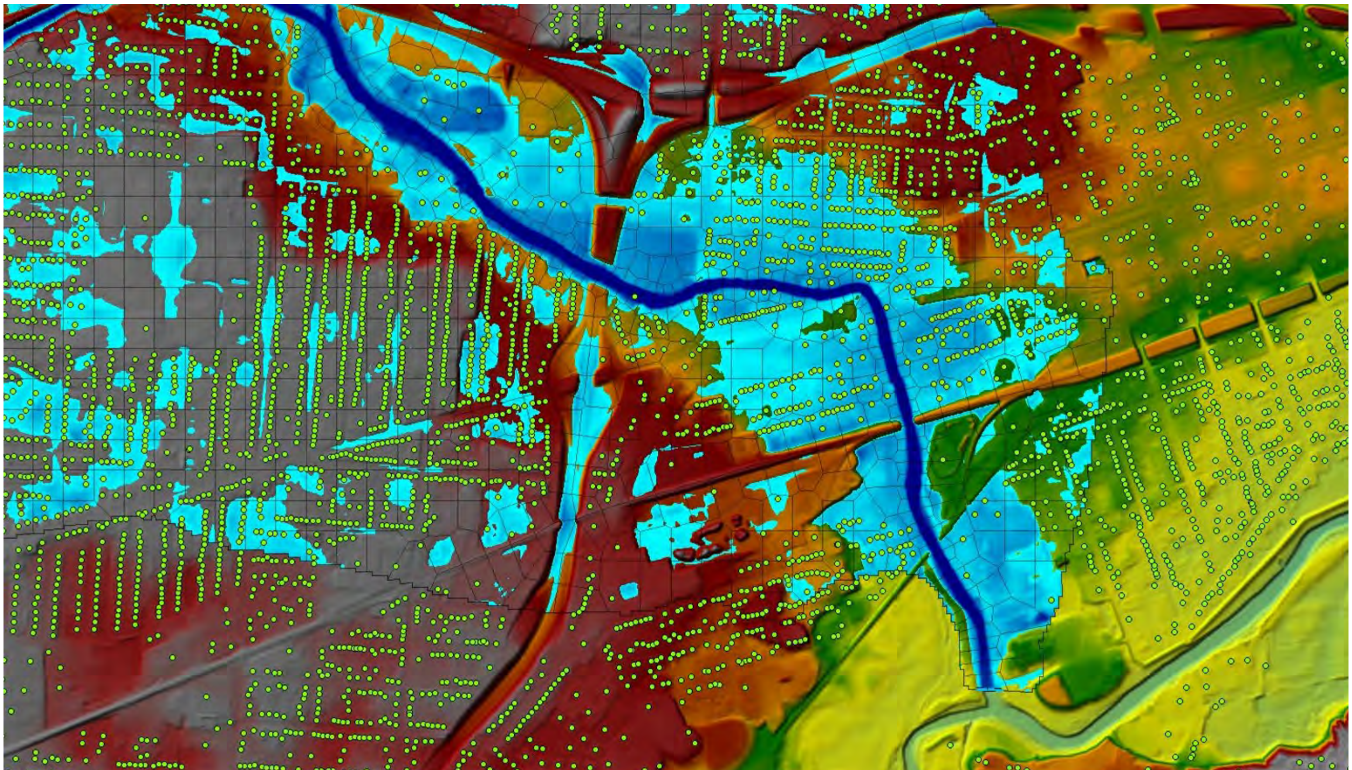

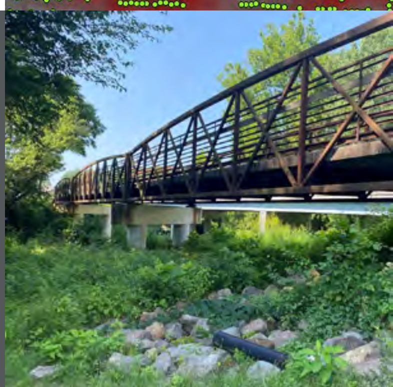

Raccoon Creek Flood Damage Reduction Study

Prepared For: South Licking Watershed Conservancy District

May 22, 2025

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Executive Summary

The project study area is the Raccoon Creek Watershed, a HUC10 level watershed that consists of Raccoon Creek, Moots Run, and Lobdell Creek located in Licking County, OH (***Figure 1***). The area surrounding the watershed has been rapidly developing in the New Albany area for years, since Intel announced their intention to build a semiconductor facility in January 2022. The upper watershed of Raccoon Creek is anticipated to experience significant development and changes in land use. Therefore, the need to understand and evaluate the current and potential watershed impacts of Raccoon Creek are important so that planning and growth can be accommodated while understanding flood risks in the entire watershed.

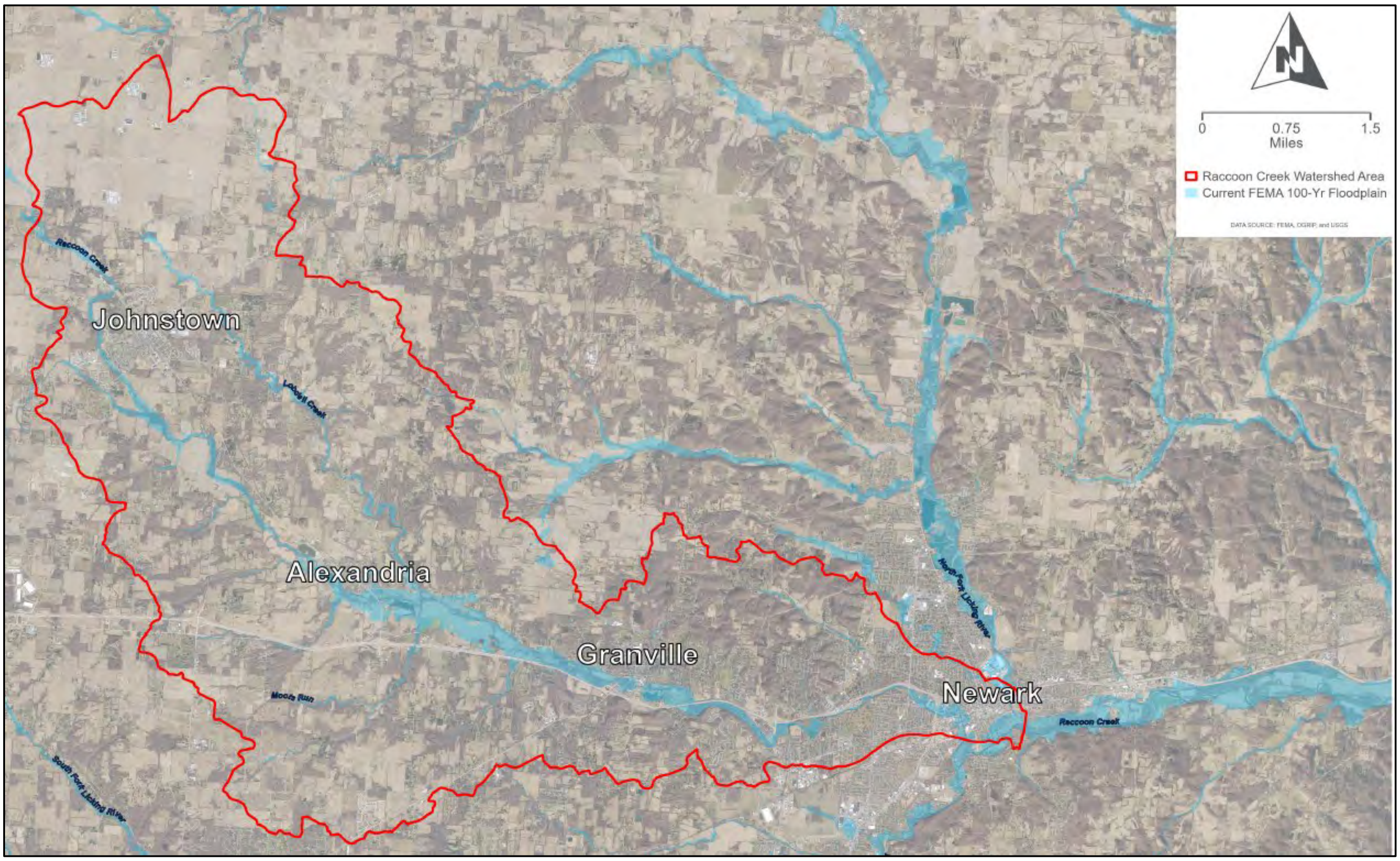

Figure 1 Study Area - Raccoon Creek Watershed, Johnstown, Alexandria, Granville and Newark

Flooding impacts in the area include roadway and utility interruptions, damage to structures, property flooding, business interruptions, debris cleanup, regional economic impacts, critical infrastructure, erosion issues, as well as other environmental and social effects. HDR was contracted by the South Licking Watershed Conservancy District (SLWCD) to complete a flood mitigation study to find solutions to prevent and reduce damage due to flooding in the watershed. This was completed with updated hydrologic (HEC-HMS) and hydraulic (HEC-RAS) models of

Raccoon Creek, Moots Run, and Lobdell Creek. The models were utilized to evaluate the 100-year flood for the three studied streams, to create flood inundation maps for the studied streams, evaluate economic impacts, and to evaluate proposed flood risk reduction of considered alternatives for the 100-year flood.

HDR collected information that SLWCD had readily available. In addition, we met with the City of Newark, Village of Granville, Alexandria, Johnstown, Licking County Engineer, and Granville Township to discuss this project and document their current flood risks and concerns. HDR and SLWCD held a public meeting to discuss the project and to gather flood risk concerns from the local citizens as well.

With the information gathered, SLWCD and HDR developed a semi-quantitative multi-factor criteria scoring system to evaluate and score potential alternatives. We utilized the scoring system in addition to the hydrologic and hydraulic (H&H) models to evaluate alternatives for flood risk reduction. We identified three major project categories; 1) watershed level (policy and other measures that can be applied to the entire watershed), 2) reach based (projects that reduce flood risks in long reaches of the creek), critical infrastructure (projects that protect utilities and first responders), and site specific (projects that are focused on damage centers and critical infrastructure). The following tables outline the twenty-one proposed alternatives, potential projects, benefits, and cost information that were identified as part of this study (each of these alternatives are described in detail in **Section 5.0**).

The implementation and phasing of alternatives could be driven by several factors. The alternatives identified in this report are simply alternatives and have not been evaluated fully for feasibility. A more rigorous feasibility analysis will be required for alternatives to be carried forward into the South Fork Licking River Watershed Plan (Watershed Plan) update. Cost estimates and benefits presented in this report will have to be refined for a feasibility level evaluation. Implementation factors to be considered before inclusion in the Watershed Plan update could include risks, funding availability, political influence, development pressures, and many other external factors. The alternatives presented in this report will have to be evaluated further before inclusion into the South Fork Licking River Watershed Plan update.

1.0 Study Overview

1.1 Introduction

The area surrounding the Raccoon Creek watershed has been rapidly developing in the New Albany area for years, since Intel announced their intention to build a semiconductor facility in January 2022. The upper watershed of Raccoon Creek itself has experienced significant development and potential changes in future land use. Therefore, the need to understand and evaluate the current and potential watershed impacts of Raccoon Creek are important so that planning and growth can be accommodated while understanding flood risks in the entire watershed.

The South Licking Watershed Conservancy District (SLWCD) issued a local request for qualifications (RFQ) and HDR was contracted to complete a flood mitigation study for the Raccoon Creek Watershed. The purpose of the flood study is to quantify flood risk and identify potential alternatives to existing watershed problems. This will be done by identifying areas of flood risk in the watershed, collecting historical flooding records, identifying repetitive loss properties, and refining Hydrologic and Hydraulic (H&H) models using updated information. Current watershed problems consist of flood risk due to increased rainfall, debris accumulation, and sediment and erosion increases. Flooding impacts in the area include, but are not limited to, roadway and utility interruptions, damage to structures, property flooding, business interruptions, debris cleanup, regional economic impacts, critical infrastructure, erosion issues, as well as other environmental and social effects.

In addition to SLWCD, the Licking County Soil and Water Conservation District (LCSWCD), a local organization in Licking County that is chartered by the State of Ohio, works to conserve land, soil, water, forest, wildlife and other related resources for the local benefit through work with landowners and stakeholders, is a major stakeholder. Based on the LCSWCD's mission and values, the organization is supporting the SLWCD in the Raccoon Creek Watershed and throughout this study.

The project study area is the Raccoon Creek Watershed, a HUC10 level watershed that consists of Raccoon Creek, Moots Run, and Lobdell Creek located in Licking County, OH **Figure 1.** Raccoon Creek itself is the largest stream in the watershed and encompasses approximately 83.6 square miles of area and is primarily used for agriculture. The Village of Granville, OH is the only incorporated area along Raccoon Creek. Lobdell Creek, which is a larger tributary branching from Raccoon Creek, is approximately nineteen square miles long. This area is also used for agriculture and the only incorporated community near Lobdell Creek is the Village of Alexandria, OH. Other nearby communities in the watershed include Newark and Johnstown, OH, which are also a focal point of this study.

1.2 Data Collection and Review

HDR received several reports and related data to support this study. The following reports and data were the most impactful and provided the most detail regarding flood risk in the Raccoon Creek Watershed.

South Fork Licking River Watershed Plan and Environmental Impact Statement prepared by the South Licking Water Conservancy District and U.S. Department of Agriculture. (1980, June). This plan included both structural and non-structural flood risk reduction projects. The structural projects that fall within the Raccoon Creek watershed include a multi-purpose reservoir on Lobdell Creek, a dry dam on Kiber Run, a dry dam on Simpson Run, obstruction removals on Raccoon Creek, and streambank stabilization of critical areas.

South Licking Silver Jackets – Raccoon Creek Logjam Model, Hydrology and Hydraulics Appendix (USACE Huntington District, January 2023). This report is summarized in Section 1.2. The project team utilized the HEC-MS hydrologic model and the HEC-RAS hydraulic model created by the United States Army Corps of Engineers (USACE) as a starting point for the updates and the modeling detailed in Section 3.0. the report was focused on identifying the blockages and logjams that contribute to flood risk, erosion, and bank stability. The woody debris was mapped using aerial imagery dated March 2019 from the Licking County Auditor and categorized in the following manner:

- Fallen Trees are represented as a single tree.
- Small logjams are represented as more than one tree or multiple pieces of debris.
- Large logjams are represented as piles of debris overtaking half of the width of the stream.
- Very large logjams are represented as piles of debris overtaking the majority of the width of the stream.
- Total blockages are represented as the stream rerouting itself due to blockage.

Bridge Plans and Associated Hydrology and Hydraulics Reports. See Appendix A for the graphic of bridges that HDR received plans for. SLWCD and LCSWCD coordinated with bridge owners (the city of Newark, ODOT, and Licking County) to gather bridge plans. These data were entered into the updated HEC-RAS hydraulic model.

1.3 Purpose & Need

The purpose of this flood mitigation study is to quantify flood risk and identify potential alternatives to mitigate flood risk within the existing watershed. More specifically, the goal is also to identify solutions in precise location and general solutions that could be applicable throughout the watershed. This will be accomplished by pointedly identifying areas of flood risk in the watershed, collecting historical flooding records, identifying repetitive loss properties, and refining H&H models using updated information. There is a demonstrated need for a study of this kind. In addition to current watershed flood risk challenges, there is a rapid development of new infrastructure in the upstream portion of the watershed.

Current watershed problems consist of flood risk due to increased rainfall, debris accumulation, and sediment and erosion increases. Flooding impacts in the area include, but are not limited to, roadway and utility interruptions, damage to structures, property flooding, business interruptions, debris cleanup, regional economic impacts, critical infrastructure, erosion issues, other environmental and social effects.

1.4 Objectives & Constraints

The main deliverables of the flood mitigation study are creating a hydrologic model (HEC-HMS) of the watershed and a two-dimensional (2D) hydraulic model (HEC-RAS) of the studied streams (Raccoon Creek, Lobdell Creek, and Moots Run). The models will be utilized to evaluate alternatives, develop flood inundation maps, and evaluate economic impacts due to flooding. These deliverables will help achieve the overall objectives of the study, which are to identify feasible flood mitigation solutions in the Raccoon Creek watershed. This is especially important for areas experiencing high flood frequency. It is also essential these design alternatives and potential solutions to meet the local and specific watershed needs of Raccoon Creek.

As with any project or study, there are always constraints. The main constraints for the flood mitigation study are time, budget, available data, and the ability to acquire land in the watershed. For each study scope task, there is an allotted budget, which is associated with the time, or number of hours, to complete the perspective task by HDR. With this understanding, the project is limited by both the amount of time and available budget to complete the stated objective above. Further, the proposed 2D hydraulic model is only as good as the data available and time allowed to be put into it. This is why as built and survey information is collected, to ensure the most accurate data is in the model at this planning stage.

1.5 Study Scope

The scope of work for this study can be broken into six main tasks. These tasks include Data Collection and Review, Survey, Stakeholder Support and Project Management, Hydrologic and Hydraulic (H&H) Analyses Update, Alternatives Analysis, and Flood Damage Reduction Study Mitigation Report. Each task is further explained in detail below:

Task 1 – Data Collection and Review

Technical data collection and review reflect the first steps in any watershed-scale flood mitigation study. The technical data collected for this study included maps, shapefiles from the United States Department of Agriculture (USDA) on soils, Licking County Auditor, LiDAR topography, FEMA Flood Insurance Study (FIS), the South Fork Licking River Watershed Plan and Environmental Impact Statement, National Weather Service rainfall data, and the USACE and Silver Jackets Raccoon Creek Log Jam Study. The additional hydraulic analysis of bridges, past field survey channel cross-sections at critical locations along Raccoon Creek and tributaries, historical flooding pictures, and past field survey identifying the depths of flooding at flood prone structures were collected and reviewed. This data assisted in focusing HDR’s field reconnaissance and documentation of areas of significant channel bank erosion and areas with potential flooding threats on buildings and public infrastructure. Additional reviews of information collected from the public on prior flooding occurrences were also collected at public meetings and used to develop this report. Data collection and review are discussed throughout this report, but Section 1.2 and Section 4.1 present good overviews of how the data was applied to this study.

Task 2 – Survey

Site survey and photo documentation at critical bridge locations were conducted to collect topographic survey, channel survey, and stream crossing/structures survey for Raccoon Creek, Lobdell Creek and Moots Run. This information was gathered as needed to update the watershed hydrologic and hydraulic models and to develop alternatives for flood mitigation. As-built plans were utilized, where available, to maximize the field survey budget. At bridge locations where surveys were not completed, as-built plans of the bridge, culvert, or other structure were utilized to add the feature into the model. Section 3.2 provides more detail on the survey task and structures associated with this study.

Task 3 – Stakeholder Support & Project Management

Stakeholder engagement is a critical element of any flood mitigation study. Coordination with the LCSWCD, SLWCD, and additional stakeholders will be required for project updates, flood mitigation study review status, and data sharing for outstanding or missing data throughout the project duration. All tasks will be organized and attending coordination meetings will be needed to ensure project success. The LCSWCD and SLWCD will lead any public outreach and meetings to seek project input. Participating in public meetings will be important to further ensure project success. Two public meetings and monthly progress meetings are anticipated.

Task 4 – Hydrologic and Hydraulic (H&H) Analyses Update

H&H modeling and analyses were necessary to develop flood mitigation alternatives. The USACE HEC-RAS two-dimensional (2D) model was used as a basis to further develop and refine any data collection and survey information. Hydrologic analysis was verified using the closest United States Geologic Survey (USGS) Gages in the watershed. Modeling results were used to identify flood prone structures through inundation mapping, flooding depths, and the potential for recurrence intervals that could cause flood damage. The updated models were utilized to determine flood mitigation alternatives and evaluate the flood risk reduction of a few select alternatives.

Task 5 – Alternatives Analysis

Multiple feasible alternatives were developed working through data collection, stakeholder involvement and modeling tasks. A few of these alternatives were evaluated in the HEC-RAS hydraulic model. A total of twenty-one alternatives were categorized into four categories and then a multi-criteria decision scoring system was developed to score alternatives within each of the four categories. The categorization and screening processes that make up the plan formulation process, are described below (and in Section 4.0). The alternatives were placed into one of the following four categories:

1) Watershed Alternatives – These alternatives are broad-based and cover the watershed area, are policy driven, or regulate the studied streams (Raccoon Creek, Lobdell Creek, and Moots Run).
2) Reach-Based Alternatives – These alternatives include regional projects that impact reaches of the studied streams. They are typically a discrete project whose benefits carry downstream through a reach of the studied streams.

3) Critical Infrastructure Alternatives – The alternatives include discrete projects that protect critical infrastructure such as a wastewater treatment plant, a water treatment plant, utilities, and first responders.
4) Site-Specific Alternatives – These alternatives are discrete flood risk reduction projects that were formulated based on concentration of damages and known losses based on the data collected. These alternatives include levees and/or floodwalls to reduce flood risk to more densely populated areas.

The analysis of the alternatives includes a range of quantitative analysis (HEC-RAS modeling, construction cost estimating, and HAZUS economic analysis), semiquantitative analysis (multi-criteria decision support), and general descriptors (non-quantitative value statements). Each of the twenty-one alternatives and their analysis are described in detail in Section 5.0.

Task 6 – Flood Damage Reduction Study and Feasibility Report
This document, the Raccoon Creek Flood Damage Reduction Study, is a culmination of the above tasks.

2.0 Existing & Future Project Conditions

2.1 Setting

The South Licking Watershed is in central Ohio, east of the city of Columbus. It is located in portions of Licking, Fairfield, and Perry counties, totaling 180,000 acres. The headwaters originate in Licking County and flow in the southeast direction. One of the South Licking Watershed's biggest tributaries is Raccoon Creek (U.S. Department of Agriculture, 1980).

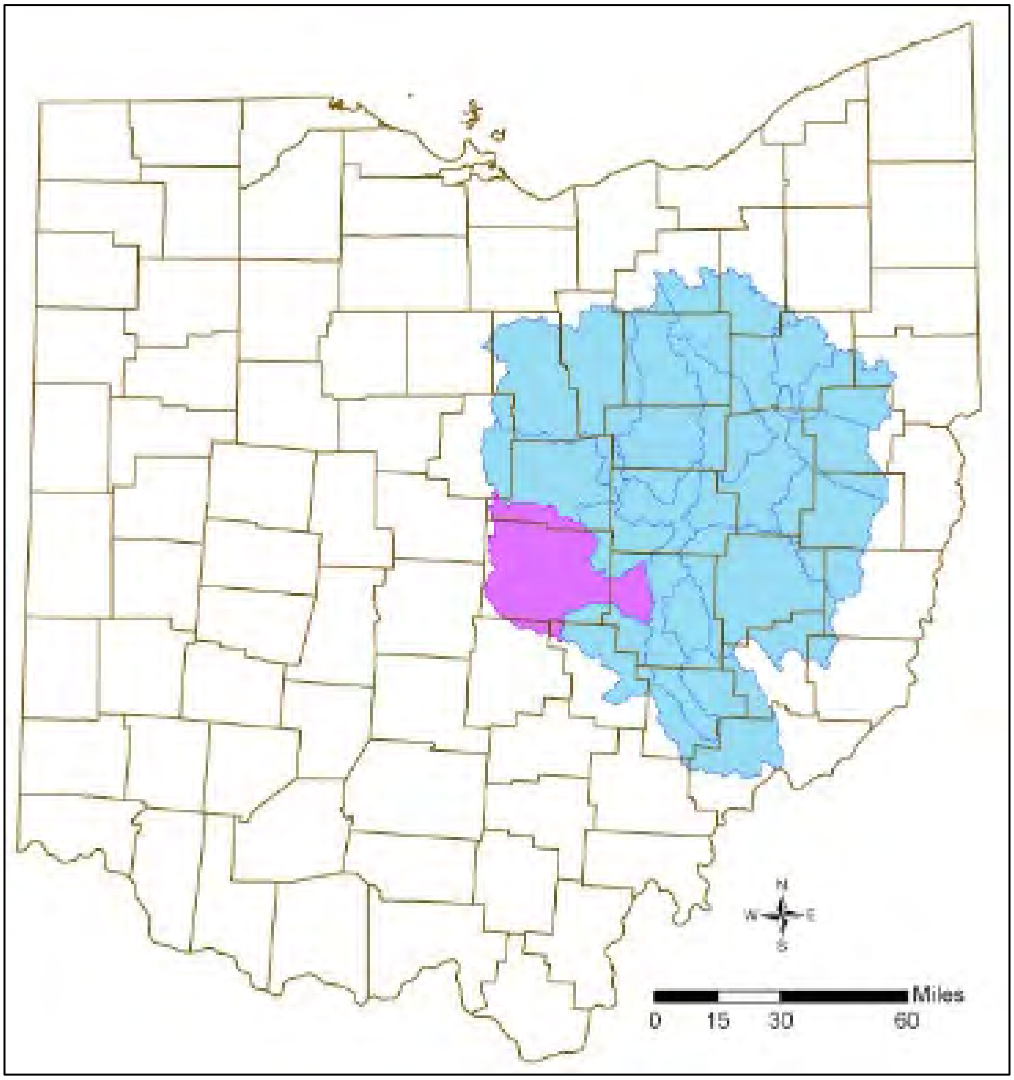

Figure 2 Licking River watershed (magenta) in relation to the larger Muskingum River watershed (light blue)

Figure 3 Raccoon Creek Topo Map (Licking County OH)

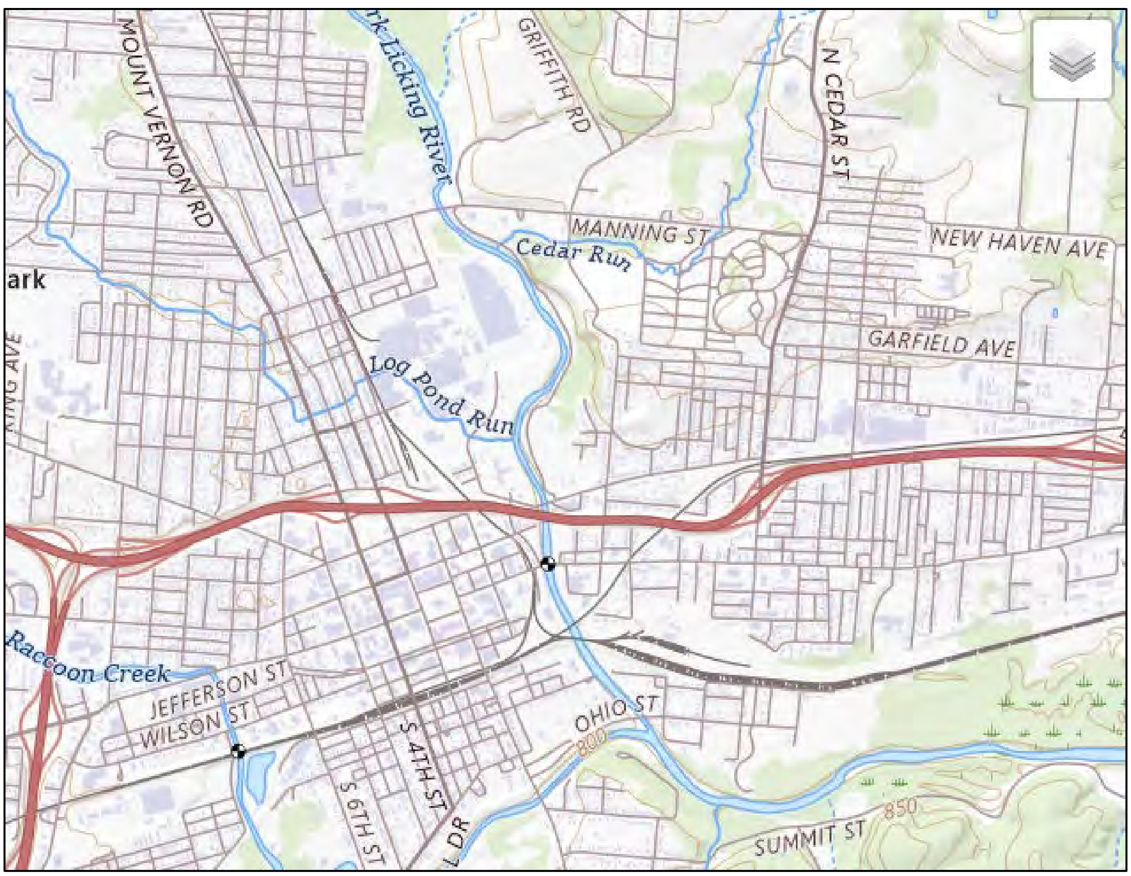

Figure 4 Log Pond Run Topo Map (Licking County OH)
(Raccoon Creek, Log Pond Run and South Fork Licking River merging in Newark.)

2.2 Natural Environment

Of the natural environment, the highly erodible soils and subsequent tree falls, snags, and log jams contribute the most to flood risk and channel instability in the Raccoon Creek Watershed. The following section details the current state of the natural environment and recent findings.

Historically, there have been numerous flooding incidents along Raccoon Creek, Moots Run and Lobdell Creek. These occurrences have been especially prevalent south of Johnstown, OH in the unincorporated area and in the surrounding Villages (Alexandria and Granville). A source of flooding and documented flood risk concern has been logjams within the Raccoon Creek and South Fork Licking River watershed. SLWCD aims to provide public information and support on watershed issues and oversees the South Licking watershed. The watershed has experienced increased flooding which is believed to be due to logjams.

The SLWCD initiated a logjam inundation study in partnership with the United States Army Corps of Engineers (USACE) and Silver Jackets, an interagency team focused on flood risk priorities, which was completed in January 2023. The USACE developed a HEC-RAS 2D hydraulic model of the watershed aimed at capturing the effects of logjams in this watershed and prioritizing the removal. The area of interest modeled by USACE was Raccoon and Lobdell Creek. The outcome of analysis was to prioritize logjam removal in order of risk and provide an analysis of Raccoon Creek to determine which logjam removal would lead to the most benefit in flood reduction.

A hydrologic model was used to simulate the response within the Raccoon Creek watershed to rainfall and to develop peak flow estimates for use in the hydraulic model. A HEC-HMS hydrological model was also developed to collect appropriate rainfall events, dividing the watershed into sub-watersheds, estimating hydrologic characteristics, and evaluating the storage and routing for water. These data points were used in conjunction with the HEC-RAS 2D model.

To complete the logjam inundation study, stream gages were used to calibrate the model, which is a process to adjust modeling results and increase model confidence and back check any modeling results. There are two active gages with 15-minute data intervals able to be used in the study **Figure 5**. This real-time data from USGS was propagated through the HEC-HMS model.

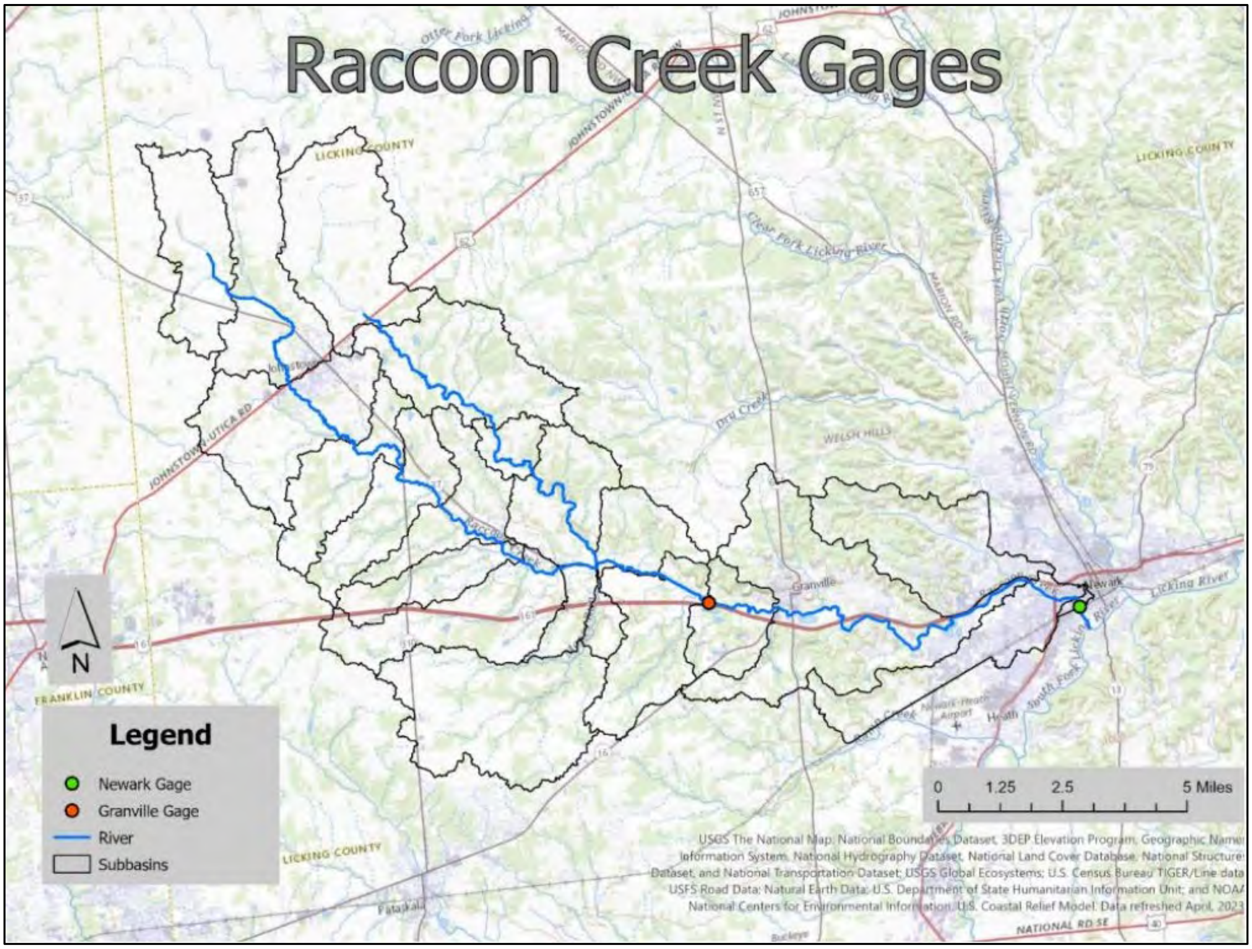

Figure 5 Raccoon Creek Gages

The stream gage locations are along Raccoon Creek near Granville, OH (depicted in red above) and below Wilson Street in Newark, OH (depicted in green above).

This information was used to categorize the logjam blockages and provide a visual of where in the watershed blockages were occurring **Figure 6**. Woody debris was mapped using aerial imagery dated March 2019 from the Licking County Auditor. Debris was categorized in the following manner:

- Fallen Trees are represented as a single tree
- Small logjams are represented as more than one tree or multiple pieces of debris
- Large logjams are represented as piles of debris overtaking half of the width of the stream
- Very large logjams are represented as piles of debris overtaking the majority of the width of the stream
- Total blockages are represented as the stream rerouting itself due to blockage

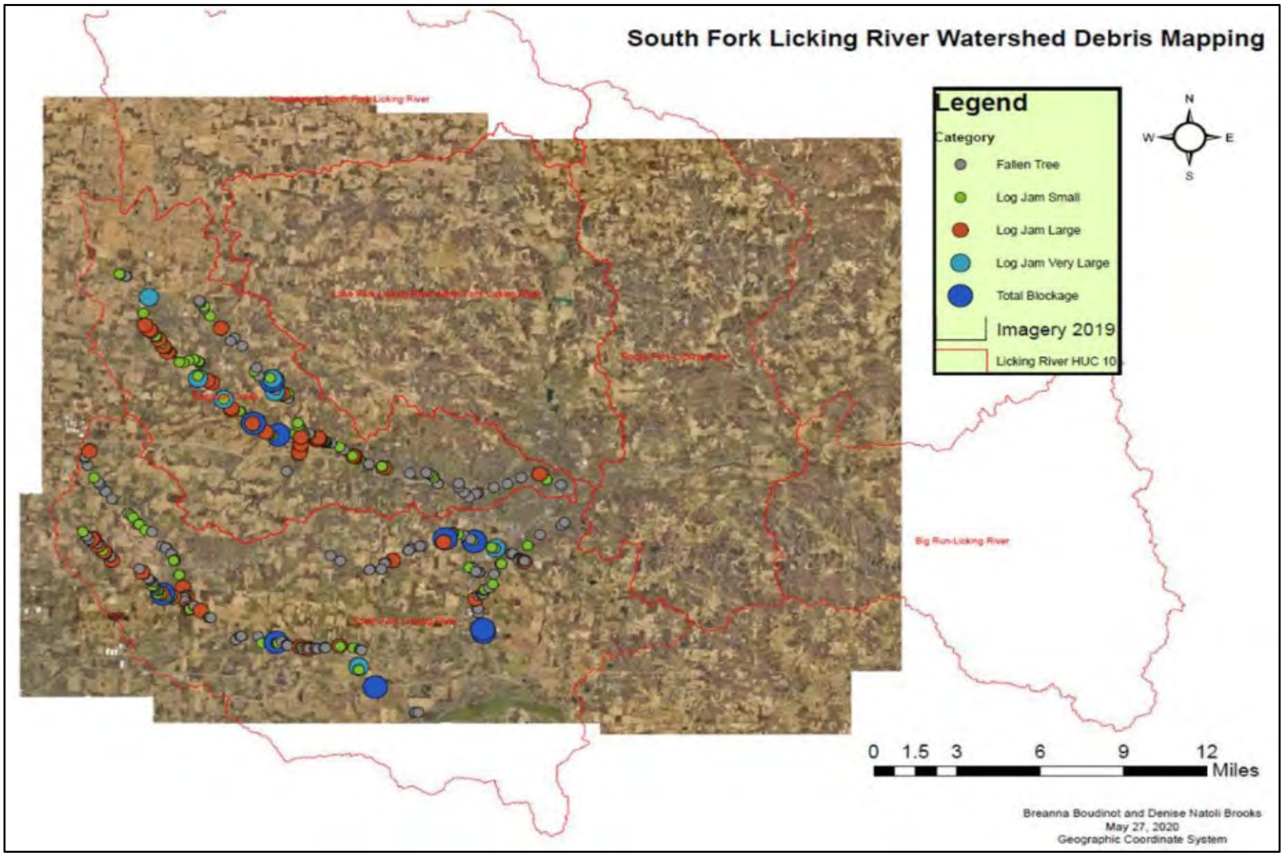

Figure 6 South Fork Licking River Watershed Debris Mapping
(Represents the number of debris and debris location mapped in the South Fork Licking watershed.)

The logjams were modeled with bridge structures and followed logjam modeling methods displayed in **Table 1.** Logjams were grouped based on their approximate location in the watershed. Logjams that were closer in proximity were modeled as a group to represent the largest logjams or multiple small blockages at a bridge structure. A total of 25 logjams groupings were used. Single fallen trees and small logjams were excluded due to the limited impact of the blockage. Additional analysis was run with flow conditions from March 2020. Logjams were ranked from least to most impactful based on the change in water surface elevations between validations with no logjams and a new logjam model run. Inundation of buildings or structures was used as an additional factor for impact.

Table 1 Logjam modeling methods used for the HEC-RAS 2D model

Total Blockage	Total blockage with 1x1 culvert
Very Large Logjam	Total blockage with 2x2 culvert
Large Logjam	Total blockage with 5x5 culvert
Small Logjam	1.0 wide pier with deck and floating debris 100x6
Fallen Tree	0.5 wide pier with deck and floating debris 100x3

Results found there to be 32, 124, 34, 135, 48, and 22 types of blockages in Lobdell Creek, Raccoon Creek, Ramp Creek, South Fork, Muddy Fork, and unnamed tributaries, respectively in the South Licking watershed **Table 6**. Please note the South Fork and Muddy Fork are not in the

Raccoon Creek watershed, which is the focus of the LCSWCD flood mitigation study. Raccoon Creek had two locations of total blockage and Lobdell Creek had one location of total blockage (**Figure 7 & Figure 8**) These three blockages were near Alexandria, OH (**Figure 6**).

Table 2 Debris throughout the South Fork Licking watershed (categorized by stream.)

	Lobdell Creek	Raccoon Creek	Ramp Creek	South Fork	Muddy Fork	Unnamed Tributary	Total by Size
Fallen Tree	17	49	24	99	24	17	230
Log Jam Small	10	50	3	27	15	2	107
Log Jam Large	2	20	3	14	8	3	50
Log Jam Very Large	2	3	1	1	0	0	7
Total Blockage	1	2	3	4	1	0	11
Total by River	32	124	34	145	48	22	405

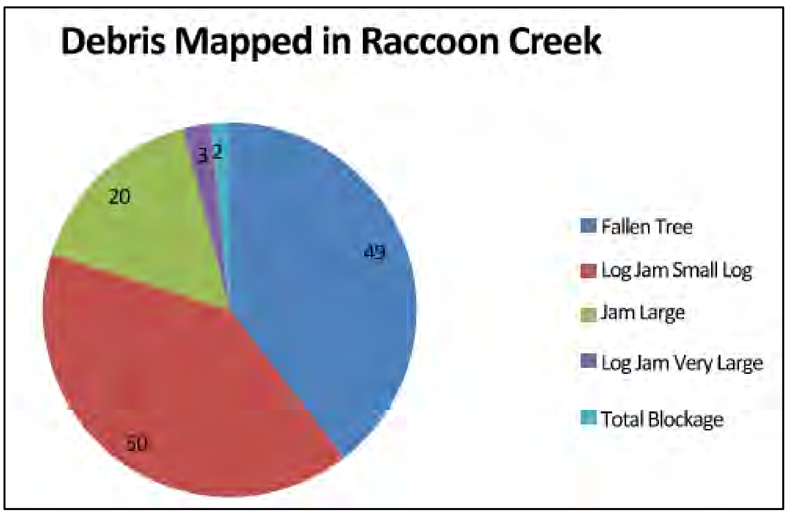

Figure 7 Debris mapped in Raccoon Creek

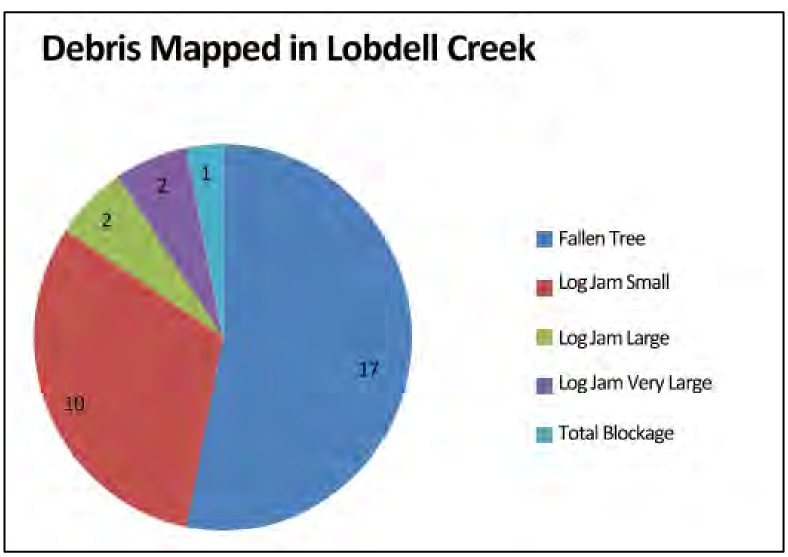

Figure 8 Lobdell Creek mapped debris

Only one logjam was ranked as most impactful due to water surface elevations near structures. This inundated structure was a football field located in Newark, OH (**Figure 9**). More significant logjams did not inundate buildings but did have a significant impact on water surface elevations. Twelve more significant logjams were observed. Less significant logjams had no structural impacts and had minor water surface elevation changes. Four less significant logjams were observed. The least significant logjams had no structural impacts and had no water surface elevation increases. Eight least significant logjams were observed. The study recommendations were to prioritize logjams having the most impact to reduce flood damage within the watershed.

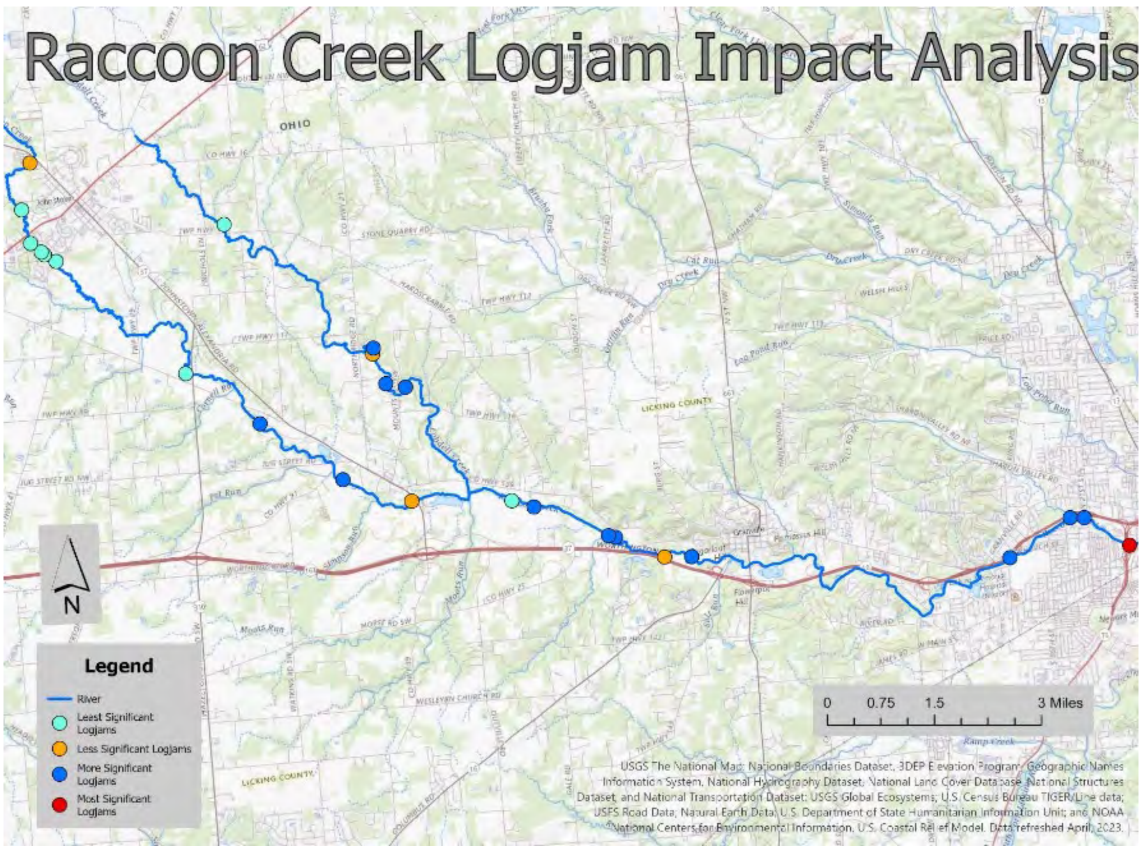

Figure 9 Raccoon Creek logjam impact analysis.
Raccoon Creek logjam impact analysis displayed above. One most significant logjam is observed near Newark, OH.

2.3 Physical Environment

The physical environment is considered soils, geology, weather, wind, climate and

Soils and Geology

Soils in Licking County belong to all four hydrologic soil groups (groups A-D), ranging from a low to high infiltration rate. The soil is generally characterized as silt loams (USGS Web Soil Survey). Glacier deposits from the Wisconsin era characterize the geology of the area, leaving behind sand, soils and gravel. As shown in **Figure 10**, more recent alluvial deposits were deposited in the floodplains of present day streams, including Raccoon Creek, as denoted by the gray color below.

Weather

The average wind speed in the watershed is around 9.4 miles per hour, with the highest wind speed typically occurring in April at 35 miles per hour. The wind direction is generally towards the East. The average relative humidity is around 65 percent, and the average sky cover is 0.67 (National Weather Service [NWS] and NOAA climate website).

Climate

The climate for the Raccoon Creek Watershed is temperate with relatively cool to cold winters and mild to warm summers. The mean annual precipitation is around 41.7 inches, producing a dry harvest season during late summer and early fall. The average yearly snowfall is about 18 inches. The average daily high temperature varies from a low of 35 degrees F° in January, to as high as 84 degrees F° in July (Weather averages Newark Ohio, from NWS Climate website).

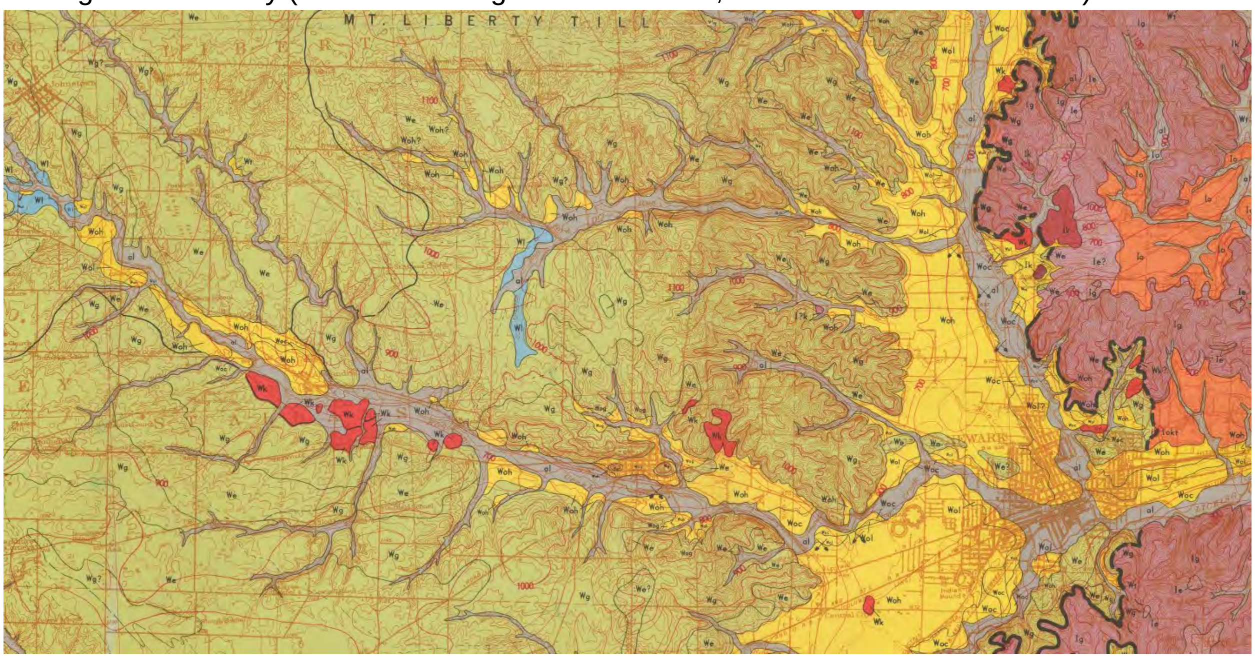

Figure 10 Glacial map of Licking County, Ohio (Forsyth, 1966)

Water Quality

There is currently a Nine-Element Nonpoint Source Implementation Strategic Plan (NPS-IS Plan) for Raccoon Creek being developed that will likely supersede the water quality information below. A 2008 Ohio Environmental Protection Agency (OEPA) study of the Licking River Watershed found the stream health of the project area to be good, and exceptional between Granville and Newark (Ohio EPA, 2023). While the water quality was considered good, pollutant sources were also identified. These current pollutant sources include the Johnstown Wastewater Treatment Plant (WWTP), agricultural runoff, land development, yard maintenance and residential area runoff. These sources have caused elevated nutrient levels, sedimentation, ammonia and lowered dissolved oxygen levels (**Figure 11**). Specific water quality issues attributed to land development and agriculture, included low dissolved oxygen levels, and increased sedimentation and nutrient levels.

The Wastewater Treatment Plant outflows in the area were evaluated in the context of quantity and impacts to flood flows. This Study focuses solely on water quantity and flood risk. Water quality impacts from various Wastewater Treatment plants and other sources were not evaluated as part of this study.

Table 3 below summarizes the current permitted flows and the requested permitted flows of each of the WWTPs in the watershed in terms of millions of gallons per day (MGD) and cubic feet per second (cfs). The impacts of the WWTP outflows are negligible on rainfall driven flood flows. For example, Moots Run WWTP outflow of 4.7 cfs versus the modeled 100-year flood flow of 1,076 cfs is less than 1% of the total flood flow.

However, WWTP discharges could contribute to higher erosion rates that may increase the risk of tree falls and subsequent logjams and debris blockages. This, in turn, could increase flood risk associated with logjams and debris blockages. T**able 3** below shows the impacts of WWTP discharges to Mean Annual Flows as a percentage. For example, the permit request for increasing the Moots Run WWTP discharge to 4.7 cfs is a 43% increase in the annual mean flow of 10.9 cfs.

Table 3 Wastewater Treatment Plan Discharges Versus Mean Annual Flows

Wastewater Treatment Plant (WWTP) Name	Current Permitted Average Design Flow (MGD / cfs)	Permit Request Average Design Flow (MGD / cfs)	Mean Annual Flow (cfs)*	Maximum WWTP Flow as % of Mean Annual Flow
Johnstown WWTP	1.2 MGD / 1.9 cfs	2.4 MGD / 3.7 cfs	16.8 cfs	**22%**
Alexandria WWTP	0.08 MGD / 0.1 cfs	N/A	38.3 cfs	**0.2 %**
Pet Run WWTP	No Current Plant	1 MGD / 1.6 cfs	2.94 cfs	**54%**
Moots Run WWTP	No Current Plant	3 MGD / 4.7 cfs	10.9 cfs	**43%**
Granville WWTP	0.911 MGD / 1.4 cfs	N/A	86.6 cfs	**1.6%**

Station	Stream Name	River Mile	Assessment Unit (05040006)	Cause(s) of Impairment	Source(s) of Impairment	IR Cat.[1]	Action[2]	Method[3]	Parameter[4]
R14S13	RACCOON CREEK	23.70	03 01	Nutrients	Johnstown WWTP, Agriculture, Rural (Residential Areas)	5	Other	Follow-up	-
				Ammonia (Total)	Johnstown WWTP, Agriculture, Rural (Residential Areas)	5	Other	Follow-up	-
				Sedimentation/Siltation	Agriculture, Rural (Residential Areas), Site Clearance (Land Development or Redevelopment)	5	TMDL	QHEI-sed	Sediment
300418	MUDDY FORK LICKING R.	3.70	04 01	Sedimentation/Siltation	Agriculture, Yard Maintenance, Site Clearance (Land Development or Redevelopment)	5	TMDL	QHEI-sed	Sediment
				Oxygen, Dissolved	Agriculture, Yard Maintenance, Site Clearance (Land Development or Redevelopment)	5	Other	Follow-up	-
				Organic Enrichment Biological Indicators	Agriculture, Yard Maintenance, Site Clearance (Land Development or Redevelopment)	5	Other	Follow-up	-
R14P15	MUDDY FORK	0.08	04 01	Sedimentation/Siltation	Agriculture, Rural (Residential Areas), Yard Maintenance, Site Clearance (Land Development or Redevelopment)	5	TMDL	QHEI-sed	Sediment
				Organic Enrichment Biological Indicators	Agriculture, Rural (Residential Areas), Yard Maintenance, Site Clearance (Land Development or Redevelopment)	5	Other	Follow-up	-

Figure 11 Nutrients, Ammonia, and Sedimentation/Siltation In Raccoon Creek Watershed
(Found to cause impairment in the Raccoon Creek watershed in the 2008 OPEA study on water quality.)

Cultural Resources

The Raccoon Creek Watershed is home to the Newark Earthworks, landscapes built over 2000 years ago by the Hopewell Native Americans. Recently named a UNESCO World Heritage Site, the earthworks served as a gathering place for Native Americans and are precisely aligned with the cycles of the sun and moon. The Great Circle Earthworks in Newark is one of the largest sites at 1200 feet in diameter (“Where Earth meets sky”, 2023).

2.4 Built Environment

The largest city in the Raccoon Creek Watershed is Newark, OH, with a population of 51,257 (Facts & Statistics, 2022). Other notable communities in the watershed include Alexandria, Granville, and Johnstown. Much of the Raccoon Creek Watershed is rural, but the City of Newark is experiencing urban growth and has an expanding manufacturing sector. Alexandria and Johnstown are more agriculturally developed.

Impervious Surfaces and Building Concentrations

In terms of a built environment, development generally requires a greater area of impervious surfaces due to the commercial buildings, transportation infrastructure, industrial facilities, and residential dwellings, which are required to support a concentrated population. Impervious surfaces prevent the infiltration of precipitation into the ground. This decreases the rate of soil absorption and causes a greater volume of water to enter the streams within a shorter period, as the rate of runoff increases. Altogether, the presence of impervious surfaces can increase the risk of flooding during precipitation events. With this understanding, the City of Newark would likely be at greater risk.

Aerial imaging in (**Figure 12)** shows that the greatest concentration of buildings and impervious surfaces is in the City of Newark, OH. The communities of Johnstown, Alexandria and Granville are much less densely populated than Newark. As such, the concentration of buildings in these areas is minimal and the surrounding areas are more suited towards agriculture.

Figure 12 Urban Development (Relative Size and Concentration)

Zoning

The figures below depict how Alexandria, (**Figure 17**) Granville, (**Figure 16**) Johnstown (**Figure 14**) and Newark (**Figure 13**) are zoned for development. Alexandria has mostly residential zoning area, with a small business district and a conservation area. As shown in the zoning map of **Figure 17**, some of the Old Alexandria Residential area lies within the floodplain for Raccoon Creek. Downstream, Johnstown has a central business zone, commercial area, and a small industrial area along Ohio State Route 37. The rest of its municipal area is residential that transitions into rural residential areas outside of the city limits. The future land use map of Johnstown (**Figure 15)** predicts the residential area to expand. Further downstream. Granville is mostly agricultural with residential areas. The general business zone is also located within the flood plain for Raccoon Creek. The zoning of Newark illustrates a concentrated downtown commercial district, high-density single-family residential district, and industrial district. Further from the city center of Newark, there are medium and low-density single-family residence districts, conservation areas, and a church, school, and institutional district. According to the zoning code, the industrial district along the

Licking River is most at risk of flooding due to the proximity of the area to the river and being in the floodplain.

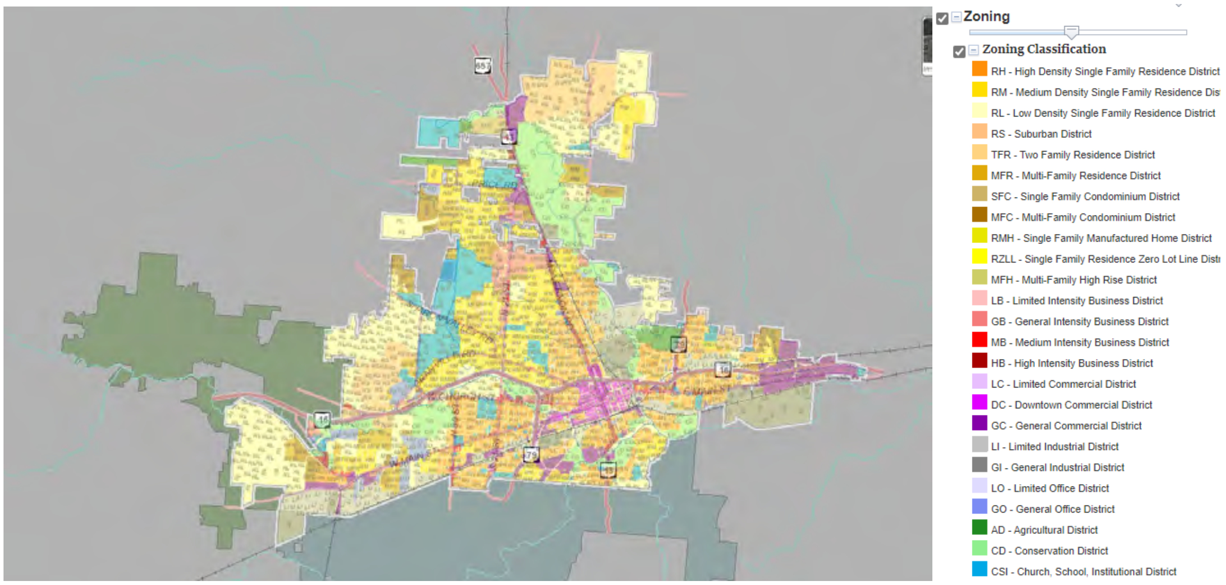

Figure 13 Zoning map of Newark, Ohio
(T&M Associates).

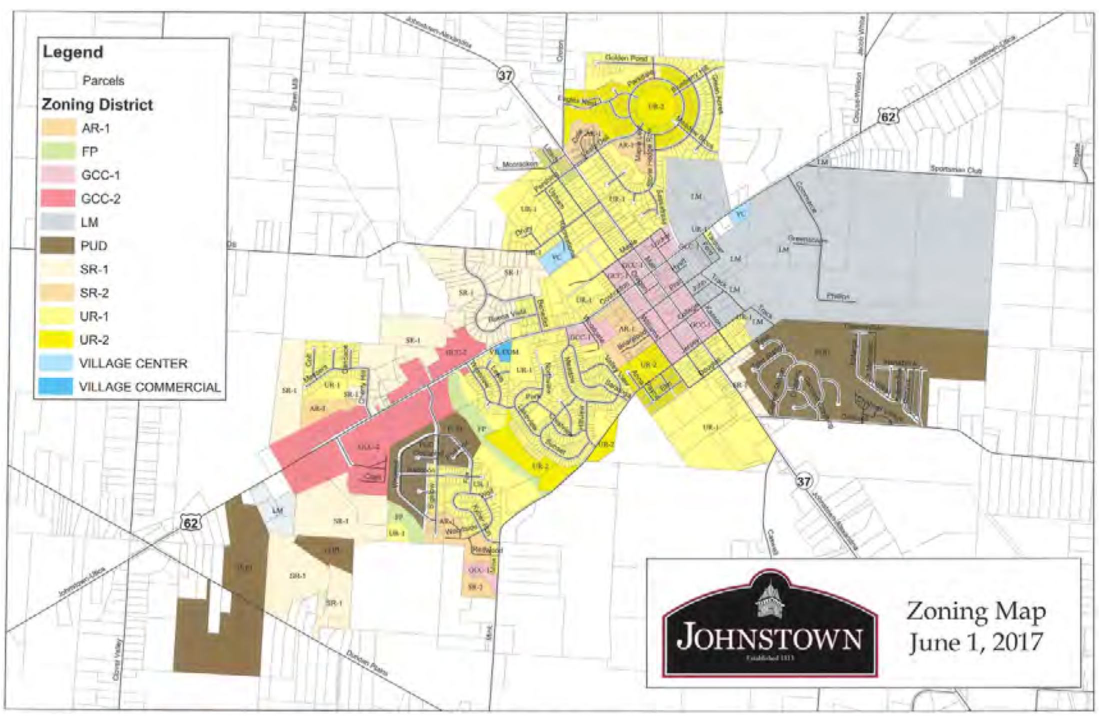

Figure 14 Zoning map of Johnstown, Ohio

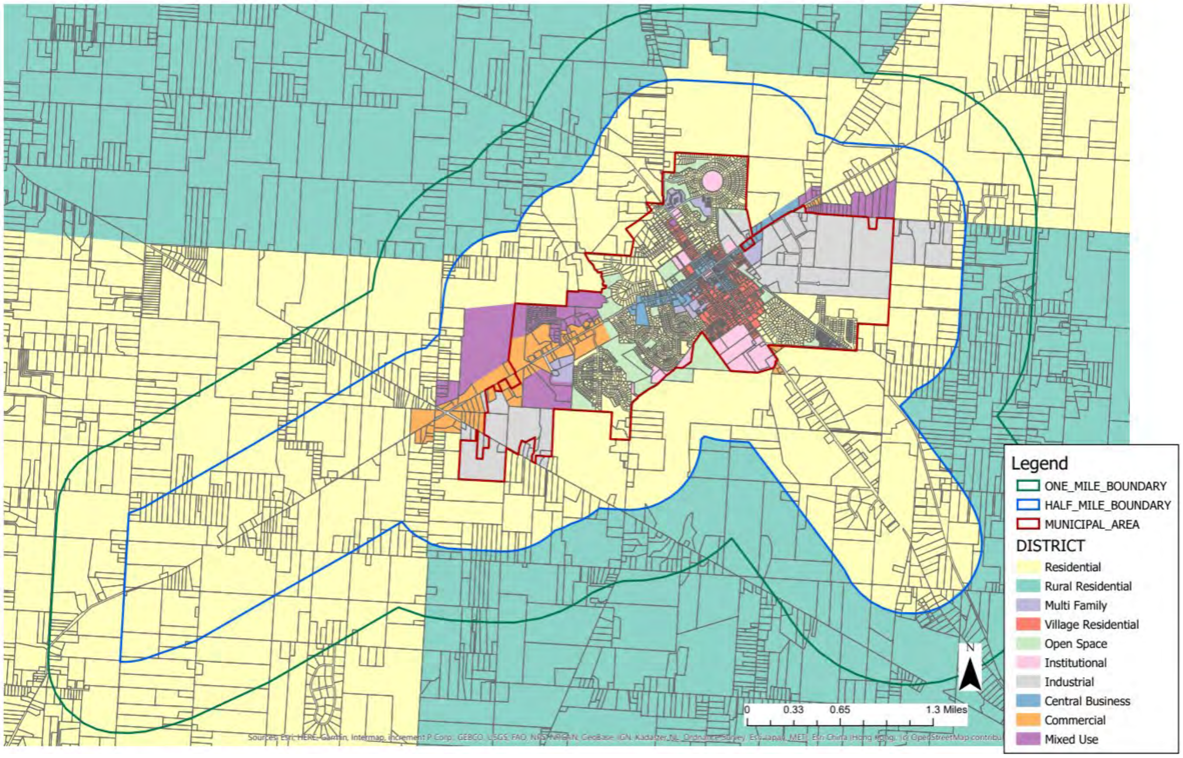

Figure 15 Future land use map of Johnstown, Ohio
(Future Land Use Map, 2020)

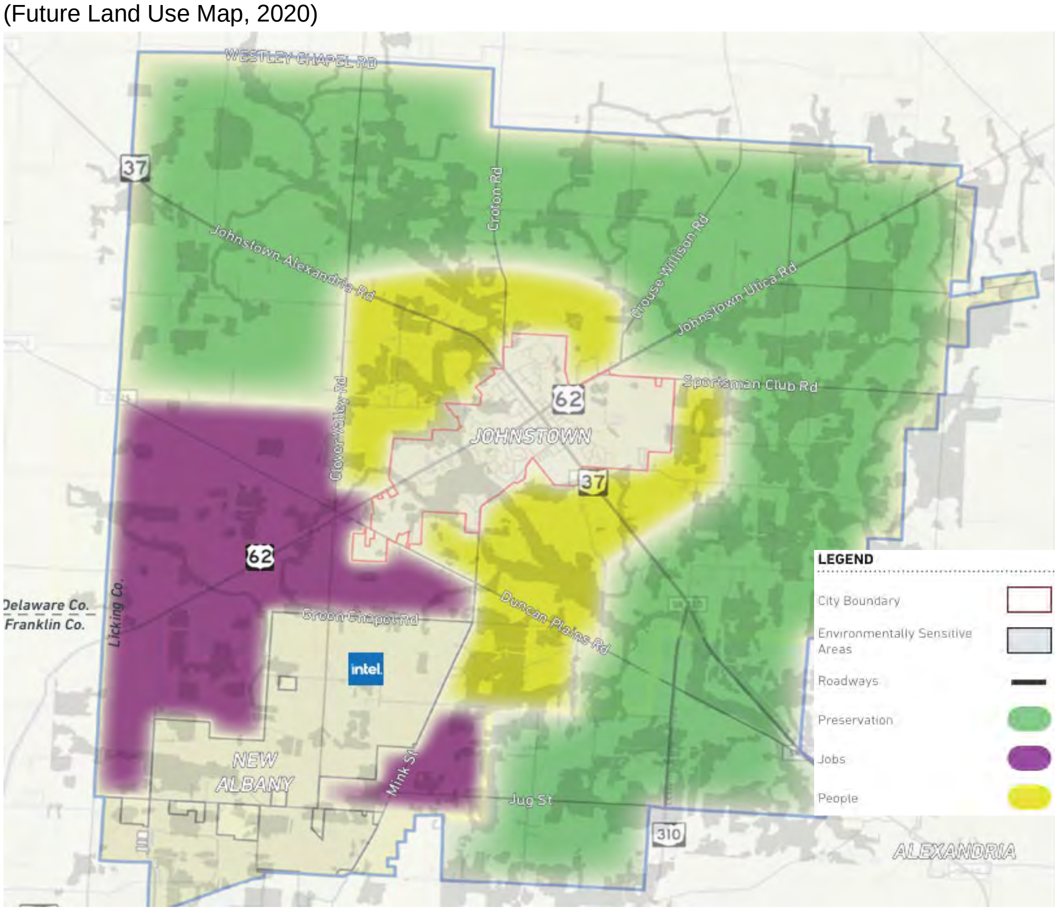

Figure 16 Growth Framework Map, Johnstown, Ohio (from 2024 Comprehensive Plan)

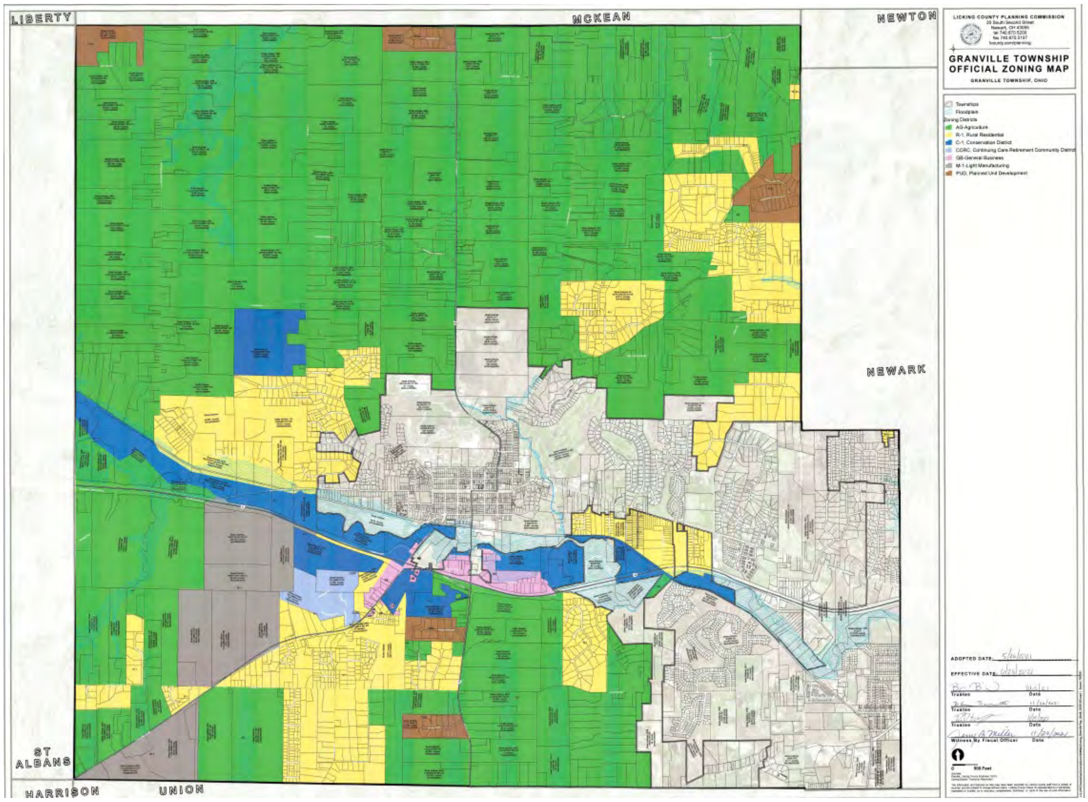

Figure 17 Zoning map of Granville, Ohio

Figure 18 Zoning map of Alexandria, Ohio

Future Development

New development in the industrial sector is growing rapidly in the area south of Johnstown and Alexandria. The large plots of available land have made this area suitable for data centers and tech companies, such as Google, Meta, Microsoft, and Amazon. Intel is constructing Intel One Ohio, a 1,000-acre facility for semiconductor manufacturing near the same location. To accommodate a greater workforce, residential development has also been planned. As a result, Newark is experiencing increased mixed-use development in the downtown district.

Fure development will drive WWTP capacity increases and demand for services in the watershed. The WWTP current discharges, proposed permit expansions, and the new WWTP at Moots Run are discussed in Section 2.3, Water Quality. The WWTP outflows in the area were evaluated in the context of quantity and impacts to flood flows. This Study focuses solely on water quantity and flood risk. Water quality impacts from various Wastewater Treatment plants and other sources were not evaluated as part of this study.

2.5 Economic Environment

Alexandria, Johnstown and Granville, OH have been mainly agricultural areas, but are experiencing increasing industrial development. Newark, OH has already been experiencing increased development with the largest economy within the project area and a population of about 50,000. Overall, the largest employment sector in Newark is manufacturing. The economy of the watershed area, especially Newark, is greatly impacted by its proximity to Columbus and the need for manufacturing.

At a county level, Licking County is expected to grow its economy substantially in the future due to large investments from tech companies like Microsoft and Intel. Intel has purchased nearly 1,000 acres in nearby New Albany, investing more than $28 billion in a new semiconductor facility (Intel in Ohio). Microsoft also purchased six parcels of land totaling over 700 acres with plans to build data centers (Burd, 2024). Amazon, Google, and Meta also have recently constructed data centers in this area. As a result of this future growth, the Ohio Department of Transportation has pledged $90 million to improve the local transportation infrastructure in anticipation of the larger workforce.

With a focus on development and the economic environment, it is also important to mitigate any potential flooding in the area and demonstrates a need for the watershed level mitigation study. Flooding harms the local economy through both direct and indirect losses. Flooding impacts residential homes, infrastructure, commercial businesses, agricultural productivity, ecosystem health and utility outages. Nationally, the U.S. Joint Economic Committee estimates that the total cost of flooding annually is between $179.8 and $496 billion (U.S. Joint Economic Committee, 2024). That is a broad range of potential flooding costs. The cost of flood damage to residential areas, infrastructure and businesses could place considerable strain on the local economy and cause an overall loss of economic productivity.

3.0 Hydrologic and Hydraulic Model

3.1 Background Information

Silver Jackets Study

A logjam and inundation study performed by the United States Army Corps of Engineers (USACE) and an interdisciplinary task force called the Silver Jackets was completed in early 2023. This study utilized HEC-HMS for hydrology and HEC-RAS 2D for hydraulics. The study concluded that logjams contributed to the flooding of a local football field, but while raising water surface elevations significantly during large storm events, did not affect other structures. Logjams of varying severity were identified in the study as well. While some background information and the final white paper were reviewed prior to this study, the Silver Jackets model files were not available to the HDR team. The information from the Silver Jackets study was incorporated into the existing conditions HEC-RAS model and the HEC-RAS model that was used to estimate debris loading, and resulting flood risks, in the study area. See the detailed discussion in Section 2.3 above as to how the information was incorporated into the HEC-RAS model.

Flood Insurance Studies

The Federal Emergency Management Agency (FEMA) Flood Insurance Rate Maps (FIRMs) are a standard reference for flooding in a given region and are available for Raccoon Creek. Flood Insurance Studies (FIS) document the hydrology and hydraulics associated with the FIRMs. While the FIS are often based on older versions of models than the current industry standard, they can form a basis of comparison for up-to-date studies. For this project, the FIRMs were reviewed and used to validate the model results. Detailed model inputs and results were requested from FEMA but have not yet been provided to HDR.

Stream Gauges

The United States Geological Survey (USGS) provides stream gage data on its website. For this project, gage 03145483 (Raccoon Creek, near Granville, OH) was used to validate both flow and stage data. This was the only field data used to validate this model. Additional validation and calibration are possible and would be required for certain applications. However, this is outside the scope of this study. Data from this stream gage was also used to prepare a flood frequency analysis. See the Hydraulics section below for more information.

3.2 Model Development

Hydrology

HDR developed a HEC-HMS (version 4.11) model to estimate 100-year, 24-hour flow hydrographs for the Raccoon Creek watershed near Newark, Ohio. The purpose of this section is to document the major assumptions, parameter assignments, and results of the HEC-HMS modeling. The scaled 100-year, 24-hour subbasin outflow hydrographs from HEC-HMS based on effective flood-frequency analysis for the watershed are inputs into the Racoon Creek HEC-RAS 2D model which will be used to evaluate flooding in the watershed.

BASIN DELINEATION

The Racoon Creek watershed, upstream of the confluence with South Fork Licking River, was delineated through HEC-HMS geoprocessing tools based on a one-meter digital elevation model (DEM) from the USGS National Elevation Dataset (NED). All geographic data, including the DEM, are based on the North American Datum of 1983 (NAD 83) horizontal datum, Ohio South (US survey feet) projection, and North American Vertical Datum of 1988 (NAVD 88) vertical datum. The geoprocessing of the DEM included: terrain reconditioning, preprocess sinks, and preprocess drainage.

The terrain reconditioning created an external boundary wall to the Racoon Creek watershed based on the USGS and Natural Resources Conservation Service (NRCS) Watershed Boundary Dataset (WBD) at a Hydrologic Unit Code (HUC) 12 scale. The delineation resulted in a watershed area of 102.1 square miles and 39 subbasins, with an average area of 2.6 square miles (see **Figure 18**).

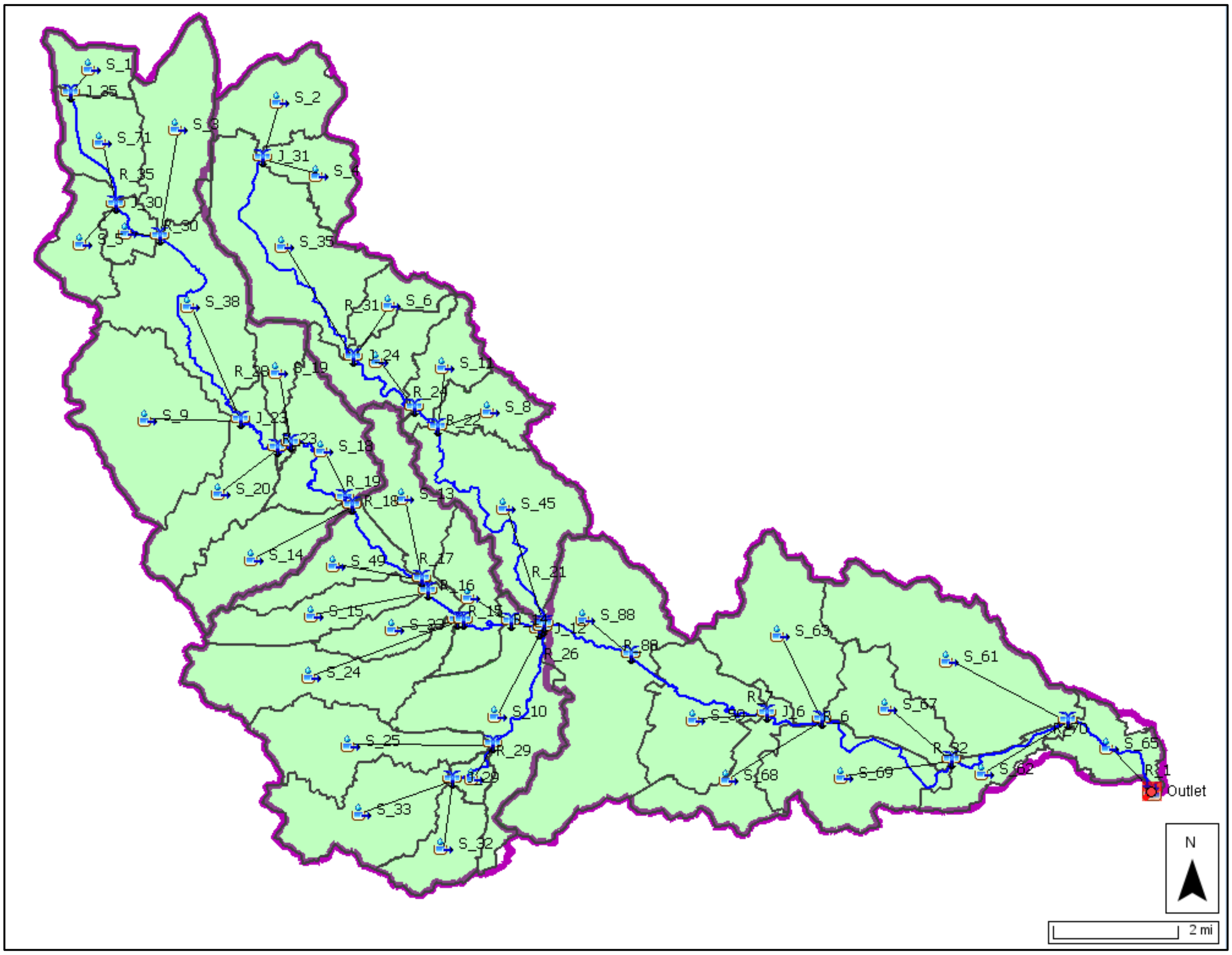

Figure 19 HEC-HMS Basin Model of Racoon Creek

BASIN PARAMETERS

HDR selected the following basin modeling methodologies:

- Loss Method: SCS Curve Number

- Transform Method: SCS Unit Hydrograph
- Baseflow Method: Recession
- Routing Method: Lag

Loss Method

HDR assigned the base SCS Curve Numbers for each subbasin as the basin averaged values of a Curve Number raster. The Curve Number raster was developed from the National Land Cover Database (NLCD) and the corresponding Curve number values in TR-55.

Transform Method

HDR assigned the base SCS Unit Hydrograph lag time with the following formula:

$$T_{lag} = \frac{L^{0.8}(S+1)^{0.7}}{1900\sqrt{Y}}$$

where,

T_{lag} = lag time in hours
L = hydraulic length of watershed in feet (assumed to be HEC-HMS subbasin longest flow length)
Y = watershed slope in percent (assumed to be HEC-HMS subbasin slope)
S = maximum retention in watershed in inches as defined by

$$S = \frac{1000}{CN} - 10$$

CN = SCS Curve Number for the watershed (assumed to be subbasin average Curve Number, described in Loss Method Section)

Baseflow Method

HDR assigned the recession baseflow method assuming that the recession constant and the ratio to peak is 0.5, and the initial discharge is 0 cubic feet per second.

Routing Method

HDR assigned the initial lag to each reach by dividing the reach length by the mean velocity using Manning's formula:

$$v = \frac{1.486}{n} R_h^{\frac{2}{3}} S^{\frac{1}{2}}$$

where,

v = cross-sectional mean velocity (feet per second)
n = Manning coefficient of roughness (assumed to be 0.045 for all reaches)
R_h = hydraulic radius (assumed to be 3 feet)
S = slope in feet/feet (assumed to be average reach slope)

HEC-HMS CALIBRATION

HDR calibrated the HEC-HMS model based on the June 5-8, 2024, storm. Both observed precipitation and streamflow were recorded at the USGS stream gage near Raccoon Creek near

Granville, Ohio. The meteorologic model for the June 2024 storm is a user-specified hyetograph from the USGS gage, which assumes rainfall recorded at the USGS gage was uniform over the watershed. HDR calibrated the HEC-HMS basin parameters by scaling the base parameters until the simulated hydrograph shape and peak flow approximately matched the USGS gage record (see **Figure 19**). The reach routing parameters are the exception to the calibration approach. Instead of scaling the calculated velocity, HDR selected an average velocity of 2.5 miles per hour for all reaches.

100-YEAR, 24-HOUR EVENT

HDR simulated the 100-year, 24-hour storm with the calibrated basin model. The 100-year, 24-hour storm meteorologic model was a Hypothetical Storm, using the user-specified State of Ohio SCS temporal pattern found in the Ohio Department of Natural Resources' *Probable Maximum Precipitation Application Guidelines*. The storm duration is 24 hours. The precipitation method is set to a point depth. The area reduction is based on TP40, and the storm area is the watershed area of 102.1 square miles. The spatial distribution is variable by subbasin, with subbasin averaged rainfall depths from National Oceanic and Atmospheric Administration (NOAA) Atlas 14 grid for the 100-year, 24-hour storm.

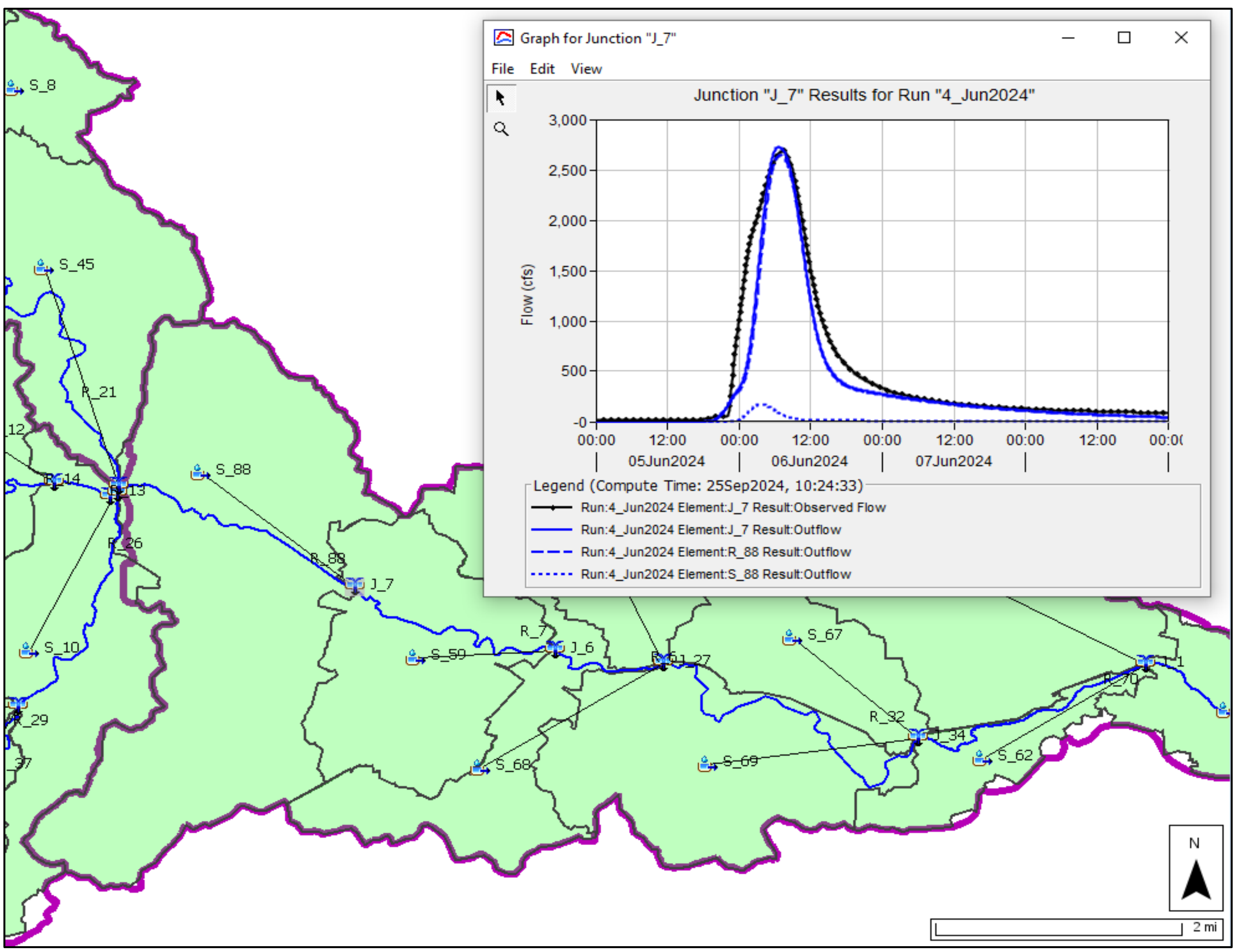

Figure 20 June 2024 HEC-HMS Racoon Creek Flood Simulation

HYDRAULICS DEVELOPMENT

HDR linked the subbasin outflows from the Racoon Creek watershed HEC-HMS model, upstream of the confluence with South Fork Licking River to HEC-RAS to simulate flooding. The HEC-HMS modeling is based on assumptions and parameter selections described in this section.

Hydraulics

The scope of work for the project called for a HEC-RAS 2D model of the subject watershed. This platform allows the modeling of an entire watershed using publicly available and surveyed data and provides hydraulic results for specific areas as required by a project. HEC-RAS can provide both spatial output for mapping and numerical results at points or profiles for planning and design of future improvements. This study is a 2D model, meaning that the simulated hydraulic gradient has both a streamwise and lateral component, as opposed to a 1D model that only simulates a hydraulic gradient in the streamwise direction. The 2D model can provide clarity on the routing and storage of flow not captured in a more focused 1D model. However, it is important to note that most floodplain models from FEMA are in 1D platforms like HEC-2 or HEC-RAS 1D, so a 2D model may not replicate the results of published studies. Replication of the FIS results are outside the scope of this project, as the model developed here is for planning purposes, not for detailed design.

HYDRAULIC MODEL DEVELOPMENT

The watershed area delineated in the HEC-HMS model was also used in HEC-RAS as the basis for the study. As discussed above, a one-meter DEM for the USGS was used to delineate the watershed. The same dataset was used as the terrain base in HEC-RAS. Because hydrology was developed in HEC-HMS, land cover, soil, and infiltration data were not active in the HEC-RAS model.

Figure 21 HEC-RAS 2D Model Domain

Mesh Development

Using the tools available in the HEC-RAS RASMapper, a 2D mesh was prepared with a default cell size of 500 feet by 500 feet. For most of the watershed, the default cell size was retained as the HEC-HMS hydrology only adds flow at specific locations in the stream channel. In these stream channels, additional details were added to the mesh using breaklines and more closely spaced cell center points. Since this is a coarse scaled model of the entire watershed, detailed breaklines were used only for streambank and some roadway features near the main channel. Hydraulic structures, buildings, and roadways away from the main channel were not included when preparing the mesh. Increased mesh densities were also used near major bridge crossings over the channels of Raccoon Creek, Lobdell Creek, and Moots Run to provide more detail and allow better representation of debris blockages.

Boundary Conditions

The downstream boundary condition for the model was located at the confluence of Raccoon Creek and the South Fork of the Licking River. This was a normal depth boundary with a friction slope of 0.0025 feet per foot, based on the USGS terrain data. Inflow boundary conditions were added for each subcatchment generated by the HEC-HMS model. Flows were added to a cell face near the downstream outlet of each subcatchment.

Point inflows in a HEC-RAS model do not replicate the continuous flow increases along a river reach. However, splitting the point flows into many subcatchments mitigates this effect in the more downstream reaches of the model. Since the most critical areas in this watershed are built-up areas near the four communities, downstream of several subcatchment outlets, the hydraulic simulations from these areas are more physically accurate. The largest impacted area, in Newark, is at the downstream reach of the model, with nearly all subcatchments upstream.

Major Structural Features and New Bridge Survey Data

The Silver Jackets study and information from the SLWCD indicated that debris buildup at bridges and throughout the watershed is a concern during storm events, as logjams can restrict flow. Since the USGS terrain data did not contain bridge information, detailed bridge opening was incorporated into the HEC-RAS model using the available data. Data for 15 key bridges (**Table 7**) crossings were obtained from site survey, including deck elevations, pier width and spacing, and deck thickness. For other bridges, where record plans were available, information from the drawings was used in the model. All other structures used placeholder data based on inferences from surrounding structures and publicly available image data.

Table 4 Bridges that were Surveyed

ID #	Bridge Name	Location	Stream Crossing
1	Scenic Railroad bridge	Newark	Raccoon Creek
2	CSX Railroad bridge	Newark	Raccoon Creek
3	Wilson Street	Newark	Raccoon Creek

ID #	Bridge Name	Location	Stream Crossing
4	Jefferson Street	Newark	Raccoon Creek
5	W. Main Street	Newark	Raccoon Creek
6	N. 11th Street	Newark	Raccoon Creek
7	Church Street	Newark	Raccoon Creek
8	N. 21st Street	Newark	Raccoon Creek
9	Church Street	Newark	Raccoon Creek
10	Cherry Valley Road	Newark	Raccoon Creek
11	Moots Run Road	Alexandria	Moots Run
12	Raccoon Valley Road	Alexandria	Moots Run
12A	Raccoon Valley Road	Alexandria	Moots Run
13	Jersey Mill Road	Alexandria	Raccoon Creek
14	Mink Street	Johnstown	Raccoon Creek

Appendix A includes the detailed survey results for the bridges that were surveyed. Survey work completed and data collected included the following:

- Established site control, vertical and horizontal used to locate the bridge
    - Ohio State Plane (South Zone) established by ODOT VRS
    - North American Vertical Datum of 1988
- Located centerline of road at the beginning and end of the approach slabs, centerline of road at the forward and rear abutments, middle of the bridge, and edge of bridge to determine bridge width and noted the bridge type (slab, beam, box culvert, other)
- Located the bottom of beam at the forward and rear abutments and at the center of each pier and deck thickness was noted on all bridges
- Located the creek bottom and ground at the center of each pier
- Located each pier and note width and type (rounded nose, square, cylinder, other) and note the number of piers and the spacing between piers.

There are two low-head dams in the Raccoon Creek watershed. Due to lack of as-builts and bathymetry, these were not included in the current version of the model. Low-head dams' impact on large flood flows (in the 100-year range) is generally negligible. Adding these structures may increase the model's accuracy and will be required for any future floodplain regulatory modeling.

Recurrence Intervals

2-, 5-, 10-, 25-, 50-, 100-, and 500-year storms were included in the baseline model runs. Each event used a 24-hour duration based on the ODNR PMP guidance as discussed in the Hydrology section. The 100-year storm was used for model validation, with comparisons to the USGS gage data and FIS profiles from FEMA. As additional checks, HDR simulated the peak 100-year flow from the PMP distribution as a steady state flow and the 100-year, 24-hour event using the SCS Type II distribution.

The 100-year, 24-hour hydrograph was from the HEC-HMS model. The other recurrence interval hydrographs were prepared by scaling proportionally according to a flood frequency analysis performed in HEC-SSP. This analysis used the Bulletin 17B methodology and the local USGS gage data to develop flows for event return period at the gage location near Granville. HDR considered this location representative of the entire watershed for the purposes of this analysis. Scaling was applied using a multiplier in the unsteady flow settings in HEC-RAS.

SIMULATION SETTINGS

Model runs were unsteady flow simulations in HEC-RAS. The program was set to run for 72 hours total, with the first 24 hours including the event, and additional time at the end to account for flow routing through the watershed.

The simulation used a variable timestep with a minimum of 7.5 seconds and a maximum of 8.0 minutes.

The Shallow Water Equations (Eulerian-Lagrangian Method) were chosen over the standard Diffusion Wave equations as the system is steep in some places and hydraulic jumps were expected at several bridge openings based on the FIS.

MODEL COMPARISON

While model calibration was outside the scope of this project, FIS data are publicly available and can be used to compare the results of the model to previous studies. **Table 4** compares the flows in the steady state model to the posted flows in the FIS study. These comparisons are made at the same location in the hydraulic model.

Table 5 Flow Comparison

Location	FIS Flows (cfs)	Model Flows (cfs)
Confluence with SFLR	13,528	14,150
Confluence with Moots Run	9,257	9,370
Confluence with Simpson Run	6,558	5,520
Confluence with Pet Run	5,862	4,604
Confluence with Kiber Run	2,829	2,290
Upper Study Limit	1,133	1,244

Specific water surface elevation comparison between the 100-yerar FIS and the current HEC-RAS 2D model at key points along the main channel are included in Table 3.

Table 6 WATER Surface Elevation Comparison (downstream of structure)

Location	FIS 100-yr WSE	Model 100-yr WSE*	+/- (ft)
CSX Railroad Bridge	821.0	821.0	0
W Main St, Newark	825.0	825.0	0
11th St N, Newark	827.5	827.5	0
W Church St, Newark	846.0	844.1	-1.9

Location	FIS 100-yr WSE	Model 100-yr WSE*	+/- (ft)
Cherry Valley Rd	879.0	879.2	+0.2
OH-16, Granville	899.0	901.0	+2.0
OH-661	912.0	913.1	+1.1
Confluence with Lobdell Creek and Moots Run	934.1	935.0	+1.0
Jersey Mill Rd	963.5	964.3	+0.8
Caswell Rd	1042.0	1042.0	0
Mink St	1054.1	1054.1	0
US-62	1060.4	1060.4	0

using the Ohio PMP distribution

Because the model methodology differs significantly from that used for the FIS, including the platform, input data, and hydrology, close convergence between the models is not expected. The results given by the 2D HEC-RAS model are generally within a foot of the FIS, with divergence at locations where model parameters likely differ significantly, like bridge openings and areas where roadways act as a barrier to flow in the FEMA model. Should project recommendations include work that will impact the floodplain, additional study will be required to align the project models to the satisfaction of the floodplain authorities. For the purposes of this study, HDR considers this level of convergence sufficient to make planning-level decisions about the potential flooding impacts in the watershed.

Further Study to meet FEMA Floodplain Regulatory Requirements

Further study is warranted to utilize this planning level model and update it to meet FEMA criteria for floodplain mapping and regulation. Following FEMA's Guidance for Flood Risk Analysis and Mapping, Hydraulics: Two-Dimensional Analysis (December 2020 Guidance Document 81) in future studies will allow the model to be utilized in updating the entire FIS for Raccoon Creek, Moots Run, and Lobdell Creek.

Additional refinements to large-scale H&H models are always possible. The most useful avenue for further study would be model calibration using high water mark information, flood event data, stage, and discharge stream gages throughout the watershed. Other avenues for further refinement could include:

- Detailed land use and Manning's roughness delineation, especially in and near the main channel.
- Additional bridge opening surveys to better represent hydraulic conditions at all structures. These would include the bridges that were not surveyed as part of this study and where as-built plans are non-existent. See exhibit in **Appendix A** showing all bridges and their status (surveyed as part of this study, entered from plan set information, estimated from terrain and aerial photography). The surveys should include the surrounding roadway embankments, pier, and stream channel cross-sections upstream and downstream of the structure.
    - The double bridge crossing of Raccoon Valley Road over Lobdell Creek could be modeled as a single structure for better model stability

  - There are several structures outside the main channels in the watershed that are not included in the model, including bike or multi-use paths and private drives, which could be included to better capture flow in these floodplain areas
  - Additional bridge opening surveys should include an understanding of roughness characteristics of the streambank under the bridge and immediately upstream and downstream, including in overbank areas.
- Stream channel bathymetry to increase hydraulic accuracy.
- Spatially adjusted, gauge-adjusted radar rainfall precipitation to account for rainfall differences over a large watershed.
- Incorporate building footprints, roadway breaklines, and other physical features into the terrain model to improve routing. This could also include increased mesh density in some areas, which would increase model runtimes.
- Add pipe networks (available in HEC-RAS 6.6) to increase routing detail during smaller events. The City of Newark has a municipal separate stormwater system that is not represented in this model.
- Additional mesh density and breaklines to better capture realistic flow behavior near features like bridges, elevated roadway embankments, culvert openings, and other hydraulically important features.
- The Log Pond diversion in Newark should be incorporated into the hydraulic model to capture the diversion amount and impacts to Raccoon Creek discharges upstream and downstream.

Finally, any improvements that affect the floodplain must be approved by FEMA and local floodplain authorities, so the models used to prepare the FIS should be obtained and replicated. Alternatively, additional modeling and documentation could be prepared to obtain a Letter of Map Revision (LOMR) from FEMA to re-baseline the maps in the area. This could involve extending the scope of the study downstream.

4.0 Plan Formulation & Evaluation

4.1 Plan Formulation and Data Gathering

Information regarding flood risk in the watershed was gathered through multiple sources by the project team. The major sources of data to identify and flood risk and formulate potential projects and alternatives included the following sources.

Data provided by SLWCD and LCSWCD

See Section 1.2 above for details of the data provided. For plan formulation purposes, the following reports bridge information provided excellent insight into flood risk and the needs of the watershed.

- ***South Fork Licking River Watershed Plan and Environmental Impact Statement prepared by the South Licking Water Conservancy District and U.S. Department of Agriculture. (1980, June).*** This plan included both structural and non-structural flood risk reduction projects. The structural projects that fall within the Raccoon Creek watershed include a multi-purpose reservoir on Lobdell Creek, a dry dam on Kiber Run, a dry dam on Simpson Run, obstruction removals on Raccoon Creek, and streambank stabilization of critical areas.
- ***South Licking Silver Jackets – Raccoon Creek Logjam Model, Hydrology and Hydraulics Appendix (USACE Huntington District, January 2023).*** This report is summarized in Section 1.2. The project team utilized the HEC-MS hydrologic model and the HEC-RAS hydraulic model created by the USACE as a starting point for the updates and the modeling detailed in Section 3.0. the report was focused on identifying the blockages and logjams that contribute to flood risk, erosion, and bank stability. The woody debris was mapped using aerial imagery dated March 2019 from the Licking County Auditor and categorized in the following manner:
    - Fallen Trees are represented as a single tree
    - Small logjams are represented as more than one tree or multiple pieces of debris
    - Large logjams are represented as piles of debris overtaking half of the width of the stream
    - Very large logjams are represented as piles of debris overtaking the majority of the width of the stream
    - Total blockages are represented as the stream rerouting itself due to blockage
- ***Bridge Plans and Associated Hydrology and Hydraulics Reports.*** See Appendix A for the graphic of bridges that we received plans for. SLWCD and LCSWCD coordinated with bridge owners (the city of Newark, ODOT, and Licking County) to gather bridge plans. These were entered into the updated HEC-RAS hydraulic model.

First Public Meeting – Church of Christ at Alexandria (July 18, 2024). This public meeting was held to discuss this project, the Raccoon Creek Flood Study and the Nine Element Plan focusing on water quality projects and restoration. During the presentation, HDR gave instructions and requested that all participants look at foamcore mounted hard copies of the studied streams and indicate where they are aware of flood risk issues **Figure 21** below was share with the public to show how to mark flood risks using the colored push pins and foam core mounted exhibits in the back of the room. The 100-year FEMA Floodplain was shown on the watershed exhibits which include the Johnstown area, the Alexandria area, the Granville area, and the Newark area. The PowerPoint presentation contents and photos showing the resulting flood risk data collected for this public meeting are included in **Appendix B**.

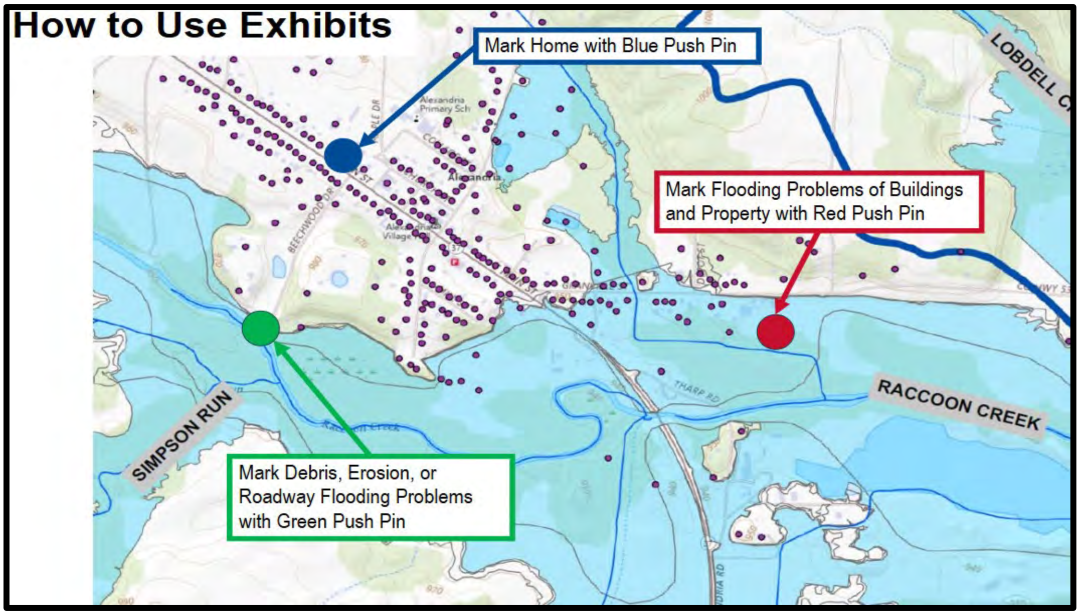

Figure 22 Public use of Exhibits (Demonstrates how the public meeting participants were asked to identify known flood risks in the study area using colored push pins on a foam core board)

Second Public Meeting - Hartford Fair Open House (August 4, 2024). This was an informal event that was used to collect flood risk data from the public attending the fair. HDR was there to answer questions on the Raccoon Creek Flood Study and demonstrate how the people could mark flood risk issues in the project area using the same approach as the first public meeting (**Figure 21**). The data collected for this public meeting is also included in Appendix B.

Raccoon Creek Flood Study Meeting with Municipalities and Agencies (August 19, 2024). The meeting was hosted by SLWCD and LCSWCD and facilitated by HDR. The attendees included representatives from Johnstown, Alexandria, Granville, Granville Township, Newark, and the Licking County Engineer. Attendees discussed flood risk challenges and proposed projects. Information and data collected from the first and second public meeting was discussed and shared. The main purpose of the meeting was to discuss planned projects and potential alternatives to be addressed during this planning study. The project types discussed included drainage and stormwater projects, bridge replacement projects, roadway projects, erosion and streambank stabilization projects, roadway projects, utility projects, and potential regulatory changes. Slides from a presentation, summarizing the content of this meeting, are provided in Appendix B.

Alternatives Meeting with Project Team (November 13, 2024). The meeting included the project team. The main goal was to identify all flood risk reduction alternatives and determine the screening and selection approach for ranking and selection. Alternatives were developed by HDR before the meeting and were listed and reviewed at a high level during the meeting to capture as many as possible within the watershed. The previous meetings and data collection, detailed above, culminated in a list of 21 viable flood risk reduction alternatives.

The 21 alternatives eclipsed the original scope of work for the study that required only three alternatives to be evaluated. The alternatives also ranged from discrete projects to projects that cover the entire watershed. Therefore, the project team devised and agreed to an approach where all 21 alternatives could be evaluated using varying degrees of detail. This led to the development of the plan formulation approach described below.

4.2 Plan Evaluation Process

The twenty-one alternatives were categorized into four categories and then a multi-criteria decision scoring system was developed to score alternatives within each of the four categories. The categorization and screening processes that make up the plan formulation process, are described below. The 21 alternatives were placed into one of the following four categories:

5) Watershed Alternatives – These alternatives are broad-based and cover the watershed area, are policy driven, or regulate the studied streams (Raccoon Creek, Lobdell Creek, and Moots Run).
6) Reach-Based Alternatives – These alternatives include regional projects that impact reaches of the studied streams. They are typically a discrete project whose benefits carry downstream through a reach of the studied streams.
7) Critical Infrastructure Alternatives – The alternatives include discrete projects that protect critical infrastructure such as a wastewater treatment plant, a water treatment plant, utilities, and first responders.
8) Site-Specific Alternatives – These alternatives are discrete flood risk reduction projects that were formulated based on localized concentration of damages and known losses based on the data collected. These alternatives include levees and/or floodwalls to reduce flood risk to more densely populated areas.

The screening process is outlined as follows:

1) Categorize each of the alternatives into one of the four categories above.
2) Rank each alternative within the categories utilizing the multi-criteria decision support scoring system (described in detail below).
3) Where possible, develop conceptual (reconnaissance-level) cost estimates for each alternative.
4) Describe the benefits of each alternative, verbally.
5) Select the appropriate alternatives to evaluate through detailed hydrologic and hydraulic modeling and economics. We are unable to model the benefits of all alternatives due to physical limitations and scope and budget constraints. A few select alternatives will be evaluated using a benefit cost ratio (BCR) approach. The economic benefits were derived using the HEC-RAS model inundation output and FEMA's HAZUS program (described in detail below). Benefits were calculated using HAZUS damages for the existing inundation conditions and subtracting the reduced HAZUS damages from the proposed inundation conditions.
6) Describe the alternatives analysis outcome and the next possible steps for each alternative.

4.3 Multi-Criteria Decision Support

Given the geographic extent of the study area and limited scope and budget, the project team decided to develop a multi-criteria ranking system to screen alternatives. This system allows screening and relative ranking of alternatives to identify those alternatives that align best with the flood resiliency, planning goals, and public interest as defined by the project team. A few of the alternatives were evaluated using economics and a detailed benefit cost analysis (BCA). In addition, some alternatives have a budgetary planning cost associated with them to aid in implementation planning.

The multi-criteria ranking system allowed the project team to rate each alternative semi-quantitatively. We assigned semi-quantitative scoring for each of the following project elements: Flood Risk Reduction; Critical Infrastructure; Operations and Maintenance; Real Estate; Environmental Impacts; Constructability; Community Benefits; Transportation Impacts; and Permitting. The scoring of each criterion is set up so that the highest benefits score is highest at 3 and the least at 0, or no benefits. Therefore, with nine criteria, the highest alternative score (most beneficial) is 27 total points. The theoretical scale of ranking is 0 to 27. **Table 7** provides detailed definitions and scoring of each of the nine criteria.

Table 7 Multi-Criteria Developed by the Study Team

Flood Risk Reduction

Ranking (Positive Impacts)	Definition
High - 3	Reduces flood risk for a range of flood events up to, and including the 100-year event magnitude
Medium - 2	Reduces flood risk for events below the 100-year event magnitude
Low - 1	Negligible flood reduction benefits difficult to quantify in hydraulic model and economic model
None	No quantifiable flood reduction benefits

Critical Infrastructure

Ranking (Positive Impacts)	Definition
High - 3	Alternative results in a utility, medical facility, fire station, or police station being protected up to and possibly **above the 100-year event**
Medium - 2	Alternative results in a utility, medical facility, fire station, or police station being protected for events **less than the 100-year event**
Low - 1	Benefits limited to roadway and crossings to allow emergency vehicles and evacuation
None	No critical infrastructure benefit

Operations & Maintenance Impacts

Ranking (Positive Impacts)	Definition
High - 3	Passive alternative requiring only limited Operation and Maintenance - For example mowing of a levee or routing bridge maintenance
Medium - 2	Alternative requires limited active operation to perform - For example, a gate closure in a floodwall or levee
Low - 1	Very high cost of operation and maintenance - For example a sandbag closure or manual floodwall
None	Operation and Maintenance burden is extensive

Real Estate

Ranking (Positive Impacts)	Definition
High - 3	Project does not require real estate acquisition (permanent nor temporary)
Medium - 2	Project requires real estate acquisition, but the land owner expresses a willingness to collaborate, it is owned by state or local government, or an agreement is in place
Low - 1	Project requires real estate acquisition of one land owner but there is not an agreement is in place
None	Real estate involve multiple parcels of private owners that are unaware of the project

Environmental Impacts

Ranking (Positive Impacts)	Definition
High - 3	Creates new habitat and has no significant impacts to wetland resources or cultural and historic resources
Medium - 2	No significant impacts to wetland resources or cultural and historic resources
Low - 1	Impacts to wetland resources or cultural and historic resources requiring mitigation
None	Impacts to wetland resources or cultural and historic resources that cannot be mitigated

Constructability

Ranking (Positive Impacts)	Definition
High - 3	Routine construction Methods with little to no in-water construction and sufficient real estate for site access, staging, and construction. Large, qualified contractor pool
Medium - 2	In the water construction limited to routine means and methods or limited real estate that could restrict access, staging and construction. Smaller, qualified contractor pool
Low - 1	Non-routine and specialized construction in the water and in proximity to infrastructure. Limited contractor pool
None	Extremely difficult construction and unique project type

Community Benefits

Ranking (Positive Impacts)	Definition
High - 3	Provides community access to amenities in the watershed, creates educational opportunities, or creates new recreational opportunities
Medium - 2	Benefits are limited to positive environmental or flood risk reduction impacts that are visible to the community
Low - 1	Benefits are limited to positive environmental or flood risk reduction impacts that are **not** visible to the community
None	No discernable community benefits

Transportation Impacts

Ranking (Positive Impacts)	Definition
High - 3	Transportation routes in the project impact area are **above** the 100-year water surface elevation
Medium - 2	Transportation routes in the project impact area are below the 100-year water surface elevation but are improved from current conditions
Low - 1	The project will include signage or warnings of flooded roadways, but will not reduce the frequency of inundation significantly
None	The project does not reduce risks to transportation

Permitting

Ranking (Positive Impacts)	Definition
High - 3	Permitting is not required, or is routine in nature. For example, a bridge replacement project
Medium - 2	Permits may require additional information and coordination but can be covered under federal, state, or local permits with a precedence of approval
Low - 1	Permits require **unique and detailed** coordination, analysis, and agreements with the regulatory authority
None	Regulatory agencies may not be able to make a determination on permit

4.4 Economic Benefits Evaluation

FEMA's HAZUS program is a nationally standardized risk assessment tool designed to estimate potential losses from natural disasters like earthquakes, hurricanes, floods, and tsunamis. It uses

Geographic Information Systems (GIS) technology to provide insights into disaster planning, mitigation, and emergency response. Key features of HAZUS include:

- Economic Loss Estimation: It estimates economic impacts such as repair and reconstruction costs, business interruptions, and lost jobs.
- Physical Damage Assessment: It assesses damage to buildings, infrastructure, and critical facilities.
- Social Impact Analysis: It estimates social impacts like displaced households and shelter requirements.
- Mitigation Planning: It helps planners identify effective mitigation actions to minimize potential losses.
- Real-Time Response: It can be used during real-time events to estimate impacts and inform response strategies.

For this study, the focus was on flooding and defining the economic impacts of alternatives using the economic loss estimation, physical damage assessment, and social impact analysis output from HAZUS. This was accomplished by evaluating the existing flood depth conditions (from the HEC-RAS model) and proposed flood depth conditions (with alternative HEC-RAS model) in the HAZUS program. For any flooding scenario evaluated the program returns a table of damages based on census tract block.

The HAZUS output table categorizes losses into the following occupancy types: AGR – Agricultural; COM – Commercial; EDU – Educational; GOV – Governmental; IND – Industrial; REL – Religion; and RES – Residential. The following are the damages computed and reported in the HAZUS output table headings:

- **Total Loss** – Total of all categories
- **Building Loss** - Cost to repair or replace damaged structures
- **Contents Loss** - Damage to furniture, equipment, and other contents
- **Inventory Loss** - Loss of raw materials, finished goods, or supplies
- **Relocation Cost** - Expenses related to temporary relocation of businesses or residents
- **Income Loss** - Reduction in business income due to downtime
- **Rental Income Loss** - Loss of rental revenues from damaged properties
- **Wage Loss** - Loss of wages due to workforce displacement or business closures
- **Direct Output Loss** - A metric that estimates the value of lost productivity or economic output (e.g., goods and services) due to business interruptions caused by the disaster. HAZUS distinguishes between property-related economic losses (physical and financial damages captured in the Total Loss Output calculation) and productivity-related losses (measured by Direct Output Loss).

The HAZUS program, developed by FEMA, can be utilized for many federal grant programs and is widely accepted. For alternatives below that do not net a positive BCR (greater than 1.0), more refined economic evaluation and plan formulation may be warranted in future phases. It should be noted that the BCR is not the only way to evaluate and select the merit of an alternative. There are many other factors that may support project implementation, such as those described in the multi-criteria decision support section above.

Total flood losses were estimated for the updated 100-Year hydrologic (HEC-HMS) and hydraulic (HEC-RAS) models using steady state discharges using HAZUS. See HAZUS output in **Table 7**.

Table 8 Total HAZUS Flood Losses using Steady State Discharges

Occupancy Type	Total Loss	Building Loss	Contents Loss	Inventory Loss	Relocation Cost	Income Loss	Rental Income Loss	Wage Loss	Direct Output Loss
AGR	**$456,000**	$41,000	$154,000	$157,000	$17,000	$65,000	$0	$22,000	$262,000
COM	**$97,822,000**	$7,916,000	$22,591,000	$6,096,000	$7,096,000	$24,747,000	$5,240,000	$24,136,000	$56,287,000
EDU	**$43,000**	$2,000	$14,000	$0	$0	$7,000	$0	$20,000	$186,000
GOV	**$3,113,000**	$19,000	$139,000	$0	$127,000	$92,000	$51,000	$2,685,000	$618,000
IND	**$8,400,000**	$2,159,000	$4,446,000	$759,000	$360,000	$221,000	$66,000	$389,000	$1,669,000
REL	**$3,014,000**	$172,000	$1,128,000	$0	$209,000	$437,000	$21,000	$1,047,000	$5,866,000
RES	**$33,660,000**	$10,750,000	$6,325,000	$0	$4,594,000	$2,373,000	$4,035,000	$5,583,000	$12,441,000
Total	**$146,508,000**	**$21,059,000**	**$34,797,000**	**$7,012,000**	**$12,403,000**	**$27,942,000**	**$9,413,000**	**$33,882,000**	**$77,329,000**

Total flood losses were estimated for the updated 100-Year hydrologic (HEC-HMS) and hydraulic (HEC-RAS) models using unsteady state discharges using HAZUS. See HAZUS output in **Table 8**.

Table 9 Total HAZUS Flood Losses using Unsteady State Discharges

Occupancy Type	Total Loss	Building Loss	Contents Loss	Inventory Loss	Relocation Cost	Income Loss	Rental Income Loss	Wage Loss	Direct Output Loss
AGR	**$169,000**	$12,000	$57,000	$57,000	$4,000	$30,000	$0	$9,000	$119,000
COM	**$13,157,000**	$846,000	$2,406,000	$386,000	$708,000	$4,737,000	$543,000	$3,531,000	$8,384,000
EDU	**$14,000**	$0	$4,000	$0	$0	$3,000	$0	$7,000	$79,000
GOV	**$241,000**	$1,000	$12,000	$0	$0	$6,000	$0	$222,000	$48,000
IND	**$1,062,000**	$281,000	$632,000	$74,000	$19,000	$18,000	$5,000	$33,000	$159,000
REL	**$214,000**	$9,000	$76,000	$0	$2,000	$37,000	$0	$90,000	$523,000
RES	**$5,169,000**	$1,741,000	$1,099,000	$0	$470,000	$457,000	$328,000	$1,074,000	$2,395,000
Total	**$20,026,000**	**$2,890,000**	**$4,286,000**	**$517,000**	**$1,203,000**	**$5,288,000**	**$876,000**	**$4,966,000**	**$11,707,000**

The difference in total damages estimated by HAZUS is significant between the two possible routing methods, steady state ($146,508,000) and unsteady state ($20,026,000). For this study, HDR has chosen to utilize both the steady state (constant discharges throughout the system) and unsteady state (routing hydrographs through the system) hydraulic models for economic analysis as follows:

- For the analysis of debris loading and its economic impacts, HDR has determined a range between the unsteady state and the steady state discharge hydraulic model is appropriate. This is because the hydraulic model runs with debris loading is not trying to replicate debris loading and how it moves through the system, but rather, it is an attempt to identify potential maximum economic impacts of the high debris load in the watershed at various critical bridges and locations as supported by the USACE Silver Jackets Study (2023). This is a rather broad range, as presented below, but really highlights the potential negative flood risk presented by debris and blockages in this watershed.

- For the analysis of floodwalls and levees, HDR has selected to utilize the steady state discharge hydraulic model. This is because these flood risk reduction structures are usually formulated based on FEMA water surface elevations. HDR is recommending that the steady state discharge model be utilized for future floodplain mapping (see the **important note** below regarding future FEMA regulatory modeling).
- For the analysis of reservoirs and off channel storage, HDR is recommending utilizing the unsteady state hydraulic model. The unsteady state hydraulic model is better able to model the storage, and attenuation impacts of these alternatives and route them downstream to pick up subsequent benefits.

Important note: HDR recommends utilizing the steady state discharge for floodplain regulation in accordance with FEMA practice for the following reasons:

- To reduce the uncertainties associated with the unsteady model. These uncertainties include storm direction, storm centering, rainfall intensity variability, and other physical processes that are too detailed to capture in watershed scale models.
- The steady state discharge is utilized in a majority of FEMA FIS and Mapping nationally.
- Steady state model results provide a conservative high estimation of the water surface elevation. This conservatism can cover some debris blockage and mitigate for the uncertainties that are inherent in unsteady routing models.

4.5 Cost Estimating and Benefit Cost Ratios

The opinions of cost and benefit cost ratios provided in this report are intended to allow a comparative evaluation between alternatives and do not constitute a detailed evaluation or prediction of actual construction costs or project feasibility.

Construction cost estimates contained in this report are considered Class 5 estimates in accordance with the Association for the Advancement of Cost Engineering (AACE), which is appropriate for conceptual or screening-level estimates. For the purposes of this report, a contingency of 50% was applied to each alternative sub-total.

Engineering, analysis, design, bidding services permitting, and construction administration are not included in the cost estimates in this report. In addition, the cost estimates do not include land or easement costs. The costs and benefit cost ratios developed in this report should be refined for the alternatives that are selected for the Watershed Plan update. This refinement should also include evaluating damages at events below and above the 100-year flood to estimate expected annual damages or similar when moving to feasibility analysis.

5.0 Alternatives Assessment

The following sections detail the twenty-one alternatives, by category, and their assessment using the plan formulation process described above.

5.1 Proposed Watershed Alternatives (WA)

Watershed Alternatives are broad-based and cover the watershed area, are policy driven, or regulate the studied streams (Raccoon Creek, Lobdell Creek, and Moots Run). The following watershed alternatives (WA) were identified and evaluated:

- ***WA-1.*** Federal Emergency Management Agency (FEMA) Flood Insurance Study (FIS) Update for Raccoon Creek, Moots Run, and Lobdell Creek
- ***WA-2.*** Risk Informed Streambank Stabilization Program and Mitigation Fund
- ***WA-3.*** More Restrictive Zoning, Stormwater Permitting, Setbacks and Buffers
- ***WA-4.*** Flood Warning System Update

Utilizing the multi-criteria decision support system, the project team produced the following relative ranking of these alternatives. It should be noted that all alternatives are ranked high, which indicates they have similar merits and benefits.

Table 10 Multi-criteria Ranking of Watershed Alternatives

Criteria		WA-1	WA-2	WA-3	WA-4
1	Flood Risk Reduction	3	3	2	3
2	Critical Infrastructure	3	2	2	3
3	Operations and Maintenance	3	1	3	1
4	Real Estate	3	2	3	3
5	Environmental Impacts	3	3	3	3
6	Constructability	3	3	3	3
7	Community Benefits	3	3	3	3
8	Transportation Impacts	2	2	2	2
9	Permitting	3	3	3	3
	Totals	26	22	24	24

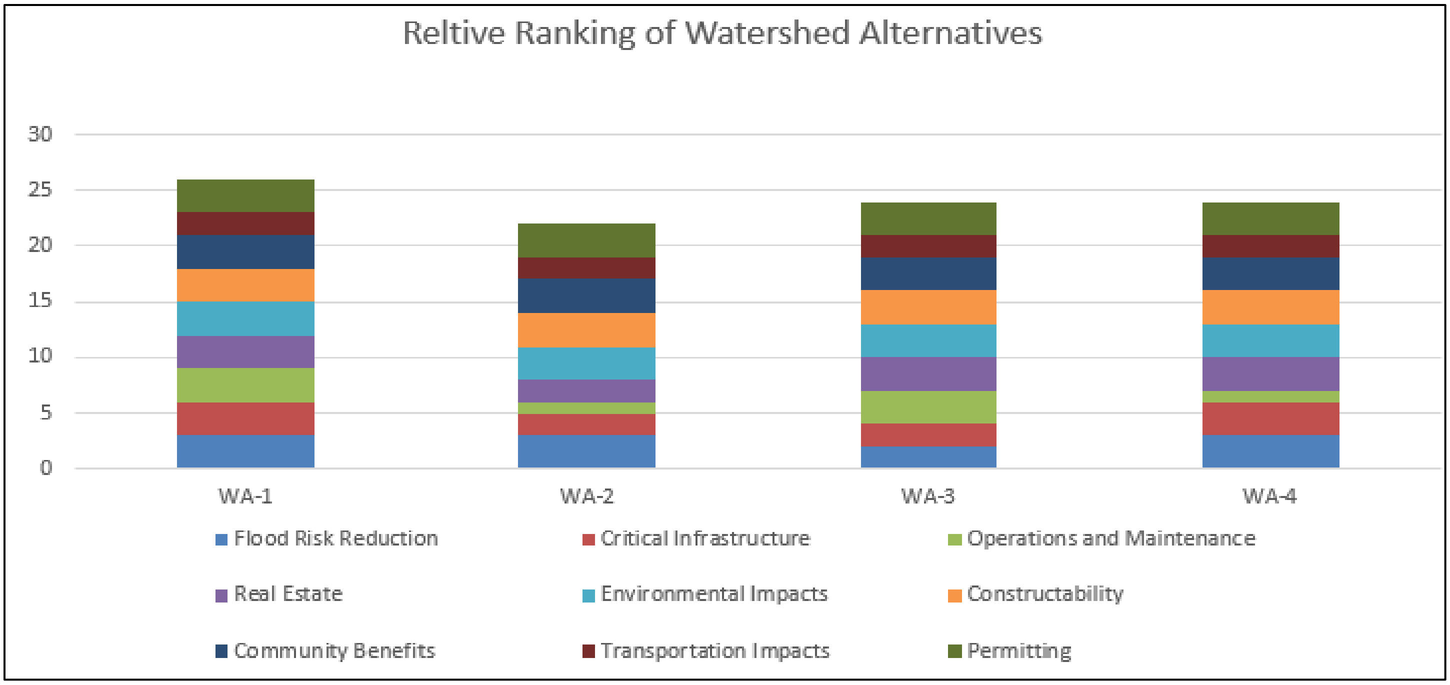

Figure 23 Multi-criteria Ranking of Watershed Alternatives

WA-1. **FEMA FIS Update for Raccoon Creek, Moots Run, and Lobdell Creek**

This alternative is to utilize the hydrologic (HEC-HMS) and hydraulic (HEC-RAS) models developed as part of this planning study to develop regulatory models and mapping for the entire reaches of Racoon Creek, Lobdell Creek, and Moots Run. These model and mapping updates will be in accordance with FEMA criteria and Licking County floodplain regulations.

Further model development is required to utilize the planning level models and update them to meet FEMA criteria for floodplain mapping and regulation. Following FEMA's Guidance for Flood Risk Analysis and Mapping, Hydraulics: Two-Dimensional Analysis (December 2020 Guidance Document 81) in this alternative will allow the model to be utilized in updating the entire FIS for Raccoon Creek, Moots Run, and Lobdell Creek. For hydraulic model details, we suggest performing all the updates detailed in Section 3.2 above. In addition, HDR suggests utilizing the steady state discharges for the mapping of the FEMA regulatory floodplain, floodway, and various recurrence intervals.

Benefits. This will provide an updated regulatory model for floodplain management. The model will be a 2-dimensional hydraulic model that will reflect updates to land use, topography, physical crossings, and other details that are lacking in the current effective 1-dimenisoinal FEMA model. The benefits are widespread, covering the entire watershed. In general, FEMA's floodplain regulations offer several benefits that help communities become more resilient to flooding and other natural disasters including:

1. Reduced Flood Risk: By implementing floodplain management practices, communities can minimize the risk of flooding and its associated damages.
2. Economic Savings: Effective floodplain management can lead to lower flood insurance premiums and reduced costs for disaster recovery and rebuilding.

3. Environmental Protection: Floodplain regulations help preserve natural floodplains, which provide critical habitats for wildlife and maintain water quality.
4. Community Safety: These regulations ensure safer building practices and land use in flood-prone areas, protecting lives and property.
5. Enhanced Resilience: Communities that adopt higher standards of floodplain management are better prepared to withstand and recover from flood events

Costs. Costs for the additional data collection, model updates, coordination with regulatory officials (FEMA, State of Ohio, and Licking County), FEMA submittals, FEMA review coordination, and final map and report submittals, are estimated to be approximately $350,000. This is not a detailed cost estimate, but rather, an order of magnitude cost estimate to complete the work. Coordination efforts and requirements of the federal, state, and local agencies may significantly impact the efforts required to develop the updated FEMA floodplain mapping.

WA-2. **Risk Informed Streambank Stabilization and Debris Management Program and Mitigation Fund**

The Raccoon Creek watershed, located in Licking County, OH, has been rapidly developing in recent years with business, retail, and housing developments. The current watershed is a mix of urban, agricultural, and heavily forested land use with highly erodible streambank soils. This combination of large woody debris sources and highly erodible soils currently generate log jams and debris dams at roadway crossings and bridges that greatly compounds flooding as noted in the USACE Silver Jackets Study (2023). The HEC-RAS hydraulic model with debris loading (as described in Section 2.3) was utilized to estimate the total potential increase in flooding due to debris loading at bridges throughout the study area.

Developing a risk informed streambank stabilization program and mitigation fund, will reduce flood damage by actively managing the stream corridor through the development of a risk informed framework that overlays debris loading, critical crossings, and bank erosion severity. This framework will be utilized to develop an operations and maintenance plan for debris and also develop a nature-based stream bank stabilization and stream restoration master plan for the entire studied watershed (over 20 miles of streambank).

The banking part of this alternative will function in policy and implementation, similar to wetland banking where developers in the watershed would offset negative hydrologic run-off impacts (increased base flows and impervious surface impacts) by funding streambank stabilization working through the risk informed stream restoration plan. The funding provided by developers would go to repair the highest risk locations to reduce risks within the watershed.

Benefits. This will provide a risk informed plan and an adaptive management plan that will allow SLWCD actively manage the large debris loading within the basin. The banking and regulatory element will also provide a funding stream tied to development that will encourage responsible development and active flood risk reduction.

The total economic benefits of this program associated with the 100-year event could range from approximately **$350 Million dollars** ($370 Million [**Table 11**] minus $20 Million [**Table 8**] for the unsteady model conditions) up to **$407 Million dollars** ($554 Million [**Table 10**] minus $147 Million [**Table 7**] for the steady model conditions). These flood risk reduction benefits reflect the importance of managing debris and blockages to reduce flood risks within the watershed. It should be noted that the hydraulic model runs with debris loading is not trying to replicate debris loading and how it moves through the system, but rather, it is an attempt to identify potential maximum economic impacts of the high debris load in the watershed at various critical bridges and locations.

Table 11 Total HAZUS Flood Losses with Debris Loading using Steady State Discharges

Occupancy Type	Total Loss	Building Loss	Contents Loss	Inventory Loss	Relocation Cost	Income Loss	Rental Income Loss	Wage Loss	Direct Output Loss
AGR	**$1,854,000**	$245,000	$624,000	$707,000	$39,000	$174,000	$0	$65,000	$671,000
COM	**$384,230,000**	$41,575,000	$112,269,000	$25,802,000	$22,440,000	$79,189,000	$16,294,000	$86,661,000	$199,133,000
EDU	**$587,000**	$8,000	$36,000	$0	$62,000	$142,000	$2,000	$337,000	$2,926,000
GOV	**$4,285,000**	$71,000	$463,000	$0	$162,000	$117,000	$65,000	$3,407,000	$784,000
IND	**$48,898,000**	$12,069,000	$30,307,000	$4,402,000	$700,000	$473,000	$130,000	$817,000	$3,478,000
REL	**$8,418,000**	$587,000	$3,624,000	$0	$536,000	$1,071,000	$55,000	$2,545,000	$14,222,000
RES	**$106,665,000**	$47,808,000	$23,848,000	$0	$11,815,000	$4,166,000	$9,222,000	$9,806,000	$21,853,000
Total	**$554,937,000**	**$102,363,000**	**$171,171,000**	**$30,911,000**	**$35,754,000**	**$85,332,000**	**$25,768,000**	**$103,638,000**	**$243,067,000**

Table 12 Total HAZUS Flood Losses with Debris Loading using Unsteady State Discharges

Occupancy Type	Total Loss	Building Loss	Contents Loss	Inventory Loss	Relocation Cost	Income Loss	Rental Income Loss	Wage Loss	Direct Output Loss
AGR	**$1,315,000**	$148,000	$443,000	$505,000	$35,000	$135,000	$0	$49,000	$525,000
COM	**$257,155,000**	$26,321,000	$75,045,000	$20,251,000	$15,256,000	$52,317,000	$11,209,000	$56,756,000	$130,268,000
EDU	**$92,000**	$7,000	$30,000	$0	$0	$16,000	$0	$39,000	$353,000
GOV	**$1,118,000**	$25,000	$168,000	$0	$25,000	$29,000	$10,000	$861,000	$195,000
IND	**$41,647,000**	$9,946,000	$25,985,000	$3,838,000	$642,000	$411,000	$117,000	$708,000	$3,001,000
REL	**$6,782,000**	$454,000	$3,046,000	$0	$426,000	$835,000	$43,000	$1,978,000	$11,048,000
RES	**$62,126,000**	$31,459,000	$14,861,000	$0	$8,279,000	$911,000	$4,470,000	$2,146,000	$4,784,000
Total	**$370,235,000**	**$68,360,000**	**$119,578,000**	**$24,594,000**	**$24,663,000**	**$54,654,000**	**$15,849,000**	**$62,537,000**	**$150,174,000**

Costs. Development of the initial Risk Informed Streambank Stabilization and Debris Management Master Plan will include additional data collection (Stream assessment, soil erodibility assessment, stream mechanics, model evaluation of velocities, vegetation assessment, etc.), criteria definitions, risk definitions, risk weighting, bench testing of the tool, hydraulic model updates, and coordination with regulatory officials (Licking County, SLWCD, LCSWCD, and local communities). The costs associated with the initial Master Plan are estimated to be approximately $400,000. As regulatory and banking aspects evolve, additional costs will likely be required for full implementation, management of the program, and subsequent updates and adaptive management as lessons are learned in the implementation of the program. This is not a detailed cost estimate, but rather, an order of magnitude cost estimate to complete the initial work. Details and adoption of the

Risk Informed Streambank Stabilization and Debris Management Master Plan will require further investment.

***WA-3.* More Restrictive Zoning, Stormwater Permitting, Setbacks and Buffers**

This alternative is not singular. It could be comprised of various elements. This could include more rigorous stormwater requirements for future development that is focused on pervious surface and aggregate land use changes through urbanization of certain areas of the watershed. The upper watershed is particularly at risk due to the smaller watershed area and rapid development and conversion of open lands to other purposes that have a high percentage of impervious surfaces. the relative effect development will have larger impacts in the smaller upper watershed catchment area. Managing run-off and infiltration to higher standards (i.e., regulating to the 100-year rainfall event instead of the critical storm or lesser rainfall event) may be required to avoid higher baseflows downstream and off site that may result in higher erosion rates and increased streambank instabilities. Instituting infiltration zones, runoff buffers, green infrastructure, and other common site-scale management options can offset some of the negative flood risk impacts of development.

Benefits. Zoning restrictions and changes, such as those suggested above, offer several benefits to communities and property owners:

1. Maintains Community Standards: Zoning ensures that land use is compatible with the surrounding area, preserving the character and aesthetics of neighborhoods.
2. Protects Property Values: By preventing incompatible land uses, zoning helps maintain and potentially increase property values.
3. Promotes Public Safety: Zoning regulations can help ensure that buildings and land uses are safe and appropriate for their locations, reducing risks to residents.
4. Encourages Efficient Land Use: Zoning helps organize land use in a way that maximizes efficiency and sustainability, promoting orderly development.
5. Supports Economic Development: By designating specific areas for commercial and industrial use, zoning can attract businesses and create jobs while keeping residential areas peaceful.
6. Environmental Protection: Zoning can protect natural resources and open spaces by restricting development in sensitive areas and limiting downstream flooding and erosion impacts

Costs. Due to complexities, costs were not developed for this alternative.

***WA-4.* Flood Warning System Update**

This alternative includes adding additional rainfall and stream gages in the watersheds and linking them with the updated hydrologic and hydraulic models to enhance the current flood warning system in the watershed. The models would utilize gage adjusted radar runoff data to evaluate actual storm events and check action levels at various critical locations within the watershed. It is possible that a forecast feature could be added into the warning system to allow longer warning times.

Benefits. Flood warning systems offer several important benefits that help communities prepare for, and respond to, flood events including:

1. Early Detection: They provide timely alerts about impending floods, allowing residents and authorities to take necessary precautions.
2. Reduced Loss of Life: Early warnings can help evacuate people from high-risk areas, such as the assisted living facility in Granville, possibly reducing the risk of fatalities.
3. Property Protection: By giving advance notice, these systems can minimize damage to homes, businesses, and infrastructure by allowing people to protect in place or remove vehicles. This is a function of warning time and may not be applicable in the upper watershed where warning times are shorter in duration.
4. Cost Savings: Effective flood warning systems can reduce the costs associated with disaster response, recovery, and rebuilding.

Costs. Due to complexities and the wide range of how this alternative can be implemented, costs were not developed for this alternative.

5.2 Proposed Reach-Based Alternatives (RBA)

Reach-Based Alternatives include regional projects that impact reaches of the studied streams. They are typically a discrete project whose benefits carry downstream through a reach of the studied streams. The following Reach-Based alternatives (RBA) were identified and evaluated:

- ***RBA-1.*** Detention Areas between SR 62 and the Johnstown Wastewater Treatment Plant (WWTP)
- ***RBA-2.*** Dam on Lobdell Creek
- ***RBA-3.*** Detention Areas south of Granville Water Treatment Plant (WTP)
- ***RBA-4.*** Bridge improvements at State Route (SR) 661 (main Street) in Granville
- ***RBA-5.*** Bridge and Conveyance Improvements in downtown Newark (Wilson Street, Jefferson Street, and West Main Street)
- ***RBA-6.*** Debris boom(s) upstream of critical bridges
- ***RBA-7.*** Nine Element Plan Water Quality Projects and Restoration

Utilizing the multi-criteria decision support system, the project team produced the following relative ranking of these alternatives. HEC-RAS inundation output and HAZUS were used to estimate the benefits associated with alternatives RAB-1, RBA-2, and RBA-3. Construction cost estimates were developed for those alternatives as well to evaluate the BCR.

Table 13 Multi-criteria Ranking of Reach-Based Alternatives

Criteria		RBA-1	RBA-2	RBA-3	RBA-4	RBA-5	RBA-6	RBA-7
1	Flood Risk Reduction	2	2	2	2	2	2	0
2	Critical Infrastructure	2	2	2	1	1	1	1
3	Operations and Maintenance	3	0	3	2	2	0	3
4	Real Estate	2	1	2	2	2	3	2
5	Environmental Impacts	3	1	3	2	2	2	3
6	Constructability	3	2	3	2	2	2	3
7	Community Benefits	2	3	2	2	2	2	2
8	Transportation Impacts	2	2	2	2	2	2	2

Criteria		RBA-1	RBA-2	RBA-3	RBA-4	RBA-5	RBA-6	RBA-7
9	Permitting	2	1	2	2	2	1	3
	Totals	21	14	21	17	17	15	19

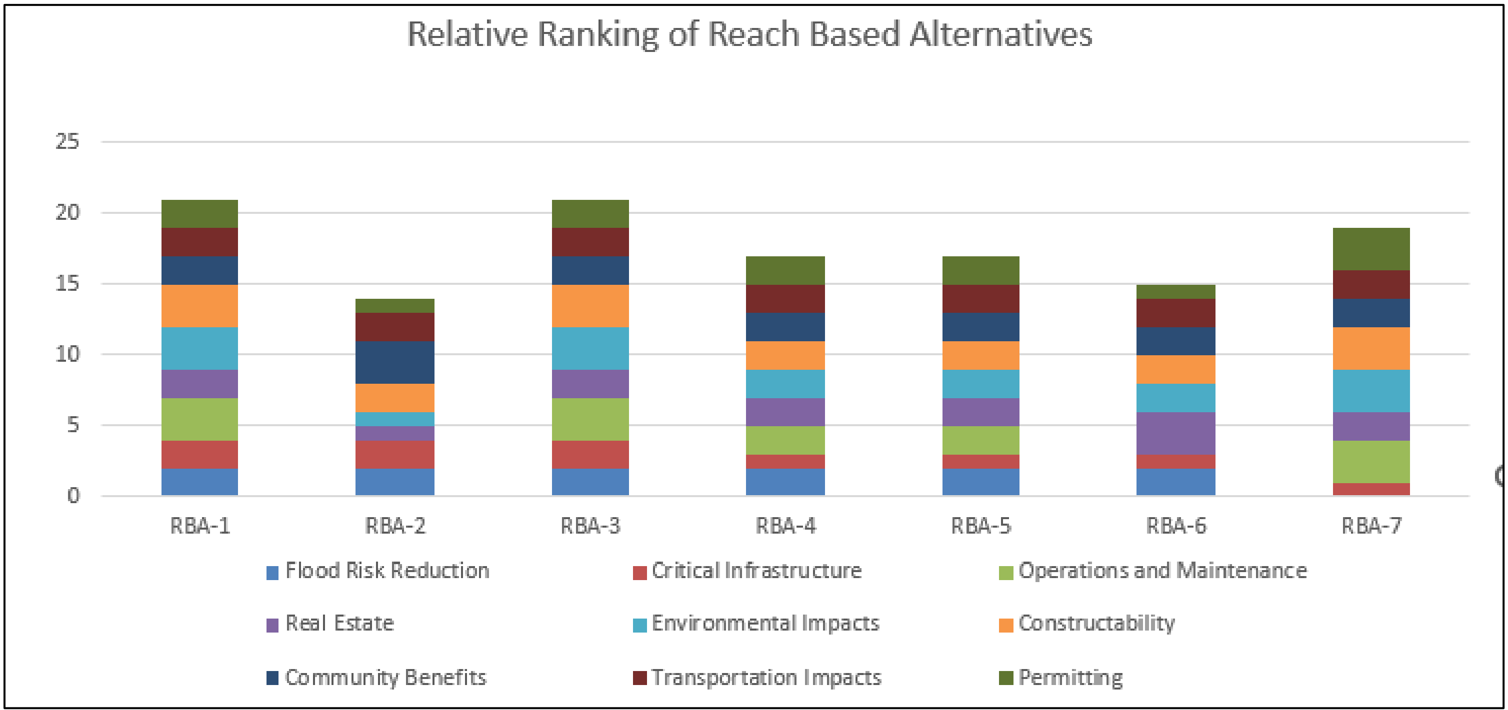

Figure 24 Multi-criteria Ranking of Reach-Based Alternatives

RBA-1. Detention Areas between SR 62 and the Johnstown Wastewater Treatment Plant (WWTP)

This alternative includes adding off-channel storage areas between SR 62 and Mink Street. During discharges in the range of 1- to 2-year flood events, Raccoon Creek would overflow into the constructed storage areas flowing over turf-reinforced weirs. This would provide off line storage of approximately 89 acre-feet of runoff from upstream of the detention areas.

Benefits. This would result in a decrease in downstream discharges due to storage attenuation. In addition to flood risk reduction, the ponding areas will revert to wetlands and provide water quality and habitat benefits that are not captured in the economics and discharge reductions.

Table 14 HAZUS output for the combined HEC-RAS model run for Alternatives RBA-1 and RBA-3

Occupancy Type	Total Loss	Building Loss	Contents Loss	Inventory Loss	Relocation Cost	Income Loss	Rental Income Loss	Wage Loss	Direct Output Loss
AGR	**$166,000**	$12,000	$56,000	$56,000	$4,000	$29,000	$0	$9,000	$119,000
COM	**$12,429,000**	$796,000	$2,251,000	$363,000	$660,000	$4,504,000	$507,000	$3,348,000	$7,951,000
EDU	**$12,000**	$0	$3,000	$0	$0	$2,000	$0	$7,000	$77,000
GOV	**$240,000**	$1,000	$12,000	$0	$0	$6,000	$0	$221,000	$48,000
IND	**$1,036,000**	$270,000	$619,000	$74,000	$19,000	$17,000	$5,000	$32,000	$152,000
REL	**$204,000**	$9,000	$73,000	$0	$2,000	$34,000	$0	$86,000	$499,000
RES	**$4,901,000**	$1,681,000	$1,062,000	$0	$455,000	$417,000	$304,000	$982,000	$2,189,000
Total	**$18,988,000**	**$2,769,000**	**$4,076,000**	**$493,000**	**$1,140,000**	**$5,009,000**	**$816,000**	**$4,685,000**	**$11,035,000**

Due to scope and study budget constraints, a single HEC-RAS unsteady discharge model was run for the 100-year event that included both RBA-1 (Johnstown Area Detention Basins) and RBA-3 (Granville Area Detention Basins) depicted in the topography and digital terrain model. The HAZUS Economics results are shown below. Based on the HAZUS output, the **benefits of $1,038,000** are derived by subtracting the reduced damages of $18,988,000 from the existing damages of $20,026,000.

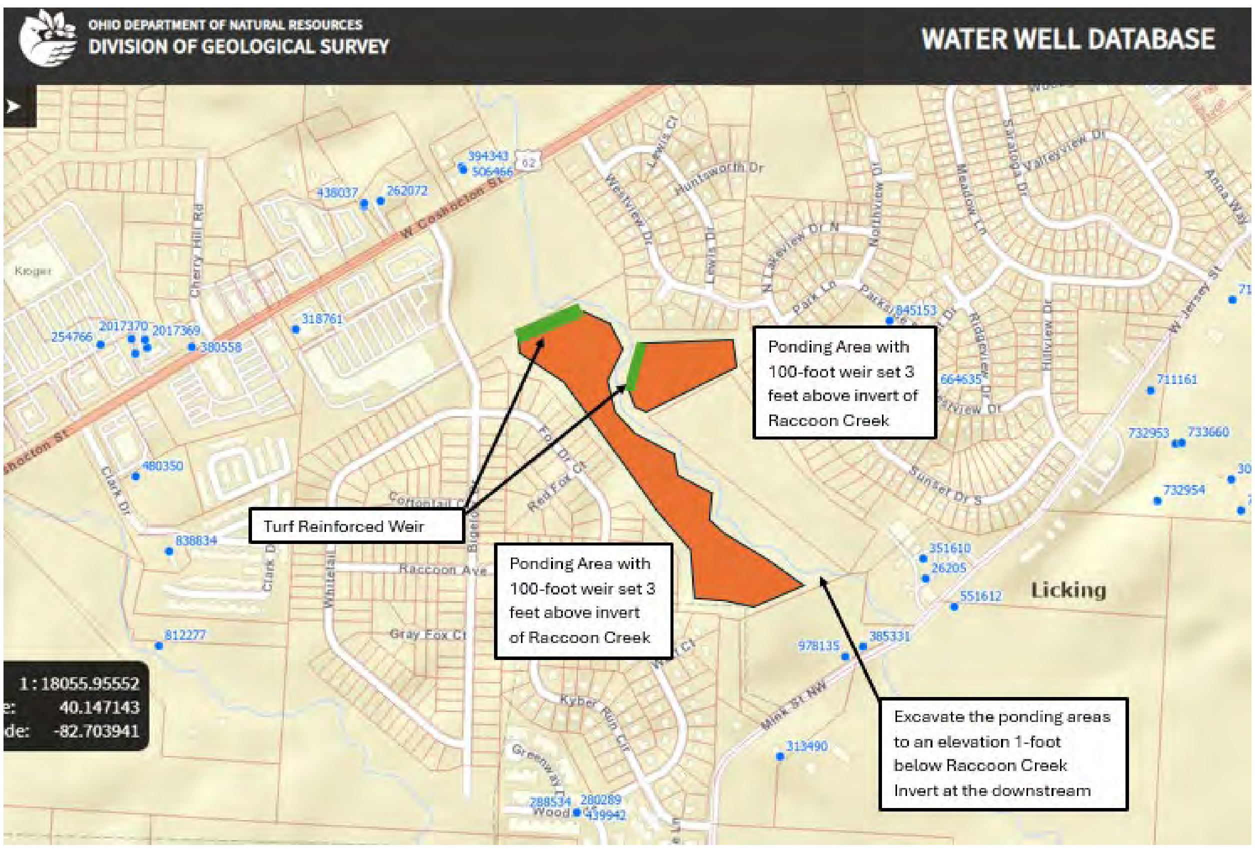

Figure 25 Off-channel Detention Areas in Johnstown

Costs. The costs for this alternative are shown below. It is assumed that there are no land or easement costs. Engineering, analysis, design, bidding services permitting, and construction administration are not included in the cost estimate below.

Table 15 Cost Estimate for RBA-1, Detention Areas in Johnstown

Item	Qty	Unit	Unit Cost	Cost
Mobilization/Demobilization	1	LS	$ 50,000	$ 50,000
Sediment and Erosion Control	13.43	Ac	$ 5,000	$ 67,149
Excavation	143,000	CY	$ 10	$ 1,430,000
Turf Reinforcing Mat for Weir	333	SY	$ 20	$ 6,660
			Subtotal	**$ 1,553,809**
			50% Contingency	$ 776,904
			Total Estimated Construction Cost	**$ 2,330,713**

BCR Discussion. Using the benefit of $1,038,000 and dividing by the costs of RBA-1 and RBA-2 ($2,330,713 plus $7,025,468 = $9,356,181), yields a combined BCR for RBA-1 and RBA-3 of 0.11. This is well below the threshold of a 1.0 for BCR. However, the projects provide significant flood risk benefits, but not enough to offset the costs. If the projects can be justified for habitat creation, preservation of floodplain, wetland creation, and water quality benefits, the flood damage reduction benefits would be realized.

The overall BCR will not justify construction of the detention areas, but the other benefits to water quality, reduction in lower flows, and habitat creation may warrant taking a closer look at the project. The excavation costs could also be offset if there is another project that requires large volumes of fill. Floods of smaller magnitude than the 100-year event will also be reduced to a greater extent due to the ratio of storage volume to runoff volume increasing as the rainfall amounts decrease.

RBA-2. Dam on Lobdell Creek

This alternative is the construction of a multi-purpose reservoir on Lobdell Creek near the Lobdell Preserve. This dam was identified in the 1980 South Fork Licking River Watershed Plan and Environmental Impact Statement prepared by the South Licking Water Conservancy District and U.S. Department of Agriculture.

Due to the downstream hazards, the dam will likely be a high hazard class I Dam as defined by ODNR Dam Safety criteria. This will require that the emergency spillway engages no more frequently than the 100-year event and that the dam can safely the Probable Maximum Flood (PMF) as defined by ODNR Dam Safety. ODNR dam permitting and oversight through design and construction will be required. In general, we have assumed that the dam is an earthen embankment, with a principal outlet, lake drain, emergency spillway that can pass the 100-year event, and roller compacted concrete (RCC) overtopping protection that will allow the dam to safely pass the PMF event. Elevations of the normal pool, emergency spillway and top of dam were estimated based on structures located upstream of the dam. The general physical characteristics of the dam include:

- Top of Dam: El. 1010
- Emergency Spillway: El. 1008
- Top of Dam Length: 648 Feet

- Dam Height: 38 feet (El. 1010 – El. 972)
- Normal Pool: EL 1003
- Storage at Normal Pool: Approximately 697 Acre-feet
- Active Flood Storage: From EL 1003 to 1008
- Low Level Outlet Capacity - 200 CFS typical Drop Inlet Configuration
- Lake Drain: Valve on the Drop Inlet Tower

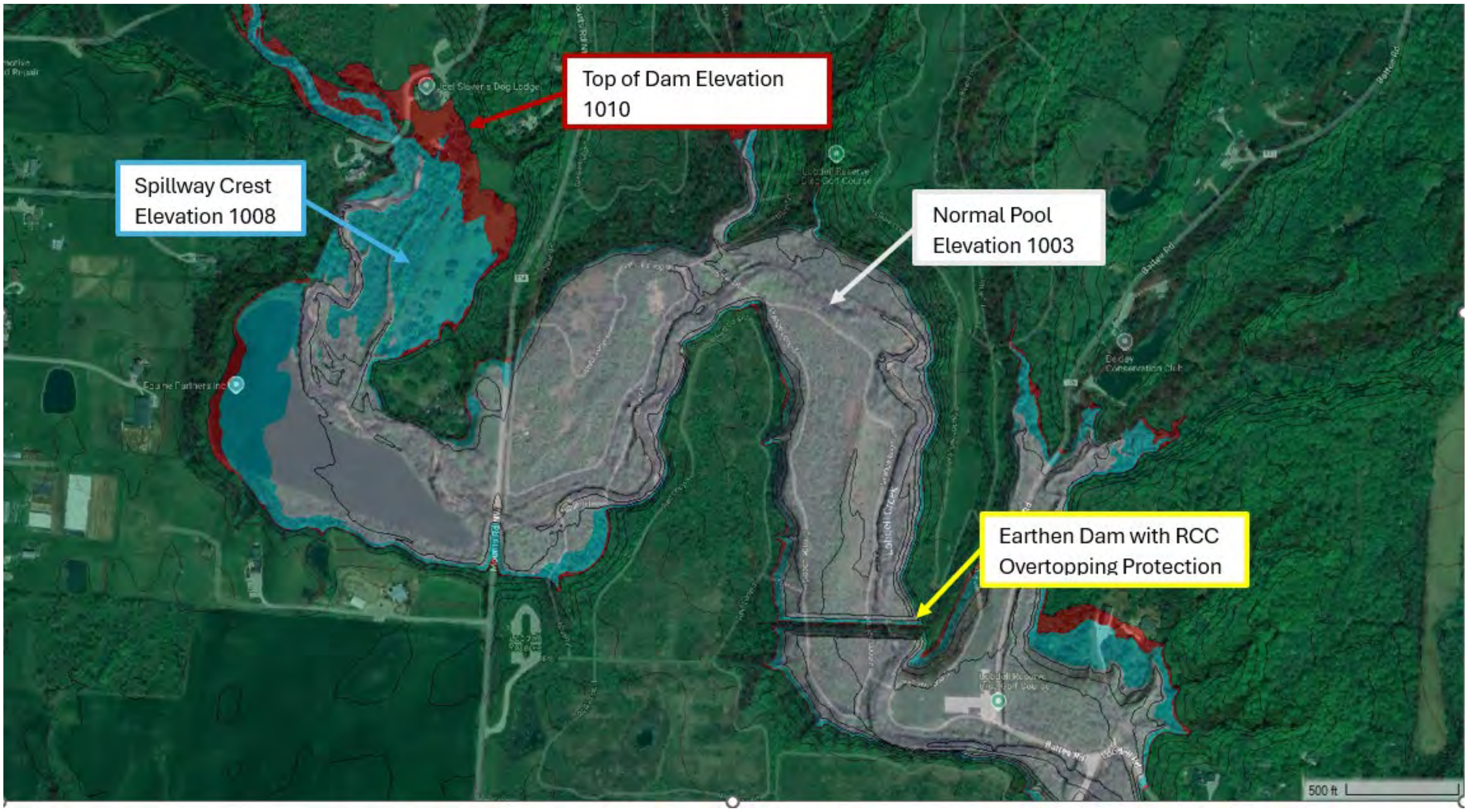

Figure 26 Lobdell Creek Multipurpose Reservoir Dam

Benefits. The construction of the multipurpose reservoir reduces downstream discharges for events up to the 100-year event, resulting in flood damage reduction through avoided damages. In addition to reduced discharges, the multi-purpose reservoir recreational benefits the community and potential water supply.

The HAZUS Economics results are shown below. Based on the HAZUS output, total **benefits of $6,078,000** are derived by subtracting the reduced damages of $13,948,000 from the existing damages of $20,026,000.

Table 16 HAZUS output for the HEC-RAS model run with Lobdell Creek Dam

Occupancy Type	Total Loss	Building Loss	Contents Loss	Inventory Loss	Relocation Cost	Income Loss	Rental Income Loss	Wage Loss	Direct Output Loss
AGR	**$153,000**	$11,000	$52,000	$51,000	$4,000	$27,000	$0	$8,000	$111,000
COM	**$8,658,000**	$580,000	$1,646,000	$296,000	$411,000	$3,099,000	$320,000	$2,306,000	$5,466,000
EDU	**$9,000**	$0	$2,000	$0	$0	$2,000	$0	$5,000	$58,000
GOV	**$239,000**	$1,000	$12,000	$0	$0	$6,000	$0	$220,000	$48,000
IND	**$888,000**	$220,000	$534,000	$64,000	$18,000	$16,000	$5,000	$31,000	$144,000
REL	**$173,000**	$7,000	$63,000	$0	$2,000	$28,000	$0	$73,000	$426,000
RES	**$3,828,000**	$1,481,000	$902,000	$0	$387,000	$257,000	$195,000	$606,000	$1,351,000
Total	**$13,948,000**	**$2,300,000**	**$3,211,000**	**$411,000**	**$822,000**	**$3,435,000**	**$520,000**	**$3,249,000**	**$7,604,000**

Costs. The costs for this alternative are shown below. It is assumed that there is not any land, easement, environmental, or cultural resource conflicts or costs associated with constructing the dam. Engineering, analysis, design, bidding services permitting, and construction administration are not included in the cost estimate below.

Table 17 Construction Cost Estimate for Lobdell Creek Dam

Item	Qty	Unit	Unit Cost	Cost
Mobilization/Demobilization	1	LS	$ 200,000	$ 200,000
Sediment and Erosion Control	3	Ac	$ 10,000	$ 30,000
Control of Water	1	LS	$ 50,000	$ 50,000
Inspection Trench Excavation	1,536	CY	$ 20	$ 30,720
Inspection Trench Backfill	1,536	CY	$ 30	$ 46,080
Earthfill	114,912	CY	$ 16	$ 1,838,592
Roller Compacted Concrete	744	CY	$ 290	$ 215,760
6' x 6' Box Outlet	260	LF	$ 800	$ 208,000
Drop inlet and Trash Rack	1	LS	$ 40,000	$ 40,000
Lake Drain	1	LS	$ 20,000	$ 20,000
			Subtotal	**$ 2,679,152**
			50% Contingency	$ 1,339,576
			Total Estimated Construction Cost	**$ 4,018,728**

BCR Discussion. Using the benefit of $6,078,000 and dividing by the cost $4,018,728, yields a combined BCR of 1.51. This is well above the threshold of a 1.0 for BCR and the project appears to be a viable candidate to carry forward towards implementation. However, further study and detail (see next steps below) is required to better estimate the construction costs associated with a high hazard Class I Dam.

Next Steps. Perform preliminary engineering and permitting to better define construction costs. Part of the preliminary engineering that can impact the cost estimates include, detailed survey, environmental impacts, detailed hydrology and hydraulics, and the geotechnical exploration and testing program. These all represent risks to the cost estimate presented above.

RBA-3. Detention Areas south of Granville Water Treatment Plant (WTP)

This alternative includes adding off-channel storage areas between SR 62 and Mink Street. During discharges in the range of 1- to 2-year flood events, Raccoon Creek would overflow into the constructed storage areas flowing over turf-reinforced weirs. This would provide off line storage of approximately 260 acre-feet of runoff from upstream of the detention areas.

> **Benefits.** This would result in a decrease in downstream discharges due to storage attenuation. In addition to flood risk reduction, the ponding areas will revert to wetlands and provide water quality and habitat benefits that are not captured in the economics and discharge reductions.

Due to budget constraints, a single HEC-RAS unsteady discharge model was run for the 100-year event that included both RBA-1 (Johnstown Area Detention Basins) and RBA-3 (Granville Area Detention Basins) depicted in the topography and digital terrain model. The HAZUS Economics results are shown under the RBA-1 detailed write-up above. Based on the HAZUS output, **benefits of $1,038,000** are derived by subtracting the reduced damages of $18,988,000 from the existing damages of $20,026,000.

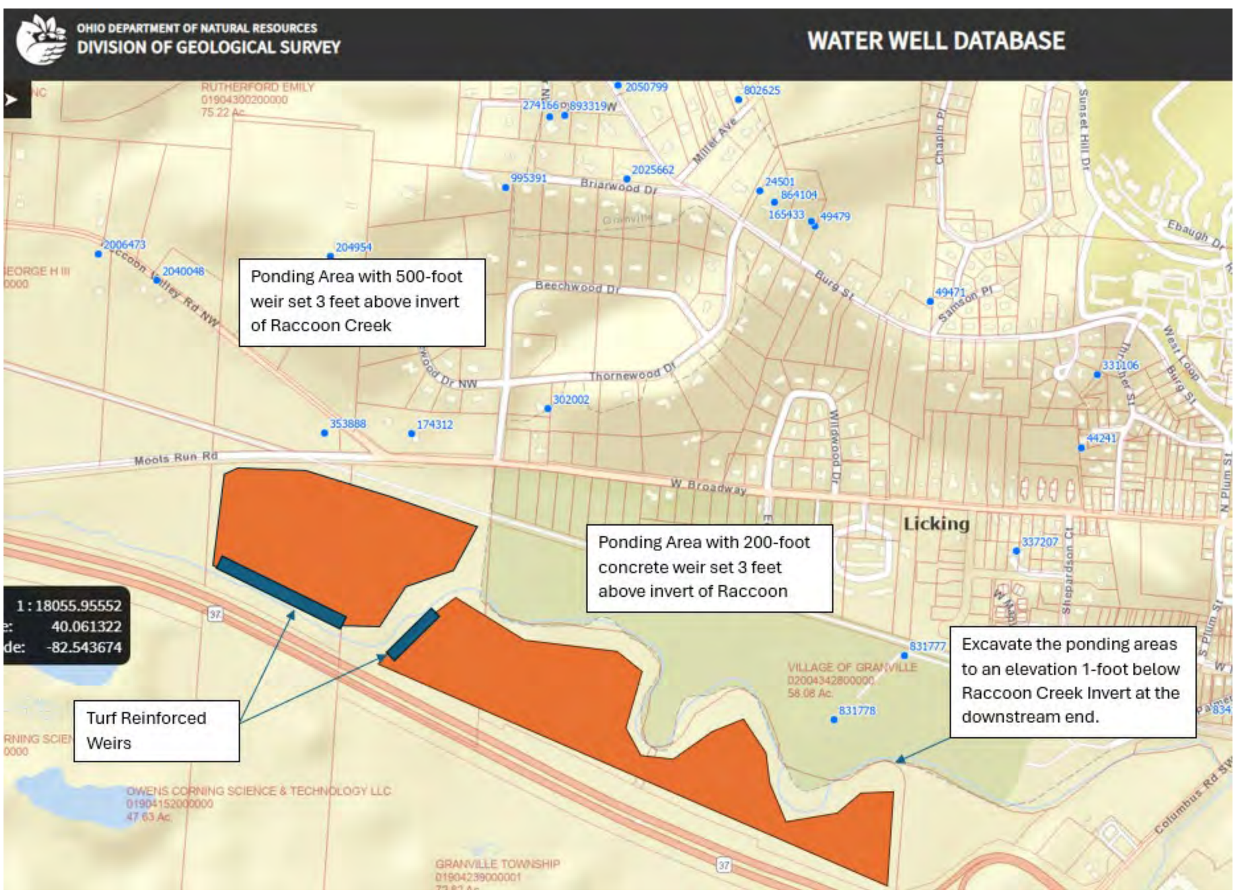

Figure 27 Off-channel Detention Areas in Granville

Costs. The costs for this alternative are shown below. It is assumed that there are no land or easement costs. Engineering, analysis, design, bidding services permitting, and construction administration are not included in the cost estimate below.

Table 18 Cost Estimate for RBA-3, Detention Areas in the Granville Area

Item	Qty	Unit	Unit Cost	Cost
Mobilization/Demobilization	1	LS	$ 250,000	$ 250,000
Sediment and Erosion Control	43.62	Ac	$ 5,000	$ 218,090
Excavation	420,556	CY	$ 10	$ 4,205,556
Turf Reinforcing Mat for Weir	500	SY	$ 20	$ 10,000
			Subtotal	**$ 4,683,646**
			50% Contingency	$ 2,341,823
			Total Estimated Construction Cost	**$ 7,025,468**

BCR Discussion. Using the benefit of $1,038,000 and dividing by the costs of RBA-1 and RBA-2 ($2,330,713 plus $7,025,468 = $9,356,181), yields a combined BCR for RBA-1 and RBA-3 of 0.11. This is well below the threshold of a 1.0 for BCR. However, the projects provide significant flood risk benefits, but not enough to offset the costs. If the projects can be justified for habitat creation, preservation of floodplain, wetland creation, and water quality benefits, the flood damage reduction benefits would be realized.

The overall BCR will not justify construction of the detention areas, but the other benefits to water quality, reduction in lower flows, and habitat creation may warrant taking a closer look at the project. The excavation costs could also be offset if there is another project that requires large volumes of fill. Floods of smaller magnitude than the 100-year event will also be reduced to a greater extent due to the ratio of storage volume to runoff volume increasing as the rainfall amounts decrease. Evaluating a range of lower flows and picking up the incremental damages will increase the BCR, but It will still likely remain under 1.0 due to estimated construction costs.

RBA-4. Bridge improvements at State Route (SR) 661 (Main Street) in Granville

This alternative includes widening the SR 661 (Main Street) bridge in Granville or adding additional conveyance immediately beside the existing bridge opening. This could pass more flows downstream. However, it could adversely affect the commercial properties and Granville Township Fire Station downstream of the bridge.

Benefits. This could reduce flood damages upstream starting from the Granville Square Apartments, the assisted living facility, the Granville Water Treatment Plant, Denison University Physical Plant, and any other impacted structures upstream. As mentioned above, care should be exercised to not increase downstream flooding by improving the channel as well as the bridge.

Costs. Due to complexities and the wide range of how this alternative can be implemented, it was not hydraulically modeled. Therefore, costs were not developed for this alternative. It may not have a large BCR, but it should be considered if the bridges are being replaced.

Next Steps. It is recommended that SLWCD and LCSWCD coordinate with bridge owner so that when/if replacement is required, increasing the hydraulic capacity can be an option that is considered. This may require additional funding outside the normal funding channels for bridges and transportation. Funding sources may include the FEMA Hazard Mitigation Grant Program (HMGP) or other flood hazard mitigation grants.

RBA-5. Bridge and Conveyance Improvements in downtown Newark (Wilson Street, Jefferson Street, and West Main Street)

This alternative includes widening the Wilson Street, Jefferson Street, and West Main Street bridges in Newark or adding additional conveyance immediately beside the existing bridge openings. This could pass more flows downstream. However, it could adversely affect the residential and commercial properties downstream of the bridges. It would require channel improvements as well to convey the additional discharges without raising the flood elevations.

Benefits. This could reduce flood damage upstream starting immediately downstream from the West Main Street Bridge all the way to Wilson Street bridge. As mentioned above, care should be exercised to not increase downstream flooding by improving the channel as well as the bridge.

Costs. Due to complexities and the wide range of how this alternative can be implemented, it was not hydraulically modeled. Therefore, costs were not developed for this alternative. It may not have a large BCR, but it should be considered if the bridges are being replaced.

Next Steps. It is recommended that SLWCD and LCSWCD coordinate with bridge owner so that when/if replacement is required, increasing the hydraulic capacity can be an option that is considered. This may require additional funding outside the normal funding channels for bridges and transportation. Funding sources may include the FEMA Hazard Mitigation Grant Program (HMGP) or other flood hazard mitigation grants.

RBA-6. Debris boom(s) upstream of critical bridges

This alternative includes adding debris booms upstream of more heavily populated areas. The ideal location would be upstream of a lot of structures where there is a history of large debris loads.

Benefits. Debris booms would reduce flood risk be removing debris upstream of critical bridges near damage centers. A debris boom would also lower operation and maintenance costs associated with log jams and debris removal because the debris will not be as wide-spread and will be captured at locations where access is easier and allows routine clearing. Enhance public safety is another benefit to any people boating or wading in the streams.

Costs. The costs associated with this alternative were not developed because at this point, there is not a good indication of where to place debris booms. The watershed has widespread debris loading and the sources and travel paths are not well known at this time. It may also take real estate for a flowing easement upstream and an access agreement for operations and maintenance.

Next Steps. As operation and maintenance activities are conducted. Particularly with respect to the log jam remove by the USACE, we suggest tracking migration and loading patterns within the watershed. WA-2, the Risk-Informed Streambank Stabilization and Debris Management Program, will also help to identify likely locations for operations and maintenance and possible debris boom locations.

RBA-7. Nine Element Plan Water Quality Projects and Restoration
This alternative includes adding restoration, floodplain preservation, and wetland creation projects identified in the Nine-Element Nonpoint Source Implementation Strategic Plan (NPS-IS Plan) for Raccoon Creek to the final alternatives list in this study. These projects have a water quality focus, but many may provide flood risk reduction benefits as well. Documenting the projects in this study will allow for implementation with flood risk reduction grants and funding, as appropriate.

Benefits. The Nine-Element Nonpoint Source Implementation Strategic Plan (NPS-IS Plan) offers several benefits for managing and improving water quality. Many of the projects that meet water quality objectives also have a water quantity component. Being secondary in nature, the flood risk reduction benefits are more difficult to quantify for the types of projects identified in the NPS-IS Plan. Many of the projects will stabilize the streambanks and reduce erosion as well. This will reduce debris loading and subsequent flood damage throughout the watershed.

Costs. The NPS-IS Plan will detail projects and costs associated with implementation. HDR suggests combining this flood study and the NPS-IS plan via reference into an update to the 1980 Watershed Plan that will serve as the masterplan for flood risk and water quality throughout the watershed.

5.3 Proposed Critical Infrastructure Alternatives (CIA)

Critical infrastructure is defined as buildings that are essential for the delivery of vital services or protection of a community. These facilities include wastewater treatment plants, water treatment plants, police and fire stations, healthcare facilities, schools, and power stations. They present an immediate threat to life, public health, and safety if flooded. The following critical infrastructure alternatives were considered as part of the watershed alternatives (WA) and were identified and evaluated:

- ***CIA-1.*** Levee/Floodwall at Johnstown WWTP
- ***CIA-2.*** Levee at Alexandria WWTP
- ***CIA-3.*** Levee at Granville WTP
- ***CIA-4*** Levee/Floodwall at Denison University Physical Plant
- ***CIA-5.*** Levee at Granville Township Fire Department
- ***CIA-6.*** Levee/Floodwall at Granville WWTP

Table 19 Multi-criteria Ranking of Critical Infrastructure Alternatives

Criteria		CIA-1	CIA-2	CIA-3	CIA-4	CIA-5	CIA-6
1	Flood Risk Reduction	3	3	3	3	3	3
2	Critical Infrastructure	3	3	3	3	3	3

Criteria		CIA-1	CIA-2	CIA-3	CIA-4	CIA-5	CIA-6
3	Operations and Maintenance	2	2	2	2	2	2
4	Real Estate	3	3	3	3	3	3
5	Environmental Impacts	2	2	2	1	2	2
6	Constructability	3	3	3	3	3	3
7	Community Benefits	2	2	2	2	2	2
8	Transportation Impacts	0	0	0	0	1	0
9	Permitting	3	3	3	3	3	3
	Totals	21	21	21	20	22	21

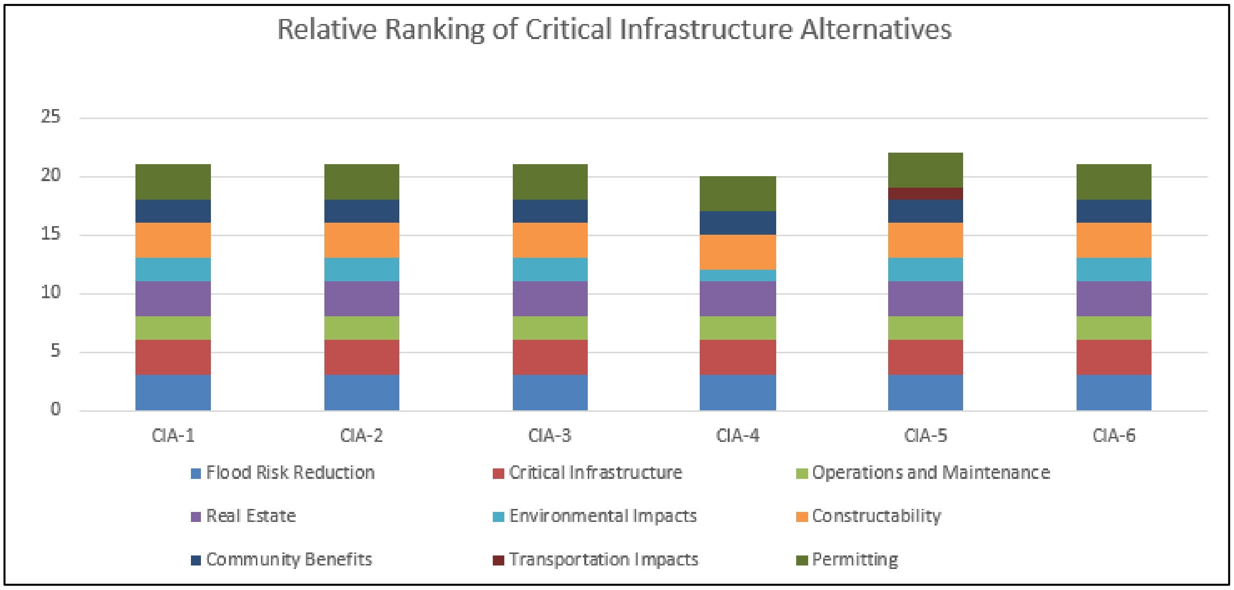

Figure 28 Multi-criteria Ranking of Critical Infrastructure Alternatives

CIA-1. Levee/Floodwall at Johnstown WWTP

The Wastewater Treatment Plant at Johnstown serves a large population outside the floodplain and flooding at the plant could shut down wastewater treatment and possibly cause uncontrolled release of wastewater, fuels and chemicals stored on site into Racoon Creek. This alternative is to construct a floodwall that protects the facility from the 100-year event plus 4 feet of freeboard. The general physical characteristics of the levee/floodwall include:

- 100-Year Flood Elevation is 1055.0 +/- (FEMA and updated HEC-RAS model)
    - Top of protection 1059.0 provides 4-feet of freeboard above the 100-year event
- 535 feet of 6-foot levee with 3:1 side slopes and 12-foot top width and toe drains
- 100 feet of 4-foot reinforced concrete I-Wall
- 1 vehicular gate closure
- 1 Gatewell for interior drainage and toe drain outlet

Benefits. The WWTP plant would maintain service to the community during a flood event and reduce possible service interruptions.

Costs. The costs for this alternative are shown below. It is assumed that there is not any land, easement, environmental, or cultural resource conflicts or costs associated with constructing levee/floodwall system. Engineering, analysis, design, bidding services permitting, and construction administration are not included in the cost estimate below. It is noted that future preliminary engineering and permitting will better define construction costs. Part of the preliminary engineering that can impact the cost estimates include, detailed survey, environmental impacts, detailed hydrology and hydraulics, and the geotechnical exploration and testing program. These all represent risks to the cost estimate presented below.

Table 20 Cost Estimate for CIA-1, Levee/Floodwall at Johnstown WWTP

Item	Qty	Unit	Unit Cost	Cost
Mobilization/Demobilization	1	LS	$ 60,000	$ 60,000
Sediment and Erosion Control	1	Ac	$ 10,000	$ 10,000
Floodwall	100	LF	$ 1,600	$ 160,000
Levee	535	LF	$ 330	$ 176,550
Gatwell and Interior Drain Outlet	1	LS	$ 30,000	$ 30,000
Vehicle Gate	1	LS	$ 200,000	$ 200,000
			Subtotal	**$ 636,550**
			50% Contingency	$ 318,275
			Total Estimated Construction Cost	**$ 954,825**

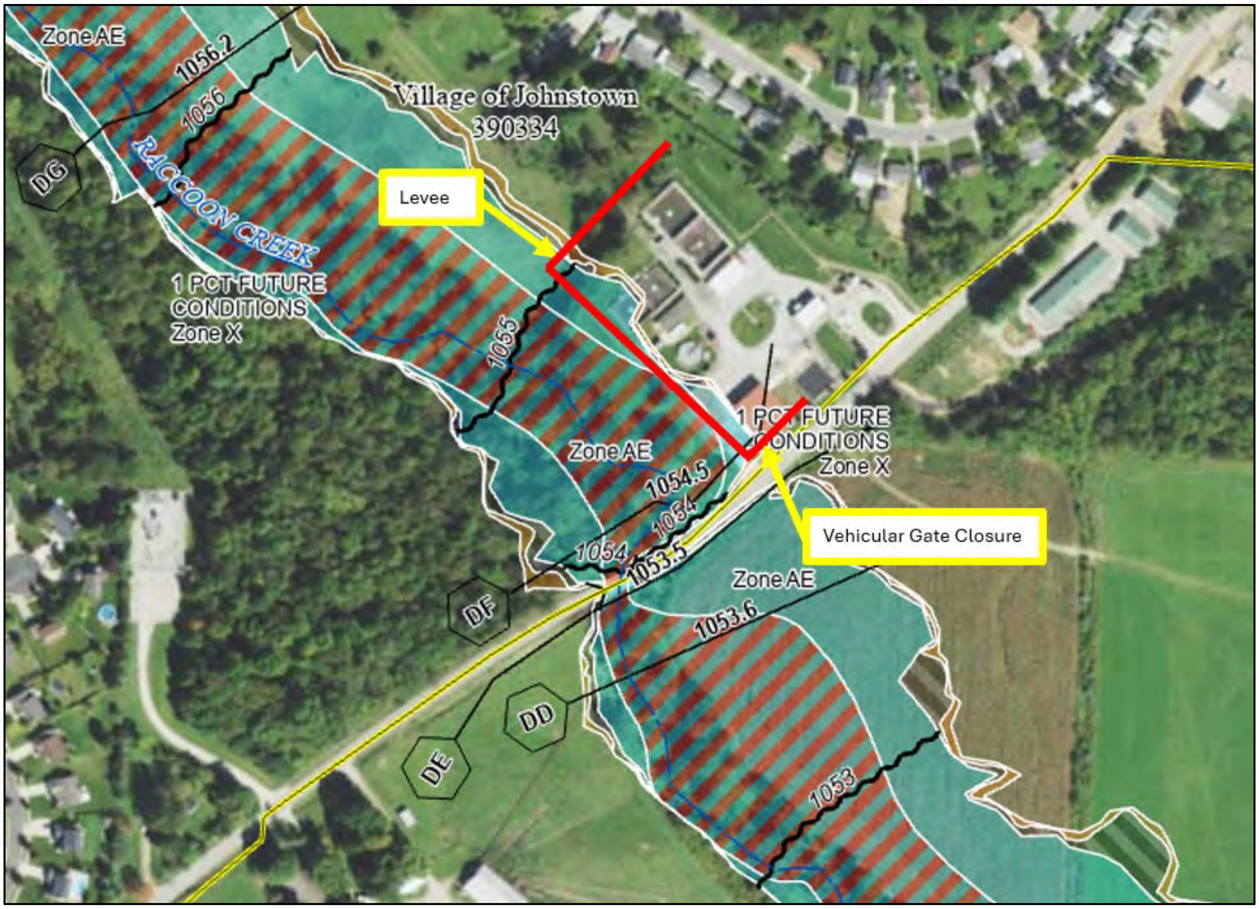

Figure 29 Levee/Floodwall at Johnstown WWTP

CIA-2. Levee at Alexandria WWTP

The Wastewater Treatment Plant at Alexandria serves a population outside the floodplain and flooding at the plant could shut down wastewater treatment and possibly cause uncontrolled release of wastewater, fuels and chemicals stored on site into Racoon Creek. This alternative is to construct a levee that protects the facility from the 100-year event plus 4 feet of freeboard. The general physical characteristics of the levee include:

- 100-Year Flood Elevation is 946.8 +/- (FEMA and updated HEC-RAS model)
  - Top of protection 950.8 provides 4-feet of freeboard above the 100-year event
- 869 feet of 8-foot levee with 3:1 side slopes and 12-foot top width and toe drains
- 1 vehicular gate closure
- 1 gatewell for interior drainage and toe drain outlet

Benefits. The WWTP would maintain service to the community during a flood event and reduce service interruptions to short periods of time.

Costs. The costs for this alternative are shown below. It is assumed that there is not any land, easement, environmental, or cultural resource conflicts or costs associated with constructing levee/floodwall system. Engineering, analysis, design, bidding services permitting, and construction administration are not included in the cost estimate below. It is noted that future preliminary engineering and permitting will better define construction costs. Part of the preliminary engineering that can impact the cost estimates include, detailed survey, environmental impacts, detailed hydrology and hydraulics, and the geotechnical exploration and testing program. These all represent risks to the cost estimate presented below.

Table 21 Cost Estimate for CIA-2, Levee at the Alexandria WWTP

Item	Qty	Unit	Unit Cost	Cost
Mobilization/Demobilization	1	LS	$ 60,000	$ 60,000
Sediment and Erosion Control	1	Ac	$ 10,000	$ 10,000
Levee	869	LF	$ 490	$ 425,810
Gatwell and Interior Drain Outlet	1	LS	$ 30,000	$ 30,000
Vehicle Gate	1	LS	$ 200,000	$ 200,000
			Subtotal	**$ 725,810**
			50% Contingency	$ 362,905
			Total Estimated Construction Cost	**$ 1,088,715**

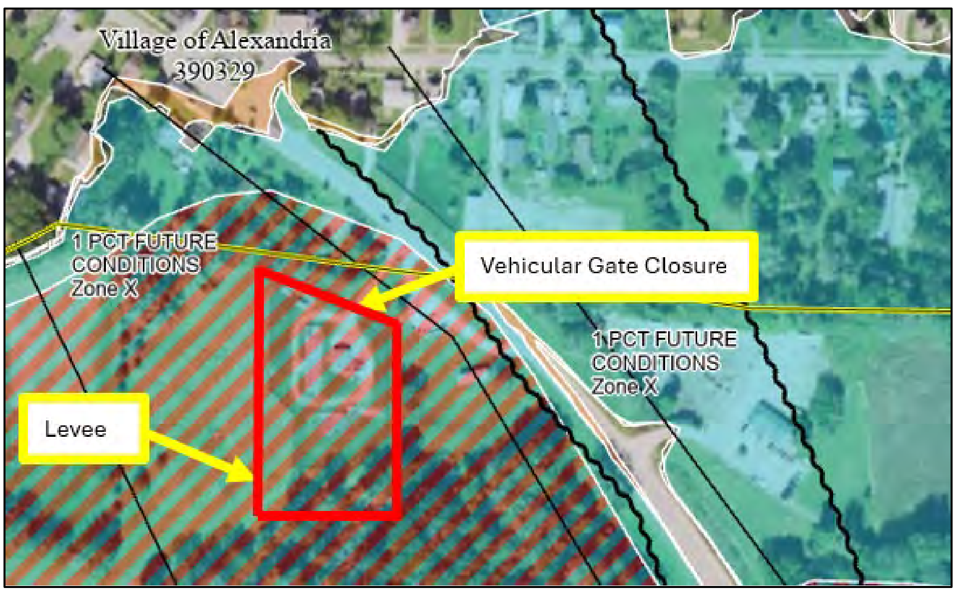

Figure 30 Levee/Floodwall at Alexandria WWTP

CIA-3. Levee at Granville WTP

The Water Treatment Plant at Granville serves a population outside the floodplain and flooding at the plant could drinking water treatment and possibly cause uncontrolled release of fuels and chemicals stored on site into Racoon Creek. This alternative is to construct a levee that protects the facility from the 100-year event plus 4 feet of freeboard. The general physical characteristics of the levee include:

- 100-Year Flood Elevation is 914.0 +/- (FEMA and updated HEC-RAS model)
  - o Top of protection 918.0 provides 4-feet of freeboard above the 100-year event
- 754 feet of 6-foot levee with 3:1 side slopes and 12-foot top width and toe drains
- 1 vehicular gate closure
- 1 Gatewell for interior drainage and toe drain outlet

Benefits. The WTP would maintain service to the community during a flood event and any service interruptions would likely be reduced to short periods of time.

Costs. The costs for this alternative are shown below. It is assumed that there is not any land, easement, environmental, or cultural resource conflicts or costs associated with constructing levee/floodwall system. Engineering, analysis, design, bidding services permitting, and construction administration are not included in the cost estimate below. It is noted that future preliminary engineering and permitting will better define construction costs. Part of the preliminary engineering that can impact the cost estimates include, detailed survey, environmental impacts, detailed hydrology and hydraulics, and the geotechnical exploration and testing program. These all represent risks to the cost estimate presented below.

Table 22 Cost Estimate for CIA-2, Levee at the Granville WTP

Item	Qty	Unit	Unit Cost	Cost
Mobilization/Demobilization	1	LS	$ 55,000	$ 55,000
Sediment and Erosion Control	1	Ac	$ 10,000	$ 10,000
Levee	754	LF	$ 330	$ 248,820
Gatwell and Interior Drain Outlet	1	LS	$ 30,000	$ 30,000
Vehicle Gate	1	LS	$ 200,000	$ 200,000
			Subtotal	**$ 543,820**
			50% Contingency	$ 271,910
			Total Estimated Construction Cost	**$ 815,730**

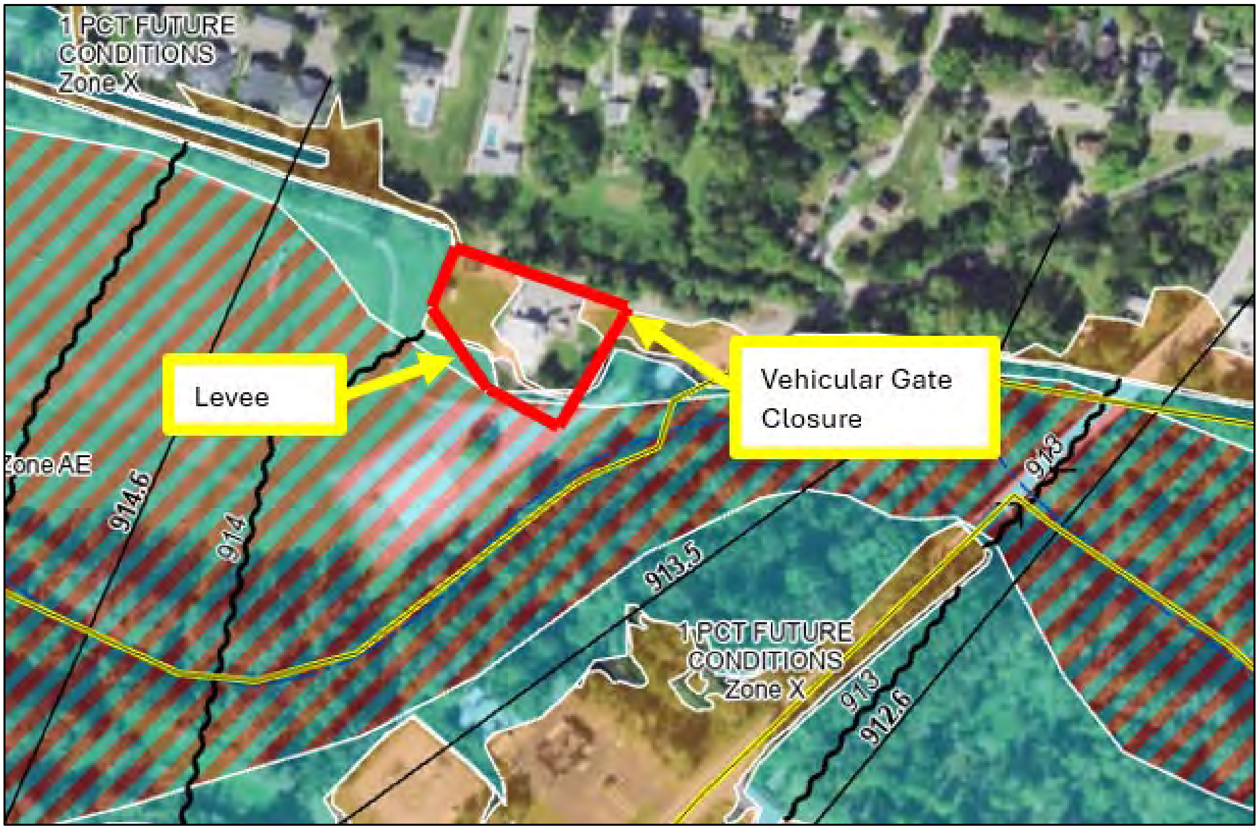

Figure 31 Levee at Granville WTP

CIA-4 Levee/Floodwall at Denison University Physical Plant

The Denison University Physical Plant in Granville serves the University population outside the floodplain and flooding at the plant could shutdown utility service and possibly cause uncontrolled release of wastewater, fuels and chemicals stored on site into Racoon Creek. This alternative is to construct a floodwall that protects the facility from the 100-year event plus 4 feet of freeboard. The general physical characteristics of the levee/floodwall include:

- 100-Year Flood Elevation is 912.0 +/- (FEMA and updated HEC-RAS model)
    - Top of protection 916.0 provides 4-feet of freeboard above the 100-year event
- 540 feet of 6-foot levee with 3:1 side slopes and 12-foot top width and toe drains
- 50 feet of 6-foot reinforced concrete L-Wall
- 1 vehicular gate closure
- 1 Gatewell for interior drainage and toe drain outlet

Benefits. The physical plant would maintain utility services to the university during a flood event and reduce possible service interruptions.

Costs. The costs for this alternative are shown below. It is assumed that there is not any land, easement, environmental, or cultural resource conflicts or costs associated with constructing levee/floodwall system. Engineering, analysis, design, bidding services permitting, and construction administration are not included in the cost estimate below. It is noted that future preliminary engineering and permitting will better define construction costs. Part of the preliminary engineering that can impact the cost estimates include, detailed survey, environmental impacts, detailed hydrology and hydraulics, and the geotechnical exploration and testing program. These all represent risks to the cost estimate presented below.

Table 23 Cost Estimate for CIA-2, Levee at the Granville WTP

Item	Qty	Unit	Unit Cost	Cost
Mobilization/Demobilization	1	LS	$ 55,000	$ 55,000
Sediment and Erosion Control	1	Ac	$ 10,000	$ 10,000
Floodwall	50	LF	$ 2,700	$ 135,000
Levee	540	LF	$ 330	$ 178,200
Gatwell and Interior Drain Outlet	1	LS	$ 30,000	$ 30,000
Vehicle Gate	1	LS	$ 200,000	$ 200,000
			Subtotal	**$ 608,200**
			50% Contingency	$ 304,100
			Total Estimated Construction Cost	**$ 912,300**

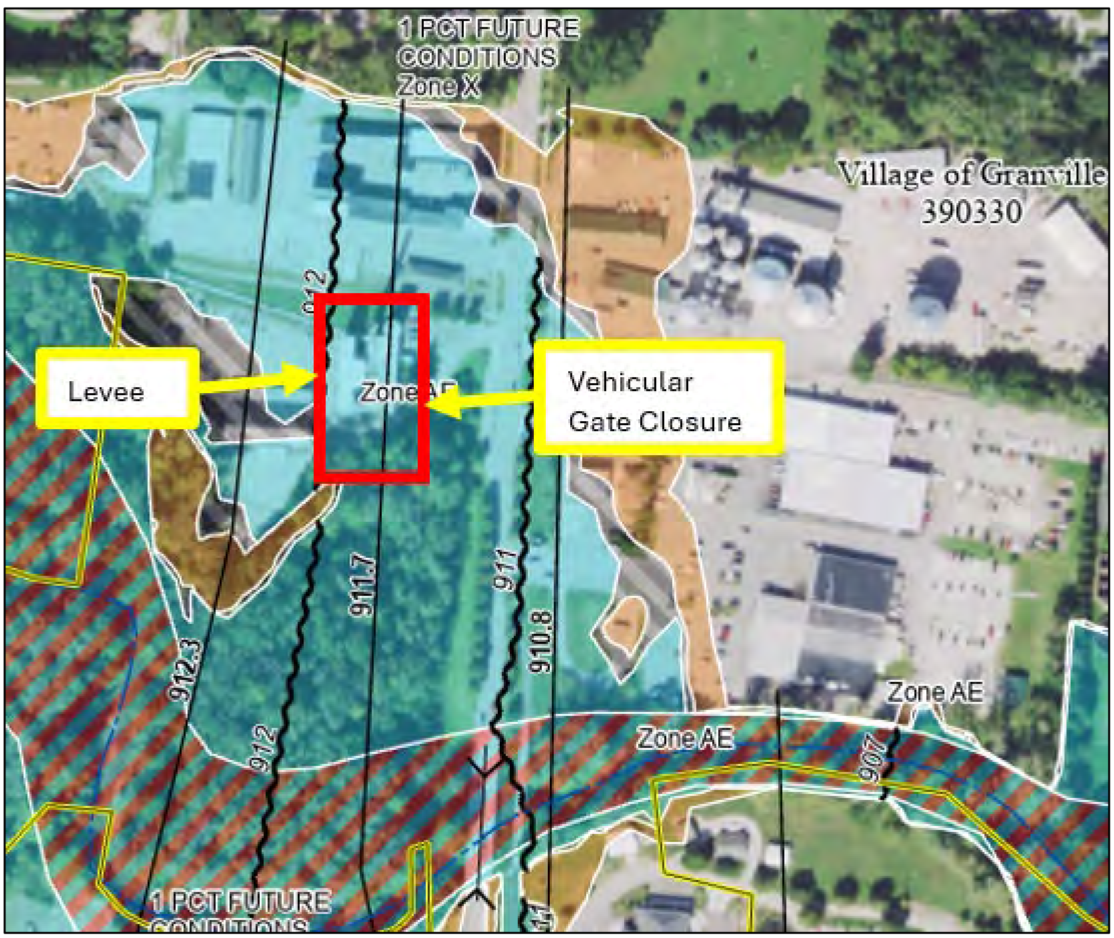

Figure 32 Levee/Floodwall at Denison University Physical Plant

CIA-5. Levee at Granville Township Fire Department

The Granville Township Fire Department serves a population outside the floodplain and flooding at facility could displace first responders, damage emergency response vehicles, and damage materials stored on site. Flooding could also lead to uncontrolled release of fuels and chemicals stored on site into Racoon Creek. This alternative is to construct a levee that protects the low-lying area on the south side of the facility from the 100-year event plus 4 feet of freeboard. The general physical characteristics of the levee include:

- 100-Year Flood Elevation is 911.0 +/- (FEMA and updated HEC-RAS model)
  - Top of protection 915.0 provides 4-feet of freeboard above the 100-year event
- 140 feet of 4-foot levee with 3:1 side slopes and 12-foot top width and toe drains
- 1 vehicular gate closure
- 1 Gatewell for interior drainage and toe drain outlet

Benefits. The fire department would maintain service to the community during a flood event and any service interruptions would likely be reduced to short periods of time. HDR suggests a contingency plan be developed to move equipment and materials when flood waters are forecast to reach stages that would make access in and out of the facility difficult.

Costs. The costs for this alternative are shown below. It is assumed that there is not any land, easement, environmental, or cultural resource conflicts or costs associated with constructing levee/floodwall system. Engineering, analysis, design, bidding services permitting, and construction administration are not included in the cost estimate below. It is noted that future preliminary engineering and permitting will better define construction costs. Part of the preliminary engineering that can impact the cost estimates include, detailed survey, environmental impacts, detailed hydrology and hydraulics, and the geotechnical exploration and testing program. These all represent risks to the cost estimate presented below.

Table 24 Cost Estimate for CIA-5, Levee at the Granville Township Fire Department

Item	Qty	Unit	Unit Cost	Cost
Mobilization/Demobilization	1	LS	$ 10,000	$ 10,000
Sediment and Erosion Control	1	Ac	$ 10,000	$ 10,000
Levee	140	LF	$ 210	$ 29,400
Gatwell and Interior Drain Outlet	1	LS	$ 30,000	$ 30,000
			Subtotal	**$ 79,400**
			50% Contingency	$ 39,700
			Total Estimated Construction Cost	**$ 119,100**

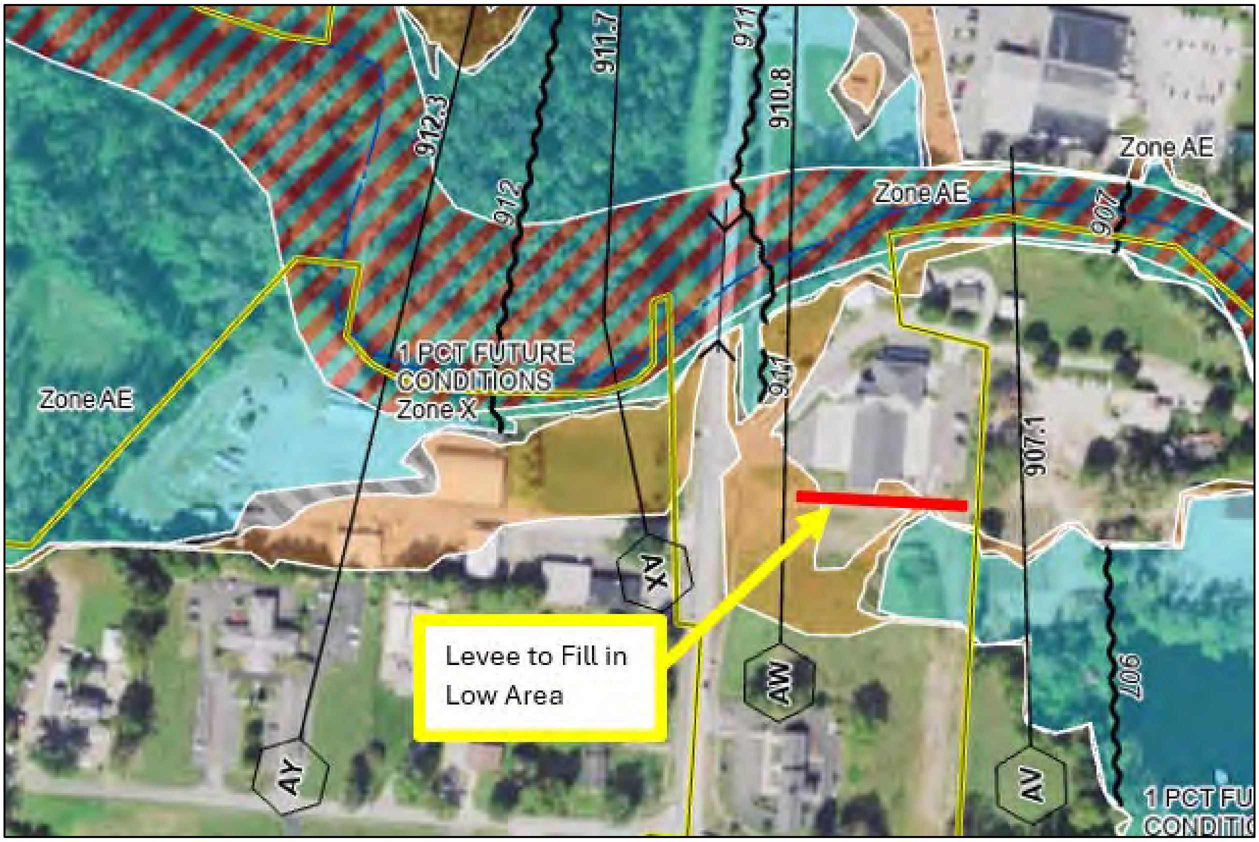

Figure 33 Levee at Granville Township Fire Department

CIA-6. Levee/Floodwall at Granville WWTP

The Wastewater Treatment Plant at Granville serves a large population outside the floodplain and flooding at the plant could shut down wastewater treatment and possibly cause uncontrolled release of wastewater, fuels and chemicals stored on site into Racoon Creek. This alternative is to construct a floodwall that protects the facility from the 100-year event plus 4 feet of freeboard. The general physical characteristics of the levee/floodwall include:

- 100-Year Flood Elevation is 907.0 +/- (FEMA and updated HEC-RAS model)
  - Top of protection 911.0 provides 4-feet of freeboard above the 100-year event
- 1,047 feet of 6-foot levee with 3:1 side slopes and 12-foot top width and toe drains
- 300 feet of 6-foot reinforced concrete L-Wall
- 1 vehicular gate closure
- 1 Gatewell for interior drainage and toe drain outlet

Benefits. The WWTP plant would maintain service to the community during a flood event and reduce possible service interruptions.

Costs. The costs for this alternative are shown below. It is assumed that there is not any land, easement, environmental, or cultural resource conflicts or costs associated with constructing levee/floodwall system. Engineering, analysis, design, bidding services permitting, and construction administration are not included in the cost estimate below. It is noted that future preliminary engineering and permitting will better define construction costs. Part of the preliminary engineering that can impact the cost estimates include, detailed survey, environmental impacts, detailed hydrology and hydraulics, and the geotechnical exploration and testing program. These all represent risks to the cost estimate presented below.

Table 25 Cost Estimate for CIA-6, Levee/Floodwall at the Granville WWTP

Item	Qty	Unit	Unit Cost	Cost
Mobilization/Demobilization	1	LS	$ 100,000	$ 100,000
Sediment and Erosion Control	1	Ac	$ 10,000	$ 10,000
Levee	1,047	LF	$ 330	$ 345,510
Floodwall	300	LF	$ 2,700	$ 810,000
Gatwell and Interior Drain Outlet	1	LS	$ 30,000	$ 30,000
Vehicle Gate	1	LS	$ 200,000	$ 200,000
			Subtotal	**$ 1,495,510**
			50% Contingency	$ 747,755
			Total Estimated Construction Cost	**$ 2,243,265**

Figure 34 Levee/Floodwall at Granville WWTP

5.4 Proposed Site-Specific Alternatives (SSA)

Site-Specific Alternatives are discrete flood risk reduction projects that were formulated based on localized concentration of damages and known losses based on the data collected. These alternatives include levees and/or floodwalls to reduce flood risk to more densely populated areas. The following watershed alternatives (WA) were identified and evaluated:

Site Specific Alternatives (SSA)

- ***SSA-1.*** Levee/Floodwall from Granville Square Apartments to Granville WTP
- ***SSA-2.*** Levee on left of bank Raccoon Creek from SR 79 Bridge downstream to 11th Street Bridge (White Field)
- ***SSA-3.*** Floodwall on the left bank of Raccoon Creek from 11th Street Bridge downstream to CSX Bridge
- ***SSA-4.*** Levee/Floodwall on right bank of Raccoon Creek from 11th Street Bridge downstream to Scenic Buckeye Railroad Bridge

Table 26 Multi-criteria Ranking of Site-Specific Alternatives

Criteria		SSA-1	SSA-2	SSA-3	SSA-4
1	Flood Risk Reduction	3	3	3	3
2	Critical Infrastructure	2	2	2	2
3	Operations and Maintenance	2	2	2	2
4	Real Estate	2	2	1	1
5	Environmental Impacts	2	2	2	2
6	Constructability	3	3	3	3
7	Community Benefits	2	2	2	2
8	Transportation Impacts	0	0	0	0
9	Permitting	2	2	2	2
	Totals	18	18	17	17

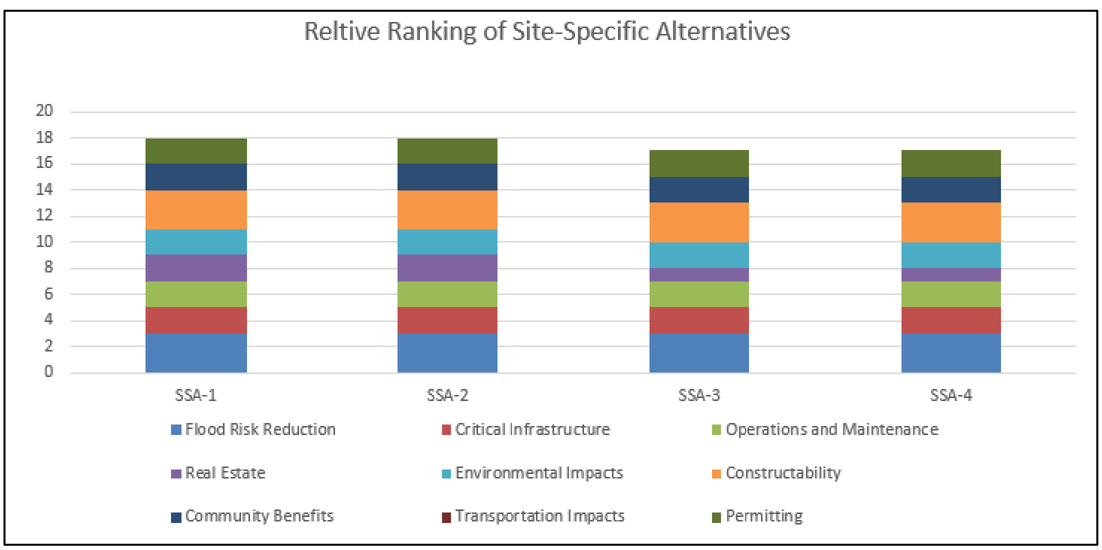

Figure 35 Multi-criteria Ranking of Site-Specific Alternatives

SSA-1. Levee/Floodwall from Granville Square Apartments to Granville WTP
This alternative involves building a levee along the north side alignment of the bike path and tying into natural high ground at the west end and east end. A short stretch of T-wall will be required due to site constraints. Real estate and obstructed views may be issues if the project advances to preliminary design stage. The general physical characteristics of the levee/floodwall include:

- 100-Year Flood Elevation is 915.5 +/- (FEMA and updated HEC-RAS model)
    - Top of protection 919.5 provides 4-feet of freeboard above the 100-year event
- 1,545 feet of 9-foot levee with 3:1 side slopes and 12-foot top width and toe drains
- 400 feet of 9-foot reinforced concrete T-Wall
- 4 Gatewells for interior drainage and toe drain outlet

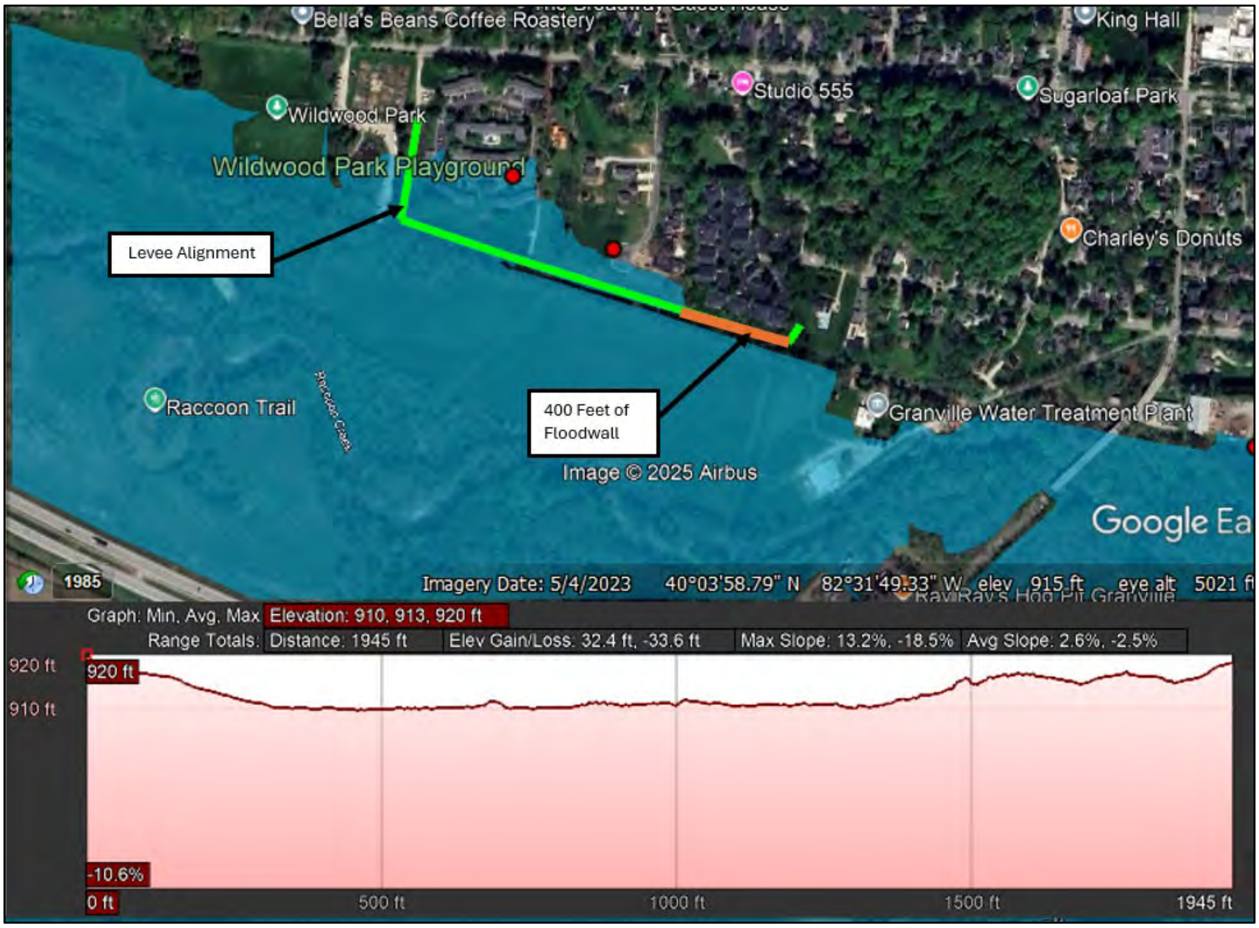

Figure 36 Levee/Floodwall near Granville Square Apartments

Benefits. The construction of the levee/floodwall system protects the structures behind the levee for events up to the 100-year event plus 4- feet of freeboard, resulting in flood damage reduction through avoided damages.

The HAZUS Economics results are shown below. Based on the HAZUS output, total **benefits of $3,929,000** are derived by subtracting the reduced damages of $142,579,000 from the existing damages of $146,508,000.

Table 27 HAZUS output for the HEC-RAS Steady State Model run with SSA-1 Levee Area Protected

Occupancy Type	Total Loss	Building Loss	Contents Loss	Inventory Loss	Relocation Cost	Income Loss	Rental Income Loss	Wage Loss	Direct Output Loss
AGR	**$451,000**	$40,000	$153,000	$156,000	$16,000	$64,000	$0	$22,000	$256,000
COM	**$95,400,000**	$7,831,000	$22,326,000	$6,096,000	$6,930,000	$23,793,000	$5,116,000	$23,308,000	$54,345,000
EDU	**$42,000**	$2,000	$14,000	$0	$0	$7,000	$0	$19,000	$174,000
GOV	**$3,040,000**	$19,000	$136,000	$0	$126,000	$91,000	$50,000	$2,618,000	$601,000
IND	**$8,418,000**	$2,157,000	$4,469,000	$760,000	$362,000	$219,000	$66,000	$385,000	$1,652,000
REL	**$2,929,000**	$170,000	$1,112,000	$0	$200,000	$422,000	$19,000	$1,006,000	$5,639,000
RES	**$32,299,000**	$10,502,000	$6,227,000	$0	$4,383,000	$2,211,000	$3,772,000	$5,204,000	$11,599,000
Total	**$142,579,000**	**$20,721,000**	**$34,437,000**	**$7,012,000**	**$12,017,000**	**$26,807,000**	**$9,023,000**	**$32,562,000**	**$74,266,000**

Table 28 Cost Estimate for SSA-1, Levee/Floodwall near Granville Square Apartments

Item	Qty	Unit	Unit Cost	Cost
Mobilization/Demobilization	1	LS	$ 200,000	$ 200,000
Sediment and Erosion Control	2	Ac	$ 10,000	$ 20,000
Levee	1,545	LF	$ 580	$ 896,100
9-foot T-wall Floodwall	400	LF	$ 3,800	$ 1,520,000
Gatwell and Interior Drain Outlet	4	LS	$ 30,000	$ 120,000
Bikepath Repavement	1	LS	$ 200,000	$ 200,000
			Subtotal	**$ 2,956,100**
			50% Contingency	$ 1,478,050
			Total Estimated Construction Cost	**$ 4,434,150**

BCR Discussion. Using the benefit of $3,929,000 and dividing by the costs of SSA-1 ($3,404,625), yields a combined BCR of 0.89. This is below the threshold of a 1.0 for BCR. However, the project could be optimized using the bike path, reducing the freeboard, or eliminating the floodwall segment on the east end, to reduce costs to the point where the BCR is greater than 1.0. Further study and detail (see next steps below) is required to better estimate the construction costs associated with levee/floodwall system. Real estate and the bike path conflicts may drive the layout and feasibility of the system moving forward.

Next Steps. Perform preliminary engineering and permitting to better define construction costs. Elements of preliminary engineering that can impact the cost estimates include detailed survey, real estate, environmental impacts, detailed hydrology, and hydraulics (interior drainage and riverine), and the geotechnical exploration and testing program. These all represent risks to the cost estimate presented above.

***SSA-2.* Levee on left of bank Raccoon Creek from SR 79 Bridge downstream to 11th Street Bridge (White Field)**

This alternative involves building a levee along the left bank of Raccoon Creek between State Route 79 and the 11th Street Bridge tying into high ground at the west end and east end. This will protect White Field. Real estate, obstructed views, terminating at roadway embankments (will need to be analyzed as levees), and coordination with Newark City Schools may be issues if the project advances to preliminary design stage. The general physical characteristics of the levee/floodwall include:

- 100-Year Flood Elevation is 829.0 +/- (FEMA) and 826.0 +/- (updated HEC-RAS model)
    - Top of protection 829.0 is set because it Is the top of the 11th Street Bridge. Any higher elevation would require bridge replacement and work well beyond the limits shown below. This provides 0-feet of freeboard above the 100-year FEMA elevation, but approximately 3-feet of freeboard above the current HEC-RAS model 100-year event
- 727 feet of 6-foot levee with 3:1 side slopes and 12-foot top width and toe drains
- 3 Gatewells for interior drainage and toe drain outlet
- Existing interior drainage improvements – This includes adding flap gates and gatewells to existing storm drains in the protected area
- 1 Vehicle gate

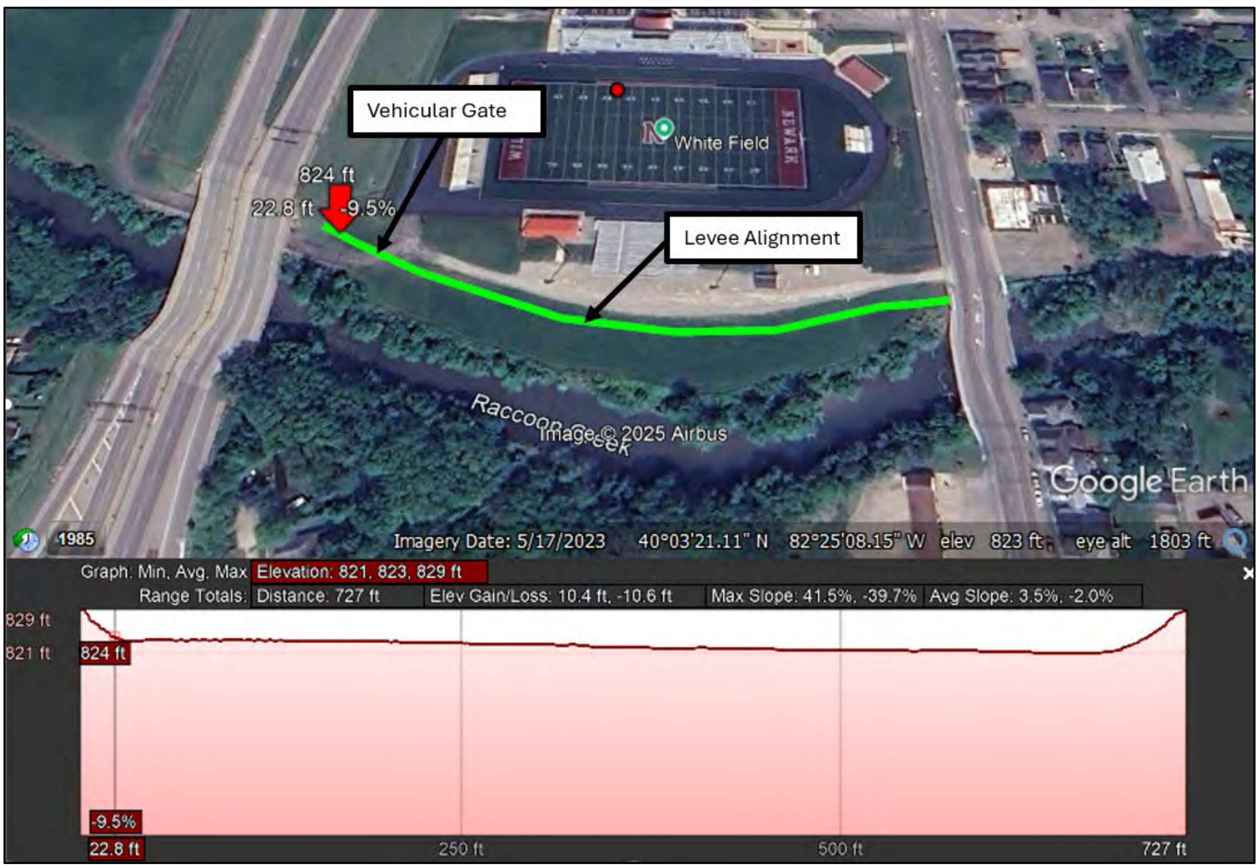

Figure 37 SSA-2, Levee between SR 79 and 11th Street

Benefits. The construction of the levee system protects the structures behind the levee for events up to an elevation of 829.0, resulting in flood damage reduction through avoided damages.

The HAZUS Economics results are shown below. Based on the HAZUS output, total **benefits of $6,754,000** are derived by subtracting the reduced damages of $139,754,000 from the existing damages of $146,508,000.

Table 29 HAZUS output for the HEC-RAS Steady State Model run with SSA-2 Levee Area Protected

Occupancy Type	Total Loss	Building Loss	Contents Loss	Inventory Loss	Relocation Cost	Income Loss	Rental Income Loss	Wage Loss	Direct Output Loss
AGR	$451,000	$40,000	$153,000	$156,000	$16,000	$64,000	$0	$22,000	$256,000
COM	$92,715,000	$7,723,000	$21,661,000	$5,833,000	$6,754,000	$23,174,000	$4,990,000	$22,580,000	$52,605,000
EDU	$42,000	$2,000	$14,000	$0	$0	$7,000	$0	$19,000	$174,000
GOV	$2,866,000	$19,000	$131,000	$0	$124,000	$86,000	$49,000	$2,457,000	$565,000
IND	$8,471,000	$2,177,000	$4,492,000	$766,000	$362,000	$221,000	$66,000	$387,000	$1,659,000
REL	$2,929,000	$170,000	$1,112,000	$0	$200,000	$422,000	$19,000	$1,006,000	$5,639,000
RES	$32,280,000	$10,519,000	$6,214,000	$0	$4,384,000	$2,211,000	$3,748,000	$5,204,000	$11,599,000
Total	**$139,754,000**	**$20,650,000**	**$33,777,000**	**$6,755,000**	**$11,840,000**	**$26,185,000**	**$8,872,000**	**$31,675,000**	**$72,497,000**

Table 30 Multi-criteria Ranking of Reach-Based Alternatives

Item	Qty	Unit	Unit Cost	Cost
Mobilization/Demobilization	1	LS	$ 90,000	$ 90,000
Sediment and Erosion Control	2	Ac	$ 10,000	$ 20,000
Levee	727	LF	$ 330	$ 239,910
Gatwell and Interior Drain Outlet	3	LS	$ 30,000	$ 90,000
Exisitng Interior Drainage Improvements	1	LS	$ 400,000	$ 400,000
Vehicle Gate	1	LS	$ 200,000	$ 200,000
			Subtotal	**$ 1,039,910**
			50% Contingency	$ 519,955
			Total Estimated Construction Cost	**$ 1,559,865**

BCR Discussion. Using the benefit of $6,754,000 and dividing by the costs of SSA-2 ($1,559,865), yields a combined BCR of 4.33. This is well above the threshold of a 1.0 for BCR and the project appears to be a viable candidate to carry forward towards implementation. However, further study and detail (see next steps below) is required to better estimate the construction costs associated with levee/floodwall system. Real estate and tying into the roadway embankment may drive the layout and feasibility of the system moving forward.

Next Steps. Perform preliminary engineering and permitting to better define construction costs. Elements of preliminary engineering that can impact the cost estimates include detailed survey, real estate, ODOT coordination, environmental impacts, detailed hydrology, and hydraulics (interior drainage and riverine), and the geotechnical exploration and testing program. These all represent risks to the cost estimate presented above.

***SSA-3.* Floodwall on the left bank of Raccoon Creek from 11th Street Bridge downstream to CSX Bridge**

This alternative involves building a levee/floodwall along the left bank of Raccoon Creek between the 11th Street Bridge downstream to the CSX bridge tying into the embankments. This will protect the area to the north. Real estate, obstructed views, terminating at roadway and railroad embankments (will need to be analyzed as levees), and coordination with multiple property owners are significant challenges if the project advances to preliminary design stage. The general physical characteristics of the levee/floodwall include:

- 100-Year Flood Elevation ranges from 829.0 +/- (at 11th Street Bridge) to 824.0 at the CSX Bridge. The updated HEC-RAS model is similar.
    - Top of protection varies and is tied into the bridge crossings to reduce the number of vehicular gates and bridge modifications. This will protect up to the 100-year event without freeboard.
        - Top of Protection from 11th Street bridge to W. Main Street bridge is 829.0 to 826.0 – Avoids Road Crossing
        - Top of Protection from W. Main Street bridge to CSX bridge is 826.0 to 826.0 – Need Roadway Gates at Jefferson and Wilson Street bridges
- 2,563 feet of 6-foot T-Wall
- 8 Gatewells for interior drainage
- Existing interior drainage improvements – This includes adding flap gates and gatewells to existing storm drains in the protected area
- 1 storm water pump station
- Utility relocations and treatment (for seepage)
- 2 Vehicle gates (Jefferson Street and Wilson Street bridges)

Benefits. The construction of the levee system protects the structures behind the levee for events up to an elevation range upstream of 829.0 to downstream of 824.0, resulting in flood damage reduction through avoided damages.

The HAZUS Economics results are shown below. Based on the HAZUS output, total **benefits of $31,669,000** are derived by subtracting the reduced damages of $114,839,000 from the existing damages of $146,508,000.

Table 31 HAZUS output for the HEC-RAS Steady State Model run with SSA-3 Levee Area Protected

Occupancy Type	Total Loss	Building Loss	Contents Loss	Inventory Loss	Relocation Cost	Income Loss	Rental Income Loss	Wage Loss	Direct Output Loss
AGR	**$451,000**	$40,000	$153,000	$156,000	$16,000	$64,000	$0	$22,000	$256,000
COM	**$79,205,000**	$6,339,000	$17,976,000	$4,187,000	$5,421,000	$21,494,000	$3,990,000	$19,798,000	$46,406,000
EDU	**$42,000**	$2,000	$14,000	$0	$0	$7,000	$0	$19,000	$174,000
GOV	**$3,037,000**	$19,000	$135,000	$0	$126,000	$91,000	$50,000	$2,616,000	$601,000
IND	**$6,570,000**	$1,795,000	$3,552,000	$522,000	$270,000	$138,000	$45,000	$248,000	$1,066,000
REL	**$710,000**	$40,000	$275,000	$0	$16,000	$109,000	$1,000	$269,000	$1,529,000
RES	**$24,824,000**	$7,169,000	$4,746,000	$0	$2,502,000	$2,211,000	$2,992,000	$5,204,000	$11,599,000
Total	**$114,839,000**	**$15,404,000**	**$26,851,000**	**$4,865,000**	**$8,351,000**	**$24,114,000**	**$7,078,000**	**$28,176,000**	**$61,631,000**

Figure 38 SSA-3, Levee between 11th Street and CSX Bridge

Table 32 Cost Estimate for SSA-3, Levee between 11th Street and CSX Bridge

Item	Qty	Unit	Unit Cost	Cost
Mobilization/Demobilization	1	LS	$ 500,000	$ 500,000
Sediment and Erosion Control	4	Ac	$ 10,000	$ 40,000
L-Wall	2,563	LF	$ 2,700	$ 6,920,100
Gatwell and Interior Drain Outlet	8	LS	$ 30,000	$ 240,000
Exisitng Interior Drainage Improvements	1	LS	$ 800,000	$ 800,000
Stormwater Pump Station	1	LS	$ 1,000,000	$ 1,000,000
Utility relocations and treatment	1	LS	$ 1,000,000	$ 1,000,000
Vehicle Gate	2	EA	$ 400,000	$ 800,000
			Subtotal	**$ 11,300,100**
			50% Contingency	$ 5,650,050
			Total Estimated Construction Cost	**$ 16,950,150**

BCR Discussion. Using the benefit of $31,669,000 and dividing by the costs of SSA-3 ($16,950,150), yields a combined BCR of 1.87. This is well above the threshold of a 1.0 for BCR and the project appears to be a viable candidate to carry forward towards implementation. However, further study and detail (see next steps below) is required to better estimate the construction costs associated with levee/floodwall system. Real estate and tying into the CSX railway embankment may drive the layout and feasibility of the system moving forward.

Next Steps. Perform preliminary engineering and permitting to better define construction costs. Elements of preliminary engineering that can impact the cost estimates include detailed survey, real estate, CSX coordination, environmental impacts, detailed hydrology, and hydraulics (interior drainage and riverine), and the geotechnical exploration and testing program. These all represent risks to the cost estimate presented above.

SSA-4. **Levee/Floodwall on right bank of Raccoon Creek from 11th Street Bridge downstream to Buckeye Scenic Railroad Bridge**

This alternative involves building a levee/floodwall along the right bank of Raccoon Creek between the 11th Street Bridge downstream to the Buckeye Scenic Railroad bridge tying into the embankments. This will protect the area to the south and west of the alignment. Real estate, obstructed views, terminating at roadway and railroad embankments (will need to be analyzed as levees), and coordination with multiple property owners are significant challenges if the project advances to preliminary design stage. The general physical characteristics of the levee/floodwall include:

- 100-Year Flood Elevation ranges from 829.0 +/- (at 11th Street Bridge) to 820.0 at the Buckeye Scenic Railway Bridge. The updated HEC-RAS model is similar.
    - Top of protection varies and is tied into the bridge crossings to reduce the number of vehicular gates and bridge modifications. This will protect up to the 100-year event without freeboard.
        - Top of Protection from 11th Street bridge to W. Main Street bridge is 829.0 to 826.0 – Avoids Road Crossing
        - Top of Protection from W. Main Street bridge to Buckeye Scenic Railway bridge is 826.0 to 824.0 – Need Roadway Gates at Jefferson and Wilson Street bridges
- 1,000 feet of 6-foot levee with 3:1 side slopes and 12-foot top width and toe drains
- 2,537 feet of 6-foot T-Wall
- 8 Gatewells for interior drainage
- Existing interior drainage improvements – This includes adding flap gates and gatewells to existing storm drains in the protected area
- 1 storm water pump station
- Utility relocations and treatment (for seepage)
- 2 Vehicle gates (Jefferson Street and Wilson Street bridges)

Benefits. The construction of the levee system protects the structures behind the levee for events up to an elevation range upstream of 829.0 to downstream of 824.0, resulting in flood damage reduction through avoided damages.

The HAZUS Economics results are shown below. Based on the HAZUS output, total **benefits of $27,740,000** are derived by subtracting the reduced damages of $118,768,000 from the existing damages of $146,508,000.

Table 33 HAZUS Output for the HEC-RAS Steady State Model run with SSA-4 Levee Area Protected

Occupancy Type	Total Loss	Building Loss	Contents Loss	Inventory Loss	Relocation Cost	Income Loss	Rental Income Loss	Wage Loss	Direct Output Loss
AGR	**$451,000**	$40,000	$153,000	$156,000	$16,000	$64,000	$0	$22,000	$256,000
COM	**$77,697,000**	$6,457,000	$18,150,000	$4,522,000	$5,366,000	$19,513,000	$3,956,000	$19,733,000	$45,815,000
EDU	**$42,000**	$2,000	$14,000	$0	$0	$7,000	$0	$19,000	$174,000
GOV	**$3,040,000**	$19,000	$136,000	$0	$126,000	$91,000	$50,000	$2,618,000	$601,000
IND	**$5,054,000**	$1,271,000	$2,755,000	$487,000	$150,000	$129,000	$31,000	$231,000	$1,003,000
REL	**$2,929,000**	$170,000	$1,112,000	$0	$200,000	$422,000	$19,000	$1,006,000	$5,639,000
RES	**$29,555,000**	$9,340,000	$5,715,000	$0	$3,590,000	$2,211,000	$3,495,000	$5,204,000	$11,599,000
Total	**$118,768,000**	**$17,299,000**	**$28,035,000**	**$5,165,000**	**$9,448,000**	**$22,437,000**	**$7,551,000**	**$28,833,000**	**$65,087,000**

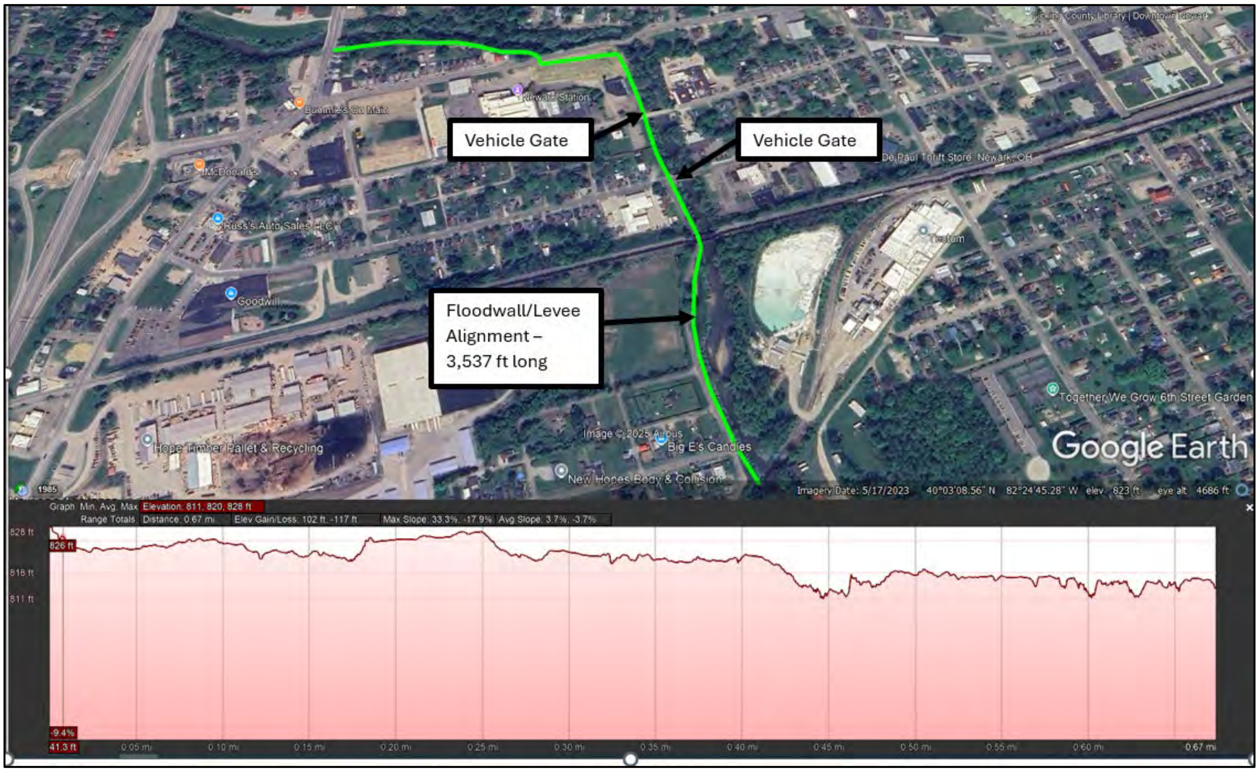

Figure 39 SSA-4, Levee between 11th Street and Buckeye Scenic Railroad Bridge

BCR Discussion. Using the benefit of $27,740,000 and dividing by the costs of SSA-4 ($18,239,850 from Table 26 below), yields a combined BCR of 1.52. This is well above the threshold of a 1.0 for BCR and the project appears to be a viable candidate to carry forward towards implementation. However, further study and detail (see next steps below) is required to better estimate the construction costs associated with levee/floodwall system. Real estate and tying into the Buckeye Scenic Railway embankment may drive the layout and feasibility of the system moving forward.

Table 34 Cost Estimate for SSA-4, Levee between 11th Street and Buckeye Scenic Railroad Bridge

Item	Qty	Unit	Unit Cost	Cost
Mobilization/Demobilization	1	LS	$ 850,000	$ 850,000
Sediment and Erosion Control	4	Ac	$ 10,000	$ 40,000
Levee	1,000	LF	$ 580	$ 580,000
L-Wall	2,537	LF	$ 2,700	$ 6,849,900
Gatwell and Interior Drain Outlet	8	LS	$ 30,000	$ 240,000
Exisitng Interior Drainage Improvements	1	LS	$ 800,000	$ 800,000
Stormwater Pump Station	1	LS	$ 1,000,000	$ 1,000,000
Utility relocations and treatment	1	LS	$ 1,000,000	$ 1,000,000
Vehicle Gate	2	EA	$ 400,000	$ 800,000
			Subtotal	**$ 12,159,900**
			50% Contingency	$ 6,079,950
			Total Estimated Construction Cost	**$ 18,239,850**

Next Steps. Perform preliminary engineering and permitting to better define construction costs. Elements of the preliminary engineering that can impact the cost estimates include detailed survey, real estate, railroad coordination, environmental impacts, detailed hydrology, and hydraulics (interior drainage and riverine), and the geotechnical exploration and testing program. These all represent risks to the cost estimate presented above.

6.0 Conclusions

The implementation and phasing of alternatives could be driven by a number of factors including risks, funding availability, political influence, development pressures, and many other external factors. However, HDR would recommend completing the FEMA Regulatory Mapping updates (WA-1) as the priority amongst the twenty-one alternatives. This is because all the other alternative's advancement will utilize the flood elevations and discharge information from the regulatory maps to design and formulate their implementation.

Summaries of the alternative's evaluations, by category, are included below.

Table 35 Watershed Alternatives (WA)

Alternative	Description	Estimated Implementation Cost [a]	Notes
WA-1	Federal Emergency Management Agency (FEMA) Flood Insurance Study (FIS) Update for Raccoon Creek, Moots Run, and Lobdell Creek	$350,000	Assumes HEC-RAS 2D modeling for this study will be used as a starting point
WA-2	Risk Informed Streambank Stabilization Program and Mitigation Fund	$400,000	Initial screening tool and streambank assessment to prioritize restoration reaches
WA-3	More Restrictive Zoning, Stormwater Permitting, Setbacks and Buffers	N/A[b]	Could vary greatly, no estimate provided
WA-4	Flood Warning System Update	N/A[b]	Utilize the model from WA-1 to identify warning thresholds and link to existing gage data and action levels
a – Estimated study funding required **b** – Costs range greatly varied based on scope of implementation			

Table 36 Reach-Based Alternatives (RBA)

Alternative	Description	Flood Reduction Benefits[a]	Estimated Cost	Benefit-to-Cost Ratio
RBA-1	Detention Areas between SR 62 and the Johnstown Wastewater Treatment Plant	$1,038,000	$2,330,713	0.11[b]
RBA-2	Dam on Lobdell Creek	$6,078,000	$4,018,728	1.51
RBA-3	Detention Areas south of Granville Water Treatment Plant	$1,038,000	$7,025,468	0.11[b]
RBA-4	Bridge improvements at State Route 661 (main Street) in Granville	N/A[c]	N/A[c]	N/A[c]
RBA-5	Bridge and Conveyance Improvements in downtown Newark	N/A[c]	N/A[c]	N/A[c]

Alternative	Description	Flood Reduction Benefits[a]	Estimated Cost	Benefit-to-Cost Ratio
RBA-6	Debris Booms	N/A[c]	N/A[c]	N/A[c]
RBA-7	Nine Element Plan Water Quality Projects	N/A[c]	N/A[c]	N/A[c]

a – Benefits derived from HAZUS damages for 100-year event (existing damaged minus proposed damages)

b – A single BCR for RBA-1 and RBA-3 was calculated based on both projects being implemented due to budgetary constraints. The benefits were derived from HAZUS using a single HEC-RAS model with both alternatives incorporated divided by the combined costs ($2,330,713 plus $7,025,468)

c – Due to complexities and the wide range of how this alternative can be implemented, it was not hydraulically modeled. Therefore, costs and BCR were not derived

Table 37 Critical Infrastructure Alternatives (CIA)

Alternative	Description	Flood Reduction Benefits [a]	Estimated Construction Cost [b]
CIA-1	Levee/Floodwall at Johnstown WWTP	N/A	$954,825
CIA-2	Levee/Floodwall at Alexandria WWTP	N/A	$1,088,715
CIA-3	Levee/Floodwall at Granville WTP	N/A	$815,730
CIA-4	Levee/Floodwall at Denison Physical Plant	N/A	$912,300
CIA-5	Levee Floodwall at Granville Township Fire Department	N/A	$119,100
CIA-6	Levee/Floodwall at Granville WWTP	N/A	$2,243,265

a – Benefits not estimated because they are much larger than flood impacts to individual facility. The impacts are to community well beyond the floodplain

Table 38 Site-specific alternatives (SSA)

Site Specific Alternatives				
Alternative	Description	Flood Reduction Benefits [a]	Estimated Construction Cost	Benefit-to-Cost Ratio
SSA-1	Levee/Floodwall from Granville Square Apartments to Granville Water Treatment Plant	$3,929,000	$4,434,150	0.89
SSA-2	Levee/Floodwall on left of bank Raccoon Creek from SR 79 Bridge downstream to 11th Street Bridge (White Field)	$6,754,000	$1,559,865	4.33
SSA-3	Levee/Floodwall on left bank of Raccoon Creek from 11th Street Bridge downstream to CSX Bridge	$31,669,000	$16,950,150	1.87
SSA-4	Levee/Floodwall on right bank of Raccoon Creek from 11th Street Bridge downstream to Scenic Buckeye Railroad Bridge	$27,740,000	$18,239,850	1.52

a – Estimated using HAZUS damages by Census Block Protected for the 100-year flood event

6.1 Decisions and Limitations of this Study

This report does not contain an exhaustive or complete evaluation of all potential or possible design alternatives. Any decisions based on this report are the responsibility of the SLWCD. Decisions by SLWCD should consider the limitations and residual risks associated with the alternatives identified in this report. HDR does not warrant or guarantee our work or recommendations.

The opinions of cost and benefit cost ratios provided in this report are intended to allow a comparative evaluation between alternatives and do not constitute a detailed evaluation or prediction of actual construction costs or project feasibility.

Developed construction cost estimates were considered Class 5 estimates in accordance with the Association for the Advancement of Cost Engineering (AACE), which is appropriate for conceptual or screening-level estimates. For the purposes of this report, a contingency of 50% was applied to each alternative sub-total. The opinions of cost provided in this report are intended to allow a comparative evaluation between alternatives and do not constitute a detailed evaluation or prediction of actual construction costs.

No detailed analysis, inspection, investigation, or calculations were completed in the development of alternatives presented in this report. This is simply documenting the information available and discussion of flood risk reduction alternatives. The opinions in the report are based on the conditions and information available at the time the document was published. HDR did not verify information supplied by others except as specifically indicated in this report. Any use which a third party makes of this document is the responsibility of said third party. Such third party agrees that HDR shall not be responsible for costs or damages of any kind, if any, suffered by it or any other party because of decisions made or actions taken based on this document.

No part of the peer review process or the findings presented in this document is intended to provide legal advice or representation.

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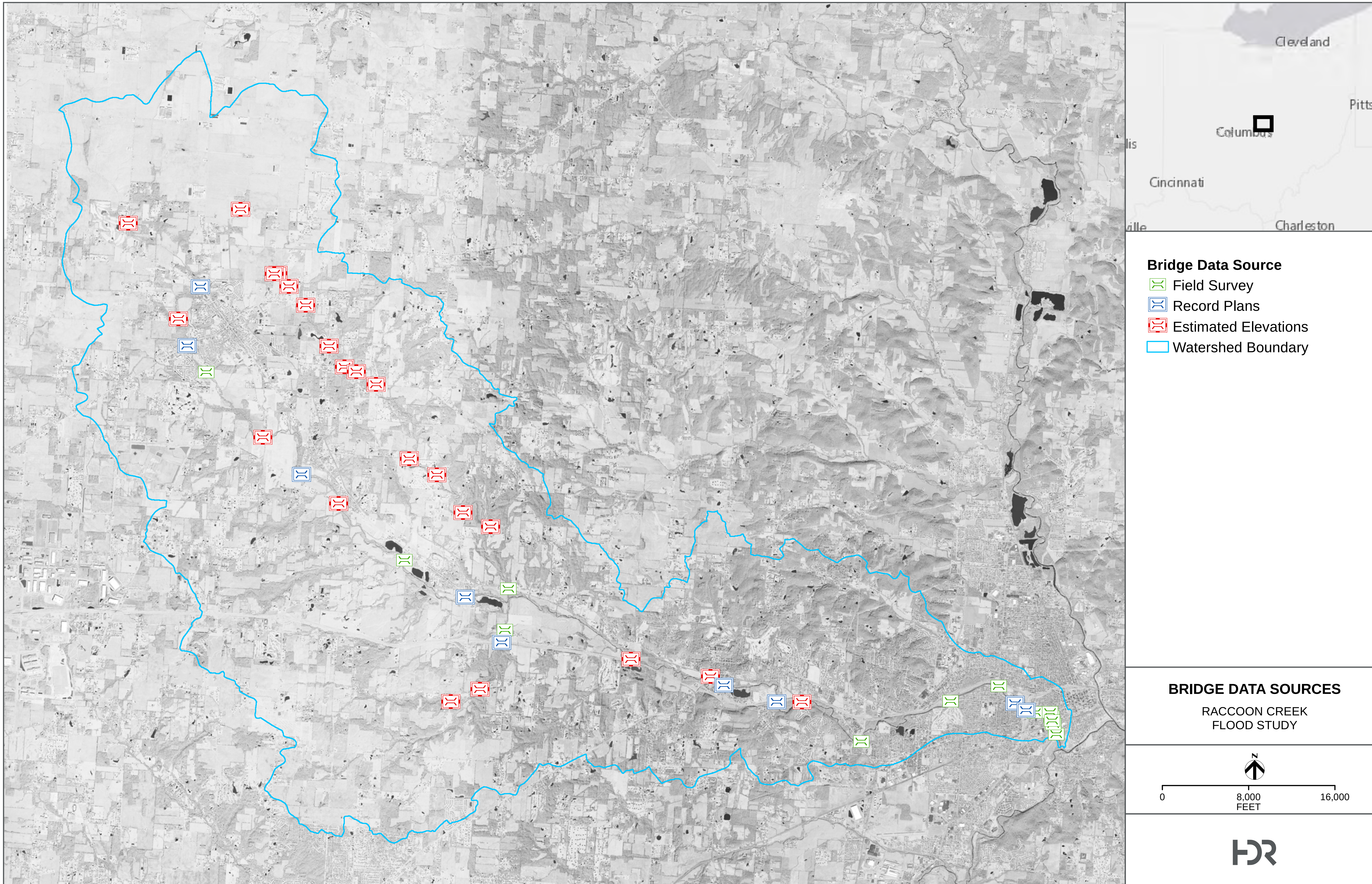
Where Earth meets sky. Hopewell Ceremonial Earthworks. (2023, September 28).

Zoning Map. Granville Township. (2021, June 5).

Appendix A – Bridge Survey Data

- Bridge Locations Map
- Survey Data for Surveyed Bridges



PATH: C:\PROJECTS_LOCAL\RACCOON CREEK\GIS\MAP.MXD - USER: HSTEPHENSO - DATE: 11/11/2024

SITE	Bridge Name	Inspector Initials	Inspection Date	City	Stream Name	Station		Bridge Type	Bridge Width (ft) (3)	Bridge Elevation Left (looking at downstream of bridge) (4)	Bridge Elevation Middle (5)	Bridge Elevation Right (6)
						Begin Bridge (1)	End Bridge (2)					
1	***Buckeye Scenic Railroad bridge***	*JW*	*8/9/2024*	*Newark*	*Raccoon Creek*	*0+00*	*1+52*	*Steel Truss*	*10'*	*824.60*	*824.67*	*824.65*
2	**CSX Railroad bridge**	JW	8/9/2024	Newark	Raccoon Creek	0+00	1+45	Beam	33'	835.57	835.84	835.91
3	**Wilson Street**	JW	8/12/2024	Newark	Raccoon Creek	0+00	1+60	Concrete beams	42'	822.14	822.39	822.17
4	**Jefferson Street**	JW	8/12/2024	Newark	Raccoon Creek	0+00	1+70	Slab	39'	821.46	822.35	820.62
5	**W. Main Street**	JW	8/14/2024	Newark	Raccoon Creek	0+00	1+44	Truss	28'	825.48	826.2	826.42
6	**N. 11th Street**	JW	8/14/2024	Newark	Raccoon Creek	0+00	1+07	Concrete beams	64.5'	828.62	828.64	828.68
7	**Church Street**	JW	12/4/2024	Newark	Raccoon Creek	0+00	2+70	Concrete beams	28'	831.98	833.64	832.97
8	**N. 21st Street**	JW	8/14/2024	Newark	Raccoon Creek	0+00	1+56	Slab	66'	835.78	835.5	835.22
9	**Church Street**	JW	8/15/2024	Newark	Raccoon Creek	0+00	2+09	Concrete beams	43'	856.69	858.46	860.1
10	**Cherry Valley Road**	JW	8/28/2024	Newark	Raccoon Creek	0+00	1+60	Arch/Steel Truss	25' ep - ep	892.15	892.4	892.78
11	**Moots Run Road**	JW	8/23/2024	Alexandria	Moots Run	0+00	1+44	Slab	41'	965.11	966.3	968.06
12	**Raccoon Valley Road**	JW	8/23/2024	Alexandria	Moots Run	0+00	0+91	Slab	28'	937.47	937.63	937.63
12A	**Raccoon Valley Road**	JW	8/23/2024	Alexandria	Moots Run	0+00	0+76	Truss	18'	938.68	938.58	938.72
13	**Jersey Mill Road**	JW	8/28/2024	Alexandria	Raccoon Creek	0+00	0+66	Beam	21.6'	869.8	969.1	968.53
14	**Mink Street**	JW	8/28/2024	Johnstown	Raccoon Creek	0+00	0+85	Concrete beams	26'	1056.54	1057.3	1057.98

SITE	Bridge Name	Stream Bottom Elevation		High Chord (5)	Pier Width (9)	Pier Type (rounded nose, square, cylinder, other)	Pier Spacing (ft) (10)	Number of Piers	Bottom of Deck (BFLOOR)	Bottom of Beam (BOB)	Notes
		Upstream (7)	Downstream (8)								
1	***Buckeye Scenic Railroad bridge***	*801.16*	*801.15*	*824.67*	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*	*821.41*	*Sandstone abutments*
2	**CSX Railroad bridge**	802.87	801.61	835.84	4.25'	varies	45.5'	1		829.28	Pier downstream is square and upstream is rounded
3	**Wilson Street**	803.78	803.23	822.39	N/A	N/A	N/A	N/A		817.77	top of bridge elevations are at e/road at the sidewalk
4	**Jefferson Street**	800.89	801.1	822.35	3' cap	cylinder	35'	2	820.77		deck thickness = 1.42'
5	**W. Main Street**	804.19	803.94	826.2	N/A	N/A	N/A	N/A		824.47	deck thickness = 0.67'
6	**N. 11th Street**	807.52	808	828.64	N/A	N/A	N/A	N/A		824.01	4' concrete beams, 0.67' +/- deck thickness
7	**Church Street**	808.25	807.03	833.64	4.5' cap	rounded nose	90'	2		828.5	deck thickness = 1.00'
8	**N. 21st Street**	812.86	812.72	835.5	2.25'	rounded nose	40'	3	833.63		Bridge is wider on the north end
9	**Church Street**	824.74	823.99	858.46	2.25'	rounded nose	67'	2		855.76	2.2' concrete beams 0.67' +/- deck thickness
10	**Cherry Valley Road**	864.47	864.12	892.4	varies	see photos	varies	see photos			Old arch bridge is under a newly constructed temporary steel truss bridge.
11	**Moots Run Road**	940.11	939.76	966.3	3.25'	rounded nose	41.9'	2	964.16		width of piers vary from abutments and from pier to pier
12	**Raccoon Valley Road**	929.93	929.85	937.63	N/A	N/A	N/A	N/A	934.55		asphalt road surface
12A	**Raccoon Valley Road**	929.97	930.55	938.58	N/A	N/A	N/A	N/A		935.33	bikepath bridge beside Site 12
13	**Jersey Mill Road**	953.23	952.18	969.1	N/A	N/A	N/A	N/A		965.84	deck thickness = 0.60'
14	**Mink Street**	1044.34	1044.23	1057.3	N/A	N/A	N/A	N/A		1055.35	1.38' concrete beams 0.67' +/- deck thickness

Appendix B – Public Meeting Presentations and Data Collection

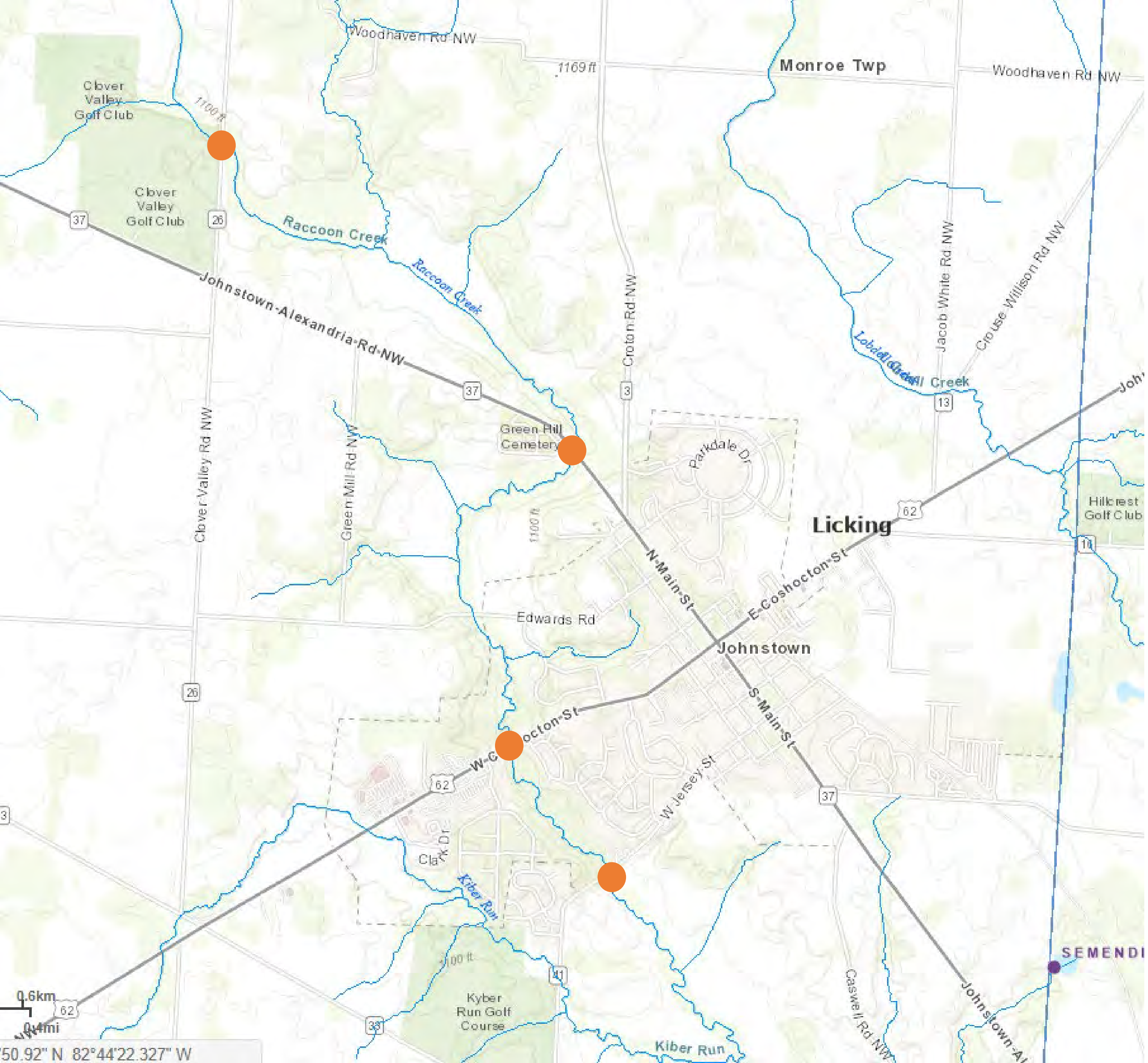
- Field Visit Presentation 04-15-24 (PowerPoint)
- Raccoon Creek Public Meeting 07-18-24 (PowerPoint)
- Raccoon Creek Meeting with Municipalities and Stakeholders 08-19-24 (PowerPoint)
- Raccoon Creek Alternatives Meeting 11-13-24 (PowerPoint)
- Public Meeting Data Collection – 07-18-24 (photos of pins and maps)
- Hartford Fair Data Collection – 08-04-24 (photos of pins and maps)

Field Visit Presentation 04-15-24 (PowerPoint)

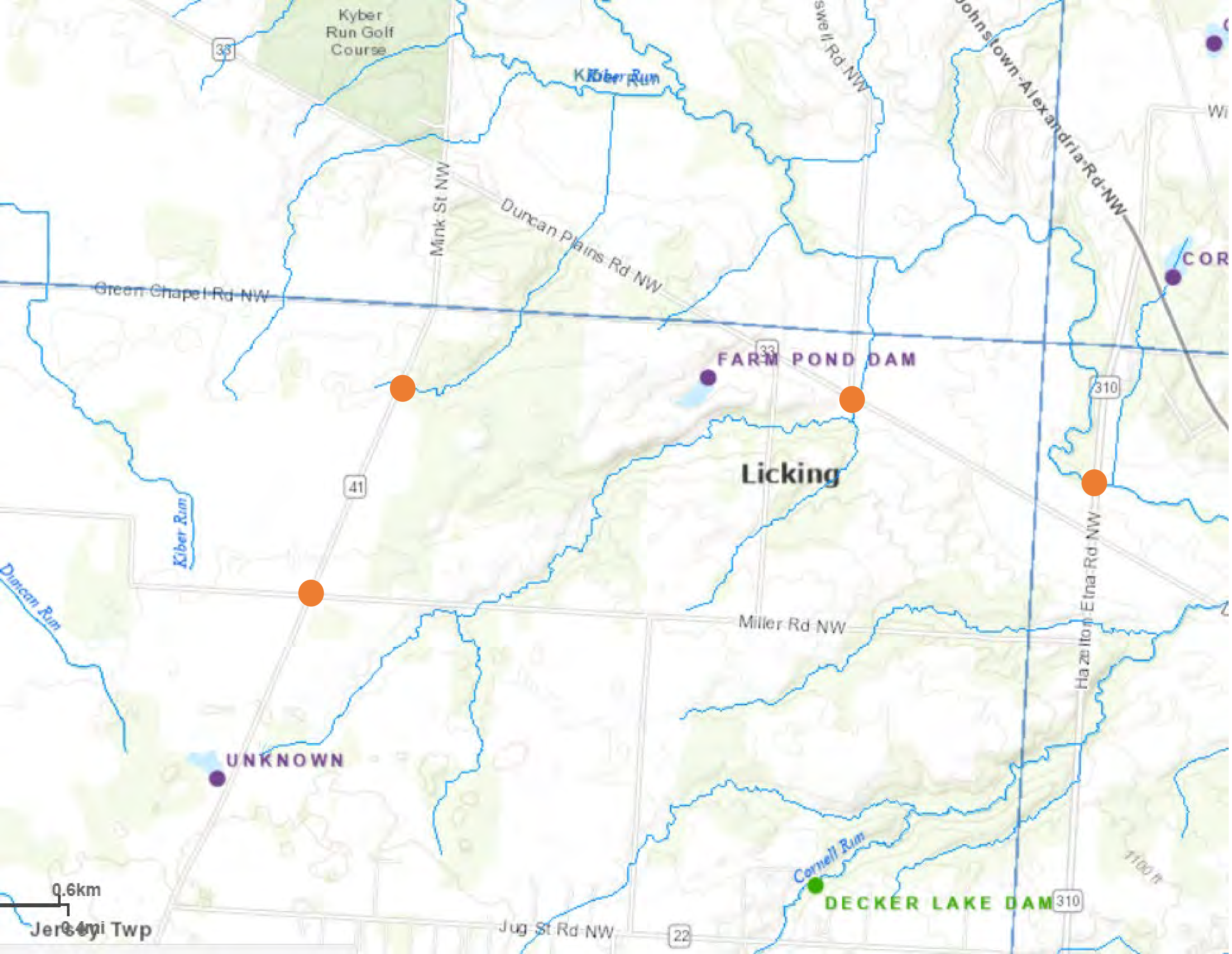
Raccoon Creek Flood Damage Reduction Study

Kick-Off Meeting Materials

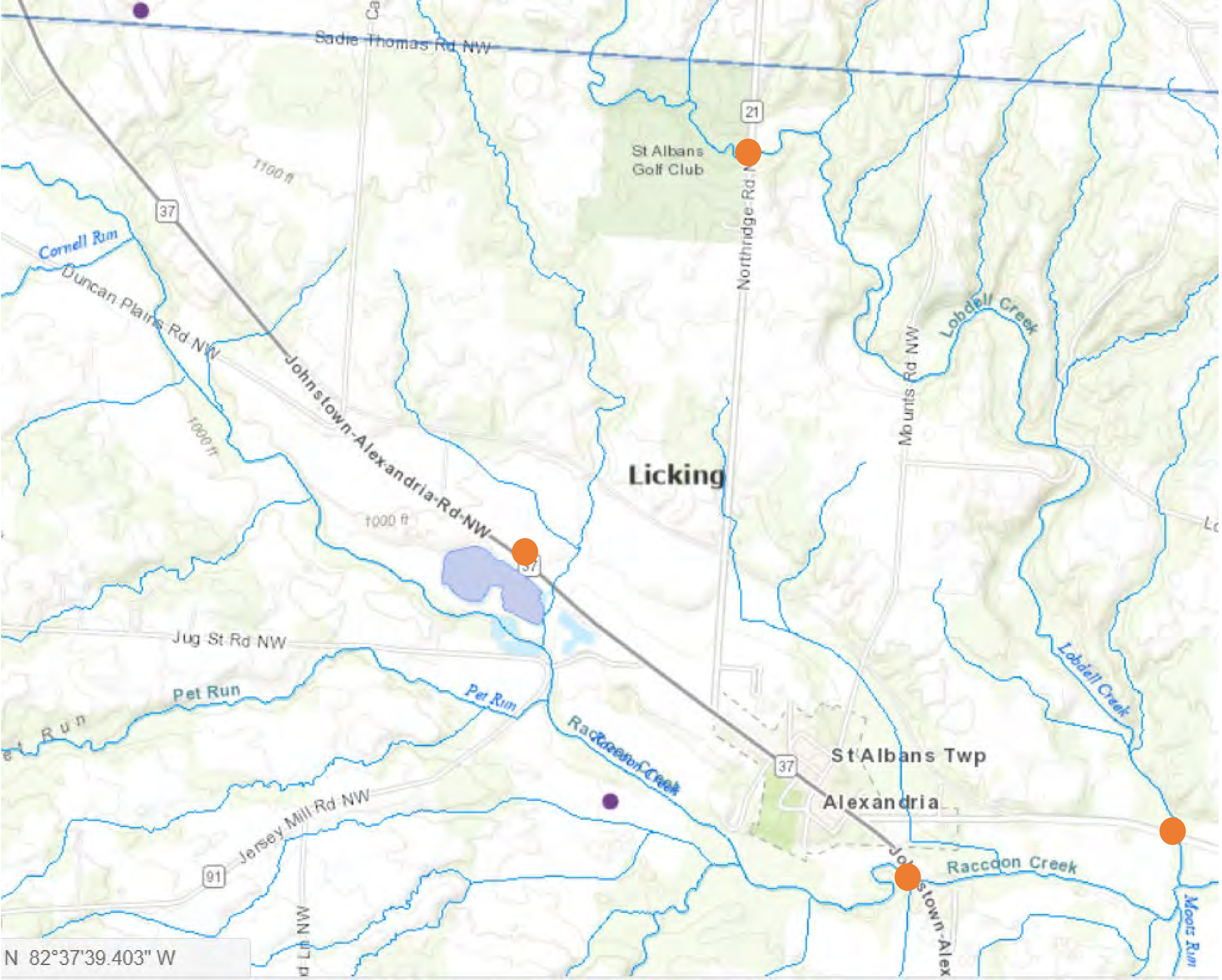
April 15, 2024



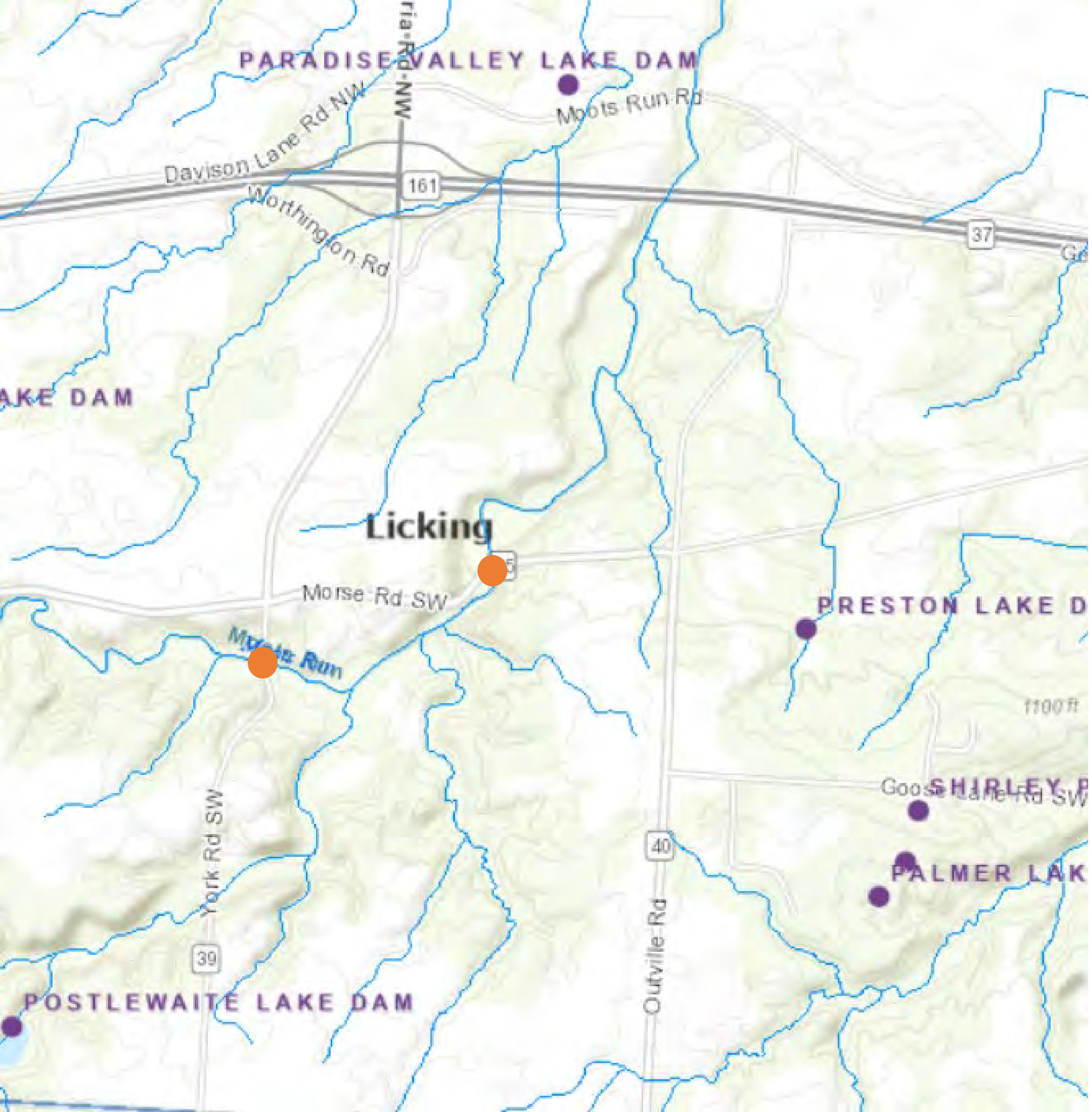
Observation Point During 04/09/24 Field Visit



Observation Point During 04/09/24 Field Visit



Observation Point During 04/09/24 Field Visit



Observation Point During 04/09/24 Field Visit

Observation Point During 04/09/24 Field Visit

Initial Field Observations

- From upper watershed north of Johnstown to south of Granville
- Large woody debris (LWD) and logjams throughout Watershed
- Highly Erodible Soils on Banks
- Some land use lacked buffers on stream banks
- Structural damage centers Johnstown, Alexandria, and New Albany
    - Need modeling to confirm and additional areas could be located on non-modeled tributaries
- Off-Channel and detention solutions will have to account for groundwater elevations and dam safety regulations
- Bike trail (elevated rail converted to bike path) in Granville behind apartments and condos has flap gates on storm sewer penetrations

Initial Thoughts on Alternatives

- Opportunities for delay and convey (upstream to downstream)
  - Delay - Reduce runoff and peak flows in tributaries where opportunities exist
  - Convey – pass flows through damage centers with increased conveyance
- Snagging and Clearing
  - Remove log jams
  - Remove LWD in floodplain where accessible
  - Disposal, re-use in bio-engineering, and mulching (on site or Hope Timber for example)
- Natural channel design and bio-engineering
  - Use LWD and engineering to stabilize bank reaches
  - Consider filter on highly erodible banks and willow stakings

Initial Thoughts on Alternatives, Continued

- Channel improvements & two-stage ditches
  - Located for conveyance and peak attenuation – mindful of slower velocities that may cause debris accumulation
- Regional storage
  - Groundwater, increased residual risk, and dam safety regulations
  - Potential process water/water supply to offset operations & maintenance (O&M)
- Off-channel storage – Similar to Alexandria quarry
  - Groundwater levels will dictate active storage unless lined
  - Potential process water/water supply to offset operations & maintenance (O&M)

Initial Thoughts on Alternatives, Continued

- Roadway crossing improvements
  - Located for conveyance – consider timing and downstream consequences
  - Emergency routes and arterial routes for commerce
- Non-structural measures
  - Elevating, relocating, ring wall, diversion, flood warning systems, etc.
  - Usually for small groups or single structures
- Structural Measures
  - Levees, floodwalls, diversions to protect larger groups of structures
- Regulatory framework for development in watershed

General Ranking / Screening of Alternatives

Identification	Project Types	Flood Damage Reduction $	Economic Benefits $	Other Social Effects	Hydrologic & Hydraulic Impacts	Jurisdiction: Ownership	Environmental Impacts	Cultural & Historic Impacts	Operation & Maintenance	Constructability	Service Life	Recreation Impacts
1	Snagging and Clearing					☐	☐			☐		☐
2	Debris Boom / Collector				☐	☐	☐			☐		☐
3	Streambank Stabilization					☐	☐			☐		☐
4	Stream Restoration					☐	☐	☐		☐		
5	Edge of Field Buffer	☐	☐	☐		☐	☐	☐	☐	☐		☐
6	Diversion						☐	☐		☐		
7	Roadway Crossing / Bridge Improvements				☐		☐	☐				☐
8	Levee / Floodwall	☐	☐	☐	☐	☐	☐	☐		☐		☐
9	Non-Structural Measures	☐	☐	☐					☐	☐		☐

Detailed Ranking – Selected Alternatives

- Flood Damage Reduction Benefits ($)
  - USACE National Economic Development (plus cleanup and cars)
  - Regional Economic Development
- Implementation Costs ($)
  - Engineering, Design and Construction
- Operation & Maintenance Costs ($)
- Life-Cyle Length (Years)
- Other Social Effects
  - Emergency Facilities
  - Critical Infrastructure
- Environmental Effects

Permitting Matrix for Alternatives

Permit Type	Construction Activity								
	Dredge & Sediment Trap	*Stream Restoration and Relocation*	*Bank Stabilization*	*Embankment Armoring*	*Floodwall / Levee*	*Utility and Roadway Protection*	*Non-Structural Floodproofing*	*Bridge Replacement*	*Timeframe (Months)*
Section 404	NWP # 18, 27	NWP # 27	NWP # 13	NWP # 3, 13	NWP # 3	NWP #3, 13		NWP # 12	12
Section 401	Individual 401 or Directors Authorization if impacts exceed thresholds	Individual 401 or Directors Authorization if impacts exceed thresholds	Individual 401 or Directors Authorization if impacts exceed thresholds	Individual 401 or Directors Authorization if impacts exceed thresholds	Should be covered under NWP #3			Individual 401 or Directors Authorization if impacts exceed thresholds	18
FEMA LOMR / CLOMR					MT-2 Form			MT-2 Form	12
County Floodplain Permit		Depends			Jurisdiction			Jurisdiction	3
Local Floodplain Permit		Depends			Jurisdiction			Jurisdiction	3

Raccoon Creek Public Meeting 07-18-24 (PowerPoint)

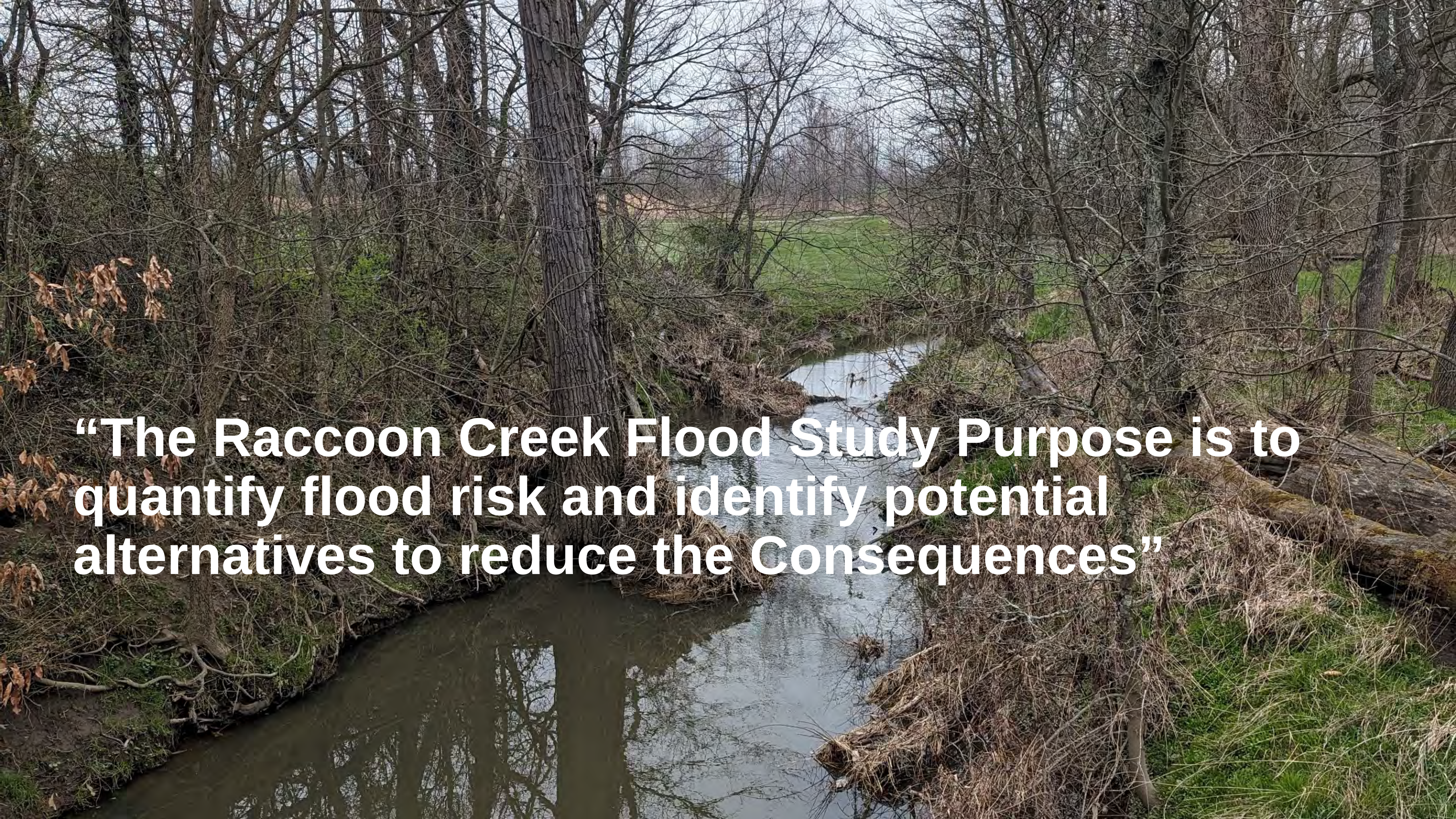
Raccoon Creek Flood Study Public Meeting

HDR

July 18, 2024

AGENDA

01 Study Purpose


“The Raccoon Creek Flood Study Purpose is to quantify flood risk and identify potential alternatives to reduce the Consequences”

Studied Water Courses

- Raccoon Creek, Lobdell Creek, and Moots Run

Flood Risk Concerns

- Rainfall Driven Flooding
- Debris Induced Flooding
- Sediment and Erosion Induced Flooding

Flood Impacts

- Roadway and Utility Interruptions
- Damage to Structures (economic and loss of use)
- Property Flooding (crop damage and loss of use)
- Business Interruptions
- Debris Cleanup
- Regional Economic Impacts
- Critical Infrastructure
- Erosion Issues
- Other Environmental and Social Effects

Flood Study Scope

March 2025 Delivery

- Data Collection & Review
- Survey
- Stakeholder Support & Project Management
- Hydrologic & Hydraulic Analyses
- Alternatives Analysis
- Flood Mitigation Report

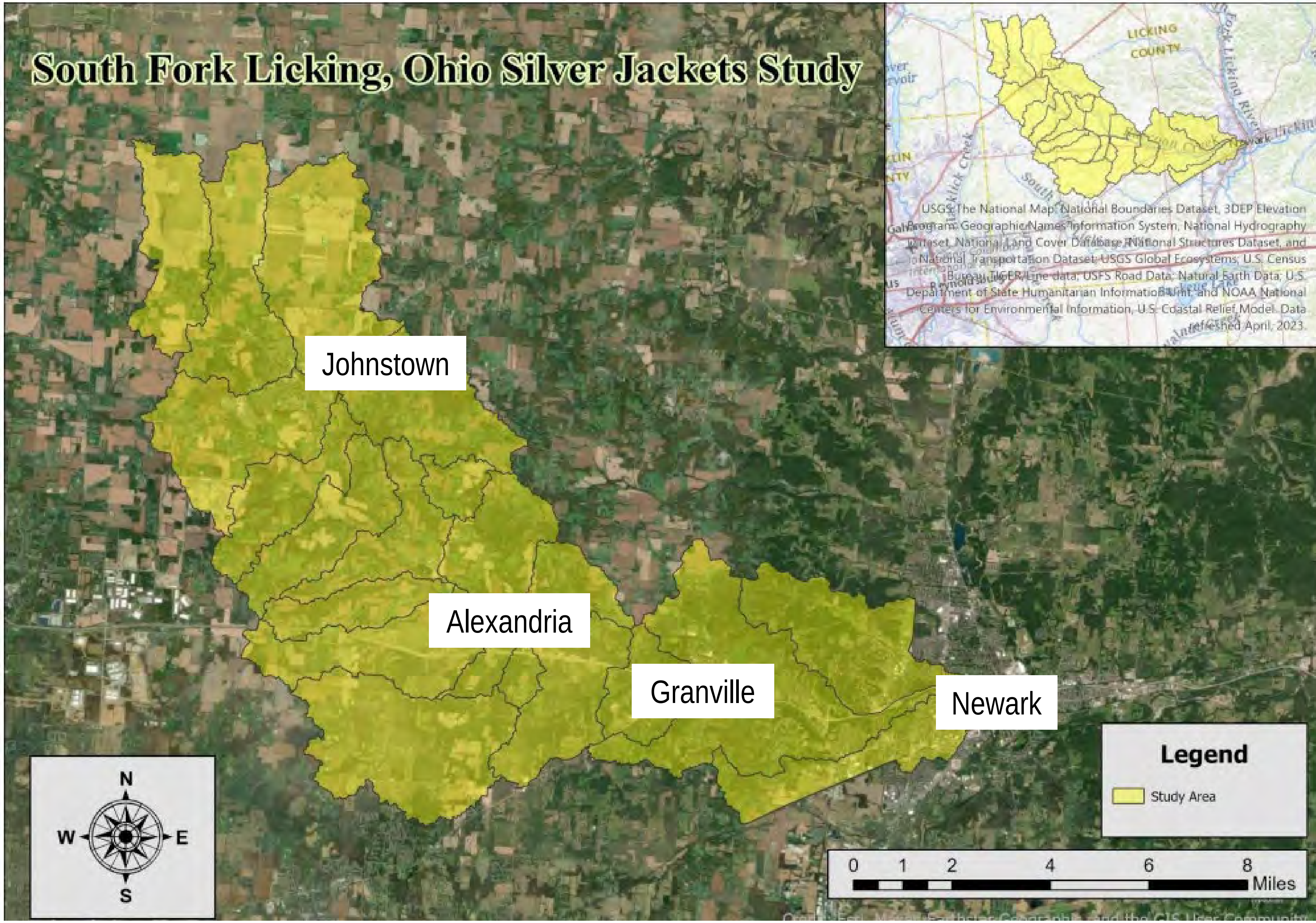
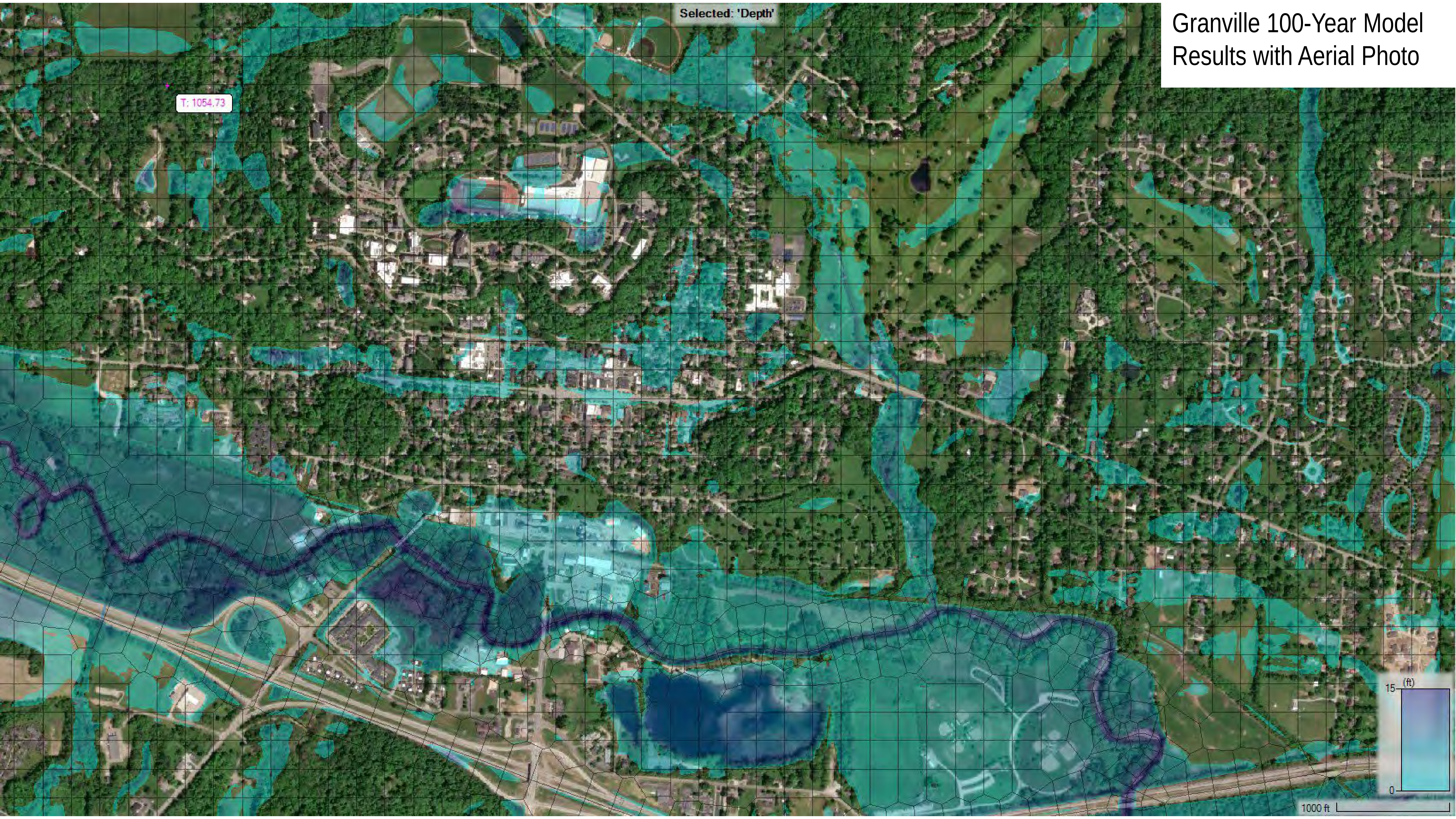


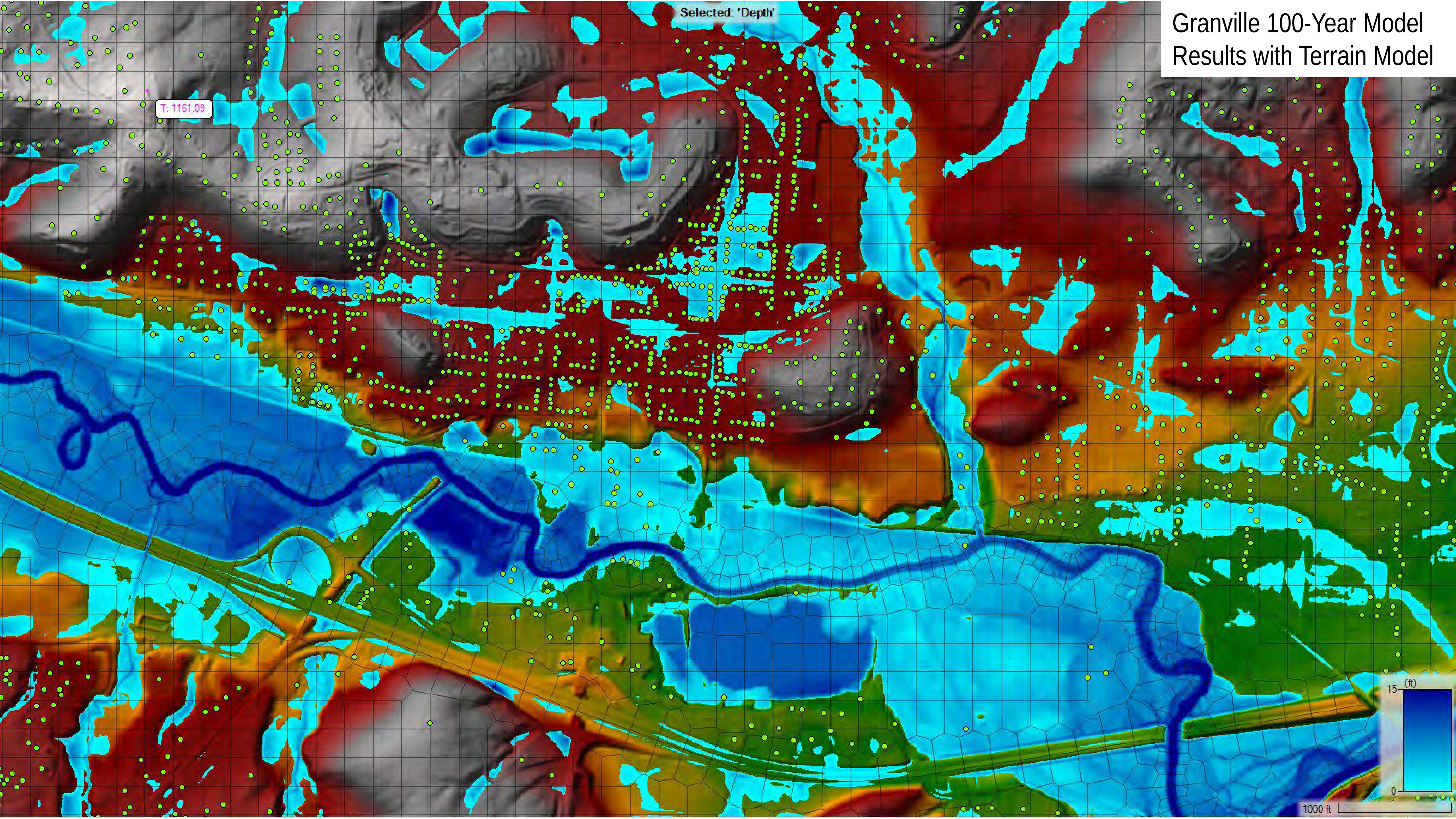
FIGURE - U.S. Army Corps of Engineers Silver Jackets Model and Logjam Study Area and Hydrologic and Hydraulic Model Study Area

02 Modeling Examples

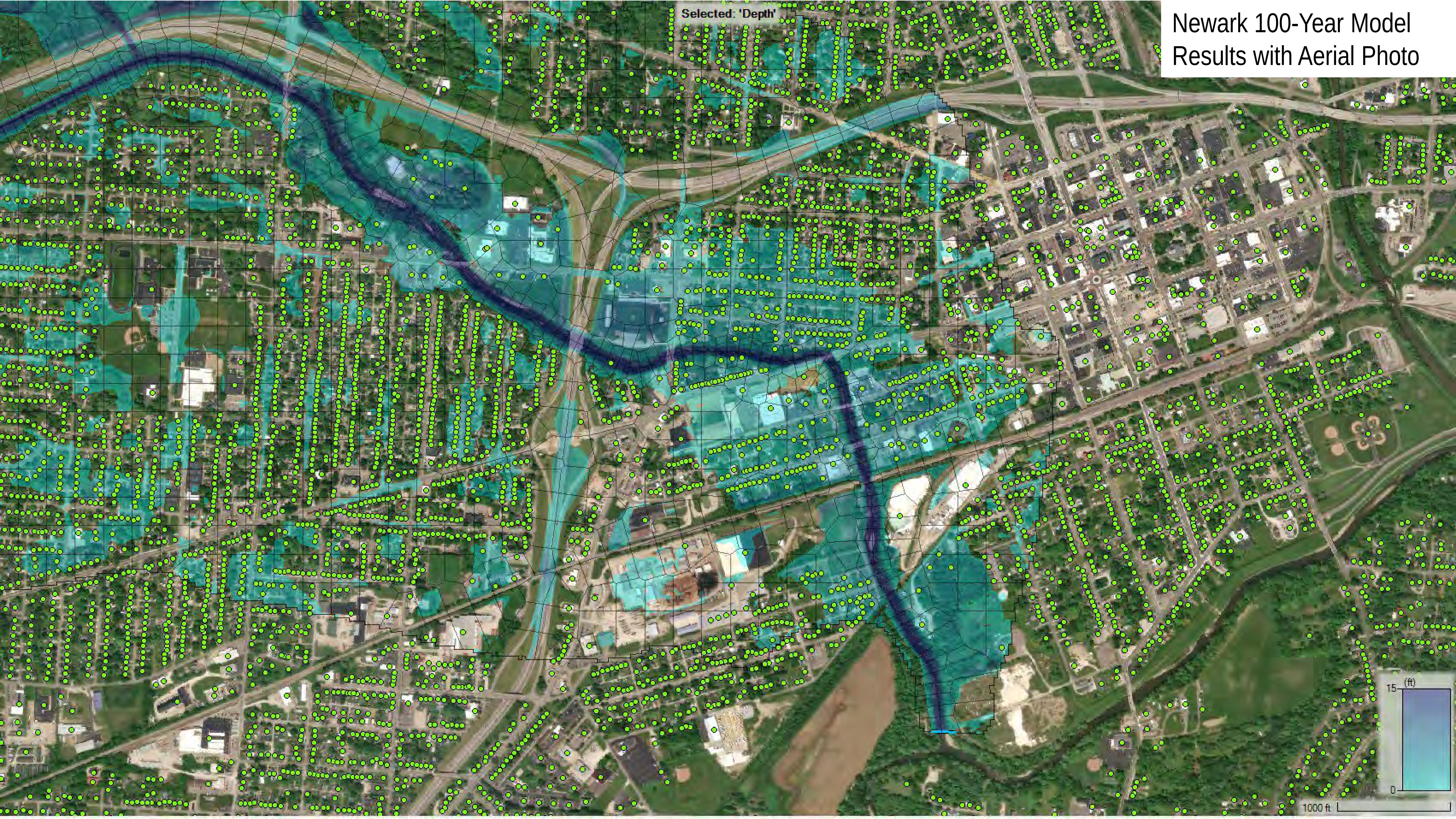
Granville 100-Year Model Results with Aerial Photo



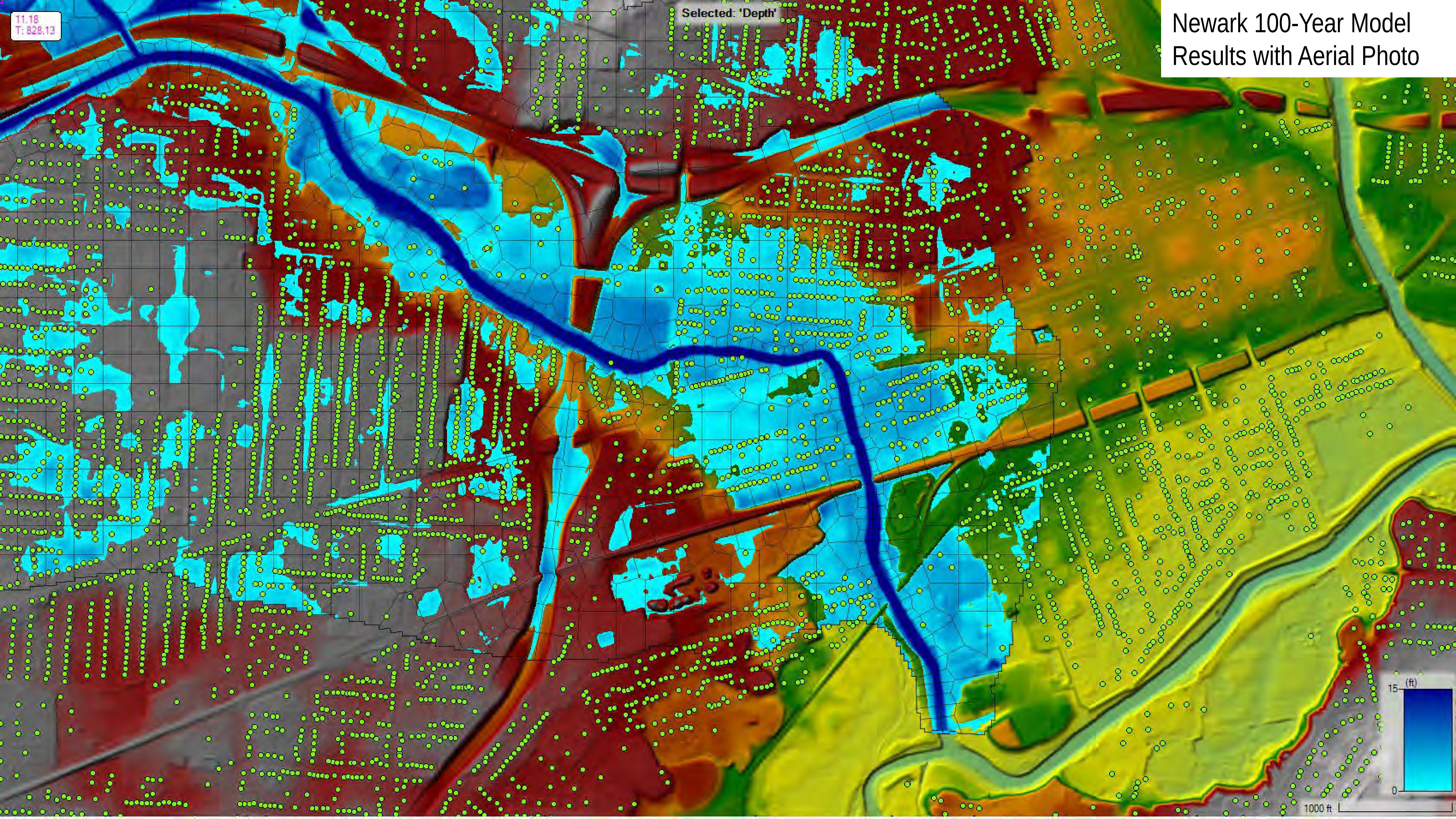
Granville 100-Year Model Results with Terrain Model



Newark 100-Year Model Results with Aerial Photo



Newark 100-Year Model Results with Aerial Photo



03 Instructions for Exhibits

Five Flood Study Exhibits at the Meeting Today

1. Overall Study Area – Showing FEMA 100-Year Floodplain
2. Johnstown Area – Showing FEMA 100-Year Floodplain and Structure Locations
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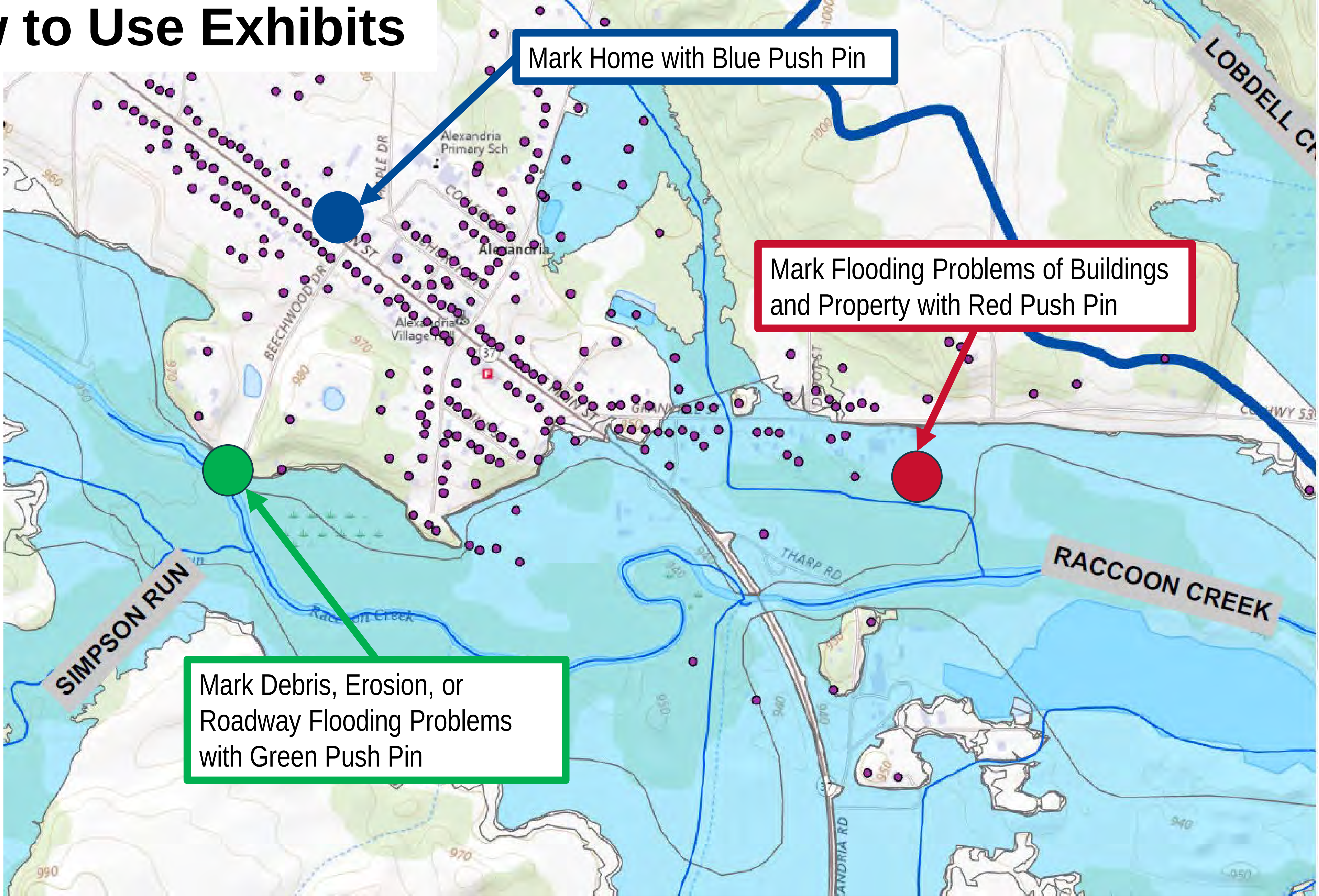
PURPOSE: Show Extent of FEMA Floodplain and Collect Flooding Data for Study

How to Use Exhibits



04

Next Steps

Flood Study Scope
March 2025 Delivery

- Data Collection & Review
- Survey
- Stakeholder Support & Project Management
- Hydrologic & Hydraulic Analyses
- Alternatives Analysis
- Flood Mitigation Report

Next Public Meeting to Share Study Results and Alternatives – Date TBD

The HDR Team

David Moore, PE
Project Manager

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Ashlee Balcerzak
Water Resource Engineer

Courtney Chervenak
Water Resource Engineer

Henry Stephenson, PE
Hydrologic and Hydraulic Modeling Lead

HDR

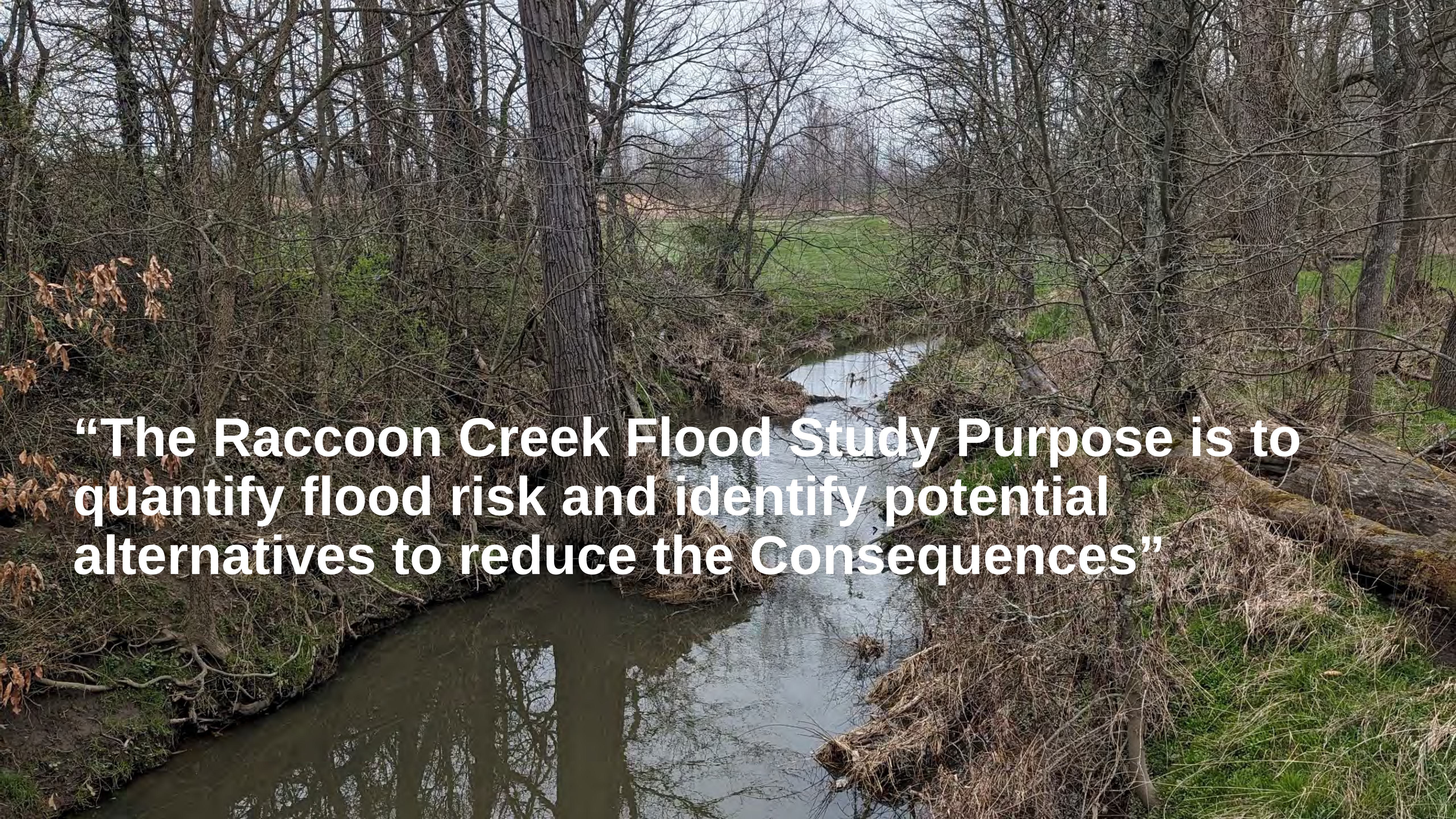
Raccoon Creek Meeting with Municipalities and Stakeholders 08-19-24 (PowerPoint)

Raccoon Creek Flood Study Meeting with Municipalities and Agencies

August 19, 2024

AGENDA

01 Study Purpose


“The Raccoon Creek Flood Study Purpose is to quantify flood risk and identify potential alternatives to reduce the Consequences”

Studied Water Courses

- Raccoon Creek, Lobdell Creek, and Moots Run

Flood Risk Concerns

- Rainfall Driven Flooding
- Debris Induced Flooding
- Sediment and Erosion Induced Flooding

Flood Impacts

- Roadway and Utility Interruptions
- Damage to Structures (economic and loss of use)
- Property Flooding (crop damage and loss of use)
- Business Interruptions
- Debris Cleanup
- Regional Economic Impacts
- Critical Infrastructure
- Erosion Issues
- Other Environmental and Social Effects

Flood Study Scope
March 2025 Delivery

- Data Collection & Review
- Survey
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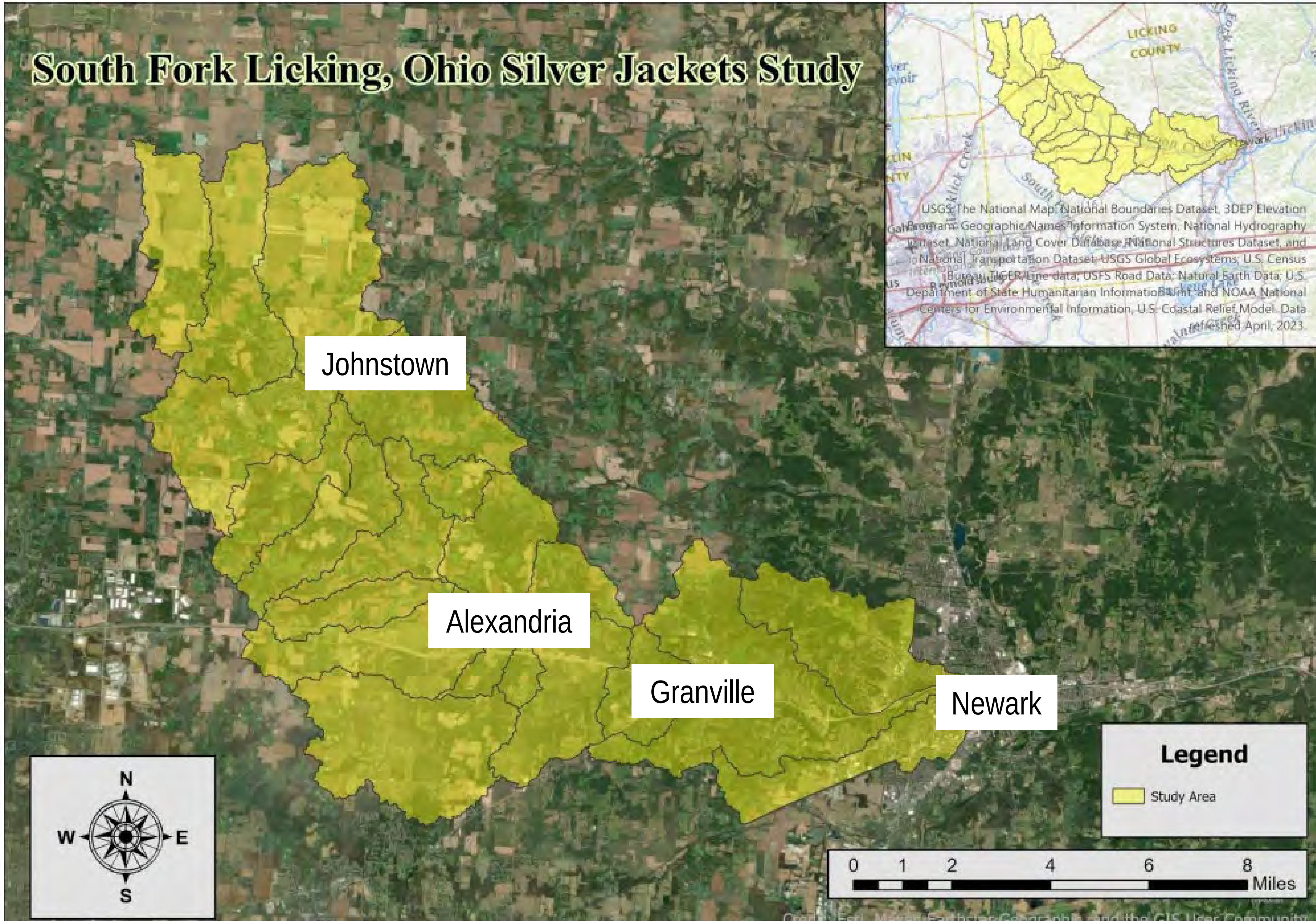

FIGURE - U.S. Army Corps of Engineers Silver Jackets Model and Logjam Study Area and Hydrologic and Hydraulic Model Study Area

02

Modeling Examples

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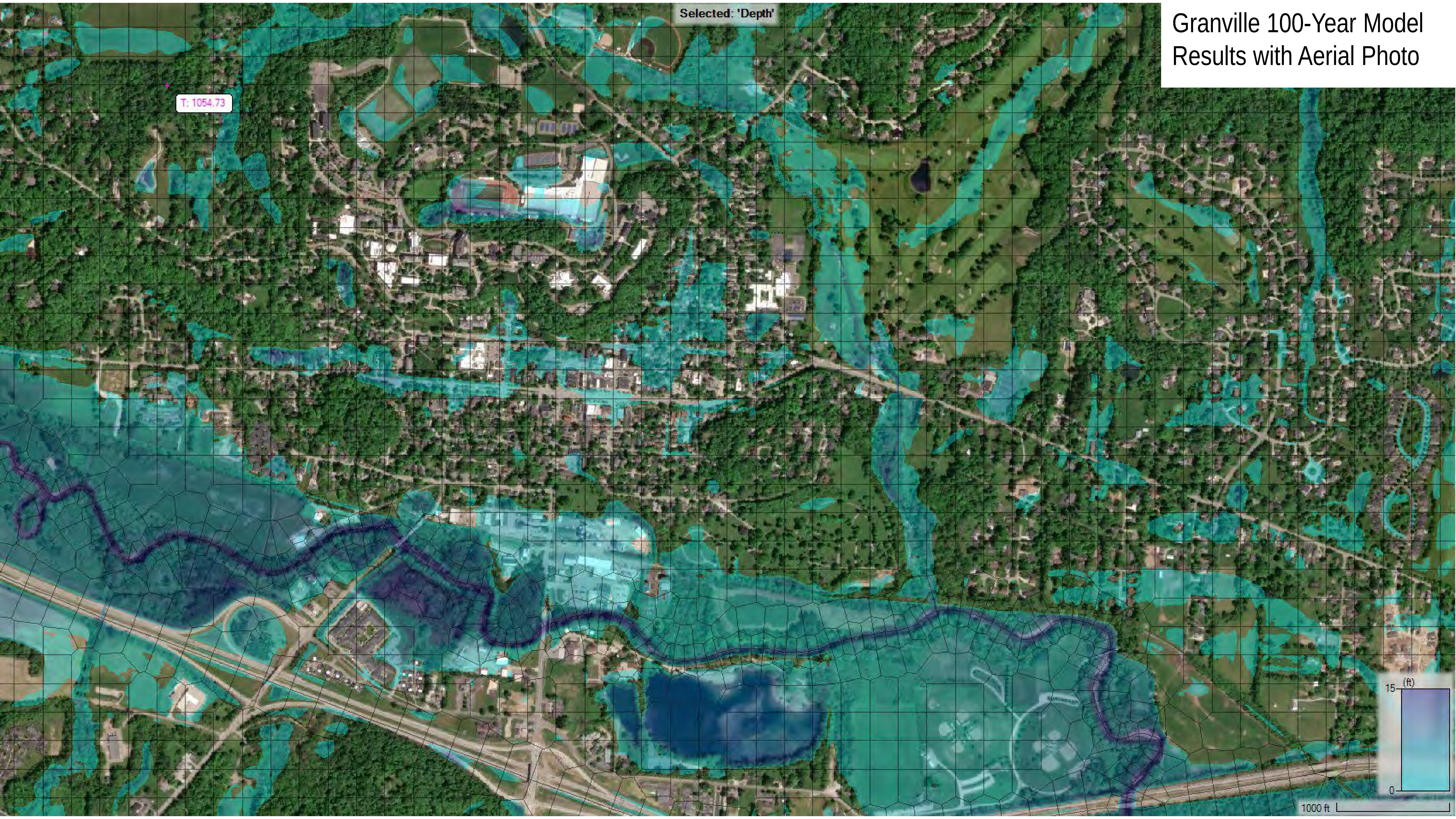

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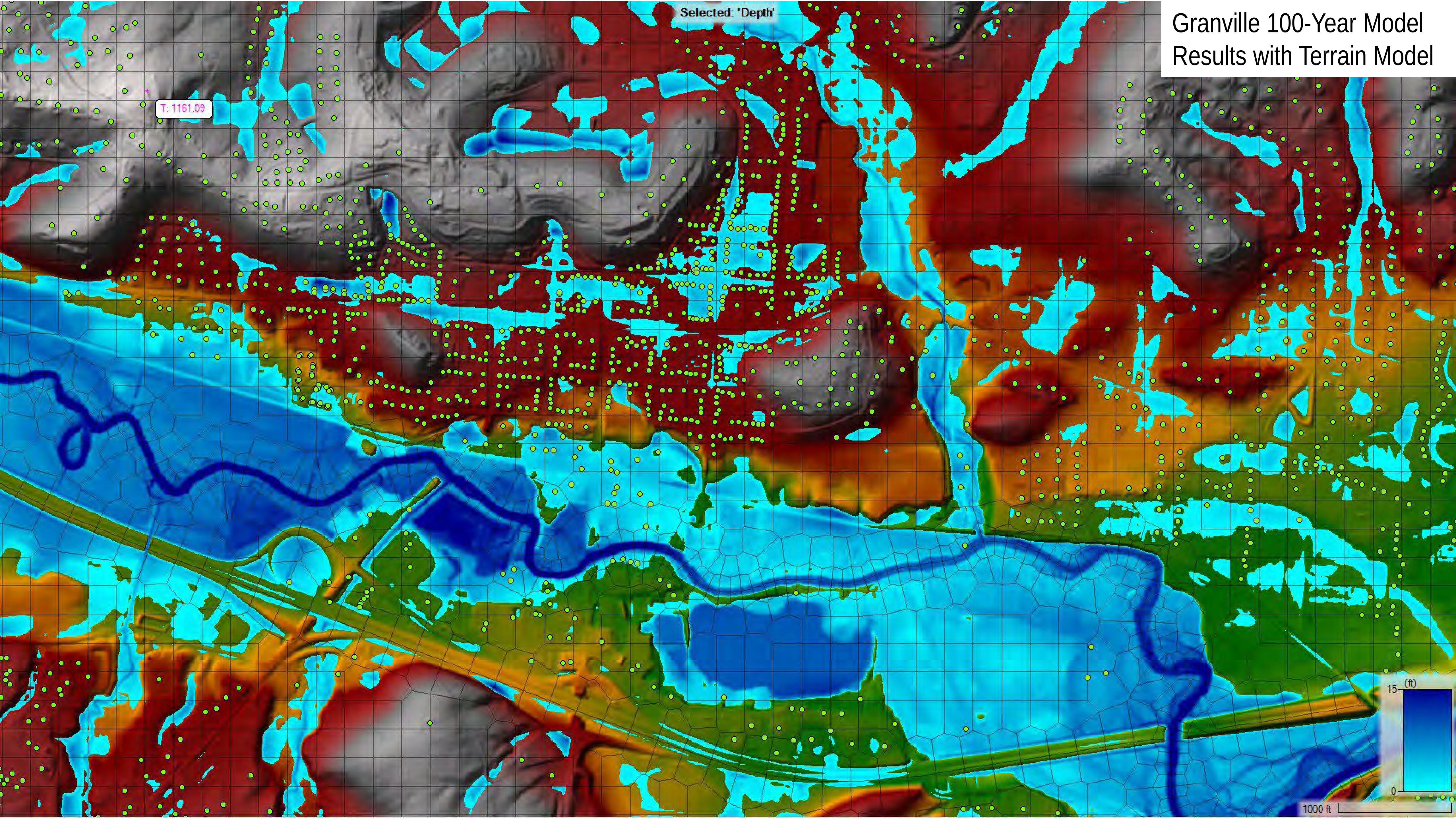
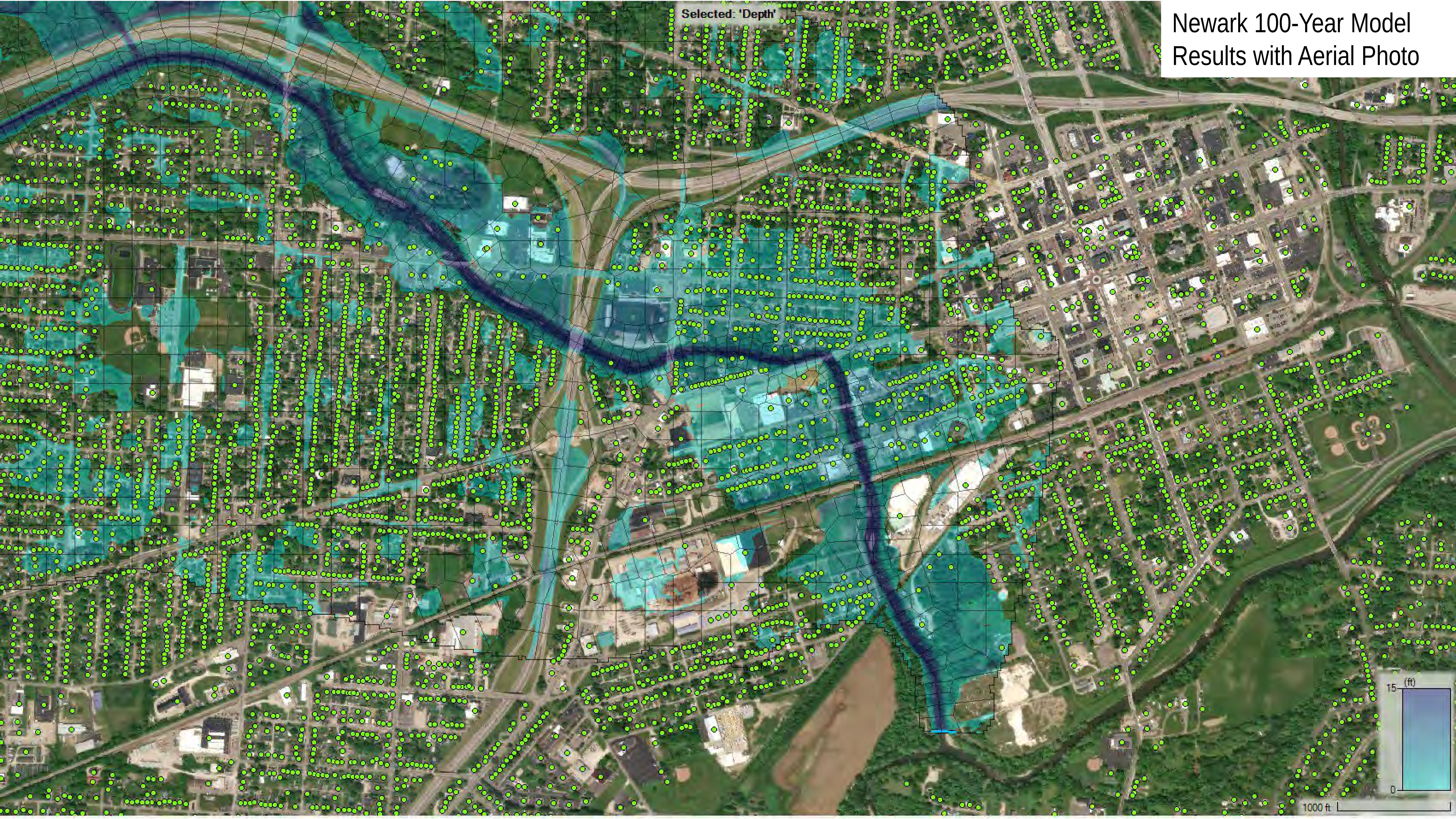
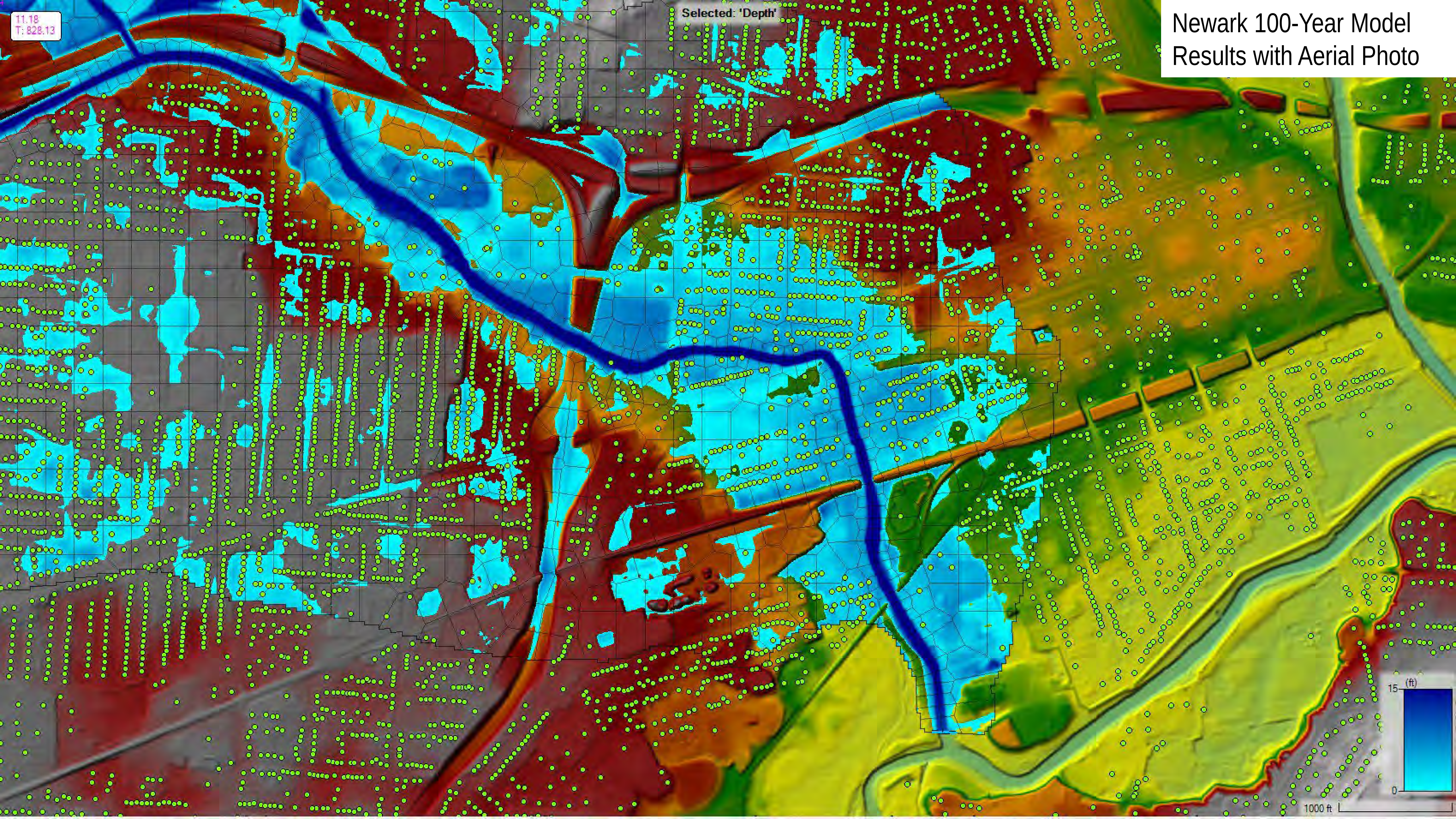


Newark 100-Year Model Results with Aerial Photo



Newark 100-Year Model Results with Aerial Photo



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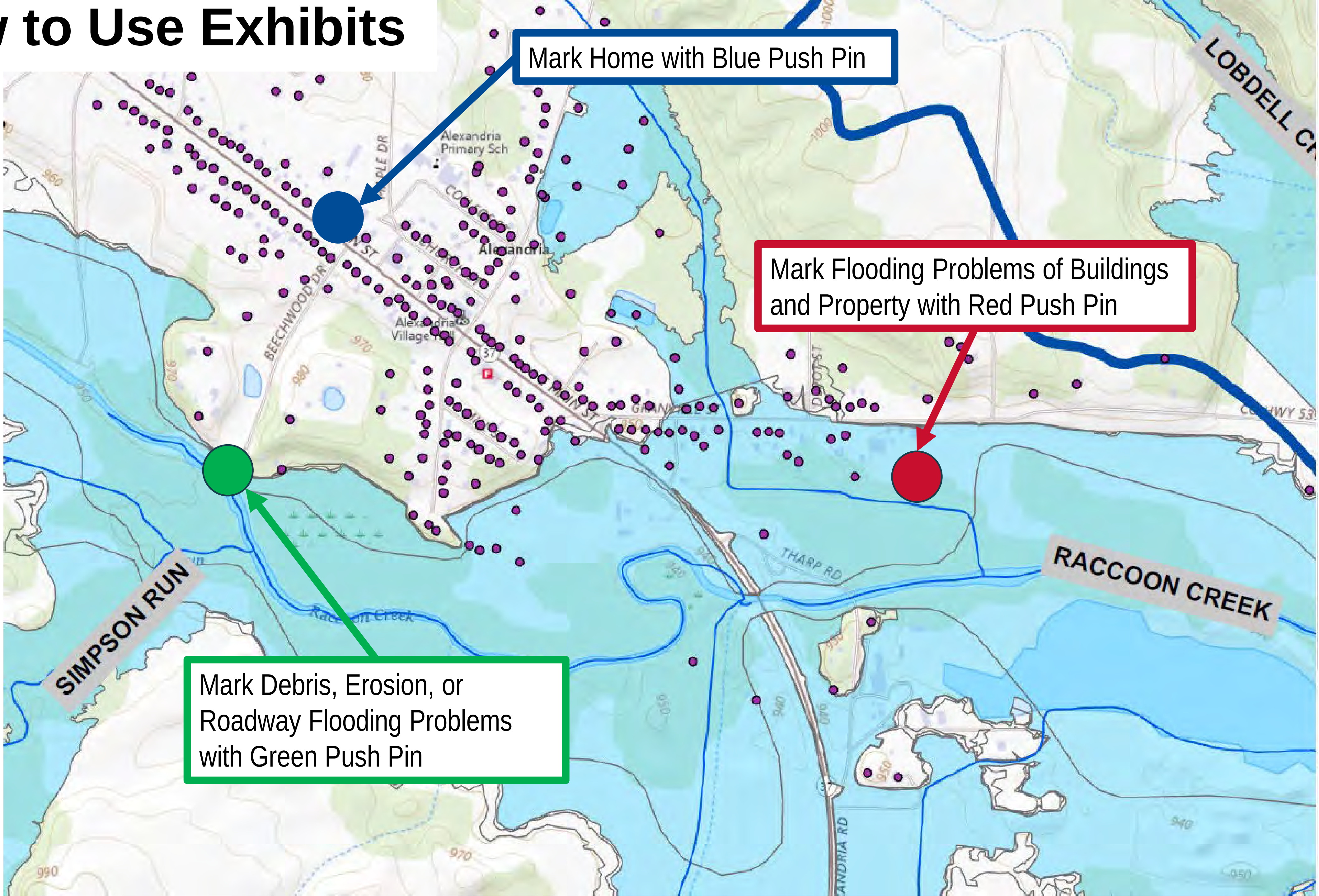
PURPOSE: Show Extent of FEMA Floodplain and Collect Flooding Data for Study

How to Use Exhibits



04 Data Collection

Upcoming Projects Information

- Drainage and Stormwater Projects
- Bridge Projects
- Roadway Projects
- Utility Projects
- Development Projects
- General CIP or Plan
- Regulatory Changes

Tools in the Toolbox

Regulatory Tools

- FEMA Modeling and Maps
- Floodplain Regulations
- Development Regulations

Watershed Tools

- Flood Warning System Enhancement using model
- Best Management Practices
- Erosion Remediation and Debris Collection
- Nine Element Plan

Tools in the Toolbox, Continued

Localized Projects

- Debris Booms and Access
- Large Erosion Control Projects and Sediment Traps
- Dams: Dry Dams and Permanent Pool Dams

Site-Specific Projects

- Levees/Floodwalls
- Pump Stations
- Bridge Improvement/Replacement
- Channel Improvement
- Road Raise/Relocation
- Non-Structural Improvements
- Relocation
- Low-Head Dam Removal
- Diversions
- Off Channel Storage

Follow-Up Questions or Additional Data

David Moore, PE
Project Manager

David.L.Moore@HDRinc.com

Raccoon Creek Alternatives Meeting 11-13-24 (PowerPoint)

Raccoon Creek Flood Study Progress Meeting and Alternatives

November 13, 2024

AGENDA

01 Project Status Update

02 Modeling Examples

03 Alternatives Development

04 Data Collection

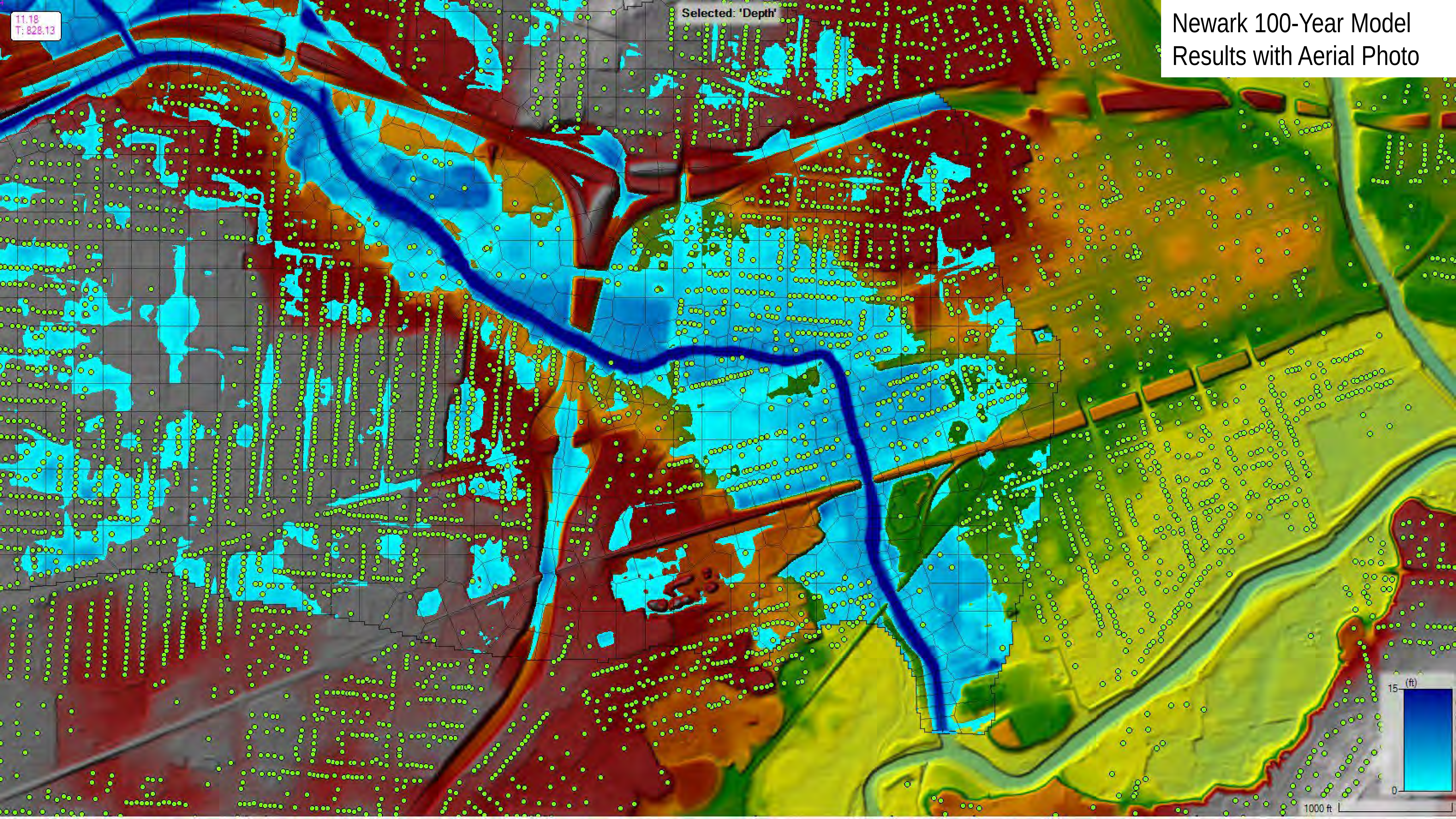
01

Project Status Update

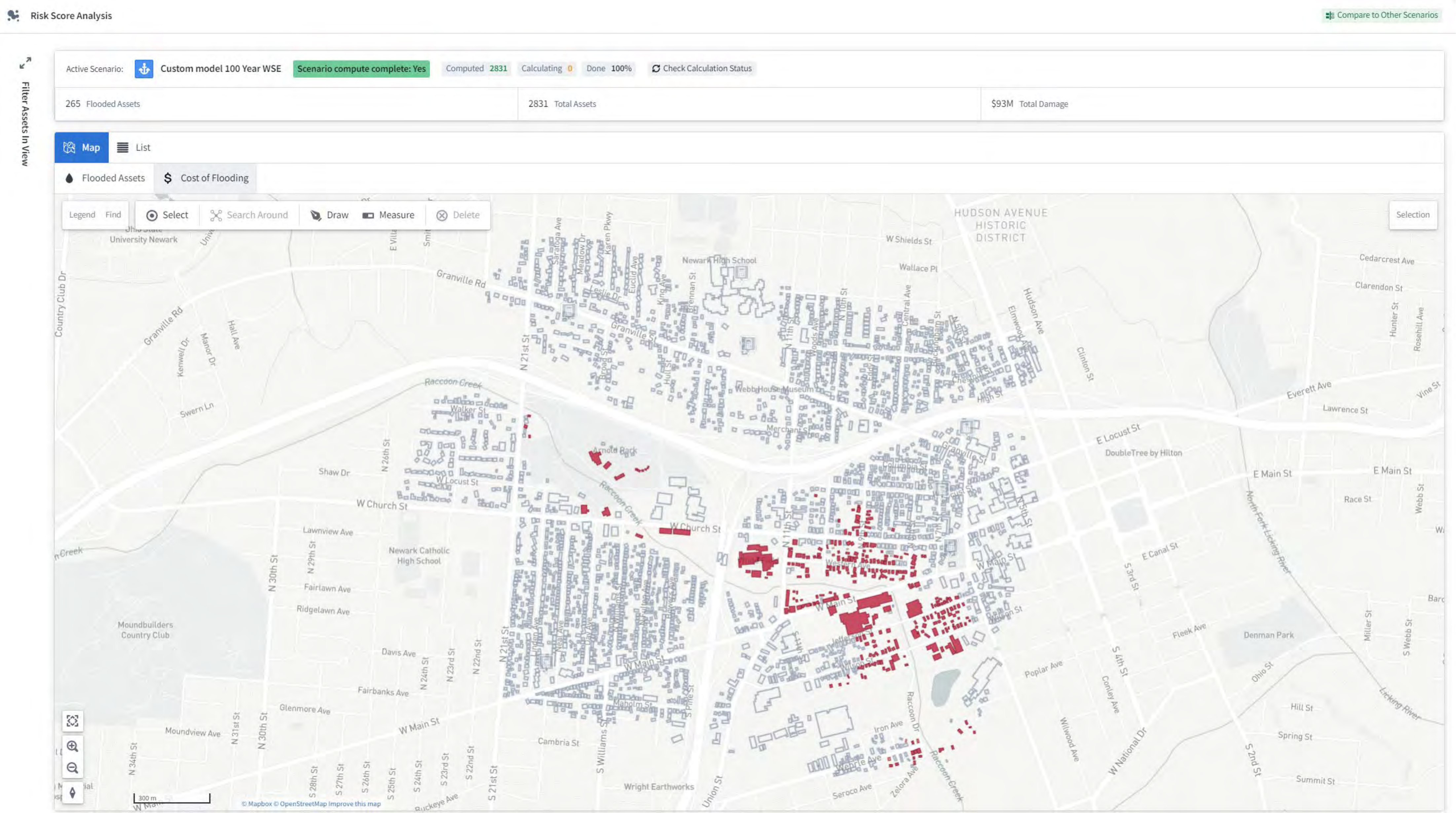
Project Status Update

- Task 1 (*Complete*): Data Collected and Everything Reviewed
  - April Flood Drone Footage from Alexandria and Granville (use for model verification)
- Task 2 (*Complete*): Survey – Critical Bridges Surveyed, Plan Set Bridges, Approximated Bridges
  - See Bridge Exhibit
- Task 3 (*70 % Complete*): Stakeholder Support & Project Management
- Task 4 (*95% Complete*): : Hydrologic and Hydraulic Model Analyses Update
- Task 5 (*25% Complete*): : Alternatives Analysis
  - Economics – HDR FAST Tool and existing conditions economics (example slides)
  - Multi-Factor Criteria Approach Outlined (Spreadsheet)
  - Alternatives screening and development (Initial goals this meeting)
- Schedule
  - Draft Alternatives Analysis and Report
  - Final Public Meeting?
  - Finalize Alternatives
  - Draft Flood Mitigation Report
  - Final Mitigation Report

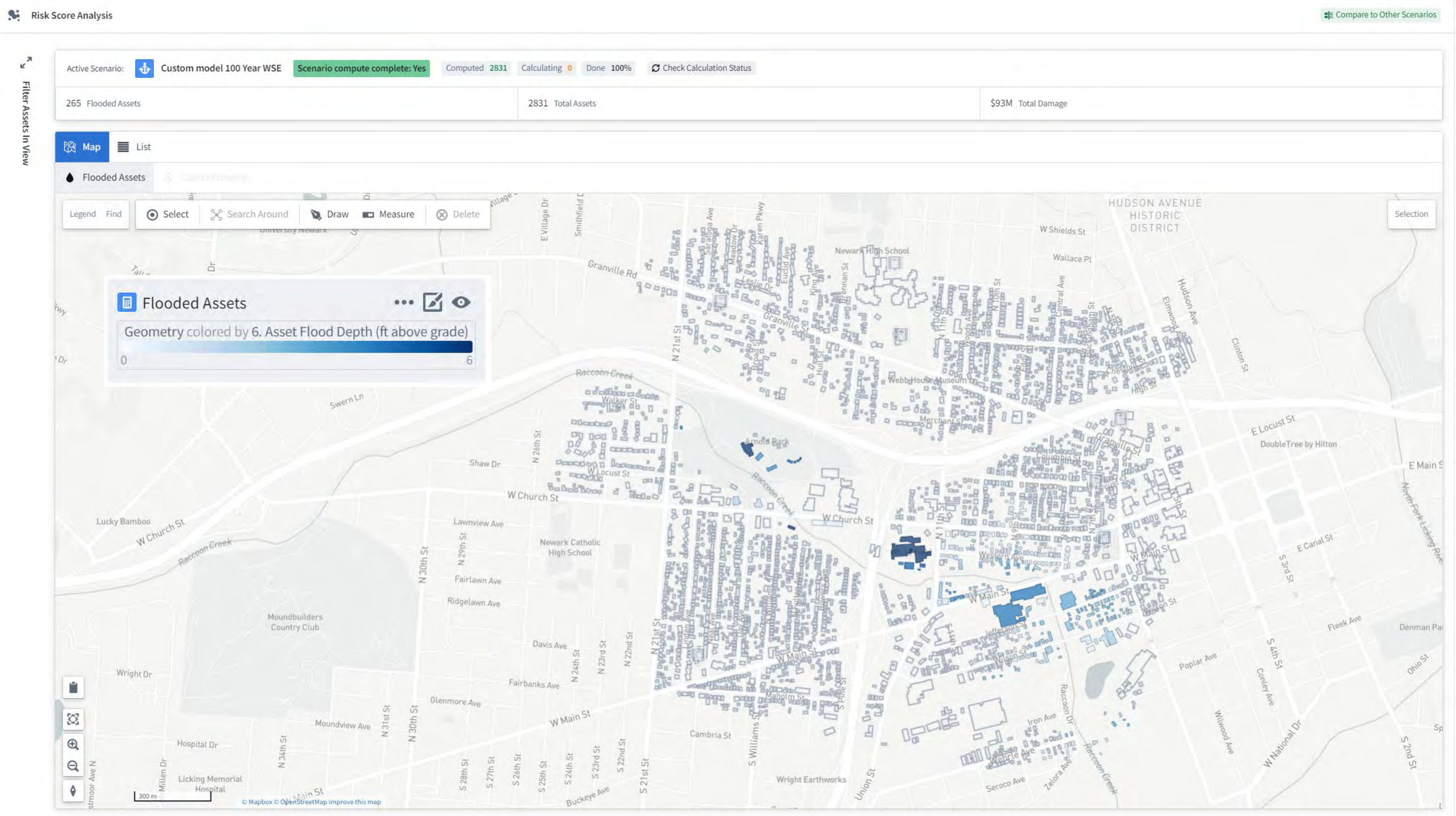
Newark 100-Year Model Results with Aerial Photo



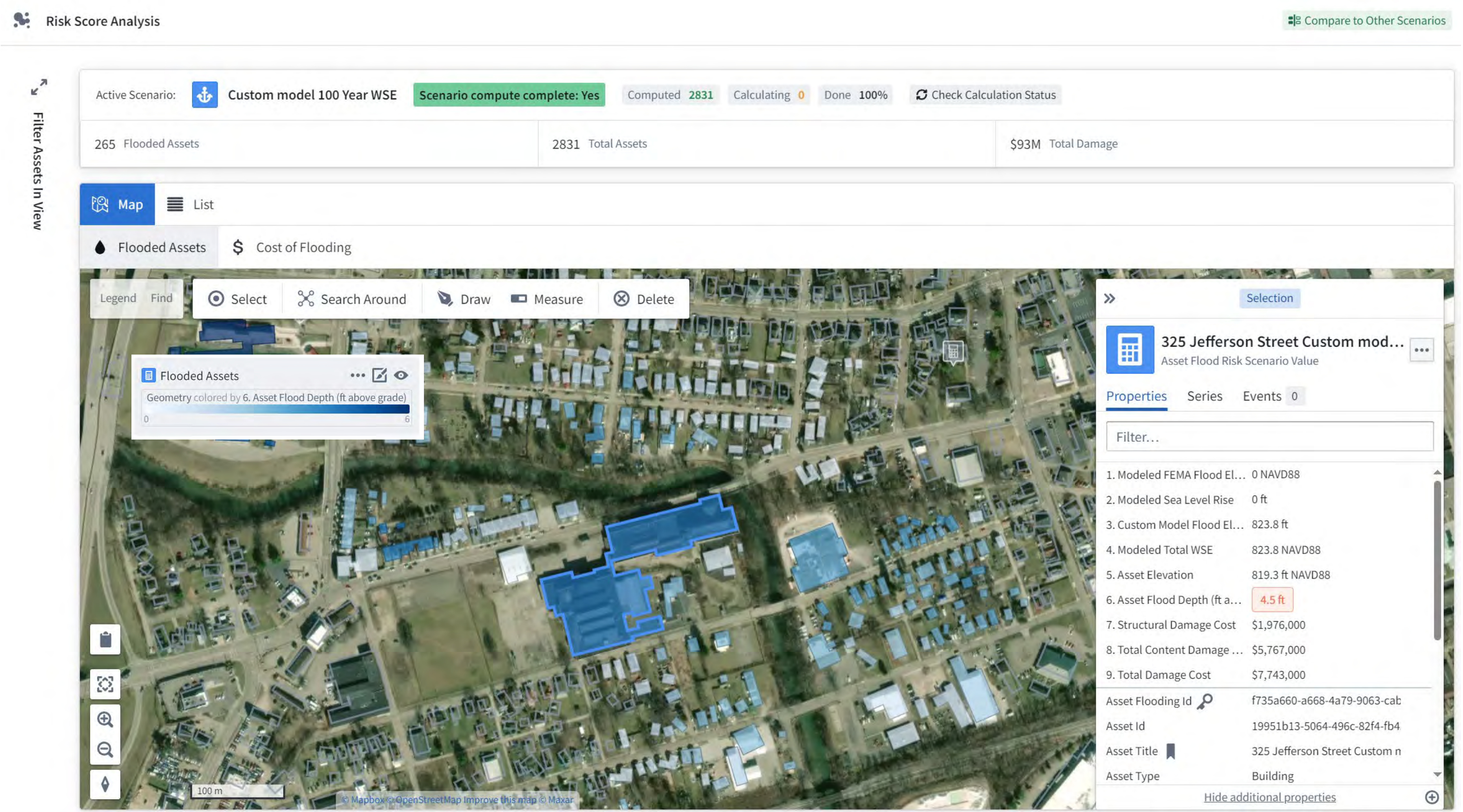
Economic Damage Map – Downtown Area



Flood Depth Map – Downtown Area



Flood Depth Detail Map – Jefferson Station



02 H&H Model Update

Hydrologic Model

- HEC-HMS Model
- Model has been verified using USGS gage
- Show model results versus FEMA Discharges
- Estimate land use changes in the upper watershed for 100-year event (assuming lower events can be mitigated by on site storage and stormwater management)
- Will be used for Dam and Reservoir Evaluation(s)

Hydrology Comparison

Location	FIS Flows (cfs)	Model Flows (cfs)
Confluence with SFLR	13,528	14,150
Confluence with Moots Run	9,257	9,370
Confluence with Simpson Run	6,558	5,520
Confluence with Pet Run	5,862	4,604
Confluence with Kyber Run	2,829	2,290
Upper Study Limit	1,133	1,244

HEC-RAS 2D model Existing Conditions

- New Geometry – Surveyed bridges, bridges from plan sets, estimated bridge data
- Model has been verified using USGS gage
- Would like to check results with April drone footage as well
- Hydrology inputs:
  - HEC-HMS (updated HDR model)
  - FEMA discharges (published in Flood Insurance Study [FIS])
- Unsteady versus Steady discharge
  - Unsteady shows less inundation than steady due to physics
  - Steady is used in current FIS

Approach for FEMA Floodplain Regulation (outside current scope of work but Alternative #1)

- What Discharges? Published if they are higher or HEC-HMS?
- Steady state or unsteady state HEC-RAS model runs
- Update all bridges
- Create work maps and all other products needed to update the entire FIS and mapping through FEMA's physical map revision process (outside the current scope of work)
- Formal submittal and FEMA review process
- Scope to advance FEMA as appendix to Flood Study Report - This report will include a scope of work needed to advance the planning models through the FEMA process based on the approach developed by this group

03 Alternatives Development

Studied Water Courses

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Basin-Wide New Policy Candidate:

- Stream Restoration and Streambank Stabilization based on prioritized, and risk informed decision making (RIDM). reduce flood damages by actively managing the stream corridor through the development of a risk informed framework that overlays debris loading, critical crossings, and bank erosion severity. This framework will be utilized in future phases to develop a nature-based stream bank stabilization and stream restoration comprehensive plan for the entire studied watershed (over twenty miles of streambank).

- Others?

Reach Approach

- Erosion and Sediment and debris booms (model with and without debris to estimate benefits)
- Bridge improvements
- Compound channel and conveyance improvements
- Off Channel Storage

Meeting goal: Discuss and set selection criteria

- Levees/floodwalls (WWTP locations, Granville Square Apartments, Newark area)
- Detention
- Dams from 1980 plan
- Stormwater – Verbal discussion our model does not cover stormwater

Meeting goal: Discuss and set selection criteria

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- Diversions
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Follow-Up Questions or Additional Data

David Moore, PE
Project Manager

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Public Meeting Data Collection – 07-18-24 (photos of pins and maps)


N
0
0.75
1.5
Miles
Raccoon Creek Watershed Area
Current FEMA 100-Yr Floodplain
DATA SOURCE: FEMA, OGRIP, and USGS
Johnstown
Alexandria
Granville
Newark
R1
R2
R3
G1
G2
G3
G4
G5
G6
B1
Raccoon Creek
Lobdell Creek
Moots Run
North Fork Licking River
South Fork Licking River
Raccoon Creek
HDR
RACCOON CREEK WATERSHED OVERVIEW MAP
RACCOON CREEK WATERSHED STUDY


FIRE
N
0
0.75
1.5
Miles
National Structure Inventory
Current FEMA 100-Yr Floodplain
JOHNSTOWN-ALEXANDRIA RD
R4
Alexandria
MAIN ST
R5
B2
B3
STRUCTURES IN ALEXANDRIA, OH WITHIN THE RACCOON CREEK WATERSHED
RACCOON CREEK WATERSHED STUDY
HDR

0
0.75
1.5
Miles
National Structure Inventory
Current FEMA 100-Yr Floodplain
B4
R6
NORTH ST RD
PEARL ST
R7
R8
R9
Granville
BROADWAY
B5
R12
R11
R13
MAIN ST
STATE ROUTE 37
RAMP
RAMP
RAMP
R10
STATE ROUTE 16
STATE ROUTE 16 RAMP
LANCASTER RD
COLUMBUS RD
STRUCTURES IN GRANVILLE, OH WITHIN THE RACCOON CREEK WATERSHED
RACCOON CREEK WATERSHED STUDY


N
0
0.75
1.5
Miles
National Structure Inventory
Current FEMA 100-Yr Floodplain
FALLSBURG RD
MT VERNON RD
CEDAR ST
R14
STATE ROUTE 16
HUDSON AVE
Newark
G7
R16
R15
B6
STATE ROUTE 79
R17
NATIONAL DR
HEBRON RD
JACKSONTOWN RD
STRUCTURES IN NEWARK, OH WITHIN THE RACCOON CREEK WATERSHED
RACCOON CREEK WATERSHED STUDY

Hartford Fair Data Collection – 08-04-24 (photos of pins and maps)


0
0.75
1.5
Miles
Raccoon Creek Watershed Area
Current FEMA 100-Yr Floodplain
Johnstown
Alexandria
Granville
Newark
Raccoon Creek
R1
R2
B1
RACCOON CREEK WATERSHED OVERVIEW MAP
RACCOON CREEK WATERSHED STUDY
HDR


JOHNSTOWN-ALEXANDRIA RD
JOHNSTOWN-U
Johnstown
COSHOCTON ST
MAIN ST
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0.75
1.5
Miles
National Structure Inventory
Current FEMA 100-Yr Floodplain
STRUCTURES IN JOHNSTOWN, OH WITHIN THE RACCOON CREEK WATERSHED
RACCOON CREEK WATERSHED STUDY


N
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0.75
1.5
Miles
National Structure Inventory
Current FEMA 100-Yr Floodplain
JOHNSTOWN-ALEXANDRIA RD
R1
Alexandria
MAIN ST
STRUCTURES IN ALEXANDRIA, OH WITHIN THE RACCOON CREEK WATERSHED
RACCOON CREEK WATERSHED STUDY
FDR


0
0.75
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National Structure Inventory
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NORTH ST RD
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RAMP
MAIN ST
STATE ROUTE 16
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COLUMBUS RD
LANCASTER RD
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RACCOON CREEK WATERSHED STUDY

HDR