HYDRAULIC ANALYSIS OF

CLEAR CREEK

In Downtown Bloomington

Prepared For:

City of Bloomington Utilities

Department of Engineering

Prepared by:

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February 2, 2023

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Project Description and Background Information

The center of Bloomington, including its historic downtown, adjacent neighborhoods, and main academic core of Indiana University's campus, are drained by two large underground culvert systems that join and then discharge stormwater into Clear Creek south of downtown. The larger of the two, the Clear Creek culvert, begins on the edge of the Indiana University campus near the intersection of Indiana Avenue at 6th Street. It winds southwesterly under downtown to outlet near the intersection of 1st and Walnut Streets. The Spankers Branch culvert serves the northwestern portion of downtown and joins the Clear Creek culvert in Walnut Street, just north of 1st Street. The Spanker's Branch culvert does not have a defined entrance location. It splits into smaller storm sewer pipes as it continues upstream. Both culvert systems were built many decades ago along the path of natural streams that were enclosed as the areas around them were developed.

The culvert systems were internally inspected in 1999. Each was found to have sections with structural deterioration and were built with various sizes and materials, including combinations of masonry block, stone arches, steel beams and reinforced concrete. Many sections were identified that were deemed undersized for the stormwater they were estimated to receive. Ever since that inspection, the City of Bloomington Utilities (through its stormwater utility) has been undertaking a program to replace and upgrade portions of the culvert systems to improve capacity and reduce flooding in the downtown area.

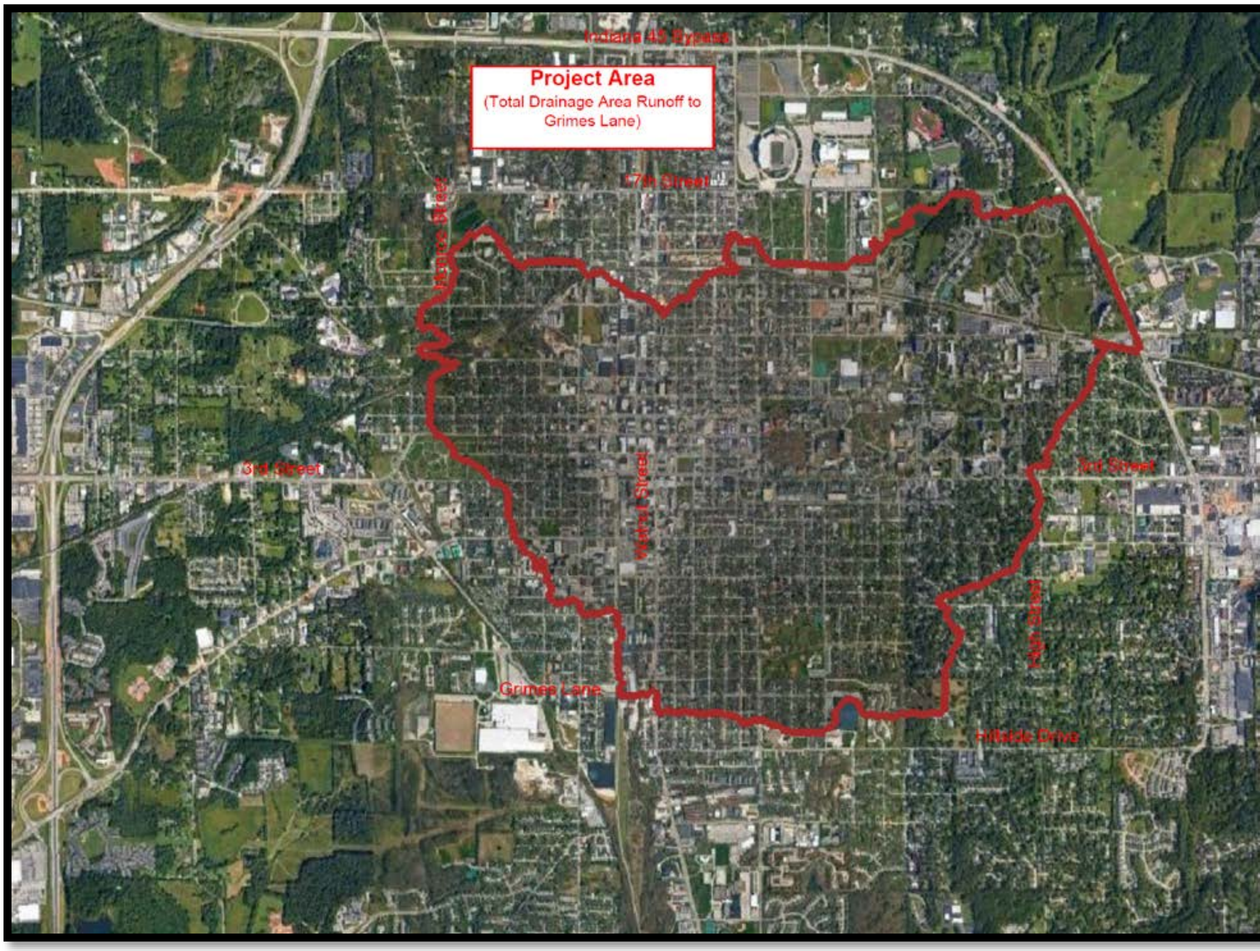
The Clear Creek system has received most of the attention because it has historically seen the most flooding. A 2022 project replaced a large section crossing under 3rd and 4th Streets. A future project is expected to address the upstream section from Dunn Street to Indiana Avenue.

As a result of these ongoing efforts, flooding conditions in the downtown area have decreased over the last 20+ years in terms of frequency, depth, and duration. Nonetheless, some flooding still occurs. Most recently, a heavy storm in June 2021 resulted in both property damage and loss of life when a car was pushed off the Clear Creek bridge at Dodds Street after entering high waters. Recent events, combined with the evidence that higher intensity storms appear to be returning with greater frequency, have pointed to the need to better understand the hydraulic performance of these critical stormwater assets.

The area of interest includes the downtown culvert system and a portion of Clear Creek south of downtown. It is approximately bounded by 14th Street at the north, Grimes Lane at the south, Monroe Street on the west, and High Street on the East. The drainage area is served by the culverts to 1st Street where they emerge and become Clear Creek. The study area also includes approximately 2,200' of Clear Creek as it flows south to Grimes Lane. This reach of Clear Creek includes five bridges and is included in this study as it includes the location of the recent flood-related fatality.

The overall area of study is shown in the drainage basin outlines as seen in the figure below:

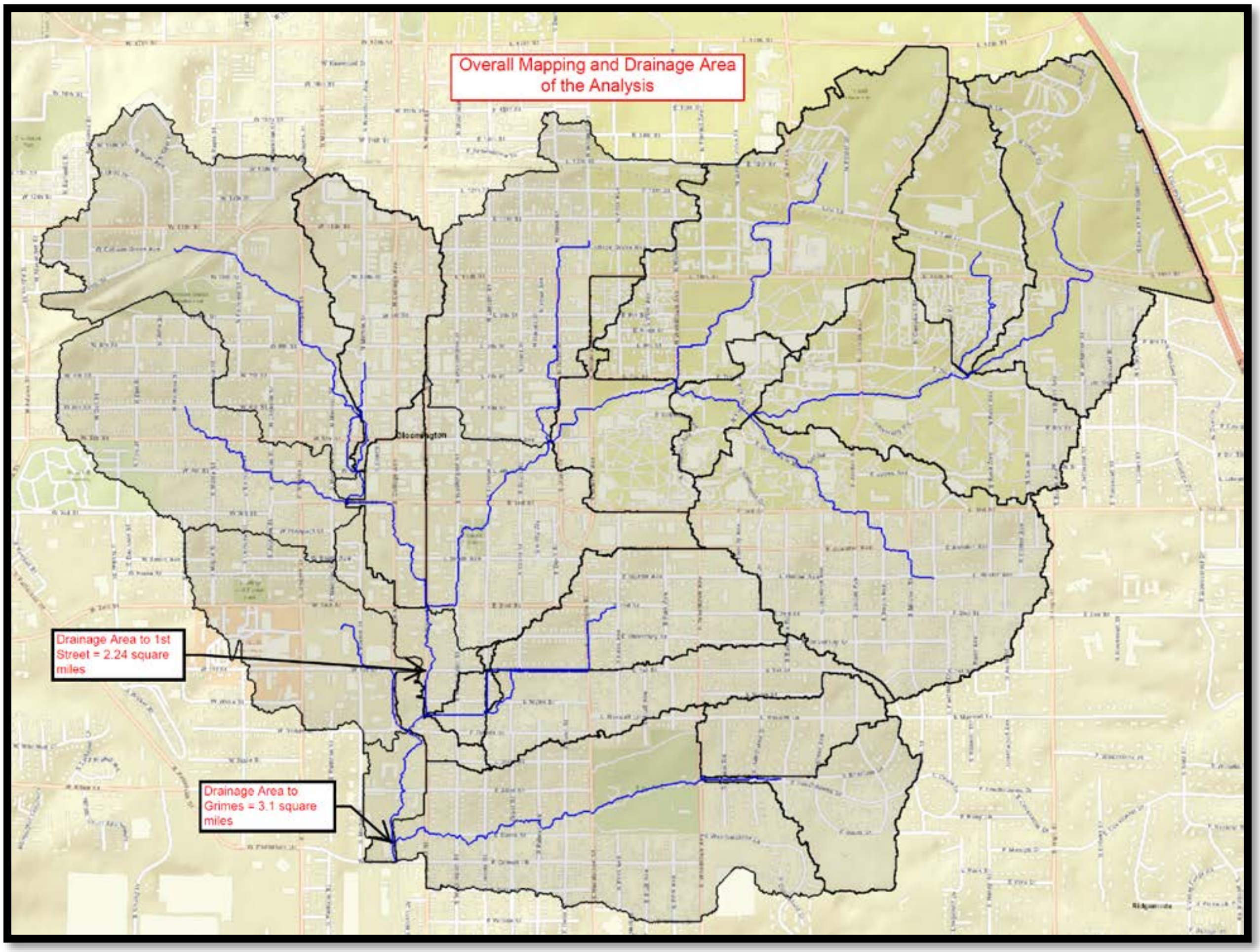
Figure 1: Overall Area of Study



The contributing drainage area near 1st Street where the Clear Creek emerges from the culvert section is approximately 2.24 square miles (1431 acres). The total contributing area at the limit of the study of Clear Creek just south of Grimes Street is approximately 3.1 square miles (1990 acres).

The delineated drainage basin areas are shown in the next figure with the downstream points of the analysis shown at the Clear Creek culvert outlet and the Clear Creek bridge at Grimes Lane:

Figure 2: Overall Drainage Area and Delineated Sub-Basins



The surface area is predominately impervious urban area with small areas of forest and grass. The watershed has rolling topography with storm sewer networks and other drainage facilities to convey the flow through manmade channels, pipes, and culverts.

<u>Modeling methods:</u>

The hydrologic and hydraulic modeling for this study were prepared using the US Army Corps of Engineers software developed by the Hydraulic Engineering Center (HEC). HEC-HMS

(Hydraulic Modeling Software) and HEC-RAS (River Analysis System) were used together to develop simulations of different rainfall events and the hydraulic impacts for the watershed.

Target stormwater capacity / Goals for the System:

Prior to the year 2000, the City established a capacity goal for the Clear Creek culvert system of 1,800 cubic feet per second (cfs) for the section north of the connection with Spanker's Branch. This goal was based on the rainfall data and modeling procedures of the time without formal analysis. This goal has been applied to projects since that time as upgrades and replacements have been completed.

By today's modeling methods, a 100-year storm has been estimated at 1235 cfs at Indiana Avenue, indicating that the 1,800 cfs is a high value at that location and provides additional capacity when used for upgrades and replacements.

The capacity analysis target is primarily based on the goal to carry a 100-year storm event which is used by FEMA and IDNR as a standard large storm event flow rate. The analysis then shows the impacts and/or overall deficiencies of the system to help make future decisions on improvements that may be needed.

Existing Conditions:

Surface Analysis:

The topography was analyzed to determine where areas of potential surface flooding might exist. The analysis is based on a condition where no inlets are working. Whether due to the culvert not having capacity and not accepting more water, culvert blockage, or clogged inlets, these are the places where problems will first occur.

Especially in an urban location, it is essential to have adequate capacity of the storm system to reduce the probability of flooding. It is also preferred to anticipate that individual inlets may become clogged and that the resulting surface flooding is minimized by having additional inlets nearby to prevent deeper flooding until an inlet can be cleared. Low areas are normal but pose a higher risk of flooding.

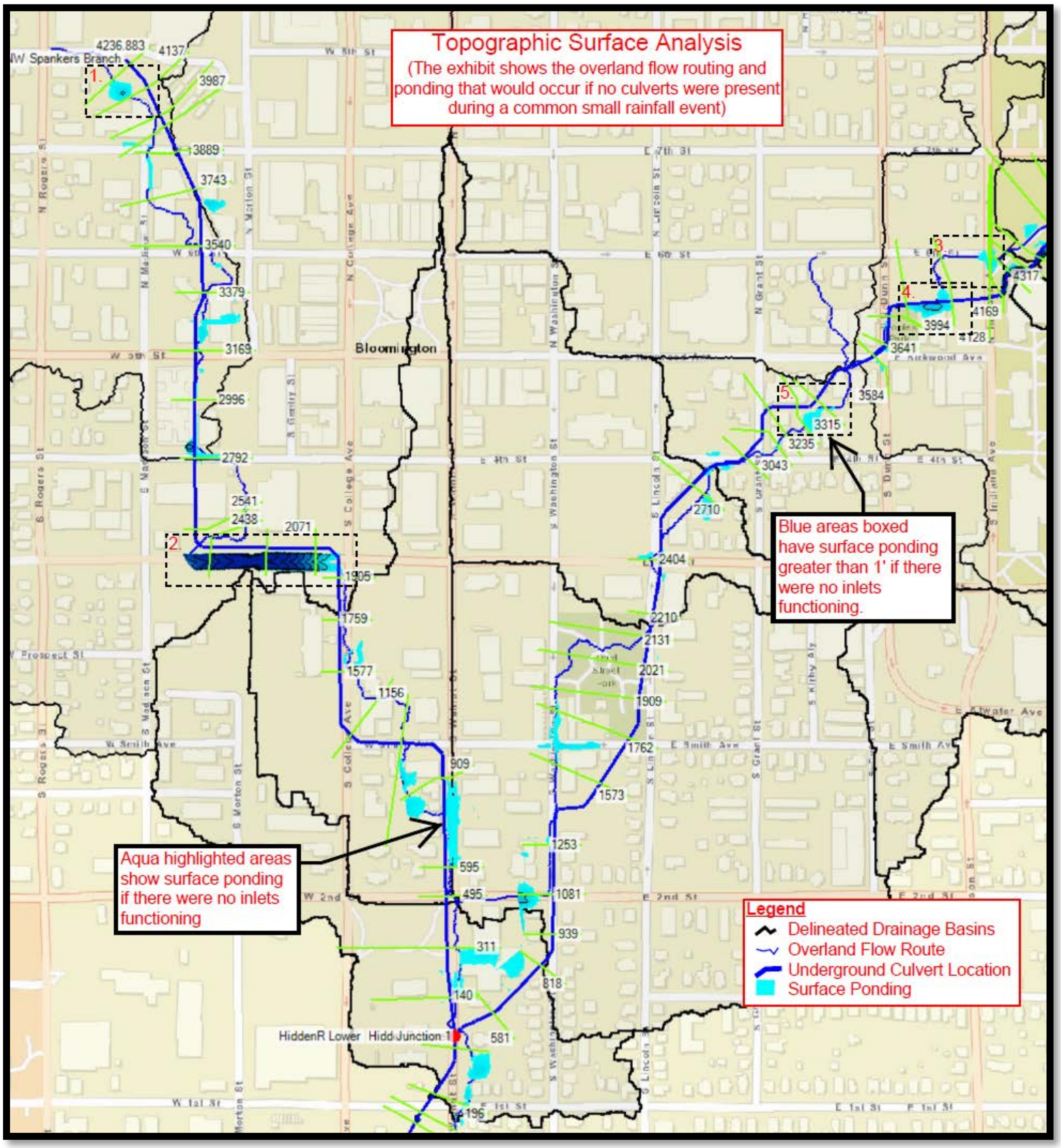
The surface analysis highlights the low areas along the underground culvert network where flooding is likely to first occur. Some of those areas are as follows:

1. Spankers Branch between 7^{th} and 8^{th} Street (In a Parking Lot SW of 8^{th} and the B-Line Trail)
2. Spankers Branch at 3^{rd} Street (where the road goes under the Railroad Crossing.)
3. Clear Creek between Dunn Street and Indiana Avenue. (In the alleyway above the Culvert)
4. Clear Creek at Kirkwood and Dunn.

5. Clear Creek between 4th and Kirkwood (In the parking lots and alleyway between Grant St. and Dunn Street.)
6. Clear Creek between 3rd and 4th, and Lincoln and Grant (In the parking lot in the center of the block, and along 4th Street.)

The exhibit below shows locations of the initial findings of where the model suggests surface flooding is most likely to flood in the event of inlet failure:

Figure 3: Topographic Surface Analysis



Existing Drainage Capacities of the Underground Networks:

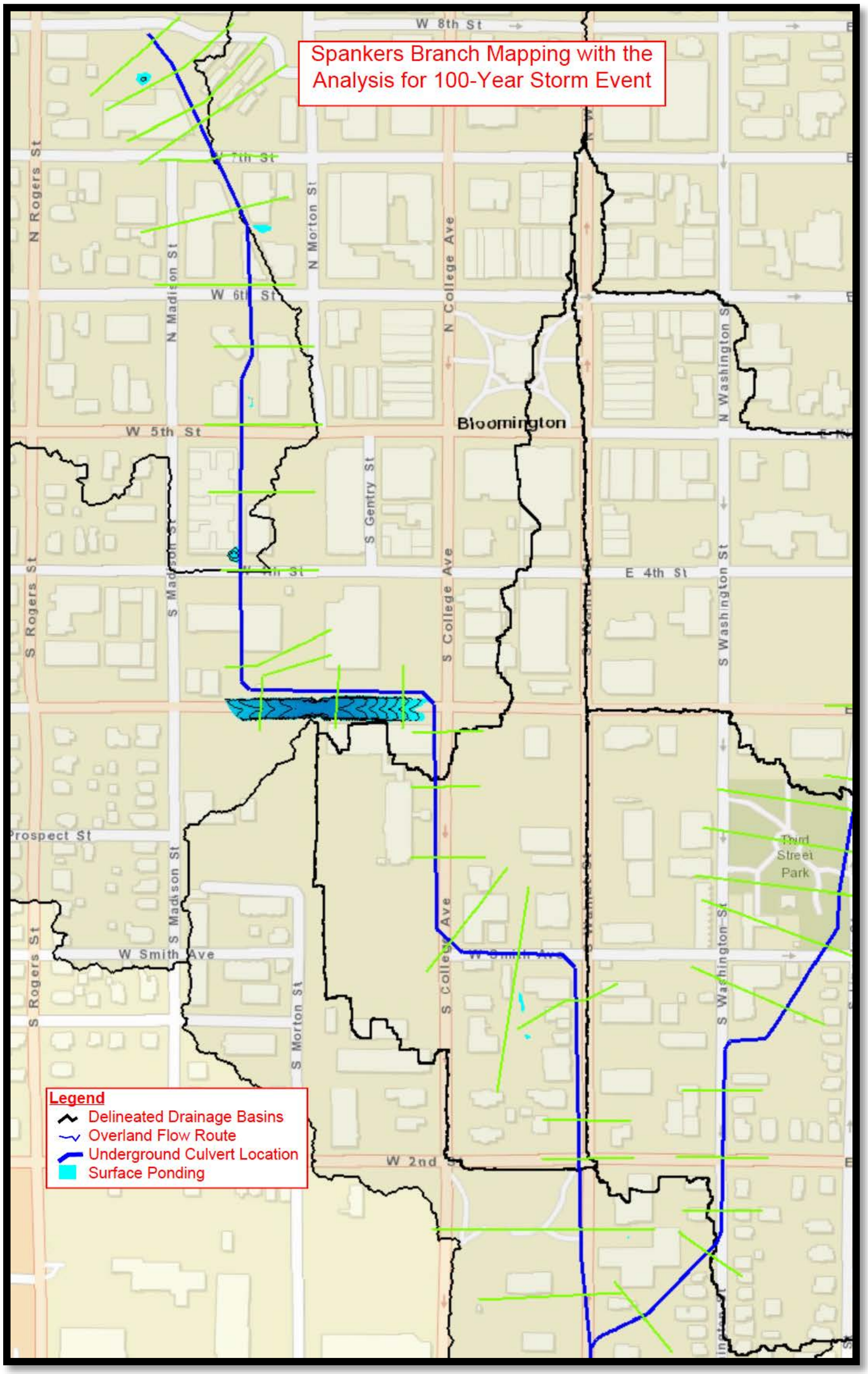
Spankers Branch:

In terms of overall culvert capacity, the Spanker's Branch culvert was determined to have adequate capacity to carry the computed 100-year storm event under gravity flow. The culvert analyzed started at 6th Street at the north end, extending to where it outflows into the Clear Creek culvert in Walnut Street, just north of 1st Street. The Third Street roadway under the railroad has an increased risk of flooding due to the low elevations, but the culvert adjacent has the capacity to carry the flow.

With regard to the previous figure of the "Topographic Surface Analysis", Spanker Branch has extensive sections where the adequate performance of inlets is essential for the prevention of street flooding. There are multiple locations throughout the corridor that are highlighted in aqua color showing flooding that would occur if the inlets were to fail, but the culvert itself is able to convey the stormwater once it is able to enter the culvert.

Applying the estimated 100-year storm to the Pre-2022 condition, the following potential flooding might be expected, except for the flooding shown at 3rd Street:

Figure 4: Spankers Branch Analysis, 100-Year Storm, Pre-2022 Condition



Clear Creek Underground Network:

Due to ongoing replacement projects, the Clear Creek Culvert was modeled for its size and configuration for its pre-2022, post-2022, and future planned project conditions. This allows for a more detailed review of the June 2021 storm event in addition to offering better estimates of the potential flooding conditions after the ongoing projects. The ongoing projects are:

1. The post-2022 project which replaced sections between 2nd/Washington and 4th/Grant Street.
2. The future planned project that would replace the section between Dunn Street and Indiana Avenue.

Clear Creek Underground Network: (Pre-2022 Conditions)

The analysis of the Clear Creek in its pre-2022 condition was as follows:
Starting about 150 feet upstream of the Indiana Avenue culvert inlet, there is an access drive for Franklin Hall with a small bridge over the waterway. This access drive will be referred to as the Franklin Access Drive herein. Due to its proximity to the culvert and possible impacts, additional analysis was completed. When analyzing the bridge and drive, they act as a detention pond outlet structure by holding back water as storage in Dunn Meadow during high flow events. The detention storage in Dunn Meadow naturally reduces the peak flow to the downstream culvert, but when it overtops during large storm events, it overtops directly to Indiana Avenue at 6th Street, bypassing the culvert opening on the east side of Indiana. The overtopping flow out of Dunn Meadow goes over the access drive directly to Indiana Avenue near 6th Street. The small bridge opening limits the flow through the bridge to 74 cfs of the 1235 cfs flow rate computed during a 100-year storm, so most of the flow is streaming directly to Indiana Avenue. Once the flow goes into Indiana Avenue, a ponding condition occurs at Indiana and 6th Street. Once the water builds sufficiently, much of it flows over Indiana Avenue towards Dunn and Kirkwood while some does flow south along the east side of Indiana Avenue to the Clear Creek entrance under Indiana Avenue.

The first section of culvert under Indiana Avenue is an arched culvert that extends for 80 feet before flowing through a longer box culvert section to Dunn Street at 13.2 ft. wide by about 4.9 ft. tall. The existing arched culvert and box culvert from Indiana to Dunn is undersized for the computed 100-year storm flow of 1235 cfs. The existing culvert arched entrance is approximately 73.85 square feet and can convey about 366 cfs during a 100-year storm event before roadway overtopping occurs. It has much more capacity than the Franklin access drive immediately upstream, but it is still not large enough to convey a large storm flow rate into the Clear Creek culvert section. This results in a backwater condition at the upstream end during large storm events. Ponding in Dunn Meadow at the upstream end will occur during these events, and then roadway overtopping when Dunn Meadow is filled to capacity. Once overtopping of Indiana Avenue occurs, the flow follows the natural topography until it can make its way back into the downstream culvert through inlets. A low point in the surface elevations in the alley behind the Von Lee building offers a low area where surface ponding can occur until the water drains through inlets into the culvert.

The next section, where the culvert connects to Dunn Street and travels under Kirkwood towards Grant Street, has adequate capacity to carry the 100-year storm event of 1572 cfs. The computed culvert capacity with pressure flow is 1803 cfs, prior to backing up through the inlets. However, at the downstream end of this section, the culvert connected to an older section that was undersized that would result in water backing up into this section. This older section downstream was under construction in 2022.

The section reconstructed in 2022 starts just east of Grant Street where the existing culvert was about 13.5 feet wide x 5' tall for a short stretch, then went through a smaller 12 feet wide x 5 feet tall arched section as it crossed the northwest corner from Grant Street to 4th Street. The small opening limited flow significantly. The maximum flow computed prior to having water backup into the streets near Grant and 4th Street was 702 cfs. As a comparison, a 10-year storm event was computed to be 1035 cfs along this stretch, so even a 10-year storm would have resulted in roadway flooding and probable backup of water upstream of this section. The flow rate computed for the 100-year storm event is 1648 cfs.

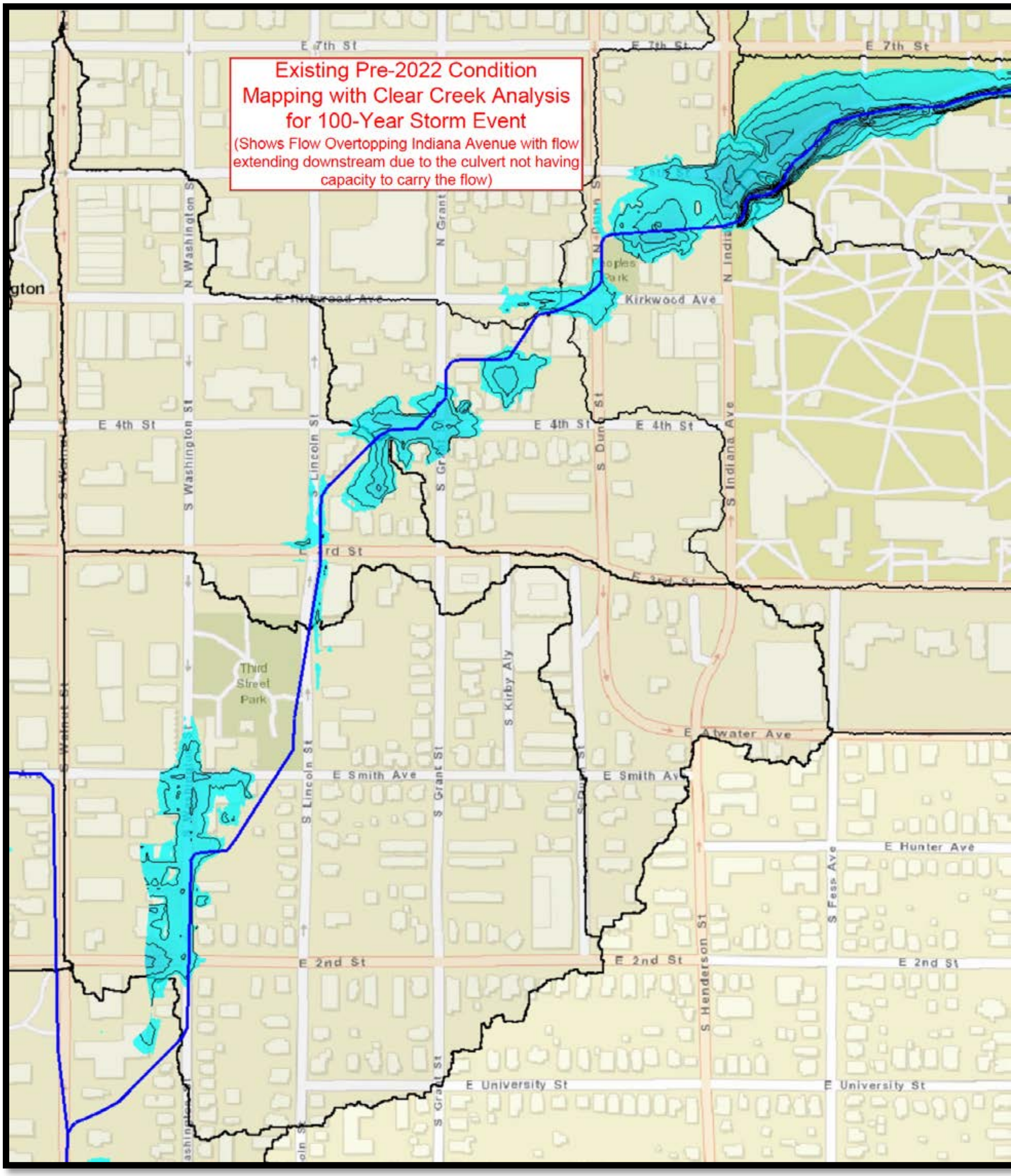
South of 4th Street to the connection at Washington Street, the culvert was approximately 13.5 feet wide x 5 feet tall. This section was reconstructed in 2022. The section had a computed flow rate capacity of 817 cfs prior to starting to backup into the roadways above it resulting in areas of flooding along the corridor.

The portion of the Clear Creek culvert south of the connection at Washington Street was determined to have adequate capacity to carry the computed 100-year storm event of 2487 cfs.

To summarize the pre-2022 condition during large storm events, water staged up in Dunn Meadow, then overtopped Indiana Avenue due to inadequate capacity and mostly bypassed the culvert opening. Starting with one section of inadequate capacity and roadway overtopping, surface flooding extended downstream as the water searched for inlets to flow into where the culvert had adequate capacity. The overland flow resulted in flooding through the alleyway and parking lot adjacent to Indiana Avenue between Indiana and Dunn. The water then traveled towards Dunn Street and Kirkwood, then towards Grant and 4th Streets. There were multiple locations of minor flooding downstream of 4th Street until the Spankers Branch connection where the culvert opened up to 30 feet wide x 6.3 feet tall. The culvert then had the capacity to carry the 100-year flow.

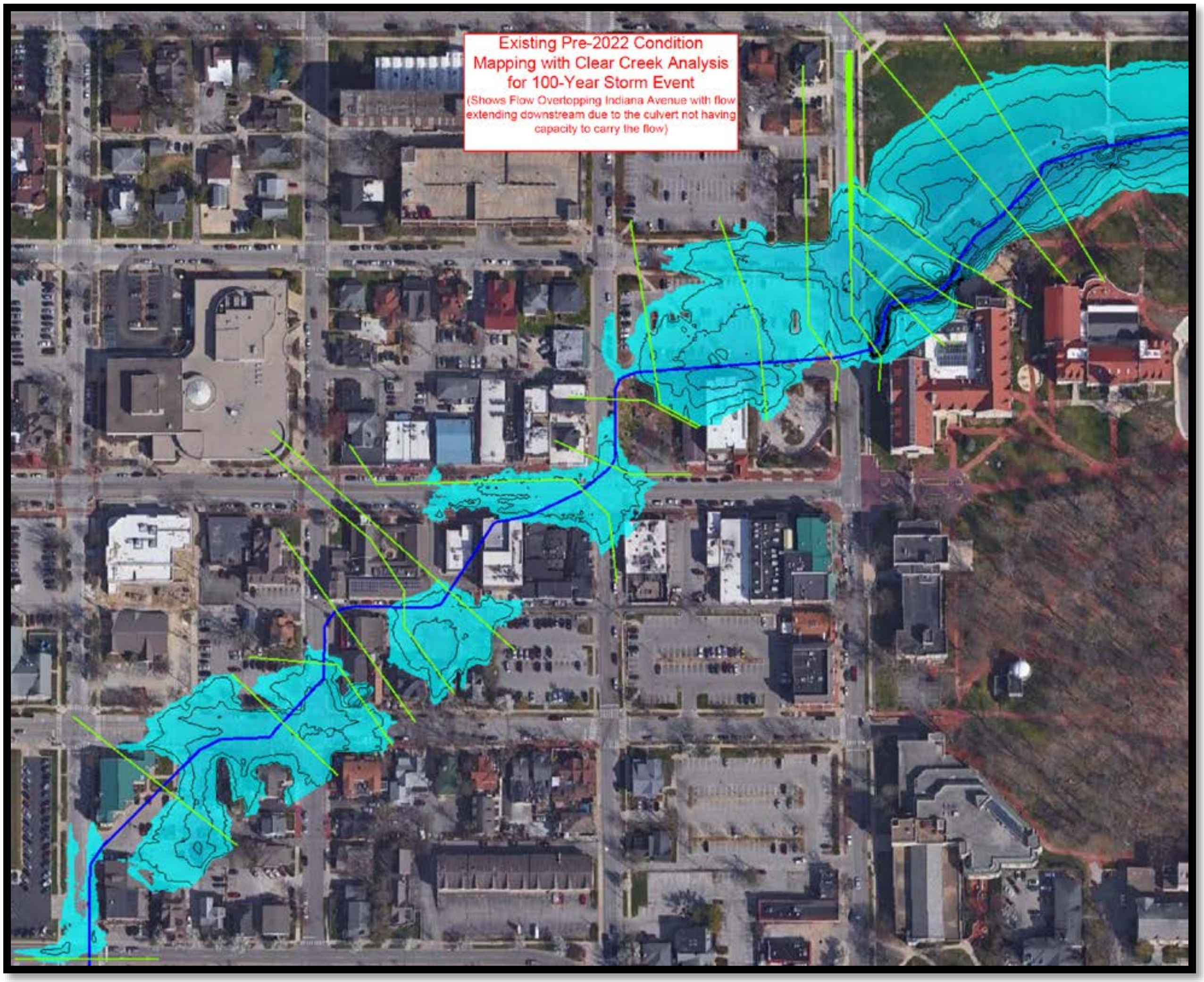
Applying the estimated 100-year storm to the Pre-2022 condition, the following potential flooding conditions might be expected:

Figure 5: Clear Creek Analysis, 100-Year Storm, Pre-2022 Condition



The next exhibit is the same modeling, but shown on an aerial photograph and a closer view of the upstream section where most of the flooding occurs:

Figure 6: Clear Creek Analysis, 100-Year Storm, Pre-2022 Condition, Aerial of the Upstream Section



<u>Clear Creek - 1st Street to Grimes Lane:</u>

Clear Creek, from the underground culvert outlet at 1st Street to approximately 450 feet south of Grimes Lane is a defined channel section. The section is a defined rectangular section with walls for about 2,500 linear feet ranging from 19 to 27 feet wide, and 7.5 feet to 10 feet tall. On average it is about 25 feet wide by 9 feet tall. The banks of the creek have been armored with vertical walls. The walls date back to the early-1900's to mid-1900's, so there are areas of deterioration throughout the length of this reach. The channel bottom throughout the length is a mix of exposed bedrock, larger rock and stone pieces, and gravel. The channel also has miscellaneous trash, debris, and other various minor obstructions. Outside of the defined channel but in the adjacent floodplain are commercial properties with parking lots and buildings, along with some areas of grass, trees, gravel, fences and miscellaneous obstructions. Five bridges or business crossings go over the channel within the 2,500 linear feet. Outside of the channel, the ground is generally flat for roughly 50 feet to 125 feet then slopes up and away from the channel.

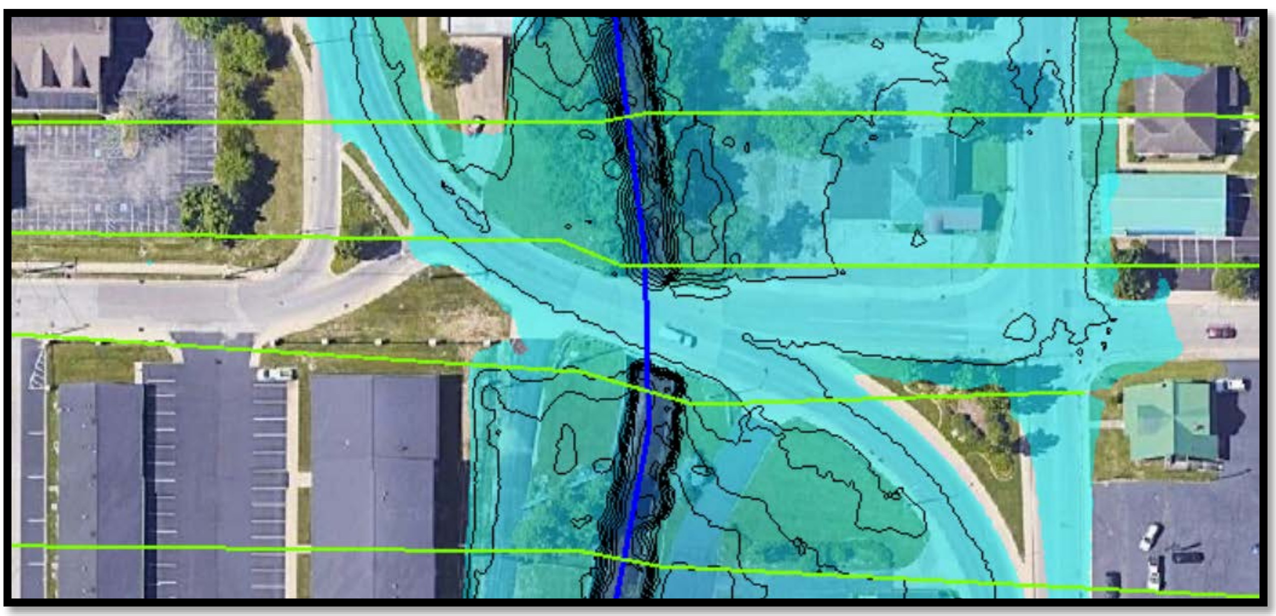
The channel can contain normal rainfall events, but there is a history of channel overtopping during larger rainfall events. The modeling also predicts this overtopping. During these large storm events, water not only leaves the channel but is also flowing over the bridges.

The bridges along the corridor span the waterway from top of bank to top of bank leaving the area under the bridges to closely match the area of the channels upstream and downstream of each bridge. Therefore, the flow through the defined channel section is similar to the flow through the bridges. Bridge information is estimated below:

Dodds/College Avenue Bridge:

- Q100 = 2487 cfs
- Area Opening under bridge: 187.13 sf
- Flow under bridge: 927.56 cfs
- Estimated Water Depth over Lowest Point in Road or Bridge = 1.74 ft

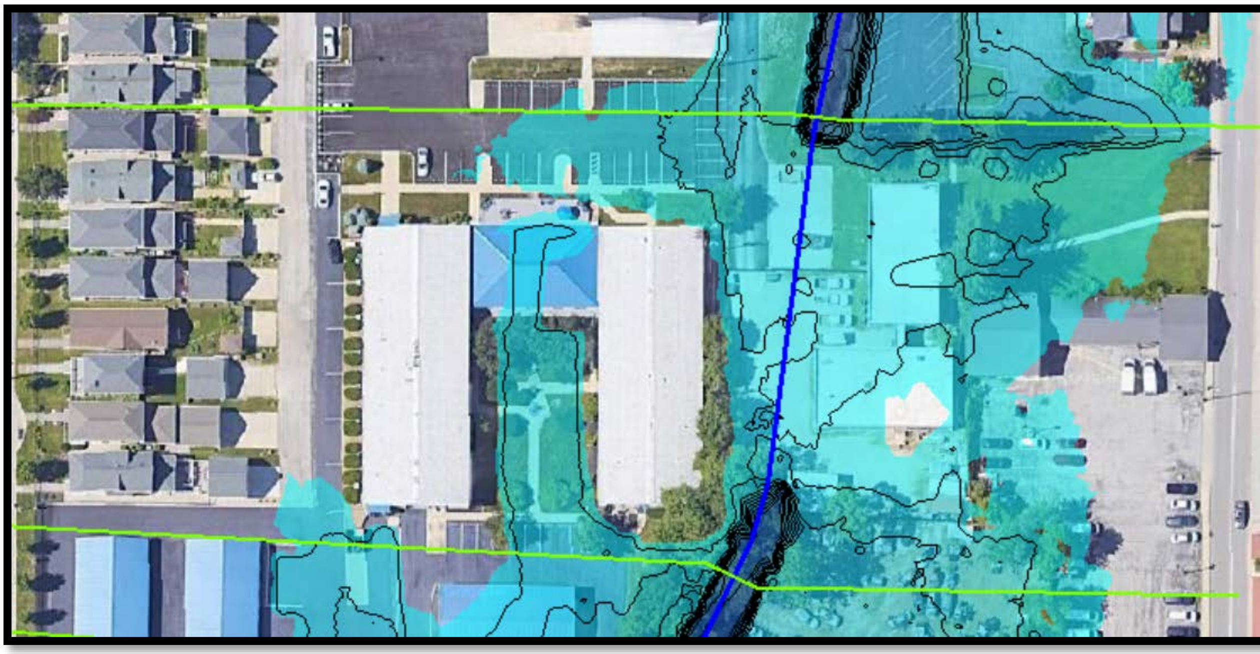
Figure 7: Dodds/College Avenue, Clear Creek Analysis, 100-Year Storm



Loren Wood Builders Crossing:

- Q100 = 2570 cfs
- Area Opening under bridge: 175.00 sf
- Flow under bridge: 1281.00 cfs
- Estimated Water Depth over Lowest Point in Road or Bridge = 1.97 ft

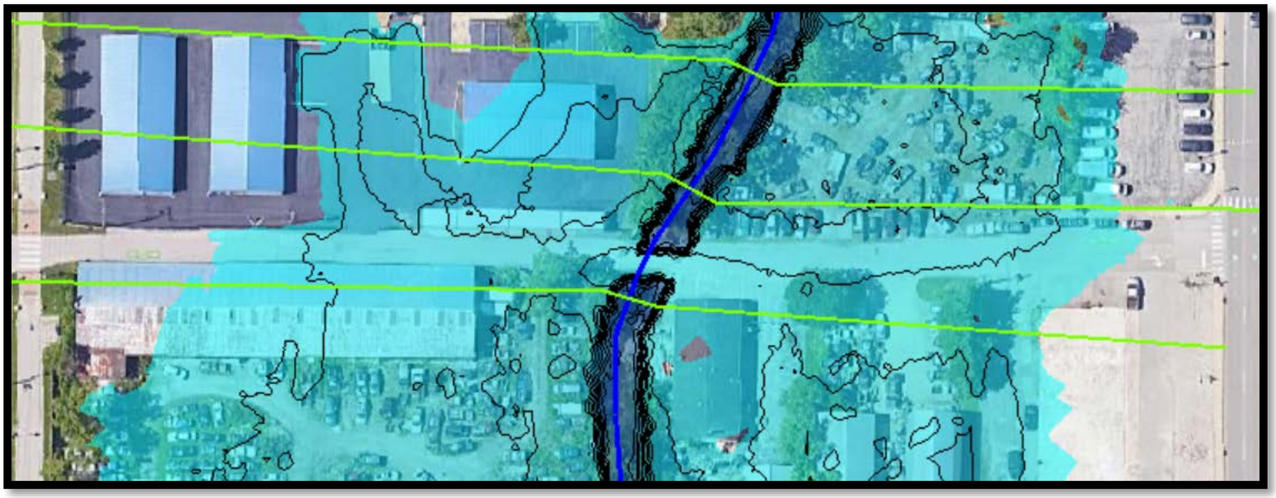
Figure 8: Loren Wood Builders, Clear Creek Analysis, 100-Year Storm



Allen Street Bridge:

- Q100 = 2570 cfs
- Area Opening under bridge (u/s face): 171.60 sf
- Flow under bridge: 532.57 cfs
- Estimated Water Depth over Lowest Point in Road or Bridge = 2.58 ft

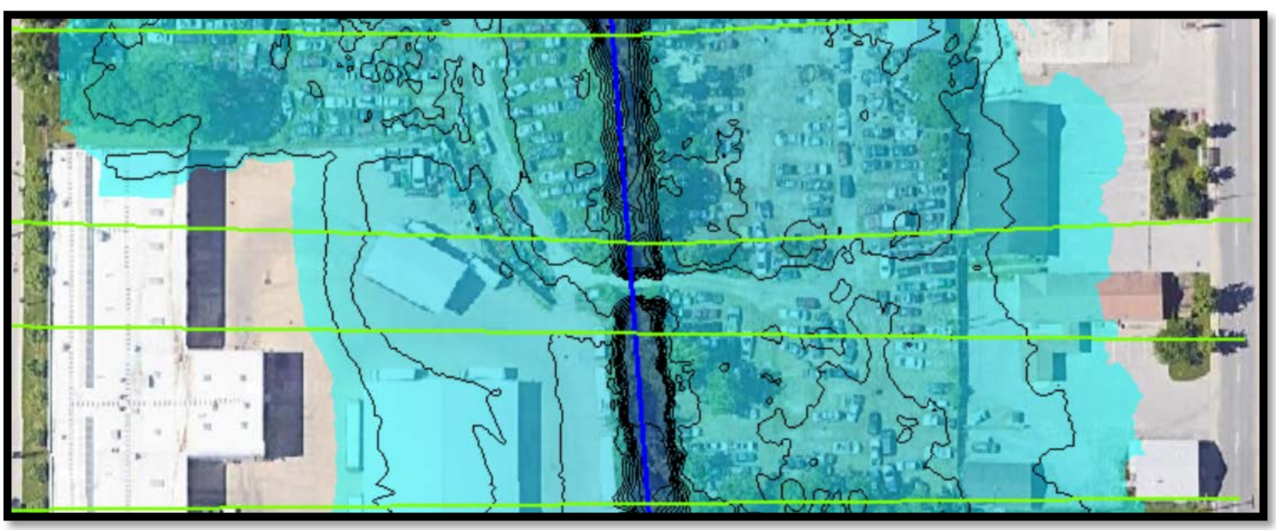
Figure 9: Allen Street, Clear Creek Analysis, 100-Year Storm



Auto Heaven Bridge:

- Q100 = 2570 cfs
- Area Opening under bridge (u/s face): 158 sf
- Flow under bridge: 548 cfs
- Water Depth over Lowest Point in Road or Bridge = 2.68 ft

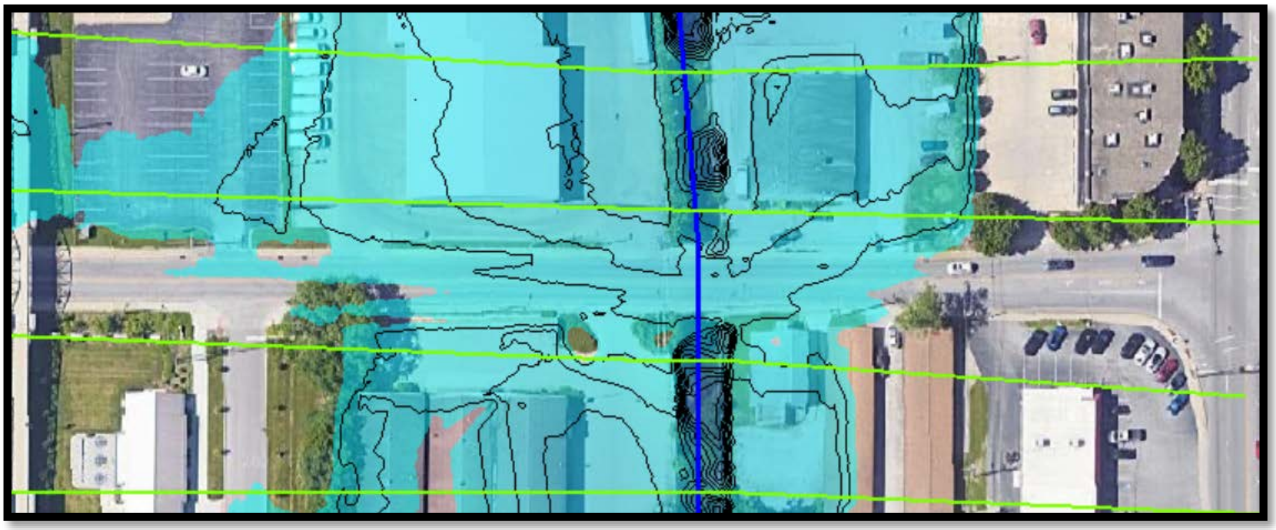
Figure 10: Auto Heaven, Clear Creek Analysis, 100-Year Storm



Grimes Lane Bridge:

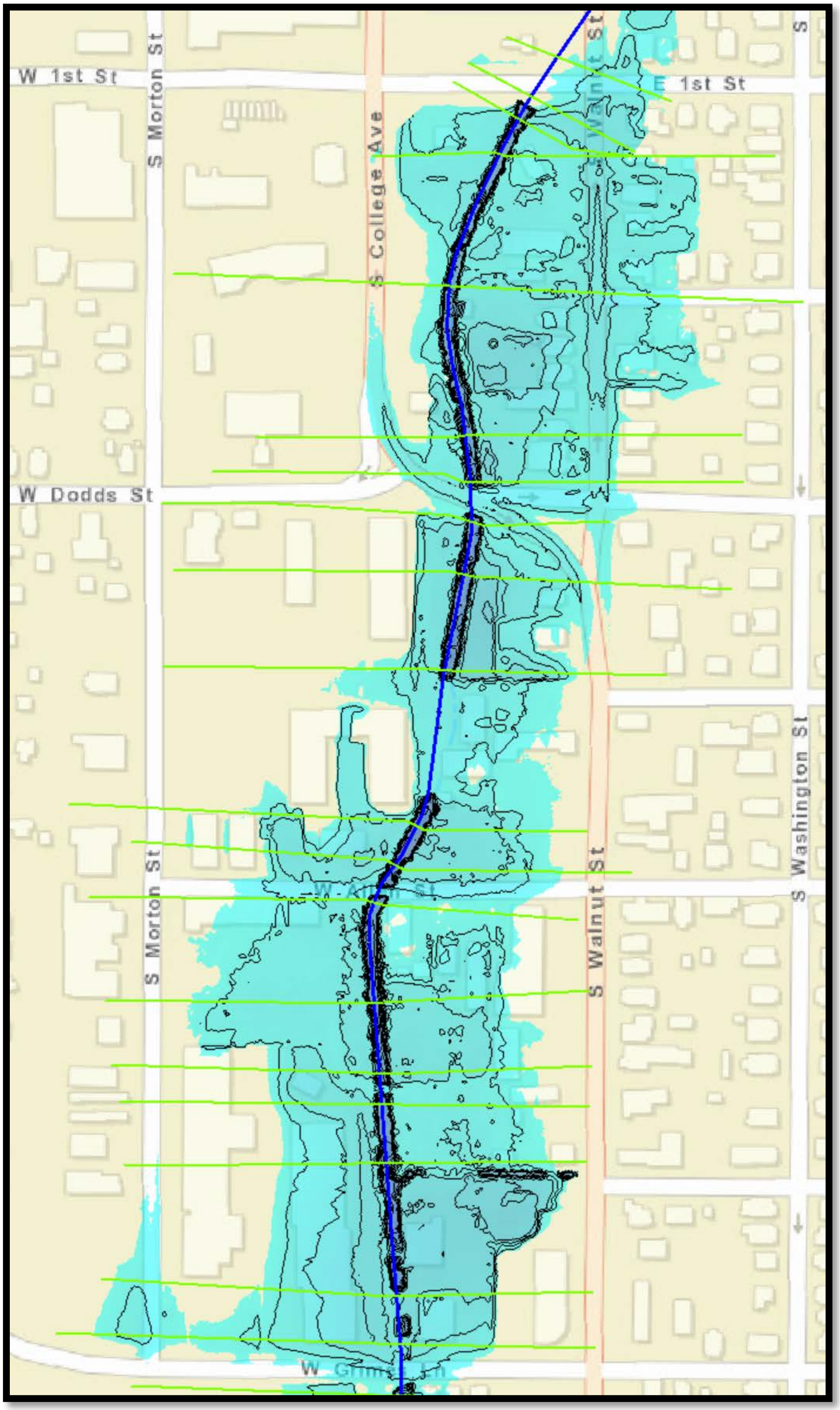
- Q100 = 2620 cfs
- Area Opening under bridge (u/s face): 142.07 sf
- Flow under bridge: 1110.07 cfs
- Water Depth over Lowest Point in Road or Bridge = 2.52 ft

Figure 11: Grimes Lane, Clear Creek Analysis, 100-Year Storm



As shown in the bridge computation results above and the overall view of the section below, the bridges and channels between them have limited flow capacity when comparing them to the Q100 flow rate. During large storm events, the modeling suggests that the water will back up in these sections between the bridges until the water can overtop the bridges. The water spreads out within the sections and overtops the bridges, creating flooding in the low sections outside of the channel.

Figure 12: 1st Street to Grimes Lane, Clear Creek Analysis, 100-Year Storm



June 18-19, 2021 Storm Event Review: Using the Pre-2022 condition for Clear Creek from Indiana Avenue to Grimes Lane.

Due to the recency and severity of impacts during the June 2021 storm event, the following estimate of that event is provided below:

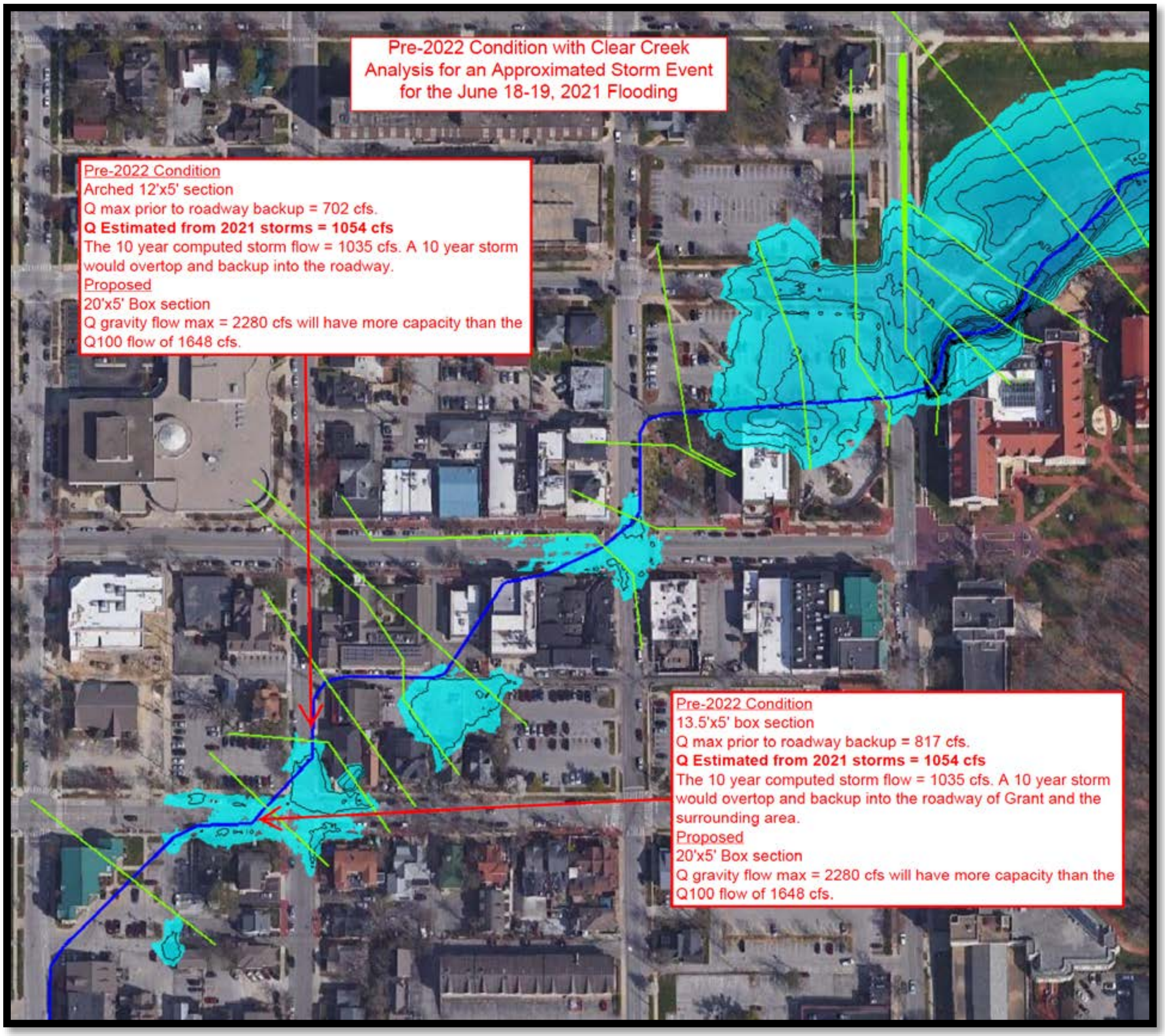
Officially, per NOAA records, the 4.95” recorded on June 18 for a 24-hour event, or the 6.07” of rainfall for a 2-day event, suggests approximately a 20 year storm event. When looking closer at actual events, rain data suggests that the storm was probably statistically closer to a 50-year storm in terms of frequency because its duration was of especially short duration for the amount of rainfall. It also occurred within 1 day of a heavy storm with already saturated ground conditions. This resulted in a notably high peak flow in a short period of time.

Roadway overtopping at Indiana and 6th occurred and water flowed overland in a southwesterly direction. It was reported by an adjacent property owner that the inlet behind the Von Lee building became plugged with leaves, mulch or other debris during this event, slowing water from entering the culvert. This deepened the flooding conditions and this water then flowed overland to Kirkwood and Dunn and beyond. Street inlets were unable to keep up with the overland flow in the short term. The culvert sections closer to 4th Street, as previously discussed, had a capacity of 593 cfs at that time, suggesting the culvert itself was also unable to convey the water resulting in a general system backup. It is also widely reported that the flooding, while significant, dropped very quickly once the rain eased and peak flow had passed, suggesting that the inlets and overall system were at full capacity for a time.

The peak from the Clear Creek culvert, when added to the flow from Spankers Branch at Walnut Street, created a high flow condition extending to the outlet at 1st Street then into the channel section of Clear Creek. As the peak flow continued down Clear Creek, the flooding overtopped the bridges and inundated properties within the floodway. Three of the five bridges listed do not carry vehicular traffic. The roadway overtopping at Dodds Street and Grimes Lane would have presented the most severe hazard because they were in use by traffic.

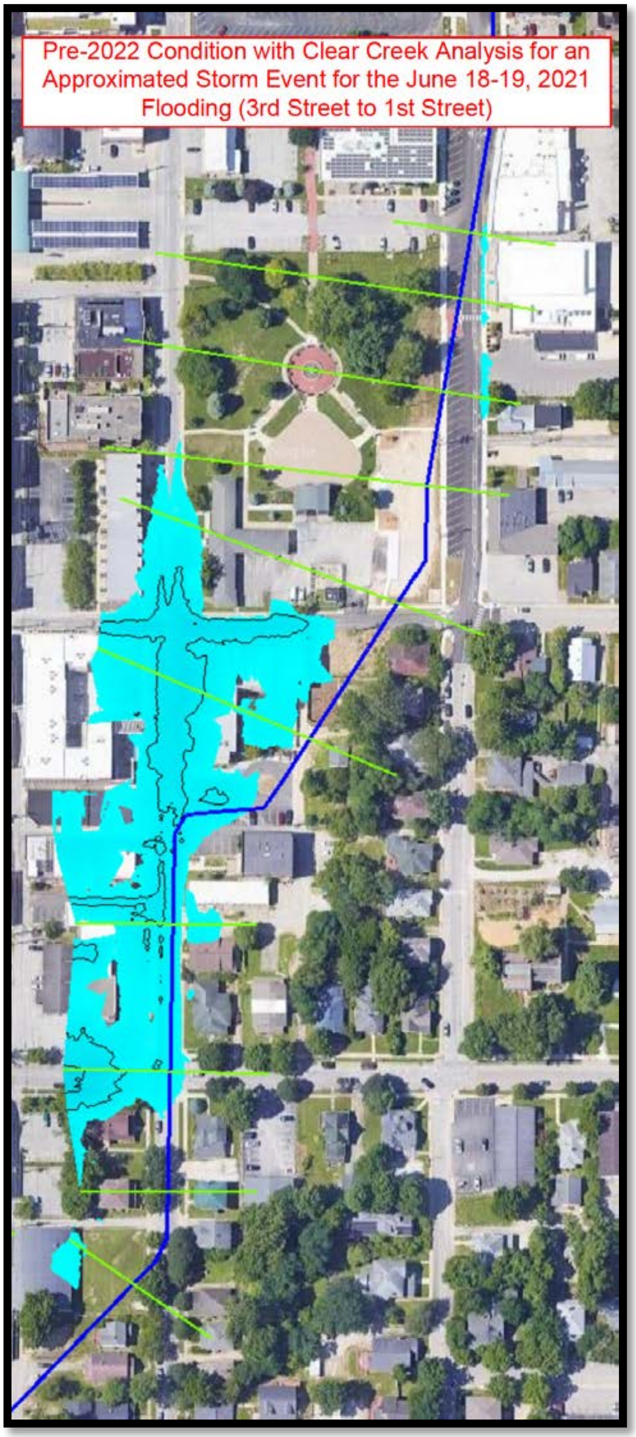
The exhibit below is an approximate model of the June 18-19, 2021 storm event at the upstream section of Clear Creek using the Pre-2022 condition.

Figure 13: Clear Creek Analysis, June 18-19, 2021 Storm Event, Pre-2022 Condition, Upstream Section



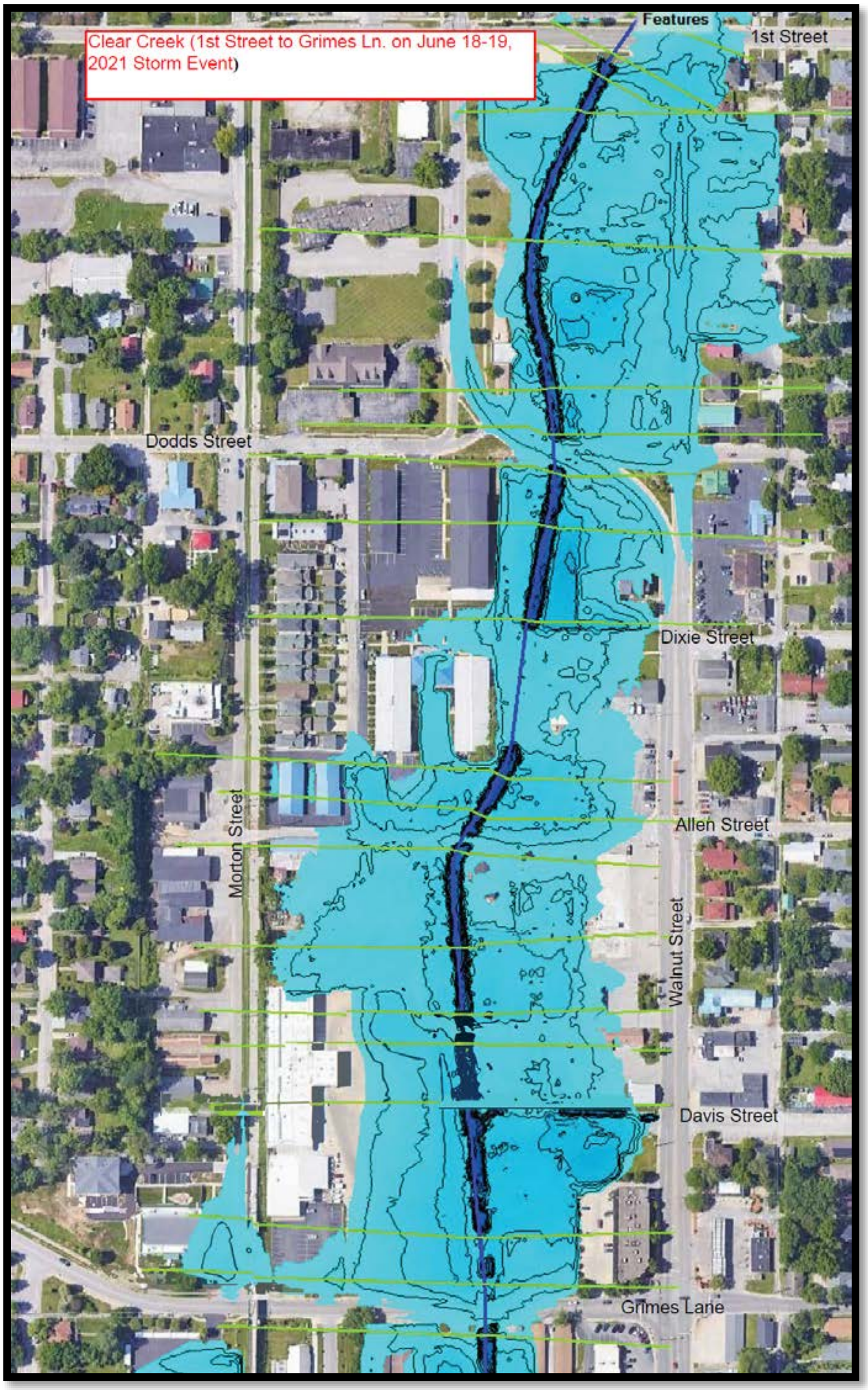
The exhibit below is an approximate model of the June 18-19, 2021 storm event south of 3rd Street.

Figure 14: Clear Creek Analysis, June 18-19, 2021 Storm Event, Pre-2022 Condition, 3rd Street to 1st Street



The next exhibit is an approximate model of the June 18-19, 2021 storm event with the flooding along Clear Creek from 1st Street at the upstream end to Grimes Lane at the downstream end.

Figure 15: Clear Creek, June 18-19, 2021 Storm Event



The following exhibits show a close-up view of each of the bridges with approximate model of the June 18-19, 2021 storm event with the flooding along Clear Creek from 1st Street to Grimes Lane.

Figure 16: Dodds/College Avenue, Clear Creek Analysis, 2021 Storm Event

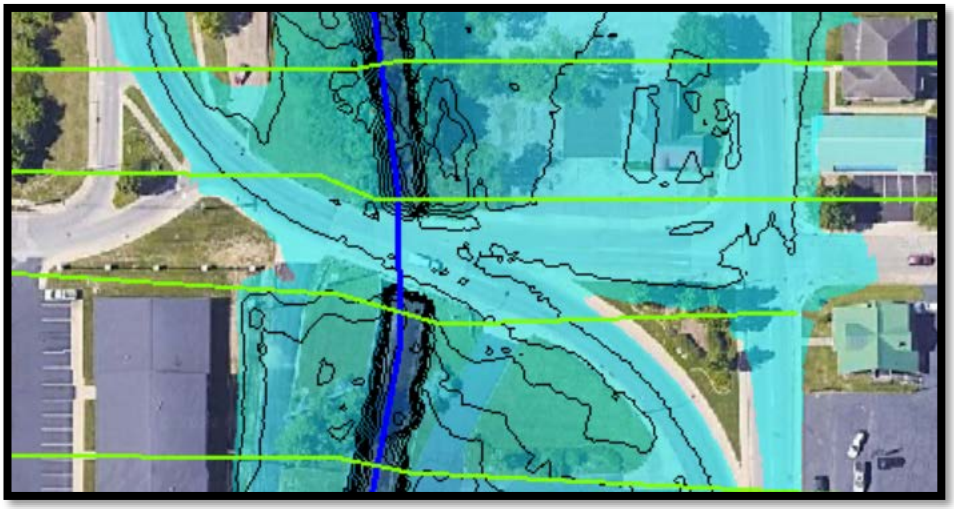


Figure 17: Loren Wood Builders, Clear Creek Analysis, 2021 Storm Event

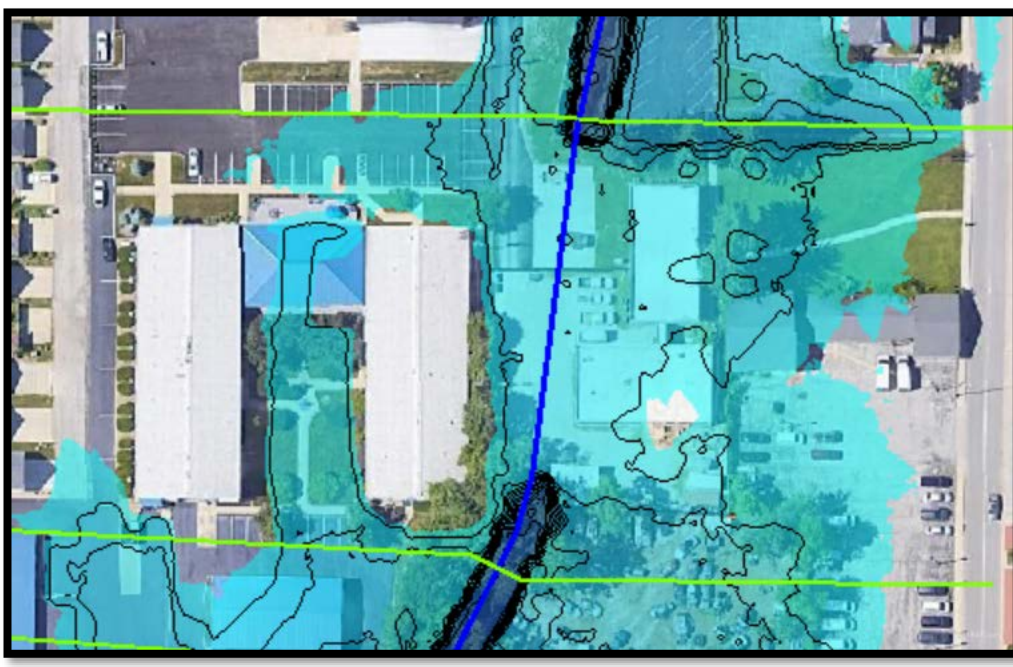


Figure 18: Allen Street, Clear Creek Analysis, 2021 Storm Event

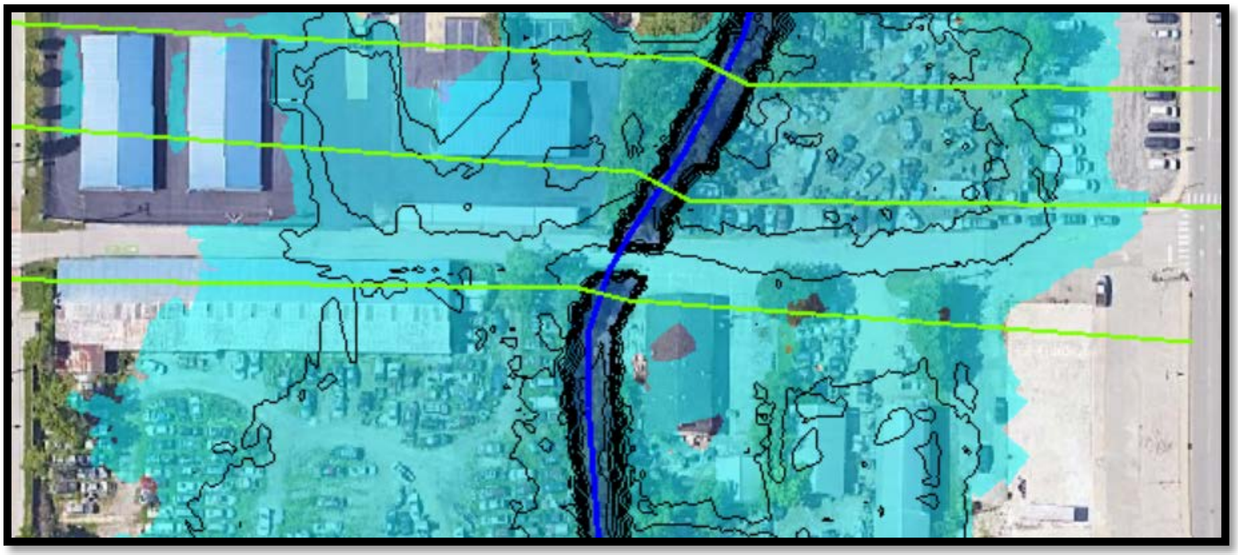


Figure 19: Auto Heaven, Clear Creek Analysis, 2021 Storm Event

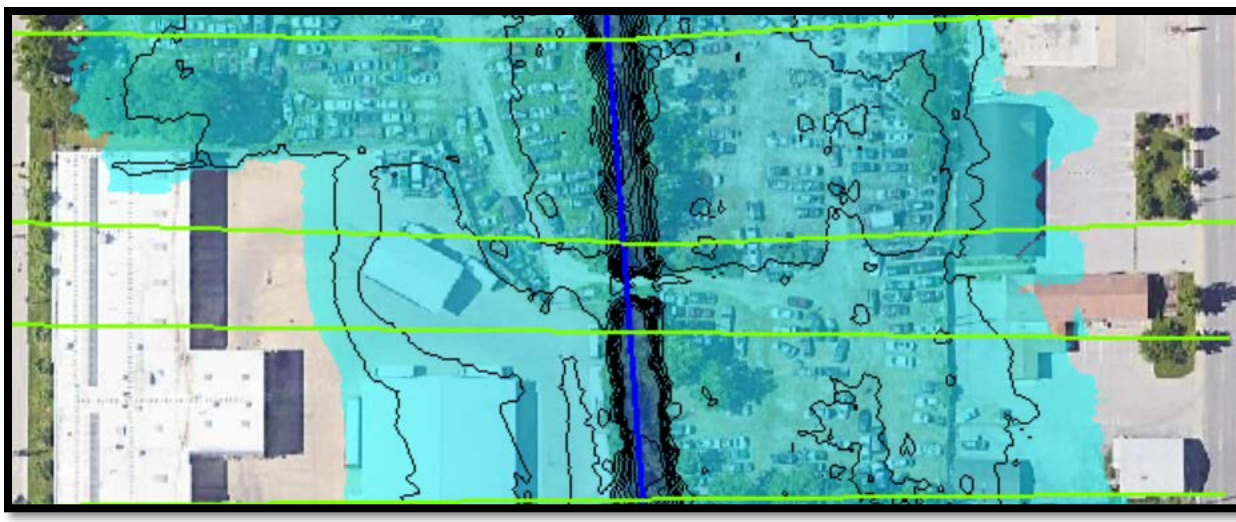
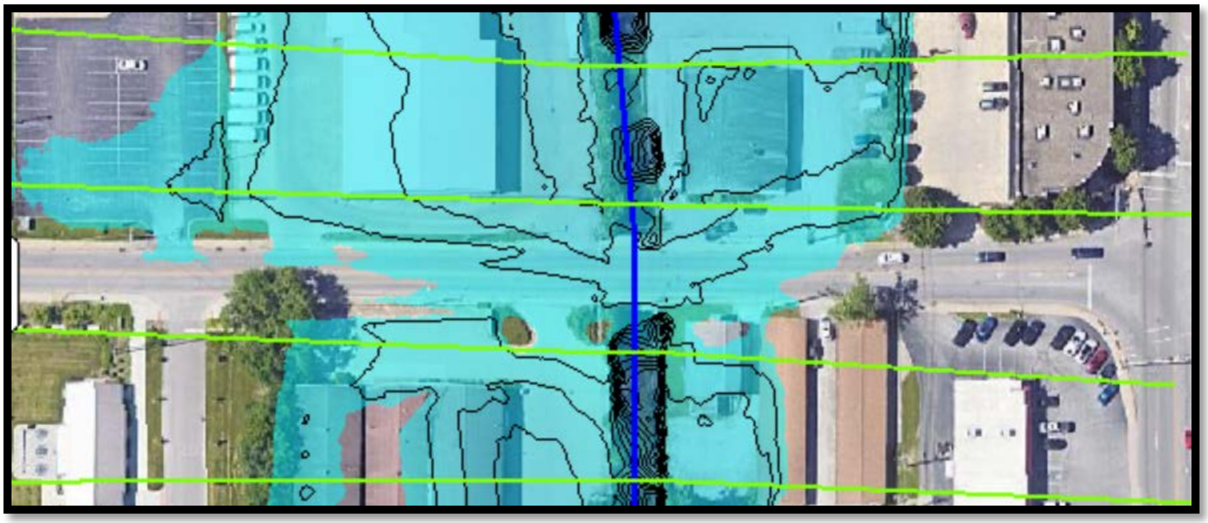


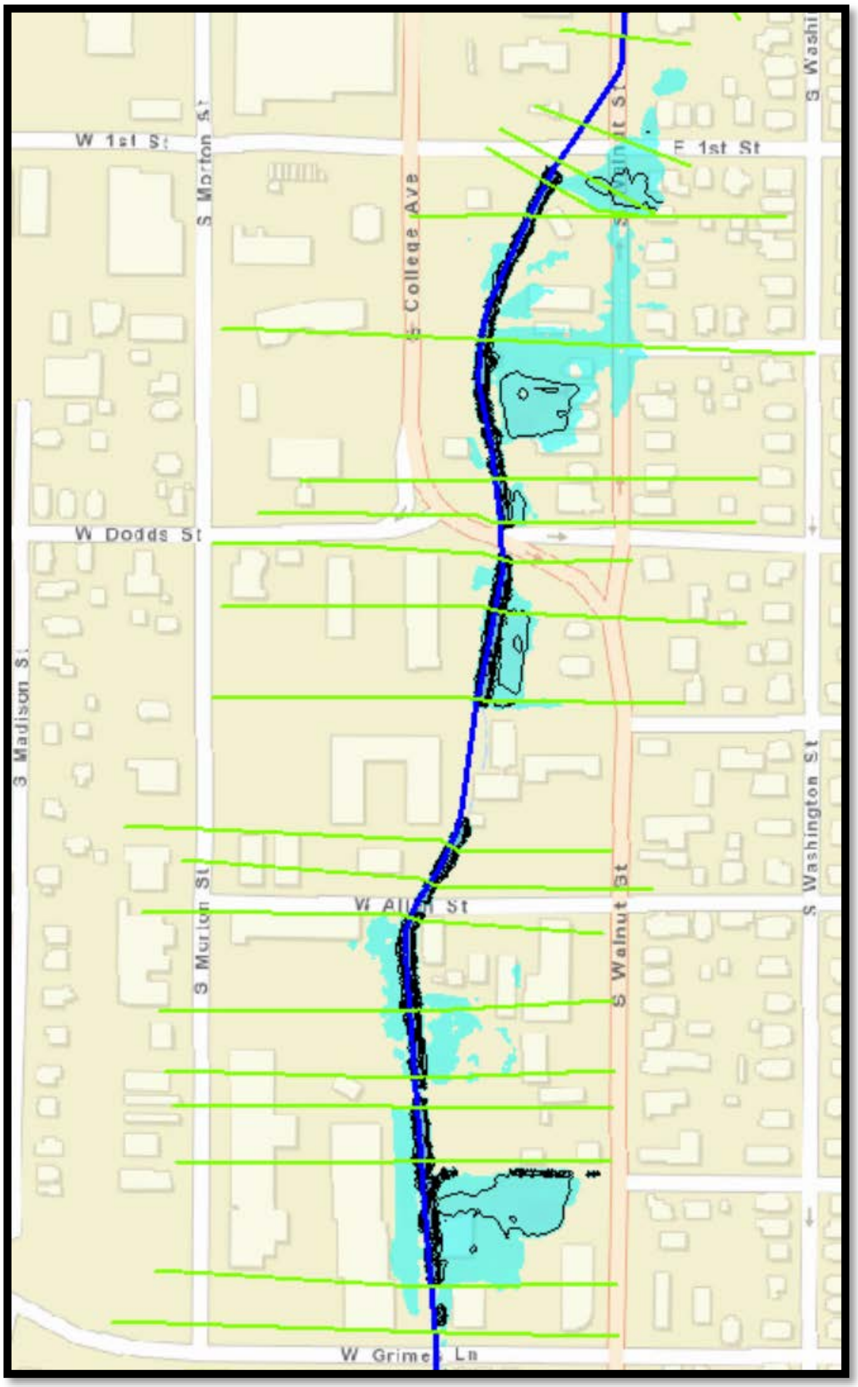
Figure 20: Grimes Lane, Clear Creek Analysis, 2021 Storm Event



2 Year Storm Event Review: Clear Creek from 1st Street to Grimes Lane.

The next exhibit is a model of a 2-year storm event to determine the approximate storm that would fill the limits of the defined channel and would have very limited flooding outside of the channel limits.

Figure 21: Clear Creek, 1st Street to Grimes Lane, 2yr Storm Event

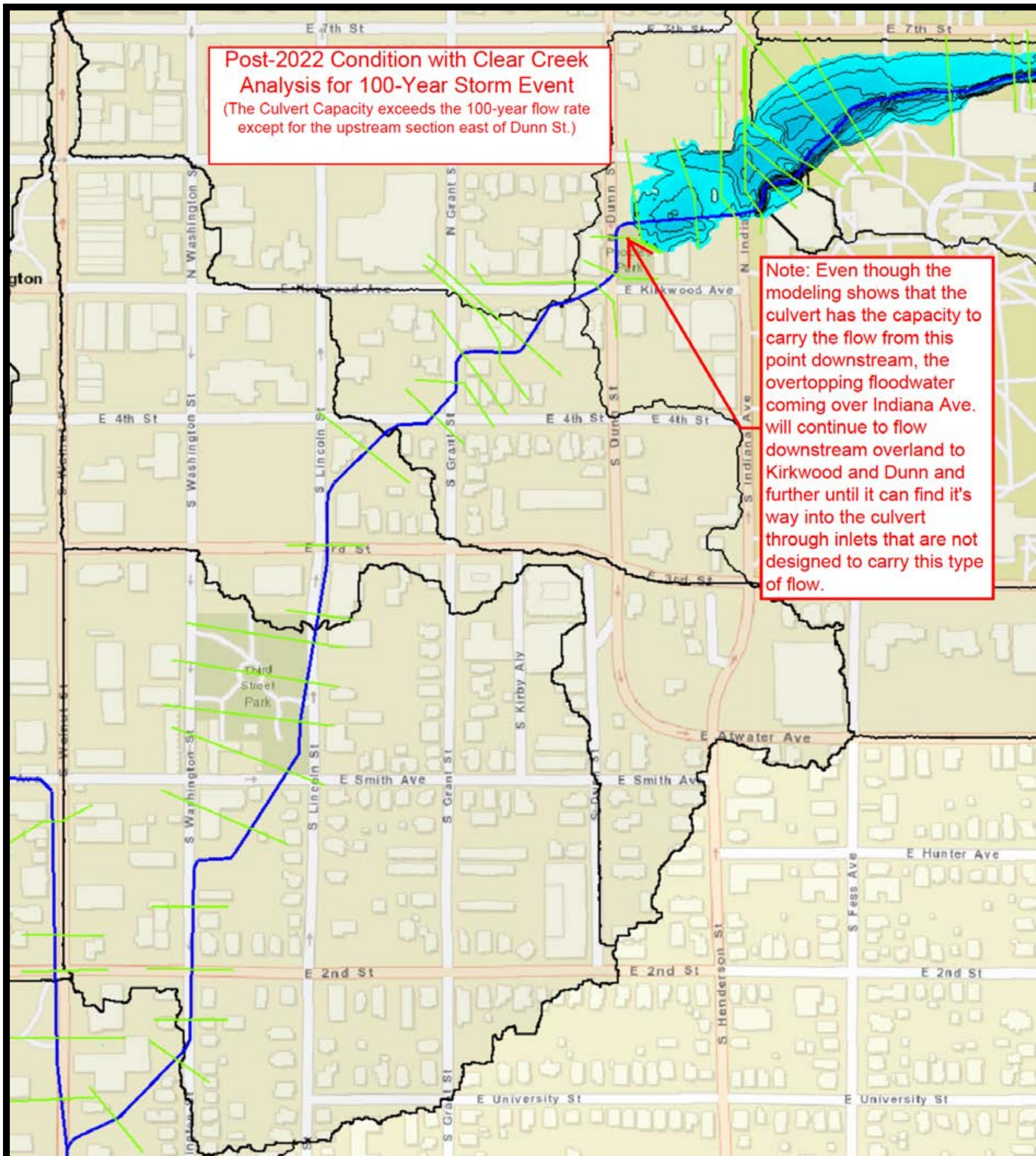


Proposed Conditions:

Clear Creek: (Post-2022 Culvert Improvement Project)

Applying the estimated 100-year storm to the post-2022 condition, the modeling resulted in the following exhibit:

Figure 22: Clear Creek Analysis, 100-year Storm Event, Post-2022 Condition



Until improvements are made to the sections upstream of Dunn Street, and to the opening condition, the conditions in the alley behind the Von Lee Building and at Indiana Avenue and Dunn Meadow will continue to persist. The 2022 project will provide a much-improved condition downstream of Kirkwood Avenue with the culvert system having the capacity to carry the 100-year flow.

While the culvert itself will have adequate capacity from Dunn Street to the south, the upstream conditions will continue to have negative impacts to Kirkwood and Dunn because stormwater will be seeking inlet capacity in order to enter the culvert.

The roadway overtopping at Indiana Avenue results in flow down the alleyway and parking lot adjacent to it between Indiana and Dunn, then to Dunn Street and Kirkwood, then towards Grant and 4^{th} Streets. Once the flow gets to Dunn Street, the underground culvert has capacity below the roadway and can start to capture flow into inlets along the flooded corridor. Street inlets, though present, are not designed to handle the full flow of the roadway overtopping that starts at Indiana Avenue. Inlets drain the overflow at a slower rate resulting in ponding and extended flow above the culvert until enough inlets and time have allowed water to drain into the culvert. The reported clogged inlet behind the Von Lee Building demonstrates the impact that even a single failed inlet can have in increasing the problems downstream.

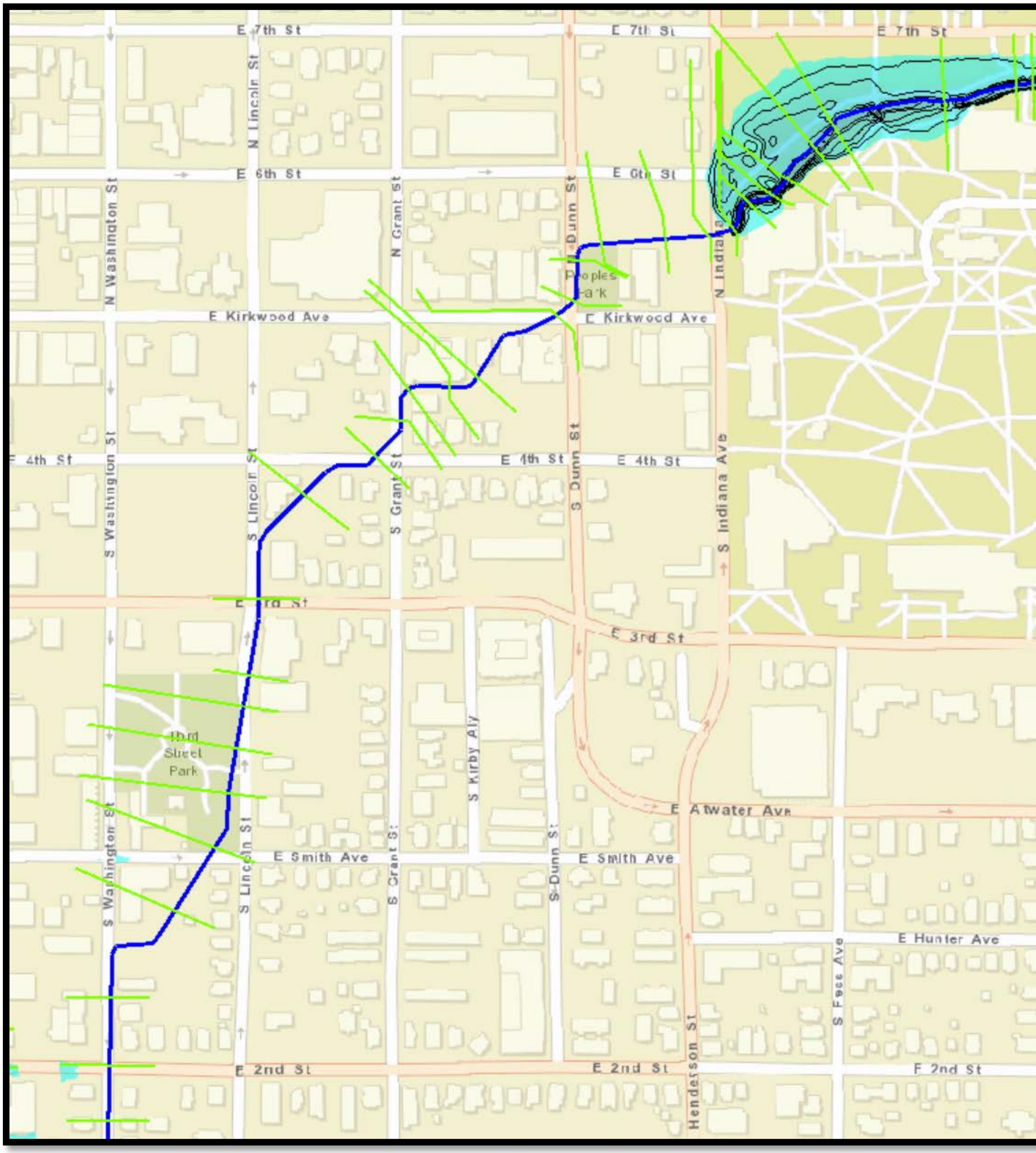
Clear Creek Planned Improvements:

The proposed condition includes the planned improvements of the culvert from the upstream entrance at Indiana Avenue to Dunn Street along with the Post 2022 Construction of the Culvert Improvements south of Kirkwood Avenue.

The planned improvements include a 22 feet wide x 4.75 feet tall concrete culvert structure with wingwalls at the upstream entrance, additional inlets, and modifications on the east side of Indiana Avenue. The new structure will tie into past improvements of the culvert at Dunn Street. The proposed flow rate is designed to carry 1668 cfs under gravity flow, which exceeds the 100-year flow rate of 1235 cfs. The additional capacity will help reduce the probability of roadway overtopping and flooding of the downstream roadways and businesses. Additional inlets are planned in the alley between Indiana and Dunn to provide redundancy and reduce the impacts of a single clogged inlet in case of roadway overtopping. Modifications on the east side of Indiana Avenue include regrading of the area to the east of the sidewalk. The regrading will include lowering of the sidewalk between the waterway and the Franklin Access Drive to help facilitate as much flow as possible towards the culvert opening when Dunn Meadow overtops the Franklin Access Drive.

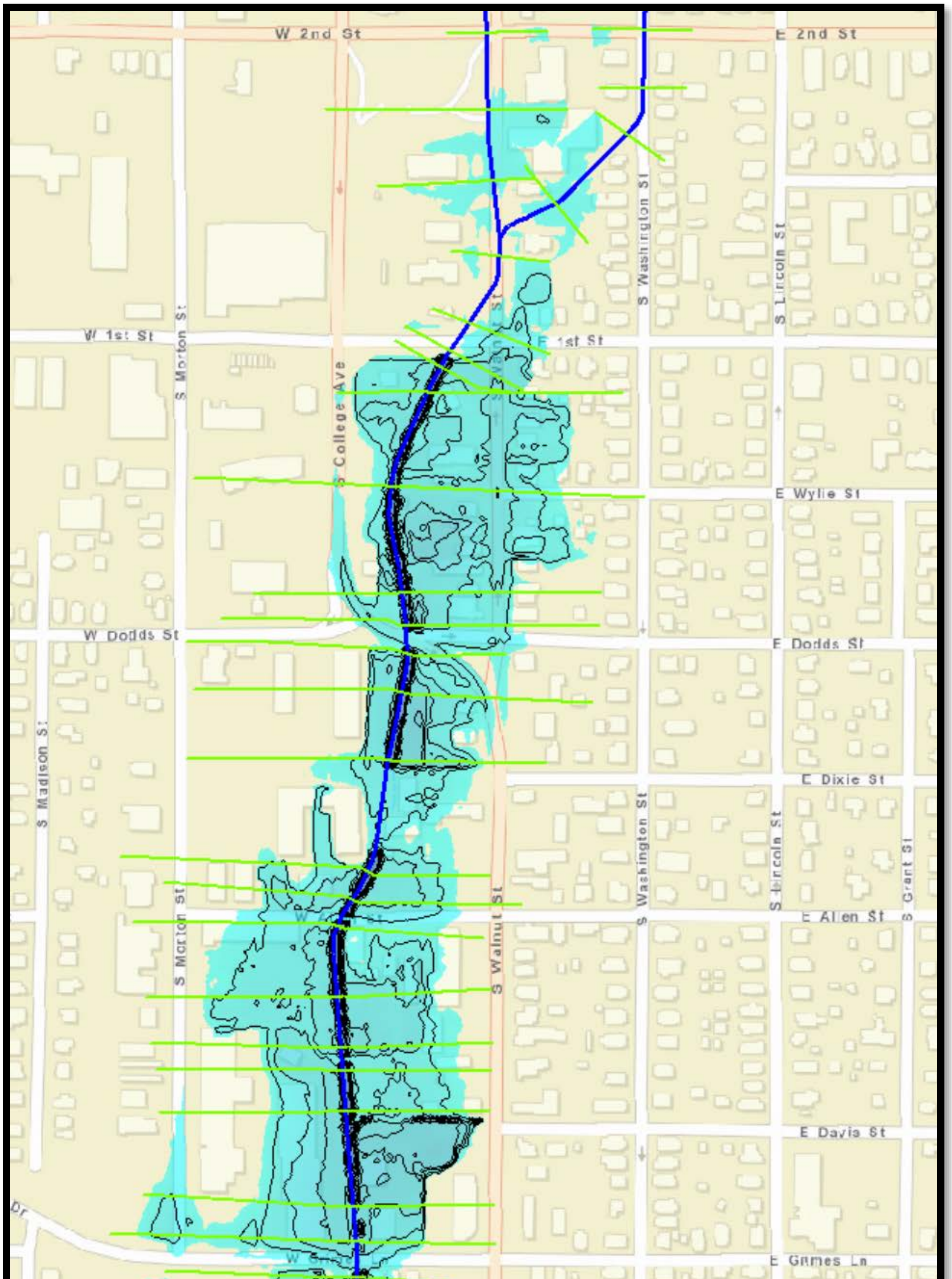
Applying the estimated 100-year storm to the Proposed Condition, the following potential flooding conditions might be expected:

Figure 23: Clear Creek, 100-year Storm Event, Proposed Condition, Indiana to 2nd Street



Applying the estimated 100-year storm to the Proposed Condition, the following potential flooding conditions might be expected at the south end of the study in the floodplain. No improvements are currently planned through this open channel section. Recommendations are discussed further in the recommendations section from 1st Street to Grimes Lane:

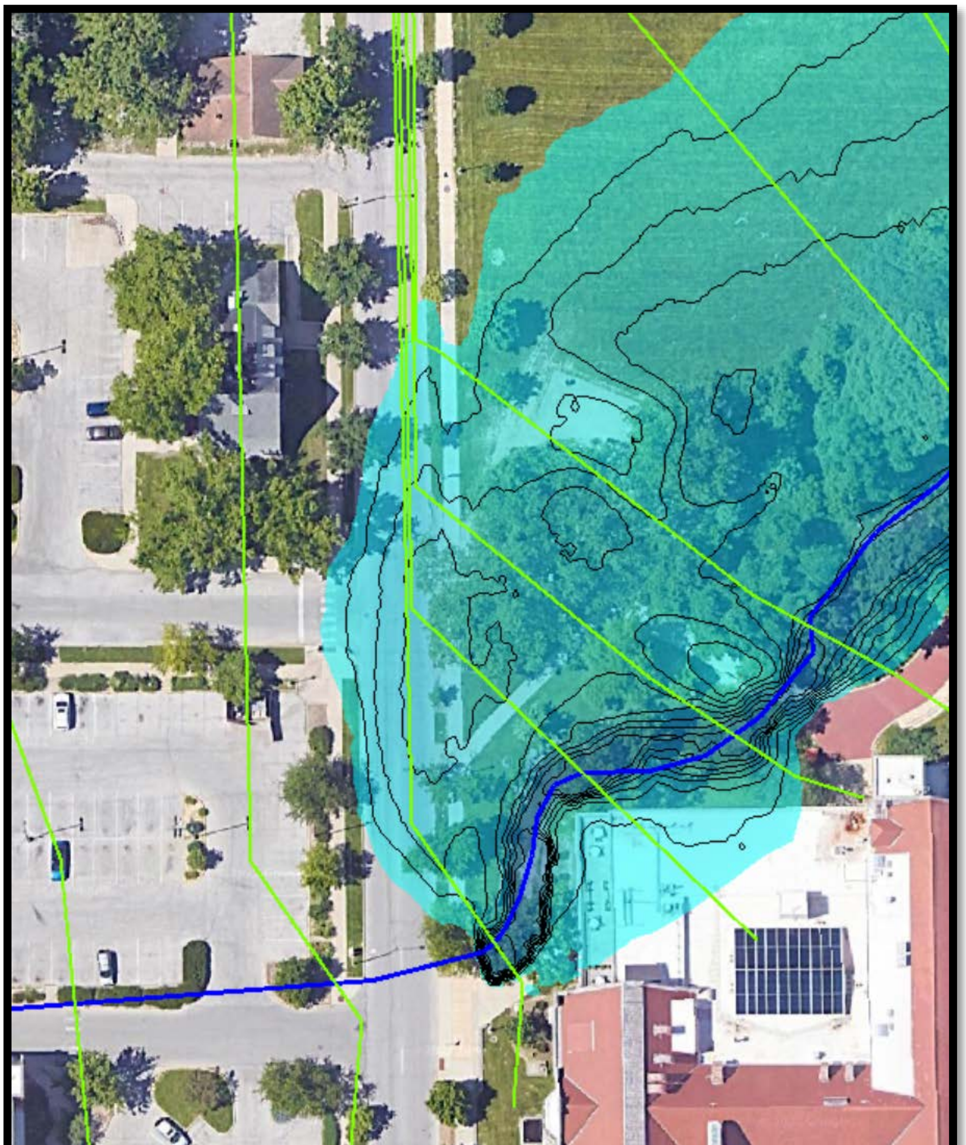
Figure 24: Clear Creek, 100-year Storm Event, Proposed Condition, 2nd Street to Grimes



The figure below shows a close-up view of Indiana Avenue during a proposed condition where the proposed culvert has the capacity to capture the 100-Year storm event prior to flowing downtown. Grading improvements planned in this area with the future "Downtown Culvert Reconstruction Dunn Street to Indiana Avenue" will help reduce and shorten the time of standing water in Indiana during the peak of the storm.

Note: Although the results below show water overtopping into Indiana Avenue during the 100-Year Storm event, the maximum depth computed is less than 8 inches deep at the inlet on the east side of the road. As a comparison, prior to the proposed condition, maximum depth computed at the same location is more than 3 feet 9 inches, making Indiana Avenue impassible even with large vehicles during the peak.

Figure 25: Clear Creek, 100-year Storm Event, Proposed Condition, Indiana Avenue



Proposed Modifications or Recommendations:

Detention location review:

Additional storage along the culvert branches was reviewed to see if there were any areas that could be redeveloped as storage where there would be a significant reduction of flooding. The storage volume required that would actually provide significant benefits was estimated to be a minimum of 3 acre-ft. When using underground storage facilities, 3 acre-ft of volume may take up to 2 city blocks. Unfortunately, due to the area being 100% developed, there were no areas large enough to provide significant storage and deemed feasible (available and affordable) for conversion to detention. Dunn Meadow, which currently provides significant detention to the study area, is discussed in later recommendations.

Design improvements for the culvert between Indiana and Dunn:

Replacement of the culvert from Dunn Street to the upstream opening (east of Indiana) provides the biggest opportunity to further reduce flooding along the enclosed (culvert portion) of the Clear Creek system.

At its recommended size of 22' wide and 4.75" tall, the increased sized culvert will have adequate capacity to convey the 100-year storm event flow rate of 1235 cfs, with additional capacity for a total 1668 cfs under gravity flow. With the increased capacity, inlets will be able to drain freely into the culvert along the stretch from Indiana Avenue to Dunn Street. Above that section, there is a larger than normal sag in the roadway where water can be captured and sent down inlets prior to overtopping towards Kirkwood and Dunn. Additional inlets are recommended to be added in that alley. It is also important to modify conditions upstream of the Clear Creek culvert to reduce the roadway overtopping at Indiana and 6th.

Recommended improvements on IU property east of Indiana Avenue:

The modeling and topographical review revealed that it is the Franklin Access Drive bridge just upstream of the Clear Creek culvert where the creek backups first occur. The opening of the Franklin Access Drive bridge is undersized (or intentionally sized to create detention storage within Dunn Meadow), resulting in overtopping of the drive during large storm events. Topography shows that the water overtops the drive at the low point near the entrance drive to Indiana, resulting in the flow going directly into Indiana Avenue at 6th Street. Water which enters Indiana Avenue initially ponds in the intersection. Some water will then make its way southeast to the culvert opening, but most will flow west and then south overland to find the low area behind the Von Lee Building.

It is recommended that additional modifications be made to the Franklin Access Drive and the sidewalks between the access drive and Indiana Avenue. Water that accumulates near Indiana Avenue and eventually overtops it needs to be redirected back to the creek channel and into the culvert. A short section of access drive reconstruction and sidewalk reconstruction, combined with the grading of a swale back to the creek would greatly assist in reducing the overtopping of Indiana Avenue, especially when the culvert opening has been rebuilt to its greater target capacity. The goal must be to direct the upstream creek flow into the Clear Creek Culvert because downstream inlets, no matter how many are provided, are not going to provide enough capacity to receive overland creek flow. The culvert will have the capacity if the water can be redirected to enter it.

Another option at this location, instead of reconstructing the Franklin Access Drive, could be to create a small berm along the upstream side of the drive to help direct the flow overtopping location to the southeast. If the drive overtopping location can be shifted southeast, the water will then flow over the drive in a more direct route to the culvert opening.

Dunn Meadow recommendations:

Dunn Meadow has for decades provided an important and substantial reduction to downstream (and downtown) flooding conditions. Whether this was planned or simply the result of construction performed many decades ago, the importance of Dunn Meadow in offering the only significant detention/storage volume upstream of the culvert should not be understated.

It is IU's bridge under the service road that provides the first measure of inlet control for the current Clear Creek Culvert. Its capacity is estimated to be 74 cfs before the service road overtops and the water flows overland to the west toward 6th Street. It's fair to say that the temporary inundation of Dunn Meadow has provided a measure of flood reduction to downstream areas. The currently under-sized entrance to the culvert itself provides a second inlet control, though a bit higher in capacity than the waterway opening of IU's small bridge.

Coordination between City Utilities and Indiana University is critical if and when IU wishes to make changes to the current bridge or to Dunn Meadow. Most of the watershed upstream of the culvert is IU campus property, and changes in the watershed have a significant impact on flow conditions at the entry to the Clear Creek Culvert. Any change to IU's bridge and service road will impact the conditions under which water is to enter the culvert system.

There are potential modifications to Dunn Meadow that could be of good benefit if the areas were designed with this use in mind. It may be possible to enhance the area so that it provides multiple benefits that include increased stormwater storage when it is needed, but also includes infrastructure including control structures that allow it to both fill and drain in a more controlled manner. Ultimately the utility and aesthetics of the area could be enhanced by improving its capacity to hold water but also draining and drying much more quickly to reduce the time is it unavailable.

In the long-term, it should be recognized that rainfall patterns are changing, and they often result in more frequent and more severe runoff conditions. Long term coordination between the City and Indiana University is important to the better protection of the downstream and downtown areas, and adaptation to rainfall trends should take into account the importance of Dunn Meadow.

Recommended improvements for Clear Creek from 1st Street to Grimes Lane

At this time, there are no known proposed improvement projects to the channel or bridges south of 1st Street. Monroe County is the jurisdictional authority for the bridges that are not privately owned. The City, the County, and the adjacent property owners have a shared interest in improving the flooding conditions in the areas, but their interests and resources are not the same. There are several recommendations that should be considered.

The study area is a combination of two separate and distinct sections. The upstream section is entirely enclosed in a large storm culvert system, whereas the downstream section is an open channel (occasionally crossed by bridges). The focus in recent history has been on the culvert sections under downtown, and it is noteworthy that these will have taken approximately 25 years to replace. Improving this system is a long term commitment, and the downstream channel section should be viewed with a similar consideration.

- As bridges are in need of work, the County and City should cooperate in having the bridges replaced with properly sized waterway openings. Investments in rehabilitation should not be favored unless absolutely necessary to achieve a shorter-term safety or maintenance need. The dollars should be saved and invested in replacement where possible. The Allen Street Bridge is not currently open to vehicular traffic, and if this condition is made permanent, that bridge could be replaced with a smaller and much less expensive bicycle/pedestrian bridge.

- Channel sections need to be widened to increase capacity. When widening, the sides should be sloped to make the waterway safer. Sloping the channel walls, if done properly, should result in a more stable creek bank, involve less structural investment, and can reduce the hazard that the vertical walls present.

- Conducting regular maintenance to clear debris and obstructions is very beneficial to getting the maximum out of the available channel cross section. Opportunities to make small modifications to open the channel's waterway to its full extent should be leveraged.

- Remove or reroute utility lines that cross the waterway and create obstacles within the waterway. These reduce the available capacity.

- Plans for new construction in the floodway should be reviewed and only approved based on advancing the City toward its goals of protecting and increasing the capacity in these sections. If necessary, a local ordinance or policy could be put in place to require City approval along with the IDNR Construction in a Floodway Permit Approval that is necessary for construction in this section of the creek. IDNR generally only requires that conditions not be made worse. This modeling shows the goal for this section must be to make considerable improvements. Construction along the corridor could be directed to focus on flooding reduction and coordination with City goals.

- The City of Bloomington could consider future purchases of property along the corridor as greenway space. It would give the City more control over the area, the ability to remove structures and improve waterway capacity. The City should keep its eye out for opportunities to purchase property or to require easements for drainage in conjunction with site redevelopments.

- Generally speaking, the City should closely monitor and even model prospective changes as they are made. It would be beneficial to make changes from downstream to upstream over time, but funding and opportunities seldom work out that smoothly. It will be important to ensure that each improvement does not make conditions worse at a point farther downstream. Each undersized section has the unintended consequence (and benefit to those downstream), of slowing water in that section and thus providing some measure of relief to those downstream.