FINAL

RESULTS OF RANDOLPH STREET CULVERT STUDY

B&V PROJECT NO. 402842
B&V FILE NO. 40.0000

PREPARED FOR

City of Leavenworth

NOVEMBER 25, 2019

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November 25th, 2019

MEMORANDUM

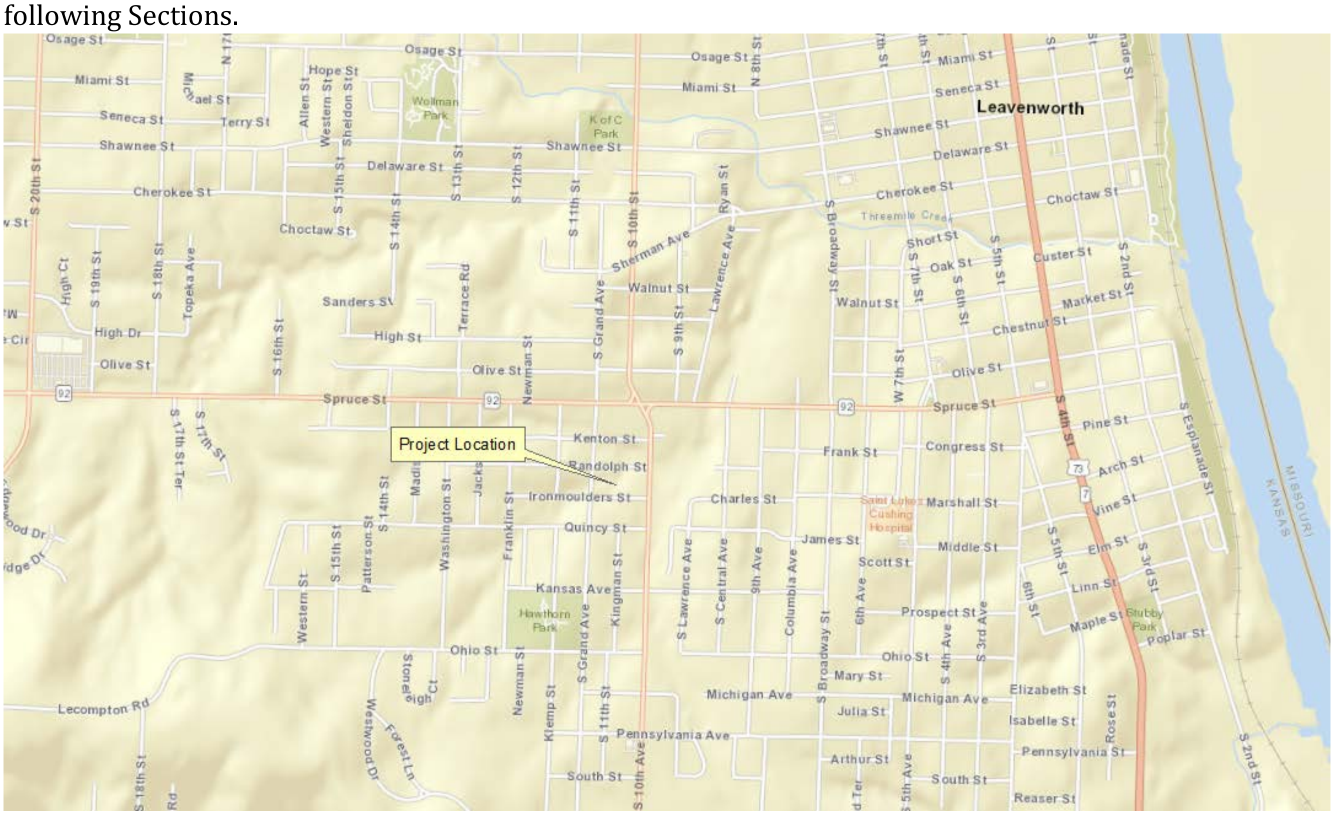
City of Leavenworth
Leavenworth Randolph St Culvert Study

B&V Project Number 402842
B&V File Number 40.000
City Project Number 2019-901

Attention: Michael G. McDonald, Director of Public Works - Leavenworth, Kansas

Subject: Results of Randolph Street Culvert Study

This memorandum summarizes the results of the Randolph Street Culvert Study that evaluated the flood risk for the area that is located adjacent to, and southeast of, the intersection of Randolph Street and Grand Avenue, as shown below. The Randolph Street Culvert inlet is located within the Rock of Ages parking lot and outfalls into a creek to the east. Specifically, this Study completed hydrologic and hydraulic calculations to estimate the impacts of overland flow and develop two conceptual project alternatives to mitigate existing flood risk. Additionally, an analysis of rainfall data captured by the City of Leavenworth, an evaluation of existing drainage recommendations, and cost estimates for each project alternative were also developed. These are summarized in the following Sections.



Location Map

Vicinity Map

1.0 Field Visit and Data Review

The Black & Veatch team conducted a visit of the project site on August 8th, 2019. The visit included above-ground evaluation only from the Rock of Ages church parking lot, Randolph Street and Grand Street. The evaluations indicated that the creek, which historically conveyed flows to the east through the project area, has been filled and stormwater conveyance provided instead by the Randolph Street culvert.

The Rock of Ages church has flooded frequently due to stormwater overtopping the Randolph Street culvert and flowing overland to the church, as shown in **Figure 1-1** below. This photograph shows flooding of the main church building and is believed to be from July 2015. The church does have a small inlet capturing stormwater and conveying it to the Randolph Street Culvert, however, it has been insufficient to mitigate past flooding.

Figure 1-1 Historic Flooding of Rock of Ages Church on July 6th, 2015 (source: City of Leavenworth, Kansas)

Data gathered and reviewed for this study included:

- The Technical Memorandum Grand Avenue Culvert along Three-Mile Creek – Black & Veatch, January 26, 2000. This memorandum summarizes a study previously completed by Black & Veatch and included solutions to mitigate flooding at the project site. In support of this study, an XP-SWMM model was developed which was also reviewed, and pipe invert elevations were used to inform modeling completed for this study.
  - The geodatabase '*Leavenworth.gdb*', which included spatial data for use in ESRI's ArcMap software provided by the City. This dataset included the following information used for this study:
    - Sanitary manholes, lines, and laterals
    - Storm sewer inlets, structures, lines, detention basins, and ponds
    - Road centerlines
    - A ground elevation digital elevation model (DEM) and 2-foot interval ground elevation contours
  - Rainfall data in 15-minute increments from City rain gages
  - Video from August 26, 2019 rainfall event of channel upstream of Rock of Ages Church. This video shows bank-full flow of the channel.

2.0 Rainfall Analysis

Rainfall data provided by the City was analyzed to determine the 15-minute intensities of storm events in recent years. Specifically, the available period of record extended from 8/20/2010 to 8/22/2019. The data was organized by water years and the 15-minute annual maximum intensities were identified. Similarly, the 15-minute intensities for different frequencies based on the National Oceanic and Atmospheric Administration (NOAA) Atlas 14 annual maximum series were obtained for the area of interest.

The NOAA Atlas 14 estimates were used to determine the recurrence interval of the recorded rainfall intensities. The considered rainfall intensity events and their corresponding recurrence interval are listed in **Table 2-1**. A histogram of recurrence intervals for recorded storm events is shown in **Figure 2-1**.

For the period of record, the two highest 15-minute rainfall intensities are close to but below a 9-year recurrence interval from NOAA Atlas 14. The rest of the annual maximum intensities are below a 4-year recurrence interval. While the occurrence of two events with a recurrence interval greater than a 5-year event within a 10-year span is slightly unexpected, a typical rainfall frequency analysis would consider multiple decades of data wherein the occurrence of 5-year and greater events would be expected to average to produce results similar to the NOAA Atlas 14 published values. Therefore, the NOAA Atlas 14 estimates appear to reflect the high intensity rainfall trends in the area as captured in recent rainfall data.

It should be noted that an analysis of annual maximum series is the industry standard for rainfall frequency analyses and only considers the highest event in a year. The results are generally used for design purposes. It is possible that a year with a high-intensity event could have smaller events that also cause flooding multiple times in that same year. Such a pattern would not be captured by the NOAA Atlas 14 rainfall frequency analysis, which only considers annual maxima.

Table 2-1 Observed Annual Maximum Rainfall Intensities, Water Years (WYs) 2011-2019

WATER YEAR	DATE	15-MIN INTENSITY (IN/HR)	RECURRENCE INTERVAL (YEARS)
WY2016	6/10/2016	4.80	8.9
WY2014	8/6/2014	4.72	8.3
WY2011	8/7/2011	3.56	3.1
WY2015	7/6/2015	3.48	2.9
WY2018	3/9/2018	3.12	2.2
WY2017	6/17/2017	2.96	1.9
WY2012	9/3/2012	2.80	1.6
WY2019	8/16/2019	2.68	1.5
WY2013	5/27/2013	2.28	1.1

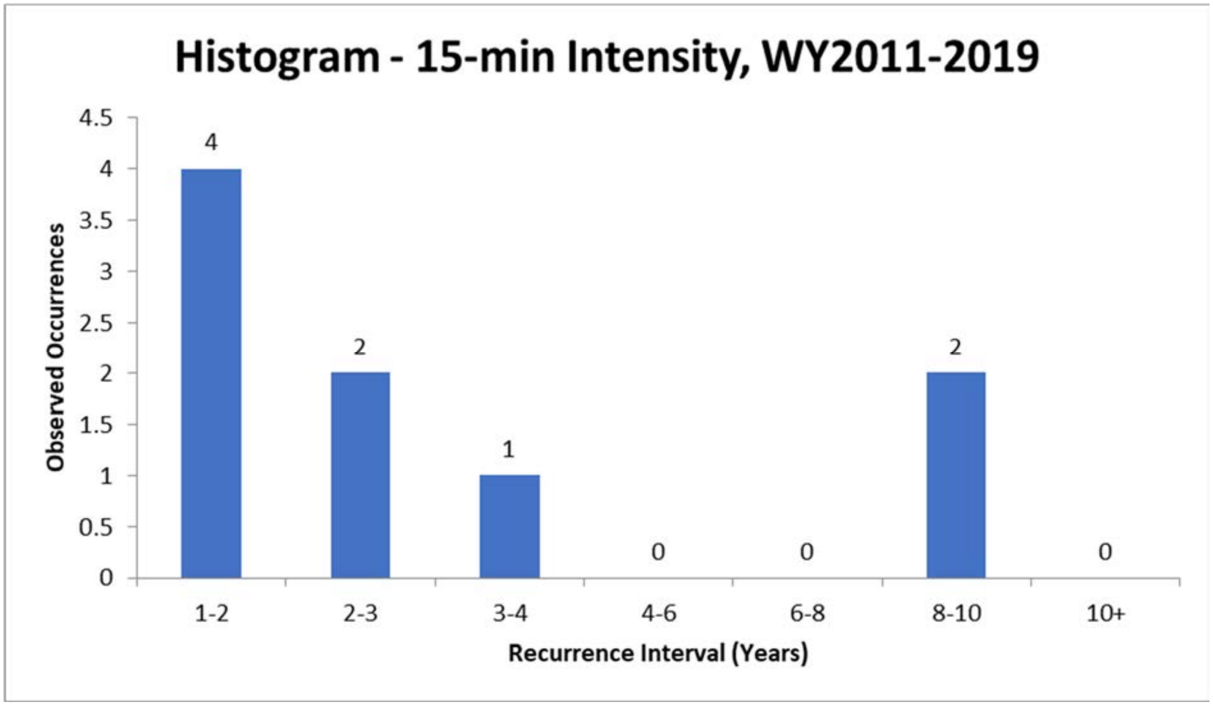


Figure 2-1 Histogram of Observed Annual Maximum Rainfall Intensities

3.0 Hydrologic Calculations

Hydrologic calculations were completed using the United States Army Corps of Engineers (USACE) Hydrologic Engineering Center Hydrologic Modeling System (HEC-HMS) modeling software version 4.3. Development of the model and its inputs are described below.

3.1 MODEL DEVELOPMENT

Utilizing topographic information provided by the City of Leavenworth, the watershed contributing to the Randolph Street culvert was delineated. The overall watershed area, shown in **Figure 3-1** as 'Drainage Area 2', is 202.5 acres or approximately 0.3 square miles. The upper watershed is a steep hill and as the water flows to the north-northeast the slope gets shallower. The overall average slope of the watershed is approximately 5%.

The Kansas Department of Transportation (KDOT) Design Manual Volume I (Part C) Bureau of Road Design Elements of Drainage and Culvert Design (KDOT Drainage Design Manual) dated December 2016 was used for the development of the HEC-HMS model. Rainfall depth values to be used as a frequency storm within HEC-HMS were derived from the December 2014 edition of the KDOT Rainfall Intensity table for Leavenworth County. This guidance was used because it utilizes shorter duration, higher intensity rainfall events that are consistent with the types of events the City has observed to cause flooding.

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Figure 3-1 Drainage Area Map

The Hydrologic Soil Group (HSG) varies throughout the watershed. In the upper watershed, the dominant HSG is Group D meaning the soil has a high runoff potential. In the middle of the watershed, the dominant HSG is Group C meaning the soil has a relatively high runoff potential. Near the Randolph Street Culvert the HSG changes to Group B meaning the soil has a relatively low runoff potential. The soils information was captured from the National Resources Conservation Service Web Soil Survey's Soil Survey Geographic Database (SSURGO).

The dominant land use classification within the watershed is residential with lots ranging from a quarter acre to a half acre. Other land use classifications within the watershed include woods-grass combination in a good hydrologic condition, woods in a good hydrologic condition, open space in a good hydrologic condition, and commercial and business. Land use designations were assigned based on review of aerial photography and using classifications from the KDOT Design Manual.

The National Resource Conservation Service (NRCS) Curve Number (CN) was determined from the land use and HSG within the watershed. A weighted CN for the overall watershed was calculated to be 77 for the 2- to 25-year storm events, 80 for the 50-year storm event, and 86 for the 100-year storm event. The lag time for the watershed was calculated to be 9.3 minutes.

The 2-, 5-, 10-, 25-, 50-, and 100-year storm events were evaluated within HEC-HMS using an alternating block hyetograph consistently with the frequency storm option in HEC-HMS. This storm is made up of high peak storm intensities, including 5- and 15-minute intensities, as well as longer duration storm volumes, including 1-, 2-, 3-, 6-, 12-, and 24-hour durations. Values input are provided in **Table 3-1** below. The storm durations match the requirements provided within Table 11.53-1 of the KDOT Drainage Design Manual. The City of Leavenworth also provided rainfall data for a storm on August 29, 2019 for review within HEC-HMS.

Table 3-1 Rainfall Intensities Utilized to Create Theoretical Hyetographs

DURATION	2-YEAR INTENSITIES, INCHES/ HOUR	5-YEAR INTENSITIES, INCHES/ HOUR	10-YEAR INTENSITIES, INCHES/ HOUR	25-YEAR INTENSITIES, INCHES/ HOUR	50-YEAR INTENSITIES, INCHES/ HOUR	100-YEAR INTENSITIES, INCHES/ HOUR
5-minute	5.63	7.09	8.33	10.07	11.45	12.84
15-minute	3.35	4.24	4.96	6.00	6.84	7.64
1-hour	1.57	2.00	2.37	2.89	3.30	3.72
2-hour	0.98	1.25	1.48	1.81	2.08	2.35
3-hour	0.73	0.94	1.12	1.38	1.58	1.79
6-hour	0.44	0.56	0.67	0.83	0.95	1.08
12-hour	-*	-*	0.39	0.48	0.55	0.62
24-hour	-*	-*	-*	0.27	0.31	0.35

* - Values not listed in this table were not applicable because of the duration of the event used. The 2- and 5-year storms utilized a 6-hour storm, and the 10-year event utilized a 12-hour storm.

3.2 RESULTS

The peak flow results for HEC-HMS are provided in **Table 3-2**. As a check to the HEC-HMS results, the Rational Method was also calculated for the overall watershed, and these are listed below as well. The Rational Method was done in accordance to the guidelines within the Kansas City Metropolitan Chapter American Public Works Association Standard Specifications & Design Criteria Section 5600 Storm Drainage Systems & Facilities (APWA 5600) dated February 16, 2011.

Table 3-2 Randolph Street Storm Sewer HEC-HMS and Rational Method Peak Flow Results

STORM EVENT	HEC-HMS (CUBIC FEET PER SECOND)	RATIONAL METHOD (CUBIC FEET PER SECOND)	PERCENT DIFFERENCE
August 29, 2019	130	n/a	n/a
2-year, 6-hour	200	340	n/a
5-year, 6-hour	350	410	-70%
10-year, 12-hour	560	470	-17%
25-year, 24-hour	850	600	16%
50-year, 24-hour	1,100	700	29%
100-year, 24-hour	1,420	830	36%

The results show the Rational Method is generally higher than the HEC-HMS results for the 2-year and 5-year storm events and lower for the 10-year to 100-year storm events, with an average difference between the two methods of 6%. This indicates overall consistency between the two methods and the HEC-HMS results were considered validated and used for this study.

The Randolph Street Culvert has a connection from another pipe near the outlet that has a different watershed than the Randolph Street Culvert which is designated as 'Drainage Area 1' in **Figure 3-1**. The watershed for this connection was reviewed and a Manning's calculation was done on the pipe to determine the peak flow. The watershed has an area of approximately 92 acres. Due to its adjacency to the drainage area to the Randolph Street Culvert and its similar size, it is expected that rainfall events would cause a response in both watersheds on a frequent basis and it was assumed that peak flows would be coincidental with the Randolph Street Culvert watershed.

Stormwater conveyance in this drainage area is a series of varying open channels and closed conduits, resulting in inefficient conveyance and lower velocities. The time of concentration for this drainage area was estimated to be 14.1 minutes. Peak flows conveyed to the Randolph Street Culvert from this drainage area were calculated using Rational Method and are summarized in **Table 3-3** below.

Table 3-3 Rational Method Peak Flow Results for North Drainage Area

STORM EVENT	RATIONAL METHOD (CUBIC FEET PER SECOND)
2-year	180
5-year	220
10-year	250
25-year	320
50-year	390
100-year	440

4.0 Hydraulic Calculations

Hydraulic calculations were completed using the USACE Hydrologic Engineering Center River Analysis System (HEC-RAS) modeling software version 5.0.7. To simulate overland flow at the project site, the model's two-dimensional modeling option was used. Development of the model and its inputs are described below.

4.1 MODEL DEVELOPMENT

The HEC-RAS two-dimensional model was developed using the terrain data provided by the City of Leavenworth. The terrain is a raster created from Light Detection and Ranging (LIDAR) data with grid cells of 1 meter by 1 meter (3.28 feet by 3.28 feet). The model domain starts upstream of the culvert under Ironmoulders Street, east of Grand Avenue, and continues to the east toward the creek and north to Randolph Street. The hydrographs developed in HEC-HMS were input into the model upstream of the Ironmoulders Street culvert. This was done to simulate realistic velocities in the channel between Ironmoulders Street and Grand Avenue.

The coarse definition of the LIDAR data created a terrain that did not accurately define the channels within the model domain from Ironmoulders to Grand Avenue and Grand Avenue to the Randolph Street Culvert. In order to better define these channels, terrain modifications were done within HEC-RAS. This was done by creating a one-dimensional cross section through the channels and exporting out the terrain. Once exported, the new channel terrains were combined with the terrain data provided by the City of Leavenworth. Without additional survey information for the area, the channel geometries were based on a constant slope between the culverts they connect with. The church building east of the Randolph Street Culvert was also created and combined into the terrain to provide the obstruction to flow for the model results.

A land use, or Manning's roughness, layer was developed using ArcMap 10.6.1 to provide roughness values for the terrain.

The model domain includes the culverts under Ironmoulders Street, Grand Avenue, and the Randolph Street Culvert. As-built information was provided for the culvert under Grand Avenue. No as-built information was available for the other two culverts. Without information for the culvert under Ironmoulders, the same culvert under Grand Avenue was used. The Randolph Street Culvert was modeled using a rating curve developed from an XP-SWMM model as described in the following subsection.

4.2 RATING CURVE DEVELOPMENT

A discharge rating curve of the Randolph Street Culvert was developed using an XPSWMM model. Only pipe flow was considered in the model. The existing culvert consists primarily of 6'x6' stone arch pipes. The only exceptions are two sections of 60-inch CMP: the first section comprises the most upstream 95-feet of the sewer, and the second is a 40-foot long section that is located approximately 196-feet from the culvert entrance and beneath Randolph Street.

The storm sewer was modeled based on these segments and Manning's n values of 0.024 and 0.025 were assigned based on a previous XPSWMM model of the system.

The outfall of the culvert is located at a creek east of the intersection of 10th St and Randolph St. There is the potential for the capacity of the culvert to be affected by high flows in this creek, therefore, a backwater analysis was performed to determine the influence of the creek on the culvert capacity.

The area of the watershed upstream of the outfall is 122 acres, and this watershed is shown as 'Drainage Area 3' in **Figure 3-1**. Rational Method as described in APWA 5600 was used to estimate flows in the creek up to the 100-year event. The resulting flows and a representative cross section of the creek (shown in **Figure 4-1**) were used to determine the normal water surface elevation at the outfall. The general slope of the creek at this location was estimated to be 0.00769 feet/feet using the DEM provided by the City. A Manning's roughness of 0.1 consistent with the heavy vegetation in the channel indicated by aerial photography. The calculated water surface elevations (WSEs) for different frequencies are listed in **Table 4-1**.

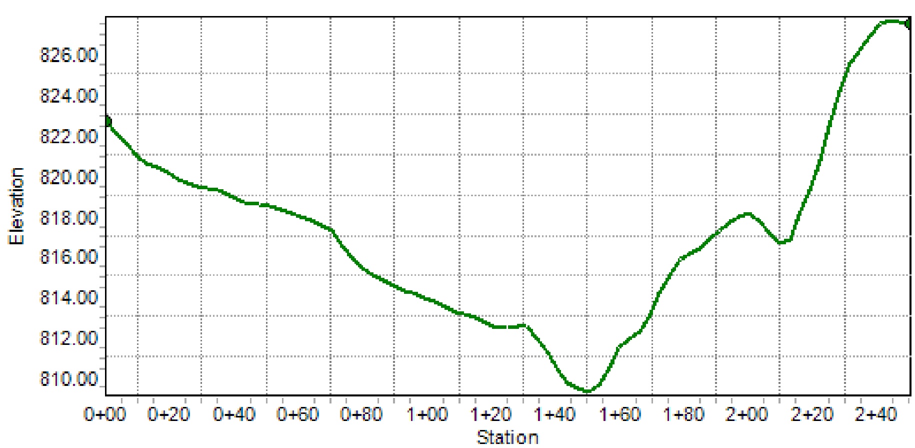

Figure 4-1 Representative Cross Section of Creek at Randolph Culvert Outfall

Table 4-1 Estimated Water Surface Elevations at Randolph Culvert Outfall

FREQUENCY (YEARS)	FLOW (CUBIC FEET PER SECOND)	WSE (FEET NAVD88)
10	330	814.06
25	420	814.47
50	520	814.81
100	590	815.06

The invert of the outfall is at elevation 812.8 ft. The calculated water surface elevations are higher than the invert but do not fully submerge the storm sewer outfall. Backwater influence was determined by considering two scenarios: one in which the culvert has no submergence (free-flowing); and another in which the backwater elevation is half a pipe diameter above the invert (el. 815.3'), which is higher than the estimated 100-year WSE. The difference in capacity was found to be not significant, nonetheless, the rating curve was developed by modeling the pipe half submerged.

An additional rating curve was developed assuming the original conditions of the culverts (6'x6' stone arch pipe). The Manning's n value was assumed to be 0.017, which is the highest value of the suggested range in the XPSWMM documentation for this type of pipes. The rating curves for both existing conditions (shown in blue) and a scenario in which all the existing pipes are upgraded to the original 6'x6' stone arch pipe ('Full Restored Stone Arch Sewer', shown in green) are shown in **Figure 4-2** as well as the ground elevation at the culvert entrance as indicated in the GIS data.

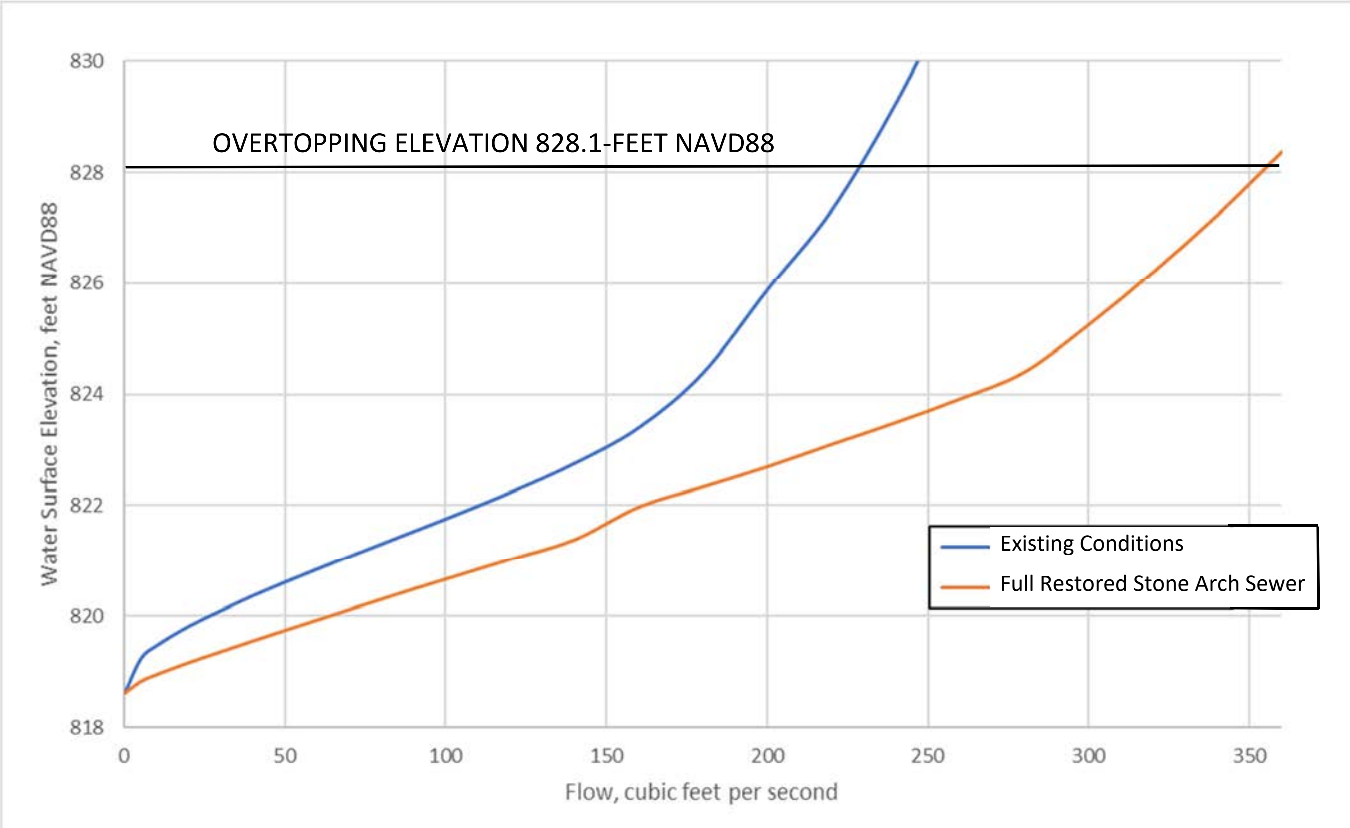

Figure 4-2 Randolph St Culvert Rating Curve, Existing and Original Conditions

4.3 RESULTS

The HEC-RAS model was run for the 2-, 5-, 10-, 25-, 50-, and 100-year storm events. The August 29, 2019 storm event was also modeled within HEC-RAS. This actual storm event was used to help validate the model as the Randolph Street Culvert did not overtop during this storm event.

The overflow for the culvert was of key interest to determine the amount of overtopping at the Randolph Street Culvert during different storm events. **Figure 4-3** provides the location the overtopping calculated within HEC-RAS, shown as a red line. The minimum overtopping elevation along this red line indicated by the ground DEM was 828.1 feet NAVD88.

Figure 4-3 Randolph Street Culvert Overtopping Results Location

Table 4-2 provides the results of the overtopping at the Randolph Street Culvert.

Table 4-2 Randolph Street Culvert Overtopping Results

STORM EVENT	OVERFLOW RATE (CUBIC FEET PER SECOND)	OVERFLOW VOLUME (ACRE-FEET)
August 29, 2019	0	0.00
2-year, 6-hour	0	0.00
5-year, 6-hour	100	1.35
10-year, 12-hour	280	6.19
25-year, 24-hour	580	14.53
50-year, 24-hour	840	23.56
100-year, 24-hour	1,170	35.39

The results for the August 29, 2019 simulation indicated a minor overtopping of the Randolph Street Culvert with no overtopping flow. This correlated well with the video provided by the City of bank-full flow on this date. It should also be noted that the event which caused flooding on July 6th, 2015 shown in **Figure 1-1** is calculated to be a 10-year, 1-hour event based on the 2.46 inches recorded by the City's rain gage system. This is also consistent with the modeled overtopping results.

The results provided within **Table 4-2** were used to develop concept alternative and mitigation strategies for overtopping over the Randolph Street Culvert. Further discussion on concept alternatives are provided in the following section.

5.0 Conceptual Project Alternatives

A base alternative and two conceptual alternatives were developed for this project. These alternatives were evaluated against the storm events described in **Section 3.1**, and as a result their anticipated performance for both short, high-intensity events and longer, lower-intensity events has been quantified. All the alternatives developed provide a 5-year level of service such that flooding associated with that event at the church will be minimized or eliminated.

The Base Alternative is to keep the same layout of the storm drainage system but to upsize to accommodate larger storm events.

The first concept alternative, Alternative 1, is an off-line detention basin at the northwest corner of Grand Avenue and Ironmoulders Street. The goal of this basin would be to capture the volume of water which floods the project site when the capacity of the Randolph Street Culvert is exceeded.

The second concept alternative, Alternative 2, is to separate the connection with the other pipe and create two dedicated culverts into the creek to the east. All three alternatives are discussed below and cost estimates in the following section. On-site retention and a berm within the Rock of Ages parking lot are not feasible based on the topography. **Figure 5-1** provides the location and layout of the Base Alternative and the two concept alternatives.

Cost estimates were developed for each project alternative using quantities developed in ArcGIS with unit costs estimated based on local firm experience and Kansas Department of Transportation bid tabs.

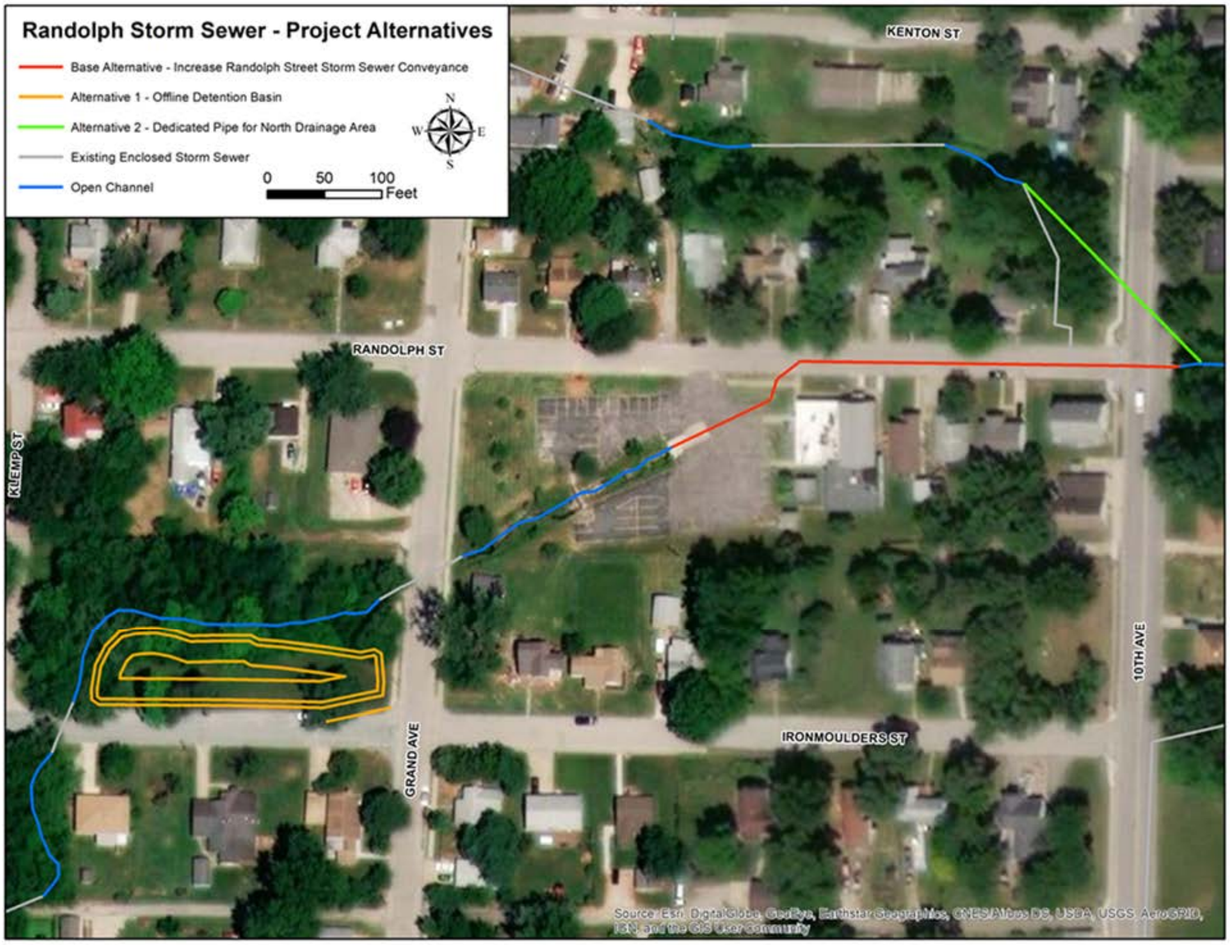

Figure 5-1 Concept Alternative Layouts

5.1 BASE ALTERNATIVE

The Base Alternative which would remove the existing pipe system and replace it with the same system layout but larger pipe sizes. Manning's equation was used to determine the estimated pipe sizing for the 2-, 5-, and 10-year storm events for the Randolph Street Culvert both up and downstream of its confluence with the culvert conveying flows from the north (shown in **Figure 5-1**). **Table 5-1** provides the results for the pipe sizing calculations.

Table 5-1 Base Alternative Randolph Street Culvert Pipe Sizes

			UPSTREAM CONFLUENCE		DOWNSTREAM CONFLUENCE	
Storm Event	Diameter Upstream of Confluence – equivalent round pipe (ft)	Diameter Downstream of Confluence– equivalent round pipe (ft)	Reinforced Concrete Box Culvert Height (ft)	Reinforced Concrete Box Culvert Width (ft)	Reinforced Concrete Box Culvert Height (ft)	Reinforced Concrete Box Culvert Width (ft)
2-year, 6-hour	5	7	n/a	n/a	6	6
5-year, 6-hour	6	8	n/a	n/a	6	7
10-year, 12-hour	8*	9*	6	7	6	10

* Note that some storm events in this table have both an equivalent round pipe diameter and a reinforced concrete box (RCB) culvert with a maximum height of 6-feet was specified. This was done in order to increase culvert capacity while avoiding a vertical conflict with a sanitary sewer which crosses beneath the Randolph Street Culvert associated with deepening the culvert beyond its existing height of 6-feet.

The results indicate that a 5-year level of service could nearly be achieved by restoring Randolph Street Culvert to its original 6-foot by 6-foot brick arch pipe. The condition of the pipes comprising the Randolph Street Culvert is unknown, so it is not possible to formulate a rehabilitation cost estimate at this time. **Table 5-2** provides a cost estimate where the entire sewer has been replaced with 6-foot by 7-foot RCB to provide a 5-year level of service, and this provides an 'upper bound' for cost of this alternative.

Should the sewer be found to be in overall good condition, the City can elect to restore the original capacity of the sewer by improving the CMP portions only at a greatly decreased cost. To illustrate this, rating curves were developed for two pipe rehabilitation scenarios as shown in **Figure 5-2**: the 'Remove Randolph St CMP Only' rating curve (shown in yellow) is for a scenario in which the 40-foot section of 60-inch CMP located beneath Randolph Street is removed and replaced with 6'x6' stone arch pipe, and the 'Remove All CMP' rating curve (shown in green) is for the same scenario with the addition of the upstream 60-inch CMP also being removed completely. The 'Remove Randolph St CMP Only' rating curve shows only a marginal improvement and does not achieve a 5-

year level of service, indicating that improvements to the upstream 60-inch CMP must also be completed to provide reduction in flooding at the project site.

The 'Existing Conditions' and 'Full Restored Stone Arch Sewer' lines on the **Figure 5-2** graph are the same as those shown in **Figure 4-2** and were retained in this figure for reference.

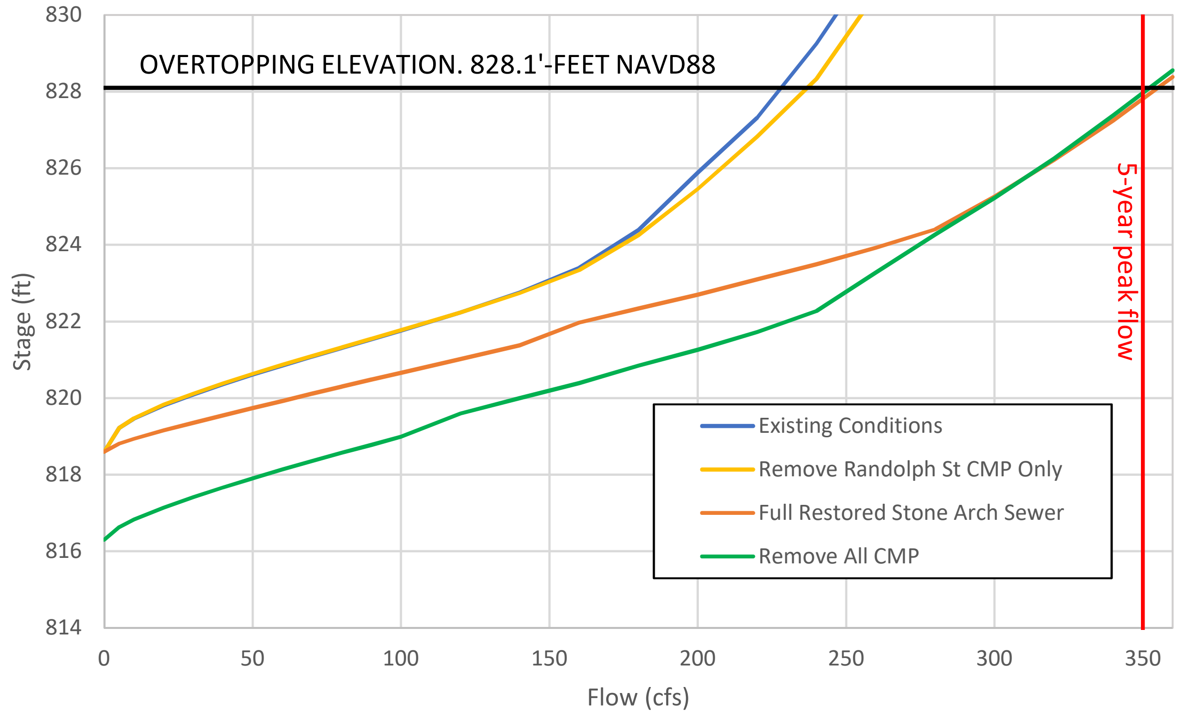

Figure 5-2 Sewer Rehabilitation Alternatives Rating Curves

Table 5-2 Base Alternative Conceptual Cost Estimate – 5-year Level of Service

ITEM	QUANTITY	UNIT	UNIT COST	ITEM COST
Asphalt and Curb/Gutter Removal & Replacement	600	SY	$140	$84,000
6’x6’ Stone Arch Pipe Removal	470	LF	$65	$30,550
Construct 18-inch RCP	42	LF	$100	$4,200
Remove and Replace 36-inch RCP	180	LF	$320	$57,600
Construct 72-inch RCP	380	LF	$550	$209,000
Construct 6-foot by 7-foot RCB	90	LF	$900	$81,000
Construct Storm Sewer Headwall (Culvert Inlets and Outlet)	3	EA	$30,000	$90,000
Construct Storm Sewer Inlet	2	EA	$4,500	$9,000
Construct Manhole	2	EA	$5,000	$10,000
Construct 6-inch Sidewalk	7	SY	$65	$455
Seed Disturbed Turf	40	SY	$0.65	$26
Construction Subtotal:				$576,000
Utility Relocate (5%)				$29,000
Mobilization (3%):				$17,000
Contractor Markups, Overhead, Fees, and Profit (15%):				$86,000
Subtotal with Allowances:				$708,000
Contingency (40%):				$212,400
Probable Cost Estimate:				$920,400
Permitting (5%):				$46,000
Engineering (15%):				$138,000
Total Conceptual Cost Estimate (rounded to next $1,000):				$1,105,000

Note: This cost represents an upper limit, and if the scope of this alternative were reduce to the rehabilitation or replacement of the 60-inch CMP pipe with pipes which restore the sewer to its original capacity, the cost could decrease significantly.

5.2 ALTERNATIVE 1

The off-line basin within Alternative 1 is proposed for the northwest corner of Grand Avenue and Ironmoulders Street, adjacent to the existing channel. The off-line basin connects to the channel with inlet and outlet culverts. The inlet culverts have been located perpendicular to the flow path north of the culvert under Ironmoulders Street and the outlet culverts will be located west of the culvert under Grand Avenue, as shown in **Figure 5-3**.

The basin inlet would be comprised of eight, 24-inch reinforced concrete pipe (RCP) culverts and the outlet would include two, 24-inch RCP culverts. This will be refined as part of future studies, which should also evaluate the feasibility of more cost-effective configurations such as a submerged, riprap-lined inlet weir and multi-stage pipe outlet. Culvert inlets and outlets made of RCP were assumed for this effort to provide an appropriate conceptual-level cost estimate. No modeling of this basin was completed, therefore the routing in and out of the basin will need to be evaluated as part of a future design phase to verify the adequacy of these culverts.

The concept alternative grading used a maximum 3:1 basin side slope to determine an overall volume that could be provided. A basin with a depth of 6-feet with 5-feet of ponding and 1-foot of freeboard was developed. A total of 1.40 acre-feet could be held within the 5-feet of ponding, which would capture the volume overflowing into the church parking lot for a 5-year storm event.

Table 5-3 provides a cost estimate for this alternative.

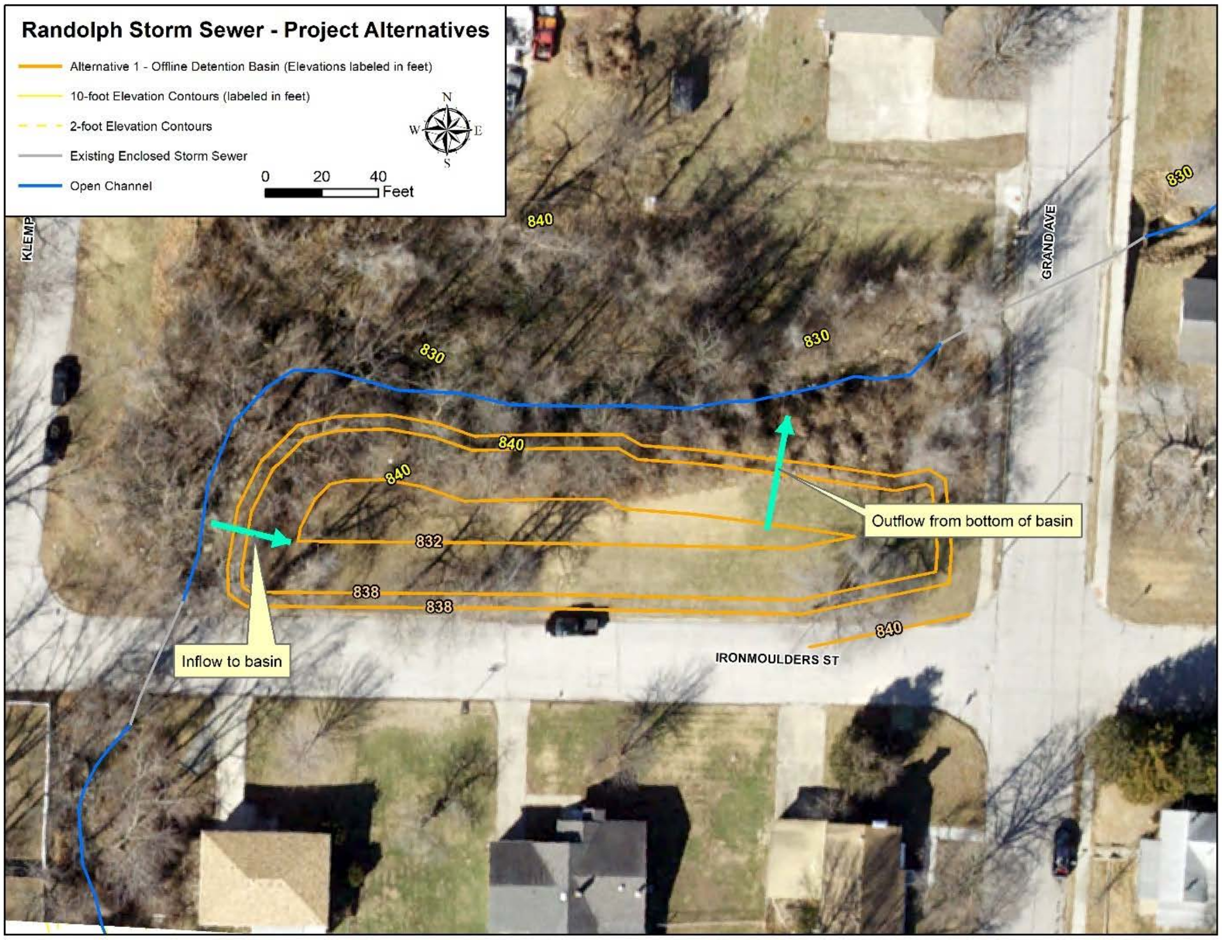

Figure 5-3 Alternative 1 Offline Detention Basin Layout and Grading Contours

Table 5-3 Alternative 1 Conceptual Cost Estimate – 5-year Level of Service

ITEM	QUANTITY	UNIT	UNIT COST	ITEM COST
Construct 24-inch RCP	500	LF	$140	$70,000
Clearing/Grubbing	1	LS	$10,000	$10,000
Excavation & Haul/Grading	3,057	CY	$42	$128,211
Construct Storm Sewer Inlet/Outlet	20	EA	$2,500	$50,000
Resolve Utility Conflict	1	EA	$5,000	$5,000
Seed Graded Basin	1,350	SY	$1	$1,350
Construction Subtotal:				$265,000
Utility Relocate (5%)				$13,000
Mobilization (3%):				$8,000
Contractor Markups, Overhead, Fees, and Profit (15%):				$40,000
Subtotal with Allowances:				$326,000
Contingency (40%):				$97,800
Probable Cost Estimate:				$423,800
Permitting (5%):				$21,000
Engineering (15%):				$64,000
Total Conceptual Cost Estimate (rounded to next $1,000):				$509,000

5.3 ALTERNATIVE 2

Alternative 2 includes replacement of the existing 36-inch culvert conveying flow into the Randolph Street Culvert with a storm sewer which conveys flow beneath 10th Avenue directly to the open channel to the east, as shown in **Figure 5-4**. This would eliminate the possible backwater impacts of the bottleneck created by the connection and would make additional capacity available to convey stormwater away from Rock of Ages church.

Figure 5-4 Alternative 2 Layout

Manning's equation was used to determine the estimated pipe sizing for the 2- and 5-year storm events for the Randolph Street Culvert and North Culvert. **Table 5-4** provides the results for the pipe sizing calculations.

Table 5-4 Alternative #2 Pipe Sizes

STORM EVENT	NORTH CULVERT DIAMETER– EQUIVALENT ROUND PIPE (FT)	BOX CULVERT HEIGHT (FT)	BOX CULVERT WIDTH (FT)
2-year, 6-hour	5*	3	6
5-year, 6-hour	5*	3	7
10-year, 12-hour	6*	3	8

* Note that some storm events in this table have both an equivalent round pipe diameter and a reinforced concrete box (RCB) culvert with a maximum height of 3-feet was specified. This was done in order to increase culvert capacity while avoiding a vertical conflict with a sanitary sewer which crosses beneath the existing culverts associated with deepening the culvert beyond its existing height of 3-feet.

Table 5-5 provides a cost estimate for this alternative for a 5-year level of service.

Table 5-5 Alternative 2 Conceptual Cost Estimate - 5-year Level of Service

ITEM	QUANTITY	UNIT	UNIT COST	ITEM COST
Asphalt and Curb/Gutter Removal & Replacement	150	SY	$140	$21,000
36-inch CMP Removal	180	LF	55	$9,900
Construct 18-inch RCP	42	LF	$100.00	$4,200
Construct 3-foot by 7-foot RCB	250	LF	$750.00	$187,500
Construct Storm Sewer Headwall (Culvert Inlets and Outlet)	2	EA	$30,000	$60,000
Construct Manhole	1	EA	$4,990.19	$4,990
Resolve Utility Conflict	1	EA	$5,000.00	$5,000
Construct 6-inch Sidewalk	7	SY	$61.49	$430
Seed Disturbed Turf	40	SY	$0.65	$26
Construction Subtotal:				$293,000
Utility Relocate (5%)				$15,000
Mobilization (3%):				$9,000
Contractor Markups, Overhead, Fees, and Profit (15%):				$44,000
Subtotal with Allowances:				$361,000
Contingency (40%):				$108,300
Probable Cost Estimate:				$469,300
Permitting (5%):				$23,000
Engineering (15%):				$70,000
Total Conceptual Cost Estimate (rounded to next $1,000):				$563,000

5.4 PERMITTING

Because the construction proposed as part of each of the three alternatives encompasses a small area located outside of the regulatory floodplain, permitting is not anticipated to be a large effort. The following permits are applicable to the three project alternatives and are discussed briefly in the following bullets.

- Kansas Department of Health and Environment (KDHE) – *Construction Stormwater Permit*
  - This permit is required when a construction activity disturbs an area that is one or more acres and is intended to protect the quality of stormwater runoff. The area disturbed by the three project alternatives is not proposed to be an acre or more, so acquiring a permit is not anticipated. However, KDHE does sometimes require a permit for areas of disturbance less than one acre, and consultation with the State should take place at the initiation of project design to determine if a Construction Stormwater Permit will be required.
- Environmental Protection Agency and United States Army Corps of Engineers (USACE), Kansas City District – *Clean Water Act Section 404 Permit*
  - This permit is required when any of the waters of the United States will be disturbed by either dredging (i.e. removal of material) or fill activities. The three project alternatives are not anticipated to have major impacts to waters of the United States, with only minimal disturbances at inlets and outlets to enclosed systems, and it is anticipated that these activities will require minimal effort to acquire a 404 permit under Nationwide Permit Category 7 (*Outfall Structures and Associated Intake Structures*). This category does require a pre-construction notice be submitted prior to award of the permit, and time for USACE review of the pre-construction notice and Nationwide Permit application must be accounted for any future project design schedules.
- Federal Emergency Management Agency – *Floodplain Permit*
  - No action is anticipated to be required, as the three proposed project areas are located outside of the FEMA regulatory floodplain.

6.0 Recommendations

It is recommended that the City seek to achieve at least a 5-year level of service for the project site such that the Randolph Street culvert can convey the calculated 5-year flow without overtopping. It is recommended that this be done using one of the following approaches utilizing the project alternatives developed in this memorandum. It is anticipated that when constructed, any approach will decrease the frequency with which the Rock of Ages church experiences inundation due to overtopping of the Randolph Street Culvert.

6.1 PRIORITIZATION OF FUTURE WORK

Future work discussed in this memorandum is recommended to be prioritized as follows:

- **Priority Work** – Assess the condition of the Randolph Street Culvert. Internal investigation of the pipe using closed circuit television video (CCTV) should be completed to assess the condition of the portion of the Randolph Street Culvert comprised of stone arch pipe. If this assessment finds these portions to be in good condition, then the Base Alternative is recommended to be refined to reflect only removal of 60-inch CMP with the goal of restoring the original capacity of the sewer. This would be accomplished by replacing the 95-feet of 60-inch CMP at the upstream end of the sewer with a 6'x'6 arch pipe (or equivalent) or removing it completely and constructing an open channel in its place and by replacing the 40-foot portion of 60-inch CMP beneath Randolph Street with a 6'x6' arch pipe. Both of these sections of CMP should be improved simultaneously, as limited improvements will be achieved if they are done independently of each other. Constructing both of these improvements would provide the same capacity as replacing the entire storm sewer at a much lower cost.

  Conversely if the internal inspections of the pipe show that the stone arch pipe is in generally poor condition or near failure, it is recommended to replace it fully per the Base Alternative recommendations to provide a 5-year level of service.

  Additionally, it is recommended to replace the inlet to the Randolph Street Culvert as a Priority Work activity.

- **Secondary Priority Work** – Work designated as a Secondary Priority is dependent upon the construction completed for the Base Alternative:
  - If only replacement of the 60-inch CMP is required, then it is recommended to construct Alternative #2 and construct new pipe conveyance to route the stormwater entering the Randolph Street Culvert from the north to a new outfall to the open channel located east of 10th Avenue.
  - If the Randolph Street Culvert is fully replaced, then it is recommended to construct the upstream, offline detention basin described in Alternative 1. Because the Base Alternative was sized to convey a 5-year event including the inflows from the area to the north, the detention basin will provide a provide additional protection and a higher level of service than a 5-year for the project area.

6.2 ANALYSIS LIMITATIONS AND NEXT STEPS

The analysis documented in this memorandum has the following limitations:

- The hydraulic modeling completed to capture overland flood depths was done using a coarse DEM with grid cells of 3.28 feet by 3.28 feet. This DEM was appropriate for a conceptual analysis but should be reevaluated as part of future design efforts.
- Dynamic routing of flows into and out of the detention basin proposed in Alternative 1 was not completed in the hydraulic model; instead, the basin conceptual design was created such that the basin would contain the calculated volume flooding the Rock of Ages church.
- No information on the culvert beneath Ironmoulders Street immediately upstream of the Alternative 1 detention basin was available, and the hydraulics of this culvert could have an impact on the flow into the proposed detention basin.
- Hydrologic and hydraulic modeling were completed per the scope of work for Drainage Area 2 as flow from this watershed drains directly to the project site. However, it was identified during this analysis that stormwater runoff from Drainage Areas 1 and 3 also has the potential to influence the project site. These drainage areas were evaluated using more approximate methods (i.e. Rational Method for hydrology and Manning's equation for hydraulics) to remain within the scope of this study while also identifying their potential impacts.
- The confluence of the 36-inch RCP from the north into the Randolph Street Culvert which creates the bottleneck to be addressed by Alternative 2 was not field-investigated as part of this effort, and should be surveyed as part of future study.
- The condition of the Randolph Street Culvert comprised of stone arch pipe is not known and has been assumed to be in poor condition due to its past failures. If this is not the case and the stone arch pipe is in good condition, it may be feasible to restore conveyance through more limited measures which only replace the 60-inch CMP.
- Future development within the drainage area to the project site was not accounted for, and all flows calculated represent existing conditions only.

Following approval of a project alternative (or alternatives) by the City, these limitations should be addressed by the following recommended next steps:

- Completion of a field survey by a licensed land surveyor, to include:
  - Capture of ground elevations for areas of construction,
  - The locations of all utilities,
  - The boundaries of all impacted properties,
  - Trees and vegetation impacted by the proposed project,
  - Below-ground survey of stormwater structures (including the bottleneck addressed by Alternative 2, if appropriate) to capture pipe and structure (i.e. manholes, junction boxes, and inlets) material and condition; pipe size; pipe and structure invert elevations; and any other relevant information,

  - Survey of the Ironmoulders culvert, should Alternative 1 be chosen by the City for additional design.
- Refining the hydrologic and hydraulic analysis
  - Completing hydrologic and hydraulics modeling of Drainage Areas 1 and 3, where the HEC-HMS model is extended to include runoff and routing calculations for these drainage areas, and where the 2-dimensional HEC-RAS model is extended to include the open channel east of 10th Avenue and the XP-SWMM model is extended to include the incoming 36-inch RCP culverts which create the bottleneck on the Randolph Street Culvert. These refinements should be completed using survey data.
  - Refining the HEC-RAS model to include routing into and out of the detention basin proposed in Alternative 1, if the City chooses this alternative for further design. This refinement should include survey data describing the upstream Ironmoulders Street culvert.