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PUBLIC SERVICES

Beaver Creek Tributary B Detention Evaluation

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List of Abbreviations and Acronyms

Abbreviation	Definition	Abbreviation	Definition
1D	One-Dimensional	HMR	Hydrometeorological Report
2D	Two-Dimensional	HMS	Hydrologic Modeling System
ACB	Articulated Concrete Block	HSG	Hydrologic Soil Group
ALW	Arran Lakes West	IPaC	Information for Planning and Conservation
ALWD	Arran Lakes West Dam	LOS	Level of Service
BC	Beaver Creek	NAD83	North American Datum of 1983
BCTB	Beaver Creek Tributary B	NAVD88	North American Vertical Datum of 1988
BL	Bailey Lake	NCAC	North Carolina Administrative Code
BLD	Bailey Lake Dam	NCDOT	North Carolina Department of Transportation
BV3	Beaver Creek (3)	NCDS	North Carolina Dam Safety
CA	Concern Area	NWP	Nationwide Permit
CMSM	Consultant Management and Standards Manual	PMP	Probable Maximum Precipitation
CPS	Culvert Proposed Solution	PS	Proposed Solution
CWA	Clean Water Act	PSD	Proposed Storm Drain
DAD	Depth-Area-Duration	PVC	Polyvinylchloride Pipe
DPS	Dam Proposed Solution	PWC	Public Works Commission
EAP	Emergency Action Plan	RAS	River Analysis System
EIF	Existing Infrastructure	SDF	Spillway Design Flood
ELU	Existing Landuse	SHPO	State Historic Preservation Office
ePCN	Electronic Pre-Construction Notification	US	United States
ERF	Existing Rainfall	USACE	United States' Army Corps of Engineers
FLU	Future Landuse	USFWS	United States Fish and Wildlife Service
FRF	Future Rainfall	WSE	Water Surface Elevation
HEC	Hydrologic Engineering Center		

Executive Summary

Through ongoing stormwater master planning efforts, the City of Fayetteville (City) has identified numerous flooding concerns and developed conceptual proposed solutions (PSs) to reduce the frequency and severity of inundation within many of the studied areas. However, the City also recognizes that while reducing local flooding, improvements to drainage systems throughout watersheds may result in higher discharges rates to receiving waters, thus causing or exacerbating downstream flooding. Given that concern, the City contracted Hazen and Sawyer (Hazen) to evaluate potential downstream impacts on Beaver Creek Tributary B (BCTB) due to simulated implementation of drainage system improvements within the Tributary's watershed. More specifically, the main concerns in this watershed are possible impacts to Arran Lakes West Dam (ALWD), located in the lower quarter of the basin, approximately 1-mile upstream of the confluence with Beaver Creek (BC). In addition to assessing impacts, the City has directed Hazen to evaluate potential implementation of detention practices to mitigate peak flow increases.

Evaluations began with assessing potential downstream flow increases as well as associated impacts. Overall, six of the 12 PSs located upstream of ALWD were determined to cause increased 10-year storm flows in BCTB. Additionally, all 12 may cause small (≤ 0.2-feet) incremental water surface elevation (WSE) increases at ALWD with a cumulative increase of 1-foot and 0.2-foot in the 10- and 100-year storms, respectively. These increases, however, do not result in a lowered level of service (LOS) for the dam, based upon standard recurrence intervals. In addition to the WSE changes at ALWD, implementation of the PSs may also cause a decrease in LOS at Carloway Drive (25-year to 10-year) and a private driveway to an electrical substation (5-year to 2-year). Flood frequency may also increase for two structures (7182 Silverston Court and 1936 Abbeydale Lane) in the 10-year storm and two (1924 and 1948 Abbeydale Lane) in the 100-year. All of these roadway and building impacts are located upstream of ALWD and Bailey Lake Dam (BLD), which is situated immediately upstream of ALWD.

Following determination of the effects and impacts, implementation of potential detention facilities was assessed considering both local and regional detention options. Local detention evaluations investigated the size and cost of constructing detention basins near the outfall of each PS location to mitigate peak flow increases prior to discharge into BCTB. Several simplifying assumptions were used to facilitate this portion of the evaluation, including:

- Storage facilities were 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 assessed improvements to ALWD or BLD with the goal of either mitigating flow increases or protecting ALWD from increased overtopping. Specifically, improvements included upsizing the ALWD spillway, rehabilitating BLD which is currently breached, and providing overtopping protection on ALWD without spillway improvements.

The local detention assessment estimated that basin footprints may range between 0.5- and 3.0 -acres (**Table ES-1**) with costs of $1,200,000 to $6,300,000 (total of $33,000,000) (**Table ES-2**). However, if only those PSs demonstrated to cause 10-year BCTB flow increases are considered, the total is $21,000,000. According to a benefit-cost analysis (BCA), per Federal Emergency Management Agency (FEMA) guidelines, the benefit-cost ratio is 0.85, which is the highest among alternatives considered in this study. The primary reason for this being the highest ratio is that local detention mitigates flow increases prior to discharging into BCTB, thus eliminating or reducing downstream impacts (roadway overtopping, structure flooding, and simulated dam failure due to overtopping).

Table ES-1: Local Detention Basin Sizing Summary

PS	Peak Discharge (cfs)			Outlet Orifice Size (in)	10-Year Storage Volume (ac-ft)	Total Required Area (acre)	Potential Available Open-Space (acre)
	Existing Infrastructure	Proposed Infrastructure (without Detention)	Proposed Infrastructure (with Detention)				
PS01	62	184	184	32	7.5	3.0	1.3
PS03	29	36	36	22	1.3	0.5	-
PS05	66	141	141	30	3.8	1.5	-
PS08	10	13	13	15	1.3	0.5	-
PS14	8	36	36	10	1.3	0.5	-
PS20	28	67	67	20	3.8	1.5	1.1
PS22	32	47	47	22	2.5	1.0	0.7
PS24	113	186	186	42	6.3	2.5	10+
PS26	36	57	57	24	1.3	0.5	-
PS28	24	29	29	19	1.3	0.5	-
PS29	74	192	192	33	5.0	2.0	-
PS31	27	166	166	20	8.8	3.5	-

Note: Rows in gray shading indicate PS likely to increase BCTB 10-year peak discharge without detention

Table ES-2: Local Detention Estimated Project Costs

PS[1]	Project Name	Project Cost[2]	PS[1]	Project Name	Project Cost[2]
PS01	Rockford Dr	$4,600,000	**PS22**	Graham Rd	$1,400,000
PS03	Hyannis Dr	$1,300,000	**PS24**	Raeford Rd	$2,300,000
PS05	Rhemish Dr	$4,200,000	**PS26**	Birchcreft Dr	$1,400,000
PS08	Carloway Dr	$1,700,000	**PS28**	Lakeridge Dr	$1,200,000
PS14	Stoneclave Pl	$1,900,000	**PS29**	Baywater Dr	$4,400,000
PS20	Manassas St	$2,100,000	**PS31**	Berriedale Drive	$6,300,000

[1] Rows in gray shading indicate PS likely to increase BCTB 10-year peak discharge without detention
[2] 2021 Values; presented as such for consistency with BV3 Study cost estimating tool; add 2.1% annual escalation for future values (per watershed planning program guidance)

Regional detention evaluations identified that mitigation of flow increases at ALWD via spillway improvements was likely to cause additional upstream WSE impacts due to increased attenuation. Further, such mitigation was shown to provide no direct downstream benefits as no impacts below the Dam were identified by this Study. While a cost for this improvement was developed and discussed later, this alternative was ultimately not recommended for consideration. Given the potential impacts and lack

of direct downstream benefits for this alternative, the primary benefit of regional detention was determined to be protection of ALWD from increased overtopping, and thus assumed failure, discussed below.

Protection of ALWD was assessed via two conceptual improvements: (1) rehabilitating BLD to mitigate peak flow increases at ALWD and (2) installation of overtopping protection on ALWD. The BLD alternative considered repair of the breached embankment and construction of a new riser-barrel spillway system. This concept was demonstrated to effectively mitigate peak flow increases; however, does necessarily increase WSEs upstream of the Dam. The original (pre-breach) spillway configuration and flood pool extents were unknown; however, inundation assessments indicated that no additional habitable buildings and three accessory structures were likely to be impacted compared to existing conditions. The second improvement, ALWD overtopping protection, reduces the risk of overtopping-related failure and thus directly benefits ALWD. All other alternatives (BLD rehabilitation and local detention) are located upstream and thus provide indirect and uncertain protection of ALWD. This protection is thereby reliant upon appropriate installation and maintenance of the upstream practices. Lastly, while the overtopping protection alternative does not mitigate increased flows, no direct impacts were determined to occur as a result.

The costs associated with the regional detention alternatives ranged between $8,500,000 and $12,900,000 (**Table ES-3**). However, these may be increased by up to $1,200,000 if the Carloway Drive culvert is upsized to maintain existing LOS. The BCA computed ratios of 0.49 and 0.67 for BLD rehabilitation and ALWD overtopping protection, respectively. The BLD alternative ratio is lower due to the relatively higher cost, while the benefits of either alternative are generally the same. Based upon these assessments, the regional detention alternative that best protects ALWD is overtopping protection.

Table ES-3: Regional Detention Estimated Project Costs

PS	Project Name	Project Cost[1]
DPS1	Arran Lakes West Dam Overtopping Protection	$8,500,000
DPS2	Arran Lakes West Dam Spillway Improvement	$10,300,000
DPS3	Bailey Lake Dam Rehabilitation	$12,900,000
CPS1	Carloway Dr	$1,200,000

[1] 2021 Values; presented as such for consistency with BV3 Study cost estimating tool; add 2.1% annual escalation for future values (per tool)

In consideration of the above findings, two alternatives appear to be best suited to either mitigate increased flows and / or protect ALWD from increase overtopping: (1) implementation of local detention or (2) installation of overtopping protection on ALWD. The former provides the most benefits as this alternative mitigates flow increases prior to entering BCTB and thus all associated downstream impacts. However, this does not directly address protection of ALWD and requires detention facilities at many, if not all, drain system improvement locations. The latter directly protects ALWD and is not reliant upon design, construction, and maintenance of numerous upstream detention facilities. **As such, based on the estimated project cost and technical evaluations presented herein, overtopping protection of ALWD provides the most direct, effective, and economical solution.** However, selection of this alternative must also consider other factors, such as risks inherent to owning and operating a *high hazard* dam, criticality of inspections and maintenance, and development and updating of an emergency action plan. Further, implementation of this alternative may also require upsizing the Carloway Drive culvert.

1. Project Background

Through ongoing stormwater master planning efforts, the City of Fayetteville (City) has identified numerous flooding concerns and developed conceptual solutions to reduce the frequency and severity of inundation within many of the studied areas. However, the City also recognizes that while reducing local flooding, improvements to drainage systems throughout watersheds may result in higher discharges rates to receiving waters, thus causing or exacerbating downstream flooding. Given that concern, the City contracted Hazen and Sawyer (Hazen) to evaluate potential downstream impacts on Beaver Creek Tributary B (BCTB) due to simulated implementation of drainage system improvements within the Tributary's watershed. More specifically, primary concerns in this watershed are possible impacts to Arran Lakes West Dam (ALWD), located in the lower quarter of the basin, approximately 1-mile upstream of the confluence with Beaver Creek (BC). In addition to assessing impacts, the City has directed Hazen to evaluate implementation of detention practices to mitigate peak flow increases.

1.1 Project Area

The BCTB watershed is located approximately 8-miles southeast of downtown Fayetteville and is generally oriented from northwest to southeast, beginning at South Reilly Road and terminating at the confluence with Beaver Creek approximately 800-feet southwest of Fisher Road (**Figure 1-1**). The predominant land use is residential, though relatively small areas of institutional (school campus), commercial, open space, and forest are located throughout the basin. Closed-conveyance drainage systems (secondary systems) are also present throughout the watershed and serve to collect and convey runoff to BCTB. Additional data and descriptions of existing watershed conditions are provided in the Beaver Creek (3) Watershed Study Report (BV3 Study), discussed in **Section 1.2**.

This study of BCTB begins approximately 450-feet south of Raeford Road, adjacent to the Manassas Street – Graham Road intersection, at the outfall of a large secondary drainage system. The stream continues south-southeast through culvert crossings at Carloway Drive (**Picture 1-1**), Strickland Bridge Road (**Picture 1-2**), a private driveway to an electrical substation (**Picture 1-3**), and Horsepen Branch (**Picture 1-4**). The tributary then passes through Bailey Lake (BL), approximately 4,300-feet southeast of Horsepen Branch. The Lake is impounded by Bailey Lake Dam (BLD), a privately-owned earthen facility located between the two segments of Windlock Drive located on either side of the tributary. The dam is breached, which appears to have occurred between 1993 and early 1999 (**Picture 1-5**). A small pool remains in the former impoundment due to beaver activity. The embankment is heavily wooded, but overall shows no other signs of failure; however, the side slopes of the breach are fairly steep and exhibit areas of concentrated erosion. The breach bottom is formed of riprap / medium sized stone and also shows no signs of active erosion. An 8-inch polyvinylchloride (PVC) water main owned by the Fayetteville Public Works Commission (PWC) runs through the entire length of dam, including an aerial crossing that traverses the breach. Additional information regarding BLD is provided in **Table 1-1**. Note that information presented in this table has been revised based upon data collection and analyses performed as part of this Study.

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STORMWATER SERVICES

BEAVER CREEK TRIBUTARY B
DETENTION EVALUATION

OVERALL PROJECT MAP

DATE: JUNE 2023

FIGURE: 1-1

PATH: O:\31537-000\31537-001\GIS\PROJECTS\31537-001_WDPV3.APRX

REFERENCE: ROAD NAMES (CUMBERLAND COUNTY), AERIAL IMAGERY (NC ONEMAP, NC CENTER FOR GEOGRAPHIC INFORMATION AND ANALYSIS, NC 911 BOARD)

Picture 1-1: Carloway Drive Culvert

Picture 1-2: Strickland Bridge Road Culvert

Picture 1-3: Electrical Substation Culvert

Picture 1-4: Horsepen Branch Culvert

Picture 1-5: Bailey Lake Dam

Table 1-1: Revised Dam Inventory Information

Dam Name	Arran Lakes West Dam	Bailey Lake Dam
State Identification Number	CUMBE-067	CUMBE-079
National Identification Number	NC02141	NC02153
County	Cumberland	Cumberland
Jurisdictional Status	Jurisdictional	Jurisdictional
Dam Status	Impounding	Breached
Hazard Class	High	High
Dam Type	Earth	Earth
Dam Purpose	Recreation	Recreation
Year Constructed	1977	*Unknown*
Regional Office	Fayetteville	Fayetteville
Quadrangle	Fayetteville	Fayetteville
Latitude and Longitude	35.0098, -78.9876	35.0154, -78.9942
River or Stream	Beaver Creek Tributary B	Beaver Creek Tributary B
River Basin	Cape Fear	Cape Fear
Nearest Downstream City	Hope Mills (2-mi)	Hope Mills (2-mi)
Structural Height (ft)	16.4	18.3
Normal Freeboard (ft)	6.7	16.0
Hydraulic Height (ft)	2.0	9.6
Upstream Slope	4H:1V	2.2H:1V
Downstream Slope	2.75H:1V	4H:1V
Low Flow Requirement (cfs)	N/A	N/A
Maximum Spillway Capacity (cfs)	440	N/A
Normal Pool Elevation (ft)	148.35	159.0
Drainage Area (ac)	1,530	1,070
Surface Area (ac)	10.6	1.1
Normal Pool Capacity (ac-ft)	52.4	0.0
Maximum Impoundment Capacity (ac-ft)	177	161
Presence of Bottom Drain	Yes (Operability Unknown)	None
Last Inspection	01/13/2021	03/17/2021
Primary Spillway	Dual 6’ Diameter Concrete Risers with 48” RCP Barrels	None / Breached
Auxiliary Spillway	None	None

Immediately downstream of BLD is the headwater area of Arran Lakes West (ALW) containing braided marsh. The normal pool area of the Lake begins approximately 1,300-feet further downstream. ALWD is a privately-owned earthen embankment with a public (City) roadway on the top of dam and an approximate 10.6-acre impoundment (**Picture 1-6**). The principal spillway consists of dual 6-foot diameter risers and 48-inch barrels. No formal auxiliary spillway is present, though a low area on the left (East) end of the embankment functionally serves as an overflow spillway. The embankment is in fair condition, with no signs of erosion or settlement; however, woody vegetation on the upstream shoreline and heavy tree growth on the downstream embankment face are present. Additional information regarding ALWD is provided in **Table 1-1**

Picture 1-6: Arran Lakes West Dam

Downstream of ALWD, BCTB continues southeast, alternating between channelized segments, woody braided wetland, and braided marsh. Approximately 3,000-feet downstream of the dam are apparent remnants of breached embankment (**Picture 1-7**) and the final culvert crossing, Fisher Road (**Picture 1-8**), is located another 600-feet downstream, near the confluence with BC (approximately 800-feet further downstream in a woody braided wetland).

Picture 1-7: Breached Embankment

Picture 1-8: Fisher Road Culvert

1.2 Previous Studies

As mentioned previously, the BCTB watershed was studied as part of the City's watershed master planning efforts under the Beaver Creek (3) Watershed Master Plan. This study analyzed numerous secondary systems as well as several culverts along BCTB to delineate and evaluate concern areas (CAs), which were then prioritized based upon severity of flooding impacts. The City then selected a subset of CAs for additional study, including development of conceptual improvements, called proposed solutions (PSs). Ultimately, 23 PSs were identified in the BV3 Study, 12 of which are located upstream of ALWD and are included in this detention evaluation (PS locations shown in **Figure 1-1**, above).

1.3 Existing Conditions

Flooding concerns associated with secondary systems in the BCTB watershed are presented in detail within the BV3 Study; however, that study included only a short segment of the BCTB primary system. As such, information regarding secondary system flooding may be obtained from the BV3 Study report, while a detailed assessment of flooding along the entire primary system tributary is presented herein. Runoff hydrographs used in this evaluation were obtained from the BV3 Study, as outlined in **Section 2**, except for those pertaining to future landuse conditions, discussed later.

1.4 Evaluation Methodologies

This study builds upon the BV3 Study, including use of hydrologic and hydraulic data and models generated for the master plan. Efforts under this current study may be generally divided into two categories: (1) local detention and (2) regional detention. Each approach is aimed to address potential peak flow increases due to implementation of the selected PSs. More specifically, local detention is focused on simulated implementation of detention facilities at each selected PS location. Regional detention considers improvements to ALWD and / or BLD to protect ALWD from increased flows by either mitigating flow increases or armoring the ALWD embankment to protect against overtopping failure. The following sections outline the data and methodologies used in these detention evaluations.

1.4.1 General Standards

Three computer models were used in this evaluation to perform various hydrologic and hydraulic computations. Local detention evaluations utilized the BV3 Study's InfoWorks ICM model (version 2021.9.0), which includes both hydrologic and hydraulic calculations. Regional detention analyses, as well as assessing impacts on BCTB from implementing PSs without detention, utilized United States' Army Corps of Engineers' (USACE) Hydrologic Engineering Center (HEC) Hydrologic Modeling System (HMS) version 4.10 and River Analysis System (RAS) version 6.3.1. HEC-HMS and HEC-RAS models for this detention evaluation were developed beyond the extent and nature of those models developed and utilized for the BV3 Study, as discussed later in this report. Spatial analyses were conducted using the North Carolina State Plane, North American Datum of 1983 (NAD83) horizontal coordinate system. Vertical data were referenced to the North American Vertical Datum of 1988 (NAVD88).

1.4.2 Precipitation

Evaluations considered two types of precipitation: (1) recurrence interval based design storms (e.g., 10-year, 24-hour) and (2) the probable maximum precipitation (PMP). The former was used to evaluate both local and regional detention opportunities, while the latter was necessary to assess overall dam improvements to ensure compliance with North Carolina Dam Safety (NCDS).

Precipitation depths and temporal distributions for recurrence interval design storms were obtained from the BV3 Study, including both existing rainfall (ERF) and future rainfall (FRF). Additional information regarding precipitation for these events is presented in the City's Consultant Management and Standards Manual (CMSM). Depths and distributions for PMP storms were based upon Hydrometeorological

Report 51 (HMR-51). This method utilizes depth-area-duration[1] (DAD) relationships, as well as the orientation of the storm as compared to the watershed to generate a PMP depth. Each dam's watershed was assessed to establish DAD relationships; however, given the proximity of the two dams, and similarity between the watersheds, these relationships were nearly identical for both facilities (differences of ≤ 0.02-inches). As such, a single set of DAD values was used as shown in **Figure 1-2** (tabular data provided in **Appendix B**). The PMP was simulated in HMS for each dam's watershed and the input values were optimized to generate the maximum dam discharge in the 72-hour storm. The resulting temporal rainfall distribution was exported to compute 6-, 12-, 24-, and 48-hour distributions by extracting the most intense period for each duration, shown in **Figure 1-3** (tabular data provided in **Appendix B**). These distributions were then input to HMS to determine the storm duration resulting in the highest dam discharge, otherwise classified as the controlling storm.

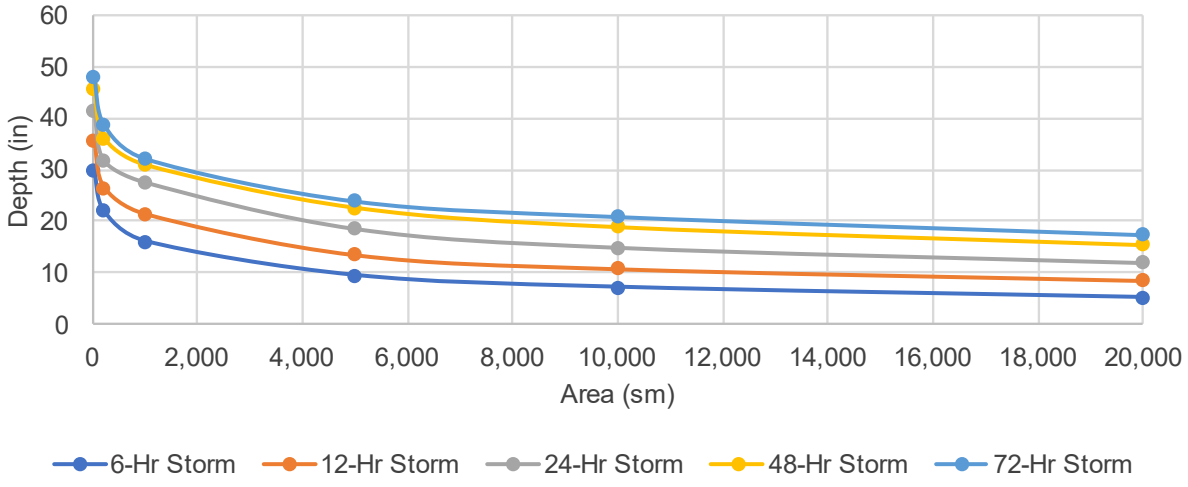


Figure 1-2: DAD Relationships

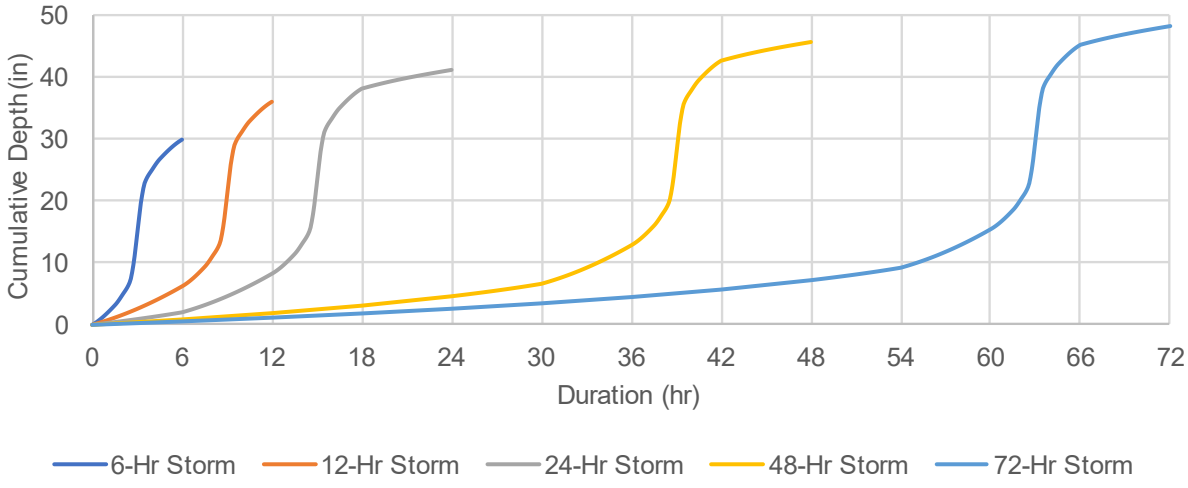


Figure 1-3: PMP Temporal Distributions

[1] Depth of PMP, Area of watershed, and Duration of PMP

1.4.3 Landcover

Existing landuse (ELU) was evaluated in the BV3 Study and not reassessed for this evaluation. However, future landuse (FLU) was analyzed based on zoning data for dam analyses to ensure compliance with NCDS regulations. More specifically, simulations involving PMP and spillway design flood (SDF) events utilized FLU; local detention and recurrence interval storm simulations utilized ELU. Overall, the predominant FLU was low-density residential within hydrologic soil group (HSG) A.

Table 1-2: Future Landuse Summary

Landuse / HSG	Runoff Curve Number				Proportion of Watershed (%)				Total (%)
	A	B	C	D	A	B	C	D	
Low Density Residential	61	75	83	87	59	6	12	6	82
Office/Institutional	89	92	94	95	3	1	0	0	4
Parks/OpenSpace	39	61	74	80	1	0	1	3	4
Neighborhood Mixed Use	89	92	94	95	2	0	0	0	3
Industrial / Employment Center	89	92	94	95	1	0	0	1	2
Medium Density Residential	77	85	90	92	2	0	0	0	2
High Density Residential	81	88	91	93	1	0	0	0	1
Highway Commercial	89	92	94	95	1	0	0	0	1
Neighborhood Improvement	81	88	91	93	0	0	0	0	0

1.4.4 Simulation of Proposed Solution Implementation

Simulated implementation of the PSs was performed using HMS by inputting the difference between ICM model EIF and PSD hydrographs as discharge gages. This configuration therefore included both existing subbasin hydrology as well as the increased discharge from the PSs. The discharge gages were set to input flow to the same downstream nodes as the PS's parent subbasin. Flow changes were then assessed between EIF and PSD scenarios at the nearest downstream model node located along BCTB. Resulting hydrographs for the 10- and 100-year storms were also simulated in RAS to ascertain impacts on roads and buildings. Roads were assessed via level of service (LOS) changes and buildings were evaluated based on model-predicted inundation extents (e.g. lowest adjacent grade versus water surface elevation).

1.4.5 Local Detention

The goal of local detention was to mitigate peak flow increases at each PS location due to simulated implementation of storm drainage improvements. This was accomplished by computing preliminary storage volumes and outlet sizes for each PS such that peak outflows from proposed storm drain (PSD) improvements were no greater than outflows with existing infrastructure (EIF). Detailed design, including grading, siting, and storm drain computations were excluded from the evaluation. To expedite this process, several key assumptions / parameters were used, as outlined below:

- Storage facilities were 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

Sizing of the basins and outlet works were based upon outflow hydrographs obtained from the BV3 Study InfoWorks ICM model. Both piped and overland flow were accounted for in the hydrographs. Simulated conditions included ELU, FRF, as well as both EIF and proposed storm drain infrastructure (PSD). Initial basin sizes were generated by computing excess volume between EIF and PSD scenarios. Orifice sizes were originally estimated by computing the required opening area to pass the EIF outflow with 5-feet of head (the assumed maximum 10-year storage depth). These two parameters, as well as the PSD hydrographs, were then input to a new InfoWorks ICM model for simulation of local detention. The basin and orifice sizes were then adjusted as needed to ensure a 10-year depth between 4- and 5-feet, as well as a peak outflow rate at or below existing conditions. Representation of local detention opportunities within the model reflects a hypothetical condition suitable for a planning-level assessment but would require further evaluation and refinement as part of detailed design efforts.

1.4.6 Regional Detention

Regional detention was evaluated via HMS and RAS by revising the dam and / or spillway configurations in the models. The HMS model was obtained from the BV3 Study, but to decrease run time and data management requirements, the model was pared down to include only BCTB by removing model elements representing areas outside of the BCTB watershed. The RAS model was newly developed for this evaluation and utilized two-dimensional (2D) flow computations. The RAS model previously developed for the BV3 Study was a 1D, steady state model, which was limited with regards to extent and functionality in the context of this detention analysis. Regional detention was assessed for both mitigation of peak flow increases as well as protection of ALWD (without flow mitigation). Further, improvements to both dams were evaluated as part of this study. Assessments of flow mitigation alternatives focused on both the 10- and 100-year storm events under ELU / FRF conditions, while simulations for protection of ALWD utilized the spillway design flood (SDF), which is a fractional PMP storm (assuming FLU and ERF), discussed later. The conceptual dam and spillway improvements included: (1) leveling dam tops at or near existing high point elevations, (2) replacing the ALWD riser-barrel spillway with a new, larger riser-barrel outlet, and (3) repairing the BLD breach and adding a new riser-barrel spillway. Additionally, overtopping protection was also considered for both dams to address overtopping of the dams.

2. Effects and Impacts of Proposed Solution Implementation

Upon development of the hydrologic and hydraulic models, the next step in this evaluation was to assess the effects and impacts of implementing the proposed solutions throughout the BCTB watershed. As previously mentioned, improvements to the secondary systems are likely to result in higher peak discharge rates and volumes from the areas these systems serve. This in turn may cause flowrates and water surface elevations (WSEs) in the Tributary to also increase.

2.1 Effects of Implementation

Evaluating the effects of PS implementation began with computation of peak discharges from each project for both EIF and PSD simulations. Overall, outflows from the secondary systems increased from 25- to over 500-percent in the 10-year, 24-hour storm (**Table 2-1**). However, due to differences in PS and Tributary hydrograph timing, only six of the twelve were demonstrated to have an effect on peak discharges in BCTB (**Table 2-2**). Hydrographs for these six (PS01, PS20, PS22, PS24, PS29, PS31) are provided in **Figure 2-1** through **Figure 2-6**, which show Tributary hydrographs for EIF, PSD (subject PS implementation only), PSD (all PS implementation), as well as the subject PS outflow hydrograph. For an example of a PS that does not affect BCTB flows, hydrographs for PS05 are shown in **Figure 2-7**.

Table 2-1: Proposed Solution 10-Year Storm Peak Discharges

Proposed Solution #	Existing Peak Outflow	Proposed Peak Outflow	Change (%)	Proposed Solution #	Existing Peak Outflow	Proposed Peak Outflow	Change (%)
PS01	62	184	195	**PS22**	32	47	48
PS03	29	36	25	**PS24**	113	186	65
PS05	66	141	113	**PS26**	36	57	57
PS08	10	13	28	**PS28**	24	29	25
PS14	8	36	373	**PS29**	74	192	160
PS20	28	67	138	**PS31**	27	166	524

Table 2-2: Beaver Creek Tributary B 10-Year Storm Peak Discharges

Proposed Solution #	Tributary Peak Flow (cfs)		Proposed Solution #	Tributary Peak Flow (cfs)	
	Existing Infrastructure	Subject PS Implemented		Existing Infrastructure	Subject PS Implemented
PS01	350	**367**	**PS22**	192	**208**
PS03	305	305	**PS24**	158	**239**
PS05	305	305	**PS26**	736	736
PS08	281	281	**PS28**	736	736
PS14	281	281	**PS29**	736	**751**
PS20	192	**205**	**PS31**	736	**767**

Values in bold, orange text indicate BCTB peak flow increase due to implementation of subject PS.

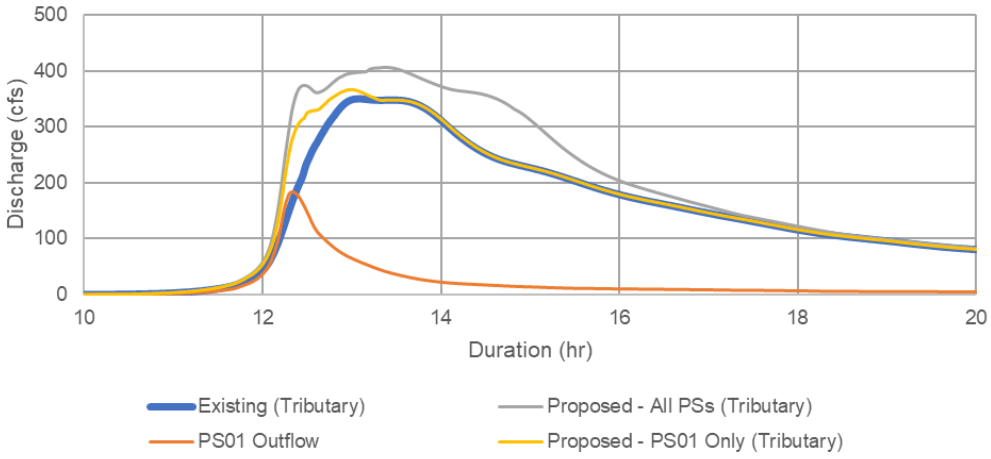


Figure 2-1: PS01 Hydrographs

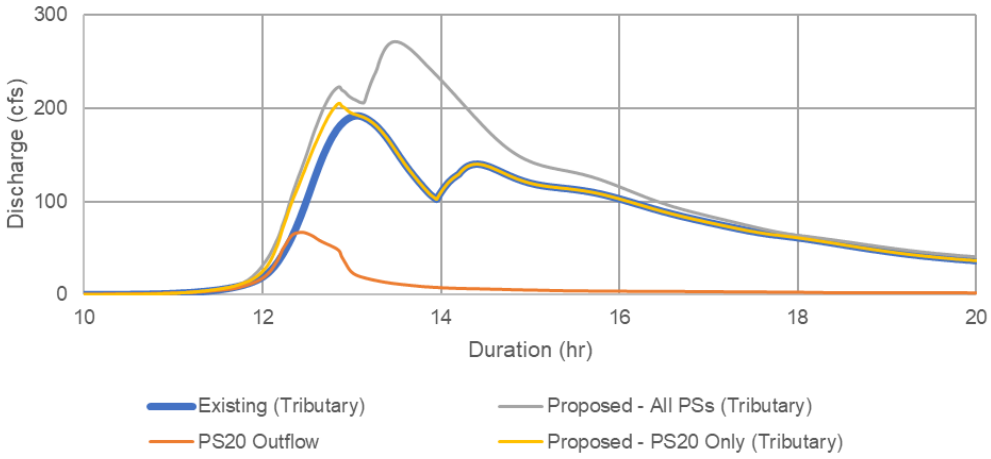


Figure 2-2: PS20 Hydrographs

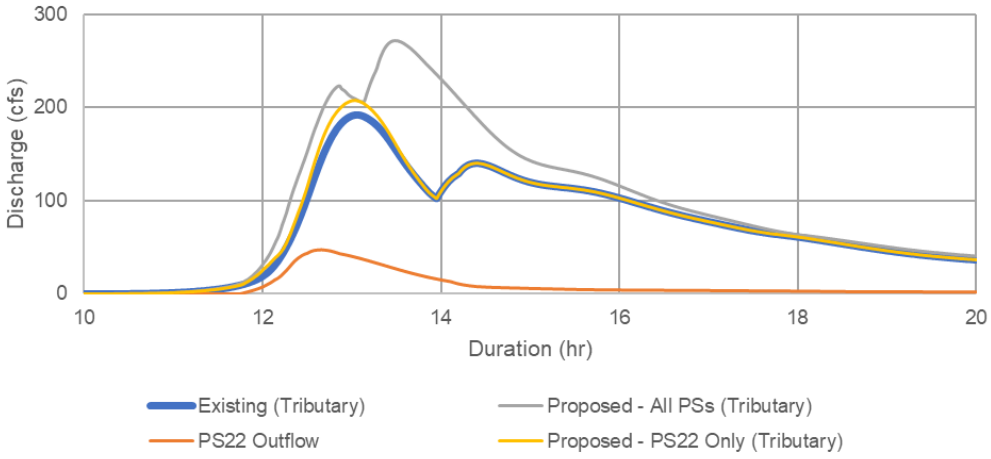


Figure 2-3: PS22 Hydrographs

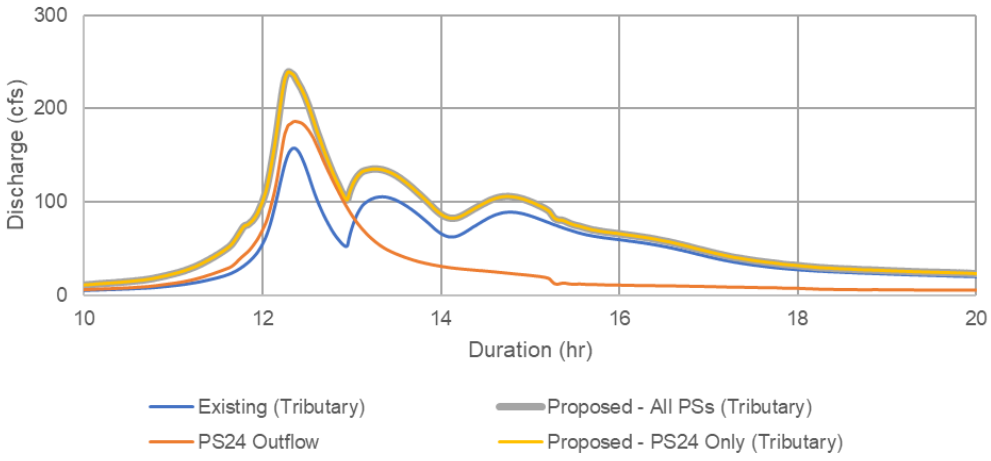


Figure 2-4: PS24 Hydrographs

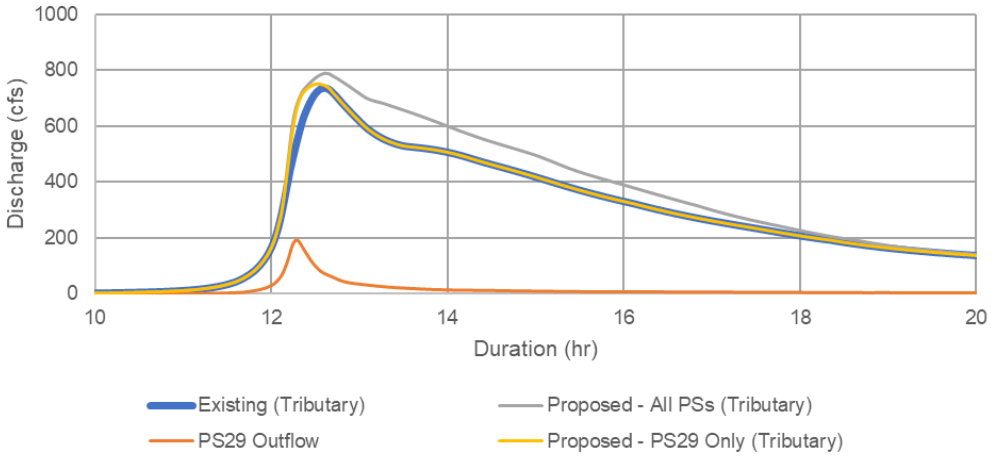


Figure 2-5: PS29 Hydrographs

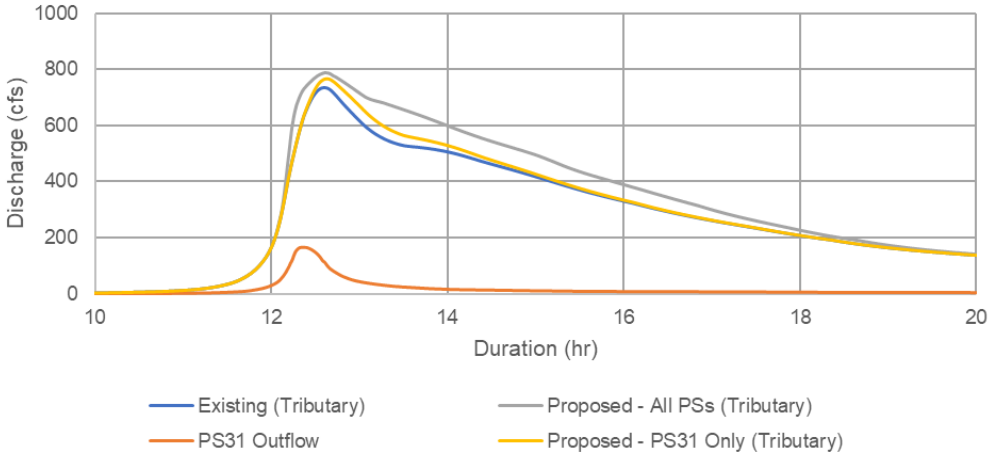


Figure 2-6: PS31 Hydrographs

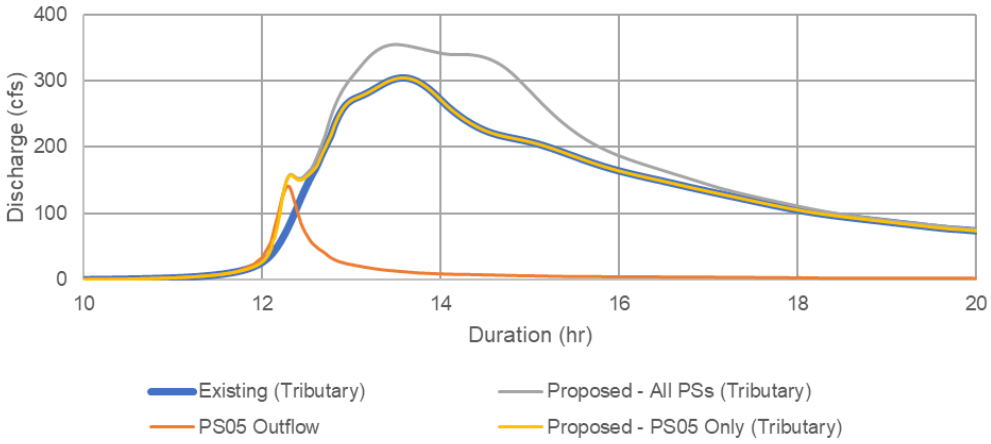


Figure 2-7: PS05 Hydrographs

In addition to Tributary peak flows, effects on ALW were also assessed in terms of peak WSE and consequently, peak discharge from the dam. Utilizing the same models and simulations as discussed above, WSE changes at the Lake were observed for every PS except one (PS08). However, the majority of the WSE increases were small and within a reasonable margin of error for this study (< 0.1-feet). These results are summarized in **Table 2-3**, which presents data for both the 10- and 100-year storms. Four PSs resulted in WSE increases of > 0.1-feet in the 10-year storm (PS01, PS22, PS24, and PS31), while all other projects had increases of < 0.1-feet. Additionally, all PSs indicated WSE increases of < 0.1-feet in the 100-year storm. Relative discharge increases from the Dam were larger for the 100-yr storm as a result of the Dam overtopping in this event, but not the 10-year storm. The cumulative effect of implementing all PSs caused 1.0 and 0.2-foot increases in the 10- and 100-year storms, respectively. Similarly, discharges from the dam also increased for most PS implementations due to the small increases in WSEs. The increases ranged from 1- to 102-cfs with a cumulative increase of 327-cfs for implementation of all PSs.

Table 2-3: Effects on Arran Lakes West from Proposed Solution Implementation

Scenario	10-Year Storm				100-Year Storm			
	WSE (ft)	Change (ft)	Discharge (cfs)	Change (cfs)	WSE (ft)	Change (ft)	Discharge (cfs)	Change (cfs)
Existing	152.2	-	425	-	155.6	-	1,103	-
PS01	152.5	0.2	429	4	155.6	< 0.1	1,205	102
PS03	152.2	< 0.1	425	0	155.6	< 0.1	1,103	0
PS05	152.3	< 0.1	426	1	155.6	< 0.1	1,129	26
PS08	152.2	< 0.1	425	0	155.6	< 0.1	1,103	0
PS14	152.2	< 0.1	426	1	155.6	< 0.1	1,123	20
PS20	152.3	< 0.1	427	2	155.6	< 0.1	1,130	27
PS22	152.3	0.1	426	1	155.6	< 0.1	1,118	15
PS24	152.4	0.2	428	3	155.6	< 0.1	1,156	53
PS26	152.2	< 0.1	425	0	155.6	< 0.1	1,104	1
PS28	152.2	< 0.1	425	0	155.6	< 0.1	1,103	0
PS29	152.3	< 0.1	426	1	155.6	< 0.1	1,133	30
PS31	152.5	0.3	430	5	155.6	< 0.1	1,179	76
All PSs	153.2	1.0	441	16	155.8	0.2	1,430	327

2.2 Impacts of Implementation

The impacts of implementation were assessed by comparison of flooding frequency between EIF and PSD for both buildings and roadways. In regards to building impacts, a total of four additional structures are at-risk of flooding in the 10- and 100-year events due to implementation of all PSs (7182 Silverstone Court and 1936 Abbeydale Lane in the 10-year; 1924 Abbeydale Lane and 1948 Abbeydale Lane in the 100-year). Each of these buildings are located in the vicinity of the Carloway Drive culvert crossing, upstream of both BLD and ALWD. The buildings are shown on the inundation maps provided in **Appendix E**. Roadway impacts were also limited, with LOS decreasing at two crossings: Carloway Drive (25-year to 10-year) and a private driveway to an electrical substation (5-year to 2-year). Both crossings are located upstream of BLD and ALWD. Lastly, while Lakeridge Drive, the roadway on top of ALWD, was not shown to have an LOS decrease, the depth of dam overtopping was shown to increase by up to 0.3-feet for the 25- through 100-year storms. As such, the frequency of overtopping may also slightly increase. No other impacts were identified downstream of BLD and ALWD.

3. Local Detention Evaluation

Local detention evaluations were conducted for each PS upstream of ALWD and included preliminary sizing of outlets and basins to mitigate 10-year peak flow increases. Overall, storage volumes to detain the 10-year event ranged between 1.3- and 8.8-acre-feet (**Table 3-1**). Required property areas were estimated to be 0.5 to 3.5-acres when considering final grading, building setbacks, and additional volume for partial storage of larger events. In terms of parcels, the overall 75th percentile lot size was approximately 1/3-acre, thus between 2 and 11 properties may require acquisition, depending upon the PS of interest. Note that this is based upon an assumed maximum depth of 5-feet in the 10-year storm; detailed design may indicate that additional depth, and thus less area, is feasible, or vice versa. Additionally, details of local topography and hydraulic grade lines are likely to affect basin size and configuration, along with associated property acquisition needs.

Table 3-1: Local Detention Basin Sizing Summary

PS	Peak Discharge (cfs)			Outlet Orifice Size (in)	10-Year Storage Volume (ac-ft)	Total Required Area (acre)	Potential Available Open-Space (acre)
	Existing Infrastructure	Proposed Infrastructure (without Detention)	Proposed Infrastructure (with Detention)				
PS01	62	184	184	32	7.5	3.0	1.3
PS03	29	36	36	22	1.3	0.5	-
PS05	66	141	141	30	3.8	1.5	-
PS08	10	13	13	15	1.3	0.5	-
PS14	8	36	36	10	1.3	0.5	-
PS20	28	67	67	20	3.8	1.5	1.1
PS22	32	47	47	22	2.5	1.0	0.7
PS24	113	186	186	42	6.3	2.5	10+
PS26	36	57	57	24	1.3	0.5	-
PS28	24	29	29	19	1.3	0.5	-
PS29	74	192	192	33	5.0	2.0	-
PS31	27	166	166	20	8.8	3.5	-

Note: Rows in gray shading indicate PS likely to increase BCTB 10-year peak discharge without detention

A review of best available aerial imagery, as well as Cumberland County (County) parcel data, identified potentially available open-space lots at four PS locations: PS01, PS20, PS22, and PS24 (portion of lot at PS24). These may be suitable to provide all or part of the total required area for construction of a detention facility and thus reduce or eliminate demolition of homes and buildings. Note that while no City-owned properties were identified in the vicinity of the PSs, Seventy-First High School, owned by the County, is located within PS24. This project is currently under construction by the North Carolina Department of Transportation (NCDOT) and the school property contains large amounts of open space (> 10-acres). Implementing detention at all other PSs is likely to require demolition of existing homes as the amount of available open space is not sufficient for the estimated basin areas.

Upon estimation of the required and available open-space areas, project cost estimates were developed utilizing unit costs established by WK Dickson with the City of Fayetteville for use throughout the City's watershed planning efforts. Except for land acquisition and building buyout costs, all line items and unit

prices were applied as established for the City's watershed planning efforts. Unit costs for land acquisition and building buyouts were computed as part of this study and customized to each PS (note this study utilized a unit of acres, whereas the BV3 Study placeholder for these line items used square feet). Parcels located within at least one lot of proposed improvements from the BV3 study were used to compute total property, total land, and total building values from County parcel data. The County tax values for these parcels were first escalated to 2021 dollars via 5% annual increases[2] and then total property and total land tax values were normalized on a per acre basis. The 75th percentile cost for each value type was then computed for each PS to establish the unit costs for acquisitions.

Other primary components of the estimates were: clearing and grubbing, excavation, detention basin outlet structures (piping was excluded as these costs are covered by the BV3 PS estimates), fine grading, seeding, turf reinforcement matting, as well as property / building acquisitions[3] and building demolition. Estimates also contained items for miscellaneous site work, with quantities based upon the computed total required area of each facility. These included: removal and installation of fencing, removal and replacement of curbing, removal of trees, and planting of trees and shrubs (e.g. landscape screening). Additional information may be found in the itemized cost estimates provided in **Appendix F**.

Overall, costs[4] for implementation of local detention facilities ranged from $1,200,000 to $6,300,000, with an average of $2,700,000 and total of $33,000,000 (**Table 3-2**). If considering only those PSs demonstrated to increase BCTB 10-year peak flows, the average is $3,500,000 and the total is $21,000,000 among the six projects.

Table 3-2: Local Detention Estimated Project Costs

PS[1]	Project Name	Project Cost[2]	PS[1]	Project Name	Project Cost[2]
PS01	Rockford Dr	$4,600,000	**PS22**	Graham Rd	$1,400,000
PS03	Hyannis Dr	$1,300,000	**PS24**	Raeford Rd	$2,300,000
PS05	Rhemish Dr	$4,200,000	**PS26**	Birchcreft Dr	$1,400,000
PS08	Carloway Dr	$1,700,000	**PS28**	Lakeridge Dr	$1,200,000
PS14	Stoneclave Pl	$1,900,000	**PS29**	Baywater Dr	$4,400,000
PS20	Manassas St	$2,100,000	**PS31**	Berriedale Drive	$6,300,000

[1] Rows in gray shading indicate PS likely to increase BCTB 10-year peak discharge without detention
[2] 2021 Values; presented as such for consistency with BV3 Study cost estimating tool; add 2.1% annual escalation for future values (per tool)

[2] 5% annual increase per BV3 Study cost estimating tool; last County valuation year of 2017.

[3] The quantities for building buyouts were reduced by the identified amounts of available space at each PS location (open-space acquisition costs were then included under land acquisition); except for PS24, which is located on County-owned property, thus no acquisition costs were considered. The quantities for building demolition were based upon the 75th percentile building size per each PS location.

[4] 2021 Values; presented as such for consistency with the City's watershed planning unit costs; add 2.1% annual escalation for future values

4. Regional Detention Evaluation

4.1 Regulatory Evaluation

Evaluation of regional detention initiated with confirming NCDS regulatory requirements such that any considered improvements were developed in compliance with applicable rules and regulations. This began with determination of the controlling storm by comparison of dam discharges for each PMP temporal distribution (with future land use conditions). Ultimately, the 72-hour storm was identified as the controlling event for both dams, as shown in **Table 4-1**.

Table 4-1: Controlling Storm Evaluation

PMP Event	Depth (in)	Peak Discharge (cfs)	
		ALWD	BLD
6-hr	29.8	11,497	7,055
12-hr	36.0	13,064	8,205
24-hr	41.1	13,259	8,339
48-hr	45.7	13,501	8,501
72-hr	**48.3**	**13,590**	**8,553**

With the controlling storm established, determination of the SDF was assessed in accordance with applicable regulations, including: §143-215.25A.a.6 (Dam Safety Law) and 15A NCAC 02K .0105 (Dam Safety Code). As summarized in **Table 4-2**, each dam is less than 35-feet in height with total storage capacities less than 750-acre feet, placing each within NCDS's *small* size category. Additionally, both are also less than 25-feet in height which is the minimum threshold for NCDS jurisdiction per §143-215.25A.a.6. However, per this law, if NCDS determines that failure of the dams may cause loss of human life or significant damage to downstream property, then the facilities are not exempt from NCDS jurisdiction and are considered *Class C* (*High Hazard)* dams.

Table 4-2: Spillway Design Flood Determination

Dam Name	Arran Lakes West Dam	Bailey Lake Dam
Structural Height (ft)	16.4	18.3
Maximum Impoundment Capacity (ac-ft)	161	177
Applicable NCDS Size Class	Small (< 35-ft and < 750-ac-ft)	Small (< 35-ft and < 750-ac-ft)
Downstream Hazards	Road and Habitable Structure Impacts	Road and Habitable Structure Impacts
Hazard Class	C (High)	C (High)
Spillway Design Flood	1/3 PMP	1/3 PMP

Based upon this Study, failure of either dam is likely to cause downstream impacts and thus are likely to remain as *Class C* dams under NCDS jurisdiction. Given the size and hazard classifications, the spillway design flood (SDF) was then verified as the 1/3 PMP per 15A NCAC 02K.0105 with a controlling storm duration of 72-hours, as noted previously.

4.2 Proposed Dam Improvements

4.2.1 Peak Flow Increase Mitigation

Numerous scenarios were assessed to evaluate the feasibility of mitigating peak flow increases by improving either BLD or ALWD. Improvements at ALWD considered replacing the existing dual riser-barrel spillways with a new spillway, permanent lowering of normal pool, pre-storm drawdown of the pool, and leveling the dam top as well as providing overtopping protection. Rehabilitation of BLD was assumed to include repair of the embankment and existing breach, installation of a new combined spillway (e.g. including both principal and emergency spillways), and leveling of the dam top and installing overtopping protection. The following sections present improvements to both facilities to address flow mitigation; information regarding additional dam improvements (e.g. overtopping protection) are discussed later.

4.2.1.1 Arran Lakes West Dam

Initial assessments of spillway improvements at ALWD considered replacement of the existing spillway with a new riser-barrel system. The best performing configuration included a 10-foot long weir which provided the necessary detention to mitigate peak flows, but also resulted in a 2.2-foot Lake WSE increase in the 10-year storm compared to existing infrastructure (**Table 4-3**). Longer weirs reduced the upstream WSE increase but did not mitigate downstream flow increases. Such impacts were considered undesirable, thus conceptual spillway improvements were combined with permanent lowering of the normal pool by up to 1-foot in order to increase flood storage. Again, several configurations were considered, with the best performing option being a dual 84-inch diameter riser and 48-inch barrel (similar to the existing spillway – dual 72-inch riser and 48-inch barrel). This new spillway, along with lowering of the normal pool by 1-foot, achieved downstream flow mitigation goals and minimized WSE increases in the lake (0.5-feet in the 10-year storm compared to existing infrastructure). Given the relatively improved performance of this configuration compared to others considered, the 100-year storm was also simulated. This indicated a potential 0.3-foot WSE increase in the Lake compared to existing infrastructure, but also nearly a 280-cfs discharge increase downstream of the Dam.

Table 4-3: Arran Lakes West Dam Regional Detention 10-Year Storm Summary

Infrastructure Scenario	WSE (ft)	Change (ft)	Outflow (cfs)	Change (cfs)
Existing Storm + Existing Dam	152.2	-	425	-
Proposed Storm + Existing Dam	153.2	1.0	441	16
10'L Weir	154.5	2.2	423	-3
Dual 84" Riser + 1' Lower Normal Pool	**152.8**	**0.5**	**424**	**-2**
Existing Storm + Existing Dam + Pre-Storm Drawdown	152.2	-0.1	424	-2

Values shown in orange, bold text indicate improvement alternative selected for consideration (e.g. further analysis and cost estimating)

The final ALWD improvement assessed pre-storm drawdown of the impoundment to increase flood storage. While this option provided the necessary flow mitigation without increasing Lake WSEs, the magnitude of drawdown (6-feet) was relatively substantial. Such a drawdown requires at least 6-days to ensure the rate does not exceed 1-foot per day. Therefore, drawdown efforts must begin 7-days in advance of a storm, during which additional rainfall may result in a decrease of flood storage and thus reduced mitigation benefits, along with substantial uncertainty in forecast storm events so far in advance.

In consideration of all the configurations evaluated, the most effective ALWD improvement to mitigate flows while minimizing Lake impacts appears to be replacing the spillway with a dual 84-inch riser and lowering normal pool by 1-foot. This alternative was therefore used in further analyses, including development of cost estimates. However, as previously noted, the only impacts identified at or downstream of ALWD are relatively small WSE increases, and thus small discharge increases, at the Dam itself. As such, implementation of regional detention at ALWD does not provide additional downstream benefits as defined in this study and therefore is not likely to be cost-effective. Given this finding, other alternatives should be considered such as improvements to BLD to mitigate flow increases at ALWD or improving ALWD to withstand overtopping (existing and future). These concepts are presented in the following sections.

4.2.1.2 Bailey Lake Dam

Multiple BLD spillway configurations were evaluated to optimize a solution for eliminating potential impacts at ALWD. Ultimately, a multi-weir riser and 8-foot wide by 8-foot high barrel were determined to achieve this goal. Specifically, an 8-foot wide by 2.5-foot high orifice opening at elevation 157.9 provided sufficient detention in the 10-year storm (**Table 4-4**). A second, higher weir, at elevation 167.5 and 32-feet long was demonstrated to pass the 100-year storm with no increase in outflow compared to existing conditions. This improvement therefore mitigates flow increases such that no impacts occur at ALWD, but do however, cause WSE increases upstream of BLD compared to the existing breached condition. The original BLD spillway configuration and flood pool extents are unknown; however, based upon modeling for this study, implementation of these improvements was shown to likely impact three additional accessory structures (e.g. sheds, etc), but no additional habitable buildings, when compared to existing conditions.

Table 4-4: Bailey Lake Dam Regional Detention 10-Year Storm Summary

Infrastructure Scenario	BLD				ALWD			
	WSE (ft)	Change (ft)	Outflow (cfs)	Change (cfs)	WSE (ft)	Change (ft)	Outflow (cfs)	Change (cfs)
Existing Storm + Existing Dam	162.8	-	378	-	152.2	-	425	-
Proposed Storm + Existing Dam	163.3	0.5	449	71	153.2	1.0	441	16
Bailey Lake Dam Rehabilitation	167.4	4.6	260	-118	151.6	-0.6	413	-12

Upon consideration of alternatives for mitigation of peak flow via regional detention, the apparent best-case solution is rehabilitation of BLD. This alternative provides not only the desired mitigation, but also has fewer secondary impacts (e.g. upstream WSE increases). However, as previously mentioned, the only impacts identified due to PS implementation were to ALWD. As such, rehabilitation of BLD to benefit only ALWD may not present the best solution, given that ALWD can be separately improved to withstand changes in flows without mitigation, as discussed in the following section.

4.2.2 Dam Overtopping Mitigation

The ALWD improvements discussed above each involve replacement of the spillway system. However, in all scenarios the Dam overtops frequently (50-year storm under existing conditions), thus any improvement also requires installation of overtopping protection to reduce the risk of erosion and associated embankment failure. Given that flow mitigation isn't required by Dam Safety if this protection is added, the most cost-effective regional detention alternative to protect ALWD is to install this protection and not rely upon flow mitigation via spillway improvements.

Implementation of overtopping protection is likely to cause little change in hydraulic capacity, thereby not exacerbating or creating additional flood concerns. Under this assumption, expected flows and WSEs will generally be the same as those previously presented for pre- and post-project conditions. As such, potential upstream flow increases from PS implementation will be passed downstream of the Dam. However, limited development is present in this area no impacts from PS implementation were identified in this study. Additional considerations are also necessary for construction of overtopping protection (e.g. embankment repairs, roadway work, etc.); however, those primarily pertain to cost and not flooding and are discussed in the following section.

4.2.3 Regional Detention Cost Estimates

Project cost estimates were developed using the watershed planning program unit costs for three dam improvement alternatives and one culvert crossing improvement (Carloway Drive). The culvert project was included with regional detention costs since implementation of the PSs without local detention may decrease the crossing's LOS. Carloway Drive is located upstream of both dams, thus regional detention solutions cannot address the decreased LOS. As such, the actual cost of regional detention must also consider culvert improvements. Detailed descriptions of each alternative are provided below:

- Dam Proposed Solution 1 (DPS1): Arran Lakes West Dam Overtopping Protection
    - Acquire ALW parcel(s); recommend acquisition of two residential properties located on downstream left side of dam, located within flowpath of existing dam top overflow section.
    - Perform geotechnical investigations
    - Perform principal spillway inspection
    - Remove trees, woody vegetation, guardrails, and pavement from embankment
    - Strip topsoil and excavate unsuitable materials from embankment
    - Relocate, adjust, and / or support subsurface utilities
    - Re-route existing storm drain to remove from dam and discharge directly to Tributary
    - Install blanket and toe drains on downstream face

  - Install overtopping protection (e.g articulated concrete block (ACB)) on up- and downstream faces
  - Install reinforced concrete slabs on top of dam (designed for overtopping, connection to ACB, and for vehicular traffic)
  - Place large boulders along road shoulder in lieu of guardrails
  - Perform site restoration (fine grading, seeding, erosion control matting, etc)
  - Assumptions: embankment material is largely suitable and may remain; excavated materials are largely suitable for reuse; embankment is geotechnically stable; principal spillway is in fair or better condition (e.g. only relatively minor work required – joint repairs, trashrack installation, etc.)

- Dam Proposed Solution 2 (DPS2): Arran Lakes West Dam Spillway Improvement

  - All components of DPS1, plus the following items
  - Construct, in phases, temporary earthen cofferdams around work areas
  - Excavate and remove entirety of dual spillways (phased such that one existing / new spillway may be used for flow bypass)
  - Install dual 84-inch diameter risers and 48-inch barrels; new endwall(s); new risers will be set 1-foot below existing riser crest elevation

- Dam Proposed Solution 3 (DPS3): Bailey Lake Dam Rehabilitation

  - Acquire BLD parcel(s); recommend acquisition of portions of adjacent properties for access / ensure ownership of entire embankment
  - Perform geotechnical investigations
  - Remove trees and woody vegetation from embankment
  - Strip topsoil and excavate unsuitable materials from embankment
  - Relocate, adjust, and / or support subsurface utilities
  - Construct, in phases, temporary earthen cofferdams around work areas
  - Grade, in phases, temporary diversion channels and berms
  - Install blanket and toe drains on downstream face
  - Install overtopping protection (e.g ACB) on embankment
  - Perform site restoration (fine grading, seeding, erosion control matting, etc)
  - Assumptions: embankment material is largely suitable and may remain; excavated materials are largely suitable for reuse; embankment is geotechnically stable

- Culvert Proposed Solution 1 (CPS1): Carloway Drive Culvert Replacement

  - Remove trees, woody vegetation, and asphalt from embankment
  - Excavate and remove existing culvert barrels and endwalls (phased such that one existing / new barrel may be used for flow bypass)
  - Install temporary sandbag cofferdams / flow diversions
  - Relocate, adjust, and / or support subsurface utilities
  - Install double 6-foot by 5-foot reinforced concrete box culvert, with one barrel buried 1-foot
  - Install endwalls
  - Install outlet protection / energy dissipator
  - Perform site restoration (fine grading, seeding, erosion control matting, paving, etc)

Alternative DPS1 is the lowest cost option among dam improvements with a total project cost of $8,500,000[5] (**Table 4-5**). However, if the spillway is in need of replacement due to structural condition, the cost is likely to closer to that of DPS2 ($10,300,000), which includes the cost of DPS1 (overtopping protection) as well as replacement of the spillway. DPS3 is the most expensive dam improvement, with an estimated cost of $12,900,000. This alternative is more expensive due to substantially larger quantities of earthwork required to repair the embankment from tree removals and filling of the existing breach. The spillway system is also more expensive as it is a larger, more complex, custom structure compared to the risers at ALWD.

Table 4-5: Regional Detention Estimated Project Costs

PS	Project Name	Project Cost[1]
DPS1	Arran Lakes West Dam Overtopping Protection	$8,500,000
DPS2	Arran Lakes West Dam Spillway Improvement	$10,300,000
DPS3	Bailey Lake Dam Rehabilitation	$12,900,000
CPS1	Carloway Dr	$1,200,000

[1] 2021 Values; presented as such for consistency with BV3 Study cost estimating tool; add 2.1% annual escalation for future values (per tool)

4.3 Summary

Evaluations of regional detention determined that mitigation of flow increases may be challenging to accomplish without secondary impacts and permanent pool changes. Further, the only identified impacts from PS implementation are to ALWD, thus mitigating flows at this facility provides no discernable benefits. Similarly, mitigating flows at BLD provides only the benefit of protecting ALWD.

Based upon these findings, the ALWD mitigation alternative (DPS2) is recommended to be eliminated from consideration. Further, the BLD mitigation alternative (DPS3) is an indirect means to protect ALWD and comes at a higher cost and risk than addressing the protection concerns directly via overtopping protection (DPS1). As such, DPS3 is also recommended to be eliminated from consideration. The remaining alternative, DPS1 (ALWD overtopping protection only), provides the most direct, effective, and economical means to protect the facility from potential flow increases. This alternative is approximately one-half the cost of local detention, but does require the acquisition, improvement, maintenance, and operation of a *high hazard* dam which are critical considerations when selecting the preferred solution. Additional comparisons, a summary of the benefit-cost analysis, and final conclusions are provided in **Section 6**.

[5] 2021 Values; presented as such for consistency with BV3 Study cost estimating tool; add 2.1% annual escalation for future values (per tool)

5. Environmental Evaluation

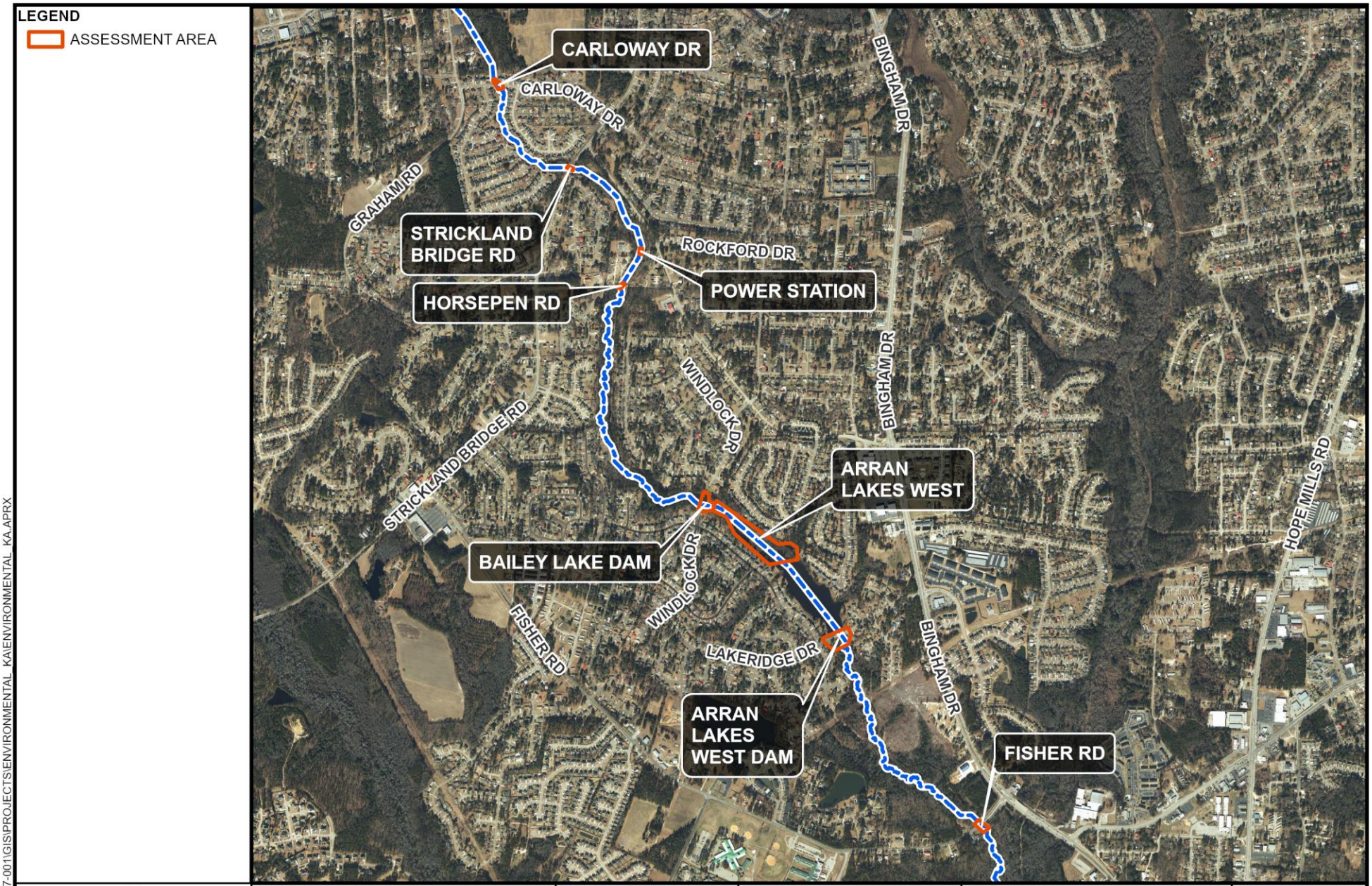
Hazen conducted a review of natural resources at key locations within the study extents to assist in evaluating the feasibility of detention alternatives and likely next steps for detailed design and implementation. This consisted of desktop review of publicly available published information and onsite evaluation of existing conditions. The areas evaluated for the project include proposed culvert replacements, dam improvements, and lake improvements within the watershed of BCTB, in the western portion of Fayetteville (**Figure 5-1**). The findings of the environmental evaluation are described in the following sections.

5.1 Waters of the U.S.

Jurisdictional waters of the United States (US) include open waters, streams, and wetlands. Wetlands, as defined by federal regulations [33 Code of Federal Regulations 328.3] are "…areas that are inundated or saturated by an accumulation of surface or groundwater at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions." The USACE requires the presence of three parameters (hydrophytic vegetation, hydric soils, and evidence of hydrology) in support of a jurisdictional wetland determination (Environmental Laboratory, 1987). The boundary between wetlands and deepwater habitat is defined as the maximum depth where rooted emergent vegetation may be found. Rooted emergent vegetation is generally present at depths less than six feet below mean low water during the growing season.

Hazen biologists conducted a determination of the presence of jurisdictional waters in the vicinity of the proposed project components. The determinations were performed on April 26, 2023. Within the area assessed, streams, wetlands, open waters, and stream-wetland complexes were identified. **Figure 5-2** depicts the classification of jurisdictional features in proximity to each of the project components. The streams consist of BCTB and open waters include inundated areas associated with impoundments online with BCTB. Wetlands generally consist of low-lying areas abutting the stream in the upper reaches, small stream swamp above the impoundments, inundated areas with rooted vegetation, and fringe marsh along the lake margins. The features are regulated under the Clean Water Act (CWA). BCTB flows south through the upper portion of the watershed and turns to a southeasterly course near Fisher Road. The stream ranges from a non-jurisdictional drainageway in the upper portion of the watershed to a perennial stream and a small-stream swamp complex upstream of Bailey Lake. Downstream of ALWD, BCTB flows in a defined channel as a perennial stream to its mouth at Beaver Creek.

Wetlands are present within the likely work areas associated with the following: the electrical substation driveway culvert, Horsepen Branch cuvlert, Bailey Lake, and Arran Lakes West. Wetlands at the electrical substation consist of distinct wetlands abutting the stream channel; wetlands at Horsepen Branch consist of a small-stream swamp without a well-defined stream channel. At BLD and ALWD, wetlands abut the inundated areas behind the respective dams, providing a transition zone from open water to uplands. Arran Lakes West contains wetland pockets interspersed in the area of inundation as well as fringe wetlands that form the transition zone from open water to uplands. The limits of the jurisdictional waters of the US were not delineated or surveyed for the purpose of the PER. The wetland / upland boundary was not fully identified or located throughout the work area associated with each area. Upon selection of a preferred alternative and identification of the limits of disturbance associated with the



Hazen

4011 WESTCHASE BLVD
SUITE 500
RALEIGH, NC 27607

FAYETTEVILLE NC
AMERICA'S CAN DO CITY

STORMWATER SERVICES

BEAVER CREEK TRIBUTARY B
DETENTION EVALUATION

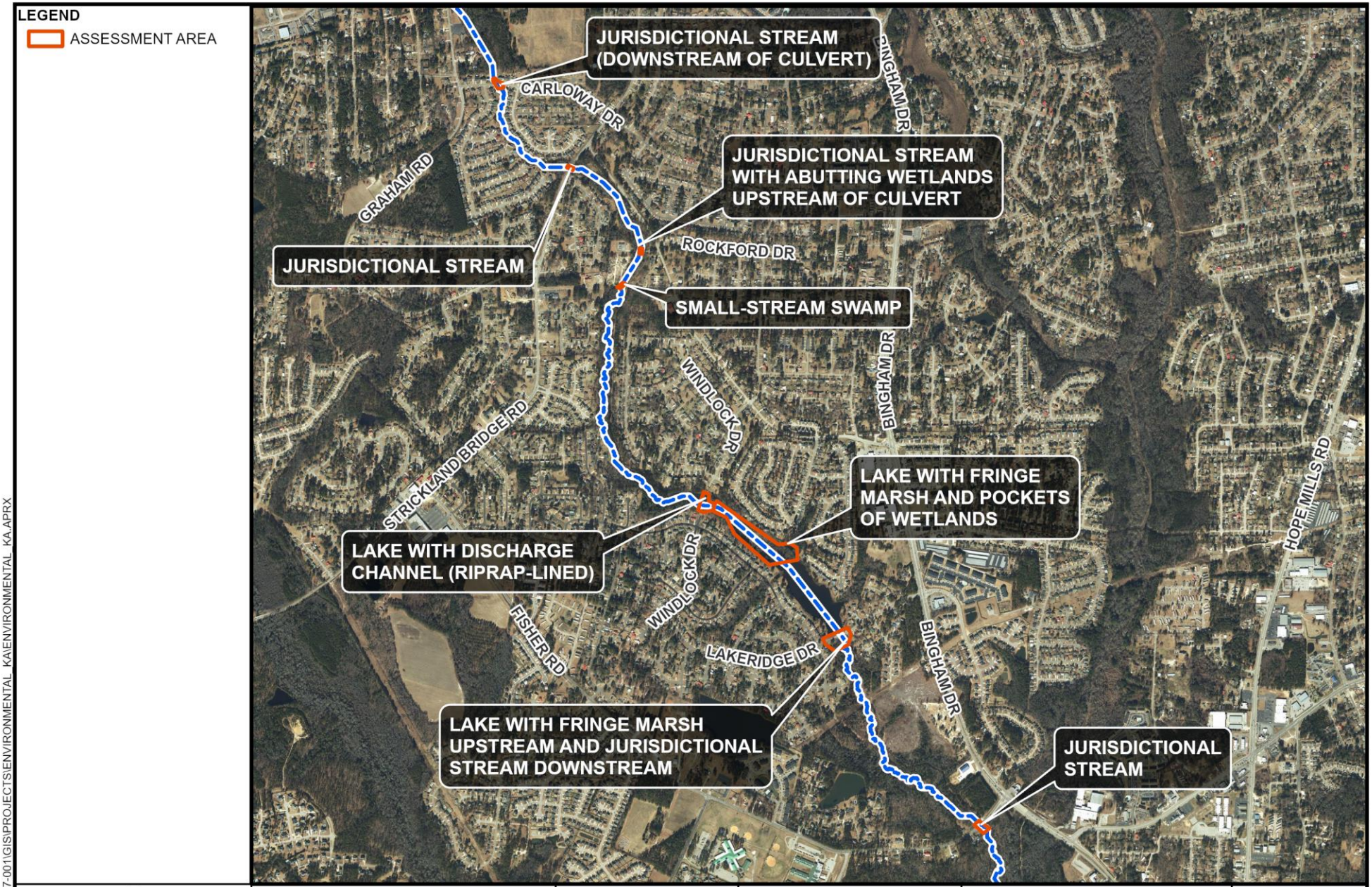
ENVIRONMENTAL EVALUATION
ASSESSMENT AREAS

DATE: JUNE 2023

FIGURE: 5-1

PATH: O:\31537-000\31537-001\GIS\PROJECTS\ENVIRONMENTAL KA\ENVIRONMENTAL KA.APRX

REFERENCE: AERIAL IMAGERY (NC ONEMAP, NC CENTER FOR GEOGRAPHIC INFORMATION AND ANALYSIS, NC 911 BOARD)



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Hazen
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SUITE 500
RALEIGH, NC 27607

FAYETTEVILLE NC
AMERICA'S CAN DO CITY
STORMWATER SERVICES

BEAVER CREEK TRIBUTARY B
DETENTION EVALUATION

ENVIRONMENTAL EVALUATION
JURISDICTIONAL FEATURES

DATE: JUNE 2023

FIGURE: 5-2

REFERENCE: AERIAL IMAGERY (NC ONEMAP, NC CENTER FOR GEOGRAPHIC INFORMATION AND ANALYSIS, NC 911 BOARD)

5.2 Federally Protected Species

The US Fish and Wildlife Service (USFWS) identifies species of plants and animals that are in the process of decline and at risk of extinction. Federal law, under the provisions of Section 7 of the Endangered Species Act of 1973, as amended, requires that any action likely to adversely affect a federally protected species be subject to review by USFWS. Other species may receive additional protection under separate federal laws.

Hazen consulted the Information for Planning and Conservation (IPaC) tool, which is maintained by USFWS, in April 2023. On the IPaC report, USFWS identified five endangered species, one candidate species, and one proposed endangered species as being known or expected to occur within the vicinity of the project. **Table 5-1** below presents the species that are identified on the IPaC report as federally endangered or proposed endangered as well as the availability of suitable habitat at each CA. Surveys for federally protected species may be necessary, depending on the extent and nature of the proposed work at each CA.

Table 5-1: Federally Protected Species Information

Scientific Name	Common Name	Federal Status	Habitat Needs	Area with Suitable Habitat[1]
Perimyotis subflavus	Tricolored bat	Proposed endangered	Roost in dense growth of trees and underbrush; hibernate in culverts or tree cavities	1, 2, 3, 4, 5, 6, 7, 8
Picoides borealis	Red-cockaded woodpecker	Endangered	Pine-dominated forest with open understory covering 3 acres or more	2, 4, 5
Lindera melissifolia	Pondberry	Endangered	Wetlands and pond margins	5, 6, 7
Lysimachia asperulaefolia	Rough-leaved loosestrife	Endangered	Edge of longleaf pine uplands and pond pine pocosins; areas maintained by fire or similar	7, 8
Rhus michauxii	Michaux's sumac	Endangered	Sandy or rocky open woods over basic soils; often on the edge of maintained areas	7, 8
Schwalbea americana	American chaffseed	Endangered	Open to partly open areas on moist acidic sandy loams or sandy peat loam	4, 6, 7, 8

[1] Area identifier codes are as follows:
1 – Carloway Drive
2 – Strickland Bridge Road
3 – Power Station
4 – Horsepen Branch
5 – Bailey Lake Dam
6 – Arran Lakes West
7 – Arran Lakes West Dam
8 – Fisher Road

5.3 Historic and Cultural Resources

Hazen utilized the HPOWEB online mapping tool managed by the State Historic Preservation Office (SHPO) to perform a desktop review of the project site and vicinity. The nearest resource of potential historic significance that was identified on HPOWEB is the Shaw-Gillis Historic District. The historic district was determined eligible for listing on the National Register of Historic Places in 1998. The Shaw-Gillis district is located more than 1.5 miles from the nearest area of interest. As such, no impact to the eligible resource will occur as a result of the proposed project.

Archaeological resources may be present in the vicinity of the areas of interest. Previous land-disturbing activities to support the construction of the existing culverts, dams, roadways, and buried utilities have likely disturbed any archaeological resources that may have been present, with the exception of Arran Lakes West. Hazen recommends that coordination with the SHPO be initiated early in the design phase. SHPO may request archaeological resource survey to ensure project compliance with the National Historic Preservation Act.

5.4 Permitting

Permits to disturb the various resources identified in or immediately adjacent to the construction areas may be required by federal law. Permits that may be necessary are discussed in the following paragraphs. Permitting requirements will depend on the final design and the requirements of each applicable regulation.

Jurisdictional waters are present within the work areas. Construction activities associated with the projects may impact protected resources, including jurisdictional waters of the US. The design team must work to avoid or minimize impacts to sensitive resources in the vicinity to the extent feasible. The project team must strive to develop a design that minimizes permanently impacting protected resources and reduces the temporary impacts to protected resources to no more than necessary to accomplish each repair.

Impacts to jurisdictional waters of the US may require acquisition of a Section 404 of the CWA permit from the USACE prior to commencement of construction activities. Work within jurisdictional waters of the US may qualify for authorization under a Nationwide Permit (NWP), specifically NWP 3 for maintenance of existing, currently serviceable structures. The NWP 3 is likely applicable to all areas of interest except for Arran Lakes West and Bailey Lake. Dredging work in the backwater area of ALW, if performed, is expected to require a Standard Permit under Section 404 of the CWA and an Individual Section 401 Water Quality Certification. Mitigation for permanent impacts to jurisdictional waters of the US may be required, depending upon the total area of permanent impacts resulting from the project.

Since acquisition of the permits or certifications from the aforementioned regulatory agencies may be required prior to commencement of construction activities, submittal of the electronic Pre-Construction Notification form (ePCN) at the earliest opportunity is recommended. It should be noted that submittal of the ePCN should not occur until design of the proposed activities is at a point where the limit of disturbance is not going to change. Any changes to the location and extent of land disturbance that impact jurisdictional waters of the US after submittal of the ePCN or receipt of permits described herein may require permit modifications, which may delay receipt of the permit(s) and may impact construction activities and schedule.

Details on habitat for federally protected species and cultural resources will be included in the ePCN, if the ePCN is required. In support of the ePCN, habitat assessments for federally protected species within and immediately adjacent to the work areas will be needed, and surveys may be necessary in areas with suitable habitat for one or more federally protected species. Archaeological surveys may be requested by SHPO. If surveys are requested, then the survey findings should be summarized in the ePCN, and the survey report should be attached to the ePCN to facilitate the permit application review process.

6. Conclusions

Evaluation of detention alternatives within the BCTB watershed identified two feasible solutions:

1. Local Detention: Installation of at least six detention facilities at locations of drainage system improvements
2. Regional Detention: Construction of overtopping protection at ALWD to withstand existing and potential future overtopping levels

Local detention involves the construction of detention facilities at drainage system improvement locations to ensure post-construction peak outflows do not exceed pre-construction flows. Based upon results of this evaluation, six drainage system improvements were found to impact BCTB flows, thus at a minimum, six detention facilities (one at each improvement location) are required to realize the full benefits of local detention. This alternative is likely to provide the most benefits compared to other options, as peak flow increases are mitigated prior to entering BCTB. As such, risks along the stream (e.g. decreases in culvert LOS, building inundation, dam overtopping / failure) are reduced. This was evident in the benefit-cost analysis (BCA) which estimated a ratio of 0.85, the highest among those alternatives analyzed (**Table 6-1**; additional information regarding the BCA is provided in **Appendix G**). However, the increased benefits do come at an increased cost, with the total for the six facilities estimated to be $21,000,000. In addition to cost, other important considerations for this alternative include:

- Increased maintenance burdens on the City for at least six additional detention facilities.
- Most storm drainage improvement projects that discharge upstream of a dam may have some impact on the Dam's performance. Depending upon the City's policy, each of these improvement projects may require detention if mitigation is required.
- Challenges and perceptions associated with property acquisition and possible building demolition to construct detention facilities
- Benefits to ALWD rely upon accurate construction and sufficient maintenance of each detention facility
- The facilities do not directly protect ALWD, thus adverse events at the Dam may be perceived as being caused by upstream changes, including PS implementation with or without local detention

Table 6-1: Alternative Costs and Benefit-Cost Ratios

Alternative	2021 Cost	BCA Ratio
Local Detention	$21,000,000	0.85
Arran Lakes West Dam Overtopping Protection	$10,000,000	0.67

The second alternative is to protect ALWD via construction of overtopping protection on the Dam. This option does not rely on nor provide mitigation of peak flow increases; however, it does directly achieve the primary goal of protecting the Dam. The cost is approximately one-half of local detention at $8,5000,000 plus the cost of improving one culvert crossing, Carloway Drive, to maintain LOS ($1,200,000). The benefit-cost ratio is however, also lower at 0.67 since the benefits are largely limited to ALWD itself (reduced risk of failure). Other considerations for this alternative include:

- Risks inherent to owning and operating a *high hazard* dam
- Criticality of routine inspections and proper maintenance
- Development and updating of an emergency action plan (EAP)
- Various perceptions of the City acquiring and improving a dam to mitigate other City projects

Ultimately, neither of the alternatives provides a benefit value greater than the project cost given the variables included in this BCA (per FEMA's Benefit-Cost Analysis Reference Guide). **Based on the technical evaluation presented in the previous sections, the most direct, effective, and economical alternative to protect ALWD is regional detention alternative DPS1 – installation of overtopping protection on ALWD. However, the other considerations listed above must also be weighed by the City when determining the preferred solution**.

Appendix A: Reference Documents

The following documents are included via reference only:

- BV3 Study InfoWorks ICM Model
- BV3 Study HEC-HMS Model
- BV3 Study Final Report
- BV3 Study GIS Files

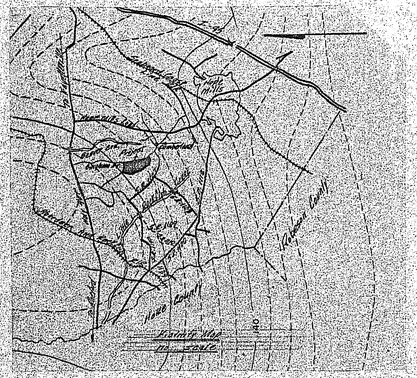
The following documents are provided in electronic format only via the electronic appendices:

- Detention Analysis InfoWorks ICM Model
- Detention Analysis HEC-HMS Model
- Detention Analysis HEC-RAS Model
- PMP Temporal Distribution Tabular Data
- Field Survey Files in SHP format

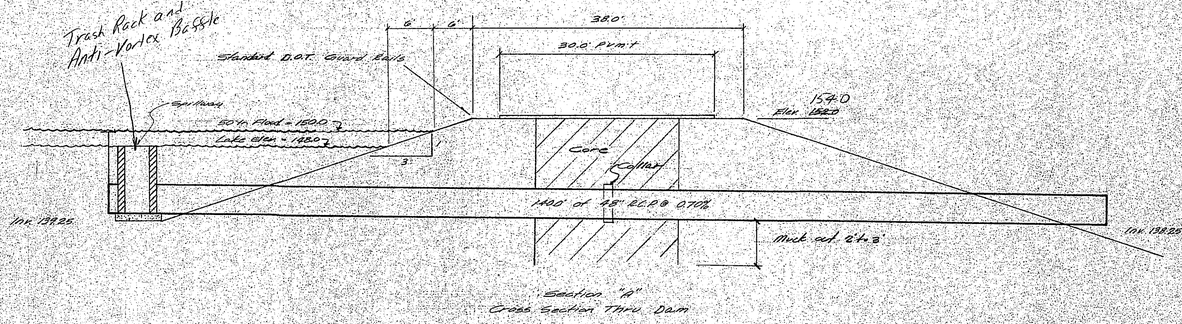
The following pages present other reference documents utilized in this Study.

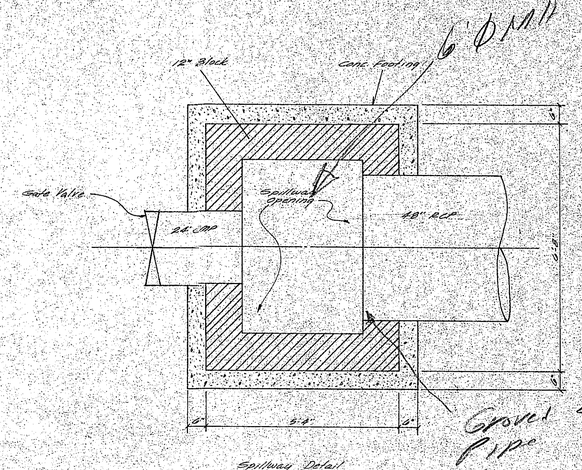
ALWD Original Design Drawing

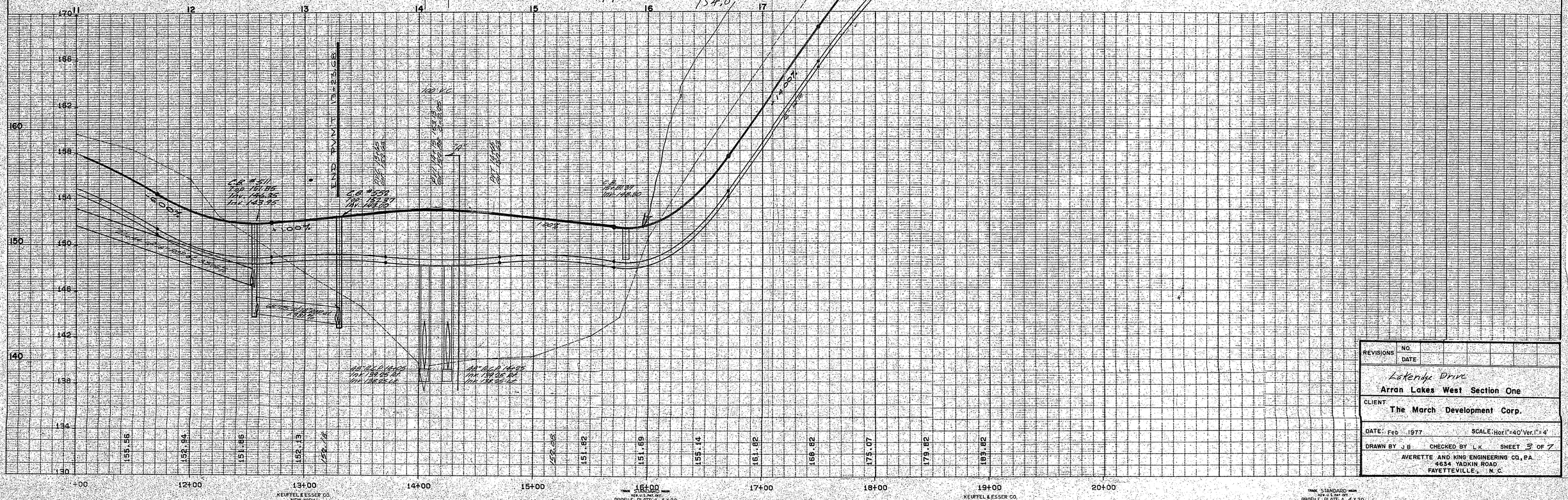
Arran Lakes West Section One, Averette and King Engineering Co, PA, 02/1977 (one page)



SEE SHEET ___ FOR PLAN VIEW






161+05 Spillway. See Detail this Sheet
161+25 Spillway Same As 161+05 w/o 24" CMP & Gate Valve.
Elev. over Min. Roadway
Dam
154.0
+8.00%
-4.00%
+1.00%
-1.00%
+1.00%
100' V.C.
CB #510
Inv. 1792.5
Inv. 1792.5
CB #509
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Inv. 1792.00

NCDS Documentation

FAYETTEVILLE NC
PUBLIC SERVICES

May 18, 2021

RECEIVED

MAY 21 2021

DEMLR
Fayetteville Regional Office

Mr. Timothy L. LaBounty, PE
Regional Engineer
Department of Environmental Quality
225 Green Street, Suite 714
Fayetteville, NC 28301

RE: Arran Lake West Dam - CUMBE-067

Dear Mr. LaBounty:

The City has recently received several calls and written inquiries from concerned citizens as it relates to the elevated water surface elevation of the lake within the Arran Lakes West subdivision. From a visual inspection it appears as though one of the riser structures is completely blocked with debris and the other riser's trash guard is significantly obstructed with vegetative debris. These riser obstructions were noted in your Notice of Inspection for the Arran Lake West Dam, dated January 27, 2021. Currently, the water surface elevation is 18-24" higher than the historical normal pool level.

Arran Lakes West Dam is a privately owned and maintained dam. The legal owners of the dam, ALW Lake Association, Inc., are either non-responsive or now defunct. The City only maintains the road surface of Lakeridge Drive and associated infrastructure within the public right-of-way. Therefore, the City is unable to perform maintenance or take repair actions on the dam to remove the riser obstructions.

The intent of this letter is to notify you of the current state of the dam. The City would also like to inquire if Dam Safety has the ability to perform the needed maintenance or has the authority to direct the legal owner to do so?

Please keep the City informed of any action taken to resolve the obstructed riser structures. You may contact me at (910) 433-1656 or by email at jmiles@ci.fay.nc.us.

Sincerely,

Jason Miles, PE
Assistant Public Services Director – Engineering

CC: Douglas J. Hewett, ICMA-CM, City Manager
Sheila Thomas-Ambat, PE – Public Services Director
Paul Allen, Assistant City Attorney

ROY COOPER
Governor
ELIZABETH S. BISER
Secretary
DOUGLAS R. ANSEL
Interim Director

NORTH CAROLINA
Environmental Quality

NOTICE OF INSPECTION

December 21, 2022

ALW Lake Association, Inc.
Attn: Herbert H. Thorp, Registered Agent
2925 Skye Drive
Fayetteville, NC 28303

City of Fayetteville
Attn: Douglas Hewitt, Manager
433 Hay Street
Fayetteville, NC 28301

RE: Arran Lakes West Dam
CUMBE-067
Cumberland County, North Carolina
Cape Fear River Basin

Dear Sirs:

The Dam Safety Law of 1967 provides for the certification and inspection of dams in the interest of public health, safety, and welfare, in order to reduce the risk of failure of such dams; to prevent injuries to persons, damage to property; and to insure the maintenance of stream flows.

Our records indicate you are the owner(s) of portions of the dam and/or operator(s) of utilities and/or roadways on the dam located on Lakeridge Drive. This dam was inspected on December 20, 2022, by personnel of the Division of Energy, Mineral and Land Resources (DEMLR). This inspection revealed the conditions outlined below:

1. Trees and bushes are growing on the upstream and downstream slopes, toe and abutments of the dam. This type of growth and/or debris can cause problems and even failure of the dam by creating holes when trees are uprooted due to wind or ice; by creating habitat for burrowing wildlife; by leaving possible seepage holes when trees die and their roots decay; and by causing erosion of the dam around this growth should the dam overtop during heavy rains. Therefore, we recommend that this type of growth be removed and a good grass cover be established on the dam and extending about one-half the dam height beyond the downstream toe.

which could ultimately result in failure of the structure, (B) reduce the possibility of damage to the dam due to the uprooting of trees by wind or other natural causes, and (C) facilitate ease of inspection and increase the likelihood of early detection of more serious problems connected with the dam.

3. Periodically remove all trees and/or debris from the auxiliary spillway. This will reduce the possibility of its capacity being reduced by the entrapment of debris, should it become active.

4. Periodically check the operation of all drain valve facilities. This will insure satisfactory operation of the drains should an emergency situation arise.

5. Periodically monitor the subject dam and appurtenant works with respect to elements affecting its safety. This is in light of the legal duties, obligations, and liabilities arising from the ownership and/or operation of a dam.

During this inspection, we also investigated the potential for property damage and loss of life in the event that your dam fails. This investigation determined that failure of your dam could result in severe property damage and/or possible loss of life downstream. Therefore, we are listing your dam in the "High Hazard" category.

Please note that any repair, modification, or permanent breach of your dam will require prior approval from the Division of Energy, Mineral, and Land Resources (DEMLR) under the Dam Safety Law of 1967 (NCGS §143-215.23). Essentially, the Dam Safety Law requires dam owners to submit plans prepared by a legally qualified professional engineer for review and approval by DEMLR. The engineer's design and application submittal must meet the requirements of Title 15A Subchapter 2K of the North Carolina Administrative Code, which sets out minimum design standards for dams under the jurisdiction of the Dam Safety Law to protect the downstream public from the consequences of dam failure.

Please be advised that though we make every reasonable effort to determine the safety of your dam, our resources limit us to surficial inspection. There is no certainty regarding the internal stability of the dam. Dams, and especially their spillways and conduits, deteriorate with age. Therefore, you are advised to keep a close watch on your dam and to notify us if you detect any changes, especially cracks, ground movements, or changes in seepage rate or color.

Tropical Storm Season Dam Safety Preparedness Guidance

As a result of previous historic tropical storm activity and severe flooding experienced in North Carolina, we are recommending that dam owners lower normal operating levels (NOL) of their impoundments between June and November. Lowering of operating levels is typically accomplished by operating drain, pump and/or siphon systems. Drawdown rates should not exceed one (1) vertical foot per day unless otherwise approved by this office and/or the dam's current engineer(s) of record. Your efforts are intended to assist in providing storage capacity as well as

ROY COOPER
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Secretary
DOUGLAS R. ANSEL
Interim Director

NORTH CAROLINA
Environmental Quality

NOTICE OF INSPECTION

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Energy, Mineral and Land Resources
ENVIRONMENTAL QUALITY

PAT MCCRORY
Governor

DONALD R. VAN DER VAART
Secretary

TRACY DAVIS
Director

NOTICE OF DEFICIENCY

December 19, 2016

CERTIFIED MAIL
RETURN RECEIPT REQUESTED
7010 1870 0003 4775 1560

ALW Lake Association, Inc.
119 N. Cool Spring Street
Fayetteville NC 28301

CERTIFIED MAIL
RETURN RECEIPT REQUESTED
7010 1870 0003 4775 1577

City of Fayetteville
Attn: Doug Hewett, Manager
433 Hay Street
Fayetteville, NC 28301

RE: Arran Lakes West Dam
CUMBE-067
Cumberland County
Cape Fear River Basin

Dear Gentlemen,

The Dam Safety Law of 1967, as amended, provides for the certification and inspection of dams in the interest of public health, safety, and welfare, in order to reduce the risk of failure of such dams; to prevent injuries to persons, damage to property; and to insure the maintenance of stream flows.

An inspection of the referenced dam was conducted on October 24th and December 14th 2016 by staff of the Division of Energy, Mineral, and Land Resources (DEMLR) Fayetteville Regional Office. Prior to this inspection, Hurricane Matthew occurred October 8, 2016. The inspection revealed the conditions outlined below:

1. The spillway riser pipe inlets are obstructed with debris which could cause overtopping of the dam. We recommend that the debris be removed.

2. There is localized head cutting on the right-side of the downstream slope of the dam and evidence of apparent overtopping flow over the crest of the dam.

3. Trees and bushes are growing on the dam. This type of growth can cause problems by creating holes when trees are uprooted due to wind or ice; by leaving possible seepage holes when trees die and their roots decay; and by causing erosion of the dam around this growth should the dam overtop during heavy rains. Therefore, we recommend that this type of growth be removed and a good grass cover be established on the dam.

Should this dam be repaired, an updated emergency action plan (EAP) will be required for this dam if one is not already on file. If an existing EAP has not been updated in the past year, the downstream hazards shall be checked and all contact information should be verified. Two copies of the EAP shall be submitted to DEMLR and a copy shall be provided to the local emergency management office. North Carolina has recently completed and adopted an EAP template for owners of high hazard dams. The template and associated guidance can be obtained by visiting the Dam Safety Programs website at http://deq.nc.gov/about/divisions/energy-mineral-land-resources/energy-mineral-land-permits/dam-safety.

Please advise this Office of your intended action in this matter. If positive action is not taken on or before February 18, 2017, your case will be referred for appropriate enforcement action. Enforcement could include a civil penalty of up to $500.00 per day of violation, and/or issuance of a Dam Safety Order requiring the repair or removal of this dam, and/or injunctive relief to gain compliance. Should you have any questions, please contact me at (910) 433-3300.

Sincerely,

Timothy L. LaBounty, PE
Regional Engineer
DEMLR

TL/rah

cc: Fayetteville Regional Office File

DAM SAFETY INSPECTION REPORT

Name	County	No.	Inspected By	Date
Arran Lakes West Dam	Cumberland	067	Lori Britt / Jodi Pace	12/8/2015

Owner	Address	Phone No.
City of Fayetteville, Ted Vorhees, Manager ALW Lake Association, Inc.	433 Hay Street, Fayetteville, NC 28301 119 N. Cool Spring St., Fayetteville NC 28301	

Type of Dam ☐ Concrete Gravity ☐ Concrete Arch ☐ Other ☒ Embankment ☐ Concrete Buttress ☐ Stone Masonry

Type of Inspection ☐ Initial ☐ Follow up ☒ Periodic ☐ Other

Site Conditions ☐ Wet ☒ Dry ☐ Snow Cover ☐ Other

Hazard Description
Lakeridge Road, Fisher Road, residences

Condition Assessment
☐ Satisfactory ☐ Fair ☒ Poor ☐ Unsatisfactory ☐ Not rated

Hazard Class
☐ Low (A) ☐ Intermediate (B) ☒ High (C)

Remarks
at normal pool, spillway activated.

Action
☐ None ☐ Maintenance ☐ Monitoring ☐ Minor Repair ☒ Engineering

Recommendations
☐ Inspection letter ☒ Deficiency letter ☐ RE notice ☐ Engineering study ☐ Inspection by RE ☐ Inspection by DSE ☐ Dam safety order ☐ Enforcement ☐ Periodic reinspection ☐ Other reinspection

AREA	PROBLEMS	COMMENTS
UPSTREAM SLOPE / FACE	☐ 1. None ☒ 2. Trees ☒ 3. High bushes ☐ 4. Burrows ☐ 5. Wave erosion ☐ 6. Livestock damage ☐ 7. Slides ☐ 8. Depressions ☐ 9. Bulges ☐ 10. Sparse rip rap ☐ 11. Displaced rip rap ☐ 12. Cracks ☐ 13. Undermining ☐ 14. Holes ☐ 15. Spalling ☐ 16. Displaced joints ☐ 17. Deteriorated joints ☐ 18. Exposed reinforcement ☐ 19. Other	COVER: ☒ Vegetation ☐ Rip rap ☐ Concrete ☐ Asphalt ☐ Other 2,3 - Small trees and woody vegetation. Proper inspection not possible.
TOP OF DAM	☐ 1. None ☐ 2. Trees ☐ 3. High bushes ☐ 4. Burrows ☐ 5. Ruts ☐ 6. Livestock damage ☐ 7. Depressions ☐ 8. Unlevel ☐ 9. Misalignment ☐ 10. Has overtopped ☐ 11. Cracks ☐ 12. Spalling ☐ 13. Deteriorated joints ☐ 14. Displaced joints ☐ 15. Exposed reinforcement ☐ 16. Other	COVER: ☒ Vegetation ☐ Gravel ☐ Concrete ☒ Asphalt ☐ Other guardrail located on upstream side.
DOWNSTREAM SLOPE / FACE	☐ 1. None ☒ 2. Trees ☒ 3. High bushes ☐ 4. Burrows ☒ 5. Erosion ☐ 6. Livestock damage ☒ 7. Slides ☐ 8. Depressions ☐ 9. Bulges ☐ 10. Wetness ☒ 11. Seepage ☐ 12. Boils ☐ 13. Cracks ☐ 14. Holes ☐ 15. Spalling ☐ 16. Displaced joints ☐ 17. Deteriorated joints ☐ 18. Exposed reinforcement ☐ 19. Other	COVER: ☒ Vegetation ☐ Rip rap ☐ Concrete ☐ Other 2,3 - small trees and woody vegetation, dense. Proper inspection not possible. 5 - Erosion from foot traffic 7 - Old slides noted 11 - seepage noted around secondary spillway outlet.
TOE CONTACT	☐ 1. None ☒ 2. Trees ☒ 3. High bushes ☐ 4. Burrows ☐ 5. Erosion ☐ 6. Livestock damage ☐ 7. Slides ☐ 8. Depressions ☐ 9. Bulges ☒ 10. Wetness ☐ 11. Seepage ☐ 12. Boils ☐ 13. Cracks ☐ 14. Holes ☐ 15. Spalling ☐ 16. Displaced joints ☐ 17. Deteriorated joints ☐ 18. Exposed reinforcement ☐ 19. Other	COVER: ☒ Vegetation ☐ Rip rap ☐ Concrete ☐ Other 2,3 - trees, woody vegeation 10 - wetness in the area of PWC sewer easement

ROY COOPER
Governor
MICHAEL S. REGAN
Secretary
BRIAN WRENN
Director

NORTH CAROLINA
Environmental Quality

NOTICE OF INSPECTION

January 27, 2021

ALW Lake Association, Inc.
c/o Thorpe and Clarke, PA
Attn: F. Stuart Clarke
150 N. McPherson Church Road, Suite B
Fayetteville, NC 28303

City of Fayetteville
Attn: Douglas Hewitt, Manager
433 Hay Street
Fayetteville, NC 28301

RE: Arran Lakes West Dam
CUMBE-067
Cumberland County, North Carolina
Cape Fear River Basin

Dear Sirs:

The Dam Safety Law of 1967 provides for the certification and inspection of dams in the interest of public health, safety, and welfare, in order to reduce the risk of failure of such dams; to prevent injuries to persons, damage to property; and to insure the maintenance of stream flows.

Our records indicate you are the owner(s) of portions of the dam and/or operator(s) of utilities and/or roadways on the dam located on Lakeridge Drive. This dam was inspected on January 13, 2021 by personnel of the Division of Energy, Mineral and Land Resources (DEMLR). This inspection revealed the conditions outlined below:

1. Trees and bushes are growing on the upstream and downstream slopes, toe and abutments of the dam. This type of growth and/or debris can cause problems and even failure of the dam by creating holes when trees are uprooted due to wind or ice; by creating habitat for burrowing wildlife; by leaving possible seepage holes when trees die and their roots decay; and by causing erosion of the dam around this growth should the dam overtop during heavy rains. Therefore, we recommend that this type of growth be removed and a good grass cover be established on the dam and extending about one-half the dam height beyond the downstream toe.

formation of a root system which might significantly increase seepage through the dam which could ultimately result in failure of the structure, (B) reduce the possibility of damage to the dam due to the uprooting of trees by wind or other natural causes, and (C) facilitate ease of inspection and increase the likelihood of early detection of more serious problems connected with the dam.

3. Periodically remove all trees and/or debris from the auxiliary spillway. This will reduce the possibility of its capacity being reduced by the entrapment of debris, should it become active.

4. Periodically check the operation of all drain valve facilities. This will insure satisfactory operation of the drains should an emergency situation arise.

5. Periodically monitor the subject dam and appurtenant works with respect to elements affecting its safety. This is in light of the legal duties, obligations, and liabilities arising from the ownership and/or operation of a dam.

During this inspection, we also investigated the potential for property damage and loss of life in the event that your dam fails. This investigation determined that failure of your dam could result in severe property damage and/or possible loss of life downstream. Therefore, we are listing your dam in the "High Hazard" category.

Please note that any repair, modification, or permanent breach of your dam will require prior approval from the Division of Energy, Mineral, and Land Resources (DEMLR) under the Dam Safety Law of 1967 (NCGS §143-215.23). Essentially, the Dam Safety Law requires dam owners to submit plans prepared by a legally-qualified professional engineer for review and approval by DEMLR. The engineer's design and application submittal must meet the requirements of Title 15A Subchapter 2K of the North Carolina Administrative Code, which sets out minimum design standards for dams under the jurisdiction of the Dam Safety Law to protect the downstream public from the consequences of dam failure.

Please be advised that though we make every reasonable effort to determine the safety of your dam, our resources limit us to surficial inspection. There is no certainty regarding the internal stability of the dam. Dams, and especially their spillways and conduits, deteriorate with age. Therefore, you are advised to keep a close watch on your dam and to notify us if you detect any changes, especially cracks, ground movements, or changes in seepage rate or color.

Tropical Storm Season Dam Safety Preparedness Guidance

As a result of previous historic tropical storm activity and severe flooding experienced in North Carolina, we are recommending that dam owners lower normal operating levels (NOL) of their impoundments between June and November. Lowering of operating levels is typically accomplished by operating drain, pump and/or siphon systems. Drawdown rates should not exceed one (1) vertical foot per day unless otherwise approved by this office and/or the dam's current engineer(s) of record. Your efforts are intended to assist in providing storage capacity as well as

DAM SAFETY INSPECTION REPORT

Name	County	No.	Inspected By	Date
Aaran Lakes West Dam	Cumberland	067	M. Joyner, T. LaBounty	1/13/2021

Owner	Address	Phone No.
ALW Lake Association, Inc.	119 N. Cool Spring St., Fayetteville NC 28301	

Type of Dam ☐Concrete Gravity ☐Concrete Arch ☐Other ☒Embankment ☐Concrete Buttress ☐Stone Masonry

Type of Inspection ☐Initial ☐Follow up ☒Periodic ☐Other

Site Conditions ☐Wet ☒Dry ☐Snow Cover ☐Other

Hazard Description
Lakeridge Road, Fisher Road, residences

Condition Assessment ☐Satisfactory ☒Fair ☐Poor ☐Unsatisfactory ☐Not rated

Hazard Class ☐Low (A) ☐Intermediate (B) ☒High (C)

Remarks
At NP

Action ☐None ☒Maintenance ☐Monitoring ☐Minor Repair ☐Engineering

Recommendations ☒Inspection letter ☐Deficiency letter ☐RE notice ☐Engineering study ☐Inspection by RE ☐Inspection by DSE ☐Dam safety order ☐Enforcement ☐Periodic reinspection ☐Other reinspection

AREA	PROBLEMS	COMMENTS
UPSTREAM SLOPE / FACE	☐1. None ☒2. Trees ☒3. High bushes ☐4. Burrows ☐5. Wave erosion ☐6. Livestock damage ☐7. Slides ☐8. Depressions ☐9. Bulges ☐10. Sparse rip rap ☐11. Displaced rip rap ☐12. Cracks ☐13. Undermining ☐14. Holes ☐15. Spalling ☐16. Displaced joints ☐17. Deteriorated joints ☐18. Exposed reinforcement ☐19. Other	COVER: ☒Vegetation ☐Rip rap ☐Concrete ☐Asphalt ☐Other 2,3 - Small trees and woody vegetation.
TOP OF DAM	☒1. None ☐2. Trees ☐3. High bushes ☐4. Burrows ☐5. Ruts ☐6. Livestock damage ☐7. Depressions ☐8. Unlevel ☐9. Misalignment ☐10. Has overtopped ☐11. Cracks ☐12. Spalling ☐13. Deteriorated joints ☐14. Displaced joints ☐15. Exposed reinforcement ☐16. Other	COVER: ☒Vegetation ☐Gravel ☐Concrete ☒Asphalt ☐Other Guardrail located on upstream side.
DOWNSTREAM SLOPE / FACE	☐1. None ☒2. Trees ☒3. High bushes ☐4. Burrows ☐5. Erosion ☐6. Livestock damage ☐7. Slides ☐8. Depressions ☐9. Bulges ☐10. Wetness ☐11. Seepage ☐12. Boils ☐13. Cracks ☐14. Holes ☐15. Spalling ☐16. Displaced joints ☐17. Deteriorated joints ☐18. Exposed reinforcement ☐19. Other	COVER: ☒Vegetation ☐Rip rap ☐Concrete ☐Other 2,3 - small trees and woody vegetation.
TOE CONTACT	☐1. None ☒2. Trees ☒3. High bushes ☐4. Burrows ☐5. Erosion ☐6. Livestock damage ☐7. Slides ☐8. Depressions ☐9. Bulges ☒10. Wetness ☒11. Seepage ☐12. Boils ☐13. Cracks ☐14. Holes ☐15. Spalling ☐16. Displaced joints ☐17. Deteriorated joints ☐18. Exposed reinforcement ☐19. Other	COVER: ☒Vegetation ☐Rip rap ☐Concrete ☐Other 2,3 - trees, woody vegeation 10/11 - Wetness/seepage on right side of contact area of toe of dam.

MOORMAN, KIZER & REITZEL, INC.
Engineers, Planners and Surveyors
115 BROADFOOT AVENUE • POST OFFICE BOX 53774
FAYETTEVILLE, NORTH CAROLINA 28305

TELEPHONE: (910) 484-5191
FAX: (910) 484-0388

RECEIVED
FEB 13 1995
LAND QUALITY SECTION
FAYETTEVILLE REGIONAL OFFICE

January 24, 1995

RECEIVED
DEHNR
JAN 31 1995
LAND QUALITY SECTION

Mr. James K. Leumas, P.E.
Dam Safety Engineer
Land Quality Section
NCDEHNR
PO Box 27687
Raleigh, NC 27611-7687

REF: Arran Lakes West Dam
Cumberland County, NC
26-067-H

Dear Mr. Leumas:

This correspondence is being submitted to inform your office that the proposed repairs and modifications to be made to the Arran Lakes West Dam have been completed and are ready to be inspected. The work undertaken on this dam follows closely the plans submitted to you on September 13, 1994, and approved by your office on September 30, 1994. The project began in earnest in November of 1994, and was completed the week of January 9, 1995.

As per our plans and your office's comments, the following items were addressed during the construction activities and repairs on this dam.

1) A new 24" gate has been installed on Riser "B" as shown on Sheet 2 of 3. This gate has been operated several times during the various construction phases and has worked adequately throughout.

2) The existing 18" gate on Barrel "A" has been replaced by a new 24" gate as shown on Sheet 2 of 3. Again, this gate has been operated several times and has worked adequately. There have been times when trash buildups around the seals have created leaks, but these have been alleviated by opening and shutting the gate.

3) The first four pipe joints in each barrel have been grouted as shown on Sheet 2 of 3. The grouting was accomplished by using a mix of hydraulic cement on the joints themselves in order to seal off any leaks and then injecting a synthetic urethane grout to fill the voids around the pipe annulus.

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*                                        *
*   FLOOD HYDROGRAPH PACKAGE (HEC-1)     *
*         FEBRUARY 1981                  *
*         REVISED 01 JUN 88              *
*                                        *
*  RUN DATE  08/22/1994  TIME  14:18:25  *
*                                        *
**********
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RECEIVED
AUG 25 1994
LAND QUALITY SECTION
FAYETTEVILLE REGIONAL OFFICE

****
*   *
*   U.S. ARMY CORPS OF ENGINEERS   *
* THE HYDROLOGIC ENGINEERING CENTER   *
*   609 SECOND STREET   *
*   DAVIS, CALIFORNIA 95616   *
*   (916) 551-1748   *
*   *
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X     X  XXXXXXX   XXXXX          X
X     X  X        X     X        XX
X     X  X        X              X
XXXXXXX  XXXX     X        XXXXX  X
X     X  X        X              X
X     X  X        X     X        X
X     X  XXXXXXX  XXXXX          XXX
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THIS PROGRAM REPLACES ALL PREVIOUS VERSIONS OF HEC-1 KNOWN AS HEC1 (JAN 73), HEC1GS, HEC1DB, AND HEC1KW.

THE DEFINITIONS OF VARIABLES -RTIMP- AND -RTIOR- HAVE CHANGED FROM THOSE USED WITH THE 1973-STYLE INPUT STRUCTURE.
THE DEFINITION OF -AMSKK- ON RM-CARD WAS CHANGED WITH REVISIONS DATED 28 SEP 81. THIS IS THE FORTRAN77 VERSION
NEW OPTIONS: DAMBREAK OUTFLOW SUBMERGENCE , SINGLE EVENT DAMAGE CALCULATION, DSS:WRITE STAGE FREQUENCY,
DSS:READ TIME SERIES AT DESIRED CALCULATION INTERVAL LOSS RATE:GREEN AND AMPT INFILTRATION
KINEMATIC WAVE: NEW FINITE DIFFERENCE ALGORITHM

1 HEC-1 INPUT PAGE 1

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LINE          ID.....1.....2.....3.....4.....5.....6.....7.....8.....9.....10

  1           ID   BAILEY LAKE DAM AND ARRAN LAKES WEST DAM
  2           ID   CUMBERLAND COUNTY
  3           ID   SUNNY DAY BREACH OF BAILEY LAKE DAM
  4           ID   BAILEY2.DAT     JKL     08.19.94
  5           IT       5       0       0     300
  6           IO       5       0

  7           KK       1     INFLOW TO BAILEY LAKE DAM
  8           KM       DRAINAGE AREA = 1100.95 ACRES = 1.7202 SQUARE MILES PLANIMETERED BY JKL
  9           BA   1.7202
 10           KM       PRECIPITATION DATA FROM HYDRO-35 FOR 5-, 15-, AND 60-MINUTE
 11           KM       DURATIONS AND FROM TP-40 FOR 2-, 3-, AND 6-HOUR DURATIONS
 12           PH       2       0     .01     .02     .03     .04     .05     .06
 13           KM       CURVE NUMBER DEVELOPED FROM FAYETTEVILLE AND CLIFDALE QUAD MAPS
 14           KM       ESTIMATED 60 % 1/4-ACRE RESIDENTIAL, 30 % PASTURE (FAIR)
 15           KM       AND 10 % WOODS (FAIR) AND FROM SOIL TYPES FROM SCS SOIL SURVEY
 16           KM       ESTIMATE 40 % "A" SOILS, 45 % "B" SOILS AND 15 % "D" SOILS
 17           LS       0      67
 18           KM       LAG TIME DERIVED FROM   [L**0.8 X (S+1)**0.7] / [1900 X Y**0.5]
 19           KM       HYDRAULIC LENGTH, L = 16,000 FEET, S = (CN/1000) - 10, AND
 20           KM       Y = AVERAGE WATERSHED SLOPE IN PERCENT = 1.84 %
 21           UD   3.11

 22           KK       2    ROUTE THRU BAILEY LAKE DAM
 23           RS       1    ELEV  166.23
 24           KM       SURFACE AREA AT NORMAL POOL = 9.76 ACRES PLANIMETERED BY JKL
 25           KM       SURFACE AREAS FROM MARK SEFFELS
 26           SA       0   10.03   11.47   15.69   18.58   22.07
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*          REVISED 01 JUN 88          *
*                                     *
*  RUN DATE  08/22/1994  TIME  14:18:25 *
*                                     *
***************************************
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*          609 SECOND STREET          *
*        DAVIS, CALIFORNIA 95616      *
*           (916) 551-1748            *
*                                     *
***************************************
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BAILEY LAKE DAM AND ARRAN LAKES WEST DAM
CUMBERLAND COUNTY
SUNNY DAY BREACH OF BAILEY LAKE DAM
BAILEY2.DAT JKL 08.19.94

6 IO OUTPUT CONTROL VARIABLES

IPRNT	5	PRINT CONTROL
IPLOT	0	PLOT CONTROL
QSCAL	0.	HYDROGRAPH PLOT SCALE

IT HYDROGRAPH TIME DATA

NMIN	5	MINUTES IN COMPUTATION INTERVAL
IDATE 1	0	STARTING DATE
ITIME	0000	STARTING TIME
NQ	300	NUMBER OF HYDROGRAPH ORDINATES
NDDATE 2	0	ENDING DATE
NDTIME	0055	ENDING TIME
ICENT	19	CENTURY MARK

COMPUTATION INTERVAL .08 HOURS
TOTAL TIME BASE 24.92 HOURS

ENGLISH UNITS

DRAINAGE AREA	SQUARE MILES
PRECIPITATION DEPTH	INCHES
LENGTH, ELEVATION	FEET
FLOW	CUBIC FEET PER SECOND
STORAGE VOLUME	ACRE-FEET
SURFACE AREA	ACRES
TEMPERATURE	DEGREES FAHRENHEIT

1

RUNOFF SUMMARY
FLOW IN CUBIC FEET PER SECOND
TIME IN HOURS, AREA IN SQUARE MILES

OPERATION	STATION	PEAK FLOW	TIME OF PEAK	AVERAGE FLOW FOR MAXIMUM PERIOD 6-HOUR	24-HOUR	72-HOUR	BASIN AREA	MAXIMUM STAGE	TIME OF MAX STAGE
HYDROGRAPH AT	1	0.	.08	0.	0.	0.	1.72		
ROUTED TO	2	2495.	.50	80.	20.	19.	1.72		
								166.23	.01
HYDROGRAPH AT	3	0.	.08	0.	0.	0.	.75		
2 COMBINED AT	4	2495.	.50	80.	20.	19.	2.47		
ROUTED TO	5	328.	.58	78.	20.	19.	2.47		
								150.83	.58

1 SUMMARY OF DAM OVERTOPPING/BREACH ANALYSIS FOR STATION 2

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1*****************************************
*                                       *
*   FLOOD HYDROGRAPH PACKAGE (HEC-1)    *
*         FEBRUARY 1981                 *
*         REVISED 01 JUN 88             *
*                                       *
*  RUN DATE  08/22/1994  TIME  14:12:23 *
*                                       *
*****************************************
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RECEIVED
AUG 23 1994
LAND QUALITY SECTION
FAYETTEVILLE REGIONAL OFFICE

****
*   *
*   U.S. ARMY CORPS OF ENGINEERS   *
*   THE HYDROLOGIC ENGINEERING CENTER   *
*   609 SECOND STREET   *
*   DAVIS, CALIFORNIA 95616   *
*   (916) 551-1748   *
*   *
****

```
X     X  XXXXXXX   XXXXX          X
X     X  X        X     X        XX
X     X  X        X              X
XXXXXXX  XXXX     X        XXXXX  X
X     X  X        X              X
X     X  X        X     X        X
X     X  XXXXXXX  XXXXX          XXX
```

THIS PROGRAM REPLACES ALL PREVIOUS VERSIONS OF HEC-1 KNOWN AS HEC1 (JAN 73), HEC1GS, HEC1DB, AND HEC1KW.

THE DEFINITIONS OF VARIABLES -RTIMP- AND -RTIOR- HAVE CHANGED FROM THOSE USED WITH THE 1973-STYLE INPUT STRUCTURE.
THE DEFINITION OF -AMSKK- ON RM-CARD WAS CHANGED WITH REVISIONS DATED 28 SEP 81. THIS IS THE FORTRAN77 VERSION
NEW OPTIONS: DAMBREAK OUTFLOW SUBMERGENCE , SINGLE EVENT DAMAGE CALCULATION, DSS:WRITE STAGE FREQUENCY,
DSS:READ TIME SERIES AT DESIRED CALCULATION INTERVAL LOSS RATE:GREEN AND AMPT INFILTRATION
KINEMATIC WAVE: NEW FINITE DIFFERENCE ALGORITHM


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LINE          ID.....1.....2.....3.....4.....5.....6.....7.....8.....9.....10

   1          ID   BAILEY LAKE DAM AND ARRAN LAKES WEST DAM
   2          ID   CUMBERLAND COUNTY
   3          ID   25-YR 6-HR STORM WITHOUT AND WITH BREACH OF BAILEY LAKE DAM
   4          ID   BAILEY1.DAT     JKL     08.22.94
   5          IT       5       0       0     300
   6          IO       5       0
   7          JP       2

   8          KK       1     INFLOW TO BAILEY LAKE DAM
   9          KM       DRAINAGE AREA = 1100.95 ACRES = 1.7202 SQUARE MILES PLANIMETERED BY JKL
  10          BA  1.7202
  11          KM       PRECIPITATION DATA FROM HYDRO-35 FOR 5-, 15-, AND 60-MINUTE
  12          KM       DURATIONS AND FROM TP-40 FOR 2-, 3-, AND 6-HOUR DURATIONS
  13          PH       4       0     .67    1.49    3.17    3.56    3.93    4.92
  14          KM       CURVE NUMBER DEVELOPED FROM FAYETTEVILLE AND CLIFDALE QUAD MAPS
  15          KM       ESTIMATED 60 % 1/4-ACRE RESIDENTIAL, 30 % PASTURE (FAIR)
  16          KM       AND 10 % WOODS (FAIR) AND FROM SOIL TYPES FROM SCS SOIL SURVEY
  17          KM       ESTIMATE 40 % "A" SOILS, 45 % "B" SOILS AND 15 % "D" SOILS
  18          LS       0      67
  19          KM       LAG TIME DERIVED FROM   [L**0.8 X (S+1)**0.7] / [1900 X Y**0.5]
  20          KM       HYDRAULIC LENGTH, L = 16,000 FEET, S = (CN/1000) - 10, AND
  21          KM       Y = AVERAGE WATERSHED SLOPE IN PERCENT = 1.84 %
  22          UD    3.11

  23          KK       2    ROUTE THRU BAILEY LAKE DAM
  24          RS       1    ELEV  166.23
  25          KM       SURFACE AREA AT NORMAL POOL = 9.76 ACRES PLANIMETERED ON QUAD BY JKL
  26          KM       SURFACE AREAS FROM MARK SEFFELS ON 8.22.94
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 27          SA       0   10.03   11.47   15.69   18.58   22.07
 28          SE  154.53    166     168     170     172     174
 29          KM       RATING CURVE DEVELOPED FROM PSPWY = 3-FT X 4-FT BOX RISER AND
 30          KM       30-INCH DIAMETER RCP BARREL, BARREL LENGTH = 62 FEET WITH OUTLET
 31          KM       INVERT ELEVATION = 154.07
 32          KM       ESPWY IS 1-FOOT BOTTOM WIDTH, AVG. 20H:1V SIDE SLOPES CHANNEL WITH
 33          KM       CONTROL SECTION AT INVERT ELEVATION 172.3
 34          SQ       0       6      29      62      71      73      74      75      77      78
 35          SQ      79      81      82      84     106     168     281
 36          SE  166.23   166.5     167   167.5     168   168.5     169   169.5     170   170.5
 37          SE     171   171.5     172   172.5     173   173.5     174
 38          KM       CREST LENGTH OF DAM TAKEN FROM ENGR'S PLANS
 39          KM       = 350 FEET
 40          ST     174     350     2.8     1.5
 41          KP       2
 42          KM       BREACH OF BAILEY LAKE DAM
 43          SB  154.53      40       1      .5  172.97

 44          KK       3
 45          KM       INFLOW TO ARRAN LAKES WEST DAM
 46          KM       DRAINAGE AREA = 477.10 ACRES = 0.7455 SQUARE MILES PLANIMETERED BY JKL
 47          BA    .7455
 48          KM       PRECIPITATION DATA FROM HYDRO-35 FOR 5-, 15-, AND 60-MINUTE
 49          KM       DURATIONS AND FROM TP-40 FOR 2-, 3-, AND 6-HOUR DURATIONS
 50          PH       4       0     .67    1.49    3.17    3.56    3.93    4.92
 51          KM       CURVE NUMBER DEVELOPED FROM FAYETTEVILLE QUAD MAP
 52          KM       ESTIMATED 75 % 1/4-ACRE RESIDENTIAL, 10 % PASTURE (FAIR)
1                                      HEC-1 INPUT                                    PAGE  2

      LINE          ID.....1.....2.....3.....4.....5.....6.....7.....8.....9.....10

 53          KM       AND 15 % WOODS (FAIR) AND FROM SOIL TYPES FROM SCS SOIL SURVEY
 54          KM       ESTIMATE 50 % "A" SOILS, 15 % "B" SOILS, 15 % "C" SOILS
 55          KM       AND 20 % "D" SOILS
 56          LS       0      69
 57          KM       LAG TIME DERIVED FROM   [L**0.8 X (S+1)**0.7] / [1900 X Y**0.5]
 58          KM       HYDRAULIC LENGTH, L = 6,000 FEET, S = (CN/1000) - 10, AND
 59          KM       Y = 1.9 % = AVERAGE WATERSHED SLOPE IN PERCENT
 60          UD    1.32

 61          KK       4
 62          KM       COMBINE OUTFLOW FROM BAILEY LAKE DAM WITH INFLOW TO ARRAN LAKES
 63          KM       WEST DAM
 64          HC       2

 65          KK       5    ROUTE THRU ARRAN LAKES WEST DAM
 66          RS       1    ELEV     148
 67          KM       SURFACE AREA AT NORMAL POOL = 12.10 ACRES PLANIMETERED BY JKL
 68          KM       SURFACE AREAS AT ELEV. 150 AND 152 FROM ENGR'S PLANS
 69          KM       SURFACE AREA AT ELEV 160 PLANIMETERED FROM QUAD BY JKL
 70          SA       0   12.10    12.2    15.7   32.74
 71          SE  139.25     148     150     152     160
 72          KM       RATING CURVE DEVELOPED FROM TWIN PSPWY'S = 72-INCH DIAMETER RISERS AND
 73          KM       48-INCH DIAMETER BARRELS, EACH BARREL LENGTH = 140 FEET WITH OUTLET
 74          KM       INVERT ELEVATION = 138.25; BARRELS ARE RCP
 75          KM       NO ESPWY
 76          SQ       0      41     117     215     315     323     331     339     346     353
 77          SQ     361     368     374
 78          SE     148   148.5     149   149.5     150   150.5     151   151.5     152   152.5
 79          SE     153   153.5     154
 80          KM       CREST LENGTH OF DAM TAKEN FROM ENGR'S PLANS
 81          KM       = 400 FEET
 82          ST     154     400     2.8     1.5
 83          ZZ
1*****************************************                ****************************************
 *                                    *                *                                      *
```

ROUTED TO

+	2	1.72	1	FLOW	115.
				TIME	10.42
			2	FLOW	6120.
				TIME	10.08

** PEAK STAGES IN FEET **

1	STAGE	173.07
	TIME	10.42
2	STAGE	172.99
	TIME	9.66

HYDROGRAPH AT

+	3	.75	1	FLOW	355.
				TIME	4.50
			2	FLOW	355.
				TIME	4.50

2 COMBINED AT

+	4	2.47	1	FLOW	375.
				TIME	4.67
			2	FLOW	6123.
				TIME	10.08

ROUTED TO

+	5	2.47	1	FLOW	301.
				TIME	5.50
			2	FLOW	2733.
				TIME	10.17

** PEAK STAGES IN FEET **

1	STAGE	149.93
	TIME	5.50
2	STAGE	155.63
	TIME	10.17

1 SUMMARY OF DAM OVERTOPPING/BREACH ANALYSIS FOR STATION 2

PLAN 1 .....

	INITIAL VALUE	SPILLWAY CREST	TOP OF DAM
ELEVATION	166.23	174.00	174.00
STORAGE	41.	162.	162.
OUTFLOW	0.	281.	281.

RATIO OF PMF	MAXIMUM RESERVOIR W.S.ELEV	MAXIMUM DEPTH OVER DAM	MAXIMUM STORAGE AC-FT	MAXIMUM OUTFLOW CFS	DURATION OVER TOP HOURS	TIME OF MAX OUTFLOW HOURS	TIME OF FAILURE HOURS
1.00	173.07	.00	142.	115.	.00	10.42	.00

PLAN 2 .....

	INITIAL VALUE	SPILLWAY CREST	TOP OF DAM
ELEVATION	166.23	174.00	174.00
STORAGE	41.	162.	162.
OUTFLOW	0.	281.	281.

RATIO OF PMF	MAXIMUM RESERVOIR W.S.ELEV	MAXIMUM DEPTH OVER DAM	MAXIMUM STORAGE AC-FT	MAXIMUM OUTFLOW CFS	DURATION OVER TOP HOURS	TIME OF MAX OUTFLOW HOURS	TIME OF FAILURE HOURS
1.00	172.99	.00	140.	6120.	.00	10.08	9.58

1 SUMMARY OF DAM OVERTOPPING/BREACH ANALYSIS FOR STATION 5

PLAN 1 .....

	INITIAL VALUE	SPILLWAY CREST	TOP OF DAM

```
1*****************************************
*                                       *
*   FLOOD HYDROGRAPH PACKAGE  (HEC-1)   *
*             FEBRUARY 1981             *
*           REVISED 01 JUN 88           *
*                                       *
*  RUN DATE  08/22/1994  TIME  14:02:53 *
*                                       *
*****************************************
```

RECEIVED
AUG 25 1994
LAND QUALITY SECTION
FAYETTEVILLE REGIONAL OFFICE

****
*   *
* U.S. ARMY CORPS OF ENGINEERS   *
* THE HYDROLOGIC ENGINEERING CENTER   *
*   609 SECOND STREET   *
*   DAVIS, CALIFORNIA 95616   *
*   (916) 551-1748   *
*   *
****

```
X     X  XXXXXXX   XXXXX          X
X     X  X        X     X        XX
X     X  X        X              X
XXXXXXX  XXXX     X       XXXXX  X
X     X  X        X              X
X     X  X        X     X        X
X     X  XXXXXXX  XXXXX          XXX
```

THIS PROGRAM REPLACES ALL PREVIOUS VERSIONS OF HEC-1 KNOWN AS HEC1 (JAN 73), HEC1GS, HEC1DB, AND HEC1KW.

THE DEFINITIONS OF VARIABLES -RTIMP- AND -RTIOR- HAVE CHANGED FROM THOSE USED WITH THE 1973-STYLE INPUT STRUCTURE.
THE DEFINITION OF -AMSKK- ON RM-CARD WAS CHANGED WITH REVISIONS DATED 28 SEP 81. THIS IS THE FORTRAN77 VERSION
NEW OPTIONS: DAMBREAK OUTFLOW SUBMERGENCE , SINGLE EVENT DAMAGE CALCULATION, DSS:WRITE STAGE FREQUENCY,
DSS:READ TIME SERIES AT DESIRED CALCULATION INTERVAL LOSS RATE:GREEN AND AMPT INFILTRATION
KINEMATIC WAVE: NEW FINITE DIFFERENCE ALGORITHM


```
LINE      ID.....1.....2.....3.....4.....5.....6.....7.....8.....9.....10

  1       ID   BAILEY LAKE DAM AND ARRAN LAKES WEST DAM
  2       ID   CUMBERLAND COUNTY
  3       ID   50-YR 6-HR STORM WITHOUT AND WITH BREACH OF BAILEY LAKE DAM
  4       ID   BAILEY1.DAT     JKL     08.22.94
  5       IT       5       0       0     300
  6       IO       5       0
  7       JP       2

  8       KK       1     INFLOW TO BAILEY LAKE DAM
  9       KM       DRAINAGE AREA = 1100.95 ACRES = 1.7202 SQUARE MILES PLANIMETERED BY JKL
 10       BA  1.7202
 11       KM       PRECIPITATION DATA FROM HYDRO-35 FOR 5-, 15-, AND 60-MINUTE
 12       KM       DURATIONS AND FROM TP-40 FOR 2-, 3-, AND 6-HOUR DURATIONS
 13       PH       2       0     .74    1.66    3.58    4.02    4.47    5.58
 14       KM       CURVE NUMBER DEVELOPED FROM FAYETTEVILLE AND CLIFDALE QUAD MAPS
 15       KM       ESTIMATED 60 % 1/4-ACRE RESIDENTIAL, 30 % PASTURE (FAIR)
 16       KM       AND 10 % WOODS (FAIR) AND FROM SOIL TYPES FROM SCS SOIL SURVEY
 17       KM       ESTIMATE 40 % "A" SOILS, 45 % "B" SOILS AND 15 % "D" SOILS
 18       LS       0      67
 19       KM       LAG TIME DERIVED FROM   [L**0.8 X (S+1)**0.7] / [1900 X Y**0.5]
 20       KM       HYDRAULIC LENGTH, L = 16,000 FEET, S = (CN/1000) - 10, AND
 21       KM       Y = AVERAGE WATERSHED SLOPE IN PERCENT = 1.84 %
 22       UD    3.11

 23       KK       2    ROUTE THRU BAILEY LAKE DAM
 24       RS       1    ELEV  166.23
 25       KM       SURFACE AREA AT NORMAL POOL = 9.76 ACRES PLANIMETERED ON QUAD BY JKL
 26       KM       SURFACE AREAS FROM MARK SEFFELS ON 8.22.94
```

```
 27          SA       0   10.03   11.47   15.69   18.58   22.07
 28          SE  154.53     166     168     170     172     174
 29          KM       RATING CURVE DEVELOPED FROM PSPWY = 3-FT X 4-FT BOX RISER AND
 30          KM       30-INCH DIAMETER RCP BARREL, BARREL LENGTH = 62 FEET WITH OUTLET
 31          KM       INVERT ELEVATION = 154.07
 32          KM       ESPWY IS 1-FOOT BOTTOM WIDTH, AVG. 20H:1V SIDE SLOPES CHANNEL WITH
 33          KM       CONTROL SECTION AT INVERT ELEVATION 172.3
 34          SQ       0       6      29      62      71      73      74      75      77      78
 35          SQ      79      81      82      84     106     168     281
 36          SE  166.23   166.5     167   167.5     168   168.5     169   169.5     170   170.5
 37          SE     171   171.5     172   172.5     173   173.5     174
 38          KM       CREST LENGTH OF DAM TAKEN FROM ENGR'S PLANS
 39          KM       = 350 FEET
 40          ST     174     350     2.8     1.5
 41          KP       2
 42          KM       BREACH OF BAILEY LAKE DAM
 43          SB  154.53      40       1      .5  173.73

 44          KK       3
 45          KM       INFLOW TO ARRAN LAKES WEST DAM
 46          KM       DRAINAGE AREA = 477.10 ACRES = 0.7455 SQUARE MILES PLANIMETERED BY JKL
 47          BA    .7455
 48          KM       PRECIPITATION DATA FROM HYDRO-35 FOR 5-, 15-, AND 60-MINUTE
 49          KM       DURATIONS AND FROM TP-40 FOR 2-, 3-, AND 6-HOUR DURATIONS
 50          PH       2       0     .74    1.66    3.58    4.02    4.47    5.58
 51          KM       CURVE NUMBER DEVELOPED FROM FAYETTEVILLE QUAD MAP
 52          KM       ESTIMATED 75 % 1/4-ACRE RESIDENTIAL, 10 % PASTURE (FAIR)
1                                    HEC-1 INPUT                                    PAGE  2

 LINE        ID.......1.......2.......3.......4.......5.......6.......7.......8.......9......10

 53          KM       AND 15 % WOODS (FAIR) AND FROM SOIL TYPES FROM SCS SOIL SURVEY
 54          KM       ESTIMATE 50 % "A" SOILS, 15 % "B" SOILS, 15 % "C" SOILS
 55          KM       AND 20 % "D" SOILS
 56          LS       0      69
 57          KM       LAG TIME DERIVED FROM   [L**0.8 X (S+1)**0.7] / [1900 X Y**0.5]
 58          KM       HYDRAULIC LENGTH, L = 6,000 FEET, S = (CN/1000) - 10, AND
 59          KM       Y = 1.9 % = AVERAGE WATERSHED SLOPE IN PERCENT
 60          UD    1.32

 61          KK       4
 62          KM       COMBINE OUTFLOW FROM BAILEY LAKE DAM WITH INFLOW TO ARRAN LAKES
 63          KM       WEST DAM
 64          HC       2

 65          KK       5    ROUTE THRU ARRAN LAKES WEST DAM
 66          RS       1    ELEV     148
 67          KM       SURFACE AREA AT NORMAL POOL = 12.10 ACRES PLANIMETERED BY JKL
 68          KM       SURFACE AREAS AT ELEV. 150 AND 152 FROM ENGR'S PLANS
 69          KM       SURFACE AREA AT ELEV 160 PLANIMETERED FROM QUAD BY JKL
 70          SA       0   12.10    12.2    15.7   32.74
 71          SE  139.25     148     150     152     160
 72          KM       RATING CURVE DEVELOPED FROM TWIN PSPWY'S = 72-INCH DIAMETER RISERS AND
 73          KM       48-INCH DIAMETER BARRELS, EACH BARREL LENGTH = 140 FEET WITH OUTLET
 74          KM       INVERT ELEVATION = 138.25; BARRELS ARE RCP
 75          KM       NO ESPWY
 76          SQ       0      41     117     215     315     323     331     339     346     353
 77          SQ     361     368     374
 78          SE     148   148.5     149   149.5     150   150.5     151   151.5     152   152.5
 79          SE     153   153.5     154
 80          KM       CREST LENGTH OF DAM TAKEN FROM ENGR'S PLANS
 81          KM       = 400 FEET
 82          ST     154     400     2.8     1.5
 83          ZZ
1*****************************************                                        *****************************************
 *                                   *                                        *                                       *
```

ROUTED TO

+	2	1.72	1	FLOW	242.
				TIME	9.33
			2	FLOW	6729.
				TIME	9.25

** PEAK STAGES IN FEET **

1	STAGE	173.83
	TIME	9.33
2	STAGE	173.77
	TIME	8.81

HYDROGRAPH AT

+	3	.75	1	FLOW	450.
				TIME	4.50
			2	FLOW	450.
				TIME	4.50

2 COMBINED AT

+	4	2.47	1	FLOW	478.
				TIME	4.67
			2	FLOW	6739.
				TIME	9.25

ROUTED TO

+	5	2.47	1	FLOW	324.
				TIME	5.75
			2	FLOW	3815.
				TIME	9.33

** PEAK STAGES IN FEET **

1	STAGE	150.55
	TIME	5.75
2	STAGE	156.10
	TIME	9.33

1 SUMMARY OF DAM OVERTOPPING/BREACH ANALYSIS FOR STATION 2

PLAN 1 .....

	INITIAL VALUE	SPILLWAY CREST	TOP OF DAM
ELEVATION	166.23	174.00	174.00
STORAGE	41.	162.	162.
OUTFLOW	0.	281.	281.

RATIO OF PMF	MAXIMUM RESERVOIR W.S.ELEV	MAXIMUM DEPTH OVER DAM	MAXIMUM STORAGE AC-FT	MAXIMUM OUTFLOW CFS	DURATION OVER TOP HOURS	TIME OF MAX OUTFLOW HOURS	TIME OF FAILURE HOURS
1.00	173.83	.00	158.	242.	.00	9.33	.00

PLAN 2 .....

	INITIAL VALUE	SPILLWAY CREST	TOP OF DAM
ELEVATION	166.23	174.00	174.00
STORAGE	41.	162.	162.
OUTFLOW	0.	281.	281.

RATIO OF PMF	MAXIMUM RESERVOIR W.S.ELEV	MAXIMUM DEPTH OVER DAM	MAXIMUM STORAGE AC-FT	MAXIMUM OUTFLOW CFS	DURATION OVER TOP HOURS	TIME OF MAX OUTFLOW HOURS	TIME OF FAILURE HOURS
1.00	173.77	.00	157.	6747.	.00	9.24	8.75

1 SUMMARY OF DAM OVERTOPPING/BREACH ANALYSIS FOR STATION 5

PLAN 1 .....

	INITIAL VALUE	SPILLWAY CREST	TOP OF DAM

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1*****************************************
*                                       *
*   FLOOD HYDROGRAPH PACKAGE  (HEC-1)   *
*             FEBRUARY 1981             *
*           REVISED 01 JUN 88           *
*                                       *
*  RUN DATE  08/22/1994  TIME  13:55:57 *
*                                       *
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LAND QUALITY SECTION
FAYETTEVILLE REGIONAL OFFICE

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*****************************************
*                                       *
*     U.S. ARMY CORPS OF ENGINEERS      *
*  THE HYDROLOGIC ENGINEERING CENTER    *
*          609 SECOND STREET            *
*        DAVIS, CALIFORNIA 95616        *
*          (916) 551-1748               *
*                                       *
*****************************************
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```
X     X  XXXXXXX   XXXXX          X
X     X  X        X     X        XX
X     X  X        X              X
XXXXXXX  XXXX     X       XXXXX  X
X     X  X        X              X
X     X  X        X     X        X
X     X  XXXXXXX   XXXXX         XXX
```

THIS PROGRAM REPLACES ALL PREVIOUS VERSIONS OF HEC-1 KNOWN AS HEC1 (JAN 73), HEC1GS, HEC1DB, AND HEC1KW.

THE DEFINITIONS OF VARIABLES -RTIMP- AND -RTIOR- HAVE CHANGED FROM THOSE USED WITH THE 1973-STYLE INPUT STRUCTURE.
THE DEFINITION OF -AMSKK- ON RM-CARD WAS CHANGED WITH REVISIONS DATED 28 SEP 81. THIS IS THE FORTRAN77 VERSION
NEW OPTIONS: DAMBREAK OUTFLOW SUBMERGENCE , SINGLE EVENT DAMAGE CALCULATION, DSS:WRITE STAGE FREQUENCY,
DSS:READ TIME SERIES AT DESIRED CALCULATION INTERVAL LOSS RATE:GREEN AND AMPT INFILTRATION
KINEMATIC WAVE: NEW FINITE DIFFERENCE ALGORITHM


```
LINE          ID.....1.....2.....3.....4.....5.....6.....7.....8.....9.....10

  1           ID   BAILEY LAKE DAM AND ARRAN LAKES WEST DAM
  2           ID   CUMBERLAND COUNTY
  3           ID   100-YR 6-HR STORM WITHOUT AND WITH BREACH OF BAILEY LAKE DAM
  4           ID   BAILEY1.DAT     JKL     08.22.94
  5           IT       5       0       0     300
  6           IO       5       0
  7           JP       2

  8           KK       1     INFLOW TO BAILEY LAKE DAM
  9           KM       DRAINAGE AREA = 1100.95 ACRES = 1.7202 SQUARE MILES PLANIMETERED BY JKL
 10           BA  1.7202
 11           KM       PRECIPITATION DATA FROM HYDRO-35 FOR 5-, 15-, AND 60-MINUTE
 12           KM       DURATIONS AND FROM TP-40 FOR 2-, 3-, AND 6-HOUR DURATIONS
 13           PH       1       0     .81    1.82    4.00    4.50    4.98    6.24
 14           KM       CURVE NUMBER DEVELOPED FROM FAYETTEVILLE AND CLIFDALE QUAD MAPS
 15           KM       ESTIMATED 60 % 1/4-ACRE RESIDENTIAL, 30 % PASTURE (FAIR)
 16           KM       AND 10 % WOODS (FAIR) AND FROM SOIL TYPES FROM SCS SOIL SURVEY
 17           KM       ESTIMATE 40 % "A" SOILS, 45 % "B" SOILS AND 15 % "D" SOILS
 18           LS       0      67
 19           KM       LAG TIME DERIVED FROM   [L**0.8 X (S+1)**0.7] / [1900 X Y**0.5]
 20           KM       HYDRAULIC LENGTH, L = 16,000 FEET, S = (CN/1000) - 10, AND
 21           KM       Y = AVERAGE WATERSHED SLOPE IN PERCENT = 1.84 %
 22           UD    3.11

 23           KK       2    ROUTE THRU BAILEY LAKE DAM
 24           RS       1    ELEV  166.23
 25           KM       SURFACE AREA AT NORMAL POOL = 9.76 ACRES PLANIMETERED ON QUAD BY JKL
 26           KM       SURFACE AREAS FROM MARK SEFFELS ON 8.22.94
```

```
 27          SA       0   10.03   11.47   15.69   18.58   22.07
 28          SE  154.53     166     168     170     172     174
 29          KM       RATING CURVE DEVELOPED FROM PSPWY = 3-FT X 4-FT BOX RISER AND
 30          KM       30-INCH DIAMETER RCP BARREL, BARREL LENGTH = 62 FEET WITH OUTLET
 31          KM       INVERT ELEVATION = 154.07
 32          KM       ESPWY IS 1-FOOT BOTTOM WIDTH, AVG. 20H:1V SIDE SLOPES CHANNEL WITH
 33          KM       CONTROL SECTION AT INVERT ELEVATION 172.3
 34          SQ       0       6      29      62      71      73      74      75      77      78
 35          SQ      79      81      82      84     106     168     281
 36          SE  166.23   166.5     167   167.5     168   168.5     169   169.5     170   170.5
 37          SE     171   171.5     172   172.5     173   173.5     174
 38          KM       CREST LENGTH OF DAM TAKEN FROM ENGR'S PLANS
 39          KM       = 350 FEET
 40          ST     174     350     2.8     1.5
 41          KP       2
 42          KM       BREACH OF BAILEY LAKE DAM
 43          SB  154.53      40       1      .5  174.11

 44          KK       3
 45          KM       INFLOW TO ARRAN LAKES WEST DAM
 46          KM       DRAINAGE AREA = 477.10 ACRES = 0.7455 SQUARE MILES PLANIMETERED BY JKL
 47          BA    .7455
 48          KM       PRECIPITATION DATA FROM HYDRO-35 FOR 5-, 15-, AND 60-MINUTE
 49          KM       DURATIONS AND FROM TP-40 FOR 2-, 3-, AND 6-HOUR DURATIONS
 50          PH       1       0     .81    1.82    4.00    4.50    4.98    6.24
 51          KM       CURVE NUMBER DEVELOPED FROM FAYETTEVILLE QUAD MAP
 52          KM       ESTIMATED 75 % 1/4-ACRE RESIDENTIAL, 10 % PASTURE (FAIR)
1                                      HEC-1 INPUT                                    PAGE  2

LINE        ID.......1.......2.......3.......4.......5.......6.......7.......8.......9......10

 53          KM       AND 15 % WOODS (FAIR) AND FROM SOIL TYPES FROM SCS SOIL SURVEY
 54          KM       ESTIMATE 50 % "A" SOILS, 15 % "B" SOILS, 15 % "C" SOILS
 55          KM       AND 20 % "D" SOILS
 56          LS       0      69
 57          KM       LAG TIME DERIVED FROM   [L**0.8 X (S+1)**0.7] / [1900 X Y**0.5]
 58          KM       HYDRAULIC LENGTH, L = 6,000 FEET, S = (CN/1000) - 10, AND
 59          KM       Y = 1.9 % = AVERAGE WATERSHED SLOPE IN PERCENT
 60          UD    1.32

 61          KK       4
 62          KM       COMBINE OUTFLOW FROM BAILEY LAKE DAM WITH INFLOW TO ARRAN LAKES
 63          KM       WEST DAM
 64          HC       2

 65          KK       5    ROUTE THRU ARRAN LAKES WEST DAM
 66          RS       1    ELEV     148
 67          KM       SURFACE AREA AT NORMAL POOL = 12.10 ACRES PLANIMETERED BY JKL
 68          KM       SURFACE AREAS AT ELEV. 150 AND 152 FROM ENGR'S PLANS
 69          KM       SURFACE AREA AT ELEV 160 PLANIMETERED FROM QUAD BY JKL
 70          SA       0   12.10    12.2    15.7   32.74
 71          SE  139.25     148     150     152     160
 72          KM       RATING CURVE DEVELOPED FROM TWIN PSPWY'S = 72-INCH DIAMETER RISERS AND
 73          KM       48-INCH DIAMETER BARRELS, EACH BARREL LENGTH = 140 FEET WITH OUTLET
 74          KM       INVERT ELEVATION = 138.25; BARRELS ARE RCP
 75          KM       NO ESPWY
 76          SQ       0      41     117     215     315     323     331     339     346     353
 77          SQ     361     368     374
 78          SE     148   148.5     149   149.5     150   150.5     151   151.5     152   152.5
 79          SE     153   153.5     154
 80          KM       CREST LENGTH OF DAM TAKEN FROM ENGR'S PLANS
 81          KM       = 400 FEET
 82          ST     154     400     2.8     1.5
 83          ZZ
1*****************************************                                    ****************************************
*                                       *                                    *                                      *
```

ROUTED TO

+	2	1.72	1	FLOW	426.
				TIME	8.42
			2	FLOW	7200.
				TIME	8.50

** PEAK STAGES IN FEET **

1	STAGE	174.21
	TIME	8.42
2	STAGE	174.16
	TIME	8.06

HYDROGRAPH AT

+	3	.75	1	FLOW	552.
				TIME	4.50
			2	FLOW	552.
				TIME	4.50

2 COMBINED AT

+	4	2.47	1	FLOW	590.
				TIME	4.67
			2	FLOW	7229.
				TIME	8.50

ROUTED TO

+	5	2.47	1	FLOW	341.
				TIME	9.33
			2	FLOW	4854.
				TIME	8.58

** PEAK STAGES IN FEET **

1	STAGE	151.62
	TIME	9.33
2	STAGE	156.51
	TIME	8.58

1 SUMMARY OF DAM OVERTOPPING/BREACH ANALYSIS FOR STATION 2

PLAN 1 .....

	INITIAL VALUE	SPILLWAY CREST	TOP OF DAM
ELEVATION	166.23	174.00	174.00
STORAGE	41.	162.	162.
OUTFLOW	0.	281.	281.

RATIO OF PMF	MAXIMUM RESERVOIR W.S.ELEV	MAXIMUM DEPTH OVER DAM	MAXIMUM STORAGE AC-FT	MAXIMUM OUTFLOW CFS	DURATION OVER TOP HOURS	TIME OF MAX OUTFLOW HOURS	TIME OF FAILURE HOURS
1.00	174.21	.21	166.	426.	2.08	8.42	.00

PLAN 2 .....

	INITIAL VALUE	SPILLWAY CREST	TOP OF DAM
ELEVATION	166.23	174.00	174.00
STORAGE	41.	162.	162.
OUTFLOW	0.	281.	281.

RATIO OF PMF	MAXIMUM RESERVOIR W.S.ELEV	MAXIMUM DEPTH OVER DAM	MAXIMUM STORAGE AC-FT	MAXIMUM OUTFLOW CFS	DURATION OVER TOP HOURS	TIME OF MAX OUTFLOW HOURS	TIME OF FAILURE HOURS
1.00	174.16	.16	165.	7203.	.43	8.49	8.00

1 SUMMARY OF DAM OVERTOPPING/BREACH ANALYSIS FOR STATION 5

PLAN 1 .....

	INITIAL VALUE	SPILLWAY CREST	TOP OF DAM

```
1*****************************************
*                                       *
*   FLOOD HYDROGRAPH PACKAGE  (HEC-1)   *
*             FEBRUARY 1981             *
*            REVISED 01 JUN 88          *
*                                       *
*  RUN DATE  08/22/1994  TIME  14:09:46 *
*                                       *
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RECEIVED
AUG 25 1994
LAND QUALITY SECTION
FAYETTEVILLE REGIONAL OFFICE

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*****************************************
*                                       *
*    U.S. ARMY CORPS OF ENGINEERS       *
*  THE HYDROLOGIC ENGINEERING CENTER    *
*         609 SECOND STREET             *
*        DAVIS, CALIFORNIA 95616        *
*          (916) 551-1748               *
*                                       *
*****************************************
```

```
X     X  XXXXXXX   XXXXX          X
X     X  X        X     X        XX
X     X  X        X              X
XXXXXXX  XXXX     X        XXXXX  X
X     X  X        X              X
X     X  X        X     X        X
X     X  XXXXXXX   XXXXX          XXX
```

THIS PROGRAM REPLACES ALL PREVIOUS VERSIONS OF HEC-1 KNOWN AS HEC1 (JAN 73), HEC1GS, HEC1DB, AND HEC1KW.

THE DEFINITIONS OF VARIABLES -RTIMP- AND -RTIOR- HAVE CHANGED FROM THOSE USED WITH THE 1973-STYLE INPUT STRUCTURE.
THE DEFINITION OF -AMSKK- ON RM-CARD WAS CHANGED WITH REVISIONS DATED 28 SEP 81. THIS IS THE FORTRAN77 VERSION
NEW OPTIONS: DAMBREAK OUTFLOW SUBMERGENCE , SINGLE EVENT DAMAGE CALCULATION, DSS:WRITE STAGE FREQUENCY,
DSS:READ TIME SERIES AT DESIRED CALCULATION INTERVAL LOSS RATE:GREEN AND AMPT INFILTRATION
KINEMATIC WAVE: NEW FINITE DIFFERENCE ALGORITHM


```
LINE      ID.....1.....2.....3.....4.....5.....6.....7.....8.....9.....10

  1       ID   BAILEY LAKE DAM AND ARRAN LAKES WEST DAM
  2       ID   CUMBERLAND COUNTY
  3       ID   1/3 PMP 6-HR STORM WITHOUT AND WITH BREACH OF BAILEY LAKE DAM
  4       ID   BAILEY4.DAT     JKL     08.22.94
  5       IT       5       0       0     300
  6       IO       5       0
  7       JP       2

  8       KK       1     INFLOW TO BAILEY LAKE DAM
  9       KM       DRAINAGE AREA = 1100.95 ACRES = 1.7202 SQUARE MILES PLANIMETERED BY JKL
 10       BA  1.7202
 11       KM       TEMPORAL DISTRIBUTION FOR THE 1/3 PMP STORM FROM SCS TR-60
 12       IN       5
 13       PB  10.02
 14       PC  .0000   .0056   .0112   .0169   .0227   .0287   .0348   .0412   .0480   .0551
 15       PC  .0624   .0702   .0783   .0867   .0955   .1046   .1140   .1238   .1343   .1455
 16       PC  .1580   .1717   .1869   .2043   .2183   .2683   .3501   .4140   .4783   .5401
 17       PC  .5908   .6188   .6390   .6578   .6747   .6909   .7050   .7182   .7310   .7434
 18       PC  .7552   .7666   .7775   .7879   .7979   .8077   .8172   .8264   .8354   .8442
 19       PC  .8527   .8568   .8690   .8768   .8844   .8918   .8990   .9061   .9130   .9198
 20       PC  .9265   .9331   .9396   .9460   .9523   .9585   .9646   .9706   .9766   .9825
 21       PC  .9883   .9942  1.0000
 22       KM       CURVE NUMBER DEVELOPED FROM FAYETTEVILLE AND CLIFDALE QUAD MAPS
 23       KM       ESTIMATED 60 % 1/4-ACRE RESIDENTIAL, 30 % PASTURE (FAIR)
 24       KM       AND 10 % WOODS (FAIR) AND FROM SOIL TYPES FROM SCS SOIL SURVEY
 25       KM       ESTIMATE 40 % "A" SOILS, 45 % "B" SOILS AND 15 % "D" SOILS
 26       LS       0      67
 27       KM       LAG TIME DERIVED FROM   [L**0.8 X (s+1)**0.7] / [1900 X Y**0.5]
```

```
 28          KM       HYDRAULIC LENGTH, L = 16,000 FEET, S = (CN/1000) - 10, AND
 29          KM       Y = AVERAGE WATERSHED SLOPE IN PERCENT = 1.84 %
 30          UD    3.11

 31          KK       2    ROUTE THRU BAILEY LAKE DAM
 32          RS       1    ELEV  166.23
 33          KM       SURFACE AREA AT NORMAL POOL = 9.76 ACRES PLANIMETERED ON QUAD BY JKL
 34          KM       SURFACE AREAS FROM MARK SEFFELS ON 8.22.94
 35          SA       0   10.03   11.47   15.69   18.58   22.07
 36          SE  154.53     166     168     170     172     174
 37          KM       RATING CURVE DEVELOPED FROM PSPWY = 3-FT X 4-FT BOX RISER AND
 38          KM       30-INCH DIAMETER RCP BARREL, BARREL LENGTH = 62 FEET WITH OUTLET
 39          KM       INVERT ELEVATION = 154.07
 40          KM       ESPWY IS 1-FOOT BOTTOM WIDTH, AVG. 20H:1V SIDE SLOPES CHANNEL WITH
 41          KM       CONTROL SECTION AT INVERT ELEVATION 172.3
 42          SQ       0       6      29      62      71      73      74      75      77      78
 43          SQ      79      81      82      84     106     168     281
 44          SE  166.23   166.5     167   167.5     168   168.5     169   169.5     170   170.5
 45          SE     171   171.5     172   172.5     173   173.5     174
 46          KM       CREST LENGTH OF DAM TAKEN FROM ENGR'S PLANS
 47          KM       = 350 FEET
 48          ST     174     350     2.8     1.5
 49          KP       2
 50          KM       BREACH OF BAILEY LAKE DAM
 51          SB  154.53      40       1      .5  174.72
1                                    HEC-1 INPUT                                    PAGE  2

LINE         ID.......1.......2.......3.......4.......5.......6.......7.......8.......9......10

 52          KK       3
 53          KM       INFLOW TO ARRAN LAKES WEST DAM
 54          KM       DRAINAGE AREA = 477.10 ACRES = 0.7455 SQUARE MILES PLANIMETERED BY JKL
 55          BA   .7455
 56          KM       CURVE NUMBER DEVELOPED FROM FAYETTEVILLE QUAD MAP
 57          KM       ESTIMATED 75 % 1/4-ACRE RESIDENTIAL, 10 % PASTURE (FAIR)
 58          KM       AND 15 % WOODS (FAIR) AND FROM SOIL TYPES FROM SCS SOIL SURVEY
 59          KM       ESTIMATE 50 % "A" SOILS, 15 % "B" SOILS, 15 % "C" SOILS
 60          KM       AND 20 % "D" SOILS
 61          LS       0      69
 62          KM       LAG TIME DERIVED FROM   [L**0.8 X (S+1)**0.7] / [1900 X Y**0.5]
 63          KM       HYDRAULIC LENGTH, L = 6,000 FEET, S = (CN/1000) - 10, AND
 64          KM       Y = 1.9 % = AVERAGE WATERSHED SLOPE IN PERCENT
 65          UD    1.32

 66          KK       4
 67          KM       COMBINE OUTFLOW FROM BAILEY LAKE DAM WITH INFLOW TO ARRAN LAKES
 68          KM       WEST DAM
 69          HC       2

 70          KK       5    ROUTE THRU ARRAN LAKES WEST DAM
 71          RS       1    ELEV     148
 72          KM       SURFACE AREA AT NORMAL POOL = 12.10 ACRES PLANIMETERED BY JKL
 73          KM       SURFACE AREAS AT ELEV. 150 AND 152 FROM ENGR'S PLANS
 74          KM       SURFACE AREA AT ELEV 160 PLANIMETERED FROM QUAD BY JKL
 75          SA       0   12.10    12.2    15.7   32.74
 76          SE  139.25     148     150     152     160
 77          KM       RATING CURVE DEVELOPED FROM TWIN PSPWY'S = 72-INCH DIAMETER RISERS AND
 78          KM       48-INCH DIAMETER BARRELS, EACH BARREL LENGTH = 140 FEET WITH OUTLET
 79          KM       INVERT ELEVATION = 138.25; BARRELS ARE RCP
 80          KM       NO ESPWY
 81          SQ       0      41     117     215     315     323     331     339     346     353
 82          SQ     361     368     374
 83          SE     148   148.5     149   149.5     150   150.5     151   151.5     152   152.5
 84          SE     153   153.5     154
 85          KM       CREST LENGTH OF DAM TAKEN FROM ENGR'S PLANS
```

+	1	1.72	1	FLOW	1212.
				TIME	6.25
			2	FLOW	1212.
				TIME	6.25
ROUTED TO					
+	2	1.72	1	FLOW	1201.
				TIME	6.58
			2	FLOW	8469.
				TIME	6.50
			** PEAK STAGES IN FEET **		
			1	STAGE	174.82
				TIME	6.58
			2	STAGE	174.76
				TIME	6.06
HYDROGRAPH AT					
+	3	.75	1	FLOW	930.
				TIME	3.92
			2	FLOW	930.
				TIME	3.92
2 COMBINED AT					
+	4	2.47	1	FLOW	1591.
				TIME	6.33
			2	FLOW	8851.
				TIME	6.50
ROUTED TO					
+	5	2.47	1	FLOW	1575.
				TIME	6.58
			2	FLOW	7022.
				TIME	6.58
			** PEAK STAGES IN FEET **		
			1	STAGE	155.04
				TIME	6.58
			2	STAGE	157.27
				TIME	6.58

1 SUMMARY OF DAM OVERTOPPING/BREACH ANALYSIS FOR STATION 2

PLAN 1 .....

	INITIAL VALUE	SPILLWAY CREST	TOP OF DAM
ELEVATION	166.23	174.00	174.00
STORAGE	41.	162.	162.
OUTFLOW	0.	281.	281.

RATIO OF PMF	MAXIMUM RESERVOIR W.S.ELEV	MAXIMUM DEPTH OVER DAM	MAXIMUM STORAGE AC-FT	MAXIMUM OUTFLOW CFS	DURATION OVER TOP HOURS	TIME OF MAX OUTFLOW HOURS	TIME OF FAILURE HOURS
1.00	174.82	.82	181.	1201.	5.67	6.58	.00

PLAN 2 .....

	INITIAL VALUE	SPILLWAY CREST	TOP OF DAM
ELEVATION	166.23	174.00	174.00
STORAGE	41.	162.	162.
OUTFLOW	0.	281.	281.

RATIO OF PMF	MAXIMUM RESERVOIR W.S.ELEV	MAXIMUM DEPTH OVER DAM	MAXIMUM STORAGE AC-FT	MAXIMUM OUTFLOW CFS	DURATION OVER TOP HOURS	TIME OF MAX OUTFLOW HOURS	TIME OF FAILURE HOURS

NRCD Land Quality Section
Stage - Discharge Data for BAILEY LAKE DAM, CUMBERLAND COUNTY

**** DROP SPILLWAY *****

Box or Pipe riser (B or P) :	Box riser
Box Perimeter (ft) :	14.000
Box Cross Section (sq ft) :	12.000
Top of riser elev (ft) :	166.230
Weir coeff (3.1) :	3.100
Trash rack coeff (0.3) :	0.300
Orifice coeff (0.5) :	0.600
Barrel dia (in) :	30.000
Barrel length (ft) :	62.000
Barrel outlet elev (ft) :	154.070
Manning number :	0.013
Entrance coeff Ke (1.0) :	1.000
Bend coeff Kb (1.0) :	1.000

***** CHANNEL SPILLWAY *****

Channel bottom elevation (ft) :	172.300
Bottom width (ft) :	1.000
Side slope (z:1) :	20.000
Width coeff (2.5) :	2.800
Side slope coeff (2.5) :	2.500

Elev	Weir	Orif	Pipe	Chanl	Total
166.00	0.00	0.00	0.00	0.00	0.00
166.50	6.09	30.02	66.94	0.00	6.09
167.00	29.32	50.70	68.42	0.00	29.32
167.50	62.11	65.11	69.87	0.00	62.11
168.00	102.20	76.87	71.29	0.00	71.29
168.50	148.43	87.05	72.68	0.00	72.68
169.00	200.08	96.17	74.05	0.00	74.05
169.50	256.63	104.48	75.39	0.00	75.39
170.00	317.69	112.19	76.70	0.00	76.70
170.50	382.94	119.40	78.00	0.00	78.00
171.00	452.13	126.19	79.27	0.00	79.27
171.50	525.06	132.64	80.53	0.00	80.53
172.00	601.52	138.79	81.76	0.00	81.76
172.50	681.38	144.68	82.98	1.14	84.12
173.00	764.49	150.34	84.18	22.14	106.32
173.50	850.73	155.79	85.36	82.55	167.91
174.00	939.99	161.06	86.53	194.61	281.14
166.23	0.00	0.00	0.00	0.00	0.00

NRCD Land Quality Section
Stage - Discharge Data for ARRAN LAKES WEST DAM, CUMBERLAND COUNTY JKL 08.1

NRCD Land Quality Section
Stage - Discharge Data for

**** DROP SPILLWAY *****

Box or Pipe riser (B or P) :	Pipe riser
Riser pipe diameter (in) :	72.000
Top of riser elev (ft) :	148.000
Weir coeff (3.1) :	3.100
Trash rack coeff (0.3) :	0.300
Orifice coeff (0.5) :	0.600
Barrel dia (in) :	48.000
Barrel length (ft) :	140.000
Barrel outlet elev (ft) :	138.250
Manning number :	0.013
Entrance coeff Ke (1.0) :	1.000
Bend coeff Kb (1.0) :	1.000

Need to Double!

Elev	Weir	Orif	Pipe	Total	
148.00	0.00	0.00	0.00	0.00	0
148.50	20.66	96.27	145.01	20.66	41.32
149.00	58.43	136.14	149.34	58.43	116.86
149.50	107.35	166.74	153.55	107.35	214.70
150.00	165.28	192.53	157.64	157.64	315.28
150.50	230.98	215.26	161.63	161.63	323.26
151.00	303.63	235.80	165.53	165.53	331.06
151.50	382.62	254.70	169.33	169.33	338.66
152.00	467.47	272.28	173.06	173.06	346.12
152.50	557.80	288.80	176.70	176.70	353.40
153.00	653.31	304.42	180.27	180.27	360.54
153.50	753.71	319.28	183.77	183.77	367.54
154.00	858.80	333.48	187.20	187.20	374.40

19 Aug 94

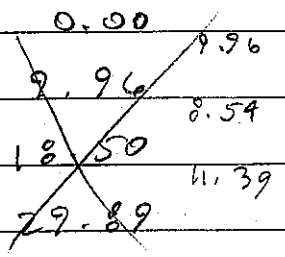
dkc

Sheet 1 of 2

Bailey Lake Dam

Cumberland County

Surface Area @ NP (from Quad)



0.00
8.54
11.39
19.93
8.54
28.47
8.54
37.01
11.38
48.39
8.54
56.93
11.39
68.32

Avg = 9.96 acres

@ 160 contour

0.00 14.23
14.23 15.66
29.89 15.66
45.55 14.23
59.78

Avg = 14.95 ac

@ 170 contour

0.00 28.47
28.47 27.04
55.51 28.47
83.98 28.46
112.44

Avg = 28.11 ac

Drainage Area (Fayetteville Quad)

0.00 402.80
402.80 397.11
799.91 397.4
1197.02 401.38
1598.40

Avg = 399.60 ac

Cliffdale Quad

0.00 704.55
704.55 698.85
1403.40 703.12
2106.52 698.86
2805.38

Avg = 701.35 ac

Total Drainage Area

= 399.60 + 701.35 = 1100.95 ac

= 1.7202 mi²

Hydraulic length = 16,000' ±

Avg watershed Slope 0.36 × 3.20% + 0.64 × 1.07 = 1.84%

50/1100 = 4.54%
40/2300 = 1.74%
40/1200 = 3.33%
Avg 3.20

13/1000 = 1.3%
10/1200 = 0.83%
Avg = 1.07%

19 Aug 94

Arran Lakes West Dam

Cumberland County

Sheet 1 of 2

Surface Area @ NP

0.00
11.39
12.81
24.20
11.38
35.58
12.81
48.39

AVG = 12.10 ac

Surface Area @ 160 Contour

0.00
34.16
32.74
66.90
32.73
99.63
32.74
132.37

AVG = 33.19 ac

Drainage Area below Bailey Lake Drainage Area (Does not include D.A. @ Bailey Lake Dam)

0.00
478.24
481.08
959.32
473.97
1433.29
473.97
1907.26
478.24
2385.50

AVG = 477.10 ac = 0.7455 mi²

Hydraulic length = 6,000' ±

Avg watershed Slope 40/2100 = 1.9% ±

Land Use

1/4 acre Residential 75%

Pasture, fair 10%

Woods, fair 15%

Soils - JT Johnston D GdB Gilead C L2B Lakeland A

BzD Bibb B V2D Vaucluse C AuA Autryville A

CzB Candor A W2B Wagram A NoA Norfolk B

N.C. Department of Environment, Health, and Natural Resources
Division of Land Resources, Land Quality Section

Telephone Log

Date: 8/22/94 Sheet 1 of 1

Time: 9:30 ☑ am ☐ pm Call: Placed ☑ Received ☐ Returned ☐

1. Project: BAILEY LAKE DAM County: CUMBERLAND

2. Conversation with: MARK SHEFFELS Telephone: (910) 488-5637

3. Affiliation: AVIRETT ENGINEERING CO., P.A.

4. Content of conversation: I ASKED MARK FOR DATA REGARDING SURFACE AREA VS. ELEVATIONS FOR SUBJECT DAM

EL 166.	10.03 ACRES	BAILEY LAKE DAM
168	11.47 ACRES	
170	15.69 ACRES	
172	18.58 ACRES	
174	22.07 ACRES	

FOR ARRAN LAKES WEST DAM, CUMBERLAND COUNTY

EL 150	12.2 ACRES
152	15.7 ACRES

1:30 PM (8/22/94) I CALLED DOT TRAFFIC COUNT AND SPOKE TO ANN STRICKLAND. SHE GAVE ME THE FOLLOWING TRAFFIC COUNT DATA! (SR 1107 IS D/S HAZARD)
LAST TRAFFIC COUNTS FROM 1993

1) SR 1107 (JUST WEST OF SR 1141) = 6,800 VPD
2) SR 1107 (JUST WEST OF SR 1108) = 5,200 VPD
3) SR 1108 (JUST SOUTH OF SR 1107) = 4,400 VPD
4) SR 1141 (JUST EAST OF SR 1107) = 13,400 VPD

cc: JOE GLASS Filed by: JIM LEMMAS

Intercoastal Diving, Inc. performed this portion of the work, which consisted of first cleaning the pipe joints of buildups and then boring injection ports at the pipe joints and halfway between the joints. At this point, the joints were grouted up with hydraulic cement and then the synthetic urethane grout was pumped into the injection ports. Each joint had between 4 and 8 injection ports. The synthetic urethane grout consisted of Prime Flex 900 LV, which is expected to expand 5 to 7 times its original volume. Approximately 14 gallons of this urethane grout was injected around Barrel "B" and 30 gallons was injected around Barrel "A".

The injection ports around Barrel "B" showed good communication and normal grout consumption (± 2 gals/joint), but Barrel "A" did not exhibit these good characteristics. while the injection ports in Barrel "A" showed some signs of communication, it was not the definitive characteristics hoped for. This combined with the amount of grout used on Barrel "A" have aroused some concerns, but these have been alleviated by periodically inspecting the joints at various lake levels. The joints have been inspected with the lake empty, half full, and full. During all of these inspections, the same conditions were prevalent, with some slight moisture seeps on the walls of the 1st and 3rd joints in Barrel "A", but no leaks. Considering the fact that these seeps have not changed in size or intensity with the various heads, I do not believe they present a concern. There were no visible problems or seeps in Barrel "B". As an added precaution, all the pipe joints in each barrel were cleaned and grouted back with hydraulic cement.

4) A rip-rap wave protection strip was installed along the front face of the dam as shown and detailed on Sheet 1 of 3.

5) Both the upstream and downstream faces of the dam were cleaned and graded. All growth, including trees, were removed from the downstream face. All depressions and ruts on the dam were repaired, with critical areas being rip-rapped in order to provide additional protection.

6) As of this date, the entire dam has been seeded and mulched twice to insure that all open areas are provided with a ground cover. There has been some germination of the temporary winter grassing, but none of the permanent grassing will come up until Spring.

Routine inspections were performed during all the above listed construction phases on this project form start to finish. As much as possible, these inspections were made while construction was in progress. Copies of these reports have been included for your review and files.

To the best of our knowledge, the work performed on this project has been completed and installed in accordance with the approved plans and specifications. We are therefore requesting permission to impound water in the lake at Arran Lakes West Dam, and would appreciate your expeditious review of our As-Built drawings and supporting information. The Owners would like to raise the lake level as soon as possible in order to quiet the homeowners and possibly change over ownership to them.

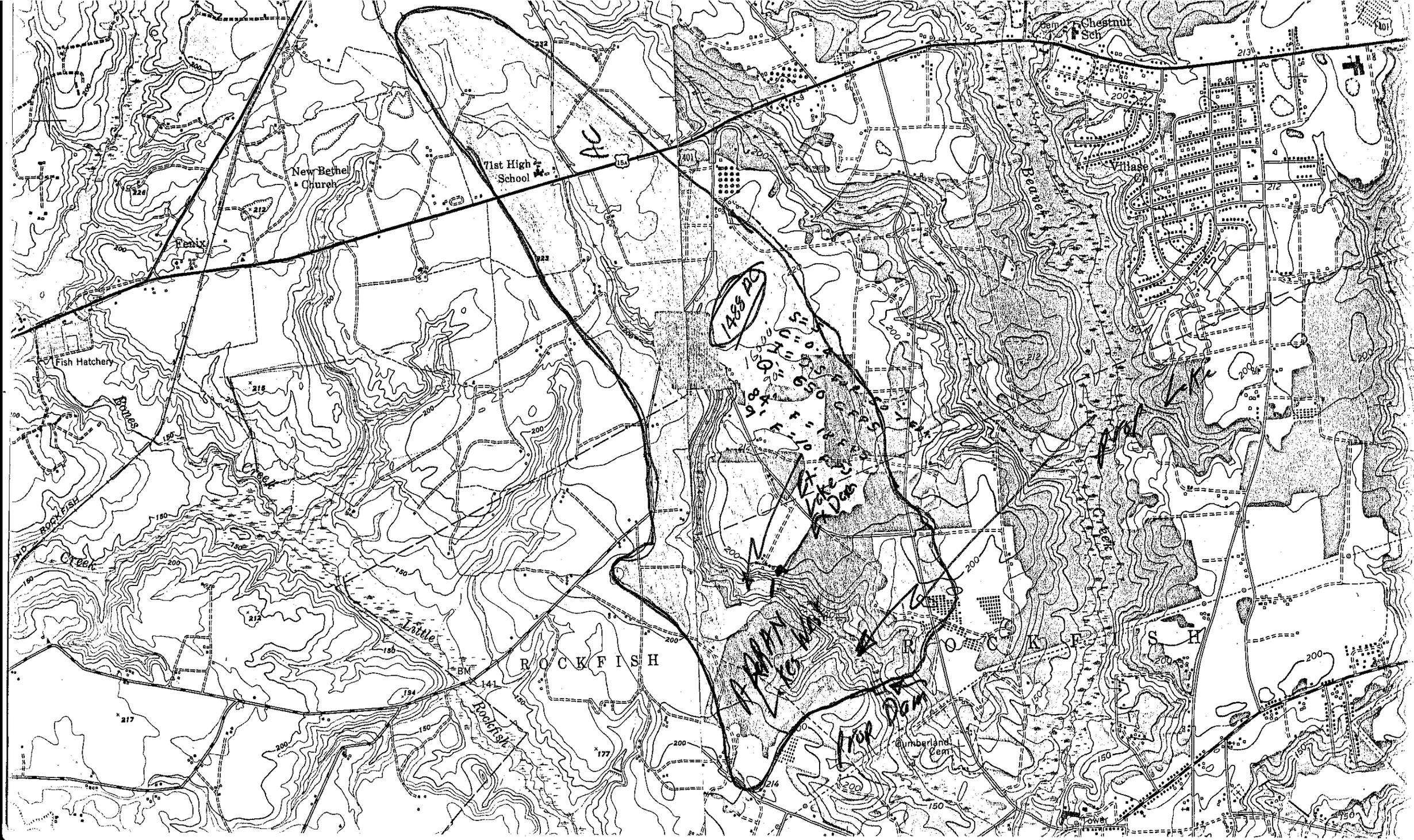
Feel free to contact me if you have any questions or require further information to help expedite your review. I would be happy to meet with you or a representative of NCDEHNR on site to walk through the work that has been completed, if that would be helpful.

Sincerely,

MOORMAN, KIZER & REITZEL, INC.

James M. Kizer, Jr.

JMKjr.:boa
Encls.


Chestnut Sch
71st High School
New Bethel Church
Fenix
Fish Hatchery
Beaver
Village Ch
Rocky Branch
Creek
Little Rockfish
Creek
ROCKFISH
ROCKFISH
Cumberland Cem
Tower
1485 AC
Lake
Dam
Lake
Dam

Beaver
Creek
ROCKFISH
Rockfish
Little
Village
Chestnut
School
71st High
School
Bethel
Church
Cumberland
Cem.
BM
141
1485 PC

Appendix B: Precipitation Data

Depth-Area-Duration Values for ALWD and BLD

Area (sm)	PMP Depth (in)				
	6-hr	12-hr	24-hr	48-hr	72-hr
10	29.99	35.68	41.60	45.75	48.09
200	21.93	26.51	31.69	36.12	38.66
1,000	16.05	21.30	27.45	30.91	32.04
5,000	9.43	13.38	18.45	22.66	23.84
10,000	7.14	10.69	14.81	18.94	20.87
20,000	5.14	8.43	11.86	15.48	17.38

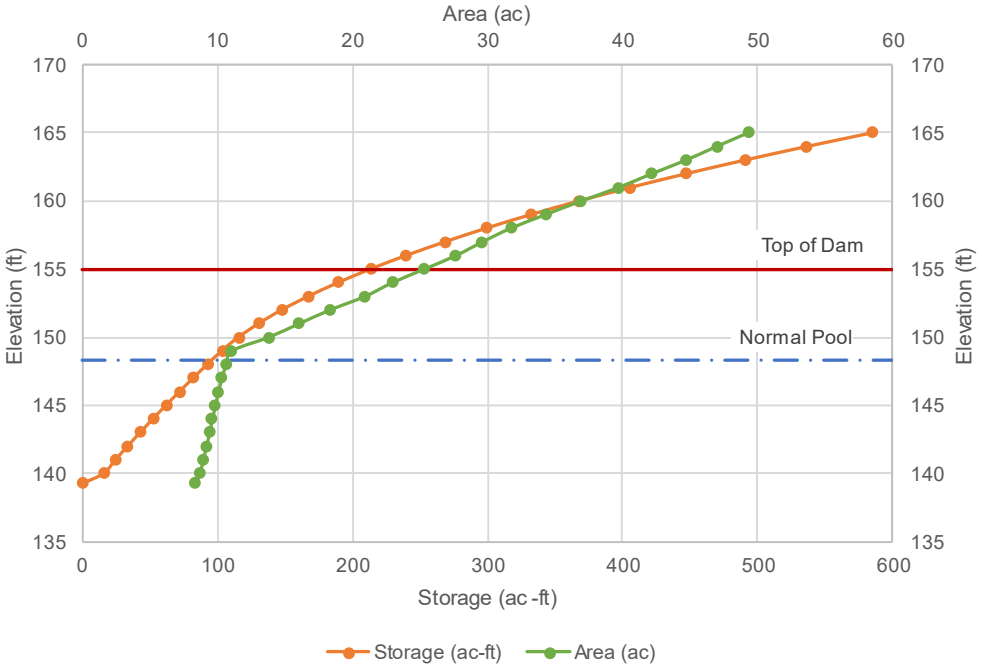
Depths for watersheds with central coordinates of:		
Dam	**X (ft)**	**Y (ft)**
ALWD	2,000,026	464,493
BLD	1,998,935	466,246

PMP Temporal Distributions

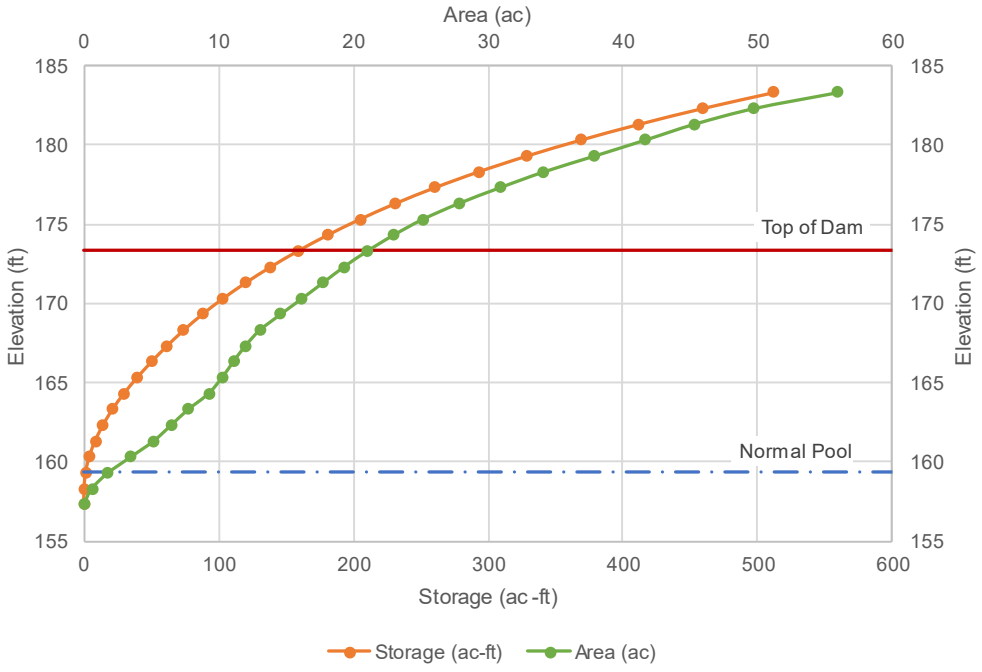
(See electronic appendix)

Appendix C: Hydrologic Analyses

Regional Detention Evaluation



ALWD Elevation-Area-Storage



BLD Elevation-Area-Storage

ALWD Watershed Runoff Curve Numbers

Subbasin	A (sm)	Existing Landuse (BV3 Study)		Future Landuse (Detention Study)	
		RCN	RCN x A	RCN	RCN x A
BV3_0206	0.23	73.3	17.0	73	17.0
BV3_0207	0.18	68.1	12.4	68	12.4
BV3_0208	0.20	66.5	13.4	68	13.7
BV3_0209	0.10	68.2	6.7	68	6.7
BV3_0210	0.15	72.4	10.7	72	10.7
BV3_0211	0.15	65.9	9.7	67	9.8
BV3_0212	0.27	69.3	19.2	74	20.4
BV3_0213	0.07	88.9	6.2	89	6.3
BV3_0214	0.10	73.0	7.3	73	7.3
BV3_0215	0.13	65.8	8.8	66	8.8
BV3_0216	0.06	81.5	5.2	88	5.6
BV3_0219	0.21	64.3	13.7	67	14.2
BV3_0220	0.07	74.2	5.5	82	6.0
BV3_0221	0.13	65.6	8.9	66	8.9
BV3_0222	0.07	65.9	4.4	66	4.4
BV3_0223	0.12	63.2	7.4	63	7.4
BV3_0224	0.13	52.4	6.9	65	8.6
ALWD Watershed					
Total	**2.39**	**-**	**164**	**-**	**169**
RCN	**-**	**68**		**70**	

BLD Watershed Runoff Curve Number

Subbasin	A (sm)	Existing Landuse (BV3 Study)		Future Landuse (Detention Study)	
		RCN	RCN x A	RCN	RCN x A
BV3_0207	0.18	68.1	12.4	12.4	68
BV3_0208	0.20	66.5	13.4	13.7	68
BV3_0209	0.10	68.2	6.7	6.7	68
BV3_0210	0.15	72.4	10.7	10.7	72
BV3_0211	0.15	65.9	9.7	9.8	67
BV3_0212	0.28	69.3	19.2	20.4	74
BV3_0213	0.07	88.9	6.2	6.3	89
BV3_0214	0.10	73.0	7.3	7.3	73
BV3_0215	0.13	65.8	8.8	8.8	66
BV3_0216	0.06	81.5	5.2	5.6	88
BV3_0223	0.12	63.2	7.4	7.4	63
BV3_0224	0.13	52.4	6.9	8.6	65
ALWD Watershed					
Total	**1.67**	**-**	**114**	**-**	**118**
RCN	**-**	**68**		**71**	

ALWD and BLD Watershed Lag

Basin	ALWD	BLD
FLU RCN	73	73
S (in)	3.70	3.70
S (%)	5.01	4.91
L (ft)	24,158	21,423
LT (min)	**134**	**123**

ALWD Stage-Storage

Stage Note	Stage (ft)	Elevation (ft)	Storage (ac-ft)
Lake Invert (Estimated)	0.0	137.5	0.000
(Estimated Bathymetry)	0.5	138.0	0.001
	1.5	139.0	0.08
	2.5	140.0	0.43
	3.5	141.0	1.2
	4.5	142.0	2.5
	5.5	143.0	4.7
	6.5	144.0	8.0
	7.5	145.0	13
	8.5	146.0	19
	9.5	147.0	28
	10.5	148.0	39
Normal Pool	11.5	149.0	52
	12.5	150.0	65
	13.5	151.0	80
	14.5	152.0	97
	15.5	153.0	117
North Section Overtopping	16.5	154.0	139
Top of Dam	17.5	155.0	163
	18.5	156.0	190

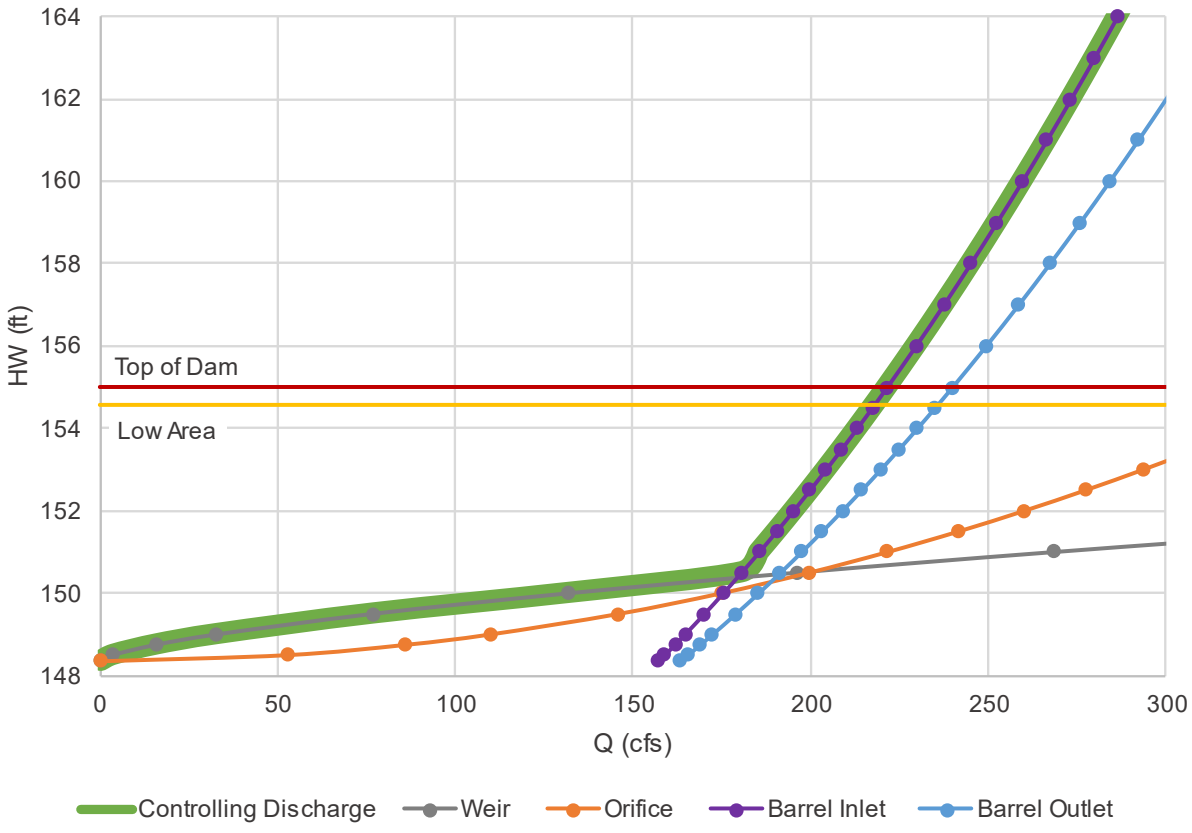
BLD Stage-Storage

Stage Note	Stage (ft)	Elevation (ft)	Storage (ac-ft)
Lake Invert	0	154.2	0.00
	1	155.0	0.01
	2	156.0	0.1
	3	157.0	0.6
	4	158.0	1.5
*** Normal Pool**	5	159.0	2.9
	5	159.3	3.5
	6	160.0	5.3
	7	161.0	9.1
	8	162.0	15
	9	163.0	21
	10	164.0	29
	11	165.0	39
	12	166.0	49
	13	167.0	60
	14	168.0	72
	15	169.0	86
	16	170.0	101
	17	171.0	117
	18	172.0	135
Top of Dam	19	173.0	155
	20	174.0	176

* Normal pool due to beaver dam in breach

Appendix D: Hydraulic Analyses

Regional Detention Evaluation



ALWD Spillway Rating Curve

ALWD Principal Spillway Outlet Rating Curve

HW Note	WSE (ft)		Computed Flow (cfs)[1]				Hydraulic Control	Discharge (cfs)	
	HW	TW[2]	Weir	Orifice	Barrel Inlet	Barrel Outlet		Controlling[3]	Total[4]
Normal Pool	**148.35**	142.60	0	0	157	197	Weir	0	0
	148.50	142.60	4	53	159	200	Weir	4	7
	148.75	142.60	16	86	162	204	Weir	16	31
	149.00	142.60	33	110	165	208	Weir	33	65
	149.50	142.60	77	146	170	216	Weir	77	153
	150.00	142.60	132	175	175	224	Weir	132	264
	150.50	142.60	196	200	181	231	Barrel Inlet	181	361
	151.00	142.60	268	222	186	239	Barrel Inlet	186	371
	151.50	142.60	348	242	190	246	Barrel Inlet	190	381
	152.00	142.60	434	260	195	252	Barrel Inlet	195	390
	152.50	142.60	526	277	200	259	Barrel Inlet	200	400
	153.00	142.60	624	294	204	266	Barrel Inlet	204	409
	153.50	142.60	727	309	209	272	Barrel Inlet	209	417
	154.00	142.60	835	324	213	278	Barrel Inlet	213	426
Overtopping[5]	**154.50**	142.60	949	338	217	284	Barrel Inlet	217	435
Top of Dam[5]	**155.00**	142.60	1,067	351	221	290	Barrel Inlet	221	443
	156.00	142.60	1,316	377	230	301	Barrel Inlet	230	459
	157.00	142.60	1,582	400	237	312	Barrel Inlet	237	475
	158.00	142.60	1,865	423	245	323	Barrel Inlet	245	490
	159.00	142.60	2,162	444	252	333	Barrel Inlet	252	505
	160.00	142.60	2,473	465	260	343	Barrel Inlet	260	519
	161.00	142.60	2,799	484	267	353	Barrel Inlet	267	533
	162.00	142.60	3,137	503	273	363	Barrel Inlet	273	547
	163.00	142.60	3,488	521	280	372	Barrel Inlet	280	560
	164.00	142.60	3,851	539	286	381	Barrel Inlet	286	573
	165.00	142.60	4,226	556	293	390	Barrel Inlet	293	585

[1] Computed flow for one riser-barrel outlet

[2] Tailwater elevation assumed equal to crown of pipe outlet

[3] Lowest computed flow among spillway components for one riser-barrel outlet

[4] Combined discharge for both riser-barrel outlets

[5] Apparent intended top of dam elevation does not extend full length of dam; a 100-foot long section on the left side of the embankment is approximately 6-inches lower than the top of dam, and may be intended to serve as an auxiliary spillway.

Existing Conditions Storm-in-Progress Dam Breach Parameter Calculation Inputs

Spillway Design Flood	ALWD		BLD	
Dam	**ALWD**	**BLD[2]**	**ALWD**	**BLD**
Top of Dam Elevation (ft)	155	N/A	155	173.5
Breach Bottom Elevation (ft)	139.3	N/A	139.3	156.7
Pool Elevation at Failure (ft)	157.1[1]	N/A	156.9[3]	167.4[4]
Pool Volume at Failure (ac-ft)	269	N/A	269	62
Failure Mode	Overtopping	N/A	Overtopping	Piping[3]
Dam Top Width (ft)	60	N/A	60	15
Upstream Face Slope (H:V)	4.0	N/A	4.0	2.0
Downstream Face Slope (H:V)	2.8	N/A	2.8	3.0
Earth Fill Type[5]	Fine Homogeneous	N/A	Fine Homogeneous	Fine Homogeneous

[1] Failure of ALWD assumed to occur at peak WSE during ALWD SDF.

[2] BLD does not overtop during ALWD SDF and thus not assumed to fail.

[3] Failure of ALWD assumed to occur at peak WSE during BLD SDF with failure of BLD.

[4] Failure of BLD assumed to occur at peak WSE during BLD SDF.

[5] Materials of construction unknown; assumed condition which produces largest breach parameters.

Existing Conditions ALWD Breach Parameters for ALWD SDF

Parameter Set	MacDonald et al	Froehlich (1995)	Froehlich (2008)	Von Thun & Gillette
Center Station (ft)	125	125	125	**125**
Final Bottom Width (ft)	27	43	56	**57**
Final Bottom Elevation (ft)	139.3	139.3	139.3	**139.3**
Left Side Slope (H:V)	0.5	1.4	1	**0.5**
Right Side Slope (H:V)	0.5	1.4	1	**0.5**
Breach Weir Coefficient	2.6	2.6	2.6	**2.6**
Breach Formation Time (hr)	0.27	0.52	0.67	**0.36**
Failure Mode	Overtopping	Overtopping	Overtopping	**Overtopping**
Piping Coefficient	N/A	N/A	N/A	**N/A**
Initial Piping Elevation (ft)	N/A	N/A	N/A	**N/A**
Failure Trigger[1]	Set Time	Set Time	Set Time	**Set Time**
Start Date[1]	03Jan2023	03Jan2023	03Jan2023	**03Jan2023**
Start Time[1]	15:54	15:54	15:54	**15:54**
Peak Breach Discharge (cfs)[2]	7,313	8,957	8,200	**11,244**

[1] Failure assumed to occur at time of peak WSE during ALWD SDF. BLD does not overtop during ALWD SDF and thus not assumed to fail.

[2] Values shown in orange text indicate parameter set with highest peak breach discharge.

Existing Conditions BLD Breach Parameters for BLD SDF

Parameter Set	MacDonald et al	Froehlich (1995)	Froehlich (2008)	Von Thun & Gillette
Center Station (ft)	35	35	35	35
Final Bottom Width (ft)	7	14	23	38
Final Bottom Elevation (ft)	156.7	156.7	156.7	156.7
Left Side Slope (H:V)	0.5	0.9	0.7	0.5
Right Side Slope (H:V)	0.5	0.9	0.7	0.5
Breach Weir Coefficient	2.6	2.6	2.6	2.6
Breach Formation Time (hr)	0.15	0.23	0.30	0.32
Failure Mode[1]	Piping	Piping	Piping	Piping
Piping Coefficient	0.5	0.5	0.5	0.5
Initial Piping Elevation (ft)	167.4	167.4	167.4	167.4
Failure Trigger[2]	Set Time	Set Time	Set Time	Set Time
Start Date[2]	03Jan2023	03Jan2023	03Jan2023	03Jan2023
Start Time[2]	15:57	15:57	15:57	15:57
Peak Breach Discharge (cfs)[3]	3,232	3,656	3,925	4,388

[1] BLD does not overtop during BLD SDF and thus assumed to fail via piping.

[2] Failure assumed to occur at time of peak WSE during BLD SDF.

[3] Values shown in orange text indicate parameter set with highest peak breach discharge.

Existing Conditions ALWD Breach Parameters for BLD SDF

Parameter Set	MacDonald et al	Froehlich (1995)	Froehlich (2008)	Von Thun & Gillette
Center Station (ft)	125	125	125	125
Final Bottom Width (ft)	27	43	56	56
Final Bottom Elevation (ft)	139.3	139.3	139.3	139.3
Left Side Slope (H:V)	0.5	1.4	1	0.5
Right Side Slope (H:V)	0.5	1.4	1	0.5
Breach Weir Coefficient	2.6	2.6	2.6	2.6
Breach Formation Time (hr)	0.27	0.52	0.67	0.36
Failure Mode	Overtopping	Overtopping	Overtopping	Overtopping
Piping Coefficient	N/A	N/A	N/A	N/A
Initial Piping Elevation (ft)	N/A	N/A	N/A	N/A
Failure Trigger[1]	Set Time	Set Time	Set Time	Set Time
Start Date[1]	03Jan2023	03Jan2023	03Jan2023	03Jan2023
Start Time[1]	16:23	16:23	16:23	16:23
Peak Breach Discharge (cfs)[2]	7,313	8,957	8,200	10,491

[1] Failure assumed to occur at time of peak WSE during BLD SDF with failure of BLD.

[2] Values shown in orange text indicate parameter set with highest peak breach discharge.

Appendix E: Inundation Hazard Mapping

LEGEND

- BCTB CENTERLINE
- PROPOSED SOLUTION AREA

INUNDATION BOUNDARY

- EXISTING 10-YR
- EXISTING 100-YR
- PROPOSED 10-YR (ALL PS, NO DETENTION)
- PROPOSED 100-YR (ALL PS, NO DETENTION)

AT-RISK BUILDING

- EXISTING 10-YR
- EXISTING 100-YR
- PROPOSED 10-YR (ADDITIONAL BUILDINGS)
- PROPOSED 100-YR (ADDITIONAL BUILDINGS)

DAM / CULVERT

- CULVERT (DECREASED LOS)
- CULVERT (NO LOS CHANGE)
- DAM (NO LOS CHANGE)

0 125 250 500 FEET

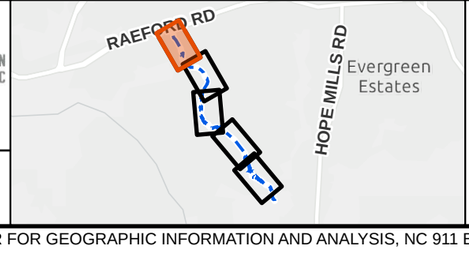
1" = 250'

Hazen

4011 WESTCHASE BLVD
SUITE 500
RALEIGH, NC 27607

FAYETTEVILLE NC
AMERICA'S CAN DO CITY

STORMWATER SERVICES



BEAVER CREEK TRIBUTARY B DETENTION EVALUATION

INUNDATION HAZARD MAPPING

DATE: JUNE 2023

MAP #: 1

PATH: O:\31537-000\31537-001\GIS\PROJECTS\31537-001_WDPV3.APRX

REFERENCE: ROAD NAMES (CUMBERLAND COUNTY), AERIAL IMAGERY (ESRI, HERE, GARMIN, SAFEGRAPH, METI/NASA, USGS, EPA, NPS, USDA, NC ONEMAP, NC CENTER FOR GEOGRAPHIC INFORMATION AND ANALYSIS, NC 911 BOARD)

LEGEND

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- PROPOSED SOLUTION AREA

INUNDATION BOUNDARY

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- EXISTING 100-YR
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DAM / CULVERT

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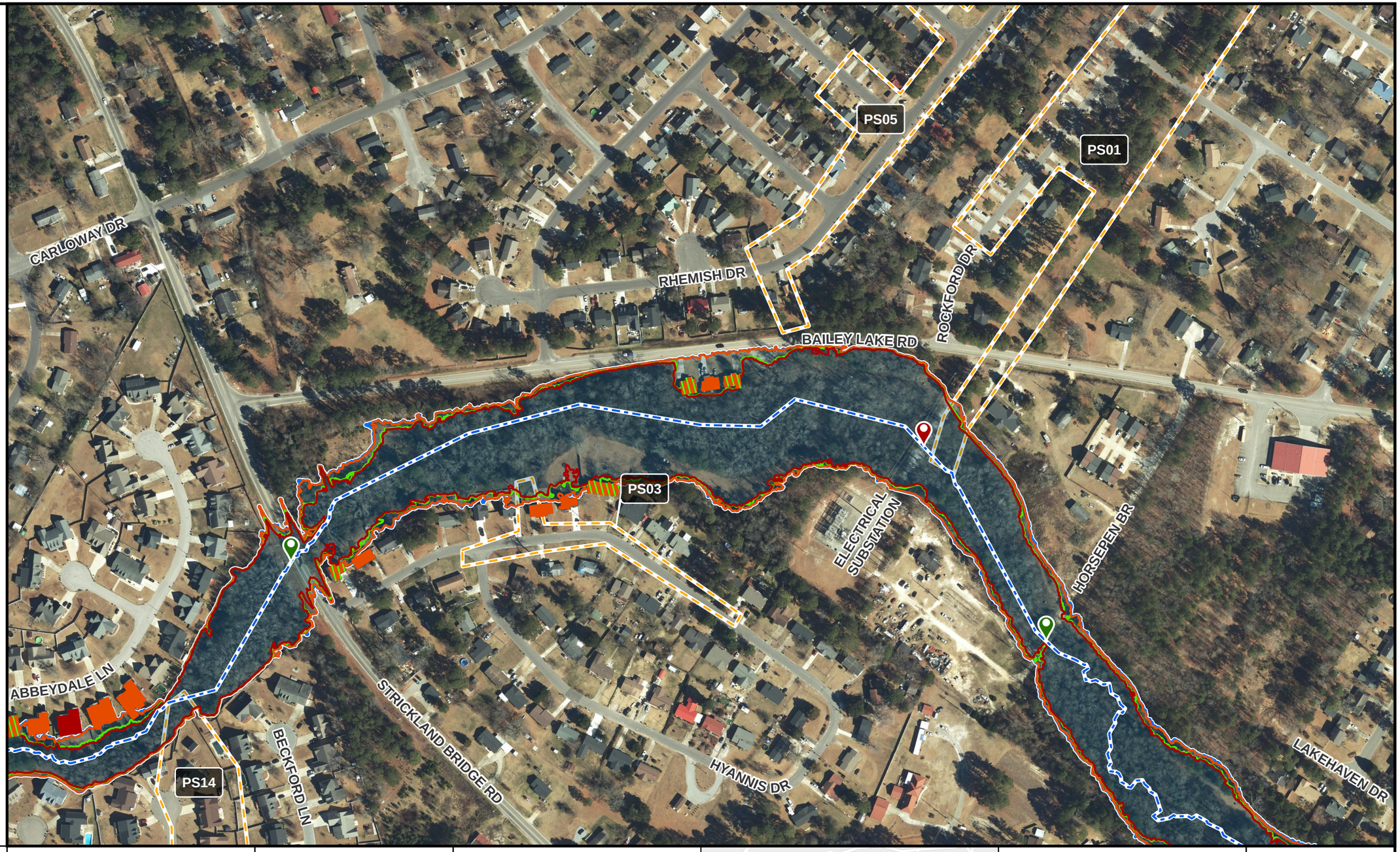


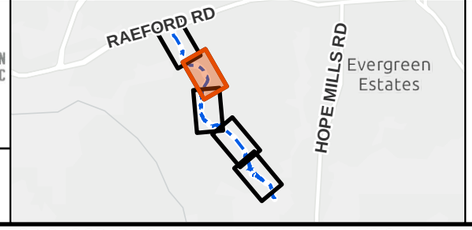
0 125 250 500 FEET

1" = 250'

Hazen
4011 WESTCHASE BLVD
SUITE 500
RALEIGH, NC 27607

FAYETTEVILLE NC
AMERICA'S CAN DO CITY

STORMWATER SERVICES



BEAVER CREEK TRIBUTARY B DETENTION EVALUATION

INUNDATION HAZARD MAPPING

DATE: JUNE 2023

MAP #: 2

PATH: O:\31537-000\31537-001\GIS\PROJECTS\31537-001_WDPV3.APRX

REFERENCE: ROAD NAMES (CUMBERLAND COUNTY), AERIAL IMAGERY (ESRI, HERE, GARMIN, SAFEGRAPH, METI/NASA, USGS, EPA, NPS, USDA, NC ONEMAP, NC CENTER FOR GEOGRAPHIC INFORMATION AND ANALYSIS, NC 911 BOARD)

LEGEND

- BCTB CENTERLINE
- PROPOSED SOLUTION AREA

INUNDATION BOUNDARY

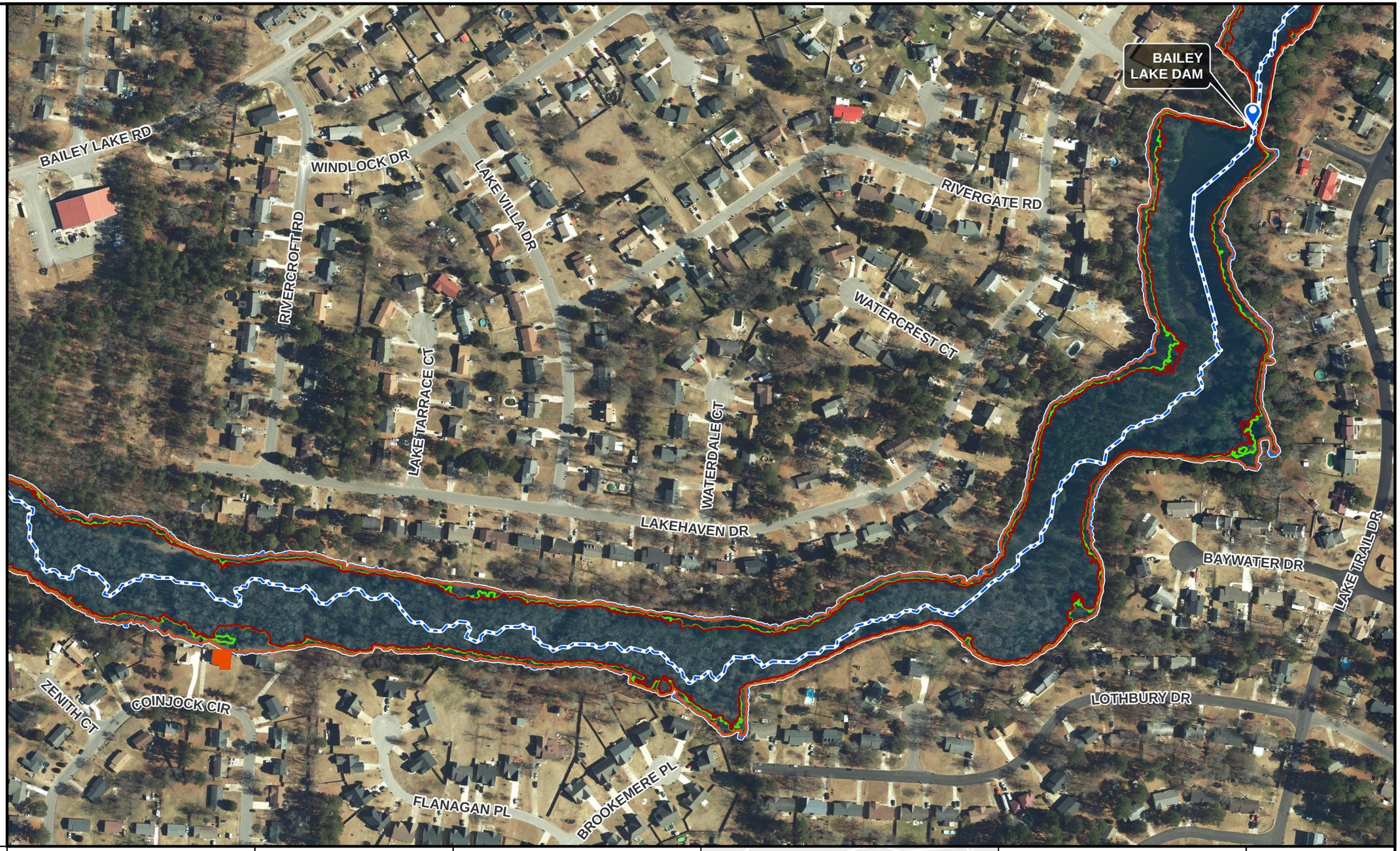
- EXISTING 10-YR
- EXISTING 100-YR
- PROPOSED 10-YR (ALL PS, NO DETENTION)
- PROPOSED 100-YR (ALL PS, NO DETENTION)

AT-RISK BUILDING

- EXISTING 10-YR
- EXISTING 100-YR
- PROPOSED 10-YR (ADDITIONAL BUILDINGS)
- PROPOSED 100-YR (ADDITIONAL BUILDINGS)

DAM / CULVERT

- CULVERT (DECREASED LOS)
- CULVERT (NO LOS CHANGE)
- DAM (NO LOS CHANGE)



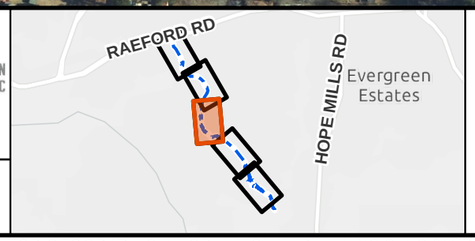
0 125 250 500 FEET

1" = 250'

Hazen
4011 WESTCHASE BLVD
SUITE 500
RALEIGH, NC 27607

FAYETTEVILLE NC
AMERICA'S CAN DO CITY

STORMWATER SERVICES



BEAVER CREEK TRIBUTARY B DETENTION EVALUATION

INUNDATION HAZARD MAPPING

DATE: JUNE 2023

MAP #: 3

PATH: O:\31537-000\31537-001\GIS\PROJECTS\31537-001_WDPV3.APRX

REFERENCE: ROAD NAMES (CUMBERLAND COUNTY), AERIAL IMAGERY (ESRI, HERE, GARMIN, SAFEGRAPH, METI/NASA, USGS, EPA, NPS, USDA, NC ONEMAP, NC CENTER FOR GEOGRAPHIC INFORMATION AND ANALYSIS, NC 911 BOARD)

LEGEND

- BCTB CENTERLINE
- PROPOSED SOLUTION AREA

INUNDATION BOUNDARY

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- EXISTING 100-YR
- PROPOSED 10-YR (ALL PS, NO DETENTION)
- PROPOSED 100-YR (ALL PS, NO DETENTION)

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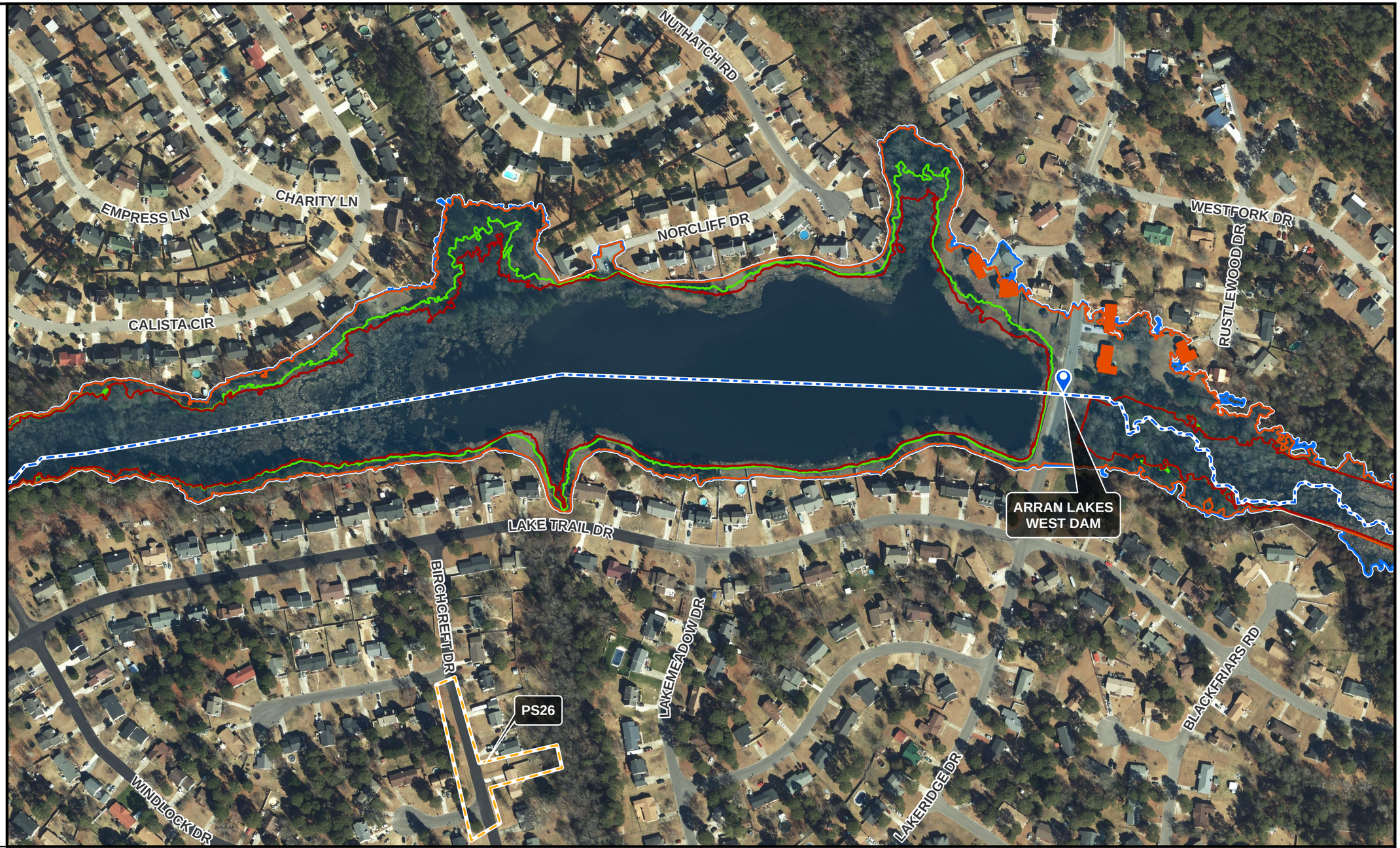
- EXISTING 100-YR
- PROPOSED 10-YR (ADDITIONAL BUILDINGS)
- PROPOSED 100-YR (ADDITIONAL BUILDINGS)

DAM / CULVERT

- CULVERT (DECREASED LOS)
- CULVERT (NO LOS CHANGE)
- DAM (NO LOS CHANGE)



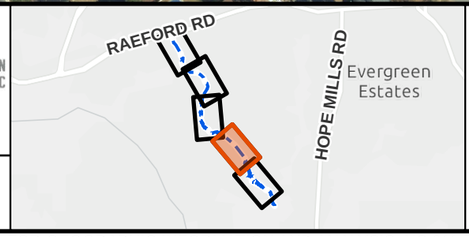
0 125 250 500 FEET

1" = 250'

Hazen
4011 WESTCHASE BLVD
SUITE 500
RALEIGH, NC 27607

FAYETTEVILLE NC
AMERICA'S CAN DO CITY

STORMWATER SERVICES



BEAVER CREEK TRIBUTARY B DETENTION EVALUATION

INUNDATION HAZARD MAPPING

DATE: JUNE 2023

MAP #: 4

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REFERENCE: ROAD NAMES (CUMBERLAND COUNTY), AERIAL IMAGERY (ESRI, HERE, GARMIN, SAFEGRAPH, METI/NASA, USGS, EPA, NPS, USDA, NC ONEMAP, NC CENTER FOR GEOGRAPHIC INFORMATION AND ANALYSIS, NC 911 BOARD)

LEGEND

- BCTB CENTERLINE
- PROPOSED SOLUTION AREA

INUNDATION BOUNDARY

- EXISTING 10-YR
- EXISTING 100-YR
- PROPOSED 10-YR (ALL PS, NO DETENTION)
- PROPOSED 100-YR (ALL PS, NO DETENTION)

AT-RISK BUILDING

- EXISTING 10-YR
- EXISTING 100-YR
- PROPOSED 10-YR (ADDITIONAL BUILDINGS)
- PROPOSED 100-YR (ADDITIONAL BUILDINGS)

DAM / CULVERT

- CULVERT (DECREASED LOS)
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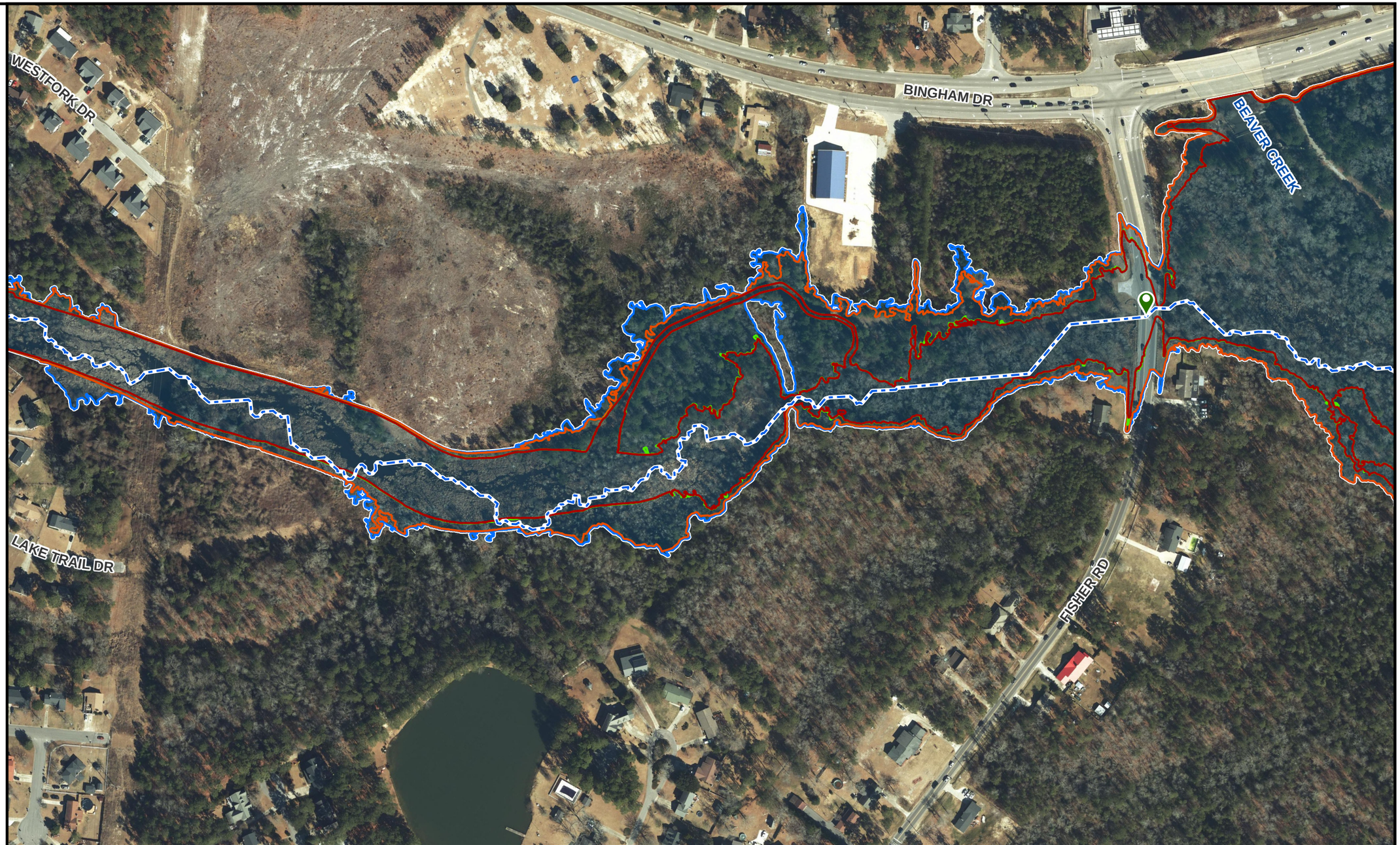
- DAM (NO LOS CHANGE)



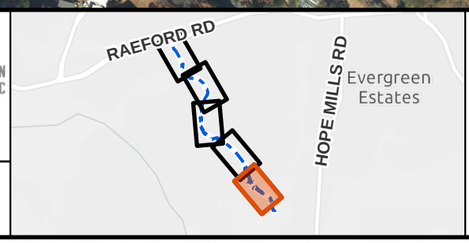
0 125 250 500 FEET

1" = 250'

Hazen
4011 WESTCHASE BLVD
SUITE 500
RALEIGH, NC 27607

FAYETTEVILLE NC
AMERICA'S CAN DO CITY

STORMWATER SERVICES



BEAVER CREEK TRIBUTARY B DETENTION EVALUATION

INUNDATION HAZARD MAPPING

DATE: JUNE 2023

MAP #: 5

PATH: O:\31537-000\31537-001\GIS\PROJECTS\31537-001_WDPV3.APRX

REFERENCE: ROAD NAMES (CUMBERLAND COUNTY), AERIAL IMAGERY (ESRI, HERE, GARMIN, SAFEGRAPH, METI/NASA, USGS, EPA, NPS, USDA, NC ONEMAP, NC CENTER FOR GEOGRAPHIC INFORMATION AND ANALYSIS, NC 911 BOARD)

Appendix F: Proposed Solution Cost Estimates

Beaver Creek Tributary B Detention Evaluation

Summary of Proposed Solutions Cost Estimates (PSCE)[1]

WATERSHED	Beaver Creek 3 (BV3)	% SUBMITTAL	Alternatives Evaluation
STUDY GROUP	Priority 1	CONSULTANT	Hazen
WA / PO NUMBERS	42463	DATE	Report Date

PS NAME	PROPOSED SOLUTION DESCRIPTION	CONCERN AREA(S) IMPROVED	TOTAL
PS01	Rockford Dr	CA01	$ 4,582,067
PS03	Hyannis Dr	CA03	$ 1,250,149
PS05	Rhemish Dr	CA05	$ 4,143,448
PS08	Carloway Dr	CA08	$ 1,662,204
PS14	Stoneclave Pl	CA14	$ 1,874,637
PS20	Manassas St	CA20	$ 2,039,619
PS22	Graham Rd	CA22	$ 1,337,631
PS24	Raeford Rd (Westbound)	CA24	$ 2,226,111
PS26	Birchcreft Dr	CA26	$ 1,304,592
PS28	Lakeridge Dr	CA28	$ 1,154,074
PS29	Baywater Dr	CA29	$ 4,362,232
PS31	Berriedale Drive Improvements	CA31	$ 6,252,775
DPS1	Arran Lakes West Dam Overtopping Protection	N/A	$ 8,505,231
DPS2	Arran Lakes West Dam Spillway Improvement	N/A	$ 10,340,360
DPS3	Bailey Lake Dam Rehabilitation	N/A	$ 12,862,841
CPS1	Carloway Dr Culvert Replacement	N/A	$ 1,201,592
LOCAL DETENTION (ALL) - TOTAL COST (2021 COSTS)			**$ 32,189,538**
COST ESCALATION FACTOR		2.1%	$ 675,980
LOCAL DETENTION (ALL) (2022 COSTS)			**$ 32,865,519**
LOCAL DETENTION (ALL) (2023 COSTS)			**$ 33,555,700**
LOCAL DETENTION (ALL) (2024 COSTS)			**$ 34,260,370**
LOCAL DETENTION (ALL) (2025 COSTS)			**$ 34,979,840**
LOCAL DETENTION (ALL) (2026 COSTS)			**$ 35,714,420**
LOCAL DETENTION (PS01, 20, 22, 24, 29, 31) - TOTAL COST (2021 COSTS)			**$ 20,800,434**
COST ESCALATION FACTOR		2.1%	$ 436,809
LOCAL DETENTION (PS01, 20, 22, 24, 29, 31) (2022 COSTS)			**$ 21,237,243**
LOCAL DETENTION (PS01, 20, 22, 24, 29, 31) (2023 COSTS)			**$ 21,683,230**
LOCAL DETENTION (PS01, 20, 22, 24, 29, 31) (2024 COSTS)			**$ 22,138,580**
LOCAL DETENTION (PS01, 20, 22, 24, 29, 31) (2025 COSTS)			**$ 22,603,500**
LOCAL DETENTION (PS01, 20, 22, 24, 29, 31) (2026 COSTS)			**$ 23,078,180**
REGIONAL DETENTION (DPS1) - TOTAL COST (2021 COSTS)			**$ 8,505,231**
COST ESCALATION FACTOR		2.1%	$ 178,610
REGIONAL DETENTION (DPS1) (2022 COSTS)			**$ 8,683,841**
REGIONAL DETENTION (DPS1) (2023 COSTS)			**$ 8,866,210**
REGIONAL DETENTION (DPS1) (2024 COSTS)			**$ 9,052,410**
REGIONAL DETENTION (DPS1) (2025 COSTS)			**$ 9,242,520**
REGIONAL DETENTION (DPS1) (2026 COSTS)			**$ 9,436,620**
REGIONAL DETENTION (DPS2) - TOTAL COST (2021 COSTS)			**$ 10,340,360**
COST ESCALATION FACTOR		2.1%	$ 217,148
REGIONAL DETENTION (DPS2) (2022 COSTS)			**$ 10,557,507**
REGIONAL DETENTION (DPS2) (2023 COSTS)			**$ 10,779,220**
REGIONAL DETENTION (DPS2) (2024 COSTS)			**$ 11,005,590**
REGIONAL DETENTION (DPS2) (2025 COSTS)			**$ 11,236,710**
REGIONAL DETENTION (DPS2) (2026 COSTS)			**$ 11,472,690**
REGIONAL DETENTION (DPS3) - TOTAL COST (2021 COSTS)			**$ 12,862,841**
COST ESCALATION FACTOR		2.1%	$ 270,120
REGIONAL DETENTION (DPS3) (2022 COSTS)			**$ 13,132,961**
REGIONAL DETENTION (DPS3) (2023 COSTS)			**$ 13,408,760**
REGIONAL DETENTION (DPS3) (2024 COSTS)			**$ 13,690,350**
REGIONAL DETENTION (DPS3) (2025 COSTS)			**$ 13,977,850**
REGIONAL DETENTION (DPS3) (2026 COSTS)			**$ 14,271,390**
CULVERT REPLACEMENT (CPS1) - TOTAL COST (2021 COSTS)			**$ 1,201,592**
COST ESCALATION FACTOR		2.1%	$ 25,233
CULVERT REPLACEMENT (CPS1) (2022 COSTS)			**$ 1,226,825**
CULVERT REPLACEMENT (CPS1) (2023 COSTS)			**$ 1,252,590**
CULVERT REPLACEMENT (CPS1) (2024 COSTS)			**$ 1,278,900**
CULVERT REPLACEMENT (CPS1) (2025 COSTS)			**$ 1,305,760**
CULVERT REPLACEMENT (CPS1) (2026 COSTS)			**$ 1,333,190**

1 - PSCE classified as an AACE Class 5 Estimate with accuracy range or -50 to +100.

Beaver Creek Tributary B Detention Evaluation
Proposed Solution Cost Estimate (PSCE)

PROPOSED SOLUTION NAME	PS01	PHASE	Local Detention Evaluation
PROPOSED SOLUTION DESC	Rockford Dr	CONSULTANT	Hazen
STUDY GROUP	Priority 1	DATE	06/12/2023

DETENTION FOR CONCERN AREA(S)

CA01

NO.	CATEGORY	ITEM	QTY	UNIT	UNIT PRICE	TOTAL
1	EARTHWORK	CLEARING AND GRUBBING	3.0	AC	$ 25,000	$ 75,000
2	EARTHWORK	SELECT BORROW MATERIAL	250	CY	$ 60	$ 15,000
3	EARTHWORK	UNDERCUT EXCAVATION	250	CY	$ 60	$ 15,000
4	EARTHWORK	UNCLASSIFIED EXCAVATION	12,500	CY	$ 55	$ 687,500
5	EARTHWORK	FINE GRADING	7,500	SY	$ 15	$ 112,500
6	DRAINAGE - STRUCTURES	DETENTION BASIN OUTLET	1	EA	$ 12,000	$ 12,000
7	RIP RAP AND SEEDING	SEEDING AND MULCHING, AC	3.0	AC	$ 5,500	$ 16,500
8	RIP RAP AND SEEDING	TURF REINFORCEMENT MATTING	1,750	SY	$ 10	$ 17,500
9	STREAM WORK	TREES IN CONTAINERS	60	EA	$ 500	$ 30,000
10	STREAM WORK	CONTAINER PLANTS	120	EA	$ 50	$ 6,000
11	MISCELLANEOUS	TREE PROTECTION FENCE	725	LF	$ 5	$ 3,625
12	MISCELLANEOUS	TREE REMOVAL, 4"-8"	15	EA	$ 1,500	$ 22,500
13	MISCELLANEOUS	TREE REMOVAL, 8"-12"	15	EA	$ 2,500	$ 37,500
14	MISCELLANEOUS	TREE REMOVAL, 12"-18"	15	EA	$ 4,000	$ 60,000
15	MISCELLANEOUS	REMOVE AND DISPOSE OF EXISTING FENCE	500	LF	$ 12	$ 6,000
16	MISCELLANEOUS	INSTALL NEW CHAIN LINK FENCE	1,450	LF	$ 40	$ 58,000
17	MISCELLANEOUS	LAND ACQUISITION (PS01)	0.9	AC	$ 55,000	$ 49,451
18	MISCELLANEOUS	BUILDING BUYOUTS (PS01)	2.1	AC	$ 324,000	$ 680,692
19	MISCELLANEOUS	BUILDING DEMOLITION AND DISPOSAL	12,000	SF	$ 20	$ 240,000
20	STREET WORK	REMOVE AND REPLACE ASPHALT ROLL CURB AND GUTTER	20	LF	$ 70	$ 1,400

SUBTOTAL		$ 2,146,167

PROJECT COSTS	% OF CONSTRUCTION	$ 536,542
MOBILIZATION	5%	$ 107,308
EROSION CONTROL	5%	$ 107,308
TRAFFIC CONTROL	5%	$ 107,308
MINOR UTILITY CONFLICT	10%	$ 214,617

ADDITIONAL COSTS	% OF CONSTRUCTION	$ 1,899,358
CONSTRUCTION CONTINGENCY	30%	$ 643,850
PROJECT MANAGEMENT	10%	$ 214,617
SURVEY	3%	$ 64,385
DESIGN AND PERMITTING	20%	$ 429,233
GEOTECHNICAL INVESTIGATION	1%	$ 21,462
STRUCTURAL EVALUATION	2%	$ 42,923
REAL ESTATE ACQUISITION	5%	$ 107,308
MATERIALS TESTING	1%	$ 21,462
UTILITY RELOCATION	5%	$ 107,308
CONSTRUCTION INSPECTIONS	10%	$ 214,617
BONDING	2%	$ 32,193

PROPOSED SOLUTION TOTAL (2021 COSTS)		**$ 4,582,067**
COST ESCALATION FACTOR	2.1%	$ 96,230
PROPOSED SOLUTION TOTAL (2022 COSTS)		**$ 4,678,297**
PROPOSED SOLUTION TOTAL (2023 COSTS)		**$ 4,776,550**
PROPOSED SOLUTION TOTAL (2024 COSTS)		**$ 4,876,860**
PROPOSED SOLUTION TOTAL (2025 COSTS)		**$ 4,979,280**
PROPOSED SOLUTION TOTAL (2026 COSTS)		**$ 5,083,850**

NOTES

1 - PSCE classified as an AACE Class 5 Estimate with accuracy range or -50 to +100.

2 - Unit Cost Items (Categorization, Description, Unit and Price) were prepared by WK Dickson for the City and submitted on October 1, 2021. Refer to the memo from WK Dickson to the City, dated October 8, 2021 for assumptions and background information.

Beaver Creek Tributary B Detention Evaluation
Proposed Solution Cost Estimate (PSCE)

PROPOSED SOLUTION NAME	PS03	PHASE	Local Detention Evaluation
PROPOSED SOLUTION DESC	Hyannis Dr	CONSULTANT	Hazen
STUDY GROUP	Priority 1	DATE	06/12/2023

DETENTION FOR CONCERN AREA(S)

CA03

NO.	CATEGORY	ITEM	QTY	UNIT	UNIT PRICE	TOTAL
1	EARTHWORK	CLEARING AND GRUBBING	0.5	AC	$ 25,000	$ 12,500
2	EARTHWORK	SELECT BORROW MATERIAL	50	CY	$ 60	$ 3,000
3	EARTHWORK	UNDERCUT EXCAVATION	50	CY	$ 60	$ 3,000
4	EARTHWORK	UNCLASSIFIED EXCAVATION	2,500	CY	$ 55	$ 137,500
5	EARTHWORK	FINE GRADING	1,500	SY	$ 15	$ 22,500
6	DRAINAGE - STRUCTURES	DETENTION BASIN OUTLET	1	EA	$ 12,000	$ 12,000
7	RIP RAP AND SEEDING	SEEDING AND MULCHING, AC	0.5	AC	$ 5,500	$ 2,750
8	RIP RAP AND SEEDING	TURF REINFORCEMENT MATTING	1,000	SY	$ 10	$ 10,000
9	STREAM WORK	TREES IN CONTAINERS	10	EA	$ 500	$ 5,000
10	STREAM WORK	CONTAINER PLANTS	20	EA	$ 50	$ 1,000
11	MISCELLANEOUS	TREE PROTECTION FENCE	300	LF	$ 5	$ 1,500
12	MISCELLANEOUS	TREE REMOVAL, 4"-8"	5	EA	$ 1,500	$ 7,500
13	MISCELLANEOUS	TREE REMOVAL, 8"-12"	5	EA	$ 2,500	$ 12,500
14	MISCELLANEOUS	TREE REMOVAL, 12"-18"	5	EA	$ 4,000	$ 20,000
15	MISCELLANEOUS	REMOVE AND DISPOSE OF EXISTING FENCE	200	LF	$ 12	$ 2,400
16	MISCELLANEOUS	INSTALL NEW CHAIN LINK FENCE	600	LF	$ 40	$ 24,000
17	MISCELLANEOUS	BUILDING BUYOUTS (PS03)	0.5	AC	$ 474,000	$ 237,000
18	MISCELLANEOUS	BUILDING DEMOLITION AND DISPOSAL	3,500	SF	$ 20	$ 70,000
19	STREET WORK	REMOVE AND REPLACE ASPHALT ROLL CURB AND GUTTER	20	LF	$ 70	$ 1,400

SUBTOTAL		$ 585,550
PROJECT COSTS	% OF CONSTRUCTION	$ 146,388
MOBILIZATION	5%	$ 29,278
EROSION CONTROL	5%	$ 29,278
TRAFFIC CONTROL	5%	$ 29,278
MINOR UTILITY CONFLICT	10%	$ 58,555

ADDITIONAL COSTS	% OF CONSTRUCTION	$ 518,212
CONSTRUCTION CONTINGENCY	30%	$ 175,665
PROJECT MANAGEMENT	10%	$ 58,555
SURVEY	3%	$ 17,567
DESIGN AND PERMITTING	20%	$ 117,110
GEOTECHNICAL INVESTIGATION	1%	$ 5,856
STRUCTURAL EVALUATION	2%	$ 11,711
REAL ESTATE ACQUISITION	5%	$ 29,278
MATERIALS TESTING	1%	$ 5,856
UTILITY RELOCATION	5%	$ 29,278
CONSTRUCTION INSPECTIONS	10%	$ 58,555
BONDING	2%	$ 8,783

PROPOSED SOLUTION TOTAL (2021 COSTS)		**$ 1,250,149**
COST ESCALATION FACTOR	2.1%	$ 26,260
PROPOSED SOLUTION TOTAL (2022 COSTS)		**$ 1,276,409**
PROPOSED SOLUTION TOTAL (2023 COSTS)		**$ 1,303,220**
PROPOSED SOLUTION TOTAL (2024 COSTS)		**$ 1,330,590**
PROPOSED SOLUTION TOTAL (2025 COSTS)		**$ 1,358,540**
PROPOSED SOLUTION TOTAL (2026 COSTS)		**$ 1,387,070**

NOTES

1 - PSCE classified as an AACE Class 5 Estimate with accuracy range or -50 to +100.

2 - Unit Cost Items (Categorization, Description, Unit and Price) were prepared by WK Dickson for the City and submitted on October 1, 2021. Refer to the memo from WK Dickson to the City, dated October 8, 2021 for assumptions and background information.

Beaver Creek Tributary B Detention Evaluation
Proposed Solution Cost Estimate (PSCE)

PROPOSED SOLUTION NAME	PS05	PHASE	Local Detention Evaluation
PROPOSED SOLUTION DESC	Rhemish Dr	CONSULTANT	Hazen
STUDY GROUP	Priority 1	DATE	06/12/2023

DETENTION FOR CONCERN AREA(S)

CA05

NO.	CATEGORY	ITEM	QTY	UNIT	UNIT PRICE	TOTAL
1	EARTHWORK	CLEARING AND GRUBBING	1.5	AC	$ 25,000	$ 37,500
2	EARTHWORK	SELECT BORROW MATERIAL	150	CY	$ 60	$ 9,000
3	EARTHWORK	UNDERCUT EXCAVATION	150	CY	$ 60	$ 9,000
4	EARTHWORK	UNCLASSIFIED EXCAVATION	6,700	CY	$ 55	$ 368,500
5	EARTHWORK	FINE GRADING	4,000	SY	$ 15	$ 60,000
6	DRAINAGE - STRUCTURES	DETENTION BASIN OUTLET	1	EA	$ 12,000	$ 12,000
7	RIP RAP AND SEEDING	SEEDING AND MULCHING, AC	1.5	AC	$ 5,500	$ 8,250
8	RIP RAP AND SEEDING	TURF REINFORCEMENT MATTING	1,500	SY	$ 10	$ 15,000
9	STREAM WORK	TREES IN CONTAINERS	30	EA	$ 500	$ 15,000
10	STREAM WORK	CONTAINER PLANTS	55	EA	$ 50	$ 2,750
11	MISCELLANEOUS	TREE PROTECTION FENCE	525	LF	$ 5	$ 2,625
12	MISCELLANEOUS	TREE REMOVAL, 4"-8"	10	EA	$ 1,500	$ 15,000
13	MISCELLANEOUS	TREE REMOVAL, 8"-12"	10	EA	$ 2,500	$ 25,000
14	MISCELLANEOUS	TREE REMOVAL, 12"-18"	10	EA	$ 4,000	$ 40,000
15	MISCELLANEOUS	REMOVE AND DISPOSE OF EXISTING FENCE	350	LF	$ 12	$ 4,200
16	MISCELLANEOUS	INSTALL NEW CHAIN LINK FENCE	1,025	LF	$ 40	$ 41,000
17	MISCELLANEOUS	BUILDING BUYOUTS (PS05)	1.5	AC	$ 663,000	$ 994,500
18	MISCELLANEOUS	BUILDING DEMOLITION AND DISPOSAL	14,000	SF	$ 20	$ 280,000
19	STREET WORK	REMOVE AND REPLACE ASPHALT ROLL CURB AND GUTTER	20	LF	$ 70	$ 1,400

SUBTOTAL		$ 1,940,725

PROJECT COSTS	% OF CONSTRUCTION	
		$ 485,181
MOBILIZATION	5%	$ 97,036
EROSION CONTROL	5%	$ 97,036
TRAFFIC CONTROL	5%	$ 97,036
MINOR UTILITY CONFLICT	10%	$ 194,073

ADDITIONAL COSTS	% OF CONSTRUCTION	
		$ 1,717,542
CONSTRUCTION CONTINGENCY	30%	$ 582,218
PROJECT MANAGEMENT	10%	$ 194,073
SURVEY	3%	$ 58,222
DESIGN AND PERMITTING	20%	$ 388,145
GEOTECHNICAL INVESTIGATION	1%	$ 19,407
STRUCTURAL EVALUATION	2%	$ 38,815
REAL ESTATE ACQUISITION	5%	$ 97,036
MATERIALS TESTING	1%	$ 19,407
UTILITY RELOCATION	5%	$ 97,036
CONSTRUCTION INSPECTIONS	10%	$ 194,073
BONDING	2%	$ 29,111

PROPOSED SOLUTION TOTAL (2021 COSTS)		**$ 4,143,448**
COST ESCALATION FACTOR	2.1%	$ 87,020
PROPOSED SOLUTION TOTAL (2022 COSTS)		**$ 4,230,468**
PROPOSED SOLUTION TOTAL (2023 COSTS)		**$ 4,319,310**
PROPOSED SOLUTION TOTAL (2024 COSTS)		**$ 4,410,020**
PROPOSED SOLUTION TOTAL (2025 COSTS)		**$ 4,502,640**
PROPOSED SOLUTION TOTAL (2026 COSTS)		**$ 4,597,200**

NOTES

1 - PSCE classified as an AACE Class 5 Estimate with accuracy range or -50 to +100.

2 - Unit Cost Items (Categorization, Description, Unit and Price) were prepared by WK Dickson for the City and submitted on October 1, 2021. Refer to the memo from WK Dickson to the City, dated October 8, 2021 for assumptions and background information.

Beaver Creek Tributary B Detention Evaluation
Proposed Solution Cost Estimate (PSCE)

PROPOSED SOLUTION NAME	PS08	PHASE	Local Detention Evaluation
PROPOSED SOLUTION DESC	Carloway Dr	CONSULTANT	Hazen
STUDY GROUP	Priority 1	DATE	06/12/2023

DETENTION FOR CONCERN AREA(S)

CA08

NO.	CATEGORY	ITEM	QTY	UNIT	UNIT PRICE	TOTAL
1	EARTHWORK	CLEARING AND GRUBBING	0.5	AC	$ 25,000	$ 12,500
2	EARTHWORK	SELECT BORROW MATERIAL	50	CY	$ 60	$ 3,000
3	EARTHWORK	UNDERCUT EXCAVATION	50	CY	$ 60	$ 3,000
4	EARTHWORK	UNCLASSIFIED EXCAVATION	2,500	CY	$ 55	$ 137,500
5	EARTHWORK	FINE GRADING	1,500	SY	$ 15	$ 22,500
6	DRAINAGE - STRUCTURES	DETENTION BASIN OUTLET	1	EA	$ 12,000	$ 12,000
7	RIP RAP AND SEEDING	SEEDING AND MULCHING, AC	0.5	AC	$ 5,500	$ 2,750
8	RIP RAP AND SEEDING	TURF REINFORCEMENT MATTING	1,000	SY	$ 10	$ 10,000
9	STREAM WORK	TREES IN CONTAINERS	10	EA	$ 500	$ 5,000
10	STREAM WORK	CONTAINER PLANTS	20	EA	$ 50	$ 1,000
11	MISCELLANEOUS	TREE PROTECTION FENCE	300	LF	$ 5	$ 1,500
12	MISCELLANEOUS	TREE REMOVAL, 4"-8"	5	EA	$ 1,500	$ 7,500
13	MISCELLANEOUS	TREE REMOVAL, 8"-12"	5	EA	$ 2,500	$ 12,500
14	MISCELLANEOUS	TREE REMOVAL, 12"-18"	5	EA	$ 4,000	$ 20,000
15	MISCELLANEOUS	REMOVE AND DISPOSE OF EXISTING FENCE	200	LF	$ 12	$ 2,400
16	MISCELLANEOUS	INSTALL NEW CHAIN LINK FENCE	600	LF	$ 40	$ 24,000
17	MISCELLANEOUS	BUILDING BUYOUTS (PS08)	0.5	AC	$ 830,000	$ 415,000
18	MISCELLANEOUS	BUILDING DEMOLITION AND DISPOSAL	4,250	SF	$ 20	$ 85,000
19	STREET WORK	REMOVE AND REPLACE ASPHALT ROLL CURB AND GUTTER	20	LF	$ 70	$ 1,400

SUBTOTAL		$ 778,550
PROJECT COSTS	% OF CONSTRUCTION	$ 194,638
MOBILIZATION	5%	$ 38,928
EROSION CONTROL	5%	$ 38,928
TRAFFIC CONTROL	5%	$ 38,928
MINOR UTILITY CONFLICT	10%	$ 77,855

ADDITIONAL COSTS	% OF CONSTRUCTION	$ 689,017
CONSTRUCTION CONTINGENCY	30%	$ 233,565
PROJECT MANAGEMENT	10%	$ 77,855
SURVEY	3%	$ 23,357
DESIGN AND PERMITTING	20%	$ 155,710
GEOTECHNICAL INVESTIGATION	1%	$ 7,786
STRUCTURAL EVALUATION	2%	$ 15,571
REAL ESTATE ACQUISITION	5%	$ 38,928
MATERIALS TESTING	1%	$ 7,786
UTILITY RELOCATION	5%	$ 38,928
CONSTRUCTION INSPECTIONS	10%	$ 77,855
BONDING	2%	$ 11,678

PROPOSED SOLUTION TOTAL (2021 COSTS)		**$ 1,662,204**
COST ESCALATION FACTOR	2.1%	$ 34,910
PROPOSED SOLUTION TOTAL (2022 COSTS)		**$ 1,697,114**
PROPOSED SOLUTION TOTAL (2023 COSTS)		**$ 1,732,760**
PROPOSED SOLUTION TOTAL (2024 COSTS)		**$ 1,769,150**
PROPOSED SOLUTION TOTAL (2025 COSTS)		**$ 1,806,310**
PROPOSED SOLUTION TOTAL (2026 COSTS)		**$ 1,844,250**

NOTES

1 - PSCE classified as an AACE Class 5 Estimate with accuracy range or -50 to +100.

2 - Unit Cost Items (Categorization, Description, Unit and Price) were prepared by WK Dickson for the City and submitted on October 1, 2021. Refer to the memo from WK Dickson to the City, dated October 8, 2021 for assumptions and background information.

Beaver Creek Tributary B Detention Evaluation
Proposed Solution Cost Estimate (PSCE)

PROPOSED SOLUTION NAME	PS14	PHASE	Local Detention Evaluation
PROPOSED SOLUTION DESC	Stoneclave Pl	CONSULTANT	Hazen
STUDY GROUP	Priority 1	DATE	06/12/2023

DETENTION FOR CONCERN AREA(S)

CA14

NO.	CATEGORY	ITEM	QTY	UNIT	UNIT PRICE	TOTAL
1	EARTHWORK	CLEARING AND GRUBBING	0.5	AC	$ 25,000	$ 12,500
2	EARTHWORK	SELECT BORROW MATERIAL	50	CY	$ 60	$ 3,000
3	EARTHWORK	UNDERCUT EXCAVATION	50	CY	$ 60	$ 3,000
4	EARTHWORK	UNCLASSIFIED EXCAVATION	2,500	CY	$ 55	$ 137,500
5	EARTHWORK	FINE GRADING	1,500	SY	$ 15	$ 22,500
6	DRAINAGE - STRUCTURES	DETENTION BASIN OUTLET	1	EA	$ 12,000	$ 12,000
7	RIP RAP AND SEEDING	SEEDING AND MULCHING, AC	0.5	AC	$ 5,500	$ 2,750
8	RIP RAP AND SEEDING	TURF REINFORCEMENT MATTING	1,000	SY	$ 10	$ 10,000
9	STREAM WORK	TREES IN CONTAINERS	10	EA	$ 500	$ 5,000
10	STREAM WORK	CONTAINER PLANTS	20	EA	$ 50	$ 1,000
11	MISCELLANEOUS	TREE PROTECTION FENCE	300	LF	$ 5	$ 1,500
12	MISCELLANEOUS	TREE REMOVAL, 4"-8"	5	EA	$ 1,500	$ 7,500
13	MISCELLANEOUS	TREE REMOVAL, 8"-12"	5	EA	$ 2,500	$ 12,500
14	MISCELLANEOUS	TREE REMOVAL, 12"-18"	5	EA	$ 4,000	$ 20,000
15	MISCELLANEOUS	REMOVE AND DISPOSE OF EXISTING FENCE	200	LF	$ 12	$ 2,400
16	MISCELLANEOUS	INSTALL NEW CHAIN LINK FENCE	600	LF	$ 40	$ 24,000
17	MISCELLANEOUS	BUILDING BUYOUTS (PS14)	0.5	AC	$ 949,000	$ 474,500
18	MISCELLANEOUS	BUILDING DEMOLITION AND DISPOSAL	6,250	SF	$ 20	$ 125,000
19	STREET WORK	REMOVE AND REPLACE ASPHALT ROLL CURB AND GUTTER	20	LF	$ 70	$ 1,400

SUBTOTAL		$ 878,050
PROJECT COSTS	% OF CONSTRUCTION	$ 219,513
MOBILIZATION	5%	$ 43,903
EROSION CONTROL	5%	$ 43,903
TRAFFIC CONTROL	5%	$ 43,903
MINOR UTILITY CONFLICT	10%	$ 87,805

ADDITIONAL COSTS	% OF CONSTRUCTION	$ 777,074
CONSTRUCTION CONTINGENCY	30%	$ 263,415
PROJECT MANAGEMENT	10%	$ 87,805
SURVEY	3%	$ 26,342
DESIGN AND PERMITTING	20%	$ 175,610
GEOTECHNICAL INVESTIGATION	1%	$ 8,781
STRUCTURAL EVALUATION	2%	$ 17,561
REAL ESTATE ACQUISITION	5%	$ 43,903
MATERIALS TESTING	1%	$ 8,781
UTILITY RELOCATION	5%	$ 43,903
CONSTRUCTION INSPECTIONS	10%	$ 87,805
BONDING	2%	$ 13,171

PROPOSED SOLUTION TOTAL (2021 COSTS)		**$ 1,874,637**
COST ESCALATION FACTOR	2.1%	$ 39,370
PROPOSED SOLUTION TOTAL (2022 COSTS)		**$ 1,914,007**
PROPOSED SOLUTION TOTAL (2023 COSTS)		**$ 1,954,210**
PROPOSED SOLUTION TOTAL (2024 COSTS)		**$ 1,995,250**
PROPOSED SOLUTION TOTAL (2025 COSTS)		**$ 2,037,160**
PROPOSED SOLUTION TOTAL (2026 COSTS)		**$ 2,079,950**

NOTES

1 - PSCE classified as an AACE Class 5 Estimate with accuracy range or -50 to +100.

2 - Unit Cost Items (Categorization, Description, Unit and Price) were prepared by WK Dickson for the City and submitted on October 1, 2021. Refer to the memo from WK Dickson to the City, dated October 8, 2021 for assumptions and background information.

Beaver Creek Tributary B Detention Evaluation
Proposed Solution Cost Estimate (PSCE)

PROPOSED SOLUTION NAME	PS20	PHASE	Local Detention Evaluation
PROPOSED SOLUTION DESC	Manassas St	CONSULTANT	Hazen
STUDY GROUP	Priority 1	DATE	06/12/2023

DETENTION FOR CONCERN AREA(S)

CA20

NO.	CATEGORY	ITEM	QTY	UNIT	UNIT PRICE	TOTAL
1	EARTHWORK	CLEARING AND GRUBBING	1.5	AC	$ 25,000	$ 37,500
2	EARTHWORK	SELECT BORROW MATERIAL	150	CY	$ 60	$ 9,000
3	EARTHWORK	UNDERCUT EXCAVATION	150	CY	$ 60	$ 9,000
4	EARTHWORK	UNCLASSIFIED EXCAVATION	6,700	CY	$ 55	$ 368,500
5	EARTHWORK	FINE GRADING	4,000	SY	$ 15	$ 60,000
6	DRAINAGE - STRUCTURES	DETENTION BASIN OUTLET	1	EA	$ 12,000	$ 12,000
7	RIP RAP AND SEEDING	SEEDING AND MULCHING, AC	1.5	AC	$ 5,500	$ 8,250
8	RIP RAP AND SEEDING	TURF REINFORCEMENT MATTING	1,500	SY	$ 10	$ 15,000
9	STREAM WORK	TREES IN CONTAINERS	30	EA	$ 500	$ 15,000
10	STREAM WORK	CONTAINER PLANTS	55	EA	$ 50	$ 2,750
11	MISCELLANEOUS	TREE PROTECTION FENCE	525	LF	$ 5	$ 2,625
12	MISCELLANEOUS	TREE REMOVAL, 4"-8"	10	EA	$ 1,500	$ 15,000
13	MISCELLANEOUS	TREE REMOVAL, 8"-12"	10	EA	$ 2,500	$ 25,000
14	MISCELLANEOUS	TREE REMOVAL, 12"-18"	10	EA	$ 4,000	$ 40,000
15	MISCELLANEOUS	REMOVE AND DISPOSE OF EXISTING FENCE	350	LF	$ 12	$ 4,200
16	MISCELLANEOUS	INSTALL NEW CHAIN LINK FENCE	1,025	LF	$ 40	$ 41,000
17	MISCELLANEOUS	LAND ACQUISITION (PS20)	1.1	AC	$ 81,000	$ 89,100
18	MISCELLANEOUS	BUILDING BUYOUTS (PS20)	0.4	AC	$ 400,000	$ 160,000
19	MISCELLANEOUS	BUILDING DEMOLITION AND DISPOSAL	2,000	SF	$ 20	$ 40,000
20	STREET WORK	REMOVE AND REPLACE ASPHALT ROLL CURB AND GUTTER	20	LF	$ 70	$ 1,400

SUBTOTAL		$ 955,325

PROJECT COSTS	% OF CONSTRUCTION	$ 238,831
MOBILIZATION	5%	$ 47,766
EROSION CONTROL	5%	$ 47,766
TRAFFIC CONTROL	5%	$ 47,766
MINOR UTILITY CONFLICT	10%	$ 95,533

ADDITIONAL COSTS	% OF CONSTRUCTION	$ 845,463
CONSTRUCTION CONTINGENCY	30%	$ 286,598
PROJECT MANAGEMENT	10%	$ 95,533
SURVEY	3%	$ 28,660
DESIGN AND PERMITTING	20%	$ 191,065
GEOTECHNICAL INVESTIGATION	1%	$ 9,553
STRUCTURAL EVALUATION	2%	$ 19,107
REAL ESTATE ACQUISITION	5%	$ 47,766
MATERIALS TESTING	1%	$ 9,553
UTILITY RELOCATION	5%	$ 47,766
CONSTRUCTION INSPECTIONS	10%	$ 95,533
BONDING	2%	$ 14,330

PROPOSED SOLUTION TOTAL (2021 COSTS)		**$ 2,039,619**
COST ESCALATION FACTOR	2.1%	$ 42,840
PROPOSED SOLUTION TOTAL (2022 COSTS)		**$ 2,082,459**
PROPOSED SOLUTION TOTAL (2023 COSTS)		**$ 2,126,200**
PROPOSED SOLUTION TOTAL (2024 COSTS)		**$ 2,170,860**
PROPOSED SOLUTION TOTAL (2025 COSTS)		**$ 2,216,450**
PROPOSED SOLUTION TOTAL (2026 COSTS)		**$ 2,263,000**

NOTES

1 - PSCE classified as an AACE Class 5 Estimate with accuracy range or -50 to +100.

2 - Unit Cost Items (Categorization, Description, Unit and Price) were prepared by WK Dickson for the City and submitted on October 1, 2021. Refer to the memo from WK Dickson to the City, dated October 8, 2021 for assumptions and background information.

Beaver Creek Tributary B Detention Evaluation
Proposed Solution Cost Estimate (PSCE)

PROPOSED SOLUTION NAME	PS22	PHASE	Local Detention Evaluation
PROPOSED SOLUTION DESC	Graham Rd	CONSULTANT	Hazen
STUDY GROUP	Priority 1	DATE	06/12/2023

DETENTION FOR CONCERN AREA(S)

CA22

NO.	CATEGORY	ITEM	QTY	UNIT	UNIT PRICE	TOTAL
1	EARTHWORK	CLEARING AND GRUBBING	1.0	AC	$ 25,000	$ 25,000
2	EARTHWORK	SELECT BORROW MATERIAL	100	CY	$ 60	$ 6,000
3	EARTHWORK	UNDERCUT EXCAVATION	100	CY	$ 60	$ 6,000
4	EARTHWORK	UNCLASSIFIED EXCAVATION	4,200	CY	$ 55	$ 231,000
5	EARTHWORK	FINE GRADING	2,500	SY	$ 15	$ 37,500
6	DRAINAGE - STRUCTURES	DETENTION BASIN OUTLET	1	EA	$ 12,000	$ 12,000
7	RIP RAP AND SEEDING	SEEDING AND MULCHING, AC	1.0	AC	$ 5,500	$ 5,500
8	RIP RAP AND SEEDING	TURF REINFORCEMENT MATTING	1,000	SY	$ 10	$ 10,000
9	STREAM WORK	TREES IN CONTAINERS	20	EA	$ 500	$ 10,000
10	STREAM WORK	CONTAINER PLANTS	40	EA	$ 50	$ 2,000
11	MISCELLANEOUS	TREE PROTECTION FENCE	425	LF	$ 5	$ 2,125
12	MISCELLANEOUS	TREE REMOVAL, 4"-8"	5	EA	$ 1,500	$ 7,500
13	MISCELLANEOUS	TREE REMOVAL, 8"-12"	5	EA	$ 2,500	$ 12,500
14	MISCELLANEOUS	TREE REMOVAL, 12"-18"	5	EA	$ 4,000	$ 20,000
15	MISCELLANEOUS	REMOVE AND DISPOSE OF EXISTING FENCE	300	LF	$ 12	$ 3,600
16	MISCELLANEOUS	INSTALL NEW CHAIN LINK FENCE	850	LF	$ 40	$ 34,000
17	MISCELLANEOUS	LAND ACQUISITION (PS22)	0.8	AC	$ 82,000	$ 65,600
18	MISCELLANEOUS	BUILDING BUYOUTS (PS22)	0.2	AC	$ 549,000	$ 109,800
19	MISCELLANEOUS	BUILDING DEMOLITION AND DISPOSAL	1,250	SF	$ 20	$ 25,000
20	STREET WORK	REMOVE AND REPLACE ASPHALT ROLL CURB AND GUTTER	20	LF	$ 70	$ 1,400

SUBTOTAL		$ 626,525

PROJECT COSTS	% OF CONSTRUCTION	$ 156,631
MOBILIZATION	5%	$ 31,326
EROSION CONTROL	5%	$ 31,326
TRAFFIC CONTROL	5%	$ 31,326
MINOR UTILITY CONFLICT	10%	$ 62,653

ADDITIONAL COSTS	% OF CONSTRUCTION	$ 554,475
CONSTRUCTION CONTINGENCY	30%	$ 187,958
PROJECT MANAGEMENT	10%	$ 62,653
SURVEY	3%	$ 18,796
DESIGN AND PERMITTING	20%	$ 125,305
GEOTECHNICAL INVESTIGATION	1%	$ 6,265
STRUCTURAL EVALUATION	2%	$ 12,531
REAL ESTATE ACQUISITION	5%	$ 31,326
MATERIALS TESTING	1%	$ 6,265
UTILITY RELOCATION	5%	$ 31,326
CONSTRUCTION INSPECTIONS	10%	$ 62,653
BONDING	2%	$ 9,398

PROPOSED SOLUTION TOTAL (2021 COSTS)		**$ 1,337,631**
COST ESCALATION FACTOR	2.1%	$ 28,100
PROPOSED SOLUTION TOTAL (2022 COSTS)		**$ 1,365,731**
PROPOSED SOLUTION TOTAL (2023 COSTS)		**$ 1,394,420**
PROPOSED SOLUTION TOTAL (2024 COSTS)		**$ 1,423,710**
PROPOSED SOLUTION TOTAL (2025 COSTS)		**$ 1,453,610**
PROPOSED SOLUTION TOTAL (2026 COSTS)		**$ 1,484,140**

NOTES

1 - PSCE classified as an AACE Class 5 Estimate with accuracy range or -50 to +100.

2 - Unit Cost Items (Categorization, Description, Unit and Price) were prepared by WK Dickson for the City and submitted on October 1, 2021. Refer to the memo from WK Dickson to the City, dated October 8, 2021 for assumptions and background information.

Beaver Creek Tributary B Detention Evaluation
Proposed Solution Cost Estimate (PSCE)

PROPOSED SOLUTION NAME	PS24	PHASE	Local Detention Evaluation
PROPOSED SOLUTION DESC	Raeford Rd (Westbound)	CONSULTANT	Hazen
STUDY GROUP	Priority 1	DATE	06/12/2023

DETENTION FOR CONCERN AREA(S)

CA24

NO.	CATEGORY	ITEM	QTY	UNIT	UNIT PRICE	TOTAL
1	EARTHWORK	CLEARING AND GRUBBING	2.5	AC	$ 25,000	$ 62,500
2	EARTHWORK	SELECT BORROW MATERIAL	225	CY	$ 60	$ 13,500
3	EARTHWORK	UNDERCUT EXCAVATION	225	CY	$ 60	$ 13,500
4	EARTHWORK	UNCLASSIFIED EXCAVATION	10,900	CY	$ 55	$ 599,500
5	EARTHWORK	FINE GRADING	6,500	SY	$ 15	$ 97,500
6	DRAINAGE - STRUCTURES	DETENTION BASIN OUTLET	1	EA	$ 12,000	$ 12,000
7	RIP RAP AND SEEDING	SEEDING AND MULCHING, AC	2.5	AC	$ 5,500	$ 13,750
8	RIP RAP AND SEEDING	TURF REINFORCEMENT MATTING	1,750	SY	$ 10	$ 17,500
9	STREAM WORK	TREES IN CONTAINERS	50	EA	$ 500	$ 25,000
10	STREAM WORK	CONTAINER PLANTS	95	EA	$ 50	$ 4,750
11	MISCELLANEOUS	TREE PROTECTION FENCE	675	LF	$ 5	$ 3,375
12	MISCELLANEOUS	TREE REMOVAL, 4"-8"	15	EA	$ 1,500	$ 22,500
13	MISCELLANEOUS	TREE REMOVAL, 8"-12"	15	EA	$ 2,500	$ 37,500
14	MISCELLANEOUS	TREE REMOVAL, 12"-18"	15	EA	$ 4,000	$ 60,000
15	MISCELLANEOUS	REMOVE AND DISPOSE OF EXISTING FENCE	450	LF	$ 12	$ 5,400
16	MISCELLANEOUS	INSTALL NEW CHAIN LINK FENCE	1,325	LF	$ 40	$ 53,000
17	MISCELLANEOUS	LAND ACQUISITION (PS24)	2.5	AC	$ -	$ -
18	STREET WORK	REMOVE AND REPLACE ASPHALT ROLL CURB AND GUTTER	20	LF	$ 70	$ 1,400

SUBTOTAL		$ 1,042,675
PROJECT COSTS	% OF CONSTRUCTION	$ 260,669
MOBILIZATION	5%	$ 52,134
EROSION CONTROL	5%	$ 52,134
TRAFFIC CONTROL	5%	$ 52,134
MINOR UTILITY CONFLICT	10%	$ 104,268

ADDITIONAL COSTS	% OF CONSTRUCTION	$ 922,767
CONSTRUCTION CONTINGENCY	30%	$ 312,803
PROJECT MANAGEMENT	10%	$ 104,268
SURVEY	3%	$ 31,280
DESIGN AND PERMITTING	20%	$ 208,535
GEOTECHNICAL INVESTIGATION	1%	$ 10,427
STRUCTURAL EVALUATION	2%	$ 20,854
REAL ESTATE ACQUISITION	5%	$ 52,134
MATERIALS TESTING	1%	$ 10,427
UTILITY RELOCATION	5%	$ 52,134
CONSTRUCTION INSPECTIONS	10%	$ 104,268
BONDING	2%	$ 15,640

PROPOSED SOLUTION TOTAL (2021 COSTS)		**$ 2,226,111**
COST ESCALATION FACTOR	2.1%	$ 46,750
PROPOSED SOLUTION TOTAL (2022 COSTS)		**$ 2,272,861**
PROPOSED SOLUTION TOTAL (2023 COSTS)		**$ 2,320,600**
PROPOSED SOLUTION TOTAL (2024 COSTS)		**$ 2,369,340**
PROPOSED SOLUTION TOTAL (2025 COSTS)		**$ 2,419,100**
PROPOSED SOLUTION TOTAL (2026 COSTS)		**$ 2,469,910**

NOTES

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2 - Unit Cost Items (Categorization, Description, Unit and Price) were prepared by WK Dickson for the City and submitted on October 1, 2021. Refer to the memo from WK Dickson to the City, dated October 8, 2021 for assumptions and background information.

Beaver Creek Tributary B Detention Evaluation
Proposed Solution Cost Estimate (PSCE)

PROPOSED SOLUTION NAME	PS26	PHASE	Local Detention Evaluation
PROPOSED SOLUTION DESC	Birchcreft Dr	CONSULTANT	Hazen
STUDY GROUP	Priority 1	DATE	06/12/2023

DETENTION FOR CONCERN AREA(S)

CA26

NO.	CATEGORY	ITEM	QTY	UNIT	UNIT PRICE	TOTAL
1	EARTHWORK	CLEARING AND GRUBBING	0.5	AC	$ 25,000	$ 12,500
2	EARTHWORK	SELECT BORROW MATERIAL	50	CY	$ 60	$ 3,000
3	EARTHWORK	UNDERCUT EXCAVATION	50	CY	$ 60	$ 3,000
4	EARTHWORK	UNCLASSIFIED EXCAVATION	2,500	CY	$ 55	$ 137,500
5	EARTHWORK	FINE GRADING	1,500	SY	$ 15	$ 22,500
6	DRAINAGE - STRUCTURES	DETENTION BASIN OUTLET	1	EA	$ 12,000	$ 12,000
7	RIP RAP AND SEEDING	SEEDING AND MULCHING, AC	0.5	AC	$ 5,500	$ 2,750
8	RIP RAP AND SEEDING	TURF REINFORCEMENT MATTING	1,000	SY	$ 10	$ 10,000
9	STREAM WORK	TREES IN CONTAINERS	10	EA	$ 500	$ 5,000
10	STREAM WORK	CONTAINER PLANTS	20	EA	$ 50	$ 1,000
11	MISCELLANEOUS	TREE PROTECTION FENCE	300	LF	$ 5	$ 1,500
12	MISCELLANEOUS	TREE REMOVAL, 4"-8"	5	EA	$ 1,500	$ 7,500
13	MISCELLANEOUS	TREE REMOVAL, 8"-12"	5	EA	$ 2,500	$ 12,500
14	MISCELLANEOUS	TREE REMOVAL, 12"-18"	5	EA	$ 4,000	$ 20,000
15	MISCELLANEOUS	REMOVE AND DISPOSE OF EXISTING FENCE	200	LF	$ 12	$ 2,400
16	MISCELLANEOUS	INSTALL NEW CHAIN LINK FENCE	600	LF	$ 40	$ 24,000
17	MISCELLANEOUS	BUILDING BUYOUTS (PS26)	0.5	AC	$ 525,000	$ 262,500
18	MISCELLANEOUS	BUILDING DEMOLITION AND DISPOSAL	3,500	SF	$ 20	$ 70,000
19	STREET WORK	REMOVE AND REPLACE ASPHALT ROLL CURB AND GUTTER	20	LF	$ 70	$ 1,400

SUBTOTAL		$ 611,050
PROJECT COSTS	% OF CONSTRUCTION	$ 152,763
MOBILIZATION	5%	$ 30,553
EROSION CONTROL	5%	$ 30,553
TRAFFIC CONTROL	5%	$ 30,553
MINOR UTILITY CONFLICT	10%	$ 61,105

ADDITIONAL COSTS	% OF CONSTRUCTION	$ 540,779
CONSTRUCTION CONTINGENCY	30%	$ 183,315
PROJECT MANAGEMENT	10%	$ 61,105
SURVEY	3%	$ 18,332
DESIGN AND PERMITTING	20%	$ 122,210
GEOTECHNICAL INVESTIGATION	1%	$ 6,111
STRUCTURAL EVALUATION	2%	$ 12,221
REAL ESTATE ACQUISITION	5%	$ 30,553
MATERIALS TESTING	1%	$ 6,111
UTILITY RELOCATION	5%	$ 30,553
CONSTRUCTION INSPECTIONS	10%	$ 61,105
BONDING	2%	$ 9,166

PROPOSED SOLUTION TOTAL (2021 COSTS)		**$ 1,304,592**
COST ESCALATION FACTOR	2.1%	$ 27,400
PROPOSED SOLUTION TOTAL (2022 COSTS)		**$ 1,331,992**
PROPOSED SOLUTION TOTAL (2023 COSTS)		**$ 1,359,970**
PROPOSED SOLUTION TOTAL (2024 COSTS)		**$ 1,388,530**
PROPOSED SOLUTION TOTAL (2025 COSTS)		**$ 1,417,690**
PROPOSED SOLUTION TOTAL (2026 COSTS)		**$ 1,447,470**

NOTES

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2 - Unit Cost Items (Categorization, Description, Unit and Price) were prepared by WK Dickson for the City and submitted on October 1, 2021. Refer to the memo from WK Dickson to the City, dated October 8, 2021 for assumptions and background information.

Beaver Creek Tributary B Detention Evaluation
Proposed Solution Cost Estimate (PSCE)

PROPOSED SOLUTION NAME	PS28	PHASE	Local Detention Evaluation
PROPOSED SOLUTION DESC	Lakeridge Dr	CONSULTANT	Hazen
STUDY GROUP	Priority 1	DATE	06/12/2023

DETENTION FOR CONCERN AREA(S)

CA28

NO.	CATEGORY	ITEM	QTY	UNIT	UNIT PRICE	TOTAL
1	EARTHWORK	CLEARING AND GRUBBING	0.5	AC	$ 25,000	$ 12,500
2	EARTHWORK	SELECT BORROW MATERIAL	50	CY	$ 60	$ 3,000
3	EARTHWORK	UNDERCUT EXCAVATION	50	CY	$ 60	$ 3,000
4	EARTHWORK	UNCLASSIFIED EXCAVATION	2,500	CY	$ 55	$ 137,500
5	EARTHWORK	FINE GRADING	1,500	SY	$ 15	$ 22,500
6	DRAINAGE - STRUCTURES	DETENTION BASIN OUTLET	1	EA	$ 12,000	$ 12,000
7	RIP RAP AND SEEDING	SEEDING AND MULCHING, AC	0.5	AC	$ 5,500	$ 2,750
8	RIP RAP AND SEEDING	TURF REINFORCEMENT MATTING	1,000	SY	$ 10	$ 10,000
9	STREAM WORK	TREES IN CONTAINERS	10	EA	$ 500	$ 5,000
10	STREAM WORK	CONTAINER PLANTS	20	EA	$ 50	$ 1,000
11	MISCELLANEOUS	TREE PROTECTION FENCE	300	LF	$ 5	$ 1,500
12	MISCELLANEOUS	TREE REMOVAL, 4"-8"	5	EA	$ 1,500	$ 7,500
13	MISCELLANEOUS	TREE REMOVAL, 8"-12"	5	EA	$ 2,500	$ 12,500
14	MISCELLANEOUS	TREE REMOVAL, 12"-18"	5	EA	$ 4,000	$ 20,000
15	MISCELLANEOUS	REMOVE AND DISPOSE OF EXISTING FENCE	200	LF	$ 12	$ 2,400
16	MISCELLANEOUS	INSTALL NEW CHAIN LINK FENCE	600	LF	$ 40	$ 24,000
17	MISCELLANEOUS	BUILDING BUYOUTS (PS28)	0.5	AC	$ 414,000	$ 207,000
18	MISCELLANEOUS	BUILDING DEMOLITION AND DISPOSAL	2,750	SF	$ 20	$ 55,000
19	STREET WORK	REMOVE AND REPLACE ASPHALT ROLL CURB AND GUTTER	20	LF	$ 70	$ 1,400

SUBTOTAL		$ 540,550
PROJECT COSTS	% OF CONSTRUCTION	$ 135,138
MOBILIZATION	5%	$ 27,028
EROSION CONTROL	5%	$ 27,028
TRAFFIC CONTROL	5%	$ 27,028
MINOR UTILITY CONFLICT	10%	$ 54,055

ADDITIONAL COSTS	% OF CONSTRUCTION	$ 478,387
CONSTRUCTION CONTINGENCY	30%	$ 162,165
PROJECT MANAGEMENT	10%	$ 54,055
SURVEY	3%	$ 16,217
DESIGN AND PERMITTING	20%	$ 108,110
GEOTECHNICAL INVESTIGATION	1%	$ 5,406
STRUCTURAL EVALUATION	2%	$ 10,811
REAL ESTATE ACQUISITION	5%	$ 27,028
MATERIALS TESTING	1%	$ 5,406
UTILITY RELOCATION	5%	$ 27,028
CONSTRUCTION INSPECTIONS	10%	$ 54,055
BONDING	2%	$ 8,108

PROPOSED SOLUTION TOTAL (2021 COSTS)		**$ 1,154,074**
COST ESCALATION FACTOR	2.1%	$ 24,240
PROPOSED SOLUTION TOTAL (2022 COSTS)		**$ 1,178,314**
PROPOSED SOLUTION TOTAL (2023 COSTS)		**$ 1,203,060**
PROPOSED SOLUTION TOTAL (2024 COSTS)		**$ 1,228,330**
PROPOSED SOLUTION TOTAL (2025 COSTS)		**$ 1,254,130**
PROPOSED SOLUTION TOTAL (2026 COSTS)		**$ 1,280,470**

NOTES

1 - PSCE classified as an AACE Class 5 Estimate with accuracy range or -50 to +100.

2 - Unit Cost Items (Categorization, Description, Unit and Price) were prepared by WK Dickson for the City and submitted on October 1, 2021. Refer to the memo from WK Dickson to the City, dated October 8, 2021 for assumptions and background information.

Beaver Creek Tributary B Detention Evaluation
Proposed Solution Cost Estimate (PSCE)

PROPOSED SOLUTION NAME	PS29	PHASE	Local Detention Evaluation
PROPOSED SOLUTION DESC	Baywater Dr	CONSULTANT	Hazen
STUDY GROUP	Priority 1	DATE	06/12/2023

DETENTION FOR CONCERN AREA(S)

CA29

NO.	CATEGORY	ITEM	QTY	UNIT	UNIT PRICE	TOTAL
1	EARTHWORK	CLEARING AND GRUBBING	2.0	AC	$ 25,000	$ 50,000
2	EARTHWORK	SELECT BORROW MATERIAL	175	CY	$ 60	$ 10,500
3	EARTHWORK	UNDERCUT EXCAVATION	175	CY	$ 60	$ 10,500
4	EARTHWORK	UNCLASSIFIED EXCAVATION	8,400	CY	$ 55	$ 462,000
5	EARTHWORK	FINE GRADING	5,000	SY	$ 15	$ 75,000
6	DRAINAGE - STRUCTURES	DETENTION BASIN OUTLET	1	EA	$ 12,000	$ 12,000
7	RIP RAP AND SEEDING	SEEDING AND MULCHING, AC	2.0	AC	$ 5,500	$ 11,000
8	RIP RAP AND SEEDING	TURF REINFORCEMENT MATTING	1,500	SY	$ 10	$ 15,000
9	STREAM WORK	TREES IN CONTAINERS	40	EA	$ 500	$ 20,000
10	STREAM WORK	CONTAINER PLANTS	80	EA	$ 50	$ 4,000
11	MISCELLANEOUS	TREE PROTECTION FENCE	600	LF	$ 5	$ 3,000
12	MISCELLANEOUS	TREE REMOVAL, 4"-8"	10	EA	$ 1,500	$ 15,000
13	MISCELLANEOUS	TREE REMOVAL, 8"-12"	10	EA	$ 2,500	$ 25,000
14	MISCELLANEOUS	TREE REMOVAL, 12"-18"	10	EA	$ 4,000	$ 40,000
15	MISCELLANEOUS	REMOVE AND DISPOSE OF EXISTING FENCE	400	LF	$ 12	$ 4,800
16	MISCELLANEOUS	INSTALL NEW CHAIN LINK FENCE	1,200	LF	$ 40	$ 48,000
17	MISCELLANEOUS	BUILDING BUYOUTS (PS29)	2.0	AC	$ 493,000	$ 986,000
18	MISCELLANEOUS	BUILDING DEMOLITION AND DISPOSAL	12,500	SF	$ 20	$ 250,000
19	STREET WORK	REMOVE AND REPLACE ASPHALT ROLL CURB AND GUTTER	20	LF	$ 70	$ 1,400

SUBTOTAL		$ 2,043,200
PROJECT COSTS	% OF CONSTRUCTION	$ 510,800
MOBILIZATION	5%	$ 102,160
EROSION CONTROL	5%	$ 102,160
TRAFFIC CONTROL	5%	$ 102,160
MINOR UTILITY CONFLICT	10%	$ 204,320

ADDITIONAL COSTS	% OF CONSTRUCTION	$ 1,808,232
CONSTRUCTION CONTINGENCY	30%	$ 612,960
PROJECT MANAGEMENT	10%	$ 204,320
SURVEY	3%	$ 61,296
DESIGN AND PERMITTING	20%	$ 408,640
GEOTECHNICAL INVESTIGATION	1%	$ 20,432
STRUCTURAL EVALUATION	2%	$ 40,864
REAL ESTATE ACQUISITION	5%	$ 102,160
MATERIALS TESTING	1%	$ 20,432
UTILITY RELOCATION	5%	$ 102,160
CONSTRUCTION INSPECTIONS	10%	$ 204,320
BONDING	2%	$ 30,648

PROPOSED SOLUTION TOTAL (2021 COSTS)		**$ 4,362,232**
COST ESCALATION FACTOR	2.1%	$ 91,610
PROPOSED SOLUTION TOTAL (2022 COSTS)		**$ 4,453,842**
PROPOSED SOLUTION TOTAL (2023 COSTS)		**$ 4,547,380**
PROPOSED SOLUTION TOTAL (2024 COSTS)		**$ 4,642,880**
PROPOSED SOLUTION TOTAL (2025 COSTS)		**$ 4,740,390**
PROPOSED SOLUTION TOTAL (2026 COSTS)		**$ 4,839,940**

NOTES

1 - PSCE classified as an AACE Class 5 Estimate with accuracy range or -50 to +100.

2 - Unit Cost Items (Categorization, Description, Unit and Price) were prepared by WK Dickson for the City and submitted on October 1, 2021. Refer to the memo from WK Dickson to the City, dated October 8, 2021 for assumptions and background information.

Beaver Creek Tributary B Detention Evaluation
Proposed Solution Cost Estimate (PSCE)

PROPOSED SOLUTION NAME	PS31	PHASE	Local Detention Evaluation
PROPOSED SOLUTION DESC	Berriedale Drive Improvements	CONSULTANT	Hazen
STUDY GROUP	Priority 1	DATE	06/12/2023

DETENTION FOR CONCERN AREA(S)

CA31

NO.	CATEGORY	ITEM	QTY	UNIT	UNIT PRICE	TOTAL
1	EARTHWORK	CLEARING AND GRUBBING	3.5	AC	$ 25,000	$ 87,500
2	EARTHWORK	SELECT BORROW MATERIAL	300	CY	$ 60	$ 18,000
3	EARTHWORK	UNDERCUT EXCAVATION	300	CY	$ 60	$ 18,000
4	EARTHWORK	UNCLASSIFIED EXCAVATION	14,600	CY	$ 55	$ 803,000
5	EARTHWORK	FINE GRADING	8,750	SY	$ 15	$ 131,250
6	DRAINAGE - STRUCTURES	DETENTION BASIN OUTLET	1	EA	$ 12,000	$ 12,000
7	RIP RAP AND SEEDING	SEEDING AND MULCHING, AC	3.5	AC	$ 5,500	$ 19,250
8	RIP RAP AND SEEDING	TURF REINFORCEMENT MATTING	2,000	SY	$ 10	$ 20,000
9	STREAM WORK	TREES IN CONTAINERS	70	EA	$ 500	$ 35,000
10	STREAM WORK	CONTAINER PLANTS	140	EA	$ 50	$ 7,000
11	MISCELLANEOUS	TREE PROTECTION FENCE	800	LF	$ 5	$ 4,000
12	MISCELLANEOUS	TREE REMOVAL, 4"-8"	20	EA	$ 1,500	$ 30,000
13	MISCELLANEOUS	TREE REMOVAL, 8"-12"	20	EA	$ 2,500	$ 50,000
14	MISCELLANEOUS	TREE REMOVAL, 12"-18"	20	EA	$ 4,000	$ 80,000
15	MISCELLANEOUS	REMOVE AND DISPOSE OF EXISTING FENCE	525	LF	$ 12	$ 6,300
16	MISCELLANEOUS	INSTALL NEW CHAIN LINK FENCE	1,575	LF	$ 40	$ 63,000
17	MISCELLANEOUS	BUILDING BUYOUTS (PS31)	3.5	AC	$ 338,000	$ 1,183,000
18	MISCELLANEOUS	BUILDING DEMOLITION AND DISPOSAL	18,000	SF	$ 20	$ 360,000
19	STREET WORK	REMOVE AND REPLACE ASPHALT ROLL CURB AND GUTTER	20	LF	$ 70	$ 1,400

SUBTOTAL		$ 2,928,700
PROJECT COSTS	% OF CONSTRUCTION	$ 732,175
MOBILIZATION	5%	$ 146,435
EROSION CONTROL	5%	$ 146,435
TRAFFIC CONTROL	5%	$ 146,435
MINOR UTILITY CONFLICT	10%	$ 292,870

ADDITIONAL COSTS	% OF CONSTRUCTION	$ 2,591,900
CONSTRUCTION CONTINGENCY	30%	$ 878,610
PROJECT MANAGEMENT	10%	$ 292,870
SURVEY	3%	$ 87,861
DESIGN AND PERMITTING	20%	$ 585,740
GEOTECHNICAL INVESTIGATION	1%	$ 29,287
STRUCTURAL EVALUATION	2%	$ 58,574
REAL ESTATE ACQUISITION	5%	$ 146,435
MATERIALS TESTING	1%	$ 29,287
UTILITY RELOCATION	5%	$ 146,435
CONSTRUCTION INSPECTIONS	10%	$ 292,870
BONDING	2%	$ 43,931

PROPOSED SOLUTION TOTAL (2021 COSTS)		**$ 6,252,775**
COST ESCALATION FACTOR	2.1%	$ 131,310
PROPOSED SOLUTION TOTAL (2022 COSTS)		**$ 6,384,085**
PROPOSED SOLUTION TOTAL (2023 COSTS)		**$ 6,518,160**
PROPOSED SOLUTION TOTAL (2024 COSTS)		**$ 6,655,050**
PROPOSED SOLUTION TOTAL (2025 COSTS)		**$ 6,794,810**
PROPOSED SOLUTION TOTAL (2026 COSTS)		**$ 6,937,510**

NOTES

1 - PSCE classified as an AACE Class 5 Estimate with accuracy range or -50 to +100.

2 - Unit Cost Items (Categorization, Description, Unit and Price) were prepared by WK Dickson for the City and submitted on October 1, 2021. Refer to the memo from WK Dickson to the City, dated October 8, 2021 for assumptions and background information.

Beaver Creek Tributary B Detention Evaluation
Proposed Solution Cost Estimate (PSCE)

PROPOSED SOLUTION NAME	DPS1	PHASE	Regional Detention Evaluation
PROPOSED SOLUTION DESC	Arran Lakes West Dam Overtopping Protection	CONSULTANT	Hazen
STUDY GROUP	Priority 1	DATE	06/12/2023

DETENTION FOR CONCERN AREA(S)

N/A

NO.	CATEGORY	ITEM	QTY	UNIT	UNIT PRICE	TOTAL
1	EARTHWORK	CLEARING AND GRUBBING	1.7	AC	$ 25,000	$ 42,500
2	EARTHWORK	SELECT BORROW MATERIAL	1,750	CY	$ 60	$ 105,000
3	EARTHWORK	UNDERCUT EXCAVATION	75	CY	$ 60	$ 4,500
4	EARTHWORK	UNCLASSIFIED EXCAVATION	3,000	CY	$ 55	$ 165,000
5	EARTHWORK	FINE GRADING	5,500	SY	$ 15	$ 82,500
6	DRAINAGE - PIPES	24" RCP, CLASS III, 0'-6' DEPTH	200	LF	$ 180	$ 36,000
7	DRAINAGE - STRUCTURES	INSTALL STANDARD CATCH BASIN, 0'-6' DEPTH	2	EA	$ 6,000	$ 12,000
8	DRAINAGE - STRUCTURES	INSTALL SW MANHOLE, 0'-6' DEPTH	1	EA	$ 6,000	$ 6,000
9	RIP RAP AND SEEDING	SEEDING AND MULCHING, AC	0.4	AC	$ 5,500	$ 2,200
10	RIP RAP AND SEEDING	TURF REINFORCEMENT MATTING	2,000	SY	$ 10	$ 20,000
11	RIP RAP AND SEEDING	LARGE BOULDER	75	TN	$ 350	$ 26,250
12	MISCELLANEOUS	TREE PROTECTION FENCE	625	LF	$ 5	$ 3,125
13	MISCELLANEOUS	TREE REMOVAL, 4"-8"	70	EA	$ 1,500	$ 105,000
14	MISCELLANEOUS	TREE REMOVAL, 8"-12"	55	EA	$ 2,500	$ 137,500
15	MISCELLANEOUS	TREE REMOVAL, 12"-18"	35	EA	$ 4,000	$ 140,000
16	MISCELLANEOUS	REMOVE AND DISPOSE OF EXISTING FENCE	120	LF	$ 12	$ 1,440
17	MISCELLANEOUS	INSTALL NEW CHAIN LINK FENCE	120	LF	$ 40	$ 4,800
18	MISCELLANEOUS	LAND ACQUISITION (ALWD)	20	AC	$ 1,500	$ 30,000
19	MISCELLANEOUS	BUILDING BUYOUTS (ALWD)	0.8	AC	$ 423,000	$ 328,248
20	MISCELLANEOUS	BUILDING DEMOLITION AND DISPOSAL	5,250	SF	$ 20	$ 105,000
21	DAM WORK	DAM EMBANKMENT OVERTOPPING PROTECTION MATTING	3,750	SY	$ 180	$ 675,000
22	DAM WORK	DAM EMBANKMENT OVERTOPPING PROTECTION CONCRETE SLAB	300	CY	$ 1,000	$ 300,000
23	DAM WORK	DAM EMBANKMENT OVERTOPPING PROTECTION ANCHOR TRENCH	1,325	CY	$ 1,000	$ 1,325,000
24	STREET WORK	REMOVE AND DISPOSE OF EXISTING ASPHALT PAVEMENT	1,500	SY	$ 20	$ 30,000
25	STREET WORK	PERMANENT PAVEMENT PATCH	400	SY	$ 85	$ 34,000
26	STREET WORK	REMOVE AND REPLACE ASPHALT ROLL CURB AND GUTTER	250	LF	$ 70	$ 17,500

SUBTOTAL		$ 3,738,563
PROJECT COSTS	% OF CONSTRUCTION	$ 1,308,497
MOBILIZATION	5%	$ 186,928
EROSION CONTROL	5%	$ 186,928
TRAFFIC CONTROL	5%	$ 186,928
MODERATE UTILITY CONFLICT	20%	$ 747,713
ADDITIONAL COSTS	% OF CONSTRUCTION	$ 3,458,171
CONSTRUCTION CONTINGENCY	30%	$ 1,121,569
PROJECT MANAGEMENT	10%	$ 373,856
SURVEY	3%	$ 112,157
DESIGN AND PERMITTING	20%	$ 747,713
GEOTECHNICAL INVESTIGATION	1%	$ 37,386
SUPPLEMENTAL GEOTECHNICAL INVESTIGATION FOR DAM WORK	4%	$ 149,543
STRUCTURAL EVALUATION	2%	$ 74,771
REAL ESTATE ACQUISITION	5%	$ 186,928
MATERIALS TESTING	1%	$ 37,386
UTILITY RELOCATION	5%	$ 186,928
CONSTRUCTION INSPECTIONS	10%	$ 373,856
BONDING	2%	$ 56,078
PROPOSED SOLUTION TOTAL (2021 COSTS)		**$ 8,505,231**
COST ESCALATION FACTOR	2.1%	$ 178,610
PROPOSED SOLUTION TOTAL (2022 COSTS)		**$ 8,683,841**
PROPOSED SOLUTION TOTAL (2023 COSTS)		**$ 8,866,210**
PROPOSED SOLUTION TOTAL (2024 COSTS)		**$ 9,052,410**
PROPOSED SOLUTION TOTAL (2025 COSTS)		**$ 9,242,520**
PROPOSED SOLUTION TOTAL (2026 COSTS)		**$ 9,436,620**

NOTES

1 - PSCE classified as an AACE Class 5 Estimate with accuracy range or -50 to +100.

2 - Unit Cost Items (Categorization, Description, Unit and Price) were prepared by WK Dickson for the City and submitted on October 1, 2021. Refer to the memo from WK Dickson to the City, dated October 8, 2021 for assumptions and background information.

Beaver Creek Tributary B Detention Evaluation
Proposed Solution Cost Estimate (PSCE)

PROPOSED SOLUTION NAME	DPS2	PHASE	Regional Detention Evaluation
PROPOSED SOLUTION DESC	Arran Lakes West Dam Spillway Improvement	CONSULTANT	Hazen
STUDY GROUP	Priority 1	DATE	06/12/2023

DETENTION FOR CONCERN AREA(S)

N/A

NO.	CATEGORY	ITEM	QTY	UNIT	UNIT PRICE	TOTAL
1	EARTHWORK	CLEARING AND GRUBBING	1.7	AC	$ 25,000	$ 42,500
2	EARTHWORK	SELECT BORROW MATERIAL	1,750	CY	$ 60	$ 105,000
3	EARTHWORK	UNDERCUT EXCAVATION	75	CY	$ 60	$ 4,500
4	EARTHWORK	UNCLASSIFIED EXCAVATION	3,000	CY	$ 55	$ 165,000
5	EARTHWORK	FINE GRADING	5,500	SY	$ 15	$ 82,500
6	DRAINAGE - PIPES	24" RCP, CLASS III, 0'-6' DEPTH	200	LF	$ 180	$ 36,000
7	DRAINAGE - PIPES	48" RCP, CLASS III, 12'-14' DEPTH	300	LF	$ 620	$ 186,000
8	DRAINAGE - STRUCTURES	24" RCP CONCRETE HEADWALL	1	EA	$ 4,000	$ 4,000
9	DRAINAGE - STRUCTURES	DUAL 48" RCP CONCRETE HEADWALL	1	EA	$ 9,650	$ 9,650
10	DRAINAGE - STRUCTURES	INSTALL STANDARD CATCH BASIN, 0'-6' DEPTH	2	EA	$ 6,000	$ 12,000
11	DRAINAGE - STRUCTURES	INSTALL SW MANHOLE, 0'-6' DEPTH	1	EA	$ 6,000	$ 6,000
12	RIP RAP AND SEEDING	RIP RAP, CLASS II WITH FILTER FABRIC	2,600	TN	$ 215	$ 559,000
13	RIP RAP AND SEEDING	SEEDING AND MULCHING, AC	0.4	AC	$ 5,500	$ 2,200
14	RIP RAP AND SEEDING	TURF REINFORCEMENT MATTING	2,000	SY	$ 10	$ 20,000
15	RIP RAP AND SEEDING	LARGE BOULDER	75	TN	$ 350	$ 26,250
16	MISCELLANEOUS	TREE PROTECTION FENCE	625	LF	$ 5	$ 3,125
17	MISCELLANEOUS	TREE REMOVAL, 4"-8"	70	EA	$ 1,500	$ 105,000
18	MISCELLANEOUS	TREE REMOVAL, 8"-12"	55	EA	$ 2,500	$ 137,500
19	MISCELLANEOUS	TREE REMOVAL, 12"-18"	35	EA	$ 4,000	$ 140,000
20	MISCELLANEOUS	REMOVE AND DISPOSE OF EXISTING FENCE	120	LF	$ 12	$ 1,440
21	MISCELLANEOUS	INSTALL NEW CHAIN LINK FENCE	120	LF	$ 40	$ 4,800
22	MISCELLANEOUS	LAND ACQUISITION (ALWD)	20	AC	$ 1,500	$ 30,000
23	MISCELLANEOUS	BUILDING BUYOUTS (ALWD)	0.8	AC	$ 423,000	$ 328,248
24	MISCELLANEOUS	BUILDING DEMOLITION AND DISPOSAL	5,250	SF	$ 20	$ 105,000
25	DAM WORK	DAM EMBANKMENT OVERTOPPING PROTECTION MATTING	3,750	SY	$ 180	$ 675,000
26	DAM WORK	DAM EMBANKMENT OVERTOPPING PROTECTION CONCRETE SLAB	300	CY	$ 1,000	$ 300,000
27	DAM WORK	DAM EMBANKMENT OVERTOPPING PROTECTION ANCHOR TRENCH	1,325	CY	$ 1,000	$ 1,325,000
28	DAM WORK	ARRAN LAKES WEST DAM PRINCIPAL SPILLWAY	2	EA	$ 24,000	$ 48,000
29	STREET WORK	REMOVE AND DISPOSE OF EXISTING ASPHALT PAVEMENT	1,500	SY	$ 20	$ 30,000
30	STREET WORK	PERMANENT PAVEMENT PATCH	400	SY	$ 85	$ 34,000
31	STREET WORK	REMOVE AND REPLACE ASPHALT ROLL CURB AND GUTTER	250	LF	$ 70	$ 17,500

SUBTOTAL		$ 4,545,213
PROJECT COSTS	% OF CONSTRUCTION	$ 1,590,825
MOBILIZATION	5%	$ 227,261
EROSION CONTROL	5%	$ 227,261
TRAFFIC CONTROL	5%	$ 227,261
MODERATE UTILITY CONFLICT	20%	$ 909,043
ADDITIONAL COSTS	% OF CONSTRUCTION	$ 4,204,322
CONSTRUCTION CONTINGENCY	30%	$ 1,363,564
PROJECT MANAGEMENT	10%	$ 454,521
SURVEY	3%	$ 136,356
DESIGN AND PERMITTING	20%	$ 909,043
GEOTECHNICAL INVESTIGATION	1%	$ 45,452
SUPPLEMENTAL GEOTECHNICAL INVESTIGATION FOR DAM WORK	4%	$ 181,809
STRUCTURAL EVALUATION	2%	$ 90,904
REAL ESTATE ACQUISITION	5%	$ 227,261
MATERIALS TESTING	1%	$ 45,452
UTILITY RELOCATION	5%	$ 227,261
CONSTRUCTION INSPECTIONS	10%	$ 454,521
BONDING	2%	$ 68,178

PROPOSED SOLUTION TOTAL (2021 COSTS)		**$ 10,340,360**
COST ESCALATION FACTOR	2.1%	$ 217,150
PROPOSED SOLUTION TOTAL (2022 COSTS)		**$ 10,557,510**
PROPOSED SOLUTION TOTAL (2023 COSTS)		**$ 10,779,220**
PROPOSED SOLUTION TOTAL (2024 COSTS)		**$ 11,005,590**
PROPOSED SOLUTION TOTAL (2025 COSTS)		**$ 11,236,710**
PROPOSED SOLUTION TOTAL (2026 COSTS)		**$ 11,472,690**

NOTES

1 - PSCE classified as an AACE Class 5 Estimate with accuracy range or -50 to +100.

2 - Unit Cost Items (Categorization, Description, Unit and Price) were prepared by WK Dickson for the City and submitted on October 1, 2021. Refer to the memo from WK Dickson to the City, dated October 8, 2021 for assumptions and background information.

Beaver Creek Tributary B Detention Evaluation
Proposed Solution Cost Estimate (PSCE)

PROPOSED SOLUTION NAME	DPS3	PHASE	Regional Detention Evaluation
PROPOSED SOLUTION DESC	Bailey Lake Dam Rehabilitation	CONSULTANT	Hazen
STUDY GROUP	Priority 1	DATE	06/12/2023

DETENTION FOR CONCERN AREA(S)

N/A

NO.	CATEGORY	ITEM	QTY	UNIT	UNIT PRICE	TOTAL
1	EARTHWORK	CLEARING AND GRUBBING	1.3	AC	$ 25,000	$ 32,500
2	EARTHWORK	SELECT BORROW MATERIAL	4,250	CY	$ 60	$ 255,000
3	EARTHWORK	UNDERCUT EXCAVATION	20	CY	$ 60	$ 1,200
4	EARTHWORK	UNCLASSIFIED EXCAVATION	12,000	CY	$ 55	$ 660,000
5	EARTHWORK	FINE GRADING	5,250	SY	$ 15	$ 78,750
6	DRAINAGE - PIPES	8' x 8' RCP BOX CULVERT, 0'-6' DEPTH	105	LF	$ 1,650	$ 173,250
7	DRAINAGE - STRUCTURES	8' x 8' RCP BOX CULVERT WINGWALLS, 0'-6' DEPTH (9' WW NCDOT CW4509)	1	EA	$ 36,000	$ 36,000
8	RIP RAP AND SEEDING	RIP RAP, CLASS II WITH FILTER FABRIC	6,250	TN	$ 215	$ 1,343,750
9	RIP RAP AND SEEDING	SEEDING AND MULCHING, AC	1.0	AC	$ 5,500	$ 5,500
10	RIP RAP AND SEEDING	TURF REINFORCEMENT MATTING	1,400	SY	$ 10	$ 14,000
11	MISCELLANEOUS	TREE PROTECTION FENCE	1,000	LF	$ 5	$ 5,000
12	MISCELLANEOUS	TREE REMOVAL, 4"-8"	80	EA	$ 1,500	$ 120,000
13	MISCELLANEOUS	TREE REMOVAL, 8"-12"	65	EA	$ 2,500	$ 162,500
14	MISCELLANEOUS	TREE REMOVAL, 12"-18"	55	EA	$ 4,000	$ 220,000
15	MISCELLANEOUS	REMOVE AND DISPOSE OF EXISTING FENCE	450	LF	$ 12	$ 5,400
16	MISCELLANEOUS	INSTALL NEW CHAIN LINK FENCE	150	LF	$ 40	$ 6,000
17	MISCELLANEOUS	INSTALL 6' PRIVACY FENCE	250	LF	$ 50	$ 12,500
18	MISCELLANEOUS	LAND ACQUISITION (BLD)	13	AC	$ 21,000	$ 273,000
19	DAM WORK	DAM EMBANKMENT OVERTOPPING PROTECTION MATTING	5,250	SY	$ 180	$ 945,000
20	DAM WORK	DAM EMBANKMENT OVERTOPPING PROTECTION ANCHOR TRENCH	1,500	CY	$ 1,000	$ 1,500,000
21	DAM WORK	BAILEY LAKE DAM PRINCIPAL SPILLWAY	1	EA	$ 64,600	$ 64,600

SUBTOTAL		$ 5,913,950
PROJECT COSTS	% OF CONSTRUCTION	$ 1,478,488
MOBILIZATION	5%	$ 295,698
EROSION CONTROL	5%	$ 295,698
TRAFFIC CONTROL	5%	$ 295,698
MINOR UTILITY CONFLICT	10%	$ 591,395

ADDITIONAL COSTS	% OF CONSTRUCTION	$ 5,470,404
CONSTRUCTION CONTINGENCY	30%	$ 1,774,185
PROJECT MANAGEMENT	10%	$ 591,395
SURVEY	3%	$ 177,419
DESIGN AND PERMITTING	20%	$ 1,182,790
GEOTECHNICAL INVESTIGATION	1%	$ 59,140
SUPPLEMENTAL GEOTECHNICAL INVESTIGATION FOR DAM WORK	4%	$ 236,558
STRUCTURAL EVALUATION	2%	$ 118,279
REAL ESTATE ACQUISITION	5%	$ 295,698
MATERIALS TESTING	1%	$ 59,140
UTILITY RELOCATION	5%	$ 295,698
CONSTRUCTION INSPECTIONS	10%	$ 591,395
BONDING	2%	$ 88,709

PROPOSED SOLUTION TOTAL (2021 COSTS)		**$ 12,862,841**
COST ESCALATION FACTOR	2.1%	$ 270,120
PROPOSED SOLUTION TOTAL (2022 COSTS)		**$ 13,132,961**
PROPOSED SOLUTION TOTAL (2023 COSTS)		**$ 13,408,760**
PROPOSED SOLUTION TOTAL (2024 COSTS)		**$ 13,690,350**
PROPOSED SOLUTION TOTAL (2025 COSTS)		**$ 13,977,850**
PROPOSED SOLUTION TOTAL (2026 COSTS)		**$ 14,271,390**

NOTES

1 - PSCE classified as an AACE Class 5 Estimate with accuracy range or -50 to +100.

2 - Unit Cost Items (Categorization, Description, Unit and Price) were prepared by WK Dickson for the City and submitted on October 1, 2021. Refer to the memo from WK Dickson to the City, dated October 8, 2021 for assumptions and background information.

Beaver Creek Tributary B Detention Evaluation
Proposed Solution Cost Estimate (PSCE)

PROPOSED SOLUTION NAME	CPS1	PHASE	Regional Detention Evaluation
PROPOSED SOLUTION DESC	Carloway Dr Culvert Replacement	CONSULTANT	Hazen
STUDY GROUP	Priority 1	DATE	06/12/2023

DETENTION FOR CONCERN AREA(S)

N/A

NO.	CATEGORY	ITEM	QTY	UNIT	UNIT PRICE	TOTAL
1	DEMOLITION	REMOVE AND DISPOSE OF EXISTING SW STRUCTURE	2	EA	$ 1,200	$ 2,400
2	DEMOLITION	REMOVE AND DISPOSE OF EXISTING 48" RCP	240	LF	$ 65	$ 15,600
3	EARTHWORK	CLEARING AND GRUBBING	0.2	AC	$ 25,000	$ 5,000
4	EARTHWORK	SELECT BORROW MATERIAL	190	CY	$ 60	$ 11,400
5	EARTHWORK	UNDERCUT EXCAVATION	190	CY	$ 60	$ 11,400
6	EARTHWORK	FINE GRADING	975	SY	$ 15	$ 14,625
7	DRAINAGE - PIPES	6' x 5' RCP BOX CULVERT, 0'-6' DEPTH	160	LF	$ 1,175	$ 188,000
8	DRAINAGE - STRUCTURES	DUAL 6' x 5' RCP BOX CULVERT WINGWALLS, 0'-6' DEPTH (6' WW NCDOT CW4506)	1	EA	$ 34,000	$ 34,000
9	RIP RAP AND SEEDING	RIP RAP, CLASS A WITH FILTER FABRIC	600	TN	$ 125	$ 75,000
10	RIP RAP AND SEEDING	SODDING, CENTIPEDE GRASS	900	SY	$ 30	$ 27,000
11	STREAM WORK	TREES IN CONTAINERS	5	EA	$ 500	$ 2,500
12	STREAM WORK	CONTAINER PLANTS	30	EA	$ 50	$ 1,500
13	STREAM WORK	TEMPORARY STREAM DIVSERION	1	EA	$ 25,000	$ 25,000
14	MISCELLANEOUS	TREE PROTECTION FENCE	300	LF	$ 5	$ 1,500
15	MISCELLANEOUS	TREE REMOVAL, 4"-8"	10	EA	$ 1,500	$ 15,000
16	MISCELLANEOUS	TREE REMOVAL, 8"-12"	10	EA	$ 2,500	$ 25,000
17	MISCELLANEOUS	TREE REMOVAL, 12"-18"	10	EA	$ 4,000	$ 40,000
18	STREET WORK	REMOVE AND DISPOSE OF EXISTING ASPHALT PAVEMENT	300	SY	$ 20	$ 6,000
19	STREET WORK	PERMANENT PAVEMENT PATCH	300	SY	$ 85	$ 25,500
20	STREET WORK	REMOVE AND REPLACE ASPHALT ROLL CURB AND GUTTER	160	LF	$ 70	$ 11,200

SUBTOTAL		$ 537,625
PROJECT COSTS	% OF CONSTRUCTION	$ 188,169
MOBILIZATION	5%	$ 26,881
EROSION CONTROL	5%	$ 26,881
TRAFFIC CONTROL	5%	$ 26,881
MODERATE UTILITY CONFLICT	20%	$ 107,525

ADDITIONAL COSTS	% OF CONSTRUCTION	$ 475,798
CONSTRUCTION CONTINGENCY	30%	$ 161,288
PROJECT MANAGEMENT	10%	$ 53,763
SURVEY	3%	$ 16,129
DESIGN AND PERMITTING	20%	$ 107,525
GEOTECHNICAL INVESTIGATION	1%	$ 5,376
STRUCTURAL EVALUATION	2%	$ 10,753
REAL ESTATE ACQUISITION	5%	$ 26,881
MATERIALS TESTING	1%	$ 5,376
UTILITY RELOCATION	5%	$ 26,881
CONSTRUCTION INSPECTIONS	10%	$ 53,763
BONDING	2%	$ 8,064

PROPOSED SOLUTION TOTAL (2021 COSTS)		**$ 1,201,592**
COST ESCALATION FACTOR	2.1%	$ 25,240
PROPOSED SOLUTION TOTAL (2022 COSTS)		**$ 1,226,832**
PROPOSED SOLUTION TOTAL (2023 COSTS)		**$ 1,252,600**
PROPOSED SOLUTION TOTAL (2024 COSTS)		**$ 1,278,910**
PROPOSED SOLUTION TOTAL (2025 COSTS)		**$ 1,305,770**
PROPOSED SOLUTION TOTAL (2026 COSTS)		**$ 1,333,200**

NOTES

1 - PSCE classified as an AACE Class 5 Estimate with accuracy range or -50 to +100.

2 - Unit Cost Items (Categorization, Description, Unit and Price) were prepared by WK Dickson for the City and submitted on October 1, 2021. Refer to the memo from WK Dickson to the City, dated October 8, 2021 for assumptions and background information.

Appendix G: Benefit-Cost Analysis

Hazen *Memorandum*

June 13, 2023

To: City of Fayetteville

From: Dan Minkler, Senior Principal Business Analyst
Malia Turner, Senior Principal Business Analyst
Tim Devine, Senior Associate
Bill Price, Senior Associate

Re: Beaver Creek Tributary B Detention Evaluation Benefit-Cost Analysis

A simplified benefit cost analysis (BCA), based on the Federal Emergency Management Agency's (FEMA's) *Benefit-Cost Analysis Reference Guide,* was performed using estimated flooding damage costs for the Beaver Creek Tributary B Detention Evaluation project. The BCA evaluated the relative benefits and merits of the various conceptual projects and possibility for FEMA federal funding eligibility.

The goal of the analysis was to determine if the net present value (NPV) of the benefits of the mitigation projects, defined by avoided or prevented flood damage costs, exceeds the NPV of project costs. Three drainage mitigation projects were compared against a Do-Nothing scenario: Local Detention, Regional Detention, and Dam Improvement. After performing the BCA, the most favorable project was determined to be Local Detention; project benefits were estimated to be $17,779,751 and project costs were estimated to be $20,800,000. **The BCA ratio for the Local Detention project was 0.85 using a 3% default discount rate for FY22.** In comparison, the BCA ratios for the Dam Improvement and Regional Detention projects were 0.67 and 0.49, respectively. A table containing all summary details for the BCA analysis can be found in the BCA Results section. A ratio of at least 1.0 indicates the project will be cost-effective, as the value of benefits exceeds project cost.

For the analysis, the FEMA BCA Toolkit version 6.0 was used to estimate the present value of the future risk reduction benefits of the project. The project configuration inputs included location, hazard type, mitigation action type, property type, estimated initial project costs, and estimated project useful life (years). The damages and future risk reduction benefits calculations included professional expected damages ($) before and after mitigation, ecosystem services benefits, and social benefits (i.e., salary compensation). The Methodology section of this report further details the inputs used in the BCA as well as the assumptions made. A detailed report of the analysis can also be viewed in **Appendix A**.

Methodology

This cost-benefit analysis was performed in accordance with FEMA guidelines for quantifying the future risk reduction benefits of hazard mitigation projects. The following data inputs were used to calculate the project's future risk reduction benefits. All monetary values are in 2021 dollars.

Project Useful Life

The proposed drainage improvements are assumed to have a 50-year useful life in accordance with Appendix D of the FEMA BCA Reference Guide's standard value for "concrete infrastructure, flood walls, roads, bridges, major drainage system."

Damage Estimates

Final damages were estimated using calculated Professional Expected Damages because historical information on previous flooding and damage expenses was not available. Hazen conducted a hydraulic model study of the 2, 5, 10, 25, 50, and 100-year flood events and calculated the flood level in feet above the lowest-adjacent grade (LAG) for all structures in the vicinity. Buildings, contents, and displacement damages were estimated using generic Depth-Damage Function (DDF) curves provided by the US Army Corps of Engineers (USACE). The portion of the DDF Curves used in this analysis is shown in **Table 1**. Additionally, infrastructure damages were estimated based on Hazen's typical estimates for road overtopping repairs and dam failure costs.

Table 1: Generic Riverine Depth-Damage Function Curve for 2-Story Without Basement Structures Outside Coastal A Zone

Flood Depth (ft)	Building DDF (%)	Contents DDF (%)	Displacement DDF (days)
1	15.2%	8.7%	45
2	20.9%	12.2%	90
3	26.3%	15.5%	135

Assumptions:

1. For depths of flooding in between feet, the lesser number is used (e.g., 1.4 ft. would be rounded to 1 ft.)
2. The houses affected by the project are each located on slab foundations.

DDF Curve building damage estimations were made by first calculating Building replacement values (BRV for each residential property that was expected to incur flooding damage in the study under the different flood recurrence events. To calculate the BRV, the BCA Toolkit default building replacement cost-per-square-foot value, $100/sq ft, was assumed. The BRV for each house was then multiplied by the DDF Curve building damage percentages to obtain a total estimated damage per house. The final sum of all the estimated damages for all impacted houses was then input into the BCA calculator. Building contents damages were calculated by multiplying the BRV by the corresponding DDF Curve content damage percentages. Damages resulting from displacement of persons were calculated by multiplying the assumed number of persons per household (2.48, which was rounded to 2), by the corresponding number of days displaced in the DDF displacement curve.

Infrastructure damages were assigned to the Do-Nothing and mitigation scenarios based on the hydraulic model results. Two types of repair damages costs were considered: road overtopping and dam failure. Road overtopping costs were assigned when flood heights breached a critical threshold at the at-risk road

locations surrounding Beaver Creek. A full list of which roads overtopped during the different scenarios can be found in Appendix B. For the dam failure and repair, the assumption was made that the dam would only fail for the 100-year storm in the Do-Nothing scenario. The costs associated with the dam and overtopping repairs are summarized in Table 2.

Table 2: Infrastructure Repair Cost Estimations

Location	Infrastructure Type	Repair Cost
Carloway Dr	Road	$1,250,000
Strickland Bridge Road	Road	$1,750,000
Power Station	Road	$2,000,000
Horsepen Br	Road	$2,000,000
Fisher Rd	Road	$3,000,000
Arran Lakes West Dam	Dam	$18,000,000

Social Benefits

Social benefits were also calculated and included in the future risk reduction benefits total. The two inputs provided for the BCA under the social benefits section were the total number of residents and total number of working residents. The number of residents living and working within the buildings was calculated using statistics provided by the US Census Bureau. **Table 3** calculates each of the social inputs used.

Table 3: United States Census Bureau Statistics for Fayetteville, North Carolina as of July 2021

	US Census Bureau Estimate	# of Households	Input Total (persons)
Average Persons per Household	2.42	32	77
Total Percent of Population 16+ in Civilian Labor Force	51.5%	32	40

Assumptions:

1. The houses included in the project area follow the estimates provided by the US Census Bureau

BCA Results

The results of the BCA analysis for the three mitigation projects considered are presented below in **Table 4**.

Table 4: BCA Analysis Results Summary

	Using 7% Discount Rate			Using 3% Discount Rate		
Project	**Benefits**	**Cost**	**BCR (B/C)**	**Benefits**	**Cost**	**BCR (B/C)**
Local Detention	$9,784,189	$20,800,000	0.47	$17,776,751	$20,800,000	0.85
Regional Detention	$3,672,887	$12,900,000	0.28	$6,382,994	$12,900,000	0.49
Dam Improvement	$3,498,226	$10,300,000	0.38	$6,896,328	$10,300,000	0.67

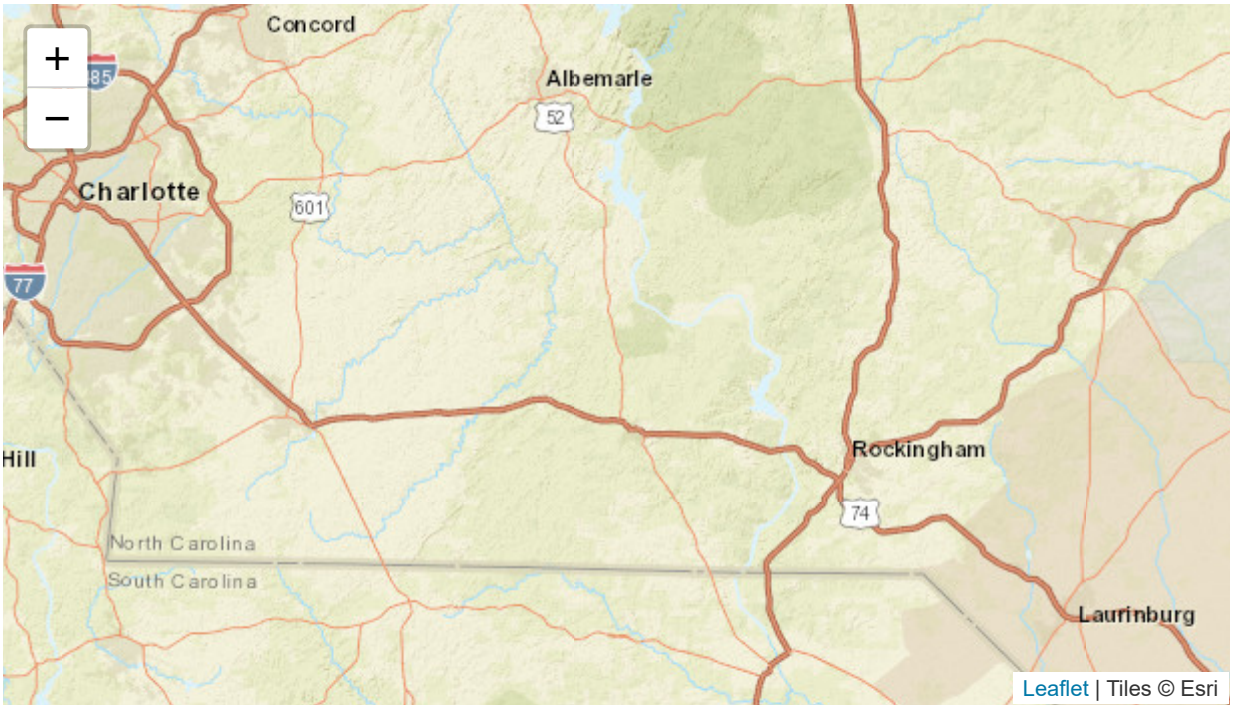
Appendix A: Benefit-Cost Analysis Reports

Benefit-Cost Calculator

V.6.0 (Build 20230324.2039 | Release Notes)

Benefit-Cost Analysis

Project Name: Local Detention @ Fayetteville



				Using 7% Discount Rate			Using 3% Discount Rate (For FY22 BRIC and FMA only)			
Map Marker ▲	Mitigation Title ▼	Property Type	Hazard	Benefits (B)	Costs (C)	BCR (B/C)	Benefits (B)	Costs (C)	BCR (B/C)	
1	Drainage Improvement @ Cumberland County, North Carolina		DFA - Riverine Flood	$ 9,784,189	$ 20,800,000	0.47	$ 17,776,751	$ 20,800,000	0.85	
TOTAL (SELECTED)				**$ 9,784,189**	**$ 20,800,000**	**0.47**	**$ 17,776,751**	**$ 20,800,000**	**0.85**	
TOTAL				**$ 9,784,189**	**$ 20,800,000**	**0.47**	**$ 17,776,751**	**$ 20,800,000**	**0.85**	

Property Configuration

Property Title:	Drainage Improvement @ Cumberland County, North Carolina
Property Location:	28304, Cumberland, North Carolina
Property Coordinates:	35.0486249, -78.8273922
Hazard Type:	Riverine Flood
Mitigation Action Type:	Drainage Improvement
Property Type:	Residential Building
Analysis Method Type:	Professional Expected Damages

Cost Estimation

Drainage Improvement @ Cumberland County, North Carolina

Project Useful Life (years):	50
Project Cost:	$20,800,000
Number of Maintenance Years:	50 Use Default:Yes
Annual Maintenance Cost:	$0

Damage Analysis Parameters - Damage Frequency Assessment

Drainage Improvement @ Cumberland County, North Carolina

Year of Analysis was Conducted:	2023
Year Property was Built:	1984
Analysis Duration:	40 Use Default:Yes

Professional Expected Damages Before Mitigation

Drainage Improvement @ Cumberland County, North Carolina

	OTHER	OPTIONAL DAMAGES			VOLUNTEER COSTS		TOTAL
Recurrence Interval (years)	Damages ($)	Structures ($)	Contents ($)	Disp. ($)	Number of Volunteers	Number of Days	Damages ($)
2	2,000,000	0	0	0	0	0	2,000,000
5	5,750,000	42,681.6	24,429.6	25,918.2	0	0	5,843,029
10	8,750,000	98,070.4	56,132.4	77,754.6	0	0	8,981,957
25	10,000,000	221,910.5	127,406.2	207,345.6	0	0	10,556,662
50	10,000,000	325,495.9	187,707.1	311,018.4	0	0	10,824,221
100	28,000,000	601,515.74	346,666.84	544,282.2	0	0	29,492,465

Annualized Damages Before Mitigation

Drainage Improvement @ Cumberland County, North Carolina

Annualized Recurrence Interval (years)	Damages and Losses ($)	Annualized Damages and Losses ($)
2	2,000,000	1,025,546
5	5,843,029	724,444
10	8,981,957	584,252
25	10,556,662	213,792
50	10,824,221	178,671
100	29,492,465	294,922
	Sum Damages and Losses ($)	Sum Annualized Damages and Losses ($)
	67,698,335	3,021,627

Professional Expected Damages After Mitigation

Drainage Improvement @ Cumberland County, North Carolina

	OTHER	OPTIONAL DAMAGES			VOLUNTEER COSTS		TOTAL
Recurrence Interval (years)	Damages ($)	Structures ($)	Contents ($)	Disp. ($)	Number of Volunteers	Number of Days	Damages ($)
2	2,000,000	0	0	0	0	0	2,000,000
5	3,750,000	0	0	0	0	0	3,750,000
10	8,750,000	42,681.6	24,429	25,918.2	0	0	8,843,029
25	8,750,000	155,222.4	88,844.4	129,591	0	0	9,123,658
50	10,000,000	221,910.5	127,406.2	207,345.6	0	0	10,556,662
100	10,000,000	439,042.94	252,697.84	388,773	0	0	11,080,514

Annualized Damages After Mitigation

Drainage Improvement @ Cumberland County, North Carolina

Annualized Recurrence Interval (years)	Damages and Losses ($)	Annualized Damages and Losses ($)
2	2,000,000	821,584
5	3,750,000	575,859
10	8,843,029	538,935
25	9,123,658	196,281
50	10,556,662	108,154
100	11,080,514	110,804
	Sum Damages and Losses ($)	Sum Annualized Damages and Losses ($)
	45,353,863	2,351,617

Standard Benefits - Ecosystem Services

Drainage Improvement @ Cumberland County, North Carolina

Total Project Area (acres):	15.36
Percentage of Urban Green Open Space:	0.00%
Percentage of Rural Green Open Space:	0.00%
Percentage of Riparian:	0.00%
Percentage of Coastal Wetlands:	0.00%
Percentage of Inland Wetlands:	0.00%
Percentage of Forests:	0.00%
Percentage of Coral Reefs:	0.00%
Percentage of Shellfish Reefs:	0.00%
Percentage of Beaches and Dunes:	0.00%
Expected Annual Ecosystem Services Benefits:	$0

Additional Benefits - Social

Drainage Improvement @ Cumberland County, North Carolina

Number of Workers:	40
Expected Annual Social Benefits:	$537,551

Benefits-Costs Summary

Drainage Improvement @ Cumberland County, North Carolina

Total Standard Mitigation Benefits:	$9,246,638
Total Social Benefits:	$537,551
Total Mitigation Project Benefits:	$9,784,189
Total Mitigation Project Cost:	$20,800,000
Benefit Cost Ratio - Standard:	0.44
Benefit Cost Ratio - Standard + Social:	0.47

Benefit-Cost Calculator

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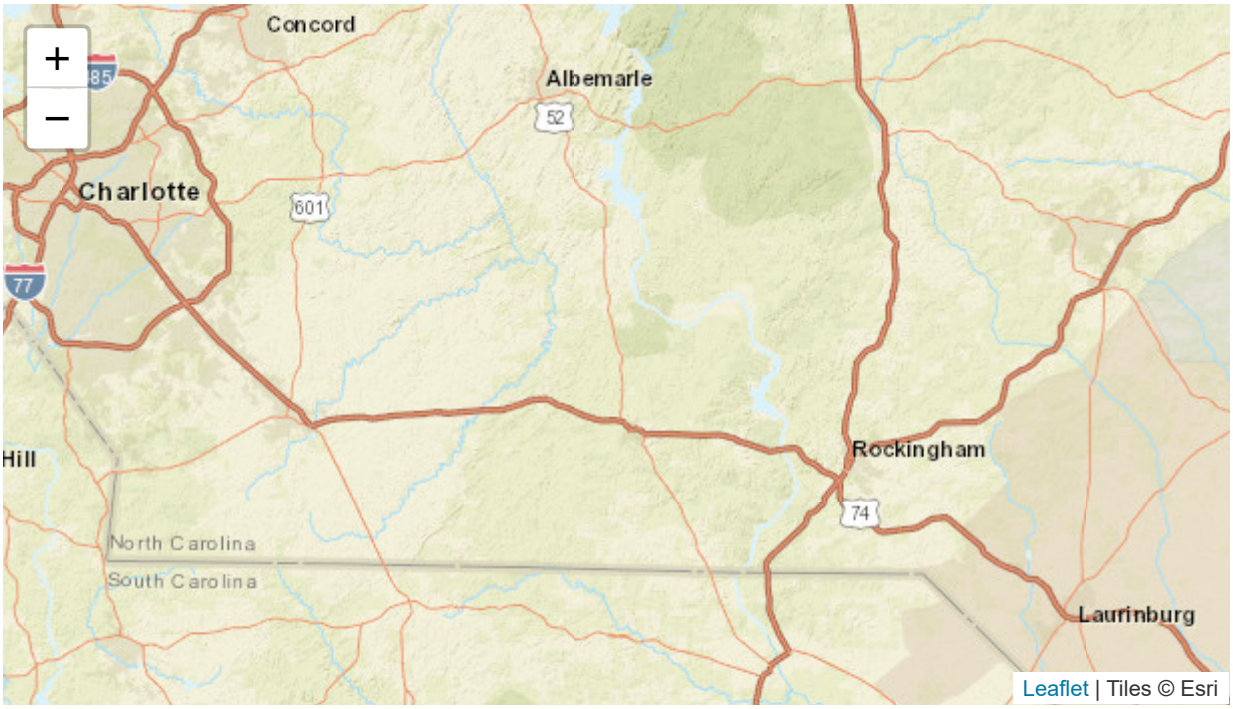
Benefit-Cost Analysis

Project Name: Regional Detention @ Fayetteville



				Using 7% Discount Rate			Using 3% Discount Rate (For FY22 BRIC and FMA only)			
Map Marker ▲	Mitigation Title	Property Type	Hazard	Benefits (B)	Costs (C)	BCR (B/C)	Benefits (B)	Costs (C)	BCR (B/C)	
1	Drainage Improvement @ Cumberland County, North Carolina		DFA - Riverine Flood	$ 3,672,887	$ 12,900,000	0.28	$ 6,382,994	$ 12,900,000	0.49	
TOTAL (SELECTED)				**$ 3,672,887**	**$ 12,900,000**	**0.28**	**$ 6,382,994**	**$ 12,900,000**	**0.49**	
TOTAL				**$ 3,672,887**	**$ 12,900,000**	**0.28**	**$ 6,382,994**	**$ 12,900,000**	**0.49**	

Property Configuration

Property Title:	Drainage Improvement @ Cumberland County, North Carolina
Property Location:	28304, Cumberland, North Carolina
Property Coordinates:	35.0486249, -78.8273922
Hazard Type:	Riverine Flood
Mitigation Action Type:	Drainage Improvement
Property Type:	Residential Building
Analysis Method Type:	Professional Expected Damages

Cost Estimation

Drainage Improvement @ Cumberland County, North Carolina

Project Useful Life (years):	50
Project Cost:	$12,900,000
Number of Maintenance Years:	50 Use Default:Yes
Annual Maintenance Cost:	$0

Damage Analysis Parameters - Damage Frequency Assessment

Drainage Improvement @ Cumberland County, North Carolina

Year of Analysis was Conducted:	2023
Year Property was Built:	1984
Analysis Duration:	40 Use Default:Yes

Professional Expected Damages Before Mitigation

Drainage Improvement @ Cumberland County, North Carolina

	OTHER	OPTIONAL DAMAGES			VOLUNTEER COSTS		TOTAL
Recurrence Interval (years)	Damages ($)	Structures ($)	Contents ($)	Disp. ($)	Number of Volunteers	Number of Days	Damages ($)
2	2,000,000	0	0	0	0	0	2,000,000
5	5,750,000	42,681	24,429.6	25,918.6	0	0	5,843,029
10	8,750,000	98,070.4	56,132.4	77,754.6	0	0	8,981,957
25	10,000,000	221,910.5	127,406.2	207,345	0	0	10,556,662
50	10,000,000	325,495.9	187,707.1	311,018.4	0	0	10,824,221
100	28,000,000	601,515.74	346,666.84	544,282.2	0	0	29,492,465

Annualized Damages Before Mitigation

Drainage Improvement @ Cumberland County, North Carolina

Annualized Recurrence Interval (years)	Damages and Losses ($)	Annualized Damages and Losses ($)
2	2,000,000	1,025,546
5	5,843,029	724,444
10	8,981,957	584,252
25	10,556,662	213,792
50	10,824,221	178,671
100	29,492,465	294,922
	Sum Damages and Losses ($)	Sum Annualized Damages and Losses ($)
	67,698,334	3,021,627

Professional Expected Damages After Mitigation

Drainage Improvement @ Cumberland County, North Carolina

	OTHER	OPTIONAL DAMAGES			VOLUNTEER COSTS		TOTAL
Recurrence Interval (years)	Damages ($)	Structures ($)	Contents ($)	Disp. ($)	Number of Volunteers	Number of Days	Damages ($)
2	2,000,000	0	0	0	0	0	2,000,000
5	5,750,000	42,681.6	24,429.6	25,918.2	0	0	5,843,029
10	8,750,000	98,070.4	56,132.4	77,754.6	0	0	8,981,957
25	10,000,000	201,400	115,275	155,509.2	0	0	10,472,184
50	10,000,000	316,591.3	1,822,265.4	285,100.2	0	0	12,423,957
100	10,000,000	601,515.74	346,666.84	544,282.2	0	0	11,492,465

Annualized Damages After Mitigation

Drainage Improvement @ Cumberland County, North Carolina

Annualized Recurrence Interval (years)	Damages and Losses ($)	Annualized Damages and Losses ($)
2	2,000,000	1,025,546
5	5,843,029	724,444
10	8,981,957	581,909
25	10,472,184	228,128
50	12,423,957	119,491
100	11,492,465	114,923
	Sum Damages and Losses ($)	Sum Annualized Damages and Losses ($)
	51,213,593	2,794,441

Standard Benefits - Ecosystem Services

Drainage Improvement @ Cumberland County, North Carolina

Total Project Area (acres):	15.36
Percentage of Urban Green Open Space:	0.00%
Percentage of Rural Green Open Space:	0.00%
Percentage of Riparian:	0.00%
Percentage of Coastal Wetlands:	0.00%
Percentage of Inland Wetlands:	0.00%
Percentage of Forests:	0.00%
Percentage of Coral Reefs:	0.00%
Percentage of Shellfish Reefs:	0.00%
Percentage of Beaches and Dunes:	0.00%
Expected Annual Ecosystem Services Benefits:	$0

Additional Benefits - Social

Drainage Improvement @ Cumberland County, North Carolina

Number of Workers:	40
Expected Annual Social Benefits:	$537,551

Benefits-Costs Summary

Drainage Improvement @ Cumberland County, North Carolina

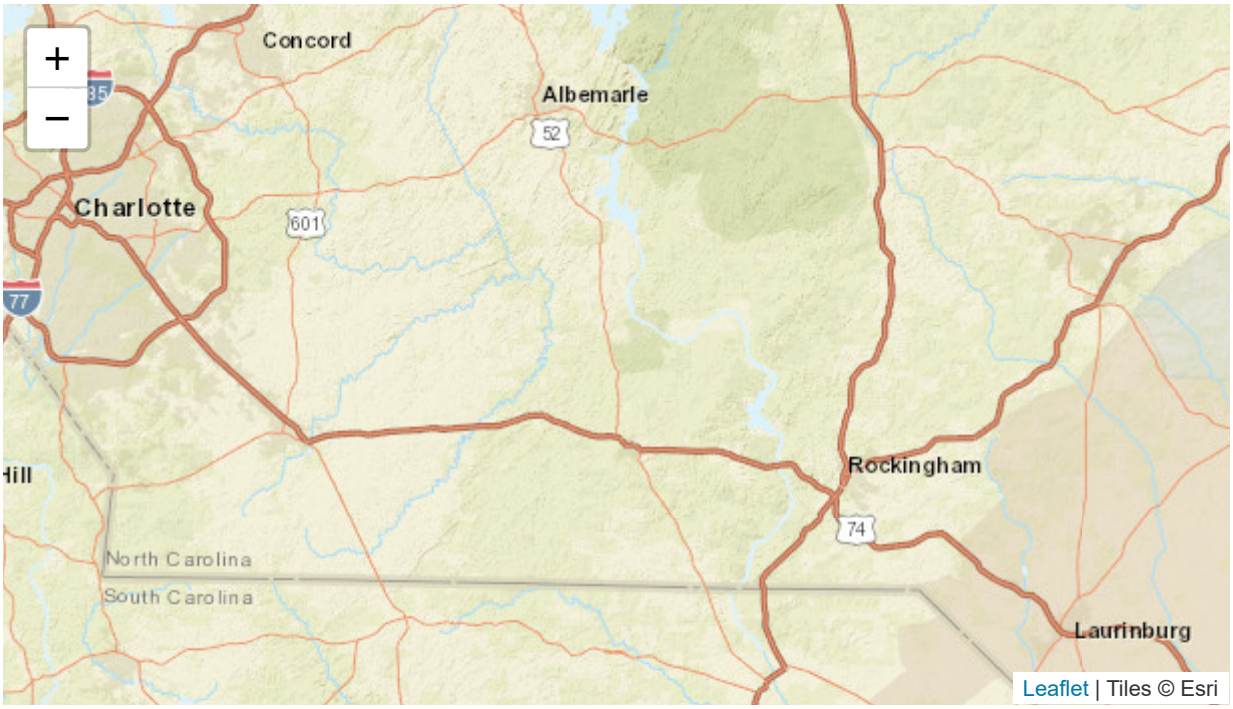
Total Standard Mitigation Benefits:	$3,135,336
Total Social Benefits:	$537,551
Total Mitigation Project Benefits:	$3,672,887
Total Mitigation Project Cost:	$12,900,000
Benefit Cost Ratio - Standard:	0.24
Benefit Cost Ratio - Standard + Social:	0.28

Benefit-Cost Calculator

V.6.0 (Build 20230324.2039 | Release Notes)

Benefit-Cost Analysis

Project Name: Dam Improvement



				Using 7% Discount Rate			Using 3% Discount Rate (For FY22 BRIC and FMA only)			
Map Marker ▲	Mitigation Title	Property Type	Hazard	Benefits (B)	Costs (C)	BCR (B/C)	Benefits (B)	Costs (C)	BCR (B/C)	
1	Drainage Improvement @ Cumberland County, North Carolina		DFA - Riverine Flood	$ 3,948,226	$ 10,300,000	0.38	$ 6,896,328	$ 10,300,000	0.67	
TOTAL (SELECTED)				**$ 3,948,226**	**$ 10,300,000**	**0.38**	**$ 6,896,328**	**$ 10,300,000**	**0.67**	
TOTAL				**$ 3,948,226**	**$ 10,300,000**	**0.38**	**$ 6,896,328**	**$ 10,300,000**	**0.67**	

Property Configuration

Property Title:	Drainage Improvement @ Cumberland County, North Carolina
Property Location:	28304, Cumberland, North Carolina
Property Coordinates:	35.0486249, -78.8273922
Hazard Type:	Riverine Flood
Mitigation Action Type:	Drainage Improvement
Property Type:	Residential Building
Analysis Method Type:	Professional Expected Damages

Cost Estimation

Drainage Improvement @ Cumberland County, North Carolina

Project Useful Life (years):	50
Project Cost:	$10,300,000
Number of Maintenance Years:	50 Use Default:Yes
Annual Maintenance Cost:	$0

Damage Analysis Parameters - Damage Frequency Assessment

Drainage Improvement @ Cumberland County, North Carolina

Year of Analysis was Conducted:	2023
Year Property was Built:	1984
Analysis Duration:	40 Use Default:Yes

Professional Expected Damages Before Mitigation

Drainage Improvement @ Cumberland County, North Carolina

	OTHER	OPTIONAL DAMAGES			VOLUNTEER COSTS		TOTAL
Recurrence Interval (years)	Damages ($)	Structures ($)	Contents ($)	Disp. ($)	Number of Volunteers	Number of Days	Damages ($)
2	2,000,000	0	0	0	0	0	2,000,000
5	5,750,000	42,681.6	24,429.6	25,918.2	0	0	5,843,029
10	8,750,000	98,070.4	56,132.4	77,754.6	0	0	8,981,957
25	10,000,000	221,910.5	127,406.2	207,345.6	0	0	10,556,662
50	10,000,000	325,495.9	187,707.1	311,018.4	0	0	10,824,221
100	28,000,000	601,515.74	346,666.84	544,282.2	0	0	29,492,465

Annualized Damages Before Mitigation

Drainage Improvement @ Cumberland County, North Carolina

Annualized Recurrence Interval (years)	Damages and Losses ($)	Annualized Damages and Losses ($)
2	2,000,000	1,025,546
5	5,843,029	724,444
10	8,981,957	584,252
25	10,556,662	213,792
50	10,824,221	178,671
100	29,492,465	294,922
	Sum Damages and Losses ($)	Sum Annualized Damages and Losses ($)
	67,698,335	3,021,627

Professional Expected Damages After Mitigation

Drainage Improvement @ Cumberland County, North Carolina

	OTHER	OPTIONAL DAMAGES			VOLUNTEER COSTS		TOTAL
Recurrence Interval (years)	Damages ($)	Structures ($)	Contents ($)	Disp. ($)	Number of Volunteers	Number of Days	Damages ($)
2	2,000,000	0	0	0	0	0	2,000,000
5	5,750,000	42,681.6	24,429.6	25,918.2	0	0	5,843,029
10	8,750,000	98,070.4	56,132.4	77,754.6	0	0	8,981,957
25	10,000,000	221,910.5	127,406.2	207,345.6	0	0	10,556,662
50	10,000,000	325,495.9	187,707.1	311,018.4	0	0	10,824,221
100	10,000,000	601,515.74	346,666.84	544,282.2	0	0	11,492,465

Annualized Damages After Mitigation

Drainage Improvement @ Cumberland County, North Carolina

Annualized Recurrence Interval (years)	Damages and Losses ($)	Annualized Damages and Losses ($)
2	2,000,000	1,025,546
5	5,843,029	724,444
10	8,981,957	584,252
25	10,556,662	213,792
50	10,824,221	111,533
100	11,492,465	114,923
	Sum Damages and Losses ($)	Sum Annualized Damages and Losses ($)
	49,698,335	2,774,490

Standard Benefits - Ecosystem Services

Drainage Improvement @ Cumberland County, North Carolina

Total Project Area (acres):	15.36
Percentage of Urban Green Open Space:	0.00%
Percentage of Rural Green Open Space:	0.00%
Percentage of Riparian:	0.00%
Percentage of Coastal Wetlands:	0.00%
Percentage of Inland Wetlands:	0.00%
Percentage of Forests:	0.00%
Percentage of Coral Reefs:	0.00%
Percentage of Shellfish Reefs:	0.00%
Percentage of Beaches and Dunes:	0.00%
Expected Annual Ecosystem Services Benefits:	$0

Additional Benefits - Social

Drainage Improvement @ Cumberland County, North Carolina

Number of Workers:	40
Expected Annual Social Benefits:	$537,551

Benefits-Costs Summary

Drainage Improvement @ Cumberland County, North Carolina

Total Standard Mitigation Benefits:	$3,410,675
Total Social Benefits:	$537,551
Total Mitigation Project Benefits:	$3,948,226
Total Mitigation Project Cost:	$10,300,000
Benefit Cost Ratio - Standard:	0.33
Benefit Cost Ratio - Standard + Social:	0.38

Appendix B: Before and After Mitigation Depth-Damage Function Curve Costs

This appendix is provided in electronic format only, via the electronic appendix.