REPORT

AUGUST 2024

Marsh Creek Stream Assessment

Prepared for:

City of Raleigh

CDM Smith

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SECTION 1

Stream Assessment

OBJECTIVE

The goal of the Marsh Creek Stream Assessment was to perform a rapid inventory of streams to collect information that will **inform the City of Raleigh's strategic planning and the Marsh Creek Watershed Study, develop future stream restoration opportunities, and further partnerships with the community.**

FAST FACTS

- **Approximately 21 miles of stream reaches** were inventoried along the mainstem and major tributaries of Marsh Creek. A little more than **1.3 miles** of these stream reaches are on city owned property. Most of the remaining streams are on privately owned property.
- A total of 1,093 **inventory points** were collected during the stream assessment: 259 stream condition points, 203 points of interest, and 631 stormwater infrastructure assessment points.
- The **stream assessment extents** were developed using a 25-acre threshold.

KEY TAKEAWAYS

- Stream reaches were assessed for **streambank erosion, canopy cover, substrate, anthropogenic and hydrologic alterations, and buffer encroachment**.
- Miscellaneous stream issues that catalog **potential water quality impacts, constrictions along the stream, impacts of stream erosion, and potential projects** were also documented.
- Approximately **30 percent** of the stream reaches assessed have **anthropogenic alterations** with **channelization** and hardening with **rip-rap** being most prevalent.
- Of the stream reaches assessed, **82 percent would benefit from some level of stream restoration or preservation.**
- Approximately **90 percent** of the riparian area along assessed stream reaches have **full or at least partially intact buffers;** invasive plant species are pervasive and threaten the quality of the existing riparian buffer in the Marsh Creek watershed.
- Of the 631 stormwater inlets and outlets that were assessed, **53[a] percent were observed to have at least one type of maintenance concern.** However, most maintenance concerns had low condition assessment ratings (low = minor issue).

Ownership = 6% City, 33% Private with Public Runoff, 7% Private,5% State, and 2% Unknown.

1.1 Stream Assessment Introduction and Programmatic Considerations

During March – May 2024, stream assessments were performed throughout the Marsh Creek watershed. The assessments included streams entirely within the corporate limits of the City of Raleigh (City) and were performed on City property as well as, state and private property. The goal of the stream assessments was to perform a rapid inventory of stream condition within the Marsh Creek watershed. The initial methodology was developed for the Hare Snipe Watershed Study with minor modifications added for the Pigeon House Watershed Study and then most recently for the Marsh Creek Stream Assessment. The most recent version of the stream methods is included as Appendix A. The information gathered during the stream assessments will inform the City's strategic planning, develop future stream restoration opportunities, and further partnerships with the community.

This section provides the results of the rapid stream assessments for the Marsh Creek watershed and identification of stream reaches that may benefit from restoration activities by restoration type.

1.1.1 Strategic Planning

The stream restoration projects will further develop the Growth and Natural Resources component of the City of Raleigh FY21-25 Strategic Plan (Strategic Plan). The goal of the Growth and Natural Resources component of the Strategic Plan is to encourage a diverse and vibrant built environment that preserves and protects the community's natural resources, strives for environmental equity and justice, and encourages sustainable growth that complements existing development. An objective of the Strategic Plan is to identify opportunities to refine and enhance policies and programs that protect and improve environmental resources. An initiative under that objective is to develop and establish a stream restoration prioritization plan. The data collected from this study will help inform the direction of this strategic initiative.

1.1.2 Stream Restoration Opportunities

The stream assessment data was used to identify stream restoration opportunities across the watershed that will be further examined during the Marsh Creek Watershed Study and through other City programs. City ownership or level of access can be a defining factor in selection of potential stream restoration locations. Of the 20.7 miles of assessed stream, approximately 1.3 miles are on or adjacent to City owned property, 19.3 miles are within private property and less than 0.1 miles are on state property.

Given equal stream restoration project opportunities, those on City property are typically prioritized. Stream restoration on City property is done in coordination with the City department that manages the property, such as the Parks, Recreation and Cultural Resources Department.

The Stormwater Division has several programs to assist private property owners with stream bank stabilization on their property:

- Drainage Assistance Program - The Drainage Assistance Program offers support for homeowners experiencing flooding or severe erosion threatening a structure. Through this program, the

Stormwater Division addresses erosion on a case-by-case basis using cost-effective stabilization methods.

- Stream Stabilization Program - The Stream Stabilization Program helps with minor to moderate erosion issues caused by stormwater runoff coming from public streets or public properties not otherwise covered by the Drainage Assistance Program.
- Buffer Builder Bag (B3) Program – This is a voluntary program that provides private property owners with free native shrub and tree seedlings to help improve or create a streamside buffer on their property.
- Stream Bank Repair Workshops – The City's Drainage Assistance Program in partnership with NC State University's Department of Biological and Agricultural Engineering Cooperative Extension provides workshops that teach property owners small-scale solutions for eroding stream banks. This program is geared to those experiencing minor to moderate erosion. Attendees at these workshops participate in hands-on streambank protection and invasives treatment projects, including installation of live-stakes and other native plants to assist in the re-establishment of streamside buffers.

1.1.3 Stormwater Volunteer Programs and Community Partnerships

The Stormwater Division also partners with the community to monitor and protect the City's watersheds. Residents participating in the City's Stormwater Volunteer programs (Stream Monitoring, Adopt a Stream, Storm Drain Marking, Green Stormwater Infrastructure (GSI) Visual Monitoring) help track the condition of GSI and streams, clean and protect local waterways, and provide data to inform the direction of the City's water quality initiatives. The public engagement component of the watershed study and stream assessment results will help raise awareness and inform continuous improvement of program implementation.

Stormwater Volunteer Programs

- Stream Monitoring Program – As part of the stream monitoring program, volunteers learn more about Raleigh's waterways and collect data on the overall health/quality of a stream. There are currently no volunteer monitoring locations in the Marsh Creek watershed.
- Adopt a Stream – Volunteers choose a stream to clean throughout the year. They remove trash from streams and identify other sources of pollution, like bacteria or paint/oil spills. The City of Raleigh provides safety gear and trash bags to volunteers. Approximately 2.6 miles of stream have been adopted in Marsh Creek watershed.
- Storm Drain Marking Program – With this program volunteers attach markers to neighborhood storm drains to remind others to avoid dumping harmful items into the drain. This helps reduce water pollution and protect the environment, too. 331 storm drains have been marked by volunteers in the Marsh Creek watershed.
- GSI Visual Monitoring Pilot Program- Citizen scientists complete an on-line survey and photograph using a phone stand at select constructed GSI and water quality improvements over time. This creates a timelapse of changes over time and provides the City with community feedback. Since this is a recent pilot program, only two monitoring locations have been

established to date at Walnut Creek Wetland Park and Glen Eden Pilot Park. However, a third location is in the works (Wooten Meadow Park), with opportunities to establish future monitoring locations in Marsh Creek watershed as projects are completed.

Community Partnerships

- Instream Trash Collector Expansion Program – Raleigh Stormwater is partnering with Sound Rivers to expand the number and locations of instream trash collector devices throughout the City of Raleigh over the next few years. This partnership program will enhance local stream health through trash removal and by providing partner-led community engagement and stormwater-related education.
- Marsh Creek watershed Litter Study – Community partners, including North Carolina Sea Grant and NC State University, recently received grant funding to conduct a litter study in Marsh Creek watershed. Partners will conduct research and test litter reduction strategies, investigate land-based litter in urban areas and human attitudes and behaviors that contribute to these sources; document the downstream transport of litter; and evaluate approaches for preventing both direct and inadvertent litter from entering the stormwater system and streams. Raleigh Stormwater is partnering in the effort by providing staff support, funding, and two instream trash collectors in Marsh Creek.
- 'The Workforce – The Great Raleigh Cleanup and City of Raleigh Beautification Program' - this partnership, funded by the City and coordinated by the Great Raleigh Cleanup nonprofit-provides employment opportunities for people experiencing homelessness to support City beautification projects through litter pickup and removal.

1.2 Stream Assessment Overview

CDM Smith assessed approximately 20.7 miles of stream channel within the Marsh Creek watershed during March-May 2024 (**Table 1-1 and Figure 1-1**). The assessed stream reaches included Marsh Creek, Pew Pond, Beaman Lake, and numerous unnamed tributaries. Initial stream assessment extents were developed using a 25-acre threshold. The initial assessment extents were updated based on field conditions to generate the actual assessment extents. For example, if a portion of the stream was identified as intermittent or lacking stream characteristics then the assessment ended, and the extents were edited accordingly. The initial stream extents ran through several small ponds, which were removed from the final stream extents. Piped reaches were assessed only at their inflows/outflows, which is discussed further in section 1.5. The actual assessment extents shown in Figure 1-1 were developed from the City's channels GIS layer. A subset of this layer was extracted that coincides with the actual assessment extents and then minor modifications were made in a few locations to reflect observed field conditions, such as, where the stream path varied from that shown in the channels GIS layer. Figure 1-1 also includes the stream segment IDs which were added according to the stream assessment methods detailed in **Appendix A**, **Section 4.2.5**, as part of the Marsh Creek Stream Assessment.

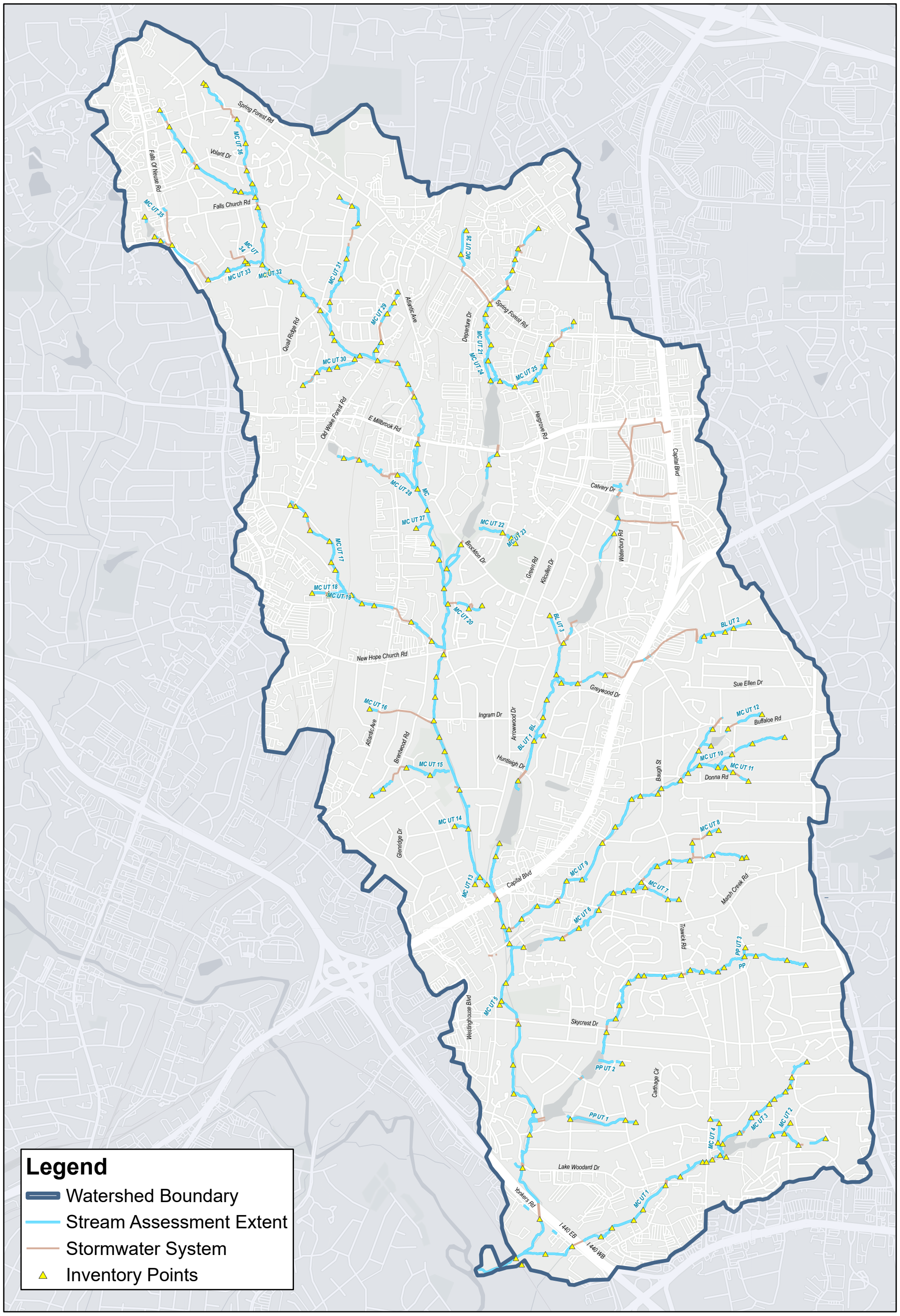

Figure 1-1 Stream Assessment Extents

Marsh Creek Watershed Study

City of Raleigh, North Carolina

CDM Smith

Table 1-1 Watershed Area and Stream Miles Assessed

Watershed	Drainage Area (mi^2)	Length Assessed (miles)	Length Assessed on City Property (miles)
Marsh Creek	9.5	20.7	1.3

A total of 1,093 inventory points were collected during the stream assessment. Points were taken to capture stream condition, infrastructure condition, or a miscellaneous point of interest. Stream condition points are located at the upstream end of each assessed reach and document conditions occurring from the upstream point to the next downstream point (Section 1.3 and 1.6). Miscellaneous points were taken wherever a point of interest was found (Section 1.4). Points for stormwater infrastructure were taken at the outfall of pipes (Section 1.5). An overview of the categories of data collected during this inventory are listed in **Table 1-2**.

Data were collected using mobile GIS and are stored at the online collaboration site. All information is contained in the MarshCreek_FieldAssessment Map and the file names are as follows:

- Stream Condition - StreamAssessment_UpstreamPoints
- Miscellaneous and Other Points of Interest - StreamAssessment_MiscPoints
- Stormwater Infrastructure – StreamAssessment_PipeIO

In addition, 360 video of the stream channel was collected throughout the stream assessment extents. The telemetry data of the video is being processed to develop GIS points at regular intervals along each reach. These points will be linked to the 360 video which is currently hosted on YouTube. A GIS file of the data will be placed on the MarshCreek_FieldAssessment Map. The file name will be 360 Video Data (20 ft interval).

Table 1-2 Stream Assessment Data Collection Categories

Category	Description
Stream Condition	
Bank Erosion	The extent of bank erosion documented in quartiles of streambank exposure (percentage of streambank with exposed soil)
Substrate	The type of substrate predominantly found in the streambed
Stream Canopy Cover	The extent of shade provided by the canopy over the stream
Riparian Buffer	Reaches where land use practices have encroached upon the 50-foot riparian buffer
Anthropogenic Alterations	Reaches where channel morphology has been altered due to direct or indirect human activity (anthropogenic causes)
Hydrologic Alternations	Reaches where changes in land use have led to channel morphology alterations due to modified watershed hydrology and sediment input
Stream Restoration Projects	Restoration measures that may be utilized to repair stream reaches
Stormwater Infrastructure	
Condition Assessment	Maintenance issues or infrastructure concerns at stormwater outfalls
Dry Weather Flow	Review of specific NPDES outfalls for potential dry weather flow
Miscellaneous and Other Points of Interest	
Miscellaneous and Other Points of Interest	Other problems or unique features such as potential water quality impacts, stream erosion impacts, stream constrictions, or potential project information

1.3 Stream Condition

Six stream condition characteristics were collected as part of the stream assessment:

- Streambank Erosion
- Substrate
- Stream Canopy Cover
- Riparian Buffer
- Anthropogenic Alterations
- Hydrologic Alterations

The stream assessment field team collected stream condition points using the ArcGIS Field Maps mobile application. Stream condition data were collected in a single GIS feature layer (StreamAssessment_Upstream Points). Data points were placed on the upstream end of each assessed reach. In general, stream condition assessment reach segments were divided up based on observed changes in stream conditions, such as hydraulic and/or geomorphic characteristics. Segments were also created at areas of notable change, for example confluences of an incoming tributary, or at a roadway crossing. The reach lengths varied from 55 linear feet to 1,500 linear feet with a mean length of about 420 feet. Streambank erosion and riparian buffer data sets include information for the left and right bank/buffer conditions. Left and right sides of the stream are designated as looking downstream.

1.3.1 Streambank Erosion

Observed streambank erosion was classified into one of four quartiles (0-25 percent, 25-50 percent, 50-75 percent, or 75-100 percent) of erosion on both left and right stream banks for each stream segment (**Table 1-3**). Streambank erosion characteristics are average conditions for the length of each stream condition assessment reach. Specific locations where stream erosion was observed to impact infrastructure (e.g., roads, culverts, storm outfalls, buildings, utilities) were collected in the miscellaneous and other points of interest category. Average streambank heights were recorded for each reach. **Photo 1-1** illustrates examples of the quartile classification used to document streambank erosion observed in the Marsh Creek watershed.

Table 1-3 Streambank Erosion

Percent Exposed Streambank	Total Streambank Length (ft) [a]	Percent of Total Streambank Length (%)
0-25 percent	77,299	35%
25-50 percent	64,678	30%
50-75 percent	58,924	27%
75-100 percent	17,372	8%

a. Lengths in table represent summation of streambank erosion for left and right banks under each category

Photo 1-1 Stream bank erosion from 0-25 percent at the end of Leafcrest Court (upper left), 25-50 percent near Huntleigh Drive (upper right), 50-75 percent near Volant Drive (lower left), and 75- 100% near Oates Drive (lower right).

In general, streams in the Marsh Creek watershed are eroding in response to recent and historic land use changes. Deforestation and mill pond construction in the late 18th century by European settlers, straightening of many streams by farmers in the early 20th century, and more recent urban development have led to sedimentation and erosion in most of the stream segments within the Marsh Creek watershed. Most are historically incised and detached from their floodplains and are still cutting down through drainages that were filled with sediments from deforestation and damming. The streams are currently receiving higher and more pulsed rates of inflow from stormwater runoff associated with increased development and density, leading to further erosion in the confined channels. Hot spots for erosion exist throughout the watershed as the streams try to gain equilibrium, but areas near the headwaters where development is denser and more recent, and lower reaches where they are more

detached from the floodplain have higher bed and bank erosion (**Figure 1-2)**. Erosion was observed within more than 25 percent of most stream segments, indicating they are subject to active erosion.

1.3.2 Substrate

Substrate composition of a streambed plays a key role in providing suitable habitat for aquatic life. Bedforms with riffle pool formations provide habitat diversity. Streambed substrate provides insight into stream habitat quality and hydrologic conditions. On a larger scale in the Marsh Creek watershed, coarser grain materials were observed in the upper watershed tributaries (darker dots on **Figure 1-3**). The upper watershed areas have been impacted by the erosive flows from runoff, which moves the finer grain sediments from the channel downstream. Areas with substrate sizes of gravel or larger match well with areas of higher streambank erosion. The finer grain materials, primarily sand, are deposited in the larger tributaries and continually moved downstream (lighter dots on Figure 1-3).

The dominant streambed material observed within each stream condition assessment reach was classified into one of eight classifications based on the size and type of bed material **(Table 1-4**). The predominate bed material observed was sand (44 percent), which when in excess can cover riffle pool complexes and native bedforms providing poor quality habitat for aquatic life.

Table 1-4 Substrate

Dominant Substrate	Total Streambed Length (ft)	Percent of Total Streambed Length (%)
Bedrock	2,081	2%
Boulder (256-4096 mm)	4,775	4%
Cobble (64-256 mm)	20,701	19%
Gravel (2-64 mm)	18,595	17%
Sand (0.062-2mm)	47,679	44%
Silt/clay (<0.062mm)	10,388	10%
Detritus	479	0%
Artificial	4,438	4%

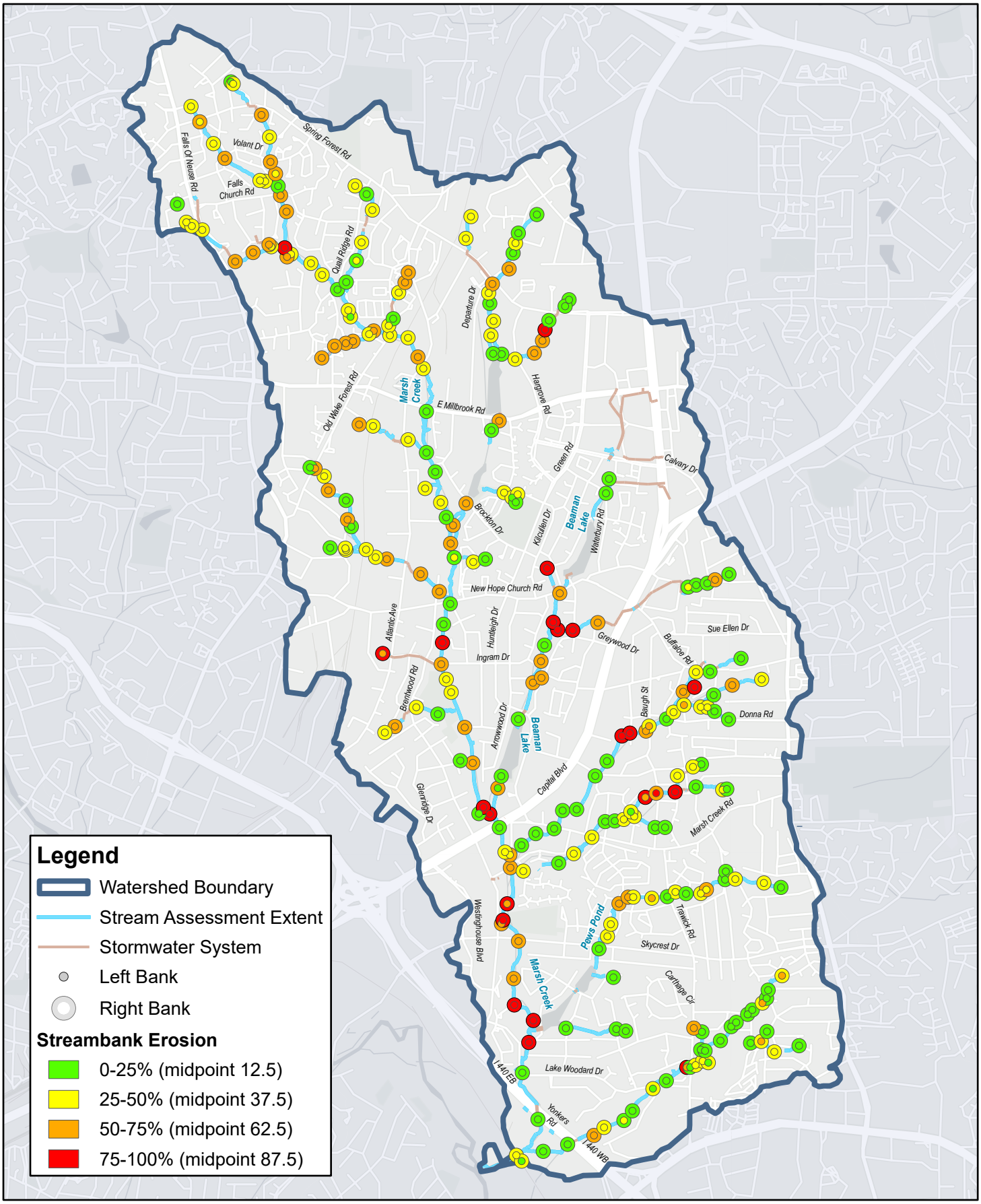

Figure 1-2 Streambank Erosion
Marsh Creek Watershed Study
City of Raleigh, North Carolina

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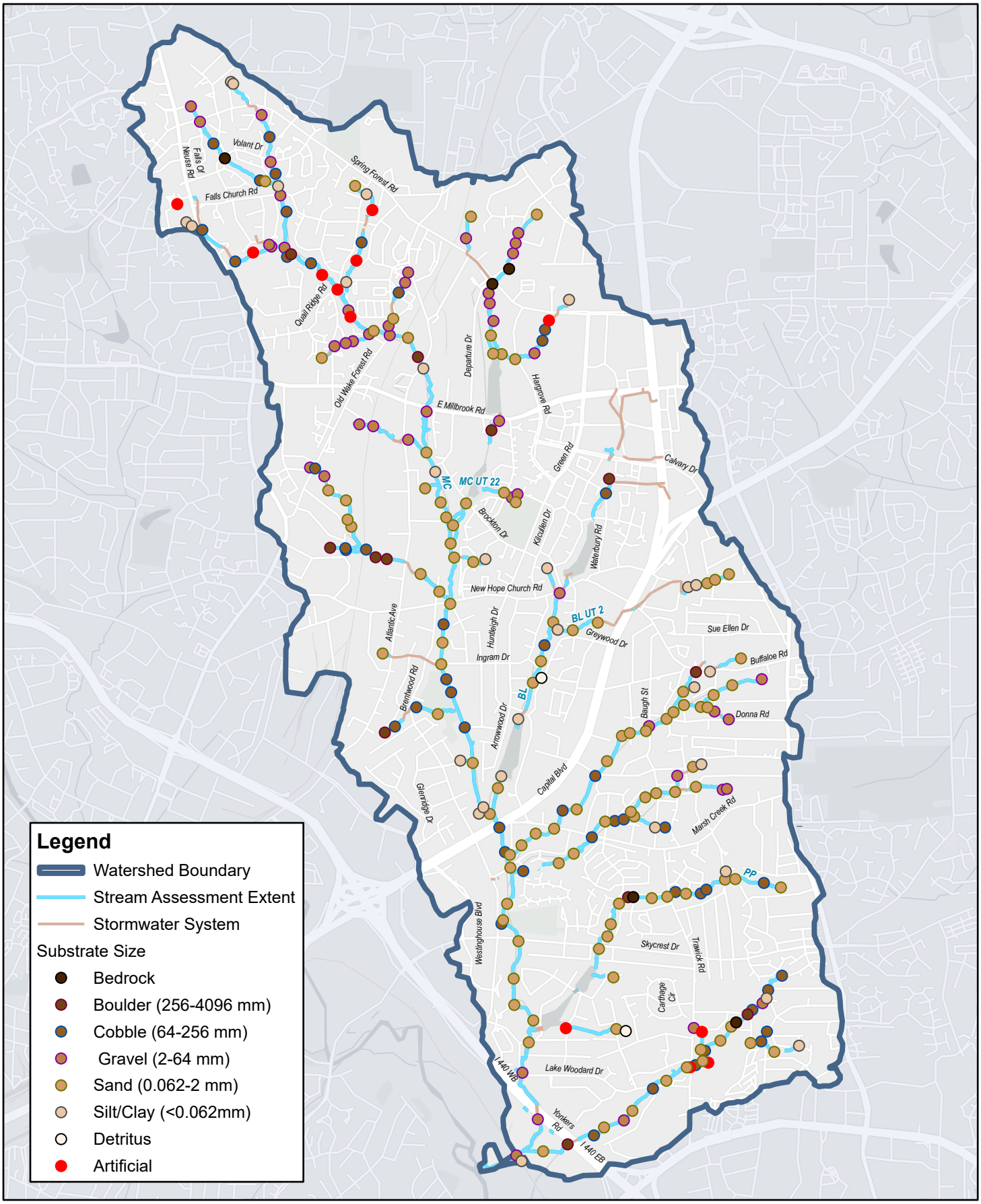

Figure 1-3 Substrate

Marsh Creek Watershed Study

City of Raleigh, North Carolina

CDM Smith

1.3.3 Stream Canopy Cover

The tree canopy and vegetation in the riparian buffer provide shade for streams that helps regulate water temperature, which if elevated can affect water quality and aquatic life. Overall decent canopy coverage was observed throughout the Marsh Creek watershed (**Figure 1-4**). Stream canopy cover within each stream condition assessment reach was classified into three categories based on the amount of shading provided to the stream channel, full shade, partial shade, or limited to no shading (**Table 1-5**). Most reaches had at least partial or full canopies. Canopy coverage was lower in denser residential and commercial areas, and higher in floodplain areas and larger undeveloped parcels.

Table 1-5 Stream Canopy Cover

Stream Shading Amount	Total Streambed Length (ft)	Percent of Total Streambed Length (%)
Full	39,933	37%
Partial	61,158	56%
Limited to None	8,045	7%

1.3.4 Riparian Buffer

Riparian buffers help protect water quality by preventing pollutants from entering streams. They intercept sediment and nutrients contained in overland runoff and help stabilize streambanks, reducing erosion. Riparian buffers provide a connection to terrestrial habitats and ecosystem diversity. They help maintain instream habitat by filtering pollutants in runoff, moderating water temperatures, and reducing erosion. Overall, the Marsh Creek watershed has good buffer extents (**Figure 1-5**). Approximately 90 percent of the assessed stream bank lengths have full or at least partial buffer extents. Areas with no buffer or encroachment are generally near higher density residential and commercial areas, and adjacent to roadways and utilities (**Figure 1-6**). Additionally, approximately 75 percent of stream lengths with partial buffer extents are from encroachments of lawns (53 percent) or maintained utilities (22 percent) and provide some vegetative coverage in those buffer areas. While having some vegetation present in the buffer is better than none, utilities and lawns in the buffer will dimmish the benefits provided by the riparian buffer. Consequences include increased runoff to the stream, less pollutant reduction with the potential for increases if lawns are fertilized, reduced cooling due to less dense vegetation and understory, and reduced bank stabilization from deep root systems when compared to a natural buffer.

Table 1-6 classifies the quality and encroachment of a 50-foot stream buffer into one of four categories: none (no buffer present), partial (a portion of the 50-ft buffer is present), poor quality (buffer intact with poor quality), or good quality (buffer intact with good quality). For areas with full buffers present, the quality of the full buffer was considered poor if the buffer was visibly impaired, primarily by the presence of invasive species. If encroachment into the buffer was present, then **Table 1-7** documents the type of land cover impacting the buffer. Riparian buffer information was collected for both left and right banks.

Invasive species presence and abundance in the riparian buffer was assessed using three categories of minimal, moderate, or significant for both the left and right bank buffer areas (**Table 1-8 and Figure 1-7**). During the stream assessment, it was observed that invasive species are pervasive in the Marsh Creek

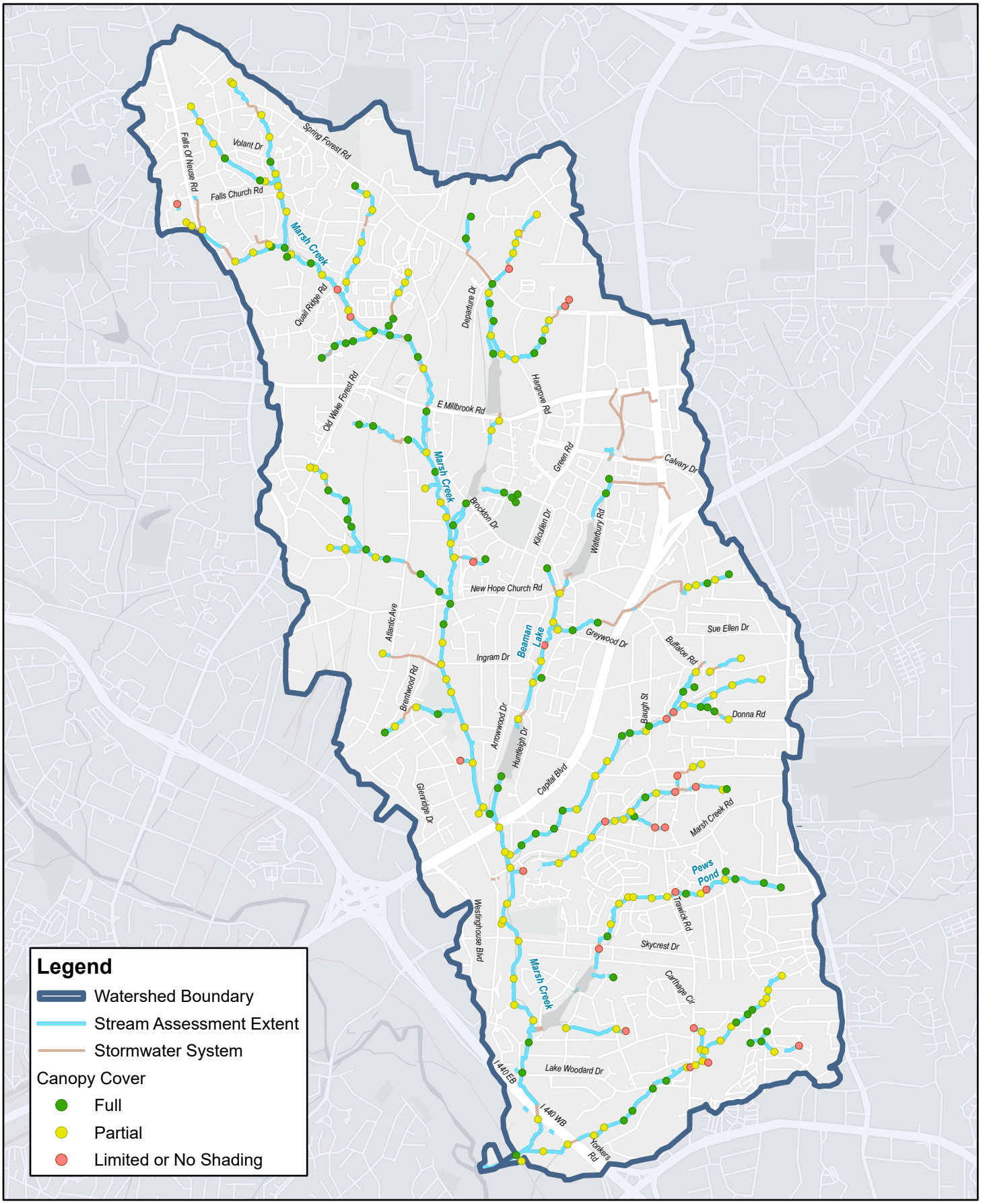

Figure 1-4 Stream Canopy Cover

Marsh Creek Watershed Study

City of Raleigh, North Carolina

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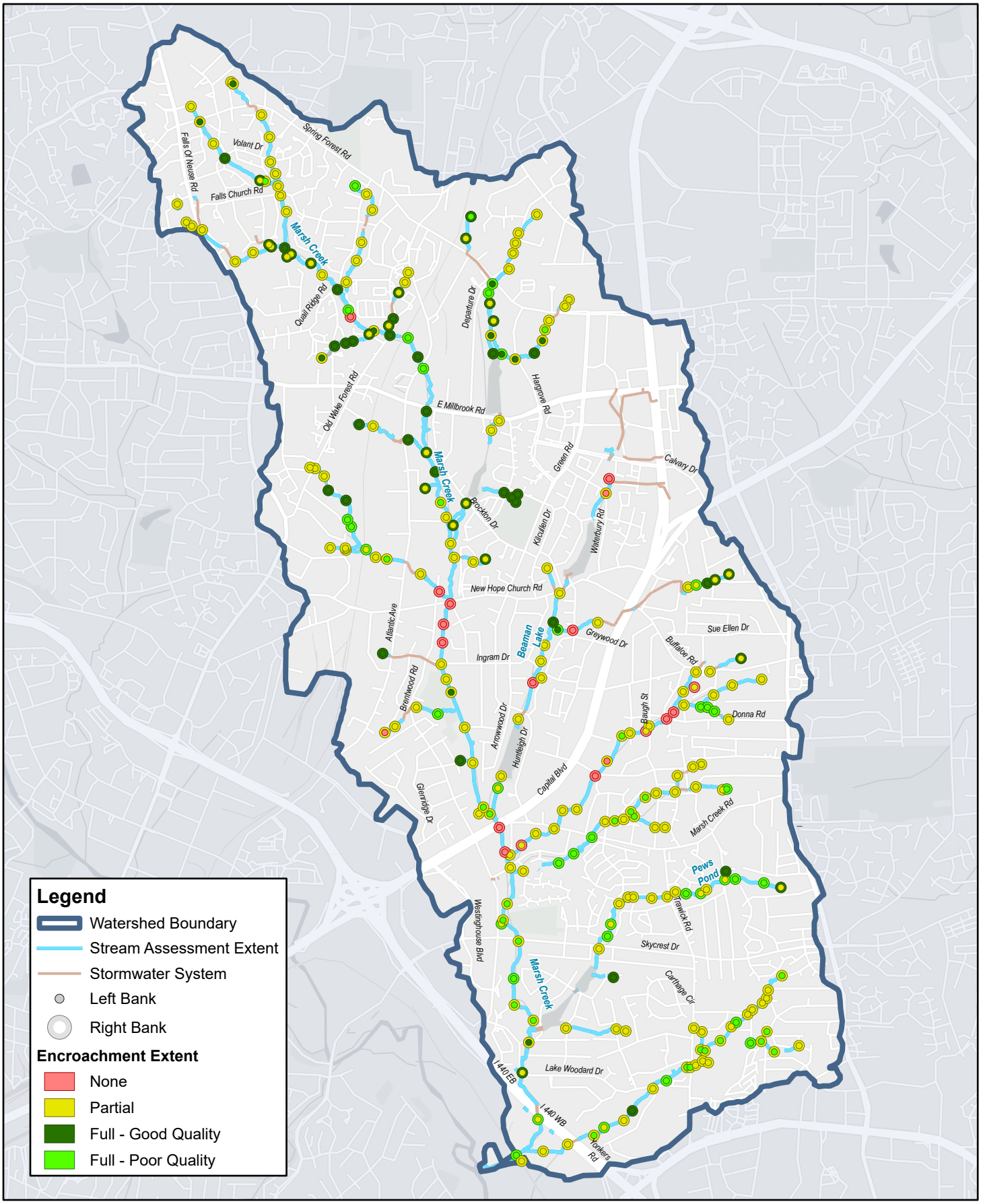

Figure 1-5 Riparian Buffer

Marsh Creek Watershed Study

City of Raleigh, North Carolina

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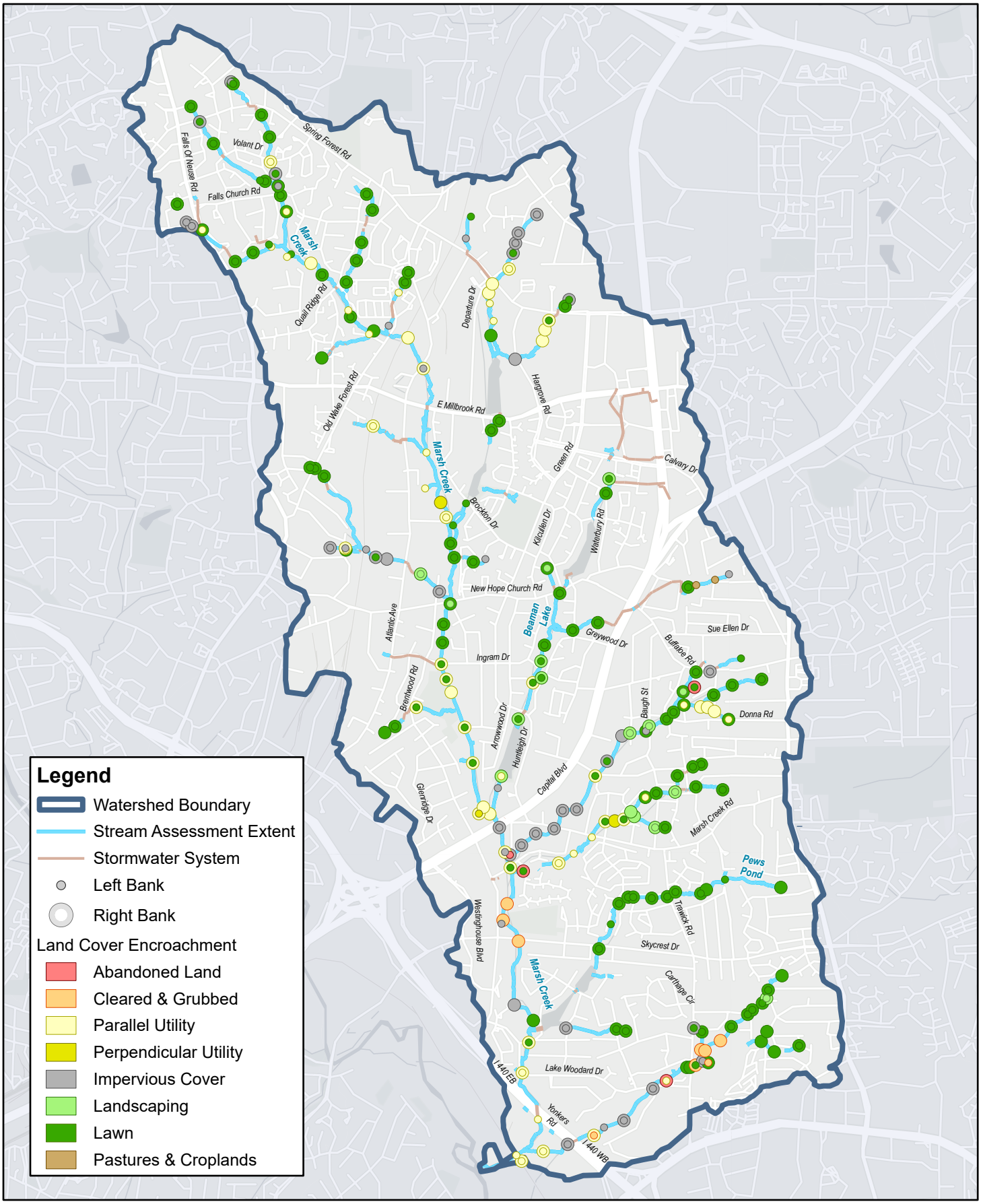

Figure 1-6 Riparian Buffer Encroachment Land Cover

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City of Raleigh, North Carolina

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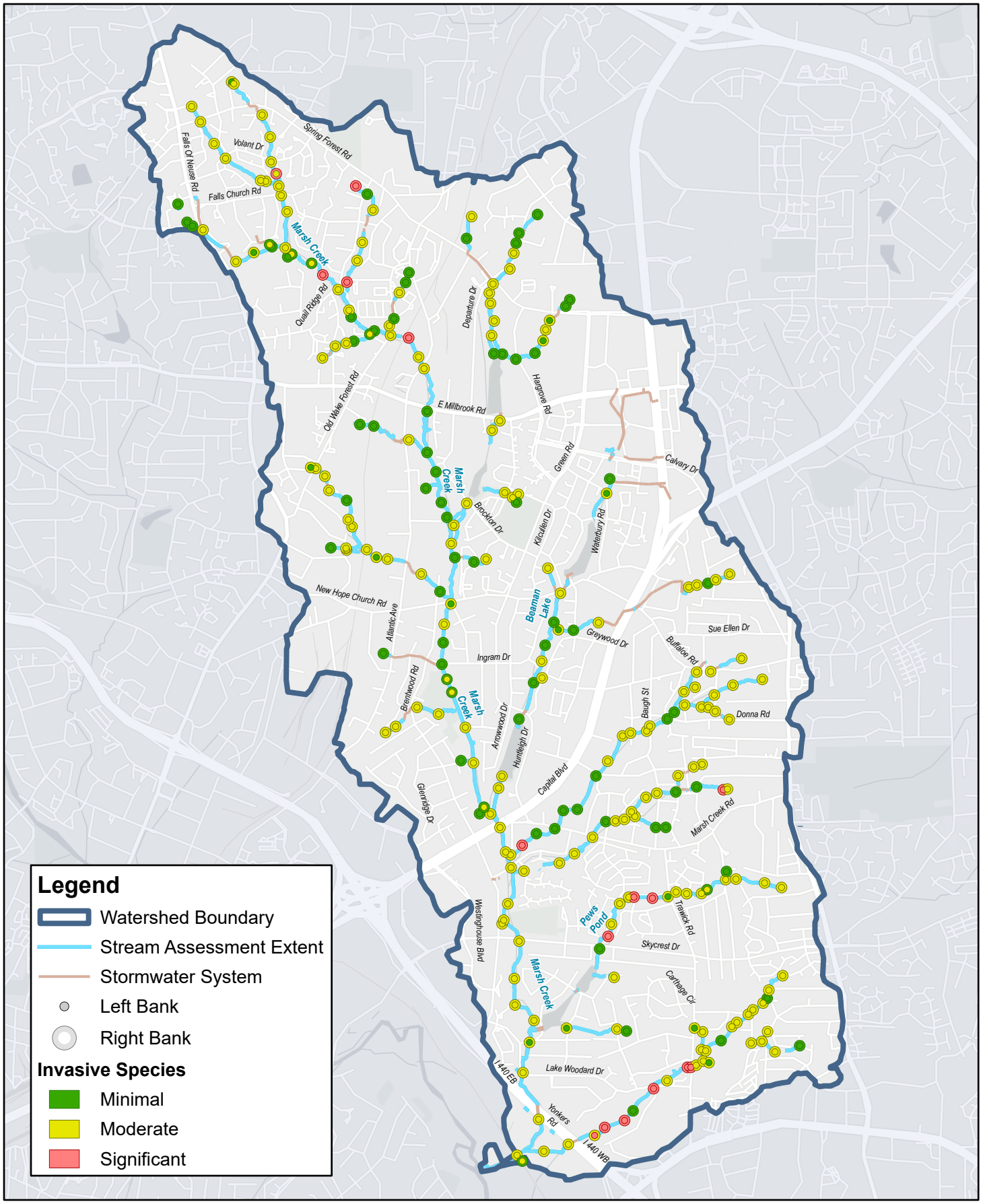

Figure 1-7 Invasive Species
Marsh Creek Watershed Study
City of Raleigh, North Carolina

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watershed with 73 percent of the assessed stream reaches classified as having moderate to significant amounts of invasive species. Table 1-7 shows that more than half (53 percent) of the fully intact buffers are impacted by invasives specifies. A similar compilation of data for the partial buffers indicates that 78 percent have moderate (71 percent) or significant (8 percent) amounts of invasive specifies present. Invasive species outcompete native plant species often by limiting or killing beneficial native canopy and understory species. Invasive climbing vines like English ivy or wisteria can also increase the risk of trees falling due to their weight. Once established they provide a homogeneous plant species composition that is poor habitat for natural communities and less effective at filtering sediment and nutrients from runoff.

Table 1-6 Riparian Buffer

Buffer Extent		Total Streambank Length (ft) [a]	Percent of Total Streambank Length (%)
None		15,634	7%
Partial		131,634	60%
Full (buffer intact)[a]	Good Quality	33,286	15%
	Poor Quality	37,720	17%

a. The total streambank length with a fully intact buffer is 71,006 feet, or 32% of the streambank length.

Table 1-7 Type of Riparian Buffer Encroachment

Land Cover in Buffer	Total Streambank Length (ft) [a]	Percent of Total Streambank Length (%)
Abandoned Land	938	1%
Cleared and Grubbed	3,682	3%
Cleared/Maintained Utilities, Parallel	30,775	21%
Cleared/Maintained Utilities, Perpendicular	741	1%
Impervious Cover	25,062	17%
Landscaping	7,422	5%
Lawn	76,716	53%
Pastures and Cropland	429	<1%

Lengths in table represent summation of streambank buffer for left and right banks under each category.

Table 1-8 Invasive Species in Riparian Buffer

Extent of Invasives in Buffer	Total Streambank Length (ft) [a]	Percent of Total Streambank Length (%)
Minimal	58,775	27%
Moderate	146,789	67%
Significant	12,709	6%

Lengths in table represent summation of streambank buffer for left and right banks under each category.

Moderate amounts of invasive species were prevalent throughout the watershed with smaller pockets of significant amounts of invasives. The presence of invasive species can undermine the benefits provided by the riparian buffer. Removal and management of invasive species helps maintain native species communities that provide better habitat and water quality benefits. The predominant invasive species observed included Privet, English Ivy, Autumn Olive, Kudzu, Wisteria, Multiflora Rose, Leatherleaf Mahonia, Golden Bamboo, and Japanese Honeysuckle, as illustrated in **Photos 1-2 and 1-3**.

Photo 1-2 Significant invasive species downstream of Trawick Road near Bond Street (Wisteria, Kudzu, Privet, Multiflora Rose, and Japanese Honeysuckle)

Photo 1-3 Moderate invasive species in buffer understory upstream of Skycrest Drive near Brentwood Road (Privet)

1.3.5 Anthropogenic Alterations

Anthropogenic alterations are direct modifications to the stream channel as a result of human activity that affect the channel dimension, pattern, or profile. To document anthropogenic alterations within each stream condition assessment reach they were placed into one of five categories listed on **Table 1-9** bioengineered/restoration, concrete channel, riprap channel, channelized reach, and other. Anthropogenic alterations classified as "other" typically contain a buildup of anthropogenic material such as concrete slabs and other hardened debris. The "notes" field within the data provides more detail on the characteristics of "other" alterations.

Table 1-9 Anthropogenic Alterations

Alteration	Hardened Alteration	Count	Total Streambed Length (ft)	Percent of Total Streambed Length (%)
Bioengineered/restoration	X	3	768	1%
Concrete Channel	X	10	1,576	1%
Riprap Channel	X	99	18,490	17%
Other	X	5	1,203	1%
Channelized reach	-	56	21,352	20%
Unaltered (no Anthropogenic Alterations)	-	87	71,699	66%

Occasionally, one reach will have an overlapping sections of hardened and channelized reaches, leading to a total streambed length greater than the sum of stream assessed.

Hardening, channelizing, and piping of stream channels have the potential to increase flow velocities in and adjacent to the alterations by reducing bed and bank friction. Additionally, reduced stream lengths associated with channelizing and piping shorten the water conveyance distance and time in the channel and increase the channel slope producing higher flow rates and erosion. Anthropogenic alterations, given enough quantity, can produce watershed wide increases in flow velocities and the resulting erosion. Within the Marsh Creek watershed 18 percent of all the assessed stream lengths had riprap or concrete lined channels and/or streambanks. This data collection category does not currently differentiate between right or left bank or both, so there is at least presence on one bank, but many hardened stream lengths were fully lined channels or present on both banks.

Channelized reaches where the stream has been straightened were observed along 20 percent of all the assessed stream lengths. Approximately 6 percent of the total streambed length has been both hardened and channelized, resulting in a total streambed length column total of 106 percent. This data collection category does not currently specify the location of channelized, hardened reaches, so this estimate of overlap could be a little low. Regardless, the amount of channel hardening and straightening in the Marsh Creek watershed is significant. Around 30 percent of the total streambed length assessed has been hardened or channelized or both. Areas with concentrated anthropogenic alterations are located in the headwater tributaries and along the central mainstem of Marsh Creek. Reaches with multiple alterations are shown as dual points/circles in **Figure 1-8**. These areas correspond well with areas of high streambank erosion. Riprap channel lengths were primarily associated with culverts and utility crossings.

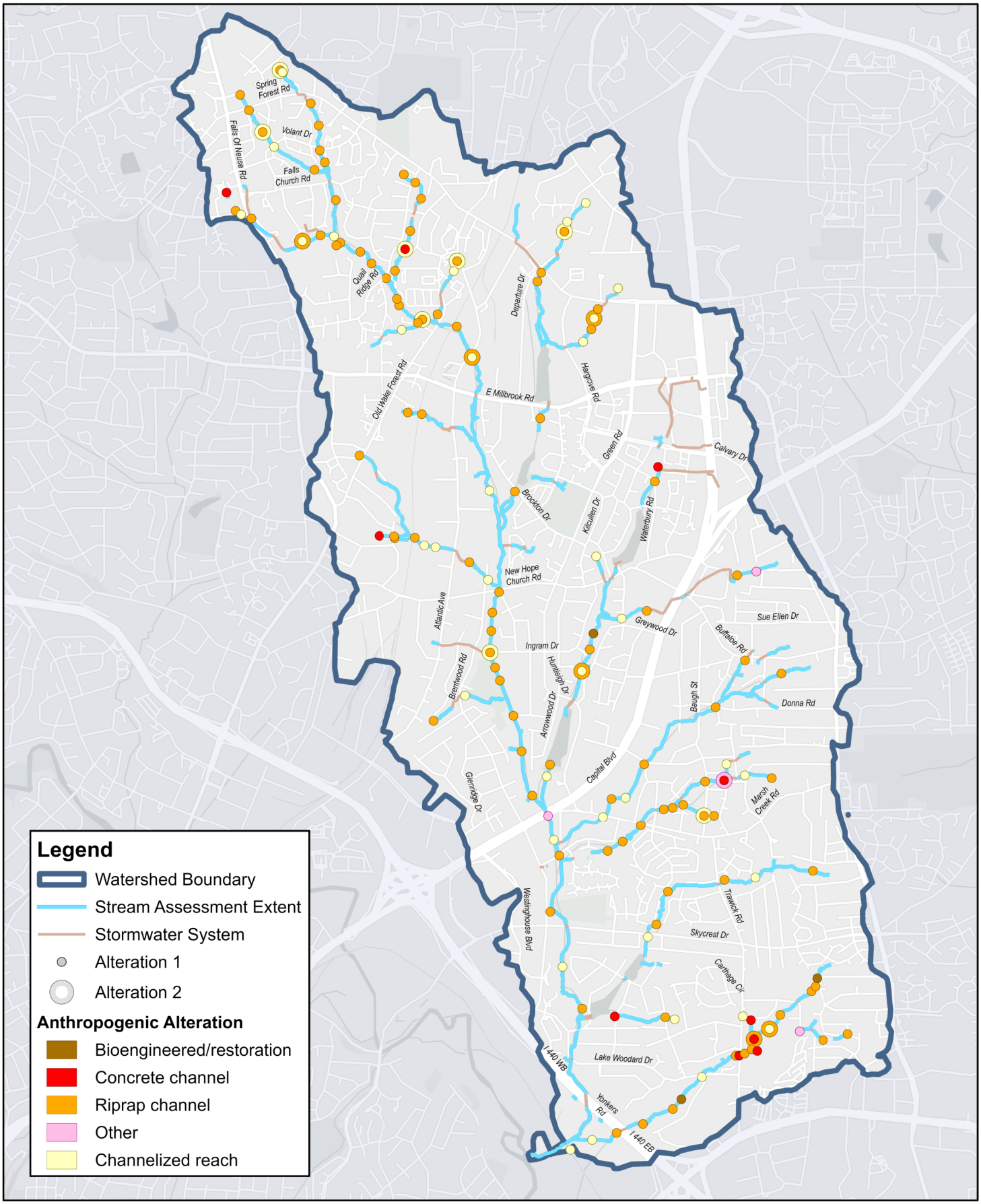

Figure 1-8 Anthropogenic Alterations

Marsh Creek Watershed Study

City of Raleigh, North Carolina

CDM Smith

Stormwater systems or piped reaches, shown as light brown lines on Figure 1-8, are not included in the total assessed stream lengths. However, they also account for a significant amount of adverse anthropogenic alteration within the Marsh Creek watershed. These reaches have the greatest loss of stream function and value and produce the highest and most concentrated flow velocities, adding to watershed wide increases in erosion associated with anthropogenic alterations.

For all hardened channels, a condition rating was assigned to assess structural integrity and functionality. The rating ranges from zero to five, with zero being 'No Issues' and five being 'partial to full failure'. Most hardened structures showed some deterioration, with concentrations of structures having more deterioration being observed along the central mainstem of Marsh Creek and the central portion of the lower tributary (MC UT 1) to Marsh Creek (**Figure 1-9**). Hardened channels with high scores most often correspond to riprap channels that have been heavily eroded.

1.3.6 Hydrologic Alterations

Hydrologic alterations are defined as changes to the channel morphology due to changes in watershed hydrology and sediment input. Hydrologic alterations are attributed to land use changes such as conversion of forested land, agricultural practices, and residential and urban development. Stream channels that were historically incised due to early land use changes are continuing to be incised by recent land use changes.

Hydrologic alterations within each stream condition assessment reach were classified into six categories: channel aggradation, channel incision, channel widening, incision and widening, headcut, and knickpoint. The channel aggradation, channel incision, channel widening, and incision and widening categories were recorded for the full length of each assessment reach when the alterations were present. Headcut and knickpoint categories were at individual locations and may occur within assessment reaches with the other hydrologic alteration categories. Examples of hydrologic alterations within Marsh Creek are shown in **Photo 1-4.**

Figure 1-10 and **Table 1-10** show that approximately 89 percent of stream channel lengths assessed within the Marsh Creek watershed are either incising, widening, or both incising and widening. Hydrologic alterations are prevalent throughout the watershed, with concentrations of reaches showing both incision and widening near the headwaters of tributaries and along the mainstem of Marsh Creek. Bedrock and culvert knickpoints maintain channel grades at locations along the mainstem and tributaries. Temporary channel aggradation is occurring above knickpoints that are holding sediment moving downstream, but those areas are small and fluctuate with flow events. No full stream assessment reaches showed channel aggradation. In many locations, stream incision and streambank erosion has exposed and/or is threatening existing infrastructure (e.g., culverts, roads, utilities, structures). Because of widescale hydraulic alterations within the stream, protection of existing infrastructure and installation of future infrastructure should be planned to anticipate further channel erosion.

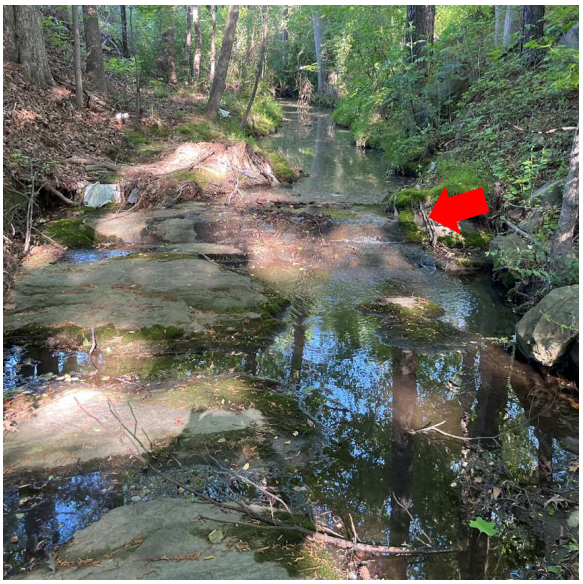

Photo 1-4
Upper Left - Knickpoint (labeled as 2-4 feet in height) near Atlantic Avenue

Upper Right – Headcut near Willow Oak Road

Middle Left – Incised Channel near Turtle Cove

Middle Right – Widened Channel near Julian Drive

Lower Left – Incised and Widened channel near Old Creek Court

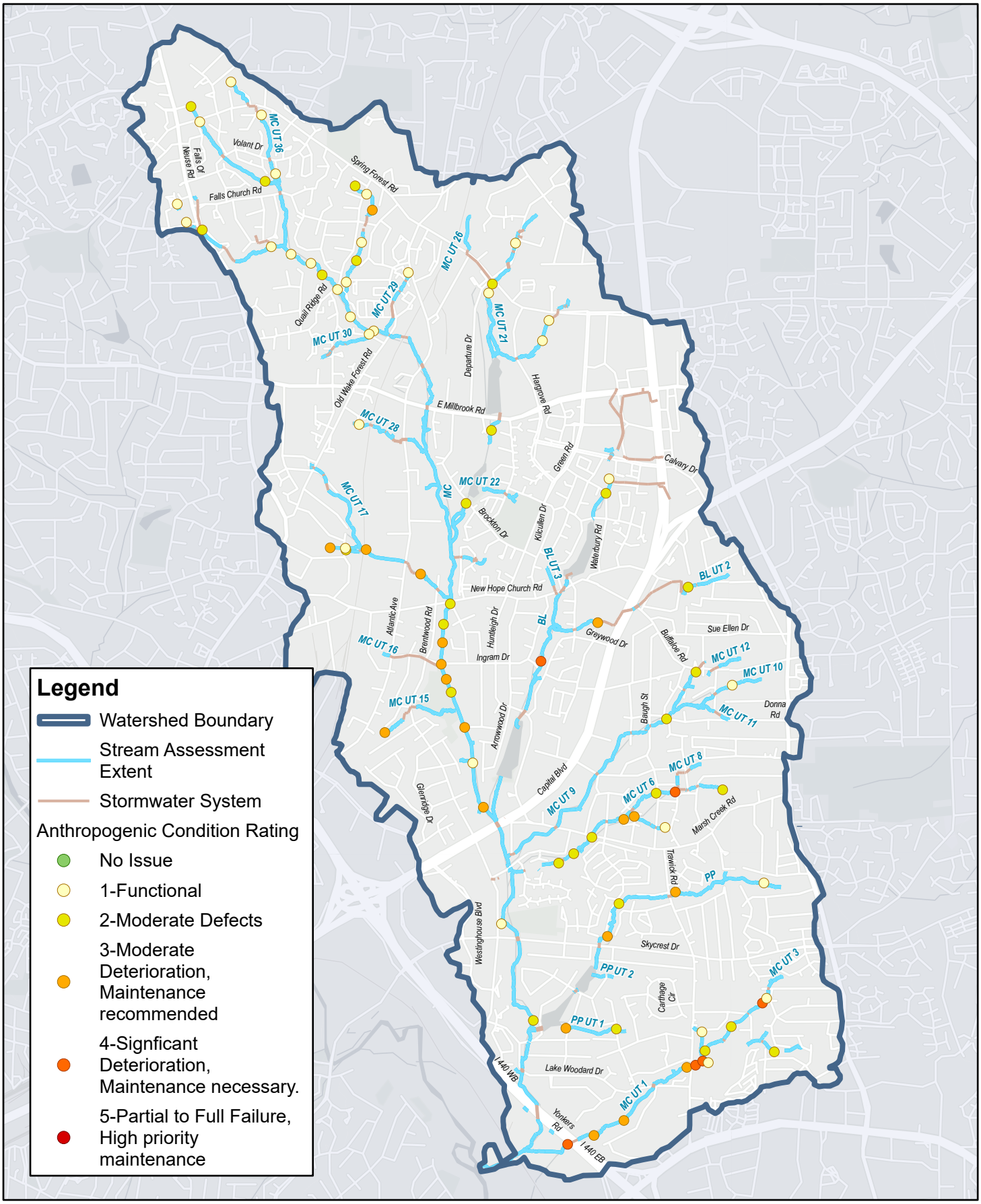

Figure 1-9 Structural Condition Rating for Hardened Anthropogenic Alterations

Marsh Creek Watershed Study

City of Raleigh, North Carolina

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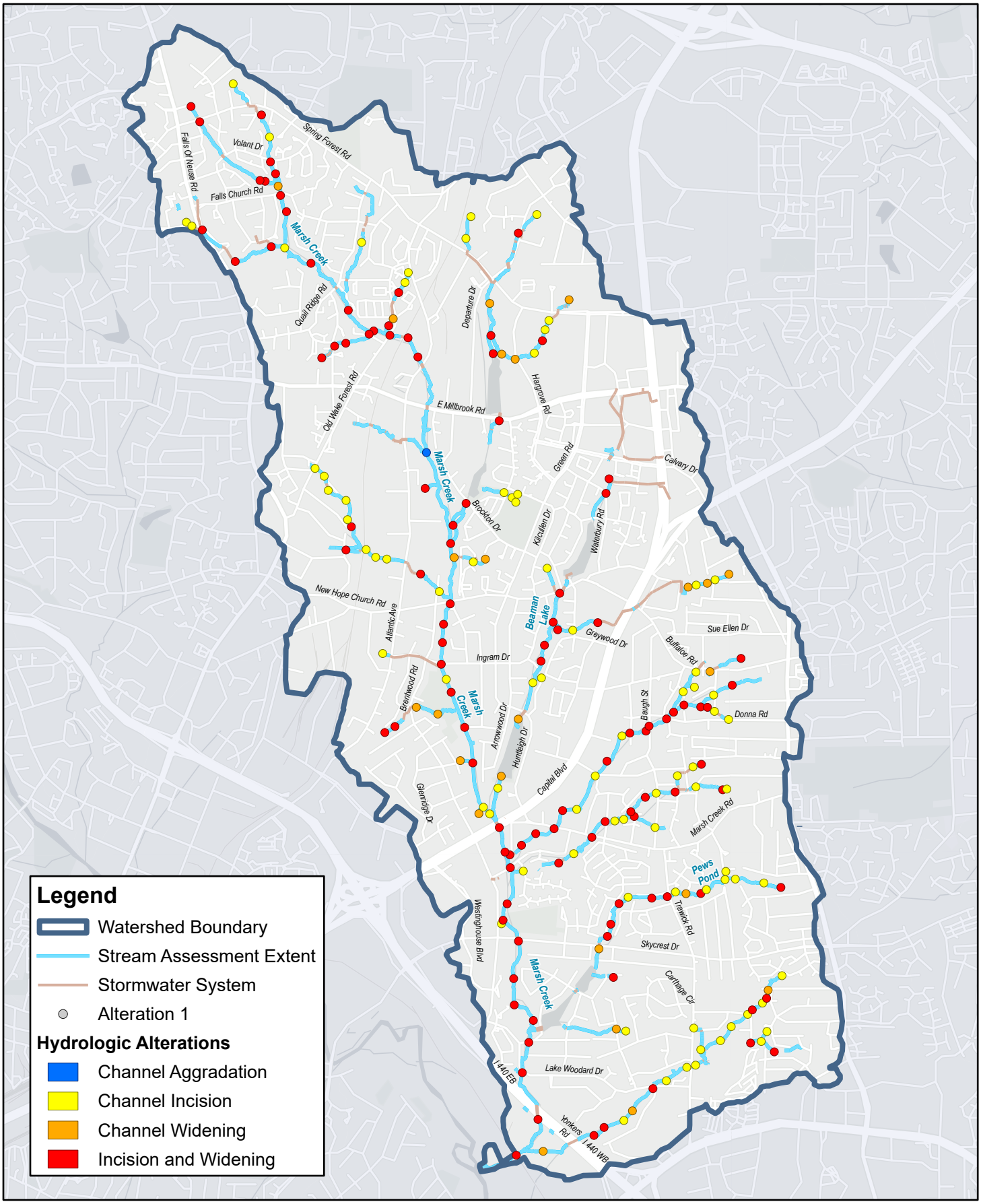

Figure 1-10 Hydrologic Alterations

Marsh Creek Watershed Study

City of Raleigh, North Carolina

CDM Smith

Table 1-10 Hydrologic Alterations

Alteration	Count	Total Streambed Length (ft)	Percent of Total Streambed Length (%)
Channel Aggradation	0	0	0
Channel Incision	86	30,991	28%
Channel Widening	37	15,238	14%
Incision and Widening	110	53,230	49%
Headcut	8	-	-
Knickpoint	48	-	-
No Hydrologic Alteration[a]	-	9,677	9%

a. Stream assessment reaches with no hydrologic alterations have streambeds/banks anthropogenically hardened or a bedrock streambed.

1.4 Miscellaneous and Other Points of Interest

The miscellaneous and other points of interest category was used to identify a range of other relevant stream assessment information including locations of debris blockages in the stream or severe erosion that may impact non-stormwater infrastructure. The stream team dropped points in the field into the mobile GIS application at the location of the observation. All miscellaneous/other points of interest data were collected in a single GIS feature layer (StreamAssessment_MiscPoints). A photograph was taken for each point and may be accessed in the StreamAssessment_MiscPoints file. Key categories of information collected included:

1. Stream erosion impacts – locations where the erosion on the stream may impact non stormwater infrastructure such as roads, structures, or utilities. Also, as part of the stream assessment methods update, eroded Stormwater Control Measure (SCM) outfalls/outfall channels were added to the data collection.
2. Project projects/project related – documents locations for potential SCM/GSI projects, stream reference reaches and wetlands.
3. Potential water quality impacts – items observed in or adjacent to the stream that may impact stream water quality such as direct downspout connections to the stream, potential sewer/septic leak or failure, construction site sediment and erosion control failures, trash or dumping site and unknown illicit discharges.
4. Stream Constrictions – items in the stream that may block or constrict the flow of water such as debris jams, inline structures, utility structures, or pedestrian bridges.
5. Other - documents any conditions encountered but not covered by other assessment categories.

Figures showing the location of these points are included in the following section. In addition, a table is included for each category that summarizes the number of occurrences and percentage breakdown for that category. These percentage breakdowns apply only the occurrence of these points and are not applicable to the overall stream assessment lengths.

1.4.1 Stream Erosion Impacts

Figure 1-11 and **Table 1-11** catalog a total of 30 stream erosion impacts. Erosion near a structure was the most prevalent observed impact followed by erosion near a sewer line. There were several areas where the streambank has exposed or eroded to within 10 feet of a structure or sewer line.

Table 1-11 Stream Erosion Impacts

Category	Stream Erosion Impact Data Points	
	Count	Percent of Total (%)
Erosion near Structure	12	40%
Erosion near Sewer line	18	60%
Erosion near Road	-	0%
Erosion near Stormwater Control Measure outfall/channel	-	0%

1.4.2 Potential Projects/Project Related

Project related information is listed in **Table 1-12** and illustrated on **Figure 1-12**. Three suitable reference reaches were observed in the watershed and seven wetland areas were visible from within the stream. These were all found at the headwaters of ponds or former ponds. No potential SCM and Regenerative Stormwater Conveyance (RSC) locations were identified during stream assessment. However, opportunities for these types of projects will be evaluated in subsequent phases of the project.

Table 1-12 Project Related Data Points

Category	Project Related Data Points	
	Count	Percent of Total (%)
Potential Regenerative Stormwater Conveyance location	0	0%
Potential Stormwater Control Measure location	0	0%
Reference Reach[a]	3	30%
Existing Wetland	7	70%

a. The total length of reference reaches are 528 linear feet, 0.5% of the assessed watershed.

1.4.3 Potential Water Quality Impacts

Water quality impacts were also denoted during field condition assessment (**Table 1-13** and **Figure 1-13**). Five cases of potential illicit discharge or sewer/septic leak were immediately reported to Raleigh Stormwater upon discovery. The City's illicit discharge team responded to the locations reported by the stream assessment team and provided follow-up with the appropriate parties to address the discharge. In addition to these five cases, there were two sites that demonstrated characteristics that were unnatural in appearance, but not field-confirmed as an illicit discharge. As a result, these sites were are recommended for follow-up investigation by the City. The City's illicit discharge team has conducted follow-up at these sites.

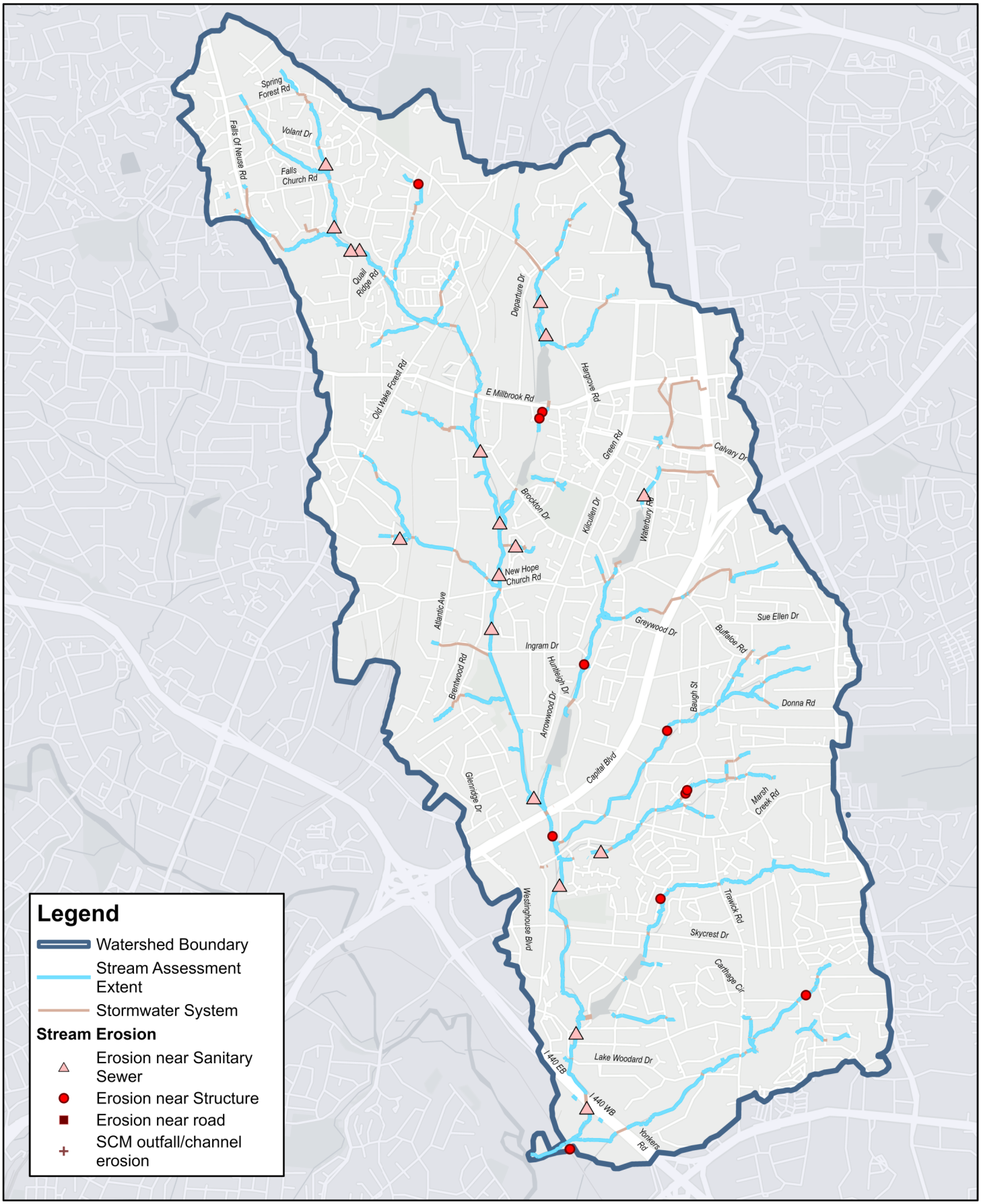

Figure 1-11 Stream Erosion Impacts

Marsh Creek Watershed Study

City of Raleigh, North Carolina

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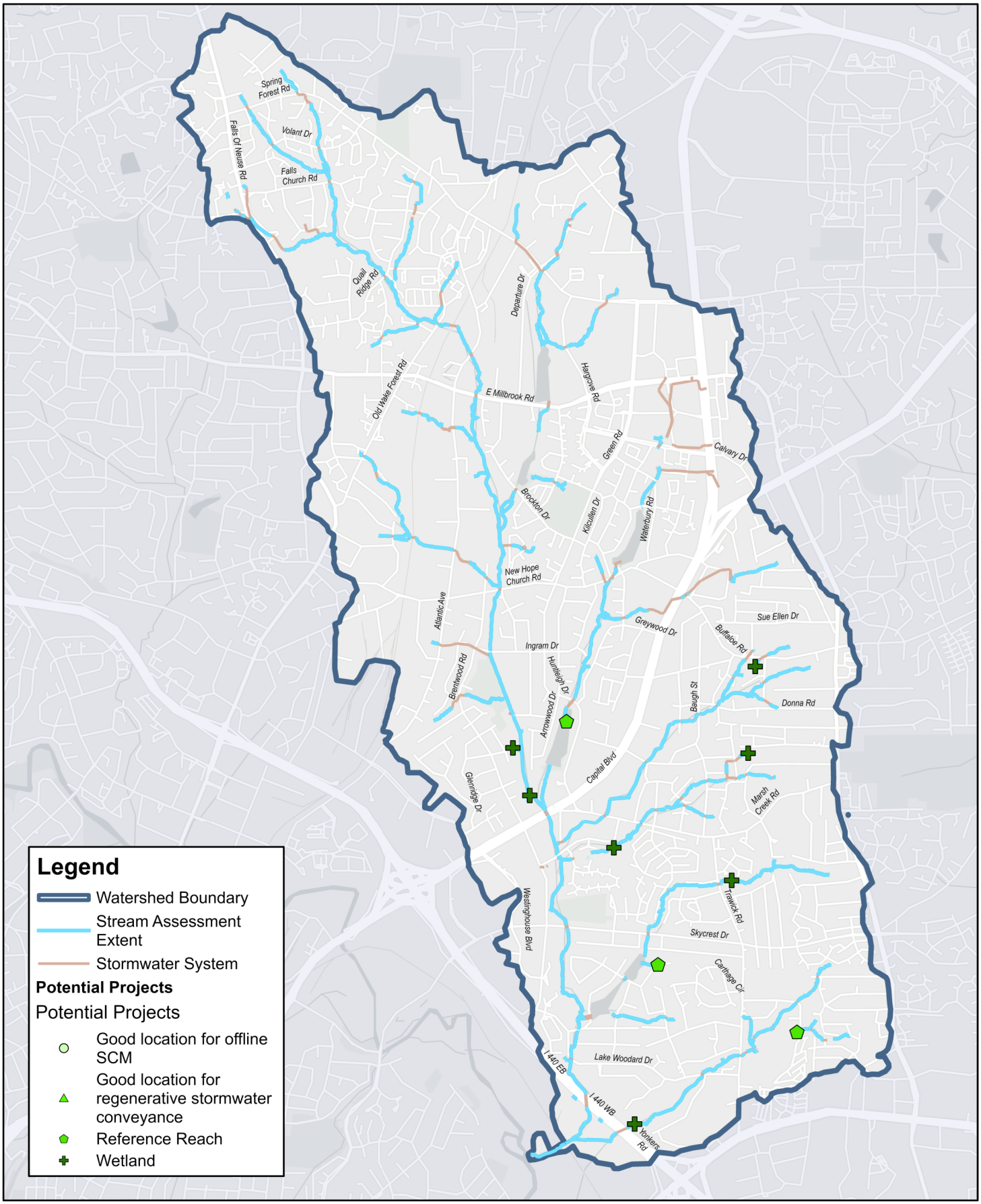

Figure 1-12 Potential Projects

Marsh Creek Watershed Study

City of Raleigh, North Carolina

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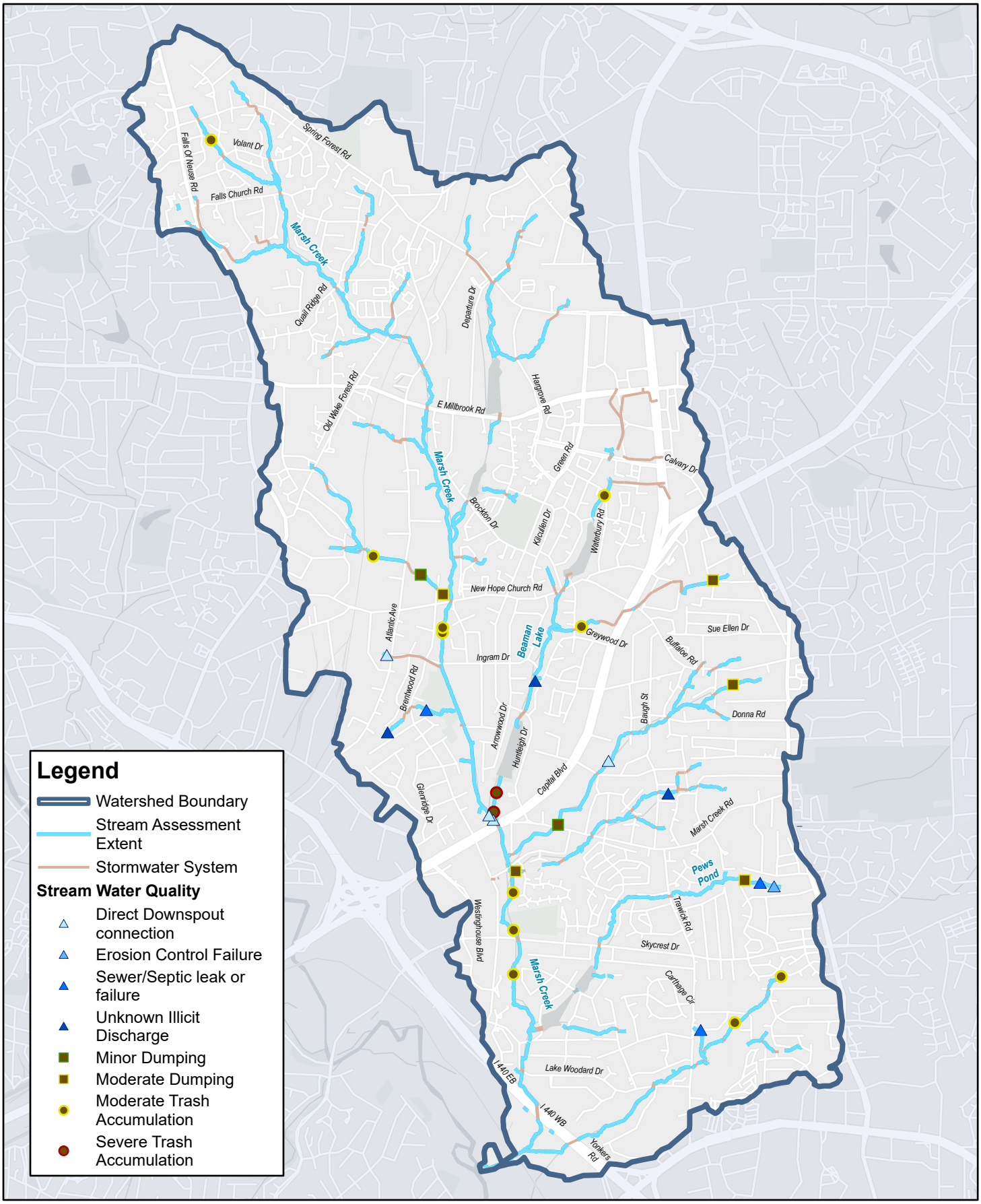

Figure 1-13 Stream Water Quality

Marsh Creek Watershed Study

City of Raleigh, North Carolina

CDM Smith

Table 1-13 Potential Stream Water Quality Impacts

Category	Potential Water Quality Impact Data Points	
	Count	Percent of Total (%)
Direct downspout connection	4	13%
Sediment and erosion control failure	1	3%
Sewer/septic leak or failure	3	10%
Unknown illicit discharge	3	10%
Trash/dumping site	20	65%

Instances of trash accumulation and dumping were recorded during the assessment and a severity rating was assigned (**Table 1-14**). Dumping is classified as the intentional discarding of waste into the stream/stream bank. Dumping could consist of a range of items such as garbage bags of waste, yard trimmings, or discarded construction material. Trash accumulation was denoted for areas that had a buildup of trash in the stream from upland wash off. It should be noted that small amounts of trash were commonly observed throughout the watershed and the points shown on Figure 1-13 and listed Table 1-14 denote locations of trash accumulation above the typical baseline threshold commonly observed.

When recording points for trash accumulation, potential locations for an instream trash collector were assessed. An instream trash collector is a device placed into the stream that can passively collect trash that flows through it. The City noted that areas with good access (ideally on a public parcel), moderate stream flow, chronic trash accumulation, and near mature trees (to anchor the trash collector) would make the best locations for an instream trash collector. Areas that matched these criteria were noted in the comments of the miscellaneous points. CDM Smith also informed the City of potential instream trash collector locations via email sent on 6/25/24.

Table 1-14 Trash or Dumping Severity

Category	Potential Water Quality Impact Data Points	
	Count	Percent of Total (%)
Minor Dumping	2	10%
Moderate Dumping	5	25%
Severe Dumping	-	0%
Minor Trash Accumulation	-	0%
Moderate Trash Accumulation	11	55%
Severe Trash Accumulation	2	10%

1.4.4 Stream Constrictions

Stream constrictions where the stream channel cross section was reduced by debris or could potentially be blocked by objects such as bridges or utility structures were documented as part of the stream assessment (**Table 1-15** and **Figure 1-14**). There were 8 constrictions causing complete blockage of the stream channel, most of which were due to fallen trees accumulating debris.

Table 1-15 Stream Constrictions

Category	Stream Constriction Data Points	
	Count	Percent of Total (%)
Blockage	8	9%
Bridge	20	22%
Inline structure	2	2%
Utility structure	61	67%

1.5 Stormwater Infrastructure

As part of the stream assessment, stormwater infrastructure that was readily observable from the stream channel was evaluated for maintenance issues and dry weather flow. This included infrastructure located near City streets or on City property and infrastructure on private property. In addition, a specific subset of stormwater outfalls associated with the City's MS4 NPDES (Municipal Separate Storm Sewer Systems National Pollutant Discharge Elimination System) permit were assessed for dry weather flow. The observations were recorded into a copy of the City's GIS layer for stormwater pipe inlets and outlets (StreamAssessment_PipeIO).

1.5.1 Condition Assessment

Observations of stormwater maintenance issues or infrastructure concerns such as sediment blockages or structural issues were recorded as part of the stream assessment. The observations were divided into two categories: structural condition assessment (**Table 1-16**) and blockage condition assessment (**Table 1-17**). Each category was rated according to severity with zero being no issues observed and five being the most severe. Where both structural and blockage issues are occurring for the same feature, a second maintenance concern is recorded. For example, a single stormwater outfall may have both structural damage and a debris blockage. In these situations, **Figure 1-15** uses stacked symbols (Issue 1 and Issue 2) to show both maintenance issues. Refer to the Watershed Study Methodology Report for more details on how the ratings were assigned.

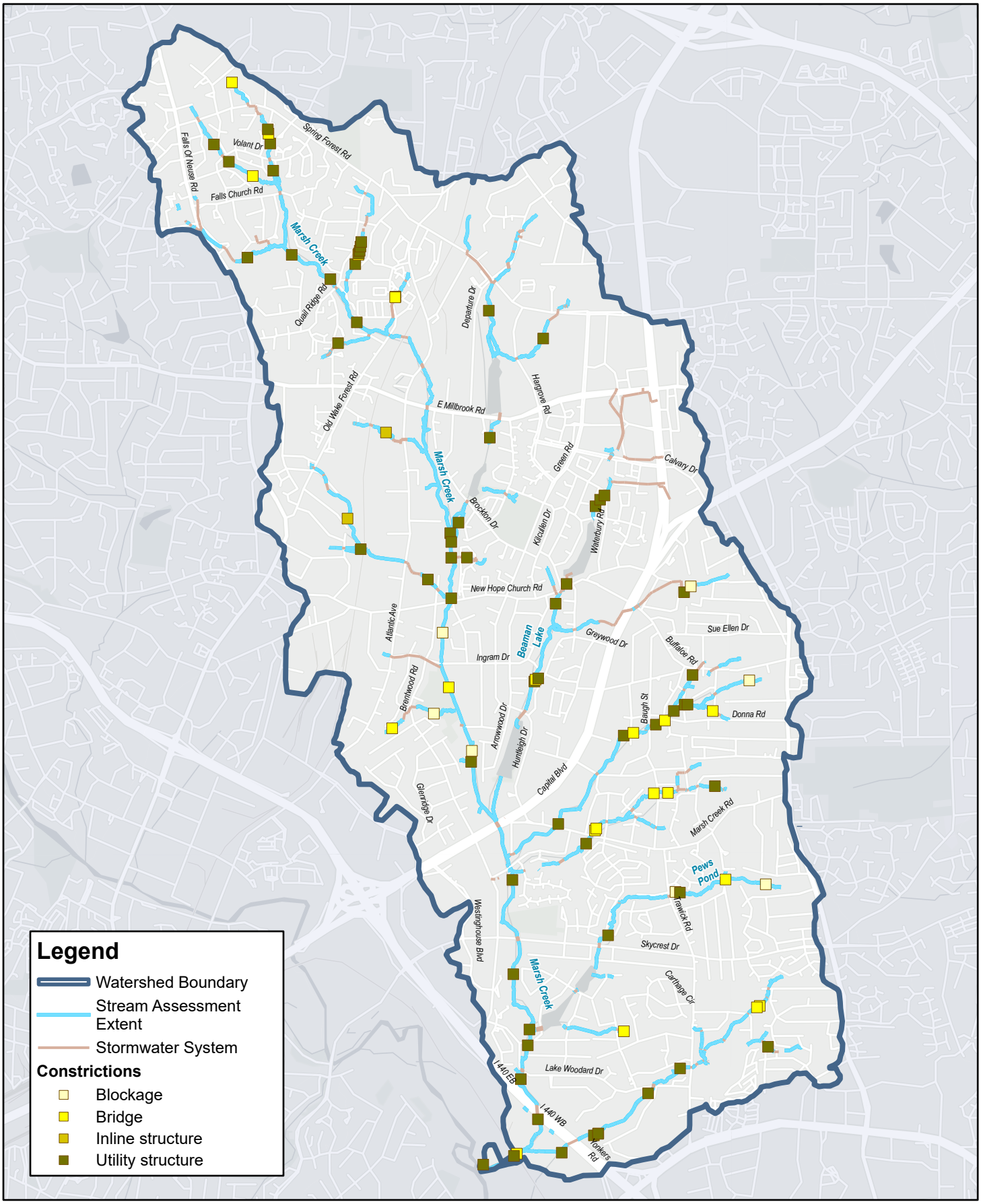

Figure 1-14 Constrictions
Marsh Creek Watershed Study
City of Raleigh, North Carolina

CDM Smith

Table 1-16 Structural Condition Assessment Rating

Rating	Description	Stormwater Structures Assessed	
		Count	Percent of Total (%)
0	No Issues	444	70%
1	Functional, Minor Defects	91	14%
2	Moderate Defects	46	7%
3	Moderate Deterioration, Maintenance recommended	31	5%
4	Significant Deterioration, Maintenance necessary	11	2%
5	Partial to Full Failure, High priority maintenance	8	1%

Table 1-17 Blockage Condition Assessment Rating

Rating	Description	Stormwater Structures Assessed	
		Count	Percent of Total (%)
0	No blockage of the flow area	473	75%
1	<10% flow area, Limited to no impact on function	50	8%
2	10-20% flow area, Minor impact on function	33	5%
3	20-30% flow area, Moderate impact on function. Maintenance recommended.	46	7%
4	30-50% flow area, Significant impact on function. Maintenance needed.	20	3%
5	>50% flow area, Severe impact on function. High priority maintenance.	9	1%

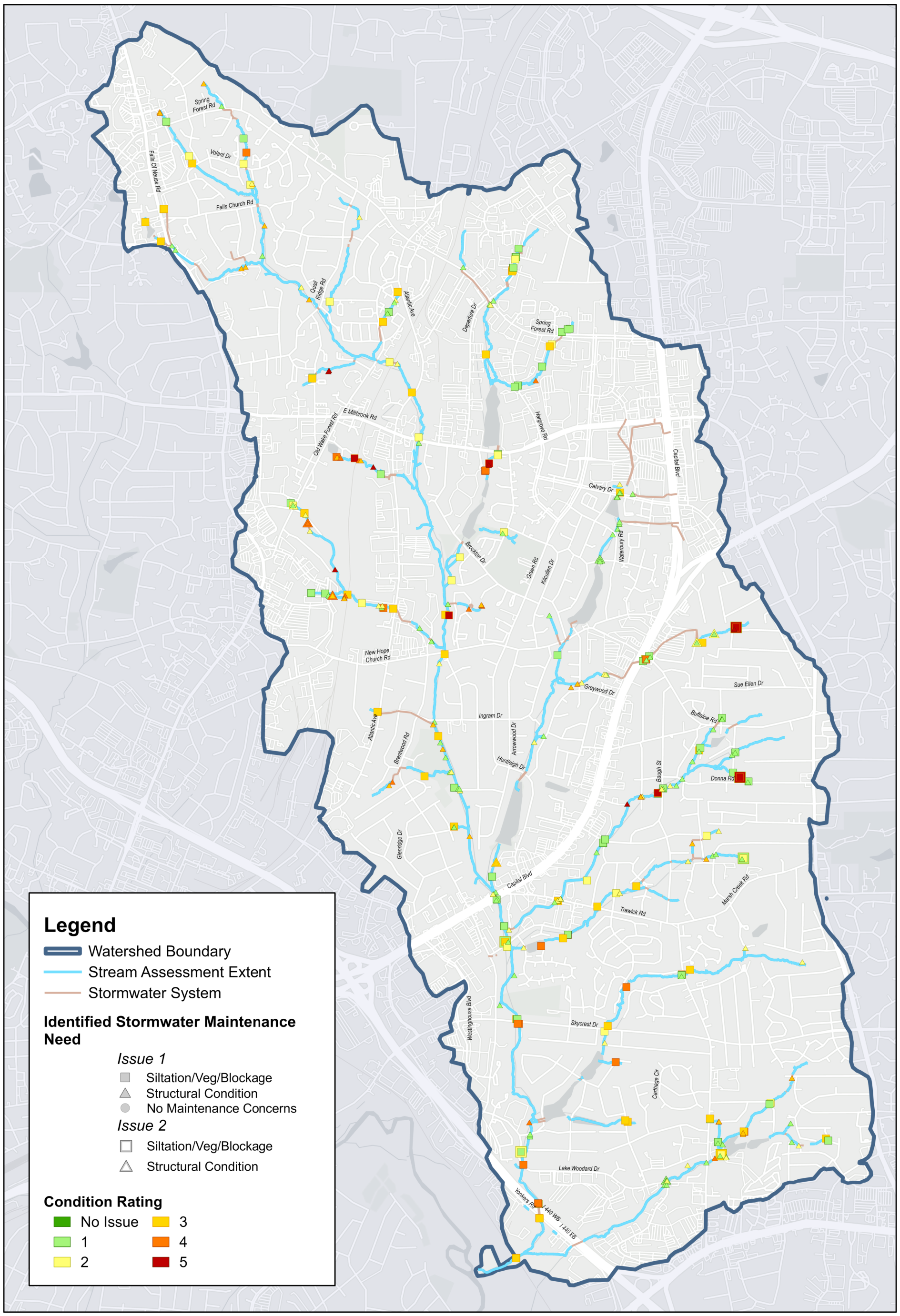

Figure 1-15 Stormwater Infrastructure Condition Assessment

Marsh Creek Watershed Study

City of Raleigh, North Carolina

CDM Smith

Photo 1-5 Example of Stormwater Infrastructure with a High Condition Assessment Score

Eight locations along the stream assessment extents were identified where infrastructure is in a critical state of deterioration. These are given a rating of 5 in Table 1-16. One example is near 3316 Hobby Court, a headwall and pipe section collapsed due to erosion (**Photo 1-5**). A photograph was taken of each documented issue and may be accessed via the online GIS data (StreamAssessment_PipeIO). It should be noted that all assets visible from the stream were assessed regardless of ownership. Ownership information is included in the GIS data. Maintenance and repair of infrastructure located on private property is the owner's responsibility.

1.5.2 Dry Weather Flow

The results of the dry weather flow assessment at NPDES outfalls are listed in **Table 1-18** and shown on **Figure 1-16**. The table includes only NPDES Major outfalls which are those classified as 1a: Major Outfall – General and 1b: Major Outfall – Industrial Area. The stream team assessed only the outfalls that were observed from the stream. As a result, not all of the NPDES Major outfalls were assessed. 29 NPDES Major outfalls are in the Marsh Creek watershed, and 19 of these were evaluated as part of the stream assessment.

Eight of the assessed outfalls did not have flow. If an outfall was found to have flow, but the infrastructure was downstream of a flowing stream, and there were no signs of an illicit discharge then no further investigation was required. This was the case for nine of the assessed outfalls. However, two outfalls are recommended for further investigation.

Table 1-18 Assessment of Flow at NPDES Major Outfalls

Description	Outfalls Assessed	
	Count	Percent of Total (%)
No Flow	8	42%
Has Flow, No Further Investigation Required	9	47%
Has Flow, Further Investigation Recommended	2	11%

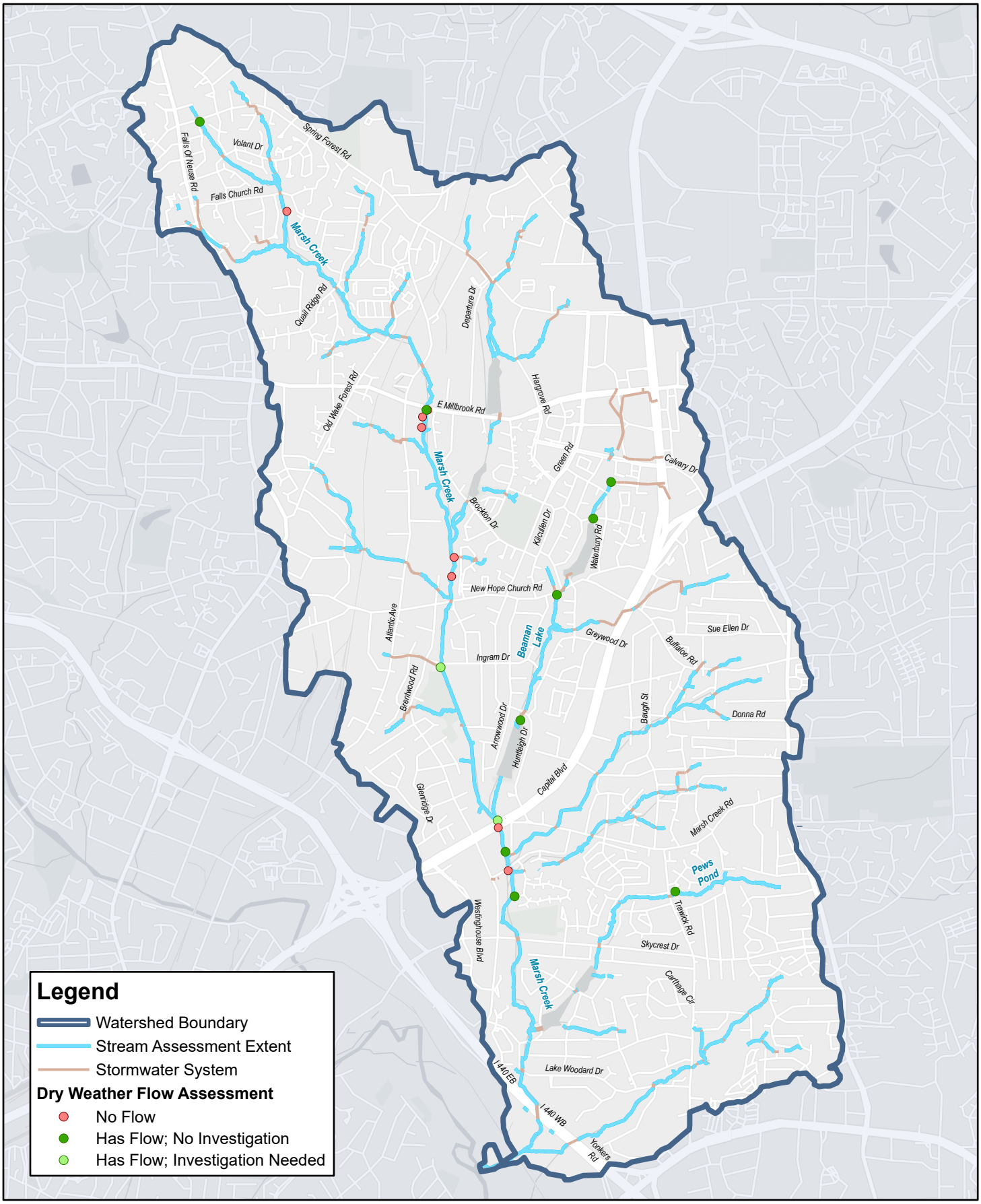

Figure 1-16 Dry Weather Flow Assessment

Marsh Creek Watershed Study

City of Raleigh, North Carolina

CDM Smith

1.6 Stream Restoration Opportunities

Locations of potential stream restoration opportunities were documented when observed during the field data collection in the same file as the stream conditions information (StreamAssessment_Upstream Points). Stream reaches with potential restoration opportunities were typically characterized by streambank erosion, channel incision, widening, or straightening, and/or reduced or poor quality riparian buffers. Overall stream condition, nearby constraints or threatened infrastructure (e.g., utility easements or existing stormwater infrastructure), geography (e.g., floodplain confined by steep slopes), and property access were considered when determining potential restoration locations. Restoration measures were classified into these six primary restoration method types:

- Rosgen Priority 1 – Replace the incised channel by re-locating the channel within the floodplain. Construct the new channel with a bankfull height at the original floodplain elevation. Design the dimension, pattern, and profile to a stable form. Fill the existing channel to create floodplain.
- Rosgen Priority 2 - Replace the incised channel by re-locating the channel. Construct a new bankfull discharge channel with streambed elevation at the same elevation of the existing channel and excavate new lower floodplain.
- Bank Protection - Designed to protect the streambank from erosion or failure with structural measures. Used along banks where infrastructure protection is important or when space or erosive velocities are the constraint. Examples are rootwads, boulder revetments, lunkers, and A-jacks (interconnected cement stakes). Riprap may also be considered if it is already onsite or if there is the need for additional protection around existing road or utility infrastructure.
- Bank Stabilization and Bioengineering - Non-structural measures to stabilize banks to protect against erosion by re-grading the streambanks to a stable angle and geometry, planting with native plantings, and use of biodegradable materials to stabilize the banks. Includes re-grading, live stakes, branch packing or layering, mattresses, fascines, and joint planting.
- Mixed Bank Protection and Bank Stabilization - Combination of bank protection and stabilization measures where structural measures are put along the bank's toe and stabilization measures along the rest of the bank. This is best used when most of the erosive velocities are undermining the toe of the bank, leading to bank failure or slumping.
- Preservation - Protection and conservation of the relatively natural state and functions of a stream to maintain existing conditions and prevent degradation.

The count and stream lengths of the stream restoration opportunities is shown in **Table 1-19.**

Table 1-19 Stream Restoration Opportunities by Type

Type	Stream Reach Count	Total Streambed Length (ft)	Percent of Total Streambed Length Assessed (%)
Rosgen Priority 1 Channel Restoration	2	1,570	1%
Rosgen Priority 2 Channel Restoration	45	20,187	18%
Bank Protection	6	2,665	2%
Mixed Bank Protection/Bank Stabilization	77	32,585	30%
Bank Stabilization/ Bioengineering	25	9,091	8%
Preservation	53	23,837	22%
No Stream Restoration Opportunity Identified	51	19,201	18%

In Marsh Creek, potential sites for a Priority 1 restoration lie in the upper mainstem and tributaries to the lower mainstem. This restoration option would likely require a larger channel than the historic channel to accommodate increased peak flows, a slightly steeper channel slope than the historic channel to better connect channel grades, and some lowering of the current floodplain elevation. These modifications are more characteristic of other Rosgen Priority restoration options. Though an ideal Rosgen Priority 1 restoration site is difficult to find there are a couple locations within the Marsh Creek watershed that could closely approach one. More Rosgen Priority 2 stream restoration options exist in urban watersheds than Priority 1 options because the challenges of matching back to existing grade are less. However, they are still limited by available room to relocate the channel and excavate the floodplain. All potential stream restoration opportunities identified during stream assessment are shown on **Figure 1-17**.

In practice, most stream restoration sites incorporate a mix of Rosgen Priority restoration options. In the Marsh Creek watershed, the majority of stream restoration possibilities are some form of or combination of minor channel relocation, bank stabilization, or preservation. Perhaps more important than the specific type of restoration project in deciding on a potential stream restoration location is accessibility and property ownership. For each potential restoration reach an accessibility score was assigned ranging from 1 to 5, with one being easiest and five being poorest accessibility (**Table 1-20**).

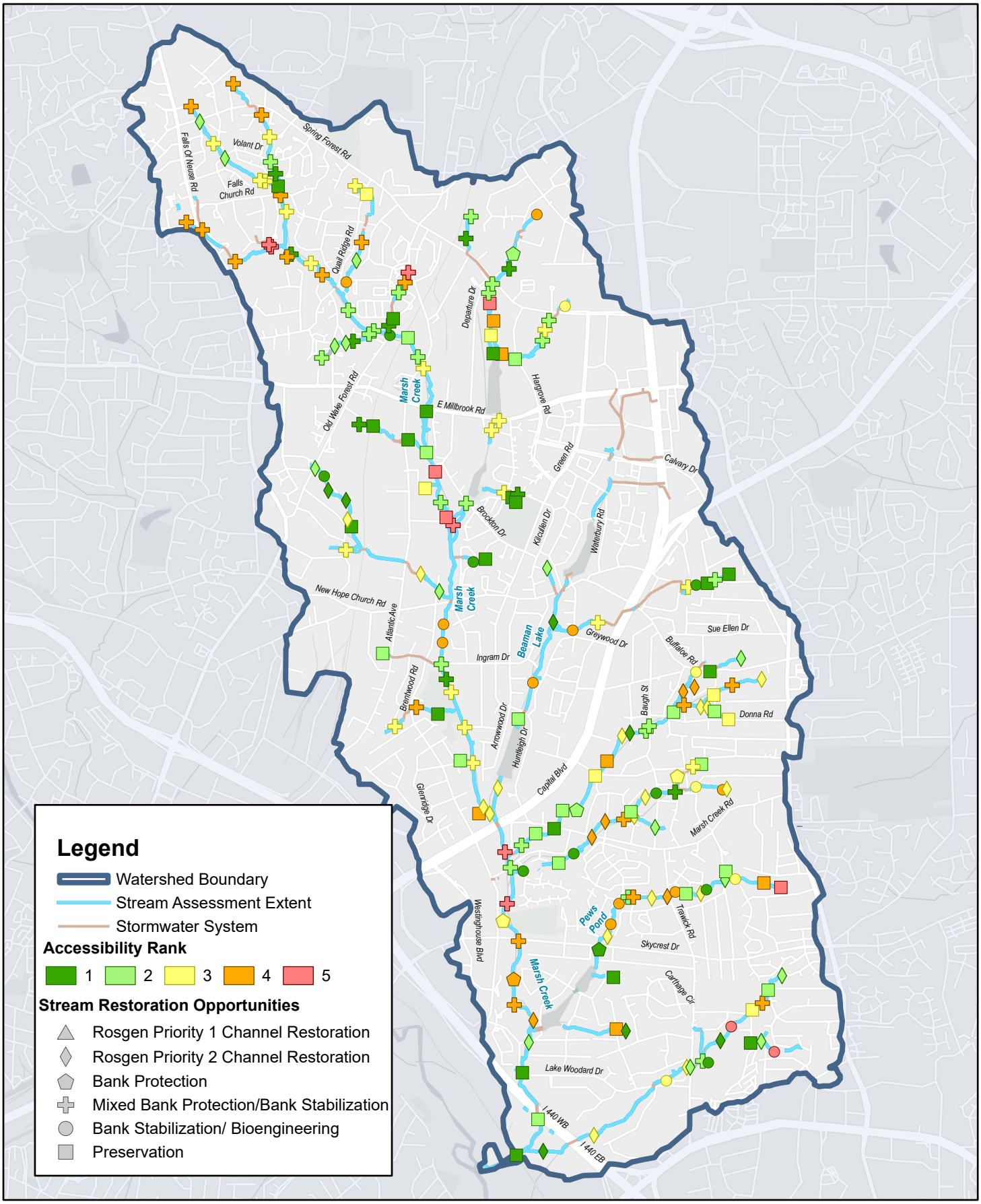

Figure 1-17 Stream Restoration Opportunities

Marsh Creek Watershed Study

City of Raleigh, North Carolina

CDM Smith

Table 1-20 Accessibility Score of Stream Restoration Opportunities

Accessibility Score	Description	Stream Reach Count	Total Streambed Length (ft)	Percent of Total Streambed Length Assessed (%)
1	Easily accessible and only involves 1 parcel	41	16,094	15%
2	Easily accessible and involves 2 parcels	61	23,641	21%
3	Easily accessible by foot only or involves 2-3 parcels	50	23,480	21%
4	Moderately accessible or involves 3-4 parcels	43	20,294	19%
5	Poor accessibility or involves more than 5 parcels	14	6,425	6%
-	No Stream Restoration Opportunity Identified	51	19,201	18%

Stream accessibility score is also shown on Figure 1-17. Looking at larger areas of green on Figure 1-17, groups of connected reaches with restoration potentials can be seen in many of the tributary upper watersheds, some of the tributary lower reaches, and the very lower portion of Marsh Creek near its confluence with Crabtree Creek. These areas provide the best potential for connecting longer stream restoration lengths. Individual reaches will require closer investigation to validate the appropriateness of the proposed restoration methods and accessibility. Each stream restoration opportunity is site specific and ultimate site selection is dependent on factors including feasibility, access, and overall watershed benefits.

1.7 Stream Assessment Data Application

As noted in the introduction, the data gathered in the stream assessment may be used to inform the City's strategic planning, develop future stream restoration opportunities, and further education, outreach, and partnerships with the community. Furthermore, the stream assessment data can be used to support additional stormwater programs such the asset management program and components of the MS4 NPDES program. This section reviews several next steps and ways the stream assessment data may be used.

1.7.1 Development of Stream Restoration Projects

Of the streams assessed in the Marsh Creek watershed, almost 70 percent have been impacted to the point that some level of stream restoration or stabilization would be beneficial. However, the City implementing restoration projects for this length of stream is not practicable from a feasibility perspective with regard to funding, accessibility, and property ownership.

As a part of the Marsh Creek Watershed Study, the stream restoration opportunities identified in this section will be narrowed and/or combined into a smaller subset to generate proposed stream restoration projects. These concept level stream restoration projects will be identified using accessibility, property ownership, flooding and erosive velocities from the water quantity model, threats to infrastructure and buildings, and areas of concerns as guidance to determine locations that are both feasible and, if possible, provide multiple benefits such as floodplain reconnection and nutrient reduction.

1.7.2 Infrastructure Conditions for Further Evaluation

The City has recently began implementing an asset management program for stormwater infrastructure. The initial risk score for evaluated stormwater assets was developed largely using available surrogate data (CDM Smith 2021). The City has begun the process of condition assessment inspections to provide site specific evaluations of assets; however, due the enormity of this task the process is not complete.

The information collected as part of the stream assessment can be leveraged to benefit this program. The stream assessment team evaluated pipe inlets/outlets that were encountered along the stream channel using a rating scale that is similar to that used as part of the asset management program with zero being no issues observed and five being the most severe. The stream assessment evaluations can be used to prioritize stormwater asset condition assessments. Assets with high ratings should be prioritized for inspection while inspections for those with lower ratings may be completed at a later time.

1.7.3 Hardened Channels Assessment

In the Risk Framework for the City's stormwater asset management program, stream/drainage channels were divided into two types: constructed and natural (CDM Smith 2021). The framework notes that constructed channels would be included in a future phase of the implementation plan. As a part of the stream assessment, information was collected on constructed channels which are noted as hardened and/or straightened channels in the Anthropogenic Alterations results included in Section 1.3.5. For all hardened channels, a condition rating was assigned to assess the structural integrity and functionality. The rating is similar to that used as part of the asset management program for other stormwater infrastructure assets and ranges from zero to five, with zero being 'No Issues' and five being 'partial to full failure.'

The City has developed a standard operating procedures (SOP) for crossline conveyances (CLC) that divides the inspection process into three assessment levels based on the complexity and detail of the inspection needed to fully assess the infrastructure condition. A similar approach has not yet been developed for hardened channels. However, the information collected for the stream assessment may be used to guide inspection process for hardened channels by providing an initial prioritization of inspection based on the condition rating.

1.7.4 Using 360 Video as Baseline Conditions

As the City continues to develop watershed studies and the stormwater asset management program, understanding how the stream is changing and the impacts these changes may have provides valuable insight for planning and prioritization. The 360-video collected as part of the stream assessment provides a visual baseline documentation of the stream conditions for the assessment extents. This information may be used in a range of applications to better understand how quickly the stream is changing and how this may impact not only infrastructure, roadways, and structures but also impacts to water quality and downstream sediment loading. The 360-video may be used as a baseline for comparison to historic documentation or as a comparison point for information collected in the future.

1.7.5 Applying an Equity Lens

As a part of the Hare Snipe Watershed Study, the City developed a Watershed Study Equity Framework (Brown and Caldwell 2023a). This framework was developed to guide the Raleigh Stormwater on ways to incorporate equity into relevant elements of a water study such as community engagement, project identification, alternatives analysis, and project prioritization. One of the goals of the plan is to use the data and benchmarking to drive decision making.

To help achieve this goal, data collected as part of the stream assessment may be analyzed through an equity lens. One way of doing this is by overlaying several key data sources:

- Stream and riparian condition data collected as part of the stream assessment such as stream bank erosion and buffer encroachment.
- Preferred equity analysis layer (CDC Social Vulnerability Index, Wake County Community Vulnerability Series, or other established City layer).
- Existing stream related programs and projects undertaken by the City such as those discussed in Sections 1.1.2 and 1.1.3.

The combination of these data will provide an assessment of where resources have been allocated compared to needs based on observed stream conditions and may provide insight as to where additional resources should be invested.

1.8 References

Brown and Caldwell, 2023. *Hare Snipe Creek Watershed Study Methodology,* Prepared for the City of Raleigh, Raleigh, North Carolina, March 24, 2023.

Brown and Caldwell, 2023a. *Hare Snipe Creek Watershed Study*, Prepared for the City of Raleigh, Raleigh, North Carolina, March 20, 2023.

CDM Smith, 2021. *Phase 1 Final Implementation Plan City of Raleigh Stormwater MS4 Asset Management Program,* July 2021.