NPS Form 10-900
(Rev. 10-90)

OMB No. 1024-0018

883

United States Department of the Interior
National Park Service

NATIONAL REGISTER OF HISTORIC PLACES REGISTRATION FORM

1. Name of Property

historic name: Pensacola Dam

other names/site number Grand River Dam

2. Location

street & number State Highway 28 over Grand River, ½ mile east of intersection with State Highway 82
not for publication N/A city or town Langley vicinity X
state Oklahoma code OK county Mayes code 097 zip code 74301-4603

3. State/Federal Agency Certification

As the designated authority under the National Historic Preservation Act of 1966, as amended, I hereby certify that this _X_ nomination ____ request for determination of eligibility meets the documentation standards for registering properties in the National Register of Historic Places and meets the procedural and professional requirements set forth in 36 CFR Part 60. In my opinion, the property _X_ meets ____ does not meet the National Register Criteria. I recommend that this property be considered significant ___ nationally _X_ statewide _ locally. (N/A See continuation sheet for additional comments.)

7-21-03

Signature of certifying official Date

Oklahoma Historical Society, SHPO

State or Federal agency and bureau

In my opinion, the property ____ meets ____ does not meet the National Register criteria. (___ See continuation sheet for additional comments.)

Signature of commenting or other official Date

State or Federal agency and bureau

4. National Park Service Certification

I, hereby certify that this property is:

_√_ entered in the National Register

___ See continuation sheet.

____ determined eligible for the National Register

___ See continuation sheet.

____ determined not eligible for the National Register

____ removed from the National Register

____ other (explain):

SEP 2 2003

Signature of Keeper Date of Action

5. Classification

Ownership of Property (Check as many boxes as apply)

_ private
_ public-local
X public-State
_ public-Federal

Category of Property (Check only one box)

_ building(s)
X district
_ site
_ structure
_ object

Number of Resources within Property

Contributing	Noncontributing	
2	1	buildings
___	___	sites
4	___	structures
___	___	objects
6	1	Total

Number of contributing resources previously listed in the National Register 0

Name of related multiple property listing (Enter "N/A" if property is not part of a multiple property listing.) N/A

6. Function or Use

Historic Functions (Enter categories from instructions)
Cat: INDUSTRY/PROCESSING/ EXTRACTION Sub: energy facility

Current Functions (Enter categories from instructions)
Cat: INDUSTRY/PROCESSING/ EXTRACTION Sub: energy facility

7. Description

Architectural Classification (Enter categories from instructions)
OTHER: Multiple Arch Dam
MODERN MOVEMENT: Moderne

Materials (Enter categories from instructions)
foundation CONCRETE
roof ASPHALT
walls CONCRETE

other

Narrative Description (Describe the historic and current condition of the property on one or more continuation sheets)

8. Statement of Significance

Applicable National Register Criteria (Mark "x" in one or more boxes for the criteria qualifying the property for National Register listing)

___ A Property is associated with events that have made a significant contribution to the broad patterns of our history.

___ B Property is associated with the lives of persons significant in our past.

_X_ C Property embodies the distinctive characteristics of a type, period, or method of construction or represents the work of a master, or possesses high artistic values, or represents a significant and distinguishable entity whose components lack individual distinction.

___ D Property has yielded, or is likely to yield information important in prehistory or history.

Criteria Considerations (Mark "X" in all the boxes that apply.)

____ A owned by a religious institution or used for religious purposes.

____ B removed from its original location.

____ C a birthplace or a grave.

____ D a cemetery.

____ E a reconstructed building, object, or structure.

____ F a commemorative property.

____ G less than 50 years of age or achieved significance within the past 50 years.

Areas of Significance (Enter categories from instructions)
ENGINEERING

Period of Significance 1938-1940

8. Statement of Significance (Continued)

Significant Dates 1938
1941

Significant Person (Complete if Criterion B is marked above)
N/A

Cultural Affiliation N/A

Architect/Builder Forsythe, John Duncan, Architect
Holway, W.R., Contractor

Narrative Statement of Significance (Explain the significance of the property on one or more continuation sheets.)

9. Major Bibliographical References

(Cite the books, articles, and other sources used in preparing this form on one or more continuation sheets.)

Previous documentation on file (NPS)
X preliminary determination of individual listing (36 CFR 67) has been requested.
_ previously listed in the National Register
_ previously determined eligible by the National Register
_ designated a National Historic Landmark
_ recorded by Historic American Buildings Survey # ________
_ recorded by Historic American Engineering Record # ________

Primary Location of Additional Data
X State Historic Preservation Office
___ Other State agency
___ Federal agency
___ Local government
___ University
_ Other
Name of repository: ____________________

10. Geographical Data

Acreage of Property 57 acres more or less

UTM References (Place additional UTM references on a continuation sheet)

	Zone	Easting	Northing		Zone	Easting	Northing
1	15	318540	4038480	3	15	317090	4037510
2	15	318600	4038390	4	15	317020	4037630

Verbal Boundary Description (Describe the boundaries of the property on a continuation sheet.)

Boundary Justification (Explain why the boundaries were selected on a continuation sheet.)

11. Form Prepared By

name/title Glen Vaughn-Roberson/Director of the Certified Local Governments Program for Oklahoma

Organization State Historic Preservation Office date June 17, 2003

street & number 2704 Villa Prom, Shepherd Mall telephone 405/521-6329

city or town Oklahoma City state Oklahoma zip code 73107-2441

Additional Documentation

Submit the following items with the completed form:

Continuation Sheets

Maps

A USGS map (7.5 or 15 minute series) indicating the property's location.

A sketch map for historic districts and properties having large acreage or numerous resources.

Photographs

Representative black and white photographs of the property.

Additional items (Check with the SHPO or FPO for any additional items)

Property Owner

(Complete this item at the request of the SHPO or FPO.)

name Grand River Dam Authority

street & number 707 South Wilson Street telephone 918/256-5545

city or town Vinita state Oklahoma zip code 74301-4603

Narrative Description

The Pensacola Dam Complex, the first hydroelectric system and flood control facility in Oklahoma, is located on the Grand River, a major contributor to the Arkansas River basin system, between the towns of Disney and Langley in Mayes County, Oklahoma. The old water channel of the Grand River is approximately one mile wide at the dam site. On the west side of the channel, almost vertical cliffs of limestone and chert extend upward some 850 to 900 feet above the floor. On the east side, the rock surface slopes gently upward 900 feet above the center of the channel bottom. Experienced engineers considered limestone and chert, "ideal" rock for the foundation of a multiple arch dam.

Three buildings - a powerhouse, a substation, and an observation house - and four structures – the multi-arched Pensacola Dam(in some places referred to as the Grand River Dam), two spillways, and a pumping/intake structure situated on the up stream west end of the dam - compose the district. The architecture of the powerhouse and observation house expresses a Streamline Moderne style with rectangular gray concrete buildings that are shaped like machines for the purpose of housing machines. The windows, balustrades, buttresses, flat roofs, and rounded corners of the buildings accentuate the horizontal and understate the vertical to compliment what Oklahomans acclaim to be the longest multi-arched dam in the world. Across the top of the dam, the two-lane, blacktop State Highway 28 runs like a giant black ribbon for over a mile connecting the two towns. At night, 1400 lights on poles set into the curbs illuminate the road. The dam impounds The Grand Lake O' The Cherokees, a 43,500 acre-lake with 1,300 miles of shoreline.

DESCRIPTION

The concrete multiple arch Pensacola Dam - sometimes called the Grand River Dam - with its gated spillways stands as the central feature of the complex (photograph # 1). The top of the dam sits 150 feet above bedrock. Advertised as the longest multi-arched dam in the world, the fifty-one arch barrels section traverses the Grand River for 4,284 feet; the length of the dam plus the spillways total 6,565 feet. The arch section arises 140 feet in height from its bedrock foundation to its crown. The arches rest on double-wall hollow buttresses measuring eighty-four feet center to center (photograph # 2). The clear span of each arch is sixty feet wide at its base tapering to twenty-four feet at its top (photograph #1). The arches slope at a 45-degree angle. The barrel walls of the reinforced concrete arches begin at four feet four inches in thickness at the bottom and taper to a thickness of two feet four inches at the crown. (Photograph 4). Each buttress consists of an upstream transverse slab twenty-four feet wide. The sidewalls of each buttress change in thickness from five feet at the foundation to two feet two inches at its top. Inside each buttress, transverse walls eighteen inches thick and placed twenty-eight feet apart in centers, arise from the foundation, run parallel to the front wall, and act as stiffeners." The sidewalls are sloping planes, descending one and one half inches horizontal to one inch vertical. These buttresses are wider than were any double-wall buttresses built prior to 1938 and were designed to withstand compressed water pressure up to 500 pounds per square inch.

The three gravity type gated spillways sit on the Disney or east side of the valley 185 feet above the valley floor (photographs 11 & 12). The main spillway, 861 feet long, is a part of the dam (photograph # 6). The two smaller spillways sit a little less than one mile further east on the valley cliff facing the southwest. The plane of the spillway, from gate to river bottom, are shaped in an elongated S fashion (photograph #6) -- an ogee. At the main spillway, two sixty-ton hoists operate twenty-one tainter gates that stand twenty-five feet high and thirty-six feet wide. The floodgates' lip is at elevation 730 and the top of the gates are at elevation 755. The floodgates sit on steel reinforced concrete piers measuring five feet wide. It is at the top of the main spillway where the State Highway 28 roadbed with its cement rail of balustrades (photograph #3) begins its run westward across the spillway and over the multiple arch dam to where the entire structure abuts with the exposed rock cliffs on the western side of the valley. The bridge has a twenty-foot roadbed and a four-foot sidewalk that runs the length of its upriver side (photograph #3). Arches sit on reinforced concrete girders and support the bridge section over the spillway. Along the multiple-arch section, girders rest on top of spandrel arch barrels to supply support for the bridge on the upstream side, while open spandrel arches extend out from the buttresses to support the bridge on the downstream side. The two smaller spillways have a total of twenty-one gates, each thirty-seven feet wide and fifteen feet high. Piers, five feet wide and measuring forty-one feet center to center, support the gates and a highway bridge similar to that of the main dam. (photographs #11 & #12)

Adjacent to the west side of the canyon on the down river side of the dam sits the Streamline Moderne styled, concrete-walled, five-story powerhouse (photograph # 1) designed by John Duncan Forsyth, a master architect in the state of Oklahoma. Forsyth is best known for his local creations of the Marland Mansion in Ponca City (a National historic Landmark), the Lamerton House in Enid, listed in the National Register of Historic Places, and the Will Rogers Memorial in Claremore. The entire powerhouse building is 279 feet long, seventy-two feet wide, and eighty feet high. Standing outside of the building and looking north at the south wall of the powerhouse one sees a flat roof. Under it twelve bay sections fashioned by recessed vertical grooves divide the wall (photograph # 13). The observer also sees stretch bands of glass block windows, three rows of twelve windows per bay. The fourth floor, which bumps out from the fifth floor, also has a flat roof. Rectangular bands of six windows in groups of three on top and three underneath per bay interrupt the smooth straight lines of the natural-colored facade of nine bay sections. Glass block windows run continuous around the curved southeast corner of this floor (photograph # 13). A tall round ornamental light fixture of the Art Deco style stands left of the current main entrance located on the east end of the building. (Photograph # 15). Moving to the west side of the building, the observer finds affixed six feet up from the ground on the wall on each side of the former main entrance, two Art Deco light fixtures, replicates of the larger one standing the east side. (Photograph #14). On the dam side of the powerhouse, the north wall is of solid natural color concrete with a row of natural light bay windows along the top floor. From these windows one can see the six penstocks (water pipes) (photograph #9) carry water under pressure from the pumping/intake building, located on the up-river side of the dam, through the dam arches, and into the bottom floor of the two story basement. From there, somewhat narrower penstocks deliver the water under tremendous pressure to the turbines. The speed rings, scroll cases, and turbine shafts are located in the top floor of the basement. Here one sees further examples of the Streamline Moderne style in the rounded overhead corners and curved inlaid lights of the turbine shaft access stations (photograph # 17). Six turbines with a total electricity generating capacity of 92 megawatts sit in a line that extends three-quarters of the length of the building join an eight-foot high power switchboard standing behind a ten-foot high glass wall to dominate the ground floor (photograph #16). The two top floors (fourth and fifth) are filled with various types of cranes, pulleys, observation platforms, and crosswalks. The turbines are powered by undershot waterwheels (photograph #17) fed by steel pipes running below the dam from the intake house. (photographs #9 & #10)

The upstream side of the dam sees the rectangular concrete pumping/intake structure rising 150 feet from the bottom of the Grand Lake O' The Cherokees. Thirty buttresses, fifteen on each of the two lengthy sides, provide additional support to the walls. A balustrade runs the entire length of the south side of the flat roof and continues around corners to extend along the shorter east and west sides. The north side of the roof has an iron railing painted white. A seventy-foot walkway with balustrades that match those on the roof of the pumping/intake house connects the building to the dam (photograph # 7).

The substation sits on the summit of the west cliff. A twelve-feet in diameter tunnel containing power cables and a 100-foot elevator shaft runs to the powerhouse. The substation is a two by two-asymmetrical concrete building of a flat roofed one-story wing-extending west joins the flat roofed two-story wing. Both wings have rectangular bay windows (photograph # 8).

The observation house completes the facility. The natural color concrete asymmetrical building has three sections, all of differing heights. The rectangular shaped main section has a flat roof and bay windows along the south and east walls. Extending from the east wall is another one-story flat roof section with curved corner edges. The final section stands two stories tall and serves as the north part of the building. The observation house is a noncontributing structure due to the additions made to the building in the 1980s and the 1990s.

Statement of Significance

The Pensacola Dam Complex is eligible for the National Register of Historic Places under Criterion C as the first hydroelectric facility in the State of Oklahoma and for being the only Oklahoma example of a multiple-arch dam. The Pensacola Dam Complex is used today exactly as it was first intended when the dam open in March of 1940. The entire complex was completed in November of 1941 at a total cost of $21 million. With the exception of the observation house, which has had two additions since 1940, the remainder of the facility has maintained its historic and engineering integrity.

Historical Summary

The story of the Pensacola Dam Complex begins in the summer of 1895, when Henry Holderman, a Cherokee Nation citizen, his brother, Bret, and two engineering students from the Spaulding Institute in Muskogee, Indian Territory stepped into a twenty-foot houseboat moored just south of the present day Kansas-Oklahoma (known in those days Indian Territory) border and began to pilot one hundred and twenty-five miles down the length of the Grand River. Now and then, the party paddled ashore whenever they encountered sites along the way that looked like feasible dam locations. Holderman would then hammer steel spikes into the ground to mark the spots. When the journey ended at the confluence of the Grand River with the Arkansas River, just south of Ft. Gibson, the party of four had completed the first engineering survey of the Grand River.(1)

It was only the first of many steps Holderman would take to bring hydroelectric power to the Cherokee people. At the age of sixteen, Holderman, armed with a fifth grade education, left Indian Territory and the Grand River to travel the world. During t he coming years, he worked on dam projects in Africa and India, where he learned the principals of engineering and the fundamentals of flood control and irrigation. He returned to Indian Territory a young man with a fortified dream. He would bring electricity and flood control to the farmers, shopkeepers, and ranchers living within the Cherokee Nation; he would build his dam across the Grand River. He sold his land holdings, and in later years those of his wife's and children's, to raise money to secure the rights to the prospective dam sites he had found. When that money ran out, he borrowed thousands of dollars from friends, fought with lawyers and utility company executives, and even served time in jail for inadvertently cashing a worthless check while struggling to finance his crusade. Three times he nearly saw his dam built. Once in 1914, a consortium of British capitalists agreed to build the dam. But Germany invaded Belgium just as excavation was to begin and all plans ended. In 1920, news of "Holderman's dam" reached Chicago businessmen who agreed to issue twenty million dollars in stock to finance construction. Fearing the Chicago investors were more intent on engineering a "get-rich-scheme" and not a dam, Holderman vetoed the deal. Nine years later, Canadian investors and engineers went so far as to conduct their own survey and drill core samples at the sites, only to have the stock market crash of 1929 destroy their plans.(2) As the nation dove deeper into economic depression, Holderman began to tell friends he feared his dam would never be built.

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1 "Henry C. Holderman – Indian Genius," The West, November 1968, 12.
2 Ibid, 15

But it was in the mist of the Great Depression that state and federal government officials began to investigate the merits of Holderman's crusade. In 1931 the federal government authorized the U.S. Army Corps of Engineers to include the Grand River as part of a larger study on flood control along the Mississippi River Valley. Although the Corps' conclusions recommended that flood control along the Grand and Arkansas watershed was of local importance only and that there was no need for federal government action, they did print the report for any persons interested in the findings. It is this Corps report that is first to list the "Pensacola site," as a possible site for a dam. Finding no better way to identify the location, the engineers named it after a store sitting on a dilapidated Cherokee plantation that had been established in 1840 by Joe Martin from Georgia.(3)

The Corps of Engineer's report found an interested audience in the form of the Oklahoma State Legislature. After a long, heated debate between those legislators who wanted an electricity producing entity modeled on the Tennessee Valley Authority (TVA) and those of the legislature who spoke in opposition on behalf of the utility companies the state legislature passed an Enabling Act creating the Grand River Dam Authority (GRDA) in April 1935.(4) Like the famous TVA, its function was to administrator a "conservation and reclamation district," that consisted of fourteen counties in Northeast Oklahoma.(5) The legislation further granted authority to the GRDA to develop hydroelectric power and to control flooding along the Grand River. Four months after the legislation went into effect, the first Board of Directors consisting of nine men, led by J. Howard Langley of Pryor as chairman, held its first meeting.(6)

Now that the organization was up and running, the next obvious issue at hand was funding. For that, the Board of Directors and the State Legislature turned to elected officials in Washington, primarily, Senator Thomas Gore and Congressman Wesley E. Disney, whose congressional district included the fourteen counties of the GRDA. For two years these men introduced legislation to create funding. They formed legislative alliances with fellow congressional members, especially with men such as Senator George Norris of Nebraska, who was leading his own battle to bring hydroelectricity and flood control to the Mississippi River Valley and Nebraska. They lobbied members of the Roosevelt administration, especially Harold Ickes, the Secretary of the Interior, who oversaw the vast Public Works Administration that dispensed funding for bridges, dams, and other water related projects. The argument continuously put forth by the Oklahomans centered on the thousands of impoverished farmers living in rural areas of eastern Oklahoma who longed for inexpensive electricity.(7) When they had electricity to sell, and there were times when they did not, the private electric companies charged seventeen cents per kilowatt-hour. The board members of the GRDA were convinced a well constructed, intelligently operated hydroelectric plant could generate electricity cheap enough to sell for as little at five to seven cents per kilowatt-hour and still allow the authority to make a profit.(8) Senator Gore and Congressman Disney also trumpeted the prospects of irrigation and flood control within the Grand River

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3W.R. Holway, A History of the Grand River Dam Authority, State of Oklahoma, 1935 – 1968 (Tulsa, Oklahoma: by the author, 1968), 5.

4Oklahoma State Senate, Senate Committee on Waters and Water Courses, Grand River Authority, 15th session, 1936. Supplement Senate Bill 395, 2.

5Ibid.

6Eldon L. Jackson, "History of the Grand River Dam," (Master's thesis, Oklahoma Agricultural and Mechanical College, 1939), 21.

7Wesley Disney, "Why Build the Grand River Dam?" (Speech, date delivered unknown) Wesley Disney Collection, Box 2, Folder 2, Carl Albert Center, University of Oklahoma, Norman.

8Wesley Disney to E. W. Marland, 10 October 1936, typed, Wesley Disney Collection, Box 1, Folder 2, Carl Albert Center, University of Oklahoma, Norman.

watershed. Never to be overlooked was the vision of thousands of men put to work building what was being called during this pre-construction phase, the Grand River Dam nor the hundreds of new full-time jobs running the dam would create. In 1937, after several delays, President Roosevelt gave his personal approval. Secretary Ickes and the Board of Directors signed a contract in August of 1937 for $11,563,000 as a loan and $8,437,000 as a grant to build the newly renamed, Pensacola Dam.(9) The GRDA, now assured of cash, issued its first in a series of revenue bonds that would eventually total seven million dollars. The Authority hired W. R. Holway of Tulsa to serve as the Chief Engineer and, with encouragement from Secretary Ickes, chose R. L. Wright from California as General Manager. The General Contractor was Massman Construction out of Kansas City, Missouri. The Authority settled on Vinita, Oklahoma as its headquarters.(10)

From his first days of being involved in the project, Holman was intent on building a multiple arch dam instead of a massive gravity dam more common in the United States. There were several reasons to contemplate using multiple-arch construction. The limestone bedrock surveys found that the bottom of the Grand River Canyon floor was perfect. No one need fear the dam might slip on the bedrock and crack the walls. Second, multiple arched dams were less costly to construct. In this case, Holman calculated the difference in cost would run to at least two million dollars.(11) The lion's share of those savings would be in the needed amounts of concrete, steel, and other materials, always a construction concern during the depression. Last, multiple arched dams had one more attribute especially persuasive during the depression and especially popular with Secretary Ickes and his PWA – it would require significant manpower to construct. Especially needed would be men with skills; some times, unusual skills, such as the ship builders from New England towns who would come to the dam site to construct the boat-shaped forms for the huge arches into which tons of concrete were poured. More men would be needed who had the ability to piece together and lay the penstock tubes that would carry millions of gallons of water to the turbines. In early 1937, Holway and the Board of Directors hired Victor H. Cohrane as a consultant engineer. Cohrane had exhibited valuable expertise as the designer of the Buchanan Dam, a multiple arch dam in Texas. Cohrane also held patents on the type of hollow buttresses Holway saw as necessary for building a safe dam at an economical price.

Workers turned the first shovel of dirt in February 1938. Contractors first built cofferdams on the east side of the river. The east cofferdam remained until the arches of the main dam were well above ordinary high water levels. Workers removed the east cofferdam and then on the west side of the river built another one to divert water flow away from the nascent Powerhouse. By the time workers closed the gates of the dam in March of 1940, contractors and sub-contractors had employed over 3,000 men – ninety per cent of whom were from Oklahoma. Workers earned sixteen dollars per week, operated in shifts around the clock, and generated a little over a million man-hours of work.(12) Because the twenty-six months of construction included the eighteen driest months of record in eastern Oklahoma, workers finished the dam months ahead of schedule.

9Virginia Smith to Senator Elmer Thomas, 16 September 1937, telegram, Elmer Thomas Collection, Box 6, Folder 16, Carl Albert Center, University of Oklahoma, Norman; U.S. Russell, "Grand River Hydro-electric Project is Approved," Harlow's Weekly, no date, Wesley Disney Collection, Box 1,
Folder 7, University of Oklahoma, Norman.

10W. R. Holway to Senator Elmer Thomas, 10 October 1937, Elmer Thomas Collection, Box 6, Folder 16, Carl Albert Collection, University of Oklahoma, Norman; Miami Daily News Press, October 22, 1937, 1.

11Holway, A History of the Grand River Dam Authority, section VII, 16.

12Grand River Dam Authority, "Pensacola Dam, Grand Lake O' the Cherokees, pamphlet, (Vinita, Oklahoma: GRDA, 2002), 3.

During that time, workers excavated 2,870,000 cubic yards of earth, 590,000 cubic yards of rock, poured 655,000 barrels of cement, 535,000 cubic yards of concrete, used twenty million pounds of reinforcing steel, ten million pounds of structural steel, and seventy-five thousand pounds of copper. The total cost of construction came to twenty-seven million dollars.(13)

In November of 1941, just before stringing the power lines that would complete the entire project, the federal government, under authority given to it by the Federal Power Act, took control of the entire complex to utilize hydroelectricity for a potential war effort. Pearl Harbor insured federal administration for the length of the war. In the summer of 1946, the federal government returned control of the hydroelectric complex to the GRDA, while the Corps continued to manage the flood control features of the dam, as it does to this day. During the war years, the Pensacola turbines annually produced 180,000,000 kilowatt-hours.(14) Because Holman built the Power Station to have the capacity to house ten turbines, the Authority was able to add two new ones in the 1950s to bring the total to six. The Grand River Dam Authority began a major upgrade project in the fall of 1997. Today, the Pensacola Dam complex generates an average annual energy production of 355,875,000 kilowatt-hours distributed over eighteen eastern and northeastern counties in the State of Oklahoma.(15)

ENGINEERING SIGNIFICANCE

All one needs do to construct a dam is to follow the axiom engineers dub, (George) Dillman's Hydraulic Principle, "construct one water-tight surface and build the remainder of the structure to support that surface."(16) For thousands of years, humans have followed Dillman's dictum – even before Dillman's mother gave birth to him. Dam construction was so widespread among the ancient Egyptians, Greeks, Babylonians, Chinese, and ancestors of Modern European state that archeologists and historians have named these prehistoric cultures as "hydraulic societies."

Whatever era of human history a dam was built, its structure was composed of available materials – earth, stone, concrete, wood, steel, or a combination of any of these, -- strong enough and heavy enough to hold back a large volume of water. Whatever the materials engineers use, the type of dam can be defined by its function and/or its structure. Those dams that receive their strength from their mass are called gravity dams. Gravity dams built of earth and stone professionals call embankment dams. The gravity dam is the most simple to engineer and we find this type in the oldest known dams in the world found in Java. These are by far the most widely built anywhere in the world because they are constructed with materials found in the local area and they can be built with relatively unskilled labor. They are especially popular in the State of Oklahoma for smaller farm ponds. The Grand Coulee dam in Washington State of the early 1940s is an example of a gravity type structure constructed with

13W.R. Holway, "Dams on the Grand River," The Chronicles of Oklahoma, XXVI, no 3, (Autumn, 1948): 332.

14Grand River Dam Authority, "The Grand River Project of Oklahoma," Vertical file at Oklahoma State University, Division of Engineering Special Collections, (Vinita, Oklahoma, 1947): 4.

15Joseph R. Moody, Jr., "Grand River Dam Authority Pensacola Hydroelectric Plan License Amendment to Plant Upgrade," (Vinita, Oklahoma), B1.

16Donald Jackson, Building the Ultimate Dam: John Eastwood and the Control of Water in the West (Laurence, Kansas: University Press of Kansas, 1995), 14.

concrete. An Oklahoma example of a gravity embankment dam is the Canton Lake Dam in Oklahoma constructed during the 1940s by the Army Corps of Engineers. The Tulsa, Oklahoma District Corps of Engineers and the State Historic Preservation Office of Oklahoma have determined by consensus that Canton Lake Dam is eligible for the National Register of Historic Places under Criteria A for it's association with the implementation of the 1936 Flood Control Act.(17)

The buttress dam is the second most widely recognized type of dam. Buttress dams share many of the characteristics of the gravity structures while adopting new technology for building materials, such as steel. With origins going back to early Roman days, the modern buttress dams come from architecture's flying buttresses that gave support to cathedrals of the medieval and renaissance eras. Buttress dams consist of a wall that is the face of the dam and the buttresses that reinforces the face. The weight of the water pressing against the dam pushes down on the structure putting stress not just on the face, but also on the buttresses that direct the stress into the ground.

Solid rock canyon floors and walls can offer the engineers the option of constructing arched dams. While using the same materials as a gravity dam, arch dams need fewer materials and get their strength from the floor and the walls of the canyon. The water pressure pushes against the dam wall, and because the wall is an arch, it disperses the pressure into the canyon walls. Thus, arch dams use nature for support. Hoover Dam, built with much fan fare between 1931 and 1935 is an excellent example of an arched dam of reinforced concrete.

When the dam is composed of a series of arches, engineers call it a multiple arch dam. Within a small degree of variance, all multiple arch dams were constructed in much the same design. Multiple arch dams in our century are of concrete or reinforced concrete with buttresses added for strength. After utilizing Dillman's Hydraulic Principle, the essential aspect of building a successful multiple arch dam is its foundation. In what was considered as "the Bible" for dam construction during the first part of the twentieth century, The Design and Construction of Dams, edited by Edward Wegmann and published in 1924, Fred A Noetzli advised a foundation "founded on, and well 'keyed' (into) solid rock so as to provide safety against sliding between masonry and foundation."(18) If need be, engineers could grout seams in the rock or deep cut trenches. Water seeping where the bottom of the dam met the rock foundation was a common problem to be addressed with construction of all designs of dams. However, because of their lighter weight compared to massive gravity dams, multiple arch dams had the additional issue of literally sliding under water pressure. Trenching and/or grouting were the two accepted practices to prevent sliding. Sloping the arch barrels also attacks the stability issue. If the arch barrels slope at a forty-five to fifty-five degree angle, the water pressure is distributed in a downward direction, not outward, and thus, the water aids its own capture by providing the gravity required to prevent sliding. While cautioning the builder to use exacting formulas for determining the height, slant, and open side width of the arches, Noetzli had this to say about multiple arch dams, " The arches are mainly in compression (due to water pressure) and could ordinarily fail only by crushing of the concrete. This fact gives the arches of multiple-arch dams a large factor of safety, in spite of the relatively thin cross-sections." Noetzli went on to say, "The actual saving in cost, in most cases, has been between 20 percent and 40 per cent."(19)

17Melvena Heisch to David Combs, March 21, 2001, "Canton Lake Dam Safety Project," file 008601, Oklahoma Historical Society, State Historic Preservation Office.

18Fred A. Noetzli, "Multiple-Arch Dams," in The Design and Construction of Dams: Including Masonry, Earth, Structures, Also the Principal Types of Movable Dams, Edward Wegmann and Fred A. Noetzli (London: John Wiley & Sons, Inc., 1927), 439.

19Ibid.

The "exacting formulas" Noetzli was referring to was the "cylinder formula" discovered by Francois Zola in the 1830s:

$$T = \frac{(P \times R)}{Q}$$

T = thickness of the arch
P= hydrostatic pressure
R=radius of the cylinder or arch
Q=maximum allowable stress (20)

In the 1880s, two engineers, James Schuyler and Frank E. Brown from Yale added to the science of arch dam construction with their discovery that if the incline of the arch was at a suitable angle, arch thickness did not have to be the same from the top to the bottom. Viewing an arch dam as layers of arches attached one on top of the other, both men came to the conclusion that each layer of arches could taper in thickness beginning with the foundation and concluding at the crest by reducing the radius of each succeeding arch layer. Schuyler and Brown's theory and design were easily adaptable to the multiple arch design by simply applying their calculations to each arch.(21)

Once engineers have determined the proper slope, height, and thickness of the arches, the next decision is determining the number and the size of the buttresses, and the spacing between them. Fewer buttresses were needed on shorter, smaller dams. The taller the dam and the longer its length, the narrower the buttresses can be. The great "breakthrough" in buttressed dams came in 1897 from Henry Goldmark proposed a concrete dam with seven inclined upstream arches reinforced by buttresses placed thirty-two feet apart. As Goldmark saw it, " arch rings act simply to transfer the water pressure to adjacent piers, which must be of sufficient size and strength to withstand the entire hydrostatic pressure that comes on both the piers and the arches."(22) The dam was never built but Goldmark's plan lived on to influence other engineers.

John S. Eastwood, a construction engineer whose career ran from the latter decades of the nineteenth century until his death in 1924, built the world's first reinforced concrete multiple arch dam at Hume Lake, California, during the years 1908-1909. Characterizing his design as "The Ultimate Dam," Eastwood declared the audacious assertion that he could build dams using fewer materials, yet not sacrifice strength or durability. (23) He further contended that his design would cut construction costs by an astounding thirty to forty percent, which, of true, would open the possibility of flood control, water storage, and hydroelectric projects heretofore cost prohibited. Noetzli's later calculations on saved costs agreed with Eastwood's projections. (24) From 1906 until 1924, Eastwood set about to prove his claims to skeptics by building a number of multiple arch dams for such varied purposes and in such diverse locations as red wood lumbering in the Sierra Nevada; hydroelectric power for Fresno, Los Angeles, San Francisco, and British Columbia; municipal water supply for Salt lake City and San Diego; irrigation projects in

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20Jackson, Building the Ultimate Dam, 25.
21Ibid, 26.
22Ibid, 31.
23Ibid, 2.
24Noetzli, "Multiple-Arch Dams," 439.

California, Utah, Idaho, NM, and Sinaloa, Mexico; flood control with the Bartlett Dam outside Phoenix, Arizona; and gold mining in Amador County, California.

The Pensacola Dam represents the tradition of the multiple arch buttress dam design. The dam sits on the Grand River Canyon floor of Boone's chert formation of solid limestone, considered ideal for a multiple arch dam because it contains few crevices or caverns, thus satisfying Fred A. Noetzli's emphasis on a solid foundation. Workers grouted the few small seams to insure watertight rock. The arches of the dam slope at a forty-five degree angle to stabilize any potential sliding. The wall thickness of each reinforced concrete arch is well within safety limits using Zola's formula. The spacing and size of the buttresses conform to Goldmark's observation.

As to its claim as the nation's longest multiple arch dam, the Pensacola has fifty-one arches that run over 6,100 feet in length. The other claimant to the title is the Buchanan Dam, built during the approximate same time, sits on the Colorado River outside Burnet, Texas. It runs over 10,987.55 feet in length. However, the Buchanan has only twenty-nine arches. The remainder of the dam is actually of an earth fill gravity structure.(25)

The Pensacola also holds its own in size when compared to more famous dams in the United States. The Grand Coulee dam on the Columbia River stands five hundred and fifty feet high, and is 4,300 feet long compared to the Pensacola at over 6,100 feet in length.(26) The Wilson Dam, a concrete gravity dam and part of the famous Tennessee Valley Authority, runs 4,535 feet in length is one hundred and thirty seven feet high with a width at its base of one hundred sixty feet.(27) The Pensacola dam, true to the argument that multiple arch dams take lesser amounts of materials, is longer and taller than the Wilson Dam, and yet is only one hundred feet wide at the base. Two multiple arch dams built in France after World War II are Pensacola's greatest challengers to the title of "World's Longest Multiple Arch Dam." The Calacuccia Dam built between 1965 and 1968 over the Gola River in the vicinity of Haute-Corse is two hundred and sixty five meters long.(28) The Barrage de la Girotte built between 1946 to1948 is only five hundred and seventy meters long.(29) No other multiple arch dam in the world comes close to the Pensacola in length.

If multiple arch dams are so successful and can be built at lower costs than dams of other designs, why have so few been built? The reasons for the decline in popularity of multiple arch dams like the Pensacola in the United States can be traced to three controversies of the 1920s. The first was the problems of three multiple arched dam in the State of California during the decade of the twenties: the concrete deterioration at Gem lake Dam in the early 1920s; the tragic collapse of the St. Francis Dam in March of 1928, which killed 400 people and caused millions of dollars in property damage; and temperature cracks that appeared at Eastwood's Lake Hodges Dam. None of the problems were ever traced directly to any inherent

25Buchanan Dam, 12 June 2003, Lower Colorado River Authority <http://www.lcra.org/water/ Buchanan. html>

26Grand Coulee Dam 20 March 2003 < http://www. grandcouleedam.com/scda/GCD/ grandcouleedam/grandcouleedam.html >

27Department of the Interior, National Park Service, National Register of Historic Places Inventory - - Nomination Form, Wilson Dam, Item 7 (November 13, 1966), 1.

28Calacuccia Dam 20 March 2003 <http://www.structurae.de/en/structures/data/str01452.php >

29Barrage de la Girotte 20 March 2003 <http://www.structurae.de/en/structures/data/str00132.php >

structural deficiencies of multiple arch dams. But the fact that they were multiple arch dams gave the design a blackened eye within professional engineering circles.(30)

Voices began to arise in engineering circles questioning the ability of multiple arched dams to withstand earthquake shocks. Second, engineers dedicated to gravity dam design, such as John R. Freeman, the one time President of the American Society of Mechanical Engineers and a nationally recognized consulting engineer specializing in water power and municipal water supply, saw Eastwood's dream dams as nothing more than cheap, inferior, and unsafe nightmarish substitutes for proven massive gravity dams. Freeman, especially, lent his voice in corporation boardrooms and at scientific conventions to the crusade against the multiple arch technologies, even to the point of injecting his tirades into affairs between Eastwood and his potential clients. Because they were business competitors, Eastwood took Freeman's assaults as personal, a claim Freeman always denied, though once one has read the latter's words it is difficult not to be sympathetic to Eastwood's point of view.(31) Eastwood, by far the leading proponent of multiple arch dams, died in 1924. Freeman and his circle of allies lived years after. Third, the New Deal era is associated with large scale, massive public projects that proved not only utilitarian in putting people back to work, but which also captured the imagination of the public. Hoover Dam, Grand Coulee Dam, the Tennessee Valley Authority dams were all gravity structures. The more massive the dam, the more public acclaim and awe they received. The Grand Coulee Dam, the federal government advertised, was especially notable for using more materials than the largest Egyptian pyramid.(32) So pervasive was the Roosevelt Administration's fascination with size, that one historian has labeled it, "the New Deal's celebration of mass."(33).Thus, the potentials of the multiple arch technology so confidently espoused by Eastwood never found fulfillment. The decedents of "the Ultimate Dam" number only ten in the United States. No new multiple arch dams have been built in the United States since the outbreak of World War II, making the Pensacola Dam complex - finished in November 1941 - one of the last built of its kind.

30Jackson, Building the Ultimate Dam , 238.

31Ibid, 123.

32Grand Coulee Dam20 March 2003 < http://www. grandcouleedam.com/scda/GCD/ grandcouleedam/grandcouleedam.html > _

33Jackson, Building the Ultimate Dam, 246.

Multiple Arch Dams in the United States

Name	Location	Purpose	Year	Builder
Little Rock Dam	Little Rock, California	Irrigation	No Data	J. Eastwood
Lake Hume	Hume, Cal.; 10 Mile Creek; Sequoyah N.P	Hydroelectric	1909	J. Eastwood
Bear Valley	Big Bear, California	Irrigation	1910 - 1911	J. Eastwood
Three Mile Falls	Umatilla, Oregon	No Data	1914	U.S. Reclamation
Lake Hodges	San Diequtio R. Rancho Santa Fe, California	Fresh water	1918	J. Eastwood
Fish Creek	Casey, Idaho	Irrigation	1920	J. Eastwood
Cave Creek	Cave Creek, Ariz.	Hydroelectric	1923	J. Eastwood
Victoria Dam	Victoria River	Hydroelectric	1931	
Buchanan Dam	Burnet, TX; Colorado River	Hydroelectric	1938	V. Cohrane
Bartlett Dam	Cave Creek, Ariz.	Hydroelectric	1939	U.S Reclamation
Pensacola	Grand River, OK	Hydroelectric	1940	W.R. Holway

CONCLUSION

The Pensacola Dam, sometimes called the Grand River Dam, is eligible for listing on the National Register of Historic Places under Criterion C as an excellent example of multiple arch dam engineering. Its fifty-one arch structure is not only the longest multiple-arch dam in the United States, but Pensacola was the first hydroelectric dam in the State of Oklahoma. It continues to play a vital role in resource development and flood control along the Grand River.

The dam complex retains the highest degrees of historic integrity. Modernization of some of the electrical equipment in the powerhouse, the addition of new turbines, and the updating of the observation house have had no effect on the ability of the dam complex to tell its fascinating story. As the longest multiple arch dam in the United States, possibly the last of its kind built, the Pensacola Dam is significant on the national level under Criterion C. It remains the culmination of an engineering design that proved too innovative for conventional wisdom.

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Section 10

UTM Coordinates, continued

	Zone	Easting	Northing
5	15	319890	4038920
6	15	320250	4038900

Verbal Boundary Description

Beginning at a point 100' west of where SH 28 meets the dam, proceed northwest 150' to a point just north of, and including, the observation building. Proceed in a northeasterly direction, parallel to the dam, to the east bank of Grand Lake O' the Cherokees, thence southeast, crossing SH 28, to a point 150' SE of the road, thence southwest, paralleling the dam, to a point 100' west of the west bank of Grand (Neosho) River, thence northeast to point of beginning.

Spillway #1 and #2 are located in the N 1/6, NE ¼, Section 13, Township 23 North, Range 21 East.
The dam is located in the S1/2, Section 14, Township 23 North, Range 21 East

Boundary Justification

The boundary includes the resources historically associated with the Pensacola Dam complex.