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National Park Service

National Register of Historic Places Multiple Property Documentation Form

This form is used for documenting multiple property groups relating to one or several historic contexts. See instructions in *How to Complete the Multiple Property Documentation Form* (National Register Bulletin 16B). Complete each item by entering the requested information. For additional space, use continuation sheets (Form 10-900-a). Use a typewriter, word processor, or computer to complete all items.

X New Submission ___ Amended Submission

A. Name of Multiple Property Listing

Historic Bridges of Texas, 1866-1945

B. Associated Historic Contexts

(Name each associated historic context, identifying theme, geographical area, and chronological period for each.)

Historic Bridges of Texas, 1866-1945

C. Form Prepared by

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D. Certification

As the designated authority under the National Historic Preservation Act of 1966, as amended, I hereby certify that this documentation form meets the National Register documentation standards and sets forth requirements for the listing of related properties consistent with the National Register criteria. This submission meets the procedural and professional requirements set forth in 36 CFR Part 60 and the Secretary of the Interior's Standards and Guidelines for Archeology and Historic Preservation. (☐ See continuation sheet for additional comments.)

Curtis Tunnell 9-6-96

Signature and title of certifying official Date

State Historic Preservation Officer, Texas Historical Commission

State or Federal agency and bureau

I hereby certify that this multiple property documentation form has been approved by the National Register as a basis for evaluating related properties for listing in the National Register.

Signature of the Keeper Date of Action

STATEMENT OF HISTORIC CONTEXTS
HISTORIC BRIDGES OF TEXAS, 1866-1945

I. GEOGRAPHICAL FACTORS

Since the early 1800s, bridge designers and builders in Texas have encountered diverse topography, extreme weather variations, and a wide range of soils and drainage. Topographical conditions are particularly varied in the eastern two-thirds of the state, presenting bridge designers and builders with a significant challenge. This large area, encompassing the Interior Lowlands and Coastal Lowlands regions of Texas, exhibits a topography ranging from dense forests and rocky hill country to rolling plains, coastal prairies and low-lying marshlands. Sparse vegetation, thin soils and steep slopes produce high velocity runoff and currents in several large river basins, such as the Brazos, Colorado and Trinity, compelling bridge engineers to use long span lengths with relatively few piers. Areas with rocky soils, such as those in Central Texas, can carry bridge foundations to bedrock fairly easily, eliminating the need for unusual or difficult foundation designs. Some of the areas along the Gulf Coast and in East Texas, however, have soft clay and marshland soils that often require relatively short spans and deep foundation pilings.[1]

The extensive network of rivers, streams and tributaries found in the Coastal Lowlands are particularly prone to severe flooding, drift accumulation and fast flowing currents. Weather disturbances of tropical origin are responsible for the tremendous flood-producing storms that affect this area of the state. Seasonal floods can quickly turn small intermittent streams into fast-flowing torrents of water that wreak havoc and destruction on roads and bridges. From the state's earliest history, there are tales of floods that washed bridges downstream, destroyed timber approach spans and undermined bridge piers. Tropical storms, navigational factors and the presence of islands and peninsulas along the Gulf of Mexico have also influenced bridge design and construction across the Gulf and the lower Sabine River, affecting the strength, length and height of many spans.[2]

The arid, flat regions of west Texas and the Panhandle have presented the bridge engineer with few opportunities for bridge construction. With its infrequent streams and rivers and predominantly dry climate, this region of the Great Plains has historically required relatively few bridge crossings. The Trans-Pecos Region in far west Texas is an isolated region of the state with low annual rainfall and no significant surface streams other than the Rio Grande. The region was under the control of the Comanches and Apaches for much of the 19th century and no significant Anglo settlement occurred until after Texas became a state in 1845. Low population density resulted in little demand for roads and bridges in this area during the state's first hundred years. Deep canyons and the potential for cloudbursts and heavy rainstorms in the Davis and Guadalupe mountains (which form part of the Rocky Mountain region of the western United States) continued to impede transportation advances in that area of the state for decades to come.[3]

II. TRANSPORTATION ON THE EARLY TEXAS FRONTIER

The development and evolution of Texas is reflected and, to a great extent, shaped by efforts to improve transportation, with rivers, streams and other bodies of water playing a critical and prominent role in this history. The earliest transportation routes in the state were Indian paths that were subsequently followed by Spanish explorers during the 16th and 17th centuries. These paths generally marked the easiest line of travel: avoiding natural obstacles, staying near sources of food and water, and crossing streams at narrow shallow points. In the early 18th century, the Spanish consolidated their claims to Texas, establishing a line of missions and presidios along the same basic routes followed in earlier explorations. These roads generally extended in a northeasterly direction from Mexico, passing through Laredo and Presidio del Rio Grande at the border, connecting early settlements such as San Antonio, Nacogdoches, Goliad, and Victoria, and continuing into Louisiana. Because of Indian depredations and extreme weather conditions, the Spanish settlements stagnated and in some cases declined. The roads never evolved beyond primitive paths serving as seasonal trails for travel by explorers, pioneers and traders.[4]

With Mexico gaining independence from Spain in 1821, Anglo-American land promoters began surveying and mapping major settlement routes into Texas, and immigrants began rushing over the Sabine and Red rivers from Louisiana and Arkansas. Between 1821 and 1835, Stephen F. Austin and others received land grants from the Mexican government permitting some 13,500 families to come to Texas. An established route was not always available for a settler's entire journey through the vast Texas territory. More often than not, travelers had to blaze their own trails into the wilderness, with river and stream crossings providing the most hazardous and laborious conditions.[5] One sojourner, recalling the difficulties of travel, commented:

> At crossing places of streams, the banks would have to be worked in order to get over at all. If creeks were up, they would often be compelled to camp for days at a time in order to cross. It was always the rule when traveling to cross a stream when reached, if practicable, before camping, so as to be on the farther side when morning came.[6]

However frightening these early transportation experiences were, the difficulties did not deter the flood of immigrants coming to Texas. Many of these pioneers settled near rivers, expecting that they would facilitate trade and transportation. Mexican decrees called for the improvement of several Texas rivers, including the Guadalupe, Brazos and Colorado; however, few if any successful efforts were made to clear rivers of accumulated drift, deposits, rafts and other obstacles during the Mexican period. In the 1830s, steamboats made successful if limited runs on the Brazos, Trinity, Neches, Sabine, Guadalupe and Red rivers. The turnaround point was dictated by the depth of water and the presence of obstacles; the schedule and route therefore varied seasonally. Many rivers were suitable for navigation only after heavy rains and were typically shallow enough to ford. These conditions hindered large-scale navigation for commerce but allowed limited seasonal travel in certain regions of the state near the coast.[7]

From 1821 to 1836, the population of Texas (excluding native Indians) grew from about 2,240 to about 39,470, an increase of more than 700 percent. Despite the growth in population, overland travel conditions remained wretched, consisting primarily of a mass of wagon ruts or simple cow trails, traveled either by horseback or by wagons drawn by oxen or mules. On the eve of the Texas Republic, only San Antonio and a few other prosperous communities boasted timber footbridges consisting of hewn timbers laid across timber piles and abutments with a plank deck.[8]

Independence brought few internal improvements to the Texas Republic (1836-1845). The financially strapped government was unable to subsidize roadwork, relying primarily on counties and settled communities to provide the populace with roads and bridges. One of the first acts of the Congress of Texas (December 20, 1836) was to authorize county courts to lay out and construct roads, establish ferries, contract for toll bridges, and to require that all free males work on public roads. However, with a thinly spread population scattered over a vast, sparsely populated rural area, the addition of civil labor led to only slight progress in the construction of roads and bridges. While the counties implemented these measures as best as they could, in most cases insufficient funds and manpower prevented any substantial road improvements and routes remained functional only in dry weather.[9]

Unable to afford major bridge construction, most counties authorized private landowners to operate ferries at larger crossings, with travelers continuing to ford most small creeks and streams. Immigration continued at a steady pace, bringing the state's settled population to nearly 142,000 by 1847. Several new towns located primarily in the south central and southeast portions of the state were established during this period. Despite this growth, the Republic remained a thinly populated frontier with most occupants continuing to live in primitive and isolated conditions. The self-sufficient population had little need to travel, relying primarily on freighters and stagecoaches to deliver the mail and to furnish needed goods and supplies.[10]

By the time Texas obtained statehood in 1845, it was crisscrossed by a system of primitive roads, largely contained within a region east and south of Clarksville, Nacogdoches and San Antonio, with the west remaining largely uncharted. Few roads penetrated the interior until 1849 when California gold strikes produced several new routes across the state. These roads were supplemented by military roads laid out in the 1850s to connect a cordon of forts that stretched northeast to Fort Worth, south to Brownsville and west to El Paso. Immigrants flooded into Texas at an unprecedented rate, with the settled population exceeding 600,000 by 1860. While the settlers began to push farther north and west into the state, virtually all of the populace remained east of San Antonio. The agriculturally rich soils and abundant supply of rivers and streams in east, central and north Texas was a major attraction to farmers and other immigrants arriving in Texas. Because of the state's limited railroad mileage and navigational deficiencies, however, the population remained heavily dependent on overland travel. In the late 1840s and 1850s, state legislation passed that strengthened county powers to lay out and designate roads. Overall, however, road conditions remained miserable. Without adequate drainage, the soft roads were frequently muddy, stalling traffic and slowing trade between the interior and the Gulf ports. These deplorable conditions slowed trade and prevented substantial growth in agricultural commerce and agribusiness.[11]

The expense and technical expertise required to erect large bridges continued to obstruct road progress in the state during the mid-19th century. The people of Texas still forded streams and rivers, although in some places a ferry, raft, canoe or crudely built toll bridge, perhaps consisting only of timbers laid in the streambed, assisted the traveler. Most of the more primitive structures were built by county draftees with little or no knowledge of bridge engineering or construction. These bridges were usually short-lived, collapsing under heavy loads or falling victim to the first major flood waters of a season. Occasionally, however, a county or community would take special efforts to construct a more sophisticated bridge, such as a timber pile-and-beam structure or timber truss. In Texas, timber pile-and-beam bridges (also called pile-and-frame trestle) were typically comprised of log piles hand-driven into the streambed, hewn logs stretching from one group of log piles to the next, light beams placed transversely across the girders, and a plank deck nailed to the beams. Early timber trusses consisted of logs arranged in a primitive fashion to form simple triangular shapes, such as the "A" configuration. A prominent truss bridge, erected just prior to statehood, was the Preston Avenue bridge over Buffalo Bayou in Houston. Completed in 1843, the bridge included two simple triangular-shaped trusses called king posts supported by upright timber piers. With an overall length of 100 feet and a deck width of 16 feet, the bridge was an important and large-scale structure for its time. An article in the December 21, 1843, issue of the *Houston Morning Star* declared it "the most substantial bridge that has ever been erected in Texas."[12]

By the 1850s, a growing number of communities were clamoring for bridges, particularly at major waterways where ferries and fording were impractical. With minimal public funding for bridge and road improvements, many counties relied on private initiatives to span major crossings. Local civic and business leaders created and funded private bridge corporations in an effort to promote regional trade and boost a community's economic standing. Once completed, these privately owned structures operated as toll bridges, with each county setting the charges and regulations for their use. The monies accrued from tolls repaid the shareholders and covered maintenance expenses. Frequently, when a county's financial status improved, perhaps several years or more after the toll bridge was completed, the county commissioners court would purchase the bridge from the corporation and open it for free passage.[13]

Between 1850 and 1870, the Texas Legislature granted charters to more than 100 toll-bridge corporations. Without railroad connections to eastern U.S. bridge fabricators, most of these early structures were built using local materials such as timber and stone. One of the earliest of these was the Commerce Street Bridge at the Trinity River in Dallas. Constructed in 1854 by the Dallas Bridge and Causeway Company, the footbridge featured two main "wooden arches with approaches." As was typical for the period, the bridge's piers and abutments consisted of timber cribs filled with chunks of limestone. The timber used for the bridge was apparently hauled by ox teams from a nearby forest and hewn using a circular saw set up near the bridge site. Unfortunately for the citizens of Dallas, the bridge collapsed under the weight of heavy traffic in 1858 and a ferry operation had to be re-established at the site.[14]

While most of the early toll bridges were simple, timber structures, a few more substantial bridges were built in the late 1860s and 1870s. One such example was the Waco Suspension Bridge (refer to nomination of Waco Suspension Bridge, MLB004-31-001, NRHP 1970), completed in 1869 over the Brazos River in Waco. The bridge was a venture of the Waco Bridge Company, a corporation made up of local civic and business leaders, which in 1866 obtained a charter from the Texas Legislature to erect and operate a toll bridge on the Brazos River for 25 years. Lacking railroad connections to Waco, the company paid to have the wire cables and manufactured bridge materials hauled overland to the bridge site. The bridge was built using local labor and simple construction methods. The completed structure featured a massive 473-foot suspension span with castellated brick towers, wire cables and a wooden plank deck. The bridge served heavy traffic volumes, carrying everything from immigrants' wagons to cattle heading to northern markets, and was critical to Waco's rise as a major crossroads and trading center. As the first bridge completed over the Brazos River and the earliest example of permanent bridge construction in Texas, the Waco Suspension Bridge was a major technological feat that influenced Texas bridge building for decades to follow.[15]

In 1872, the Dallas Bridge Company completed an early metal truss bridge at the Commerce Street crossing of the Trinity River in Dallas. Although plans for the structure began in 1860, they were delayed by the Civil War and were not renewed until the spring of 1868. After a review of several sites, the company decided to build the new bridge at the same site as the old 1850s timber structure. Three years later, a contract was let for the substructure work, which featured three substantial masonry piers rising more than 50 feet above the river's low-water mark. In 1871, the company contracted with King Iron Bridge Company of Iola, Kansas (later of Topeka, Kansas and Cleveland, Ohio) for two wrought iron bowstring truss bridges. The spans were fabricated in the Midwest and shipped to the bridge site where they were then erected on the newly completed masonry piers. The bridge was built at a cost of $65,000 which included the construction of a wooden tollhouse. Completed in March of 1872, the new bridge (including approaches) stretched approximately 300 feet across the river. Ten years after its completion, the bridge was sold to Dallas County which then opened it to the public as a free bridge. The Commerce Street bridge was a prominent landmark and one of few truss bridges in the state at the time. Willard Richardson of the *Galveston News*, claimed that the bridge was "one of the handsomest iron bridges we have ever seen." As an early example of metal truss bridge construction in Texas, the Commerce Street bridge set a precedent for future metal truss work in the state.[16]

Despite the monumental achievement of the Waco Suspension Bridge, the Commerce Street Bridge and a few other iron bridges in the 1870s, the vast majority of communities continued to rely on timber bridges and ferries for another decade or more. In the Piney Woods region of East Texas, timber bridges were prevalent into the 20th century and are still used to a limited extent on some low-volume roadways. Although timber bridges had short life spans and often had to be rebuilt and replaced every so often, their simplicity and ease of construction made them a popular type in Texas. In San Antonio, for example, an assortment of timber bridges amounting to at least six different structures were used at the Commerce Street crossing of the San Antonio River between 1803 and 1870. A more permanent structure, an iron truss bridge, was not built at this site until 1880. In Houston, many timber bridges and ferries existed in the late-19th century but few if any permanent bridges—such as metal truss or concrete arch spans—were constructed until the 20th century. Several free ferries were still operating in the outlying areas of Houston into the 1940s.[17]

Generally, the most technologically advanced bridges in Texas prior to the 1900s were on early railroad lines, such as those radiating from the Houston and Galveston area. By the early 1870s, these routes included several large truss spans, perhaps constructed of iron or a combination of iron and timber. With minimal local resources and no state or federal participation, bridge improvements on Texas roadways continued to lag behind the railroads for another three decades or more.[18]

During the 1870s, the responsibility for road and bridge construction continued to rest with local governments. Although the Reconstruction government authorized a modest state road tax in 1869, the measure was rescinded four years later when the Redeemer Democrats gained control of the state. In 1871, state legislation passed allowing counties to levy a modest road tax, but a severe depression caused the tax to be severely cut at the next legislative session. The constitution of 1876 reflected the frugal and conservation state of mind of the new government, and its intent to reduce indebtedness in the state. Claiming that the Radical Republicans had placed an extreme financial burden on the state, the writers of the 1876 Constitution placed all responsibility for road and bridge improvements on the shoulders of local governments. Paradoxically, the constitution also included provisions that severely restricted the ability of local governments to raise funds for road and bridge projects. The local governments were placed in a difficult predicament. While, on the one hand, they were encumbered with the responsibility to build and maintain the state's roads and bridges, they were also refused access to mechanisms such as taxation and bonding that would allow them to fund these improvements. In the decades following 1876, good roads advocates undertook considerable efforts to overcome these constitutional limitations and to promote greater state involvement in road and bridge improvements.[19]

By 1880, the state stood at the brink of a major economic revolution. Railroads from the Midwest and Northeast had penetrated Texas by the early 1870s, and within 10 years they laid down more than 3,200 miles of track. These railroad connections provided thousands of farmers and communities in Texas with easy access to large U.S. markets for cotton and other agricultural goods. Immigration increased rapidly in rural and urban areas, bringing the settled population to 1.5 million by 1880. Railroad expansion also influenced population distribution and settlement patterns, prompting rapid growth in the state's eastern, central and southern regions and more limited growth in the panhandle and the state's far western area. Overall, however, the population of late-19th century Texas remained heavily concentrated in the southeast, central and northeast portions of the state. As the population increased and the state's economy developed, residents began accelerating their demands for improved bridge and road conditions, setting the stage for a more dynamic era of bridge-building activity.[20]

III. EARLY ADVANCES IN BRIDGE DESIGN AND TECHNOLOGY

Bridge Precedents

The rugged travel conditions and primitive timber bridges of early Texas reflect common themes in American history. As settlers pushed south and west across the frontier, they depended on fording, ferrying and simple timber structures to meet basic transportation requirements. Early bridge construction was conditioned, to a large extent, by the urgency of transportation across vast expanses of territory, and the versatility of the American settler. Travelers in Texas and elsewhere relied on practical experience, as well as the materials and tools at hand, to blaze trails and build simple timber bridges, such as pile-and-beam structures. Although these bridges were not constructed for permanence, they met the basic transportation needs of settlers. According to Donald C. Jackson, engineering historian, timber bridges were popular in this country because they

> represented local engineering solutions to the problem at hand: they did not require extensive amounts of labor to build, they used local materials, and they could be quickly rebuilt if destroyed. They also required only rudimentary design and construction skills.[21]

Populations in the more industrialized areas of the country began experimenting with more permanent bridges in the late 17th and early 18th centuries. While timber bridges had many advantages, they were limited in terms of their durability, length of individual span and load-bearing capacity. The first permanent bridge type in America was the masonry arch, a form which the Romans had perfected and the Europeans had used for centuries. The arch construction combined with the weight of stone and its durability to produce a structure capable of sustaining heavy loads and ensuring over a long period of time. As an expensive and time-consuming bridge to build, the masonry arch was usually reserved for long and important crossings. When the early American railroads began to forge their away across the country in the 1830s and 1840s, they also relied on masonry arches, primarily for crossing mountains and deep river gorges. The railroads continued to use masonry arches on a limited basis until the mid-1800s, when metal trusses proved more economical. By the late 19th century, masonry was still used occasionally, especially when strength and durability were major factors and stone was available near the bridge site.[22]

Large limestone deposits and other factors prompted some railroads in Texas to use masonry construction on a limited basis. The Gulf, Colorado and Santa Fe Railway, for example, built at least a dozen stone arch bridges on its line between Dallas and Paris from 1898 through 1912. While stone arch bridges were found occasionally on railroad lines in the state, they were rarely seen on Texas roadways. Masonry arches reached their peak popularity in the United States during the mid-19th century, a period when travel conditions in Texas were still at a very primitive stage. The high costs and labor intensive requirements of masonry arches made them an impractical type for Texas roadways during this period. By the time Texas communities began building more permanent structures in the 1880s, metal truss bridges were the preferred type for intermediate to long crossings. An unpopular type in early Texas history, the masonry arch is most often associated with the state's works relief programs during the Great Depression. Nevertheless, the state bridge inventory revealed a few early examples of masonry arch construction, primarily in the north and central regions.[23]

The major impetus for greater advancement in bridge construction came with the railroad's expansion across the Northeast and Midwest during the 1830s and 1840s. The railroads provided a powerful stimulus for modifying and improving older bridge forms and for inventing new types with improved efficiency and strength.

Evolution of Metal Truss Types

The first important bridge type to result from the railroad's technological experiments was the metal truss bridge. This type has its origins in the timber truss bridge, which was first used in this country during the late 18th century. Early trusses consisted of an assemblage of small timber members that were connected together to form a rigid structural framework. Such structures usually were comprised of simple triangular shapes (king posts or queen posts) which were combined with an arch when a longer span was required. By the 1820s, several American builders had dropped the arch configuration and were designing long timber trusses made up entirely of triangular-shaped patterns. In cold climates such as New England, timber trusses were weatherboarded or covered as a protection against deterioration and extreme weather conditions. While Texas' relatively mild climate precluded any widespread use of these structures, a few covered bridges were built in the state, primarily in the mid-1800s. One of the better known examples was constructed in 1854 over the San Marcos River in Gonzales. Constructed with slave labor, the Gonzales bridge, also called the "covered tunnel," extended more than 100 feet in length and was supported by large rock masonry piers.[24]

Railroad expansion created the major impetus for advances in truss design in the decades that followed. As trains became heavier and loading increased, many inventors and engineers in the United States began to search for the most practical and efficient metal truss design. Some of these designs were based on sound engineering principles and were used extensively by the railroads. The vast majority of these inventions, however, were more fantastic than practical and were employed, at best, one or two times. During the 1840s and 1850's, designers such as Richard Osbourne, Albert Fink and S.S. Post created inefficient truss designs with fanciful or overly redundant configurations.[25]

While many of the new truss configurations were very similar in appearance, they could usually be distinguished by the arrangement of truss members and the types of forces (compressive or tensile) carried by the vertical and diagonal web members. Each bridge was comprised of two trusses, one on each side of the roadway, with the top chord resisting compressive or squeezing forces and the bottom chord taking tensile or stretching forces. Diagonals and verticals connected the two chords, carrying either tension or compression or, in some cases, both types of forces. The basic pattern repeated in segments, called panels, across the length of a truss.[26]

Although some railroad trusses were executed only in wood, many were constructed as composite iron and timber structures. By the 1860s, an increasing number of trusses were completed in metal, first in cast iron and wrought iron, and later in steel. Iron and steel bridges offered many advantages over timber structures, particularly in terms of their strength, durability and resistance to fire. The conversion from timber to metal bridges occurred most rapidly in the Northeast and Midwest due to superior rail connections and the presence of an established iron and steel industry. In Texas and other remote areas of the country, shipping costs prevented widespread use of iron and steel in bridge-building until at least the late 1800s. The population was predominantly rural and an abundant supply of timber existed.[27]

Two popular railroad truss types were the Howe and the Pratt. The Howe truss (patented 1840) consisted of parallel upper and lower chords joined together by a complex system of wrought iron rods and wood diagonals that extended over one panel length. The wood diagonals of the Howe truss carried compression while its wrought iron verticals acted in tension. In the settled areas of Texas where timber was abundant, the railroads probably constructed Howe trusses either completely in wood or as composite structures with both wood and iron. The Pratt truss, patented in 1844 by Thomas and Caleb Pratt, reversed the stress pattern of the Howe, making the vertical members stand in compression and the diagonals in tension. Although originally constructed in wood and iron, the Pratt was quickly modified for all iron and steel construction, becoming the predominant truss type of the 19th century.[28]

Bridge Suppliers, Fabricators and Builders

The railroad's interest in stronger rails and bridges prompted significant progress in American iron and steel production during the mid- to late-19th century. Bridge engineers first began to use cast iron for truss compression members in the 1840s. As a material that contains more carbon than does wrought iron, as well as a number of other impurities, cast iron is a very strong but brittle material. The railroads quickly adapted cast iron to bridge construction, employing it either alone or in combination with timber. The use of cast iron in bridges was brought to a sudden end in the 1870s with the collapse of several major bridge structures, such as the Ashtabula Bridge in Ohio. Wrought iron, which has a significantly lower amount of carbon than cast iron, was first employed in trusses during the 1840s. By the mid-19th century, American rolling mills were using this material to produce a wide variety of structural shapes, such as I-beams, channels, angle sections and plates. As an extremely durable material that functions well in both tension and compression, wrought iron continued to gain popularity during the mid-19th century and by 1870 had superseded cast iron and timber as the standard material for truss construction.[29]

The railroads' demand for a metal that was stronger and more durable than wrought iron brought about a growing interest in steel production after the end of the Civil War. During the next two decades, the Bessemer converter and open-hearth processes were perfected, making possible the production of large amounts of American steel at low cost. United States steel production rose from 16,000 tons in 1865 to nearly 5 million tons in 1892. During the mid- to late 1880s, many of the U.S. eastern and midwestern rolling mills began retooling their machines to produce structural shapes in steel, prompting a much greater use of steel in bridge building in the years that followed. From about 1890 to 1900, bridge fabricators used both wrought iron and steel members rather indiscriminately. By the turn of the century, steel had replaced wrought iron as the universal material for truss construction.[30]

Until about 1850, most railroads designed and built their own bridges from timber or a combination of timber and iron. In the following decades, however, railroads became more dependent on metal truss bridges, and a new industry of foundries and fabricating shops emerged. These industries formed, drilled, assembled and riveted the various truss members and prepared them for shipment and erection at the bridge site. Private bridge fabricators began opening shops in the United States during the mid-19th century and by 1860 the vast majority of the railroads were relying almost exclusively on private companies to fill their demand for metal truss spans. Typically, bridge fabricators sold the bridge components unassembled, shipping them to the bridge location for on-site erection. While most bridge-building companies manufactured proven truss types, such as the Pratt, Whipple and Warren, a few smaller companies specialized in a few unusual types of truss designs. By 1890, there were more than 40 bridge fabrication shops in the United States, concentrated primarily in the Northeast and Midwest.[31]

Bridge manufacturing was a complicated task that involved at least three distinctive processes, including: the production of iron and steel from raw materials, the rolling of iron and steel into structural shapes, and the fabrication of bridge members and connection pieces. Through the puddling, open-hearth and Bessemer processes, integrated rolling mills converted iron ore, coke, limestone and other substances into cast iron, wrought iron and steel. These materials were then rolled into various structural shapes, such as I-beams, channels, angles, plates and bars. As the industry evolved, the mills began producing metal products in standardized shapes and sizes. Most of the rolling mills were in the country's eastern and midwestern steel belt, a region that contains the country's largest iron ore deposits. Historians working on the Texas bridge survey noted the names of rolling mills imprinted on metal truss bridge members, typically on I-beams and channels. Several of the more common names observed on Texas bridges were "CARNEGIE" (Pittsburgh), "CAMBRIA" (Johnstown, Pennsylvania), and "ILLINOIS" (Chicago).[32]

Bridge fabricators utilized a series of manufacturing processes to fashion standardized metal products into finished bridge members. One of the bridge fabricator's primary tasks was to create composite or built-up members using channels, angles, plates and other metal components acquired from the rolling mills. By the late 1800s, American bridge fabrication had evolved into a complex yet highly standardized manufacturing process that was generally divided into five operating departments: the engineering shop, templet shop, riveting shop, machine shop and forge shop.[33] Engineering historian David A. Simmons provides a concise account of a late 19th century bridge fabrication plant:

> Following the receipt of a contract for the erection of a bridge, the first step in actually producing that structure was the preparation of detailed plans by the company engineers. These drawings were sent to the templet shop where full-size wooden patterns of each component of the bridge were made. Much of the bending, cutting, drilling, and punching necessary to fabricate the various parts of the structure was done within the riveting shop, set up in a large area of the plant that allowed for the handling of long beams. . . . The pins used to hold the main components of the truss together were produced on lathes and thread cutters in the machine shop. The . . . eyebars, were produced in the forge or blacksmith shop. Here

the ends of the bars were heated in special furnaces and formed into their final shape by powerful steam hammers.[34]

By the late 19th century, bridge manufacturing had evolved from a somewhat amateur craft to a highly refined and efficient American industry. In 1900, a trade journal noted that American bridge shops had "reached as high a state of perfection as any other class of manufactories."[35]

As bridge shops expanded, they also began diversifying their lines to include lighter spans for roadway use. During the late 19th century, bridge fabricators began producing wrought iron and steel roadway trusses in a variety of shapes and sizes. The demand was greatest for spans of 100 feet or more. Experience had shown that timber spans were somewhat impractical for span lengths of 30 feet or more, and that longer spans were necessary for more permanent bridge construction. Soon, fabricators were manufacturing trusses with lengths of 100 to 200 feet or more. Due to their efficient operations, bridge fabricators could fill orders very quickly, usually within a few weeks or even days. The expansion of the railroads throughout the country also served the bridge fabricators well, allowing them to ship their products to cities, towns and rural communities in almost every part of the country.[36]

Typically, a bridge fabricator would ship a metal truss span in a package or kit consisting of an assortment of lightweight bridge members, as well as the necessary connection pieces, such as pins, eyebars and bolts. Once the package arrived at its final destination, bridge agents or local men would haul the bridge members by wagon to the bridge site where the truss components would then be assembled and erected on piers or abutments. The addition of approach spans (usually timber or I-beam trestle) and a timber plank deck would complete the bridge. A bridge type that was lightweight, durable and easy to erect, the metal truss was well-suited to the primitive travel conditions in Texas and the rest of the country. Metal truss bridges rode a tremendous wave of popularity in late 19th century Texas, representing a significant improvement over stream fording and ferrying, and primitive timber bridges of the past.[37]

By the late 1800s, there were scores of large bridge fabrication companies in the Northeast and Midwest, and a few smaller plants in western states, but none in Texas. Many of the U.S. eastern bridge fabricators built up a substantial business designing and fabricating roadway trusses for shipment to distant locations, such as Texas, Oklahoma, Arizona and New Mexico. By 1900, truss design and fabrication was rapidly becoming standardized, and competitive pressures precipitated the closing or takeover of many bridge firms. The largest consolidation occurred in 1900 when Andrew Carnegie bought out more than 25 of the largest bridge fabricators in the country and amalgamated them into the American Bridge Company of New York City, New York. By the early 1900s, the independent bridge firm was on the decline in the United States, disappearing almost entirely after World War I. In the years that followed, bridge-building activities were often divided between consulting engineers that provided bridge designs and steel-fabricating firms that manufactured and erected the spans.[38]

Early Metal Truss Types in Texas

Many of the early truss types were adapted for highway use during the mid- to late 19th century. An early truss bridge found in Texas was the bowstring, a truss form employing an arched top chord as the primary compression member tied by a lower chord resisting tensile forces. Squire Whipple patented a design for a bowstring truss with all cast iron members in 1841. By the 1860s, other engineers such as Zenas King of Cleveland, Ohio, and David Hammond of the Wrought Iron Bridge Company of Canton, Ohio, had invented bowstring designs built from rolled wrought iron members. While King's design employed a hollow top chord with a rectangular section, Hammond's design featured a cylindrical member, also called a Phoenix column. An extremely popular bridge type during the third quarter of the 19th century, the bowstring had a high carrying capacity while using a relatively small quantity of iron. This truss form reached its height of popularity in Texas during the 1870s and 1880s.[39]

Although the popularity of the bowstring truss was fairly short-lived, these bridges were a fairly common sight in late 19th century Texas, particularly at small to intermediate sized crossings. The aforementioned 1872 bowstring truss bridge in Dallas is the earliest documented example of a metal truss roadway bridge in Texas. The type's early popularity in the state is attributed to its lightweight members and pin connections which made it relatively easy to haul over primitive roads and to erect at the bridge site. In many counties, the first metal truss spans were bowstring trusses, with subsequent bridges conforming to the Pratt or Warren configurations. In 1882, for example, Coryell County, contracted with King Iron Bridge Company "to build, paint and make complete, ready for use, by October 1, 1882 . . . the substructure and superstructure for a wrought iron tubular arch [bowstring truss] bridge of the King's latest improved patent over the Leon River . . . on the West side of Gatesville." The successor to this bridge, a Pratt through truss span, was constructed in 1904 (CVC001-75-001). While no bowstring truss bridges conforming to Hammond's design are known to remain in Texas, a number of King's bowstrings continue to serve traffic on county roads, including the 1884 span over Elm Creek on the Marlin-Groesbeck Road (FAAA02-36-001). Texas has some of the only bowstring trusses remaining in the southwestern United States.[40]

By the end of the 1880s, the Pratt truss design had largely replaced the bowstring as the standard truss type for short to intermediate spans (30 to 150 feet) and was being manufactured in a wide variety of shapes and sizes. The straightforward design, considerable strength and ease of erection made the Pratt the predominant truss type for American roadways during the late 19th and early 20th centuries. It quickly gained acceptance throughout Texas as the preferred type for short and intermediate spans, reaching its heyday of popularity from 1895 to 1910. Most of the earliest examples were built in central and north Texas, including the 1884 Hickory Creek bridge near Denton (refer to nomination of Old Alton Bridge, DNAA06-19-001, NRHP 1988) and the 1885 bridge over the Clear Fork of the Brazos near Albany (SFAA01-88-001).[41]

Two peculiar Pratt variations that were built on Texas roadways were the truss leg bedstead and the lenticular. The truss leg bedstead is a Pratt with long vertical endposts that extend below the roadway to serve as piers or abutment supports. By anchoring the end posts into the streambed, this design was intended to improve the Pratt's overall rigidity and strength. The truss leg bedstead never gained widespread popularity in the United States, and was used only occasionally for short spans during the late 19th and early 20th centuries. A few examples of the truss leg bedstead are known to survive in Texas, including an 1898 span over Elm Creek near Cameron (MMAA02-12-002) and an 1888 truss over Mulberry Creek on the old Schulenberg to Praha road (FYAA02-91-001).[42]

The lenticular configuration features curved upper and lower chords that form the shape of a lens. This truss form originated in Europe in the mid-1800s but did not arrive in the United States until some decades later. William O. Douglas patented an American version of the lenticular truss in 1878, producing hundreds of small to intermediate size lenticular spans during the next fifteen years. An 1889 bridge catalogue of the Berlin Iron Bridge Company lists a William Payson from Edna, Texas as the company's only bridge salesman outside of the New England or New York area. Through William Payson's association with the company, Texas acquired at least a dozen lenticular trusses from 1889 to 1895. At least five of these spans were built in San Antonio. The most prominent of these was a 93-foot truss originally constructed in 1890 over the St. Mary's Street crossing of the San Antonio River (BXB038-25-001). Currently, this bridge serves vehicular traffic at a river crossing in the city's Breckenridge park. Victorian flourishes such as elaborate cast- and wrought-iron railings with rosette motifs, decorative portal cresting and urn finials help to provide relief for this large utilitarian structure. A survey of other states' bridge inventories reveals that Texas has the only lenticular trusses remaining west of the Mississippi River.[43]

During the late 1840s, railroad-bridge engineers began creating Pratt-related designs with greater rigidity and longer span lengths. The earliest of these designs was the double-intersection Pratt or Whipple truss, invented by Squire Whipple, an influential American inventor best known for his groundbreaking discourse, *A Work on Bridge Building*. Whipple received a patent for his namesake design in 1847, the same year that he published his famous treatise. The Whipple configuration, with diagonals spanning two panels, provided a solution to the problem posed by long truss spans. In order to increase the length of a truss span, the height of the truss must also be increased. A corresponding increase in panel length must occur if the degree of inclination of the diagonals is to remain at 45 degrees, the angle considered most efficient at the time. The resulting panel length may exceed the limits of the timber stringers. The Whipple design introduced the double-intersection diagonal which spans two short panels at or near a 45-degree angle. By creating shorter panel lengths with each diagonal crossing two panels, the Whipple configuration provided an economical, innovative solution to the problem of spanning long distances.[44]

The Whipple was a popular type for long railroad and highway spans between 1865 and 1890. An 1885 pamphlet of the Wrought Iron Bridge Company of Canton, Ohio, indicates that the Whipple truss is best suited for spans of 150 to 300 feet with "wide or double roadways, . . . heavy traffic, where deep girders are desirable to avoid a squatty end view." While the double-intersection Pratt was a fairly uncommon type in Texas, it was used occasionally at long crossings. One of the earliest examples in the state was a six-span Whipple truss structure built in 1883 over the Colorado River in Austin. Three of the bridge's original 148-foot spans now serve a pedestrian walkway in a Travis County park. (TVAA17-11-001). One of the most impressive Whipple truss bridges that is still standing in the state is the 1887 bridge over the Guadalupe River in New Braunfels which includes two 220-foot Whipple spans (CMB005-30-001).[45]

A second variant of the Pratt that facilitated the construction of longer spans was the Parker truss, designed by railroad engineer C.H. Parker in the mid-1800s. Parker's configuration was comprised of a Pratt with deep web members and a multi-sided top chord, a design that increased the rigidity of the Pratt and allowed for span lengths up to 250 feet or more. The camelback was a sub-type of the Parker characterized by its five-sided top chord. In Texas, pin-connected Parkers and camelbacks were common from about 1905 to 1920. Relatively long span lengths are provided by the 235-foot Parker span, built in 1906, over the Little River near Gause (MMAA05-25-001) and the 200-foot camelback span, built in 1909, over the Little River at the Bryant Station Crossing (MMAA02-75-001). The Parker found extensive use in 20th century Texas as an all-riveted truss.[46]

During the 1870s, the Pratt, Parker and camelback configurations were further improved by subdividing the panels with half-length members called substruts and subties. These designs minimized buckling and distributed the loads more uniformly over the truss, enabling the construction of even longer spans. The principal subdivided types included: the Baltimore (a subdivided Pratt), Pennsylvania (a subdivided Parker) and sub-divided camelback. By 1900, the simple Parker truss and the various subdivided forms had replaced the Whipple as the standard types for long truss spans. Initially, these bridges were built with pin-connections, but by 1915 most examples were completed by field riveting. While no Baltimore trusses survive in Texas, a few Pennsylvania and subdivided camelbacks continue to serve traffic on rural roadways in the state. A typical example is the 180-foot sub-divided camelback span, built c. 1905, over the San Antonio River near Floresville (WNAA01-17-001).[47]

Another important truss type invented during the 19th century was the Warren truss, patented by English engineer James C. Warren in 1848. This configuration, which conforms to a "W" shape, is characterized by rigid diagonals that function both in tension and compression. While the Warren was initially introduced in America as a pinned truss, this configuration did not fare well against the Pratt. A few pin-connected Warren pony trusses survive in Texas, including the 60-foot span built in 1898 over the Old River in rural Burleson County (BUAA02-00-001). By the turn of the century, some bridge builders were constructing Warren trusses using a transitional connection method that combined shop-riveting with field-bolting. This intermediate type of connection is illustrated in the 1907 bridge over Jimmy's Creek near Comanche (CJAA01-04-001). It was not until field riveting technology was perfected at the turn of the century that the Warren gained widespread popularity in the United States as both a railroad and highway structure. The Warren's simple configuration and lightweight members provided many advantages, and by the early 1900s it had superseded the Pratt as the preferred type for short spans (usually 30 to 90 feet). By the 1910s, some bridge builders were also designing Warren trusses with polygonal top chords and through configurations, enabling the construction of spans up to 125 feet or more.[48]

Before the end of the century, the very longest truss spans in the United States were cantilevered spans. This sophisticated engineering practice demonstrated the high level of technical skill that American bridge builders had achieved over a relatively short period of time. Unlike a simple truss that is supported at both ends, the cantilever truss is held only at one end and, hence, must be anchored by a second span from the opposition direction. In order to extend a bridge's span length over a channel, railroads often built cantilevered trusses with a third suspended span in between the two projecting truss arms. The cantilever truss reached its greatest size in America during the 19th century with the completion of the Kansas City, Fort Scott and Memphis Railroad bridge over the Mississippi river at Memphis, Tennessee in 1892. The structure included an irregular combination of cantilevers, anchors and suspended truss spans, providing a main channel span of about 800 feet and a total length of more than 2,100 feet.[49]

A spectacular example of a cantilever bridge completed in Texas was the Pecos River built by the Galveston, Harrisburg and San Antonio Railroad between Comstock and Langtry, Texas (1891-92) The viaduct was 2,180 feet long between abutments and was comprised of a series of cantilevered and simple truss and girder spans with a central 80-foot suspended truss unit. The most extraordinary feature of the bridge was its tall steel towers that rose 320 feet above the surface of the water. According to Carl W. Condit, engineering historian, the bridge's extreme height made it appear "like a stretched thread over the water far below it." The bridge was replaced by the present structure in 1944. The cantilevered truss construction featured in the Pecos River bridge was extremely rare on Texas roadways until the 1920s.[50]

The evolution of truss connections paralleled that of truss design. Pins were first used to connect a bridge on the Lehigh Valley Railroad in 1859. A pin-connected bridge was typically assembled by inserting large metal pins through reinforced holes punched in the ends of adjoining truss members. By the early 1860s, railroad bridge engineers had developed forged eyebars to connect slender tension rods with other built-up members in a truss. The pinned technology was advantageous since it allowed trusses to be manufactured, shipped and hauled to the bridge site in small pieces. Pinning greatly facilitated erection at the bridge site and was rapidly adapted to the Pratt and related types during the late 19th century. The flexibility of the pins, however, caused considerable wear and tear around the connections and produced significant vibrations. These deficiencies prompted railroad engineers to experiment with other methods, such as combination riveting and bolting. Portable pneumatic riveting systems became available in the late 1880s, providing a more rigid and durable method of connection. Initially, bridge builders used field riveting techniques only for short spans. Eventually, this method was applied to longer truss types, such as the Parker. By 1920 field riveting had replaced pinning as the universal method for connecting trusses in Texas.[51]

Beams and Girders

The rise of rolling mills and fabricators also stimulated an interest in I-beams for short stringer spans. Several of the U.S. eastern railroads were using wrought iron I-beams in trestles and small beam structures immediately after the Civil War. By the late 19th century, many communities began employing wrought iron and steel I-beams in place of timber for simple stringer spans. During the late 1800s and early 1900s, metal I-beams were often used for short spans with lengths of 30 feet or less. Gradually, the rolling mills developed the technology to produce deeper I-beams, which increased the practical length of steel stringer spans to 40 feet or more.[52]

The transition from timber to metal stringers was relatively slow in Texas due to the abundance of timber and its easy adaptability to stringer bridge construction. Shipping charges also added significantly to the cost of using steel stringers in Texas, making them only marginally competitive against conventional timber types. It was not until the 1910s, when steel fabricators began operating in the state, that steel I-beams were used more extensively in Texas bridge construction.[53]

After the Civil War, many of the railroads began demanding stronger and more rigid beams to accommodate increasing traffic and loading requirements. By the late 19th century, many bridge fabricators were building large built-up beams called plate girders for short to intermediate spans. These girders typically consisted of metal angles and plates riveted together to form relatively large beams. The railroads used plate girders extensively for simple bridge spans, but also employed them occasionally for swing bridges as well. The pre-fabricator girders were usually placed on a flat car and shipped by rail to the bridge site. By 1916, the renowned American bridge engineer J.A.L. Waddell noted that the ordinary limit for plate girder spans was about 100 feet, although spans of 120 feet or more were common for swing spans. The transportation of large girder units was more problematic for roadway crossings, particularly when the girders had to be hauled long distances overland. Transportation difficulties and the preference for light spans prevented a more widespread use of girders on Texas roadways until the 1920s and 1930s.[54]

Suspension Bridges
This section will be completed under Phase I of the Texas Historic Bridge Inventory.

Other Technological Developments
This section is to be completed under Phase II of the Texas Historic Bridge Inventory.

IV. BRIDGE DEVELOPMENTS IN LATE 19TH AND EARLY 20TH CENTURY TEXAS

The Railroads

Railroads expanded rapidly across Texas in the 1880s and 1890s, setting the stage for a more intensive era of bridge construction. In 1872, Texas' railroad mileage ranked 28th compared with other states. In the following year, the Houston and Texas Central connected with the Missouri, Kansas, and Texas Railroad (Katy) in Denison, linking the Texas Gulf with North Texas and other markets in the Midwest, North and East. By 1890, the state had 8,710 miles of railroad track, ranking it third among other states, and by 1904, Texas had more than 10,000 miles, the most in the nation. While these lines extended west to El Paso and northeast through the Panhandle, the state's railroad mileage was largely concentrated in the eastern half of the state. The railroads brought instant prosperity to many communities and had a significant impact on the state's economy. According to Texas historians Robert A. Calvert and Arnoldo De León:

Commercial agriculture followed the tracks as cotton replaced grain and cattle as the dominant factor in economic growth. New industries grafted themselves onto commercial agriculture, turning the state from a preindustrial, rural economy into one with improved transportation facilities.[55]

The railroads overshadowed and, to some extent, replaced previous modes of transportation in Texas. A location on the railroad was suddenly critical to a community's livelihood, superseding any previous reliance on overland routes or inland ports. While roads were no longer the predominant form of travel in the state, they gained new importance as the primary means to access shipping points and accommodate travel between farms, agricultural processing centers and major towns.[56]

Local Bridge Progress

Pressure mounted for road and bridge improvements in the 1870s and early 1880s, resulting in a flurry of road and bridge legislation during the next decade. The first related piece of legislation was enacted in 1885 in response to a constitutional amendment that gave county commissioners courts the authority to levy a modest advalorem property tax (up to 15 cents per $100 of assessed value) to fund road and bridge projects. During a special session the following year, the legislature passed another measure empowering county commissioners' courts to issue bonds running 20 years or less "for the purpose of buying or constructing bridges for public uses" and to levy an annual ad valorem tax up to 15 cents on $100 valuation to pay off these bonds. An 1887 amendment re-affirmed the basic tenets of the 1884 act but, in response to concerns over property tax rates, also imposed some limitations on bridge bonding amounts.[57]

For the first time, counties were given considerable latitude to finance road and bridge improvements, opening the door for future road and bridge bonding legislation. The bridge-bonding acts of 1884 and 1887 facilitated modest bridge improvements, allowing many counties to build their first metal truss spans. Typically, bridge bonds could fund several metal truss bridges in a county, but often were insufficient to cover large monumental crossings. Counties would usually bridge the more important crossings first, replacing timber bridges at secondary crossings as additional funds became available. A county's earliest metal truss bridges were often built on stagecoach and mail routes, and on important roads linking outlying areas with county seats and other regional centers. One county that took advantage of the new bridge bonding legislation was Grayson County which issued $10,000 in bridge bonds during 1885 and used the monies to build a number of permanent-type bridges, including a 90-foot Pratt through truss span near Pilot Grove (GSAA03-39-003). Because of the legislative limitations placed on county indebtedness, however, most counties could only afford to issue bridge bonds periodically, perhaps once every five to ten years.[58]

Despite the 1884 and 1887 bridge bonding legislation, most counties still could not afford to fund bridge improvements on a large scale. During the next decade, significant progress was made to broaden county bridge-bonding powers. An 1889 act resolved questions over the authority of counties to build bridges on streams serving as county boundary lines. The law clearly affirmed that in these cases, either county on the dividing line had the authority to issue bonds for bridge improvements. Similarly, an 1895 law extended counties' bridge building authority to sites located inside the incorporated limits of cities and towns. The most consequential piece of legislation passed during this period was the 1893 bonds law which significantly expanded the bridge bonding powers of the counties. Among its various provisions, the act extended the bonding period from 20 to 40 years, raised county bridge-bonding levels to one percent of taxable property values and loosened previous limitations on a county's overall indebtedness. These provisions allowed counties to issue six times or more the amount of bridge bonds than previously allowed, stimulating an intensive period of bridge construction in the years to follow.[59]

The 1890s and early 1900s are characterized by larger and more substantial bridge projects, funded primarily by county bridge bonds. The most impressive of these was the Galveston Causeway Bridge, constructed from 1892 to 1893 by the King Iron Bridge Company of Cleveland, Ohio. The main part of the structure was comprised of 89 bowstring spans and a truss swing span that together provided a length of about 7,430 feet. A wooden pile trestle approach added another 3,880 feet, bringing the total length to 11,310 feet. They built the bridge by erecting a series of solid concrete wall piers and then floating the prefabricated and assembled bowstring trusses into position. While the initial contract amounted to $183,000, extra expenses brought the total to $191,986, a phenomenal amount for a county-funded bridge project at the time. *Engineering News* noted that the "steel work is unquestionably light, but the traffic will be light also," and concluded that it was "probably the longest iron or steel highway bridge ever constructed." Unfortunately, the structure only lasted seven years, falling prey to the September 7, 1900, tropical storm that devastated Galveston and killed an estimated 6,000 people.[60]

Another large bridge built during this period is the 1902 Pennsylvania span over the Brazos River in Waco (MLB003-31-001), built by John H. Sparks of St. Joseph, Missouri. Stretching 450 feet over the Brazos, this bridge has tremendous scale and height, and is distinguished by a 23-foot roadway that was extremely large for its time. The massive structure was relieved by curvilinear braces below the portal bracing and intermediate struts decorated with cut-out star, teardrop and three-leaf clover motifs. During the early 1900s, several postcards were made of the massive structure, including one proclaiming it "the longest single span in the U.S."[61]

Not all bridges built in the 1890s and early 1900s matched the scale and engineering significance of the Galveston and Waco structures. During this era, hundreds of metal truss bridges were built in rural areas across the state, the vast majority of them lesser structures. Most of the bridges were relatively short Pratt pony or through truss spans. In some cases, however, the bridges consisted of a series of trusses that were strung together across large creek or river crossings. One of the most important of these was a six-span Pratt through truss bridge built in 1911 over the Colorado River on the old Brady-Coleman road. (CNAA02-94-001).[62]

Bridge Building Patterns in Texas

As the demand for bridges in Texas increased, so did the activity of out-of-state bridge builders. From the 1880s to the early 1900s, Texas counties acquired hundreds of metal truss bridges from large out-of-state bridge companies. This trend was facilitated by the state's rapid railroad expansion, which allowed direct and rapid transportation of manufactured materials from the Northeast and Midwest. At least 20 different out-of-state companies sold bridges in Texas during this period, including the American Bridge Company of New York City (and elsewhere); the Berlin Iron Bridge Company of New Berlin, Connecticut; the Chicago Bridge and Iron Company of Chicago, Illinois; the George E. King Bridge Company of Des Moines, Iowa; the Kansas City Bridge and Iron Company of Kansas City, Missouri; the King Iron Bridge Company of Cleveland, Ohio; the Milwaukee Bridge and Iron Company of Milwaukee, Wisconsin; the Missouri Valley Bridge and Iron Company of Leavenworth, Kansas; the New Jersey Steel and Iron Company of Trenton, New Jersey; and the Wrought Iron Bridge Company of Canton, Ohio.[63]

The success of these companies relied largely on the skill of the agents assigned to specific territories or regions of the country. These agents obtained commissions for the bridges they sold and operated somewhat independently from the fabricators. By the mid- to late 1880s, many bridge companies employed bridge agents in Texas. By 1890, for example, C.Q. Horton, agent for the Kansas City Bridge Company had set up an office in Austin and Samuel A. Oliver, agent for King Iron Bridge Company, had set up an office in Houston. The bridge company agents usually represented a large sales territory which often covered one or more states. By 1879, Samuel A. Oliver of King Iron Bridge Company, had set up an office in Texas and was responsible for a large Southwestern territory that included Texas, Arkansas, Louisiana, New Mexico and Oklahoma, as well as Indian Territory and the Republic of Mexico. The agents traveled from county to county selling their truss bridges, bidding competitively against one another at county commissioners' court hearings held monthly throughout Texas. Typically, the agents would travel to a community either the day of or the day before the scheduled meeting to visit the bridge site and prepare estimates. The agents of the various companies would then submit their bids at the meeting that evening, with the low bidder usually winning the contract.[64]

Metal truss spans quickly gained popularity with county commissioners' courts throughout the state. Providing longer spans than the usual timber or concrete slab bridges, metal truss bridges eliminated or, in some cases, reduced the need for interior supports or piers. Also, construction was usually rapid, since the truss members were pre-fabricated before their arrival at the bridge site. The county commissioners usually requested bids for a "complete bridge," meaning that the bridge agent was responsible for constructing the truss span(s), substructure (typically iron caisson piers, steel bents or masonry piers) and approaches, and providing a finished wooden plank deck. Typically, the bridge agents would hire erection crews to assemble the bridge, build falsework, and erect the bridge in place. For larger bridges, the work often involved the use of heavy expensive erection equipment, such as steam-powered cranes, derricks and gin poles (hoisting devices). Some county commissioners courts erected small truss spans using local men or convict labor in an effort to be economical. While some bridges would serve at their original location for many years, often the counties would salvage washed-out or obsolete spans and move them to new locations. If the county commissioners could not find a new use for an old truss, they would often sell the bridge to other nearby communities and counties.[65]

A typical county commissioners' court hearing on a bridge project took place in Belton, the county seat of Bell County, on June 10, 1889. On this day, the Bell County Commissioners' Court received bids from nine bridge agents for a new "iron or wire bridge across the Lampasas River on the Belton-Austin Road." After travelling to the site, the agents submitted their drawings and bids for the project. The two lowest estimates were presented by Eddy Improved Wire Company and Missouri Valley Bridge Company for cable suspension bridges. The court rejected these bids, opting instead for a "high truss railroad plan." The contract was then awarded to F. Harris of the Pennsylvania Bridge Company for his low bid of $7,250. Over the next five months, the company constructed two stone masonry piers, erected a 196-foot Whipple truss on the piers and completed the bridge with a wood plank deck. The bridge (BLAA06-80-002) was completed in November 1889, nearly two months after the agreed upon completion date.[66]

County commissioners' courts usually expended considerable effort to select bridge sites that would not only meet public needs but also minimize construction costs and reduce the possibility of flooding damage in the future. Typically, the preferred bridge site would have high banks and a narrow streambed, and be located at right angles to the stream. The steel truss span was usually placed in the middle of the streambed, flanked by a series of timber or metal I-beam approach spans linked to the roadway on either end. Most early metal truss spans were erected on stone piers, timber or steel pile abutments, or concrete-filled tubular caissons built from riveted iron or steel plates. The bridge builders often erected the truss spans at a higher grade than the approaches and connecting roadway in an effort to safeguard the truss from heavy currents and flooding.[67]

Bridge washouts were a common occurrence in late 19th and early 20th century Texas. Frequently, spring floods would inundate a bridge's timber approaches, leaving the main truss span(s) standing alone in the middle of the creek channel. Constant flooding problems led many counties to rebuild bridge substructures and approaches on an almost regular basis. Often, the floods would also carry the main truss span(s) off its piers and into the streambed below. If the truss(es) could not be recovered, the county would commonly build a new structure at the same site, using the old substructure if possible. In cases where the truss span(s) was salvageable, the counties would then hire bridge agents or local builders to re-erect and repair the damaged structure. Bridge-related events in Caldwell County in the summer of 1902 were typical for the period. On August 15th of that year, the county commissioners' court met to review bids from three companies to rebuild two metal truss bridges that had recently washed out over Plum Creek. The contract specified that the company was "to furnish all material necessary to rebuild and construct . . . the two bridges . . . present spans to be taken out of creek and straightened up and new parts added where cannot be repaired so that for strength they will be good as when first built and complete." The court awarded the contract to C.Q. Horton of Kansas City Bridge and Iron Company, who submitted the low bid of $2,104.[68]

The process of using out-of-state bridge companies to obtain metal truss bridges was not without its faults. These bridges were typically constructed without regulations or supervision from governmental entities or consulting engineers. Typically, counties would provide brief specifications in their bridge contracts, usually consisting of one sentence, for instance, "bridge to be of ten-ton capacity." Instead of designing bridges to meet strict standards and specifications, most of the early bridge companies operating in Texas developed their own stock spans that they marketed throughout the state. Bridge agents typically operated on the basis of selling a bridge to cover a certain distance or to span a certain channel with little regard for its load carrying capacity or site conditions. Because counties almost invariably selected the design with the lowest cost, there was also a dangerous tendency for companies to cut corners. Spans that were sold on the basis of a 10-ton capacity were often much lighter, perhaps as low as six to eight tons. Without comprehensive site investigations to assess soil conditions, many bridges were also built with inadequate foundations for piers and abutments. Reflecting on early bridge building practices in the state, George G. Wickline, first State Bridge Engineer, commented that metal truss bridges "were 'trimmed down' as much as possible to meet a limited appropriation, and, in most cases, piers and abutments were skimped." Poorly built bridges and shallow substructures were often a major cause of early bridge failures in the state. In one case in 1902, the engineering press reported that a 200-foot pin-connected through truss bridge over the Colorado River at Gonzales had collapsed due to weak tubular piers.[69]

Bridge companies in Texas were also accused of "pooling," a practice in which the agents essentially rigged the bids, and reached an agreement beforehand concerning who would win the contract for a project. Significant documentation exists on the pooling practices of various bridge companies, including King Iron Bridge Company, George E. King Bridge Company, Wrought Iron Bridge Company, Milwaukee Bridge and Iron Works, Missouri Valley Bridge and Iron Works and numerous other companies that were active in Texas. Typically, bridge companies would stake out territories consisting of several or more counties within a state or larger region. When a bridge construction project was advertised, agents for each of the companies would meet and discuss the cost of the project. If an agreement was reached, the agent in whose territory the bridge was located would submit the low bid for the project, allowing for a considerable margin of profit, and the other companies would submit higher bids. Once the contract was awarded, the successful bidder would then compensate the other agents for their cooperation. If an agreement was not reached, however, then the bidding would be truly competitive. While there is no direct evidence that Texas bridge agents participated in pooling arrangements, it is likely that this type of collusion occurred in Texas, as it did elsewhere. Wickline substantiated this when he described early bridge lettings in Texas as "a competition of wits or a 'frame-up' known as a 'pool' in which a certain predetermined bidder got the job."[70]

Texas Bridge Fabricators

Prior to the early 1900s, virtually all I-beam and truss bridges in Texas were fabricated by out-of-state bridge companies. While these fabricators relied primarily on exclusive agents to market their bridge products in Texas and other states, in some cases, local engineers or contracting companies also acted as agents for these firms. These independent Texas companies usually did not have the same level of company loyalty as exclusive agents. They tended to change associations with bridge fabricators frequently, marketing trusses for one company for a year or two and then switching to another firm. For some of these companies, the marketing of metal truss bridges represented a fairly minor part of their overall operations. Often, a firm that marketed metal truss bridges also sold road machinery, structural steel for buildings and other related products, and in some cases offered engineering consulting services as well. For these companies, it was standard practice to purchase steel trusses and other products from out-of-state companies and to sell them in Texas under their own name.

A number of bridge contracting firms operated out of the Ft. Worth and Dallas area. A 1900 city directory for Ft. Worth lists both a senior and junior Montague S. Hasie as bridge builders. In this directory, Montague S. Hasie Jr. is also described as the "general Southwestern agent" for Groton Bridge and Manufacturing Company of Groton, New York. By 1902, Montague S. Hasie Sr. had moved to Dallas and had established himself as the president of the Texas Bridge Company, Inc. County commissioners' records of the early 1900s evidence that the company was actually an agent for American Bridge Company of New York, New York. A number of American Bridge Company trusses survive in Texas with documented construction dates of 1905 to 1911. By 1908, Montague S. Hasie, Jr. is also listed in the Dallas city directories as a bridge engineer and contractor. A second Dallas-based bridge firm was Hess and Skinner Engineering Company, which bid on several bridge projects in Texas during the 1910s. Various documentation materials evidence that the company was actually acting as agents for the Missouri Valley Bridge and Iron Company of Leavenworth, Kansas, during much of this period.[71]

Southwestern Bridge and Iron Company of Fort Worth was also involved in metal truss bridge projects. The 1896 to 1897 Fort Worth city directories list the company as "general contractors for bridges; iron and steel structural work, foundry and machine works." During the late 1890s, the company bid on a number of metal truss bridge projects in Texas. The officers of the company included Thomas A. Tidball, president; R.N. Hatcher, vice president; E.C. Orrick, secretary; and William T. Young, engineer. The company had a downtown office, as well as a yard along the Texas and Pacific Railroad in Fort Worth. While the company apparently operated a foundry, there is no evidence that the company performed bridge fabrication work as well. Instead, the firm probably operated as a contractor for out-of-state bridge companies, utilizing their Fort Worth yard to store bridge components until they were ready for shipment to a bridges site.[72]

El Paso Bridge and Iron Company of El Paso, is also known to have sold metal truss bridges in Texas beginning in 1908. The city directories for El Paso list a downtown El Paso location, but do not indicate whether the firm was acting as a bridge fabricator or a bridge agent for another company. With an office location in downtown El Paso, it seems unlikely that the company was a metal truss fabricator. The 1909 El Paso city directory lists three principals in the company: W.E. Robertson, E.B. Holt and W.D. Webb. By 1914, the company had also brought E. P. Rankin, Jr. into its ranks. In 1920, the El Paso city directory includes two companies under the category of "Iron and Steel." The first of these is the El Paso Bridge and Iron Company, which is listed as "engineers, designers and contractors," providing "structural steel for every purpose." The company is also shown for the first time as having a warehouse in the city. The second firm listed is the Wisconsin Bridge and Iron Company of Milwaukee, Wisconsin, with E.P. Rankin, Jr., formerly of El Paso Bridge and Iron Company, as the principal contracting engineer. The ad goes on to list the Milwaukee firm as "engineers and fabricators" specializing in various types of steel equipment and frames, including "trusses" and "girders." This chronicle of events suggests that the El Paso Bridge and Iron

Company was probably not fabricating bridges in Texas, but rather was acting as agents for out-of-state bridge fabrication companies, such as the Wisconsin Bridge and Iron Company.[73]

The Alamo Construction Company of San Antonio bid on numerous metal truss bridge projects in Texas from 1914 to 1918 or later. Various engineers were associated with the company, including a G.H. Bradford and H.L. Miles. A 1916 San Antonio city directory lists a C.G. Sheely as the firm's president. The city directories provide a downtown office location for the company, but do not mention a plant or warehouse facility. During the late 1920s, Sheely is listed as president of another company, Monarch Engineering, located at 1146 W. Laurel Street in San Antonio. A Sanborn map of the period shows a couple of office buildings at the site, but shows no evidence of a fabrication plant, foundry or warehouse.[74]

The only major Texas bridge fabricator prior to the creation of the Texas Highway Department (THD) in 1917 was Austin Bridge Company of Dallas. The Austin name first became known in Texas bridge building when George L. Austin became an agent for George E. King Bridge Company of Des Moines, Iowa in 1889. He was joined by his brother, Frank E. Austin, five years later, but by 1896, George had moved to Atlanta to operate a Georgia-based bridge contracting business. In 1902, the brothers formed a new partnership called Austin Brothers, Contractors, and agreed to split the Texas and Georgia profits equally. In addition to marketing bridges, the company sold road machinery and construction equipment. Six years later, the brothers severed their connection with George E. King Bridge Company and began to make plans to open their own bridge fabricating business. Finally, in 1910, the company purchased property in Dallas and built a small fabrication plant for bridge and building components. A second fabrication plant was opened in Atlanta.[75]

Relying on their past experience and knowledge with bridge contracting and construction in the South, the two brothers developed a sizeable bridge building business. Unlike other companies that used independent agents to market their bridges, the two brothers hired and trained their own bridge salesmen and erection crews. The company's use of in-house salesmen, its relatively low shipment fees, and its quick response times gave the firm a significant advantage over its out-of-state competitors. The Austin brothers summarized their bridge building philosophy in a 1915 company publication:

> Our long experience in building bridges throughout the Southern States under various conditions, and the mistakes we have naturally made in this line of work in the past, certainly ought to enable us to know the territory and to design the right bridges for the right places. The location of our shops, at Dallas and Atlanta, were arrived at after we had been in business many years and ascertained proper points from which we might best serve the territory. Having our own bridge shops and raw materials, our own contractors, erection men and equipment, we are able to furnish bridges complete without having to pay a profit to others.[76]

Austin Brothers continually expanded its store yard in Dallas to provide bridge customers with quicker response times to bridge orders. By keeping a large stock of rolled steel products on hand, the company could produce fabricated bridge products within a week after an order was received. A 1915 company advertisement features a photograph of the Austin Brothers store yard with the caption "more than a million pounds of steel." The advertisement explains that the "materials shown . . . consist of I-beams, channels and angles, in lengths from 20 to 70 feet, just as we received them from the rolling mills." During the year ending March 1, 1915, the company handled 360 carloads of steel through its Dallas shops. This extensive stockpile of materials verified the ad's claim that the company could "fill most any requirements, and make prompt shipments."[77]

Another marketing strategy of Austin Brothers was to develop sales literature and materials on its products. One of the company's primary sales tools was its book of standard plans that included drawings of roadway bridges in various lengths, widths and strengths. These drawings allowed the company's salesmen to prepare detailed plans and cost estimates for virtually all bridges in the field. Most of the standard plans in the book were for Warren pony trusses with 10 to 15 ton loading and lengths of 30 to 80 feet. The book also included designs for Pratt and Warren polygonal-chord pony trusses, typically in lengths of 80 to 118 feet. The company's publication, *The Highways*, provided the company with another major advertising medium. Beginning in 1912, monthly issues of the magazine were mailed to county judges and commissioners all over the South. The publication provided information on the company's stock spans and featured articles on bridge and road progress in Texas and other parts of the country.[78]

Following the example of Sears Roebuck and other successful American mail-order companies, Austin Brothers issued a 276-page catalog featuring its bridge and road products in 1915. The company's "*Catalog and Handbook for Buyers, Engineers and Builders*" encouraged counties and cities to purchase their bridges direct from the company's catalog. The catalog included instructions and advice for measuring bridge crossings and arriving at cost estimates for steel structures. While the catalog claimed that "most anyone that can use a common level and tape line" to secure basic bridge measurements, it also offered to send engineers to counties "without charge" to furnish exact bridge measurements and estimates. The various charts, drawings and photographs in the catalog provided detailed information on culvert, I-beam and truss bridge types. The section on I-beam bridges, for example, included technical data on 26 different I-beam spans with lengths of 8 to 40 feet. The catalog offered culverts and I-beam bridges in ready-to-assemble kits that were "so simple in make-up that it does not require a bridge man to erect them." The catalog asserts that all of the necessary components are included in a bridge order: "With each bridge is shipped all the necessary bolts for putting bridge together, as well as bolts for securing floor to steel joist and also full instructions as to how to build the abutments and erect the bridge complete." The catalog also included instructions for building concrete and steel abutments and piers. Most noteworthy was a plan for a concrete pier with solid web-walls and rounded end columns. This design represented a significant advancement over metal bent piers and caissons, which were common in metal truss construction during this period.[79]

Austin Brothers, Contractors, benefitted greatly from its efficient operations and dynamic marketing approach, and by the mid-1910s it had become a major force in the Texas bridge building field. Higher costs, slower response times and other factors made it increasingly difficult for out-of-state companies to compete against the prosperous Dallas firm. The business failings of several large out-of-state bridge companies accelerated this trend, and by the beginning of World War I, Austin Brothers, Contractors, had become the largest bridge builder in Texas. The company's lightweight trusses sold especially well and were built in all areas of the state, including West Texas and the Panhandle. Numerous examples of these bridge survive on Texas roadways throughout the state.[80]

Despite the company's rapid growth and success, Frank L. Austin grew tired of bridge contracting work. In 1918, the Austin brothers sold the bridge part of the business to Charles R. Moore, an enterprising employee who had served as the company's "Traveling Agent, Contracting Agent, and Chief Engineer." Within two years, Moore changed the company's name to Austin Bridge Company (also called Austin Brothers Bridge Company) and moved the bridge operations to the Wyatt Metal & Boiler Works property near the Gulf, Colorado and Santa Fe railroad tracks in Dallas. The company continued to grow and expand under the leadership of Charles R. Moore, selling a large quantity of small metal truss spans, I-beam bridges and timber structures. Most of the company's contracts for the 1920s were for simple Warren pony trusses with spans of 80 feet or less.[81]

By the mid-1930s, many counties and cities in Texas were designing and constructing their own bridges and were no longer dependent on Austin Bridge Company to provide them with pre-fabricated metal spans. Offsetting this loss was the company's contract work for THD highway bridges, oil pipeline structures and railroad bridges. Many of the THD contracts of the 1930s were for large concrete and steel girder highway bridges (including railroad underpasses). Although the company's contracts for small county spans declined during this period, it continued to market its line of small metal truss spans into the 1940s. By 1945, the company had secured more than 3,000 bridge contracts, mostly for county, city and highway bridges in Texas. While several large out-of-state fabricating firms returned to Texas after THD's creation in 1917, Austin Bridge Company continued to play a leading role in Texas bridge construction in the decades that followed. The company survives today as a subsidiary of Austin Industries in Dallas.[82]

Two other Texas companies that were involved in bridge fabrication at a relatively early date were Alamo Iron Works of San Antonio and Mosher Steel and Machinery Company of Dallas. In 1877, J. Schuhle and R.G. Nixon established a foundry and machine shop called Alamo Iron Works in central San Antonio. Within several years, George Holmgreen had taken over as the company's sole proprietor. A 1902 advertisement in the city directory indicates that the company was producing a wide range of iron products, including "ice and refrigerating machines, horse powers, pumping jacks, well drilling machines, hay presses, etc." A 1912 Sanborn map shows the company's buildings clustered around the Southern Pacific Railroad, consisting of a small foundry, a machine shop, a warehouse, blacksmith shop, pipe cutting building, gasoline engine repair shop, woodworking shop, boiler shop, office and various storage units. While there is no evidence that Alamo Iron Works fabricated metal bridges at this time, it was probably producing portal elements, finials and other decorative features for bridges in the region. Several metal truss spans in San Antonio exhibit exemplary and unusual cast iron work, providing some evidence of the company's participation in early bridge-building projects. During the 1920s, the company built a structural shop for fabricating a wide range of steel structures including buildings, towers, church steeples and bridges. In 1922, the company opened a subsidiary plant in Houston, Alamo Steel & Supply Company that operated as a supplier of reinforcing steel, structural steel, paving equipment and other equipment. Alamo Iron Works produced a wide range of highway and railroad bridges during the 1920s and 1930s. With the advent of World War II, Alamo Iron Works retooled its machines to produce war ships, but in 1946 the company resumed its regular operations.[83]

The second company, Mosher Steel, was established by Theodore Mosher in Dallas in 1885. While the company initially opened as a machine shop, a foundry was added within several years. By 1892, Mosher Steel employed 75 to 80 men, providing an annual payroll of $36,000. The Mosher Manufacturing Company was incorporated shortly after Theodore's death in 1893. Ten years later, the company extended the plant site and added a structural steel fabricating plant that concentrated primarily in steel for building construction. The company expanded into the Houston market in 1908, establishing a subsidiary called Houston Structural Steel Company. By 1918, the Mosher Manufacturing Company employed 360 men and the name of the Dallas plant was changed to Mosher Steel and Machinery Company. There is no evidence that the company was fabricating steel bridges in Texas before the creation of THD in 1917. By the early 1920s, however, both operations were fabricating metal steel spans as part of their regular operations. The two affiliated companies proclaimed their ability to design, fabricate and erect steel bridges in a 1924 advertisement of the *Texas Highway Bulletin*, which also featured a picture of a Pratt through truss span. During the 1920s, contractors for the THD relied heavily on Mosher Steel and Machinery Company and the affiliated Houston Structural Steel Company for bridge fabrication work. By the 1930s, the two Mosher-related firms were fabricating steel truss highway bridges on a fairly large scale. During 1936, the company moved its home offices to Houston, operating under the new name of Mosher Steel Company.[84]

Paragraph will be added on suspension bridge companies in Texas to complete Phase I of the Texas Historic Bridge Inventory.

V. TECHNOLOGICAL ADVANCES IN THE EARLY 20TH CENTURY

Section to cover reinforced concrete, steel cantilevers, movable spans, etc., as well as the city beautiful movement and the use of concrete types in urban areas. *This section is to be completed under Phase II of the Texas Historic Bridge Inventory.*

VI. STATE CONTROL OF BRIDGE BUILDING

Good Roads Movement

By the turn of the century, road conditions in Texas were still very primitive. While a few towns boasted hard-surfaced roads, most counties were comprised entirely of dirt roads. Without sufficient funding or guidance, most counties laid out roads following the path of least resistance. As a result, most of the narrow pathways snaked around and along property lines and natural barriers and did not connect with roads in neighboring counties. With load capacities of 7 tons or less, the light bridges on these routes were also very prone to washouts and substructure failures. This network of crude county roads and bridges bore no resemblance to an integrated and comprehensive highway system. In 1895, Roy Stone, head of the Department of Agriculture's Office of Road Inquiry, declared that Texas had made "less headway" in road improvements than any other state in the country.[85]

Rapid population growth from 1880 to 1900 magnified the state's road and bridge problems. During this 20 year period, the citizenry of Texas doubled, reaching 3 million by the turn of the century. Agitation for good roads grew as the population desperately needed to move animals and wagons more efficiently. In 1902, the Texas Farmers Congress called for state control of roads, and soon the Democratic National Convention added the development of a state road system to its platform. A year later, Texas auto owners formed the Texas Good Roads Association to press lawmakers for road improvements and a statewide road system.[86]

Reluctant to pass measures that would centralize road decision-making, the state legislature instead broadened local funding mechanisms for road and bridge improvements. A 1903 act, modelled after the bridge bonding legislation of the 1880s, finally gave counties the authority to issue bonds for road work. Laws enacted in 1907 and 1909 under authority of a 1904 constitutional amendment went one step further, empowering subdivisions of counties, such as special road districts, to vote bonds for road construction and maintenance. The road-related legislation of the early 1900s temporarily resolved the issue of good roads, clearly establishing the counties and their road districts as the custodians for the state's roads and bridges. Many local road districts formed in the years that followed, approving many hundreds of thousands of bonds for road and bridge improvements in rural and urban areas. By 1910, figures from 180 Texas counties showed a total of 14,286 motor vehicles operating in the state.[87]

Beginning in the 1910s, national and state good-roads associations began marking a system of automobile roads through the state. "A highly important activity of the Good Roads Association," notes engineering historian Joseph King, "was determining the routes followed by long distance roads." Relying largely on existing roadways and following established railroad corridors, the private highway associations pieced together the state's first long distance roadway system. In return for the promise of booming business and tourism, communities paid subscriptions to the road associations and agreed to make road and bridge improvements along the routes. Many counties and local road districts issued bonds for road and bridge work on private highway routes during the 1910s. One of the most impressive structures built on a private highway route was the 1916 bridge over the Canadian River located just north of the community of Canadian (HH0030-05-006) on the Dallas-Canadian-Denver highway. The bridge was originally built with 17 Parker through truss spans and stretched more than 2,500 feet across the river. In 1924, THD added four additional Parker through truss spans to the structure, bringing its total length to nearly 3,300 feet.[88]

Creation of the Texas State Highway Department

Agitation for good roads caused many states to establish highway departments at the turn of the century. By the end of 1910, 30 states were appropriating monies for road and bridge improvements and 19 had state offices to oversee state road funds. By 1913, all states except Florida, Indiana, Mississippi, Tennessee, South Carolina and Texas had adopted provisions for state action in highway construction.[89]

The local tradition of road building made state-controlled road building a delicate and complicated issue in Texas. During the 12-year period from 1903 to 1915, 13 different bills to create a state highway department were introduced into the state legislature but were all defeated by opposition over increased taxation and the potential loss of county road powers. Texas acted only after the passage of the Federal Aid Road Act of 1916 which appropriated $75 million to states for building rural post roads. Under a complicated apportionment formula, the bill gave the largest single appropriation to Texas but also required formation of a state highway department before federal monies could be received. Not wanting to forfeit the opportunity to receive federal monies, the 35th legislature, after lengthy deliberations, passed House Bill 2 which finally established a state highway agency for Texas. In addition to allowing the federal funds to be spent, the bill also authorized the Texas State Highway Department (commonly known as Texas Highway Department) to raise state highway monies by assessing automobiles registration fees.[90]

Administrative control of the department was vested in a three-member State Highway Commission and a State Highway Engineer. The new law directed the commission to "formulate plans and policies for the location, construction, and maintenance . . . of a comprehensive system of state highways and public roads." Under the direction of the State Highway Engineer, the agency was also to distribute state and federal road aid to counties, establish standards for the construction and maintenance of highways, ferries and bridges, and supervise the construction of state and federal aid projects. In the commission's first public hearing on June 21, 1917, it designated a tentative network of 22 state highways. These roads followed existing county roads and consisted largely of the same system of routes that had already been designated by private highway associations. By 1921, the system had grown to 46 routes, covering 15,000 miles of main roads in the state.[91]

Despite the Texas Highway Department's quick action to designate a state highway system and the guarantee of federal and state matching funds, the new agency actually wielded very little power over road and bridge building in the state. Recognizing the substantial investment that counties had already made in roads and their interest in maintaining local control over highway routes, the legislature had established a weak highway department that gave the counties primary jurisdiction over the highway system. Counties initiated all applications for state and federal aid and were awarded state and federal monies on a first-come, first-served basis. Typically, when a county wished to receive state or federal aid for a project, it would raise bonds to match state or federal monies and hire a county engineer to draft the necessary surveys, plans and estimates in accordance with THD requirements. The county submitted its application for state or federal aid to one of the department's nine division engineer offices (later called district engineer offices). After reviewing an application, the division engineer would forward the materials to the THD's Engineering Division in Austin for design approval. The Engineering Division processed applications for state and federal aid, forwarding projects with federal aid requests to the Bureau of Public Roads (BPR) of the United States Department of Agriculture for compliance with federal guidelines and standards. The county advertised for bids and awarded contracts, and its engineer supervised the construction process. The division offices inspected and monitored the construction work, employing a resident engineer to perform this work when a project was exceptionally large or complicated. Federal and state aid apportioned to the counties were paid only after the work was completed and inspected by THD engineers, with additional BPR inspections required for federal aid projects.[92]

Highway maintenance was also a responsibility of the counties. The counties signed maintenance agreements on all federal and state aid highway projects. They also continued to maintain the older unimproved sections of the state highway system. In accordance with an amendment passed by the 35th Legislature, the counties collected automobile registration fees on an annual basis, retaining half of the monies for local highway maintenance and remitting the other half to the state highway department for highway construction funding.[93]

Early Operations of the THD Bridge Division

By 1918, THD had expanded into three main divisions: Administration, Federal Equipment and Engineering, with bridge work falling under the Engineering Division. The Texas State Highway Commission approved the position of State Bridge Engineer in a January 24, 1918, resolution. The State Bridge Engineer was charged with the review and approval of bridge and culvert projects funded by federal and state aid, construction inspection and supervision of these projects, and the development of standard and special designs for bridges and culverts on the highway system. The Bridge Section was also directed to assist and advise county and city officials in matters pertaining to bridge construction and maintenance.[94]

In February 1918, the department hired George Grover Wickline to serve as the first State Bridge Engineer. His initial salary of $225 a month was THD's third highest following George A. Duren, State Highway Engineer, and David E. Colp, Secretary. A native of Stephenville, Texas, and a 1904 Civil Engineering graduate of the University of Texas, Wickline had considerable experience as a bridge and highway engineer. Like so many of the department's early engineers, Wickline began his professional career with the railroad, working first as an instrument man and then bridge inspector for the St. Louis, Brownsville and Mexico Railway Company. Wickline soon moved into highway work, initially with Dallas County and later with the City of Los Angeles, McLennan County, where he worked until September 1908. After a short stint with the El Paso and Southwestern Railroad, Wickline became assistant city engineer for El Paso. In October 1909, Wickline worked as bridge engineer for Dallas County, designing and supervising construction of highway bridges throughout the county. He left in March 1912 to work on the Texas Electric Interurban Railway in the Dallas, Waco and Corsicana area for two years. His highway experience resumed with employment as assistant highway engineer for McLennan County and then the City of Dallas from 1914 to 1916. As bridge engineer for Dallas County from September 1916 to January 1918, Wickline designed and supervised construction of the concrete viaduct at Commerce Street in downtown Dallas, the precursor to the 1930s structure currently at that location. At the time he was hired by THD, Wickline was working as a bridge engineer for the City of Dallas. Wickline managed the Bridge Section from 1918 to 1928, at which time the section became a full-fledged division. He headed the Bridge Division continuously for 25 years with the exception of a three year leave of absence from 1935 to 1938 when he oversaw the construction of the Port Arthur-Orange (or Rainbow) Bridge across the Neches River (refer to nomination of Port Arthur-Orange Bridge, JF0306-03-015, NRHP 1996). Wickline's tenure with THD lasted 25 years and ended with his sudden death in November 1943.[95]

Wickline and his small staff immediately turned their attention to developing standard designs and specifications for concrete, timber and metal bridges. These standards were needed to secure a uniform level of construction throughout the state and to provide counties with an economical and straightforward method for preparing bridge plans. Standard designs also allowed THD bridge engineers to respond quickly to bridge failures and other emergency situations. Most of the early THD standard designs and specifications corresponded closely with federal circulars and bulletins promulgated by BPR. At the time THD was created in 1917, BPR was at the national forefront of bridge design. A Division of Highway Bridges and Culverts had been established under its predecessor agency, the Office of Road Inquiry (established under the United States Department of Agriculture in 1893), in 1910. This special division conducted studies on bridge types and materials and developed standards for bridge design and construction. The agency's 1913 circular, *Typical Specifications for the Fabrication and Erection of Steel Highway Bridges*, formed the basis for bridge specifications developed by THD and other highway departments in the 1910s and 1920s. Subsequent bulletins included typical plans and specifications for bridges and culverts, and other bridge components such as piers and abutments. BPR reviewed all proposed federal aid projects for compliance with federal standards and specifications. Recognizing that states had varying geographical conditions and economic circumstances, however, BPR also allowed individual state highway departments some latitude regarding specific bridge types and designs used. In 1924, the American Association of State Highway Officials (AASHO) formed its Subcommittee on Bridges and Structures which became a leader in highway bridge design. BPR and the various state highway departments, including THD, relied heavily on the subcommittee's uniform specifications for highway bridges issued in 1924, 1925 and 1928, as well as its 1931 publication, *Standard Specifications for Highway Bridges*.[96]

Within a relatively short time frame, Wickline and his staff had developed an extensive series of standard bridge designs. The THD Bridge Section issued its first standard designs and standard specifications in 1918, producing updates and revisions of these items on a regular basis. Most of the Bridge Section's early designs were for short to medium spans. The section's focus on short-span bridge designs reflected THD's early emphasis on road surfacing projects and small drainage improvements on state highway routes. Large bridge construction was largely deferred until the 1930s. From 1918 to 1920, THD bridge engineers developed designs for short (typically 40 feet or less) timber stringer, single and multiple concrete box culvert, concrete slab, concrete deck girder and steel I-beam structures. During this same period, THD also produced standard designs for Warren and Pratt pony trusses in intermediate lengths (35 to 80 feet).[97]

The department's standard specifications, issued in 1918 and periodically thereafter, required that concrete and steel bridges be designed to carry a 15-ton motor truck, a standard that applied to virtually all federal aid bridge projects. Some of the timber trestle designs, however, were designed for 10- to 12-ton loads. While these "low type" bridges were built throughout the state, they were used most extensively in East Texas in order to take advantage of local materials and maximize the number of bridges that could be completed. Timber trestle bridges were also well suited to the many broad and shallow streams found in the East Texas area. Because timber bridges fell short of BPR requirements, they were almost always built as state aid projects.[98]

Initially, THD bridge engineers assigned identification numbers to each standard design based on a one or two letter abbreviation of its bridge type (e.g., T is for truss and CB is for concrete slab bridge) followed by the plan's chronological ranking for that bridge type (e.g., first truss design would be designated T1, second truss design would be designated T2). For example, the CB1 design was the department's first standard design for a concrete slab bridge; the DG3, in contrast, was the third standard design developed by THD for a concrete deck girder structure. The T1 design, developed in 1918, featured a rivet-connected Warren pony truss with a timber deck and represented the department's first standard design for a metal truss bridge. By the early 1920s, THD was assigning standard design numbers according to the bridge type abbreviation, roadway width and span length. For example, the T18-150 design, issued in 1922, featured a Pratt through truss with an 18-foot roadway width and an 150-foot length.[99]

From 1918 through the early 1920s, THD bridge engineers designed at least 11 standard Warren pony trusses with timber decks. These designs were probably developed primarily for use in East Texas, where timber was a relatively inexpensive decking material. The only one of the 11 designs that is still represented in Texas today is the T19-50. This 1921 design is comprised of three panels, each 16 feet 8 inches long, providing a 50 foot span. The 16-foot timber deck is comprised of timber planks placed perpendicular to the traffic flow, connected to longitudinal timber strips affixed to steel I-beam stringers underneath the floor. The best surviving example of this design was built in 1923 on the old route of State Highway 21 (now a county road) over Venado Creek just west of San Augustine in San Augustine County (SAAA01-07-002).[100]

In 1920, the THD Bridge Section released the T5 design, a Warren pony design that was available in lengths of 50, 60 and 70 feet. The 50-foot length was comprised of six truss panels while the 60 and 70 lengths included eight panels. This design includes steel floor beams suspended below the lower chords of the truss, so that in elevation the I-beams are visible hanging below the truss. In this type of floor system, the floor beams are actually bolted to vertical truss members extending below the bottom chord. The T5 was one of the most popular early truss types, and was used extensively by county engineers in the early- to mid-1920s. Representatives of the three different T5 configurations remain on the old route of State Highway 14 through Limestone County (now serving as county roadways). These examples, all built in 1921, include a 50-foot span over Big Creek between Thornton and Kosse (LTAA04-08-004), a 60-foot truss over Rocky Creek between Groesbeck and Thornton (LTAA04-01-001), and a 70-foot span over the Navasota River just north of Groesbeck (LTAA03-11-001).[101]

In 1919, the THD Bridge Section generated its first standard Pratt through truss design (T6), consisting of a 150-foot, pin-connected span with a timber deck. The department's first standard Parker through truss design was produced the following year. By the early 1920s, THD bridge engineers were generating standard designs for long Pratt and Parker through truss spans (100 to 225 feet) with large built-up steel members and substantial gusset plate and rivet connections. One of the most popular Pratt through designs was the T10-100 developed in 1920. This design featured a 100-foot span consisting of six panels, each 16 feet 8 inches long, and distinctive "X" portal bracing. An early example of this design was built on State Highway 10 over the South Paluxy River in Erath County (ER1332-01-013).[102]

The THD Bridge Section produced its first Parker through truss design in 1920. Over the next 18 years, bridge engineers would produce at least 24 different standard designs for Parker through truss bridges and at least a dozen special Parker designs. THD built Parker truss spans in lengths of 120 to 250 feet with roadway widths ranging from 16 to 24 feet. Wickline clearly showed a preference for the Parker through truss, making it the predominant long-span bridge type for Texas at an early date. Texas' use of Parker trusses distinguished it from California, Oregon and other states which often used concrete and steel arches to span the steep slopes and rocky gorges that were more common in these areas. The relatively broad creek basins and flat topography of Texas combined with the significantly higher cost of concrete bridge design and construction to make the concrete arch a relatively unpopular type for Texas. Several other states, such as Oklahoma, preferred the K-truss over the Parker, primarily for its ease of construction and its reduced secondary stresses. In several cases, Oklahoma-designed K-trusses were used over the Red River at the Texas-Oklahoma boundary. (The only surviving example of these K-trusses is located on State Highway 78 Bridge at the Red River, FN0279-02-024, NRHP 1996). A downside of the K-truss was its relatively heavy members and irregular configuration, which caused nationally recognized bridge engineer J.A.L. Waddell and others to comment on its awkward and generally "inferior appearance." Wickline, who showed an acute awareness and appreciation for bridge aesthetics, clearly preferred the more graceful profile and composition of the Parker. Considerable economy was also gained by developing a broad assortment of standard Parker designs to suit a wide range of traffic and site requirements.[103]

Complementing the standard bridge designs were a set of standard plans for other bridge components, such as abutments, piers and railings. The substructure designs included substantial concrete piers, bents and abutments. Several of the pier designs, for example, were comprised of massive reinforced concrete piers arranged in a dumbbell configuration (solid web walls connecting two square or circular columns). Similarly, a standard "U" type abutment consisted of a thick reinforced concrete backwall with large concrete wingwalls. Early standard-design railings, designated Types A through J, ranged from simple steel pipe railings (Type A) to ornamental concrete railings with urn-shaped balusters (Type J). Two of the most popular concrete railing designs, Types C and D, consisted of large reinforced concrete posts connected by two rows of reinforced concrete railings spaced approximately 1 foot apart. These heavy standard design components were characteristic of early THD bridge construction and provided a stark contrast with the thin metal piers and guardrails used on most county bridges in the state.[104]

By the early 1920s, Wickline and his small staff had developed an extensive collection of standard design bridges. The county engineers used the standard plans as basic "building blocks" that were mixed and matched as necessary to form an overall bridge design and layout. In a 1922 report, Wickline noted county engineers had used standard plans on almost every state and federal aid bridge project that had come through his office. A typical example of a bridge built from standard design components is the old State Highway 10-A bridge over Squaw Creek in Somervell County (now on county road). Completed in 1922, this bridge is composed of one 100-foot Pratt through span conforming to the T10-100 design, two 20-foot CB6 concrete slab approach spans with Type C concrete approach railings, two P2 concrete dumbbell piers, and two A9-17 concrete abutments (SVAA01-29-001).[105]

THD constantly revised and improved its metal truss designs in order to reflect technological advances and to accommodate heavier truck and automobile loads. The demand for increased roadway widths provided the primary motivation for many new bridge designs. While the earliest plans featured roadway widths of 16 to 18 feet, by 1922 roadway widths had increased to 20 feet, and by the 1930s roadway widths of 24 feet were standard. Other refinements in metal truss bridge design included the use of riveted joints in place of the earlier pin-connected joints, stiffer and more substantial truss members, and the use of framed floor beams instead of suspended floor beams.[106]

Initially, Wickline and his assistants relied heavily on county engineers and THD division engineers to prepare bridge plans and perform sufficient investigations of bridge sites. THD issued all county engineers copies of its design guidelines titled *Standards Governing the Preparation of Road Plans Involving State or Federal Aid.* These standards directed county engineers to perform in-depth investigations of all drainage areas and to perform test pits or borings for all bridge foundations. The bridge designs selected were supposed to reflect the findings of these studies. While most county engineers went to great lengths to perform the required investigations, some county engineers took a somewhat more permissive approach. Without adequate studies on drainage and soil conditions, the bridge plans were often inadequate to meet site requirements. Problems with bridge plans were usually not discovered until a bridge was actually under construction, resulting in significant project delays and cost overruns. Contractors working on bridge projects frequently requested field changes for bridges that were inadequate to cover a drainage area, citing "error discovered in drainage area" as the primary reason for these requests. Contractors encountered similar problems with bridge foundations. In a September 10, 1923, letter to division and county engineers, J. D. Fauntleroy, State Highway Engineer noted that:

> it has proven very expensive not only to the county but to the contractor to make excavations for substructure work only to find that the materials encountered are not what the plans indicated, . . . in many cases it is necessary to stop the work, order piling, rig up a driver and drive piling causing a delay to the work of a month or more. . . . On account of the excess work being generally done by Force Account and due to delays . . . the county has frequently to pay much more for the work than it would if the work were . . . based on plans prepared from accurate data.[107]

THD made relatively slow progress with bridge construction during the early 1920s. By the end of 1921, the state had awarded 430 contracts for federal and state aid highway projects, covering approximately 4,276 miles. Although many of the roadway projects included culverts and small drainage structures, only 31 (or 7 percent) of these projects were classified as bridge projects. Bridge construction increased moderately in the following years, with THD giving preference to "low type" structures such as concrete slabs, timber and concrete trestles, and I-beam stringers that were built usually to standard loading levels and possessed the additional advantages of low initial cost and low maintenance. Bridge designs that did not meet federal bridge standards were typically funded as state projects. The most popular types were reinforced concrete slabs and girders, which were built wherever short-span construction was permissible. "Low water" concrete slab and culvert bridges were frequently used in areas, such as West and Northwest Texas, that had light traffic volumes and infrequent flooding problems. Low water bridges were characterized by their relatively short or low piers that rose only a few feet above the ordinary stream level. In East Texas, short-span bridges tended to take the form of timber trestles due to the availability of local timber materials in this region.[108]

Add in information on important concrete bridges and contractors in this period under Phase II of the Texas Historic Bridge Inventory

Metal truss bridges were the major "high type" structure used in early THD bridge construction. Most of the early examples were built in the northern and central portions of the state. Large, fast-flowing streams and rivers and frequent flooding problems justified the greater expense of metal truss bridges in these areas. Dense population and high traffic volumes were also factors that led to a greater use of metal truss bridges in this region of the state. Large spans were generally preferred for streams and rivers with deep channels, high velocity currents, frequent flooding and heavy drift accumulation. One of the largest metal truss highway bridges completed by THD in the early 1920s was the Bastrop Bridge on State Highway 3-A over the Colorado River at Bastrop (refer to nomination of Colorado River Bridge at Bastrop, BP0265-10-010, NRHP 1990). Completed in 1923, the bridge was comprised of 18 concrete girder spans, each 39 feet in length, combined with three specially designed 192-foot Parker through truss spans. The bridge extended 1,285 feet across the river and was built at a cost of $167,500, making it one of the largest highway bridges completed by THD up to that time.[109]

Most contracts for THD metal truss bridges were awarded to road contractors who then subcontracted out the truss portion of the work to steel fabrication companies. Early THD bridge fabrication work was largely split between Texas and out-of-state companies. When THD formed in 1917, many out-of-state bridge companies established offices in Texas, including several who had marketed truss designs in the state during the late 19th and early 20th centuries. Some of the more active out-of-state bridge fabricators operating in Texas during the 1920s and 1930s were the Bethlehem Steel Company of Pottstown, Pennsylvania; Illinois Steel Bridge Company of St. Louis, Missouri (also of Jacksonville, Illinois); Kansas City Bridge Company of Kansas City, Missouri; Pittsburgh-Des Moines Steel Company of Des Moines, Iowa; Vincennes Steel Corporation of Vincennes, Indiana; and Virginia Bridge and Iron Company of Roanoke, Virginia. Some of the more important Texas bridge fabricators during this period included the Austin Bridge Company (or Austin Brothers Bridge Company) of Dallas; Houston Structural Steel Company (a subsidiary of Mosher Steel and Machinery Company) of Houston; Mosher Steel and Machinery Company of Dallas; and Petroleum Iron Works Company of Beaumont.[110]

Because of the department's early emphasis on highway grading and surfacing, many bridge projects were deferred until the 1930s or later. This situation placed an excessive burden on many county-built bridges that had been incorporated into the state highway system in 1917. Most of these bridges were lightweight fabricator-designed trusses with low loading capacities (7 tons or less) and narrow roadway widths (usually 16 feet or less). These bridges were usually insufficient to support the heavier and wider loads carried by motor trucks, army tanks and farm equipment. In a 1922 article, Wickline noted that there were "innumerable light-type bridges" on the highway system, and that they were "entirely too light" to meet modern traffic requirements. "Frequently," he notes, "the piers or abutments are washed out and the bridge collapses under a heavy load resulting in loss of life, injury, serious delay, and inconvenience to traffic." In a 1923 THD report, Wickline provides several accounts of light-type bridges that had collapsed under heavy highway loading. Without adequate funds to replace deficient bridges, Wickline and his staff set out to repair and strengthen the weaker structures to accommodate 10 to 15 ton loads. The preparation of plans for bridge repair and rehabilitation projects comprised a major portion of the THD Bridge Section's early work. These projects frequently involved replacing timber stringers with steel stringers, adding additional support members underneath the deck and performing other work as needed.[111]

The problem of deficient highway bridges was aggravated by counties that continued to build light-type bridges on state highways solely with county funds. This situation was largely a result of the state's weak highway law which only gave THD jurisdiction over state and federal aid highway projects. Counties retained overall control over the state highway system and could initiate locally funded bridge projects at will. The lack of state control over the highway system caused inconsistencies in bridge construction along the various state highway routes. A highway route in one county could include a new 15-ton THD bridge while, in an adjacent county, the same route could have county bridges with carrying capacities of 7 tons or less. Wickline provides the analogy of "a chain with a weak link," whereby "the heaviest load . . . carried over the highway is controlled by the weakest bridge."[112]

THD Acquires Control over State Highway Bridges

State and federal initiatives of the 1920s largely resolved the issue of state control over highways. In 1921 Congress amended the 1916 Federal Aid Highway Act to require that, after 1925, all highway construction and maintenance work be under the direct supervision of the state highway departments. In January 1923, the 38th Texas Legislature moved quickly to give THD administrative control over the state highway system. It passed one act to raise motor vehicle registration fees and a second act to institute a 1-cent-per-gallon occupation tax on gasoline (with three-fourths of revenues going to the state highway fund and the remainder to the state's permanent school fund). A proposed constitutional amendment to give the highway department complete jurisdiction over the highway system met with political and technical difficulties. It took a 1925 ruling of the State Court of Civil Appeals (Robbins vs. Limestone County) to finally resolve the issue of state highway control. In considering the case of a county that would not give THD its share of registration fees, the judge determined that the state could assume authority over public roads and that the legislature could administer these roads through its designated agencies. The 39th Legislature immediately passed the necessary laws to bring Texas into compliance with the 1921 federal aid amendment. The 1925 state highway act gave THD total control over highway construction and maintenance; however, it did not completely exclude counties from participation in highway road matters. The inadequacy of state funding and the increased statewide demand for roads meant that Texas would have to continue to accept county assistance until 1932.[113]

The state's win over county road interests did not bring immediate change to THD. In 1925, THD became embroiled in a bitter political controversy that prevented it from making any significant headway in the area of road and bridge improvements for several years. The controversy started in 1924 when a conflict erupted between then State Highway Engineer Gibb Gilchrist and BPR officials, resulting in Gilchrist's resignation from his position in early 1925. Amidst rumors of THD mismanagement of funds, Miriam Ferguson quickly seized control of the State Highway Department after becoming the Texas governor in January of that year. She immediately fired many of THD's highest ranking employees, replacing them and the three slots of the State Highway Commission with her political friends and cronies. During "Ma" Ferguson's two-year tenure as governor, the commission was accused of violating competitive bidding laws, mismanaging THD contracts and misappropriating federal and state aid funds. These scandals compromised THD's integrity and caused BPR to launch an investigation into the department's activities. After determining that THD was in serious financial condition and was neglecting highway maintenance, BPR suspended federal aid monies to Texas in January 1927.[114]

The state's relations with BPR improved almost immediately after Dan Moody became governor in 1927, resulting in the restoration of Texas' federal aid monies by April of that year. The 40th Legislature authorized an increase in the gasoline tax to boost the department's almost depleted highway fund, raising the tax from 1 to 3 cents for a six-month period from March 1927 to September 1928, after which time the tax was fixed at a rate of 2 cents per gallon. Additional legislation in 1929 reduced the level of registration fees, but raised the gasoline tax to 4 cents. Governor Moody also appointed a new State Highway Commission in 1927, which moved quickly to normalize THD operations. In 1927 and 1928, the commission cleansed THD of Ferguson appointments and reorganized the department to take on increased construction and maintenance responsibilities. With the counties no longer responsible for highway construction work, the commission began to plan and prioritize highway improvements, giving preference to projects that would "fill in the gaps" on the designated state highway system. Resident engineers, working under the department's 17 division offices, assumed the project planning responsibilities previously conducted by county engineers. The State Highway Commission also set up a stringent bidding process that awarded highway contracts to the lowest responsible bidder.[115]

Recognizing that a complete system of highways would require an agressive program to improve the state's bridges and culverts, the new highway commission established a separate Bridge Division in 1928 to oversee the state's bridge program. The commission appointed Wickline, former head of the Bridge Section, to run the new division. At the time of Wickline's appointment, the Bridge Division staff consisted of a state bridge engineer, a general assistant bridge engineer, four project-specific assistant bridge engineers and eight draftsmen and checkers. The division also included about 15 resident engineers who specially trained in bridge design and construction work. These bridge specialists would travel from site to site supervising individual bridge construction projects for THD. [116]

With the department's stability re-established and its funding levels renewed, Wickline began to move forward with an agressive bridge building program. While the level of bridge and culvert construction actually declined in 1925 and 1926, the pace picked up significantly in the following years. By the summer of 1928, Wickline reported that at least 50 new bridge projects were under way. During the biennial period ending August 31, 1930, THD awarded contracts for several hundred bridge structures, including 68 metal truss bridges. These projects amounted to 29 miles of culvert and bridge structures at an aggregate cost of nearly $15 million, more than twice the amount spent in any previous biennial period. The bridge accomplishments of this period obviously pleased Wickline, causing him to speculate that "if this rate of progress could be kept up for a few years, the day will not be far distant when all of the weak and dangerous bridges will be eliminated." Bridge projects continued at a rapid pace in the years that followed. By 1934, THD's progress with bridges had helped to "fill in many gaps on the main highways and replace a great number of weak and dangerous old structures."[117]

Many of the larger bridge projects completed in the late 1920s and early 1930s involved standard design Parker through trusses. A relatively early example was built on State Highway 23 (now US 283) over the Clear Fork of the Brazos River in northern Shackelford county (refer to nomination of State Highway 23 Bridge at the Clear Fork of the Brazos River, SF0125-04-019, NRHP 1996). Completed in 1929, the truss conforms to the T20-150, a late 1920s design comprised of eight 18-foot 9-inch panels providing a 150-foot span length and a 20-foot roadway width. By the early 1930s, the Bridge Division had generated several new Parker designs, including the T22-150 which was almost identical to the T20-150 except for its slightly wider roadway width of 22 feet. A noteworthy example of the T22-150 was built in 1933 to serve State Highway 3 (now US 90, eastbound lanes) traffic over the Nueces River west of Uvalde (refer to nomination of State Highway 3 Bridge at the Nueces River, UV0023-05-0038, NRHP 1996). Comprised of four T22-150 Parker through truss spans, the State Highway 3 bridge is the only multiple-span example of this standard design surviving in the state.[118]

Although standard bridge designs were used whenever possible, unusual site conditions or lengthy crossings often required a more customized design approach. Beginning in the early 1920s, THD bridge engineers prepared special designs for several concrete culverts at skewed angle crossings. Several long bridges also required special designs to address unusual site conditions and to provide the most economical design possible. Two early examples of specially designed THD designs were completed in 1925 (since replaced) on State Highway 3 (now US 90), a primary east-to-west route that connected Orange, Houston, San

Antonio, Del Rio and El Paso. The larger of these two designs was a steel swing bridge built over the Neches River at Beaumont to meet navigational requirements at this site. The bridge consisted of a 240-foot steel swing span, two 125-foot steel truss spans and approximately 2,735 feet of concrete and timber trestle approaches, providing a total length of about 3,225 feet. The second bridge, a cantilever truss, was built over the Brazos River at Richmond. By using a long central span, this design minimized the need for interior piers in the Brazos River. The monumental structure stretched approximately 1,120 feet and consisted of a 264-foot suspended cantilever truss span with two 132-foot truss arms, and about 592 feet of steel and concrete approaches. The Richmond Bridge was also important as the first cantilever truss built on the state highway system. Other special design bridges soon followed. Most important of these were a large swing bridge completed in 1927 (since replaced) on State Highway 3 over the Sabine River at Orange, a cantilever truss on State Highway 43 across the Brazos River at Valley Junction, also completed in 1927 (since replaced), and a Pennsylvania through truss bridge on State Highway 12 (now Loop 183/old route of US 59), completed in 1930 (refer to nomination of Colorado River Bridge, WH0089-10-039, NRHP 1993)[119]

The Moody highway commission also made interstate bridges a high priority for the department. During 1927, the commission initiated a series of feasibility studies on interstate bridge construction across the Oklahoma and Louisiana boundaries. Federal law dictated that the national government fund 50 percent of interstate bridge construction with the two bordering states each contributing 25 percent. THD's first three interstate highway bridges were completed jointly with Oklahoma in 1926. A bridge on State Highway 3 between Orange, Texas, and St. Charles, Louisiana, across the Sabine River followed the next year. A 1927 federal road act allowed states to use federal aid monies to purchase interstate toll bridges and to build free bridges in their place. State legislation of the same year authorized THD to cooperate with neighboring states on the purchase of toll bridges across interstate lines and to construct new free bridges at these same locations. By 1930, THD had reached agreements with both Oklahoma and Louisiana regarding a cooperative program to build free bridges across the Red and Sabine rivers. These efforts led to a number of major interstate bridge projects during the 1930s.[120]

While most interstate bridges were built without incident, a major political storm erupted over the Red River Bridge on State Highway 6 (now US 69) linking Denison, Texas with Durant, Oklahoma (GS0047-01-001, since replaced). The construction of the four-span Parker through truss bridge proceeded as planned during 1931 with a scheduled opening date of July 1, 1931. On June 24, however, the Red River Bridge Company obtained a restraining order against the Texas Highway Commission for a breach of contract on a toll bridge purchase near the new Denison bridge site. A federal judge ordered THD to barricade the new bridge and to keep it closed until the dispute with the toll bridge company was resolved. The situation created considerable friction between Texas and Oklahoma, causing Oklahoma Governor William H. Murray to bring in the Oklahoma National Guard and Texas Governor Ross S. Sterling to dispatch the Texas Rangers to the bridge site. The standoff at the bridge lasted nine days and ended when a federal judge rescinded the restraining order on July 25, 1931.[121]

Improved Bridge Planning and Designs

Wickline initiated a major overhaul of the state's bridge program almost immediately after THD gained control over the state highway system. In-house control over bridge projects allowed THD bridge engineers to conduct better bridge investigations and to develop a more sophisticated design approach. Wickline quickly phased out the use of dips, low-water bridges and other bridge types that created dangerous situations in times of heavy rainfall. By 1930, THD bridge engineers were designing bridges that covered the entire valley of a creek or river, so that the highway could be usable for traffic even under heavy flooding conditions. This practice resulted in higher bridge elevations, longer approach spans and the use of relief structures to accommodate stream overflow. Wickline also required resident engineers to conduct extensive surveys to determine the best and most economical bridge locations. Foundation studies constituted an important part of the preliminary site investigations. Extensive foundation soundings were required to determine the sub-soil formations on all proposed bridge sites. The data on foundation conditions also allowed THD bridge engineers to incorporate soil factors into a bridge's original design and layout and to avoid major design changes while a bridge was under construction. By 1940, THD had acquired nine test boring rigs to assist with foundation exploration work.[122]

Greater THD control over bridge projects also permitted the Bridge Division to incorporate a broader range of engineering and traffic concerns into the bridge design and selection process. By the late 1920s, bridge engineers were paying special attention to traffic and safety factors, and designing bridges with straighter roadway alignments and greater roadway widths and bridge loading capacities. In order to accommodate pedestrian concerns, THD also began installing sidewalks on bridges located in or near communities.[123]

During this period, Wickline also required that resident engineers conduct more extensive studies on stream flow characteristics and incorporate these findings into their final designs. The department's *Tenth Biennial Report* of 1936 noted that:

> in the selection of structure types consideration must be given to determine the type of substructure required, the waterway opening to be provided, the probable size and volume of drift to be cared for, and to determine the relative stability of the stream channel; that is whether the channel is being subjected to scour or straightening effects or is being silted up and decreasing in section area.

THD bridge engineers used these types of studies and investigations to determine the approapriate bridge type and substructure to use and to develop overall layouts for proposed structures. If the proposed bridge site was found to be in an area susceptible to sizable drift material during flooding, THD bridge engineers would typically employ long spans with special substructure designs (such as dumbell piers with webwalls to prevent drift from getting lodged between pier columns) which allowed debris to move freely beneath the structure. In mountainous areas with high stream velocities, large trusses with massive substructure were often used to provide greater stability and stronger bridge foundations. Areas with varying stream channels and broad floodplains often resulted in lengthy bridges with one or more related relief structures. If a bridge had navigational requirements, THD designs would typically incorporate a high vertical clearance or employ a movable span to allow for the free passage of ships beneath the bridge.[124]

Important trends in THD bridge design during the late 1920s and 1930s included the increased use of simple I-beams, as well as continuous and cantilever-suspended steel I-beam units, and the discontinuation of short to intermediate truss spans (primarily Warren pony and Pratt through truss). These trends were largely made possible by longer I-beam sections available in the rolling mills which allowed the construction of span lengths up to 90 feet. A 1937 report indicated that I-beam construction afforded many advantages over truss construction, including

> substantial economies, particularly in spans of 50 to 90 feet, reduction of substructure loads, simplicity of design and consequently, simplicity of construction, . . . reduced maintenance as compared to truss designs, improved appearance, and lastly, the possibility of low-cost future widening in the event traffic development on a given section of highway warrants such widening.[125]

Other design trends were also evident during the late 1920s and 1930s. By the late 1930s, Wickline had largely discontinued the use of simple concrete slab structures for short-span bridges, relying instead on reinforced concrete multiple box culverts built in lengths of 20 to several hundred feet. Rigid frame and concrete arch construction also came into use in limited instances. Large trusses remained the preferred type for large creeks and rivers during this period, and were often built with lengthy steel or concrete trestle approaches.[126]

By the mid-1930s, THD was using continuous trusses for long-span bridge construction. Continuous trusses were first used in the mid-19th century, but concerns over secondary stresses (those arising not from the load itself, but from deformations caused by the load), difficulties in calculating stresses (resulting from their static indeterminateness) and other factors precluded a wider use of this type until the 1920s. The limited role of continuous trusses was changed by the Ohio River Bridge built by the C. and O. Railway at Sciotoville, Ohio, from 1914 to 1917. This monumental bridge consisted of a single pair of continuous trusses extending 1,550 feet in length. Continuous trusses were particularly well-suited to use at lengthy crossings and provided several advantages over Parker through truss construction. By carrying the truss over several piers, a continuous bridge works as a unit that provides much greater rigidity than a multiple-span bridge comprised of a series of simple trusses. THD completed its first continuous truss in 1936 on State Highway 66 over the Colorado River at Marble Falls (BT0252-02-017), a structure that has since suffered significant alteration, including widening. An early example that survives in good condition is the State Highway 27 (now Loop 481) Bridge at the South Llano River in Junction (refer to nomination of State Highway 27 Bridge at the South Llano River, KM0142-16-031, NRHP 1996). Completed in 1937, the bridge consists of one three-span continuous unit 473 feet long, two three-span continuous units each 382 feet long, a 96-foot truss span and approaches, providing an overall length of 1,424 feet.[127]

THD bridge designs of the late 1920s and 1930s also showed a growing appreciation and awareness of bridge aesthetics. During this period, bridge engineers began emphasizing overall simplicity and the need to provide harmonious treatment of railings, bridge-ends and substructure. A priority was also placed on providing bridge designs that blended with the natural environment. In a 1936 report, Wickline noted that:

> the growing interest in highway beautification has made it necessary that structures be designed to blend harmoniously with the surroundings, and, in the cases of structures in or near cities, . . . that the structure . . . add to rather than detract from the general architectural beauty of the city's improvements.[128]

Special efforts were made to provide architectural treatment for bridges that were readily visible to the public. These included bridges in communities and urban areas, and structures located adjacent to parks and railroad lines. In these cases, THD bridge engineers provided a visually pleasing design and applied decorative details and ornamentation to a bridge's piers, railings and approaches.[129]

In order to provide a transition from the roadway to the bridge structure, THD bridge engineers also began designing bridges with concrete approach railings that flared out at the bridge ends. In urban locations, this end treatment often took the form of solid concrete railings with decorative inset panels (refer to nomination of State Highway 35 Bridge at the West Fork of the San Jacinto River, HR0177-06-027, NRHP 1996). In some cases, roadside plantings were also used to mark the bridge ends. By the late 1930s, THD began using lower and more streamlined railing designs. In urban locations, picket-style metal railings were often used to provide a more modern and sophisticated appearance (refer to nomination of Montopolis Bridge, TV0265-01-034, NRHP 1996). Steel bridges were also provided with a finish coat of paint that blended with the concrete substructure and railings. Relief structures were usually designed to correspond closely to the main bridge. The Bridge Division also began paying closer attention to concrete construction methods and finishes during the 1930s. This resulted in a requirement that contractors submit drawings for all forms and falsework, and use methods that eliminated board marks and irregular surfaces on concrete structures (including piers, abutments and railings) whenever possible.[130]

Add paragraph(s) on concrete arches and other bridge types employed by THD to achieve a special design aesthetic. To be added under Phase II of the Texas Historic Bridge Inventory.

The Great Depression

By the early 1930s, THD was reeling from the effects of the Great Depression. Bank closings, depressed oil prices and rapidly falling agricultural prices all produced a tremendous strain on the Texas economy. The drop in cotton prices was particularly devastating, causing widespread unemployment in rural areas of the state. These problems were magnified by the state's rapidly growing population, which had reached 5.8 million by 1930. The state had also become increasingly more urbanized since the turn of the century. The 1930 census revealed that more than 40 percent of the population of Texas resided in urban areas.[131]

The Texas Legislature began to address the state's worsening economic situation. In a series of resolutions and acts, the legislature requested that THD play a lead role in combatting the effects of the Depression. In 1931, the 42nd Legislature authorized a 30-cent-per-hour minimum wage for labor expended on state and road projects and passed another act requiring contractors to purchase Texas-manufactured products whenever possible. The legislature also requested THD to conduct its operations in such a way as to provide the greatest possible opportunity of employment for Texas citizens. It was also suggested that all future road contracts be granted exclusively to Texas contractors (defined as persons building highways in Texas on or before six months prior to April 12, 1932). The commission adopted all of the recommended resolutions and made them departmental policy. Subsequent legislation in 1933 and 1935 required THD contractors to hire workers at the prevailing wage rates in a locality, to keep records of all workers employed, and to limit the work day to no more than eight hours a day per employee.[132]

With the financial situation deteriorating in many counties, the 1932 Legislature passed House Bill 2, mandating that the state assume all county bonds for highway improvements and eliminating all county contributions for highway projects with the exception of county right-of-way contributions. The law also set aside one-fourth of THD's portion of the state's gasoline tax for reimbursement of county indebtedness. The diversion of one-fourth of the gasoline fund financially impaired the state road agency and made even more pressing the need for emergency federal funding.[133]

Beginning in 1930, Congress passed a series of emergency appropriation measures allocating massive federal aid for state road programs. Two measures passed in 1930 and 1932 provided THD with more than $12.5 million to serve as a "temporary advance" (subsequently made a grant) to help match regular federal aid monies. These provisions allowed THD to continue road projects that would have otherwise been abandoned due to insufficient matching state funds. In a small way, these provisions helped stabilize construction employment in Texas. They also allowed THD to fund a number of highway road and bridge improvements in Texas during the early 1930s. In January 1933, outgoing Governor Sterling noted that the emergency federal aid allotments had helped THD "to accomplish even more than usual progress in the midst of the depression, and to give employment to more than the ordinary number of persons."[134]

During the mid-1930s, additional federal legislation passed that had an even greater impact on THD bridge construction and operations. The first of these was the National Industrial Recovery Act of 1934 (NIRA). Under Section 204 of the act, Texas received more than $24 million in grants for highway work (no matching state monies required). This act was intended to increase employment quickly through the implementation of highway road and bridge projects. An important provision in the act authorized federal aid for highway routes located in incorporated towns, which was the first time federal aid spending was allowed in these areas. This provision allowed THD to initiate a number of important bridge projects in urban areas. In order to meet the act's intent regarding employment generation, BPR instituted various labor-related stipulations for NIRA projects. These stipulations required THD contractors to hire laborers from local unemployment lists, to follow strict guidelines regarding wages and hours of work for day laborers and to use hand labor construction methods during construction. For bridge work, the hand labor provisions applied to the painting of structural steel, the erection of form work, the use of boring holes in piles and forms, and various other aspects of bridge construction. THD funded 534 NIRA projects, including a number of large bridge projects. Two important NIRA projects included the State Highway 34 Bridge at the Trinity River over the Ellis and Kaufman county line, completed in 1934 (refer to nomination of State Highway 34 Bridge at the Trinity River, KF0173-02-008, NRHP 1996), and the Red River bridge on US 87 (former State Highway 78) north of Bonham, completed in 1938 (refer to nomination of State Highway 78 Bridge at the Red River, FN0279-02-024, NRHP 1996).[135]

Several highway bridge projects were also funded under Section 202 of NIRA, which funded "a comprehensive program of public works" that was administered by the Federal Emergency Administration of Public Works (popularly called PWA). Projects funded under this program were subject to almost identical labor provisions as Section 204 projects (as discussed above). Federal PWA funds were matched by state or local monies. An important PWA project in Texas was the $2.7 million project to fund the Port Arthur-Orange Bridge (since renamed Rainbow Bridge). Navigational requirements at this site resulted in a massive cantilever and continuous truss bridge, 7,752 feet long, with a vertical clearance of 177 feet above the channel (refer to nomination of Port Arthur-Orange Bridge, JF0306-03-015, NRHP 1996).[136]

The Hayden-Cartwright Act of 1934 extended NIRA and gave Texas another $12 million in emergency grants. Section 3 of the act also set aside federal monies for emergency construction and repair work for bridges "which have been damaged or destroyed by floods, hurricanes, earthquakes or landslides." While the special labor provisions of NIRA pertained to projects funded under the NIRA extension program, they did not apply to emergency construction work authorized under Section 3 of the act. Severe flooding in 1935 and 1936 made THD eligible to receive funding under the emergency provisions of the Hayden-Cartwright Act. THD received emergency funding to construct and repair a number of important bridges, including the Llano River bridge on US 87 (former SH 9) near Mason, constructed in 1936 (refer to nomination of State Highway 9 Bridge at the Llano River, MS0071-04-018, NRHP 1996), and the US 190 Bridge at the Colorado River over the Lampasas and San Saba county line, completed in 1940 (refer to nomination of US 190 Bridge at the Colorado River, LM0272-05-023, NRHP 1996).[137]

The Emergency Relief Appropriation Act (ERA) of 1935 gave Texas $11 million for highway construction and $12 million for grade separation projects. Similar to the NIRA provisions, ERA monies did not need to be matched with state funds. In order to get these projects under way in time to provide employment during the winter of 1937, all project plans had to be approved by July 1, 1936. This act included labor stipulations that were almost identical to NIRA. Numerous bridge projects were funded by this program, including the bridge on State Highway 63 across the Sabine River at the Texas and Louisiana state line (refer to nomination of Burr's Ferry Bridge, NW0214-04-005, NRHP 1996).[138]

While federal relief funding greatly increased THD funding levels during the Depression, highway department officials still tried to conserve resources as much as possible in an effort to maximize the effect of federal relief funds and to provide as much employment as possible. THD records of the 1930s evidence that

THD bridge engineers often salvaged old trusses and reused them at locations with lesser traffic requirements. In an effort to conserve resources, bridge engineers also relied heavily on available materials, such as stone and timber, for bridge construction during this period.[139]

THD's Railroad Grade Crossing Elimination Program

Discuss early THD program, advent of federal aid for underpass and overpass construction in 1930s, important examples (steel girders and concrete types) as part of Phase II of Texas Historic Bridge Inventory

The Onset of World War II

THD bridge construction was cut drastically as the United States made preparations to enter World War II. By the early 1940s, the War Department severely restricted the use of steel, causing a rapid decline in steel I-beam, girder and truss construction. Because of the restrictions on steel materials, THD began to use salvaged bridge members as reinforcing in concrete structures. By 1944, bridge construction was largely confined to routes serving military and essential civilian traffic. With few bridge construction projects under way, the THD Bridge Division worked on bridge rehabilitation and improvement projects. An important safety project implemented during this period was the lowering of open concrete railings (primarily Types C and D) built by THD in the 1920s and early 1930s. Apparently, the tall height (usually 3 feet) provided by these railings caused a bridge to appear extremely narrow to the traveler, causing motorists to veer unecessarily toward the center of the roadway. The lower height corrected this situation and also allowed truck overhangs to clear the railings. The lowering of the railing was achieved by eliminating the upper row of railing and lowering the railing posts.[140]

Add information on concrete bridges built during this period as part of Phase II of the Texas Historic Bridge Inventory.

VII. LOCAL BRIDGE PROGRESS FOLLOWING THE CREATION OF THD

Many counties continued to use small truss and I-beam spans on low traffic volume routes through the 1930s. These types were especially popular in remote locations, such as West and Northwest Texas, that had relatively light traffic requirements, small intermittent streams and infrequent flooding problems. In these areas, pre-fabricated types, such as metal trusses and I-beams, proved advantageous. Metal truss and I-beam spans were highly standardized by the 1920s and were available at a relatively low cost. Short to intermediate spans were also available in ready-to-assemble kits that could be shipped virtually anywhere in the state.[141]

Many Texas counties built small to medium riveted-connected truss spans at minor stream crossings during the 1920s and 1930s. The vast majority of these bridges were products of Austin Bridge Company of Dallas. The company's catalog provided easy-to-follow instructions for ordering bridges, and included various charts and drawings on its stock spans. Using the company's catalog, county commissioners could order small truss and I-beam spans with only minimal engineering experience and at relatively low cost.

Warren pony trusses were typically employed for spans of 30 to 80 feet, while I-beams were popular for lengths of 30 feet or less. A relatively long truss span was provided by the 80-foot Warren pony truss built in 1935 over Little Good Creek in Foard County (FDAA02-32-001). The Warren polygonal-chord truss was commonly used for spans of 80 to 120 feet. A typical example is the 110-foot span built in 1930 over Rough Creek in Fisher County (FSAA01-83-001).[142]

In contrast to the light Warren pony trusses built in more remote locations, some counties and communities also built more substantial trusses during the 1920s and 1930s. THD bridge engineers began disseminating standard plans and specifications for 15-ton metal truss spans to county engineers in 1918. As cities and counties became more familiar with THD designs and practices during the 1920s and 1930s, many of them began to apply the same standards to local bridge projects. Large, heavy truss spans were most common at urban locations and on local roads accommodating heavy oil equipment or machinery. By 1922, Wickline noted that:

> there is a general tendency of . . . county authorities to insist upon all new bridges—whether on a State highway or not—to be of a heavier type than that formerly used. The work of the State Highway Department is serving as a general education among county road officials in the different methods of highway and bridge construction.[143]

A number of major bridge disasters in the early 1920s also helped bring about an increased interest in more substantial bridge designs. In a 1922 article on the status of Texas bridges, Wickline provides an account of several recent bridge failures on county roads, including one on the Marlin-Belton Road across the Brazos River that caused six deaths. As a result of this disaster, Falls County agreed to build the replacement bridge to THD standards.[144]

While many counties constructed metal truss bridges through the 1930s, by the early 1940s concrete slabs and girders had largely replaced metal truss spans as the preferred types for short to intermediate crossings. Advances in welding technology resulted in a few welded-connected truss spans in the 1940s. By the mid-1940s, however, most counties had abandoned truss bridges in favor of modern concrete designs.[145]

Insert information on other bridge types (primarily I-beams and concrete types) built in large population centers during this period. To insert as part of Phase II of the Texas Historic Bridge Inventory.

VIII. EPILOGUE

By the end of World War II, metal trusses were largely obsolete in Texas except for large monumental spans. Metal truss bridge technology reached its climax in Texas with the completion of the Pecos River High Bridge in 1957 and the Corpus Christi High Bridge in 1959.

The Federal Aid Highway Act of 1944 authorized a national system of interstate highways. The high standards for the Interstate System brought significant changes in the character of highway bridges, resulting in bridges with greater widths and loading capacity. Continuous girder and I-beams became the preferred types for interstate highway construction. By the 1950s, prestressed concrete beams gained popularity due to their relatively great strength and low cost. Concrete box beams came into use in the 1960s and 1970s and are still used today when speed of construction is an important factor. The first post-tensioned segmental box girder structure in the United States was completed in Texas in 1973.

In the 1980s and 1990s two uncommon bridge types have been employed for long spans: the cable-stayed bridge and the steel arch bridge. The Loop 360 bridge in Austin, completed in 1982, employs a two-hinged steel arch span measuring 600 feet. The Veterans Memorial Bridge in Port Arthur, completed in 1991, is a cable-stayed structure with segmental box girders serving as the stiffening element. The newest cable-stayed bridge, the Fred Hartman Bridge, was built over the Houston Ship Channel in 1995. More typically, TxDOT engineers have employed prestressed I-beam, pan-form concrete girder and box beam spans for new bridges. A further innovation of the box beam concept is the trapezoidal box beam (or "U-beam") bridge, currently in limited use for short to intermediate span lengths where aesthetic considerations warrant the increased cost.

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ASSOCIATED PROPERTY TYPES

I. NAME OF PROPERTY TYPE: Metal Truss Bridges

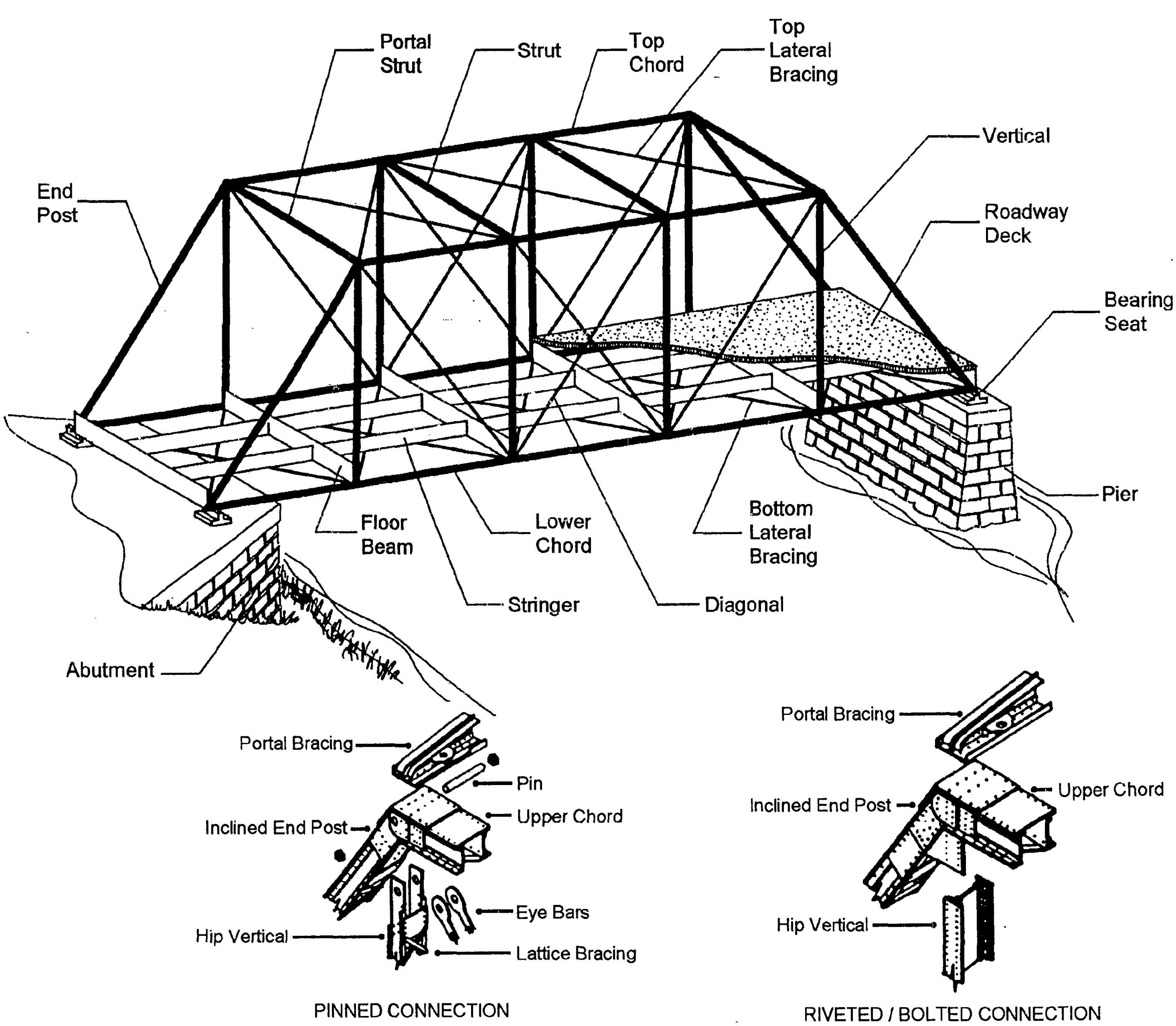
II. DESCRIPTION

A metal truss bridge is a structural unit comprised of iron and steel members that are combined in a geometric arrangement to form a rigid structural framework. Each bridge consists of two trusses, one on either side of the roadway, which are attached to one another through transverse beams underneath the deck. A truss acts like a perforated beam, with the top chord handling compressive or squeezing forces and the bottom chord carrying tensile or stretching forces. To resist the loads exerted on a truss bridge, the upper and lower chords are connected by a series of diagonal members, supplemented in most cases by verticals, with inclined posts placed on either end of the two trusses. The diagonal and vertical members are usually placed either in compression or tension, although some members can handle both types of forces. Members that are stiff, heavy posts can carry both tensile and compressive forces while members that are thin, flexible rods or bars are only capable of withstanding tension. The individual truss members are made up of various iron or steel shapes, such as angles, channels, I-beams and rods. Greater rigidity is obtained when these shapes are combined by means of rivets, lacing bars, lattice bars or batten plates. Figure F-1 shows the basic elements that make up a metal truss bridge.

The materials used in truss construction changed over the centuries, beginning with timber and shifting to cast iron, wrought iron and steel. By the early 1870s, wrought iron had surpassed cast iron and timber as the preferred material for metal truss bridges. The first metal truss bridges that were shipped to Texas in the 1870s, and most subsequent spans erected during the following two decades, were built of wrought iron. While steel manufacturing plants were established in the United States by the 1860s, cost and reliability factors prevented widespread use of steel until the 1890s. The last decade of the 19th century is generally regarded as a transitional period, with bridge fabricators employing steel and wrought-iron members rather indiscriminately. Because the rolling mills produced the same shapes and forms for the two materials, wrought iron and steel trusses appear very similar and, in many cases, are virtually identical. By 1900, steel had become the dominant material for metal truss bridge construction in the United States.

The connection methods used in truss construction have also changed over time, reflecting advances in engineering technology and the need for more rigid and durable structures. Most metal truss bridges built between 1860 and 1945 exhibit one or more of the following connection methods: pinning, bolting or riveting (refer to Figure F-1). Typically, when a fabricator received an order for a truss, the fabricator would shop-rivet the composite members together and then ship the bridge components to the site where they were assembled using one of the three connection methods. Pinning, the oldest method of the three, was popular during the late 19th and early 20th centuries. One advantage of the pin-connected (or pin and eyebar) truss

Figure F-1. Typical metal truss bridge.



Source: Commonwealth of PA, *Historic Highway Bridges;* Historic American Engineering Record.

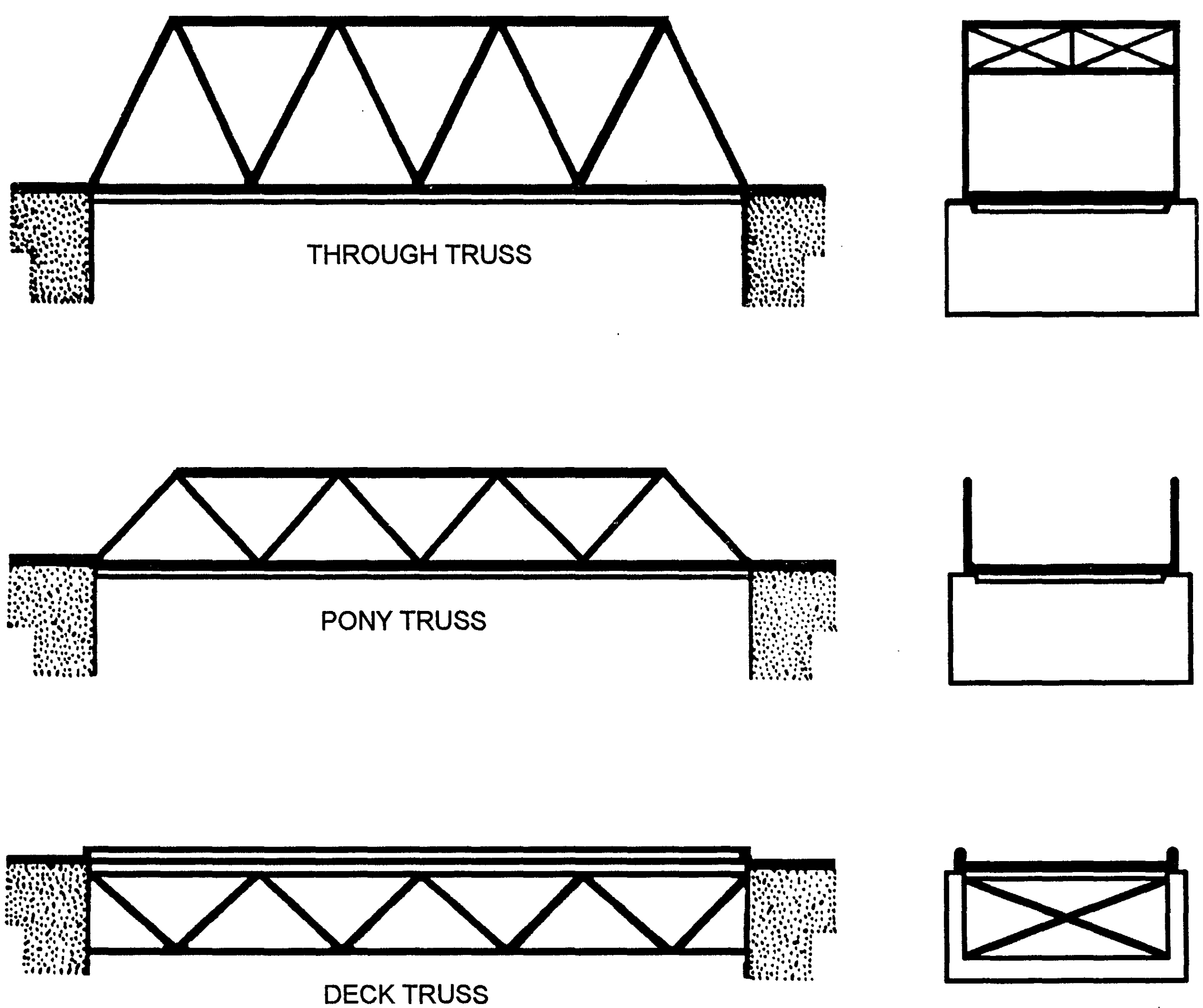
was that it could be easily erected on the site. A pin-connected span could also be readily disassembled in the event of bridge relocation, a common practice in late 19th and early 20th century Texas. The lack of rigidity of the pin connections was a major downfall, however, since it increased bridge vibrations and led to increased wear around the joints. From about 1900 to 1915, a number of bridge builders in the state used an intermediate form of connection that combined shop-riveting with field-bolting. With this approach, the truss members were shop-riveted into larger sections and then bolted together in the field. Because the larger truss sections were somewhat bulky and difficult to transport, this practice was never widely adopted. Improvements in portable pneumatic riveting equipment at the turn of the century brought about a greater use of field riveting, initially for short spans and eventually for longer trusses as well. Typically, the individual bridge members would be shipped to the site, and the members would then be riveted in the field using connection plates or gusset plates. While the first all-riveted trusses in Texas date from the early 1900s, field riveting was not standard practice in Texas until about 1920.

The basic truss pattern occurs in segments called panels that can be repeated as needed to provide the desired overall span length. If a relatively short length is needed (30 to 90 feet), a metal truss bridge is usually constructed as a pony truss with the deck attached to the bottom chord and the two sections of the truss rising above the roadway level. Because this type of truss is relatively short and rigid, no overhead lateral bracing is used. The preferred choice for longer spans (90 feet and longer) is the through truss, which is essentially a pony truss with taller web members and overhead lateral bracing joining the top chords. The pony and through truss types were prevalent in late 19th and early 20th century Texas and were particularly suited to the relatively flat topography and low stream banks found throughout most of the state. A much less common configuration in Texas was the deck truss. In rare cases, when a crossing was deep enough to accommodate the main web underneath the roadway level, the trusses were erected below the deck. Figure F-2 illustrates the three different roadway configurations.

The arrangement of the main members in a truss determines the specific truss form or type, i.e., Warren, Pratt, Parker, etc. Most truss types are named after the inventor or patent holder of that specific truss configuration. The state inventory of surviving historic bridges contains at least 20 different types of metal truss types (refer to Figure F-3). The most popular metal truss type used in late 19th and early 20th century Texas was the pin-connected Pratt. This design is distinguished by thick vertical members acting in compression and thin diagonal members placed in tension. Other salient features of the Pratt are its horizontal top chord, inclined end posts and diagonal counters. The Pratt's straightforward design and ease of erection achieved tremendous popularity in the United States and spawned a number of variations and related truss types. Two of the most important adaptations of the Pratt are the Pratt half-hip truss and the Parker truss. The Pratt half-hip, commonly used for short spans (60 feet or less), features hip verticals (or end verticals) placed in tension. The Parker is essentially a Pratt with a deeper web and a polygonal top chord. By arching the top chord, the Parker provides greater strength than the Pratt and could be used for longer span lengths, usually up to 250 feet or more.

A number of other important Pratt-related designs are represented in Texas, including the camelback,

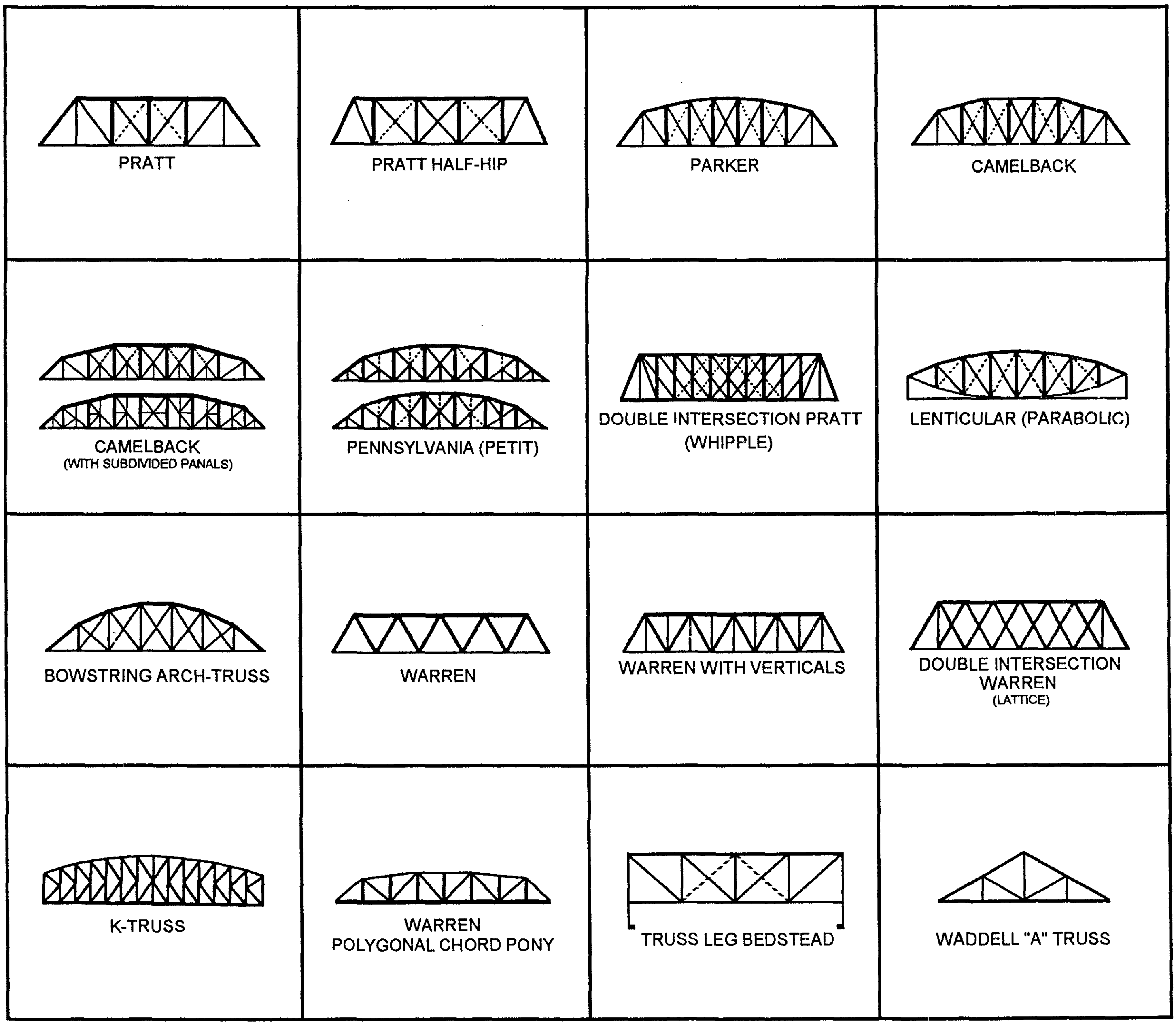
Figure F-2. Truss elevations and transverse sections.



Source: Jackson, Donald C., *Great American Bridges and Dams.*

National Register of Historic Places Continuation Sheet

Figure F-3. Major truss types represented in Texas.



NOTE: This figure shows typical configurations for these types. Examples in Texas often deviate from these prototypes.

Source: *Historic American Engineering Record.*

a Parker variant featuring a polygonal top chord with five sides (including the end posts); the camelback with sub-divided panels; the Pennsylvania truss, a Parker with sub-divided panels; and the double-intersection Pratt truss (or Whipple), in which the diagonals extend over two panel lengths. These Pratt permutations were all developed by railroad engineers during the mid- to late-1800s in an attempt to develop longer and more rigid trusses for railroad traffic. Two of the more unusual Pratt variants found in Texas are the truss leg bedstead and the lenticular truss. The truss leg bedstead is distinguished by vertical end posts that extend below the lower truss chord to serve as a pier or abutment support. The lenticular truss is an especially rare type featuring curved upper and lower chords that form a lens shape.

An early truss type that is not associated with the Pratt is the bowstring. Its curved shape resembles a bow or arch, with a curved or polygonal top chord in compression tied by a horizontal lower chord in tension. The deck is carried by a series of verticals and diagonals in the truss web that are all placed under tension. The bowstring was one of the earliest metal truss forms that bridge builders brought to Texas. Due to washouts and bridge replacements, however, few examples of this truss type remain in the state.

The most popular truss type erected in 20th century Texas was the riveted-connected Warren, a design best known for its "W" arrangement of diagonal members. In a true Warren, the triangular shapes of the truss form equilateral triangles. The Warren's relatively rigid diagonals function both in tension and compression and can be supplemented by thinner vertical members that act primarily as braces or secondary members. As is the case with most trusses, the top chords and end posts are usually in compression while the lower chord remains in tension. The Warren began to gain popularity during the early 1900s, at the same time that field riveting was coming into practice in the United States. By providing a simplified truss configuration and eliminating all redundant members, the Warren was easy to design and fabricate, and was particularly suited to the new field riveting technology. From about 1910 through the 1930s, hundreds and perhaps several thousand riveted-connected Warren pony trusses were erected throughout Texas. Because the Warren was most adaptable to short lengths (30 to 90 feet), the Pratt continued to be the preferred type for medium to long crossings (90 to 150 feet). A small number of pin-connected Warrens, erected around the turn of the century, are also extant in the state. While the Warren configuration was also used for through spans, this version was not common in Texas. Another Warren variant found in Texas is the double-intersection Warren, which is basically a Warren with a second triangular web system superimposed onto the original design.

Metal truss spans first appeared on Texas roadways in the 1870s and 1880s, after the large midwestern and eastern railroads penetrated Texas and began expanding their lines across the state. By the early 1900s, truss spans were found in virtually every corner of the state. The demand for wider and more durable bridges has led to the disappearance of many early metal truss bridges. Overall, however, this property type is still well represented in the state. Approximately 1,000 metal truss bridges dating from 1884 to 1917 remain in Texas, representing 85 percent of all metal truss spans surviving in the state.

Virtually all of the metal truss bridges constructed in Texas prior to 1917 and most of the locally built structures dating after 1917 were designed and erected by bridge fabricators. In almost all cases, these bridges were constructed without regulations or supervision from governmental entities or consulting engineers. With only vague standards and specifications guiding the bridge selection process, most bridge companies developed stock spans that they marketed throughout the state. These spans were typically lightweight structures made up of slender members, such as paired angles and thin plates, connected by pins or a loose pattern of rivets. While the bridges designed by the various companies are very similar in character, the fabricators often developed unique solutions for completing the portal bracing, web members and gusset plates (if present) of a truss. Many bridge designers also used non-functional decoration, such as bridge plaques, cresting and finials, to differentiate their trusses from those of other builders.

During this early era of metal truss bridge construction, the bridge's layout and composition were usually dictated by economic factors and the need for expediency in a bridge's construction. Typically, a metal truss span was erected in the middle of a channel and was flanked by a series of timber or I-beam approach spans connecting with the roadway on either side. At long crossings, metal truss bridges were often built with multiple truss spans (up to 20 or more) over the main channel with approaches. In an effort to minimize potential damage by rapid currents and flooding, the metal truss spans were usually placed at a higher grade than the approach spans and the adjoining roadway. In many cases, the bridge was also placed at right angles to the stream with winding approach roadways on either end.

Texas Highway Department (THD) bridges tend to exhibit the standardized characteristics and preferences of the early THD bridge division and the Bureau of Public Roads, an agency of the U.S. Department of Agriculture. In contrast with the light-type trusses designed by bridge fabricators, these were large, robust structures comprised of heavy, built-up members connected by substantial gusset plates and rivets. Truss railing typically took the form of simple steel members (angles, channels, H-beams or I-beams) placed in one or two rows across the main truss span(s). In some cases, the railings were supported by additional steel members, such as steel angles or I-beams.

In addition to the main truss, most THD bridges also include large, permanent-type approach spans, concrete decking and curbing, and prominent concrete or steel approach railings. By the late 1920s, THD bridge engineers were emphasizing overall simplicity and the need to provide harmonious treatment of railings, bridge-ends and substructure. Many of the trusses and other bridge elements (substructure, railings, approaches, etc.) constructed by THD conformed to standard plans. From about 1920 to the early 1930s, the most popular standard plan trusses used by THD were the Warren pony (50 to 80 feet), the Pratt through truss (100 to 150 feet), and the Parker through truss (120 to 250 feet).

Most THD bridges are comprised entirely of components that conform to standard THD plans. In some cases, however, custom design features, such as special railing or pier designs, were also used to address unusual engineering or aesthetic concerns. While THD bridges typically do not exhibit architectural details or special decorative elements, exceptions were made for bridges readily visible to the public, such as locations adjacent to parks and railroad lines. In cases where visibility was a factor, THD bridge engineers created visually pleasing and harmonious designs, often applying special decorative details and ornamentation to a bridge's piers, railings and approaches.

The bridges erected by THD reflect a more sophisticated engineering approach than that employed by earlier bridge builders in the state. The THD bridge design and selection process resulted from an analysis of a wide range of factors, such as soil conditions, hydraulics, flooding, drift, navigational requirements and other elements. THD bridges were designed to be large enough to accommodate floodwaters in an entire floodplain without any overflow on the approach roadways. In almost all cases, THD bridges were built at the same grade (or virtually the same grade) as the approach roadways. For large crossings, the solution was usually one or more large metal truss spans flanked by a series of relatively short concrete or metal approach spans. Alternatively, smaller structures were constructed across relief channels which help accommodate rising floodwater. In some cases, long approaches were avoided by filling in part of the floodplain; occasionally, relief structures were built in combination with a filled-in section in order to accommodate water overflow in peak seasons. THD also continually improved its design and construction practices. For example, by the early 1920s, THD had discontinued the use of pin connections in favor of riveting methods and had replaced suspended floor-beam designs with more rigid decking systems that framed the floor beams into the bottom chord.

THD also adapted its design preferences for metal truss bridges over the years. By the mid 1930s, THD was using I-beams and girders for most short and medium spans, virtually eliminating the Warren pony and Pratt through truss. The department continued to erect Parker through truss spans at mid to long-sized crossings through the late 1940s. In addition to the simple truss types discussed thus far, THD's bridge division designed several cantilever trusses beginning in the early 1920s and continuing through the 1950s; the latest cantilever truss erected in the state dates from 1970. A cantilever truss span is made up of two projecting arms that extend over interior piers, usually meeting each other mid-span. Sometimes, when it is necessary to provide a long span with no intermediate piers, the two projecting arms support an additional suspended span. Cantilever truss bridges could usually be erected using falsework for the anchor spans and cantilevered construction for the main suspended span. This truss type was most appropriate for locations where it was impractical to erect falsework and piers in the middle of the streambed and at crossings where interior piers would have impeded navigation. Visually, a cantilever bridge differs from a simple truss in that the trusses usually become deeper or taller at the points where they pass over the piers. Cantilever bridges of this property type are typically erected as through trusses. Another truss type the THD bridge division employed for long spans was the continuous truss, which has a chord and web configuration that continues uninterrupted over one or more intermediate supports or piers. Some continuous trusses have a top chord that is parallel to the bottom chord; in other examples, the top chord is bowed or shaped like a catenary curve. In Texas, continuous spans were erected both as through and deck trusses.

During the 1920s, 1930s and early 1940s, THD was responsible for designing and completing several hundred metal truss bridges on the state highway system. Many of the more modest examples have since been removed. There are only about 50 metal truss bridges remaining in the state that are products of THD design and construction.

While THD bridge engineers were not directly responsible for local bridge activities, they did significantly influence local bridge work. As local engineers became more familiar with THD designs and practices during the 1920s and 1930s, a number of them began to borrow freely from THD plans and specifications and to apply the same standards to local bridge projects. In a few cases, locally built bridges closely resemble THD built structures. In most rural areas, however, the counties continued to purchase stock metal truss spans, although not in the same quantity as they did previously. Beginning in the 1920s, many counties and cities also began to use concrete slabs, girders and other bridge types at small to mid-sized crossings. Approximately 125 metal truss bridges dating from 1917 or later survive on city and county roadways in the state.

Although the superstructure is often the most prominent aspect of a metal truss bridge, the substructure is also important. Most of the early bridges in this property type had timber pile abutments with plank endwalls. Other early abutments were constructed of stone or consisted of steel piles with sheet steel end walls. Piers were used for longer bridges that included a main truss span(s) and approaches. The early approaches usually consisted of timber or steel I-beam trestle spans. The most common pier type used for truss spans in the late 19th and early 20th centuries consisted of concrete-filled tubular caissons built from riveted iron or steel plates. Another common pier type for truss spans were simple metal pile bents built from channels or composite members. In Texas, concrete was not used extensively for substructures until about 1910. Typical THD construction featured concrete piers arranged in a dumbbell configuration, with battered cylindrical columns connected by a solid diaphragm or web wall. Alternatively, columns were squared. THD developed a series of standards for dumbbell piers that were used for most metal truss bridge construction. In addition, non-standard pier designs included solid piers with rounded, squared or, less typically, pointed (cutwater) ends.

Bridges in this property type are most commonly found in a broad central corridor of the state that extends east to Tyler and west to San Angelo. This region is crossed by several major watersheds and was the site of the state's earliest and most intensive rural settlement. While the extreme eastern portion of the state was also the site of early agricultural development, the predominance of timber precluded a more extensive use of metal truss bridges in this region. A few metal truss bridges are scattered throughout the more populated areas of the state, with several THD spans serving as gateways to communities and cities.

The boundaries of a metal truss bridge are generally defined as the main metal truss bridge and all ancillary structures designed as part of the overall solution to that drainage area. This includes relief structures and other structures that are intended to facilitate overflow from a metal truss bridge. Also encompassed by this definition are approach spans, the substructure, railings and any other features affixed to the bridge, such as bridge plaques, guard rails and decorative features.

The condition of the bridges in this property type vary greatly depending on the level of maintenance received. Metal truss bridges on the state highway system receive regular maintenance and are generally in good repair. In many cases, these bridges survive with no modern alterations evident. The most obvious modifications found on THD bridges are large singular guardrails affixed to the thinner historic railings and rebuilt portal bracing or web members. Most of the bridges on local roadways have not fared as well as the highway structures. Without paint and regular maintenance, many local bridges are in a deteriorated state. The narrow widths and winding approaches that are commonly associated with these bridges make them very susceptible to vehicular collisions. Their unstable piers and low elevations above the streambed also make them vulnerable to washouts and flooding damage.

III. SIGNIFICANCE

National Register Eligibility Under Criterion A

Bridges may be eligible for the National Register under Criterion A for their contributions to the broad patterns of transportation history at a national, state or local level (level of significance explained in more detail in following paragraphs). As structures that were built primarily to convey passengers and materials, bridges with Criterion A significance usually fall under the general area of transportation. A bridge that played an important role on an early mail or stagecoach route, for example, would be significant for transportation reasons. In some cases, a bridge's significance relates primarily to its function as a transportation structure, but is also associated with other underlying themes, such as politics/government, industry or commerce. In this situation, it would be appropriate to categorize the bridge under the general heading of transportation, but also include additional sub-headings to clarify its significance. A bridge built as a major public works project during the Great Depression, for example, would be categorized under the area of transportation with the sub-heading "Depression-era Public Works." Similarly, a bridge that is important for stimulating oil-related activities in a region would probably fall under the general transportation heading first, but also include the sub-category "Regional Economic Development." When a bridge's association with other areas of history, such as politics/government or ethnic heritage, is of equal or greater value than its association with transportation themes, then a bridge would be categorized separately under each of the applicable areas of significance.

In an effort to narrow Criterion A to examples with the most important associations, it is limited here to bridges that have contributed in a meaningful and direct way to the transportation development, expansion or economic growth of a specific geographic area in the state. Bridges that are associated with trends and developments in large geographic regions or heavily populated areas will generally have the strongest Criterion A significance. During the course of the evaluations, the Texas Historical Commission (THC) and the Texas Department of Transportation (TxDOT) asked the following questions to determine the Criterion A significance of a bridge:

- Has the bridge played a critical role in the development of a regional or statewide transportation system?

- Has the bridge significantly improved passage through a community or region and has this access allowed major economic development, growth or settlement to occur?

- Is the bridge's history directly related to major political, historical or social events at a local, state or national level?

Early metal truss bridges can have importance for serving as a critical facility for the movement of people and goods through a region. In many cases, these will be bridges at major river and stream crossings. Bridges that are documented as the earliest or one of the earliest permanent type structures erected by a county will often have considerable significance as well. Also falling in this category are early toll bridges constructed by local corporations to promote regional economic trade and travel. These structures often have considerable significance for facilitating passage across large geographic areas and for boosting a community's economic standing. Metal truss spans may also be important for serving early stagecoach and mail routes or for accommodating travel between regional population centers and county seats. While early metal truss bridges tend to be important at the local level, bridges that are associated with important travel routes across the state or with substantial economic development or settlement could have statewide significance under Criterion A.

Bridges that served on privately designated highway routes are also important for playing a critical role in the development of an early state highway system. The prospect of increased tourist traffic and trade propelled many communities along these routes to invest in more permanent bridge construction. Many of these structures, as well as other local bridges, were later incorporated into the early state highway system, serving traffic on state highway routes for years. While highway realignment and bridge replacements have displaced almost all of these structures, a few examples remain and have statewide importance for their affiliations with early Texas highway routes.

Beginning in 1917, state bridge engineers began designing and constructing bridges for a statewide network of highways. From about 1920 through the early 1940s, THD erected many metal truss spans across the state. For THD bridges to have state level of significance, they should be associated with substantial economic growth or transportation development for a large region or populated area in the state. A highway bridge that has stimulated major economic activity for a region, such as a structure that has accommodated traffic between major oil-producing centers, would meet this test. Highway bridges that serve primarily local traffic are generally disqualified from Criterion A consideration. A case could be made for local Criterion A significance, however, if a bridge has significantly contributed to an area's transportation development, expansion or growth.

Bridges can also have Criterion A significance at the local or state level based on their associations with political, historical or cultural events. An example of a bridge with cultural associations would be a structure that has been historically associated with a community's Juneteenth celebration, an event held every June 19th to commemorate the emancipation of slaves in Texas. A number of metal truss bridges are also important for their associations with the Great Depression of the 1930s and early 1940s. Bridges that are products of major federal relief measures, such as the Public Works Administration or the National Industrial Recovery Act, have statewide importance as public works projects that helped to alleviate the state's employment problems during the Great Depression.

National Register Eligibility Under Criterion B

A bridge can also be eligible under National Register Criterion B for its association with "persons significant in our past," as long as these persons were not directly involved in a structure's actual design or construction. Usually, when bridges are associated with specific individuals, it is in relation to designers, fabricators, contractors and architects, associations that are generally treated under Criterion C. Bridges are rarely associated with other historically important individuals, such as politicians, civic leaders, or prominent citizens or business leaders. It is conceivable, however, that a bridge could represent a major accomplishment or turning point in the career of an important politician or other civic leader, qualifying it for National Register consideration under Criterion B.

National Register Eligibility Under Criterion C

Most bridges with historic significance in Texas fall under Criterion C as structures with engineering merits at either the state or local level. In most cases, a bridge with local engineering significance will be distinctive or unusual in a county or several county area, or represent a local engineering or public works accomplishment. In Texas, state level of significance is usually reserved for bridges identified under a statewide comparative study, such as the Texas Historic Bridge Inventory. The following discussion expands on the National Register eligibility of bridges under Criterion C, focusing primarily on bridges with state level of significance.

According to National Register guidelines, bridges that meet Criterion C include those that embody the distinctive features of a type, period or method of construction; represent the work of a master; or possess high artistic values. Because of the uniformity in this property type, it is not practical to evaluate metal truss bridges based on typifying features. Instead, Criterion C evaluations are used to identify bridge that are outstanding examples of a particular type, period or method of construction. Another purpose of the evaluation process is to recognize bridges with additional qualities, such as rarity of type, associations with important designers, long span lengths, combined span types, decorative details and other exceptional features. In an effort to glean the best examples from a large pool of similar resources, TxDOT and the THC have generally restricted Criterion C to:

- bridges that are outstanding representatives of a particular type, period or method of construction;
- structures that are prominent works of an important bridge designer or builder;
- bridges that involved unusual design or construction efforts; and

- bridges with unique characteristics, extreme decoration or outstanding artistic merits.

All metal truss bridges surviving in Texas were built of either wrought iron or steel. While a metallurgical test is required to determine conclusively whether a truss is built of wrought iron or steel, date of construction can be a fairly reliable indicator of a bridge's material composition. In Texas, all metal truss spans built prior to 1890 are wrought iron while all spans post-dating 1900 are steel. Surviving examples of wrought iron bridges are important for representing a once preeminent form of metal truss bridge construction that is now obsolete. Bridges built before 1900 that can be conclusively documented as steel are also important as early examples utilizing modern bridge materials in the state.

Early metal truss bridges in Texas can also have significance based on the technology used to connect the bridge members. Metal truss bridges that are relatively early or late examples of a particular connection method—such as pinned or riveted construction—are significant for demonstrating the evolution and transition of various bridge technologies. Bridges with both riveted and bolted connections are also significant as examples that demonstrate an important intermediate practice in metal truss bridge design and construction.

Almost all of the metal truss bridges erected in Texas prior to World War I were products of bridge fabricators from other states. From 1870 to 1910, more than 30 different builders bid on or constructed metal truss bridges in the state. Most of these companies hired agents who set up businesses in Dallas and Houston. Some of the more prolific bridge builders operating in Texas included: the American Bridge Company of New York City (and elsewhere); the Berlin Iron Bridge Company of New Berlin, Connecticut; the Chicago Bridge and Iron Company of Chicago, Illinois; the George E. King Bridge Company of Des Moines, Iowa; the Kansas City Bridge and Iron Company of Kansas City, Missouri; the King Iron Bridge Company of Cleveland, Ohio; the Milwaukee Bridge and Iron Company of Milwaukee, Wisconsin; the Missouri Valley Bridge and Iron Company of Leavenworth, Kansas; the New Jersey Steel and Iron Company of Trenton, New Jersey; and the Wrought Iron Bridge Company of Canton, Ohio. These companies were important for introducing wrought iron and steel truss spans to Texas. Bridges with distinctive builder features and details can also be important for exemplifying the work of early bridge fabricators in Texas.

The Austin Bridge Company of Dallas, incorporated in 1910, was the first major metal truss bridge fabricator to open shop in the state. Metal truss bridges attributed to Austin Bridge Company bridges are significant as products of the preeminent Texas bridge builder. Because the company built so many similar-type bridges, only the most representative or unusual examples are recognized under Criterion C. The Austin Bridge Company's dominance prevented other Texas bridge companies from developing substantial bridge businesses in the state prior to the creation of THD in 1917. Fabricator designed bridges attributed to other Texas bridge companies are important for representing the works of small bridge builders operating in the state.

As the most prevalent forms employed in late 19th and early 20th century Texas, the Pratt (pony and through), the Warren pony and the Parker through types were important in the development of the state's transportation network. Outstanding representatives of these types can be significant for embodying the distinctive characteristics of a common type, or for demonstrating evolution or variation within a type. Usually, the best examples will exhibit a combination of typical features as revealed in their substructure, superstructure, deck, railings, decorative features and approach spans. Criteria such as span length, combination of span types, span number and age are applied to identify superior examples. Common type trusses can also be significant for representing transitional technology in construction materials or connection methods and for their associations with important bridge builders.

Although most bridges in Texas conform to the Warren, Pratt or Parker configurations, a number of more unusual truss configurations are also found in the state. For a bridge to be considered a rare type in Texas, it must be represented by 10 or fewer extant examples. These include the bowstring, camelback, camelback with subdivided panels, double-intersection Pratt (or Whipple), double-intersection Warren, K-Truss, lenticular, Pennsylvania, truss leg bedstead, modified Waddell "A" Truss and Warren polygonal-chord through. Bridges that illustrate one of these more unusual configurations have an elevated importance based on their rarity in the state and for their contributions to the evolution of bridge engineering.

Employing stringent standards and specifications for all state highway bridge construction, THD's bridge division produced the first generation of Texas bridges that were capable of withstanding heavy loads and high traffic volumes. THD bridges can be significant under Criterion C for embodying distinctive characteristics of highway bridge design and construction. Typically, these will be the most complete, earliest, or most technically complex examples of a bridge type or standard design. The best examples will usually exhibit a combination of features, such as multiple spans, combined span types, lengthy or various approach spans, distinctive railings and piers, and original pedestrian walkways. Several bridges remain as the last examples of a particular THD truss type or standard plan, and are significant for representing bridge types that were once more common on the state highway system. A few THD bridges are also important for their aesthetic or artistic merits. Bridges that were specifically designed to achieve a high aesthetic ideal or that exhibit exceptional architectural detailing or ornamentation have significance based on their artistic factors. Local bridges that conform or closely correspond to THD standard designs are also important for bringing about a higher level of standardization in state and local bridge design and for demonstrating THD's influence on local bridge practices.

While an individualized approach was required for all THD bridges, in some cases, more sophisticated design or construction work was required. Customized design work occurred most frequently at bridge sites with heavy drift, flooding, high velocity stream flows and stream bank erosion, and at crossings with navigational requirements. Bridges built during the Great Depression often required special design solutions as well. Occasionally, THD bridge engineers and contractors employed innovative or technologically advanced construction methods. Bridges that involved innovative and technically complex design or construction applications are significant based on the degree of engineering effort and expertise required, and as major accomplishments of the THD bridge program.

Exceptional Significance for Bridges Less than 50 Years Old

Benefitting from an almost perfected understanding of truss technology and cantilevering construction techniques, metal truss bridges built since 1945 tend to be large, impressive structures. A few moveable truss spans were also constructed during this period and are important based on their rarity in the state. While properties less than 50 years old generally do not qualify for National Register listing, they can be determined eligible and be listed if they are of exceptional significance. Most of the more recent examples conform closely to earlier bridges and are unlikely to qualify as outstanding examples. A few of the more grandiose and unusual structures, however, are important as major engineering accomplishments of their time and for representing structural types now extremely rare in the state. In these cases, TxDOT and the THC have made a strong argument for exceptional significance.

IV. REGISTRATION REQUIREMENTS

General Significance and Integrity Requirements

The superstructure is the defining characteristic of this property type. In order for a metal truss bridge to be eligible for the National Register, the superstructure must be in substantially original condition, retaining its original connection system and configuration of members. Not only should the steel members be intact, but they should also continue to function as a truss, without the need for additional supports or piers. The bridge needs to maintain a transportation-oriented relationship with its environment and be clearly recognizable as an engineering structure that is part of a continuous roadway or pathway. Bridges that have been abruptly disconnected or removed from a roadway and not integrated into another transportation system have difficulty conveying this significance and, in most cases, will lack integrity of setting, feeling and association (and sometimes location and design).

In addition to the superstructure, the other structural systems that comprise a bridge are, in general order of importance, the substructure, approach spans and railings (if any), flooring and guard rails (truss). Because the floor (decking materials) and guard rails are usually of nominal consequence, these features can usually be altered, replaced or even removed and the bridge can remain National Register eligible. While the substructure and approaches (spans and railings) can also withstand some alterations, replacement of parts and removal of elements, the majority of the original fabric should remain. Generally, a lesser degree of change is tolerated for these elements, particularly when they constitute a substantial portion of the overall bridge.

As a utilitarian structure subject to high traffic volumes and heavy loading, some deterioration and damage to the truss members are acceptable provided that they are fairly minor in scale and the truss continues to function as originally intended. Alterations completed during the period of significance are generally considered part of a bridge's overall historical fabric. Because these modifications often provide information on how metal truss bridges were utilized and adapted over time, they can actually add to a structure's overall significance. The most frequent types of historic alterations include raised piers, rebuilt or washed out trusses or approach spans, replaced bridge decks, and modified railings. Recent alterations, such as the addition of modern guardrails or signage, are usually acceptable provided that they are not overwhelming and the bridge still retains most of its original materials. When evaluating alterations, it is important to consider the reversibility of the changes that have been made. The easier it is to remove new materials and return a bridge to its original condition, generally, the less damaging and intrusive the alterations.

The type and level of integrity that must be present depends largely on the National Register criteria that is applied. For bridges with significance under Criterion A or B, the most important aspects of integrity are location, setting, feeling and association. In order to be National Register eligible, these bridges should convey the same basic characteristics and appearance as they did during their period of significance. Because location is of primary importance under Criteria A of B, a metal truss bridge will rarely qualify for the National Register if it does not remain on its original site.

For metal truss bridges to be eligible under Criterion C, they must retain the defining characteristics of their bridge type, construction method, period or builder. Structural integrity, as evidenced by a bridge's ability to convey its historic design, workmanship and materials, is critical for Criterion C significance. A greater degree of alteration or deterioration is generally allowed for rare or technologically unusual examples, as long as the bridge continues to convey its important character-defining features. For a rare truss, such as a lenticular truss, a deck replacement or the addition of modern approach spans would be tolerated as long as the unusual lenticular configuration remains intact. The approaches (spans and railings) and substructure are usually more important for highway bridges than for locally built structures. As integral elements in the overall design of a THD bridge, these components need to remain physically intact with few alterations or changes. Highway bridges also need to retain other original features, such as concrete or metal approach railings, that were intended to be clearly visible from the roadway. Virtually all of a highway bridges trademark features need to be present to retain integrity of feeling and association. Highway bridges that are widened or substantially altered will almost always lose integrity of design, materials and workmanship.

Relocation does not necessarily exclude a bridge from Criterion C consideration. As lightweight structures that were easy to assemble and erect, the early fabricator-designed bridges were commonly moved and reused at new sites. Early spans that are relocated can remain eligible under Criterion C, particularly if they span a body of water, a railroad crossing or other type of transportation obstacle at their new site. In some cases, a relocation will severely affect a bridge's integrity of location, setting, feeling and association. The degree of change in a bridge's environment must be weighed against its rarity and importance under Criterion C. Relocation is more problematic for THD bridges since they were designed as permanent fixtures at their original locations. Because highway bridges are site-specific structures that conform closely with their surrounding environment, they cannot be moved without losing integrity of location, setting and design.

Requirements for National Register Eligibility

A metal truss bridge is eligible for the National Register under Criterion A if it has contributed in a meaningful and direct way to the transportation development, expansion or economic growth of a specific geographic area or region. A bridge can only be eligible under Criterion A for associations that date from its period of significance; it cannot acquire significance for events that occurred prior to its construction. Metal truss spans constructed locally can qualify for Criterion A based on their associations with events that have importance at the local, regional or state level. Specific considerations for eligibility under Criterion A include:

1. **Bridges that have played a critical role in the development of a regional or statewide transportation system**. This consists of early bridges that were instrumental in forging new transportation routes through a region, such as bridges erected over critical crossings or on important trade and travel routes. These bridges typically meet Criterion A at the local level of significance. Bridges can also be important at the state level for contributing to a state transportation system. This includes early bridges that accommodated traffic on private highway association routes and THD bridges that played a substantial role in the transportation development of a large region or portion of the state.

2. **Bridges that have facilitated major economic development, growth or settlement of a region.** This consists of early bridges that boosted substantial economic activity in an area or contributed to substantial expansion or growth in a region or community. In most cases, these bridges will have a local level of significance. Highway bridges that have contributed to substantial economic development in a large region or portion of the state also qualify under this category at a state level of significance.

3. **Bridges with important political, historical or cultural associations**. Such bridges are associated with important events and patterns in our history, such as state legislation, Depression-era relief programs, political controversies, and ethnic traditions and history. Bridges with these types of associations will usually be eligible under Criterion A at the local or state level of significance.

Metal truss bridges can be eligible for the National Register under Criterion B for their associations with important persons, as long as those individuals are not the bridge's designer, fabricator or builder. Depending on the importance of the individual, a bridge could meet Criterion B at either a local or state level of significance.

Most metal truss bridges with historic significance in Texas are eligible for the National Register under Criterion C as structures with engineering importance. These requirements generally apply to bridges with state level of significance. The specific considerations for eligibility under Criterion C include:

1. **Bridges that embody the defining characteristics of a specific bridge type, design or method of construction**. Such bridges will contain enough features and traits to be considered outstanding representatives of a particular bridge type, design or method of construction. These will be the most complete, technically complex and well-preserved examples. The significance can be enhanced by unusual or outstanding features such as special design elements or ornamental detailing. This category is divided into three components:

   a. ***Locally built bridges***. This includes outstanding examples of common-type bridges, most importantly the Pratt, Parker and Warren. These bridges will exhibit a combination of noteworthy features, such as long and multiple truss spans, combined truss types, documented builder(s), early or late construction dates and distinctive builder features. Also included under this category are bridges that exemplify the pinned and riveted connection methods. Such bridges will exhibit distinctive connection features, long span lengths and early or late construction dates.

   b. ***THD bridges that remain on the state highway system***. This includes exceptional examples of THD bridge designs. To fall under this category, a bridge must exhibit a combination of typical THD design features, such as long and multiple truss spans, early or late construction dates, combined truss types, lengthy or various approach spans, distinctive railings and piers, ornamental features and pedestrian walkways. Bridges that remain as the last example of a particular THD standard design are also included and are important for representing what was once a more common bridge configuration in the state.

   c. ***THD bridges that are no longer part of the state highway system (surviving on county roads or city streets)***. Almost all of these will be short pony spans constructed by THD on the early state highway system. These bridges must meet all requirements for THD bridges delineated above. It is also important that their design, proportions, scale, materials and details clearly distinguish them as THD bridge design and construction. These bridges should be clearly recognizable as products of the THD bridge division.

2. **Bridges representing technology that is rare or unusual for Texas**. This category includes:

   a. ***Bridges constructed of wrought iron***. Metal truss bridges constructed prior to 1890 are presumed to be constructed of wrought iron, and are very unusual in Texas.

   b. ***Early bridges constructed of steel***. Steel bridges conclusively documented as pre-1900 construction are important as an early use of modern bridge-building materials.

   c. ***Bridges displaying riveted-and-bolted construction***. The use of riveted-and-bolted connections was an intermediate construction method for metal trusses used briefly in the early 20th century. Eligible bridges should be well-preserved examples with early construction dates and complete documentation.

d. ***Bridges that employ obsolete or unusual technology***. During the Great Depression and the early years of THD, material shortages and financial constraints compelled THD bridge engineers to employ obsolete or unusual construction practices, such as widening instead of replacing narrow truss spans and using timber instead of concrete as a decking material. Bridges that apply obsolete technology or labor-intensive construction methods for economic reasons represent an important variation in bridge technology and are highly unusual.

e. ***Locally built bridges that conform or that closely correspond with THD standard designs***. These bridges are important for bringing about a higher level of standardization in state and local bridge design and for demonstrating THD's influence on local bridge practices.

3. **Bridges that are exceptional examples of an important bridge engineer, fabricator or builder**. This category includes fabricator-designed metal truss bridges that remain on county and city roadways. Because these bridges were not subject to THD standards, they display a wide range of characteristics and features. The bridges included in this category will be the most technically complex, complete and well-preserved examples of fabricator-designed metal truss bridges in the state. These bridges fall under three categories:

a. ***Bridges built by important out-of-state bridge builders***. Such bridges were constructed between 1885 and 1920 by nationally prominent, out-of-state bridge builders. These bridges must contain enough builder details and other features to be clearly identifiable as products of a specific bridge fabricator or builder.

b. ***Bridges fabricated by Austin Bridge Company of Dallas***. Austin Bridge Company of Dallas was the preeminent builder of small metal truss spans in Texas from 1910 to 1940. Because the company built so many similar-type spans, only superior examples are considered National Register eligible. Such bridges will exhibit a combination of features, such as multiple spans, a combination of span types, long span lengths, rare bridge types and decorative elements.

c. ***Early bridges fabricated by other Texas bridge companies***. It is highly unusual to find metal truss bridges pre-dating THD that are products of Texas bridge fabricators other than Austin Bridge Company. Well-preserved examples of these builders are important for representing the works of smaller bridge fabricators in Texas.

4. **Bridges that are rare survivors**. This category includes rare-type bridges, i.e., types represented by 10 or fewer spans in the state. Most of the bridges in this category were built before the advent of state standard plans.

5. **Bridges employing technically complex, advanced or innovative designs or construction methods**. This category includes bridges that required exceptional engineering skill to meet unusual site conditions, structures that exhibit innovative and sophisticated design solutions, and bridges that employed unusual construction methods.

6. **Bridges with exceptional aesthetic merit**. This consists of bridges that demonstrate an exceptional level of ornamentation and architectural detailing. It also includes bridges that required special efforts on the part of the designer or others to achieve a visually pleasing and harmonious overall appearance.

7. **Bridges less than 50 years old with exceptional significance**. In order to qualify for the National Register, bridges less than 50 years of age must be major engineering accomplishments of their time or represent rare structural types in the state, such as moveable spans.

GEOGRAPHICAL DATA

The geographic boundaries for this nomination are the State of Texas.

SUMMARY OF IDENTIFICATION AND EVALUATION METHODS

I. OVERVIEW

This multiple property listing is the result of a systematic inventory of Texas bridges conducted by the Texas Department of Transportation (TxDOT) in cooperation with the Texas Historical Commission (THC). An expanded federal bridge replacement program, authorized by the Surface Transportation Assistance Act of 1978, significantly increased the number of bridge projects in the state and was the major catalyst for a state inventory of historic bridges. TxDOT initiated its historic bridge study in 1985 in an effort to document Texas' bridges and to provide a comparative evaluation of these resources. The inventory received a major boost in 1987 when the Surface Transportation and Uniform Relocation Act passed, requiring that all states inventory and evaluate their historic bridges.

The TxDOT bridge study has three primary objectives:

1) to inventory the state's highway bridges and evaluate their National Register eligibility, focusing primarily on bridges constructed prior to 1948;

2) to use the bridge inventory findings to facilitate early planning efforts for federal and state funded bridge rehabilitation and replacement projects; and

3) to utilize the information and knowledge gained during the inventory and evaluation process to develop a long term preservation plan for significant bridges in the state.

II. STUDY PARAMETERS

The bridge study, also referred to as the Texas Historic Bridge Inventory, is managed and administered by the Environmental Affairs Division of TxDOT. With more than 40,000 bridges in the state, the inventory posed a formidable and difficult task. One of TxDOT's first priorities was to define the project boundaries and establish an overall plan for the study. Since, as a general rule, bridges must be 50 years old to be eligible for inclusion in the National Register, a cutoff date of 1947 was selected to ensure that the study remained current for several years and to facilitate planning efforts for historic bridges in the future. In general, the inventory was limited to the 6,770 vehicular bridges that met the inventory's 1947 age requirements. However, in an effort to be as inclusive as possible, the researchers also screened the approximately 33,000 post-1947 bridges in the state for unusual features or engineering merits. The evaluation of post-1947 examples revealed 16 noteworthy structures that were subsequently entered into the study group.

The study population consists of bridges that TxDOT regularly inspects as part of the state's Bridge Inspection and Appraisal Program (BRINSAP). Paralleling BRINSAP's definition of bridges, the historic bridge study is restricted to those structures on public roadways that carry vehicles over an obstruction, such as water, highway or railway, with a length of 20 feet or more.[1] This includes bridges on all classes of public roadways, namely U.S. highways, state highways (including loops, spurs, farm-to-market and ranch roads), city streets and county roadways. Publicly owned bridges that fall under the jurisdiction of federal or other state agencies, such as the United States Forest Service or the Texas Parks and Wildlife Department, are outside the scope of the study. The inventory also excludes structures that do not meet the BRINSAP definition of a bridge, such as culverts less than 20 feet in length, tunnels and underpasses. Also omitted from the study are privately owned bridges, such as railroad structures, and bridges in public ownership that have been dismantled or closed to vehicular traffic. In the course of the fieldwork, many of these excluded bridges were photographed and documented; however, they were not brought fully into the study. Because timber stringer bridges require continual replacement of parts, making them difficult to date, and are generally thought to lack engineering significance, they were also excluded from the inventory.

In order to break the project into more manageable work units, TxDOT staff divided the study into three parts: phase one, covering 1,170 metal truss and suspension type bridges; the second phase, including approximately 5,600 concrete, masonry and other metal type structures (not metal trusses); and a third phase, involving approximately 20 movable spans and unusual bridges. TxDOT staff has completed phase one, the inventory and evaluation of the state's metal truss and suspension type bridges, and is currently midway through the second and third phases of the study. Each of these phases is comprised of three components: inventory and data collection; organization and analysis of bridge information; and comparison and evaluation of bridges. Simultaneous to the inventory work, TxDOT staff also initiated an effort to compile general contextual information on bridge and highway developments in the state.

The National Register nomination approach for Texas bridges reflects the general sequence and organization of the study. The initial multiple property submission consists of:

- The general components of a multiple property nomination, including statement of historic contexts, discussion of associated property types, and summary of identification and evaluation methods for all bridges covered under phases I through III of the inventory. The narratives in this nomination encompass bridges on all publicly owned roadways, including federal and state designated highways, city streets and county roads.

- Individual nominations for TxDOT owned bridges determined National Register eligible under Phase I, the inventory of metal truss and suspension type bridges, except for structures scheduled for replacement during calendar years 1995 and 1996.

Following acceptance of the initial multiple property submission, TxDOT plans to complete phases II and III of the study and to prepare additional nominations for these bridge types. This nomination will be updated and revised as necessary to incorporate new findings and research on these bridges. While the general components of the multiple property nomination covers bridges on all types of roadways, the individual nomination forms TxDOT prepared will be limited to bridges on federal and state designated highway routes.

III. INVENTORY AND DATA COLLECTION

The inventory component of the project began with the compilation of a master list of structures generated from TxDOT's bridge files. This computerized inventory contains detailed structural and inspection records on all vehicular structures in the state, and TxDOT maintains it as part of the state's Bridge Inventory, Inspection and Appraisal Program. (BRINSAP). TxDOT bridge historians downloaded the information fields on the 7,000 pre-1948 bridges into a separate database for historic bridges. These computer files contain approximately 50 data fields on each bridge, including information on location, bridge type, structure dimensions, ownership, date of construction, alterations, and structural condition. While these records provided a good starting point for TxDOT's study of historic bridges, the inventory did not include any historical information on structures beyond date of construction and, in many cases, the date field was filled in with a best guess estimate rather than an actual known date. Generally, the information in the database was more complete for bridges on the state highway system than for those on county and city roadways. A representation of the computer screen, showing the data fields entered on each bridge, is shown in Figure H-1.

The compilation of computer data was followed by an intensive field survey and photo-documentation effort. In contrast with most other state inventories that limited their fieldwork to only a select group of bridges, TxDOT's field approach for metal truss and suspension type bridges was inclusive, encompassing all 1,170 metal truss and suspension type bridges in the state. These site visits were conducted during 1985 and 1986; a more selective field survey effort is under way for the remaining bridges in the study. The fieldwork yielded significant information on bridge attributes not covered by BRINSAP, such as information on truss types, bridge connection methods, railings, deck materials, builder plaques and decorative features. In order to provide a visual record of the bridges, the field surveyors performed extensive photographic work on each bridge, recording the superstructure, substructure, deck and railings, as well as any builder plaques or ornamental features. During the course of the surveys, TxDOT field crews discovered more than 100 builder or bridge plaques affixed to trusses or their approaches. Many of these markers are artistically designed and have aesthetic value; in almost all cases, the plaques also provide specific documentation on a bridge's construction, including information on builder names and locations, names of bridge engineers, construction dates and the names of local officials at the time a bridge was completed. All information generated from the fieldwork was incorporated into the historic bridges database and entered on individual bridge inventory cards. A copy of a bridge inventory card is shown in Figure H-2.

TxDOT initiated a more intensive effort to research and document the bridges following the

Figure H-1. Sample database file on a historic bridge.

TEXAS HISTORIC BRIDGE INVENTORY DATABASE FILE

BASIC DATA:
Comment? F Memo? T District: 18 County: Ellis CSS: BOO5-55-001
Location: Rogers Street in Waxahachie Crossing: Waxahachie Creek

BRIDGE TYPE:
Main bridge type: Pratt through Span no: 1 Total no. spans: 1
Second type: NA Span no: NA
Third type: NA Span no: NA

HIGHWAY HISTORY:
TxDOT built? F
Later TxDOT service? F
Original highway name: NA
Comments: NA

NR listed? T
NR eligible? T
Widened? F
Original railings? T

HISTORIC SIGNIFICANCE:
CR A T LEVEL Local
CR B F SAL F
CR C T RTHL F

CONSTRUCTION:
Pin rivet: T
Rivet bolt: F
Welded: F

SPANS:
Deck width: 18
Total bridge length: 190
Main span length: 100

DOCUMENTATION:
Date range: 1
Construction Date: 1889
Builder name: Wrought Iron Bridge Co.

INTEGRITY:
Integrity? T
App. Deck? F
Sufficiency rating: 0.0

FEATURES:
Technological? F
Owner: City
In service: F

CHANGES:
Project? T
CSJ: 0918-22-015
Comments: City Maintenance Resolution

Date: 09 \ 01 \ 90
Effect: No Effect
Status: Bypassed

Figure H-2. Sample bridge inventory card.

SIDE 1

TEXAS HISTORIC BRIDGE INVENTORY CARD

BRIDGE I.D. #: AA01-89-001
DIST.: 13 COUNTY: Fayette

GEOGRAPHICAL DATA
Location: 1.15 Mile East of FM 615

Hwy./Rd./St.Name: CR 189
Feature Crossed: East Navidad River

UTM Coordinates: Zone:
Easting: __ __ __ __ __ __
Northing: __ __ __ __ __ __ __

☐ On-System ☒ Off System ☒ In Use

DESCRIPTION
Number of spans: 1
Total bridge length: 142' # Lanes: 1
Pavement width: 12' Width O.A.: 12'
Structure type code: __ __ __ __

Main span type: Pratt through
Length: 80'
Other span types:
Timber trestle Length: 62'
Length:
Length:
(Use back for additional spans)

HISTORICAL DATA
Construction Date: 1885
☐ Builder plate ☐ Date plate

Builder/Contractor: King Iron Bridge Co.
Local name of bridge: E. Navidad R. Bridge

SIDE 2

TECHNOLOGICAL SIGNIFICANCE

One of earliest metal truss bridges in the state. Bridge is constructed of wrought iron materials.

HISTORICAL SIGNIFICANCE
Bridge lies on old 19th century rural post office route that links rural communities to Schulerberg.

SKETCH OF SPAN ARRANGEMENT (MULTIPLE SPANS ONLY)

☐ LISTED IN NATIONAL REGISTER ☒ DETERMINED ELIGIBLE
FORM COMPLETED BY: A.B.
AFFILIATION:

completion of the fieldwork. In order to facilitate this investigation, all of the bridges were categorized according to their ownership at the time of construction. The first group, limited to structures initially built by the then Texas Highway Department (THD) for use on designated state highways, included approximately 3,300 or 49 percent of the bridges. These structures are generally referred to as highway built bridges. The second group, consisting of bridges originally constructed by county or city governments on local roadways, contained the remaining 3,500 or 51 percent of the structures in the inventory. These spans are commonly referred to as locally built bridges. An initial search of TxDOT records produced an abundance of archival materials on highway built bridges, including original construction plans, drawings and plans of major bridge alterations, bridge construction and completion photographs, project correspondence files, maintenance records and inspection reports. Using these sources, a detailed and complete history covering construction, subsequent alterations, maintenance and highway use was drawn for almost all of the highway built bridges in the inventory. Unlike the research on highway built bridges which was fairly straightforward, the documentation for locally built structures was more problematic, particularly since the records on these structures were scattered throughout public offices found in the state's 254 counties. The quality and consistency of the records also varied greatly from location to location, making it much more difficult to provide complete, reliable documentation for these structures.

Recognizing that a more aggressive research approach was needed for locally owned bridges, TxDOT initiated an intensive documentation program for these bridges during the spring of 1988. In April 1988, TxDOT contracted with Hardy, Heck and Moore, a private historic preservation consulting firm, to research county records for more specific documentation on bridge builders and construction dates. Because economic constraints precluded a records search of all 254 counties, TxDOT staff limited the investigation to a 63-county region in Central and North-Central Texas that contained nearly 80 percent of the metal truss and suspension bridges in the state.[2] The county specific research focused primarily on government documents, including the minutes of county commissioners' meetings, county road minutes, old county contract files and records from city public works departments. The handwritten or typed minutes of county commissioners' meetings were the most reliable source of information on local bridge projects, although in many cases these records provided few details, indicating only the feature crossed, the bridge's approximate location, the project cost, and the contractor's name. Without the road name, the span length or other bridge details, it was often difficult to correlate this information with existing bridges in the study. Fortunately, in some counties, the minute books provided more specific information on bridge projects, including details on local petitions for new bridges, the names and bids of companies attending contract lettings, structure descriptions and locations, progress reports on bridge work, and other details regarding the construction and completion of bridges. While the level and quality of the records varied greatly, overall the research was helpful, providing definite documentation on more than 100 metal truss and suspension bridges in the state. TxDOT staff entered the findings from this research into the individual bridge computer files and inventory cards as it was acquired.

The county historical commissions also played a major role in researching the bridges. The Texas Historical Commission transmitted a letter to all 254 county historical commissions in January 1990, requesting assistance documenting the 1,170 metal truss and suspension bridges in the inventory. The initial request for information generated responses from 63 or 24 percent of the county historical commissions and provided information on more than 100 individual bridges, including many not covered in the initial research contract. The predominant sources for the county research were city and county records, newspaper archives, local histories and oral interviews. Subsequent letters to county historical commissions are planned for other bridge types not covered under this initial correspondence.

TxDOT's documentation efforts also involved in-depth research on bridge builders working in Texas prior to the creation of THD in 1917. A list of Texas bridge agents and fabricators was compiled from city directories and the minutes of county commissioners' court meetings. TxDOT staff conducted a search of company histories and contract records for all fabricators identified on the list. Because the majority of the companies was headquartered in large Midwestern and East Coast cities, such as New York, St. Louis and Chicago, efforts to locate information on these companies required extensive research and correspondence with libraries and archives in other states. While a multitude of secondary source materials were unearthed on bridge companies in general, the research revealed original contract records for only three companies: the Berlin Iron Bridge Company of New Berlin, Connecticut; the Missouri Valley Bridge and Iron Works of Leavenworth, Kansas; and the Austin Bridge Company of Dallas, Texas. The most valuable find was the Austin Bridge Company contract records, housed at the offices of its parent company, Austin Industries, in Dallas. The company's archives contained a complete set of contract records from 1918 to 1948, including project location information, plans and drawings, and project specifications for more than 1,000 individual bridges. A comparison of contract records and existing structures provided conclusive builder and date documentation for 64 bridges. A series of standard truss designs marketed by the company during the early 1900s was also found at Austin Industries. By matching the dimensions and details of the standard truss designs with existing bridges, another 54 bridges were documented as Austin Bridge Company products. The information acquired during this documentation effort was entered into the bridge inventory files.

IV. ORGANIZATION AND ANALYSIS OF BRIDGE INFORMATION

Following the data compilation work, TxDOT staff organized and assimilated information on individual bridges, using documentation materials acquired through the documentation and fieldwork efforts. In order to facilitate this effort, individual bridge packets were assembled for each bridge, containing photographs, inventory cards with descriptive and summary data on the bridge, a print-out sheet from the database and copies of any documentation materials discovered during data collection.

Using the computerized database, researchers also generated comparative data on bridge types, construction dates and construction methods of the bridges in the study group. This analysis provided relative information on:

- the variety and frequency of bridge types in the study group, identifying both rare and common type bridges;
- the use of different bridge types and construction methods;
- the quantity, length of spans, and combination of span types used at different bridge crossings;
- the various bridge fabricators working in Texas during different historical periods and the number of bridges documented to each specific bridge builder; and
- the range and frequency of pier types, railing details, portal configurations and decorative features exhibited by bridges in the state.

This analysis formed the basis of the significance evaluations that followed.

V. CONTEXTUAL STUDY

Paralleling the documentation and data analysis work, TxDOT also conducted a contextual study on Texas bridges. The purpose of this research was to identify national and state trends in bridge engineering and transportation, and to relate these themes to specific bridges in the inventory. During the fall of 1987, TxDOT contracted with Joe King, Texas Tech University, to develop a historical study on the state's transportation system, emphasizing the early development of a road network (1845-1916) and the construction of highway bridges up to World War II. This study culminated with the report, *A Historical Overview of Texas Transportation, Emphasizing Roads and Bridges*, completed in August 1988.

Supplementing the Texas Tech research, TxDOT staff consulted a wide range of other sources to develop a complete contextual framework for the nomination. *America's Highways, 1776-1976: A History of the Federal-Aid Program* by the U.S. Department of Transportation, contributed greatly to an understanding of national transportation trends. Publications and National Register nominations on bridge inventories in other states also provided overview information. Various textbooks and journals were consulted for information on bridge technology. Two of the best sources were Carl Condit's *American Building: Materials and Techniques from the Beginnings of the Colonial Settlements to the Present* and the *Engineering News* journal (primarily articles from 1880 and 1950). Information on road and bridge development in Texas was culled from a wide variety of sources, including state legislation, local newspapers, state and local histories, theses, and magazine and journal articles. Two of the best histories on Texas road and bridge developments were *Building the Lone Star* by T. Lindsay Baker and *Good Roads for Texas: A History of the Texas Highway Department*, a thesis by John D. Huddleston. Texas history books and back issues of the *Texas Almanac* supplied considerable information on the geography of Texas and natural factors that influenced bridge construction in the state.

As previously discussed, many archival records and materials on highway bridge and road construction were discovered in offices and libraries within TxDOT. Some of the most valuable sources included: a compilation of administrative circulars on TxDOT policy; an archival collection of bridge construction and completion photographs; standard plan sheets and books for bridges, railings and substructure; volumes of road and bridge specifications dating to the early 1920s; and a collection of project correspondence files that includes detailed information on highway bridge projects (on microfilm). The most complete source on the history of TxDOT was Texas Highways' *Fifty Year Anniversary, Texas Highway Department, 1917-1967.* TxDOT's old *Biennial Reports*, published in odd years since 1919, include a feature section on bridge progress and projects under construction. Complete with photographs and descriptions of works-in-progress, these articles provided background information on THD bridge practices, including information on legislation affecting bridges, problems with specific bridge projects, and preferences and advances in bridge design and construction. Specific information on many highway department bridge projects was also culled from articles in the *Texas Parade* magazine and the *Texas Highway Bulletin* (forerunner to *Texas Highways* magazine).

VI. ORGANIZATION OF HISTORIC CONTEXT AND PROPERTY TYPE DISCUSSION

The principal themes and trends identified through this research are discussed in the historic context, *Historic Bridges of Texas, 1866-1945*. The date range 1866 to 1945 was selected in order to encompass the full range of extant bridges in Texas. The year 1866 was selected as the beginning point of the context since it marks the initiation of the Waco Suspension Bridge, the earliest example of major bridge construction in the state. A closing date of 1945 was selected to reflect the 50-year rule that generally applies to evaluations of National Register eligibility. The contextual information is organized in a thematic framework with the topics presented in chronological order. This narrative lays out the major chapters in Texas' transportation and bridge-related history, alternating this discussion with a dialogue on national trends in transportation and bridge technology. This format allows the reader to learn about specific road and bridge developments in Texas, and to gain a basic understanding of the larger transportation context.

Although the study incorporates national bridge and transportation aspects, the inventory is generally limited to the state boundaries. In order to be as encompassing as possible, the study includes bridges crossing state lines and international borders. The nominations cover numerous bridges that span the Sabine and Red rivers, state boundary lines between Texas and Louisiana and Texas and Oklahoma, as well as structures over the Rio Grande, the international border separating Texas and the Republic of Mexico.

The property type discussion is organized by bridge type or style, grouping the bridges into three major categories: 1) metal truss and suspension bridges; 2) beams, slabs and girders (concrete and metal); and 3) masonry, concrete and steel arches. Each of these sections breaks the discussion of bridges down further by sub-type and roadway affiliation (local road, or federal or state designated highway).

VII. COMPARISON AND EVALUATION OF BRIDGES

Once the collection of data and contextual study was completed, the focus shifted toward evaluations of historical significance. During 1988, a historic bridges committee, comprised of representatives from TxDOT and THC, assessed the National Register eligibility of metal truss and suspension bridges. The committee members evaluated the historical significance of metal truss and suspension bridges from 1988 to 1989, with evaluations for the remaining bridge types to follow.

In the course of developing an evaluation methodology, the members of the Texas Historic Bridges Committee (THBC) conducted a survey of other states' bridge evaluation systems. The survey revealed a wide variety of approaches, with some states using sophisticated numerical scoring systems, others adopting more qualitative approaches, and several states falling somewhere between the two. The most common methodology used was a numerical scoring system that assigns numerical values to primary bridge attributes—such as rarity of type, age and integrity—and subsequently uses this information to score individual bridges and produce a relative ranking of overall significance. A shortcoming of these numerical ranking systems is that they tend to be heavily weighted toward technological significance; in many cases, a poor or average bridge from a technical standpoint will be scored low, even if the bridge is known to have important historical associations.

The THBC developed a middle-of-the-road approach for the evaluations, relying on a combination of comparative studies, statistical data analysis and qualitative factors to assess Texas bridges. The THBC methodology closely follows National Register criteria, adapting and interpreting the criteria as necessary for application to bridges. A review of the National Register eligibility process revealed that the most relevant criteria for bridges were Criteria A and B, relating to historical associations, and Criterion C, focusing on technological and engineering significance. Paralleling the National Register concept of using individual criteria to assess historical significance, the committee developed two independent processes for the evaluations: one for historical associations and a second for technological and engineering significance. This approach, which places equal emphasis on associative and technical factors, is in direct contrast to some of the other scoring systems for bridges that are heavily weighted toward Criterion C significance.

Recognizing that a more qualitative approach was needed to assess the associative value of the bridges, the committee drafted descriptive guidelines to evaluate significance under National Register Criteria. These parameters were developed largely from knowledge and information gained from the individual bridge documentation and contextual study, and relate directly to local, state and national transportation trends identified through this research. The measures are intended to recognize bridges that meet Criteria A and B. This generally includes bridges that have played a significant role in the transportation or economic development of a community, county or region; that are associated with the development of a state highway system; that are related to significant political, social or economic events at a local, state or federal level; or that are directly associated with people significant in our past. The individual registration requirements for the various bridge types are included in more detail in the property type discussion. The committee evaluated every metal truss and suspension bridge in the inventory using the associative guidelines that were developed as part of the study. From these evaluations, seven of the state owned metal truss bridges and another 75 locally built bridges were determined eligible under Criterion A; no bridges were found to have significance under Criterion B.

Generally, a more quantitative and objective approach was adopted for the evaluations of technological and engineering significance. The THBC's approach to National Register Criterion C evolved from an analysis of the bridge data and was tailored to fit the characteristics and mix of bridges represented in the Texas study group. A preliminary survey of the bridge population revealed that many of the locally built structures were very similar in their characteristics. In all, approximately 1,040, or 95 percent, of the locally built spans conform to one of five different span types: Warren pony, Warren polygonal-chord pony, Pratt pony (hip and half-hip), Pratt through or Parker through. Recognizing that it would be difficult to perform individual evaluations on so many similar-type bridges, the committee employed a sophisticated statistical method called discriminate function analysis to winnow the number of potentially eligible bridges to a more limited and exclusive list. The computerized screening was applied to locally built structures only; it was not used to evaluate state built or rare structures.

Implementing discriminate function analysis was a multiple step process. First, THBC selected a random sample of the bridges, amounting to approximately 20 percent of the common type structures. The committee then performed a preliminary technological and engineering assessment on the sample bridges, classifying them into one of three categories: potentially eligible (coded T for "True"), not eligible (coded F for "False"), or marginally eligible (coded M for "Marginal"). These initial evaluations were extremely subjective, relying on a review of the comparative bridge data, as well as on the members' professional judgement and overall knowledge about bridges in the state. The statistical application analyzed the database information on the sample bridges and isolated the attributes that were most critical to the committee's classification decisions. The key traits identified were span length, number of spans, level of documentation, age and presence of decorative elements and unusual features. The computerized analysis assigned weights to the various attributes, simulating the decision-making process for the sample bridges as closely as possible, and then replicated the classification process for the remaining common type bridges in the study. This process was tested and fine-tuned by the committee several times until it achieved a high degree of accuracy and reliability. Based on this screening, approximately two-thirds of the bridges were coded as not eligible, and were eliminated from consideration under Criterion C. The bridges categorized as either potentially eligible or marginally eligible were forwarded to the committee for further review. This sophisticated, computerized application was advantageous since it utilized bridge information that was already stored on the computer. As a result, the information was easily manipulated and the screening of bridges was accomplished in a very consistent and expedient manner. A more detailed account of the discriminant function analysis is provided in TxDOT's May 1989 report, *Texas Historic Bridge Inventory*.

Relying primarily on the findings of the discriminant function analysis, the committee implemented a final evaluation phase for common type metal truss bridges. As part of this process, each of the better examples identified under the statistical screening process was individually reviewed. The bridges were assessed based on their significance as an early or representative example of a type or method of construction, as an exceptional or rare survivor of an important engineer or fabricator, and as a design exhibiting unusual technology or exceptional artistic merits. From these reviews, the exceptional bridges were clearly distinguished from the lesser examples, with the more marginal structures deleted from the eligible pool. Several other noteworthy bridges which had been inadvertently cut during the initial screening were also added back in, resulting in a final list for common type structures with Criterion C significance.

Because the 66 THD designed metal truss bridges in the state have similar features and share a common design and construction history, the committee developed separate guidelines for evaluating the technological and engineering significance of these structures. To facilitate this process, the bridges were grouped according to their standard design number—when documented—or alternately by bridge type and length. A study of surviving highway built trusses revealed 44 metal truss bridges conforming to 22 different standard designs. Each of the 44 structures was categorized according to its standard design, and compared with like bridges. While the remaining 22 structures did not conform to THD standard designs, many of these bridges were very similar to the standard design structures. The non-standard bridges were categorized according to bridge type and length, with the more unusual bridges evaluated separately. These side-by-side comparisons were very informative and were used to:

- identify rare survivors of standard designs;
- recognize representative and outstanding examples of standard designs when multiple bridges representing these designs are surviving;
- identify unusual bridges that do not conform to standard plans; and
- recognize highway built bridges that exhibit significant trends, variations or innovations in THD design or construction.

Using these guidelines, the committee assessed the Criterion C significance of all 66 highway department designed metal truss bridges in the study, including 41 trusses located on federal and state designated highway routes and another 25 displaced highway structures currently serving on county or city roadways.

The reviews of THD designed highway bridges also incorporated other bridge components, namely the substructure, approach spans and railings. Ancillary structures, such as relief bridges, were also considered if they were part of the overall design solution for a drainage area. These secondary components usually conform to standard designs, although occasionally they were specially designed to fit the condition or setting of a specific site. These features often add to the complexity of a bridge's design and construction, significantly enhancing its technological and engineering significance. Railings and piers designed to achieve a specific design aesthetic can also contribute to a bridge's overall importance under Criterion C. A more detailed account of the evaluation process used for highway built bridges is in TxDOT's March 1994 report titled *Summary of Evaluations of Highway Department designed Metal Truss Bridges for National Register Eligibility Under Criterion (c).*

The remaining 70, or six percent, of the examples in the metal truss and suspension bridge study were categorized as rare structural types, warranting a more individualized and hands-on evaluation approach. For the purposes of this study, a rare structural type is defined as a patented or recognized bridge type that is represented by 10 or fewer spans in the state. Twelve rare type bridges were identified under Phase I of the inventory, including: bowstring, camelback, camelback with subdivided panels, double-intersection Pratt (or Whipple), double-intersection Warren, K-Truss, lenticular, Pennsylvania, suspension, truss leg bedstead, modified Waddell "A" truss and Warren polygonal-chord through. While most of the rare structural types are on county or city roads, several of these spans serve as part of federal or state designated highway routes. Because these 70 spans are considered to possess a high degree of significance based solely on their rarity of type, these bridges were determined eligible under National Register Criterion C in all cases except when a serious integrity problem was detected.

The integrity guidelines developed by the committee corresponded closely with the seven aspects of integrity required for National Register properties. Using the National Register requirements for integrity, the study adopted three general measures to guide integrity decision-making. These include integrity of location; integrity of design, materials and workmanship; and integrity of feeling, setting and association. The integrity guidelines were derived largely from the committee's firsthand knowledge and familiarity with the bridges in the study. Using the photo-documentation, plans, and information compiled on individual structures, the committee developed a series of questions to use in evaluating integrity. These reviews relied heavily on comparative analyses that related bridges to other structures of the same type. All elements of a bridge were considered in the evaluations, including main span(s), approaches, substructure, deck, railings and decorative elements. Not all bridges were required to meet the same standard or level of integrity. Losses in integrity could be compensated, to some extent, by rarity or technological significance. A more rigid approach to integrity was adopted for highway designed bridges currently in local ownership. Generally, these structures must be readily identifiable as highway department design and construction, and maintain integrity of setting, feeling and association as a highway bridge to retain integrity. Changes in vegetation and topography, widening of approach roadways, and alterations or removal of defining features can compromise integrity in these cases.

The inventory findings were synthesized into several reports, and are also reflected in the bridge database files maintained by TxDOT historians.

1. Each state department of transportation is required to implement a Bridge Inspection and Appraisal Program (BRINSAP) in accordance with the Federal Highway Administration's *National Bridge Inspection Standards* (23 CFR 650 C). The BRINSAP definition of a bridge, which is also used for the purposes of this study, is as follows: "a structure, including supports erected over a depression or obstruction, such as water, highway, or railway, and having a track or passageway for carrying traffic or other moving loads, and having an opening measured along the center of the roadway of more than 20 feet between undercopings of abutments or spring lines of arches, or extreme ends of openings for multiple boxes".

2. The 63-county region is generally bound by the Red River to the north, Corsicana to the east, Coleman to the west and Luling to the south.

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