Hazen *Memorandum*

June 28, 2023

To: City of Fayetteville

From: Bill Price, Senior Associate

Re: Beaver Creek Tributary B Detention Evaluation – Effects of PS01 and PS05

This memorandum supplements the previously submitted *Beaver Creek Tributary B Detention Evaluation* draft report (Report) dated June 15, 2023. The purpose of this document is to present additional information regarding implementation of Proposed Solutions (PSs) 01 (Rockford Drive) and 05 (Rhemish Drive), both of which are currently in detailed design. As summarized in the Report, the City of Fayetteville (City) contracted Hazen and Sawyer (Hazen) to evaluate potential impacts from implementation of PSs throughout the Beaver Creek Tributary B (BCTB) watershed and to assess detention alternatives to mitigate identified impacts. Of particular interest to the City were impacts to Arran Lakes West Dam (ALWD). The following sections present the effects and impacts of implementing PSs 01 and 05, based upon detailed design modeling outputs (analyses presented in the previous Report were based on modeling performed as part of the Beaver Creek 3 watershed study).

Methodology

Outflow hydrographs were extracted from each design project's InfoWorks ICM model for both existing and proposed storm drain infrastructure scenarios (with future rainfall conditions). The existing infrastructure conditions hydrographs were then subtracted from the proposed condition hydrographs to compute the change in outflows. This method was used to simulate changes in flows from the PSs while maintaining hydrology for the remainder of the PS's parent subbasin modeled in HEC-HMS. The 10- and 100-year, 24-hour storms were then simulated in HEC-HMS to evaluate potential impacts.

Typical design projects are most likely to include only assessment of pre- and post-project outflows, without detailed analyses of downstream receiving waters. Based upon this standard, both projects (and all projects presented in the Report) may be required to implement detention such that post-project discharge does not exceed existing conditions. However, this approach does not account for volumetric and hydrograph timing changes which may indicate that projects do not affect receiving stream flowrates, even with higher post-project system outflows. Further, such analyses may also indicate that local detention actually increases downstream flows if the local hydrograph is delayed such that it further overlaps with the receiving stream hydrograph. In order to examine each of these approaches, assessments based on system outflows and BCTB discharges were performed for both projects. Tributary flow changes were identified in the HMS model reaches immediately downstream of the project locations. The model was also used to compare ALWD water surface elevations (WSEs) for pre- and post-project implementation.

In addition to assessing impacts, local detention evaluations were also performed based upon the 10-year pre- and post-project hydrographs. These data were used to compute preliminary detention volumes and outlet sizes, which were then optimized via routing computations. Each facility was sized to ensure post-

project discharges did not exceed pre-project. However, each was further optimized to reduce or eliminate downstream impacts noted in model results. As explained in the Report, local detention facilities were designed with the following assumptions:

- Facilities assumed to be dry detention basins
- Maximum basin depth was limited to 5-feet in the 10-year, 24-hour event
- Basins were assumed to have vertical sides
- Tailwater influences were not considered
- Computed minimum detention footprints were doubled to account for grading, embankment tops / safety benches, building setbacks, and additional area for increased storage of larger events to ensure safe passage

Regional detention (via improvements at ALWD or Bailey Lake Dam (BLD)) was not reassessed during this evaluation as the dam improvements identified in the Report would also apply to this analysis (e.g. overtopping protection at ALWD or rehabilitation of BLD).

Impact Evaluation

As summarized in **Table 1** (10-year) and **Table 2** (100-year), downstream discharges in BCTB may increase by ≤ 10-cubic feet per second (cfs) in the 10-year storm (total flow of 360-cfs) and up to 112-cfs in the 100-year (total flow of 900-cfs). Similarly at ALWD, WSEs increased by 0.2-feet and < 0.1-feet, in the 10- and 100-year storms. These relatively small Lake level increases lead to higher dam outflows as well: up to 4-cfs and 103-cfs in the two storms, respectively.

Specific to individual PSs, the Rockford Drive improvements were predicted to cause both 10-year and 100-year peak flow increases in the Tributary (8- and 109-cfs, respectively). However, the Rhemish Drive project did not increase downstream flows for either storm. This was due to the storm drainage improvements discharging flows more quickly, causing a steepening in the outflow hydrograph and eliminating interaction with the peak of the BCTB hydrograph. The combination of the two projects yielded similar flow increases as implementation of Rockford Drive (10- and 112-cfs increases, respectively).

Both projects were shown to have limited impacts at ALWD with ≤ 0.2-foot WSE increases in both storms, assuming implementation of only one project. Installation of both improvement projects was shown to have cumulative effects of a 0.2-foot and < 0.1-foot WSE increase in the 10- and 100-year storms, respectively. Discharge increases from the dam were relatively small in the 10-year storm, as Lake levels in this event (pre- and post-project) do not overtop the dam and thus are routed through the principal spillway. However, 100-year increases were relatively larger even with fairly small WSE increases. This was due to the dam overtopping in this storm (both pre- and post-project).

Based upon this assessment, implementation of these projects may increase BCTB flows by 14-percent, primarily due to the Rockford Drive improvements. Similarly, ALWD may see slightly higher WSEs and thus discharges, again mostly due to Rockford Drive, though the Rhemish Drive project does influence levels at the Dam as well. These flow and level changes are within a reasonable margin of error for this study and thus possibly negligible; however, the results as computed, are presented herein for the City's information and policy-making decisions.

Table 1: Summary of 10-Year Storm Impacts from Proposed Solution Implementation

Scenario	Result	BCTB at PS	ALWD
Existing	**Discharge (cfs)**	350 (PS01) 305 (PS05)	425
	WSE (ft)	-	152.2
PS01	**Discharge (cfs)**	**358**	**428**
	Change (cfs)	8	3
	WSE (ft)	-	**152.4**
	Change (ft)	-	0.2
PS05	**Discharge (cfs)**	305	**426**
	Change (cfs)	0	1
	WSE (ft)	-	**152.3**
	Change (ft)	-	< 0.1
PS01 + PS05	**Discharge (cfs)**	**360**	**429**
	Change (cfs)	10	4
	WSE (ft)	-	**152.4**
	Change (ft)	-	0.2

Note: *Change* values in orange, bold text indicate an increase compared to existing infrastructure conditions.

Table 2: Summary of 100-Year Storm Impacts from Proposed Solution Implementation

Scenario	Result	BCTB at PS	ALWD
Existing	**Discharge (cfs)**	788 (PS01) 657 (PS05)	1,103
	WSE (ft)	-	155.6
PS01	**Discharge (cfs)**	**897**	**1,176**
	Change (cfs)	109	76
	WSE (ft)	-	**155.6**
	Change (ft)	-	< 0.1
PS05	**Discharge (cfs)**	657	**1,129**
	Change (cfs)	0	26
	WSE (ft)	-	**155.6**
	Change (ft)	-	< 0.1
PS01 + PS05	**Discharge (cfs)**	**900**	**1,206**
	Change (cfs)	112	103
	WSE (ft)	-	**155.6**
	Change (ft)	-	< 0.1

Note: *Change* values in orange, bold text indicate an increase compared to existing infrastructure conditions.

Detention Evaluation

Local detention facilities were sized to mitigate 10-year impacts in BCTB and at ALWD. Efforts initially focused on minimizing storage footprints to reduce required property acquisitions; however, upon simulating detained outflows in HMS, changes to hydrograph timings necessitated increasing local attenuation to mitigate remaining downstream impacts, discussed below.

The detention facility for Rockford Drive was initially sized as a 1.1-acre basin with a 40-inch outlet orifice that reduced the system's peak outflow to from 167- to 77-cfs, below the existing discharge of 78-cfs. The associated storage volume, 5.3-acre-feet, was similar to that of a preliminary detention analysis performed by the team designing the Rockford Drive project (5.0-acre-feet). However, the 1.1-acre design did not fully mitigate impacts at ALWD due to delaying the system's outflows, causing the system's and Tributary's hydrographs to further overlap (**Figure 1**). Optimization of the facility determined a 1.4-acre basin and 32-inch outlet successfully mitigated all impacts to ALWD, as summarized in **Table 3**. Comparison to the PS01 detention facility presented in the Report, this design is marginally smaller by approximately 5,000-square feet. As such the cost, $4,600,000 (all values presented herein are in 2021 dollars), may be slightly lower by approximately $200,000.

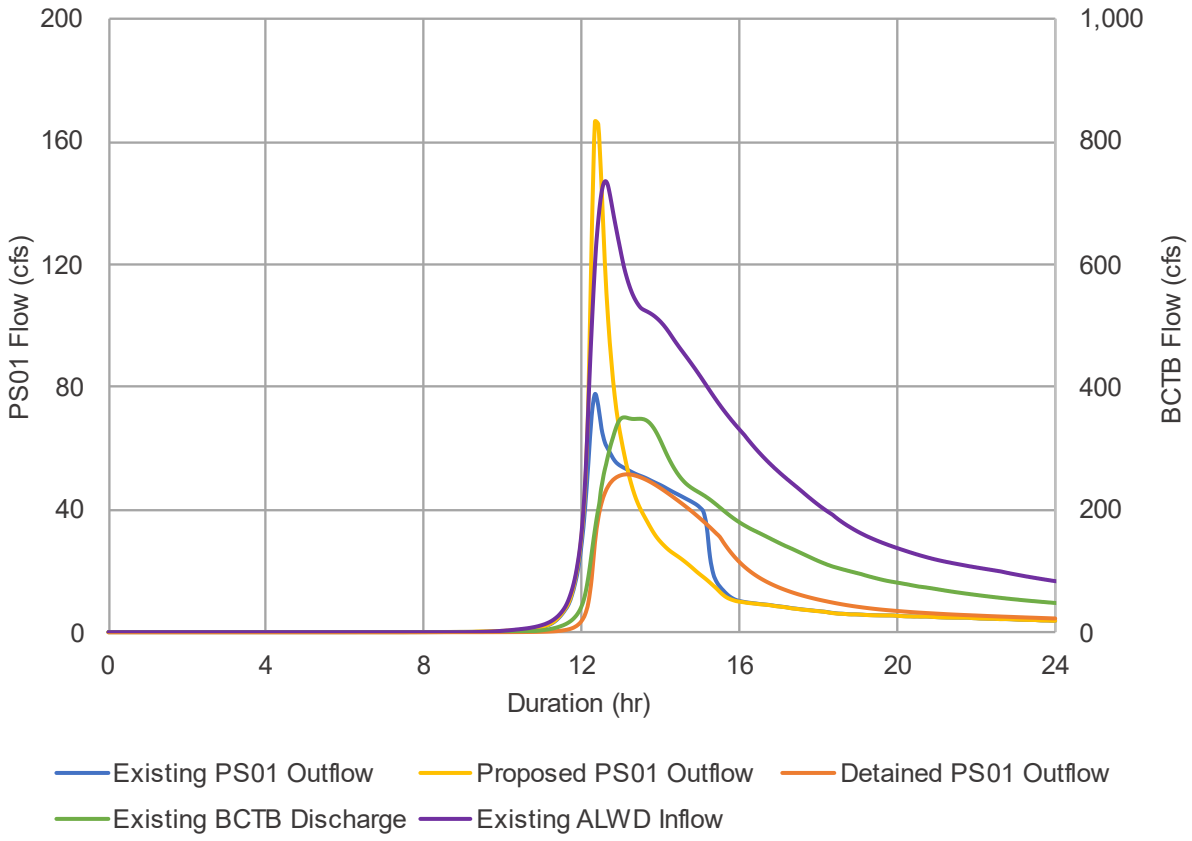

Figure 1: PS01 Hydrographs

Table 3: Summary of Local Detention Facility Conceptual Design

PS	10-Year Discharge (cfs)			Detention Basin			
	Existing	Proposed	Detained	Outlet Size (in)	Computed Storage Area (ac)	Computed Storage Volume (ac-ft)	Escalated Storage Area (ac)
PS01	78	167	51	32	1.4	6.9	2.8
PS05	66	141	40	28	0.8	3.9	1.6

Similarly, a basin for Rhemish drive was originally sized as a 0.6-acre facility with a 36-inch outlet that decreased system outflows (141- to 62-cfs and below the existing flow of 66-cfs) but did not mitigate all downstream impacts due to hydrograph timing changes (**Figure 2**). Optimization yielded a 0.8-acre basin and 28-inch outlet, which is slightly larger than the facility presented in the Report (**Table 3**). As such, the cost of the optimized basin may be approximately $200,000 more than the $4,100,000 estimate provided in the Report.

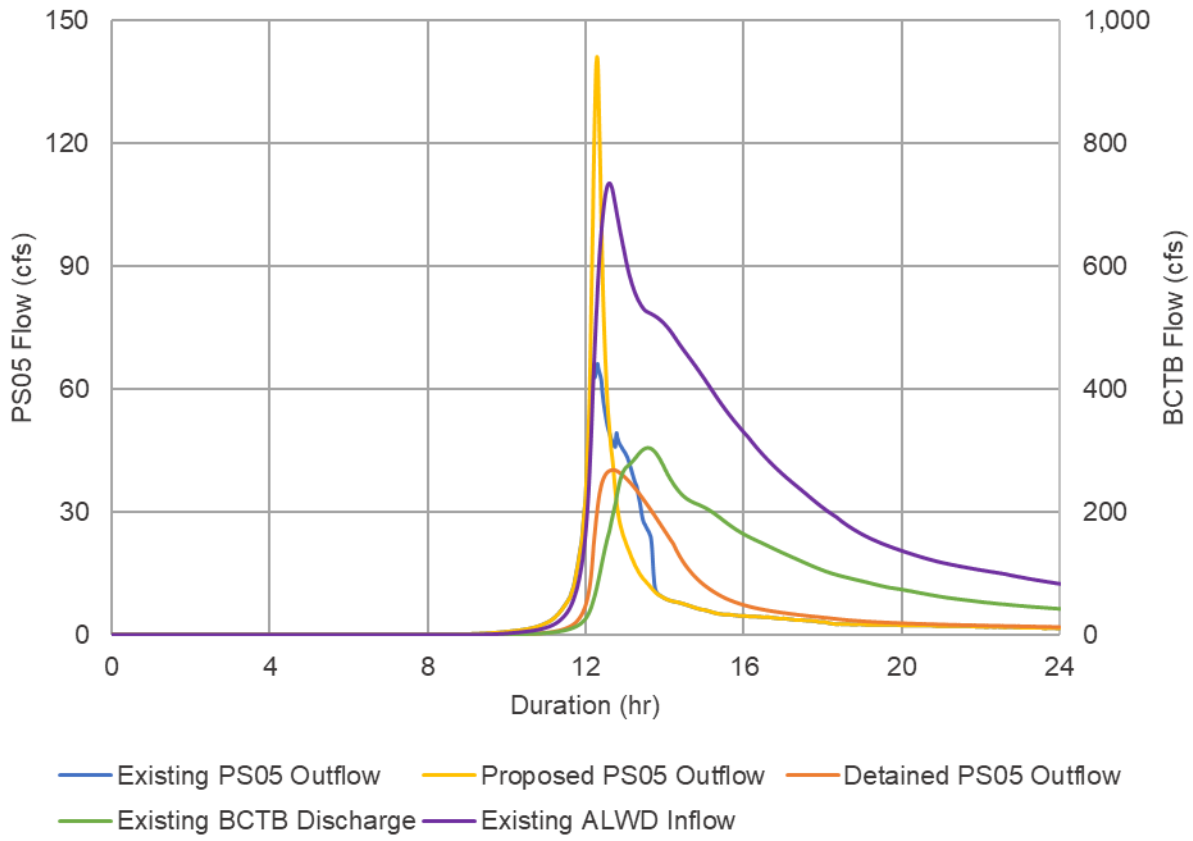

Figure 2: PS05 Hydrographs

Conclusions

Implementation of PS01 (Rockford Drive) and PS05 (Rhemish Drive) may cause limited increases to BCTB discharges, ALWD WSEs, and also ALWD outflows. An evaluation of impacts estimated that Tributary flows may increase by up to 10-cfs in the 10-year storm and 112-cfs in the 100-year. Impacts at ALWD may include a 0.2- and < 0.1-foot WSE increase as well. The small increases in Lake levels is likely to also cause a corresponding increase in dam discharges (4- and 103-cfs respectively). Overall, these impacts are relatively small and within a reasonable margin of error for this study and regular variability in storm characteristics. Though small, implementation of such drainage system improvements is likely to have some level of impact at ALWD. While no level of service (LOS) changes are expected for the facility, the depth and frequency of overtopping may slightly change based upon the analyses presented above.

As presented in the Report, protection of ALWD from these impacts may be best accomplished via one of two means: (1) implementation of local detention at PS locations or (2) installation of overtopping protection at ALWD. An evaluation utilizing model hydrographs from detailed design projects estimated local detention facility sizes of 2.8- and 1.6-acres (escalated areas) for PS01 and PS05, respectively. Based upon unit costs develop for the City's watershed planning efforts, the total cost of these two facilities may be $8,700,000, largely driven by property acquisition and earthwork costs. Regional detention (e.g. overtopping protection of ALWD) was not reassessed for this memorandum as the conclusions and design are unchanged from the previous study. Utilizing the same cost data, overtopping protection of ALWD was estimated to cost $8,500,000 (plus an additional $1,200,000 for improving the Carloway Drive culvert), as presented in the Report.

The overall findings and conclusions from this and the prior study are the same – overtopping protection of ALWD likely presents the most direct, effective, and economical solution to protect the facility from potential flow changes. Implementation of local detention may require facilities at each project location and do not provide direct benefit to ALWD. Instead, protection of the Dam is reliant upon design, construction, and maintenance of each detention facility. Alternatively, overtopping protection directly protects the facility and is largely unaffected by changes to secondary system drainage systems.