INVESTIGATION OF POTENTIAL FLOOD MITIGATION PROJECTS NEAR LAWLER, IOWA

EXECUTIVE SUMMARY

The City of Lawler is subject to flooding originating in small agricultural catchments and riverine flooding from Crane Creek, a tributary of the Turkey River. The community is interested in flood mitigation alternatives following a recent August 2021 flooding event that left many homes and businesses damaged. The total rainfall over a 24-hour period was 7.9 inches, having a return period between the 100- and 200-year storm events. Much of the flooding from this event originated from a small creek that runs through the community. Potential flood mitigation projects to reduce flooding from the creek include channel and culvert modifications to increase channel capacity, and/or construction of an upstream detention pond to attenuate flows.

The Iowa Flood Center (IFC) developed a flood model of the community to investigate how flooding develops within Lawler and the impact of flood mitigation alternatives. IFC simulated the August 2021 rainfall event along with several design storms to see how the mitigation alternatives would perform over a range of rainfall events. Overall, increasing the creek's channel capacity by construction of a concrete channel and replacement of several culverts provided the largest inundation reductions relative to existing conditions. Increasing channel capacity by constructing a larger channel cross-section with vegetated banks and culvert replacement would also provide flood reductions. While the upstream detention pond alternative was less impactful in reducing inundation, if constructed in tandem with channel modifications would reduce flood flows entering Lawler and further augmenting the creek's flood flow capacity.

Cost estimates to construct a concrete channel with riprap banks and eight culvert replacements has been developed by The Iowa Department of Transportation (IDOT) and totals $4.7M to make these improvements.

IFC has estimated costs for natural creek channel modifications, including easements and bank stabilization would be in the range of $300,000 to $500,000. The estimated additional cost to replace bridges or culverts at four locations would be in the range of $400,000 to $500,000. The total cost for this alternative would be in the range of $700,000 to $1,000,000.

IFC has estimated cost to construct the upstream detention pond and outlet structure would be in the range of $100,000 to $200,000. Assuming landowner willingness, acquiring land within the maximum pool area would range from $120,000 to $180,000 in addition to construction costs. Purchasing an easement for ponded water is also feasible if the pond is designed to be dry much of the growing season and would drain relatively quickly (within 72 hours) following a large event, minimizing damage to crops. An easement would have a significantly lower cost.

Further study and design of these alternatives by a consultant would provide more insight into flood damage reductions, improve cost estimates, and determine feasibility. Further refinement of design and cost estimates would also allow development of benefit-cost ratios for each alternative or a combination of alternatives to guide decision making.

OVERVIEW

The City of Lawler (pop. 406) is subject to flooding originating in small agricultural catchments and riverine flooding from Crane Creek, a tributary of the Turkey River. The drainage areas and creek running through Lawler are shown in Figure 1. The community is interested in flood mitigation alternatives following a recent August 2021 flooding event that left many homes and businesses damaged. Potential flood mitigation projects include channel modifications to increase flow capacity of Lawler's creek, and construction of an upstream detention pond to attenuate flows.

The Iowa Flood Center (IFC) provided technical support by developing a flood model of Lawler to investigate how flooding develops within the community and the impact of flood mitigation alternatives. IFC simulated the August 2021 rainfall event along with several design storms to see how the mitigation alternatives would perform over a range of rainfall events.

AUGUST 26-28, 2021 FLOODING EVENT

The August 2021 flooding event was initiated by multiple heavy rainfall events moving through the area from August 26 – 28. The heaviest rainfall fell from early August 27th into the 28th, shown in Figure 2, estimated using NOAA's 1-hour gauge corrected Multi-Sensor Multi-Radar (MRMS) radar rainfall estimates. A total accumulation of 7.9 inches fell during a 24-hour period from early August 27th into early August 28th. The return period for this rainfall accumulation over a 24-hour period is between the 100- and 200-year event, according to NOAA's Atlas 14 precipitation frequency estimates (NOAA Atlas 14, 2013). The most intense rainfall over a 12-hour period was between the 10- and 25-year events. Finally, the most intense rainfall over a 6-hour period was between the 5- and 10-year events. This heavy rainfall likely caused flash flooding and contributed to a large runoff volume originating in the agricultural catchments and overwhelming Lawler's creek.

In addition to localized heavy rainfall, Crane Creek was well out of bank during Lawler's flooding event. Typically, flooding on Crane Creek backs up into Lawler's creek, preventing high flows from draining quickly. Figure 4 shows flood waters in Junko Park being pumped over a small levee along Crane Creek following the August 2021 event.

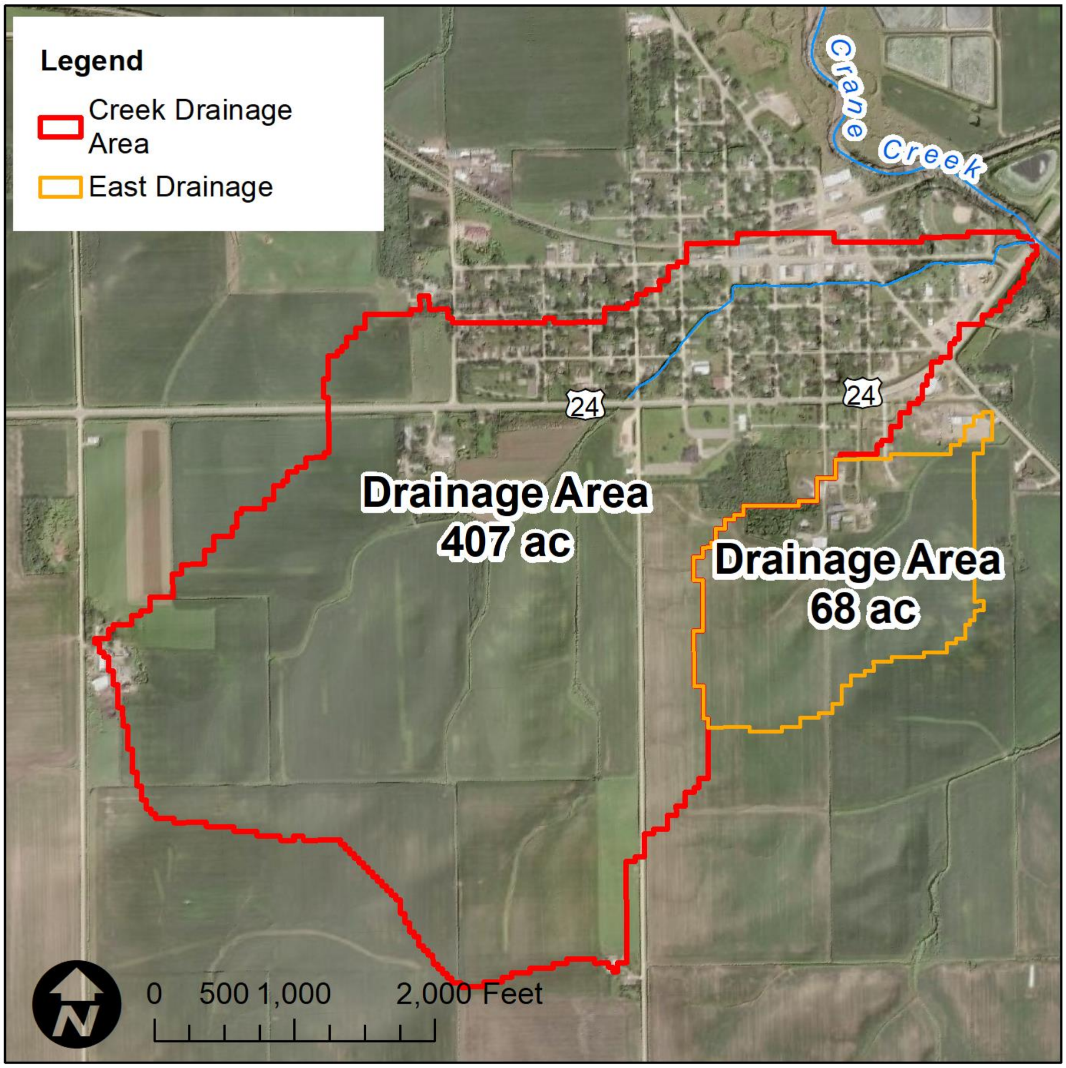

Figure 1. Agricultural catchments draining to Lawler, Iowa. The largest drainage area passes under IA-24 where a small tributary of Crane Creek continues through Lawler.

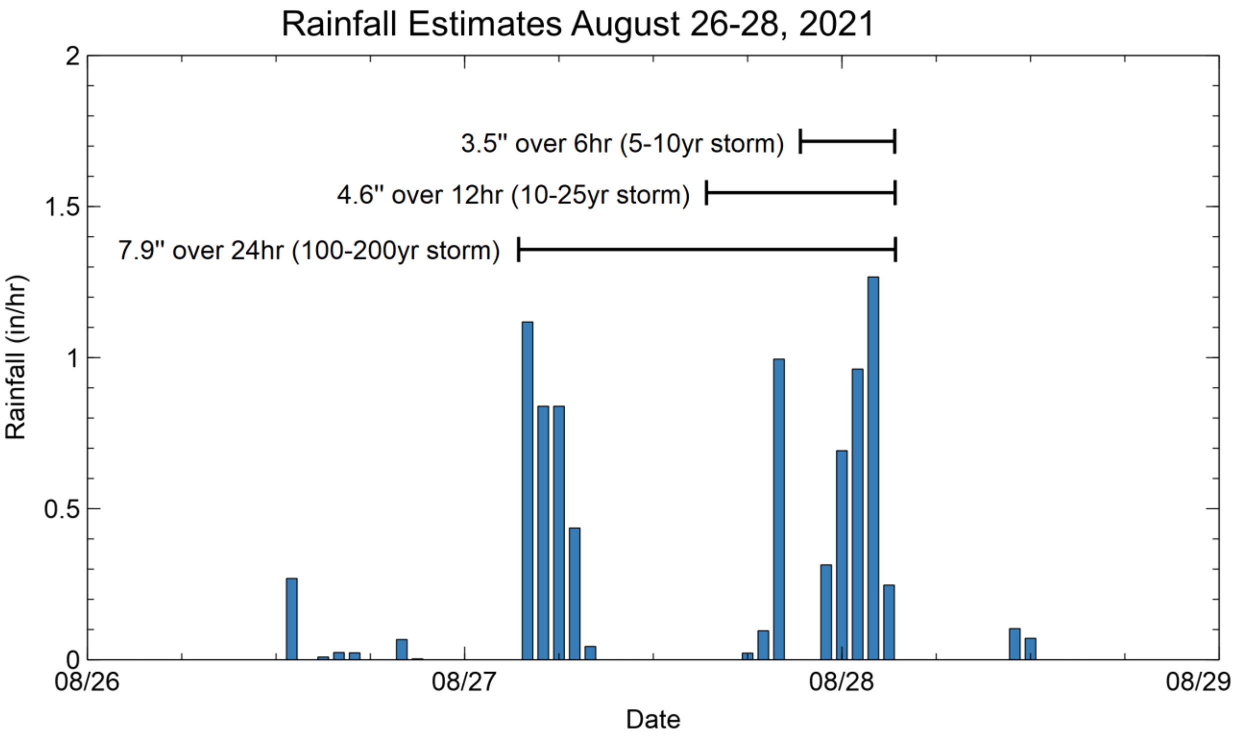

Figure 2. Rainfall during August 26-28, 2021 estimated using MRMS radar rainfall, gauge-corrected hourly accumulations.

Figure 3. Crane Creek at the IA-24 bridge crossing during the August 2021 flooding event. (Photo credit: City of Lawler)

Figure 4. Flood waters in Junko Park being pumped over a small levee along Crane Creek following the August 2021 event. (Photo credit: City of Lawler)

HYDROLOGIC AND HYDRAULIC MODELING

IFC utilized the US Army Corps of Engineers' Hydrologic Engineering Center's (HEC) River Analysis System (HEC-RAS) version 6.1 to model hydraulics and hydrology of the study area. This modeling system can simulate two-dimensional (2D) flows of overland rain-on-grid or riverine flooding. HEC-RAS has sub-grid capabilities in which hydraulic properties of mesh cells are developed using the resolution of the underlying terrain model, which is often much higher than the mesh resolution. This allows for physically accurate simulation of water flow across the landscape. HEC-RAS can also utilize higher cell resolution along break lines to capture elevations and alignments within 2D flow areas.

A HEC-RAS geometry representing existing conditions was developed and is shown in Figure 5. The model geometry is largely based on Light Detection and Ranging (LiDAR) bare earth terrain data collected in 2009. Dimensions and invert elevations of bridges and culverts were estimated using GIS measurements and photographs of structures provided the City of Lawler. Lidar data along the creek was modified to correct isolated erroneous terrain elevations and ensure the creek invert profile was consistent.

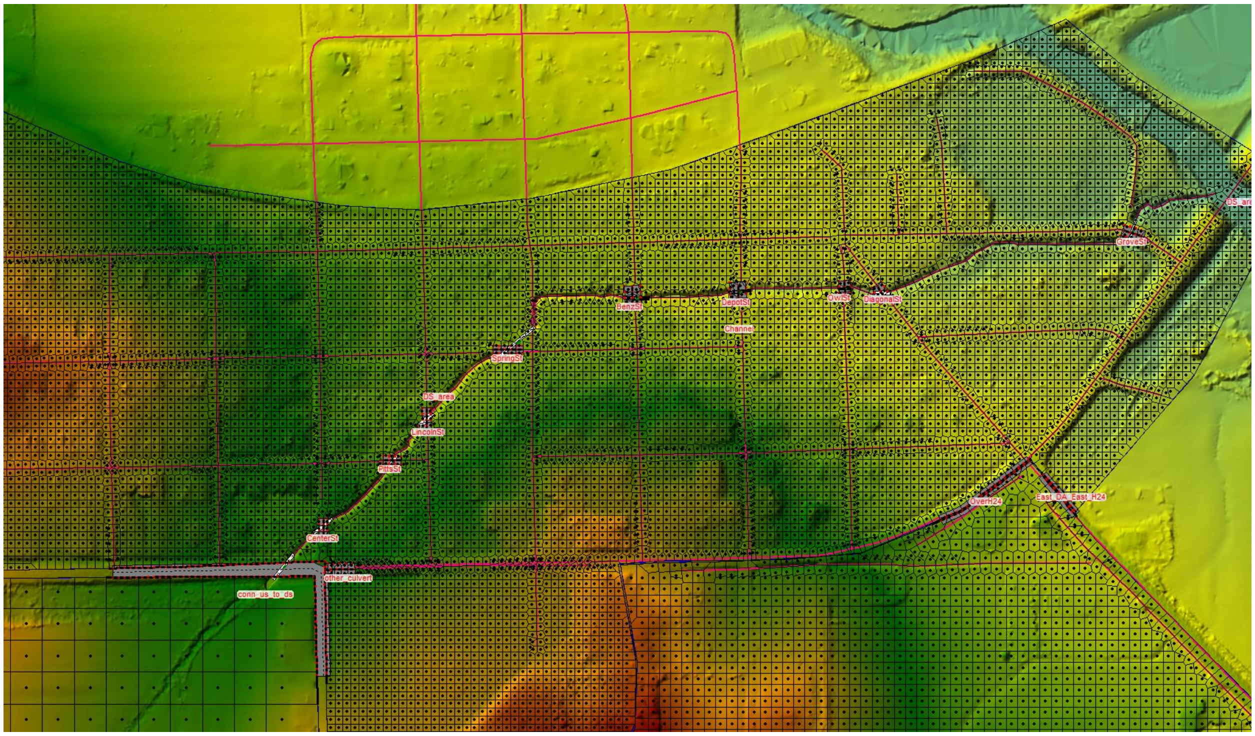

Figure 5. HEC-RAS model geometry of existing conditions in Lawler, Iowa. Individual 2D flow area cells are aligned along the creek and roadway centerlines. Bridges and culverts were also incorporated into the model using best available data.

Surface roughness values were parameterized using a 2009 high-resolution land cover dataset (HRLC) provided by Iowa DNR. Roughness values were selected based on standard values provided by Chow (1959) and USACE guidance (2022). Roughness values for each land cover type are shown in Table 1.

Table 1. Roughness values for each land cover type.

Land Cover	Manning's n Roughness Value
Barren – Fallow	0.02
Roads – Impervious	0.013
Grass 1	0.03
Grass 2	0.03
Structures	0.2
Water	0.03

Wetland	0.1
Deciduous Short	0.1
Deciduous Medium	0.1
Deciduous Tall	0.1
Coniferous Forest	0.1
Corn	0.035
Soybeans	0.035
Shadow	0.02
Creek Channel	0.035

Rainfall infiltration was accomplishing using spatially distributed SCS curve numbers. The SCS curve numbers were developed using an intersection of land use and NRCS Hydrology Soil Groups. General land use types were manually digitized based on aerial imagery, and classifications are shown in Figure 6. Hydrologic soil groups are shown in Figure 7. Further description of these soil types is available in Table 2. Dual code HSGs, such as B/D, indicate a shallow groundwater table that would inhibit infiltration, creating type D soil behavior; however, if drained, the soil would behave as type B. All dual soil types were conservatively assumed to be type D.

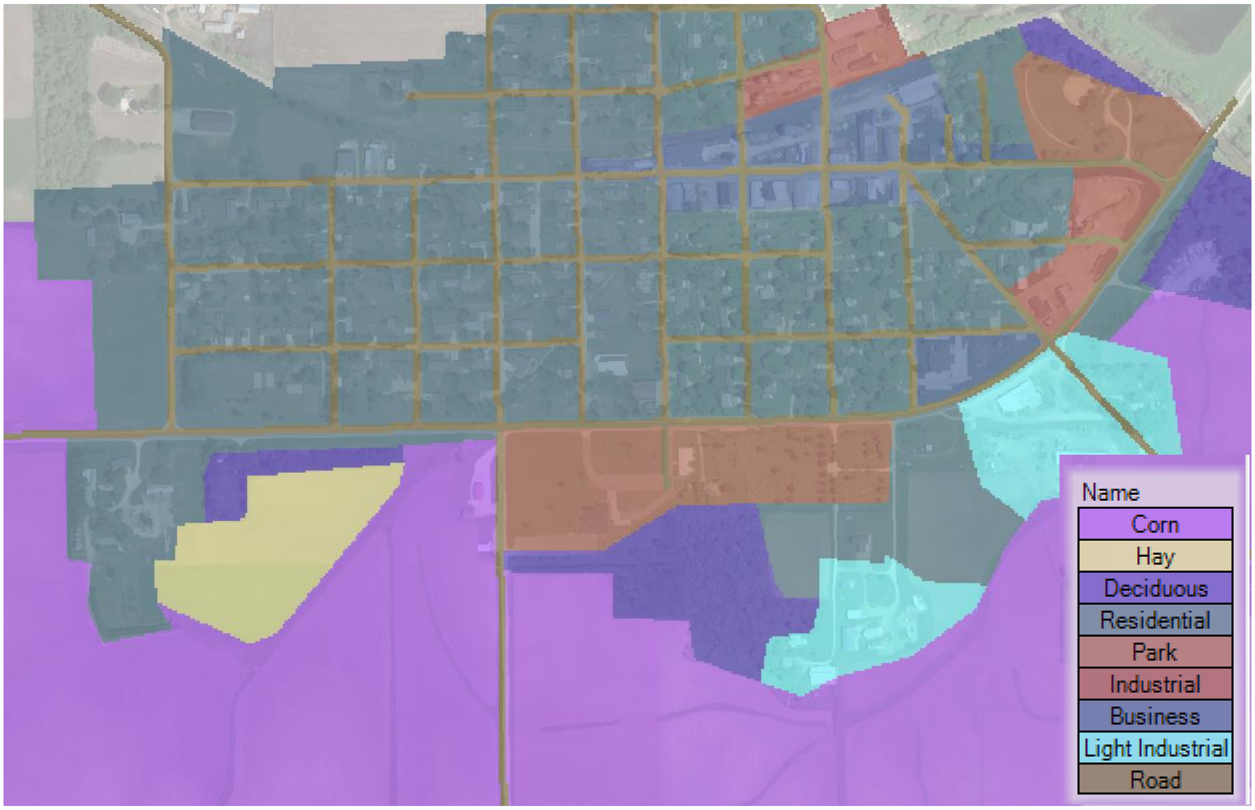

Figure 6. Land use types digitized from aerial imagery for development of spatially varying infiltration.

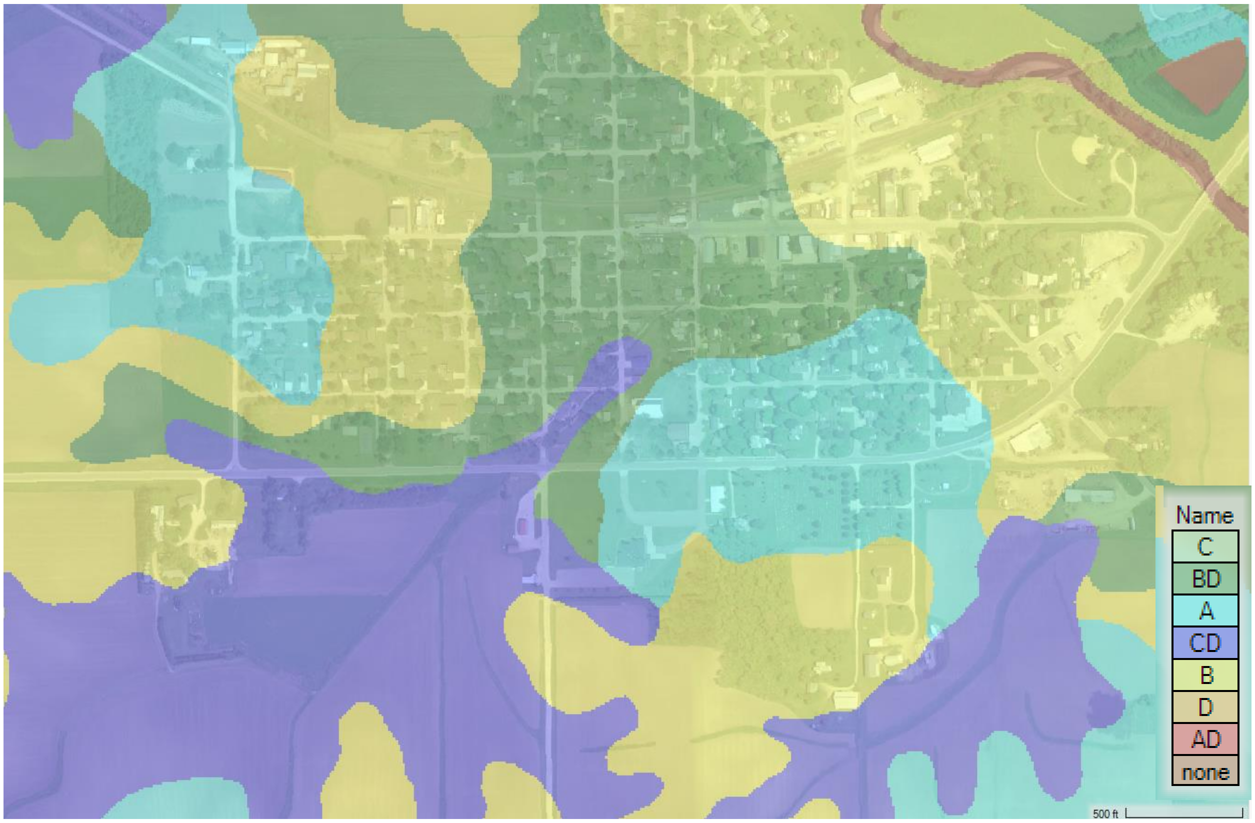

Figure 7. NRCS Hydrologic Soil Groups used to parameterize spatially varying infiltration.

Table 2. Hydrologic Soil Group parameters

Hydrologic Soil Group	Runoff Potential	Soil Texture	Composition	Minimum Infiltration Rate1 (in/hr)
A	Low	Sand, gravel	< 10% clay > 90% sand/gravel	>5.67
B	Moderately low	Loamy sand, sandy loam	10–20% clay 50–90% sand	1.42-5.67
C	Moderately high	Loam containing silt and/or clay	20–40% clay <50% sand	0.14–1.42
D	High	Clay	>40% clay <50% sand	<0.14

[1] For HSG A-C, infiltration rates based on a minimum depth to any water impermeable layer and the ground water table of 20 and 24 inches, respectively.

SIMULATION OF THE AUGUST 2021 FLOODING EVENT

The existing conditions model was used to simulate rain-on-grid hydrologic processes by applying the August 26-28, 2021 rainfall timeseries, shown in Figure 2, onto to the 2D model grid. Downstream water surface elevation of Crane Creek was estimated using photographs captured during the event. The maximum simulated depth during this period is shown in Figure 8, along with building footprints known to have sustained flood damage. This map indicates reasonable agreement between the simulation results and buildings known to have sustained flooding damage. The specific type of flood damage for each building is unknown, so other damage from groundwater or sump pump issues may have been possible. It is also possible additional buildings were damaged but were not documented.

DESIGN STORM EVENTS

Design storms were developed to investigate flooding behavior and mitigation alternative performance across a range of rainfall intensities. Total rain fall depths over a 24-hour duration for several return periods were provided by NOAA Atlas 14 (2013), shown in Table 3. These estimates have a range of uncertainty that was not considered. The estimated rainfall frequency depths were scaled using a synthetic rainfall hyetograph from NOAA Atlas 14 assuming a 3rd quantile storm event, shown in Figure 9.

An additional important caveat is that these rainfall depths are estimated based on nearby historic rainfall records, and do not represent the worst-case scenario for each return period. Climate change is not considered in these precipitation frequency depths. It is also worth noting these return periods are for rainfall depth, and do not necessarily indicate the same return period for stream flows.

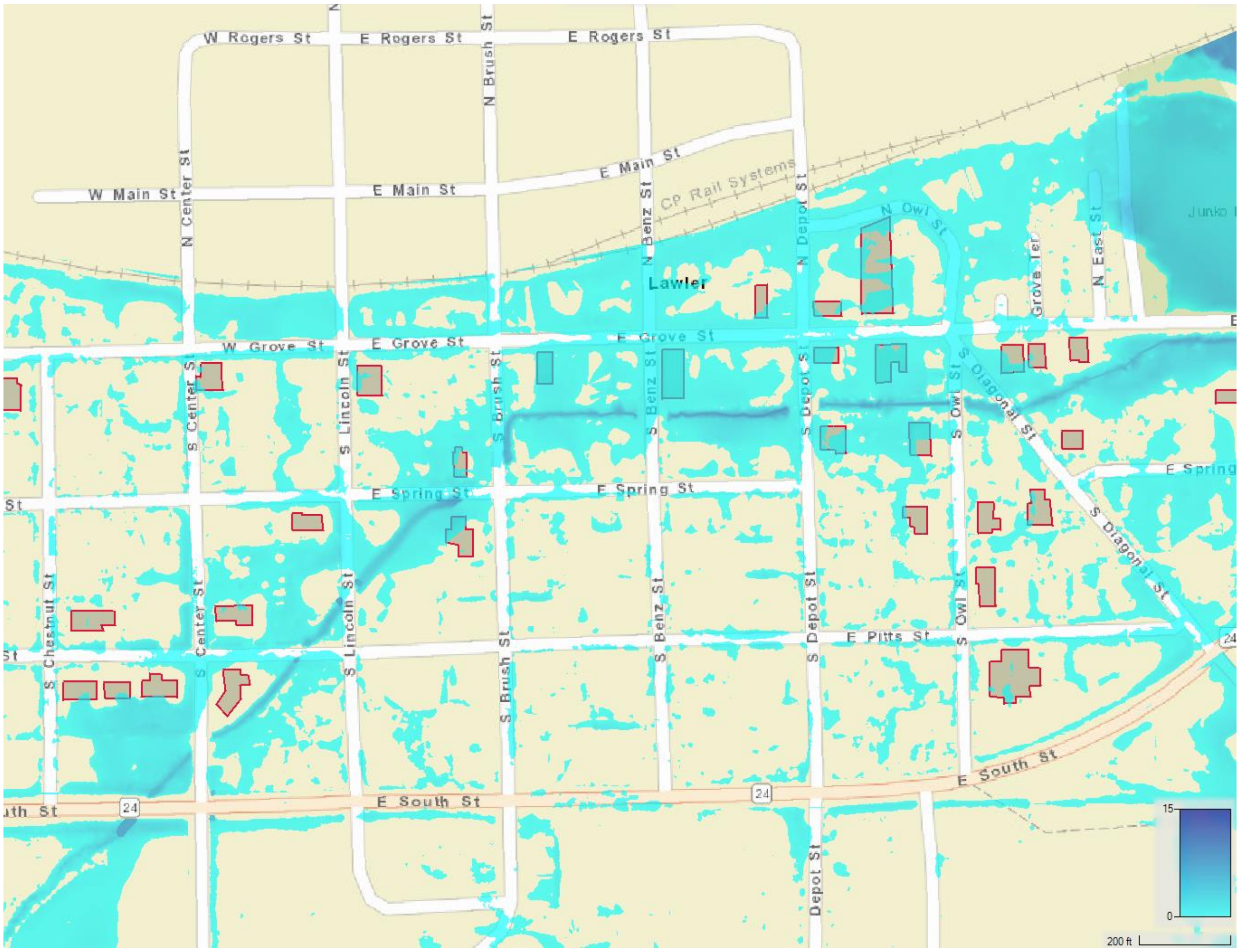

Figure 8. Maximum simulated depth for the August 2021 event, shown with building footprints known to sustained flood damage.

Table 3. NOAA Atlas 14 rainfall frequency depths (inches) for 24-hour duration for Lawler, Iowa.

Duration	Average recurrence interval (years)						
	2	5	10	25	50	100	200
24-hr	**3.08**	**3.83**	**4.53**	**5.59**	**6.49**	**7.46**	**8.52**

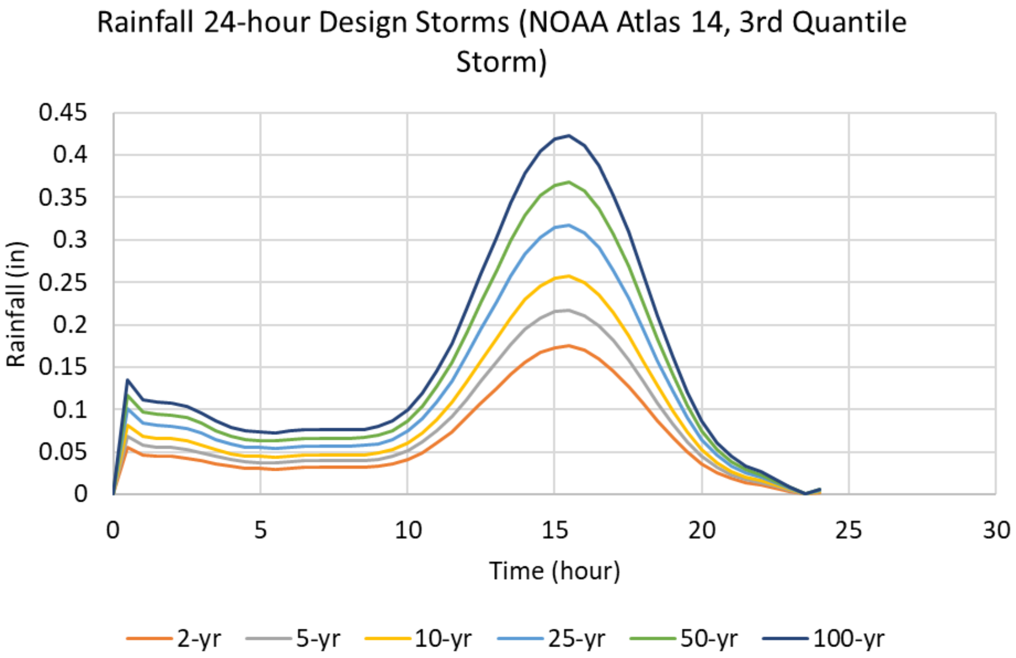

Figure 9. Design storms used to investigate flooding for a given rainfall frequency.

POTENTIAL FLOOD MITIGATION PROJECTS

Concrete Channel Construction

Increasing channel conveyance of Lawler’s creek would allow larger flows, such as the August 2021 event, to pass with less overbank flooding. For this alternative a typical channel cross-section shown in Figure 10 would be constructed from IA-24 to the mouth of the creek. This typical section is similar to what was proposed by the City of Lawler in documentation provided to IFC. It features a 3-foot high by 10-foot wide concrete channel bottom with riprap side slopes of 1:1 (horizontal:vertical).

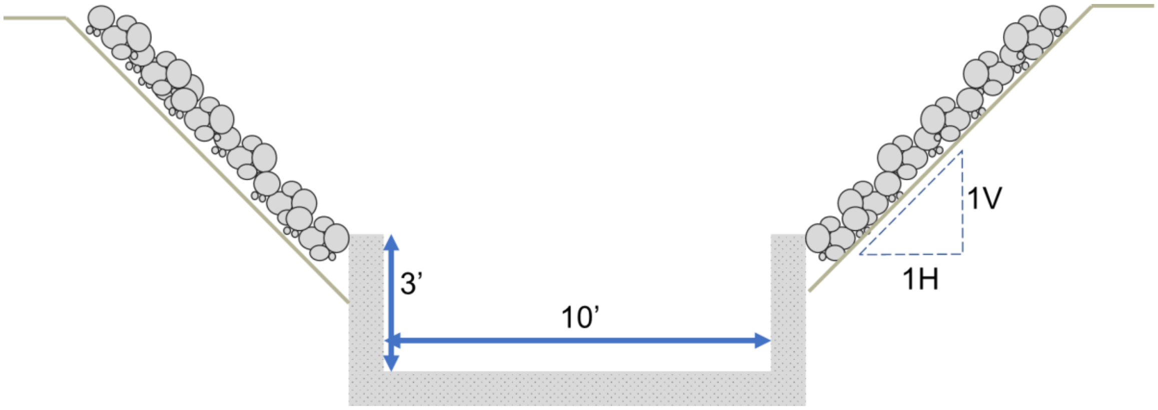

Figure 10. Cross-section utilized in modeling the concrete channel alternative. This is based on the typical cross-section proposed by the City of Lawler featuring a concrete bottom section, with riprap placed on banks.

In addition, the city proposed replacing eight culverts shown in Figure 11. These culverts were assumed to be 12-foot wide by 8-foot-high reinforced concrete box culverts. These are slightly smaller than the those used in IDOT's estimates (12-foot wide by 10-foot high by 50 feet long) generated for Lawler's proposal. The 12-foot wide by 8-foot-high reinforced concrete box culverts were used to determine the channel invert profile by assuming grade is 2 feet higher than the top of the culvert and the invert is 10 feet lower than the grade elevation. This results in the channel invert being 3-5 feet lower than the existing channel invert.

The Iowa Department of Transportation (IDOT) has assisted the city in conceptual design of the channel, selecting culvert sizes, and estimating quantities and fees for this alternative. The IDOT has estimated engineering, materials and construction of the channel along with culvert replacements would be approximately $4.7M.

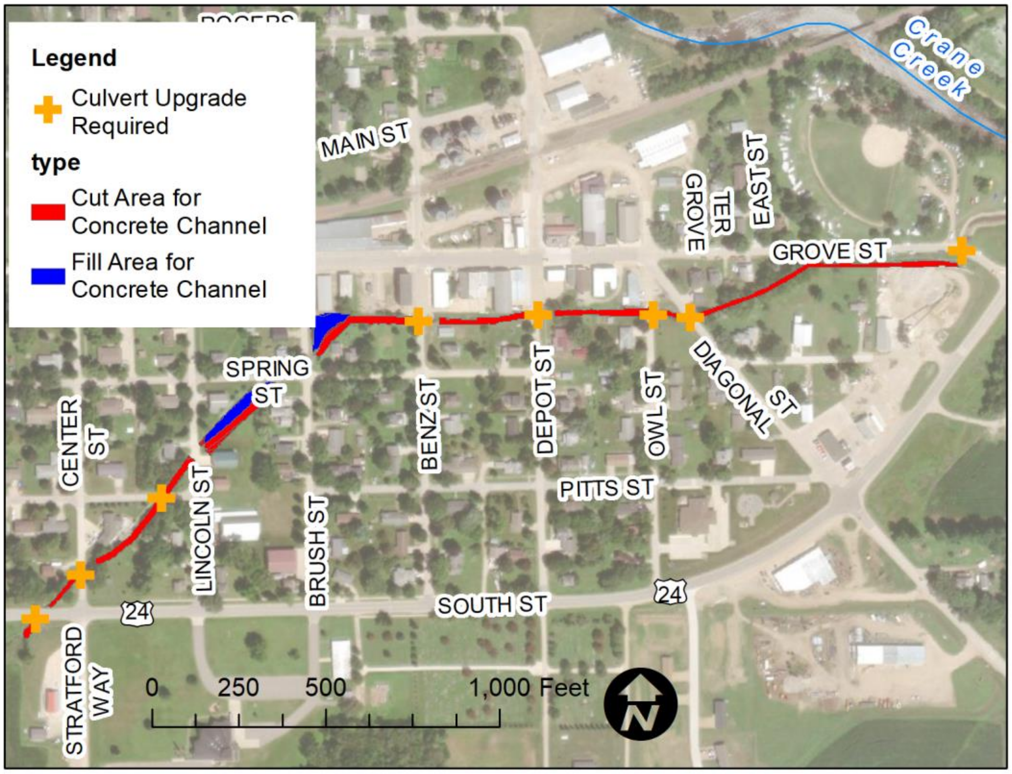

Figure 11. Proposed culvert replacements and cut/fill areas for concrete channel proposal by city of Lawler. Approximately 8000 cubic yards of material would be removed for aggregate, concrete channel and riprap placement along channel.

Natural Channel Modifications

This alternative is similar to the proposed concrete channel in providing more capacity, but would utilize more gently sloped, vegetated banks rather than riprap. As an initial investigation, a channel bottom width of 10 feet and side slopes of 2:1 (horizontal:vertical) was incorporated into the existing conditions model. Areas requiring material removal along the creek are shown in Figure 12. Cut volume would be approximately 4,500 cubic yards based on LiDAR estimates. These channel modifications would require enlarging the footprint of the stream by 50% in some locations and alteration of private property. A smaller footprint could be achieved using steeper side slopes but would risk bank failure if not properly reinforced with vegetation or riprap.

These channel modifications would likely require upgrading several culvert crossings to take full advantage of increased channel capacity. Based on photographs provided by the city, culverts at Lincoln, Benz, Depot, and Owl Streets would likely benefit from culvert upgrades to maintain consistency with upstream and downstream culvert and bridge openings. Culvert upgrades at these locations would include installing a 10-foot wide by 5-foot-high reinforced concrete box culvert. Photographs of these channel crossings are shown in Figure 13.

The estimated cost to modify the creek channel, including easements and bank stabilization would be in the range of \$300,000 to \$500,000. The estimated additional cost to replace bridges or culverts at the locations shown in Figure 12 would be in the range of \$400,000 to \$500,000.

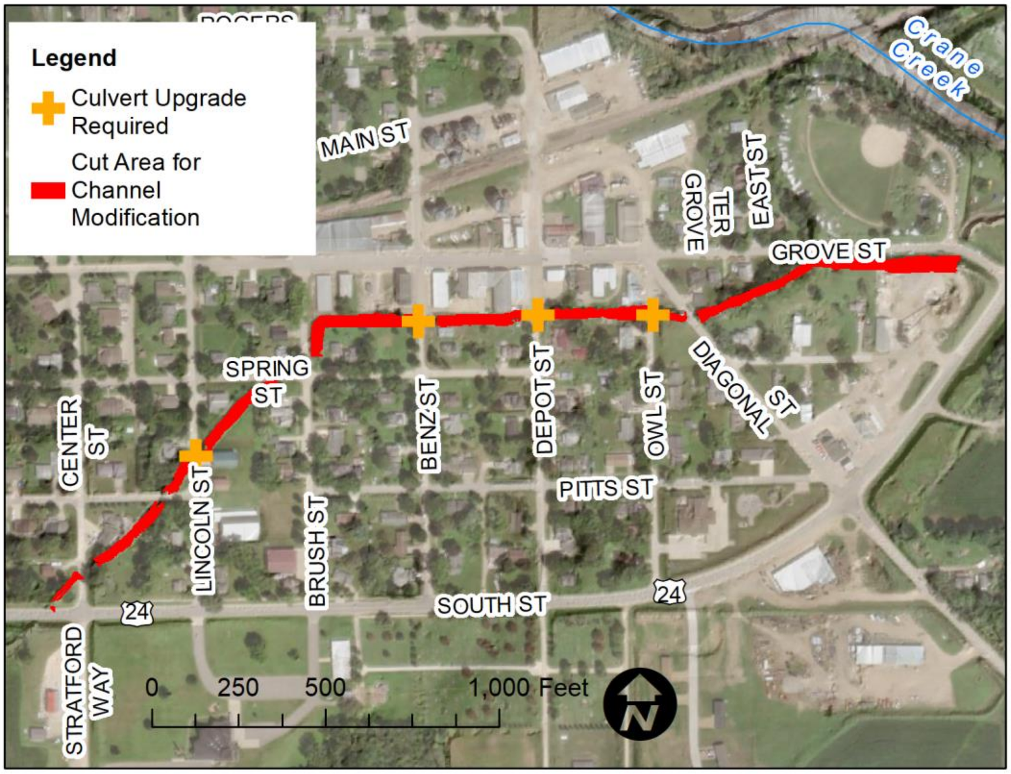

Figure 12. Cut areas required for creating a 10-foot bottom width natural channel with 2:1 (H:V) sides. Four potential culvert upgrade locations are also shown.

Figure 13. Photographs of culvert crossings that would benefit from upgrades in Lawler, Iowa.

Upstream Detention Storage

An alternative project to decrease flood flows along Lawler's creek would require construction of a dry detention pond upstream of IA-24. This project would attenuate flood flows by storing runoff and releasing lower flows over a longer period. Throttling flows in this way would allow the downstream channel to handle larger events, reducing overbank flooding.

An initial conceptual pond design featured a 10-foot high embankment, with a top width of 10-feet and 2:1 (horizontal:vertical) side slope, and is shown in Figure 14. This project would require approximately 6,200 cubic yards of fill. The pond embankment would require a footprint of 1.4 acres, and the ponded surface area at the top of the embankment is approximately 12 acres with a storage volume of 48 acre-feet.

Outlet structure design was completed using guidance from NRCS and HydroCAD software. The outlet, shown in Figure 15, features a two-stage structure with a 24-inch culvert for attenuating low flows, and 72-inch by 72-inch orifice that attenuates larger runoff volumes without overtopping the pond embankment. The spillway was designed to pass the 25-year 24-hour SCS design storm with approximately 2.75 feet of freeboard. The detention structure is meant to be dry except during wet periods.

The estimated cost to construct this pond embankment and outlet structure would be in the range of $100,000 to $200,000. Assuming landowner willingness and a fair market value range for Chickasaw County agricultural land is $10,000 to $15,000 per acre, acquiring land within the maximum pool area would be $120,000 to $180,000 in addition to construction costs. Purchasing an easement for ponded water is also feasible if the pond is designed to be dry much of the growing season and drain relatively quickly (within 72 hours) following a large event, minimizing damage to crops. An easement would have a significantly lower cost.

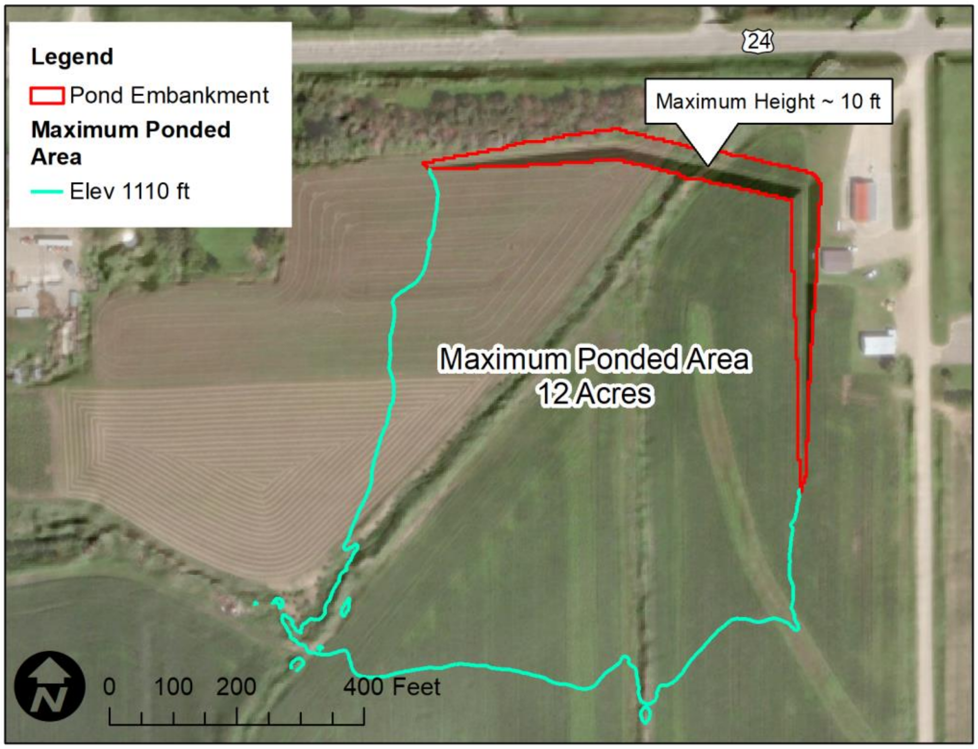

Figure 14. Conceptual design of an upstream 48 acre-ft detention pond to attenuate flow on Lawler's creek.

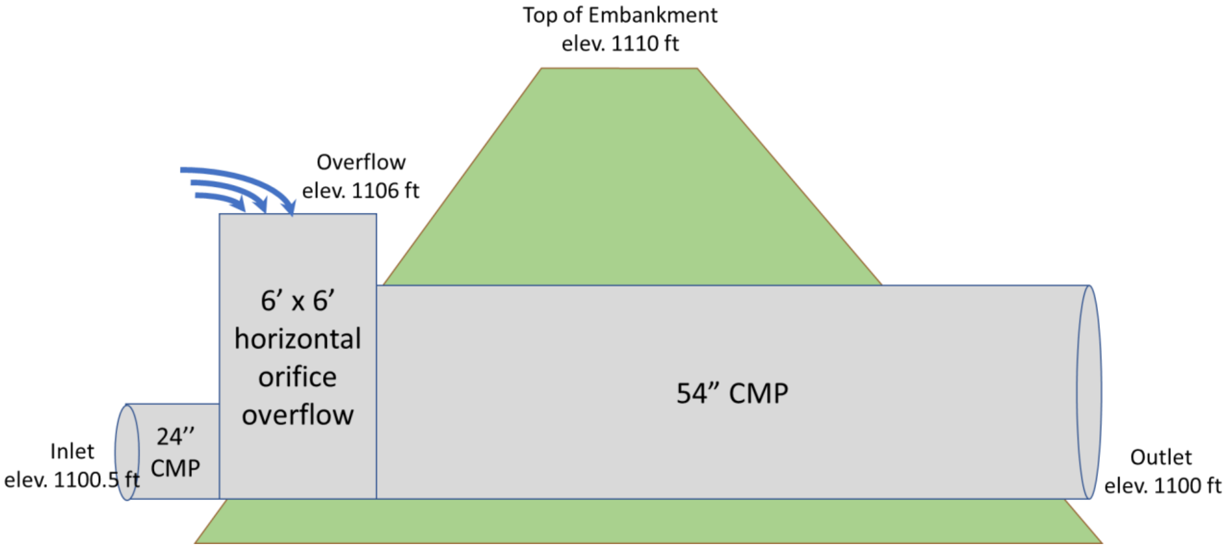

Figure 15. Conceptual drawing of the two-stage outlet structure regulating the detention pond.

SIMULATION RESULTS OF FLOOD MITIGATION ALTERNATIVES

The concrete channel, natural channel modifications and upstream detention pond alternatives were incorporated into separate geometry files for simulation of the August 26-28, 2021, rainfall event. A comparison of maximum inundation during the August 2021 event for existing conditions and with concrete channel modifications is shown in Figure 16. Similar figures comparing maximum inundation with natural channel modifications and upstream detention pond alternatives are shown in Figure 17 and Figure 18, respectively. The proposed concrete channel modifications reduced the inundated area the most, followed by the natural channel, and the least reduction was provided by addition of the upstream detention pond for this August 2021 event. Figure 19 shows the maximum inundated area for all three alternatives compared to existing conditions. All alternatives appear to make significant reductions in flooding such that several homes or businesses would have sustained less damage.

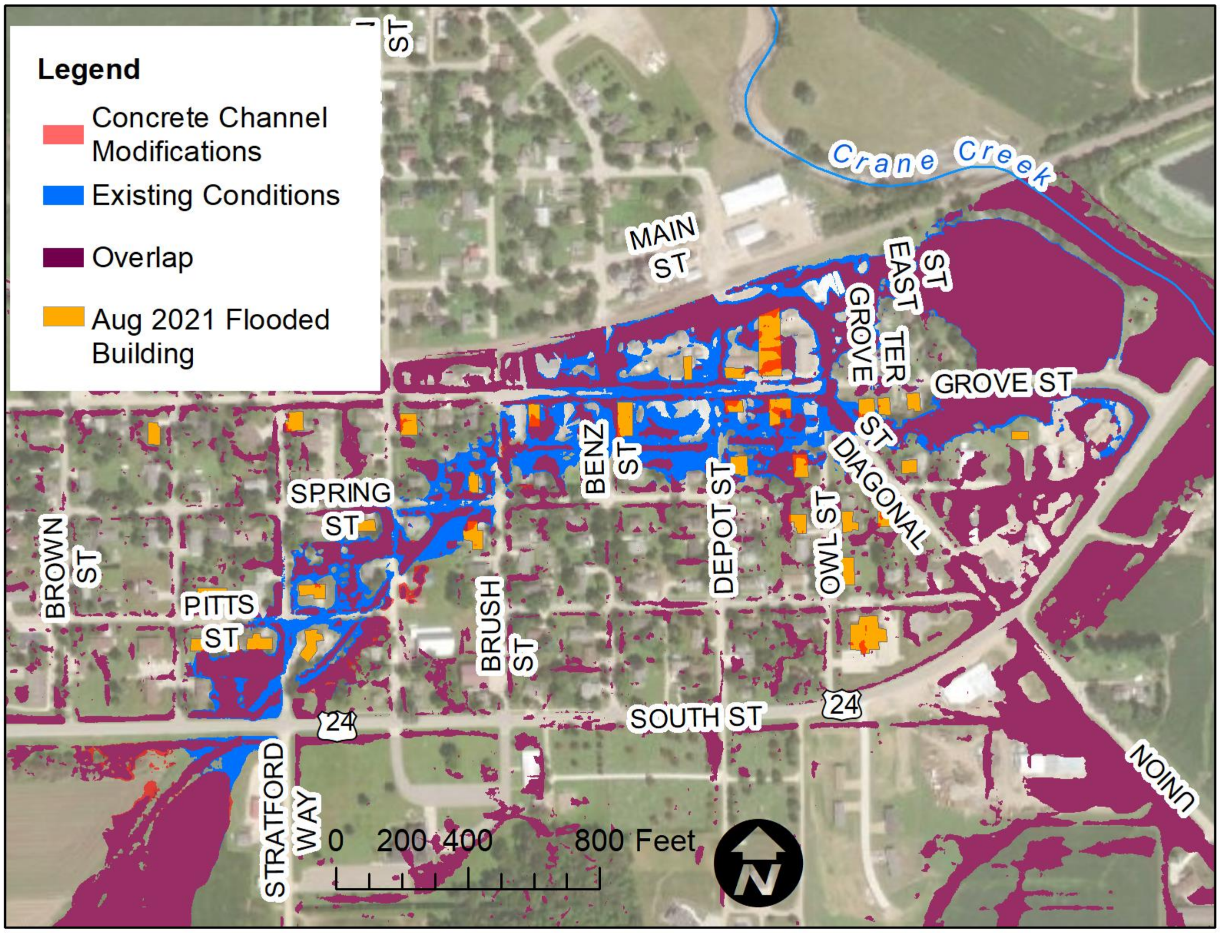

Figure 16. Maximum inundation with existing conditions and with concrete channel modifications. Areas of agreement are shown as purple.

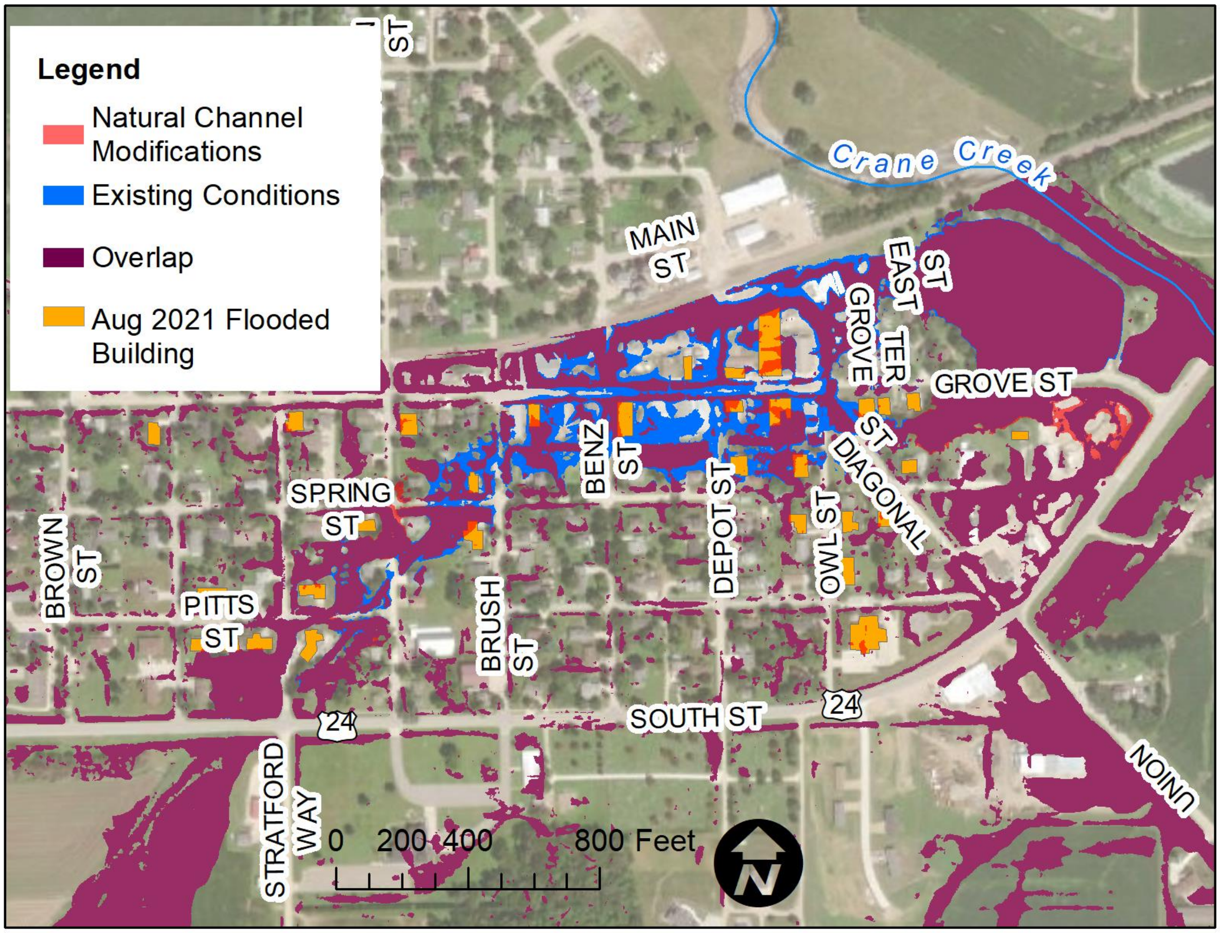

Figure 17. Maximum inundation with existing conditions and with natural channel modifications. Areas of agreement are shown as purple.

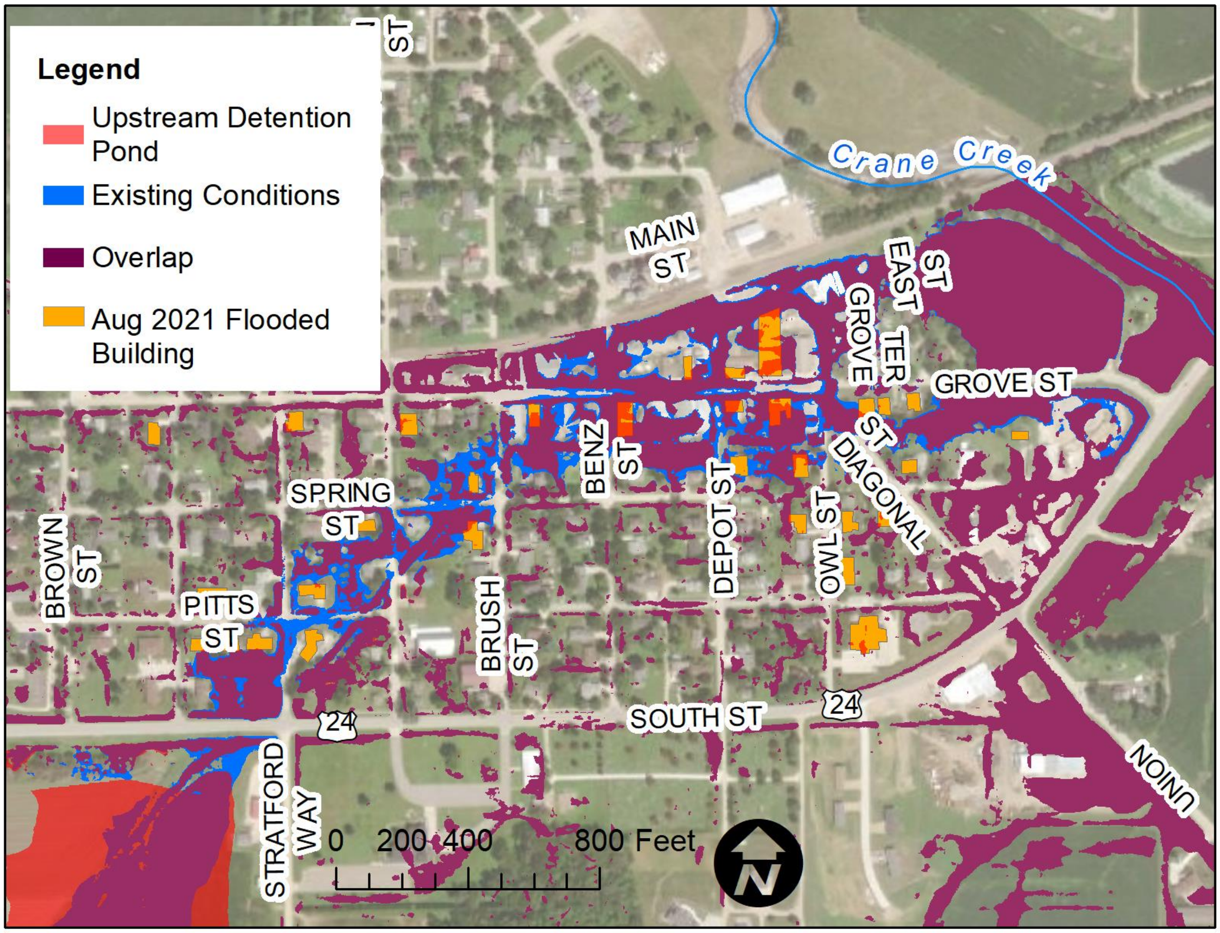

Figure 18. Maximum inundation with existing conditions and with the upstream detention pond modifications. Areas of agreement are shown as purple.

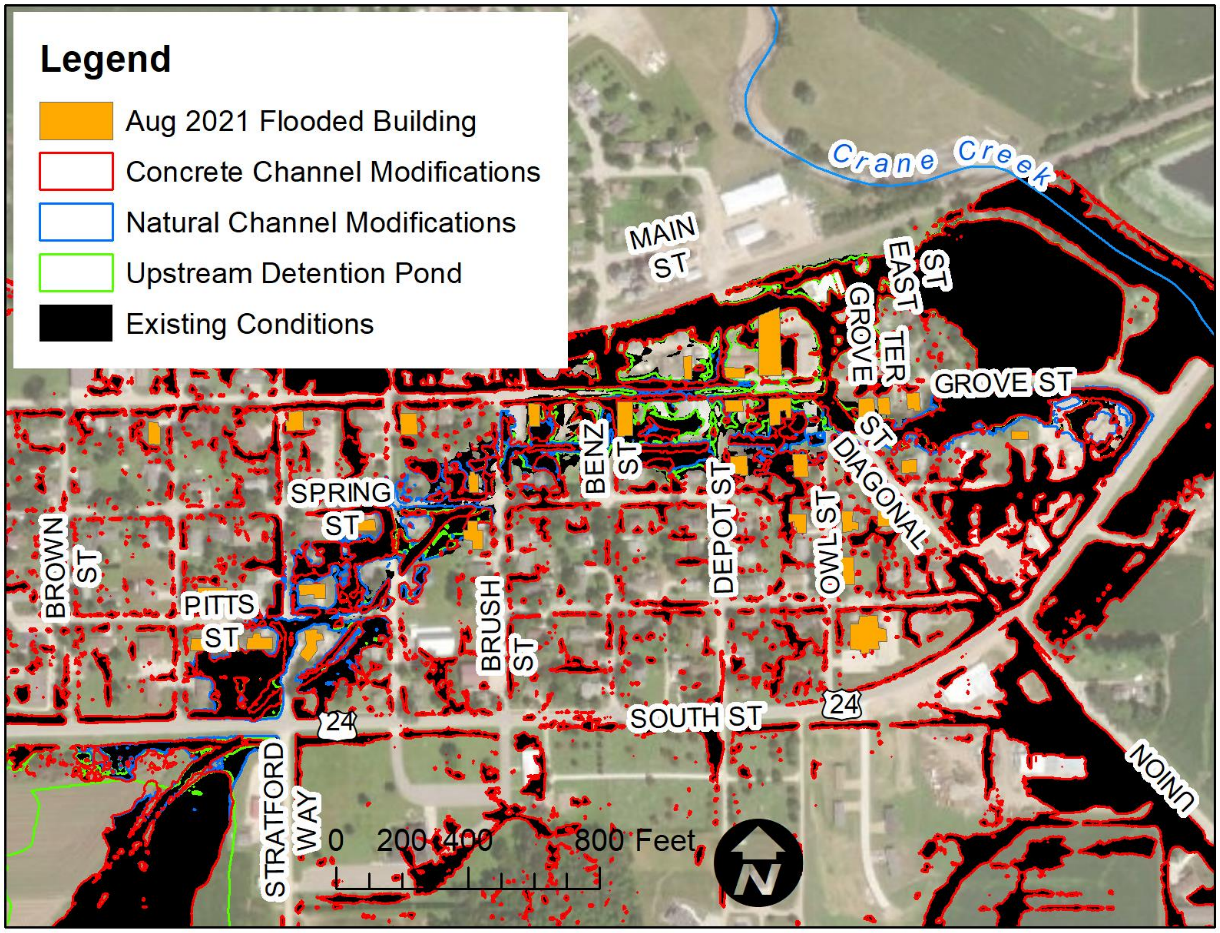

Figure 19. Maximum inundation with existing conditions and with upstream detention pond, natural channel and concrete channel modifications.

The upstream detention pond would have significantly reduced flows passing under IA-24 during the August 2021 event. A plot of flow at IA-24 for existing conditions and with the upstream detention pond is shown in Figure 20. A plot of water surface elevation in the upstream detention pond during simulation of the August 2021 event is shown in Figure 21. The maximum water surface elevation in the pond was elev. 1109.5 feet, which is just ½ foot below the pond embankment. If the August 2021 event were used as a design event, the embankment height would need to be at least 2-3 feet higher, or an auxiliary spillway would be needed to accommodate higher flows and prevent overtopping. If the August 2021 event would have caused the embankment to fail, damages would have been significantly larger, with possible loss of life.

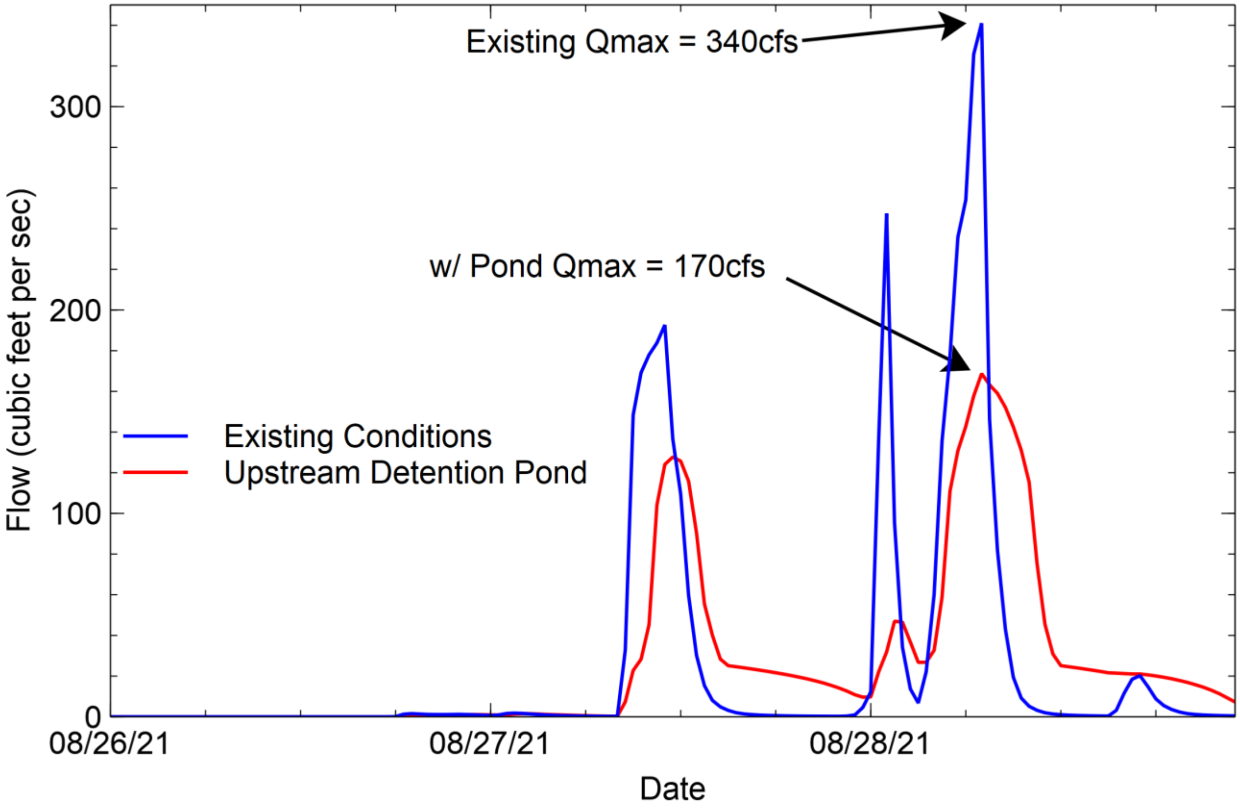

Figure 20. Flow passing under IA-24 during the August 2021 event with existing conditions or with an upstream detention pond.

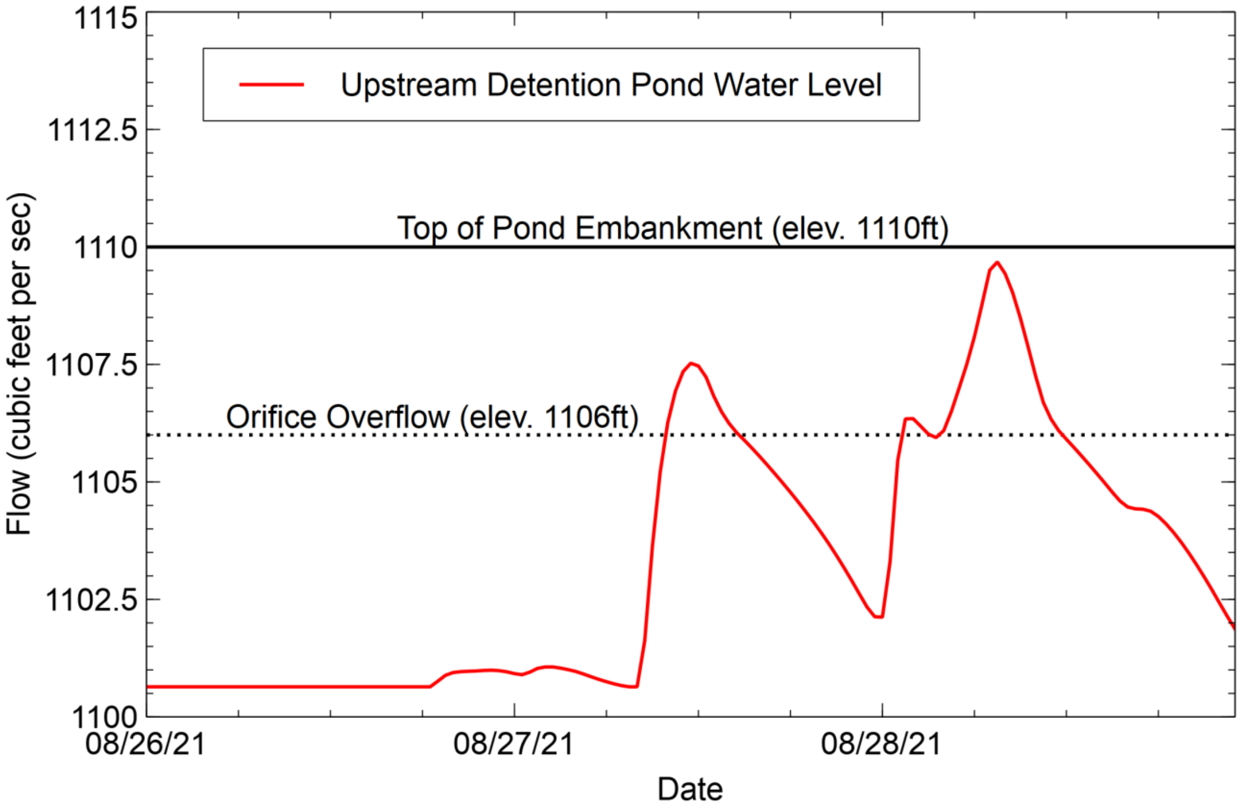

Figure 21. Pond water surface elevation during simulation of the August 26-28, 2021, event. The embankment at elev. 1110 ft was nearly overtopped.

Design storms for the 2-, 5-, 10-, 25-, 50-, 100-, 500-year rainfall depths for a 24-hour duration, shown in Figure 9, were simulated using existing conditions, concrete channel, natural channel modifications and an upstream detention pond. Estimates of inundation from creek flooding were generated for each alternative and storm event and are shown in Table 4. In general, channel modifications seem to have the largest impact on inundated area from creek flooding, with the concrete channel modifications having the largest impact. A plot comparing total inundation area for each alternative is shown in Figure 22. Drastic increases in inundated area from one storm to the next occur when flooding crosses north of Grove Street. This occurs at the 25-year event for existing conditions, 50-year event for the upstream detention pond, and the August 2021 event for natural channel modifications. It is important to note that these alternatives will not reduce flash flooding within the study area, only flooding originating from the creek.

Table 4. Creek inundation for each alternative and storm in acres.

	Creek Inundated Area (Acres)			
Storm	Existing	Concrete Channel	Natural Channel	Upstream Pond
2-yr	4.0	3.0	3.2	3.4
5-yr	5.4	3.2	4.0	5.0
10-yr	6.3	3.3	4.6	5.9
25-yr	17.0*	4.1	6.2	7.2
50-yr	19.5*	5.3	6.9	17.0*
100-yr	21.7*	5.8	7.7	18.5*
500-yr	27.4	8.0	12.3	26.9*
Aug 2021	33.6*	12.5	28.4*	28.7*
* event overtopped Grove Street				

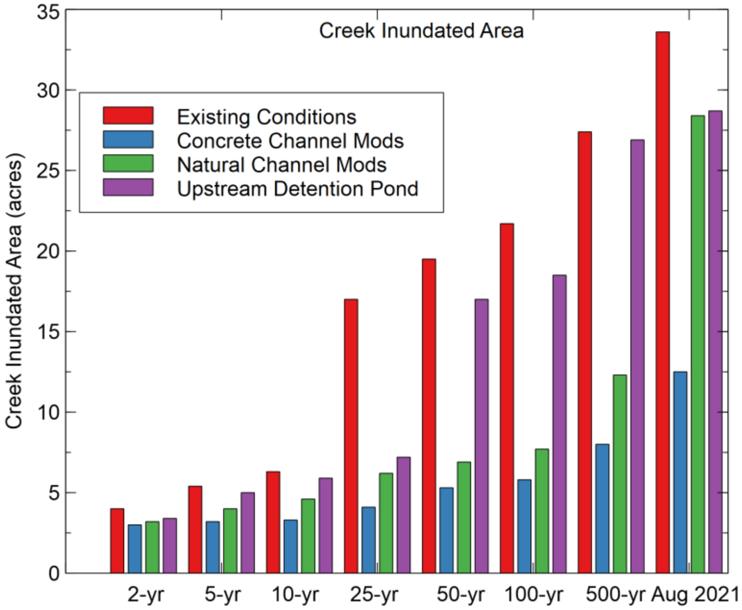

Figure 22. Creek inundation (ac) for each alternative and storm. In general, drastic increases occur when flooding crosses north of Grove Street, inundating a much larger area.

The number of buildings affected by creek inundation were also estimated by intersecting building footprints created by Microsoft, shown in Figure 23, with the inundation polygons and are summarized in Table 5 and Figure 24. Performance among the alternatives were consistent with the creek inundated area.

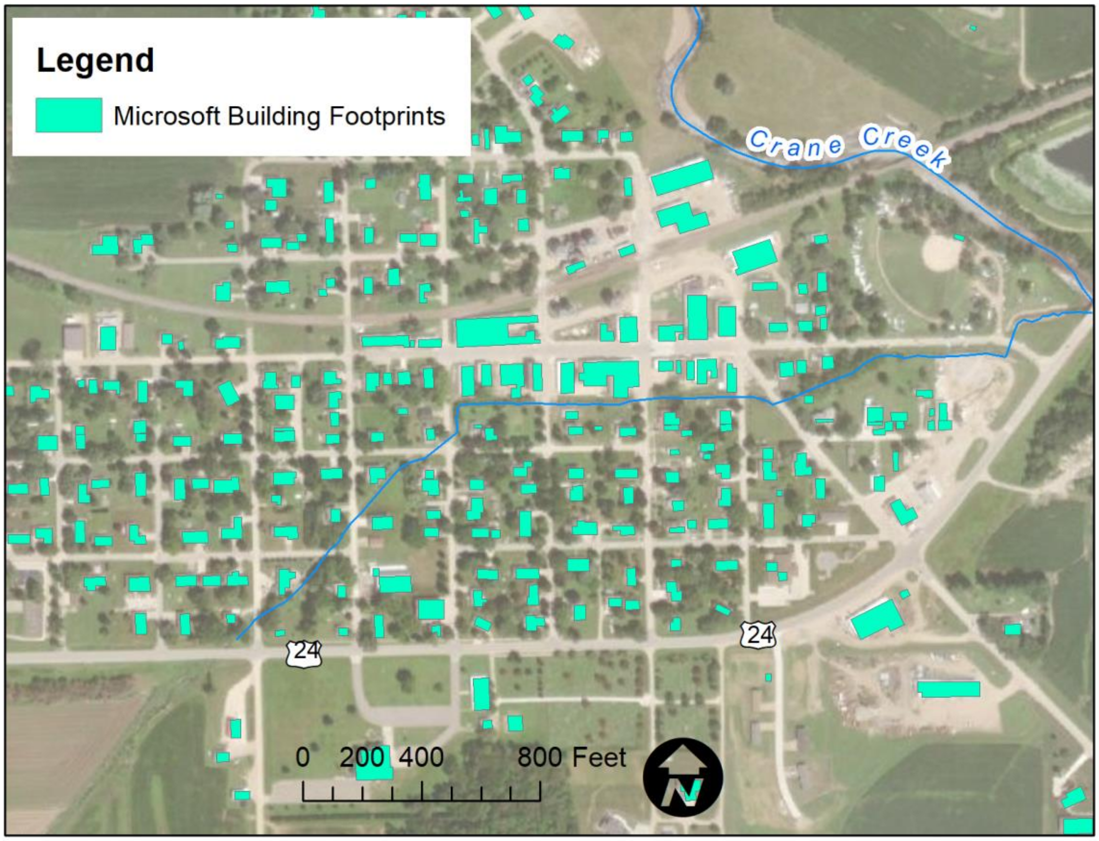

Figure 23. Microsoft building footprints used in the analysis.

Table 5. Estimated number of creek flooding affected buildings for each alternative and storm

	Affected Buildings			
Storm	Existing	Concrete Channel	Natural Channel	Upstream Pond
2-yr	5	1	4	4
5-yr	7	1	6	7
10-yr	16	7	11	15
25-yr	31*	7	13	18
50-yr	36*	11	15	30*
100-yr	44*	11	15	31*
500-yr	54*	11	21	51*
Aug 2021	62*	16	46*	52*
* event overtopped Grove Street				

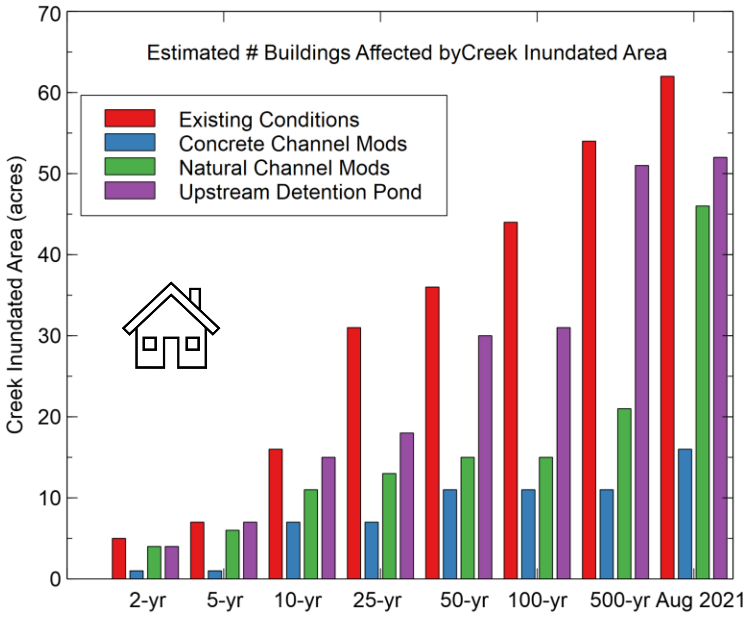

Figure 24. Estimated number of buildings affected by Creek inundation for each alternative and storm.

RECOMMENDATIONS

Based on analysis of simulation results, concrete channel modifications appear most effective in reducing inundation resulting from creek flooding. However, this alternative does not store the stormwater runoff, only conveys downstream as efficiently as possible. This is also the most expensive option, but likely the most effective and would require the least amount of maintenance.

The flood reduction from natural channel modifications is promising but needs further study and engineering design to determine feasibility and effectiveness. Developing a stable channel design with compatible planform, cross-section, and profile is challenging, and may not be feasible within the creek's current confined footprint. Further refinement of the cost estimate is also warranted.

While the upstream detention pond was less effective in reducing creek inundation, it would be beneficial to explore its feasibility. The pond structure would likely have a moderate or high hazard classification due to its proximity to a populated area and would require commensurate scrutiny during permitting process. However, if feasible and conservatively designed, it would provide flood flow reductions upstream of Lawler that would augment any additional capacity provided by channel modifications.

Further study and design of these alternatives would provide more insight into feasibility and flooding reductions. Further refinement of design and cost estimates would also allow development of benefit-cost ratios for each alternative or a combination of alternatives to guide decision making.

REFERENCES

(NOAA Atlas 14) Sanja Perica, Deborah Martin, Sandra Pavlovic, Ishani Roy, Michael St. Laurent, Carl Trypaluk, Dale Unruh, Michael Yekta, Geoffrey Bonnin (2013). NOAA Atlas 14 Volume 8 Version 2, Precipitation-Frequency Atlas of the United States, Midwestern States. NOAA, National Weather Service, Silver Spring, MD.

Chow, V.T., 1959, Open-channel hydraulics: New York, McGraw-Hill, 680 p.

United States Army Corps of Engineers. Hydrologic Engineering Center River Analysis System (HEC-RAS) version 6.1 Available online at https://www.hec.usace.army.mil/software/hec-ras/. Accessed 03/24/2022.