

RESOLUTION NO. 3441

RESOLUTION ADOPTING A NEW STORM WATER MASTER PLAN AND ASSOCIATED CAPITAL IMPROVEMENT PLAN FOR THE CITY OF LIBERTY AS DEVELOPED BY HDR ENGINEERING INC.

WHEREAS, the Storm Water Master Plan has been developed by HDR Engineering Inc. and

WHEREAS, the Storm Water Master Plan has been developed in accordance with the guidance and direction of the City of Liberty;

NOW, THEREFORE, BE IT RESOLVED that the City of Liberty does hereby adopt the Storm Water Master Plan and Associated Capital Improvement Plan for the City of Liberty as developed by HDR Engineering Inc.;

PASSED by the City Council of Liberty, Clay County, Missouri, this 27th day of January, 2025.


MAYOR Greg Carndeson

ATTEST:

Sarah Ranes
DEPUTY CITY CLERK



Flood Risk Reduction

City of Liberty - Stormwater Master Plan
Technical Memorandum

City of Liberty, MO
September 2024

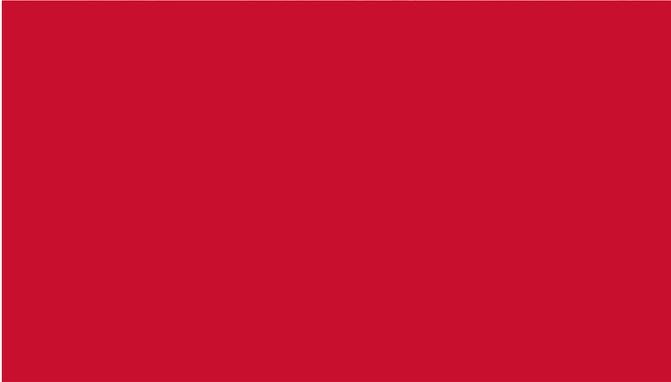


Table of Contents

1 Introduction..... 3
 2 Assessment..... 3
 2.1 Hydraulic Restrictions..... 5
 2.2 Detention 11
 3 Conclusion..... 14

Tables

Table 1: List of Potential Projects for Hydraulic Restriction Improvement 6
 Table 2: List of Potential Project Locations for Detention 13

Figures

Figure 1: FEMA Effective Mapping (2015) Within Liberty City Limits 4
 Figure 2: Potential Flood Risk Reduction Projects Identified within Rush Creek 9
 Figure 3: Potential Flood Risk Reduction Projects Identified within Cates Branch and
 Little Shoal Creek..... 10



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1 Introduction

The City of Liberty, Missouri is part of a rapidly developing Kansas City metro area, and has experienced ongoing residential, industrial and commercial growth since completion of the previous City of Liberty Stormwater Master Plan in 2003. Growth and development can sometimes lead to challenges with stormwater management including stresses and deficiencies in the existing stormwater system capacity and performance, increased flooding frequency and peak flow volumes, increased sediment loading and stream instability, and possible reduction in water quality throughout the watersheds. These challenges, in combination with evolving design standards, have contributed to the City’s need to update the Stormwater Master Plan. HDR is working with the City of Liberty to provide these updates, including performing various investigations and defining high priority projects to be included in the Capital Improvement Plan (CIP). Refer to individual technical memorandums for additional information regarding each investigation and the final Project Prioritization and CIP for concluding findings.

As part of this effort, HDR performed a flood risk reduction assessment within the Liberty city limits, which is the focus of this technical memorandum. The purpose of the assessment is to identify and characterize existing flood prone areas along FEMA mapped floodplains, where there may be opportunities to improve conditions and alleviate flooding. Potential improvements generally considered system improvements at existing hydraulic restrictions to alleviate upstream flooding as well as consideration of regional detention opportunities to better manage peak discharges within the watershed.

2 Assessment

The flood risk reduction assessment was performed as a desktop analysis and no hydrologic/hydraulic modeling activities were developed as part of this scope of work. The desktop analysis was based on review of the following:

- FEMA effective floodplain mapping, flood profiles, and hydraulic models (FEMA, 2015)
- Infoworks ICM storm sewer system model developed as part of a separate investigation for the City’s existing stormwater infrastructure (HDR, 2024)
- Public reported concerns
- 2003 Stormwater Master Plan

The primary goal of this assessment is to identify key areas susceptible to flooding that may benefit from structure improvements or regional detention. A map of the effective FEMA mapping within City limits is provided in Figure 1.

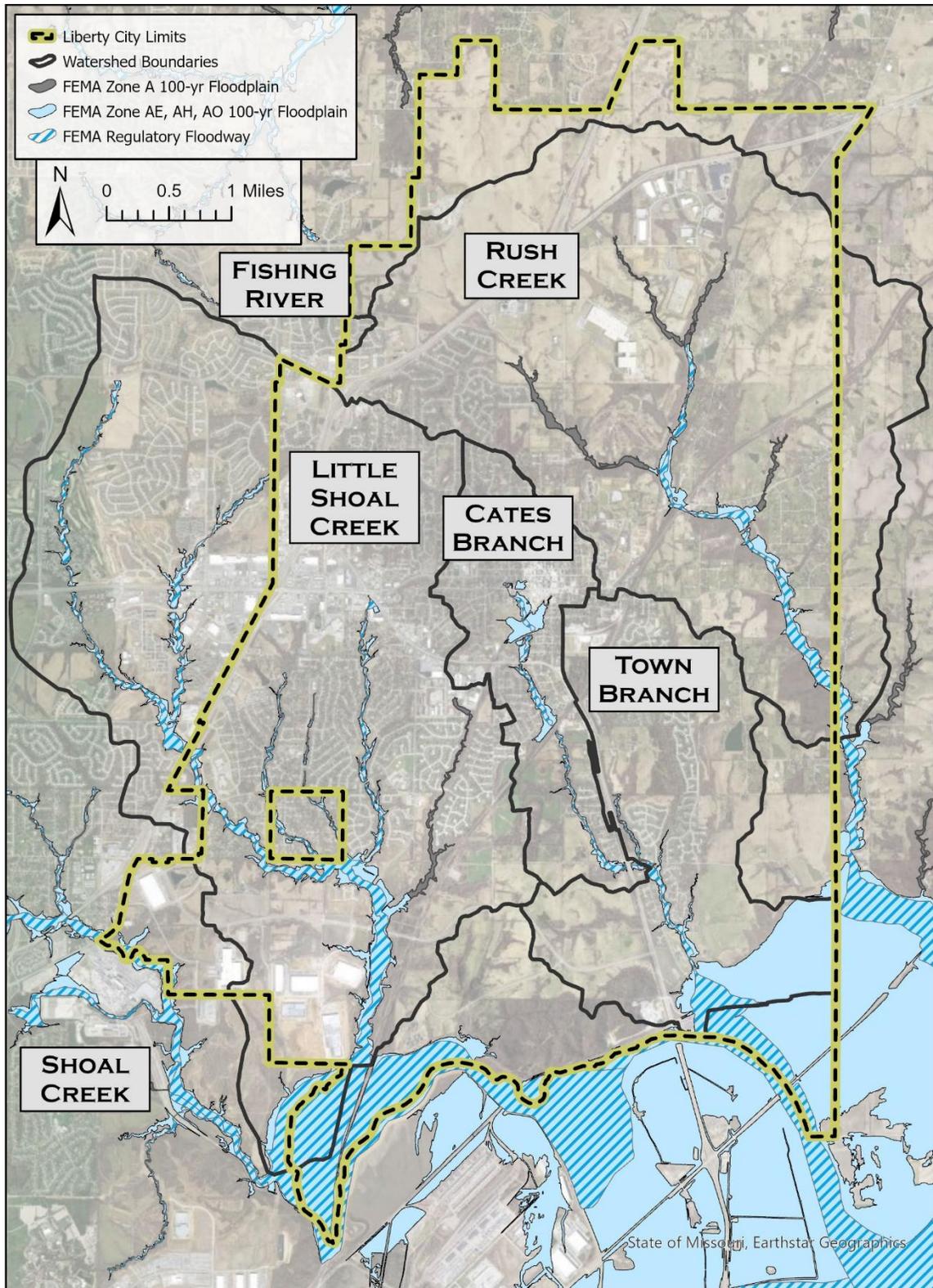


Figure 1: FEMA Effective Mapping (2015) Within Liberty City Limits

2.1 Hydraulic Restrictions

The presence of a roadway crossing over an open waterway generally changes the natural flow conditions and creates an obstruction to the open channel flow and in wider floodplains can create a significant contraction and expansion dynamic at the structure. Typically, the roadway crossing and associated drainage structure have reduced capacity in comparison to the original channel conveyance, which creates a hydraulic restriction at that point in the system. This hydraulic restriction can result in increased headwater depths upstream of the structure, potentially resulting in increased flooding hazards to upstream properties. The current FEMA regulatory mapping (effective August 2015), FEMA flood profiles from the 2015 Flood Insurance Study, and HEC-RAS hydraulic models for Cates Branch, Rush Creek, Town Branch, and Little Shoal Creek and tributaries were reviewed to identify if any such hydraulic restrictions are evident within the City's watersheds.

Hydraulic restrictions identified from the various data sources are summarized in Figures 2 and 3. The locations are designated with a project identifier starting with the prefix 'HR-'. The potential sites were evaluated and further vetted to identify areas where a hydraulic improvement would offer maximum benefit to surrounding public and private properties and increase roadway level service, which would improve public safety and reduce flooding. Considerations for right-of-way and required acquisitions were also noted as the projects were being evaluated. Project improvements that extend beyond City right-of-way can face additional challenges, including increased coordination and higher cost if additional right-of-way or easements are needed. Through this process, the overall benefit of the potential improvement was compared and only the projects with the greatest potential benefit advanced for CIP consideration. All locations are included in the Liberty Stormwater Master Plan hub site; however, for purposes of this Flood Risk Assessment, the projects were classified as those that were or were not advanced for CIP consideration. Additional details are provided in Table 1 for each potential project location.

Of the potential options, it was determined that improvements at 4 out of the 11 identified locations would offer greater benefit to the community. The project improvements would generally consist of upsizing the drainage structures to improve hydraulic conveyance, thus reducing the headwater upstream of the structure and reducing flood levels along public and private infrastructure.

Each location should be carefully evaluated during subsequent design and analysis phases to assess potential impacts to downstream properties. Increasing hydraulic conveyance at these locations could reduce attenuation of flow that may occur, increasing the volume of water passing through the hydraulic opening and potentially causing adverse impacts to downstream areas. In some cases, it may be advantageous to combine detention measures with the removal of hydraulic restrictions to mitigate these risks.

Proposed improvements would be required to meet all local, state and federal permitting requirements and applicable design standards. Project improvements should be designed

in accordance with the most recent version of APWA 5600. Current design standards are based on a design storm which aligns with the street classification and limits roadway overtopping during the 100-year event to seven (7) inches at the high point in the roadway, not to exceed fourteen (14) inches at the deepest point in the roadway. Projects should adhere to 44 CFR 60.3 and local requirements to meet floodplain ordinances and regulations and all work within the regulatory floodway would be required to demonstrate no-rise conditions for the 100-year base flood. Depending on the effective floodplain mapping, it may be prudent to obtain a Conditional Letter of Map Revision (prior to construction) and/or Letter of Map Revision (following construction) to document any changes to the regulatory mapping to allow for adjustments to insurance premiums. Additionally, new culverts within jurisdictional waters may require embedment for passage of aquatic organisms.

Table 1: List of Potential Projects for Hydraulic Restriction Improvement

Project ID	Watershed	Stormwater Challenge / Benefit	Advanced for CIP Consideration
HR-1	Rush Creek	Existing 2 - 16' W x 10' H Reinforced Concrete Box (RCB). Hydraulic restriction located along unnamed tributary to Rush Creek at Lightburne Street within a Zone A floodplain. ICM stormwater modeling indicates roadway flooding and potential property impacts. Increasing structure capacity could reduce flooding for residential properties upstream and along Lightburne Street, improving public safety. Pairing Detention D-1 with HR-1 may be beneficial in mitigating the potential risk to downstream properties due to upsizing the structure.	Yes
HR-2	Rush Creek	Existing 12' W x 12' H arch structure. Hydraulic restriction identified at railroad crossing along unnamed tributary to Rush Creek within a FEMA Zone A floodplain. Does not appear to negatively impact public or private infrastructure. Securing right-of-way and coordination with the railroad could present additional challenges. Improvement offers minimal benefit to City / watershed.	No
HR-3	Rush Creek	Existing 60" steel pipe. Minor hydraulic restriction identified at railroad crossing along unnamed tributary to Rush Creek within a FEMA Zone AE floodplain. Does not appear to negatively impact public or private infrastructure. Securing right-of-way and coordination with the railroad could present additional challenges. Improvement offers minimal benefit to City / watershed.	No



Project ID	Watershed	Stormwater Challenge / Benefit	Advanced for CIP Consideration
HR-4	Rush Creek	Existing 15' W x 12' H arch structure. Hydraulic restriction identified at railroad crossing along unnamed tributary to Rush Creek in a FEMA Zone AE. Does not appear to negatively impact public or private infrastructure. Securing right-of-way and coordination with the railroad could present additional challenges. Improvement offers minimal benefit to City / watershed.	No
HR-5	Rush Creek	Existing 44' W x 22' H arch structure. Substantial hydraulic restriction at abandoned railroad crossing along Rush Creek. Located in FEMA floodplain with regulatory floodway. FEMA flood profile indicates ~4 ft of headwater at structure. Several homes located within 100-year floodplain. Work within floodway would require no-rise certification. Increasing structure capacity could reduce headwater, reducing flooding for residential properties. Securing right-of-way and coordination with the railroad could present additional challenges. Incorporation of D-1, D-2, and D-3 may help manage peak discharges within the watershed to help mitigate any potential volume changes from upsizing the structure.	Yes
HR-6	Cates Branch	Existing 12' W x 10' H RCB. Substantial hydraulic restriction along Cates Branch at Murray Road. Located in FEMA floodplain and regulatory floodway. FEMA flood profile indicates ~ 16 ft of headwater at structure. Several homes and local streets within 100-year floodplain. Work within floodway would require no-rise certification. Increasing structure capacity could reduce flooding for residential properties and along roadways, improving public safety.	Yes
HR-7	Cates Branch	Existing 12' W x 10' H RCB. Substantial hydraulic restriction along Cates Branch at railroad crossing. Located in FEMA floodplain and regulatory floodway. Several homes and an apartment building within 100-year floodplain. Securing right-of-way and coordination with the railroad could present additional challenges.	No
HR-8	Little Shoal Creek	Existing 14' W x 10' H RCB. Substantial hydraulic restriction along Little Shoal Creek Tributary 5 and Liberty Drive crossing. Located in FEMA floodplain and regulatory floodway. Restriction does not appear to negatively impact public or private infrastructure.	No

Project ID	Watershed	Stormwater Challenge / Benefit	Advanced for CIP Consideration
HR-9	Little Shoal Creek	Existing 2 - 14' W x 10' H RCB. Substantial hydraulic restriction along Little Shoal Creek Tributary 5 and a side road located between Liberty Drive and South Wales Road within the Westboro-Canterbury Greenway. Located in FEMA floodplain and regulatory floodway. FEMA flood profile indicates ~ 7 ft of headwater at structure. Two homes within 100-year floodplain. Work within floodway would require no-rise certification. Increasing structure capacity could reduce headwater, reducing flood elevations at residential properties.	Yes
HR-10	Little Shoal Creek	Existing 2 - 15' W x 10' H RCB. Hydraulic restriction along Little Shoal Creek Tributary 5 and S. Wales Road. Located in FEMA floodplain and regulatory floodway. Restriction does not appear to negatively impact public or private infrastructure for the 100-year base flood. ICM modeling results indicate street flooding; however, appears to be from local stormwater system flooding and not the roadway crossing.	No
HR-11	Little Shoal Creek	Existing 2 - 14' W x 12' H RCB. Substantial hydraulic restriction along Little Shoal Creek at Liberty Drive crossing. Located in FEMA floodplain and regulatory floodway. Minor street flooding within 100-year floodplain, no other visible impacts to public or private infrastructure.	No

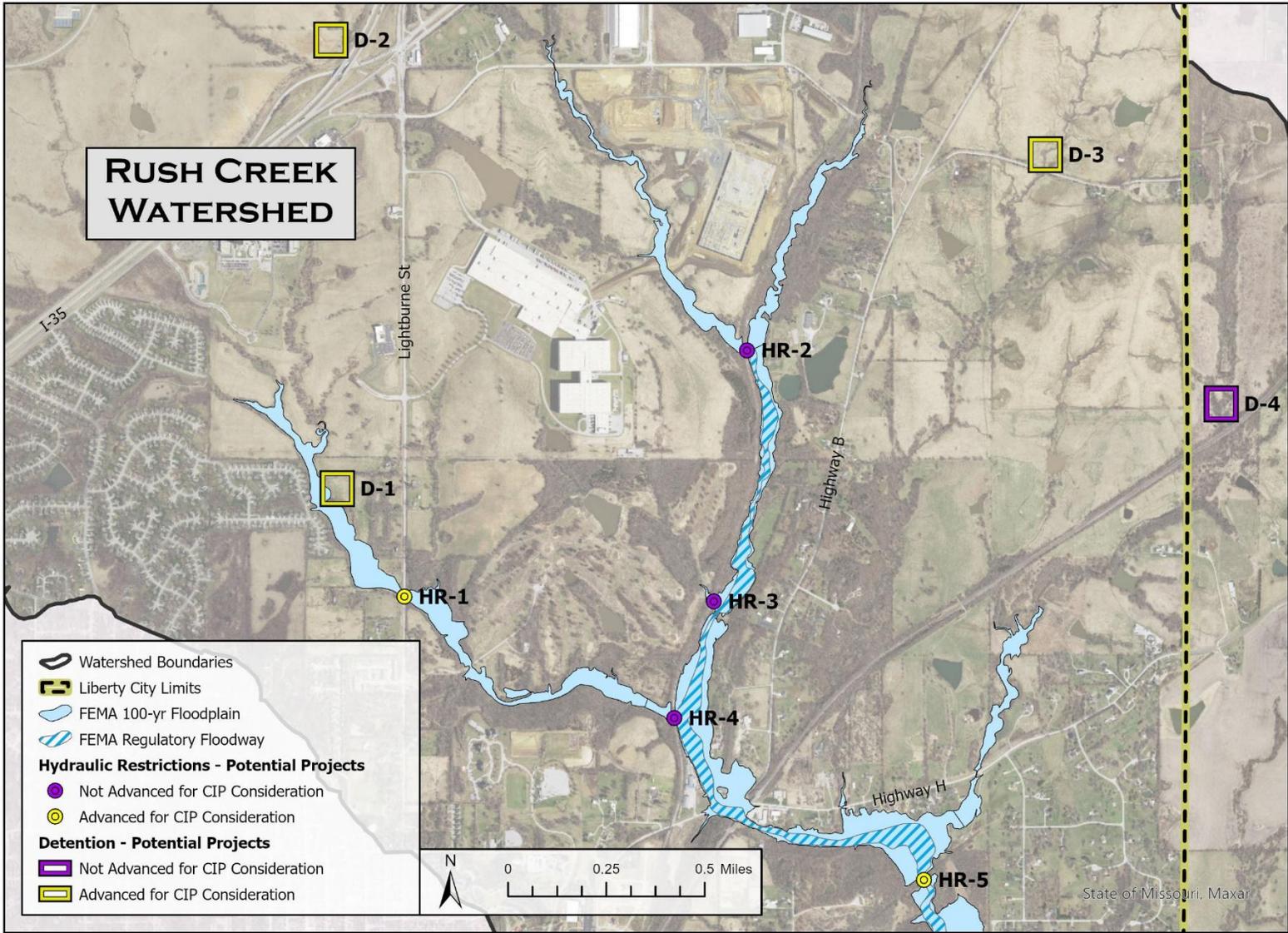


Figure 2: Potential Flood Risk Reduction Projects Identified within Rush Creek

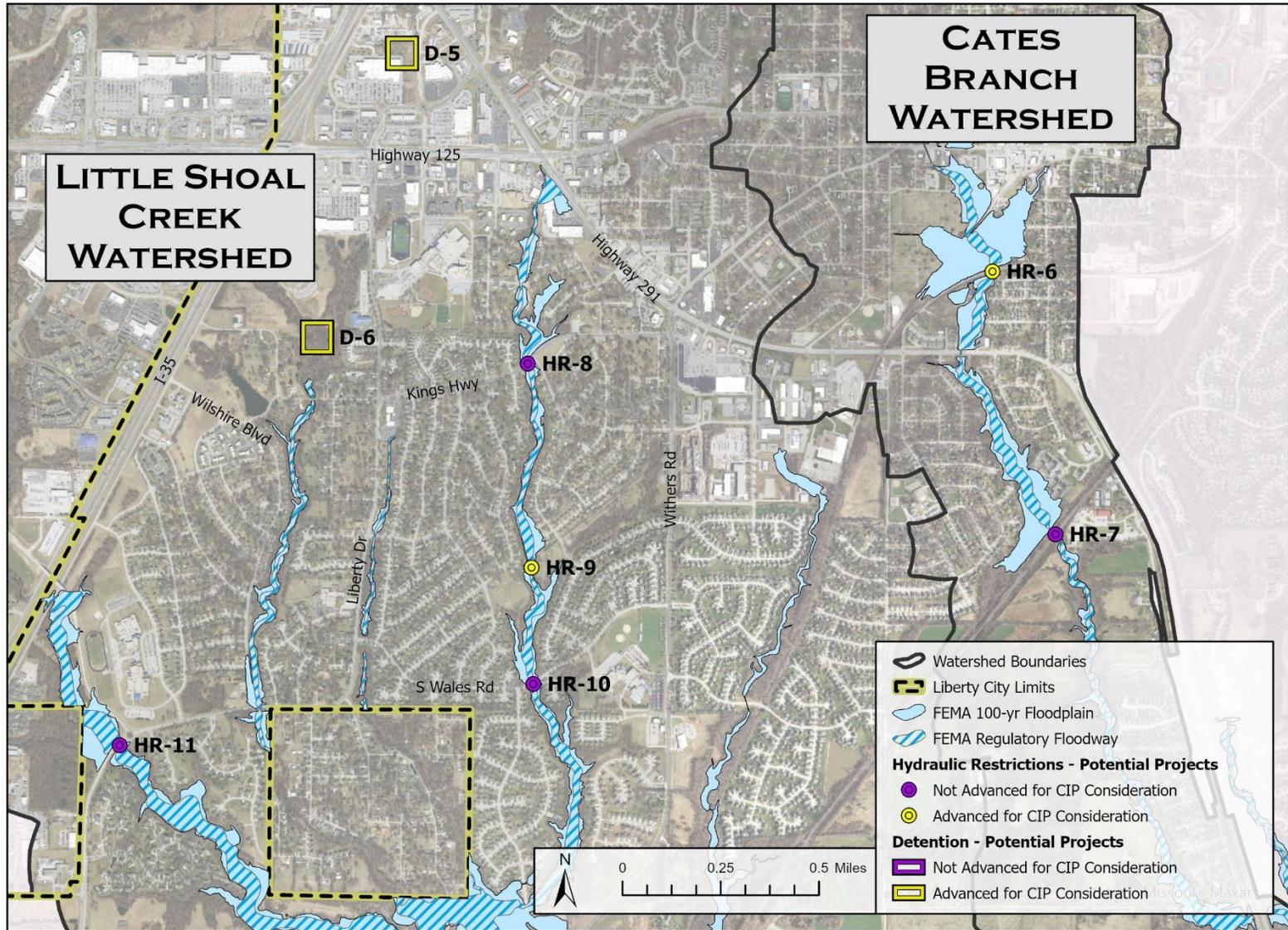


Figure 3: Potential Flood Risk Reduction Projects Identified within Cates Branch and Little Shoal Creek

2.2 Stormwater Detention

As communities continue to expand, thrive and prosper, development within the residential, industrial and commercial sectors continues to occur. This development results in watersheds with increased impervious footprints, reducing pervious areas where natural infiltration occurs. Consequently, the watersheds generate more stormwater runoff, which is potentially routed more quickly to the streams and confluence points. As such, developing watersheds often experience challenges with stormwater management including undersized stormwater infrastructure, degraded channels, and impaired water quality due to the overall increases in peak discharges throughout the system.

Stormwater detention offers an opportunity to detain or store runoff in key locations to reduce peak discharge rates downstream and help manage the timing of the storm peak. Placement of detention facilities is generally most beneficial when situated within the upstream or middle reaches of a watershed. This placement typically has the most impact to hydraulic timing within a watershed, allowing for a reduction in peak discharges, and generally results in lower construction costs and lower volume requirements which can reduce overall footprint.

The City's stormwater management program enforces management of stormwater runoff from new development or redevelopment projects disturbing greater than or equal to one (1) acre. Such projects are to limit post construction peak discharges and volumes to that of pre-development peak discharges to minimize flooding and water quality impacts downstream. The program adheres to the City of Liberty MS4 Stormwater Management Plan (December 2021), APWA Section 5600, and the Mid-America Regional Council Manual of Best Management Practices for Stormwater Quality (MARC BMP Manual). Several detention basins are present throughout the watersheds within the City limits. It is beyond this scope of work to evaluate the effectiveness or performance of existing stormwater detention facilities.

Several detention locations were evaluated in detail as part of the 2003 Stormwater Master Plan, and due to the high level, conceptual nature of this analysis, the 2003 master plan locations for detention were reconsidered as part of this assessment and for CIP consideration. No additional locations were identified as part of this effort in order to capitalize on the previous detailed efforts performed in the 2003 plan.

As part of the 2003 Stormwater Master Plan, a number of potential detention basin locations were investigated within each of the City watersheds. Of those evaluated, only six basins were recommended in the 2003 Master Plan. The rationale for selecting these six basins was reviewed and the justifications provided at each site remain valid today. Thus, these six potential detention locations were included in this investigation and are summarized in Figures 2 and 3. The locations are designated with a project identifier beginning in 'D-' to signify detention. Considerations for right-of-way and required acquisitions were included in the evaluation process. Project improvements that extend beyond City right-of-way can face

additional challenges, including increased coordination and higher cost if additional right-of-way or easements are needed. Additional details for each potential detention location are provided in Table 2.

Detention basins within Cates Branch watershed were not recommended as part of the 2003 Master Plan due to the highly developed areas and limited space available for an effectively sized detention basin. The 2003 Master Plan evaluated a couple locations within Town Branch; however, these were not deemed as high priority and were not ultimately recommended. While there is sufficient area available, the detention basins would not offer as much benefit as other locations. The Town Branch watershed provides substantial infiltration through pervious areas, flooding does not appear to be a major concern, and the 2003 Master Plan concluded that ultimate land use condition flows do not show that existing culverts are undersized. Potential detention locations within Rush Creek and Little Shoal Creek watersheds are described in more detail in Table 2. Refer to the 2003 Stormwater Master Plan for more details regarding the initial detention analysis and findings.

Additional analysis and detention modeling would be required to further assess the impact and overall benefit of each potential location. Details regarding the detention basin, including detention volume, configuration, outlet works, structure sizes and overflow configurations would be determined during the design process. As previously stated, it may be advantageous to pair detention with the removal of hydraulic restrictions to mitigate risk to downstream properties. In addition to stormwater benefit, detention basins can also offer benefits including water quality improvement and potential recreational and aesthetic value, which can be further evaluated during the design and analysis phase of these projects.

All improvements would be required to meet all local, state and federal permitting requirements and applicable design standards. Project improvements should be designed in accordance with APWA 5600 criteria and follow recommendations in the MARC BMP Manual, or the most recent versions of the guidance documents. Both APWA 5600 and the MARC BMP Manual are undergoing major updates, and the revised guidance will consist of a single combined manual. It is suggested to incorporate the latest APWA 5600 and MARC BMP Manual updates for any future projects, providing a more proactive development approach for runoff reduction (i.e. preserving or restoring areas, planting trees, and disconnecting impervious areas). Additionally, any improvements in the vicinity of FEMA regulatory floodplains or floodways should adhere to 44 CFR 60.3 and local requirements to meet floodplain ordinances and regulations.

Table 2: List of Potential Project Locations for Detention

Project ID	Watershed	Detention Challenge / Benefit	Advanced for CIP Consideration
D-1	Rush Creek	<p>The Rush Creek watershed is not highly developed, offering available space for potential detention locations within the upper and middle portions of the watershed. The 2003 Stormwater Master Plan optimized the detention analysis to provide a combination of detention in the watershed to reduce flows with the fewest basins and in the most cost-effective manner as possible. Results indicated the placement of basins D-1, D-2, D-3, and D-4 reduces flooding and eliminates the need to upsize culverts on Richfield Road (located downstream of HR-5) and along Highway H. Flooding along Highway H was also confirmed with the ICM stormwater model that was developed. These basins are referenced as RCM-2 (D-1), RCU-3 (D-2), RCU-5 (D-3) and RCU-7 (D-4) in the 2003 Stormwater Master Plan. Basin D-4 was not advanced for CIP consideration as it lies outside City limits and additional ROW and acquisitions could present additional challenges and ultimately will not rank as high as the other locations.</p>	Yes
D-2	Rush Creek		Yes
D-3	Rush Creek		Yes
D-4	Rush Creek		No
D-5	Little Shoal Creek	<p>The Little Shoal Creek watershed is heavily developed and offers limited opportunities/space for detention. These basins were recommended in the 2003 Master Plan, referencing a 1999 study that indicated two basins placed north (D-5) and south (D-6) of State Route 125 would alleviate flooding and further required culvert improvements at Kings Highway and Liberty Drive/Wilshire Blvd. These basins are referenced as LSC-1 (D-5) and LSC-2 (D-6) in the 2003 Stormwater Master Plan.</p>	Yes
D-6	Little Shoal Creek		Yes

4 Conclusion

Based on the flood risk reduction desktop assessment, several opportunities were presented to improve flooding conditions through condition improvements at several existing hydraulic restrictions or placement of regional detention basins. These potential locations were evaluated at a conceptual level to assess the locations that will offer the greatest benefit to the community.

These potential projects that advanced for consideration in the CIP will then be evaluated as part of the City CIP project prioritization, to rank, prioritize and align the projects with the communities' ultimate stormwater values and goals.

Additional analysis and design effort is warranted during future project design phases to thoroughly evaluate each area and gain a better understanding of the benefits and risks of each improvement. Required structure sizes, volumes, downstream impacts, and overall system performance will require further assessment to develop the design.

Potential project locations shared within this memorandum are available on the Flood Risk Reduction tab within the Liberty Stormwater Master Plan hub site.



City of Liberty, Missouri – Stormwater Master Plan Condition Assessment Summary Report

Presented to: City of Liberty

Prepared by: TREKK Design Group

March 2024

P.N. 23-0177

Table of Contents

1	Introduction.....	1-1
1.1	Project Objectives.....	1-1
1.2	Project Scope.....	1-1
2	Field Inspection Activities.....	2-2
2.1	General.....	2-2
2.2	Stormwater Structure Inspections	2-2
2.3	Stormwater Visual Pipe Inspections	2-11
2.4	Stormwater Pipe CCTV	2-12

List of Tables

Table 2-1	Storm Sewer Structure Inspection Summary	2-3
Table 2-2	Summary of Condition Ratings.....	2-5
Table 2-3	Summary of Overall Condition.....	2-9
Table 2-4	Summary of Visual Pipe Inspections.....	2-11
Table 2-5	Storm Sewer Pipe Inspection Summary	2-12
Table 2-6	Pipe Material & Footage Summary.....	2-14
Table 2-7	Summary of PACP Ratings.....	2-15

List of Figures

Figure 2-2	Structure Inspection Status	2-4
Figure 2-3	Structure Overall Condition Rating	2-10
Figure 2-6	CCTV Inspection Status.....	2-13
Figure 2-7	Storm Sewer PACP Quick Rating	2-16

Abbreviations

CCTV	Closed Circuit Television
City	City of Liberty, Missouri
CMP	Corrugated Metal Pipe
Ft	Feet
GIS	Graphical Interface System
GPS	Global Positioning System
HDR	HDR Engineering, Inc.
IN or in	Inch
LF or lf	Linear Feet
NASSCO	National Association of Sewer Service Companies
O&M	Operational and Maintenance
PACP	Pipeline Assessment and Certification Program
PE	Polyethylene Pipe
PVC	Polyvinyl Chloride Pipe
RCP	Reinforced Concrete Pipe
TREKK	TREKK Design Group
VCP	Vitrified Clay Pipe
%	Percent

1 Introduction

1.1 Project Objectives

The City of Liberty hired HDR Engineering Inc. (HDR) to complete a Stormwater Master Plan. The Stormwater Master Plan will evaluate the existing stormwater system, natural asset inventory, flood control assessment and ultimately prioritize projects within a Capital Improvement Plan (CIP). TREKK Design Group LLC (TRKK) was hired as a sub-consultant to HDR to perform an investigation and assessment of a portion of the existing stormwater infrastructure as part of the Stormwater Master Plan.

1.2 Project Scope

This project has two tasks, Task 1 – Stormwater Structure Inspections, Task 2 – Closed Circuit Television (CCTV) of Stormwater Pipe.

- Task 1 – Condition assessment of storm water structures utilizing TREKK360 camera.
- Task 2 - Conduct CCTV inspections of stormwater pipes in National Association of Sewer Service Companies (NASSCO) Pipeline Assessment and Certification Program (PACP) format.

This report summarizes the findings from Tasks 1 and 2.

2 Field Inspection Activities

2.1 General

The goal of the stormwater condition assessments was to inspect approximately 10% of the corrugated metal pipe (CMP) 18” and larger and the structures connected to these pipes. The City’s Geographic Information System (GIS) was provided to TREKK. A map of all the CMP pipe 18” and larger was created. The City of Liberty chose which pipes they wanted inspected.

2.2 Stormwater Structure Inspections

Inspections were attempted on structures identified for assessment. The structure inspections were completed by capturing 360 camera imaging data. Structures were inspected from the topside using the TREKK360 camera to collect panoramic photos, as well as mirrors and/or high-powered spotlights if necessary. These images were then processed to create a 360-degree perspective view and model of the stormwater structure which allowed for inspection of the structure from any angle and any elevation. The 60-degree imaging data was reviewed to complete the structure condition assessment inspection. Each structural component of the structure was documented and assigned a rating. Stormwater structure inspection PDF reports were included in the deliverables.

The following information was gathered and recorded from each stormwater structure within a web-based program:

- Address
- Location
- General Location
- Type of Asset Overview
- Asset Type
- Debris Present and Severity
- Pollution Observation
- Illicit Discharge Suspected
- Area Photo
- Top Photo
- Stormwater Marked Confirmed
- Structure Depth
- Grade
- Structure Shape, Length and Width
- Overall Condition
- Cover Type, Material, Shape and Diameter, and Condition and Defect Photos
- Frame Condition, Material, Height, Offset, Seal Condition, Frame Seal Material and Defect Photos
- Chimney Condition, Material, Height and Defect Photos
- Cone Material and Condition and Defect Photos
- Number of Grates, Grate Material, Grate Length and Width and Grate Condition and Defect Photos
- Top Slab Material, Condition, Number of Throats, Throat Material, Throat Condition and Defect Photos
- Wall Material, Condition, Channel/Bench Material, Channel/Bench Condition and Defect Photos
- Pipe Number, ID, Direction of Flow, Clock Position, Pipe Location, Shape, Pipe Material, Pipe Depth, Diameter, Pipe Seal Condition, Pipe Condition and Photos
- Pipe End Material and Condition, Headwall and Wingwall Material and Defect Photos

Area photos showing the structure top and the surrounding area were taken for each structure. Topside photos were taken from the surface looking into each structure. Any identified defects were also photographed. Photographs of each pipe within the structures were taken as well.

Each structural component within the storm structure was assigned a condition rating based on the following criteria:

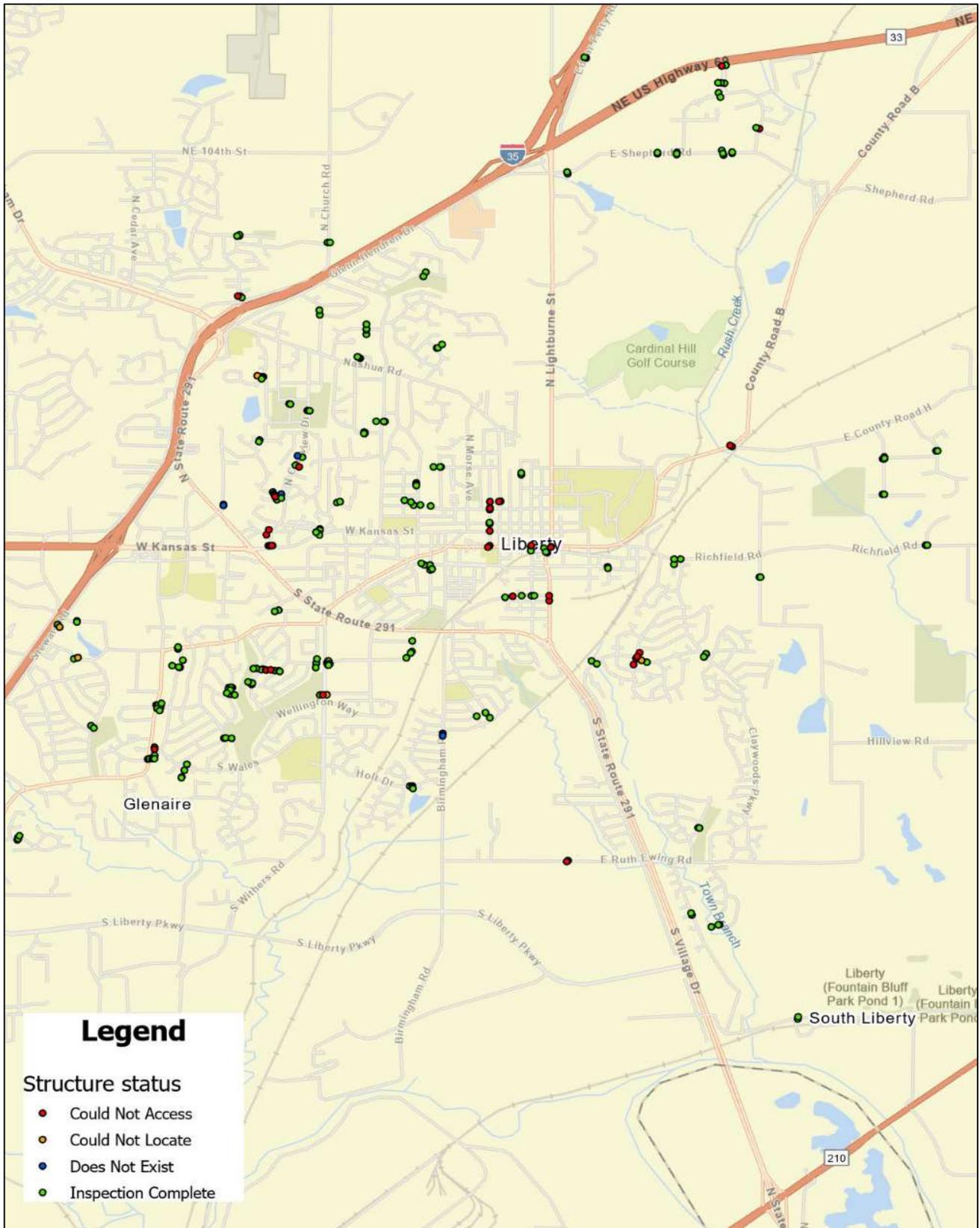
- Good – Asset shows no signs of corrosion, cracking, or fractures.
- Fair – Component shows signs of minor deterioration including light corrosion, hairline cracking, minor infiltration/inflow, or minor spalling.
- Poor – Component shows signs of major deterioration including fractures (cracks that are open), heavy corrosion, structural holes, partial or full collapses, significant infiltration/inflow, or major spalling.

A total of 281 stormwater structures were attempted to be inspected. However, it was found through the field inspections that there were portions of the GIS were not accurate. Some of the structures in the GIS did not exist in the field and were noted. Of the total 281 storm sewer structures 223 were inspected. Table 2-1 summarizes the total structures inspected and the number of structures that could not or were not inspected. Structures that could not be accessed may be buried or are in an area where they could not be reached to complete an inspection. The inspection status of each structure is represented visually in Figure 2-2.

Table 2-1 Storm Sewer Structure Inspection Summary

Structure Type	Inspection Completed	Could Not Locate	Could Not Access	Does Not Exist	Surcharged	Total
Area Inlet	10	0	0	0	0	10
Curb Inlet	98	0	0	0	0	98
Inlet/Outlet – End of Pipe	39	0	1	0	1	41
Inlet/Outlet – End Section	29	0	0	0	0	29
Grate Inlet	8	0	2	0	2	12
Inlet/Outlet – Headwall	10	0	1	0	1	12
Junction Box	13	0	1	0	1	15
Manhole	16	0	0	0	0	16
Unknown	0	6	34*	8	0	48
Total	223 (79%)	6 (2%)	39 (14%)	8 (3%)	5(2%)	281

Figure 2-1 Structure Inspection Status



Each structural component was assigned a score as described above. The majority of the stormwater structures are in good condition. The slab, throat, and walls of the structures have the largest fair and poor condition ratings. Table 2-2 summarizes the condition ratings for each structure inspected.

Table 2-2 Summary of Condition Ratings

Structure Type	Good	Fair	Poor	Not Assessed/No Component	Total
Cover Condition					
Area Inlet	9	0	0	1	30
Curb Inlet	84	1	1	12	98
Inlet/Outlet – End of Pipe	0	0	0	40	40
Inlet/Outlet – End Section	0	0	0	29	29
Grate Inlet	8	0	2	0	10
Inlet/Outlet – Headwall	0	0	0	11	11
Junction Box	13	1	0	0	14
Manhole	16	0	0	0	16
Unknown	0	0	0	53	53
Total	130 (46%)	2 (1%)	3 (1%)	146 (52%)	281
Frame Condition					
Area Inlet	8	0	0	2	10
Curb Inlet	84	2	0	12	98
Inlet/Outlet – End of Pipe	0	0	0	40	40
Inlet/Outlet – End Section	0	0	0	29	29
Grate Inlet	6	1	1	2	10
Inlet/Outlet – Headwall	0	0	0	11	11
Junction Box	9	4	0	1	14
Manhole	16	0	0	0	16
Unknown	0	0	0	53	53
Total	123 (44%)	7 (3%)	1 (0%)	150 (53%)	281
Frame Seal Condition					
Area Inlet	8	0	0	2	10
Curb Inlet	83	3	0	12	98
Inlet/Outlet – End of Pipe	0	0	0	40	40
Inlet/Outlet – End Section	0	0	0	29	29
Grate Inlet	5	2	1	2	10
Inlet/Outlet – Headwall	0	0	0	11	11
Junction Box	10	2	1	1	14
Manhole	13	3	0	0	16
Unknown	0	0	0	53	53
Total	119 (42%)	10 (4%)	2 (1%)	150 (53%)	281

Structure Type	Good	Fair	Poor	Not Assessed/No Component	Total
Chimney Condition					
Area Inlet	0	0	0	10	10
Curb Inlet	0	0	0	98	98
Inlet/Outlet – End of Pipe	0	0	0	40	40
Inlet/Outlet – End Section	0	0	0	29	29
Grate Inlet	0	0	0	10	10
Inlet/Outlet – Headwall	0	0	0	11	11
Junction Box	2	3	0	9	14
Manhole	5	3	0	8	16
Unknown	0	0	0	53	53
Total	7 (3%)	6 (2%)	0 (0%)	268 (95%)	281
Cone Condition					
Area Inlet	0	0	0	10	10
Curb Inlet	0	0	0	98	98
Inlet/Outlet – End of Pipe	0	0	0	40	40
Inlet/Outlet – End Section	0	0	0	29	29
Grate Inlet	1	0	0	9	10
Inlet/Outlet – Headwall	0	0	0	11	11
Junction Box	5	8	0	1	14
Manhole	10	5	1	0	16
Unknown	0	0	0	53	53
Total	16 (6%)	13 (5%)	1 (0%)	251 (89%)	281
Grate Condition					
Area Inlet	1	0	0	9	10
Curb Inlet	1	0	0	97	98
Inlet/Outlet – End of Pipe	0	0	0	40	40
Inlet/Outlet – End Section	0	0	0	29	29
Grate Inlet	8	1	1	0	10
Inlet/Outlet – Headwall	0	0	0	11	11
Junction Box	0	0	0	14	14
Manhole	0	0	0	16	16
Unknown	0	0	0	53	53
Total	10 (4%)	1 (0%)	1 (0%)	269 (96%)	281

Structure Type	Good	Fair	Poor	Not Assessed/No Component	Total
Top Slab Condition					
Area Inlet	9	1	0	0	10
Curb Inlet	72	21	4	1	98
Inlet/Outlet – End of Pipe	0	0	0	40	40
Inlet/Outlet – End Section	0	0	0	29	29
Grate Inlet	3	2	0	5	10
Inlet/Outlet – Headwall	0	0	0	11	11
Junction Box	0	0	0	14	14
Manhole	0	0	0	16	16
Unknown	0	0	0	53	53
Total	84 (30%)	24 (9%)	4 (1%)	169 (60%)	281
Throat Condition					
Area Inlet	9	1	0	0	10
Curb Inlet	75	19	4	0	98
Inlet/Outlet – End of Pipe	0	0	0	40	40
Inlet/Outlet – End Section	0	0	0	29	29
Grate Inlet	0	0	0	10	10
Inlet/Outlet – Headwall	0	0	0	11	11
Junction Box	0	0	0	14	14
Manhole	0	0	0	16	16
Unknown	0	0	0	53	53
Total	84 (30%)	20 (7%)	4 (1%)	173 (62%)	281
Wall Condition					
Area Inlet	9	1	0	0	10
Curb Inlet	49	40	9	0	98
Inlet/Outlet – End of Pipe	0	0	0	40	40
Inlet/Outlet – End Section	0	0	0	29	29
Grate Inlet	3	4	1	2	10
Inlet/Outlet – Headwall	0	0	0	11	11
Junction Box	8	5	0	1	14
Manhole	13	3	0	0	16
Unknown	0	0	0	53	53
Total	82 (29%)	53 (19%)	10 (4%)	136 (48%)	281

Structure Type	Good	Fair	Poor	Not Assessed/No Component	Total
Channel Bench Condition					
Area Inlet	8	2	0	0	10
Curb Inlet	89	7	2	0	98
Inlet/Outlet – End of Pipe	0	0	0	40	40
Inlet/Outlet – End Section	0	0	0	29	0
Grate Inlet	7	1	0	1	10
Inlet/Outlet – Headwall	0	0	0	11	11
Junction Box	11	1	1	1	14
Manhole	14	2	0	0	16
Unknown	0	0	0	53	53
Total	129 (46%)	13 (5%)	3 (1%)	135 (48%)	281
Pipe End Condition					
Area Inlet	0	0	0	10	10
Curb Inlet	0	0	0	98	98
Inlet/Outlet – End of Pipe	18	18	3	1	40
Inlet/Outlet – End Section	26	1	2	0	29
Grate Inlet	0	0	0	10	10
Inlet/Outlet – Headwall	3	6	1	1	11
Junction Box	0	0	0	14	14
Manhole	0	0	0	16	16
Unknown	0	0	0	53	53
Total	47 (17%)	25 (9%)	6 (2%)	203 (72%)	281
Headwall Condition					
Area Inlet	0	0	0	10	10
Curb Inlet	0	0	0	98	98
Inlet/Outlet – End of Pipe	1	0	0	39	40
Inlet/Outlet – End Section	2	0	0	27	29
Grate Inlet	0	0	0	10	10
Inlet/Outlet – Headwall	7	3	0	1	11
Junction Box	0	0	0	14	14
Manhole	0	0	0	16	16
Unknown	0	0	0	53	53
Total	10 (4%)	1 (0%)	1 (0%)	269 (96%)	281

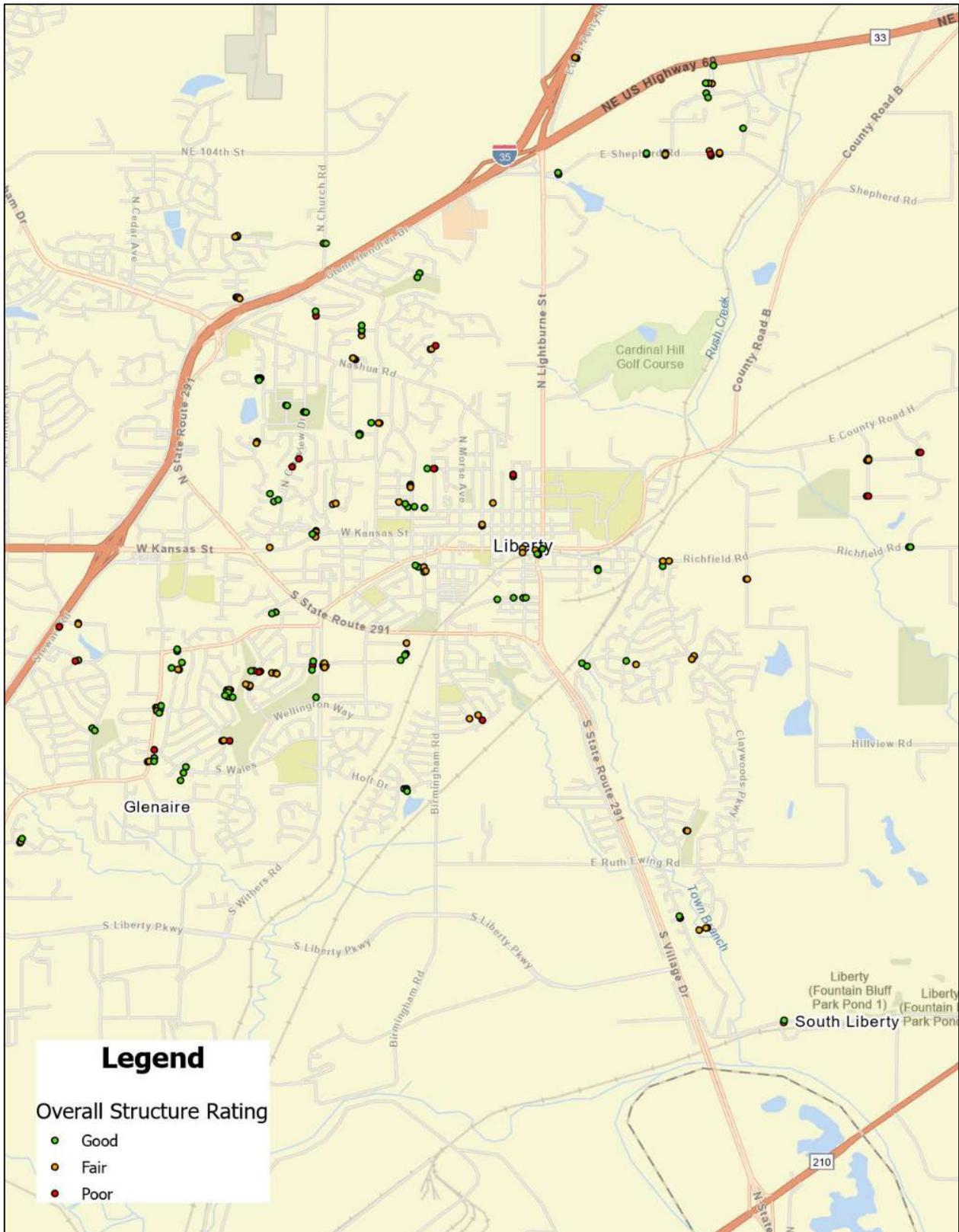
Structure Type	Good	Fair	Poor	Not Assessed/No Component	Total
Wing Wall Condition					
Area Inlet	0	0	0	10	10
Curb Inlet	0	0	0	98	98
Inlet/Outlet – End of Pipe	1	0	0	39	40
Inlet/Outlet – End Section	0	0	0	29	29
Grate Inlet	0	0	0	10	10
Inlet/Outlet – Headwall	6	0	0	5	11
Junction Box	0	0	0	14	14
Manhole	0	0	0	16	16
Unknown	0	0	0	53	53
Total	7 (3%)	0 (0%)	0 (0%)	274 (97%)	281

Each structure was given an overall structural rating based on the worst individual component rating of each structure. The overall condition rating for each structure is in Table 2-3 and shown graphically in Figure 2-3.

Table 2-3 Summary of Overall Condition

Structure Type	Good	Fair	Poor	Not Assessed/No Component	Total
Overall Condition					
Area Inlet	7	3	0	0	10
Curb Inlet	34	50	14	0	9818
Inlet/Outlet – End of Pipe	18	18	3	1	40
Inlet/Outlet – End Section	26	1	2	0	29
Grate Inlet	2	3	3	2	10
Inlet/Outlet – Headwall	3	6	1	1	11
Junction Box	1	10	2	1	14
Manhole	6	9	1	0	16
Unknown	0	0	0	53	53
Total	97 (35%)	100 (36%)	26 (9%)	58 (20%)	281

Figure 2-2 Structure Overall Condition Rating



2.3 Stormwater Visual Pipe Inspections

All incoming and outgoing stormwater pipes were inspected at each structure. Inspection results were used to identify sections of pipe that are structurally defective or require some form of maintenance. Visual pipe inspections were completed on a total of 396 pipes.

Each pipe component within the storm structure was assigned a condition rating based on the following criteria:

- Good – Asset shows no signs of deterioration, cracking, or fractures.
- Fair – Component shows signs of minor deterioration including defective pipe seals, hairline cracking, minor infiltration/inflow, or minor spalling.
- Poor – Component shows signs of major deterioration including fractures (cracks that are open), structural issues around pipe seal, structural holes, partial collapses, significant infiltration/inflow, or major spalling.

The results of the visual pipe inspections are shown in Table 2-4. Photographs were taken of each visual pipe inspection and can be found in each of the stormwater structure inspection reports.

Table 2-4 Summary of Visual Pipe Inspections

Component Observed	Good	Fair	Poor	Not Assessed/No Component	Total
Pipe Condition	326	59	10	1	396
Total	326 (82%)	59 (15%)	10 (3%)	1 (0%)	396
Pipe Seal Condition	316	57	10	13	396
Total	316 (80%)	57 (14%)	10 (3%)	13 (3%)	396

The following photos show some of the defects identified during visual pipe inspections:

C11-10-1337: Rebar intruding through pipe seal



A23-24-890: Pipe rusted through at the bottom



2.4 Stormwater Pipe CCTV

The 18” and larger CMP stormwater pipe identified for inspection was attempted to be televised. All CCTV inspections were completed per the guidelines and standards of the National Association of Sewer Service Companies (NASSCO) Pipeline Assessment and Certification Program (PACP), and pipe ratings were based on their structural condition and Operational and Maintenance (O&M) needs.

A total of 215 stormwater pipe segments were identified for CCTV. A total of 143 stormwater pipe segments were completely televised and 10 were partially televised. If the stormwater segment could not be televised from one direction it was attempted from the other direction. Some stormwater segments were able to be completely televised or the camera zoomed to see the entire pipe. Some stormwater segments were only able to be televised partially due to debris in the pipe, defects preventing the camera from passing, obstructions in the pipe, missing bottom of pipe, etc. A total of 62 stormwater pipes could not be televised due to pipes not existing, pipe surcharged, pipe not accessible, bottom of pipe missing, etc.

Table 2-5 summarizes the stormwater pipes attempted. Figure 2-6 shows this information graphically as well.

Table 2-5 Storm Sewer Pipe Inspection Summary

Inspect Status	Pipe Segments		Linear Footage Televised	
Completed	143	(67%)	12,282	(99%)
Unable to Complete – partially televised	10	(5%)	523	(4%)
Unable to Televiser – Does Not Exist	27	(12%)	0	(0%)
Unable to Televiser – Surcharged/Blockage/Debris	9	(4%)	0	(0%)
Unable to Televiser – Could Not Access	17	(8%)	0	(0%)
Unable to Televiser – Holes in Bottom	6	(3%)	0	(0%)
Unable to Televiser – City Working In Area	3	(1%)	0	(0%)
Total	215	(100%)	12,805	(100%)

Figure 2-3 CCTV Inspection Status

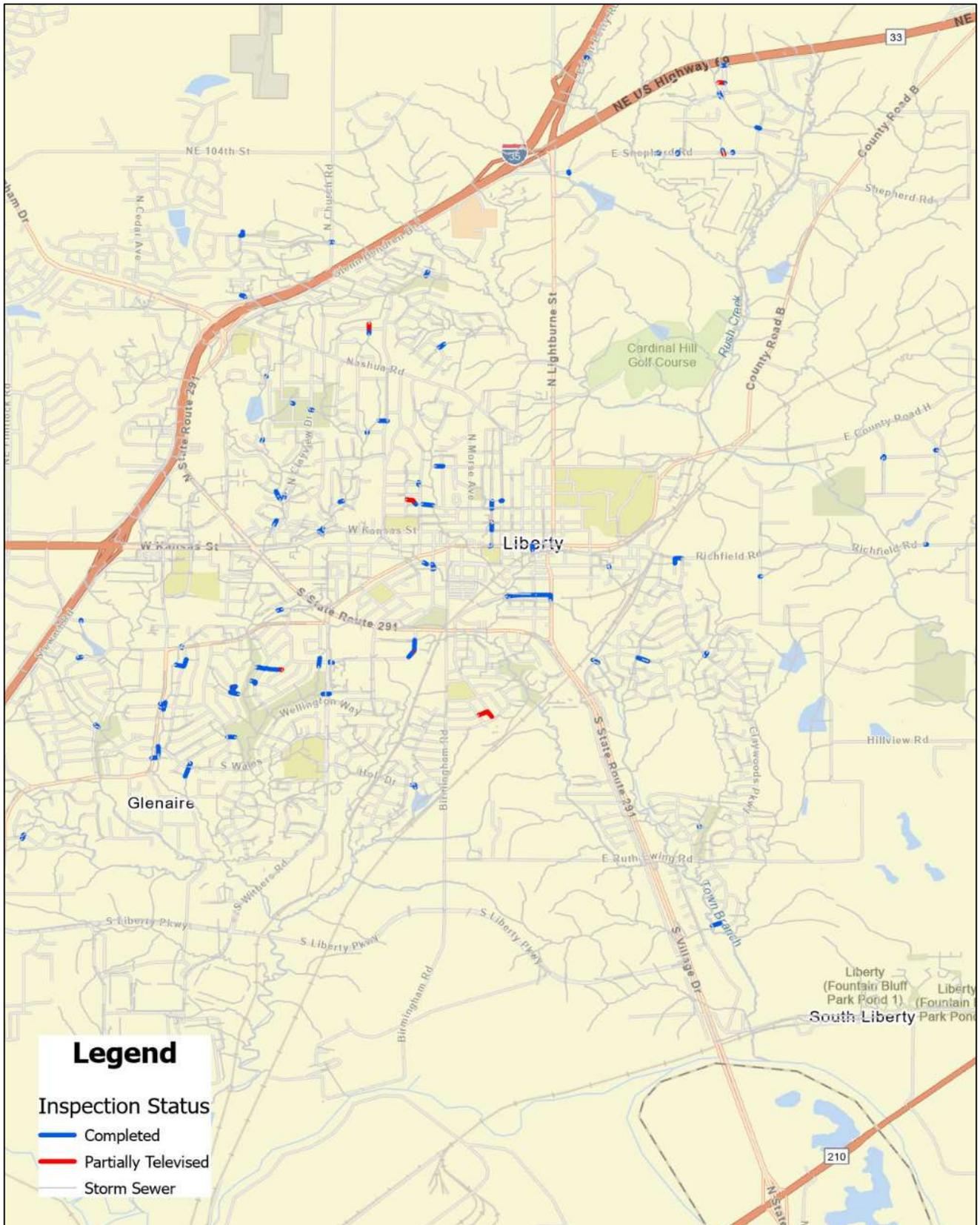


Table 2-6 summarizes the sizes and materials of the storm pipes televised completely or partially within the system. It was assumed that the pipe material does not change on segments only partially viewed or televised.

Table 2-6 Pipe Material & Footage Summary

Pipe Size	Linear Footage						Total
	CMP	CAS	PE	PVC	RCP	VCP	
12"	20	0	0	0	0	0	20
15"	290	0	0	0	0	0	290
18"	768	0	36	0	0	0	804
21"	284	0	0	0	0	0	284
22"	70	0	0	0	0	0	70
24"	1,965	0	71	0	0	0	2,036
30"	868	0	0	0	115	0	983
36"	1,772	0	0	0	1,187	0	2,959
38"	70	0	0	0	0	0	70
40"	110	0	0	0	0	0	110
42"	540	0	0	0	612	0	1,152
44"	0	0	0	0	63	0	63
48"	537	0	0	0	590	0	1,127
54"	381	0	0	0	493	0	874
60"	383	0	0	0	158	0	541
62"	0	95	0	0	0	0	95
72"	464	0	0	0	141	0	605
84"	670	0	0	0	0	0	670
102"	52	0	0	0	0	0	52
Total	9,244 (72%)	95 (1%)	107 (1%)	0 (0%)	3,359 (26%)	0 (0%)	12,805 (100%)

Each storm pipe segment that was completely or partially televised was assigned a condition rating per the PACP Condition Grading System. Condition grades are assigned for two defect categories, structural and operation and maintenance. Grades and definitions are listed below:

- 5 – most significant defect grade
- 4 – significant defect grade
- 3 – moderate defect grade
- 2 – minor to moderate defect grade
- 1 – minor defect grade

Each coded CCTV observation is assigned a grade per NASSCO PACP guidelines. The storm pipe segment is then assigned a 4-digit quick rating per the following:

- Digit 1 – Highest severity grade
- Digit 2 – Total number of occurrences of highest severity grade
- Digit 3 – Next highest severity grade
- Digit 4 – Total number of occurrences of second highest severity grade

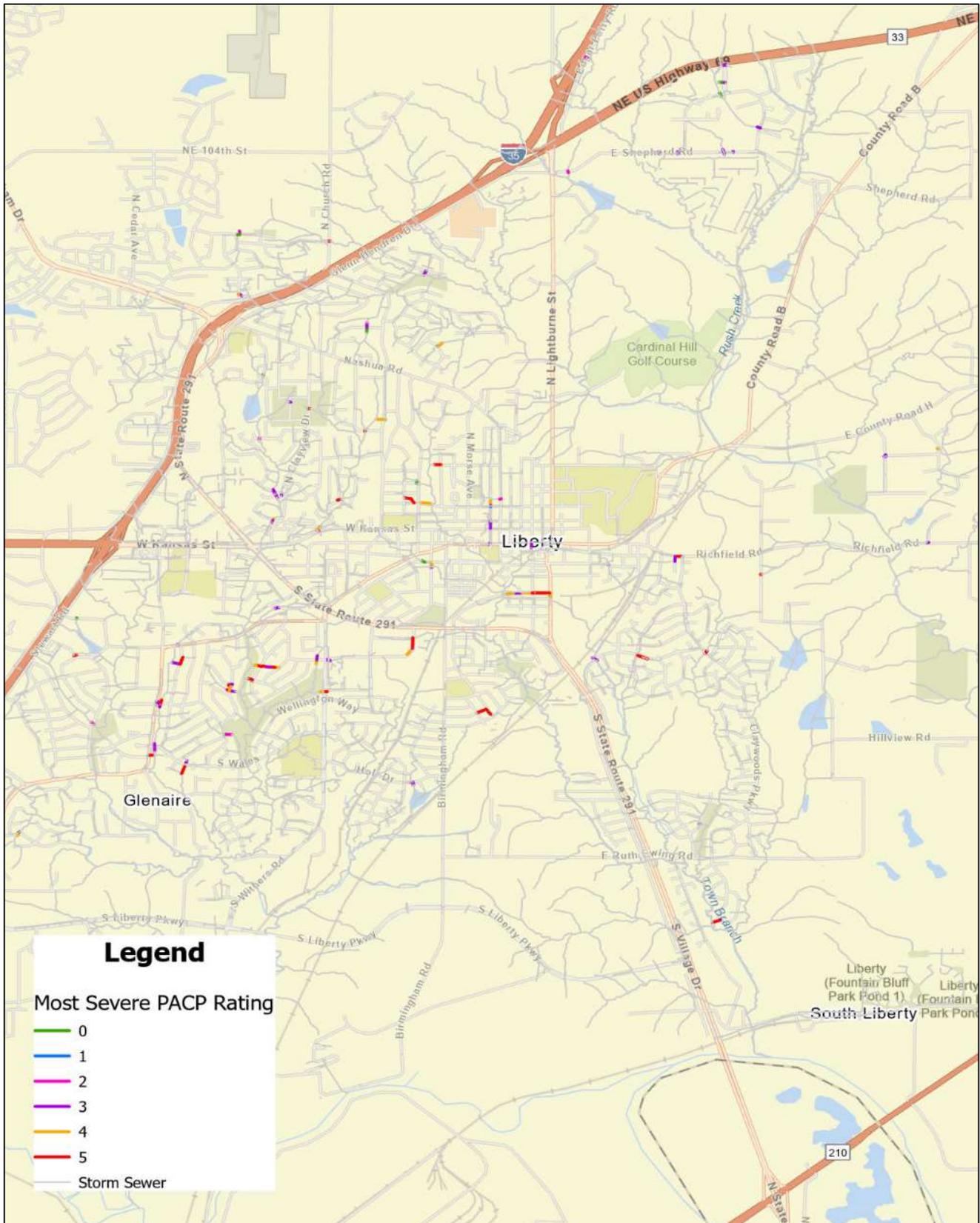
Table 2-7 summarizes the linear footage of storm pipe segments based on their highest severity PACP Quick Rating. This information is illustrated in Figure 2-7 as well.

Table 2-7 Summary of PACP Ratings

CCTV Storm Sewer Investigation – Most Severe PACP Defect (0 – 5)							
Pipe Diameter (IN)	0 (LF)	1 (LF)	2 (LF)	3 (LF)	4 (LF)	5 (LF)	Total
12"	0	0	0	0	20	0	20
15"	0	0	0	37	0	253	290
18"	36	0	9	210	41	507	803
21"	2	0	0	65	16	201	284
22"	0	0	0	70	0	0	70
24"	33	0	38	167	744	1,055	2,037
30"	0	0	0	360	233	390	983
36"	234	0	469	1,132	654	470	2,959
38"	0	0	0	0	70	0	70
40"	0	0	0	110	0	0	110
42"	321	0	93	358	43	336	1,151
44"	63	0	0	0	0	0	63
48"	236	0	37	332	176	347	1,128
54"	18	285	22	244	249	56	874
60"	27	0	0	289	131	94	541
62"	0	0	95	0	0	0	95
72"	0	0	0	605	0	0	605
84"	34	0	0	478	158	0	670
102"	0	0	0	0	52	0	52
Total	1,004 (8%)	285 (2%)	763 (6%)	4,457 (35%)	2,587 (20%)	3,709 (29%)	12,805 (100%)

An Access Database that outlines the PACP quick rating of each pipe segment was included in the deliverable.

Figure 2-4 Storm Sewer PACP Quick Rating





Stream Assessment Findings Summary

City of Liberty - Stormwater Master Plan
Technical Memorandum

City of Liberty, MO
April 10, 2024



Contents

1	Introduction.....	1
2	Existing Conditions.....	3
	2.1 Geomorphic Definitions	3
	2.2 Aerial Imagery Desktop Analysis.....	4
	2.3 Site Investigations – Rapid Site Reconnaissance	4
	2.3.1 Stream 1	7
	2.3.2 Stream 2	10
	2.3.3 Stream 3	11
	2.3.4 Stream 4	14
	2.3.5 Stream 5	16
	2.3.6 Stream 6	18
	2.3.7 Stream 7	19
	2.3.8 Stream 8	20
	2.3.9 Stream 9	21
	2.3.10 Stream 10	22
	2.4 Sediment Data Collection and Geotechnical Investigation	23
3	Conclusion and Summary of Findings.....	25
4	References.....	26

Tables

Table 2-1. Desktop Analysis Summary of Stream Meandering	4
Table 2-2. Severity Rating – Potential Impact to Infrastructure	6
Table 2-3. Infrastructure at Risk along Stream 1	7
Table 2-4. Infrastructure at Risk along Stream 2	11
Table 2-5. Infrastructure at Risk along Stream 3	12
Table 2-6 . Infrastructure at Risk along Stream 4	15
Table 2-7. Infrastructure at Risk along Stream 5	17
Table 2-8. Infrastructure at Risk along Stream 6	18
Table 2-9. Infrastructure at Risk along Stream 7	19
Table 2-10. Infrastructure at Risk along Stream 8	21
Table 2-11. Infrastructure at Risk along Stream 9	22
Table 2-12. Infrastructure at Risk along Stream 10	23
Table 2-13. Sediment Gradation Analysis at Each Stream.....	24

Figures

Figure 1-1. Stream Aerial Imagery Analysis	2
Figure 2-1. Geomorphic Characteristics and Parameters of a Meandering Stream (Source: USACE 2001)	3
Figure 2-2. Observed Stream 1 Bank Erosion (Location ID: S1.17)	7
Figure 2-3. Observed Bank Erosion Occurring in Stream 2 (Location ID: S2.30)	10
Figure 2-4. Observed Stream Bank Erosion along Stream 3 (Location ID: S3.24)	12
Figure 2-5. Knickpoint Observed within Stream 4 (Location ID: S4.35)	14
Figure 2-6. Bank Erosion Observed in Stream 5 (Location ID: S5.34)	16
Figure 2-7. Rock Riprap along Bank on Stream 6 (Location ID: S6.23)	18
Figure 2-8. Bank Failure Observed on Stream 7 (Location ID: S7.66)	19
Figure 2-9. Stream Bank Erosion observed in Stream 8 (Location ID: S8.12)	20
Figure 2-10. Stream bank erosion along Stream 9 (Location ID: S9.5)	21
Figure 2-11. Stream Bank Erosion Observed along Stream 10 (Location ID: S10.3)	22

Appendices

Appendix A: Stream Bank Assessment Maps

Appendix B: Stream Survey Tables

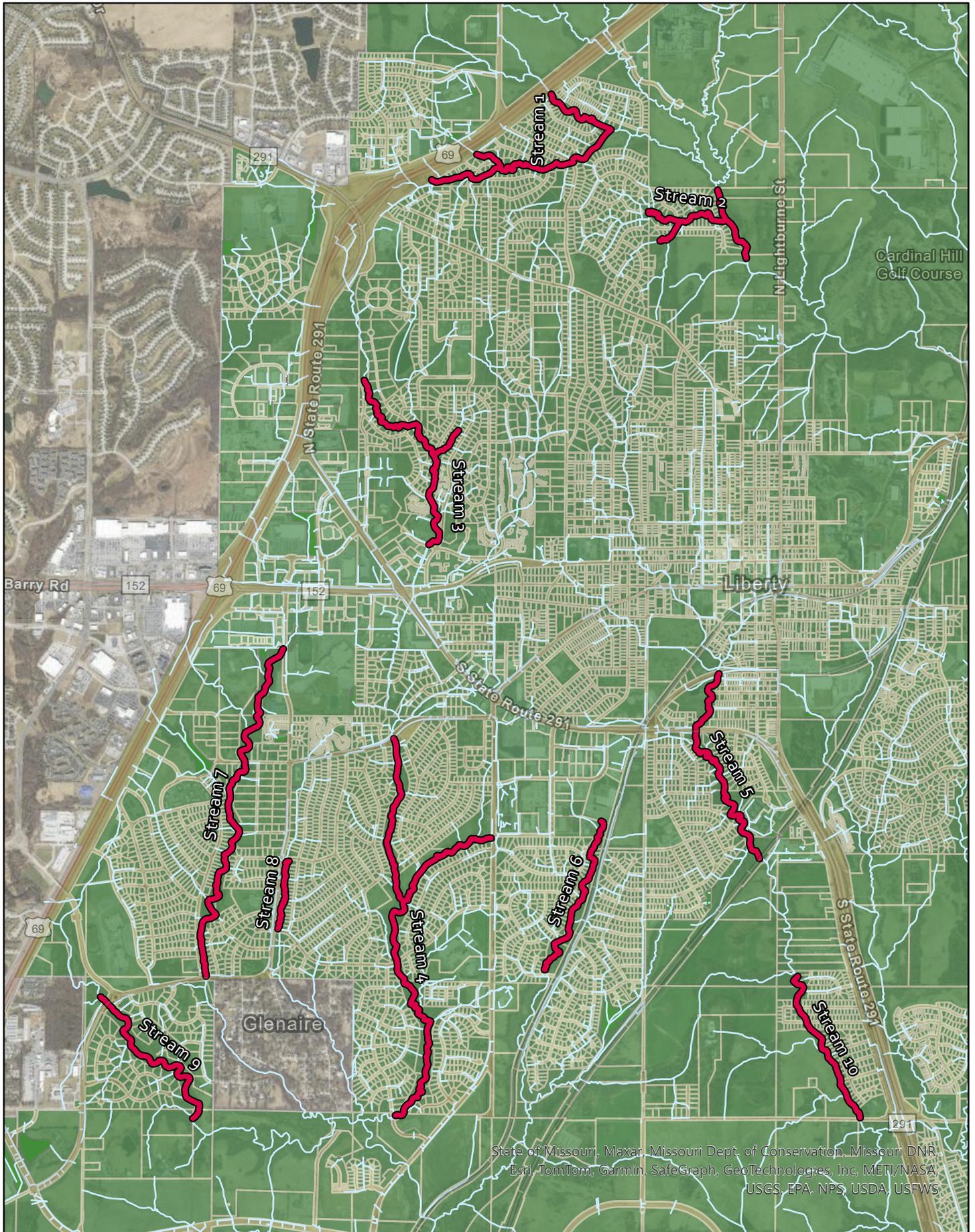
Appendix C: Bedrock Geologic Map of Liberty 7.5' Quadrangle, Clay and Jackson Counties, Missouri

1 Introduction

As part of a comprehensive stormwater master plan for the City of Liberty, Missouri, HDR has performed a rapid assessment of stream bank stability for ten streams located within City limits. The purpose of the assessment is to identify and characterize locations of stream degradation in order to prioritize areas of concern. The assessment will identify stream banks that are unstable, focusing on those in close proximity to City assets and/or private infrastructure, and streams that currently are outside of the drainage easement limits or are likely to migrate outside easements in the future.

The data collection for this effort consisted of a review of available GIS data, historic aerial imagery, and five days of on-site stream walks. City of Liberty staff identified the ten streams to be investigated during these stream walks. During the stream walks, GPS coordinates, photographs, and approximate banks heights were collected for banks which appeared to be unstable.

Comprehensive geomorphic definitions are provided to establish a foundational understanding of stream morphology and elements. Additionally, an aerial imagery desktop analysis and rapid site reconnaissance observations were recorded, providing firsthand insights into stream morphology, stability, and habitat conditions. Lastly, sediment gradation analysis of bed materials is performed to evaluate sediment dynamics and their impact on stream health.



State of Missouri, Maxar, Missouri Dept. of Conservation, Missouri DNR, Esri, TomTom, Garmin, SafeGraph, GeoTechnologies, Inc, METI/NASA, USGS, EPA, NPS, USDA, USFWS

LEGEND

-  Stream Investigated
-  Stream Lines
-  Parcels
-  LibertyCityLimits

FIGURE 1-1. STREAM AERIAL IMAGERY ANALYSIS

2 Existing Conditions

2.1 Geomorphic Definitions

The natural streams within the municipal boundaries vary from ephemeral to perennial flow streams. Ephemeral streams typically flow only in response to precipitation events or seasonal runoff, while perennial streams maintain continuous flow throughout the year, often sourced from groundwater or sustained by consistent runoff inputs.

The local streams typically follow a sinuous or meandering planform with pool and riffle morphology. Pools are typically situated within the stream bends and riffles are located within the straighter sections. Figure 2-1 depicts the geomorphic characteristics of a typical meandering stream (USACE 2001).

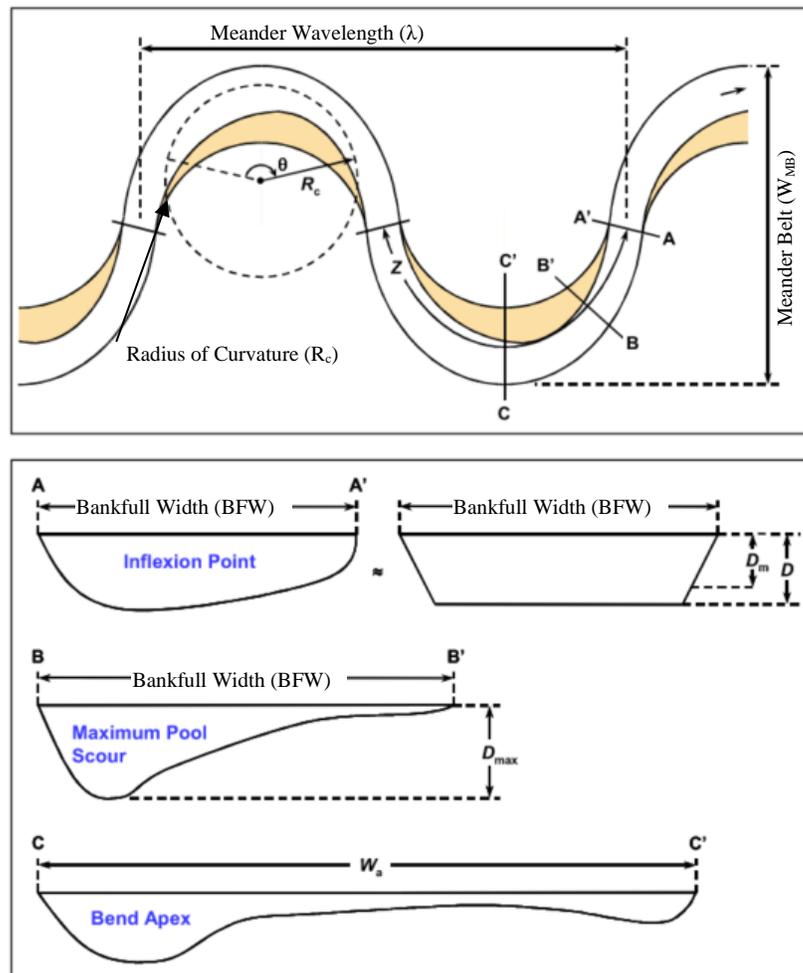


Figure 2-1. Geomorphic Characteristics and Parameters of a Meandering Stream (Source: USACE 2001)

2.2 Aerial Imagery Desktop Analysis

Google Earth aerial images from April 2003 and April 2020 were reviewed for all 10 streams identified for analysis and compared to identify major land use changes and stream instability indicators. The aerial imagery from 2003 was relatively low quality/resolution; however, it was sufficient to identify the general stream location. Comparison of the stream alignment between 2003 and 2020 allowed for the identification of channel migration and meander movement during that time period.

Table 2-1 presents comprehensive information regarding the characteristics of each investigated stream. This includes determining whether the stream exhibits meandering, its positioning relative to City-owned parcels, and if any location along the stream imposes risk of stream bank erosion near infrastructure.

Table 2-1. Desktop Analysis Summary of Stream Meandering

Stream Number	Meandering	Located Within City-Owned Parcels	Infrastructure at Risk
S1	Yes	Partial	Yes
S2	Yes	No	Yes
S3	Yes	No	Yes
S4	Yes	Yes	Yes
S5	Yes	Partial	Yes
S6	Yes	Partial	No
S7	Yes	Yes	Yes
S8	Yes	No	No
S9	Yes	No	Yes
S10	Yes	Yes	Yes

2.3 Site Investigations – Rapid Site Reconnaissance

HDR staff conducted site visits between December 5, 2023, and January 19, 2024, with the objective to perform an evaluation known as rapid site reconnaissance. This is a qualitative visual inspection and geomorphic analysis of each stream identified for investigation as shown in Figure 1-1. HDR’s team walked these streams and collected data via handheld GPS equipment. Each data point was then processed in GIS and includes site specific information along with field photographs.

The Location ID provided in this report corresponds to each survey point collected, with 1 to 4 pictures associated with each point. The nomenclature convention adheres to the following

structure: S[stream number].[point number]. For example, the Location ID “S1.72,” indicates the data point is located within stream 1 and is point 72 taken during the visit. All survey data gathered during field investigations that is discussed or shared within this report are accessible on the Stream Bank Investigations tab within the Liberty Stormwater Master Plan hub site.

The field investigations revealed notable similarities among all 10 streams. The land use within the watershed is predominantly suburban mainly characterized by single-family dwellings. The width of the riparian buffer strip varied across streams but generally extended from 2 to 6 times the stream width, often encompassing the 100-year floodplain.

The United States Department of Agriculture (USDA) soil mapping indicated mostly Silt Loam near the surface of the evaluated stream channel bottoms. Bremer Silt Loam is predominant along Stream 4, while Nodaway Silt Loam characterizes Streams 2, 6, 8, and 9. The Sharpsburg – Urban land complex is prevalent along Streams 1, 5, 7, and 10, whereas the Greenton – Urban Land Complex is prevalent within Stream 3.

MDNR mapping identified the exposed bedrock¹ as the Linn Subgroup on the Liberty quadrangle and is composed of the Cherryvale Formation, Nellie Bly Formation, Dewey Formation, and Chanute Shale, as can be observed in Appendix C (Bedrock Geological Map of the Liberty 7.5’ Quadrangle, Clay and Jackson Counties, Missouri). According to the Geologic Map of Missouri 2003, Sesquicentennial Edition, the streams explored present cyclic deposits, including limestone and shale with minor occurrences of sandstone and coal, alongside alluvium containing clay, silt, sand, and gravel. Additionally, the area features the Pleasanton Group, primarily characterized by shale and sandstone with minor occurrences of coal.

Bedrock outcrops in channels can act as bed control and limit the rate of vertical channel adjustment. However, the limestone ledge rock is thin, typically measuring 1-foot or less, and the shale is erodible leading to retreating headcuts that progress upstream.

The streambeds² are mainly comprised of sand to coarse gravel, possibly weathered limestone, with cobbles and ledge rock boulders near bedrock outcrops. Stream bank soil materials consist of finer alluvial material prone to mobilization and erosion during high-flow events. Signs of active horizontal stream instability, including exposed tree roots, bank erosion, and lateral instability, were prevalent throughout all inspected streams.

The observed streams exhibited a single-threaded flow path with a meandering course during the survey. Sinuosity, or the ratio of stream length to valley length, ranged from low to moderate for the streams within the study. Many of the streams appeared entrenched, which means the channel has been deeply incised into the surrounding landscape suggesting the channel has cut down into

¹ Bedrock is the solid rock layer that underlies the Earth's surface and can often be exposed in streambeds due to erosion.

² Streambeds refer specifically to the bottom surfaces of a watercourse.

the earth over time due to erosion. Morphologically, the streams primarily consisted of riffles and pools, indicating shallow, fast-flowing stretches alternating with deeper, slower-moving areas. Evidence of multiple cycles of downcutting was apparent from abandoned terraces above the current riverbank.

No natural or constructed levees were observed, and floodplain width varied similarly to riparian buffer strip width. Existing stream controls such as rock riprap bank protection and armored sewer crossings were noted during stream walks, with some requiring additional intervention to maintain stability. Infrequent debris dams formed by large and small woody material were observed, likely influencing stream stability.

Severity ratings were assigned to each data point along the stream segments to classify the degree of degradation. The severity rating was developed on a 5-point scale as presented in Table 2-2. The rating can then be used as guidance for the City in prioritizing and shaping future maintenance schedules.

Table 2-2. Severity Rating – Potential Impact to Infrastructure

Severity Rating	Rating Description
1	Infrastructure in good state of repair and in a stable stream section
2	Infrastructure in moderate state of repair and in a stable stream section
3	Infrastructure in good to moderate state of repair but located at an eroding bank 10-feet or taller or located at a stream flow line
4	Infrastructure in good to moderate state of repair but exposed due to an eroding bank or stream flow line
5	Infrastructure in a moderate or poor state of repair and exposed due to an eroding bank or stream flow line

The maps included in Appendix A provide visual summaries of the extensive data gathered during the stream walk investigation. This data is also available on the Stream Bank Investigation tab within the Liberty Stormwater Master Plan hub site. The maps illustrate key features along the stream banks, such as bank failures, structures, crossings, culverts, knickpoints, sanitary sewers, utilities and identified areas of infrastructure at risk.

The tables listed in the subsequent sections catalog the inventory of instability concerns at each stream segment classified with severity rating of 3 or higher, pertaining to infrastructure observed during the stream investigation. A complete inventory list of all datapoints can be found in Appendix B or on the Stream Bank Investigation tab within the Liberty Stormwater Master Plan hub site.

2.3.1 Stream 1

Investigation of Stream 1 began near N Forest Ln and concluded near houses between Carter Ct and Beagle Ct, close to North of Glenn Hendren Dr. Stream 1 detailed map is available within Appendix A, Figures 1-1 and 1-2.



Figure 2-2. Observed Stream 1 Bank Erosion (Location ID: S1.17)

Figure 2-2 illustrates the bank erosion posing a threat to nearby residences and exposing a manhole. Multiple instances of infrastructure risk were identified during investigations of Stream 1. Table 2-3 displays the inventory of instability concerns identified with severity rating of 3 or higher along Stream 1.

Table 2-3. Infrastructure at Risk along Stream 1

Location ID	Infrastructure at Risk	Description	Severity Rating
S1.2	Sanitary Sewer	Manhole exposed	3
S1.3	Other Utilities	Conduit and exposed electrical wire.	4
S1.7	Building	Nearby residential fencing.	3

Location ID	Infrastructure at Risk	Description	Severity Rating
S1.10	Building	Nearby residential fencing.	3
S1.11	Sanitary Sewer	Manhole in channel bed.	3
S1.17	Building	Residential housing at risk from bank failure. Also a sewer manhole on bank.	4
S1.18	Sanitary Sewer	Exposed manhole adjacent to house.	4
S1.20	Building	Both banks failing. House at risk.	3
S1.29	Building	Residential housing at risk from bank failure.	3
S1.36	Building	Concrete retaining wall being undercut by stream. Residential house at risk from bank failure.	5
S1.37	Building	Residential housing at risk from bank failure. Banks eroding from both sides.	5
S1.38	Building	Residential housing at risk from bank failure. Banks eroding from both sides.	5
S1.39	Sanitary Sewer	Sewer line crossing exposed. Wood piling and putting pressure on top. At risk of breaking.	4
S1.41	Building	Residential fencing at risk from bank failure.	3
S1.42	Building	Residential housing at risk from bank failure. Rock wall along residence. Stream undercutting wall. Wall has a gravel base. Evidence of wall collapsing.	4
S1.43	Building	Right bank armoring causing left bank to fail.	3
S1.46	Crossing	RCB outlet. Right wall is collapsing.	3
S1.48	Sanitary Sewer	Utility exposed. Potential for structure failure.	5
S1.49	Other	Exposed pipe crossing the stream	3
S1.50	Other Utilities	Utility pipe crossing. Dented in the center.	3
S1.51	Building	Residential housing at risk from bank failure.	3
S1.53	Sanitary Sewer	Sewage odor present.	5
S1.54	Building	Residential housing at risk from bank failure.	3
S1.57	Building	Steep bank but low slope up to houses.	3
S1.60	Building	Bank eroding nearby backyard.	3
S1.65	Building	Rip Rap on left bank causing right bank to fail.	3



Location ID	Infrastructure at Risk	Description	Severity Rating
S1.65	Building	Rip Rap on left bank causing right bank to fail.	3
S1.66	Building	Bank failing nearby fence and RCB.	3
S1.72	Building	Both banks are failing. Residential along left bank.	3
S1.73	Other	Exposed pipe crossing the stream. Both banks are failing. Residential along left bank.	3
S1.76	Building	Bank eroding nearby fence.	3
S1.80	Building	Residential house at risk from bank failure.	4
S1.81	Sanitary Sewer	Sewer crossing. Abutments are eroding.	3
S1.84	Crossing	RCB right wing wall eroding. Left wall is also but to a lesser degree.	3
S1.85	Crossing	RCB right wing wall eroding. Left wall is also but to a lesser degree.	3
S1.91	Building	Rock rip rap around culvert outfall nearby residence.	3
S1.93	Building	Residential housing nearby and could eventually be at risk from stream migration.	4
S1.99	Building	Bank eroding nearby residence.	3
S1.101	Building	Bank eroding nearby residence.	3
S1.104	Building	Residential at risk from bank failing.	4
S1.109	Building	Residential housing at risk from bank failure.	4

2.3.2 Stream 2

Investigation of Stream 2 began near Deer Drive and concluded near Duncan Drive, passing along Deer Drive. Stream 2 detailed map is available within Appendix A, Figures 1-3 and 1-4.

The erosion of the stream banks poses risks to nearby residential buildings and public infrastructure, as evidenced in the Figure 2-3, which depicts the presence of slump-off slope without vegetation and meander downcutting along the bank.



Figure 2-3. Observed Bank Erosion Occurring in Stream 2 (Location ID: S2.30)

Table 2-4 provides the inventory of instability concerns with severity rate of 3 or higher, pertaining to private or public infrastructure observed during the stream investigations along Stream 2.

Table 2-4. Infrastructure at Risk along Stream 2

Location ID	Infrastructure at Risk	Description	Severity Rating
S2.1	Other	CMP exposed and bank eroding.	3
S2.9	Building	Fence and shed at risk from bank failure.	3
S2.11	Building	Residential housing at risk from bank failure.	4
S2.12	Building	Residential housing at risk from bank failure.	4
S2.13	Building	Residential housing at risk from bank failure.	4
S2.14	Building	Residential housing at risk from bank failure.	4
S2.16	Building	Residential housing at risk from bank failure.	4
S2.22	Building	Residential housing at risk from bank failure.	4
S2.23	Building	Residential housing at risk from bank failure.	4
S2.24	Building	Residential housing at risk from bank failure.	4
S2.29	Building	Residential housing at risk from bank failure.	4
S2.30	Building	Residential housing at risk from bank failure.	3
S2.33	Building	Residential fencing at risk from bank failure.	3
S2.34	Building	Residential housing at risk from bank failure.	3
S2.38	Building	Residential housing at risk from bank failure.	3

2.3.3 Stream 3

Investigation of Stream 3 began near N Forest Avenue and concluded near N Clayview Dr. Stream 3 detailed map is available within Appendix A, Figures 1-5, 1-6, and 1-7.

Figure 2.4 illustrates stream bank erosion along Stream 3, revealing exposed tree roots and fluvial erosion increasingly close to residential areas, marked by the fence line. The erosion poses a significant risk to property boundaries.



Figure 2-4. Observed Stream Bank Erosion along Stream 3 (Location ID: S3.24)

Table 2-5 provides the inventory of instability concerns with a severity rate of 3 or higher, pertaining to private or public infrastructure observed during the stream investigations along Stream 3.

Table 2-5. Infrastructure at Risk along Stream 3

Location ID	Infrastructure at Risk	Description	Severity Rating
S3.4	Building	Residential housing at risk from bank failure.	3
S3.9	Sanitary Sewer	Exposed manhole and concrete pipe.	3
S3.10	Building	Residential housing at risk from bank failure.	3

Location ID	Infrastructure at Risk	Description	Severity Rating
S3.13	Building	House close to left bank. Right bank recently failed pushing the stream against the left bank and causing it to erode.	3
S3.14	Building	Outbuilding is close to bank and at risk from bank failure.	3
S3.17	Building	Residential housing at risk from bank failure.	3
S3.21	Building	Residential housing at risk from bank failure.	3
S3.24	Building	Residential housing at risk from bank failure.	3
S3.26	Crossing	RCB entrance is blocked by debris. Water may be flowing underneath or still entering RCB to some capacity.	5
S3.30	Crossing	RCB entrance is blocked by debris. Water may be flowing underneath or still entering RCB to some capacity.	5
S3.36	Building	Residential building at risk from bank failure.	3
S3.39	Building	Residential fencing at risk from bank failure.	3
S3.41	Sanitary Sewer	Manhole located directly within the channel.	3
S3.42	Building	Residential housing at risk from bank failure.	3
S3.44	Building	Residential housing at risk from bank failure. Building foundation close to bank and at risk. Bank failure moderate.	3
S3.45	Building	Multiple residential at risk from bank failure.	3
S3.47	Other Utilities	Underground electric line exposed.	4
S3.49	Building	Bank eroding with risk of failure nearby residence. Not an immediate threat.	3
S3.62	Building	Residential housing at risk from bank failure.	3
S3.67	Building	Residential housing at risk from bank failure.	3
S3.75	Building	Residential housing at risk from bank failure.	4

2.3.4 Stream 4

Investigation of Stream 4 began near the intersection of Buckingham Dr. and Old Withers Rd. and concluded near the intersection between W Liberty Dr. and Park Ln. Stream 4 detailed map is available within Appendix A, Figures 1-8, 1-9, 1-10, 1-11, 1-12, and 1-13.

A knickpoint is shown in Figure 2-5. A knickpoint is a location within a stream with a sharp change in the stream bed slope, most often a steep drop. A knickpoint can be an indicator of stream degradation because it often represents a sudden interruption in the stream's natural equilibrium as it actively adjusts to new conditions. As the stream flows over the knickpoint, it accelerates the erosion process downstream, leading to channel incision, widening, and increased sediment transportation. This was a typical knickpoint observed during the stream investigation.



Figure 2-5. Knickpoint Observed within Stream 4 (Location ID: S4.35)

Photographs of the actively eroding banks are provided in the geodatabase and Table 2-6 provides the inventory of instability concerns with a severity rate of 3 or higher, pertaining to private or public infrastructure observed during the stream investigations along Stream 4.



Table 2-6 . Infrastructure at Risk along Stream 4

Location ID	Infrastructure at Risk	Description	Severity Rating
S4.22	Sanitary Sewer	Exposed sewer manhole.	3
S4.34	Building	Residential housing at risk from bank failure. + Knickpoint	3
S4.43	Sanitary Sewer	Manhole exposed.	3
S4.44	Sanitary Sewer	Manhole exposed.	4
S4.45	Sanitary Sewer	Manhole exposed.	4
S4.46	Sanitary Sewer	Manhole exposed.	4
S4.47	Sanitary Sewer	Manhole exposed.	4
S4.48	Sanitary Sewer	Manhole exposed.	4
S4.49	Sanitary Sewer	Manhole exposed.	4
S4.50	Other	Pipe under water.	3
S4.51	Other	Pipe under water.	3
S4.52	Other	Pipe under water.	3
S4.53	Sanitary Sewer	Manhole exposed.	4
S4.54	Sanitary Sewer	Manhole exposed.	4
S4.57	Building	Residential housing at risk from bank failure.	3
S4.63	Building	Residential housing at risk from bank failure.	3
S4.128	Crossing	CMP eroded underneath.	3

2.3.5 Stream 5

Investigation of Stream 5 began near the intersection of W Murray St and S Main St, tracing its course downstream until it intersected with the railroad. Stream 5 detailed map is available within Appendix A, Figures 1-14, 1-15, and 1-16.



Figure 2-6. Bank Erosion Observed in Stream 5 (Location ID: S5.34)

In Figure 2-6, bank fluvial erosion on Stream 5 is depicted, with exposed orange hairy roots indicating recent exposure, likely within the last six months. Additionally, the image portrays surfing trees, which are trees leaning or falling into the stream as a result of erosion undermining the bank beneath them.

Table 2-7 provides the inventory of instability concerns with a severity rate of 3 or higher, pertaining to private or public infrastructure observed during the stream investigations along Stream 5.

Table 2-7. Infrastructure at Risk along Stream 5

Location ID	Infrastructure at Risk	Description	Severity Rating
S5.1	Crossing	Box culvert. Left wing wall is eroding.	3
S5.5	Building	Residential fencing along top of bank.	3
S5.8	Building	Residential housing at risk of bank failing.	3
S5.10	Building	Residential housing at risk of bank failing.	3
S5.30	Building	Fencing and utility lines at risk from bank failure. Sycamore recently fell.	3
S5.32	Crossing	Greenway trail low water crossing. The culvert is being filled with sediment.	3
S5.33	Crossing	Greenway trail low water crossing. The culvert is being filled with sediment.	3
S5.35	Other	Greenway trail will eventually be undercut by stream.	4
S5.36	Building	Residential fencing along top of bank. At risk of failure.	4
S5.47	Culvert	Culvert outfall creating scour hole.	3
S5.54	Building	Residential housing at risk of foundation issues from bank failure.	3
S5.56	Building	Residential housing at risk of foundation issues from bank failure. Bank has already failed recently contributing to a log jam.	3
S5.58	Other Utilities	Pipe crossing. Concrete support column eroded at base and at risk of failure.	5

2.3.6 Stream 6

Investigation of Stream 6 began behind the WestRock building located on 933 Kent St and extends downstream until crossing Hold Dr. Stream 6 detailed map is available within Appendix A, Figures 1-17 and 1-18.

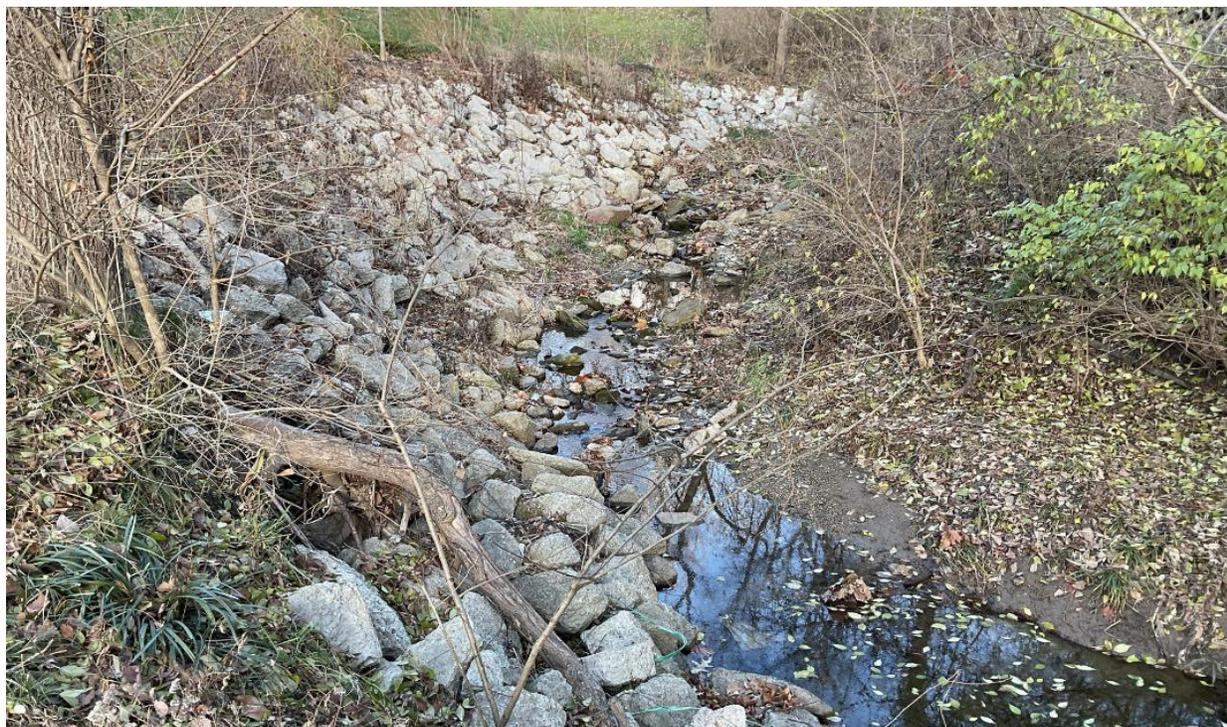


Figure 2-7. Rock Riprap along Bank on Stream 6 (Location ID: S6.23)

It was observed that rock riprap was added along multiple bank locations within the streams investigated. Figure 2-7 shows riprap encountered within Stream 6 with the purpose of bank erosion control.

Table 2-8 provides the inventory of instability concerns with a severity rate of 3 or higher, pertaining to private or public infrastructure observed during the stream investigations along Stream 6.

Table 2-8. Infrastructure at Risk along Stream 6

Location ID	Infrastructure at Risk	Description	Severity Rating
S6.9	Other	Retaining Wall failing.	3
S6.15	Building	Residential housing at risk from bank failure.	3
S6.24	Crossing	Residential bridge at failure risk due to bank erosion.	3

2.3.7 Stream 7

Investigation of Stream 7 began near intersection between Liberty Dr and Wilshire Blvd and concludes near Conistor St near Liberty High School. Stream 7 detailed map is available within Appendix A, Figures 1-19, 1-20, 1-21, and 1-22.



Figure 2-8. Bank Failure Observed on Stream 7 (Location ID: S7.66)

A bank failure estimated over 30 feet in height was observed along Stream 7. This specific location does not involve public infrastructure and thus is not listed within Table 2-9, however, is available within the Master Plan hub – Stream Bank Investigation tab.

Table 2-9 provides the inventory of instability concerns with a severity rate of 3 or higher, pertaining to private or public infrastructure observed during the stream investigations along Stream 7.

Table 2-9. Infrastructure at Risk along Stream 7

Location ID	Infrastructure at Risk	Description	Severity Rating
S7.11	Crossing	CMP outlet	4
S7.19	Crossing	Erosion on both sides of wing walls.	3

Location ID	Infrastructure at Risk	Description	Severity Rating
S7.22	Building	Erosion next to fence.	3
S7.23	Building	Residential housing at risk from bank failure.	4
S7.35	Sanitary Sewer	RCP damage.	4
S7.36	Other	CMP outlet around eroding bank	3

2.3.8 Stream 8

Investigation of Stream 8 began near Liberty Dr and High Dr. and concluded near the intersection between Liberty Dr. and S Wales. Stream 8 detailed map is available within Appendix A, Figure 1-23.

Figure 2-9 illustrates the presence of abandoned terraces, fluvial bank erosion, exposed tree roots, and at-risk backyards along Stream 8 that are indicators of stream degradation.



Figure 2-9. Stream Bank Erosion observed in Stream 8 (Location ID: S8.12)

Table 2-10 provides the inventory of instability concerns with a severity rate of 3 or higher, pertaining to private or public infrastructure observed during the stream investigations along Stream 8.

Table 2-10. Infrastructure at Risk along Stream 8

Location ID	Infrastructure at Risk	Description	Severity Rating
S8.13	Building	Banks are eroding nearby residences.	3
S8.17	Other	Non identified structure exposed and bank eroding.	3

2.3.9 Stream 9

Investigation of Stream 9 began near the Southwest of Oak Crest Dr. on Little Shoal Creek and concluded near a roundabout located between Liberty Dr. and Flintlock Rd. Stream 9 detailed map is available within Appendix A, Figures 1-24 and 1-25.



Figure 2-10. Stream bank erosion along Stream 9 (Location ID: S9.5)

Figure 2-10 shows an abandoned terrace and mini knickpoint observed on Stream 9.

Table 2-10 provides the inventory of instability concerns with a severity rate of 3 or higher, pertaining to private or public infrastructure observed during the stream investigations along Stream 9.

Table 2-11. Infrastructure at Risk along Stream 9

Location ID	Infrastructure at Risk	Description	Severity Rating
S9.14	Building	Residential housing at risk from bank failure.	3
S9.23	Other	Concrete structure exposed.	3
S9.24	Building	Residential housing at risk from bank failure.	3

2.3.10 Stream 10

Investigation of Stream 10 began near Fawn Ln and concluded near the intersection of E Ruth Ewing Rd. and Southview Dr. Stream 10 detailed map is available within Appendix A, Figures 1-26 and 1-27.



Figure 2-11. Stream Bank Erosion Observed along Stream 10 (Location ID: S10.3)

Figure 2-11 shows erosion occurring on a steep bank within Stream 10.

Table 2-12 provides the inventory of instability concerns with a severity rate of 3 or higher, pertaining to private or public infrastructure observed during the stream investigations along Stream 10.

Table 2-12. Infrastructure at Risk along Stream 10

Location ID	Infrastructure at Risk	Description	Severity Rating
S10.8	Sanitary Sewer	Bank failing and exposing sanitary sewer.	3
S10.24	Building	Nearby residential at risk from bank failure.	3
S10.39	Other Utilities	Utility poles and also residential nearby bank.	3
S10.44	Building	Backyard sheds at risk from bank failing.	4
S10.47	Building	Residential properties losing backyard to bank failure.	4

2.4 Sediment Data Collection and Geotechnical Investigation

Sediment gradation was calculated periodically from high resolution digital images taken during stream walks of the 3-inch diameter to cobble sized sediment bars. Sediment bars selected are defined as actively moving non-vegetated features typically on the inside bend of streams at meanders.

The sediment gradation analysis helps to understand or predict the movement, deposition, and erosion of sediment along riverbanks. Specifically, examining the sediment gradation present within these sediment bars provides insight into the stream's ability to mobilize various materials amidst runoff occurrences. Additionally, this analysis serves to enhance understanding regarding the potential movement of the stream, particularly in instances where the prevailing substrate and banks predominantly consist of finer materials. This is useful for assessing the stability of stream banks.

Table 2-13 provides the sediment size in millimeters at each evaluated stream reach. The terms D5, D15, D50, D85, and D100 represent percentiles that indicate the particle sizes at which a certain percentage of the sediment sample's mass lies below. For instance, D5 represents the

particle size below which 5% of the sediment sample's mass falls, or 5% of the sediment particles are smaller than this size. The analysis of digital rock/sediment gradation was performed using the Hydraulic Toolbox MFC Application.

Table 2-13. Sediment Gradation Analysis at Each Stream

Stream	D5 (mm)	D15 (mm)	D50 (mm)	D85 (mm)	D100 (mm)
S1	11.26	20.90	55.55	129.55	220.62
S2	4.88	7.90	16.15	27.13	56.33
S3	7.10	11.43	22.88	41.48	71.83
S4	9.76	16.32	31.52	60.73	122.14
S5	7.15	12.17	30.24	66.25	133.88
S6*	N/A	N/A	N/A	N/A	N/A
S7*	N/A	N/A	N/A	N/A	N/A
S8	5.00	8.05	16.75	36.89	77.76
S9	13.98	22.59	48.98	83.67	109.09
S10	6.76	11.97	31.01	71.54	131.62

* Sediment gradation analysis was not performed at Streams S6 and S7.

Sediment gradation analysis reveals varying particle size distributions among the analyzed streams, which reflects differences in flow velocities, sediment transport capacities, and environmental conditions within each stream. These differences can have implications for ecosystem dynamics, sediment transport, and general stream health. Overall, the sediment gradation analysis results displayed in Table 2-13 can be used as a potential indicator of the stream's disposition to fluvial erosion and stream bank degradation and can serve as an important tool for identifying erosion processes and stream bank stability.

3 Conclusion and Summary of Findings

Based on the rapid geomorphic analysis conducted, the natural streams within the City of Liberty should be considered mobile and are in the process of adjusting to the increased flow from urbanization. The stream banks consist of a silt loam soil material that is easily eroded, while the stream bottoms consist of shale that also is erodible. Based on field investigations, the streams show signs of down cutting, widening and meander migration.

Due to urbanization, the streams are deepening, lacking a resilient bedrock layer to impede the degradation process. With this deepening, there are successive stages of widening until eventual stabilization in the future. Further bank failures and stream widening is anticipated within these reaches. While both banks are likely to experience issues, typically, one side will undergo most of the fluvial erosion. This erosion will manifest as meander migration on aerial views; however, the inside bank typically fails to stabilize during typical meander migration processes. This means that streams will be continually changing.

As the stream continues to adjust, it is highly recommended to perform periodic rapid reconnaissance assessments to evaluate the threat to public infrastructure. The streams will continue to widen and meander causing large woody debris dams to form. This could cause flooding and additional stream stability concerns. Due to this risk, it is recommended that the debris dams should be located and removed on an annual basis.

All data shared in this report was collected during the stream assessments completed between December 2023 and January 2024 and is available within the Stream Bank Investigation tab on the Liberty Stormwater Master Plan hub site.

4 References

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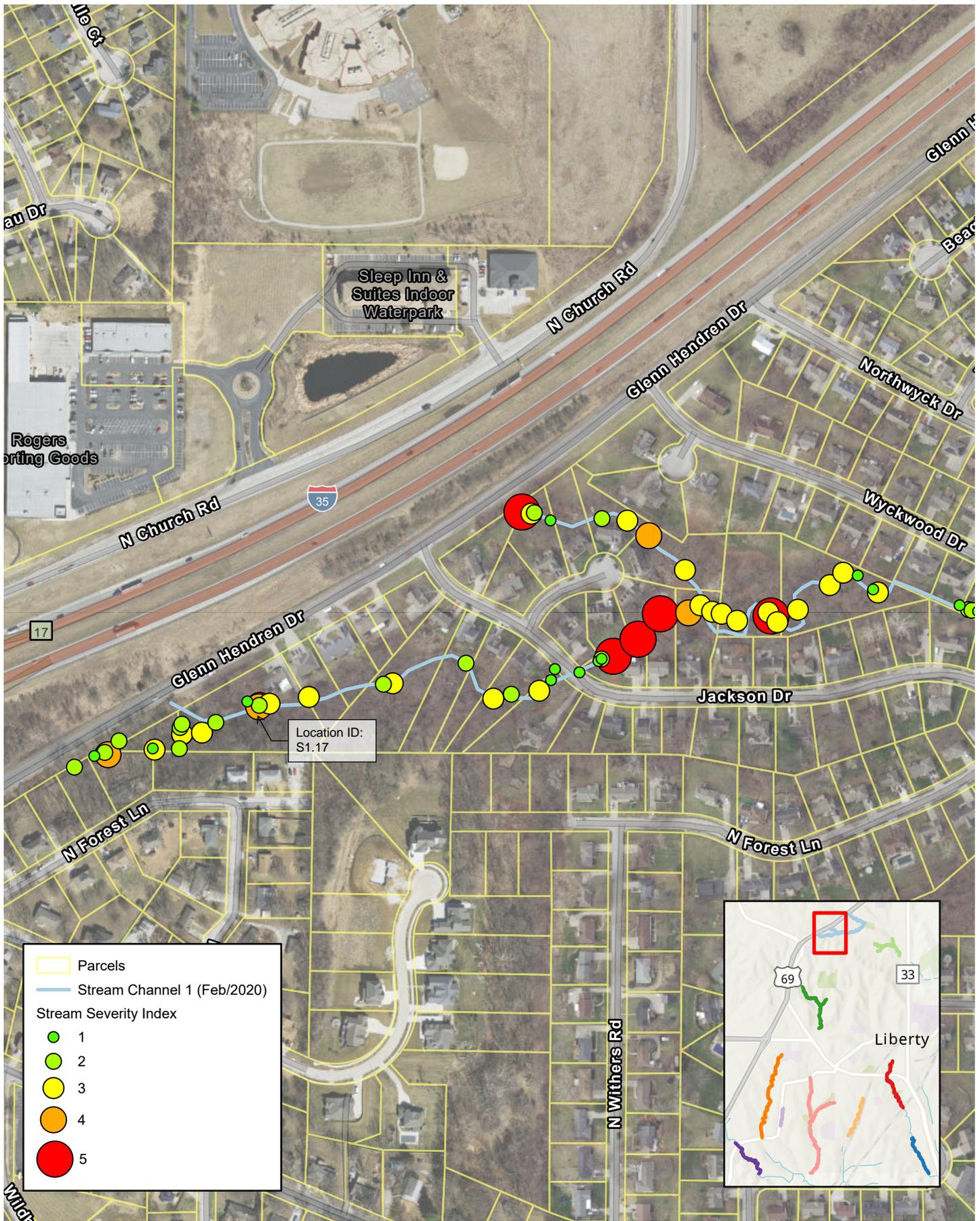
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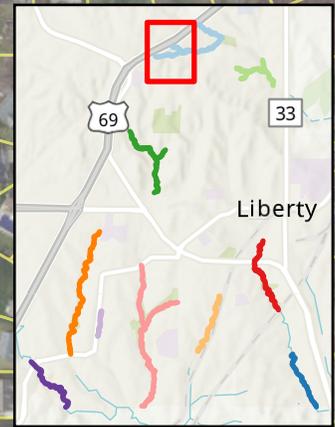
5 Appendices

Appendix A



Parcels
 Stream Channel 1 (Feb/2020)
Stream Severity Index
● 1
● 2
● 3
● 4
● 5

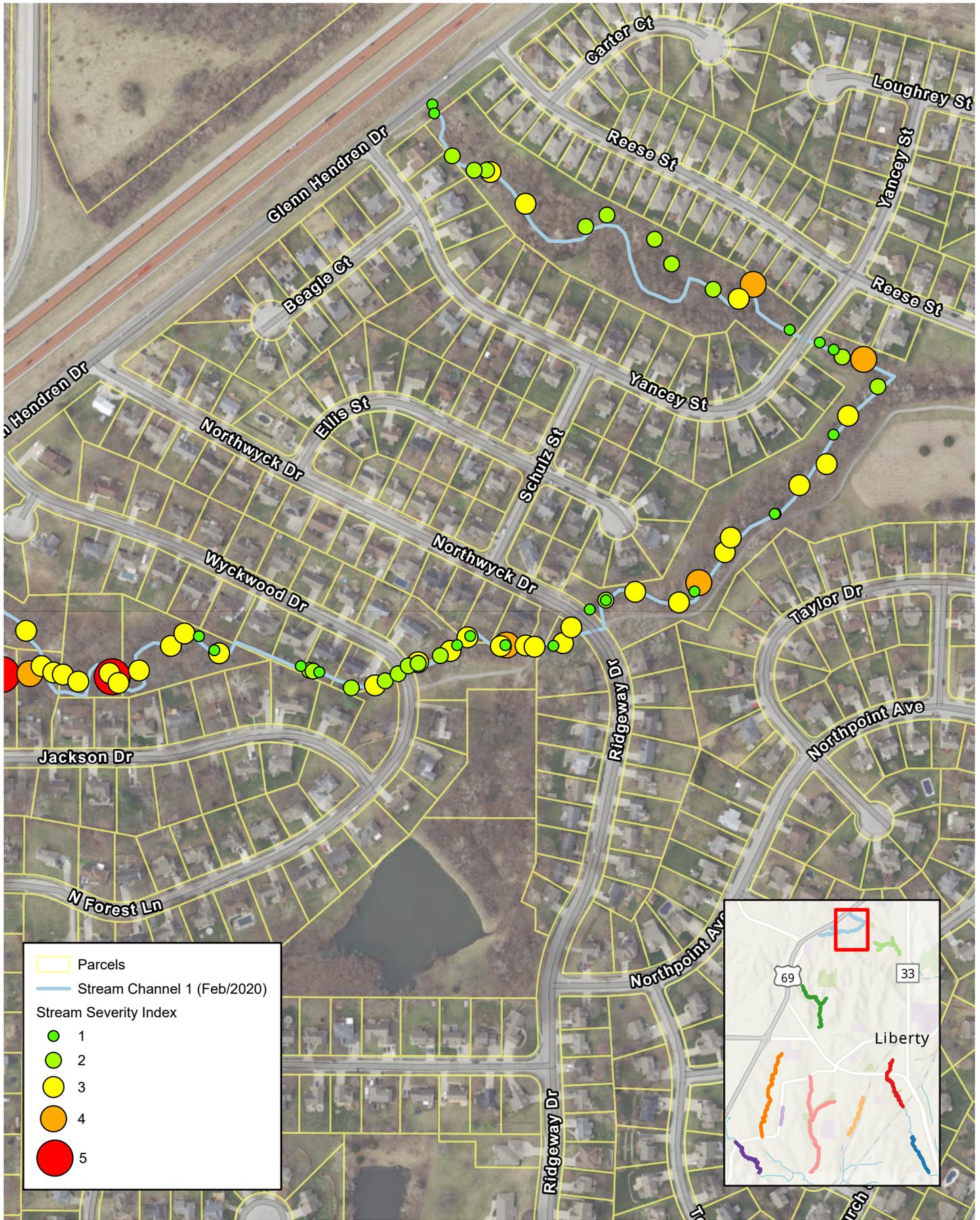
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STREAM BANK ASSESSMENT

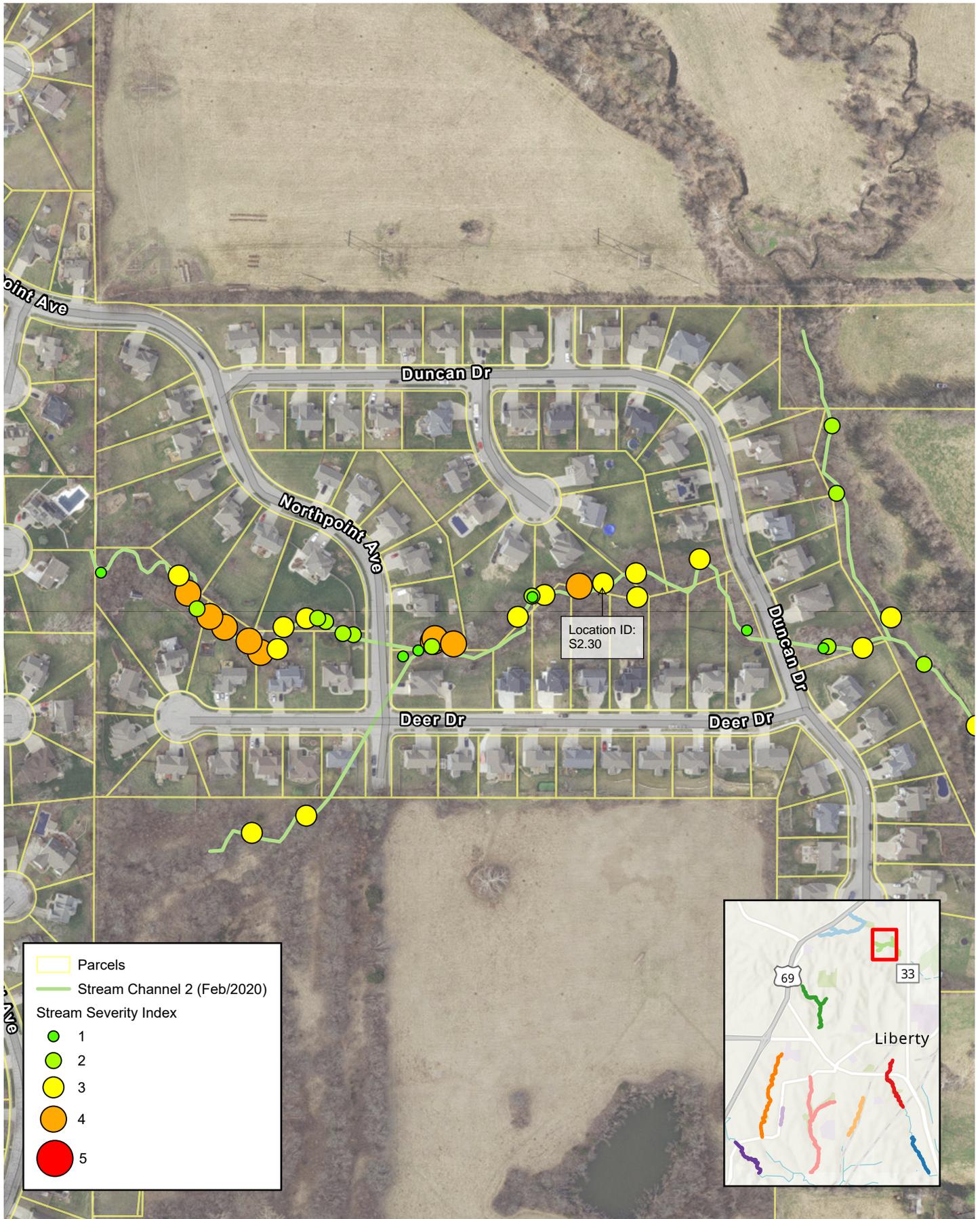
Figure 1-1



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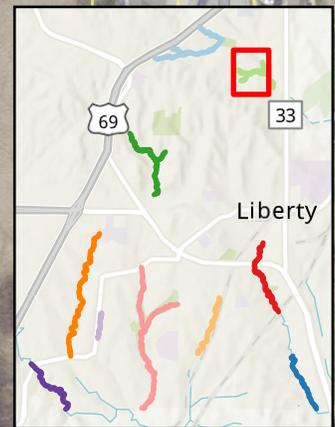
STREAM BANK ASSESSMENT

Figure 1-2



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	3
	4
	5

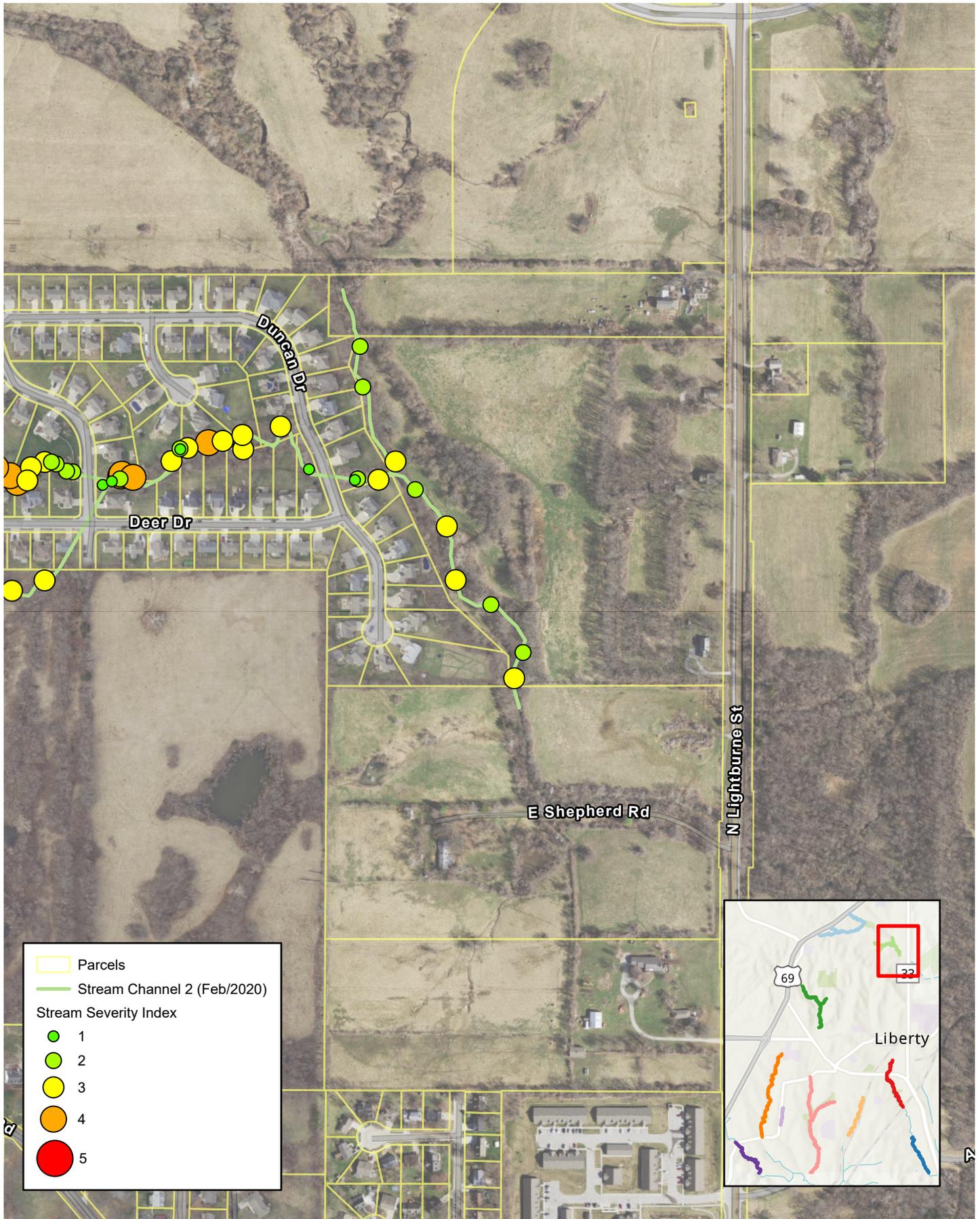
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S2.30



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STREAM BANK ASSESSMENT

Figure 1-3

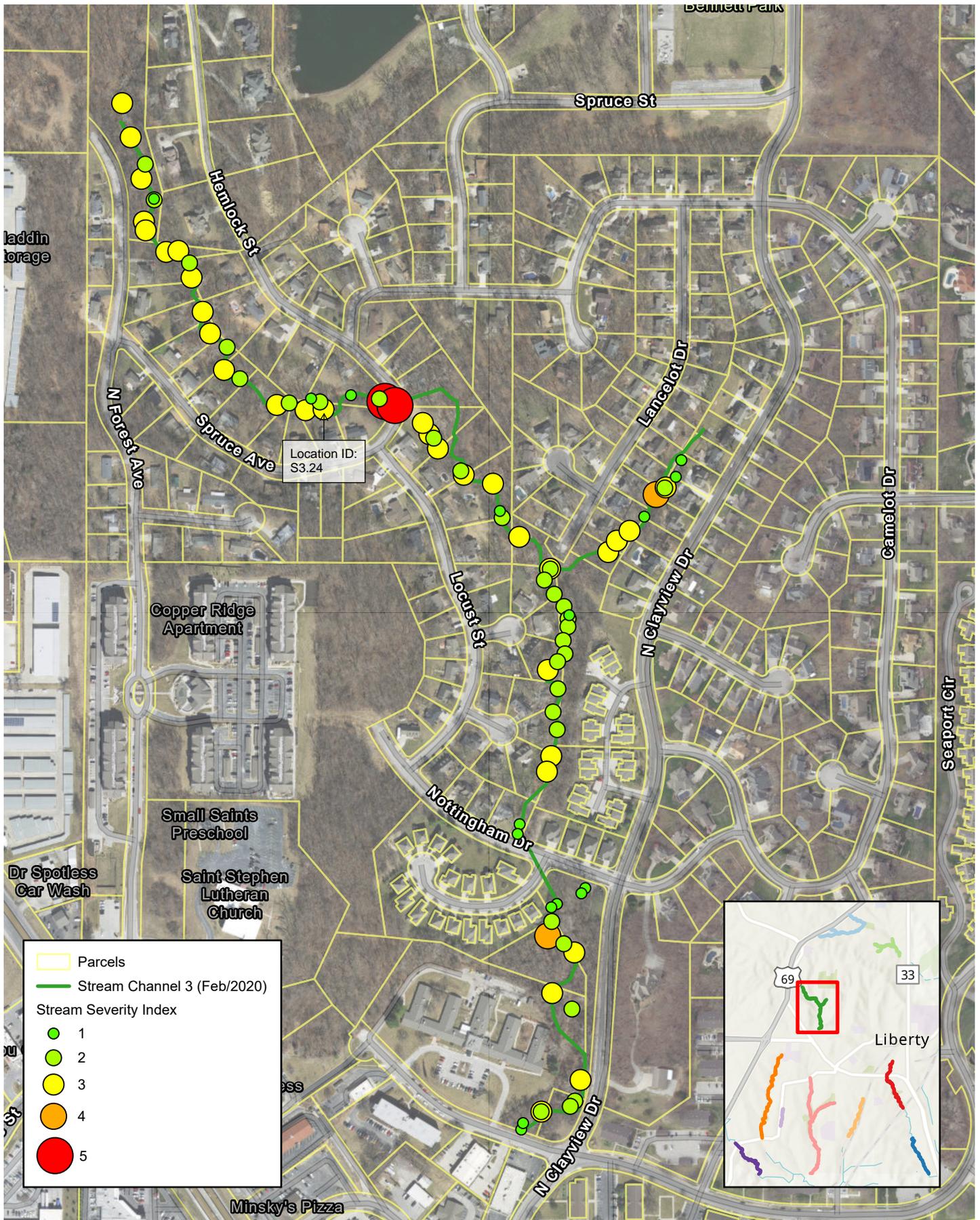


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STREAM BANK ASSESSMENT

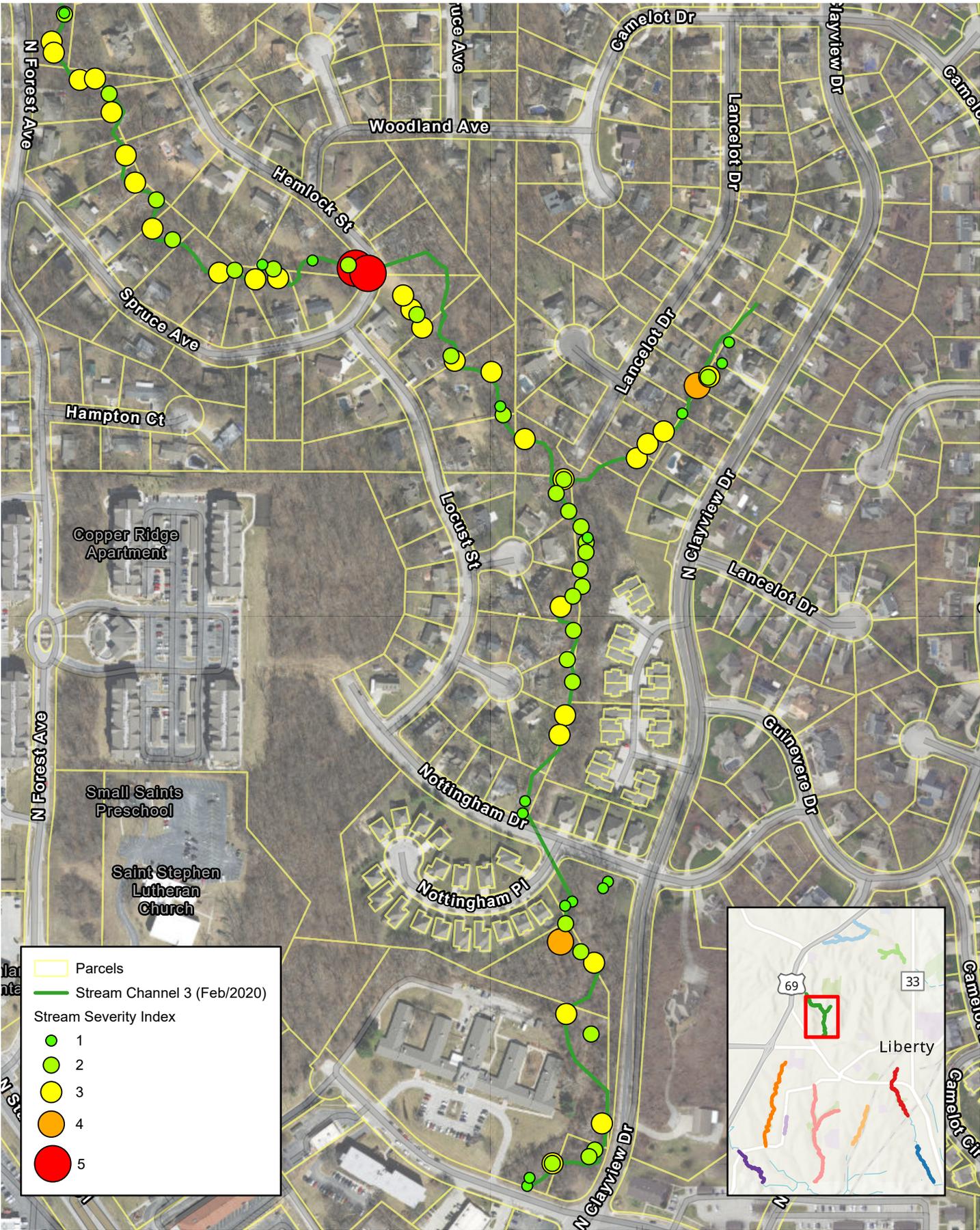
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STREAM BANK ASSESSMENT

Figure 1-5



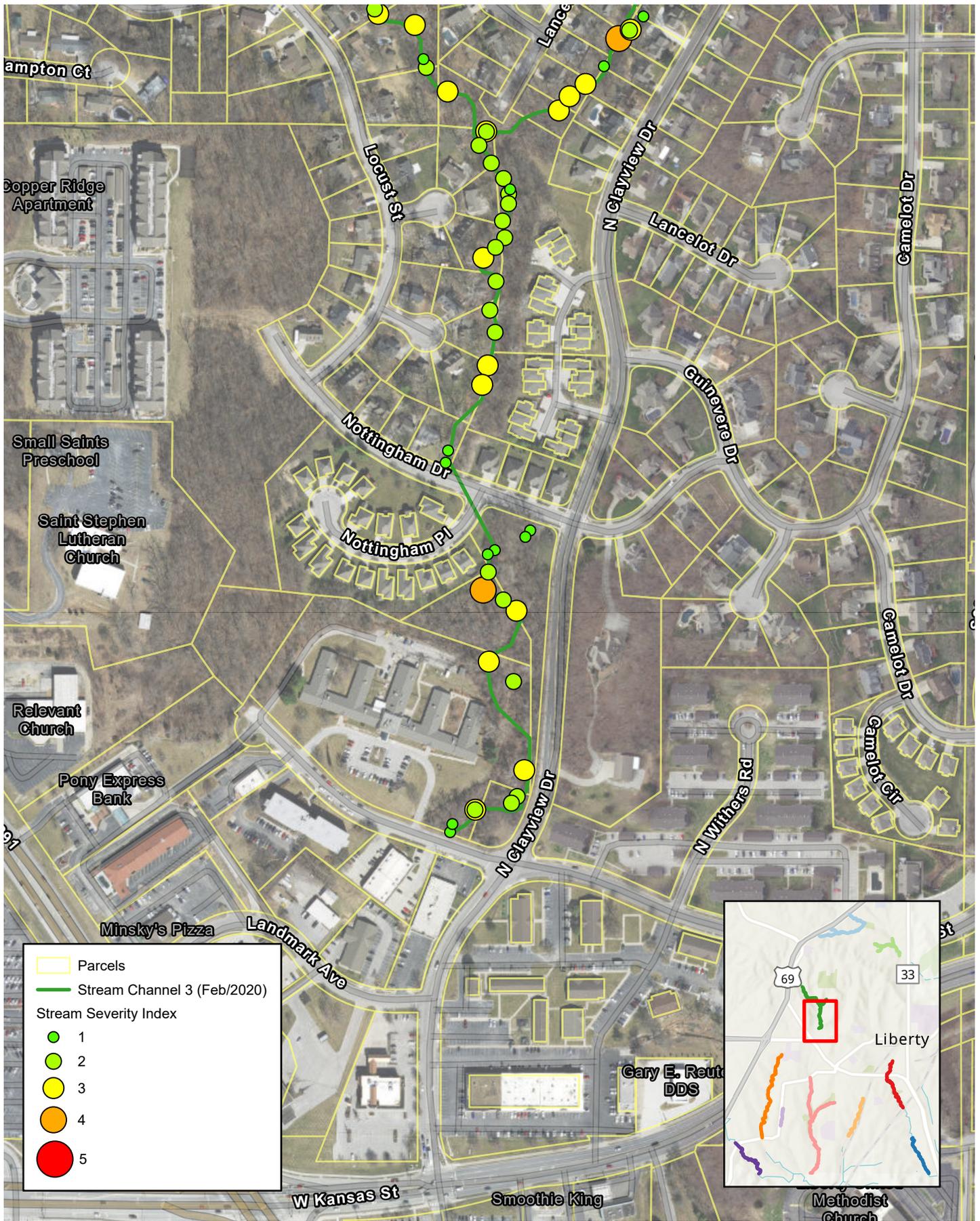
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	Stream Channel 3 (Feb/2020)
Stream Severity Index	
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	2
	3
	4
	5



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STREAM BANK ASSESSMENT

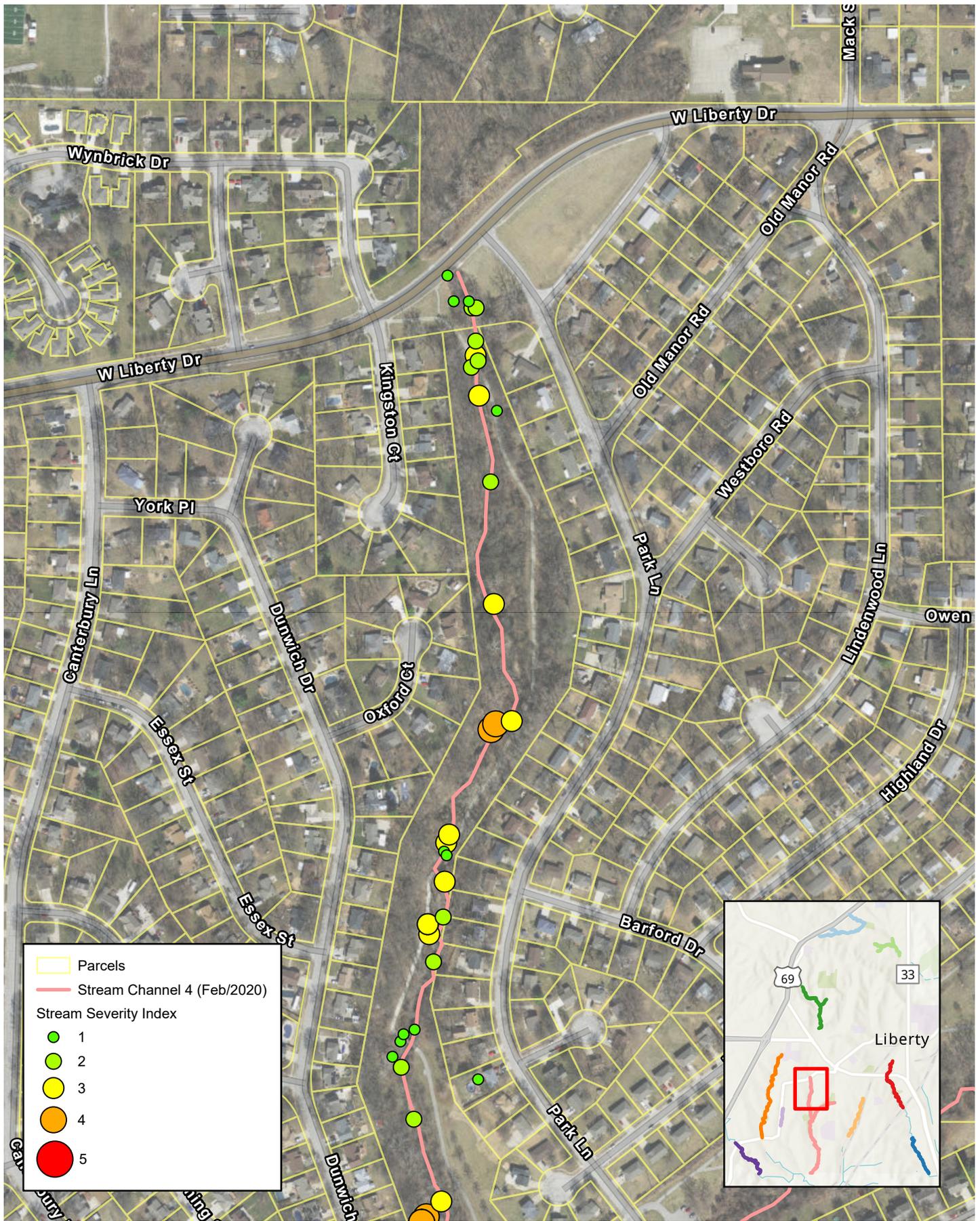
Figure 1-6



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STREAM BANK ASSESSMENT

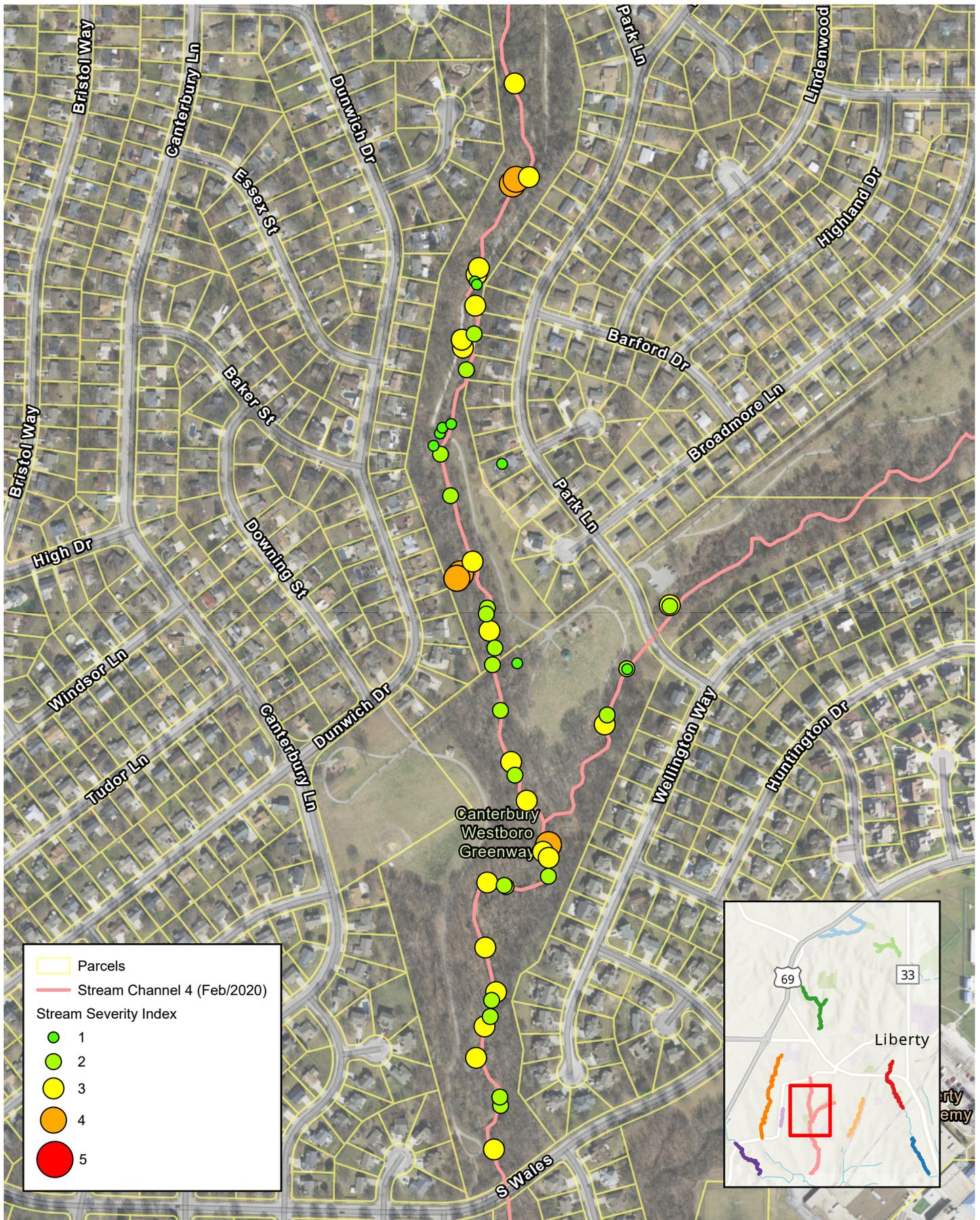
Figure 1-7



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STREAM BANK ASSESSMENT

Figure 1-8



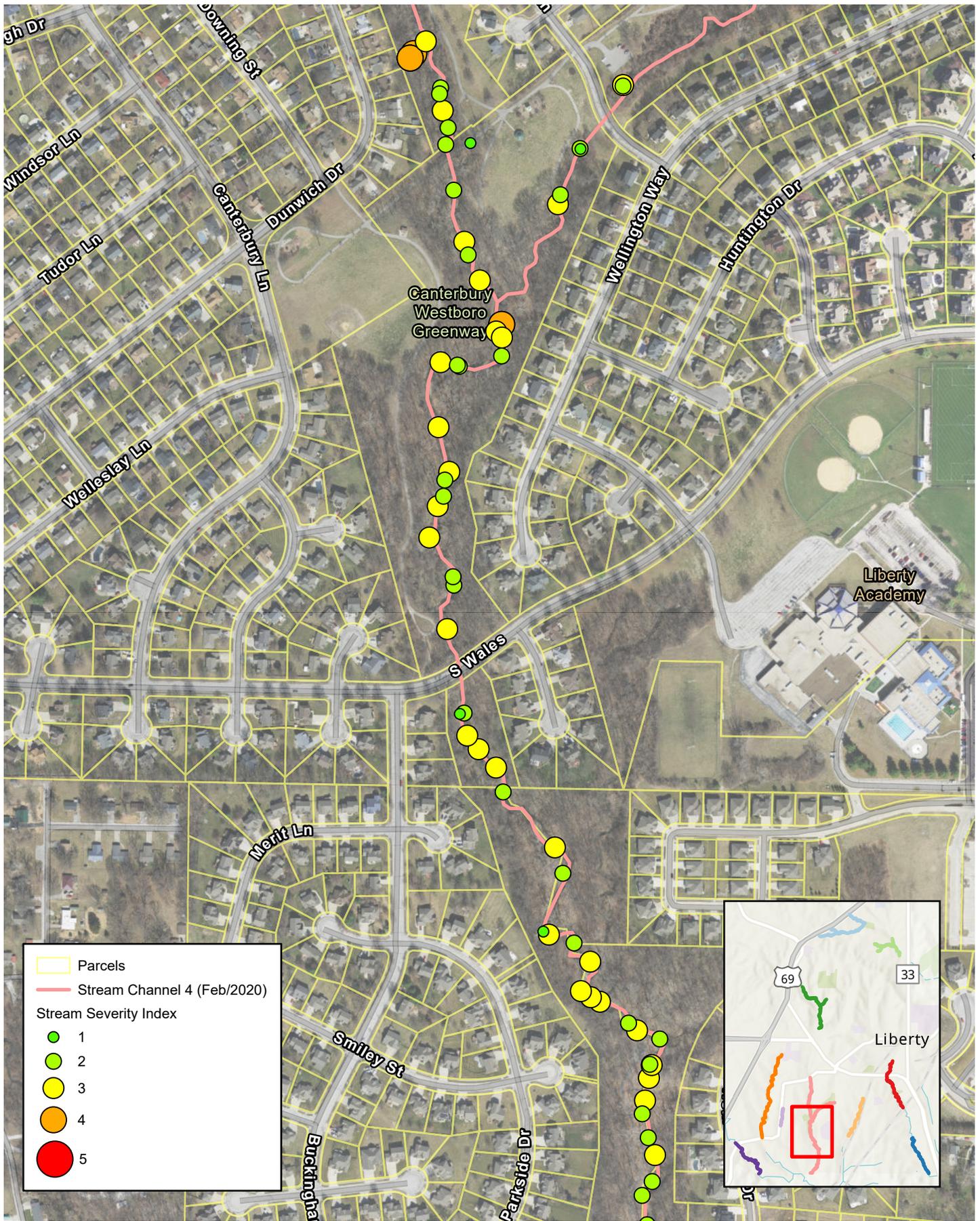
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Stream Severity Index	
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	3
	4
	5



0 320 Feet 

STREAM BANK ASSESSMENT

Figure 1-9

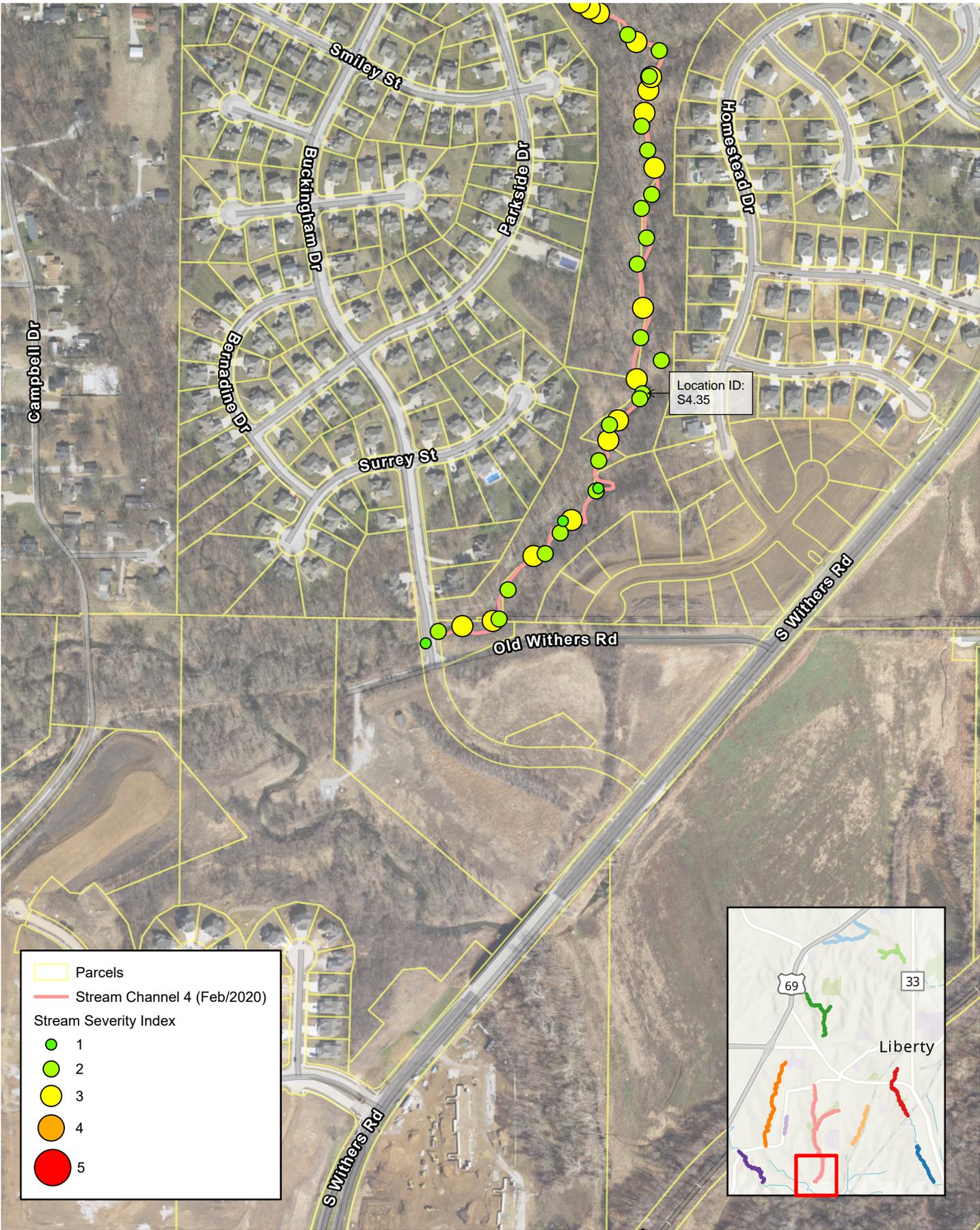


	Parcels
	Stream Channel 4 (Feb/2020)
Stream Severity Index	
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	3
	4
	5

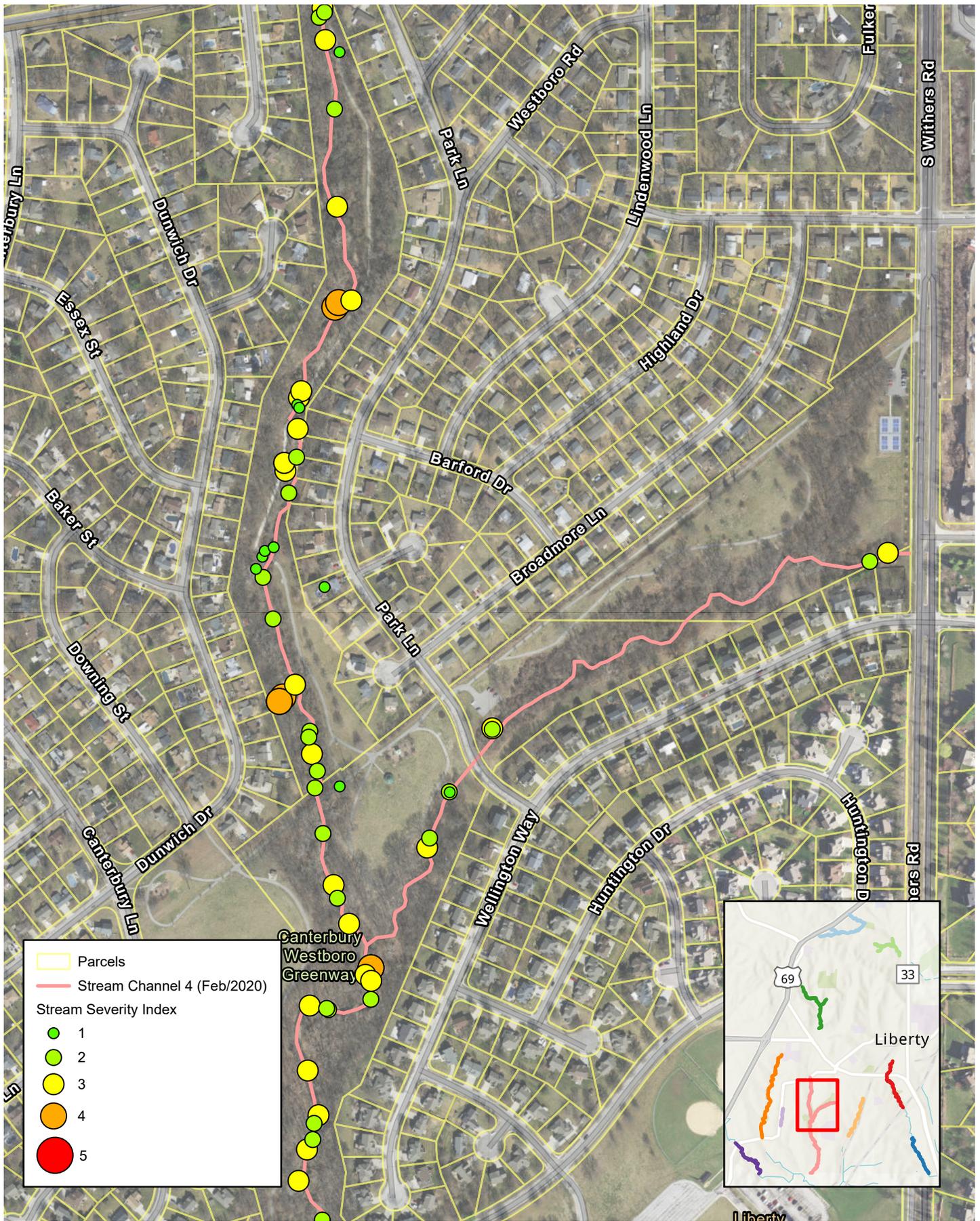


STREAM BANK ASSESSMENT

Figure 1-10



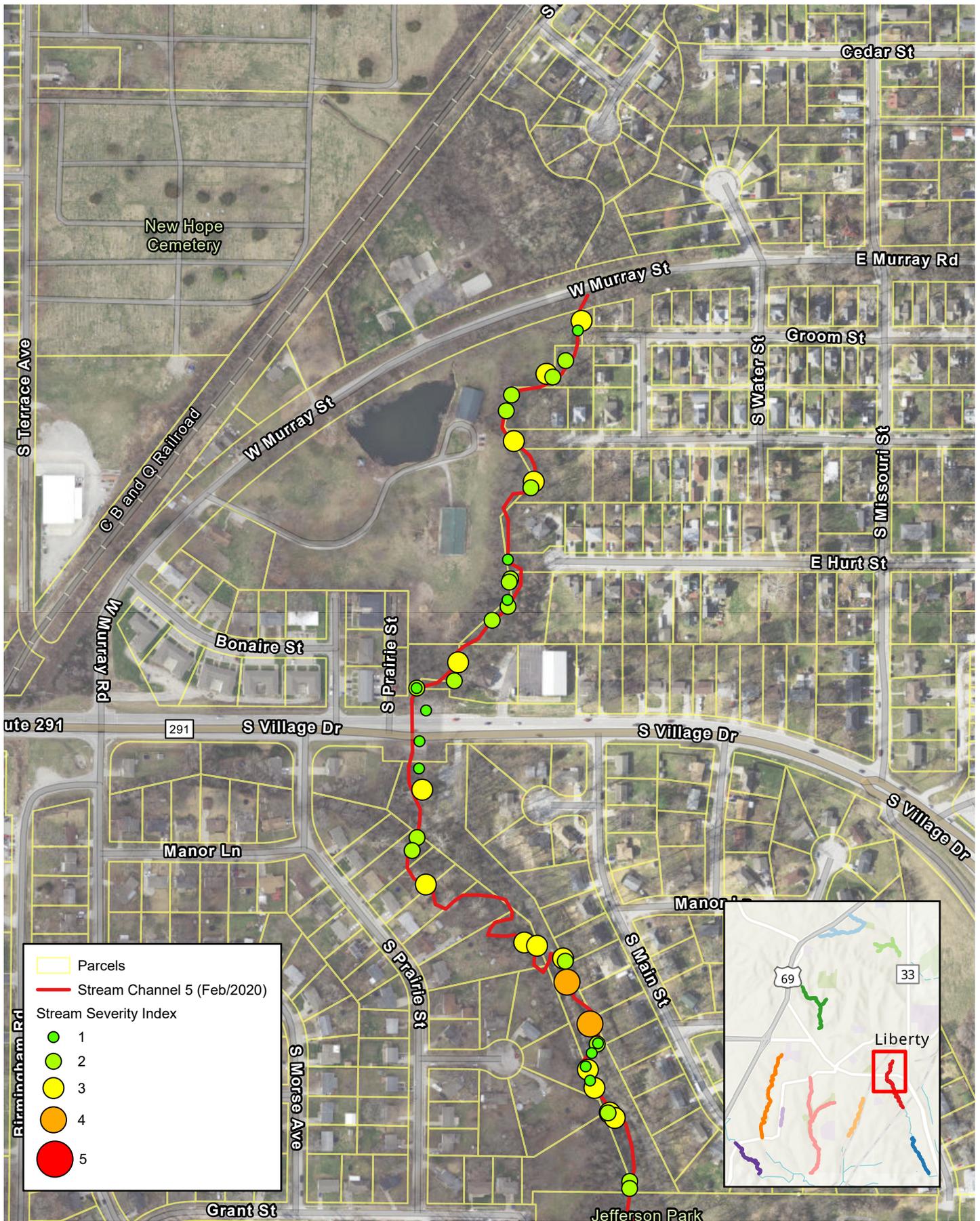
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Figure 1-12



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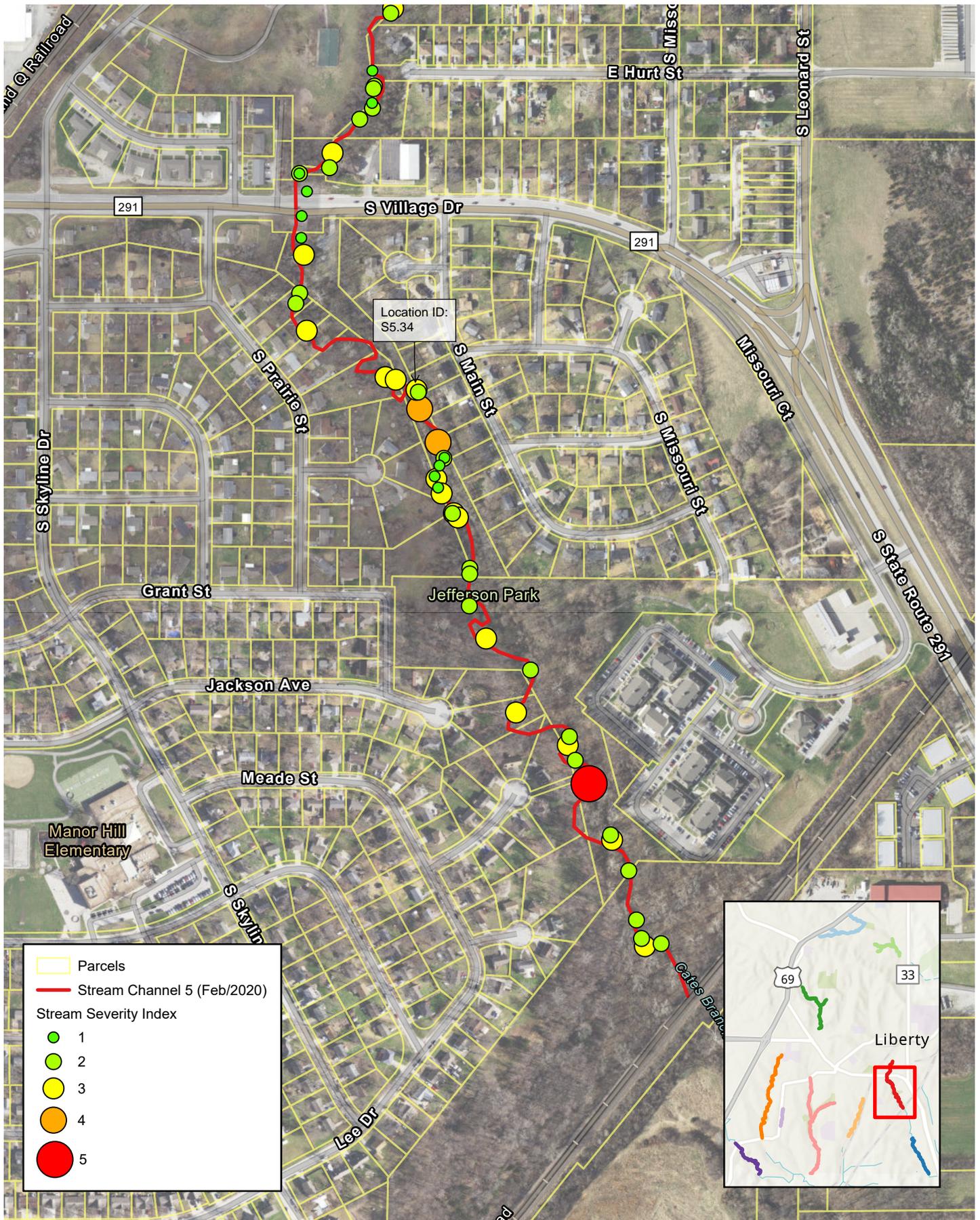
STREAM BANK ASSESSMENT

Figure 1-13



STREAM BANK ASSESSMENT

Figure 1-14

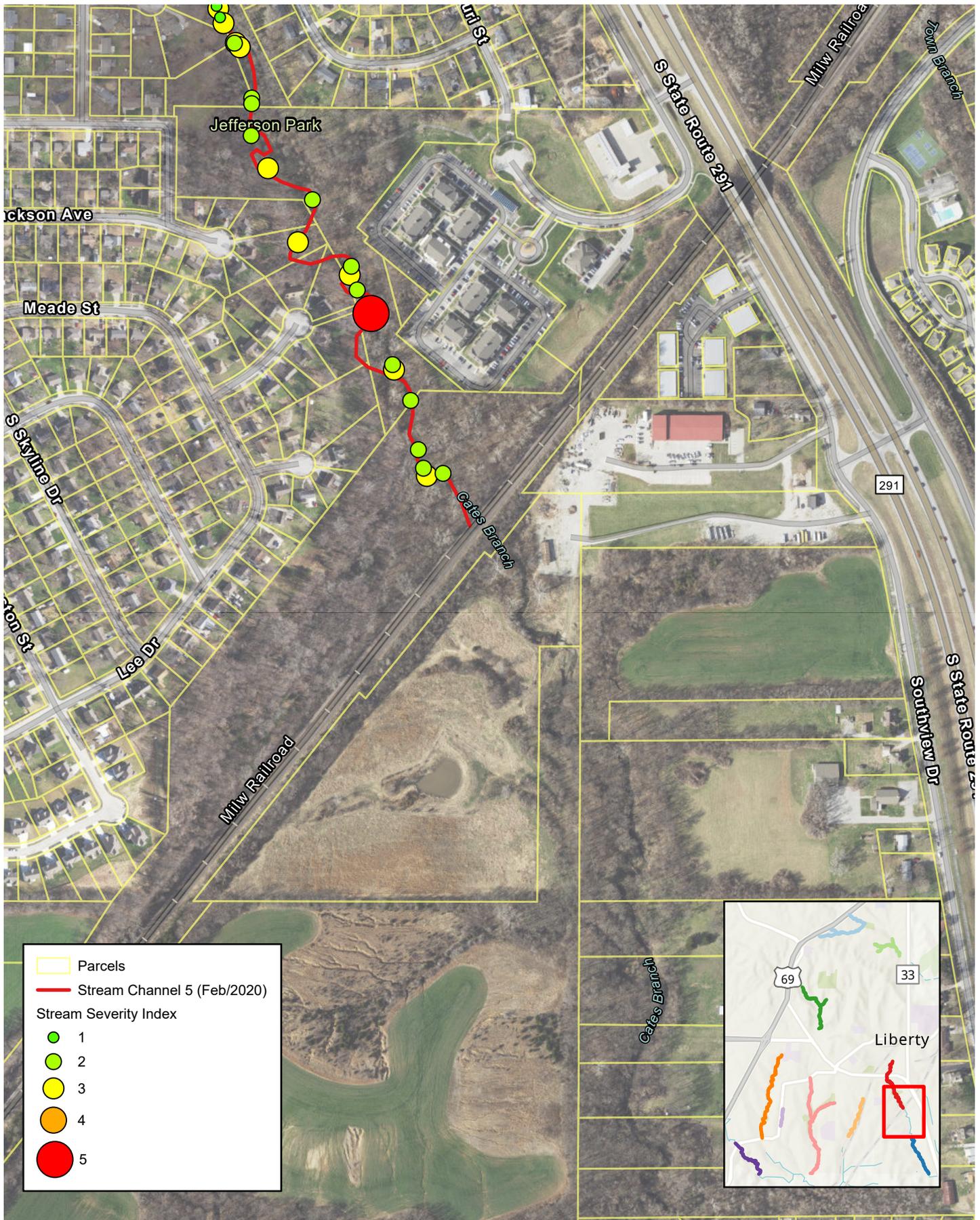


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STREAM BANK ASSESSMENT

Figure 1-15



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STREAM BANK ASSESSMENT

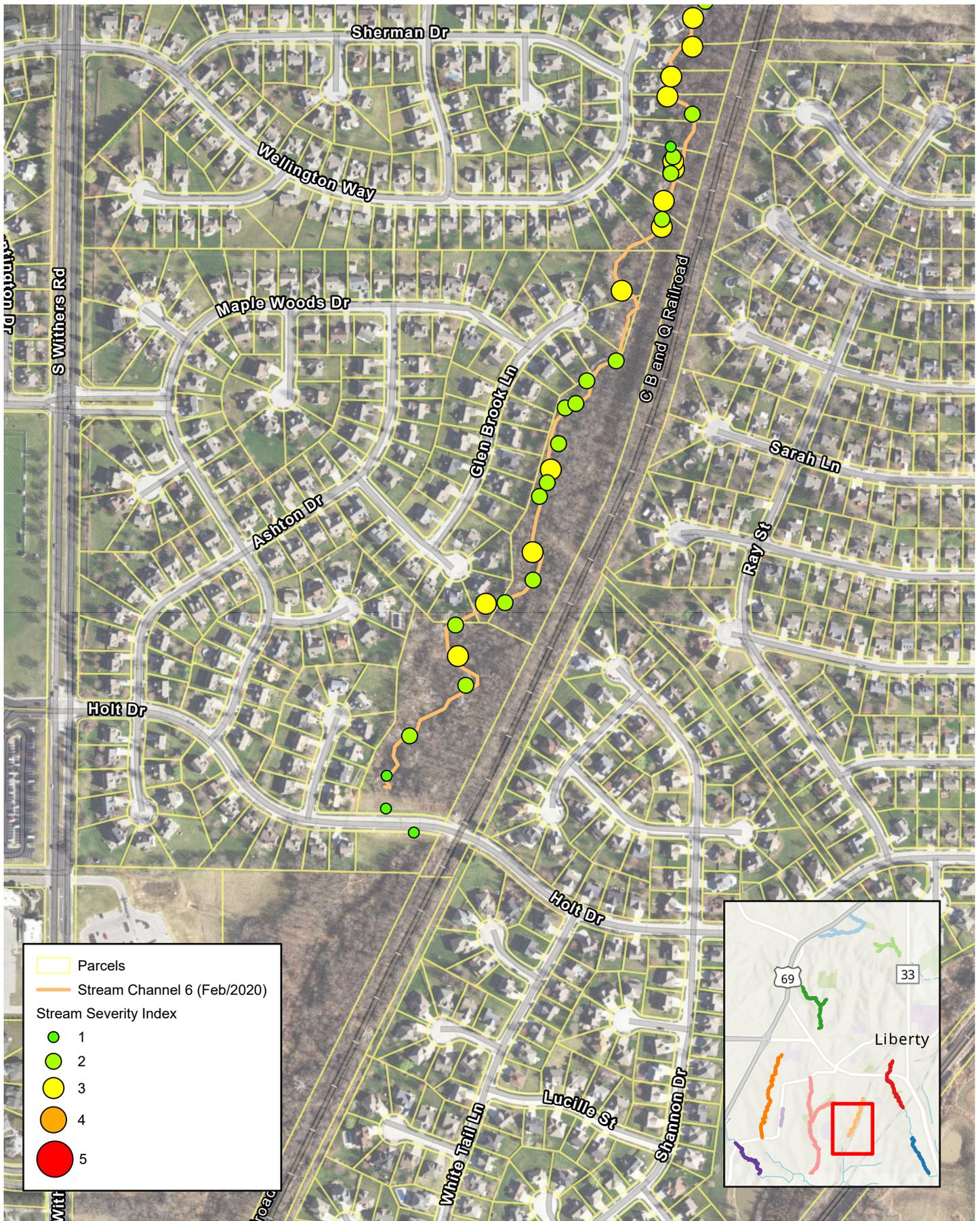
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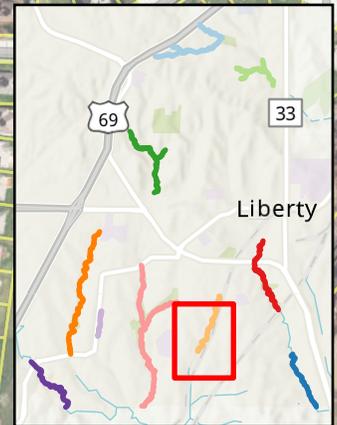
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STREAM BANK ASSESSMENT

Figure 1-17

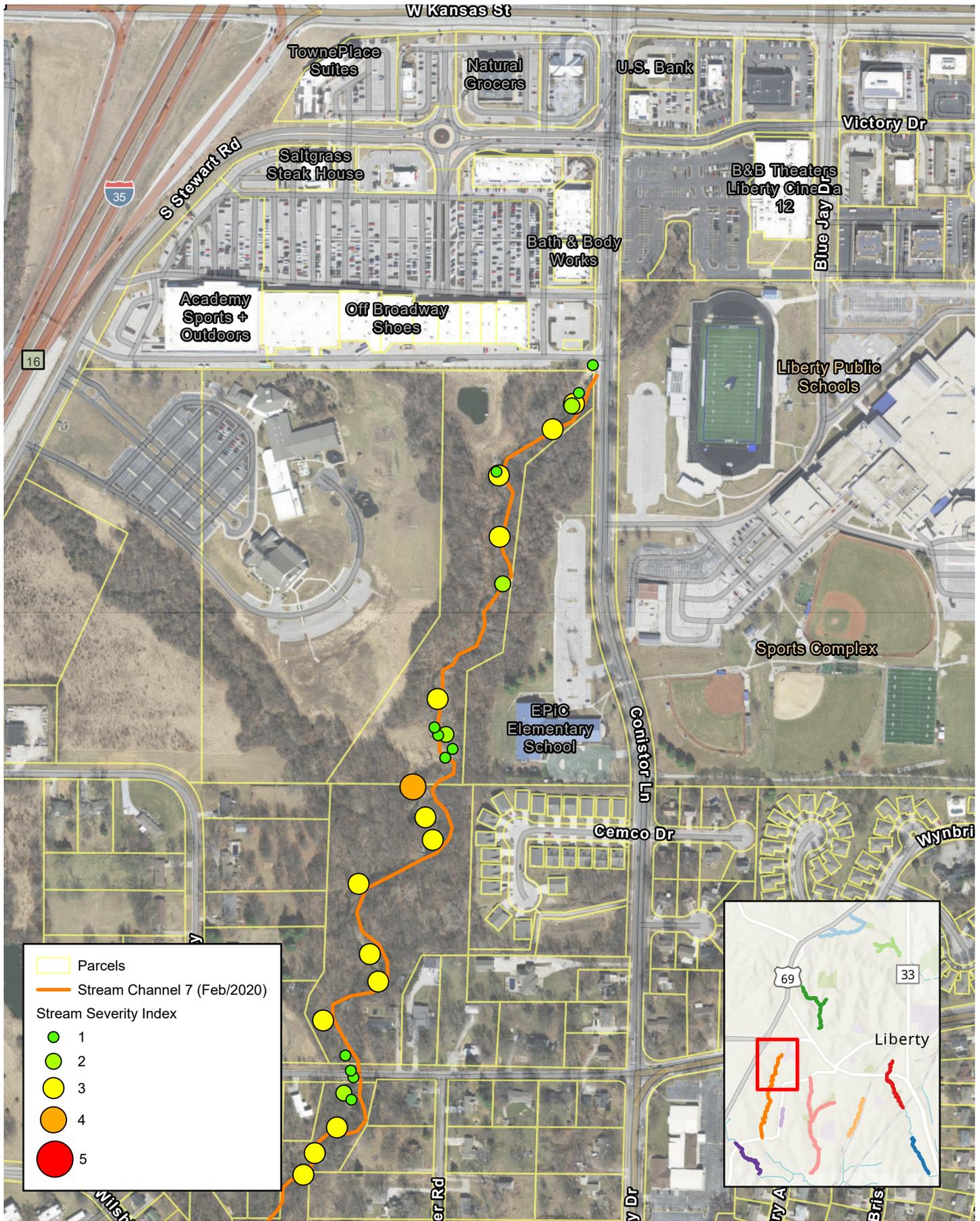


	Parcels
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Stream Severity Index	
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	3
	4
	5



STREAM BANK ASSESSMENT

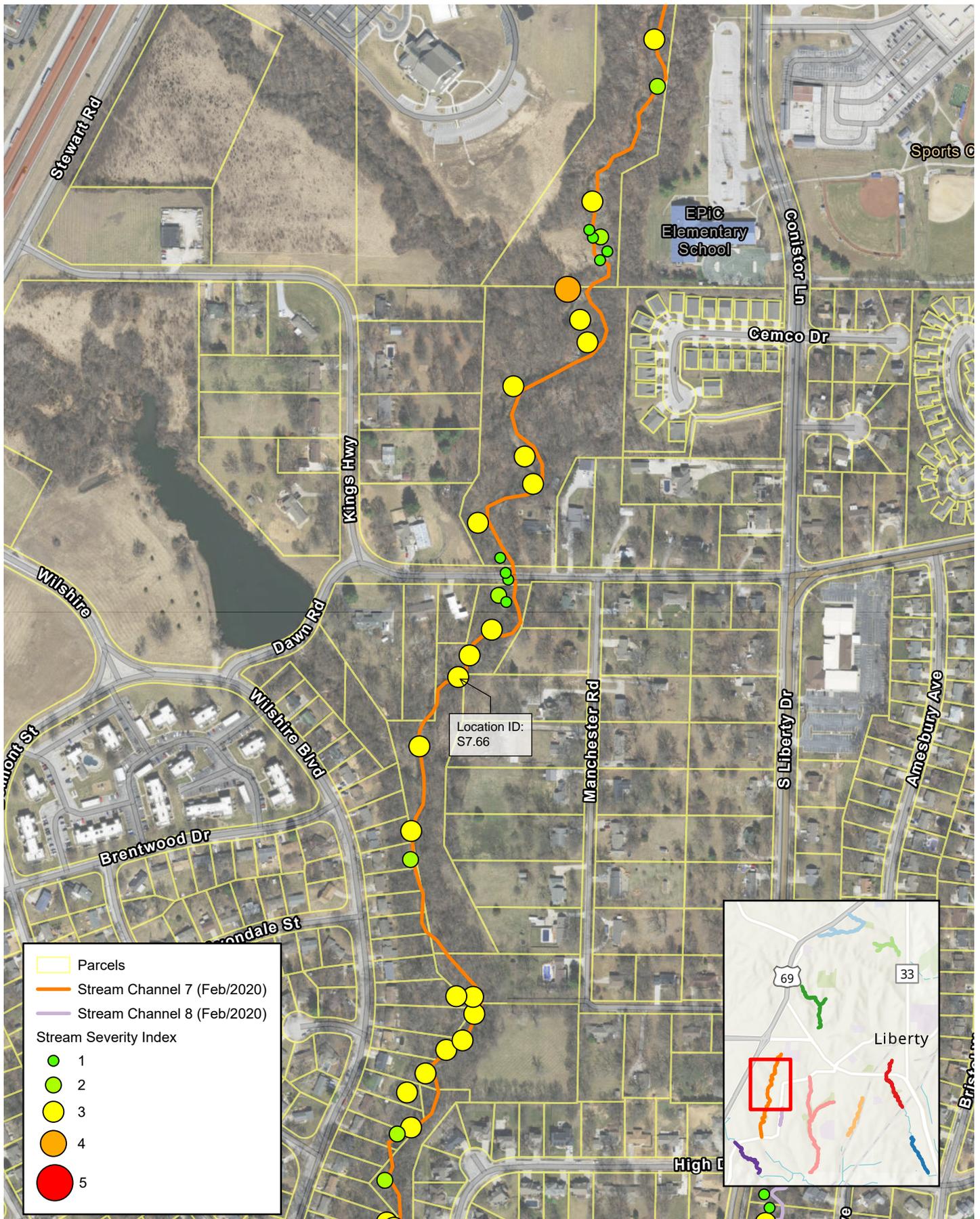
Figure 1-18



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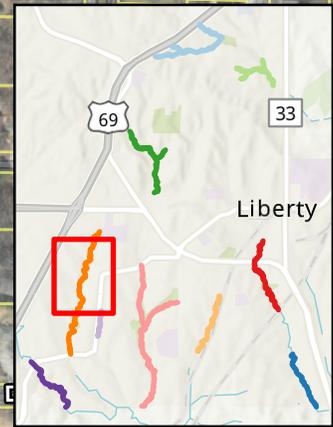
STREAM BANK ASSESSMENT

Figure 1-19



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	Stream Channel 8 (Feb/2020)
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	3
	4
	5

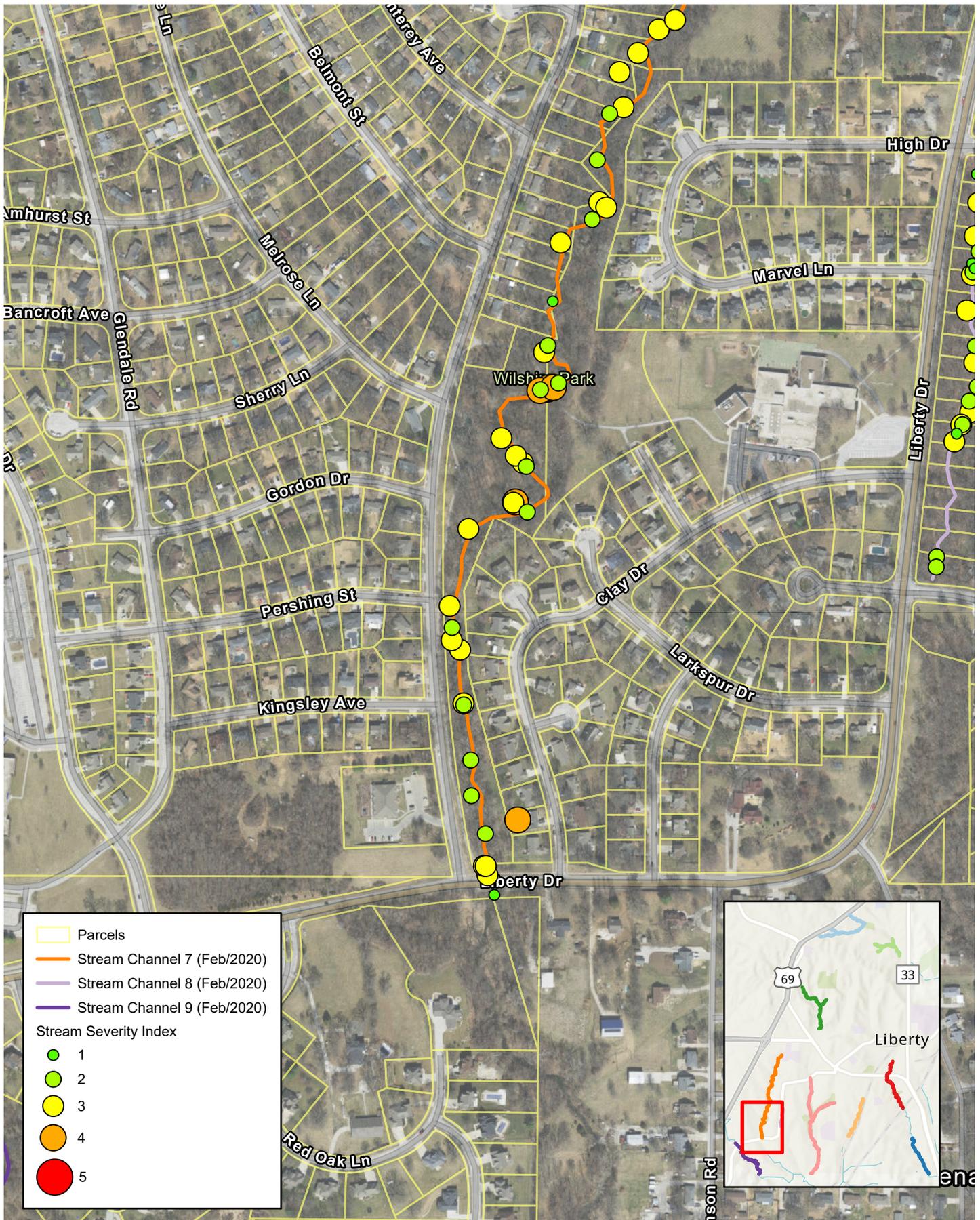
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STREAM BANK ASSESSMENT

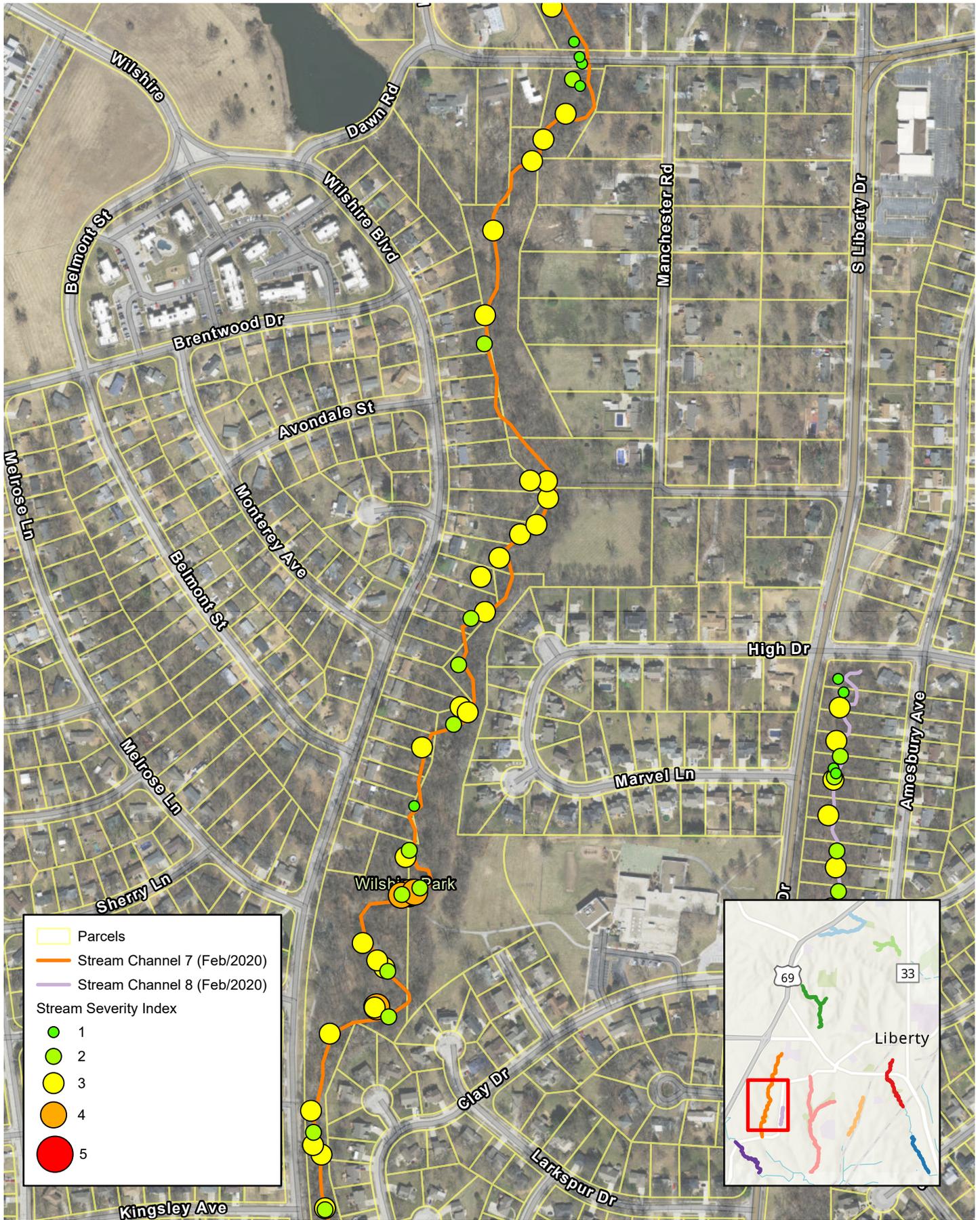
Figure 1-20



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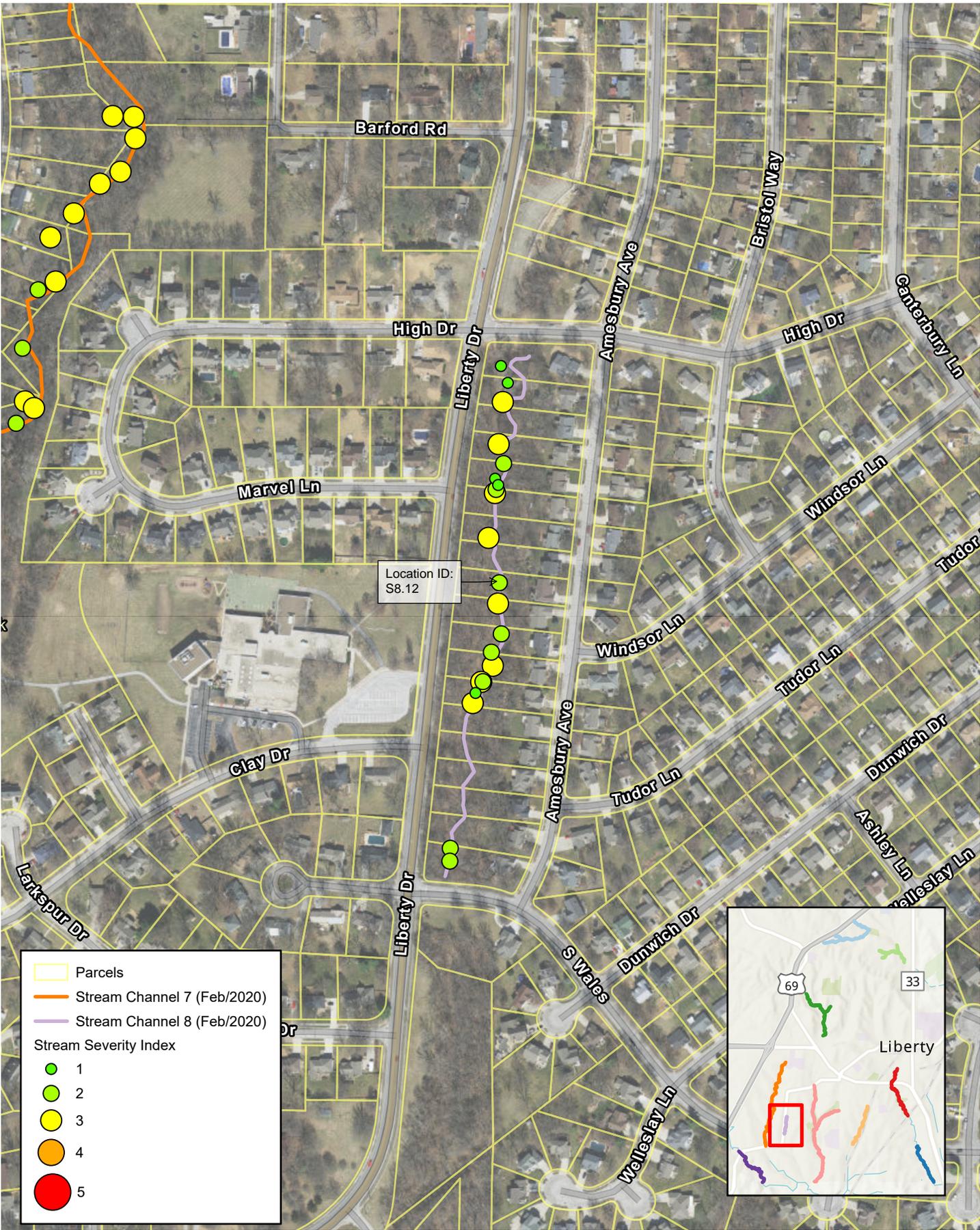
STREAM BANK ASSESSMENT

Figure 1-21



STREAM BANK ASSESSMENT

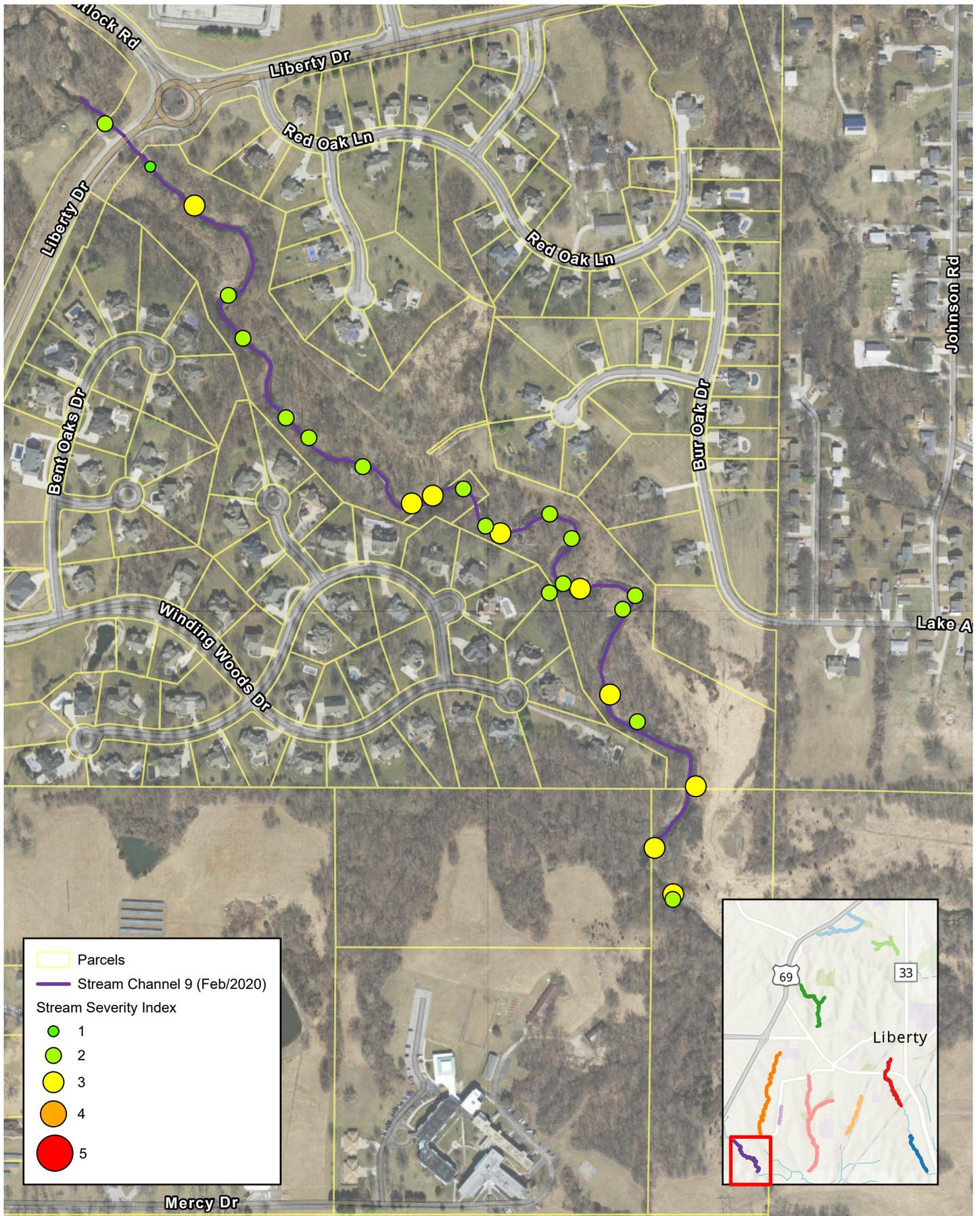
Figure 1-22



Parcels
 Stream Channel 7 (Feb/2020)
 Stream Channel 8 (Feb/2020)

Stream Severity Index

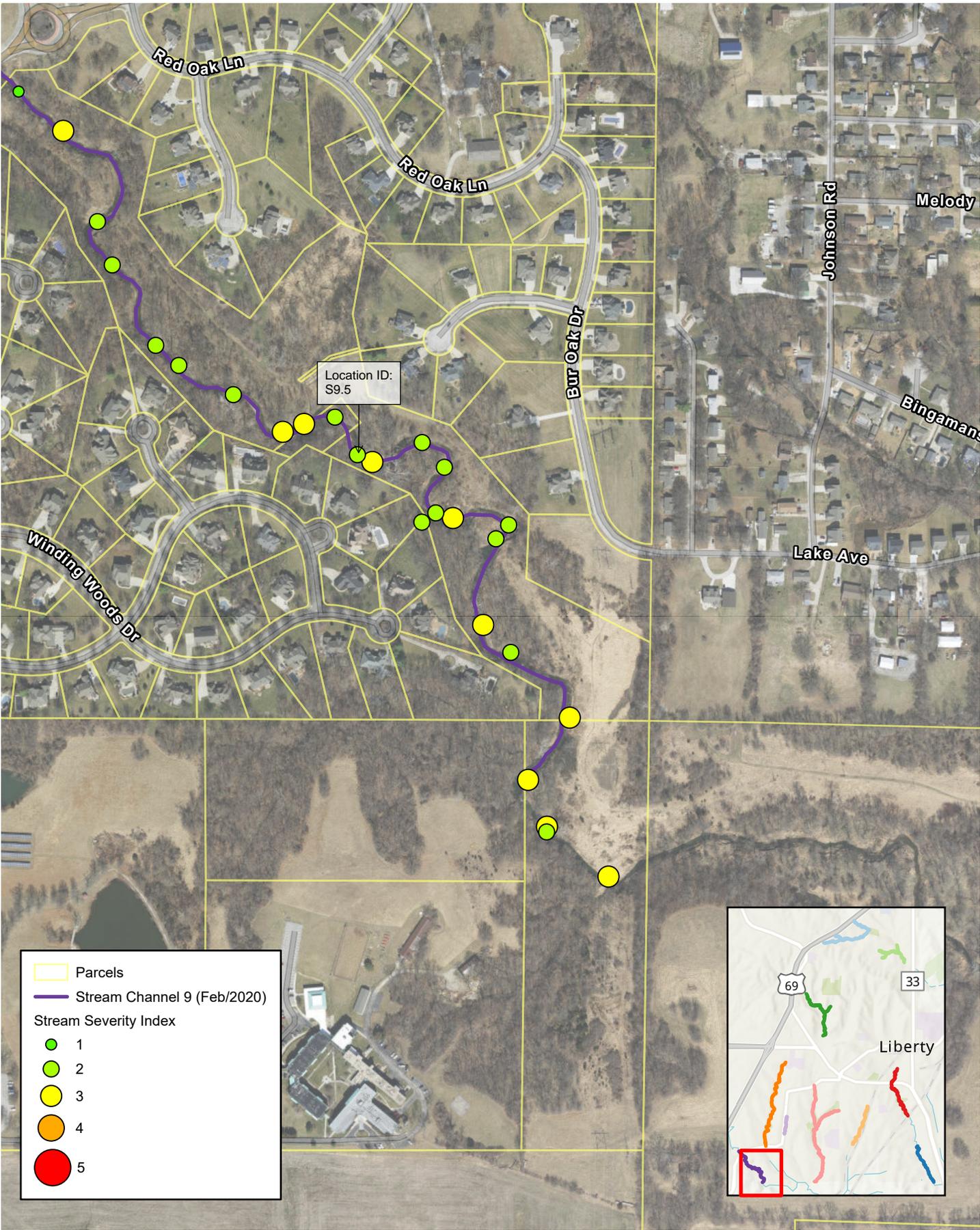
- 1
- 2
- 3
- 4
- 5



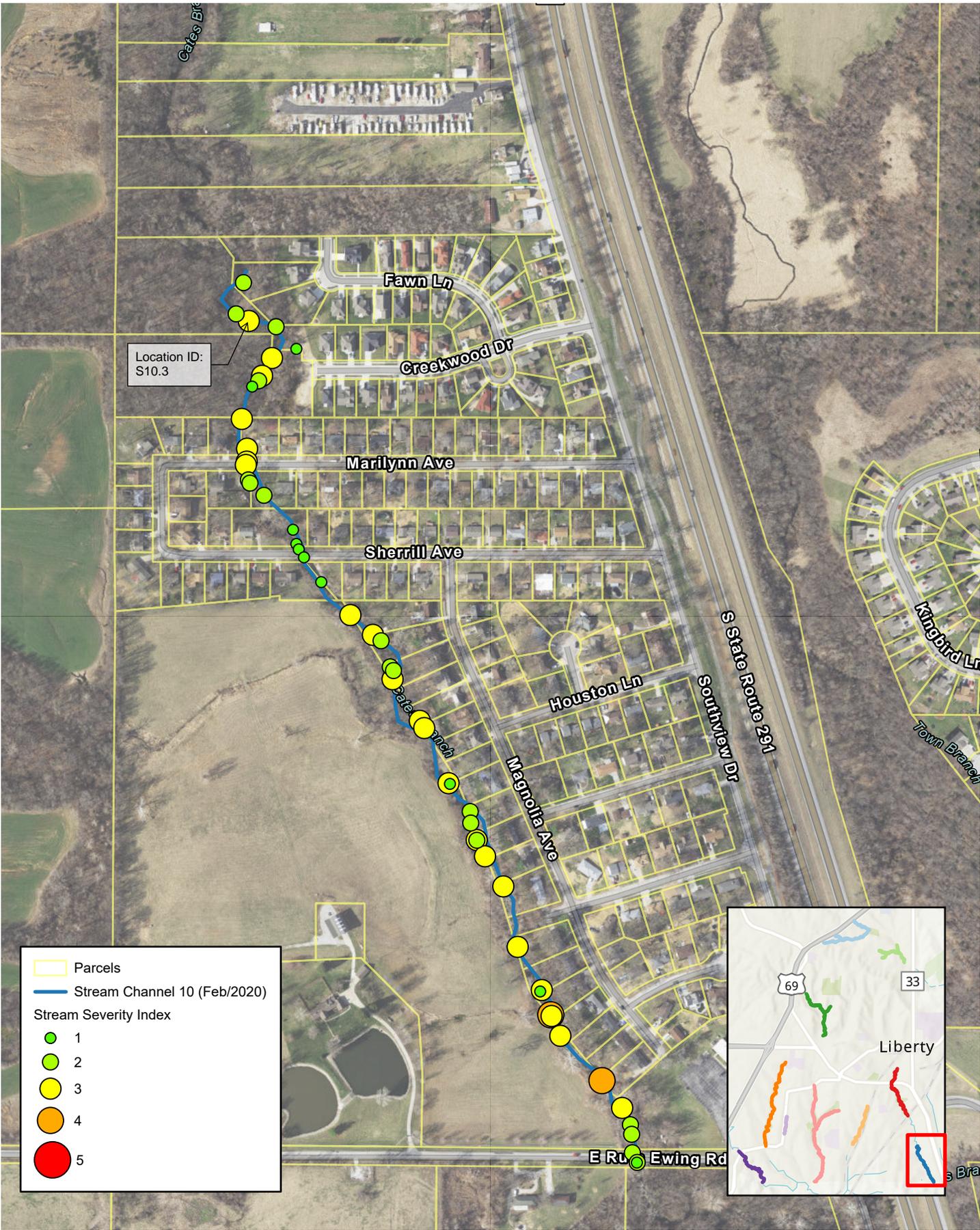
	Parcels
	Stream Channel 9 (Feb/2020)
Stream Severity Index	
	1
	2
	3
	4
	5



STREAM BANK ASSESSMENT
Figure 1-24



STREAM BANK ASSESSMENT
Figure 1-25

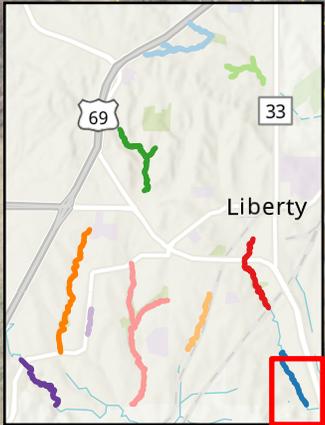


STREAM BANK ASSESSMENT

Figure 1-26



Parcels
 Stream Channel 10 (Feb/2020)
 Stream Severity Index
● 1
● 2
● 3
● 4
● 5



0 320 Feet

STREAM BANK ASSESSMENT

Figure 1-27

Appendix B

Stream Walk Survey Table

Location ID	Infrastructure at Risk	Description	Severity Rating
S1.1	Crossing	RCB.Slight erosion around walls.	2
S1.2	Sanitary Sewer	Manhole exposed	3
S1.3	Other Utilities	Conduit and exposed wire.	4
S1.4	Building	Nearby residential fencing.	2
S1.5	Bank Failure	Nearby residential fencing.	2
S1.6	Culvert	Culvert outfall.	1
S1.7	Building	Nearby residential fencing.	3
S1.8	Other	Sediment size	1
S1.9	Knickpoint	Change in channel bed slope.	2
S1.10	Building	Nearby residential fencing.	3
S1.11	Sanitary Sewer	Manhole in channel bed.	3
S1.12	Bank Failure	Bank eroding	2
S1.13	Knickpoint	Change in channel bed slope.	2
S1.14	Bank Failure	Bank eroding	3
S1.15	Bank Failure	Bank eroding	2
S1.16	Culvert	Culvert outlet to tributary.	1
S1.17	Building	Residential housing at risk from bank failure. Also a sewer manhole on bank.	4
S1.18	Sanitary Sewer	Exposed manhole adjacent to house.	4
S1.19	Knickpoint	Change in channel bed slope.	2
S1.20	Building	Both banks failing. House at risk.	3
S1.21	Bank Failure	Surfing trees	3
S1.22	Bank Failure	Bank is being undercut.	2
S1.23	Bank Failure	Bank eroding	3
S1.24	Bank Failure	Parts of the bank armored.	2
S1.25	Other	Tributary	1
S1.26	Other	Tributary	1
S1.27	Bank Failure	Bank eroding	3
S1.28	Bank Failure	Private pedestrian bridge supports indicate the stream has migrated 4 feet to the left bank since construction of the bridge.	2
S1.29	Building	Residential housing at risk from bank failure.	3
S1.30	Crossing	Culvert functioning well and in good condition.	1
S1.31	Crossing	Culvert functioning well and in good condition.	1
S1.32	Crossing	Culvert functioning well and in good condition.	1
S1.33	Crossing	Culvert functioning well and in good condition.	1
S1.34	Sanitary Sewer	Sewer pipe exposed. No leaks detected.	1
S1.35	Knickpoint	Change in channel bed slope.	2
S1.36	Building	Concrete retaining wall being undercut by stream. Residential house at risk from bank failure.	5
S1.37	Building	Residential housing at risk from bank failure. Banks eroding from both sides.	5
S1.38	Building	Residential housing at risk from bank failure. Banks eroding from both sides.	5
S1.39	Sanitary Sewer	Sewer line crossing exposed. Wood piling and putting pressure on top. At risk of breaking.	4
S1.40	Bank Failure	Both sides failing.	3
S1.41	Building	Residential fencing at risk from bank failure.	3
S1.42	Building	Residential housing at risk from bank failure. Rock wall along residence. Stream undercutting wall. Wall has a gravel base. Evidence of wall collapsing.	4
S1.43	Building	Right bank armoring causing left bank to fail.	3
S1.44	Knickpoint	Change in channel bed slope.	2
S1.45	Crossing	Culvert outlet.	1
S1.46	Crossing	RCB outlet. Right wall is collapsing.	3
S1.47	Knickpoint	Change in channel bed slope.	2
S1.48	Sanitary Sewer	Utility exposed. Potential for structure failure.	5
S1.49	Other	Exposed pipe crossing the stream	3
S1.50	Other Utilities	Utility pipe crossing. Dented in the center.	3
S1.51	Building	Residential housing at risk from bank failure.	3
S1.52	Bank Failure	Bank eroding	3
S1.53	Sanitary Sewer	Sewage odor present.	5
S1.54	Building	Residential housing at risk from bank failure.	3
S1.55	Bank Failure	Bank eroding	3
S1.56	Bank Failure	Bank eroding	3
S1.57	Bank Failure	Steep bank but low slope up to houses.	3
S1.58	Culvert	Culvert outfall.	1
S1.59	Other Utilities	Pipe outlet.	1
S1.60	Building	Bank eroding nearby backyard.	3
S1.61	Sanitary Sewer	Manhole in good condition. Bank is not at risk of failing.	1
S1.62	Knickpoint	Change in channel bed slope.	2

NOTE: Data is available digitally on the Liberty Stormwater Master Plan hub site - Stream Investigation tab.

Stream Walk Survey Table

Location ID	Infrastructure at Risk	Description	Severity Rating
S1.63	Sanitary Sewer	Pipe is exposed.	2
S1.64	Culvert	Culvert outfall.	1
S1.65	Building	Rip Rap on left bank causing right bank to fail.	3
S1.66	Building	Bank failing nearby fence and RCB.	3
S1.67	Crossing	RCB is overall in good condition. Some erosion around right bank wall.	2
S1.68	Crossing	RCB is overall in good condition. Some erosion around right bank wall.	2
S1.69	Crossing	RCB is overall in good condition. Some erosion around right bank wall.	2
S1.70	Crossing	RCB is overall in good condition. Some erosion around right bank wall.	2
S1.71	Other	RCB good conditions.	2
S1.72	Building	Both banks are failing. Residential along left bank.	3
S1.73	Other	Exposed pipe crossing the stream. Both banks are failing. Residential along left bank.	3
S1.74	Sanitary Sewer	Exposed sewer pipe in right bank.	2
S1.75	Sanitary Sewer	Sewer crossing.	1
S1.76	Building	Bank eroding nearby fence.	3
S1.77	Other Utilities	Exposed coax line.	1
S1.78	Bank Failure	Bank eroding	3
S1.79	Other Utilities	Old ceramic pipe.	1
S1.80	Building	Residential house at risk from bank failure.	4
S1.81	Sanitary Sewer	Sewer crossing. Abutments are eroding.	3
S1.82	Bank Failure	Both banks failing.	3
S1.83	Sanitary Sewer	Pipe crossing stream	1
S1.84	Crossing	RCB right wing wall eroding. Left wall is also but to a lesser degree.	3
S1.85	Crossing	RCB right wing wall eroding. Left wall is also but to a lesser degree.	3
S1.86	Crossing	Downstream from bridge	1
S1.87	Crossing	RCB downstream looks okay.	1
S1.88	Knickpoint	Change in channel bed slope. Knickpoint cause from RCB.	2
S1.89	Bank Failure	Left bank that is not armored is eroding.	3
S1.90	Other	Sediment size	1
S1.91	Building	Rock rip rap around culvert outfall nearby residence.	3
S1.92	Culvert	Culvert outfall	1
S1.93	Building	Residential housing nearby and could eventually be at risk from stream migration.	4
S1.94	Bank Failure	Bank eroding	3
S1.95	Bank Failure	Both banks failing.	3
S1.96	Culvert	Culvert outfall.	1
S1.97	Culvert	Culvert outfall.	1
S1.98	Bank Failure	Both banks eroding.	3
S1.99	Building	Bank eroding nearby residence.	3
S1.100	Other Utilities	Unknown pipe outlet.	1
S1.101	Building	Bank eroding nearby residence.	3
S1.102	Other	Sediment size	1
S1.103	Knickpoint	Change in channel bed slope. Potential sewer crossing.	2
S1.104	Building	Residential at risk from bank failing.	4
S1.105	Knickpoint	Change in channel bed slope.	2
S1.106	Crossing	CMP in good condition.	1
S1.107	Crossing	CMP in good condition.	1
S1.108	Crossing	CMP in good condition.	1
S1.109	Building	Residential housing at risk from bank failure.	4
S1.110	Bank Failure	Bank eroding	3
S1.111	Building	Residential not directly adjacent to stream bank but are at risk from stream migration.	2
S1.112	Building	Residential not directly adjacent to stream bank but are at risk from stream migration.	2
S1.113	Building	Both stream banks eroding. Residential not directly adjacent to stream bank but are at risk from stream migration.	2
S1.114	Knickpoint	Change in channel bed slope.	2
S1.115	Knickpoint	Change in channel bed slope.	2
S1.116	Other	Tributary	1
S1.117	Bank Failure	Both banks failing.	3
S1.118	Bank Failure	Both banks failing.	3
S1.119	Knickpoint	Change in channel bed slope.	2
S1.120	Building	Both banks failing. Residential housing at risk from bank failure.	2
S1.121	Knickpoint	Change in channel bed slope.	2
S1.122	Crossing	RCB in good condition.	1
S1.123	Crossing	RCB in good condition.	1
S2.1	Other	CMP exposed and bank eroding.	3
S2.2	Bank Failure	Both banks eroding on outside meander. Carries low flow.	3
S2.3	Crossing	CMP. Sediment buildup on left inside wall.	2
S2.4	Crossing	CMP. Sediment buildup on left inside wall.	2

NOTE: Data is available digitally on the Liberty Stormwater Master Plan hub site - Stream Investigation tab.

Stream Walk Survey Table

Location ID	Infrastructure at Risk	Description	Severity Rating
S2.5	Knickpoint	Change in channel bed slope.	2
S2.6	Bank Failure	Bank eroding	2
S2.7	Other	Sediment size	1
S2.8	Bank Failure	Bank eroding	3
S2.9	Building	Fence and shed at risk from bank failure.	3
S2.10	Bank Failure	Log across stream	3
S2.11	Building	House at risk from bank failure.	4
S2.12	Building	Residential housing at risk from bank failure.	4
S2.13	Building	Residential housing at risk from bank failure.	4
S2.14	Building	Residential housing at risk from bank failure.	4
S2.15	Knickpoint	Change in channel bed slope.	2
S2.16	Building	Residential housing at risk from bank failure.	4
S2.17	Bank Failure	Bank eroding	3
S2.18	Crossing	Concrete pipe and cmp outlet. In good condition.	1
S2.19	Crossing	CMP and concrete pipe.	1
S2.20	Crossing	CMP and concrete pipe. In good condition.	1
S2.21	Knickpoint	Change in channel bed slope. Log jam.	2
S2.22	Building	Residential housing at risk from bank failure.	4
S2.23	Building	Residential housing at risk from bank failure.	4
S2.24	Building	Residential housing at risk from bank failure.	4
S2.25	Bank Failure	Bank eroding with hairy roots	3
S2.26	Culvert	Culvert outfall.	1
S2.27	Knickpoint	Change in channel bed slope.	2
S2.28	Bank Failure	Bank eroding with hairy roots	3
S2.29	Building	Residential housing at risk from bank failure.	4
S2.30	Building	Residential housing at risk from bank failure.	3
S2.31	Other	Sediment size.	1
S2.32	Bank Failure	Bank eroding.	3
S2.33	Building	Residential housing at risk from bank failure.	3
S2.34	Building	Residential housing at risk from bank failure.	3
S2.35	Crossing	Double CMP. In good condition.	1
S2.36	Crossing	Double CMP. In good condition.	1
S2.37	Knickpoint	Change in channel bed slope.	2
S2.38	Building	Residential housing at risk from bank failure.	3
S2.39	Bank Failure	Banks are steep but appear stable.	3
S2.40	Knickpoint	Long knickpoint on bedrock.	2
S2.41	Knickpoint	Change in channel bed slope.	2
S2.42	Bank Failure	Banks are steep but appear stable.	3
S2.43	Bank Failure	Banks are eroding.	3
S2.44	Knickpoint	Change in channel bed slope.	2
S2.45	Bank Failure	Banks are eroding.	3
S2.46	Building	Residential buildings at low risk from bank failure.	2
S2.47	Bank Failure	Bank eroding.	2
S3.1	Bank Failure	Bank eroding.	3
S3.2	Other	Sediment size	1
S3.3	Bank Failure	Bank eroding.	3
S3.4	Building	Residential housing at risk from bank failure.	3
S3.5	Bank Failure	Bank eroding.	3
S3.6	Culvert	Culvert outfall	1
S3.7	Building	Bank eroding.	2
S3.8	Bank Failure	Bank eroding with hairy roots	3
S3.9	Sanitary Sewer	Exposed manhole and concrete pipe.	3
S3.10	Building	Residential housing at risk from bank failure.	3
S3.11	Bank Failure	Left bank is armored causing the inside meander bank to fail.	3
S3.12	Knickpoint	Change in channel bed slope.	2
S3.13	Building	House close to left bank. Right bank recently failed pushing the stream against the left bank and causing it to erode.	3
S3.14	Building	Outbuilding is close to bank and at risk from bank failure.	3
S3.15	Bank Failure	Bank eroding with hairy roots	3
S3.16	Bank Failure	Bank eroding	2
S3.17	Building	Residential housing at risk from bank failure.	3
S3.18	Bank Failure	Bank eroding with hairy roots	3
S3.19	Bank Failure	Bank eroding	3
S3.20	Bank Failure	Bank eroding with hairy roots	2
S3.21	Building	Residential housing at risk from bank failure.	3
S3.22	Building	Residential housing next to a bank eroding with hairy roots	2

NOTE: Data is available digitally on the Liberty Stormwater Master Plan hub site - Stream Investigation tab.

Stream Walk Survey Table

Location ID	Infrastructure at Risk	Description	Severity Rating
S3.23	Culvert	Culvert outfall.	1
S3.24	Building	Residential at risk from bank failure.	3
S3.25	Sanitary Sewer	No risk from erosion.	1
S3.26	Crossing	RCB entrance is blocked by debris. Water may be flowing underneath or still entering RCB to some capacity.	5
S3.27	Knickpoint	Change in channel bed slope.	2
S3.28	Crossing	Culvert appears to still be capturing all of the creeks flow.	2
S3.29	Crossing	Culvert appears to still be capturing all of the creeks flow.	2
S3.30	Crossing	RCB entrance is blocked by debris. Water may be flowing underneath or still entering RCB to some capacity.	5
S3.31	Bank Failure	Bank eroding with hairy roots	3
S3.32	Bank Failure	Bank eroding with hairy roots	3
S3.33	Other	Tributary	1
S3.34	Bank Failure	Private pedestrian bridge.	2
S3.35	Bank Failure	Bank eroding with hairy roots	3
S3.36	Building	Residential building at risk from bank failure.	3
S3.37	Sanitary Sewer	Manhole not at immediate risk from bank erosion.	1
S3.38	Knickpoint	Change in channel bed slope.	2
S3.39	Building	Residential building at risk from bank failure. (fence is at the edge of the bank)	3
S3.40	Knickpoint	Change in channel bed slope.	2
S3.41	Sanitary Sewer	Manhole located directly within the channel.	3
S3.42	Building	Residential housing at risk from bank failure.	3
S3.43	Other	Sediment size	1
S3.44	Building	Residential housing at risk from bank failure. Building foundation close to bank and at risk. Bank failure moderate.	3
S3.45	Building	Multiple residential at risk from bank failure.	3
S3.46	Culvert	Culvert outfall.	1
S3.47	Other Utilities	Electric line exposed.	4
S3.48	Knickpoint	Change in channel bed slope.	2
S3.49	Building	Bank eroding with risk of failure nearby residence. Not an immediate threat.	3
S3.50	Crossing	Culvert outfall	1
S3.51	Crossing	Culvert outfall	1
S3.52	Building	Residential housing at risk from bank failure. Bank failure not imminent.	2
S3.53	Bank Failure	Bank eroding with hairy roots	2
S3.54	Building	Residential housing at risk from bank failure. Bank failure not imminent.	2
S3.55	Other Utilities	Old storm sewer outlet.	1
S3.56	Knickpoint	Change in channel bed slope.	2
S3.57	Other	Sediment size	1
S3.58	Bank Failure	Bank eroding with hairy roots	2
S3.59	Sanitary Sewer	Located on outside meander that is eroding.	2
S3.60	Bank Failure	Bank eroding with hairy roots	2
S3.61	Knickpoint	Change in channel bed slope.	2
S3.62	Building	Residential bridge at failure risk due to bank erosion.	3
S3.63	Bank Failure	Bank eroding with hairy roots	2
S3.64	Building	Some notable erosion along right bank.	2
S3.65	Bank Failure	Bank eroding with hairy roots	2
S3.66	Bank Failure	Bank eroding with hairy roots and log trees	3
S3.67	Building	Residential housing at risk from bank failure.	3
S3.68	Crossing	CMP. Heavily armored.	1
S3.69	Crossing	CMP. Heavily armored.	1
S3.70	Crossing	CMP. Heavily armored.	1
S3.71	Crossing	CMP. Heavily armored.	1
S3.72	Crossing	CMP. Heavily armored.	1
S3.73	Crossing	CMP. Heavily armored. In good condition.	1
S3.74	Bank Failure	Bank eroding with hairy roots	2
S3.75	Building	Residential housing at risk from bank failure.	4
S3.76	Bank Failure	Bank eroding with hairy roots	2
S3.77	Bank Failure	Bank eroding with hairy roots	3
S3.78	Bank Failure	Chain link fence overhanging bank.	3
S3.79	Bank Failure	Bank eroding	2
S3.80	Bank Failure	Bank eroding with hairy roots	3
S3.81	Knickpoint	Change in channel bed slope.	2
S3.82	Bank Failure	Bank eroding with hairy roots	2
S3.83	Bank Failure	Bank eroding with hairy roots	3
S3.84	Knickpoint	Change in channel bed slope.	2
S3.85	Crossing	CMP	1

NOTE: Data is available digitally on the Liberty Stormwater Master Plan hub site - Stream Investigation tab.

Stream Walk Survey Table

Location ID	Infrastructure at Risk	Description	Severity Rating
S3.86	Crossing	CMP	1
S4.1	Sanitary Sewer	Manhole exposed	1
S4.2	Crossing	Culvert	2
S4.3	Bank Failure	channel 4 with shale	3
S4.4	Sanitary Sewer	sewer manhole	1
S4.5	Other	Tributary	1
S4.6	Other	Tributary	1
S4.8	Other	tributary down	1
S4.9	Sanitary Sewer	Sewer manhole	1
S4.10	Culvert	Culvert	1
S4.11	Crossing	RCB	1
S4.12	Culvert	CMP exposed	1
S4.13	Crossing	Upstream view from the bridge	1
S4.14	Crossing	Bridge with exposed reinforced steel and cracks	3
S4.15	Sanitary Sewer	Sewer manhole exposed	2
S4.16	Crossing	Upstream view from the bridge	1
S4.17	Crossing	Downstream view from the bridge	1
S4.18	Sanitary Sewer	Sewer manhole exposed.	1
S4.19	Culvert	Culvert exposed	1
S4.20	Crossing	Downstream view from the bridge.	1
S4.21	Crossing	Upstream view from the bridge	1
S4.22	Sanitary Sewer	Sewer manhole exposed	3
S4.23	Culvert	Culvert exposed	1
S4.24	Crossing	Downstream view from the bridge	2
S4.25	Crossing	Upstream view from the bridge	2
S4.26	Sanitary Sewer	Sewer manhole exposed	1
S4.27	Crossing	Downstream view from the bridge	1
S4.28	Crossing	Wood bridge	1
S4.29	Crossing	Wood bridge	2
S4.30	Crossing	Wood bridge	2
S4.31	Crossing	Wood bridge	2
S4.32	Crossing	Wood bridge	2
S4.33	Crossing	RCB culvert under bridge in good conditions	1
S4.34	Building	Residential housing at risk from bank failure. + Knickpoint (Change in channel bed slope.)	2
S4.35	Knickpoint	Change in channel bed slope.	2
S4.36	Knickpoint	Change in channel bed slope.	2
S4.37	Knickpoint	Change in channel bed slope.	2
S4.38	Knickpoint	Change in channel bed slope.	2
S4.39	Knickpoint	Change in channel bed slope.	2
S4.40	Knickpoint	Change in channel bed slope.	2
S4.41	Knickpoint	4 Knick points	2
S4.42	Knickpoint	Change in channel bed slope.	2
S4.43	Sanitary Sewer	Manhole exposed.	3
S4.44	Sanitary Sewer	Manhole exposed.	4
S4.45	Sanitary Sewer	Manhole exposed.	4
S4.46	Sanitary Sewer	Manhole exposed.	4
S4.47	Sanitary Sewer	Manhole exposed.	4
S4.48	Sanitary Sewer	Manhole exposed.	4
S4.49	Sanitary Sewer	Manhole exposed.	4
S4.50	Other	Pipe under water.	3
S4.51	Other	Pipe under water.	3
S4.52	Other	Pipe under water.	3
S4.53	Sanitary Sewer	Manhole exposed.	4
S4.54	Sanitary Sewer	Manhole exposed	4
S4.55	Sanitary Sewer	Manhole exposed	2
S4.56	Other	Pipe under water.	2
S4.57	Building	Residential housing at risk from bank failure.	3
S4.58	Bank Failure	Bank eroding.	3
S4.59	Bank Failure	Bank eroding.	2
S4.60	Bank Failure	Bank eroding.	3
S4.61	Bank Failure	Bank eroding.	2
S4.62	Bank Failure	Bank eroding.	3
S4.63	Building	Residential housing at risk from bank failure.	3
S4.64	Bank Failure	Bank eroding.	3
S4.65	Bank Failure	Bank eroding.	3

NOTE: Data is available digitally on the Liberty Stormwater Master Plan hub site - Stream Investigation tab.

Stream Walk Survey Table

Location ID	Infrastructure at Risk	Description	Severity Rating
S4.66	Bank Failure	Bank eroding.	3
S4.67	Bank Failure	Bank eroding.	3
S4.68	Bank Failure	Bank eroding.	3
S4.69	Bank Failure	Bank eroding.	2
S4.70	Bank Failure	Bank eroding.	3
S4.71	Bank Failure	Bank eroding.	3
S4.72	Bank Failure	Bank eroding.	3
S4.73	Bank Failure	Bank eroding.	3
S4.74	Bank Failure	Bank eroding.	3
S4.75	Bank Failure	Bank eroding.	3
S4.76	Bank Failure	Bank eroding.	3
S4.77	Bank Failure	Bank eroding.	3
S4.78	Bank Failure	Bank eroding.	3
S4.79	Bank Failure	Bank eroding.	3
S4.80	Bank Failure	Bank eroding.	3
S4.81	Bank Failure	Bank eroding	3
S4.82	Bank Failure	Bank eroding with terrace.	2
S4.83	Bank Failure	Bank eroding with hairy roots exposed.	3
S4.84	Bank Failure	Bank eroding with hairy roots exposed.	3
S4.85	Bank Failure	Bank eroding with hairy roots exposed.	3
S4.86	Bank Failure	Bank eroding with hairy roots exposed.	3
S4.87	Bank Failure	Bank eroding.	3
S4.88	Bank Failure	Bank eroding.	3
S4.89	Bank Failure	Bank eroding with hairy roots exposed.	3
S4.90	Bank Failure	Bank eroding with hairy roots exposed.	3
S4.91	Bank Failure	Bank eroding with hairy roots exposed.	3
S4.92	Bank Failure	Bank eroding with hairy roots exposed.	3
S4.93	Bank Failure	Bank eroding.	3
S4.94	Bank Failure	Bank eroding with falling trees.	3
S4.95	Bank Failure	Bank eroding.	3
S4.96	Bank Failure	Bank eroding.	3
S4.97	Bank Failure	Bank eroding with hairy roots exposed.	3
S4.98	Bank Failure	Bank eroding with hairy roots exposed.	3
S4.99	Bank Failure	Bank eroding with hairy roots exposed.	3
S4.100	Bank Failure	Bank eroding with hairy roots exposed.	3
S4.101	Other	Bed material	2
S4.102	Bank Failure	Fallen logs across stream.	3
S4.103	Bank Failure	Bank erosion	3
S4.104	Bank Failure	Bank eroding.	2
S4.105	Bank Failure	Rock rip rap	3
S4.106	Bank Failure	Bank eroding.	3
S4.107	Bank Failure	Bank eroding.	3
S4.108	Bank Failure	Bank eroding.	3
S4.109	Bank Failure	Bank eroding with orange roots exposed.	2
S4.110	Bank Failure	Bank eroding.	3
S4.111	Bank Failure	Bank eroding with hairy roots	3
S4.112	Bank Failure	Bank eroding with hairy roots	3
S4.113	Bank Failure	Bank eroding	3
S4.114	Bank Failure	Bank eroding with hairy roots	3
S4.115	Bank Failure	Bank eroding	3
S4.116	Bank Failure	Bank eroding	3
S4.117	Bank Failure	Bank eroding with hairy roots	3
S4.118	Bank Failure	Bank eroding with hairy roots	3
S4.119	Sanitary Sewer	Mainhole exposed	3
S4.120	Bank Failure	Bank eroding	3
S4.121	Bank Failure	Bank eroding with hairy roots	2
S4.122	Bank Failure	Bank eroding with hairy roots	3
S4.123	Culvert	CMP outlet	3
S4.124	Crossing	Stream is starting to undercut CMP.	2
S4.125	Other	Sediment size	1
S4.126	Bank Failure	Banks failing on outside meanders.	3
S4.127	Crossing	CMP	1
S4.128	Crossing	CMP eroded underneath.	3
S4.129	Knickpoint	Change in channel bed slope. Bedrock.	2
S4.130	Bank Failure	Banks failing on outside meanders.	3
S4.128	Crossing	CMP eroded underneath.	3

NOTE: Data is available digitally on the Liberty Stormwater Master Plan hub site - Stream Investigation tab.

Stream Walk Survey Table

Location ID	Infrastructure at Risk	Description	Severity Rating
S4.127	Knickpoint	Bedrock knickpoint	2
S5.1	Crossing	Box culvert. Left wing wall is eroding.	3
S5.2	Culvert	Culvert outfall	1
S5.3	Knickpoint	Change in channel bed slope.	2
S5.4	Bank Failure	Bank Eroding	3
S5.5	Building	Residential fencing along top of bank.	3
S5.6	Knickpoint	Change in channel bed slope.	2
S5.7	Bank Failure	Rock wall along right bank causing left bank to fail.	2
S5.8	Building	Residential housing at risk of bank failing.	3
S5.9	Other	Bed material size	1
S5.10	Building	Residential housing at risk of bank failing.	3
S5.11	Bank Failure	Bank eroding	3
S5.12	Culvert	Culvert outfall.	1
S5.13	Knickpoint	Rock run.	2
S5.14	Bank Failure	Bank eroding	2
S5.15	Other Utilities	Old pipe outlet.	1
S5.16	Bank Failure	Bank eroding	3
S5.17	Knickpoint	Change in channel bed slope.	2
S5.18	Bank Failure	Bank eroding	3
S5.19	Bank Failure	Bank eroding	3
S5.20	Knickpoint	Exposed bedrock. Occurs directly upstream of box culvert crossing.	2
S5.21	Crossing	Box culvert. In good condition.	1
S5.22	Crossing	Box culvert downstream. In good condition.	1
S5.23	Crossing	Box culvert downstream. In good condition.	1
S5.24	Crossing	Box culvert. In good condition.	1
S5.25	Bank Failure	Bank eroding	3
S5.26	Other	Bed material size.	1
S5.27	Other	Tributary	1
S5.28	Knickpoint	Change in channel bed slope. Log jam and bedrock.	2
S5.29	Bank Failure	Bank eroding	3
S5.30	Building	Fencing and utility lines at risk from bank failure. Sycamore recently fell.	3
S5.31	Bank Failure	Bank eroding	3
S5.32	Crossing	Greenway trail low water crossing. The culvert is being filled with sediment.	3
S5.33	Crossing	Greenway trail low water crossing. The culvert is being filled with sediment.	3
S5.34	Bank Failure	Bank is being undercut.	3
S5.35	Other	Greenway trail will eventually be undercut by stream.	4
S5.36	Building	Residential fencing along top of bank. At risk of failure.	4
S5.37	Knickpoint	Change in channel bed slope. Log jam	2
S5.38	Crossing	Greenway trail crossing. Culverts functioning well.	1
S5.39	Crossing	Greenway trail crossing. Culverts functioning well.	1
S5.40	Crossing	Greenway trail crossing. Culverts functioning well.	1
S5.41	Bank Failure	Bank eroding	3
S5.42	Sanitary Sewer	Manhole approximately 40 feet from bank.	1
S5.43	Bank Failure	Bank eroding	3
S5.44	Knickpoint	Change in channel bed slope.	2
S5.45	Bank Failure	Bank eroding	3
S5.46	Other	Tributary	1
S5.47	Culvert	Culvert outfall creating scour hole.	3
S5.48	Knickpoint	Change in channel bed slope.	2
S5.49	Bank Failure	Left bank starts failing right where rip rap armoring stops.	2
S5.50	Knickpoint	Change in channel bed slope.	2
S5.51	Bank Failure	Bank eroding	3
S5.52	Other	Bed sediment size.	1
S5.53	Bank Failure	Bank eroding	3
S5.54	Building	Residential housing at risk of foundation issues from bank failure.	3
S5.55	Bank Failure	Bank eroding	2
S5.56	Building	Residential housing at risk of foundation issues from bank failure. Bank has already failed recently contributing to a log jam.	3
S5.57	Knickpoint	Log jam.	2
S5.58	Other Utilities	Pipe crossing. Concrete support column eroded at base and at risk of failure.	5
S5.59	Knickpoint	Change in channel bed slope.	2
S5.60	Bank Failure	Bank eroding	3
S5.61	Bank Failure	Bank eroding	3
S5.62	Other	Tributary	1
S5.63	Bank Failure	Bank eroding	2
S5.64	Knickpoint	Change in channel bed slope.	2

NOTE: Data is available digitally on the Liberty Stormwater Master Plan hub site - Stream Investigation tab.

Stream Walk Survey Table

Location ID	Infrastructure at Risk	Description	Severity Rating
S5.65	Bank Failure	Bank eroding	3
S5.66	Crossing	Box culvert crossing under railroad. Stream is cutting behind left side of culvert.	2
S6.1	Culvert	Culvert outlet	1
S6.2	Crossing	Culvert	1
S6.3	Crossing	Culvert	1
S6.4	Crossing	Double culvert outlet	1
S6.5	Knickpoint	Change in channel bed slope. Bedrock, log jam	2
S6.6	Other	Concrete lined channel	2
S6.7	Knickpoint	Change in channel bed slope.	2
S6.8	Knickpoint	Change in channel bed slope.	2
S6.9	Other	Retaining Wall failing	3
S6.11	Bank Failure	Pool	2
S6.12	Bank Failure	Pool	3
S6.13	Bank Failure	Bank eroding	3
S6.14	Bank Failure	Bank eroding	3
S6.15	Building	Residential housing at risk from bank failure.	3
S6.16	Bank Failure	Bank eroding	2
S6.17	Bank Failure	Bank eroding	3
S6.18	Bank Failure	Bank eroding	2
S6.19	Bank Failure	Bank eroding	3
S6.20	Bank Failure	Bank eroding	3
S6.21	Bank Failure	Rip Rap	2
S6.22	Bank Failure	Bank eroding	3
S6.23	Bank Failure	Rip rap	2
S6.24	Crossing	Residential bridge at failure risk due to bank erosion.	3
S6.25	Bank Failure	Bank eroding	3
S6.26	Bank Failure	Bank eroding	2
S6.27	Building	Residential housing at risk from bank failure.	3
S6.28	Bank Failure	Bank eroding	3
S6.29	Bank Failure	Bank eroding	3
S6.30	Bank Failure	Bank eroding	3
S6.31	Bank Failure	Bank eroding	2
S6.32	Bank Failure	Bank eroding both sides	3
S6.33	Bank Failure	Bank eroding	3
S6.34	Bank Failure	Bank eroding	3
S6.35	Bank Failure	Bank eroding	3
S7.1	Crossing	RCB culvert under bridge in good conditions	2
S7.2	Crossing	Bridge View	2
S7.3	Crossing	Bridge View	2
S7.4	Crossing	Bridge	2
S7.5	Crossing	Bridge	2
S7.6	Other Utilities	Pipe crossing	1
S7.7	Other Utilities	Pipe crossing	1
S7.8	Crossing	Bridge	1
S7.9	Crossing	Bridge	1
S7.10	Crossing	Bridge	1
S7.11	Crossing	CMP outlet	4
S7.12	Crossing	Culvert	1
S7.13	Crossing	Culvert	1
S7.14	Crossing	Culvert	1
S7.15	Crossing	Culvert	1
S7.16	Culvert	Culvert outfall	1
S7.17	Crossing	Culvert	1
S7.18	Crossing	Culvert	1
S7.19	Crossing	Erosion on both sides of wing walls.	3
S7.20	Bank Failure	Erosion on both sides of the channel	2
S7.21	Bank Failure	Erosion on both sides	2
S7.22	Building	Erosion next to fence	3
S7.23	Building	Residential housing at risk from bank failure.	4
S7.24	Other	Fork in stream	1
S7.25	Sanitary Sewer	Sewer manhole	1
S7.26	Bank Failure	channel 6 - bank 12'	3
S7.27	Bank Failure	channel 6 - bank stability 12ft	3
S7.28	Other Utilities	pipe exposed on channel 7	2
S7.29	Sanitary Sewer	channel 7 MH	2
S7.30	Knickpoint	Change in channel bed slope.	2

NOTE: Data is available digitally on the Liberty Stormwater Master Plan hub site - Stream Investigation tab.

Stream Walk Survey Table

Location ID	Infrastructure at Risk	Description	Severity Rating
S7.31	Other	Pipe crossing the stream.	2
S7.32	Knickpoint	Change in channel bed slope.	2
S7.33	Knickpoint	Change in channel bed slope.	2
S7.34	Knickpoint	Change in channel bed slope.	2
S7.35	Sanitary Sewer	RCP damage.	4
S7.36	Other	CMP outlet around eroding bank	3
S7.37	Bank Failure	Bank eroding	3
S7.38	Bank Failure	Bank eroding	3
S7.39	Bank Failure	Bank eroding	3
S7.40	Bank Failure	Bank eroding	3
S7.41	Bank Failure	Bank eroding	3
S7.42	Bank Failure	Bank eroding	3
S7.43	Bank Failure	Pool	3
S7.44	Bank Failure	Bank eroding	3
S7.45	Bank Failure	Bank eroding	3
S7.46	Bank Failure	Bank eroding	3
S7.47	Bank Failure	Bank eroding	3
S7.48	Bank Failure	Bank eroding	3
S7.49	Bank Failure	Bank eroding	3
S7.50	Bank Failure	Bank eroding	3
S7.51	Bank Failure	Bank eroding	3
S7.52	Bank Failure	Bank eroding	3
S7.53	Bank Failure	Bank eroding	3
S7.54	Bank Failure	Bank eroding	3
S7.55	Bank Failure	Bank eroding	2
S7.56	Bank Failure	Bank eroding	3
S7.57	Bank Failure	Bank eroding	3
S7.58	Bank Failure	Bank eroding	3
S7.59	Bank Failure	Bank eroding	3
S7.60	Bank Failure	Bank eroding	3
S7.61	Bank Failure	Bank eroding	3
S7.62	Bank Failure	Bank eroding	3
S7.63	Bank Failure	Bank eroding	2
S7.64	Bank Failure	Bank eroding	3
S7.65	Bank Failure	Bank eroding	3
S7.66	Bank Failure	Bank eroding	3
S7.67	Bank Failure	Bank eroding	3
S7.68	Bank Failure	Bank eroding	3
S7.69	Bank Failure	Bank eroding	3
S7.70	Bank Failure	Bank eroding	3
S7.71	Bank Failure	Bank eroding	3
S7.72	Bank Failure	Bank eroding	3
S7.73	Bank Failure	Bank eroding	3
S7.74	Bank Failure	Bank eroding	3
S7.75	Bank Failure	Bank eroding	3
S7.76	Bank Failure	Bank eroding	3
S7.77	Bank Failure	Bank eroding	3
S7.78	Bank Failure	Bank eroding	3
S7.79	Bank Failure	Bank eroding	3
S7.80	Bank Failure	Bank eroding	3
S8.1	Crossing	Downstream view from bridge	1
S8.2	Crossing	CMP in good condition.	1
S8.3	Bank Failure	Bank eroding	3
S8.4	Other	Sediment size	1
S8.5	Bank Failure	Bank eroding	3
S8.6	Bank Failure	Bank eroding	2
S8.7	Culvert	Culvert outlet.	1
S8.8	Culvert	Culvert outlet.	1
S8.9	Knickpoint	Change in channel bed slope.	2
S8.10	Bank Failure	Both banks are eroding.	3
S8.11	Bank Failure	Bank eroding	3
S8.12	Bank Failure	Nearby residential.	2
S8.13	Building	Banks are eroding nearby residences.	3
S8.14	Bank Failure	Bank eroding	2
S8.15	Knickpoint	Change in channel bed slope.	2
S8.16	Bank Failure	Bank eroding	3

NOTE: Data is available digitally on the Liberty Stormwater Master Plan hub site - Stream Investigation tab.

Stream Walk Survey Table

Location ID	Infrastructure at Risk	Description	Severity Rating
S8.17	Other	Non identified structure exposed and bank eroding.	3
S8.18	Knickpoint	Change in channel bed slope. Log jam	2
S8.19	Other Utilities	Abandoned concrete structure.	1
S8.20	Bank Failure	Bank eroding	3
S8.21	Crossing	CMP is covered with debris.	2
S8.22	Crossing	CMP is covered with debris.	2
S9.1	Crossing	Bridge	1
S9.2	Crossing	Bridge	2
S9.3	Knickpoint	Change in channel bed slope.	2
S9.4	Knickpoint	Change in channel bed slope.	2
S9.5	Knickpoint	Change in channel bed slope.	2
S9.6	Knickpoint	Change in channel bed slope.	2
S9.7	Knickpoint	Change in channel bed slope.	2
S9.8	Knickpoint	Change in channel bed slope.	2
S9.9	Sanitary Sewer	RCP damage.	2
S9.10	Bank Failure	Bank eroding	3
S9.11	Bank Failure	pool	3
S9.12	Bank Failure	Bank eroding	3
S9.13	Bank Failure	Bank eroding	3
S9.14	Building	Residential housing at risk from bank failure.	3
S9.15	Bank Failure	Bank eroding	3
S9.16	Bank Failure	Tree logs across stream	3
S9.17	Bank Failure	Bank eroding	3
S9.18	Bank Failure	Bank eroding	2
S9.19	Bank Failure	Bank eroding	3
S9.20	Other	bed material	2
S9.21	Bank Failure	Bank eroding	3
S9.22	Bank Failure	Bank eroding	3
S9.23	Other	Concrete structure exposed.	3
S9.24	Building	Residential housing at risk from bank failure.	3
S9.25	Bank Failure	Bank eroding with terraces	2
S9.26	Other	Bed material	2
S9.27	Bank Failure	Bank eroding	3
S10.1	Sanitary Sewer	Manhole outside of stream bank.	1
S10.2	Bank Failure	Nearby residential housing at risk from widening stream.	3
S10.3	Bank Failure	Steep bank at risk of failing.	3
S10.4	Bank Failure	Steep bank at risk of failing.	3
S10.5	Bank Failure	Nearby residential housing at risk from widening stream.	3
S10.6	Other	Bank stabilization.	1
S10.7	Bank Failure	Bank failing opposite of rip rap armoring.	3
S10.8	Sanitary Sewer	Bank failing and exposing sanitary sewer.	3
S10.9	Culvert	Culvert outlet contributing to bank failure.	2
S10.10	Sanitary Sewer	Sewer crossing.	1
S10.11	Bank Failure	Both banks have been armored with wire baskets.	3
S10.12	Crossing	Upstream	3
S10.13	Crossing	Upstream	3
S10.14	Crossing	Downstream	3
S10.15	Crossing	Downstream. Bridge wing walls are stable and armored.	2
S10.16	Bank Failure	Bank armored with wire mesh baskets. Stream thalweg is deepening because of the bank stabilization.	2
S10.17	Sanitary Sewer	Manhole in proximity to widening stream.	2
S10.18	Sanitary Sewer	Sewer crossing.	1
S10.19	Crossing	Upstream bridge crossing.	1
S10.20	Crossing	Upstream bridge crossing.	1
S10.21	Crossing	Downstream bridge crossing. Concrete lined channel.	1
S10.22	Crossing	Downstream bridge crossing. Concrete lined channel.	1
S10.23	Bank Failure	Exposed roots.	3
S10.24	Building	Nearby residential at risk from bank failure.	3
S10.25	Knickpoint	Change in channel bed slope. Starts from concrete lined channel.	2
S10.26	Other	Bed material size.	1
S10.27	Building	Nearby residential at risk from stream widening.	2
S10.28	Knickpoint	Change in channel bed slope.	2
S10.29	Bank Failure	Surfing trees	3
S10.30	Bank Failure	Bank eroding	3
S10.31	Bank Failure	Bank eroding	3
S10.32	Bank Failure	Bank eroding.	3

NOTE: Data is available digitally on the Liberty Stormwater Master Plan hub site - Stream Investigation tab.



Stream Walk Survey Table

Location ID	Infrastructure at Risk	Description	Severity Rating
S10.33	Culvert	Culvert outfall.	1
S10.34	Knickpoint	Change in channel bed slope.	2
S10.35	Building	Nearby residential at risk from stream widening.	2
S10.36	Knickpoint	Change in channel bed slope.	2
S10.37	Bank Failure	Stream has been widening as noted by the fence.	3
S10.38	Bank Failure	Bank eroding	3
S10.39	Other Utilities	Utility poles and also residential nearby bank.	3
S10.40	Bank Failure	Both banks failing. Note the floating fence on the right bank.	3
S10.41	Other Utilities	Pole exposed	1
S10.42	Bank Failure	Both banks failing.	3
S10.43	Bank Failure	Both banks failing.	3
S10.44	Building	Backyard sheds at risk from bank failing.	4
S10.45	Bank Failure	Both banks failing.	3
S10.47	Building	Residential properties losing backyard to bank failure.	4
S10.48	Bank Failure	Bank eroding	3
S10.49	Bank Failure	Bank eroding	2
S10.50	Crossing	Bridge crossing upstream. Box culvert walls are stable. Left box is silted in.	2
S10.51	Crossing	Bridge crossing upstream.	2
S10.52	Sanitary Sewer	Sanitary sewer at downstream RCB opening.	2
S10.53	Sanitary Sewer	Pipe cross stream	1

NOTE: Data is available digitally on the Liberty Stormwater Master Plan hub site - Stream Investigation tab.



Appendix C



Project Prioritization and 10-year CIP Programming

City of Liberty - Stormwater Master Plan
Technical Memorandum

City of Liberty, MO

October 2024

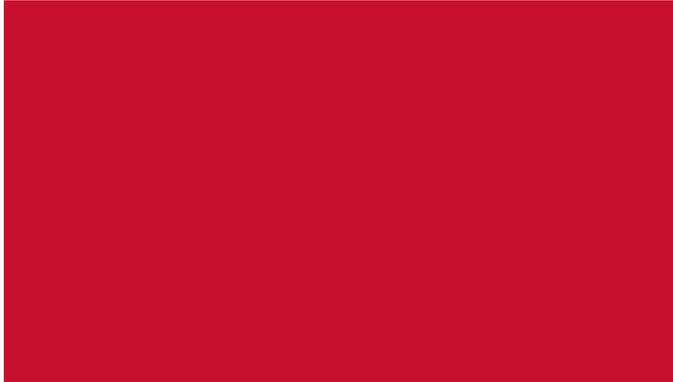


Table of Contents

1	Introduction	1
1.1	Purpose	1
1.2	Scope	1
2	Background.....	1
3	Project Pool Selection Methodology	2
3.1	Master Plan Components Leveraged in Project Pool Selection	2
3.1.1	Public Communication and Input	2
3.1.2	Investigation and Assessment of Existing Stormwater Infrastructure	2
3.1.3	Stream Channel Erosion Analysis	3
3.1.4	Flood Risk Reduction Assessment	3
3.2	Potential Project Locations	3
4	CIP Prioritization Methodology	5
4.1	Project Scoring	5
4.2	Project Weighting	7
5	Recommended Capital Improvement Projects and Approximated Cost Estimates	7
5.1	Project Cost and Analysis Assumptions	9
5.2	General Project O&M Requirements and Assumptions	12
5.3	Project Descriptions	12
5.4	Conclusion and Further Project Design Considerations	15

Tables

Table 1: Project Criteria and Associated Scoring Measure	6
Table 2: Criteria Weighting Values	7
Table 3: Enclosed System Pipe & Inlet Cost Assumptions	9
Table 4: RCB/Box Cost Assumptions	9
Table 5: Bank Stabilization Cost Assumptions	10
Table 6: Detention Cost Assumptions	10
Table 7: General Project Cost Assumptions	11
Table 8: Project Cost Overview	11

Figures

Figure 1: Potential Project Locations	4
Figure 2: Top 15 CIP Project Locations	8

Appendices

Appendix A: Project Cost Tables

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1 Introduction

1.1 Purpose

The City of Liberty is located in the northeast portion of the Kansas City metro area within Clay County, Missouri. As part of the expanding metro area, the city has experienced substantial growth since the development of the previous Stormwater Master Plan, completed in 2003. Substantial development can often lead to increases in impervious areas, changes in flow patterns and runoff volumes, sediment loading and stream instability challenges, and reduction in water quality, etc. which can lead to many challenges with stormwater management needs within the city. The evolving nature of the watersheds that make up the City of Liberty, in addition to changes in design standards, has presented a need to update the City's Stormwater Master Plan.

As part of a comprehensive stormwater master plan for the City of Liberty, Missouri, HDR Engineering, Inc. (HDR) has worked in conjunction with city staff to define high priority projects to be included in the City of Liberty Capital Improvement Plan (CIP). The goal of the City CIP program is to help maintain city assets through replacement and improvements of city infrastructure, revitalizing the city to continue to deliver reliable infrastructure and access to city residents and visitors. The Stormwater CIP prioritization and framework will aid in aligning future projects with the city's goals to continue to address the city stormwater management needs.

1.2 Scope

As part of the project prioritization and CIP programming portion of the Stormwater Master Plan development, a project prioritization methodology along with up to fifteen proposed projects and their respective projected construction costs and operation and maintenance (O&M) requirements are detailed in the technical memorandum presented herein. The project prioritization methodology shall utilize information obtained from public meeting sessions, storm sewer modeling results, the condition assessment risk model, stream bank and flood risk assessments, and should also consider sustainable stormwater solutions.

2 Background

There are four main watersheds within the City of Liberty, including Little Shoal Creek, Rush Creek, Cates Branch and Town Branch. The Little Shoal Creek watershed captures drainage from the southwest portion of the city and outlets to Shoal Creek which is ultimately tributary to the Missouri River. The Rush Creek Watershed captures drainage from a majority of the northern half of the city and outlets directly into the Missouri River. Cates Branch Watershed

captures drainage from the city center and is tributary to the Town Branch Watershed on the southeast portion of the city which outlets to Shoal Creek and ultimately the Missouri River.

The existing stormwater network consists of various open channels, ditches, and various stormwater conduits and associated structures/inlets that provide essential stormwater management functions serving over 30,000 residents and numerous visitors.

3 Project Pool Selection Methodology

3.1 Master Plan Components Leveraged in Project Pool Selection

There are 5 main components of the Stormwater Master Plan that were assessed when determining key stormwater improvement projects throughout the city that would provide maximum benefit to the community. The five components that were utilized in the project pool selection include public communication and input, field data collection, storm sewer system modeling, streambank erosion assessments and flood risk reduction assessments.

3.1.1 Public Communication and Input

As part of the stormwater master planning effort, HDR hosted a public meeting on Thursday, November 18th, 2023, to gather input from City of Liberty residents. Through comment cards, conversation and interaction with attendees, several locations of public interest were brought up for consideration. In parallel with the public meeting, a survey was distributed to residents to identify the communities' top concerns and the feedback received from the survey was reviewed and incorporated. The City of Liberty also provided HDR with areas of reported public concern received throughout the life of the study. All areas of interest were taken into consideration during the CIP project selection and ranking process.

3.1.2 Investigation and Assessment of Existing Stormwater Infrastructure

Field Data Collection

Trekk Design Group performed a condition assessment on the existing stormwater network. Approximately 223 structures were inspected and conditions were recorded. A combination of descriptions, photos, Closed Conduit Television (CCTV), and Pipeline Assessment and Certification Program (PACP) ratings were provided for the City's use. The data collected during the field inspections was leveraged during the project ranking process. Further information from the field data collection is provided under a separate cover. The Stormwater Master Plan Condition Assessment Summary Report, dated March 2024, can be accessed through the Liberty Stormwater Master Plan ArcGIS Hub Site.

Storm Sewer System Model Development

HDR developed a 2D Rain-on-Mesh Infoworks ICM model of the existing storm system, inclusive of pipe networks 36-inches or greater in diameter. Some of the model outputs consist of flooding depths, flooding hazard (function of water depth multiplied by velocity + 0.5 with the addition of a debris factor), structure flooding depth, and structure surcharge data, which are useful tools when identifying impacts and risk associated with potential deficiencies in the existing stormwater system. The ICM model results were taken into consideration to identify and prioritize likely areas of flooding concern where the existing system is inadequate.

3.1.3 Stream Channel Erosion Analysis

City of Liberty staff identified ten streams of interest to be investigated as part of a rapid assessment of stream bank stability. HDR performed stream bank assessments along the identified streams in December 2023 through January 2024. As part of the assessment, photographs and descriptions were recorded along with severity ratings for identified areas of stream degradation and instability particularly within proximity to city assets and private infrastructure. The findings from the stream assessment were utilized in identifying projects and assigning priorities within the CIP ranking. Further information from the stream bank assessment is provided under a separate cover. The Stream Assessment Findings Summary, Technical Memorandum, dated April 2024, can be accessed through the Liberty Stormwater Master Plan ArcGIS Hub Site.

3.1.4 Flood Risk Reduction Assessment

HDR performed a flood risk reduction assessment utilizing the mapped FEMA floodplains and effective FEMA modeling. As part of the assessment, HDR identified existing flood prone areas where there is potential opportunity to alleviate flooding conditions within the watershed. Potential improvements evaluated include hydraulic structure improvements in order to alleviate upstream flooding conditions due to a hydraulic restriction as well as implementation of regional detention to help manage peak discharges downstream. Locations identified as part of the Flood Risk Reduction were taken into consideration during the CIP prioritization process. The Flood Risk Reduction, Technical Memorandum, dated September 2024, can be accessed through the Liberty Stormwater Master Plan ArcGIS Hub Site.

3.2 Potential Project Locations

Based on the voiced community concerns and the project investigations and assessments described above, an overall list of potential projects was developed to help address the City's stormwater challenges. A total of 47 potential projects were identified to be included in the project pool and were then ranked according to the prioritization methodology outlined in the following sections. Of the total 47 projects, 13 were located in areas identified as community

concerns, 5 during the condition assessment, 11 from the enclosed system modeling, 9 from the flood risk assessment and 9 from the stream bank assessments (Figure 1).

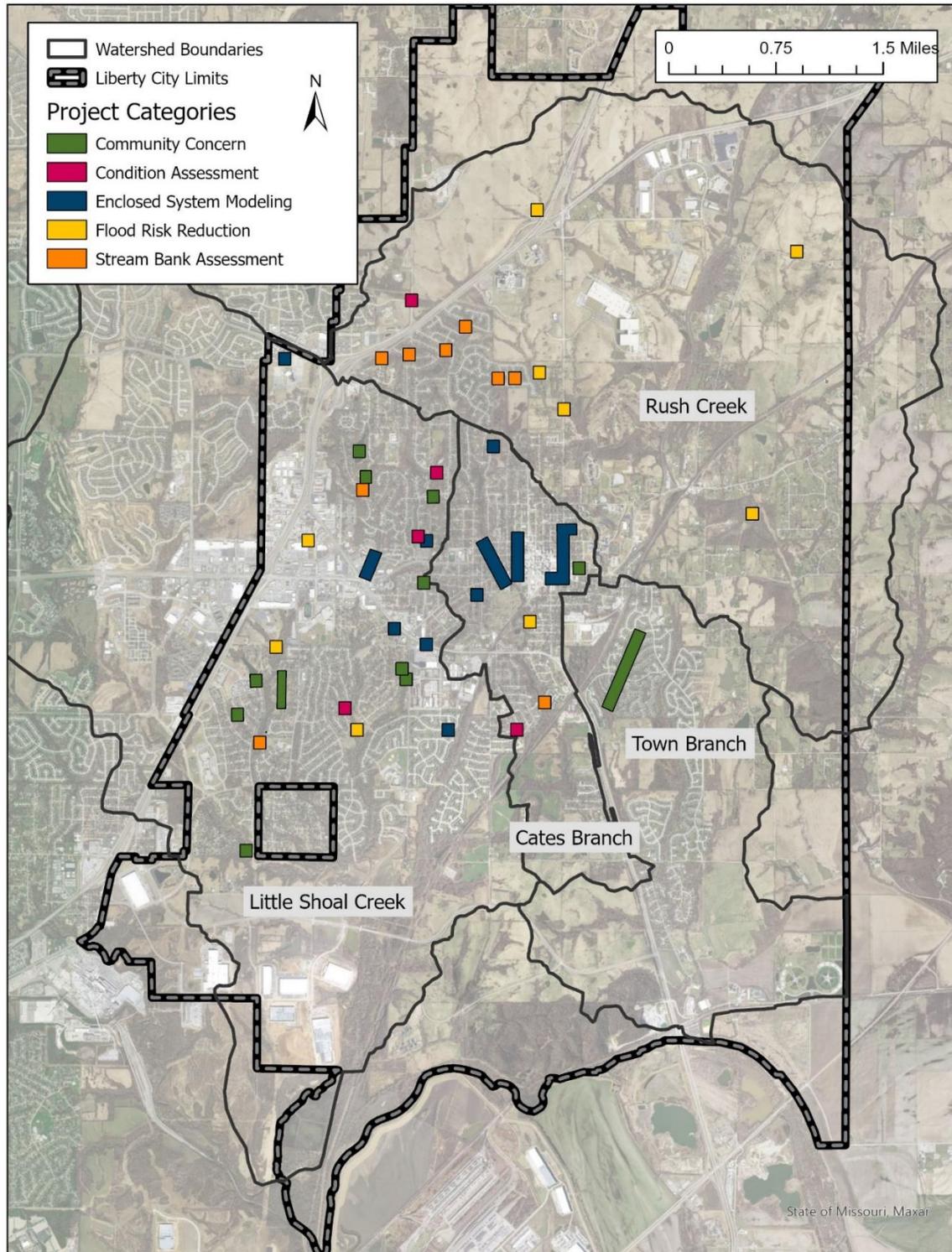


Figure 1: Potential Project Locations

4 CIP Prioritization Methodology

The CIP prioritization methodology establishes the project ranking criteria and associated weighting components were developed with consideration of the communities' values and City of Liberty stormwater management and infrastructure revitalization goals. Through workshop discussions with city staff, as well as taking into consideration public feedback, a scoring approach was developed to help prioritize stormwater improvement projects that provide maximum benefit to the community to align city funds with key stormwater projects throughout the city.

4.1 Project Scoring

The scoring criteria were developed within 3 main categories including customer service, public safety and environmental considerations, with a large priority placed on the public safety criteria which aligns with public feedback received as well as city staff priorities. Individual criteria are listed in Table 1 and summarized below.

- *Reported Public Concern:* Criteria is ranked based on whether or not a public concern has been received at the project location, and also receives a higher ranking by amount of properties that will benefit from the project.
- *Structure Condition:* Criteria assesses the condition of City stormwater assets (pipes, RCBs, manholes, inlets, etc.) and is ranked from non-functioning to good condition.
- *Roadway Level of Service:* Criteria assesses roadway flooding depths during the 10-year design storm and is ranked based on the magnitude of depth, access to critical emergency facilities and roadway classification.
- *Risk of Infrastructure and/or Utility Failure:* Criteria assesses risk to public infrastructure and residential habitable structures based on degree of erosion as well as critical facility loss due to flood impacts and is ranked from imminent risk with active erosion to inactive erosion with potential indicators of risk.
- *Habitable Structure Flooding:* Criteria identifies potential flooding impacts to critical and non-critical habitable structure for a range of rainfall events, assigning a higher ranking for more frequent flooding of structures.
- *Water Quality/Sustainable Solutions:* Criteria assesses water quality, stream stabilization, and reduction to peak discharges (i.e. detention) and is ranked from the highest degree of environmental benefit to basic detention and/or streambank stabilization.

See Table 1 for the breakdown of individual measures and associated rank per each criteria discussed above.

Table 1: Project Criteria and Associated Scoring Measure
Project Criteria Development for the City of Liberty Stormwater CIP

	<u>Criteria</u>	<u>Score</u>	<u>Measure</u>	
Customer Service	Reported Public Concern	5	Notice of issue, project improves conditions at multiple properties.	
		2	Notice of issue, project improves conditions at single property.	
		0	City has no record of prior notice of issue	
Public Safety	Structure Condition	5	Existing structure is non-functional	
		3	Existing structure is in poor condition and is deteriorating	
		1	Existing structure is in moderate condition	
		0	Existing structure is in good condition/no available data	
	Roadway Level of Service	5	Roadway flooding limits access to critical emergency facilities	
		4	Roadway flooding more than 12 inches during the 10-year storm for an arterial, collector, and/or residential with open channel DS of street	
		3	Roadway flooding less than 12 inches during the 10-year storm for an arterial, collector, and/or residential with open channel DS of street	
		2	Roadway flooding more than 12 inches during the design storm (10-year) for a residential street	
		1	Roadway flooding less than 12 inches during the design storm (10-year) for a residential street	
		0	Roadway does not flood during the 10-year storm	
	Risk of Infrastructure and/or Utility Failure	5	Project reduces risk of imminent failure of public infrastructure and assets (active erosion, and/or flooding of critical utilities)	
		4	Project reduces risk of imminent failure of residential habitable structures (active erosion)	
		3	Project reduces risk of future failure of public infrastructure and assets (active erosion - not imminent, and/or loss of access and minor damages to critical utilities)	
		2	Project reduces risk of future failure of residential habitable structures (active erosion - not imminent)	
		1	Project reduces risk of future failure of public infrastructure and assets (no active erosion - high velocity/hazard area, and/or loss of access to critical utility controls)	
		0	Project does not provide any measurable infrastructure benefit	
	Habitable Structure Flooding	5	Project reduces modeled/presumed flooding of critical structure for the 10-year design storm or multiple critical structures for the 100-year storm	
		4	Project reduces modeled/presumed flooding of non-critical structure for the 2-year design storm or multiple non-critical structures for the 10-year storm	
		3	Project reduces modeled/presumed flooding of critical structure for the 100-year storm	
		2	Project reduces modeled/presumed flooding of non-critical structure for the 10-year storm or multiple non-critical structures for the 100-year storm	
		1	Project reduces modeled/presumed flooding of non-critical structure for the 100-year storm	
		0	Project does not provide any measurable benefit to habitable structure flooding	
	Environmental	Water Quality/Sustainable Solutions	5	Project reduces runoff volume and/or improves water quality through infiltration and/or bioengineered stream stabilization and/or elimination of sanitary sewer exfiltration
			2	Project improves water quality through inert stabilization methods to correct larger sediment loads
1			Project reduces sediment generation through stormwater detention or minor scour/bank repairs	
0			Improvements do not provide water quality improvements or reduce runoff	

Note: ASCE /SEI 24-14 can be referenced as a guideline to define critical and essential facilities.

4.2 Project Weighting

In addition to the project criteria and ranking measures discussed above, a supplemental weighting component was added to the project ranking methodology in order to ensure that appropriate value was given to the criteria to further align projects with the City’s goals. The weighting component allows for criteria associated with public safety to have greater influence on the overall project score (structure condition, level of service, risk to infrastructure and utilities, and flooding of habitable structures). The environmental and community service components have less influence on project selection; however, they function to add value to further elevate projects that also check the boxes for multiple other criteria related to public safety. The highest score possible in each criteria is 5 with the lowest score being 0. As shown in the below table, to determine the total percentage of the overall score each criterion receives the maximum score of 5 is multiplied by the weighting factor. A breakdown of the individual criteria weight and maximum score is shown in Table 2 below.

Table 2: Criteria Weighting Values

Criteria	Criteria Score	Weighting	Score
Reported Public Concern	5	1.20	6.00
Structure Condition	5	2.60	13.00
Roadway Level of Service	5	4.50	22.50
Risk of Infrastructure and/or Utility Failure	5	5.20	26.00
Habitable Structure Flooding	5	4.50	22.50
Water Quality/Sustainable Solutions	5	2.00	10.00
TOTAL SCORE			100.00

5 Recommended Capital Improvement Projects and Approximated Cost Estimates

All 47 potential projects were ranked using the project prioritization criteria and weighting methodology outlined in section 4 above to establish the top 15 highest ranked projects for inclusion in the CIP. The top 15 projects represent the locations of improvement that will provide maximum benefit to the community and align with the city’s stormwater infrastructure goals as outlined in the prioritization methodology section and are represented in Figure 2. The project ranking spreadsheet can be found on the CIP tab linked in the Stormwater Masterplan Hub site.

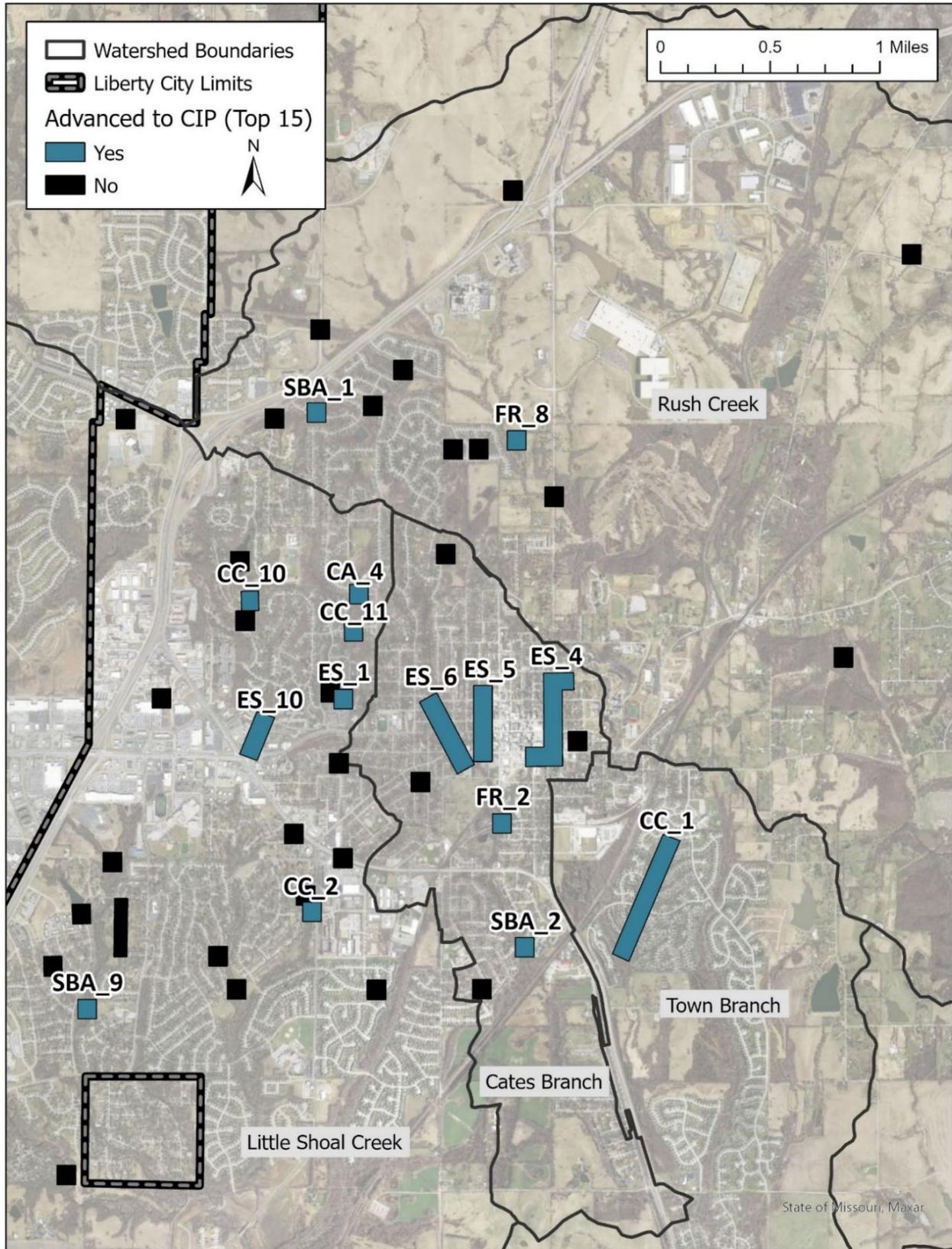


Figure 2: Top 15 CIP Project Locations



5.1 Project Cost and Analysis Assumptions

General project costs and potential O&M requirements were developed for each of the top 15 CIP projects and were generated at a preliminary/conceptual level due to the high-level analysis stage and planning nature of this CIP study. Any further refinements to cost at the time of project design and implementation should be further assessed and defined as the project stage progresses and project components and extents are finalized.

Proposed conditions modeling efforts were not included as part of this scope and as such, the cost estimates are based on the assumption that all pipes, structures, inlets and manholes in the vicinity of the problem area for the stormwater infrastructure projects will need to be replaced and potentially upsized where existing capacity is inadequate. The existing enclosed system ICM modeling generated as part of the Master Plan effort included only pipe segments equal to or greater than 36" and deemed significant as defined in the scope, therefore, all site conditions should be further assessed at the time of project analysis and design to take into consideration all necessary existing and potential proposed stormwater features contributing to site dynamic and function.

Generalized costs were developed to associate an inclusive construction cost per linear ft. of pipe for structures greater than or equal to 72" and less than 72" as shown in Table 3. Additionally, a standard unit price was determined to be applied to all storm structures. For larger RCB/box culvert structures, an assumed cost per sq. ft. of open area multiplied by structure length was applied and an additional cost per cu. Ft. of projected riprap quantities was assumed for the box culvert structures (Table 4). At the time of further investigation, project components and extents can be finalized and updated costs will need to be studied.

Table 3: Enclosed System Pipe & Inlet Cost Assumptions

Enclosed System Pipe & Inlet Cost Assumptions		
Pipe < 72"	\$350	/linear ft. of pipe
Pipe >= 72"	\$1,500	/linear ft. of pipe
Storm Structures	\$15,000	/unit

Table 4: RCB/Box Cost Assumptions

RCB/Box Cost Assumptions		
Box Culvert	\$45	/sq. ft. of box open area
Rip Rap	\$40	/cu. Ft. of Rip Rap

For the streambank stabilization projects, a generalized price per linear ft. of stabilization along the channel centerline was also developed (Table 5). The assumed length of stabilization was based on context from site photos and general site assumptions. The cost assumes inert stabilization to correct larger sediment loads, however, more robust bioengineered alternatives can be assessed at the time of implementation. At the time of

project design, further study should be conducted to determine the current extent of erosion and appropriate stabilization measures to address site specific geomorphological conditions, overall stream health and sediment transport loads. Once the design is finalized updated costs will need to be studied.

Table 5: Bank Stabilization Cost Assumptions

Bank Stabilization & Material Cost Assumptions		
Stabilization Materials	\$600	/linear ft. of bank along channel centerline

For the detention location, the cost developed during the 2003 Stormwater Master Plan was used as a baseline for the 2024 project cost and was escalated to account for inflation to determine an appropriate price associated with 2024 rates. A multiplier was developed to bring the 2003 dollars to 2024 dollars (Table 6) using a compounded inflation rate, assuming 3% yearly inflation between 2003-2020, 15% yearly inflation between 2020-2023, and a 5% inflation rate for 2024. The Turner Building Cost Index, developed by Turner Construction, was referenced to support the accuracy of the compounded inflation rate multiplier. It was determined that the compounded inflation rate multiplier of 2.6 as derived from the assumptions above aligns closely with the information obtained from the Turner Building Cost Index and is considered to be a conservative assumption. Additional analysis and detention modeling should be conducted at the time of design to further define optimal location, volume, configuration, outlet works, structure sizes and overflow configurations. Once the project components and extents have been determined, updated costs will need to be studied. Additionally, it may be advantageous to assess the watershed as a whole to determine if downstream projects may see improvement from an upstream detention facility.

Table 6: Detention Cost Assumptions

Detention Cost Assumptions	
General multiplier of 2003 \$ converted to 2024 \$	2.6

A general contracting fee was also applied to the general project costs (excluding detention, FR_8) to account for mobilization, demolition, survey, demobilization, erosion control, etc. An engineering design fee of 20% of the total construction cost and the assumed general contracting fee was applied to all projects. A 30% contingency was applied for the purposes of the planning level cost estimates and was applied to the overall project and design cost. See Table 7. Any costs associated with right-of-way acquisition, utility relocations and related public involvement were not considered as part of the initial cost assumptions and all project costs will need to be refined once the project components have been determined.



Table 7: General Project Cost Assumptions

General Project Cost Assumptions	
General Contracting Fee as % of Total Construction Cost	5%
Engineering Design Fee as % of Total Construction Cost & General Contracting Fees	20%
Contingency as % of Total Cost	30%

All general cost assumptions outlined above are considered the best available information at time of this analysis and may be subject to change due to varying market conditions. The opinion of general construction cost presented herein is based on information available to the engineer at the time of the writing of this report and the engineer’s experience and qualifications. Since the engineer has no control over the cost of labor, materials, equipment, or services furnished by others, or over the contractor’s methods of determining prices, or over competitive bidding or market conditions, the engineer does not guarantee that actual project or construction costs will not vary from the opinions of general construction costs prepared. The opinions of general cost provided in this report are intended to facilitate planning level activities and do not constitute a detailed evaluation or prediction of actual construction costs.

Total approximated project costs for all projects are outlined in Table 8 below. Refer to Appendix A for a more detailed cost breakdowns for each project.

Table 8: Project Cost Overview

Project ID	Rank	Approximate Total Project Cost
ES_6	1	\$6,010,000
CC_1	2	\$3,440,000
ES_5	3	\$7,530,000
CC_2	4	\$810,000
CC_11	5	\$520,000
ES_10	6	\$1,690,000
SBA_1	7	\$380,000
FR_8	8	\$3,550,000
FR_2	9	\$3,240,000
SBA_2	9	\$70,000
SBA_9	9	\$70,000
CC_10	12	\$150,000
ES_10	13	\$460,000
CA_4	14	\$70,000
ES_4	15	\$4,320,000
Total:		\$32,310,000

5.2 General Project O&M Requirements and Assumptions

For all stormwater infrastructure projects, it is assumed that city staff will provide routine maintenance (approximately every 5 years) of city owned structures and will perform all visual inspections and routine cleanings as necessary. Associated O&M is assumed to be rolled up in the existing city maintenance schedule and associated budget.

For all streambank stabilization projects, it is assumed that city staff will provide visual inspections following repairs, however, the intent of the streambank stabilization efforts is to allow for natural function of the stream and aquatic habitat and therefore would not likely require any routine maintenance measures. Since the City of Liberty has adopted the “modified common enemy doctrine” a public education component may be advantageous to inform residents of corridor repairs and stabilization efforts to ensure project features remain in place in the case that a residential easement encroach on the repair efforts. The goal would be to minimize potential compromise to the proposed project features due to residence lack of background and pertinent project information. Associated O&M is assumed to be rolled up in the existing city maintenance schedule and associated budget.

For the detention project, it is assumed that city staff will provide routine maintenance including visual inspection of the basin and outfall structure, as well as any necessary mowing and associated embankment upkeep. Visual inspections are recommended to occur more frequently during the first three years (once a year) of operation and then city staff can reassess inspection frequency based on performance results and past inspections. Associated O&M is assumed to be rolled up in the existing city maintenance schedule and associated budget.

5.3 Project Descriptions

ID: ES 6, Rank #1

Identified potential undersized storm piping resulting in potential flooding of roadway and residential structures based on modeling results. Recommendation: Upsize existing pipes to reduce hazard on minor arterial street and local routes and reduce flooding of several residential structures. ES_5 and FR_2 should be considered when designing engineering solutions. The proposed project location consists of several project improvements along a single stream corridor that likely work together to convey stormwater. A phased approach to project implementation may be required to maximize available city budget to complete necessary project components. This project location may also present opportunities to seek grant funds specifically due to its proximity to the city police department and emergency operations center.

ID: CC 1, Rank #2

Street Department reported a sinkhole at the southeast corner of the intersection. Investigations indicate a 24” CMP from Plum Rose connects (tee, no structure) into a 54”

CMP storm main along White Oak. The connection and mainline pipe is deteriorated. Invert is rusted. The failed connection at Plum Rose is being replaced prior to the CIP rollout as part of a separate, more immediate repair plan. Recommendation: Rehabilitate or replace/upsized existing CMP along main trunk line.

ID: ES 5, Rank #3

Identified potential undersized storm piping resulting in potential road flooding based on modeling results, limiting possible access to critical facilities. Recommendation: Upsize existing pipes and add new inlets to reduce flooding on minor arterial route and building flooding. ES_6 should be considered when designing engineering solutions. This proposed project location also consists of several project improvements along a single corridor that work together to convey stormwater. A phased approach to project implementation may be required to maximize available city budget to complete necessary project components. This project location may also present opportunities to seek grant funds specifically due to its proximity to the city police department, emergency operations center and fire department.

ID: CC 2, Rank #4

Identified potential undersized existing culvert resulting in possible standing water based on modeling results. Community reports indicate large presence of mosquitos. Recommendation: Upsize DS culvert to 72" to reduce draw down time and add local inlet/outlet protection to prevent against scour and reduce aquatic vegetation where mosquitos thrive. Upsizing the structure also will reduce potential ponding depth on local route.

ID: CC 11, Rank #5

Identified potential undersized crossroad culvert and enclosed system pipes resulting in potential roadway flooding based on modeling results. Recommendation: Upsize existing crossroad culvert and incoming enclosed system pipes to reduce potential roadway flooding on local street. Add local inlet/outlet protection to minimize scour potential, reducing silting concerns.

ID: ES 10, Rank #6

Identified potential undersized storm piping resulting in potential flooding of roadway and habitable structures based on modeling results. Members of the police department indicated known flooding issues here. Recommendation: Upsize system to reduce potential hazard and depth at buildings and on expressway. State owned/maintained infrastructure will not be included in the City CIP efforts.

ID: SBA 1, Rank #7

Identified residential structure and retaining wall at possible risk due to stream erosion during 2024 stream bank assessment (S1.36) (SBA Severity Index 5). Recommendation: Streambank stabilization extended to confluence due to sewer line exposure.

ID: FR 8, Rank #8

Reviewed proposed Detention RCM-2 from 2003 Master Plan and identified potential to reduce possible flood hazard on roadways and for a local residence. (2024 Flood Risk Assessment ID D-1) Recommendation: provide detention in this area.

ID: FR 2, Rank #9

Identified potential flood hazard for approximately 25 residential homes within floodplain based on FEMA effective modeling. (2024 Flood Risk Assessment ID HR-6) Recommendation: Upsize culvert crossing (existing 12x10 RCB) at Murray Rd to improve hydraulic capacity and reduce potential flooding extents. ES_6 should be considered when designing engineering solutions.

ID: SBA 2, Rank #9

Identified Utility Crossing Support Pier at risk of potential failure due to scour during 2024 stream bank assessment (S5.58) (SBA Severity Index 5). Recommendation: Scour mitigation.

ID: SBA 9, Rank #9

Identified bank failure at bridge during 2024 stream bank assessment. Bridge at risk of potential failure due to erosion. (S7.4) (SBA Severity Index 4). Recommendation: Scour mitigation at abutments.

ID: CC 10, Rank #12

Community feedback indicated crossroad drainage is causing water to run across roadway resulting in ponding and icing in winter. Recommendation: Add inlets and connecting pipes to outlet into existing crossroad structure to reduce potential depth on local road.

ID: ES 1, Rank #13

Identified potential flood hazard for roadway and multiple structures based on modeling results. Recommendation: Upsize existing pipes to reduce ponding depth on local street and potential building flooding upstream.

ID: CA 4, Rank #14

Identified existing parallel 30" CMP culverts with significant corrosion. Potential for pipe failure based on condition assessment. (FACILITYID = 48485to48486 and 5829to5830) Recommendation is to upsize and replace pipes.

ID: ES 4, Rank #15

Identified potential flooding hazard along Mill St. based on modeling results, potentially blocking access to emergency facilities. Recommendation: Upsize existing pipes and extend system to reduce potential hazard on minor arterial street. This proposed project location consists of several project improvements along a single corridor that work together to convey stormwater in the area. A phased approach to project implementation may be required to

maximize available city budget to complete necessary project components. This project location may also present opportunities to seek grant funds specifically due to its proximity to the city police department and emergency operations center.

5.4 Conclusion and Further Project Design Considerations

All project improvements outlined above are required to meet all local, state and federal permitting requirements and applicable design standards. Project improvements should be designed in accordance with APWA 5600 criteria and follow recommendations in the MARC BMP Manual, or the most recent versions of the guidance documents. The APWA 5600 and MARC BMP Manual are in the process of being updated and will consist of a combined manual. It is recommended that the latest APWA 5600 and MARC BMP Manual be incorporated as part of any future projects, providing a more insightful development approach for runoff reduction (i.e. preserving or restoring areas, planting trees, and disconnecting impervious areas). In addition to the design standard updates, the emerging APWA 5600 guidance contains further information regarding beneficial green infrastructure including details on green inlet implementation which may be valuable to consider during the construction of the project features in the downtown area. Additionally, any improvements in the vicinity of FEMA regulatory floodplains or floodways should adhere to 44 CFR 60.3 to meet local floodplain ordinances and regulations.

There are several grant and loan programs which Liberty may be eligible for to address the stormwater infrastructure needs identified in this master plan. Examples include:

- The EPA's Clean Water State Revolving Fund (CWSRF) supports, among other projects, "measures to manage, reduce, treat, reuse or recapture stormwater or subsurface drainage water."
- The EPA's Sewer Overflow and Stormwater Reuse Municipal Grant program (OSG) helps communities address stormwater and sewer infrastructure needs. Projects involving stormwater and subsurface drainage water are eligible for funding. Missouri has been allocated \$1,567,000 for FY2024.
- The EPA's Section 319 Grant Program, which may be used to fund urban stormwater runoff activities that are not specifically required by an NPDES permit. Frequently funded urban projects include rain garden/bioretention, porous pavement, landscaped swales, vegetated swales, wetland/riparian protection, and education and outreach.

These and other programs would likely require a significant match from the City of Liberty but offer useful funding to assist communities in meeting their stormwater goals.

APPENDICES

Appendix A: Project Cost Tables

Project ID		ES_6
Project Rank		#1
Approximate Total Pipe Length < 72"	1,190	ft
Approximate Total Pipe Length >= 72"	730	ft
Approximate Number of Storm Structures	46	inlets
Approximate Box Culvert Open Area	85	sq. ft.
Approximate Structure Length	380	ft
Approximate Total Construction Cost	\$3,660,000	
General Contracting Fee	\$190,000	
Engineering Design Fee	\$770,000	
Contingency	\$1,390,000	
Approximate Total Project Cost	\$6,010,000	

Project ID		CC_1
Project Rank		#2
Approximate Total Pipe Length < 72"	3,600	ft
Approximate Total Pipe Length >= 72"	0	ft
Approximate Number of Storm Structures	55	inlets
Approximate Total Construction Cost	\$2,090,000	
General Contracting Fee	\$110,000	
Engineering Design Fee	\$440,000	
Contingency	\$800,000	
Approximate Total Project Cost	\$3,440,000	

Project ID		ES_5
Project Rank		#3
Approximate Total Pipe Length < 72"	2,285	ft
Approximate Total Pipe Length >= 72"	1,825	ft
Approximate Number of Storm Structures	70	inlets
Approximate Total Construction Cost	\$4,590,000	
General Contracting Fee	\$230,000	
Engineering Design Fee	\$970,000	
Contingency	\$1,740,000	
Approximate Total Project Cost	\$7,530,000	

Project ID		CC_2
Project Rank		#4
Approximate Total Pipe Length < 72"	0	ft
Approximate Total Pipe Length >= 72"	295	ft
Approximate Number of Storm Structures	2	inlets
Approximate Total Construction Cost	\$480,000	
General Contracting Fee	\$30,000	
Engineering Design Fee	\$110,000	
Contingency	\$190,000	
Approximate Total Project Cost	\$810,000	

Project ID		CC_11
Project Rank		#5
Approximate Total Pipe Length < 72"	700	ft
Approximate Total Pipe Length >= 72"	0	ft
Approximate Number of Storm Structures	4	inlets
Approximate Total Construction Cost	\$310,000	
General Contracting Fee	\$20,000	
Engineering Design Fee	\$70,000	
Contingency	\$120,000	
Approximate Total Project Cost	\$520,000	

Project ID		ES_10
Project Rank		#6
Approximate Total Pipe Length < 72"	0	ft
Approximate Total Pipe Length >= 72"	595	ft
Approximate Number of Storm Structures	8	inlets
Approximate Total Construction Cost	\$1,020,000	
General Contracting Fee	\$60,000	
Engineering Design Fee	\$220,000	
Contingency	\$390,000	
Approximate Total Project Cost	\$1,690,000	

Project ID	SBA_1	
Project Rank	#7	
Approximate Stream Length	365	ft
Approximate Total Construction Cost	\$220,000	
General Contracting Fee	\$20,000	
Engineering Design Fee	\$50,000	
Contingency	\$90,000	
Approximate Total Project Cost	\$380,000	

Project ID	FR_8	
Project Rank	#8	
Estimated Project Cost (2003 SWMP)	\$870,000	
Approximate Total Construction Cost	\$2,270,000	
Engineering Design Fee	\$460,000	
Contingency	\$820,000	
Approximate Total Project Cost	\$3,550,000	

Project ID	FR_2	
Project Rank	#9	
Approximate Box Culvert Open Area	240	sq. ft.
Approximate Structure Length	155	ft
Approximate Rip Rap Area	7,200	ft. ³
Approximate Total Construction Cost	\$1,970,000	
General Contracting Fee	\$100,000	
Engineering Design Fee	\$420,000	
Contingency	\$750,000	
Total Project Cost	\$3,240,000	

Project ID	SBA_2	
Project Rank	#9	
Approximate Stream Length	50	ft
Approximate Total Construction Cost	\$30,000	
General Contracting Fee	\$10,000	
Engineering Design Fee	\$10,000	
Contingency	\$20,000	
Approximate Total Project Cost	\$70,000	

Project ID		SBA_9
Project Rank		#9
Approximate Stream Length	50	ft
Approximate Total Construction Cost	\$30,000	
General Contracting Fee	\$10,000	
Engineering Design Fee	\$10,000	
Contingency	\$20,000	
Approximate Total Project Cost	\$70,000	

Project ID		CC_10
Project Rank		#12
Approximate Total Pipe Length < 72"	142	ft
Approximate Total Pipe Length >= 72"	0	ft
Approximate Number of Storm Structures	2	inlets
Approximate Total Construction Cost	\$80,000	
General Contracting Fee	\$10,000	
Engineering Design Fee	\$20,000	
Contingency	\$40,000	
Approximate Total Project Cost	\$150,000	

Project ID		ES_1
Project Rank		#13
Approximate Total Pipe Length < 72"	449	ft
Approximate Total Pipe Length >= 72"	0	ft
Approximate Number of Storm Structures	7	inlets
Approximate Total Construction Cost	\$270,000	
General Contracting Fee	\$20,000	
Engineering Design Fee	\$60,000	
Contingency	\$110,000	
Approximate Total Project Cost	\$460,000	



Project ID		CA_4
Project Rank		#14
Approximate Total Pipe Length < 72"	80	ft
Approximate Total Pipe Length >= 72"	0	ft
Approximate Number of Storm Structures	0	inlets
Approximate Total Construction Cost	\$30,000	
General Contracting Fee	\$10,000	
Engineering Design Fee	\$10,000	
Contingency	\$20,000	
Approximate Total Project Cost	\$70,000	

Project ID		ES_4
Project Rank		#15
Approximate Total Pipe Length < 72"	2,890	ft
Approximate Total Pipe Length >= 72"	688	ft
Approximate Number of Storm Structures	38	inlets
Approximate Total Construction Cost	\$2,620,000	
General Contracting Fee	\$140,000	
Engineering Design Fee	\$560,000	
Contingency	\$1,000,000	
Approximate Total Project Cost	\$4,320,000	