BLUFF DALE SUSPENSION BRIDGE
Texas Historic Bridges Recording Project
Spanning Paluxy River at Berry's Creek Road
(County Route 149)
Bluff Dale
Erath County
Texas

HAER No. TX-36

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BLACK AND WHITE PHOTOGRAPHY

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BLUFF DALE SUSPENSION BRIDGE

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Location:	Spanning Paluxy River at Berry's Creek Road (County Route 149), Bluff Dale, Erath County, Texas. UTM: 14/591690/3579870 USGS: Bluff Dale, Texas, quadrangle (1979).
Date of Construction:	1890.
Designer:	Runyon Bridge Company, Weatherford, Texas.
Builder:	Runyon Bridge Company, Weatherford, Texas.
Present Owner:	Erath County.
Present Use:	Pedestrian bridge.
Significance:	The Bluff Dale Suspension Bridge is the oldest surviving cable-stayed suspension bridge in Texas and may also be the oldest in the United States. One of seven Texas suspension bridges surviving from before 1940, it is part of a once extensive regional tradition of vernacular suspension bridges. Repaired in 1899 by the Flinn-Moyer Bridge Company and moved in 1934, the Bluff Dale bridge is also the only known surviving example of Edwin Elijah Runyon's bridge patents. The structure was nominated to the National Register of Historic Places in 1977.
Historian:	Dr. Mark M. Brown, with appendices compiled by J. Philip Gruen, August 1996. Revised by Justin M. Spivey, February 1998.
Project Information:	This document was prepared as a part of the Texas Historic Bridges Recording Project performed during the summer of 1996 by the Historic American Engineering Record (HAER). The project was sponsored by the Texas Department of Transportation (TxDOT).

I. Introduction

The Bluff Dale Suspension Bridge is the oldest surviving cable-stayed suspension bridge in Texas and may also be the oldest in the United States. It is the one of seven Texas suspension bridges that survive from before 1940 (see Appendix B). Historic photographs, county records, and archives reveal a once-extensive concentration of suspension bridges, particularly of vernacular construction, in north-central Texas and across the Rio Grande (see Appendices C and D). The Runyon Bridge Company of Weatherford, Parker County, Texas, constructed the bridge at Bluff Dale in 1890, according to a series of patents issued to Edwin Elijah Runyon. While little is known about Runyon, analysis of the patents suggests how an apparently self-taught engineer understood the behavior of suspension bridges. Runyon's partner at Bluff Dale, William Flinn, also had an independent career constructing suspension bridges throughout north-central Texas between 1884 and his death in 1904.

Readers of this report are encouraged to consult the measured drawings and the large format photographs of the Bluff Dale Suspension Bridge prepared in conjunction with this report. In addition, readers may wish to consult HAER No. TX-46 (Beveridge Suspension Bridge), No. TX-64 (Clear Fork of the Brazos Suspension Bridge), and photographs of the Waco and Regency suspension bridges (Nos. TX-13 and TX-61).[1] After a summary of suspension bridge history, this report will examine the origins of the suspension bridge tradition in north-central Texas, the fabric and history of the Bluff Dale bridge itself, the patents employed at Bluff Dale, and the broad outlines of Runyon's and Flinn's careers.

II. General History of Suspension Bridges through the Nineteenth Century

The history of suspension bridges has been shaped by empirical builders as well as by trained engineers. The Bluff Dale bridge shows that builders operating on intuition were capable of innovative work even in a period dominated by such engineering giants as John and Washington Roebling. As many scholars have observed, the basic idea underlying the suspension bridge is one that can be, and probably was, independently discovered. There are numerous reports of, and increasing archeological evidence for, extensive experimentation and construction of both fiber rope and iron chain-link bridges in the eastern Himalayas and China as early as 285 B.C. Rumors of Chinese bridges reached Europe by 1667. Chain suspension bridges seem to have been built in the Alps in the early thirteenth century. Information about South American suspension bridges is less precise.

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[1] All: U.S. Department of the Interior, Historic American Engineering Record (HAER), Prints and Photographs Division, Library of Congress, Washington, D.C.

In 1615 Faustus Verantius published three proposals for suspension bridges.[2] One suspended the deck from a rope catenary, while the second used a combination of catenary and inclined iron chains. The inclined chains of this latter proposal anticipate the cable-stayed system employed at Bluff Dale.[3]

Reports vary, but it is generally agreed that Judge James Finley of Uniontown, Pennsylvania, built the first American suspension bridge sometime around 1801.[4] The deck was stiffened with trusses and hung on chain-link suspenders from a chain-link catenary. Truss-stiffened decks became standard features of nineteenth-century suspension bridges and such a truss is found at Bluff Dale. About twenty Finley-patent bridges were constructed before 1830. News of these developments would reach Europe and apparently influenced British engineers. Before these developments would have an impact, however, Josiah White and Erskine Hazard built what should be considered an experimental pedestrian bridge across the Schuylkill River in Philadelphia, using wire cables instead of chains.[5]

British engineers experimented with fully or partially cable-stayed bridges, but their greatest achievements were bridges using chain link cables.[6] Thomas Telford's 580-600 foot main-span Menai Straits Bridge of 1826, and I. K. Brunel's posthumously completed Clifton Suspension Bridges were monumental achievements.[7] Telford's work is associated with extensive practical experiments and with material testing.

French engineers took a different approach from their British counterparts. They preferred wire cables over chains, in part because the process of drawing wire through dies reduced internal flaws that would be undetectable in individual chain links. Drawing wire also greatly increased the tensile strength of the iron. In 1823, the first permanent wire-cable

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[2] See Tom F. Peters, *Transitions in Engineering: Guillaume Henri duFour and the Early 19th Century Cable Suspension Bridges* (Boston: Birkhäuser Verlag, 1987), pp. 27-28, for illustrations.

[3] This section is based on Peters; Emory L. Kemp, "National Styles in Engineering: The Case of the Nineteenth Century Suspension Bridge," *IA: The Journal of the Society for Industrial Archaeology* 19, No. 1 (1993): 21-36; and H. J. Hopkins, *A Span of Bridges: An Illustrated History* (Newton Abbot, United Kingdom: David and Charles, 1970).

[4] See Peters, p. 30, for an illustration of Finley's bridge.

[5] Peters, pp. 34-36.

[6] See, for examples of cable-stayed bridges, Redpath and Brown's Kings Meadows Bridge in Scotland (illustration in Peters, p. 36), or John and William Smith's first Dryburgh Abbey Bridge, 1817 (Peters, p. 37). Both bridges were constructed in 1817.

[7] The main span length of Telford's bridge depends on the source consulted.

suspension bridge was constructed in Geneva with French technology. The engineer Louis Vicat introduced the extremely important idea of spinning the main cables *in situ*. In addition, he and his colleagues, most notably Claude Navier and Albert duFour, developed mathematical models for the behavior of the bridges.

Catenary bridges like Finley's are statically determinate, that is, the forces acting on the various components can be determined using simple mathematical equations or graphical methods. Bridges with cables that directly connect the towers to the deck, as at Bluff Dale, are statically indeterminate and require more complicated calculations. During this period, the general level of American mathematics meant that most American engineers avoided indeterminate designs because of the more difficult calculations.[8]

Another Pennsylvanian's work firmly established wire cables as the standard for American suspension bridges. Charles Ellet, Jr., of Bucks County studied briefly in Paris and became familiar with the work of Navier, Vicat, and other important French suspension bridge engineers such as the Seguin brothers. Ellet's Fairmount (1842) and Wheeling (1849, HAER No. WV-2) bridges showed strong evidence of his European sojourn. The latter's clear span of 1,008'-0" briefly made it the longest bridge in the world.

But while Ellet adapted much French practice, he did not, indeed could not after the Austrian-born John Roebling patented the technology in 1847, employ the so-called method of "air-spinning" cables *in situ*.[9] Roebling's 1845 aqueduct over the Allegheny River at Pittsburgh was the first American suspension bridge to employ both cables both spun in place and tightly wrapped in wire. The advantage of this method was to ensure equal tension on all the wires in the cable and reduce slippage between the individual strands. Roebling also patented a method for manufacturing twisted wire rope of the sort that ultimately replaced the Bluff Dale bridge's original cables. The original cables at Bluff Dale used a very different approach to apply and maintain tension on the cables.

Roebling's numerous other bridges, however, pale in comparison to the international recognition that the Brooklyn Bridge secured for Roebling and for American engineering (HAER No. NY-18). Roebling used a combination of catenary and stay cables on his largest structures. The diagonal cables added stiffness, and resisted the wind-induced vertical and torsional

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[8] Dr. Dario Gasparini, professor of civil engineering at Case Western Reserve University, believes that at least some American engineers could solve the equations for statically indeterminate structures (personal conversation, June 1996). Emory Kemp, professor of civil engineering and history at West Virginia University, however, writes about the combined stayed cable and catenary design of the Brooklyn Bridge: "it would have been impossible at the time for Roebling or anyone else to perform an adequate analysis of this indeterminate structure" (Kemp, "National Styles," p. 34). Special thanks to Norman Friedman, Bridge Design Division, TxDOT, for helping with these concepts.

[9] Peters, p. 166.

movement of the main spans that destroyed many suspension bridges. In assessing the Bluff Dale Bridge against this larger international context, it is important to realize that while cable-stayed bridges had been proposed and occasionally constructed, it was not until after World War II that they became a distinctive and regularly constructed bridge type.

III. Origins of the Suspension Bridge Tradition in Texas[10]

The success of the 1869 suspension bridge across the Brazos at Waco demonstrated the potential of, and set a strong precedent for, suspension bridges throughout Texas (HAER No. TX-13). This influence must have been particularly strong in the Brazos and adjacent basins of north-central Texas. Peculiarities of Texas rivers, increasing importance of Waco as a river crossing, and remoteness of Waco from eastern industrial centers shaped the engineering solution represented by the suspension bridge. Texas rivers are subject to flash floods which can suddenly block fords such as the one at Waco. Waco became an important stop on the Chisholm Trail after the end of the Civil War, and consequently a reliable crossing became particularly critical. While the ranches and farms surrounding Bluff Dale were not located on a major cattle trail, they did have similar problems bringing livestock across the Paluxy River to the railroad depot at Bluff Dale.[11]

In seeking an appropriate solution to Waco's problem, the president of the bridge company organized by the town's citizens selected a suspension bridge over a truss bridge. The wire and other construction materials for a suspension bridge would be easier to transport from coastal ports than would a fabricated metal truss.

In structural terms, the Waco Bridge shows remarkable similarities to the work of John Roebling. The most important similarities are the hybrid catenary and diagonal cable system and the truss-stiffened deck. This is completely understandable because the Waco company consulted with, and purchased materials from, the Roebling company. Adaptation of the Roebling model to local conditions included the use of crenelated brick towers.[12]

Two examples graphically illustrate how the Waco bridge shaped Texans' concept of "bridge" and of "suspension bridge" in particular. In 1892, just one year after the completion of

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[10] What follows is an expansion of a theory suggested by Barbara Stocklin, Environmental Affairs Division, TxDOT, summer 1996.

[11] T. Lindsay Baker, *Building the Lone Star: An Illustrated Guide to Historic Sites* (College Station: Texas A&M University Press, 1986), pp. 260-62; Verna Harris, "Bluff Dale Suspension Bridge" (typescript, 1977, Bluff Dale Suspension Bridge file, Texas Historical Commission, Austin, Texas), pp. 1-2.

[12] Modern photographs reflect two re-buildings of the original bridge, in 1913-1914 and in 1976. For a photograph of the Waco Suspension Bridge close to its 1869 appearance, see Baker, *Building the Lone Star,* p. 260.

the Bluff Dale Bridge, the *Texas State Gazetteer and Business Directory* included advertisements for two different bridge companies illustrated with an engraving of the Waco Bridge.[13] That the image is exactly the same in each advertisement, that it was used for two (presumably) competing companies, and that neither company built the Waco Bridge means, at least in the minds of the printer, Waco meant "bridge". Put another way, this use of the Waco bridge engraving was the nineteenth century equivalent of the stock photograph or computer clip art: a widely understood generic image to be used as needed.[14] The second example is an oil painting of Salado College, Bell County, Texas.[15] In the foreground is a small pedestrian suspension bridge with castellated towers. Just as colonnaded plantation houses throughout the south evoke the English country home, and with it Imperial Rome, this private suspension bridge evokes the image of the Waco bridge.

The argument that visual culture impacts technological diffusion is not common in histories of American bridges. Nevertheless, the Western building tradition is replete with examples. From the Holy Sepulcher in Jerusalem to St. Peter's in Rome, architects and their patrons have long taken inspiration from structures vested with special authority by Western society. In the United States, few state capitol buildings are not modeled after the U.S. Capitol in Washington.

Whether or not the Waco Suspension Bridge inspired Texans to build suspension bridges, they did build them. The bridges listed in Appendices B, C, and D are but a few of the Texas suspension bridges encountered by HAER in documents during the summer of 1996. With the exception of Appendix B, information about Texas' suspension bridges is very incomplete due to limited time and resources, but it was compiled in an effort to begin documenting the cumulative impression conveyed while researching the extant bridges.

In his history of the Flinn-Moyer company's Beveridge Suspension Bridge (HAER No. TX-46), J. Philip Gruen concluded that suspension bridges were widely used in Texas because they required less material and labor than prefabricated metal trusses. Consequently, they were comparatively inexpensive. In addition, Gruen argued that suspension bridges rarely required the

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[13] The images are admittedly not exact renditions of the Waco Bridge, but well within the range of artistic license used by nineteenth-century graphic artists. See R. L. Polk, *Texas State Gazetteer and Business Directory*, vol. 4, (St. Louis: R. L. Polk and Company, 1892), pp. 256, 276.

[14] The use of such stock images has an ancient lineage: the same woodcut was used by the publisher to illustrate each city in the book popularly known as the Nuremberg Chronicle of 1493 (M. C. Johnsen, Special Collections Librarian, Carnegie Mellon University Libraries, Pittsburgh, Pennsylvania, personal conversation, September 16, 1996).

[15] See also Temple Junior Chamber of Commerce, *Bell County History* (Fort Worth, Texas: University Supply and Equipment Company, 1958), p. 66.

construction of mid-stream piers — a distinct advantage in avoiding unstable soil conditions and providing resistance to Texas's notorious flash floods.[16]

IV. Bluff Dale Suspension Bridge

A. Description

The Bluff Dale Suspension Bridge is the only known surviving example of a bridge with details patented by Edwin Elijah Runyon. Terms for these distinctive features will follow the usage in the patents wherever feasible; the five patents themselves will be discussed in the historical section below.

The Bluff Dale bridge is a cable-stayed suspension bridge with an overall length of 200'-0" and a main span of 140'-0".[17] Currently, the back-stay cables are built up from loosely wrapped 1"-diameter wire ropes. Historic photographs of similar bridges (see HAER photographs TX-36-12 and TX-36-14) and patent descriptions suggest that the cables were originally hand-twisted strands of heavy-gauge wire. Rectangular castings called separator blocks, now found only underneath the deck, were placed between the wires and used to twist the strands. The main cables were kept from unraveling by torsion rods, inserted into holes in the castings, then secured to the timber deck.

The towers extend approximately fourteen feet above the deck surface and consist of two 8 1/2"-diameter wrought-iron pipes arranged along an axis perpendicular to the length of the deck. Two stacked castings on top of the pipes maintain their alignment and also serve as saddles for the suspension cables.[18] The top casting supports the main group of wire ropes while the lower casting, referred to in a patent as a cross-piece, is used for the fixed suspension cables attached to two 13'-long deck beams flanking the towers on either side. An additional saddle was cast into the lower casting for a horizontal pipe, missing when recorded, that once provided lateral bracing between the towers.

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[16] In HAER No. TX-46, "Beveridge Bridge," Gruen cites Joseph E. King, *A Historical Overview of Texas Transportation, Emphasizing Roads and Bridges* (Lubbock, Texas: Center for History of Engineering and Technology, Texas Tech University, n.d.), p. 59; and Joseph E. King, *Spans of Time: Oklahoma Historic Highway Bridges* (Lubbock, Texas: Center for History of Engineering and Technology, Texas Tech University, June 1993), p. 6.

[17] The overall dimension given is from end to end of the stiffening truss, see below, and excludes earth-filled approaches and later additions to the deck.

[18] Given the general isolation of Bluff Dale and Weatherford at the time of construction, the author suspects that the castings are iron and not steel. A certain determination is not possible, however, without metallurgical testing.

Below the deck level, a complicated bent supports the towers against buckling. A series of vertical pipes with special patented castings supports the horizontal rectangular bars that form a deck beam at the tower. Cast clamps linked to the deck beam are tied together by a loop of twisted heavy wire. Additional twisted-wire cables (as opposed to the replacement wire ropes of the support span) form cross-bracing in the vertical plane below the 12'-wide deck.

Wrought-iron pipes, of alternating 13'-0" and 16'-0" lengths, support the bridge deck. The 13'-long deck beams, occurring on 10'-0" centers, are held up by the suspension cables. Though the 16'-long deck beams also occur on 10'-0" centers, they are not exactly centered between the shorter beams. The longer beams are attached to the longitudinal stiffening trusses, but are not directly supported by the suspension cables. Special castings cap the ends of the 13'-long deck beam pipes. These terminal caps are used as anchorages for the suspension cables, for the lower lateral cross-bracing, and for a truss system that stiffens the deck beam. The deck beam truss is composed of three additional castings, the middle one being the longest, held in compression by a twisted wire cable stretched between the end castings. Rectangular separator blocks, used to twist the cable, are linked by a rod inserted into holes in the blocks. Because the rod keeps the blocks from twisting relative to each other, the cable is prevented from unraveling. Similar separator blocks used to keep the lower lateral bracing in tension are bolted together. Timber stringers (not necessarily original) and deck beams have been replaced with steel I-beam stringers, vainly welded to the wrought-iron pipes, supporting a deck of embossed steel plates.

The deck is stiffened by a Howe truss railing composed of pipes, rods, and castings. Diagonal compression members leaning toward the center of the span are slightly larger in diameter than those leaning away from the center of the span. Diagonal braces, connecting the ends of the 16'-long deck beam pipes to the truss's top chord, brace the truss. Combination vertical and diagonal pipe bents with a patented cap-piece mark the end of the deck.

Stability of suspension bridges depends greatly on the cables. In the Bluff Dale bridge's current configuration, a bundle of wire ropes is embedded in a concrete anchorage below deck level and rises to the top casting on the towers. The ropes then separate and descend under the castings on the ends of the 13'-long deck beams. Except for two cables that go directly to deck beams in the center of the bridge, the ropes rise above the next deck-beam casting and continue along the length of the bridge to a symmetrical panel point, where they pass under the casting and ascend to the tower.[19] Given the close similarity of the overall cable pattern to unidentified bridges (see HAER photographs TX-36-12 and TX-36-13), it seems that the cables of the Bluff Dale bridge did not originally rise above the next deck-beam casting as they continued across the span. The lower tower castings each support two ropes, the ends of which are looped around the castings of the deck beams nearest the towers.

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[19] One of these beams is a modern steel I-beam that has been inserted in an effort to reduce the sag of the bridge. The wire rope that supports this beam is of smaller diameter than the other ropes.

Three longitudinal cables run the length of the bridge underneath the deck: one in the center, and the other two flanking the deck. The center deck cable rests in the saddle-shaped top of the center casting of each deck beam truss. Based on Runyon's patents, it is almost certain that the saddle-shaped tops of the other two deck beam truss castings were also used as rests for cables. Special patented "bearings" clamp the two outermost deck cables to the deck beams.[20]

The large-format photographs taken for this study show the current configuration, while the measured drawings show the best currently possible reconstruction of the original pattern, based on site observations and on the historical research that follows.

B. History[21]

Bluff Dale, on the Paluxy River, is also on the Stephenville-Granbury road. From Granbury there are connections to Weatherford and Fort Worth. By the mid-1870s Bluff Dale was a stop on a mail route between Fort Worth, Texas, and Yuma, Arizona. More importantly, the Fort Worth and Rio Grande Railroad reached Bluff Dale in 1889. The Paluxy River crossing at Bluff Dale was important to those on the left bank seeking direct rail connections to Fort Worth as well as those traveling by wagon to Granbury and other points. In 1890, the Erath County Commissioners' Court accepted a $4,200 bid for three bridges from the Runyon Bridge Company.[22] The company, owned by partners E. E. Runyon and William Flinn, was authorized to commence construction of the second and third bridges only when the commissioners had inspected and accepted the first. This makes particular sense because Runyon's patents were issued beginning in 1888 and thus not likely to have had an established track record. On June 12, 1890, the commissioners accepted the first bridge and authorized payment of $1,400. The remaining bridges were accepted and paid for on July 1 of the same year, proving that Runyon Bridge Company could swiftly contract and construct. Unfortunately, the county records do not seem to indicate when the commissioners authorized construction of the bridge across the Paluxy

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[20] While these "longitudinal deck cables," as they are labeled in the measured drawings, do exert a downward force, Alan Matejowsky, PE, Bridge Design Division, TxDOT, has suggested that the force might not be sufficient to improve vertical stability. Rather, he suggests, they might counter-balance the horizontal forces of the main suspension cables (personal conversation, August 1996).

[21] This section based on Harris; Baker, pp. 20-22; Erath County, Texas, *Commissioners' Court Minutes* (hereafter cited as ECCC *Minutes*), vol. E (Dick Smith Library, Tarleton State University, Stephenville, Texas), p. 88 (March 7, 1890), p. 90 (March 27, 1890), pp. 101-102 (June 12, 1890), p. 103 (July 1, 1890), p. 152 (January 5, 1891), p. 203 (November 27, 1891).

[22] The three bridges were to be built across the Bosque River: on the Stephenville-Meridian public road, the Upper Granbury public road, and the Stephenville-Palo Pinto road.

at Bluff Dale. One surviving county record, however, documents that on January 5, 1891, the Court ordered

> that the Bridge across Paluxy Creek near Bluff Dale built by the Runyon Bridge Co. be received and it is further ordered by the Court that the Treasurer pay to the Runyon Bridge Company $3557.50 balance due said Company on the Contract of said Company with Erath County for the building of four bridges in the year 1890.[23]

The repair history of the suspension bridge began at least as early as 1899. In that year the Flinn-Moyer Bridge Company, also of Weatherford, Texas, was paid $815.88 for "repairs of the County Bridge at Bluff Dale, Texas."[24] Flinn-Moyer probably installed the stiffening truss as part of this work, based on the following evidence: (1) historic photographs of "Runyon-style" bridges with similar cable stays do not have Howe trusses made of pipe (see HAER photographs TX-36-12 through TX-36-14), (2) railings described or illustrated in Runyon's patents are constructed of cable and pipe using the Pratt pattern (see below), and (3) the truss at Bluff Dale is very close to that which survives on Flinn-Moyer's Clear Fork of the Brazos Suspension Bridge of 1896 and the truss once on the Beveridge Bridge.

The Bluff Dale bridge remained in use until 1934, when it was by-passed with the construction of a new concrete bridge. The following year the bridge was moved upstream to what is now County Route 149. Local tradition holds that the bridge was lengthened by 25'-0" on either approach. A county road crew replaced the wooden deck with the present metal deck in 1983. The Bluff Dale Suspension bridge was placed on the National Register of Historic Places in 1977 and was closed to traffic in the early 1990s, when it was bypassed once again with a new concrete-girder bridge.

V. E. E. Runyon

The primary sources of information about Edwin Elijah Runyon, are the bridge contracts cited above, a business card, and a series of eight patents. In addition, there are photographs in the Weatherford Public Library of bridges that closely resemble the patent illustrations.

Six of Runyon's eight patents issued between December 1888 and March 1893 are for suspension bridges. The non-bridge patents are for a cotton-cultivating machine and a lawn mower. Based on the filing dates of the first four patents, it is known that between June 29, 1888, and April 1, 1889, Runyon lived in Mountain Spring, Cooke County, Texas. The fifth patent, the cotton cultivator, was filed May 3, 1889, from Burns, Cooke County. Between August 23, 1890, and November 2, 1892, Runyon lived in Pilot Point, Denton County, Texas.

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[23] ECCC *Minutes*, vol. E, p. 152 (January 5, 1891).

[24] Erath County, Texas, *Road Records of Erath County 1899-1904* (Dick Smith Library, Tarleton State University, Stephenville, Texas), pp. 48-49 (November 14, 1899).

An undated business card, found in William Flinn's house by a subsequent owner, and now in a family collection, indicates that at one point "Runyon Bridge Company, Pilot Point, Texas," were contractors for a "needle-beam combination suspension bridge."[25]

An analysis of Runyon's patents suggests that he had a clever and inventive mind. It is doubtful that he had any advanced engineering or mathematical training. However, Runyon was apparently aware of the de-stabilizing effect of wind loads, that bridges expand and contract with changing temperature, that it was important to place equal strain on each of the wires of a suspension cable, and that it was necessary to counteract various forces that would deform the bridge towers. On the other hand, Runyon did not seem to be as particularly concerned about stiffening the bridge deck as were Roebling and Ellet. Runyon indicated that many of his bridge components were constructed of gas (lighting) pipe because it was durable, economic, and easily available.

A. Patent No. 394,940: "Suspension-Bridge"

Runyon's first patent presents his overall concept for a suspension bridge. Distinctive features of the bridge are the tubular deck beams (called "braces" by Runyon), the deck cables, the main suspension cables and their connections, and the tower details. The deck beams consist of pipes with a "head" or cap on both ends. Twisted-wire deck cables, four of which are shown in the patent illustration, run the length of the deck above the braces. Apparently, the wooden deck surface rests directly on these deck cables, which in turn transfer the load to the deck beams. Given the close similarity of the Bluff Dale Bridge and this patent, it is important to note that Runyon described the patent bridge's deck as "preferably grooved or rabbeted, so adjoining faces will interlock."[26] It is not clear whether Bluff Dale originally had boards laid on cables or on stringers, as shown in historic photographs of other Runyon-type bridges (see HAER photographs TX-36-12 through TX-36-14). The longitudinal deck cables at Bluff Dale may be an indication of the original configuration of the deck, or may be an example of technological inertia, installed solely because they were part of the patent. The deck cables would have been rendered structurally redundant if a stringer-supported deck was originally built at Bluff Dale.

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[25] A photocopy of the business card is in the collection of Dr. Timothy L. Flinn, Strawn, Texas. The patents are: Edwin Elijah Runyon, "Suspension-Bridge," U.S. Patent No. 394,940 (December 18, 1888); "Needle-Beam for Bridges," U.S. Patent No. 400,874 (April 2, 1889); "Device for Twisting Wire Cables of Suspension-Bridges," U.S. Patent No. 404,934 (June 11, 1889); "Bent for Suspension-Bridges," U.S. Patent No. 410,201 (September 3, 1889); "Suspension-Bridge," U.S. Patent No. 446,209 (February 10, 1891); "Side Rail for Suspension-Bridges," U.S. Patent No. 493,788 (March 21, 1893); "Cotton-Cultivating Machine," U.S. Patent No. 412,980, (October 15, 1889); and "Lawn-Mower," U.S. Patent No. 445,616 (February 3, 1891).

[26] Runyon, "Suspension-Bridge," U.S. Patent No. 394,940, lines 77-78.

The patent bridge's main suspension cables are strung from their anchorages directly to the towers and thence down to the deck beams. Runyon's patent illustration shows only three panel points. The suspension cables pass underneath the deck beam at the center panel point, and are looped around the beam at the outer points. At the center of the bridge, the cables are wedged between the end caps and special deck cable clamps, which are almost identical to the clamps currently at Bluff Dale. It should be remembered, however, that at Bluff Dale the main suspension cables support the deck beams via the saddle-horn shaped section of the terminus cap.

Pipes and castings are also the main components of the patent bridge's towers and the bents that support the section of roadway immediately between adjacent towers. A mud-sill serves as the foundation. The pipes that form the towers and bents are kept engaged to the mud-sill by pins on the ends of spools. This pin-and-spool connection (alternately termed "sleeves" by Runyon) appears in Runyon's other patents and seems to be part of his mechanical vocabulary. It is also a consequence of his use of pipe as a primary structural material. A clamp links the three outermost pipes, of which two form the towers. The third pipe is shorter and forms, along with other shorter pipes, the bent. A crossbar is nailed onto the tops of the short pipes and forms the equivalent of a deck beam at this point. Grooves for the deck cables are cut into the crossbar. Finally, the tallest pipes (Runyon clearly realizes that lengths of pipe might be coupled together to obtain the necessary tower height) are capped and tied together with a grooved casting. Between the description and the illustrations, this patent represents the essential structural features of the Bluff Dale Bridge. Subsequent patents awarded to Runyon represent refinements to the basic concept.

In the patent description, Runyon commented on the purpose of his bridge design:

> It is greatly desirable to make a single span from shore to shore, or at most to have but one pier embedded in the river, because of the difficulty in sinking coffer-dams and finding strata of sufficient density to form stable anchors for the piers. It is moreover desirable in constructing a bridge that as few nails be used in securing the flooring as consistently possible, because of the tendency to impair the wood by their oxidation. It is furthermore a desideratum that the flooring should have an elastic basis which will transmit the pressure of the incumbent weight and thus diminish the strain of the piers and the connecting-cables. To practicalize all these aims in a simply-constructed bridge is therefore the purpose to which my invention is addressed.[27]

Further, Runyon notes that his objectives are

> first, to transmit a given pressure equally in either direction therefrom to the piers or abutments; second, to balance a given pressure irrespective of its location; third, to provide an elastic yielding road-bed or flooring which will transmit the pressure of an incumbent weight or strain; fourth, to increase the length or span

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[27] Ibid., lines 51-69.

> over existing conditions; fifth, to dispense with piers, except on the shore margins; sixth, to facilitate the construction and increase the life of bridges, and, seventh, to accomplish these aims with structural simplicity and economy.[28]

The limits of Runyon's understanding of the behavior of a suspension bridge can be garnered from his observation that "by reason of the elasticity of the cables the longevity of the bridge will be greatly promoted, because the strain is thus transmitted."[29]

B. Patent No. 400,874: "Needle Beam for Bridges"

Runyon's second patent, issued in April 1889, uses pipes called "needle beams" placed under the deck to keep the longitudinal deck cables properly aligned and under proper tension. Runyon sought to "construct the needle-beams of as light a structure as is consistent with the strain to which they are subjected."[30] This requirement is satisfied by using "gas-piping whose tubular structure combines lightness with durability."[31] A short cable, running perpendicular to the deck, is strung between projections at the bottom of each needle-beam end cap. The purpose of this short cable is to keep the castings, which cradle the longitudinal cables, from sliding along the needle-beam pipe, and to form the bottom chord of a truss stiffening the needle beam. A similar arrangement is found in the Bluff Dale bridge.

Inspection of the patent drawing, and subsequent changes documented at Bluff Dale, strongly suggests that Runyon's arrangements "to prevent shifting of the cables under stress of wind or because of contraction and expansion" were of limited value at best.[32] The special clamps that secure the outermost deck cables to the needle beams in the first patent were replaced in the second. In their place was an annular casting that provided a cradle for the deck cables. The new arrangement represented by the patent has no secure connection between the longitudinal cables and the deck. It is by no means clear how this arrangement could maintain the cables in their saddles against a strong gust. The arrangement at Bluff Dale seems to be an acknowledgment of this problem: the end cap was modified to accommodate cross-bracing in the horizontal plane below the deck.

The April 1889 patent is also of interest because of another modification to the end cap. Runyon moved the contact point between the main suspension cables and the needle-beams from

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[28] Ibid., lines 15-28.

[29] Ibid., lines 17-20.

[30] Runyon, "Needle-Beam for Bridges," U.S. Patent No. 400,874, lines 48-50.

[31] Ibid., lines 77-79.

[32] Ibid., lines 46-47.

between the clamps to a groove around the outer end of the cap. The grooved projection is the mechanical equivalent of the saddle-horn arrangement in use at Bluff Dale.

C. Patent No. 404,934: "Device for Twisting Wire Cables of Suspension-Bridges"

The second of three patents issued to Runyon in 1889 was a simple mechanical device "to tighten . . . wires and thus give the required tension to the several cables, so that they will receive the strain of the [bridge's] weight equally."[33] Ensuring equal tension on the individual wires was a concern that Roebling sought to address with his "air-spinning" patent.

Runyon's solution to this problem was to use a two-part casting to twist the wires with the help of the rectangular "separator blocks" found at Bluff Dale. The two halves of the casting are secured around the separator block, and handles are inserted to twist the assembly. Evidently the two-part casting was intended for repeated use, while the separator blocks remained on the twisted wires. As described in the patent, Runyon intended that one end of a metal tie-rod be bolted to one of the holes in the separator blocks while the other end extends "down to and is adapted to be connected with the tower-cables or needle-beams of the bridge."[34] The nature of the device limited its use to bundles of wires that could be twisted by hand. This in turn probably limited the scale of the bridges constructed with the device.

D. Patent No. 410,201: "Bent for Suspension-Bridges"

The Bluff Dale bridge employs Runyon's patent for a suspension bridge bent in all but the subtlest details. This is to be expected as Runyon Bridge Company contracted with Erath County for the construction of the first three of four bridges in late March 1890, not quite seven months after this fourth bridge patent was issued. While Runyon explicitly states that the bent is intended for suspension bridges like his first patent, it is not entirely clear whether the bent patent was a refinement based on further experience and new ideas or whether he intentionally patented it separately in order to better secure his rights.

The bent design serves several needs and, like the other Runyon patents, has several distinctive features. Saddle castings, resting upon a horizontal bar which is in turn supported by vertical pipes, support the horizontal cables at a point where the tower prevents a suspended deck

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[33] Runyon, "Device for Twisting Wire Cables of Suspension-Bridges," U.S. Patent No. 404,934, lines 38-41.

[34] Ibid., lines 79-80.

beam. Twisted-wire cross-bracing and additional castings — including pairs of cast pipe clamps similar to those at Bluff Dale — "prevent the outer columns from spreading."[35]

E. Patent No. 446,209: "Suspension-Bridge"

Runyon's fifth bridge patent largely consists of the addition of terminal bents and a cable clamp to his existing bridge design. A cap piece, consisting of two castings with various flanges, clamps around a horizontal pipe and fits into vertical and diagonal pipes to form a bent at the ends of the bridge deck. Two flanges on top of the cap form a saddle for the deck cables. The diagonal pipe braces the bent against deflection towards the center of the bridge. With minor variations in the design of the casting, this terminal bent was used at Bluff Dale.

Located on the back stays, between the anchorages and the bridge towers, the cable clamp connects the backstays and the suspension cables that support the panel points of the main span. The status of the clamp at Bluff Dale, however, is by no means clear: if it was ever used, it would have been discarded when the current wire ropes were installed.

It is difficult to understand how these two devices in combination with Runyon's earlier patents could

> permit the main cable to expand and contract in different temperatures without materially affecting the principal parts and causing them to become displaced by reason of the slack or increased camber.[36]

As described, the system is rigid and lacks any moving parts that might compensate for the expansion and contraction Runyon describes. Indeed, the introduction of the clamp merely introduces another part that could fail. Furthermore, unlike a turnbuckle on a tension member, the system cannot be easily adjusted: loosening the clamp would render the bridge unable to support its own weight.

To date, no evidence has surfaced to suggest that this cable clamp system was actually used at Bluff Dale or anywhere else. However, the patent is contemporary to the Bluff Dale bridge's construction, indicating that the idea was at least available then.

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[35] Runyon, "Bent for Suspension-Bridges," U.S. Patent No. 410,201, lines 77-78. The patents for Runyon's cotton cultivator and lawn mower were issued after his bent patent. While both are interesting and an indication of his mechanical imagination, neither will be discussed in this report.

[36] Runyon, "Suspension-Bridge," U.S. Patent No. 446,209, lines 25-29.

F. Patent No. 493,788: "Side Rail for Suspension-Bridges"

Both physical evidence and an 1892 patent application date strongly suggest that the features of this, Runyon's last bridge patent, were not employed at Bluff Dale. It nevertheless gives some insight into his engineering.

The patent consists of two major components: the addition of a side rail and modifications to the deck beam system. Continuing in his established design style, Runyon uses pipe, wire cable, and castings to construct a simple and durable variation on a what amounts to a Pratt truss. The vertical compression members are pipe. Diagonal tension members are constructed of cable — which given that they are "joined at their crossings by . . . twist castings" were presumably of twisted wire.[37] The bottom chord of the truss is the longitudinal deck cable at the outer edge of the bridge deck. Realizing that a cable makes for a less-than-desirable hand rail, Runyon provides for the top chord to be either cable or gas pipe. Castings, many with sleeves, pins, and counter-sunk recesses typical of his earlier patents, serve as the connectors between pipe and cable.

Runyon describes his new side rail as inexpensive, quickly installed, simple, and "much lighter than wooden structures of this nature and more lasting."[38] These observations have at least two implications. Runyon was apparently more concerned with building a light, and therefore inexpensive, structure and was not particularly concerned with strengthening the light deck against wind damage. Because this patent was filed after the completion of the Bluff Dale bridge, Runyon's comments also imply that the original railing on the Bluff Dale bridge was similar to the wooden ones in HAER photographs TX-36-12 through TX-36-14. The current stiffening truss was probably added in 1899.

The patent also addresses the needle beams. Runyon modified the system of his earlier patents by extending the needle-beam through and beyond the casting that previously capped the pipe. This additional length of pipe provides a base for inclined braces supporting the railing. Runyon also placed a flat rectangular iron bar parallel to the needle beam and integrated each end of this bar into the castings supporting the vertical compression member. Since the outermost castings no longer cap the deck beam pipes, they are free to slide inward under the tension of the transverse cable. Runyon most likely realized this, and added the flat bar to restrain the outermost castings. He does not comment on the flat bar, nor does he clearly specify how the diagonal cables of the railing pass through the castings under the verticals.

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[37] Runyon, "Side Rail for Suspension-Bridges," U.S. Patent No. 493,788, lines 74-75.

[38] Ibid., lines 82-83.

VI. William Flinn[39]

William Flinn of Weatherford, Parker County, Texas, was a partner in both the Flinn-Moyer Bridge Company and the Runyon Bridge Company. Evidence that has emerged from recently uncovered family archives and from patent research suggests that Flinn was primarily a contractor. The level of his involvement in the design of the bridges is unclear.

William Flinn was born in Iowa Point, Kansas, and arrived in Weatherford, Texas, in the early 1880s. No information has come to light about professional engineering training or how he became involved in bridge building. In late December 1884 he purchased property for a house in Weatherford and married Alice Elizabeth Thompson in May of the following year. Flinn died without a will on June 16, 1904.[40]

Bluff Dale is one of three known surviving bridges built with the involvement of William Flinn. Complicating our understanding of Flinn's business dealings is evidence that at the same time he was associated with Runyon, he also did bridge business under his own name and with an A. A. Moyer.[41] The 1890-1891 *Texas State Gazetteer and Business Directory* included an advertisement for Flinn which makes no reference to Runyon Bridge or any other company.[42] Interestingly, the advertisement makes it clear that Flinn was seeking other types of construction projects, including buildings, wind mills, cisterns, and tanks — all during the construction of the Bluff Dale Bridge. Now largely forgotten, Flinn was a prolific builder, judging by the number of bridges known through county contracts and through family photographs.[43] In 1903 the

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[39] The section is a condensed from U.S. Department of the Interior, Historic American Engineering Record (HAER) No. TX-64, "Clear Fork of the Brazos Suspension Bridge (Woodson Bridge)," 1996.

[40] Mrs. Paul Martin Flinn, "Paul Martin Flinn," in Parker County Historical Commission, *History of Parker County* (Dallas: Taylor Publishing Company, 1980), pp. 282-83; Parker County, Texas, *Deed Book,* vol. 15 (Parker County Courthouse Annex, Weatherford, Texas), pp. 354-55 (December 2, 1884); Parker County, Texas, *Probate Minutes,* vol. 8 (Parker County Courthouse Annex, Weatherford, Texas), pp. 581-83 (June 16, 1904).

[41] Flinn was awarded at least one bridge contract in Parker County in each of the years 1885, 1889, 1890, 1893, 1896, 1897, 1900, 1901, 1902, and 1903. See Parker County bridge file, Environmental Affairs Division, Texas Department of Transportation, Austin, Texas.

[42] See R. L. Polk, *Texas State Gazetteer and Business Directory,* vol. 3 (St. Louis: R. L. Polk and Company, 1890-1891), p. 1037.

[43] A preliminary tabulation suggests that more than twenty-five contracts were awarded by Parker County, where Weatherford is located, to William Flinn or to the Flinn-Moyer Bridge Company between 1885 and 1903; see Parker County bridge file.

Weatherford *Daily Herald*, admittedly a source likely to be positively predisposed, reported that Flinn was "reputed to be the most successful bridge builder in the state."[44]

VII. Conclusion

The Bluff Dale Suspension Bridge is a rare survivor of the once-common Texas suspension bridge. Economy and ease of construction, resistance to flash flooding, and possibly the precedent of the Waco Suspension Bridge made the suspension bridge a popular alternative to the prefabricated metal truss.

Bluff Dale is also a example of an extremely rare type. While cable-stayed bridges were occasionally proposed throughout the history of suspension bridges, they were constructed infrequently prior to 1945.[45] Indeed, noted suspension bridge historian Emory Kemp knows "of no other documented cable stayed bridges of the late nineteenth and early twentieth century."[46] While HAER photographs TX-36-12 through TX-36-14 show that Bluff Dale was not the only cable-stayed suspension bridge ever constructed in north-central Texas, Bluff Dale is the only one to survive. In addition to its rare status as a cable-stayed bridge, Bluff Dale is also important because it preserves the remarkable design details associated with E. E. Runyon's patents. Runyon's striking solutions show that even as late as 1890, empirical engineers were capable of innovative work.

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[44] "Parker County's Bridge Man," Weatherford *Daily Herald*, June 30, 1903.

[45] See David P. Billington and Aly Nazmy, "History and Aesthetics of Cable-Stayed Bridges," *Journal of Structural Engineering* 117, No. 10 (October 1991): 3103-3134.

[46] Emory Kemp, to author, July 8, 1996.

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APPENDIX A: Suggestions for Further Research

This recording project has raised several issues that remain unanswered due to limitations of time and resources.

1. Is Bluff Dale the oldest extant cable-stayed suspension bridge in the United States? If so, were there ever any others outside Runyon's work?

2. Who was Edwin Elijah Runyon? No deeds or wills were found for him in Parker County. Perhaps there are such records for Runyon in Cooke, Denton, or Erath counties — the only counties where Runyon is known to have resided or built bridges.

3. Did Runyon ever build suspension bridges in Oklahoma? Suspension bridges were built in Oklahoma during this period, though one published inventory makes only brief references to them. This is of interest because the towns that Runyon lived in while filing his patents were near the Oklahoma border.

4. Simple excavation should reveal whether the mud sills described in patents 394,940 and 410,201 were employed at Bluff Dale.

5. The suspension bridge over Choctaw Creek, Grayson County, Texas, should be studied to see if any of Runyon's patents were employed in its construction. This catenary suspension bridge is on private property and has pipe towers. While the connections appear to differ in detail from those at Bluff Dale, the form and function of some of them may nevertheless fall under Runyon's patents.

APPENDIX B: Extant Suspension Bridges Built in Texas Before 1940

Compiled by J. Philip Gruen

Bridge	Location	Builder	Type	Span	Year
Waco	Spanning Brazos River at Bridge Street, Waco, McLennan County	Thomas M. Griffith	Catenary	475' clear span	1869; rebuilt 1914
Bluff Dale	Spanning Paluxy River at County Route 149, Bluff Dale, Erath County	Runyon Bridge Company, Weatherford, Texas	Cable-stayed	140' clear span	1891
Clear Fork of the Brazos	Spanning Clear Fork of the Brazos River at County Route 179, Shackelford County	Flinn-Moyer Company, Weatherford, Texas	Catenary	140' clear span	1896
Beveridge	Spanning San Saba River at County Route 112, San Saba County	Flinn-Moyer Company, Weatherford, Texas	Catenary	140' clear span	1896
	Spanning Choctaw Creek, Grayson County		Catenary		
Roma-San Pedro International Bridge	Spanning Rio Grande, between Roma, Starr County, and Ciudad Aleman, Mexico	George E. Cole, engineer	Catenary	700' overall	1928
Regency	Spanning Colorado River, between San Saba and Mills counties	Austin Bridge Company, Dallas, Texas	Catenary	340'	1939

Source:

County Bridge Files, Environmental Affairs Division, TxDOT, Austin, Texas.

APPENDIX C: Preliminary List of Bridges Built with Participation of William Flinn

Compiled by J. Philip Gruen

Bridge	Location	Spanning	Type	Span	Year
Bluff Dale	County Route 149, Bluff Dale, Erath County	Paluxy River	Cable-stayed	140'	1890
(a)	Stephenville-Meridian Public Road, Erath County	Bosque River			1890
(a)	Upper Granbury Public Road, Erath County	Bosque River			1890
(a)	Stephenville-Palo Pinto Road, Erath County	Bosque River			1890
Beveridge	County Route 112, San Saba, San Saba County	San Saba River	Catenary	140'	1896
Clear Fork of the Brazos River	County Route 179, Shackelford County	Clear Fork of the Brazos River	Catenary	140'	1896
(b)	Weatherford-Millsap Road, Parker County	Grindstone Creek		50'	1902
(e)	Bell County	Leon River			ca. 1903
	Bell County				ca. 1903
	Fisher County		Steel (truss?)		ca. 1903
	Fisher County		Steel (truss?)		ca. 1903
	Parker County				ca. 1903
	Parker County				ca. 1903
	Johnson County				ca. 1903
(b)	Garner vicinity, Parker County?	Dry Creek		50'	
(c)	Rock Bluff Crossing, Weatherford, Parker County	Brazos River	Iron		
Dark Valley (d)		Brazos River			
(d)	North Main Street, Weatherford, Parker County		Steel truss		

Bridge	**Location**	**Spanning**	**Type**	**Span**	**Year**
(e)	State Route 180, between Palo Pinto and Mineral Wells, Palo Pinto County	Brazos River?			

Sources:

(a) Erath County, Texas, *Commissioners' Court Minutes,* vol. E, p. 88 (March 7, 1890), p. 90 (March 27, 1890).

(b) *Weatherford Daily Herald,* December 4, 1902.

(c) Newspaper clipping, n.d. Vertical files, Weatherford Public Library Archives, Weatherford, Texas.

(d) Parker County Historical Commission, *History of Parker County* (Dallas: Taylor Publishing Company, 1980), pp. 282-83.

(e) Timothy L. Flinn Collection, Strawn, Texas.

APPENDIX D: Preliminary List of Texas Suspension Bridges Built by Neither E. E. Runyon nor William Flinn and No Longer Standing

Compiled by J. Philip Gruen

Bridge	Location	Builder	Type	Span	Year
? of the Brazos	Spanning Brazos River at State Route 120, Newcastle, Young County		Catenary		before 1913
(a)	Spanning Red River north of Nocona	Austin Bridge Company	Catenary	700'	
Tin Top/ Hightower Valley (b)	Spanning Brazos River at Hightower Valley, Parker County	Mitchell and Pigg	Catenary	400' center span, 130' and 230' approaches	1906
Brannon's Crossing (b)	Spanning Brazos River at Brannon's Crossing, Parker County	Mitchell and Pigg	Catenary	440' center span, 60' and 160' approaches	1906

Sources:

(a) Shannon Miller, *The First 50 Years: 1918-1968.* Dallas: Austin Bridge Company, 1974.

(b) T. Lindsay Baker, "Tin Top Bridge's Forgotten Twin Spanned Brazos . . .," *Weatherford Democrat* April 18, 1983, p. 7.