COOK CREEK HYDROLOGY STUDY

SADDLEBROOKE, MO

Prepared for:

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APPENDICES

1.0 INTRODUCTION

Palmerton & Parrish, Inc. was retained by the Village of Saddlebrooke to perform a hydrologic study of Cook Creek in Christian County, Missouri. The purpose of the hydrologic study was to model flooding in Cook Creek and to recommend general improvements at two stream crossings and three culverts passing under Saddlebrooke Drive. The results of that evaluation are presented in the following pages. The drainage area for Cook Creek is located within sections 25, 26, 27, 28, 29, 32, 33, 34, 35, and 36 in township 25 north and range 21 west and sections 3, 4, 5, and 6 in township 24 north and range 21 west. Runoff was estimated using the procedures outlined in the USDA, Natural Resource Conservation Service, Technical Release 55, *Urban Hydrology for Small Watersheds* (TR-55). Stream flows at each road crossing and culvert were estimated using the U.S. Army, Corps of Engineers HEC-1 flood hydrograph software. Flood levels were modeled using the U.S. Army Corps of Engineers HEC-RAS river analysis software. Hydraulic performance of the two culvert stream crossings was performed using AutoCAD Civil 3D Hydraflow Express software. See Figure 1 in Appendix I for the general location of the Cook Creek drainage area on the Spokane and Day 7.5 Minute Topographic Quadrangles.

There are three (3) stream crossings on Cook Creek within the Village of Saddlebrooke. For the purposes of this report these crossings are referred to as Bridge 1, Bridge 2, and Bridge 3, with Bridge 1 being the furthest downstream and Bridge 3 being the furthest upstream. Bridge 1 is a reinforced concrete girder bridge with a span of approximately 50 feet. Bridges 2 and 3 are 6-feet diameter corrugated metal pipe-arch culverts. Bridge 2 has flared end sections on both ends of the pipe and approximately 4- feet of cover over the pipe. Bridge 3 has a flared end section at the pipe entrance and approximately 2-feet of cover over the pipe. Photographs of each bridge are included in Appendix IV.

There are five (5) culverts passing under Saddlebrooke Drive between Bridges 1 and 2. Each of these culverts pass stormwater from the surrounding valleys into Cook Creek. For the purposes of this report these culverts are referred to as Culverts 1, 2, 3, 4, and

5, with Culvert 1 being the furthest downstream and Culvert 5 being the furthest upstream. The Village of Saddlebrooke requested that a hydraulic analysis be performed on Culverts 1, 4, and 5 where overtopping and erosion have historically been a problem. See Figure 4 in Appendix I for the location of each culvert. Photographs of Culverts 1, 4, and 5 are included in Appendix IV.

2.0 STORMWATER RUNOFF

The Cook Creek drainage area consists of mostly undeveloped woodland with some grass covered pasture and residential properties. This drainage area was determined using the most recent versions of the USGS Selmore and Day 7.5 minute topographic quadrangles. The resulting drainage area is approximately 6.06 square miles. The runoff characteristics of the Cook Creek drainage area were modeled using the procedures outlined in TR-55. In TR-55 runoff is estimated based on land cover and soil type. Different land cover and soil types have differing rates of water infiltration and runoff. Land use was determined from February 2017 aerial photographs provided by Google Earth. Soil map units within the drainage area were obtained from the USDA, Natural Resources Conservation Service, Web Soil Survey. The output from the Web Soil Survey, including a list of the soil units in the drainage area, can be viewed in Appendix II. See Figures 1 and 2 in Appendix I for the location of the Cook Creek watershed on a topographic map and aerial photograph, respectively.

The land use and soil map units were used to determine composite curve numbers (CN) for the entire drainage area and for partial drainage areas ending at each stream crossing. The curve number used for the entire drainage area is 65.92. Curve numbers of 62.83, 61.40, and 65.33 were used for the portions of the drainage area draining to bridges 1, 2, and 3, respectively. Times of concentration were calculated for the entire drainage area and each partial drainage areas. Lag times were computed by multiplying the time of concentration by 0.6. The curve number and time of concentration calculations can be viewed in Appendix II.

3.0 STREAM FLOWS

Stream flows were estimated for the 2 year, 25 year, 50 year, and 100 year recurrence intervals. Precipitation depths for different durations of each recurrence interval were obtained from the *Rainfall Frequency Atlas of the Midwest* published by the National Weather Service and the Illinois State Water Survey in 1992. Precipitation and runoff parameters were used to develop a HEC-1 model for each bridge watershed. A critical duration analysis was performed to determine the duration that produces the highest stream flow for each recurrence interval. The 2, 3, 6, 12, and 24 hour durations were evaluated. The 2-, 3-, and 6-hour durations were distributed according to the Huff 1st quartile distribution, the 12-hour duration was distributed according to the Huff 2nd quartile distribution, and the 24-hour duration was distributed according to the Huff 3rd quartile distribution. The following Table 1 lists the precipitation depths used in the critical duration analysis. Table 2 lists the resulting flows, in cubic feet per second (cfs), for the different storm durations.

Table 1. Precipitation Depths for Each Interval and Duration.

Duration	Precipitation Depth (in.)			
(hours)	2-Year	25-Year	50-Year	100-Year
2	2.20	3.55	4.00	4.44
3	2.40	4.00	4.44	4.96
6	2.80	4.79	5.31	5.71
12	3.25	5.48	6.00	6.65
24	3.80	6.41	7.06	7.40

Table 2. Flows from Critical Duration Analysis.

Bridge	Duration (hours)	Flow (cfs) 2-Year	25-Year	50-Year	100-Year
1	2	508	**2143**	**2856**	**3624**
	3	509	2099	2722	3427
	6	439	1799	2241	2597
	12	516	1723	2042	2457
	24	**572**	1528	1785	1922
2	2	221	**1182**	**1623**	**2111**
	3	235	1169	1561	2011
	6	214	1027	1309	1538
	12	261	1026	1236	1510
	24	**322**	952	1126	1218
3	2	174	**850**	**1156**	**1492**
	3	181	837	1106	1412
	6	158	725	915	1068
	12	191	710	850	1031
	24	**228**	646	760	821

Bold values represent the highest flows per recurrence interval and duration.

4.0 FLOOD LEVELS

A HEC-RAS model was developed for the stretch of Cook Creek from US Highway 65 to Bull Creek. A topographic map of this area was developed using LiDAR ground points. This topographic map was used to generate cross sections along the stream reach that were used in the HEC-RAS model. The geometry of the three bridges was input into the model along with the 25, 50, and 100 year flows discussed in Section 3.0. Figure 3 in Appendix I shows the topographic contours and cross section locations along the reach of Cook Creek modeled in HEC-RAS. Included with this report is a CD containing the HEC-1 and HEC-RAS files used during this study.

5.0 BRIDGE HYDRAULICS

The hydraulic performance of the two culvert stream crossings was performed using AutoCAD Civil 3D Hydraflow Express software. Hydraflow Express uses the methods outlined in *Hydraulic Design of Highway Culverts* published by the Federal Highway Administration. Additionally, the hydraulic analysis included culvert and girder bridge replacement scenarios for passing the 25, 50, and 100 year recurrence intervals. A summary of the results of the hydraulic analysis is presented in the following sections.

5.1 Bridge 2

The hydraulic analysis of Bridge 2 indicates that the maximum flow through the pipe before overtopping the roadway is approximately 325 cfs. This culvert will pass the 2 year storm, but will overtop during the 25, 50, and 100 year storms. A performance curve for the existing culvert is included in Appendix III.

Additional 6-feet diameter arch culverts were added to the model to observe their ability to handle the higher flows. It took four culverts to pass the 25-year storm without overtopping, but could not pass the 50 and 100 year storms.

Various concrete box culverts were modeled. Two 6'x8' box culverts nearly passed the 25 year storm. Three 6'x8' box culverts pass the 25 year and 50 year storms. It took four 6'x8' box culverts to pass the 100 year storm.

Various girder bridge spans were simply modeled with Manning's equation as a rectangular channel. With bedrock present in the floor of the stream and assuming that the road grade will not change, a 2 feet thick bridge deck will allow for a channel height of 8 feet. Table 3 shows the different spans required to pass, without obstruction, the predicted flows of the 25-, 50-, and 100-year storm recurrence intervals under this simple model.

Table 3. Bridge 2 Estimated Bridge Spans for Various Storm Events

Span (ft)	Modeled Flow Capacity (cfs)	Storm Frequency	Predicted Flow (cfs)
18	1272	25-yr	1182
22	1644	50-yr	1623
27	2121	100-yr	2111

A HEC-RAS model was then developed with a girder bridge with a 27 feet span at the location of Bridge 3. The HEC-RAS model indicated that simple open channel modeling did not adequately predict the span that would pass the flow from the 100-year recurrence interval. The bridge span in the HEC-RAS model was progressively widened until the girder bridge would pass the flow from the 100-year recurrence interval with at least 1-foot of freeboard. The resulting span was 31 feet.

See Figures 5 and 6 in Appendix I for cross sections showing the upstream and downstream sections of Bridge 2 under existing conditions and with a hypothetical girder bridge with a 31' span, respectively. Figures 9 and 10 show the HEC-RAS stream profiles of the areas of Bridges 2 and 3 under the existing model and the girder bridge model, respectively.

5.2 Bridge 3

The hydraulic analysis of Bridge 3 indicates that the maximum flow through the pipe before overtopping the roadway is approximately 250 cfs. This culvert will pass the 2 year storm, but will overtop during the 25, 50, and 100 year storms. A performance curve for the existing culvert is included in Appendix III.

Additional 6-feet diameter arch culverts were added to the model to observe their ability to handle the higher flows. It took four culverts to pass the 25-year storm without overtopping, but could not pass the 50 and 100 year storms.

Various concrete box culverts were modeled. Two 6'x8' box culverts passed the 25 year storm. Three 6'x8' box culverts pass the 25 year and 50 year storms. It took four 6'x8' box culverts to pass the 100 year storm.

Various girder bridge spans were simply modeled with Manning's equation as a rectangular channel. With bedrock present in the floor of the stream and assuming that the road grade will not change, a 2 feet thick bridge deck will allow for a channel height of 6 feet. Table 4 shows the different spans required to pass, without obstruction, the predicted flows of the 25-, 50-, and 100-year storm recurrence intervals under this simple model.

Table 4. Bridge 3 Estimated Bridge Spans for Various Storm Events

Span (ft)	Modeled Flow Capacity (cfs)	Storm Frequency	Predicted Flow (cfs)
20	907	25-yr	850
25	1187	50-yr	1156
31	1530	100-yr	1492

A HEC-RAS model was then developed with a girder bridge with a 31 feet span at the location of Bridge 3. The HEC-RAS model indicated that a 31 feet span girder bridge will pass the flow from the 100-year recurrence interval with at least 1-foot of freeboard.

See Figures 7 and 8 in Appendix I for cross sections showing the upstream and downstream sections of Bridge 2 under existing conditions and with a hypothetical girder bridge with a 31' span, respectively. Figures 9 and 10 show the HEC-RAS stream profiles of the areas of Bridges 2 and 3 under the existing model and the girder bridge model, respectively.

6.0 CULVERT HYDRAULICS

The hydraulic performance of three of the five culverts between Bridges 1 and 2 was performed using AutoCAD Civil 3D Hydraflow Express software. Hydraflow Express uses the methods outlined in *Hydraulic Design of Highway Culverts* published by the Federal Highway Administration. Additionally, the hydraulic analysis included culvert replacement scenarios for passing the 25, 50, and 100 year recurrence intervals. A summary of the results of the hydraulic analysis is presented in the following sections. The locations of these culverts can be viewed on Figure 4 in Appendix I. Historically, problems with water overtopping the roadway and causing erosion has occurred at Culverts 1, 4, and 5. Each of these culverts pass stormwater from the surrounding valleys into Cook Creek.

Flow at each culvert was determined using the methods outlined in Section 3.0. Table 5 lists the resulting flows, in cubic feet per second (cfs), for the different storm durations.

Table 5. Flows from Critical Duration Analysis.

Culvert	Duration (hours)	Flow (cfs) 2-Year	25-Year	50-Year	100-Year
1	2	**24**	**101**	**137**	**175**
	3	21	95	122	152
	6	19	73	90	103
	12	22	68	80	95
	24	22	58	67	72
4	2	**1**	**5**	**7**	**9**
	3	1	5	6	8
	6	1	4	4	5
	12	1	3	4	5
	24	1	3	3	3
5	2	**92**	**384**	**517**	**660**
	3	83	363	470	588
	6	71	285	350	401
	12	85	266	313	373
	24	88	228	265	285

Bold values represent the highest flows per recurrence interval and duration.

6.1 Culvert 1

Culvert 1 is a 24” diameter corrugated metal pipe (CMP) with approximately 2 feet of cover. The hydraulic analysis of Culvert 1 indicates that the maximum flow through the pipe before overtopping the roadway is approximately 28.7 cfs. This culvert will pass the 2 year storm, but will overtop during the 25, 50, and 100 year storms.

A series of 30-inch culverts set at the same flowline as the existing CMP were modeled to observe their ability to handle the higher flows. It took four 30-inch culverts to pass the 100 year storm.

6.2 Culvert 4

Culvert 4 is a 30” diameter CMP with approximately 2 feet of cover. The hydraulic analysis of Culvert 4 indicates that it is capable of passing the flows from the 100 year storm from the area draining to the culvert.

It appears that flow over the roadway at Culvert 4 is due to water backing up at Culvert 5 and entering the drainage area of Culvert 4. Improving the flow at Culvert 5 should eliminate the flow of water over the roadway at Culvert 4.

6.3 Culvert 5

Culvert 5 is a 4-feet diameter corrugated metal pipe (CMP) with approximately 1.5 feet of cover. The hydraulic analysis of Culvert 5 indicates that the maximum flow through the pipe before overtopping the roadway is approximately 115 cfs. This culvert will pass the 2 year storm, but will overtop during the 25, 50, and 100 year storms.

A series of additional 4-feet diameter culverts set at the same flowline were modeled to observe their ability to handle the higher flows. Four 4-feet diameter culverts pass the 25 year storm, but will overtop during the 50, and 100 year storms.

Various concrete box culverts were also modeled. Four 4'x4' box culverts passed the 50 year storm. It took four 4'x5' box culverts to pass the 100 year storm.

7.0 CONCLUSIONS

A comprehensive runoff model of the Cook Creek drainage basin was developed to model the flooding characteristics of the section of Cook Creek between U.S. Highway 65 and Bull Creek. The HEC-RAS model for current conditions appears to be consistent with what has been observed in Cook Creek valley during recent heavy precipitation events. Replacing the existing culverts at Bridges 2 and 3 in the HEC-RAS model with 31' span girder bridges passed the flows from a 100-year recurrence interval storm with at least one foot of freeboard.

Additionally, hydraulic analyses were conducted on three culverts that pass stormwater from the surrounding valleys into Cook Creek. Replacement scenarios for each of these culverts are summarized in Section 6.0.

Please note that this analysis of potential bridge and culvert improvements is rudimentary and intended to give a general indication of what types of structures will be necessary to pass a design flood. Bridges were modeled with a minimum freeboard of one foot and replacement culverts were modeled for stormwater to not overtop the roadway.

This evaluation was performed using publically available data and common methods of modeling hydrology and hydraulic structures. We have employed accepted stormwater engineering procedures, and our opinions and conclusions are made in accordance with generally accepted principles and practices of these professions. The contents of this report are valid as of the date of preparation. However, changes in the condition of the site property can occur over time as a result of either natural processes or human activity. Should such changes occur, it might be necessary to re-evaluate some of the opinions and conclusions of this report.

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Donald Nowack, P.E., R.G. Date