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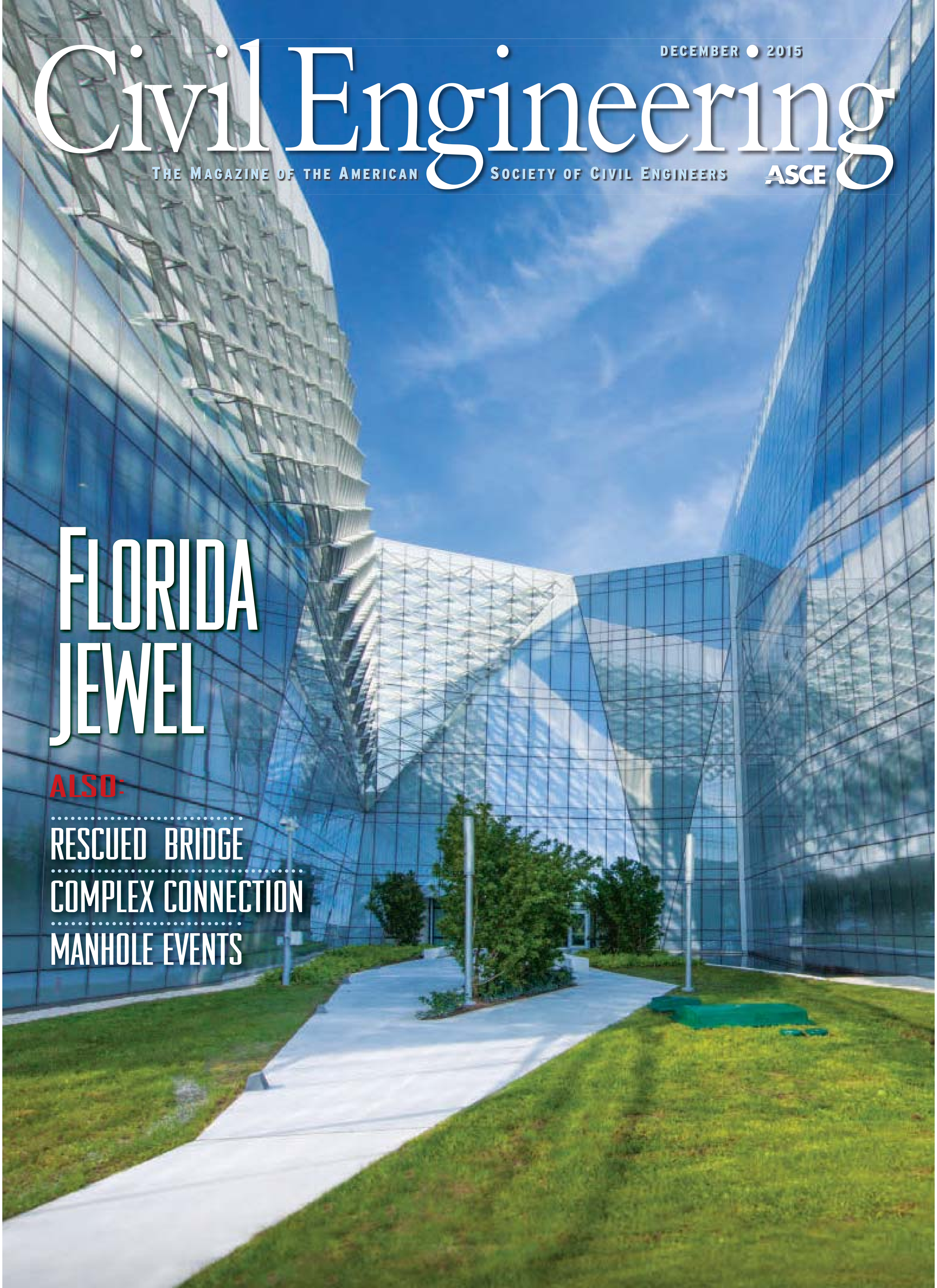


FLORIDA JEWEL

ALSO:

- RESCUED BRIDGE
- COMPLEX CONNECTION
- MANHOLE EVENTS

Lawrence Looks Ahead

For the first phase of a new, 6 mi long water transmission main, the City of Lawrence, Kansas, needed to construct a 36 in. diameter pipeline that would pass beneath a river, a major levee, two rail lines, and a park. By selecting fusible polyvinyl chloride pipe and using horizontal directional drilling to install nearly two-thirds of the initial part of the line, which is 1.25 mi long, the project team overcame several challenges, including those related to corrosion, site access, and maintenance.

By Jeff Heidrick, P.E., M.ASCE, Philip Ciesielski, P.E., Michael O'Connell, P.E., M.ASCE, and Shawn Wilson, P.E.

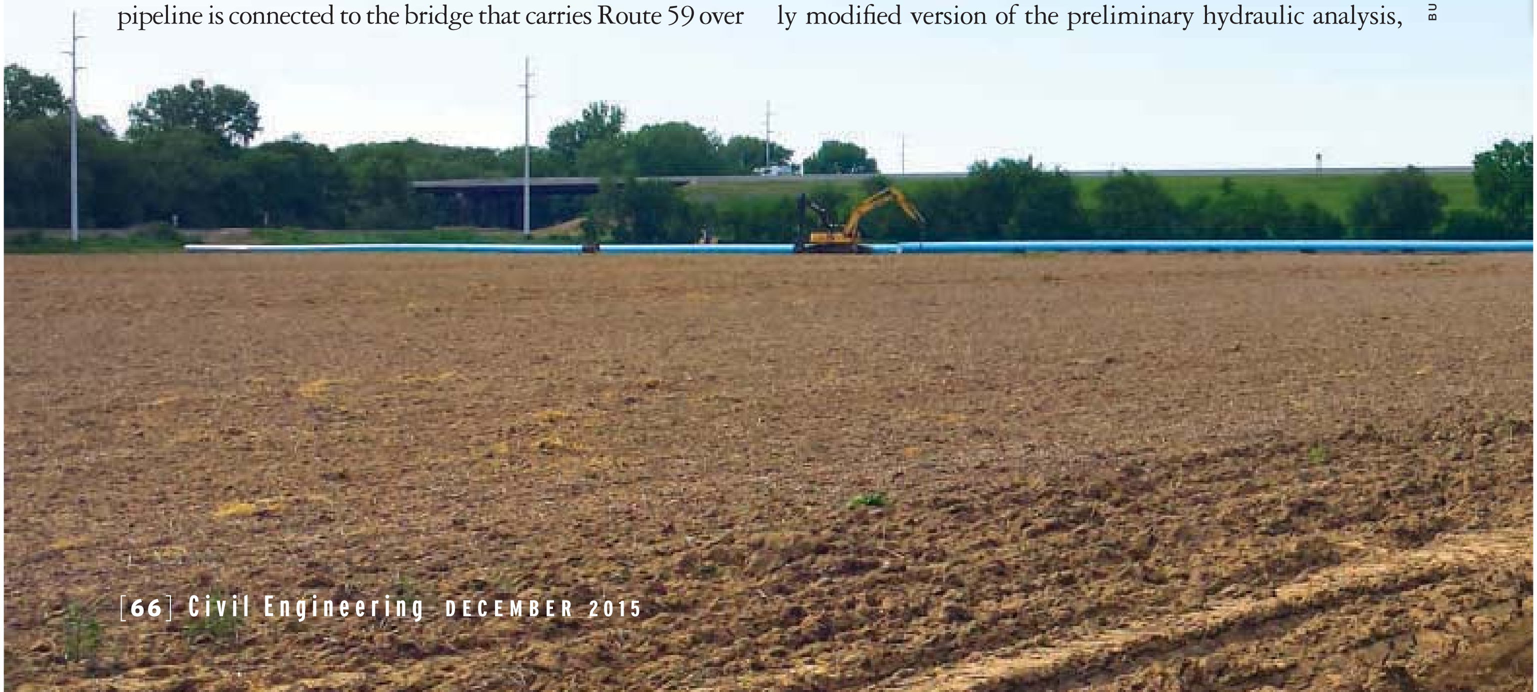
LOCATED APPROXIMATELY 25 mi west of the Kansas City metropolitan area, Lawrence has a population of approximately 97,000, including the students at the University of Kansas. The city currently treats and delivers water to customers within the city and provides treated water wholesale to five rural water districts, as well as to the University of Kansas and Baldwin City. Two of the wholesale water customers have a long-term interest in receiving additional water, and one of them provides water to two other municipalities. Both of the connections with these wholesale customers are located in the southeastern part of Lawrence.

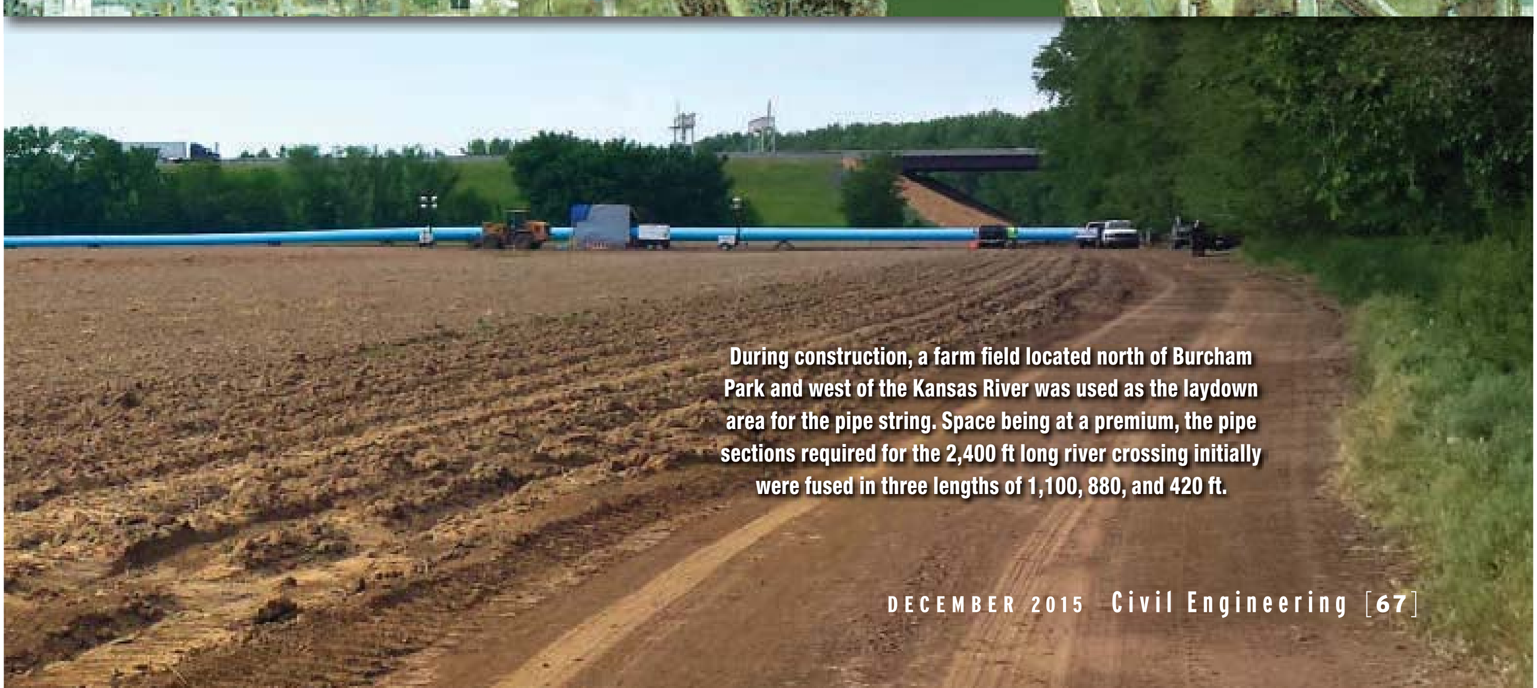
The city understood that, in addition to supplying potable water to an increasing customer base, having a redundant means of delivering water to North Lawrence would make water supply more reliable. (North Lawrence is the name given to Lawrence's northeastern section, which is separated from the rest of the city by the Kansas River.) Prior to the installation of the new, 36 in. diameter pipeline, the city supplied potable water to North Lawrence through a single transmission main 16 in. in diameter crossing the Kansas River. An aerial crossing, this section of the pipeline is connected to the bridge that carries Route 59 over the river. In recent years sections of the aerial crossing had developed pinhole leaks, creating maintenance issues and concerns about the reliability of the supply to North Lawrence. Although repairs were made to the deteriorated sections, the problems convinced the city's water supply planners of the need to add redundancy to the water delivery system.

In March 2007 an engineering consulting team led by Burns & McDonnell, of Kansas City, Missouri, completed a preliminary hydraulic analysis and transmission main routing study for the city. On the basis of its recommendations, the city decided to phase the construction of a new water transmission main, the first phase to include the Kansas River crossing. Subsequent phases would extend the transmission main to the southeastern part of Lawrence. When complete, the nearly 6 mi long water transmission main would connect to the Kaw River Water Treatment Plant, supply water to North Lawrence, and increase service to the southeastern part of the city to meet projected water demands beyond 2020.

In late 2007 the city selected Burns & McDonnell to design the initial, 1.25 mi long transmission main that would connect the Kaw River plant to North Lawrence. Using a slightly modified version of the preliminary hydraulic analysis,

BURNS & MCDONNELL ENGINEERING COMPANY, INC., *BELOW;* CITY OF LAWRENCE, KANSAS, *OPPOSITE*





During construction, a farm field located north of Burcham Park and west of the Kansas River was used as the laydown area for the pipe string. Space being at a premium, the pipe sections required for the 2,400 ft long river crossing initially were fused in three lengths of 1,100, 880, and 420 ft.

the design team determined the size that would be required for the transmission main. In addition to accounting for the significant development expected to occur in southeastern Lawrence, the modeling considered the water demands beyond 2020 expected to come from the city's wholesale customers. The hydraulic analysis indicated that, from the connection at the Kaw River plant to the final connection in southeastern Lawrence, the transmission main should have a diameter of 36 in.

With the size determined for the entire transmission main route, an analysis was carried out to determine the necessary pressure rating for the first phase of the project. The main factors considered here were the performance curves of the high-service pumps at the Kaw River plant, surges that might be generated within the system, and possible elevation changes in the initial, 1.25 mi segment of the transmission main. Based on the results of the analysis, Burns & McDonnell recommended a pressure rating of at least 200 psi.

The design of the transmission main also had to account for the possible presence of highly corrosive soils in the area. The city's water mains have experienced the deleterious effects of highly corrosive soils in the past. Therefore, preliminary design work included a geotechnical investigation of the project area. The investigation indicated that corrosive soil would be encountered in at least one area. It also noted that groundwater was present at the proposed trench depths at various locations. On the basis of these findings and from a realization that there would be limited access to the installed pipe, the design team concluded that a cathodic protection system would be required if a metallic pipe material were used.

Determining the transmission main alignment also presented numerous challenges, particularly where it crosses the Kansas River to reach North Lawrence. Besides the river itself, the transmission main would have to cross a U.S. Army Corps of Engineers levee. The river and the levee crossing both required authorization and permits from the Corps.

The alignment also crossed two railroad rights-of-way. It crossed a BNSF Railway line near the location at which the new transmission main would connect to the Kaw River plant, and it crossed a Union Pacific line close to the levee in North Lawrence. Each of the crossings would require a permit from the railroad company, and both companies required that crossings by water lines be installed within a steel casing pipe and meet the standards set by the American Railway Engineering and Maintenance-of-Way Association, of Lanham, Maryland. Those standards require that the steel casing extend across the entire width of the railroad right-of-way.

Before passing beneath the BNSF line, the water transmission main alignment would run through Burcham Park, a popular destination that offers walking trails and playground equipment and affords access to the river. The park also includes a boathouse, which is home to the University of Kansas rowing team. In addition to requiring that access to the park and boathouse be maintained throughout construction, the city stipulated that the project team coordinate its efforts with a contractor working separately nearby on the city's river intake and that it maintain access for that contractor.

The city further required that the project not disturb numerous trees on the park grounds and the surrounding areas. Any untoward effects on two wetland areas and a stream in the park also had to be minimized. For these reasons, the project team investigated alternatives to opencut installation methods in an effort to reduce the number of construction zones that would be needed.

Before finalizing the methods of construction, the design team needed to determine the pipe material that would be used. In evaluating the possible materials, particular attention was given to the following:

- Design life;
- Corrosion resistance;
- Availability in a diameter of 36 in.;
- Feasibility of installation;
- Availability of required pressure rating.

Four pipe materials were evaluated:

1) Steel pipe;
2) Ductile iron pipe;
3) High-density polyethylene (HDPE);
4) Fusible polyvinyl chloride pipe (FPVCP).

The potential design life of each of the pipe materials evaluated is reported to be in the range of 100 years. However, the actual useful life of the transmission main will depend on several factors, including the site conditions, the quality of installation, pressure ratings and associated wall thicknesses, and installation depths. Each of the pipe materials was available in a 36 in. diameter and at the required 200 psi pressure rating. In 2008, when the initial pipe material evaluation was performed, FPVCP and HDPE having a 200 psi pressure rating were not yet available from the manufacturer. However, 36 in. diameter FPVCP and HDPE with this pressure rating became available after the pipe material evaluation and preliminary design phase but before the final design was completed in 2013.

The two deciding factors in the pipe material evaluation were the corrosion resistance of the material and the feasibility of construction. The four pipe materials evaluated can be divided into two main categories: metallic and nonmetallic. Given that some of the city's water mains have experienced corrosion and that the geotechnical evaluation revealed an area of corrosive soil along the proposed alignment, metallic pipes would require a cathodic protection system. As an additional layer of corrosion protection, specialized coatings on the metallic pipe might also have been required.

The corrosion resistance of the nonmetallic pipe materials under consideration was well documented. Consequently, a cathodic protection system would not be required if a nonmetallic pipe material was selected. However, if metallic fittings were used with the nonmetallic pipe system, the fittings would require corrosion protection in the form of polyethylene encasement.

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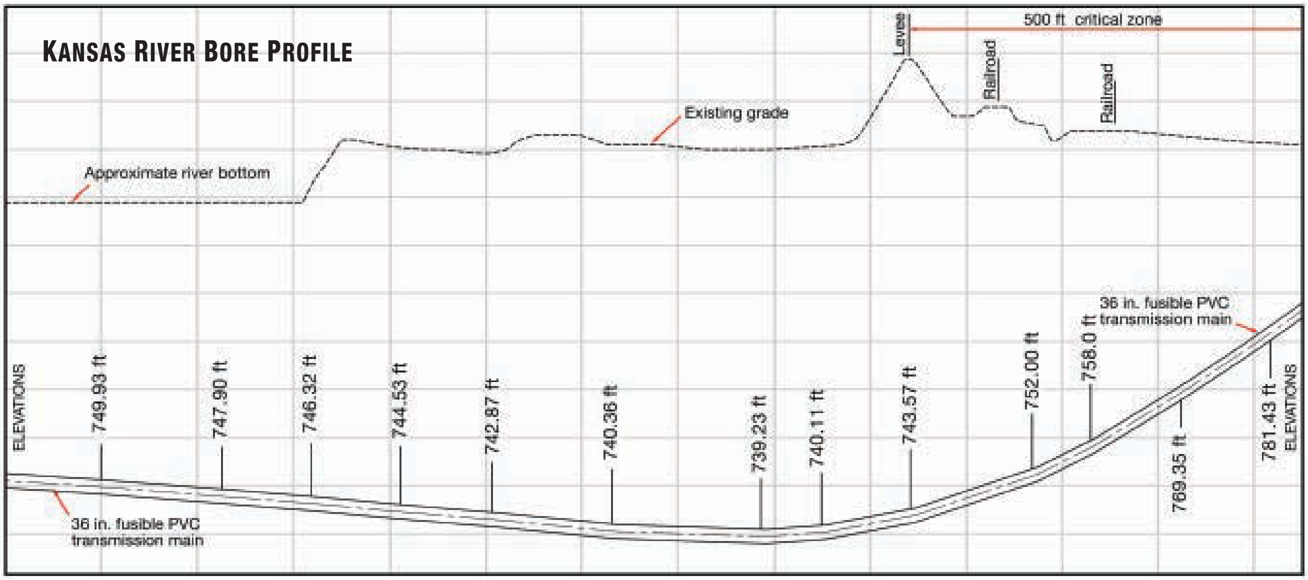

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In evaluating the various pipe materials with respect to their installation feasibility, the design team considered that the river crossing would most likely be made by horizontal directional drilling (HDD). Because the pipe would be below the river, future maintenance of the pipeline was a concern as well. Both these considerations led to the conclusion that a jointless system should be used for this crossing to facilitate HDD installation and minimize maintenance needs. Depending on the required pipe thickness, the bore hole for jointless pipe is typically smaller than for a ball-and-socket pipe system or a restrained joint system of the bell-and-spigot type. A jointless piping system will not fail as a result of deteriorated gaskets or loose joints. For these reasons, the installation feasibility assessment eliminated ductile iron pipe from further consideration.

The installation feasibility analysis also evaluated the suitability of HDD methods for installing HDPE pipe for the river crossing portion of the alignment. To this end, the design team evaluated the suitability of HDPE using the design guidelines found in the ASTM International standard ASTM F1962-05 (*Standard Guide for Use of Maxi-Horizontal Directional Drilling for Placement of Polyethylene Pipe or Conduit under Obstacles, Including River Crossings*). The analysis of critical buckling pressure during pullback revealed that HDPE had a factor of safety that was below the standard minimum recommended value. The results thus eliminated HDPE pipe from consideration at the river crossing.

Finally, the installation feasibility analysis evaluated the suitability of HDD methods for installing FPVCP for the river crossing. The design guidelines found in the standard ASTM F1962-05 were used in conjunction with the guidelines set forth in the ASCE manual *Pipeline Design for Installation by Horizontal Directional Drilling* (Reston, Virginia: ASCE Press, 2005) to evaluate the suitability of 200 psi FPVCP. Installation forces and long-term operational loads were considered, and pipe deflection, critical buckling pressure, and anticipated and allowable tensile stress were evaluated. The analysis results indicated that FPVCP would be an acceptable pipe material for the river crossing.

At this stage of the pipe material evaluation, the city expressed a preference for using one type of pipe material throughout the project. FPVCP and steel pipe were still candidates at this point. Corrosion concerns and the resulting corrosion protection systems that would need to be installed and maintained with steel pipe were considered. Because much of the HDD to be conducted for the river crossing would pass through solid rock, a major concern with steel pipe centered on whether the coating system on the outside would hold up during the installation process. This doubt ruled out steel pipe. Because it met all the necessary requirements for the project, FPVCP was selected and included in the bid for the transmission main installation project.

The design team evaluated several installation methods for this project, including opencut, jacking and boring with a casing pipe, and HDD. The method selected would depend on the requirements for each of the particular project areas along the alignment. Opencut installation methods were originally proposed wherever they would be feasible. Installing a pipeline across a Corps of Engineers levee typically involves opencut methods across the top of the levee and repair of the levee after installation. Because railroads typically require jacking and boring in order to install steel casings beneath the rail lines, this method was originally planned for the sections of the alignment that passed beneath the BNSF and Union Pacific lines. HDD would then be used for installation under the river. However, once design progressed, these initial selections were revised.

Installing the steel casing pipe for the transmission main within the railroad right-of-way by jacking and boring required excavating a bore pit and a receiving pit on the two sides of the rail line. As part of this process, the boring machine and the casing pipe would be placed within the boring pit, and the casing pipe would be "jacked" into place by hydraulic jacks. A cutting head on a rotating helical auger would be used to remove the spoil from within the casing pipe. Once the casing pipe was in place, the carrier pipe would be installed. As noted previously, railroads typically require that the steel casing pipe be installed across the

The 1.25 mi long pipeline will connect the Kaw River Water Treatment Plant, in Lawrence, Kansas, to an existing 12 in. diameter water main in the part of the city known as North Lawrence.

CITY OF LAWRENCE, KANSAS

entire width of the railroad right-of-way. Although this installation method worked for the BNSF crossing, near the Kaw River plant, lack of space precluded its use at the Union Pacific crossing, which, as mentioned above, is on the east side of the river near the levee.

As shown in the figure on page 67, the levee and the Union Pacific railroad are adjacent to each other. The 30 ft distance between the levee centerline and the west edge of the Union Pacific right-of-way was insufficient for a bore pit. Although it would have been possible to excavate the bore pit on the east side of the railroad right-of-way, there was insufficient space between the levee and the railroad for the required receiving pit. An alternative installation method was therefore considered.

Because of the need to cross the levee and the railroad, a radius of curvature was used for the layout and design that exceeded the minimum allowable bend radius for FPVCP given in the standard ASTM F1962-05 and the ASCE manual *Pipeline Design for Installation by Horizontal Directional Drilling*. For this reason, the design team used a longer bore profile curve, which reduced the pull stresses during installation. The actual radius of curvature for the bore was 3,600 ft, the minimum being 798 ft for 36 in. diameter FPVCP. Data obtained from nearby soil borings indicated that a layer of solid rock existed below the river. The HDD was designed so that the bore profile would be within this layer of rock to reduce the risk of the bore hole collapsing. Given the location of the rock layer, the radius of curvature of the proposed transmission main, and the limits on the allowable entry and exit bore angles for a bore of this size, it was not feasible to bring the bore up in the area between the river and the levee.

Exceptions were negotiated for the opencut levee crossing requirement and the railroad casing requirement. The Corps of Engineers allows HDD beneath its levees if certain requirements are met. For example, if soil borings of the project site are provided, then the directional drill must penetrate the substratum at least 300 ft from the levee centerline on the land side and may not exit closer than 300 ft on the side facing the river. For a conservative approach, the bore profile was designed to maintain a 500 ft offset from the directional drill penetration to the centerline of the levee, as shown in the figure on page 69. The design also called for the bore to pass through the rock layer under the levee crossing, which is approximately 70 ft below the top of the levee.

After the Corps approved the proposed bore, the project team needed to obtain an exception to the casing pipe requirement from Union Pacific. Based on the geotechnical reports and the fact that the bore would remain within the rock layer as it passed beneath the rail line, the railroad agreed to an exception. In effect, the rock layer here is acting as a solid casing pipe below the railroad, and the potential for settlement is low because the crossing is nearly 70 ft beneath the railroad.

After resolving the issues with the river and railroad crossings, the design team turned its attention to the area in and around Burcham Park. As previously mentioned, the city required that access to the park and the boathouse be maintained at all times and that tree removal be minimized. The other concern with the crossing in the park involved the number of utilities in the area. The city has raw water wells and a river intake in the area, along with water distribution lines and other utility lines. Existing utility crossings required that the transmission main have a depth of at least 12 ft in this area. However, an open excavation of this depth near the park entrance was not feasible. To address this problem and minimize tree removal within the park, HDD installation was designed for this area. Using HDD in the park also eliminated an opencut pipe installation through a stream that runs east to west along the north side of the park.

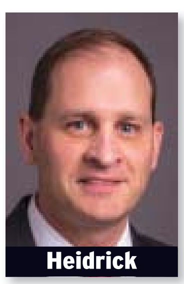
The Kansas River crossing presented higher risks than did other sections of the project. Approximately 2,400 linear ft, the river crossing was the first bore to be completed. The pipe-reaming process for this HDD bore took nearly 56 days. The pilot hole exited the ground approximately 10 ft east and 3 ft north of the design point.

Garney Construction, of Kansas City, Missouri, served as the general contractor for the project. A subcontractor to Garney Construction—Environmental Crossings, Inc., of Conroe, Texas—served as the drilling contractor. Environmental Crossings began the HDD process with a 10 in. diameter pilot hole. Once the pilot hole was through, a 26 in. diameter back ream was used. Next, the drilling contractor used a 38 in. diameter back ream. However, because of low productivity with this ream, the contractor switched to a 32 in. diameter version before returning to the 38 in. diameter ream. Subsequently, the contractor used a 42 in. diameter back ream, followed by a final ream of 48 in.

During construction a farm field located north of Burcham Park and west of the Kansas River was to be used as the laydown area for the pipe string. However, this field is bounded by the BNSF rail line to the west and Interstate 70 to the north, limiting the space available for laying down pipe. Therefore, the pipe sections required for the 2,400 ft river crossing were initially fused in three lengths: 1,100, 880, and 420 ft. Two intermediate fusions were required during the pullback process. With the 48 in. diameter bore hole open, the pipe pullback process began. Preliminary pullback activities started at 6 AM, and the actual pullback began approximately 3 hours later. Each intermediate fusion process took approximately 2 hours. After 16.5 hours, the last section of pipe was successfully pulled into place at 1:30 AM the following day. At the time of installation, the Kansas River crossing was the world's longest installation of 36 in. diameter, 200 psi FPVCP by means of HDD.

After the Kansas River was crossed, two subsequent HDD sections through Burcham Park, one 1,400 linear ft and the other 600 linear ft, were installed without issue. Approximately a third of the pipeline for the project was installed by means of opencut construction in the farm field. Essentially, this portion of the project linked the HDD sections beneath the river and Burcham Park. Construction work for the entire first phase of the transmission main was completed in January 2015, and water deliveries to North Lawrence through the new pipeline began that same month.

The City of Lawrence recognized the need for a redundant water feed to North Lawrence and additional water supplies for the southeastern part of the city to meet future demand. The $7-million first phase of this transmission main project provided the redundant water feed to North Lawrence, and the transmission main has a connection point available for the project's next phase. According to an integrated water utility plan prepared for the city by Burns & McDonnell in 2012, the future phases of the project will probably not need to be developed until 2020 at the earliest. **CE**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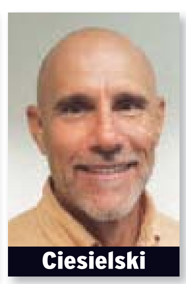
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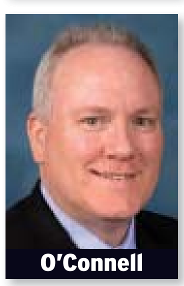
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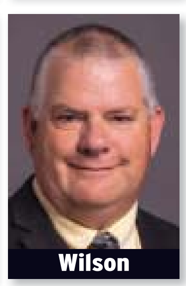
Wilson

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PROJECT CREDITS **Owner:** City of Lawrence, Kansas **Lead consulting engineer:** Burns & McDonnell, Kansas City, Missouri **General contractor:** Garney Construction, Kansas City, Missouri **Drilling contractor:** Environmental Crossings, Inc., Conroe, Texas