City of Leavenworth

Leavenworth County, Kansas

2nd & Chestnut Stone Arch Replacement Study
Tributary to the Missouri River

Hydrologic and Hydraulic Report

January 7, 2020

Leavenworth Project # 2019-895

Prepared for:

Paul Kramer – City Manager
City of Leavenworth, Kansas
100 North 5th Street
Leavenworth, KS 66048
913-680-2600 phone

Prepared by:

Wilson & Company, Inc., Engineers & Architects
800 East 101st Terrace, Suite 200
Kansas City, MO 64131
816-701-3100 phone

CHARLES DANIEL LOUGHMAN
LICENSED
24810
1/9/2020
KANSAS
PROFESSIONAL ENGINEER

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

Introduction

This report addresses the existing conditions and recommended improvements for the City of Leavenworth's storm sewer system from the open channel on Olive Street between 3rd and 4th Street to the east of 2nd Street and Chestnut Street intersection (Figure 1). The main enclosed stone arch system is approximately 880 linear feet of stone/brick arches of varying diameter with one section of corrugated metal pipe (CMP). Five lateral systems join the main channel within the project extents.

The existing enclosed arch system presents many opportunities for improvement since the existing enclosed stone arch system decreases in diameter from upstream to downstream at various points. Access to the system is limited due to the downstream sections of the pipes being up to 30 feet deep. Three sinkholes have developed along the main system alignment with the most recent sinkhole forming in Spring 2019 and rapidly increasing in size. Downstream of the sinkholes, a portion of the main system is located under the foundation of a multifamily unit at 217 Chestnut Street. Additionally, the ground level elevations is approximately the same at the upstream and downstream ends of the project, which limits the overland flow path and requires the system to be sized to convey larger storm events.

A field visit was conducted on July 16, 2019 by Wilson & Company staff to evaluate the current open channel, inlet structure, and storm sewer system condition as well as identify any potential design conflicts with utilities and property lines.

Figure 1: Location Map

Existing Conditions

The land use for the watershed is predominantly single family residential with a small number of commercial businesses and churches. The 73 acre drainage area is collected in the storm sewer system on Spruce Street and discharges through a 42″ RCP to the open channel on the vacant lot at Olive Street between 3rd Street and 4th Street. The open channel is currently overgrown with trees and vegetation along the slopes with the channel bottom being rock lined and full of construction debris and trash (Figure 2). The overgrown vegetation on the banks and debris throughout the channel bottom appear to indicate that the channel is not experiencing high velocity flow during storm events. The open channel enters the 72″ stone arch storm sewer system (Figure 3) at the northeast corner of the lot.

Figure 2: Open Channel on Olive St. between 3rd St. and 4th St., Looking Southwest

Figure 3: 72" Stone Arch Inlet in Open Channel, Looking Northeast

At the northwest corner of the intersection of Olive Street and 3rd Street, a lateral system of four inlets, south on 3rd Street, enters the main system at a junction box on the intersection's northwest corner. A sinkhole has formed around the sidewalk west of the curb inlet on the northwest corner and approximately in line with the main channel alignment (Figure 4). Downstream of the junction, the stone arch diameter decreases to 60″ and continues northeast across 3rd Street. On the east side of 3rd Street, a lateral system of two inlets from the intersection of 3rd Street and Olive Street join the main system and continue northeast under the vacant lot.

Figure 4: Sinkhole Under Sidewalk, Looking East

A field inlet connects directly to the main system on the south side of the alleyway between 2nd Street and 3rd Street. The slope of the main channel increases downstream of this inlet from 0.5% to 2%. Approximately 50 feet northeast of the field inlet, two sinkholes have developed behind the driveways and parking lots for the multifamily units at 217 Chestnut Street and 219 Chestnut Street. The first sinkhole began forming around 2016 due to deterioration in the crown of the CMP and has slowly increased in size. The second sinkhole formed just downstream of the initial sinkhole in May 2019 due to a full CMP collapse and failure. The downstream end of the second sinkhole is completely filled with soil and no water is able to flow to the rest of the system. The second sinkhole is already at least twice as large as the first sinkhole and growing rapidly. The second sinkhole is undermining the multifamily unit parking lot as slabs of concrete have fallen into the hole. The area inlet for this sump location is currently at the edge of the sinkhole with the vertical pipe visible. Figures 5-8 show the condition and extents of the sinkholes in April 2019, July 2019, and September 2019.

Downstream of the sinkholes, the main system increases to a 66" stone arch. The stone arch continues northeast underneath the corner of the multifamily unit at 217 Chestnut Street and under Chestnut Street. Two curb inlets along Chestnut Street and one inlet for the southern parking lot of the Justice Center enter the main channel at the junction box near the 2nd Street and Chestnut Street intersection. A lateral system along 2nd Street consisting of inlets for 2nd Street and the north parking lot of the Justice Center connect to the main system. The main channel continues under 2nd Street and discharges into the open channel on the northeast corner of the intersection of 2nd Street and Chestnut Street. The entire watershed at the stone arch outlet is 125 acres with the contributing drainage area being predominantly single family residential and commercial businesses.

Figure 5: Sinkhole, April 2019, Looking Southwest

Figure 6: Sinkhole July 2019, Looking Southwest

Figure 7: Sinkhole, July 2019, Looking Northeast

Figure 8: Sinkhole, September 2019, Looking Northeast

Hydrologic Analysis

HEC-HMS was utilized to calculate the peak discharges throughout the project area. Basin drainage areas were determined using LiDAR data obtained from DASC for Leavenworth County and are shown in Figure 9. Curve numbers for each drainage area were determined from KCAPWA Standard Specification & Design Criteria Section 5600 using land use descriptions obtained from parcel data. The time of concentration for each sub-basin was calculated using USDA NRCS TR-55 methodology. Table 1 lists the hydrologic conditions and parameters for each sub-basin. Rainfall data was obtained using NOAA Atlas 14 for the study area. Based on these parameters, HEC-HMS determined the peak discharges in the watershed for the 10-year, 25-year, 50-year, and 100-year rainfall events. Table 2 shows the peak discharge of each sub-basin as well as the total discharge for each storm event. Detailed hydrologic parameter calculations can be found in Appendix B.

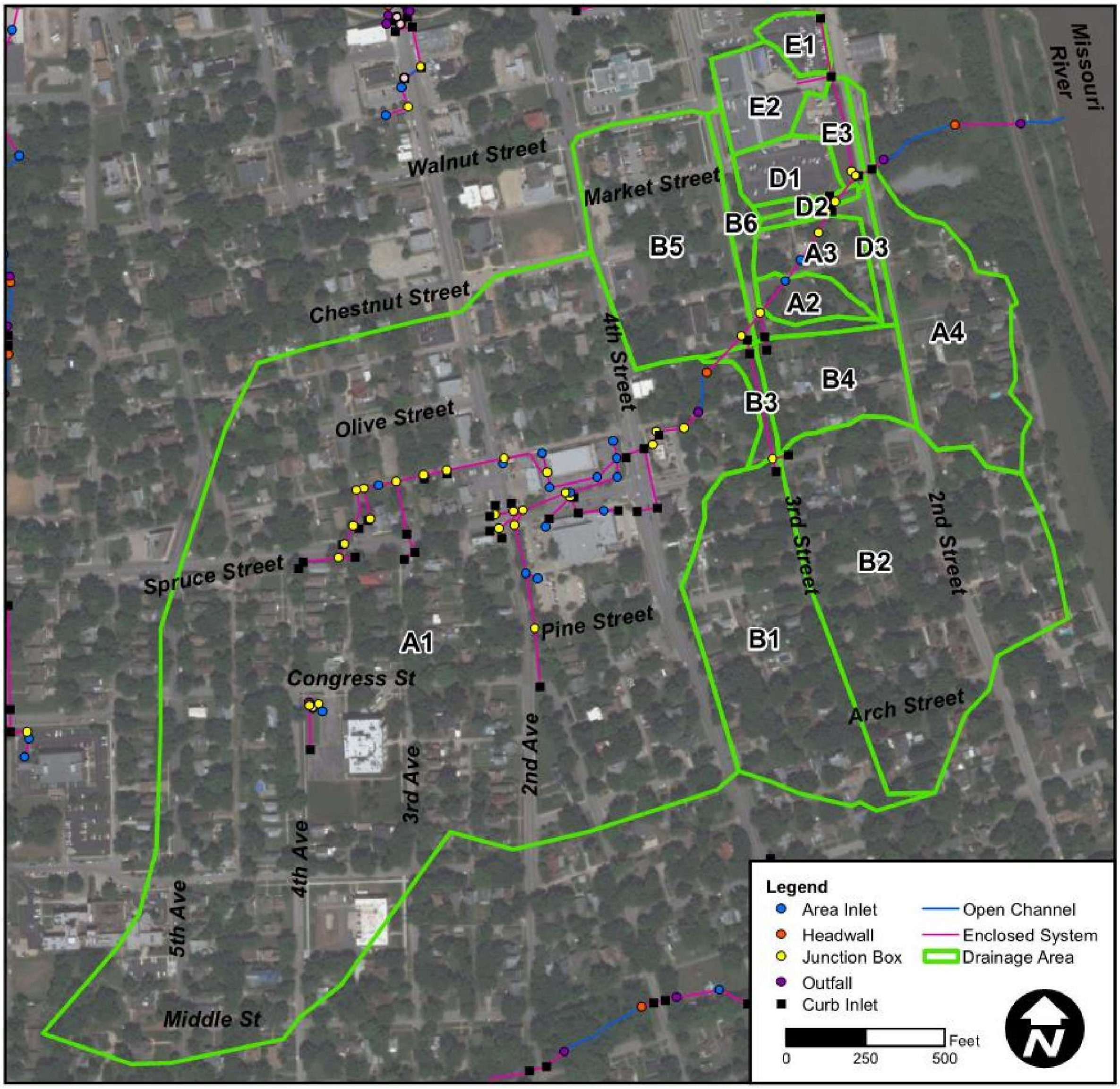


Figure 9: Drainage Area and Hydrologic Routing Map

Table 1: Hydrologic Conditions and Parameters for Each Sub-Basin

Basin	Hydrologic Parameters Used for Peak Discharge Calculations				
	Area (ac.)	$T_{concentration}$ (min.)	Curve Number	$L_{channel}$ (ft.)	$S_{average}$ (ft./ft.)
A1	73	25	88	3,972	0.032
A2	0.9	13	83	357	0.056
A3	1.6	14	83	335	0.072
A4	6	16	87	1,217	0.053
B1	12	12	86	1,219	0.039
B2	13	11	94	1,645	0.030
B3	0.6	7	89	338	0.036
B4	3	6	87	707	0.051
B5	7	12	89	1,014	0.041
B6	1.5	6	89	539	0.026
C1	0.7	6	94	335	0.072
D1	1	6	98	284	0.028
D2	0.3	13	90	226	0.035
E1	0.7	6	98	117	0.045
E2	2	6	98	461	0.030
E3	1	6	90	382	0.021

Table 2: Existing Conditions HEC-HMS Hydrologic Results for Each Sub-Basin and Per Routing

Basin	Existing Conditions Peak Discharge (cfs)				
	Area (ac.)	10-yr	25-yr	50-yr	100-yr
A1	73	163.0	209.1	245.8	283.5
A2	0.9	2.5	3.3	4.0	4.6
A3	1.6	4.3	5.6	6.7	7.8
A4	6	17.5	22.4	26.3	30.4
B1	12	28.6	36.8	43.4	50.3
B2	13	27.8	36.8	44.2	51.8
B3	0.6	2.0	2.5	2.9	3.4
B4	7	13.5	17.2	20.2	23.3
B5	3	23.8	30.2	35.3	40.5
B6	1.5	7.0	8.9	10.3	11.9
C1	0.7	3.5	4.3	5.0	5.7
D1	0.3	7.0	8.5	9.7	10.9
D2	1	0.9	1.1	1.3	5.9
E1	0.7	3.8	4.6	5.3	1.5
E2	2	9.5	11.6	13.2	14.9
E3	1	4.3	5.4	6.3	7.2
Entire Watershed	124.3	270.5	348.3	410.6	474.8

Hydraulic Analysis

Existing Condition Analysis

The enclosed main channel pipe system consists primarily of a stone arch with varying diameters from 72" to 48". Two sinkholes have developed and exposed an existing 48" CMP section at 217 Chestnut Street. The first 380 linear feet of the main system has a slope of 0.5%, while the remaining 500 linear feet has a slope of 2%. The existing system is analyzed to determine if the existing network mets capacity for the 100-year storm event. The system is analyzed to convey the 100-year flow because there is no clear 100-year overflow path. Roadway elevations at the upstream and downstream ends of the project are equal and confirm the lack of overflow path. Despite the absence of a clear overflow path, there is no known flooding of structures within the study area. City staff indicate that existing infrastructure is undersized at the intersections of 3rd Street and Olive Street as well as 2nd Street and Chestnut Street.

The main channel pipes were analyzed using Hydraflow Storm Sewers, which uses standard step methods to compute the hydraulic profile and capacity of the system. The hydraulic conditions and parameters for each pipe along the main channel as well as the capacity and expected 10-year and 100-year peak flows are shown in Table 3. All of the pipes with the exception of the 72" stone arch downstream of the open channel on Olive Street were found to be undersized for the 100-year storm event.

Figure 10: Existing Main System Hydraulic Routing Map

Table 3: Hydraulic Conditions and Parameters for Each Pipe

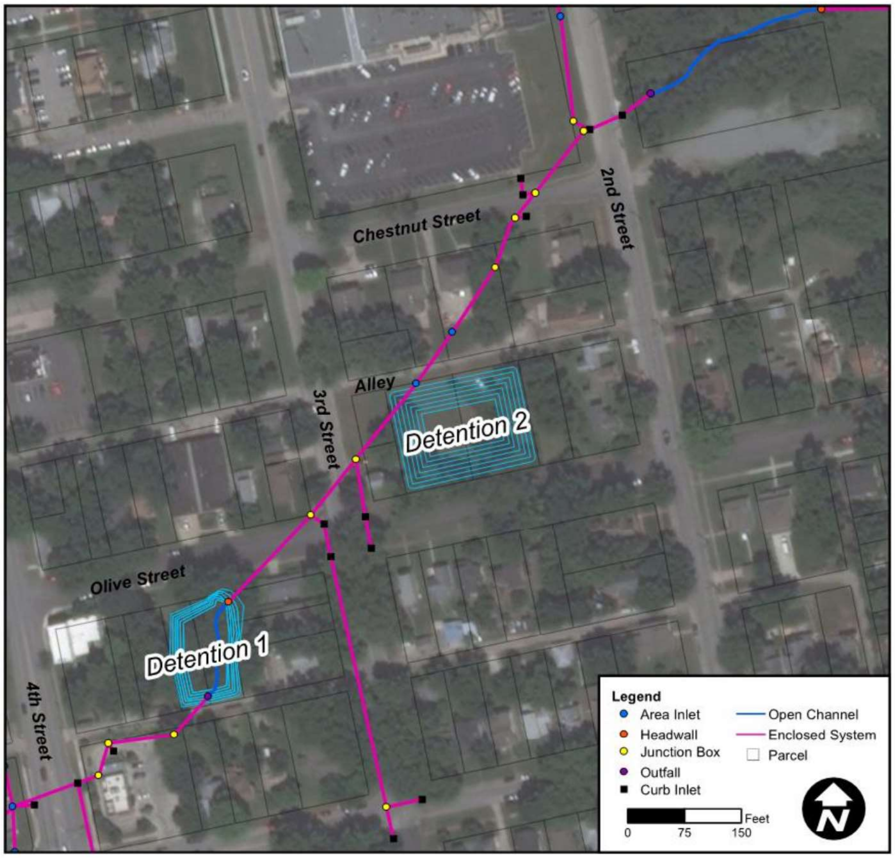
Pipe	Existing Size & Material	Main Channel Existing Conditions					
		Manning's n	Length (ft.)	Slope (ft./ft.)	Capacity (cfs)	Q: 10-yr (cfs)	Q: 100-yr (cfs)
A1	72″ Stone Arch	0.017	158	0.0051	230	185	291
A2	60″ Stone Arch	0.017	94	0.0045	133	260	408
A3	60″ Stone Arch	0.017	128	0.0049	140	268	422
A4	60″ Stone Arch	0.017	83	0.022	296	264	416
A5	48″ CMP	0.025	103	0.022	111	266	419
A6	66″ Stone Arch	0.017	71	0.022	321	263	414
A7	66″ Stone Arch	0.017	42	0.022	382	263	414
A8	66″ Stone Arch	0.017	103	0.022	384	267	420
A9	66″ Stone Arch	0.017	8	0.022	385	264	415
A10	66″ Stone Arch	0.017	47	0.022	379	275	432
A11	66″ Stone Arch	0.017	47	0.022	380	287	452

Proposed Design Alternatives

Despite no historic reports of upstream flooding, the existing system is significantly undersized for the 100-year event throughout large portions of the system. The lack of historical upstream flooding could be due to localized areas of detention in the upstream system that cannot easily be mapped or quantified. Proposed alternatives are required to reduce the event peak discharges or increase the system capacity. The follow alternatives were analyzed for their effectiveness in achieving either scenario.

Upstream Detention Analysis

Two locations were analyzed to determine if a detention could significantly reduce the main system's peak discharge. Detention 1 is located at the existing open channel on Olive Street. This location was considered since the lot is currently a deep stormwater channel and the property is owned by the city. Detention 2 is located northeast of the 3rd Street and Olive Street intersection and would detain the lateral system on 3rd Street. This property is owned by the city and is currently undeveloped with a small number of mature trees. Proposed detention locations are shown in Figure 11.



HEC-HMS was used to analyze the reservoir routing impacts at both locations. The proposed detention outlet structures were gradually reduced to determine if additional reservoir storage is available at each location. The proposed solution at the Detention 1 location includes expansion of the open channel into the adjacent Leavenworth County property. The detention pond outlet is the upstream headwall for the main system improvements. A comparison between the existing and proposed reservoir discharges and storage capacities are shown in Table 5. Detailed HEC-HMS reservoir routing parameters and inputs are shown in Appendix D.

Table 4: HEC-HMS Hydrologic Results for Proposed Detention 1

Peak Flows for Existing and Proposed Reservoir at Detention 1							
Storm	Peak Inflow (cfs)	Peak Discharge (cfs)		Peak Storage (ac.-ft.)		Peak Elevation (ft.)**	
		Existing	Proposed*	Existing	Proposed*	Existing	Proposed*
10-yr	163.0	162.9	157.9	0.0	0.9	780.0	783.3
25-yr	209.1	208.8	198.6	0.1	1.2	781.0	784.9
50-yr	245.8	245.4	229.4	0.1	1.6	781.9	786.4
100-yr	283.5	282.0	282.0	0.2	2.0	782.9	788.0

*Proposed Discharges were determined with a 60" outlet pipe
** Top of Reservoir Elevation is 790 feet

Detention 2 would detain the discharges from the lateral system along 3rd Street, which would require horizontal realignment of the lateral system. The reservoir's 36" outlet connects to the main system to the north at the alleyway inlet location. Table 6 shows the hydrologic results of the proposed reservoir at this location.

Table 5: HEC-HMS Hydrologic Results for Proposed Detention 2

Peak Flows for Proposed* Reservoir at Detention 2				
Storm	Peak Inflow (cfs)	Peak Discharge (cfs)	Peak Storage (ac.-ft.)	Peak Elevation (ft.)**
10-yr	87.9	68.5	1.2	784.1
25-yr	113.9	81.9	1.8	785.8
50-yr	134.8	91.0	2.3	787.1
100-yr	156.4	99.5	3.1	788.5

*Proposed Discharges were determined with a 36" outlet pipe
** Top of Reservoir Elevation is 790 feet

Water Quality Analysis

The two locations analyzed for detention above were also identified as potential locations for water quality. An extended dry detention basin (EDDB) was evaluated at both locations. EDDBs capture and hold the water quality storm for 40 hours to allow pollutants and sediment to settle. Detention pond outlet pipes are set above the water quality storm pond elevation to allow any storm that is larger than the water quality storm to pass onto the rest of the system. The EDDB is graded to not have any standing water. Both locations were analyzed using guidance from the MARC/APWA Manual of Best Management Practices for Stormwater Quality (BMP Manual) and USDA Urban Hydrology for Small Watersheds TR-55 runoff methodology. Water quality infrastructure details can be found in Appendix F.

Detention 1 provides an opportunity for a water quality feature due to the large upstream drainage area and existing lot conditions. The BMP Manual recommends that the water quality storm be drained over a period of 40 hours to maximize settlement of particles. However, due to the available pond size and the runoff volume, this location would require a water depth of over 12 feet. This is unrealistic for both site conditions as well as water quality benefits. Basin depths should be 2 feet to 5 feet deep to maximize water quality benefits. The EDDB at this location could be designed to capture less than the water quality storm and drain this volume over a period of 40 hours through a special perforated riser design, per BMP Manual recommendations. Based on the proposed site conditions, a water quality storm with 0.67 inches of rainfall would result in a 5 foot depth within the water quality basin.

Detention 2 is larger than the upstream proposed water quality feature location, and has less contributing drainage area. The depth of the water for the full water quality storm in this location would be 7.75 feet. To maximize water quality benefits, this basin would be designed for a maximum depth of 5 feet and would drain over a 40 hour period through a special perforated riser design. Based on the proposed site conditions, a water quality storm with 1.02 inches of rainfall would result in a 5 feet of depth within the water quality basin.

Lateral System Analysis

There are four lateral enclosed pipe systems that connect to the main channel. The existing and proposed systems were analyzed using Hydraflow Storm Sewers program to determine the existing capacity and proposed pipe sizes for the lateral systems. The majority of the systems were found to be undersized for the 10-year design storm discharge. A map of the existing pipes are shown below in Figure 12. The hydraulic conditions and parameters for each pipe in the lateral systems as well as the capacity and expected 10-year and 100-year peak flows are shown in Table 8. GIS data was used to determine the slopes of the pipes. Due to the depth of the main system, sections of the lateral system appear to have very steep slopes to accommodate connection with the main system. Hydraflow Program Results are shown in Appendix F.

.

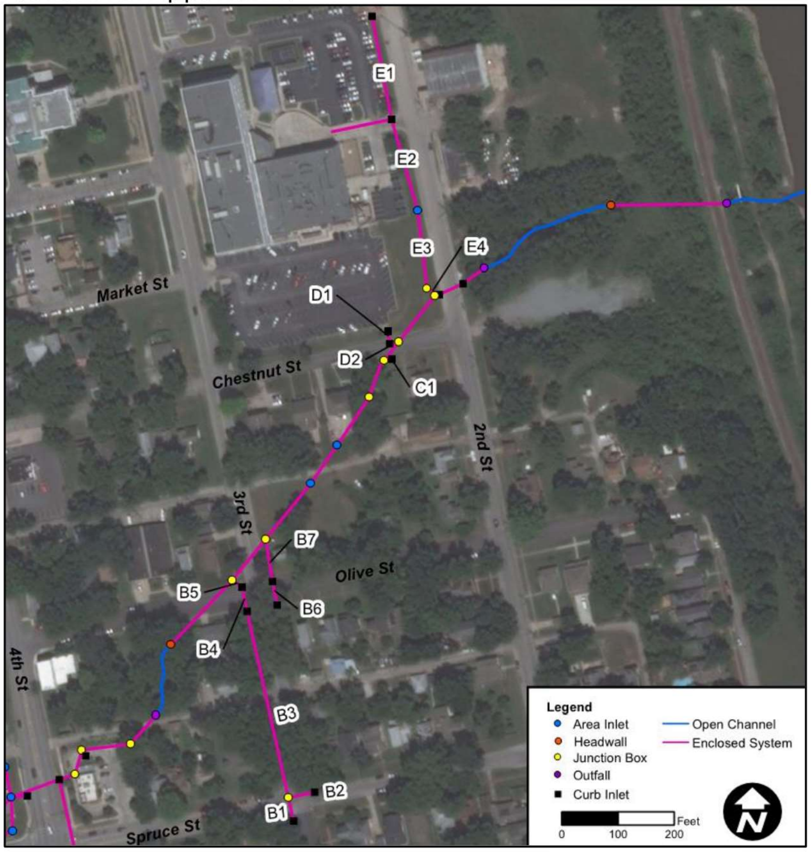


Figure 62: Existing Lateral System Hydraulic Routing Map

Table 6: Existing Lateral System Hydraulic Conditions and Parameters

Pipe	Existing Size & Material	Lateral Channels Existing Conditions					
		Manning's n	Length (ft.)	Slope (ft./ft.)	Capacity	Q - 10-yr (cfs)	Q - 100-yr (cfs)
B1	18" VCP	0.013	42	0.008	10	32	50
B2	15" VCP	0.013	48	0.009	6	36	56
B3	18" VCP	0.013	339	0.032	19	66	104
B4	18" VCP	0.013	44	0.016	13	68	106
B5	18" VCP	0.013	21	0.39	66	89	140
B6	15" VCP	0.013	42	0.029	11	15	24
B7	18" VCP	0.013	70	0.13	38	23	37
C1	12" VCP	0.013	15	0.25	18	4	7
D1	24" CMP	0.025	22	0.25	58	9	14
D2	24" CMP	0.025	17	0.25	59	7	12
E1	15" RCP	0.013	186	0.016	8	5	8
E2	18" RCP	0.013	170	0.022	16	17	26
E3	18" RCP	0.013	139	0.022	16	16	26
E4	18" RCP	0.013	24	0.022	16	16	26

Additional inlets and pipes could be added to the upstream end of the lateral watersheds to increase the capture rate, limit the amount of water that is conveyed in the curb and gutter, and decrease the distance to an inlet. Additional inlets are proposed along 3rd Street south of Olive Street and at the intersection of 3rd Street and Chestnut Street. A map of the proposed lateral addition is shown in Figure 13 below with proposed extensions shown in green.

Figure 73: Proposed Lateral System Upgrade Locations Map

Table 7: Proposed Lateral System Upgrades with Alignment Change

Lateral System			
		Pipe Size (in.)	
Pipe	Length (ft.)	Existing	Proposed
BA*	*450*	n/a	18
BB*	*62*	n/a	24
BC*	*337*	n/a	30
B1	*33*	18	36
B2	*48*	15	24
B3	*42*	18	36
B4	*44*	18	42
B5	*21*	18	n/a
B6	*42*	15	24
B7	*75*	18	n/a
BD*	*53*	n/a	42
BE*	*98*	n/a	42
C1	*15*	12	15
DA*	*340*	n/a	24
D1	*22*	24	15
D2	*17*	24	24
E1	*186*	15	15
E2	*170*	18	24
E3	*139*	18	24
E4	*24*	18	24
Outlet		n/a	36

*Proposed pipe for alignment change or system extension

Horizontal Alignment Analysis

There are two proposed options for horizontal realignment of the main system. Both involve realigning the main system to avoid the sinkhole area and remove the main channel from underneath the foundation of the multifamily unit at 217 Chestnut Street. Both horizontal realignment options are shown in Figure 14 below.

Horizontal Option 1 consists of rerouting the main system north along 3rd Street and then turning to the east along the north curb of Chestnut Street before rejoining the original alignment. This option would completely avoid the sinkhole area, keep the system within the road right-of-way, and improve access for future maintenance needs.

Horizontal Option 2 consists of following the existing alignment to the alleyway south of the sinkhole and then routing the system east on the north side of the alleyway to avoid the power poles. The main channel would then turn to the north and follow the 217 Chestnut east property line to the existing inlet on Chestnut Street. This option reduces the overall realignment length and still avoids the sinkhole area.

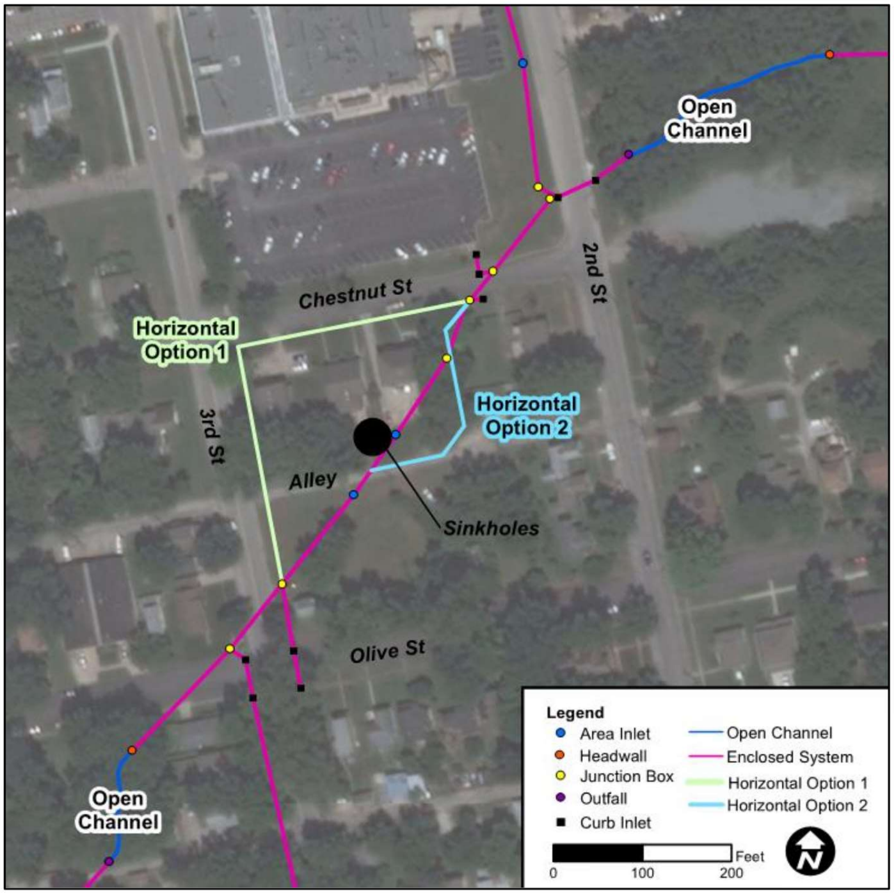


Figure 84: Proposed Horizontal Alignment Locations Map

Vertical Alignment Analysis

The existing main system can be divided into two different sections based on the slope of the pipe. The west 380 feet has an average slope of 0.5% and the east 500 feet are at a grade of 2%. Due to this change in slope, the pipe section under Chestnut Street is over 30 feet deep. Three different vertical alignment options were analyzed to determine which would provide the best solution.

- Vertical Option 1 consists of sizing the pipes for the existing grades and inverts. This option also include the addition of Detention 2 as discussed previously.
- Vertical Option 2 consists of maintaining the inverts at the upstream and downstream end of the system and installing the proposed system at a 1.2% slope throughout the entire length.
- Vertical Option 3 consists of raising the outlet elevation and maintaining the 0.5% slope throughout the entire length of the main system. This would decrease the depth of the pipes at the downstream end of the channel from 30 feet deep to 20 feet deep.

Table 10 shows the proposed pipe sizes required to convey the 100-year storm for each vertical alignment option. Figure 13 includes a map of the proposed pipes. Horizontal Alignment Option 2 was used to develop the proposed pipe sizes.

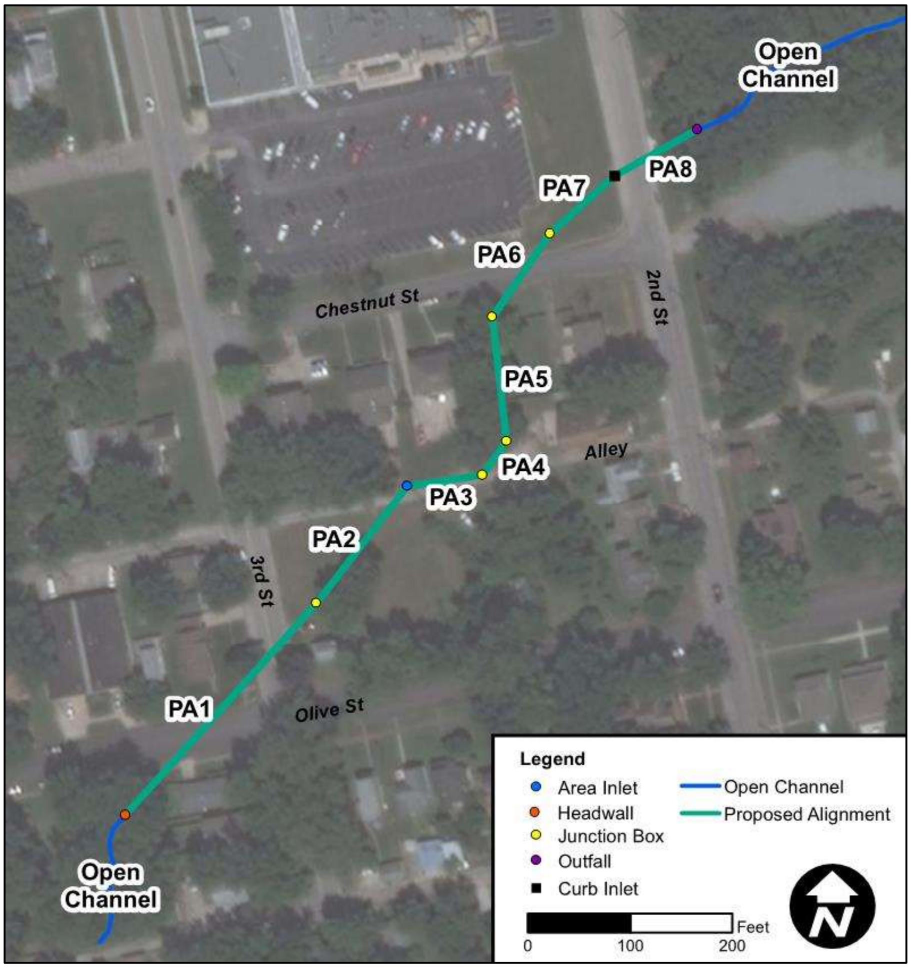


Figure 95: Proposed Main System Alignment

Table 8: Proposed Main System Upgrades for Each Alignment Change

Main Channel Proposed Pipe Sizing – Upstream to Downstream					
		Pipe Size (in.)			
Pipe	Length (ft.)	Option 1 – Existing Inverts	Option 2 – 1.2% Slope	Option 3- 0.5% Slope	Option 4 – 1.2% Slope + Detention 2
PA1	*294*	72	72	72	72
PA2	*140*	78	72	78	72
PA3	*76*	78	72	78	72
PA4	*31*	78	72	78	72
PA5	*105*	78	72	84	72
PA6	*95*	78	72	84	72
PA7	*88*	78	78	90	72
PA8	*96*	78	78	90	78

Open Channel Modification

The existing open channels at the upstream and downstream ends of the project provide opportunity to add aesthetic value and function for the community. Both open channels currently have steep slopes overgrown with vegetation.

The open channel on Olive Street between 3rd Street and 4th Street is approximately 130 ft long. Water enters the open channel through a 42" RCP from the south, travels through the open channel, and enters the enclosed system at the 72" stone arch to the north. This open channel does not provide meaningful detention for the 100-year storm event, even with expansion to include the neighboring lot. The enclosed system could be connected through this section with RCP and the open channel filled in over the new pipe. A bioswale over the new enclosed system would contain and direct any water currently captured by the open channel. Any excess water would enter the enclosed system through a specially designed inlet at the downstream end of the bioswale. This would allow the lot to be repurposed into usable green space by the community and would provide a permanent solution to controlling the overgrown vegetation.

The open channel at 2nd Street and Chestnut Street is approximately 250 feet long. Water enters the open channel through a 66" stone arch and exits the open channel through an enclosed 60" stone arch before discharging into the Kansas River. There is currently a scour hole at the upstream end of the open channel, but there does not appear to be erosion continuing along the channel. The proposed new pipe described in previous sections would discharge into the open channel at14 ft/s. An energy dissipation structure would be designed to reduce erosion at the upstream end of the open channel. Additionally, this location could be cleared of the majority of overgrowth to provide aesthetic value to the community.

Conclusion and Recommendations

The existing main system enclosed storm sewer within the project extents begins at the open channel/lot on Olive Street between 3rd Street and 4th Street. The drainage area to the open channel includes an upstream enclosed system which enters the open lot through a 42" RCP. The open channel currently has no reservoir routing capacity. The downstream enclosed system consists of stone arch pipes of varying diameters which decreases as runoff flows downstream. The system outlets to the open channel east of the Chestnut Street and 2nd Street intersection. Three visible sinkholes have formed along the main system alignment, the largest of which formed in May 2019 behind the multifamily units at 217 Chestnut Street and 219 Chestnut Street. A concept plan set is included Appendix G to graphically represent the recommended solution described below.

Although this area has not historically experienced flooding, the initial proposed rehabilitation solution of lining the pipes was found to be untenable due to the calculated peak discharges through the system. The lack of historical upstream flooding could be due to localized areas of detention in the upstream system that cannot easily be mapped or quantified. The following alternatives are recommended for design:

- **Horizontal Alignment Option 2:** For the main system alignment, this solution follows the system to maintain its existing alignment to the alleyway south of the sinkhole and then routes the system east on the north side of the alleyway to avoid overhead power poles. The main channel would then turn to the north and follow the 217 Chestnut east property line to the existing inlet on Chestnut Street. This option avoids the largest sinkhole area, removes the system from underneath the foundation of 217 Chestnut St., and maintains existing drainage patterns. Additionally, this option allows for easier phasing of the entire project area into three nearly equally sized projects.

- **Vertical Alignment Option 1:** This option maintains the existing slope and pipe inverts throughout the main system. Maintaining the existing slope provides the most optimal storm sewer sizing options and a more straight-forward approach to phase the entire project. Additionally, this options can be paired easily with Detention 2.

- **Detention 1 and Water Quality:** Detention 1at the open lot on Olive Street between 3rd Street and 4th Street did not have the capacity to detain a significant amount of discharge during the 100-year storm event. Detention 1 does have the potential to develop a water quality feature consisting of an Extended Dry Detention Basin that would discharge over a period of 40 hours.

- **Detention 2 and Water Quality:** Detention 2 is proposed on the city-owned property south of the alleyway between 2nd Street and 3rd Street. A detention pond in this location causes a 36% reduction in the peak flow for the 100-year storm from the lateral system along 3rd Street. The proposed detention basin could also be constructed to include an EDDB that would discharge the water quality design storm over a period of 40 hours, providing settlement of solids and improving the quality of water leaving the basin.

- **Lateral Realignment and Extension:** To increase the capture rate and decrease the amount of water flowing through the street curb and gutters, extension to the upstream lateral watersheds is proposed. Additional inlets and storm sewer are recommended along 3rd Street south of Olive Street and at the intersection of 3rd Street and Chestnut Street. The alignment of these lateral extensions may need to be located in the street to avoid excessive neighborhood disturbance to trees and landscaping. Additionally, existing inlets should be replaced due to deterioration and to prevent clogging from the aging inlets.

  After discussions with the City, an alternative to the proposed lateral realignment and extension could be to realign the upstream lateral system and increase capacity at the inlets, with no extension. The realignment will allow water to be directed to the detention basin and decrease the peak flow through the main system.

- **Open Channel Modification:** The open channels at the both upstream and downstream end of the enclosed system are recommended to be cleared of a significant amount of overgrown vegetation to provide aesthetic benefits to the community.

- **Energy Dissipation Structure:** Due to the velocity of water that exists the enclosed system into the open channel at 2nd Street and Olive Street, an energy dissipation structure is necessary to protect the channel from erosion. This structure will eliminate channel erosion that is currently occurring as well as ensure that no erosion continues downstream.

- **Sidewalk Improvements:** During the field visit, several sidewalks in the area were observed to be overgrown or missing due to lack of maintenance. In an effort to provide ADA accessible infrastructure, it is recommended that several sidewalks and ramps be replaced in the area while construction is being conducted. This sidewalk enhancement could also help gain local resident support for the project.

- **Construction Phasing:** Based on the previously mentioned recommendations, this project can be constructed in three separate phases.

  - **Phase 1:** This phase consists of realignment of the main system away from the sinkholes and foundation of the multifamily unit at 217 Chestnut Street. This phase will include installation of pipes between the field inlet south of the alleyway to the curb inlet on Chestnut Street. This phase includes using flowable fill to stabilize the pipes being abandoned, relocating the driveway, repairing the parking lot at 217 Chestnut Street, installing a new area inlet for the sump location, and filling the sinkhole area. Additionally, Detention 2 should be constructed at this time to ensure that the downstream pipes are not undersized for the 100-year storm event. The lateral system that connects to Detention 2 should be considered during this phase, but can be installed during one of the following phases.

  - **Phase 2:** The downstream portion of this system will be increased to the appropriate size for the 100-year storm event and the lateral system will be extended to 3rd Street and Chestnut Street intersection. Sidewalks improvements along Chestnut Street should be considered as part of this phase.

  - **Phase 3:** This phase will include replacement of the upstream portion of the system from the open channel on Olive Street to the work completed in Phase 1. The lateral system south along 3rd Street will also be included in this phase with all appropriate sidewalk improvements.

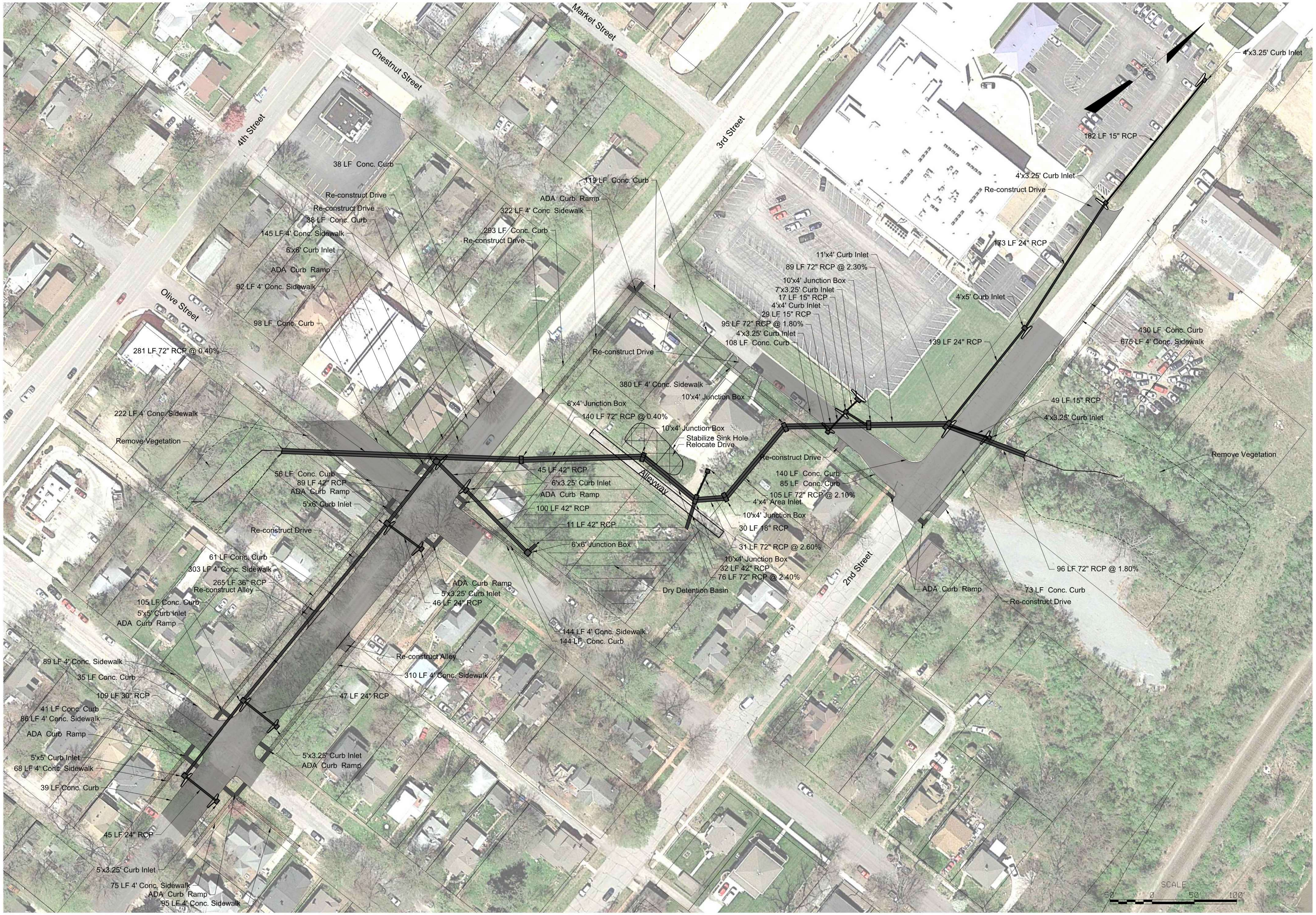
Cost Estimate

Table 9: Recommended Solution Cost Estimate

ITEM	DESCRIPTION	QTY	UNIT	UNIT PRICE	TOTAL PRICE
1	Mobilization	1	LS	$75,000.00	$75,000
2	Contractor Furnished Staking	1	LS	$20,000.00	$20,000
3	Demolition and Site Preparation	1	LS	$35,000.00	$35,000
4	Clearing and Grubbing	1	LS	$25,000.00	$25,000
5	Temporary Traffic Control	1	LS	$10,000.00	$10,000
6	Curb	1,903	LF	$25.00	$47,575
7	4' Sidewalk	1,361	SY	$40.00	$54,440
8	Sidewalk Ramp	20	EA	$1,000.00	$20,000
9	Headwall	2	EA	$10,000.00	$20,000
10	Alleyway Improvement	250	SY	$35.00	$8,750
11	Street Reconstruction	6,179	SY	$35.00	$216,265
12	6" Concrete Driveway	110	SY	$65.00	$7,150
13	Flowable Fill	137	CY	$120.00	$16,440
14	Embankment (Sinkhole)	177	CY	$45.00	$7,965
15	15" RCP	277	LF	$60.00	$16,620
16	18" RCP	30	LF	$60.00	$1,800
17	24" RCP	450	LF	$85.00	$38,250
18	30" RCP	109	LF	$85.00	$9,265
19	36" RCP	265	LF	$125.00	$33,125
20	42" RCP	277	LF	$150.00	$41,550
21	72" RCP	913	LF	$550.00	$502,150
22	Main Alignment Structure	7	EA	$20,000.00	$140,000
23	Lateral System Structure	17	EA	$4,500.00	$76,500
24	Detention Structure	1	EA	$150,000.00	$150,000
25	RC Flared End Section	2	EA	$600.00	$1,200
26	Energy Dissipation Structure	1	LS	$20,000.00	$20,000
27	Private Fence	90	LF	$35.00	$3,150
28	Temporary Erosion Control	1	LS	$20,000.00	$20,000
29	Sodding and Restoration	1	LS	$10,000.00	$10,000

WILSON & COMPANY

Total Probable Construction Cost	***$1,627,195***
Construction Contingency (20%)	***$325,439***
TOTAL PROBABLE CONSTRUCTION COST	***$1,952,634***
Administration (Permitting / Easements) (5%)	***$97,632***
Engineering Design / Survey (10%)	***$195,263***
Construction Related Services / Inspection (10%)	***$195,263***
TOTAL PROBABLE PROJECT COST	***$2,440,793***



WILSON & COMPANY
ENGINEERS & ARCHITECTS

Wilson & Company, Inc., Engineers & Architects
800 E 101st Terrace, Suite. 200
Kansas City, MO 64131
Phone (816) 701-3100
Cert. of Authority #2003007599

CONCEPT PLANS NOT FOR CONSTRUCTION

CITY PROJECT NO. 2019-895
2ND & CHESTNUT STONE ARCH REPLACEMENT STUDY

CITY OF LEAVENWORTH
PUBLIC WORKS DEPARTMENT
100 North 5th Street, Leavenworth, KS 66048
PHONE: (913) 684-0375

DATE 1/6/2020
DESIGNED BY SLWS
DRAWN BY SLWS
CHECKED BY CDL
SURVEY BOOK NO.
FILE NAME 2nd & Chestnut.dgn
SHEET 1 OF 1