filed by Barker (Boulder Daily Camera 1907c, City of Boulder, Department of Public Works 2009a).

It is unclear if work was actually halted on the project sometime in 1908, or just slowed. There is an absence of news articles about the project after January of 1908 and until 1909.

CCPC ultimately completed two plants in the state—BCH and the Shoshone plant along the Colorado River near Glenwood Springs. A third plant, planned for a site in Gore Canyon near Kremmling, was never completed (DuVall 1960).

On March 16, 1910, the stockholders of the CCPC elected (or re-elected) Myron T. Herrick as Chairman of the Board. Herrick …"is said to be one of the largest stockholders in the General Electric company, a corporation which handles millions like ordinary capitalists do thousands. S.Z. Mitchell, another General Electric representative is on the board, and Mitchell is also identified with many of the million-dollar corporations in which Henry L. Doherty, of the Denver Gas & Electric company, is a conspicuous figure. The complete board of directors selected yesterday is as follows: Myron T. Herrick, J.R. McKee, George C. Lee, Jr., George L. Peabody, Copley Armory, Irving W. Bonbright, F.C. Walcott, Starling W. Childs, Bulkeley Wells, G.H. Walbridge, and O.B. Wilcox." O.B. Wilcox stated, "…It is all nonsense to talk of the Central being behind a gigantic power trust. We will fill our own particular field and there is plenty of room for everybody" (Boulder Daily Camera 1910c).

By November of 1912, George H. Walbridge was President of CCPC and Lyman P. Hammond was Vice President. They were appointed as co-receivers by the federal court as CCPC was placed in receivership, on application by the Columbia-Knickerbocker Trust Company of New York. The action stemmed from the default of agreement charged to CCPC in permitting liens to

be obtained against its property, and inability of CCPC to make the first semi-annual payment of interest on its debts. CCPC is described as the largest producer of electric power in the state, including supplying one-half the power of the Denver Gas and Electric Co. (Boulder Daily Camera 1912).

In April 1913, the CPC was formed and took over the properties of the CCPC and ECPC (Stone 1918:318). Officers of the CPC in January of 1918, all of New York City, were George H. Walbridge, President; S.Z. Mitchell and L.P. Hammond, Vice Presidents; and Irwin W. Day, Treasurer. "The Colorado Power Company is controlled by Bonbright & Co. of New York, which firm also is closely identified with the General Electric interests" (Stone 1918:320).

PROJECT HISTORY

Construction of Barker Dam, Kossler Reservoir, BCH, and the gravity pipeline (shown on Figure 1) began in earnest in 1908-1909. By October 1909, the three dams that formed Kossler Reservoir and the 11.7-mile gravity pipeline were completed, and the first water flowed through the gravity pipeline on September 1, 1909 (Public Service Company of Colorado 1959:2). Construction on Barker Dam and various parts of the system continued until completion in 1910.

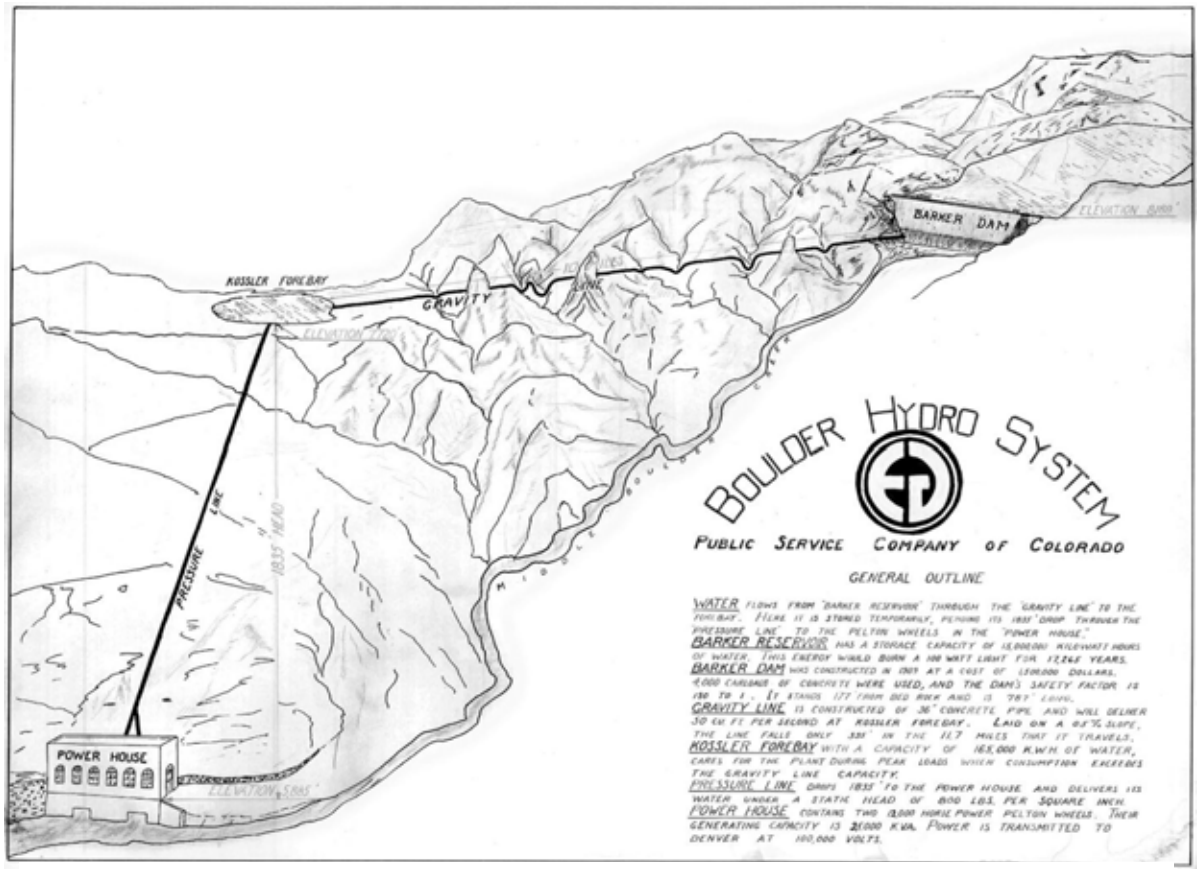

Figure 1. Boulder Hydro System – PSCo, c. 1920.
Image: Betasso Water Treatment Plant Collection.

Barker Dam was designed by the J.G. White Company, a prominent civil engineering company based in New York City with wide experience in dam construction and other large-scale projects. The actual construction was managed by W.G. Finkle and McFarland Doble, two consulting engineers from San Francisco, while the McArthur Brothers Company served as the general

contractor (DuVall 1960). Little information has been found on Finkle, Doble, or the McArthur Brothers. It is known that the MacArthur Brothers Company was involved in large construction projects across the United States.

The dam structure, which cost $2.7 million, was built with a storage capacity of 500 million gallons (12,000 acre-feet) and measures 175 feet in height with a width of 720 feet and is made of cyclopean concrete. In 1946 and 1947, PSCo modified the outlet works on Barker Dam and made improvements to the upstream face of the dam. In 1971, the spillway was enlarged with a new 125-foot ogee crest with a curved channel and a warped floor. Cosmetic improvements were made to the downstream face of the dam in 1971. The dam was secured in the early 1980s with post-tensioned anchors to increase the factor of safety. The City paid for the repair at a cost of $3,315,000 and received a perpetual right to use 8,000 acre-feet of Barker Reservoir storage from PSCo in return (City of Boulder, Department of Public Works 2009b).

The main dam at Kossler Reservoir is much smaller, standing 18 feet high with a width of 450 feet. It was built to contain approximately 5 million gallons of water. Very little design and construction documentation is available for the Kossler Reservoir dams and appurtenant facilities, and few repairs or modifications have been made over the years (City of Boulder, Department of Public Works 2009b). The City plans to install a stability berm and toe drain system on the main (southeast) Kossler Dam in 2011.

The gravity pipeline that feeds water from Barker Reservoir to Kossler Reservoir is approximately 11.7 miles in length, and consists of a cylinder made of reinforced concrete sections (Figure 2), each measuring 36 to 38 inches in diameter (Public Service Company of Colorado 1959).

Figure 2. Workers fabricating steel-reinforced concrete gravity pipeline sections at one of the work sites (perhaps Magnolia work camp) established during the project. Photo: Carnegie Branch Library for Local History, Boulder, Colorado, *Boulder Daily Camera* Collection.

Construction of the gravity pipeline required a substantial amount of engineering and work to complete. The pipeline crossed a landscape made up of steep, rugged hillsides, sheer rock faces, heavily forested areas, and meadows. Few roads existed, and supplies and materials had to be carried to work areas with great difficulty. In some areas, tunnels and inverted siphons had to be built.

Water stored at Kossler Reservoir flows to the power plant through a

steel pipeline or penstock that regulates the flow of water into the plant. The line is 58 inches in diameter at the top of the system (where it leaves Kossler Reservoir) and narrows to a line that is 44 inches in diameter near the bottom, with thicker side walls to contain the higher pressure (DuVall 1960). This line drops more than 1,800 feet in elevation (Figure 3) and gathers a pressure of 840 psi (the highest recorded at a hydroelectric plant at that time) by the time it arrives at the plant (DuVall 1960).

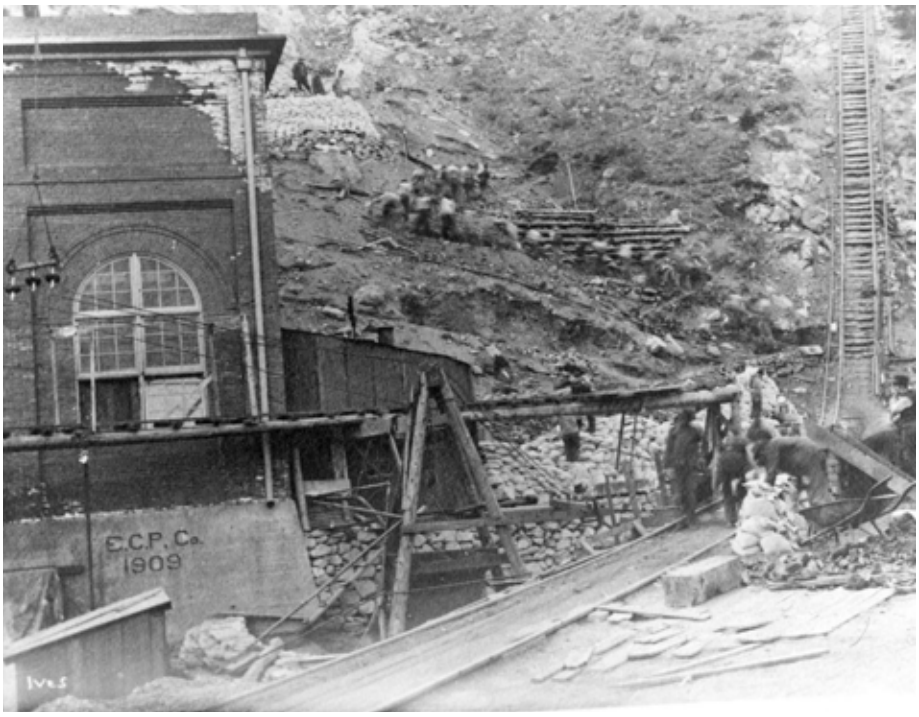

Figure 3. Construction of the BCH building and pressure line. Note the rail track used to move materials that traveled up the hill adjacent to the building. Photo: Western History Collection, The Denver Public Library.

The construction of this pipeline, which enters the building on the south side of BCH, required special engineering and fabrication techniques. The system consists of a steel line buried in the side of a steep hillside southwest of the plant. When constructed, the line consisted of steel sections held together with 2-inch rivets. The tremendous pressure generated by the water flow overwhelmed these connections, and the pipeline suffered constant leaks and joint failures. Engineers determined that a new method of joining the pipe sections was needed. A welder skilled in using acetylene gases (a new technique that was just emerging) traveled to the site from Kansas City, Missouri. The welder and workers at the plant determined that the metal around each joint had to be ball-peened (struck with the rounded end of a ball-peen hammer) during the welding process. This process strengthened the joint sufficiently. BCH has been recognized as the site that introduced the steel penstock method of welding to the world (DuVall 1960). In 1994, the Boulder Canyon Hydroelectric Facility Penstock was awarded the Historical Welded Structure Award by the American Welding Society as it was the first structure in which acetylene welding in conjunction with the ball-peen welding procedure was used and significantly advanced penstock technology when constructed in 1910.

The construction of the plant presented its own challenges. The site was located along a twisted path in Boulder Canyon, more than 1 mile from the nearest rail stop. Equipment and building materials were brought to the rail yards in Boulder where they were transferred to narrow-gauge cars for transport to Orodell (located in Four Mile Canyon). There they were unloaded and transferred to horse-drawn wagons that brought them to the power plant site. Many items were so large that individual components had to be shipped piece-by-piece. Heavy equipment, like the turbines and generators, required as many as sixteen horses to pull one wagon.

Figure 4. Interior of BCH, August 4, 1910, opening day. Note Unit B is in the foreground. Photo: Carnegie Branch Library for Local History, Boulder, Colorado, *Boulder Daily Camera* Collection.

Steel transmission towers were used to hold the wires that transmitted the power that would be generated to Boulder and Denver. The use of steel for these types of towers was unusual, but it was thought this material would better endure lightning strikes, high winds, and harsh winter conditions that the transmission lines would face (DuVall 1960).

Approximately 18 months after construction started on the buildings for the power plant, the BCH plant began generating power (on August 4, 1910). Two I.P. Morris Waterwheels were connected to two General Electric generators, each producing 5,000 kilowatts (KW) of power, for a total capacity of 10,000 KW (Figure 4).

When completed, BCH was seen as the most advanced plant of its type in the nation and was visited by a large number of engineers and power company representatives from across the country (DuVall 1960). Pictures of the plant also appeared in many technical journals and magazines (DuVall 1960).

Ownership of BCH changed hands in 1913, when the CPC purchased CCPC. In 1924, CPC merged with PSCo (McAdams and Volstad1982). The BCH site contained five houses where the plant operators and their families lived. One long-time resident and operator was Everett H. Brines, who worked at BCH for 38 years (1920-1958). He and his wife, Daisy Irene, raised six children at the site, and lived in one of the small houses there until Everett reached the mandatory retirement age of 65. Everett Brines wrote an informal memoir that included numerous stories about living and working at the plant. He recalled that he was paid $90 a month to operate the switch board at the plant. His compensation also included free rent, water, and utilities. Brines tells a story about constructing electric resistance heaters out of wire to help heat the houses at BCH. As Brines relates: “The resistance in the iron wire caused them to heat. The coils had no insulation and they were dangerous. How we ever raised the kids without more accidents, I’ll never know. June [one of his daughters] fell into one of the heaters and was burned pretty bad. She still has scars on her back…Stan [a son] also got burned and still has the scars…We finally made some screens to put on the heaters so they weren’t so dangerous” (Brines 2010:22).

Brines also recalled lightning strikes at the plant that would “throw a load on our generators and they would start to groan and make a hell of a noise” (Brines 2010:24). Brines also relates how, on November 1, 1933, he lost his right hand when he accidently touched one of the 13,000-kilovolt (KV) circuit breakers. The resulting arc burned his hand so badly it had to be amputated. Later he was given an artificial hand, but he found it troublesome and never used it (Brines 2010:28). The Brines memoir mentions many families significant to the history of western Boulder County, including Sweeney, Betasso, and Blanchard, and gives a good overview of the social life in Boulder and Boulder County during the early 20th century.

In 1928, the Unit A turbine was replaced with a larger Pelton wheel. The new turbine had a capacity of 12,000 horsepower (HP), while the original was rated for 10,200 HP. The installation of this turbine caused the closure of BCH for 1 week.

BCH was substantially rebuilt in the mid-1930s, when new generators, circuit breakers, and control panels were installed. The small tool shop on the northern side of the building was expanded, and a clerestory monitor was installed on the roof (Figure 5 shows the plant before the renovation; Figure 6 shows the plant in 1936, following the 1935 rebuild). Much of the equipment currently installed in the plant dates to this period. An article from 1932 reported that the work would cost $225,000 (Boulder Daily Camera 1932). The new generators that were installed in the plant doubled the capacity of each unit to 10,000 MW, and the total modernization project cost $287,000 (Boulder Daily Camera 1947). It is not known if any of the funds used for this reconstruction came from New Deal agencies or programs or was paid for solely by PSCo. A search of records from that period failed to identify the funding source for this work, but it should be noted that this was a substantial expenditure for any company to make during the Great Depression.

Figure 5. BCH, c. 1925, before a substantial renovation and modernization project took place in the mid-1930s.
Photo: Western History Collection, The Denver Public Library.

The plant was upgraded again in 1948, when a new transformer yard was completed on the north side of the plant. This project required the construction of a large retaining wall along Boulder Creek that created a flat area containing two transformers that serve the A and B generators inside the building. Some records suggest that the retaining wall and resulting yard may have been built in the 1930s, but the transformers were not installed until the late 1940s. The transformers are designated as Bank A and Bank B (serving the Unit A and B generators) and transfer power into the 115-KV transmission lines located above the yard (Figure 6). In addition, new power lines were built to transmit power

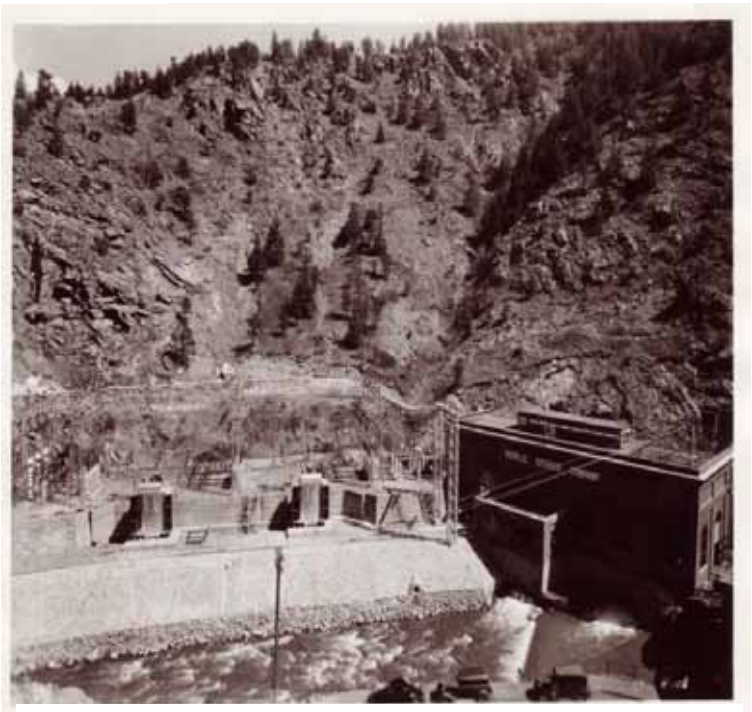

Figure 6. BCH, summer of 1936, after the 1935 rebuild and the construction of the northern transformer yard.
Photo: Betasso Water Treatment Collection.

from the plant. Two 13,000-MW lines were planned and built using 55 tons of copper wire on a 5-mile line (Boulder Daily Camera 1948)

Figure 7. A worker heating the hub of the new water wheel, June 1959.
Photo: Betasso Water Treatment Collection.

In 1959, the Unit B turbine at the plant was replaced. The new wheel was a 9-ton, 110-inch diameter wheel from the Pelton Division of the Baldwin-Lima-Hamilton Corporation of Philadelphia (Figure 7). The wheel was cast in Switzerland and machined in San Francisco, California, and was expected to last for at least 30 years (Boulder Daily Camera 1959). One of the two generators at the plant had to be rebuilt in 1964 after an operating mishap caused so much vibration that the generator broke its mounting bolts and lifted itself out of its pit, causing substantial damage (Ferguson 2008:1).

More changes occurred in the ownership of the plant during the late 1990s and early 2000s. The first change occurred when PSCo merged with the Texas-based Southwestern Public Service Company in 1997 to form New Century Energies (NCE). This was followed by the 2000 merger of NCE and the Minneapolis, Minnesota-based Northern States Power Companies, which resulted in the formation of Xcel. A year later, in 2001, the City purchased BCH, along with the Barker and Kossler Dams and Reservoirs, the Barker gravity line, and the BCH penstock from Xcel for $12.4 million (Thompson and Westmore 2002:iii). Shortly before the City purchased BCH, the Unit A generator failed and was not repaired.

The City was awarded $1.18 million in federal funds by the U.S. Department of Energy in January 2010. The money will be used to partially defray the cost of replacing the remaining operating turbine/generator at BCH (Unit B) with a new 5-MW unit. The City will leave the other c. 1936 turbine (Unit A) in place, but it will be inoperable. Even at a smaller capacity than the existing equipment, actual annual generation will increase by about 30 percent because of the increased efficiency of the new equipment and the decreased operational downtime compared to the old equipment (City of Boulder, Department of Public Works 2009a:3). The total project cost will be $5.15 million.

ELIGIBILITY

When BCH was constructed in 1910, it featured the highest head hydroelectric plant in the western United States, and possibly in the country, and helped create new sources of electrical power for the growing cities of Boulder and Denver. It is therefore recommended as eligible for nomination to the National Register of Historic Place (NRHP) under Criterion A. BCH was backed by several investors of historic importance (most notable were Myron T. Herrick and David Moffat) and is therefore recommended as eligible for nomination to the NRHP under Criterion B. The plant is notable in terms of construction difficulty and technological challenges.

The steel penstock/pressure line running from Kossler Reservoir to the plant was the first recorded use of the ball-peen hammer method of welding. Due in part to its unique engineering features and innovative construction techniques, BCH is considered eligible for listing on the NRHP under Criterion C at the local level (for power generation to Boulder and Denver), the state level (for regional power generation and playing a role in the development of hydro-electric power in Colorado), and at the national level (the technical innovations that occurred and that were used in later projects).

REFERENCES CITED

Boulder Daily Camera

1907a "Many Men Wanted -- Hydraulic Company Needs Men and Will Pay Good Wages." 11 July. Boulder, Colorado.

1907b "Hundreds Laid Off." 26 July. Boulder, Colorado.

1907c "Fight for Control of Barker Meadows." 11 September. Boulder, Colorado.

1908 "Great Power Plant Eastern Colo. Co." 4 January. Boulder, Colorado.

1909 No Title. 29 September. Boulder, Colorado.

1910a "Herrick In Control of Central Power." 6 March. Boulder, Colorado.

1910b No Title. 2 May. Boulder, Colorado.

1910c "The Boulder Plant Will be Pushed." 16 March. Boulder, Colorado.

1911 "Manufacturer Wants Pay from Power Company." 18 February. Boulder, Colorado.

1912 "Receivers Appointed for Central Power Company." 30 November. Boulder, Colorado.

1932 "Public Service Improvements Will Cost $2,000,000." No Date. Boulder, Colorado.

1947 "PSCo Had Notable Year on Boulder District, Plans More Progress." 2 February. Boulder, Colorado.

1948 "PSCo Finishes $83,000 Power Line Job — New Circuits Bring More Electricity to Boulder." 14 December. Boulder, Colorado.

1959 "Boulder Canyon Power Plant Gets Big New Water Wheel from Switzerland." 29 May. Boulder, Colorado.

Brines, Everett H.

2010 *Arrows to Atoms: The Autobiography of Everett Brines*. Manuscript on file, Betasso Water Treatment Plant. Boulder, Colorado.

City of Boulder, Department of Public Works

2009a *Modernization of the Boulder Canyon Hydroelectric Project, DE-FOA-0000120*. Boulder, Colorado.

2009b *Source Water Master Plan. Volume 2 – Detailed Plan*. Boulder, Colorado.

Curtis, L.E. and H. Hine

1906 *Central Colorado Power Company. Report of Curtis & Hine, Colorado Springs, Colorado*. 22 September 1906. Report on file, Denver Public Library Western History Department. Denver, Colorado.

DuVall, W. Clint

1960 *History and Description of Hydro-Electric Plant in Boulder Canyon Completed Fifty Years Ago*. August 4. Reprinted in *Boulder Daily Camera*. 14 July. Boulder, Colorado.

Ferguson, Andrew J.

2008 *Operation of Hydroelectric Facilities and the Boulder Canyon Hydroelectric Generating Plant*. Electronic document: http://andrewferguson.net/wp-content/uploads/2008/04/boulder-hydro-paper.pdf, accessed 24 November 2010.

Kossler, Barbara

1960 "Jack Kossler Describes Work of Constructing Gravity Line for Boulder Hydro Electric Plant." *Boulder Daily Camera*. 5 August. Boulder, Colorado.

Kranzush, Kris

2010a *Boulder Canyon Hydroelectric Project, Site 5BL752.* Cultural Resources Re-evaluation Form, Colorado Cultural Resource Survey, Form 1405. Submitted to and on file at Colorado State Historic Preservation Office. April 28. Denver, Colorado.

2010b *Boulder Canyon Hydroelectric Project*, *Site 5BL752*. Historic Architectural Component Form, Colorado Cultural Resource Survey, Form 1404. Submitted to and on file at Colorado State Historic Preservation Office. April 28. Denver, Colorado.

2010c *Boulder Canyon Hydroelectric Project, Site BL752.3*. Linear Component Form, Colorado Cultural Resource Survey, Form 1418. Submitted to and on file at Colorado State Historic Preservation Office. April 29. Denver, Colorado.

McAdams, Marilyn and Steve Volstad

1982 *The Past is Alive and Well at Shoshone (and Boulder)*. Q Magazine: Quarterly Publication for the Employee Retirees of Public Service Company of Colorado. Volume 4, Number 3, Fall Issue. Denver, Colorado.

Ohio Historical Society

2009 *Biography of Myron T. Herrick*. Electronic document: http://www.ohiohistory.org/onlinedoc/ohgovernment/governors/herrick.html, accessed 18 July 2011. Hays Presidential Center.

Pinchot, Gifford

1946 *The Long Struggle for Effective Federal Water Power Legislation.* 14 George Washington Law Review 9 (1945-1946). Available at: http://heinonline.org.

Public Service Company of Colorado

1959 *History Boulder Canyon Hydro Electric Plant and Barker Dam*. Denver, Colorado.

1960a *Boulder Canyon Hydro Electric Plant and Barker Dam*. 16 July. Printed in *Boulder Daily Camera*.

1960b *Serving Colorado for 50 Years, 1910-1960.* Pamphlet produced for the 50th anniversary of the power plant. 4 August. Text published in *Boulder Daily Camera*. 8/4/1960.

1976 *Boulder Hydroelectric.* August. Pamphlet.

State of Colorado

2011 David H. Moffat. Colorado State Archives. Available at: http://www.colorado.gov/dpa/doit/archives/index .

Stone, Wilbur Fisk, ed.
1918 *History of Colorado, Vol. 1*. S.J. Clark Publishing Co. Chicago, Illinois.

Thompson, Curtis A. and Richard A. Westmore
2002 *Middle Boulder Creek Water Source Management Work Plan: Boulder, Colorado*. GEI Consultants, Inc. Englewood, Colorado.

University of Colorado College of Engineering
2011 *Profile of W. Clinton DuVall, Electrical Engineering*. Electronic document: http://www.colorado.edu/engineering/deaa/cgi-bin/display.pl?id=41, accessed 29 June 2011.

United States Bureau of Reclamation
2010 *The History of Hydropower Development in the United States*. Available at: http://www.usbr.gov/power/edu/history.html, accessed 19 August 2011.

USLegal.com
2011 Withdrawal or Reservation of Public Lands. Available at: http://publiclands.uslegal.com.

Weiss, Manuel
1980 *Hydroelectric Plant, Site 5BL 754*. Architectural/Historical Component Form, on file at Colorado State Historical Society, Office of Archaeology and Historic Preservation. October 8. Denver, Colorado.

Acknowledgment: This material is based upon work supported by the U.S. Department of Energy under Award Number DE-EE0002675.