TIBER BRANCH WATERSHED

STORMWATER RETROFIT STUDY

Prepared for:

Howard County Department of Public Works
Bureau of Environmental Services
Stormwater Management Division
9801 Broken Land Parkway
Columbia, MD 21046

Prepared by:

Biohabitats, Inc.
2081 Clipper Park Road
Baltimore, MD 21224

In conjunction with:

McCormick Taylor
509 South Exeter Street, 4th Floor
Baltimore, MD 21202

June 2019

Contents

ACRONYM LIST

CIP	Capital Improvements Program
DPW	Department of Public Works
ESD	Environmental Site Design
FY	Fiscal Year
GI	Green Infrastructure
GIS	Geographic Information Systems
MDOT	Maryland Department of Transportation
OEM	Office of Emergency Management
RCN	Runoff Curve Number
Tc	Time of Concentration
USGS	United States Geological Survey

EXECUTIVE SUMMARY

High-intensity, short-duration rainfall events have resulted in damaging flooding within the Plumtree Branch and Tiber Branch watersheds in Ellicott City, MD in July 2016 and May 2018. In July 2018, Howard County Council enacted Council Bill #56-2018, the Tiber Branch Watershed and Plumtree Branch Watershed Safety Act, an act temporarily prohibiting approvals of development plans and zoning changes within these watersheds in order to study and make recommendations for the two watersheds.

As a result of Council Bill #56-2018, the Howard County Department of Public Works (DPW) initiated the Tiber Branch Watershed Stormwater Retrofit Study. This study evaluated the existing hydrology within the watershed, provided updated assessment information for existing storm drain infrastructure, investigated citizen drainage complaints, and identified and prioritized opportunities to address localized flooding and storm drain improvements within the Tiber Branch watershed.

The Tiber Branch Watershed Study consisted of the following activities:

- Field assessed existing storm drain infrastructure to verify mapped infrastructure, locate unmapped infrastructure, and document the condition of existing infrastructure
- Overlaid resident- and landowner-identified drainage and flooding issues with field assessment results to identify areas of concern
- Analyzed the adequacy of the storm drain network based on commonly accepted storm drain sizing approaches (i.e., size of pipe relative to drainage area), network layout, and existing condition (i.e., likely adequate or further investigation needed)
- Identified opportunities to improve drainage and flooding problems
- Prioritized opportunities based on variety of factors, including ability to address identified drainage issues, number of properties served by the opportunity, and potential impediments to implementation (i.e., site constraints)
- Developed Assessment Area profile sheets that subdivided the Tiber Branch watershed retrofit study area into 67 Assessment Areas. Each Assessment Area profile sheet summarizes the existing conditions of the storm drain network and describes opportunities to address drainage and flooding issues.

Major recommendations from this study include:

- Catchment-based approach: Address stormwater management in the Tiber Branch watershed using a catchment approach. This approach may encompass several Assessment Areas located within a given catchment and would lend itself to addressing related concerns in their entirety instead of in a piece-meal fashion due to the connectedness of runoff, the storm drain system, and receiving waters.

- Future Grading Impacts: Consider future development and associated grading of lands in the context of existing watershed boundaries. Grading of lands due to new development and repaving of roads can modify existing drainage patterns and could potentially exacerbate drainage issues downstream.
- Private Drainage Easements: Establish a program to document storm drain easements in the County's GIS database. Once known storm drain easements are documented, establish a program to acquire private drainage easements in order to take over long-term maintenance and operation of storm drain infrastructure.
- Public Outreach and Engagement: Expand on the County's public outreach efforts to educate the public on flash flooding, floodplains, hydric soils, stormwater conveyance and stormwater management. Areas for public engagement and involvement in addressing stormwater management include expanding existing stormwater management programs such as Rain Gardens for Clean Water and providing residential guidance for driveway culvert sizing and siting sump pump discharges.

1. INTRODUCTION TO THE STORMWATER RETROFIT STUDY

In response to stormwater conveyance concerns and flooding events in the Tiber Branch watershed, the Howard County Council enacted Council Bill #56-2018 in July 2018. The Bill temporarily prohibits approvals of development plans and zoning changes within the Tiber Branch watershed. An additional requirement of Council Bill #56-2018 is that the Department of Planning and Zoning, the Department of Public Works (DPW), and other County agencies analyze “public and private options for retrofitting existing public and private property that drains in whole or in part to the Tiber Branch watershed that was developed with no or superseded stormwater management requirements”. The County Council Bill #56-2018 is provided in Appendix A.

This report summarizes the Tiber Branch Watershed Retrofit Study, an effort stemming from Council Bill #56-2018, that assessed existing storm drain infrastructure, characterized citizen drainage complaints, and identified and prioritized opportunities to address flooding and inadequacies in the storm drain system.

2. OVERVIEW OF THE TIBER BRANCH WATERSHED

2.1 Watershed Profile

The Tiber Branch watershed is a 3.7 square mile (2,368 acre) area located in eastern Howard County, Maryland. This watershed contains three major tributaries, the Hudson Branch, the Tiber Branch, and the New Cut Branch, which combine to ultimately flow through Historic Ellicott City to the Patapsco River. Land use in the watershed is 40% residential, but the stream network also drains runoff from commercial development, public facilities and schools, road networks, and open space. Table 2.1 depicts a breakdown of land use in the watershed. A map of the Tiber Branch watershed study area can be found in Figure 2.1.

TABLE 2.1. PROFILE OF THE TIBER BRANCH WATERSHED

Drainage Area	2,368 acres
Current Impervious Cover	35.3% imperviousness
Stream Length	Approx. 12.0 miles
Land Use	Residential (40%) Non-Residential (32%) Open Space (18%) Undeveloped (10%)

2.2 Watershed Geology and Topography

The watershed geology, and topography provide useful context for understanding the underlying conditions of the Tiber Branch watershed. These conditions are described in further detail below and are depicted in Figure 2.2.

A diverse mix of bedrock foundations that underlay the watershed can be identified broadly by three formations: the Baltimore Gabbro Complex, Ellicott City Granodiorite, and the Oella formation (Lower Pelitic Schist). Soils in this area formed on the bedrock foundation and are typically a mix of silt loams and urban soil. About 8% of the Tiber Branch watershed, however, has hydric soils. These soils are formed in areas where the surface is normally saturated. Some of the hydric soil areas are undeveloped. Autumn Hill and Dunloggin are some of the developed locations where hydric soils are present (USDA-NRCS, 2019).

With the eastern edge of watershed lying on the fall line between the Piedmont and the Coastal Plain, the topographic relief in the Tiber Branch watershed is among the most extreme in the county, with several areas with slopes of greater than 25% grade. These steep grades are prevalent in the central-eastern areas and along stream corridors.

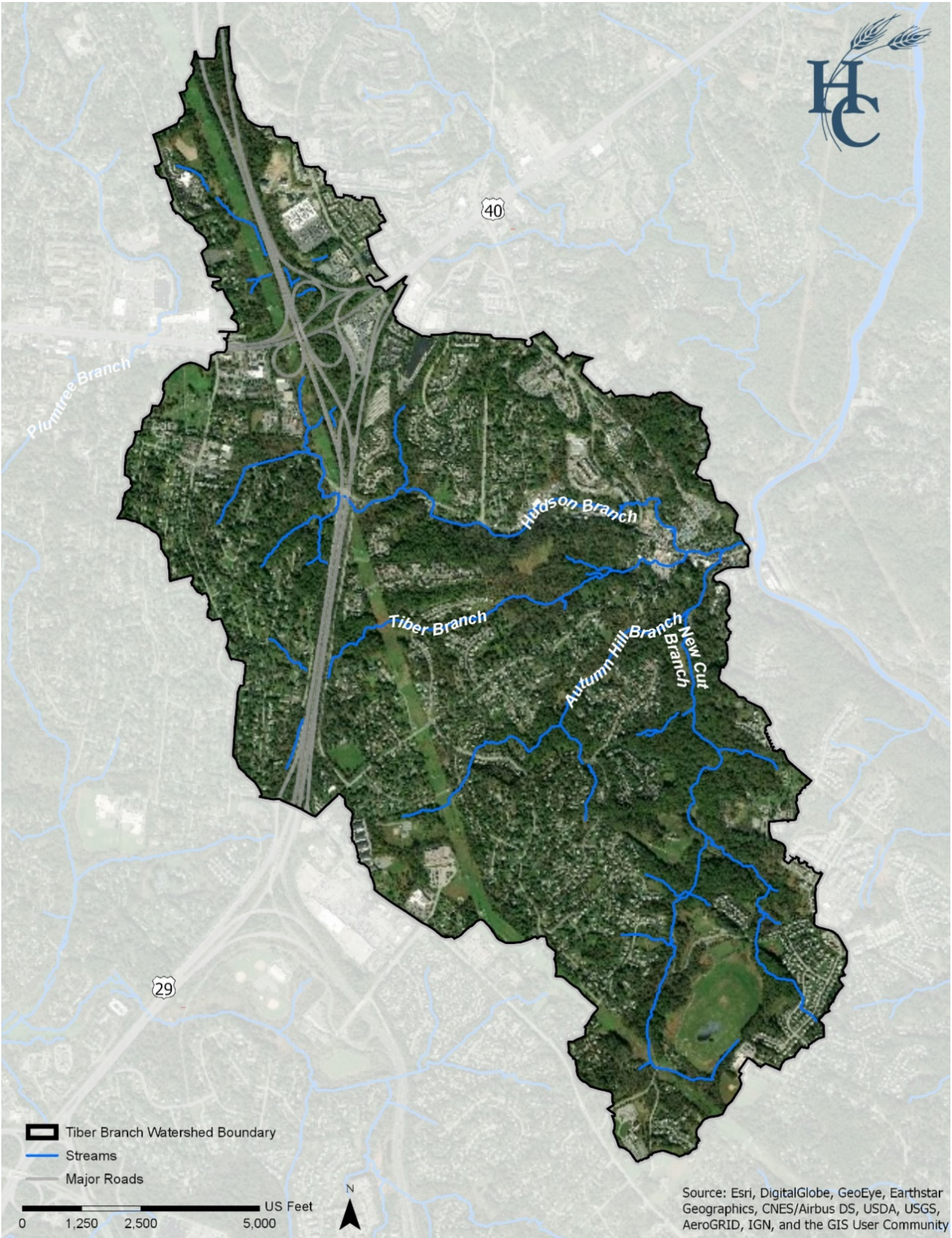


FIGURE 2.1. TIBER BRANCH WATERSHED

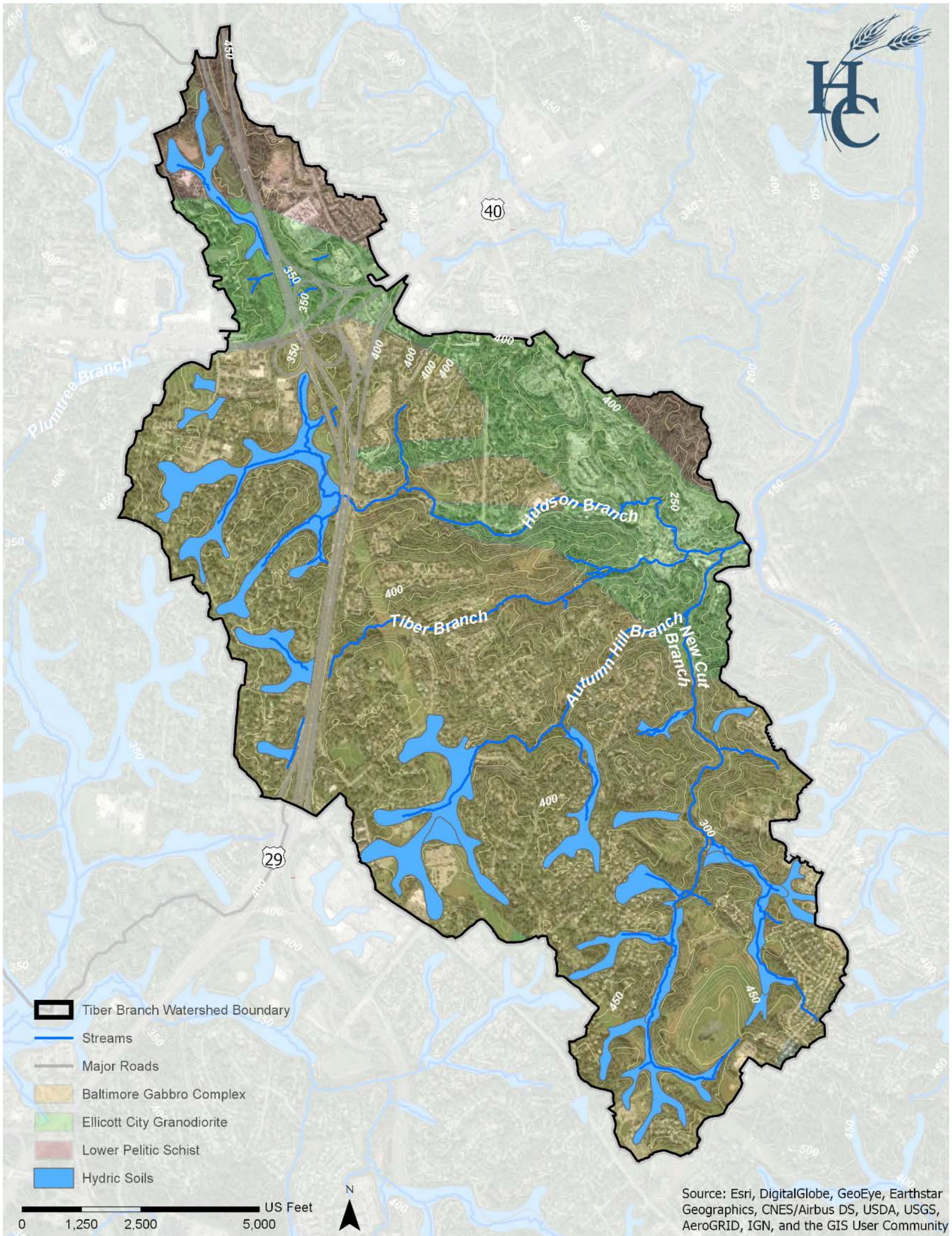


FIGURE 2.2. TIBER BRANCH WATERSHED GEOLOGY AND TOPOGRAPHY

The Tiber Branch watershed consists of three primary subwatersheds: Hudson Branch, Tiber Branch, and New Cut Branch. The north and west part of the watershed contributes runoff to the Hudson Branch subwatershed. The Hudson Branch flows north-south along US 29 then eastward, winding along Frederick Road and into historic Ellicott City. The Hudson Branch confluences with the Tiber Branch subwatershed just south of historic Main Street. From there, flows continue east through historic Ellicott City, staying on the south side of Main Street and confluencing with the New Cut Branch just east of Old Columbia Pike. The uplands of the New Cut Branch subwatershed extend from MD 103 north toward Historic Ellicott City.

2.3 Watershed Land Use

The Tiber Branch watershed has undergone many changes through the years, mainly due to the influence of urbanization on the ecosystem. These land use changes can be broadly characterized by:

- Early Exploration and Development
- Early Industry
- Suburbanization

2.3.1 Early Exploration and Development (Pre-1750)

The earliest continuous human settlement of the Patapsco River Valley was likely in the later 17th or early 18th century, when indigenous tribes, after decades of territorial wars with European Colonialists on the Eastern Shore, were forcibly moved to inhabit the Piedmont and the broader Patapsco River Valley (Merrell, 1979 and Youssi, 2006). Any settlement of displaced indigenous tribes to the area did not last long. In 1669, the colony of Maryland passed the Maryland Mill Act, providing eminent domain to lands on which any citizen could construct and operate a mill or mill dam (Hart, 1995). Historic evidence does not suggest widespread construction of mill dams along the Tiber, Hudson or New Cut Branches. However, several mills along the Patapsco River likely drove population and grain production upward in the watershed (Sharp, 2017).

Land cover during this period shifted gradually. Less densely vegetated lands above the floodplain were used first for tobacco production, then for cotton and wheat as grist mills became more common. The areas surrounding the mills likely remained mostly forested, both in the headwaters and the valleys, until the great industrial leaps of the coming century.

2.3.2 Early Industry (1750-1945)

The most notable, and perhaps most important, social and technological development in the history of the Ellicott City area is the completion of the Ellicott Mills complex on the east bank of the Patapsco River in 1774. From this moment, Ellicott City (then Ellicott Mills) became an industrial leader and

"America's First Factory Town." As industry picked up activity, the Maryland Mill Act was repealed as legislation in 1776.

The construction of the Baltimore and Ohio (B&O) railroad took place throughout the 1820s. The railroad's construction marked a major period of landscape change throughout the Patapsco River Valley and surrounding areas, as forests were felled for ties, and mountains were flattened and tunneled (Stover, 1987). These quick geological changes and rapid denuding of the landscape had major impacts on the hydrologic conditions of the area. It was during this time that the first extreme flood events were recorded in the area. The year of 1868 brought a catastrophic flood to the region, though floods were recorded as early as 1817.

2.3.3 Suburbanization (Since 1945)

Land use in the Tiber Branch watershed changed rapidly and dramatically after World War II. Two major highways completed construction around this time - US 40, with major construction completed in 1940, and US 29 ("modern Columbia Pike"), constructed in 1966.

Maryland's economy began to shift away from industry and populations moved away from the banks of rivers and tributaries to the open highlands in the west of the watershed. Headwater areas began to develop into suburbs. These changes were primarily due to the growing human population which resulted in a shift to suburban land uses to meet the increasing housing demands. The first evidence of headwater stream burial begins to appear as part of development in the 1940s. Historic hydrology from 1906 United State Geologic Survey (USGS) Quadrangle maps, alongside current hydrology in the Tiber Branch are depicted in Figure 2.3.

More than half of the development in the Tiber Branch watershed occurred prior to stormwater management requirements and therefore has no stormwater controls. A summary of stormwater management requirements over the years is summarized in Table 2.2. Table 2.3 depicts the portion of the watershed developed under each of the stormwater management eras.

2019 Howard County land use data shows that residential development makes up 40% of the total area, but the three tributaries also drain runoff from commercial development, public facilities and schools, road networks, and open space (Figure 2.4).

TABLE 2.2. STORMWATER MANAGEMENT IN THE TIBER BRANCH WATERSHED

Stormwater Management Era	State Requirements	Tiber Branch Watershed-Specific Requirements
1984 and earlier	No stormwater requirements	None; curb and gutter built to move water offsite
1985 - 2002	"2 & 10-year" stormwater management: manage the post-development discharge rate to be no more than the pre-development discharge rate for both the 2- and 10-year storms. Safely pass the 100-year post development flow from the site	In 1990, 100-year stormwater management was introduced as a requirement; developments began managing the 100-year storm with facilities such as large retention and detention ponds
2002 – 2010	State regulations changed to require a 'unified sizing criteria' to address groundwater recharge, water quality, and channel protection	10- and 100-year stormwater management required through use of facilities such as retention and detention ponds
2010 to present	Stormwater Management Act of 2007, environmental site design (ESD) on-lot micro practices were required wherever possible to address water quality, designed to manage 1-year storm	Continued 10 and 100-year stormwater management requirements

TABLE 2.3. TOTAL DEVELOPED ACREAGE IN THE TIBER BRANCH WATERSHED BY STORMWATER MANAGEMENT ERA

Stormwater Management Era	% of Total Developed Acreage
1984 and earlier	54%
1985 - 2002	29%
2002 – 2010	11%
2010 to present	6%

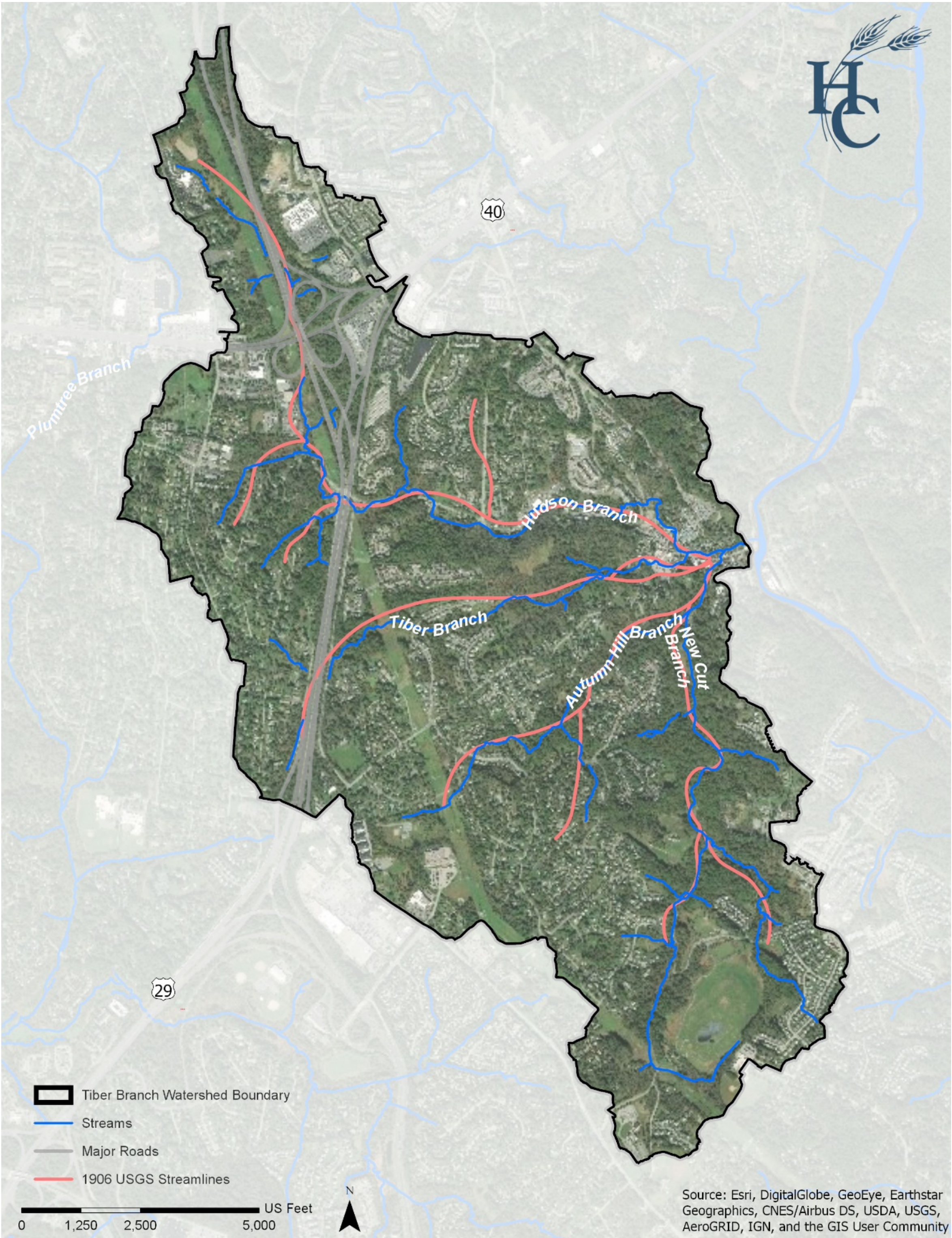


FIGURE 2.3. TIBER BRANCH HISTORIC AND CURRENT HYDROLOGY

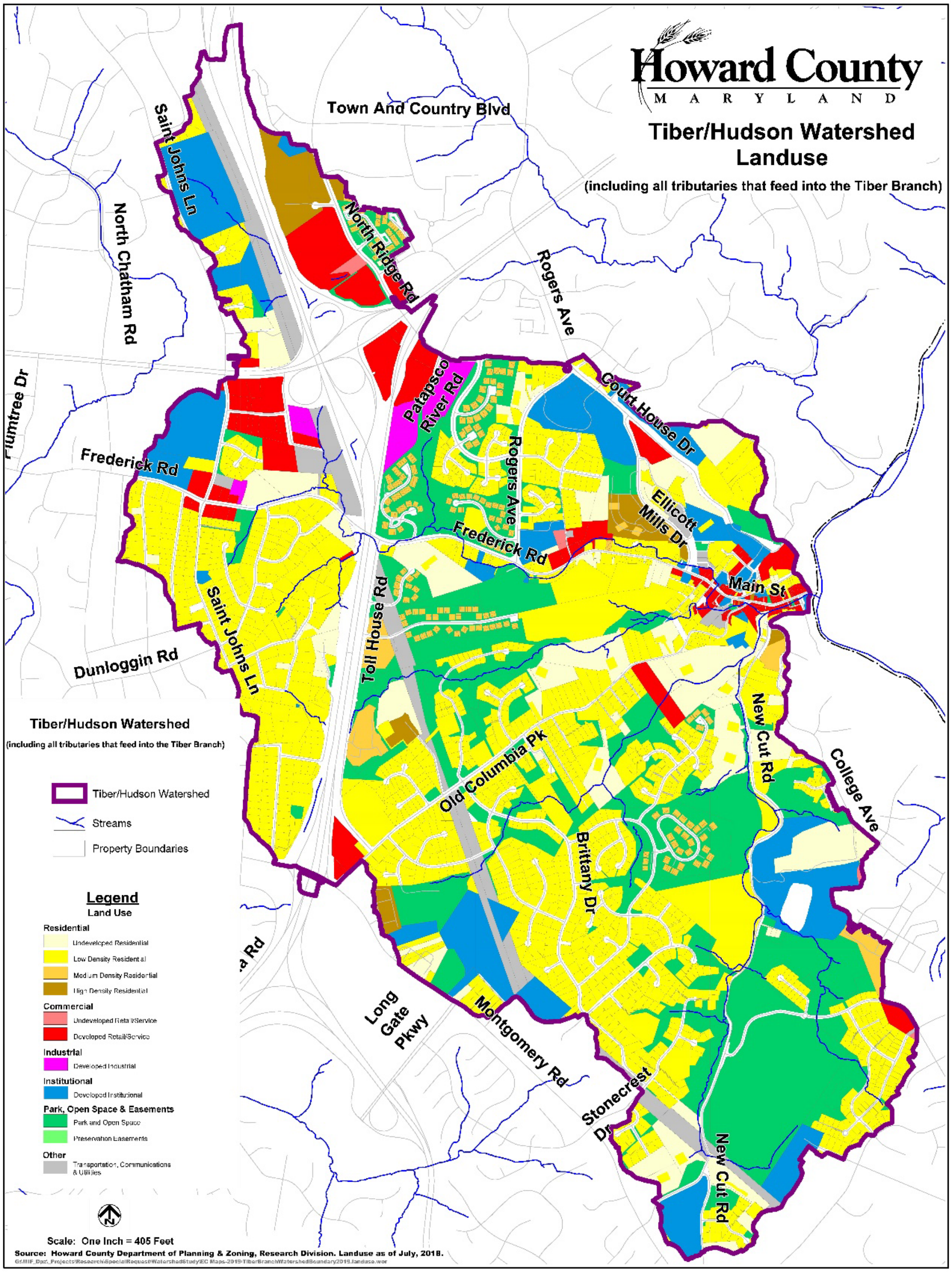


FIGURE 2.4. TIBER BRANCH WATERSHED LAND USE

2.4 Watershed Hydrology

A hydrologic analysis of the July 30, 2016 and May 27, 2018 storm events was completed as part of this report for the Tiber Branch watershed. Per Section 5 of Council Bill No. 56-2018, three land use scenarios were evaluated for each of the two storm events: existing, ultimate, and woods in good condition. For this analysis, the Tiber Branch watershed was evaluated with two drainage areas contributing to the downstream study point located at the confluence of the Tiber Branch with the Patapsco River, at the eastern edge of Historic Ellicott City. The hydrologic analysis in this report expands on the 2016 Ellicott City Hydrology and Hydraulics Study completed by McCormick Taylor.

2.4.1 Methodology

The hydrologic modeling for the July 30, 2016 and May 27, 2018 storm events was completed by utilizing local rain gauge data to generate synthetic hydrographs to replicate each storm event. The National Weather Service (NWS) provided precipitation data was collected from a tipping-bucket style rain gauge (ELYM2) located along Court Ave, within the Hudson Branch subwatershed. For the July 30, 2016 event, a distribution with three-minute (0.05 hour) intervals was developed for the 6.60 inches of rain that fell over approximately 3.7 hours. For the May 27, 2018 event, a distribution with three-minute (0.05 hour) intervals was developed for 6.36 inches of rain that feel over approximately three hours.

The drainage area for the analysis was delineated as part of the 2016 hydrology and hydraulics study and was established using Howard County GIS data and aerial imagery and verified with field reconnaissance. TR-20 was utilized to complete the hydrologic modeling for the watershed. Two subareas were utilized for the analysis based on those previously developed as part of the 2016 study; one subarea representing the Hudson Branch subwatershed (approximately 1.55 square miles), and one subarea representing New Cut and Tiber subwatersheds (approximately 2.14 square miles). The combined total watershed contributing to the watershed outlet at the Patapsco River confluence is approximately 3.7 square miles.

The runoff curve numbers (RCNs) for the three land use conditions (existing, ultimate, and woods in good condition), were developed based on Howard County GIS land use data, property lines, aerial imagery, and Howard County zoning. Hydrologic soils based on Howard County GIS and USGS data were delineated for the watershed for use in determining the RCNs. The overall watershed weighted average RCNs for the existing, ultimate, and woods conditions are 77.8, 79.7, and 61.8, respectively. Drainage Area, Hydrologic Soils, Land Use Maps, and RCN computations are included in Appendix B.

Time of concentration (Tc) is the time required for runoff to travel from the hydraulically most distant part of the drainage area to a point of investigation in the watershed. TR-55 methodology was used to compute Tc from flow path hydraulics and a maximum of 100 feet of overland flow was considered for this study. The land slope was calculated based on GIS topography. A Tc path was developed for the Tiber-New Cut subwatershed and for the Hudson Branch subwatershed. Due to the linear nature of these subwatersheds, the flow path from any point will reach channel flow quickly via overland, concentrated, and/or storm drain flow. The Tc for the Hudson Branch was computed to be 1.136 hours and the Tc used for the Tiber-New Cut subwatershed was 0.619 hours. For the woods in good condition land use analysis, the Manning's 'n' value for overland flow was modified from dense grass (0.24) to dense woods (0.80); the resulting modified Tcs for the Hudson and Tiber-New Cut subwatersheds are 1.725 hours and 0.958 hours, respectively. Time of concentration computations, TR-20 outputs, and hydrographs can be found in Appendix B.

2.4.2 Discussion of Results

The computed peak discharges along with runoff volumes for the July 30, 2016 and May 27, 2018 storm events for the three land use conditions for the Tiber Branch watershed are summarized in Table 2.4.

TABLE 2.4. TOTAL TIBER BRANCH PEAK DISCHARGE AND RUNOFF VOLUMES FOR 2016 AND 2018 FLOOD EVENTS

Land Use Condition	7/30/2016		5/27/2018	
	Peak Discharge (cfs)	Runoff Volume (ac-ft)	Peak Discharge (cfs)	Runoff Volume (ac-ft)
Existing, Good Condition	7,639	807	5,751	766
Ultimate, Good Condition	7,986	847	5,910	803
Woods in Good Condition	3,944	491	3,337	458

As simulated, the peak discharge rates for the 2016 storm were greater than the peak discharge rates for the 2018 storm. This does not fully support the flood observations made in 2018, in which some areas appeared to be as bad as, if not slightly worse than, the 2016 storm. In 2016, the "bullseye" of highest precipitation intensity occurred almost directly over the ELYM2 rain gauge, indicating that the data used for the hydrologic analysis likely represents the true intensity of that storm event. For the 2018 storm, the most intense precipitation occurred to the south of the rainfall gauge, primarily in the New Cut Branch. The rainfall data for both events was approximated by the same rain gauge, located in the Hudson Branch watershed and as such, the gauge data may not represent the full intensity of the 2018 storm. It is recommended that the 2016 event be used as a more conservative modeling scenario.

2.5 Recent Watershed Studies and Projects

The Howard County DPW, Department of Planning and Zoning, and Office of Emergency Management (OEM) have conducted various planning studies of the Tiber Branch watershed in recent years. In addition, several Capital Improvement Program (CIP) projects initiated by DPW are in the planning, design or construction phase in the watershed. As projects move forward in design, more information will be presented through community outreach efforts for each project.

3. FIELD ASSESSMENTS AND COMMUNITY INPUT

3.1 Introduction to the Assessments

To better understand drainage patterns and storm drain infrastructure conditions in the Tiber Branch watershed, a field assessment was conducted, and information was obtained from watershed residents and landowners on stormwater drainage and flooding. During the field assessment, the following information was collected:

- Qualitative data on the storm drain network (e.g. condition, pipe size, type of inlet, etc.)
- Opportunities for maintenance, inspection, retrofit, or repair of existing storm drain infrastructure
- Community drainage comments conveyed to field crews by landowners and residents
- Opportunities to address observed and documented conditions such as flooding, a lack of drainage, or conveyance systems not functioning as intended with retrofits or new projects

Community input data was also received from Stormwater Retrofit Studies survey results, Howard County DPW complaints database, and telephone or email correspondence. This community input data, along with any documented field interactions, was incorporated throughout the Tiber Branch Watershed Retrofit Study.

Figure 3.1 shows the assessment area within Tiber Branch watershed. Several areas were excluded from the assessment, including:

- Maryland Department of Transportation (MDOT) owned properties, and areas inspected and maintained by MDOT
- Historic Ellicott City, an area that has been, and is currently, the subject of several more detailed studies
- The immediate floodplain of New Cut Branch, an area that has also been the subject of more detailed studies

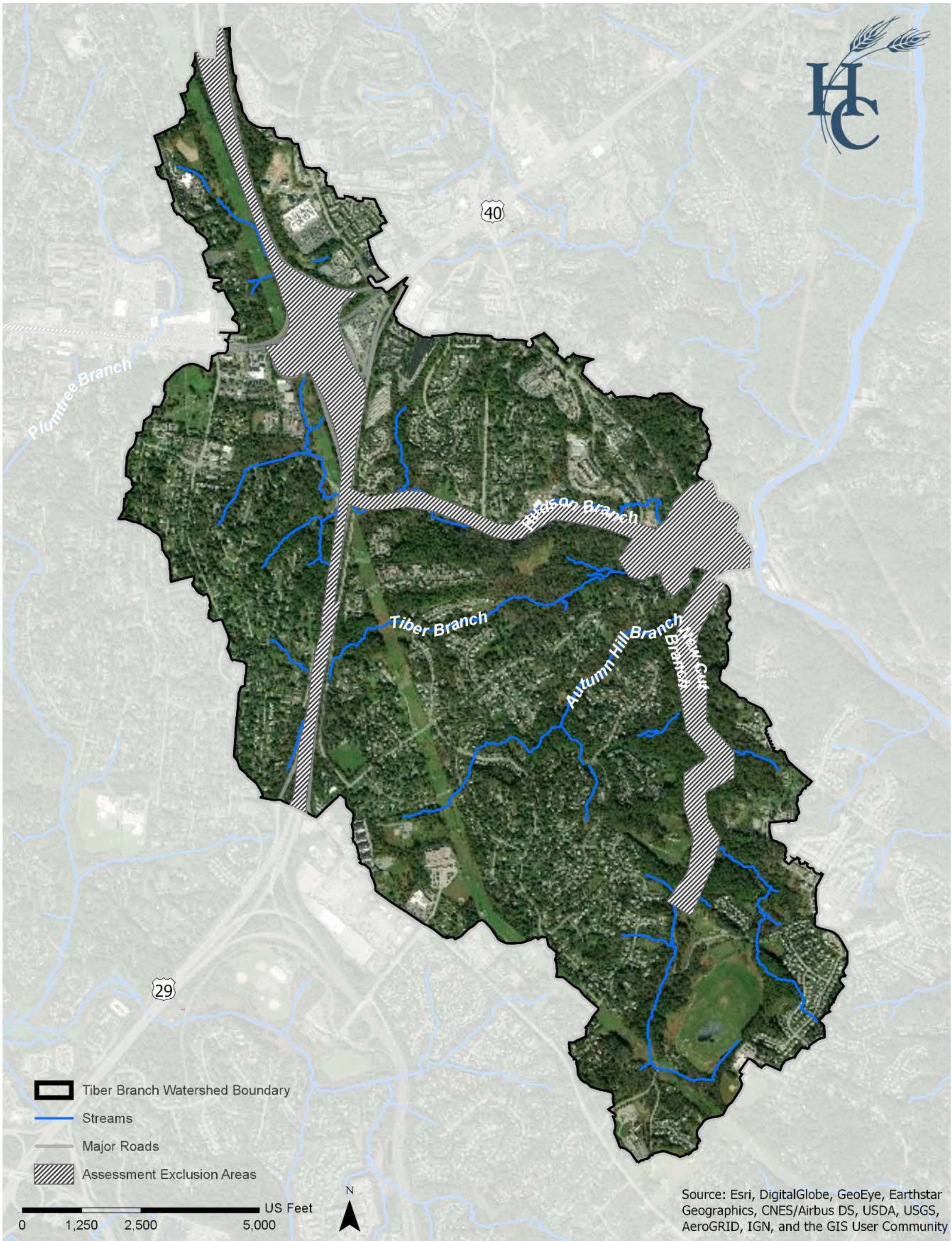


FIGURE 3.1. TIBER BRANCH WATERSHED RETROFIT STUDY AREA

3.2 Storm Drain Assessment

3.2.1 Assessment Approach

A field assessment of existing storm drain infrastructure was performed with the goal of verifying mapped infrastructure, locating unmapped infrastructure, and identifying deficiencies or maintenance concerns that were readily observable. This assessment was not intended to be a comprehensive survey of the storm drain network, but instead sought to update the County's storm drain database.

DPW maintains a database of known storm drainage assets (DPW assets database) that includes pipes, inlets, manholes, and outfalls. The DPW assets database contains the location and some limited information about each asset (e.g. where the asset information originated, pipe sizes, pipe material, etc.). Using a field-accessible version of the DPW assets database, field crews built upon this existing database (dated 2018) by verifying or editing already mapped infrastructure and logging the location of infrastructure that was not already in the DPW assets database.

A unique data input form was created for each asset type (i.e. pipe, inlet, manhole, outfall). While infrastructure data forms varied between asset type, examples of the data collected include:

- Materials
- Type (for inlets, outfalls, and manholes)
- Pipe size
- Pipe shape
- Photos of the asset

STORM DRAIN INFRASTRUCTURE ASSETS

Inlet

Manhole

Outfall

The condition of storm drain infrastructure located in the field was also documented. Conditions were rated as either:

- **Good Condition**: indicates that the storm drain infrastructure is functioning as intended, or
- **Further Investigation Recommended**: includes assets in need of inspection, cleaning, repair, or replacement, as well as inaccessible assets.

Data was also collected for swales and roadside ditches. These features often convey flow between storm drain infrastructure but were not included in the DPW assets database. These features include grass swales graded for conveyance, often along roadsides, as well as constructed concrete- or rock-lined swales. The addition of swales to the DPW assets database will improve the understanding of local drainage patterns. Field crews also identified opportunities to address observed conditions such as flooding, a lack of drainage, or conveyance systems not functioning as intended. Section 3.3 expands on these opportunities, and the data collected for them.

Best practices for collecting new data and modifying existing data in the DPW assets database are included in a document created to guide the field assessment phase (see Appendix C). Field data was collected during the period December 2018 through early March 2019.

3.2.2 Assessment Results

Field crews found that about half of the watershed's constructed assets (pipes, manholes, inlets and outfalls) were mapped within the DPW asset database. Generally, if some assets from a development were mapped, then all assets were mapped, but otherwise there was no clear pattern as to what assets had been mapped in the DPW asset database. Figure 3.2 below shows the infrastructure located throughout the field assessment phase versus infrastructure that was mapped in the DPW asset database.

Field crews rated assets as good condition or in need of further investigation, a rating that includes assets in need of inspection, cleaning, repair, or replacement. The asset type which most often fell into the "further investigation recommended" category is outfalls. About half of the outfalls in the watershed received this rating. Pipes are the asset type least likely to require further investigation.

Field crews found that infrastructure designated as "Further Investigation Recommended", does not follow any pattern. A heat map, shown in Figure 3.3 below, demonstrates this overall lack of pattern. The infrastructure conditions found during the field assessment are summarized in Figure 3.4 below.

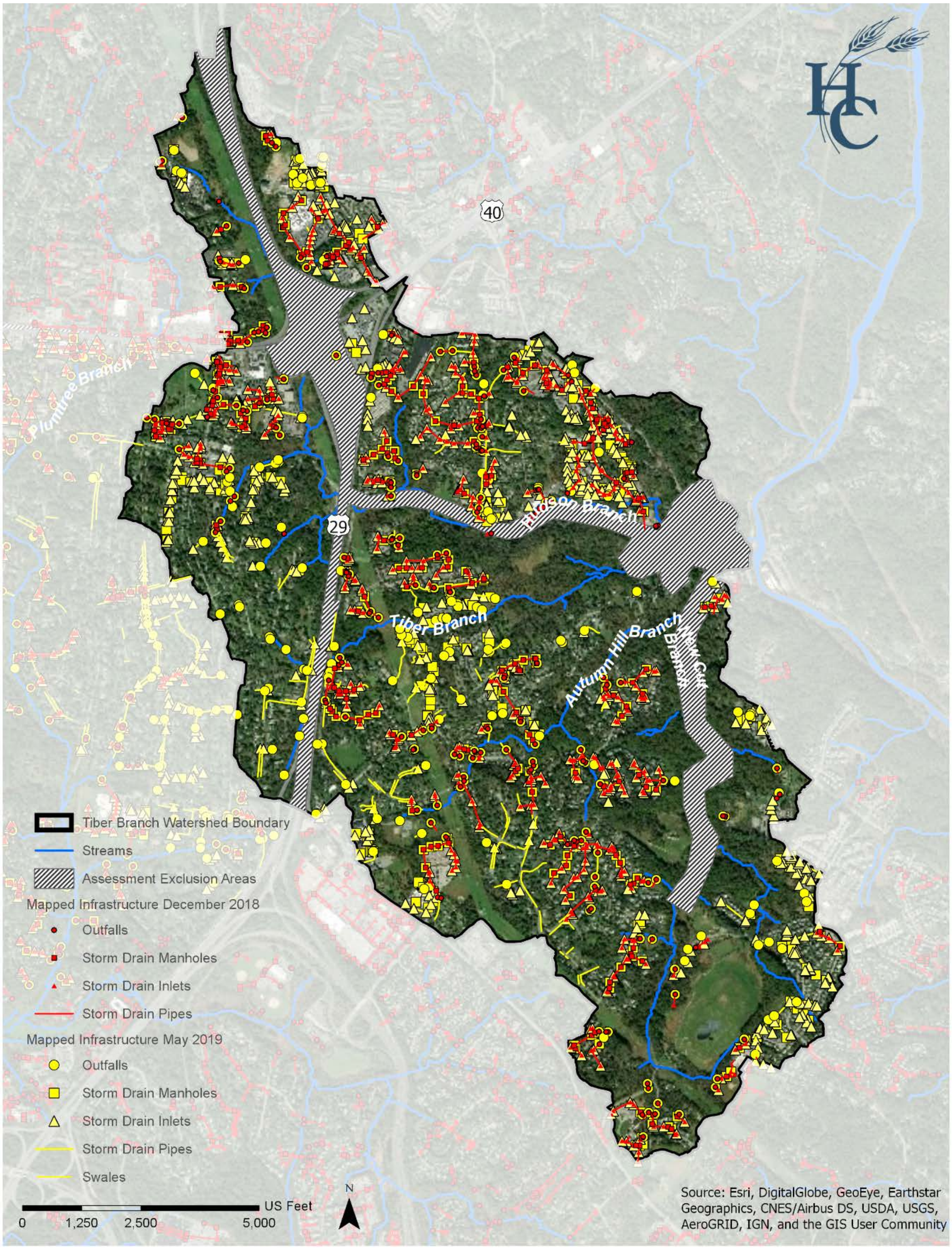


FIGURE 3.2. TIBER BRANCH WATERSHED STORM DRAIN MAPPING, PRE AND POST FIELD ASSESSMENT

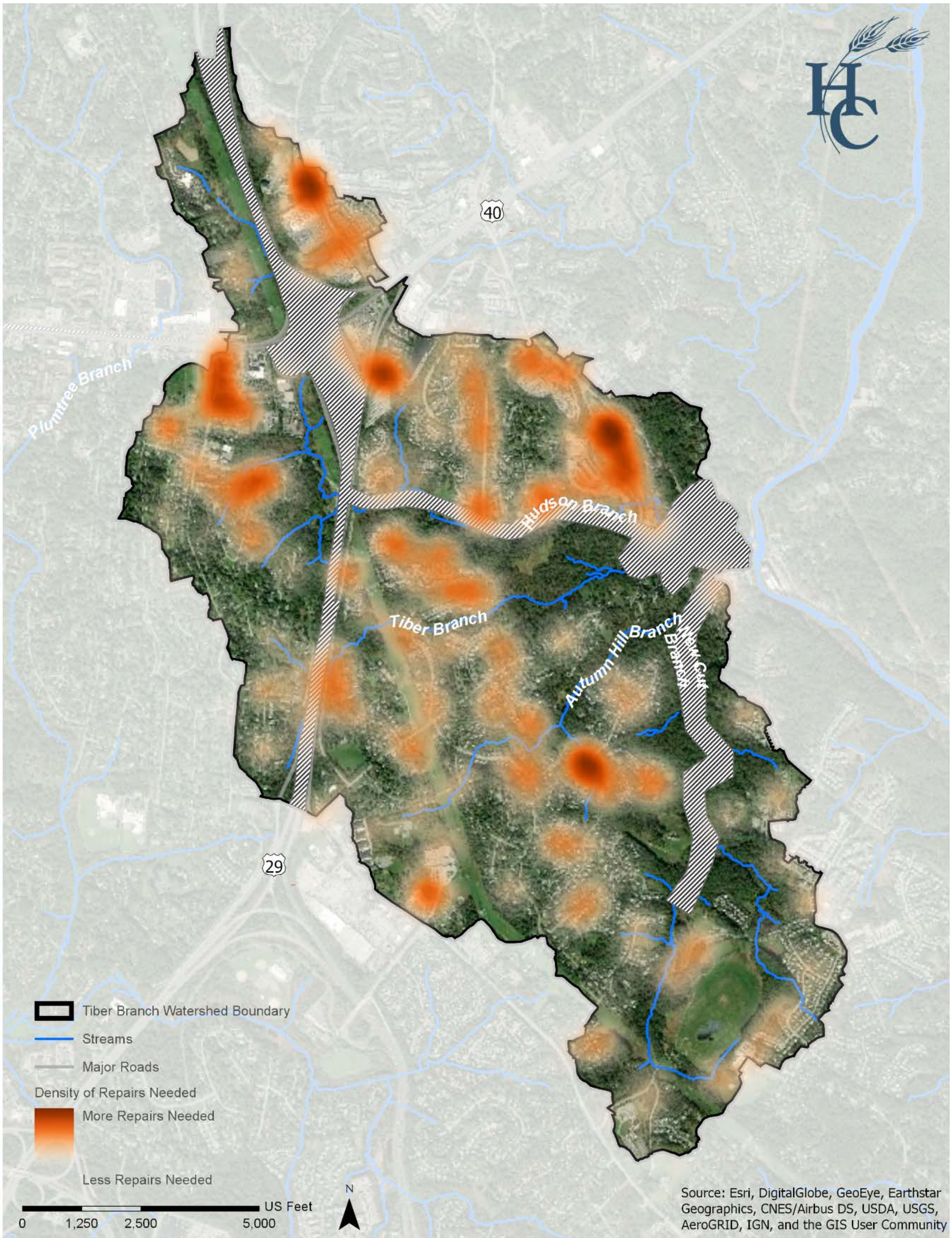


FIGURE 3.3. TIBER BRANCH WATERSHED STORM DRAIN CONDITION

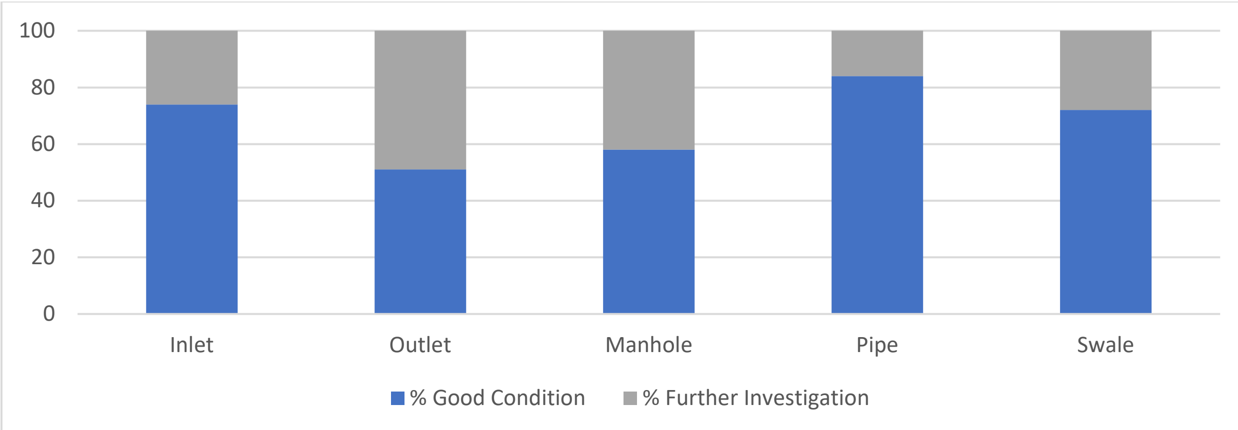


FIGURE 3.4. ASSET CONDITION BY TYPE

3.2.3 General Observations and Findings

General field observations of the Tiber Branch watershed can be found below.

- In many locations, the data in the existing DPW assets database appears to be based on the design plans versus as-built drawings, which reflect infrastructure as it was constructed. Field crews frequently found that the actual location, and other attributes, of the storm drain system differed from the DPW assets database.
- Many manholes and inlets are constructed from brick.
- Portions of the infrastructure appear to not be functioning as intended. While some pieces of infrastructure are in need of simple maintenance, such as roadside inlets clogged with leaves, many pieces of infrastructure require more involved repairs.

  Infrastructure requiring repairs, replacements or maintenance generally included the following:
  - Recommended infrastructure replacements include buried or collapsed outfalls; corroded and/or exposed pipes; and damaged inlets.
  - In many brick manholes and inlets, bricks have shifted and are in need of repair.
  - Outfalls within stream floodplains are often submerged and sometimes buried, thereby requiring maintenance.
  - Many outfalls lack a defined downstream channel and instead discharge to a flat, open space. Often these outfalls are creating flooding or erosion issues in backyards.
  - A sinkhole over a pipe sometimes served as an indicator of a needed pipe repair (e.g., sinkhole was caused by a collapsed or leaking pipe).

STORMWATER MANAGEMENT FACILITIES

Practices designed to provide water quality treatment and protect against flooding by storing water and releasing it at a controlled rate (e.g. stormwater ponds).

- Generally, areas with open section drainage systems (i.e. no curb and gutter) are not served by stormwater management facilities. These areas often drain directly to a channel or stream.
- Adjacent conveyance systems are often disconnected from each other (i.e., a swale that ends at a driveway with no culvert). Ponded water was generally observed around these locations.
- Many stream culverts (i.e., pipes conveying streams under roadways) appear not to be functioning as intended due to changes in design parameters and drainage patterns related to development within the watershed, which impacts the areas upstream and downstream of the culvert crossings.

3.3 Opportunities Assessment

3.3.1 Assessment Approach

During the field reconnaissance phase, opportunities to mitigate conveyance and localized flooding issues were collected in addition to assessing existing storm drain infrastructure data and conditions. While the first half of the field assessment work focused on documenting existing conditions, this piece identified potential sites and opportunities for future County project work.

Where field crews observed issues such as localized flooding, a lack of drainage, or existing conveyance systems not functioning as intended, the crews documented these existing conditions and any potential opportunities to address these conveyance problems. Locations that had complaint data or survey results indicating conveyance issues nearby were evaluated with special consideration for opportunities to mitigate the issues highlighted in the survey responses and complaints.

Opportunities were collected in the form of both points and areas, to allow field crews flexibility to adequately capture the full geographic extents of each opportunity. For the purposes of this report, all points and areas were grouped and will hereby be referred to as opportunities.

Each opportunity represents potential to improve the conveyance of stormwater at a given location. These

OPPORTUNITIES TO:

Improve Detention Practice

Implement ESD Practice

Improve Existing Conveyance

Install New Conveyance System

opportunities include a wide range of solutions, generally categorized under:

- **Implement and Improve Detention Practices**: large-scale practices designed to protect against flooding by storing water and releasing it at a controlled rate (e.g. stormwater ponds). This category includes both proposed new practices and improvements to existing detention practices, including maintenance of existing facilities.

- **Implement Environmental Site Design (ESD) Practices**: small-scale practices designed to provide water quality treatment through the filtering of intercepted runoff and, to a smaller degree, water quantity treatment through the storage and controlled release of water.

- **Improve Existing Conveyance Systems**: locations where an existing conveyance system comprised of storm drain networks and/or swales exists but is not functioning as intended.

- **Install New Conveyance Systems**: locations where no conveyance system exists, and field observations suggest that installation of a new conveyance system would improve conditions.

For each opportunity, the solution category and notes on potential options for implementation were recorded. Additional data collected for each opportunity included:

- Site constraints (e.g. adjacent utilities, trees, and access limitations)
- Any survey responses or complaints located nearby, as well as any field interactions with residents during the data collection
- Associated storm drain infrastructure adjacent to or associated with the opportunity
- Photos to document existing conveyance issues and any potential site constraints or factors to be considered in design

3.3.2 Assessment Results

A total of 88 opportunities were identified throughout the Tiber Branch watershed. More than half of the opportunities were characterized as improvements to the existing conveyance system. Approximately 22% of the total watershed opportunities are associated with community input data. The results of the opportunity assessment can be found in Appendix E.

Overall, opportunities are frequently located at least partially on private property, but involve County right-of-way and/or County-owned infrastructure. In these instances, the focus of the opportunity is generally to establish connections with the County right-of-way or County-owned infrastructure to alleviate flooding and other conveyance issues. Site constraints for projects are primarily potential utilities, adjacent trees, and access, due to the location of many sites on private property.

A preliminary prioritization process (discussed in detail in Section 3.3.3) was conducted to help differentiate projects based on select criteria such as ability to address a clear obstacle to runoff conveyance and few obstacles to implementation. This process is intended to inform future planning by DPW when identifying projects that will move forward to implementation through the County's CIP program.

A map of all collected opportunities can be found in Figure 3.5.

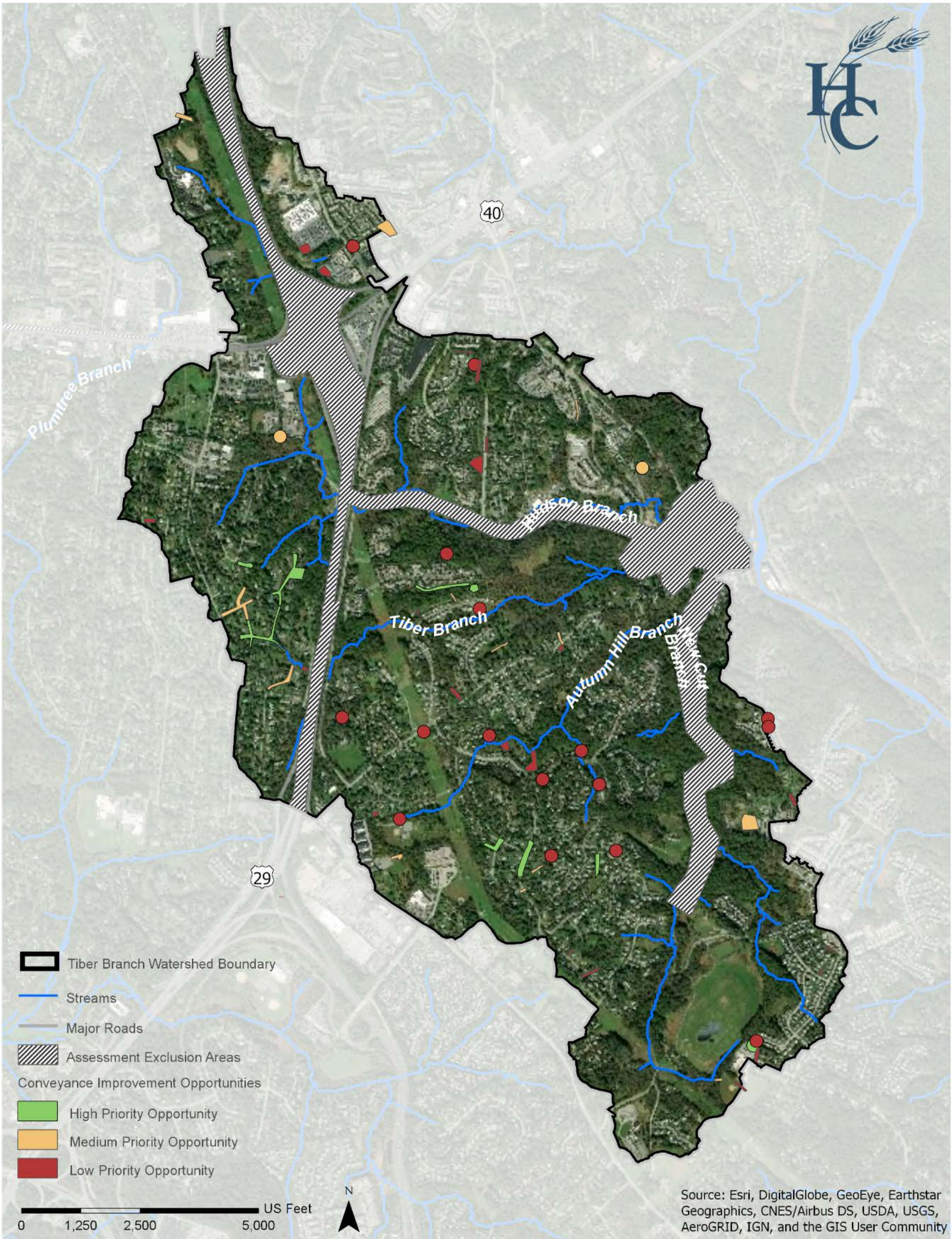


FIGURE 3.5. TIBER BRANCH WATERSHED RETROFIT AND DRAINAGE IMPROVEMENT OPPORTUNITIES

3.3.3 Opportunity Prioritization

After data collection was completed, opportunities for mitigating conveyance issues collected during the field work were compiled and reviewed. ESD Practice opportunities were omitted from the prioritization since these small-scale stormwater management practices do not directly address existing conveyance issues. The relative percentages of each category of opportunities collected can be found in Figure 3.6 below.

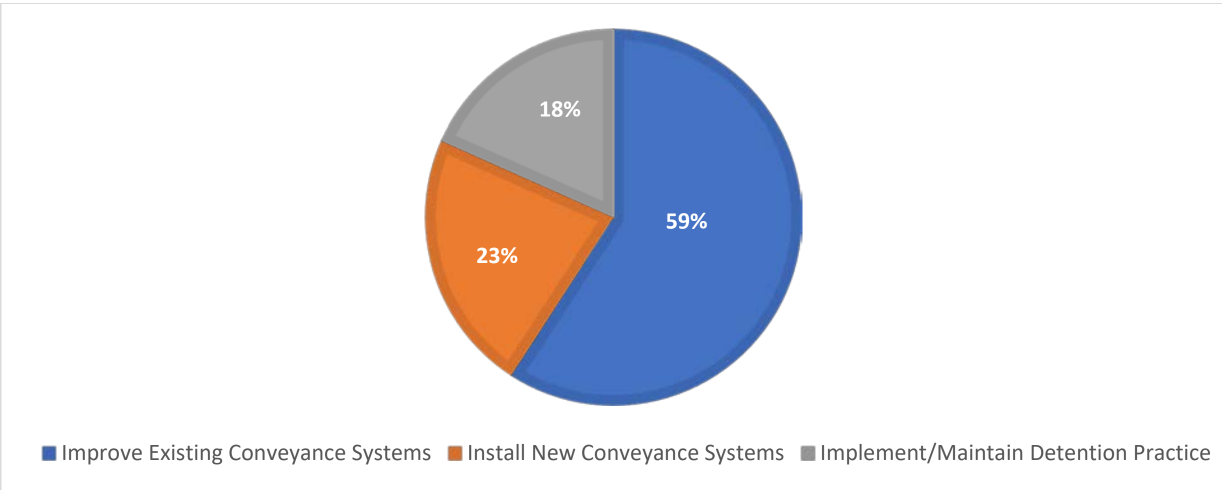


Figure 3.6. Opportunity Data Collected by Type

Opportunities were rated qualitatively and grouped with others that were similar in both the severity of the documented conveyance issue and the scope of the solution. This grouping and rating process will facilitate future usage of the opportunity data by the County and was crucial in the categorization of Assessment Areas, discussed in Section 4.2 of this report. The opportunities were evaluated by applying the criteria shown below:

- Addresses a clear obstacle to runoff conveyance and will improve conditions for smaller more frequent storm events
- Has field notes indicating there are few barriers to implementing the opportunity
- Mitigates runoff concerns for multiple properties
- Is located on publicly owned land, to the extent that field crews could evaluate
- Is located within a major flowpath and might, therefore, have benefits to downstream properties as well
- Is a relatively straightforward solution
- Is associated with areas that were the subject of community input (i.e., complaints, surveys, comments, and/or field interviews

The criteria are listed in terms of importance of the factor in consideration of the rating (i.e., those at the top of the list were weighted the most heavily). The cost of an opportunity's design, construction, or maintenance was not a factor in the rating.

Table 3.1 gives examples of how application of the opportunity criteria resulted in a high, medium, or low rating. These examples are provided to illustrate the qualitative ratings and do not apply to the complete set of opportunities evaluated.

TABLE 3.1. OPPORTUNITY RATING EXAMPLES

Priority Rating	Example
High	• Solution for a large, system-wide lack of infrastructure that impacts multiple properties and where a clear conveyance path is noticeable in the field • Addition of inlets or curbs in the public right-of-way would mitigate ponding and erosion • Conveyance solutions that would positively impact additional areas downstream • Improves conveyance conditions for smaller, more frequent storm events
Medium	• Outfall from a stormwater pond with no clear conveyance path that poses issues with downstream properties and infrastructure • Relatively simple drainage solution that mitigates issues for multiple properties • Area of concern not directly impacting properties; solution to the drainage concern needs further investigation • Drainage solution on private property or properties
Low	• Outfall from a stormwater pond with no clear conveyance path yet no downstream issues • Solutions related to maintenance of existing facilities • Solution is small and located on a single, private property • Relatively simple drainage solution that does not appear to mitigate a current concern

3.4 Community Input

3.4.1 Collection of Community Input

Community input was incorporated throughout the Tiber Branch Watershed Retrofit Study. The locations and types of community input were available to the field crews during the field assessment phase and were used to develop and prioritize opportunities for improvement of the observed issues. The primary mechanisms for obtaining community input included:

- Stormwater Retrofit Study Survey Results
- Additional Observations and Findings:

- Howard County DPW Complaints Database
- Field interactions
- Other community correspondence

3.4.2 Stormwater Retrofit Studies Survey Results

In October 2018, Howard County DPW initiated a survey of residents of the Tiber Branch watershed to better understand residents' issues and concerns related to stormwater drainage and flooding. Postcards were mailed to every address in the watershed, informing them of the Stormwater Retrofit Study and directing them to the Howard County DPW Stormwater Management Division website where a 24-question survey was available (Appendix D). Responses within the Tiber Branch watershed were provided by 35 individuals. The properties associated with the respondents are shown in Figure 3.7. Twenty-eight residents, or 80% of the respondents, cited drainage issues on their property. Their observations are summarized below:

- Of the 80% who cited issues with ponded water:
  - Most ponded water depths were listed as less than six inches,
  - Some respondents reported ponded water between six and 12 inches, and
  - One survey response reported ponded water over 12 inches in depth.
- The majority of survey responses citing drainage issues on their property also listed erosion as an issue.
- Nearly half of respondents cited problems with water getting into their homes, even though most of those dwellings already have sump pumps installed.
- Seven residents reported that the ponding usually infiltrates within 24 hours, and
- Ten residents reported that ponding does not infiltrate within 24 hours following storm events.

For a large majority of the respondents citing issues with drainage on their property, their problems with drainage predate the extremely wet period between May and October 2018, indicating that these were not isolated issues only relating to the area's wettest year on record.

When asked for the location of their drainage issues, responses included their backyards (72%), side yards (60%), front yards (32%), driveways (32%), and sidewalks (12%). Multiple locations were often listed by homeowners. When listing the source of the water causing the issues, most of the respondents believed the water to be coming from their neighbor's runoff while nearly half also stated the water is coming from a nearby roadway. Other sources of water listed included downspouts and roofs as well as nearby streams, storm drains, and outfalls.

The survey also included several questions generally related to stormwater practices. Respondents were asked questions regarding stormwater infrastructure on their property, vicinity to streams and riparian conditions, whether they have rain barrels/gardens, and whether they participate in the yard trim program. Additional questions asked residents for their input as to their ideal drainage conditions on their property and their idea of aesthetic and functional stormwater management practices. A spreadsheet showing the full results of the community input survey is included within Appendix D.

3.4.3 Additional Observations and Findings

Complaint Database

As of December 2018, DPW's complaint database contained 27 complaints from the Tiber Branch study area received between 2003 and August 2018. Complaints recorded before the database existed in 2018 have limited information within the database, however, information is on-file separately. New complaints received since 2018 are coded with a range of descriptions such as "trash" and "erosion" and are coded as "normal" priority unless health or safety risks are present. The status of the complaints entered since 2018 are recorded as:

- "Closed" when the complaint was addressed by DPW,
- "Open" or "investigating" when the complaint is considered current, or
- "Referred" when complaints were forwarded to other entities such as another county department, the state government, or homeowners association

The locations of the addresses provided by the complainant are depicted in Figure 3.7. The complainant's address is not necessarily the location of the stormwater issue but are generally located in the same vicinity.

Field Interactions

During the field work, field crews were often approached by residents who shared information on the history of the storm drainage issues in their neighborhood and commentary on specific issues they had observed. Several residents described issues during past storm events that had not been reported to the County via the survey or the complaints database. Field crews were more frequently approached in milder weather, so the frequency and location of field-interactions is somewhat weather dependent and does not necessarily correlate to the severity of drainage issues in a given area. The locations of field interactions with input relevant to the study are mapped in Figure 3.7.

Other Community Correspondence

During the field assessment phase, residents contacted DPW with comments via telephone or email. The locations of these additional community inputs are also mapped on Figure 3.7.

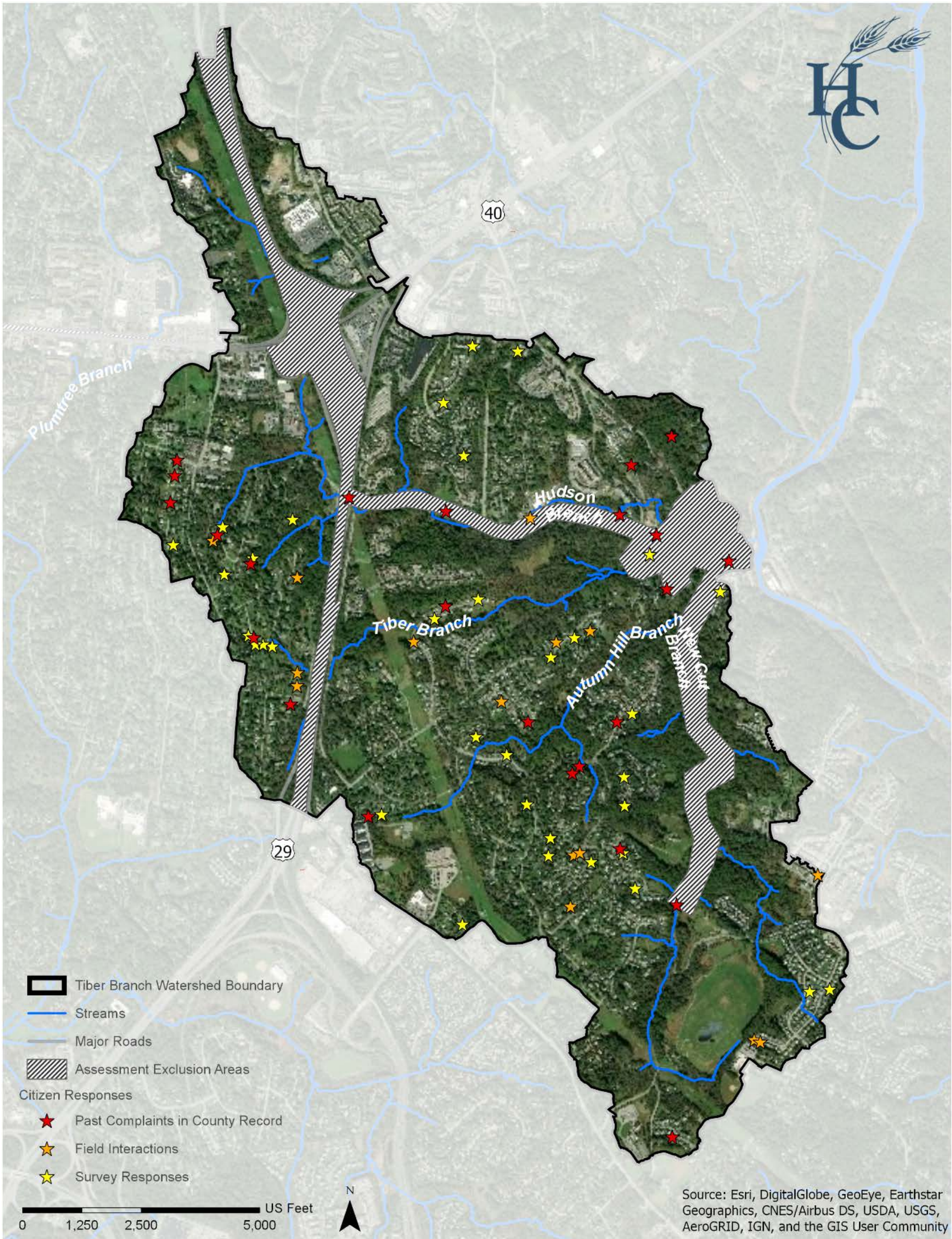


FIGURE 3.7. TIBER BRANCH WATERSHED COMMUNITY INPUT

4. STORM DRAIN ANALYSIS AND ASSESSMENT AREAS APPROACH

4.1 Storm Drain Analysis

The adequacy of a portion of the Tiber Branch watershed storm drain network was assessed as a preliminary analysis of the collected storm drain infrastructure data. The results of this analysis were used in the categorization of Assessment Areas, discussed in Section 4.2 of this report, and will also provide the County with an estimate of whether the storm drain networks are functioning as intended.

STORM DRAIN NETWORKS

Most assessed storm drain assets (i.e., inlets, manholes, and outfalls) are connected to adjacent assessed assets via pipes or swales. These connected storm drain assets, and their eventual discharge point (i.e., outfall), form **storm drain networks** throughout the watershed.

4.1.1 Analysis Approach

The adequacy of major storm drain networks was assessed for general compliance with sizing guidance, network layout, and condition. A major storm drain network was defined as having three or more contributing inlets. In the Tiber Branch watershed, 100 storm drain systems were analyzed.

A range of pipe diameters was computed for each major storm drain system using a commonly accepted storm drain sizing approach. The recorded pipe diameter of the last pipe in the network was compared to the computed range.

Storm drain systems were visually inspected to assess the spatial layout of the network. The visual inspection of the network layout consisted of verifying that pipe sizes reflected changes in contributing area and noting any constrictions. For example, if the contributing area doubled at a confluence, the pipe sizing should increase in response to that change. If a downstream pipe segment was significantly smaller than an upstream pipe segment, it was considered a constriction.

Field crews recorded the condition of individual pieces of infrastructure during the field assessment. As discussed in Section 3.2, storm drain condition was documented as either in “Good” condition or “Further Investigation Recommended.”

More information on the storm drainage system analysis methodologies can be found in Appendix F.

4.1.2 Analysis Results

The results of each component of three components of the storm drain analysis informed a final recommendation for each network. A storm drain network was considered:

- **Likely Adequate**: when the pipe size of the existing system fell within the recommended range, network layout was acceptable, and all components were in good condition.
- **Repair and Maintenance Recommended**: when pipe sizes fell within the computed range, network layout was acceptable, but condition was marked as repair recommended for one or more components.
- **Conduct More Detailed Analysis of Storm Drain Network**: when the pipe size was outside the computed range or network layout needs improvement.

As depicted in Figure 4.1. below, the majority of storm drain systems fell into either Repair and Maintenance Recommended or Conduct More Detailed Analysis of Storm Drain Network. Full results are included in Appendix F.

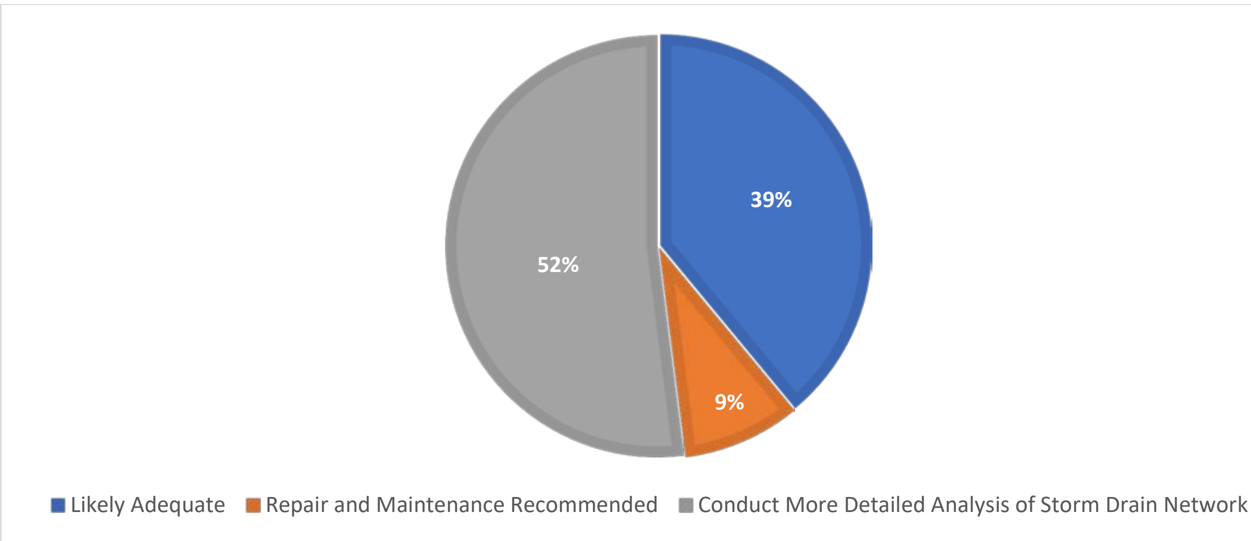


FIGURE 4.1. RESULTS OF STORM DRAIN ANALYSIS

4.2 Assessment Areas Approach to Stormwater Retrofit Planning and Implementation

4.2.1 Assessment Area Approach

Prioritized opportunities were reviewed alongside storm drain analysis results and drainage patterns within the Tiber Branch, New Cut Branch, and Hudson Branch watersheds. Assessment Areas were created based on the drainage area to stormwater outfalls along these three streams. These streams were chosen because their combined watersheds encompass all areas within the overall watershed of Tiber Branch. Sixty-seven Assessment Areas were delineated throughout the study area.

Assessment Areas were placed into one of three categories based on the results of any applicable storm drain analyses, the ratings of any identified opportunities, and community input data located within each Assessment Area. The three Assessment Area categories are (see Figure 4.2):

- **Potential Capital Projects**: have significant drainage issues or extensive repair needs and opportunities to mitigate these drainage issues were identified.
- **Repair and Maintenance Projects**: have one or more components of storm drain infrastructure marked with a condition of Repair and Maintenance Recommended.
- **Potential On-Lot Improvements**: have drainage concerns that are limited to property-to-property stormwater runoff.

Potential Capital Projects

Assessment Areas categorized as Potential Capital Projects, showed deficiencies in conveyance and evident opportunities to mitigate these conveyance issues. These areas are recommended for inclusion into the CIP where further study and preliminary designs can emerge. Thirty areas were placed into this category.

Repair and Maintenance Projects

Assessment Areas categorized as Repair and Maintenance Projects had one or more storm drain networks returned "Repair and Maintenance Recommended**"** during the storm drain analysis. The majority, thirty-two, of the Assessment Areas are categorized as Repair and Maintenance Projects.

Potential On-Lot Improvements

The final category of Assessment Areas is those where any drainage concerns are limited to property-to-property stormwater runoff. Specific opportunities were not identified by field crews, since any work performed would be the responsibility of individual residents. Only five areas were placed in the Potential On-Lot Improvements category.

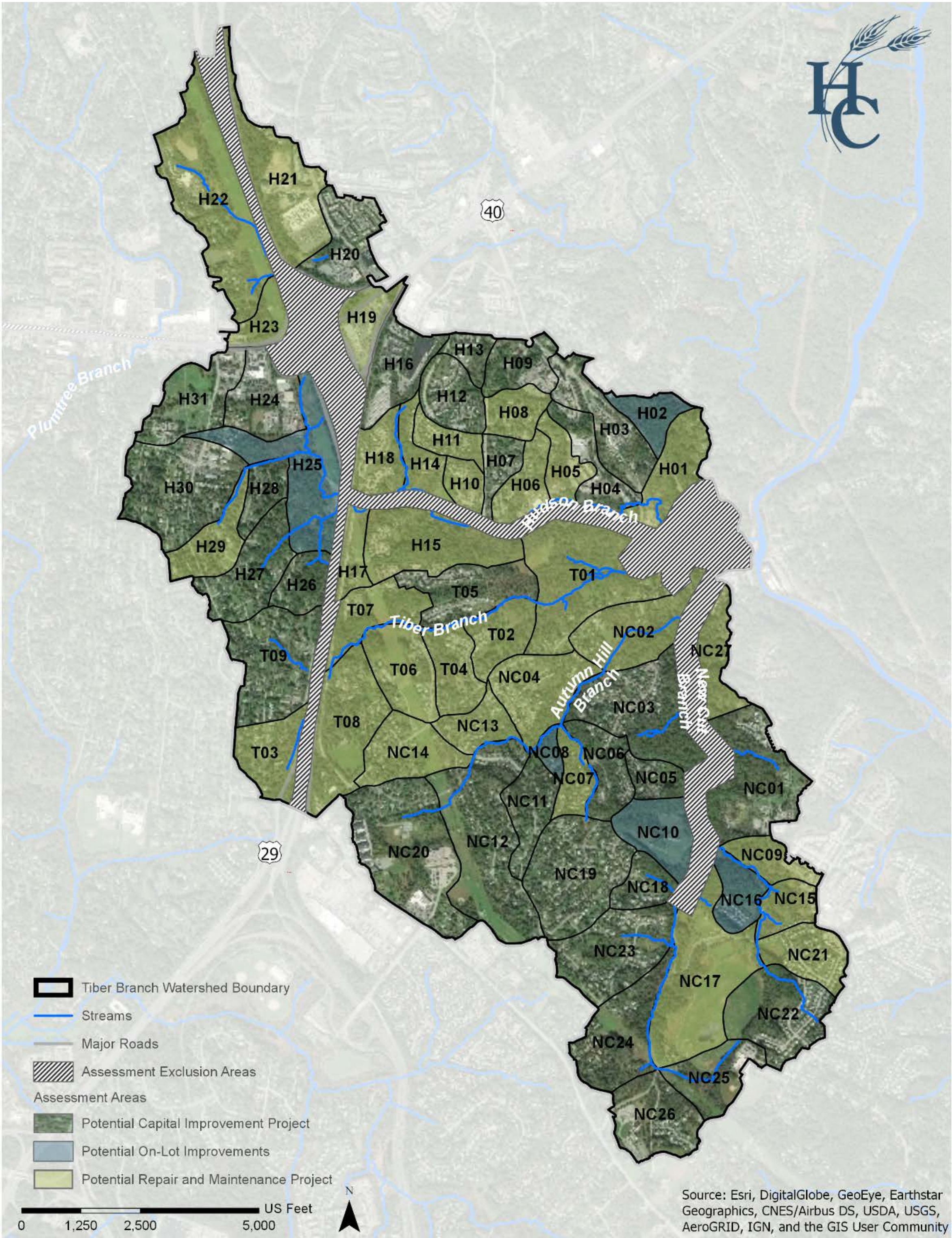


FIGURE 4.2. TIBER BRANCH WATERSHED CATCHMENTS AND ASSESSMENT AREAS

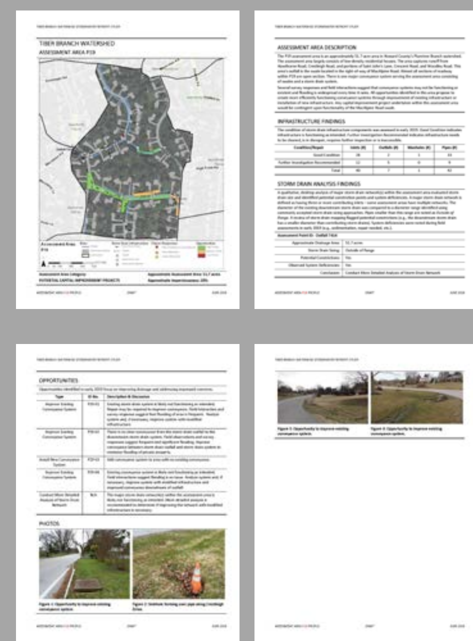
4.2.2 Assessment Area Results

Profile sheets, accompanying this report as Appendix G, were created for each Assessment Area. These profile sheets summarize the results of the Assessment Area characterization and provide an overview of each Assessment Area, including:

- A description of the characteristics and drainage patterns of the Assessment Area
- An overview of any community input received within the Assessment Area
- Field assessment infrastructure findings (i.e., number and conditions of assets found)
- Storm drain analysis results
- Opportunities identified within the Assessment Area

All results and findings reflected in this report and these Assessment Area profile sheets are conceptual. The prioritization of opportunities should be considered, and more detailed studies of these areas may be needed before any work is initiated.

ASSESSMENT AREA PROFILE SHEET



5. STORMWATER RETROFIT STUDY GENERAL FINDINGS

In addition to the individual opportunities and Assessment Area recommendations detailed in the profile sheets, general findings and watershed-scale recommendations addressing drainage and flooding issues are described below.

Catchment-Based Approach

Address stormwater management in the Tiber Branch watershed using a catchment approach. This approach may encompass several Assessment Areas located within a given catchment and would lend itself to addressing related concerns in their entirety instead of in a piece-meal fashion due to the connectedness of runoff, the storm drain system, and receiving waters. Implementing projects on individual properties, instead of regarding areas holistically, can solve local drainage issues, but can also exacerbate drainage issues downstream of the project. Aspects to consider on a catchment by catchment basis include prioritizing and upgrading stormwater infrastructure and an analysis of the locations where streams cross roadways to determine the capacities of culverts and potential contribution to flooding.

Future Grading Impacts

Consider future development and associated grading of lands in the context of existing drainage patterns. Grading of lands due to new development and repaving of roads can modify existing drainage patterns and could potentially exacerbate drainage issues downstream.

Private Drainage Easements

Establish a program to document storm drain easements in the County's GIS. Once known storm drain easements are documented, the next step could be to establish a program to acquire private drainage easements in order to take over long-term maintenance and operation of storm drain infrastructure.

DPW should consider creating a GIS layer to show existing storm drainage easements. An easement layer that links to the specific easement document would give DPW maintenance staff the ability to determine access rights and identify maintenance responsibility.

Public Outreach and Engagement

Expand on the County's public outreach efforts to educate the public on flash flooding, floodplains, hydric soils, stormwater conveyance and stormwater management. Areas for public engagement and involvement in address stormwater management include:

- Promote and implement existing stormwater management programs such as Rain Gardens for Clean Water and Cleanscapes to improve availability to homeowners. Although these programs are designed to improve water quality, rain gardens and other green infrastructure can also provide some storage of runoff during less intense storm events. Storing flows in the upland areas may decrease the frequency of lower areas flooding.

- Provide residential guidance on sizing driveway culverts to improve connectivity of roadside open channel conveyance systems.
- Provide residential guidance on locating sump pump discharge to prevent isolated flooding and erosion on residential yards.
- Encourage residents to inspect and repair infrastructure located on their private properties. If infrastructure appears to need repair or maintenance, residents are currently encouraged to reach out to DPW for assistance determining ownership and easement status, permitting requirements, and potential partnership opportunities.

REFERENCES

Hart, John. 1995. The Maryland Mill Act, 1669-1766: Economic Policy and the Confiscatory Redistribution of Private Property. The American Journal of Legal History. Vol. 39, No. 1, pp. 1-24.

McCormick Taylor. 2017. 2016 Ellicott City Hydrology/Hydraulic Study and Concept Mitigation Analysis. Prepared for Howard County Government Stormwater Management Division Bureau of Environmental Services.

Merrell, James. 1979. Cultural Continuity among the Piscataway Indians of Colonial Maryland. The William and Mary Quarterly. Vol. 36, No. 4, pp. 548-570.

Parece, T.E. & Campbell, J.B. 2015. Identifying urban watershed boundaries and area, Fairfax County, Virginia. *Photogrammetric Engineering & Remote Sensing, 81*(5), 365-372.

Sharp, Henry. 2017. America's First Factory Town: The Industrial Revolution in Maryland's Patapsco River Valley. Chesapeake Book Company.

Stover, John. 1987. History of the Baltimore and Ohio Railroad. Purdue University Press.

US Department of Agriculture, Natural Resources Conservation Service (USDA-NRCS). 2019. Custom Soil Resource Report for Howard County, Maryland, Tiber-Hudson Watershed. Downloaded April 17, 2019.

Youssi, Adam. 2006. The Susquehannock's' Prosperity & Early European Contact. Historical Society of Baltimore County.