

The Armel Unit

Pick-Sloan Missouri Basin Program

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Table of Contents

Table of Contents	1
The Armel Unit	2
Project Location	2
Historic Setting	3
Prehistoric Setting	3
Historic Setting	4
Project Authorization	10
Construction History	10
Post Construction History	16
Settlement of Project Lands	17
Uses of Project Water	17
Conclusion	17
About the Author	18
Bibliography	19
Archival and Manuscript Collections	19
Books	19
Articles	19
Other Sources	19
Index	20

The Armel Unit: Pick-Sloan Missouri Basin Program

The hills and valleys of Colorado's eastern plains are a land of contrast: hot, dry days punctuated by brief, thunderous rains that flood the surrounding countryside. The key to survival in this stark, arid, and sometimes hostile environment is water. Harnessing the destructive floods that flow through the valleys and directing the waters to productive use is the primary goal of the Armel Unit of the Pick-Sloan Missouri Basin Program.

Project Location

The Armel Unit of the Missouri Basin Program, formerly the St. Francis Unit, consists of the Bonny Dam and Reservoir. The unit is located on the eastern plains of Colorado in Yuma County, about six miles west of the Colorado-Kansas border. The dam is on the south fork of the Republican River in the Upper Republican River Basin, about 29 miles upstream from the Town of St. Francis, Kansas. The nearest town is Hale, Colorado, about two miles east of the reservoir. Wray, Colorado is approximately 30 miles north, and Burlington, Colorado, about 18 miles south of the site.¹

The primary water supply for the Bonny Reservoir is the south fork of the Republican River, which drains an area of about 1,495 square miles above the dam site, with an average annual flow of about 29,000 acre feet (a/ft). The climate of the region is semiarid, with hot, dry summers and cold winters. High winds are common, and blizzard conditions occur frequently during the winter. The growing season runs April through October, and the average annual precipitation is about 17 inches. About 60 percent of Yuma county is grasslands. Native vegetation consists mostly of short grasses, with grama and buffalo grass the most common species. Where drainage is poor, cattails, willows, and cottonwood trees are common, while on steeper slopes, sage brush and yucca are predominant. Wildlife is abundant in the region, with mule and whitetail deer, prairie dogs, and cottontail rabbits frequently found in the area. Also common are migratory ducks and geese, pheasant, quail, prairie chickens, and rattlesnakes.²

1. United States Department of Interior, Bureau of Reclamation, *Technical Record of Design and Construction: Bonny Dam* (Denver: U.S. Government Printing Office, 1981), 1, 5(map).
2. United States Department of Interior, Water and Power Resources Service, *Project Data*, 1981 (Denver: U.S. Government Printing Office, 1981), 797; Reclamation, *Technical Record of Design and Construction*, 1;

(continued...)

Historic Setting

Prehistoric Setting

Evidence of early human activities in the eastern plains of Colorado dates to the Paleo-Indian period, over 7000 years ago. Several sites near the Republican River in Eastern Colorado date to this period. One site dates to the period around 10,500 B.C., and a second site has been tentatively dated to 29,000 B.C. Other sites near the Republican River date to between 8,200 - 7,000 B.C. and before 9,000 B.C. Most of the sites are associated with hunting activities and contain the bones of mammoth, bison, and other smaller mammals. Bone tools were prominent at most sites, but a stone projectile point dating to before 9,000 B.C. was located at one site.³

Most of the sites in eastern Colorado that date to the Archaic Period, about 5,000 B.C. to A.D. 1, can be found along the northern Front Range. Researchers believe this may be due to the general dryness of eastern Colorado during this period, and the cooler climate and abundant game offered by the foothills.⁴ Those sites not located along the Front Range are generally located along the South Platte River in northeastern Colorado.⁵ One poorly documented site has been located near the headwaters of the Republican River.⁶ Prior to the end of the Archaic Period, about 1 A.D., most sites were associated with nomadic hunting activities. Sites that begin to show evidence of more permanent occupation begin to appear during the Ceramic Period, about 1 A.D. to 1,550 A.D. Numerous sites associated with this period have been located in eastern Colorado. Two sites near the Republican River contained ceramic pieces dating to around 1,000 A.D.⁷ Some researchers have suggested that, due to their similarity to sites further east, the Republican River sites may have been seasonal hunting stations used by peoples who normally resided further east.⁸

Historic records clearly attest to the occupation of Eastern Colorado during the

(...continued)

United States Department of Interior, Bureau of Reclamation, Arnel Unit, Upper Republican Division, Pick-Sloan Missouri Basin Program, Colorado, Concluding Report (March 1977), 4-5.

3. Eighmy, Jeffrey L., Colorado Plains Prehistoric Context (Denver: Colorado Historical Society, 1984), 32(map), 33, 36, 41.

4. *Ibid.*, 61-62.

5. *Ibid.*, 52(map).

6. *Ibid.*, 54.

7. *Ibid.*, 94.

8. *Ibid.*, 98-9.

Protohistoric Period (1,550 - 1800 A.D.). In addition to the historic documentation, many sites associated with this period have been located. The Cedar Village Site near Limon, consists of the remains of several structures that contained ceramic shards. These pieces have been tentatively dated to between A.D. 1,675 and 1,725. The Cedar Village Site was dated by comparison of the pieces found there with similar pieces found in western Nebraska that have been positively dated to that period.⁹

The exact date of the arrival of the modern Indian in eastern Colorado is disputed. No sites have been located that confirm their presence there prior to the first Spanish entry into the region in the 1500s. The few sites that have been associated with that period, i.e.: Cedar Village, are similar in nature to sites in Nebraska, supporting the theory that, prior to the arrival of Europeans, the Cheyenne and Arapaho and their ancestors were only infrequent visitors to Eastern Colorado.¹⁰

Historic Setting

The earliest European interest in the Colorado plains came in the form of Spanish claims to the region in the mid-1500s. These claims were based upon exploration of the Great Plains by Francisco Vasquez de Coronado, who was in search of the legendary seven cities of gold. Although claiming the region for Spain, Spanish explorers paid little attention to the region until the mid-1600s. During the 1650s and 1660s, several Spanish explorers reached the South Platte River, which they named the Rio de Chato. It was not until the early 1700s that the Spanish showed any serious interest in the Colorado plains. By then, reports had reached Spain of French traders on the plains in violation of Spains claim to the region. In an effort to ward off the French, Spanish authorities sent several military detachments into the region. One detachment, led by Pedro de Villasur, reached the junction of the North and South Platte Rivers, where they were attacked and killed by Pawnees, longtime trading partners of the French.¹¹

Following their defeat by the Pawnees, the Spanish declined to pursue their claim to the region, allowing the French more freedom in their activities. In 1793, Pierre and Paul Mallet led

9. *Ibid.*, 148-9.

10. *Ibid.*, 149-50.

11. Mehls, Steven F., *Colorado Plains Historic Context* (Denver: Colorado Historical Society, 1984), 1.

an expedition into Colorado along the South Platte River, then south to the Arkansas River, which they then followed back to the Mississippi Valley. Many other Frenchmen followed their path, and trade in guns and other European goods flourished until 1763. In that year a treaty, signed ending the Seven Years War, gave Spain all of Frances claims west of the Mississippi River.¹²

Although the Spanish had a free hand in the region, few chose to venture there. In 1766, Juan de Ulibarri explored to the Arkansas River, and in 1793, Pedro Vial explored the Smoky Hill River. Around 1800, Spanish military activity in the Colorado plains increased. The Louisiana purchase of 1803 gave most of the Colorado Plains to the United States. Because the boundaries of the purchase were unclear, the Spanish authorities patrolled the area frequently to protect their interests. As late as 1817, the Spanish army patrolled the future site of Denver. The Adams-Onís Treaty of 1819 set the border at the Arkansas River, opening the plains of Colorado to American exploration.¹³

One of the first Americans to explore the region was Lt. Zebulon Montgomery Pike. In 1806, Pike and his men headed west from St. Louis towards the Arkansas River. Not heeding warnings about Spanish troops, Pike pushed on to the front range, where they discovered Grand Mountain, later named for Pike. Pikes party continued west along the Arkansas River, and the Spanish captured it in the San Luis Valley. Following his release by the Spanish in 1810, Pike labeled the Colorado plains as desert lands.¹⁴

Ten years after Pikes journey, Major Stephen H. Long explored the South Platte River to the front range. From there his party continued south to the base of Pikes Peak. There, naturalist Edwin James became the first person recorded to climb the mountain. From Pikes Peak, the group continued south to the Arkansas River, where Long split his group in two with one group following the Arkansas River, and the other the Canadian River. Upon their return from the plains, both Long and James published accounts of their trip, emphasizing the aridity of the

12. *Ibid.*
13. *Ibid.*
14. *Ibid.*, 7.

region.¹⁵

By the 1840s, the idea of a coast to coast nation was firmly established and the sense of Manifest Destiny was at its strongest. The Oregon Migration of the 1840s was just one manifestation of Manifest Destiny. In 1842, the Army sent John C. Frémont to explore new routes for migration. During his two trips into the plains, Frémont and his parties mapped much of the Colorado plains and added significantly to knowledge of the region. Exploration, mostly by military parties, continued throughout the 1840s and 1850s. During the 1850s, several roads were established to facilitate troop and supply movement from the East. Two of these roads followed the Smoky Hill and Republican Rivers to Bents Fort. Settlers later used these roads as part of the Smoky Hill and Republican River Trails.¹⁶

The existence of gold in the Colorado mountains had been known even before the Colorado Gold Rush of 1859. As early as 1806, trappers had reported finding the mineral in the streams of the Rocky Mountains. In 1858, William Green Russell discovered gold in Dry Creek, near the future site of Denver. At about the same time, gold was discovered on Fountain Creek, near the future site of Colorado Springs. News of gold reached the Mississippi Valley in the winter of 1858-1859, and by the spring of 1859, as many as 100,000 people were headed towards Colorado.¹⁷

But gold wasn't the only thing in Colorado. For thousands of years, aboriginal Americans had inhabited the plains of Colorado and the West, and the westward exploration and migration brought Manifest Destiny into direct conflict with aboriginal traditions and ways of life. The Indians of Colorado's plains, the Pawnee, Sioux, Cheyenne, and Arapaho, were used to the coming and going of Anglo-Americans. During the fur trading era of the early 1800s, the Indians became used to having American and European products for their use. During the 1850s, many Indian groups became dependent upon Government support, but by 1859, many of these subsidies had been discontinued. With the end of Government support, many native groups found it profitable to attack freight wagons, settlers, stage stations, and ranches. In an

15. *Ibid.*

16. *Ibid.*, 8.

17. *Ibid.*, 20.

effort to make peace, the Treaty of Fort Wise was negotiated in 1861. The treaty promised the Indians safety and support. In return, the Indians would give up much of their territory and live on reservations along the Arkansas River. Although the whites felt that the Treaty of Fort Wise, and the Treaty of the Little Arkansas of 1865, were more than fair, hostilities continued in the Colorado plains. The violence reached its peak in the summer of 1864, when the Indian raids became so intense that the supply road along the South Platte River was closed, and Denver was cut off from the east.¹⁸

To combat the growing Indian threat, Territorial Governor John Evans sent Major Jacob Downing and the First Colorado Regiment to reopen the road. On May 2, 1864, Downing and his men encountered the Cheyenne and defeated them in the Battle of Cedar Creek. Believing that they had ended the Indian threat, Downing and his men returned triumphantly to Denver. But within a few weeks, the Cheyenne raids resumed with increased fervor.¹⁹

The Civil War had drawn most regular army troops to the conflict in the East. To overcome this deficiency, Colorado formed the Third Colorado Volunteers under the command of Colonel John M. Chivington. In August of 1864, the crisis came to a head with the killing of a farmer named Hungate and his family near Denver. Anxious to seek revenge, the Third Colorado Volunteers, who were nearing the end of their enlistment, left Denver in search of the Indians. On August 28, Chivington and his men located the camp of Cheyenne chief Black Kettle on the banks of Sand Creek, near Fort Lyon. At dawn, the Third Colorado attacked, killing men, women, and children.²⁰

Angered by the massacre at Sand Creek, the Indians of the Colorado plains attacked outposts along the South Platte River from Julesburg to the present day site of Greeley. Increased army presence on the plains helped to subdue the Indians, and by the end of 1865, the worst was over. Minor conflicts on the plains continued for several years until, in 1868, Cheyenne leader Roman Nose began raiding in eastern Colorado and western Kansas. The army sent Colonel George A. Custer to capture Roman Nose and his men, but throughout the summer

18. *Ibid.*, 27.

19. *Ibid.*

20. *Ibid.*

of 1868, Custer was unable to locate any hostile Indians. But Major George Forsyth's Volunteer Scouts did find Roman Nose and his men. Forsyth and his troops had tracked Roman Nose to the Arikaree River, in northeastern Colorado. On September 17, 1868, Roman Nose and over 500 warriors ambushed Forsyth and his men. The troops sought refuge on an island in the Arikaree River and held out against the Indians until the 9th U.S. Cavalry reached them over a week later. The battle had left five of Forsyth's men dead and wounded several others. One of the dead was Lt. Frederick Beecher, for whom the island and battle were named. Also killed during the battle was the Cheyenne leader Roman Nose.²¹

Two other battles occurred that would bring an end to Indian hostilities. A few months after the Battle of Beecher's Island, Custer defeated Black Kettle's people at the Battle of Washita in Oklahoma, and in May 1869, General Eugene E. Carr attacked and defeated Cheyenne leader Tall Bull and his warriors at the Battle of Summit Springs. These battles effectively ended Indian resistance to Anglo settlement in eastern Colorado.²²

With the Indian threat effectively ended, pioneers began moving west at an increasing rate. Several well used trails led to the plains of Colorado. The Overland, Santa Fe, South Platte, Republican River, and Smoky Hill trails were popular routes into the region. Travel along these trails was difficult at best, with shortages of food and water common. Rapidly changing weather, lack of wood or fuel, and the threat of Indian raids were ever present threats that added to the overall danger of the trip. The situation became so severe that the Smoky Hill Road became known as the Starvation Trail and reports of cannibalism were heard throughout the region.²³

The arrival of the railroads lessened the danger significantly. By the late 1860s, the Union Pacific and Kansas Pacific railroads were moving west. With the arrival of the Union Pacific in Cheyenne in 1868, the South Platte Trail was all but abandoned. In 1870, two railroads reached Denver, and the era of overland trail travel came to a close.²⁴

The early history of Yuma County is one of cowboys and cattle kings. In 1870, the

21. *Ibid.*, 28.

22. *Ibid.*

23. *Ibid.*, 34-5.

24. *Ibid.*, 35.

Twenty-First Outfit from Corpus Christi, Texas, established three cattle camps in the area. In the following years, several other companies established bases in the region, and for 15 years cattle roamed the plains. In 1885, Congress passed a law allowing for the removal of illegal fences, and the efforts of the cattle companies to keep homesteaders out began to fail. In 1882, the first railroad in Yuma County, the Burlington and Missouri River Railroad, began regular service through the area. The coming of the railroads coupled with the aid offered by the passage of the homestead acts encouraged thousands of settlers to move west.²⁵

Closely following the arrival of the railroads were the land companies. In the early 1880s, the Lincoln Land Company laid out several town sites in the Yuma County area including Wray, Yuma, Laird, and Eckley. These towns would become important stops along the railroad. The first settlers to the area arrived in 1865 and immediately began claiming lands around the townsite of Wray. To supplement their income from agriculture, early settlers to the area collected and sold buffalo bones. These bones brought between five and twelve dollars per ton and were ground for fertilizer or used for buttons, knife handles, and combs.²⁶

Yuma County was formed out of the eastern portion of Washington County, Colorado, in 1889, and the town of Yuma became county seat. In late 1902, the voters of the county chose to make Wray the county seat, and in May 1903, the eastern part of Adams County was added to Yuma County, doubling its size. In 1890, when the first official census of the county was taken, the population was 2,596 people. By 1930, this number had risen to 13,613 people.²⁷

Even with the influx of settlers, the cattle industry continued as the largest industry in the region. The transition from ranching to farming, a familiar pattern throughout the plains, came slower to this region, possibly due to the availability of more inviting and fertile lands elsewhere. It was not until early 1900s that farming grew appreciably. The history of farming in Yuma County is much the same as in other regions of the plains. Alternating periods of prosperity and failure, the lack of markets, grasshoppers, and droughts all combined to make agriculture a risky proposition at best. Even so, the farmers of the area held on to their dreams

25. *Ibid.*, 41; C. V. Dedman, History of Yuma County, Colorado, (Masters thesis, Colorado State Teachers College, 1932), 30, 32.

26. *Ibid.*, vii, 32, 34-5.

27. *Ibid.*, vii, ix, 29.

and made Yuma County one of the more prosperous agricultural regions in the state. The railroads opened routes to new markets, and advancements in agricultural technology helped turn the odds in favor of the farmers. By 1930, Yuma County ranked fourth in Colorado in crop production with a total crop value of almost \$5,500,000.²⁸

There are three rivers that cut through Yuma County: the Arikaree, and the north and south forks of the Republican River. While generally calm, these rivers are subject to occasional destructive floods. In 1935, the Republican River flooded causing \$9,000,000 in damage and taking 110 lives.²⁹

Project Authorization

The Flood Control Act of 1944 that created the Missouri River Basin Plan contained the authority for the construction of Bonny Dam and Reservoir. The Act called for the development of the Missouri River Basin through the joint efforts of the Army Corps of Engineers and the Bureau of Reclamation. The plan came as the result of two plans, one presented by the Corps of Engineers, and the other by the Bureau. The act combined the two plans into a single, comprehensive plan for the development of flood control, irrigation, and power generation projects in the Missouri River Basin. The Corps of Engineers plan was presented by Major General Lewis A. Pick, and the Bureaus plan by William G. Sloan, and the combined plan came to be known as the Pick-Sloan Missouri Basin Program.³⁰

In July, 1947, Congress, under the 1944 act, authorized \$800,000 to begin construction of Bonny Dam and Reservoir, with an additional \$1,700,000 authorized the following year.³¹

Construction History

The Flood Control Act of 1936 granted initial authorization for investigations into flood control and irrigation development on the Republican River. The initial investigations of the Bonny Dam site were conducted by Reclamation in 1939, with a more detailed investigation

28. Denver, Colorado. National Archives and Records Administration: Rocky Mountain Region, Records of the Bureau of Reclamation, Record Group 115, Project Histories: the Armel Unit, Pick-Sloan Missouri Basin Program, 1947-1975. 1947, Vol.I, 45. (Hereafter cited as Project History, then vol, year, and page); Dedman, History of Yuma County, 160, 162-9.

29. Reclamation, Technical Record of Design and Construction, 15; Dedman, History of Yuma County, 36.

30. Warne, William E., *The Bureau of Reclamation* (Boulder: Westview Press, 1985), 162-4.

31. Reclamation, *Technical Record of Design and Construction*, 9.

being conducted in 1941. Before choosing the location for the dam and reservoir, the Reclamation investigated several sites in the Republican River Basin. World War II caused a delay in the investigations, and it was not until 1946 that geological studies began. Investigations into suitability of the Bonny Dam site continued from 1946 until construction began in 1948.³²

All land in the project area was privately owned and consisted mostly of pasture land. Twelve separate acquisitions secured lands for the reservoir, access road, and government camp. No condemnation proceedings were necessary, and no suits were filed. Three irrigation ditches were affected by the construction of Bonny. Two, the Newton and Barnes Ditches, were abandoned following construction of the dam. The third ditch, Hale Ditch, provides water to about 520 acres of non-project lands about a mile east of the dam. Accommodations were made to ensure the continued delivery of water to Hale Ditch.³³

The Utah Construction Company of San Francisco received the contract for construction of Bonny Dam and the access road leading to the site on November 4, 1948. The bid for the contract, which allowed 1400 days for completion, was \$10,301,653.00. Notice to proceed was given on December 7, 1948, and work on the access road began on December 8. Reclamation awarded several other contracts as well. The contract for the high-pressure gate for the outlet works went to the Willamette Iron and Steel Company of Portland, Oregon, and the contract for the outlet pipe went to the Berkeley Steel Construction Company, Inc. of Berkeley, California. The contract cost for the high-pressure gate was \$13,433.40, and the outlet pipe \$93,563.00. The contract for the two, 24-inch, hollow-jet valves for the outlet works was awarded to the Northwest Marine Iron Works of Portland, Oregon, at a cost of \$7,998.00. Three small contracts for work associated with the sluiceway control gate were awarded to the Wooldridge Manufacturing Company of Sunnyvale, California, the Pacific Coast Engineering Company of Alameda, California, and the Valley Iron Works of Yakima, Washington. The contract for clearing the reservoir site went to the Asbell Brothers, Contractors, of Riverton, Wyoming. In

32. *Ibid.*, 8, 11-2.

33. *Ibid.*, 6, 31.

addition, contracts for the caretakers house, protection work and control sections, and water for project construction were awarded.³⁴

Excavations for the temporary diversion channel began on December 15, 1948, and the contractor completed half the work by the end of the year. The channel was completed, and stripping operations on the dam foundation were underway by mid January, 1949. Stripping consisted of the removal of vegetation and top soil. On average, four to six inches of material had to be removed, but in some places, it was necessary to remove four to six feet of material. Material stripped from the foundation areas was stockpiled for use in the dam embankment.³⁵

Excavations for the cutoff trench began in March 1949, and continued until completed in September of the same year. The trench, designed to provide a water tight seal between the dam and bedrock, was 6,900 feet long and was located about 129 feet upstream from the dam centerline. The depth of the trench was determined by the distance to the underlying bedrock, the greatest depth being about 43 feet. As with materials stripped from the foundation, materials excavated from the cutoff trench were stockpiled for use in the dam embankment.³⁶

During excavations for the cutoff trench, a significant amount of water entered excavated areas. A system of well points was used to combat the problem. To remove the water, well points were driven into the ground at regular intervals encircling the excavation, and pumps removed the water. Because of the expense of the well point system and the danger of excavating the entire length, the trench was excavated and backfilled in 100 foot sections.³⁷

Stripping of the spillway area began in February 1949, with excavations beginning in April. As with the cutoff trench, a large amount of water was encountered, and well points were used to remove water from the excavations. Excavation of the spillway, stilling basin, and approach channel were completed in April 1950.³⁸

Embankment placing operations began in March, 1949, and progressed at such a rapid rate that several records were set during operations. During the first year of embankment work,

34. *Ibid.*, 29-30.

35. Project History, Vol. I, xi; Reclamation, *Technical Record of Design and Construction*, 39, 41.

36. Reclamation, *Technical Record of Design and Construction*, 41.

37. *Ibid.*

38. *Ibid.*, 43-4.

the prime contractor excavated over 1,000,000 cubic yards of material in each of four consecutive months. In November, 1949, 1,334,000 cubic yards were excavated, and 1,043,000 cubic yards placed, both records.³⁹

Much of the testing performed prior to the start of construction had to do with soil permeability. Tests revealed a high degree of consolidation of materials in the right abutment when saturated. Consolidation is the process whereby, under certain circumstances, individual soil particles combine to form a more firm and stronger mass. Laboratory tests revealed that when saturated with water, the materials in the right embankment became highly consolidated. To take advantage of these circumstances, the designers called for the pre-consolidation of the right abutment for 60 days prior to the placement of embankment material. The pre-consolidation was accomplished by flooding of a series of dikes constructed on the abutment. Flooding was maintained until the desired level of saturation had been reached. The consolidation program was initiated on March 1, 1950, and, approximately 100 million gallons of water was required to complete the program.⁴⁰

Most often with the construction of earthfill dams, the materials used in construction are taken from nearby areas. At times though, proper materials are not available in the area and must be hauled in from other areas. This was the case with riprap materials used at Bonny. During investigations prior to the construction of Bonny Dam, it was determined that suitable materials for riprap could not be found in close proximity to the dam site. After investigating several alternative sites, it was determined that best source of material was quarries near Golden, Colorado, 180 miles away. Cost of transport alone was near \$1,000,000.⁴¹

On February 27, 1950, the contract for clearing the reservoir site was awarded to the Asbell Brothers of Riverton, Wyoming. The company started work immediately and finished clearing operations by mid-April. On July 2, the high pressure gate and jet valves in the outlet works were successfully tested, and on July 6, the diversion channel was closed and storage of

39. Project History, Vol. I, 1949, 38; Reclamation Dedicates Its Bonny Dam, *Engineering News-Record*, 5 June 1952, 25.

40. Reclamation, *Technical Record of Design and Construction*, 12, 44.

41. *Ibid.*, 13; USBR Seeks to Avoid Cost of Importing Riprap, Studies other Slope Protection, *Engineering News-Record*, 26 April 1951, 48.

water began. On August 4, water passed through the completed outlet system for the first time. By the end of 1950, 98% of the work had been completed, while only 53% of the contract period for construction had elapsed.⁴²

The construction of Bonny Dam provided the Bureau with the opportunity to conduct a number of tests. Although the properties of earthfill materials can be determined through laboratory testing, Reclamation installs test equipment in most of its earthfill dams to monitor the behavior of the embankment and other structures during construction and post construction operations. Prior to construction of Bonny Dam, Reclamation had no information on the performance of dams constructed of materials similar to those used at Bonny. Since this information was of great value to Reclamation, construction of the dam included several test installations.⁴³

In order to monitor the behavior of the embankment, the Bureau installed three piezometer monitoring sites, six embankment settlement units, seven foundation settlement units, and several surface settlement points. Piezometer installations are designed to monitor conditions within embankments and foundations, and transmit that information to terminal wells. Embankment settlement installations detect and measure consolidation and settlement, lateral displacement, and seepage within the embankment. Foundation settlement installations measure the vertical movement of the foundation caused by the load of the embankment, while surface settlement points are used to measure the surface movement and settlement of the embankment. Preparations for the installation of the test installations were completed by the prime contractor as part of the construction contract for the dam, but installation of the test apparatus were carried out by the Government.⁴⁴

Availability of suitable riprap material was a problem on many Great Plains dam projects. At Bonny, Reclamation constructed a test section to investigate the use of alternative materials in place of riprap. The materials that the Bureau tested as substitutes for riprap were hot-mix asphaltic concrete and compacted soil-cement. These materials were chosen after

42. Project History, Vol. I, 1950, xi-xii, 30, 33.

43. Reclamation, *Technical Record of Design and Construction*, 73.

44. *Ibid.*

almost two years of study at the laboratories of the chief engineer in Denver. Reclamation built the test embankment in an area that would be subject to the actual field conditions of wave action, freezing and thawing, wind erosion, reservoir drawdown, and all other conditions that slope protection would encounter. Initial results led to the use of asphaltic concrete on other Reclamation projects.⁴⁵

Large construction projects such as Bonny, employ a large number of workers. Many of those workers choose to live near the project, and many have families with children. In order to accommodate the increased number of children living in the area, the Utah Construction Company enlarged the school at Hale, employed two teachers, and ran buses to Arnel for the high school children.⁴⁶

A number of problems plagued construction of Bonny Dam and Reservoir. During the winter months, high winds and blizzard conditions halted work on several occasions. During summer months, high temperatures caused some delays. Rain and floods delayed construction several times. In May and June 1949, rain and high water halted construction for a total of 26 days. The same was true in August of 1950, when rains stopped embankment placement operations for 11 days. Some delays were also encountered due to labor problems. In January 1950, truck drivers hauling riprap from the railhead at Burlington went on strike, halting deliveries for several days. In June 1950, a railroad strike halted deliveries of riprap materials for 10 days. Even with delays, work on the project was completed 17 months ahead of schedule.⁴⁷

Bonny Dam is a modified, homogeneous, rolled earth-fill dam, 9,200 feet long with a height of 158 feet from the base of the foundation to the top of the crest. The crest is 30 feet wide, and the maximum width of the base of the dam from upstream toe to downstream toe is 980 feet. The volume of material in the dam is almost 9,000,000 cubic yards. Overflows are handled through a concrete overflow crest spillway in the left abutment of the dam. Located within the structure of the spillway is a partially controlled sluice way 16 and a half feet wide by

45. *Ibid.*, 85-6.

46. Project History, Vol.1, 1949, 24.

47. *Ibid.*, Vol.1, 1950, xi; Reclamation, *Technical Record of Design and Construction*, 71-2; Reclamation Dedicates Its Bonny Dam, 25.

21 and a half feet high. A 16 and a half foot by 10 and a half foot gate provides partial control of flows through the sluiceway. The crest of the sluiceway is 36 feet lower than that of the spillway. The outlet works consist of a trashrack structure and a 4-foot 8-inch diameter concrete conduit leading from the trashrack to a gate chamber. The gate chamber, which is buried in the dam embankment, contains a 4-foot by 4-foot high pressure gate. The gate chamber is connected to two valve houses by a 56-inch steel outlet pipe. Access to the gate chamber is through an 8-foot 2-inch diameter concrete conduit that also houses the outlet pipe. Each valve house has one, 24-inch hollow jet valve to control flow. One valve controls the flow to the river outlet, and the other to Hale Ditch. The total volume of concrete used in the spillway and outlet works was 31,446 cubic yards. The reservoir has a capacity of 170,160 acre feet, and a surface area of over 5,000 acres. The maximum flow capacity of the spillway is 73,300 cubic feet per second with the maximum capacity of the outlet works 200 cubic feet per second.⁴⁸

Post Construction History

Bonny Dam and Reservoir were completed and accepted by Reclamation on May 4, 1951, and transferred from construction to operations and maintenance (O&M) on May 15, 1951. Dedication took place on June 1, 1952, with the principal address being give by Michael W. Straus, the Commissioner of the Bureau of Reclamation. Since its transfer to O&M, the facility has experienced no major operational problems. The outlet works and embankment have performed as expected, with only minor modifications needed. The spillway spilled for the first time during flash floods in June 1955. In 1952, the State of Colorado and the Federal Government signed an agreement whereby the Colorado State Game and Fish Commission would administer recreation activities at the site, and in 1968, the Fish and Wildlife Division constructed several fish spawning beds at Bonny.⁴⁹

In January 1970, after renewed interest in the development of irrigation using water from

48. Water and Power Resources, *Project Data*, 797; Reclamation, *Technical Record of Design and Construction*, frontispiece, 107; United States Department of Interior, Bureau of Reclamation, *Designers Operating Criteria: Bonny Dam, St. Francis Unit, Upper Republican Division, Missouri River Basin Project, Colorado* (Denver: U.S. Government Printing Office, 1964), 16-7.

49. Project History, Vol.I, 1950, iv; Vol.XIX, 1969, 3; Reclamation Dedicates Its Bonny Dam, 25; United States Department of Interior, Bureau of Reclamation, SEED Report of Bonny Dam, Pick-Sloan Missouri Basin Program, Colorado, Missouri Basin Region, (September 1986), Sec. C-1, 11.

Bonny Reservoir, investigations into the feasibility of construction of irrigation facilities were initiated. In March 1977, after several years of investigation, the final report was issued. The report concluded that, because an economically feasible plan could not be worked out, all studies into the development of irrigation using project water should be discontinued.⁵⁰

Settlement of Project Lands

Since the Bonny Dam and Reservoir are mainly used for flood control, there are no project lands that have been opened for settlement. Studies into the feasibility of using project water for irrigation purposes have shown that such development would be economically unfeasible. Until this situation changes, it seems highly unlikely that any settlement will occur.

Uses of Project Water

Although originally designed as a multi-use project, the Bonny Dam and Reservoir are used primarily as a flood control project, providing a high degree of flood control for the upper portions of the Republican River. Although the reservoir provides water to the Hale Ditch, the use of project water to irrigate additional lands as been shown to be economically unfeasible. Outside the benefits as a flood control project, the dam and reservoir support a wide variety of recreational activities as the opportunities for quality water based recreational activities are limited in this part of Colorado. Activities include boating, fishing, hunting, and camping. The recreational activities at the site are managed by the Colorado Division of Parks and Recreation, and the annual number of visitor days at the reservoir has been as high as 180,000. In addition to management of the recreational facilities, the State of Colorado operates a fish hatchery at the site.⁵¹

Conclusion

A plaque located near the west entrance of the Bureau of Reclamation's Engineering and Research Center in Denver has the following inscription:

Dedicated to the Enhancement of Natural
Resources for the Benefit of Mankind

50. Reclamation, "Armstrong Unit, Concluding Report," I-1, VI-2.

51. Water and Power Resources, *Project Data*, 795, 797; Reclamation, "Armstrong Unit, Concluding Report," II-6.

Although designed as a multipurpose unit, the Bonny Dam and Reservoir has not lived up to the expectations of its builders. Even so, in the 24 years following the start of operations, the flood control benefits have prevented an average of over \$90,000 in damage from flooding in the Republican River Basin each year. This fact, coupled with the recreational and wildlife enhancing qualities of the unit, has made the project extremely beneficial to those who live in the area.⁵²

About the Author

William Joe Simonds was born and raised in Colorado and has a solid understanding of the importance of water in the American West and its effect on the development of that region. He attended Colorado State University where he received a BA in History in 1992 and a Masters in Public History in 1995. He lives with his wife and two children in Fort Collins, Colorado.

52. Reclamation, "Armel Unit, Concluding Report," IV-3.

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Index

Adams County, Colorado	9
Adams-Onís Treaty of 1819	5
Arapahoe Indians	4, 6
Arikaree River	8, 10
Arkansas River	5, 7
Armel, Town of	15
Asbell Brothers, Contractors	11, 13
Barnes Ditch	11
Battle of Beecher's Island	8
Battle of Cedar Creek	7
Battle of Summit Springs	8
Battle of Washita	8
Beecher, Lt. Frederick	8
Bent's Fort	6
Berkeley Steel Construction Company, Inc.	11
Black Kettle	
Cheyenne chieftain	7, 8
Bonny Dam	2, 10, 13-18
Bonny Dam and the access road	
Bonny Dam and access road	11
Bonny Reservoir	2, 10, 15-18
Bureau of Reclamation	10, 14, 16
Engineering and Research Center in Denver	17
Burlington	2, 15
Burlington and Missouri River Railroad	9
Canadian River	5
Carr, General Eugene E.	8
Cedar Village	4
Cheyenne Indians	4, 6-8
Cheyenne, Wyoming	8
Chivington, Colonel John M.	7
Civil War	7
Climate	2
Colorado	3, 4
Colorado Division of Parks and Recreation	17
Colorado Springs	6
Consolidation	13
Contractors	
Asbell Brothers, Contractors,	11, 13
Berkeley Steel Construction Company, Inc.	11
Northwest Marine Iron Works of Portland, Oregon	11
Pacific Coast Engineering Company of Alameda, California	11
Utah Construction Company of San Francisco	11
Valley Iron Works of Yakima, Washington	11
Wooldridge Manufacturing Company of Sunnyvale, California	11
Wooldridge Manufacturing Company0	11
Contracts	12
caretaker's house	12
clearing	11
high-pressure gate	11
hollow-jet valves	11
outlet pipe	11
sluiceway control gate	11
water supply	12

Coronado, Francisco Vasquez de	4
Corpus Christi, Texas	9
Custer, Colonel George A. 7, 8	7, 8
Denver	6-8, 15, 17
Downing, Major Jacob	7
Eckley	9
Evans, John	7
First Colorado Regiment	7
Forsyth, Major George A. 8	8
Fort Lyon	7
Fountain Creek	6
Frémont, John C. 6	6
Golden	13
Greeley	7
Hale Ditch	11, 16, 17
Hale, Town of	2, 15
James, Edwin	5
Julesburg	7
Kansas Pacific Railroad	8
Laird	9
Limon	4
Lincoln Land Company	9
Long, Major Steven H. 5	5
Louisiana purchase	5
Mallet	
Paul	4
Pierre	4
Manifest Destiny	6
Mississippi River	5
Mississippi Valley	5, 6
Missouri Basin Program - Armel Unit	2
Bonny Dam	2, 10, 11, 13-18
Bonny Reservoir	2, 10, 15-18
St. Francis Unit	2
Missouri River Basin	10
Missouri River Basin Plan	10
Newton Ditch	11
North Plate River	4
Northwest Marine Iron Works of Portland, Oregon	11
Oregon Migration	6
Overland Trail	8
Pacific Coast Engineering Company of Alameda, California	11
Pawnee Indians	4, 6
Pick, Major General Lewis A. 10	10
Pick-Sloan Plan	10
Pike's Peak	5
Recreation	17, 18
Republican River	2, 3, 6, 10, 17, 18
Republican River Basin	11
Republican River Trail	6, 8
Roman Nose, Cheyenne Leader	7, 8
Russell, William Green	6
San Luis Valley	5
Sand Creek	7
Sante Fe Trail	8

Sioux Indians	6
Sloan, William G.	10
Smoky Hill River	5, 6
Smoky Hill Trail	6, 8
South Platte River	3-5, 7
South Platte Trail	8
Spanish	4
St. Francis, Town of	2
Straus, Michael W.	16
Tall Bull, Cheyenne Leader	8
Third Colorado Volunteers	7
Treaty of Fort Wise	7
Treaty of the Little Arkansas	7
Twenty-First Outfit	9
U.S. Army Corps of Engineers	10
Ulibarri, Juan de	5
Union Pacific Railroad	8
Upper Republican River Basin	2
Utah Construction Company	11, 15
Valley Iron Works of Yakima, Washington	11
Vegetation	2
Vial, Pedro	5
Villasur, Pedro de	4
Washington County, Colorado	9
Wildlife	2, 18
Willamette Iron and Steel Company of Portland, Oregon	11
Wooldridge Manufacturing Company of Sunnyvale, California	11
Wray	2, 9
Yuma County, Colorado	9, 10
Yuma, Town of	9