STORMWATER MASTER PLAN

FOR

WILLISTOWN TOWNSHIP, CHESTER COUNTY, PENNSYLVANIA

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Prepared by:

Herbert, Rowland & Grubic, Inc.
501 Allendale Road, Suite 203
King of Prussia, PA 19406
484.460.7050
www.hrg-inc.com

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1. INTRODUCTION

The Willistown Stormwater Master Plan is the product of a comprehensive effort to identify stormwater and flooding issues within the Township. The intent of this document is to present the findings of the stormwater study conducted to develop the plan and provide a framework to identify potential stormwater related programmatic efforts and flood mitigation projects to be implemented by the Township.

The study was initiated by Willistown Township to assess stormwater issues and problem areas throughout the municipality caused by intense rainfall resulting in local and neighborhood-wide flooding. The study scope included field reconnaissance, Geographic Information System (GIS) database development, technical analysis, mitigation solution development, Township coordination, and technical report development.

1.1 BACKGROUND

Willistown Township (Township) is a suburban township located approximately 18 miles west of Philadelphia. The Township spans approximately 18 square miles of land and primarily consists of low-density residential developments and conservation area, with a denser section of commercial and retail on its northern border with the Borough of Malvern. Please refer to Figure 1 for a map of the Township.

The Township retained Herbert, Rowland, & Grubic, Inc. (HRG) in the summer of 2023 to conduct a stormwater study and develop a master plan for addressing stormwater issues in the municipality. The primary goal of the stormwater study and master planning efforts is to plan for the impacts of stormwater in the Township, including flooding, erosion, and waterway pollution as well as develop a foundation upon which future stormwater capital project planning may be established. The purpose of the Willistown Stormwater Master Plan (Plan) is to assess the current condition of the stormwater collection system, identify causes for historical local flooding, and recommend corrective actions. The Township will be able to use this Stormwater Master Plan to prioritize capital improvements of the stormwater management system, improve operations and maintenance procedures, and pursue financial opportunities to fund future endeavors. This report details the condition assessment, hydrologic & hydraulic (H&H) analysis and findings, and recommendations on improvements within agreed upon areas.

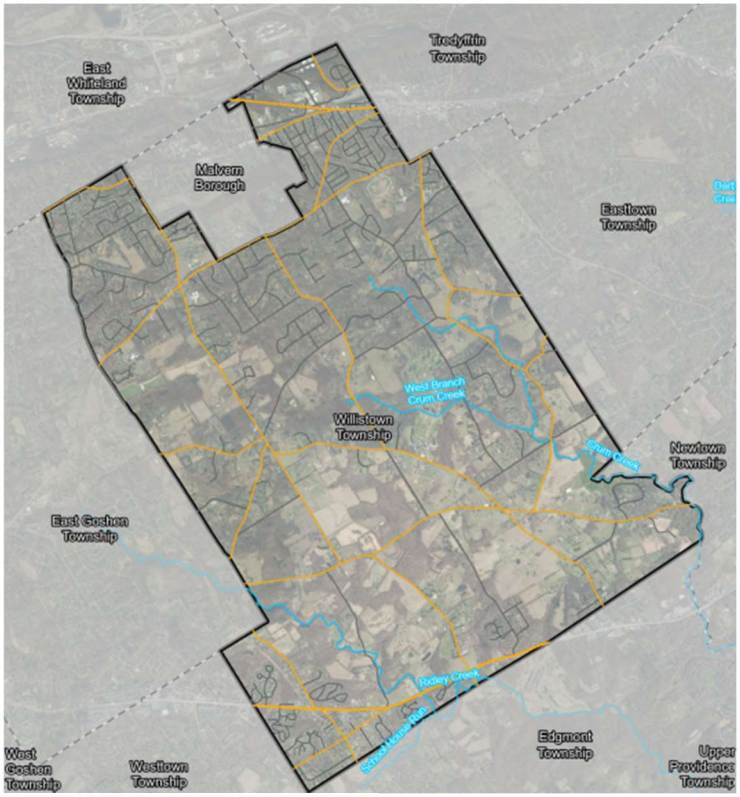


Figure 1: Map of Willistown Township

1.2 SCOPE OF STUDY

The project team prepared a detailed scope of work to meet the Township's goals in creating a Stormwater Master Plan. Existing documents from the Township's records were reviewed, including drawings from the existing infrastructure and historical flooding concerns. Once a basic understanding of the system was established, a field assessment of Township-owned stormwater infrastructure was performed. Data collected was condensed and stored in a GIS database and provided back to the Township for their use. Field data and information from other sources were utilized to create an H&H model. The H&H model included existing conditions for the entire Township. The project team presented initial findings to Township staff and worked with staff to create a system for prioritizing problem areas. A list of projects was developed from the existing conditions model and areas of historic flooding concerns. These priority areas were modeled in a more detailed manner and conceptual designs were developed. These designs are presented in this report with planning level cost estimates, and potential funding opportunities as applicable. In addition to performing the detailed H&H analysis, administrative aspects of the Township's stormwater management program were reviewed including items related to regulatory compliance and ordinance efficacy.

1.3 EXISTING DOCUMENT REVIEW

The project team worked with the Township to collect and review background information for use in the stormwater study. These included previous studies, existing stormwater infrastructure maps, MS4 documents, relevant Township Ordinances, pertinent record drawings, proposed projects, and information related to known stormwater problem areas. The following material was reviewed towards their applicability and use in the stormwater study:

- MS4 outfall screening reports for the Ridley Creek, Crum Creek, and Little Valley Creek watersheds (Developed by Willistown Township)
- Land development plans for the Applebrook Meadows Subdivision (Developed by Private Developer)
- Land development plans and other documentation for the Paoli Walk Subdivision (Developed by Private Developer)
- Land development plans for the Troutbeck Subdivision (Developed by Private Developer)
- Land development plans for the Willistown Point Subdivision (Developed by Private Developer)
- The 2022 to 2023 MS4 Annual Status Report (Developed by Yerkes Associates, Inc.)
- Stormwater infrastructure map (Developed by Willistown Township)
- Crum Creek Watershed Act 167 Stormwater Management Plan (Developed by Delaware County Planning Department and Chester County Planning Commission, dated December 2011)
- Valley Creek Watershed Act 167 Stormwater Management Plan, (Developed by Chester County Water Resources Authority, dated February 2011)
- Maps in Guidelines for Growth, the Township Comprehensive Plan (Developed by Willistown Township, dated June 2023)
- Chester County Hazard Mitigation Plan (Developed by Tetra Tech, Inc., dated July 2021)
- Pollution Reduction Plan (PRP) Outfall & Aerial Map (Developed by Yerkes Associates, Inc. dated December 2021)
- A list of known stormwater problem areas (Assembled by Willistown Township)
- Willistown Township Published Ordinances (Developed by Willistown Township):
  - Zoning Ordinance
  - Subdivision and Land Development Ordinances (SALDO)
  - Environmental Protection Ordinance
  - Flood Hazard Area Ordinance
  - Soil Erosion and Sedimentation Control Ordinance

Review of these documents provided an understanding of the current state of the Township's stormwater management program and drainage system. The outfall screening reports, and available maps were used as a starting point for the stormwater infrastructure GIS mapping and condition assessment. The current MS4 annual report and outfall inspections were reviewed to determine the Township's compliance with MS4 regulations. Land development plans were used to supplement the 2015 Chester County GIS impervious cover data for developments constructed after 2015. Further discussion of the applicability and use of existing documents is included in respective Sections below.

1.4 FLOODING HISTORY

Willistown Township does not have detailed historic flood documentation; however, their staff participated in the update to Chester County's Hazard Mitigation Plan, finalized in 2021. The County Hazard Mitigation Plan includes objectives and goals for reducing flooding throughout the County. The results of this Stormwater Master Plan may be used by the Township towards achieving the Chester County Hazard Mitigation Plan's objectives for stormwater improvements and flood mitigation. Relevant Flood Risk information mentioned in the Chester County Plan include:

- % of total Township land affected by the 100-year rainfall event = 7.7% (901 acres)
- % of total Township land affected by the 500-yr rainfall event = 8.2% (956 acres)
- Population in the 100-year rainfall event area = 151 (1.4% of total population)
- Population in the 500-year rainfall event area = 163 (1.5% of total population)
- # of events classified as either a hurricane, tropical storm, tropical depression, or extra tropical storm tracked within 65 nautical miles between 1842 and 2020 = 56

The scope of this study focused on Township-documented flood prone areas. HRG evaluated a list of problem areas provided by the Township, varying in severity of flooding. The list consisted of nineteen (19) areas that are known to have been impacted by varying stormwater events. The majority of these locations experience "nuisance" flooding during moderate rainfalls. Nuisance flooding refers to low level flooding that does not pose major risk to human life or property. A few of the areas provided have experienced property damage, with some resulting in road closures during moderate to severe rainfalls. These nineteen (19) areas were evaluated through the H&H analysis and problem area prioritization tasks of this study.

2. CONDITION ASSESSMENT AND MAPPING

The Township's stormwater study includes consideration of stormwater infrastructure location and condition for use in identifying replacement and/or upgrade needs, mapping, H&H stormwater impact forecasting tools, and mitigation planning. The Township did not have a complete Stormwater GIS Database prior to this study. As part of this study, the project team collected existing GIS data, available mapping, and field-collected data to develop a Township-wide Stormwater GIS Database to serve as a central repository for stormwater system information. The primary objectives for creating the database are:

- Develop mapping of current storm drain system that will allow the Township to more effectively communicate and track stormwater management goals, progress, and projects.
- Perform conditions assessment of accessible stormwater assets (inlets, manholes, and outfalls) to inform future maintenance and capital improvement planning efforts.
- Develop robust H&H models for use as a decision-making tool for project planning.

2.1 GIS DATABASE DEVELOPMENT

Multiple sources of data were utilized to develop a preliminary Stormwater GIS Database in a customized version of the ESRI stormwater database model, which provided the foundation for mapping and data

collection. Primary sources included mapping provided by the Township in both hard copy and digital formats, as well as data obtained from the Chester County GIS HUB. Township-supplied maps included locations of outfalls and most inlets, all of which were included for verification and further evaluation during the field data collection task of this study. Storm sewer data was collected for infrastructure that was locatable and accessible during the field data collection task, primarily for understanding drainage system connectivity.

Data obtained from the Chester County GIS HUB included aerial orthographic imagery (2018-2020), Soils Survey Geographic Database (SSURGO) data, Digital Elevation Models (DEMs), impervious surface coverage, Township parcels, private subdivisions, and stormwater infrastructure. Stormwater infrastructure data included locations and limited attribute data of both private and publicly owned inlets, outfalls, manholes, and basins. A desktop evaluation of the available data provided an understanding of gaps in stormwater infrastructure mapping and attributes as well as inconsistencies between data naming conventions and data collection methodologies. The project team's GIS staff also georeferenced existing MS4 maps provided by the Township, and digitized asset locations to map their general location. Development of the preliminary GIS database and completion of the desktop evaluation supplied the field crews with a base Existing Conditions Map, shown in Appendix A (Map 1), for more effective data collection.

2.2 FIELD DATA COLLECTION

Field data collection was performed utilizing ESRI ArcGIS field applications. Existing GIS data was uploaded to a cloud GIS account to allow for real-time viewing and navigation on field data collection devices. Stormwater infrastructure asset data was field-collected using Global Positioning System (GPS) devices with a Trimble receiver that provided one (1) centimeter accuracy of horizontal and vertical (X,Y,Z) features under typical field conditions.

Field data collection efforts focused primarily on these three (3) areas:

- Inventory – verifying/capturing location data and classifying asset types to develop a master map
- Connectivity – understanding and mapping the stormwater network (pipe connections) for system analysis
- Condition – estimating overall "health" of stormwater assets based on visual inspection, and provide a foundation for implementation of a long-term stormwater asset condition assessment and risk mitigation program

Initial field data collection was conducted in August and September of 2023. The project team established standard operating procedures for field data collection to ensure accuracy and consistency. Standardized field data collection attributes were developed directly into the GIS database for each type of stormwater infrastructure asset (inlet, manhole, storm sewer pipe, and outfall). Existing assets identified during the desktop evaluation were located in the field by the field crews. Field crews then conducted a visual inspection of the asset. The following asset data was recorded as part of the visual inspections in the field:

- GPS data
- Asset ID (with original naming convention of the preliminary GIS database)
- Inspection date
- Inspection status
- Type of asset
- Grate/cover type and size
- MS4 medallion (if applicable)
- Center depth and elevation (invert elevation in the case of outfalls)

- Asset material
- Condition assessment of manholes and inlets based on the following rankings:
  - Excellent – No visible defects
  - Good – Minor cosmetic defects (minor spalling, chipped corners, etc.)
  - Fair – Minor structural defects (major spalling, cracks smaller than 6", etc.)
  - Near Failure – Major structural defects (visible rebar, cracked metal components, etc.)
  - Failed – Failure of structural components (partially/totally collapsed walls, missing/broken metal components, etc.)
- Size and material of visible storm sewer piping/conveyance
- Inspector notes
- Asset photographs

The field crew made reasonable attempts to access all assets. However, some were not accessible for visual inspection and survey. Those assets that were not inspected are identified as such in the GIS database. Assets occasionally could not be located due to dense vegetation, paved-over/buried structures, or errors in original mapping. Confined space entry inspections were outside the scope of this study. The project team collected data for a total of 952 stormwater infrastructure assets, including 708 inlets, 42 manholes, and 202 outfalls. In addition, the project team confirmed storm sewer connections for the majority of the stormwater system. This information was used to update the preliminary GIS database and provide more accurate drainage connections in the H&H model.

Figure 2: Undercutting of outfall

A few outfall locations were noted to have drainage issues both upstream and downstream of said outfall. GPS collection of these drainage issues were outside the scope of this study. However, when visible, major deficiencies were noted in the database for future analysis and data collection. Notably, the outfall from a private basin into the tributary for the Little Valley Creek along North Cedar Hollow Road showed significant erosion issues. The outfall has experienced severe erosion underneath it and remediation should be considered in future stormwater infrastructure replacement/rehabilitation projects. Figure 2 documents evidence of the outfall's condition.

Collecting data on stream crossings was also outside of the scope of this study. However, field staff noted that many of the smaller tributary crossings were suffering from clogging or sedimentation issues that could begin affecting stormwater conveyance in the future. It is recommended that a study be performed on all creek crossings within Township boundaries to understand and address any future impacts to adjacent roadways.

While elevation (Z) data was collected with one (1) centimeter accuracy, they are typically less accurate than horizontal (X,Y) data. The data collected for this study is sufficient for planning purposes, however it is recommended that a field survey be conducted for higher level of accuracy in more detailed studies and designs.

2.3 FINAL GIS DATABASE

Field data was collected directly via ArcGIS Online and synced to the cloud environment. Field-collected data was integrated into a master Stomwater GIS Database for the Township. The Township's preferred naming convention was applied to all assets for consistency. Naming convention applied is as follows:

- Outfalls: Stream Abbreviation #
- Inlets: Stream Abbreviation – IN #
- Stormwater Pipe/Swale (Conveyance): SWC #
- Manholes: MH #

The final Stormwater GIS Database has been delivered to the Township in ArcGIS Pro format. Additionally, a map book of stormwater infrastructure was delivered in hard-copy format. The GIS database can be accessed and used by Township staff on a computer or mobile device, equipped with ArcGIS software. It is recommended Township staff build upon this Database for asset management, capital improvement project planning and tracking, NPDES MS4 mapping and project tracking, logging residential stormwater concerns, operation & maintenance tracking, hazardous spill response, etc.

2.4 CONDITIONS ASSESSMENT RESULTS

The field investigation team performed visual condition assessment of 708 inlets, 42 manholes, and 202 outfalls owned by both the township and the state. The results of this analysis may be used by Township staff to identify rehabilitation and/or replacement recommendations. Table 1 summarizes the findings of the condition assessment for the township-owned infrastructure. Appendix B includes a list of the assets reported as at or near failure. It is recommended the Township use this data to address those assets that are in most severe, failing condition.

Table 1 - Conditions Assessment Summary of Township-Owned Infrastructure

Asset Type	No Visible Defects	Minor Cosmetic Defects	Minor Structural Defects	Near Failure/Major Structural Defects	Failure
Inlets	5	101	361	41	20
Outfalls	1	28	85	31	27

Storm sewer field data collection was primarily collected for use in mapping and H&H modeling drainage system connections. Additionally, storm sewer pipe invert elevations and material were only collected for pipes that were critical to the development of the H&H model. Visual inspection of storm sewer pipes accessible from storm sewer structures or the surface was conducted. Approximately 23,000 LF of storm sewer pipes were observed to be Corrugated Metal Pipes (CMP). Table of CMP Inventory is included in Appendix C. The Township possesses and maintains approximately 12.82 miles of storm sewer pipe, based on a review of the GIS data and discussions with Township staff. A more detailed method of assessment, such as Closed-Circuit Television (CCTV), is recommended of the storm sewer system for a more accurate understanding of the condition and for prioritization of rehabilitation and replacement projects. Corrugated metal pipe has a shorter useful life than concrete pipe, and as such, it is recommended that the Township consider rehabilitation (e.g., cured-in-place pipe, pipe-bursting) or replacement of CMP within the drainage system.

3. HYDROLOGIC AND HYDRAULIC ANALYSIS

A Township-wide hydrologic and hydraulic model of storm sewer drainage conditions was developed to support the objectives of the study. The base model was then modified to simulate problem area conditions and potential mitigation solutions in greater detail. The primary objectives for creating the H&H models were to:

- Develop an H&H model of the Township-wide stormwater system for use as a decision-making tool for future stormwater management planning.
- Analyze the current stormwater needs of the Township's known problem areas.
- Prioritize problem areas for future improvements and capital improvement planning.
- Develop planning-level conceptual mitigation solutions for the top six (6) priority problem areas identified through this study.

The following models were developed for this study:

1. **Watershed Model** (Ridley Creek, Crum Creek, and Little Valley Creek) – Developed for calibration purposes towards establishing input parameters for the Existing Conditions Base Model.
2. **Existing Conditions Base Model** – Incorporates the Stormwater GIS Database developed through this study. Used as a base existing conditions model, upon which proposed models can be built to analyze various drainage scenarios.
3. **Problem Area Existing Conditions Models** (15 total) – Used to evaluate existing stormwater runoff conditions at each of the known areas of concern.
4. **Highest Priority Mitigation Solution Models** (6 total) – Used to evaluate proposed mitigation solutions for the top six (6) priority projects.

This Section summarizes the steps involved with H&H model development and analysis.

3.1 TECHNICAL APPROACH

To provide technical guidance for assessment of drainage issues, evaluation of existing storm sewer infrastructure, and identifying potential projects to reduce flooding throughout the Township, an existing conditions H&H model was prepared for the entire Township. More detailed models were developed for fifteen (15) of the nineteen (19) known areas of flooding/stormwater concerns provided as a preliminary list of problem areas by the Township. The results from the H&H models increase the overall understanding of watershed response to rainfall and help guide mitigation efforts. Through development and analysis of an H&H modeling tool, mitigation strategies can be identified and applied on a Township-wide basis to evaluate longer term watershed changes while also addressing specific issues identified by the Township.

The H&H analysis for this study was completed using the software PCSWWM, which is based on the U.S. Environmental Protection Agency (EPA) Stormwater Management Model (SWMM) Software. This model was selected due to its:

- Ability to include and integrate stand-alone GIS data for analysis.
- Ability to generate peak stormwater based on rainfall data and physical parameters of sub-catchments.
- Ability to simulate specific and continuous rainfall events through dynamic rainfall-runoff modeling.
- Ability to simulate hydrological-hydraulic responses to impacts of land use.
- Suitability for modeling urban catchment areas, including routing of surface runoff through Township's storm sewer pipes and channels.

The H&H modeling approach in this study was to:

1. Integrate and build an existing conditions model using GIS data gathered from both existing mapping and field-collected data,
2. Establish a reasonable estimate of rainfall-runoff response under existing conditions,
3. Establish a reasonable estimate of hydraulic conditions based on desktop and field observations,
4. Evaluate various combinations of conceptual mitigation solutions based on problem area prioritization analysis results.

Feedback received from Township staff has been incorporated to direct the focus of the modeling effort and to ensure significant problem areas were assessed throughout the Township.

3.2 HYDROLOGIC MODEL DEVELOPMENT

The Watershed Model and Existing Conditions Base PCSWMM models utilized available GIS data to create a baseline model for future calibration and Township-wide stormwater runoff analysis. The models are comprised of sub-catchments, reaches, junction nodes, and meteorological data. These components are the basis for peak flow and runoff volume calculations.

Table 2 provides the primary parameters used for model development and the respective sources for this information.

Table 2 – Model Data Sources

Model Parameter	Sources
Rainfall Data	NOAA 14 Precipitation Frequency Data Server
Hydrologic Soil Groups	USGS Soil Survey
Impervious Area	2015 Chester County Impervious Area Flyover, post 2015 land development plans
Stormwater Infrastructure	Existing Maps, Field Assessment
Recorded Flows	USGS StreamStats
Green-Ampt Infiltration Parameters	US Army Corps of Engineers HEC-RAS Manual
LiDAR Mosaic	2019 Pennsylvania Spatial Data Access (PASDA)

Precipitation data for Willistown was obtained through the NOAA 14 Precipitation Frequency Data Server. A rainfall event library was created to simulate storm events ranging from the 1-year to 500-year rainfall recurrence internals. Table 3 summarizes rainfall depths of each recurrence interval. For the purpose of this study the 2, 10, and 100-year storms were evaluated. During conversations with Township staff, it was learned that some of the more significant flooding damage within the Township was caused by Hurricane Ida in September 2021, and there is interest to mitigate potential risk from similar events in the future. Hurricane Ida was a tropical storm that produced high winds and large amounts of rainfall over short durations (8.6” reported in Chester County), with accumulations that exceeded 1000-year values in many parts of Northeast USA. While it can be extremely costly, and sometimes impossible, to mitigate for such events, the project team recommends planning and design of future mitigation projects include H&H analysis of simulated high-intensity rainfall events to assess the feasibility of mitigating for large rainfall events such as Hurricane Ida.

Table 3 - Rainfall Data	
Recurrence Interval	**Rainfall Depth (in)**
1-Year	2.70
2-Year	3.24
5-Year	4.08
10-Year	4.77
25-Year	5.76
50-Year	6.61
100-Year	7.51
500-Year	9.92

The hydrologic method used was the SWMM Non-Linear Runoff Routing method, in which rainfall hydrographs are applied across sub-catchment areas and treated as nonlinear reservoirs. Infiltration was included in the model using the Green-Ampt Infiltration method. This method assumes a layer of saturated soil separated by a sharp "wetting front" from a layer of unsaturated soil. As more water is ponded and allowed to soak into the ground, this front moves down until all soil above the natural water table is saturated. This method allows for a dynamic calculation of infiltration as a rain event is analyzed. No evapotranspiration was included in the model.

Drainage basin areas to study points of interest (POIs) were delineated using PCSWMM's built-in delineation tools and the 2019 LiDAR for the Pennsylvania Spatial Data Access program. POIs are inserted as outfalls in the PCSWMM Model. Each drainage basin is defined by parameters relating to soil characteristics, land use, and topography. PCSWMM divides drainage areas into subareas between pervious and impervious surfaces. This allows for routing between areas depending on land use and separating variables such as depressional storage, Mannings number, and infiltration rates to be separated based on surface conditions. Because the Green-Ampt method was used for the infiltration method, the soil characteristics included suction head, hydraulic conductivity, and an initial fractional deficit of water.

The physical characteristics from each basin including slope, area, and flow path were calculated using PCSWMM's built-in tools and the 2019 LiDAR data used for watershed delineation. Impervious area percentage was based on the 2015 Chester County Impervious Area data and supplemented by post 2015 development plans supplied by the Township. Soil characteristics for each of the drainage basins were assigned by weighted average based on USGS soils data and empirical values discussed in paper by Rawls, et al. (1983). A similar weighted average was performed using land use data for pervious Mannings roughness value. Physical characteristic data for each drainage basin are included in Table 4.

3.2.1 Watershed Descriptions

Willistown Township consists of three (3) main watersheds - Ridely, Crum, and Little Valley Creeks as depicted on the Willistown Watersheds Map in Appendix D (Map 9). Watershed descriptions were reviewed in the Act 167 plans and used to develop Watershed boundaries and model input parameters for the Watershed Model.

Ridley Creek - The Ridley Creek watershed contains approximately 14 square miles of land. Approximately 38% of the watershed lies within the Township, and 24% of the total watershed is urbanized. The majority of the urbanized area within the watershed consists of low to medium density residential developments. Non-urbanized areas consist of 43% forest, with the remainder being agricultural land and recreational green spaces. The area is underlain by many types of soil, however, soils with the Hydrologic Soil Group (HSG) of

B and C represent the majority within the watershed. This indicates that the underlying soils have moderate capacity for infiltration before generating runoff during storm events.

Crum Creek - The Crum Creek watershed contains approximately 14.3 square miles of land. Approximately 62% of the watershed lies within the Township, and 32% of the total watershed is urbanized. The majority of the urbanized area within the watershed consists of low to medium density residential developments. Non-urbanized areas consist of 45% forest, with the remainder being agricultural land and recreational green spaces. The area is underlain by many types of soil, however, soils with the HSG of B and C represent the majority within the watershed. Similar to Ridley Creek, this indicates that the underlying soils have moderate capacity for infiltration before generating runoff during storm events.

Little Valley Creek - The Little Valley Creek watershed contains approximately 3.9 square miles of land. Approximately 16% of the watershed lies within the Township, and 66% of the total watershed is urbanized. The majority of the urbanized area within the watershed consists of industrial and commercial facilities as well as medium density residential developments. Non-urbanized areas consist of 23% forest with the remainder being recreational green spaces. The area is primarily urban underlain by disturbed soils with a HSG of D. Non-urbanized areas within the watershed primarily consist of soils with an HSG classification of B, indicating a moderately high capacity for infiltration before generating runoff during storm events.

Table 4 – Watershed Physical Characteristics

SWMM Parameter	Unit	Description	Ridley Creek	Crum Creek	Little Valley Creek
Slope	Percent	Average Surface Slope	1.97	1.56	4.30
Impervious	Percent	Percent of Impervious Area	6.20	5.08	15.80
N Impervious	-	Mannings Roughness assigned to impervious area	0.011	0.011	0.011
N Pervious	-	Mannings Roughness assigned to pervious area	0.10	0.13	0.40
D Store Impervious	Inches	Depth of depression storage in impervious areas	0.05	0.075	0.05
D Store Pervious	Inches	Depth of depression storage in pervious areas	0.13	0.18	0.22
Suction Head	Inches	Soil capacity suction head	6.27	6.15	4.28
Conductivity	Inches/hour	Soil saturated hydraulic conductivity	0.24	0.24	0.16
Initial Deficit	Fraction	Initial soil moisture deficit	0.363	0.363	0.352

3.2.2 Model Calibration

For preliminary model setup and calibration purposes, four (4) drainage basins were delineated to points of interest located at their intersections with the Township boundary limits. This Watershed Map has been included in Appendix D (Map 9). Results from the United States Geological Survey (USGS) StreamStats Web application tool for watershed analysis were used for calibration purposes. The USGS StreamStats watershed analysis tool uses geospatial and historic stream gauge data to generate statistics for stream and watersheds. Watershed statistics are based on regression equations formulated to estimate streamflow statistics across the United States.

The Ridley Creek Watershed was split into two (2) separate POIs due to the creek flowing away from the Township boundary to the west and flowing back into the Township further downstream. Flow from this area, estimated by USGS StreamStats, was inserted as a separate hydrologic input. The intent of this separation was to focus the calibration on areas within the Township and not neighboring municipalities. Little Valley Creek has large areas outside of the Township contributing flow to the Township. The drainage areas were smaller than the minimum area required for USGS StreamStats calculations so only one (1) drainage area was used for calibration. These Watershed Models were used to adjust model input parameters (i.e., percentage of impervious cover, soil and land use cover, infiltration variables, and Manning's roughness value). Once the Watershed Models were developed, resulting unit flow rates (measured in cubic feet per second per acre of drainage area) at the POIs were compared to the unit flow rates from USGS StreamStats. The Chartered Institute of Water and Environmental Management (CIWEM) states that verification of calibrated models to monitored/observed data for peak flow should generally be within +25% to -15%, and +/-10% at 'critical' locations. PCSWMM Model input variables including depression storage, subarea routing, and Manning's roughness value were modified until the unit flow rates observed at the POIs were within CIWEM's recommended ranges. The final calibrated models were all less then 12% difference when compared to the USGS StreamStats results. Therefore, the calibrated models were deemed sufficient for use in Township H&H modeling. Table 5 summarizes the drainage area and calibrated flow rates for each of the delineated watersheds.

Table 5 – Model Calibration Summary

Watershed	Drainage Area (Acres)	PCSWMM Unit Runoff ($ft^3/s/acre$)	StreamStats Unit Runoff ($ft^3/s/acre$)	Percent Difference (%)
Crum Creek	9,447	0.50	0.54	-7.4
Ridley Creek North & Ridley Creek South - Combined	9,136	0.63	0.61	3.3
Little Valley Creek	1,741	0.89	0.80	11.3

Once the Watershed Model was calibrated for the four (4) drainage basins, it was assumed that the input variables in that model were acceptable and ready for use in developing the Existing Conditions Base Model towards evaluation of known problem areas, as described in Section 3.3. Smaller drainage basins were delineated specific to those Problem Areas, herein referred to as 'Problem Area Drainage Basins', and further described in Section 3.4. Refer to Appendix D for the Willistown Watersheds Map (Map 9) which shows the delineated watersheds used for watershed calibration.

3.3 HYDRAULIC MODEL DEVELOPMENT

Hydraulic analysis and flow routing were performed within the PCSWMM model for each POI. The hydraulic analysis used a dynamic flow routing approach, routing stormwater runoff through a series of links and nodes that represented inlets, manholes, storm sewer pipes, open channels, and stormwater infrastructure within the Township's drainage system.

Conduits (pipes/channels) are the conveyance element in the SWMM based models. For the Township models the following pipe information was derived from the GIS database (or assumed where data was missing):

- Conduit name/ID
- Conduit's upstream and downstream nodes

- Shape: circular, rectangular, trapezoidal channel, irregular (natural) channel, horizontal ellipse, vertical ellipse, arches, and bridge/culverts
- Dimensions: depth, width, area, side slopes, and natural section data
- Offsets: where pipes did not initiate or terminate at the invert of an upstream/downstream node, offset values were assigned to quantify the difference in elevation between the bottoms of the upstream/downstream nodes and the bottom of a pipe bottom (either measured or derived)
- Manning's roughness value: based on the material of the conduit

Junctions are the connection points for conduits and channels in SWMM based models. The junction nodes in the Township model represent manholes, inlets, or flow connection points. They also represent locations where there is a hydraulic control structure in the conveyance system or where there is a pipe size, slope, or material change. For the Township models, the following junction node information was derived from the GIS database (or assumed where data was missing):

- Junction node name/ID
- Ground/top elevation of the junction node
- Invert elevation (bottom of the junction node)
- Initial water depth above invert of the junction node
- Junction node spatial location data (x,y)

Other hydraulic components utilized in the model include outfalls, orifices, and weirs. Outfalls represent discharge points in SWMM based models. Outfalls can be simulated with boundary conditions or considered free outfalls with no conditions. All outfalls in the Township models were simulated as free outfalls. Outfall characteristics are similar to junctions with the addition of boundary conditions. Orifices in this model were assumed to function as static orifices without controls. Orifice components include:

- Upstream/downstream junction nodes
- Type of orifice: shape (circular or rectangular) and placement (side or bottom)
- Orifice coefficients
- Offset from junction node inverts
- Dimensions: depth, width, area

Weirs were also included in the model. Weir components include:

- Upstream and downstream junctions
- Type of weir
- Weir length and height to the crest
- Weir coefficient

3.4 EXISTING CONDITIONS BASE MODEL

Once the Watershed Model was calibrated, an Existing Conditions Base Model was developed that incorporated the Stormwater GIS Database for the entire Township. The input model parameters were those established through the calibrated Watershed Model. The Existing Conditions Base Model was developed to represent the features of the drainage system throughout the Township in current conditions, and to serve as a base model upon which evaluation of various existing and future condition scenarios may be built. It was assumed that none of the storm sewer pipes experienced blockage. This variable may be adjusted for various modeling scenarios in future studies. Mapping of existing conditions has been included in the H&H Base and Problem Areas Models Map (Map 15) in Appendix D.

3.5 PROBLEM AREA EXISTING CONDITIONS MODELS

Within the Existing Conditions Base Model, Problem Area Drainage Basins were delineated to fifteen (15) POIs for analysis (PA-1 through PA-15). While the Problem Area Existing Conditions Models incorporated data collected from existing maps, reports, and field collection, assumptions were necessary where measured data was not available. As the models were developed, areas where additional information was needed were identified. Additional field data was collected to supplement previously collected data and strengthen confidence in results.

The objective of modeling existing conditions at the known problem areas was to generate runoff peak flow quantities for the 2, 10, and 100-year rainfall return periods for use as an evaluation metric in problem area prioritization. The scope of this study was limited to existing conditions evaluation of known problem areas. The known problem areas were derived through discussions with Township staff and field observations. Section 4 describes the Problem Area identification and prioritization process.

3.6 HIGHEST PRIORITY MITIGATION SOLUTIONS MODELS

The top six (6) Highest Priority Areas, herein referred to as 'Priority Areas' were determined through the problem area prioritization process. Problem Area Existing Conditions Models were then revised to develop the Highest Priority Mitigation Solution Models. The scale and detail of these models was at a refined scale compared to the Problem Area Existing Conditions Models. The objective of modeling these Priority Areas was to evaluate proposed mitigation solutions and develop planning-level concepts for these solutions.

The evaluation of potential mitigation solutions involved an iterative process of modeling various alternatives to recommend a solution that maximized benefits while minimizing costs. As alternatives were evaluated, field verifications were conducted to assess the feasibility of proposed solutions.

4. PROBLEM AREAS

One of the goals of this study is to "review known areas of concern" and "identify as-yet-unidentified areas of concern" with a primary focus on areas of flooding. The strategy for achieving this goal required the identification of the existing significant flooding and wet weather problem areas, and then an evaluation of the identified Problem Areas.

4.1 PROBLEM AREA ANALYSIS APPROACH

The first task was to identify the location and nature of existing flooding and wet weather problems within the Township and gather field data to be used for further analysis of the problems. The geographic location data was used to map all the Problem Areas and obstructions on a single map. Mapping the location of the sites in this manner allows for identification of isolated problems and determination of which problems are part of more systemic problems. Systemic problems are often an indication that larger watershed problems exist, which may warrant broader area strategies. This information was used when evaluating the individual problem area mitigation options and incorporated into Township stormwater program recommendations, where appropriate.

The second part of this task was to analyze individual Problem Areas and obstructions, determine the Priority Areas, evaluate potential Mitigation Solutions, and provide recommendations. The individual Problem Areas and obstructions were evaluated and modeled to determine approximate capacities to be used for planning purposes. Then a preliminary prioritization assessment was conducted to give a Township-wide overview of the severity of the existing problems. The priority assessment also provides general guidance on the relative order in which the problems should be addressed.

4.2 PROBLEM AREA IDENTIFICATION

Identification and review of existing information concerning the Township's flooding and wet weather issues within the limits was conducted. The project team requested Township input on known problem areas and obtained additional insight during field inspection of stormwater infrastructure through site assessment and property owner communications. The responses were reviewed and incorporated into the assessment of Problem Area mitigation options. Field reconnaissance was subsequently conducted to confirm Problem Area locations, assess existing conditions, identify Problem Area causes, and gather data to complete a planning level concept solution analysis. Each reported Problem Area is listed in Table 6. Note that the solution for PA-16 is currently being addressed by the Township as follows: Phase I-Slope Stabilization was completed in 2023; Initial engineering plans for Phase II-Infrastructure have been developed; An application for grant funding has been submitted to FEMA. Additionally, three (3) of the Problem Areas, PA-17, PA-18, and PA-19 have been addressed by the Township and are therefore not included in the analysis. Refer to Appendix D for a map of Known Problem Areas (Map 14) PA-1 to PA-19.

Table 6 – Willistown Stormwater Problem Areas

Problem Area ID	Problem Description
PA-1	Failing culvert along Forest Lane at the crossing with Crum Creek. Road floods during larger storms.
PA-2	Localized flooding along Farmhouse Lane. Runoff comes from north of the Township.
PA-3	Failing culvert along Spring Road. Severe flooding with roadway overtopping causing road closures.
PA-4	Flooding of properties at the low point of Chetwynd Road.
PA-5	History of flooding in properties along the eastern side of Clover Lane.
PA-6	History of flooding along North Cedar Hollow Road.
PA-7	Flooding of properties at the low point of Bryan Avenue.
PA-8	Known issues along Paoli Pike between Warren Avenue and Devon Road.
PA-9	Natural/old swale outlets directly onto Paoli Pike between Sandy Lane and Grubb Road.
PA-10	Flooding reported in yards between Lloyd Avenue and Frazer Avenue.
PA-11	Flooding at intersection of Paoli Pike and Line Road.
PA-12	Flooding reported at culvert on Dutton Mill Road at the crossing of Hunters Run.
PA-13	Flooding reported at Harvey Lane leading to a swale between Harvey Lane and Callery Way.
PA-14	Reports of erosion at the end of Timber Lane.
PA-15	Localized flooding on Hillview Road with roadway overtopping causing road closures.
PA-16	Significant flooding along Jacqueline Drive. Steep slopes, undersized infrastructure may be the cause. - TOWNSHIP IS CURRENTLY ADDRESSING
PA-17	Flooding at the end of Four Winds Lane. A storage facility seems to have failed. - TOWNSHIP HAS ADDRESSED
PA-18	Bridge near 776 White Horse Road damaged from Hurricanes Fred and Ida. - TOWNSHIP HAS ADDRESSED
PA-19	Stormwater pipe upgrade/replacement needed near 30 Harvey Lane. - TOWNSHIP HAS ADDRESSED

4.3 PROBLEM AREA PRIORITIZATION

Once H&H modeling of the fifteen (15) Problem Areas was completed, peak flow results were utilized as a decision-making metric towards prioritizing the Problem Areas. Table 7 provides a summary of peak flow results for the 2, 10, and 100-year events. Problem Area Drainage Basin delineations PA-1 through PA-15 are included in the H&H Base and Problem Areas Models Map (Map 15) in Appendix D.

Table 7 - Problem Area Peak Flow Assessment				
Problem Area ID	Location	2-yr (cfs)	10-yr (cfs)	100-yr (cfs)
PA-1	Forest Lane	47	98	153
PA-2	Farmhouse Lane	36	111	205
PA-3	Spring Road	23	61	127
PA-4	Chetwynd Road	19	34	103
PA-5	Eastern side of Clover Lane	23	59	116
PA-6	North Cedar Hollow Road	49	69	111
PA-7	Bryan Avenue	15	19	82
PA-8	Paoli Pike between Warren Avenue and Devon Drive	139	355	773
PA-9	Paoli Pike between Sandy Lane and Grubb Road	21	54	112
PA-10	Lloyd Avenue and Frazer Avenue	12	31	63
PA-11	Paoli Pike and Line Road	99	244	515
PA-12	Dutton Mill Road and Hunters Run	361	983	2,200
PA-13	Harvey Lane and Callery Way	52	141	298
PA-14	Timber Lane	5	9	16
PA-15	Hillview Road	313	1,100	2,495

Based on the Problem Areas listed in Table 6, and feedback received from Township staff, the prioritization criteria presented in Table 8 was developed. This table summary describes the criteria along with associated scoring levels. The objective of prioritizing Problem Areas was to identify the Township's top six (6) Highest Priority Areas, for evaluation and development of planning-level mitigation concepts in this study.

Table 8 - Willistown Problem Area Prioritization for Analysis Criteria and Scoring							
Priority Score (5 = high, 1 = low)	Flood Mitigation Benefit	Property / Public Impact	Residents Affected	Feasibility	Estimated Project Time	O&M Requirements	Demand on Municipal Resources
5	Significant flooding reduction possible	Major roads inundated/ significant property damage	>50	On Township property/no permitting issues	<6 months	Low maintenance, long design life	Significant demand
3	Moderate flooding reduction possible	Local roads inundated/ moderate property damage	10-50	On private property/ moderate permitting requirements	6-12 months	Moderate maintenance, moderate design life	Moderate demand
1	Minor flooding reduction possible	Minimal property damage	<10	On State/private property/ significant permit requirements	>12 months	High maintenance, short design life	Minimal demand

Assessing each Problem Area, its likely solution and potential benefits, prioritization scores were determined based on the criteria in Table 8. The results of the prioritizations are provided in Table 9, with the top six (6) highlighted in a red box in the right-most column. Criteria weights are noted in column headings.

Table 9 - Prioritization Results and Criteria Weights									
Weight	12%	12%	12%	12%	12%	12%	30%	100%	
Problem Area ID	Flood Mitigation Benefit	Property/ Public Impact	Residents Affected	Feasibility	Estimated Project Time	O&M Requirements	Demand on Municipal Resources	Total Priority Score	Rank
PA-1	5	3	5	3	3	3	5	4.1	1
PA-2	5	1	1	3	5	5	3	3.2	8
PA-3	5	1	1	3	5	5	5	3.8	4
PA-4	5	3	1	3	5	5	5	4.1	1
PA-5	5	1	1	3	5	3	1	2.4	14
PA-6	3	5	5	1	1	5	5	3.8	4
PA-7	5	3	1	3	5	5	5	4.1	1
PA-8	1	5	5	1	1	3	3	2.8	9
PA-9	3	5	5	1	1	3	5	3.6	6
PA-10	3	1	1	3	3	5	3	2.8	9
PA-11	3	5	5	1	1	5	1	2.6	11
PA-12	3	3	5	3	3	3	3	3.2	7
PA-13	5	1	1	3	5	5	1	2.6	11
PA-14	5	1	1	3	5	5	1	2.6	11
PA-15	5	3	3	1	3	5	5	3.8	4

Based on the results of the prioritization analysis, the following emerged as the top six (6) Highest Priority Areas to be further evaluated for conceptual mitigation solutions.

4.4 HIGHEST PRIORITY AREAS

Once the Problem Areas were ranked, the top six (6) Highest Priority Areas were then confirmed for the purpose of this study. Highest Priority Mitigation Solution Models were developed for:

- PA-1: Forest Lane
- PA-3: Spring Road
- PA-4: Chetwynd Road
- PA-6: North Cedar Hollow Road
- PA-7: Bryan Avenue
- PA-15: Hillview Road

An evaluation of the Priority Areas and associated project information is provided in Section 6.

5. BASIS OF COSTS

The assessment of the top six (6) Priority Area Mitigation Solutions utilized cost estimation data for use in planning level screening, comparison of conceptual solutions, and prioritization of Problem Areas. The data was derived from recently evaluated construction cost data from publicly bid projects of similar scope and scale of those proposed in the study.

Tabulated and unit costs used in the analysis are updated frequently, considered appropriate and accurate for projects bid in 2023, and are relevant to the eastern Pennsylvania region. The cost opinions created are to be considered Level 4 cost estimates, as designated by The Association for the Advancement of Cost Engineering Recommended Practice No. 18R-97 (AACE, 2005), and actual costs are expected to fall within a range of 30% less to 50% more than the cost opinions given in Section 6. This estimate class and accuracy is appropriate for planning level use.

Quantities were calculated using aerial imagery, LiDAR, and engineering judgment. It is noted that the costs provided are considered "construction costs", which means the raw cost of building conceptual solutions. The construction cost typically includes: general conditions, overhead and profit, mobilization, demobilization, contractor's bonds and insurance, and sub-contractor's markups.

The construction cost does not include non-construction costs. Non-construction costs would include engineering design, permitting, construction engineering, land acquisition, risk contingencies, and any associated financing costs. The costs provided in Section 6 do not include non-construction costs. A typical assumption for non-construction cost is 20% to 50% of the construction cost, depending on the scope, scale, and complexity of the given project. Cost estimates will depend upon unknown externalities.

6. PLANNING-LEVEL CONCEPTS

The top six (6) Priority Areas identified through the prioritization process were further evaluated to consider mitigation solutions to address the recognized issues. These Priority Areas were evaluated through a combination of H&H modeling, evaluation of infrastructure data in the Stormwater GIS Database, discussions with Township staff, and supplemental field investigations. Field reconnaissance was conducted to confirm Problem Area locations, assess existing conditions, identify Problem Area causes, and gather data to confirm the planning-level concept solutions were feasible.

Summaries of each of the Priority Areas and Recommended Mitigation Solutions, are included in Sections 6.1 to 6.6.

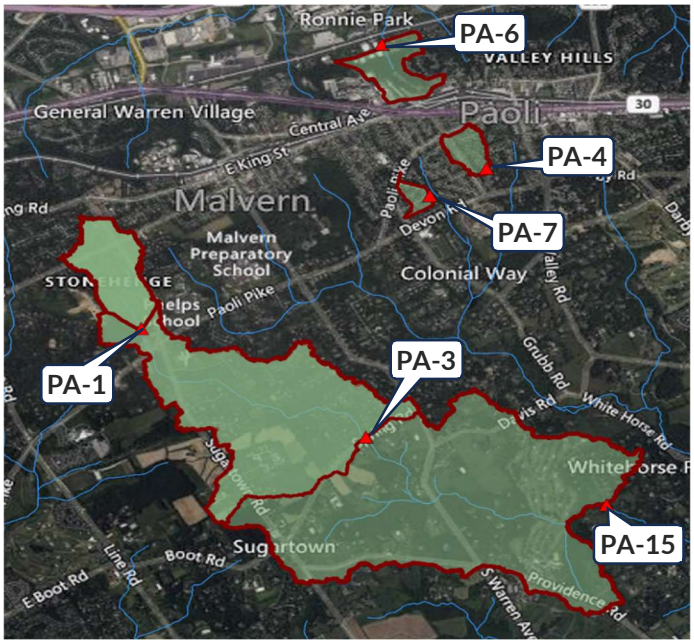
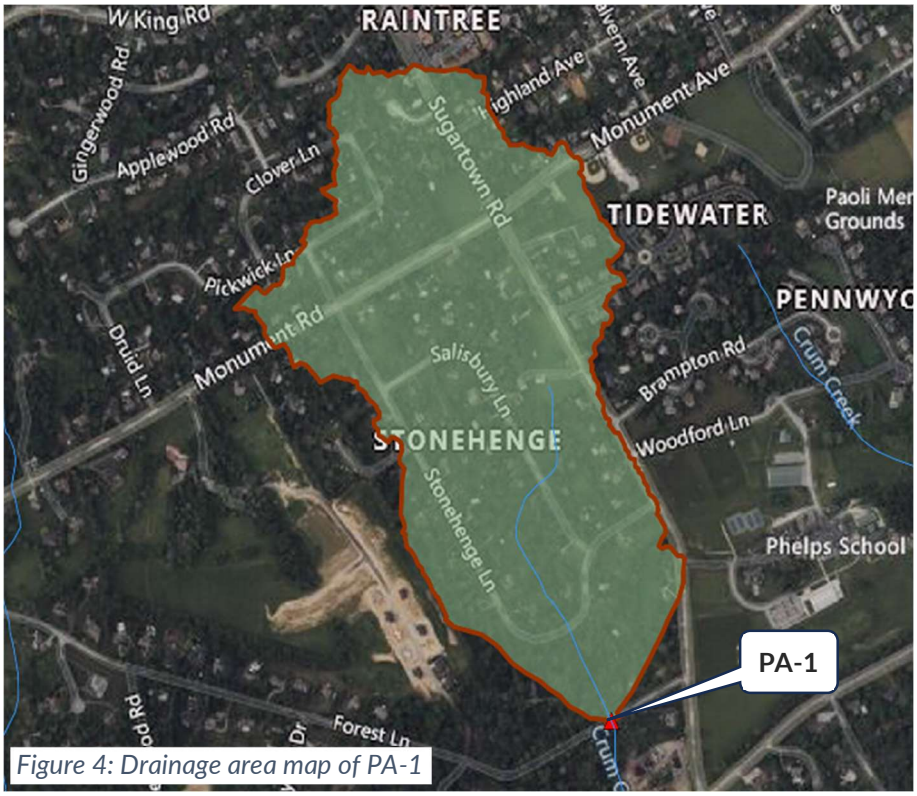


Figure 3: Drainage area map of 6 Highest Priority Areas

6.1 PA-1 FOREST LANE CONCEPT

GENERAL HIGHEST PRIORITY AREA INFORMATION	
Location:	Forest Lane
Description:	Double-barrel culvert (2 semi-elliptical 30” x 48” pipes) at Forest Lane crossing of Crum Creek
Drainage Area:	124 acres
Land Cover:	Includes development upstream along Stonehenge and Salisbury Lanes; residential property along Monument Road and Clover Lane
Drainage Area Map:	 *Figure 4: Drainage area map of PA-1*
Primary Flow Paths:	Flow conveyed from Robin Road through drainage swales abutting residential backyards along Clover Lane, then through a natural drainage channel along Sugartown Road to Crum Creek; Flow conveyed from the intersection of Stonehenge Lane and Monument Road through pipe then swale along the rear property lines of residences between Stonehenge and Salisbury Lanes. Swale discharges to Crum Creek upstream of Stonehenge Lane.
Drainage Issues:	■ Flooding at the culvert crossing ■ Sinkholes ■ Deteriorating pavement ■ Debris build-up upstream of culvert ■ Failing corrugated metal pipe (field investigation assessment)
Cause of Problem:	■ Failing and undersized culvert pipe; pipe capacity issues ■ Debris build-up at culvert; flow-blockage ■ Sediment build-up within culvert; flow-blockage ■ Lack of upstream stormwater management features; minimal stormwater controls

RECOMMENDED MITIGATION SOLUTION	
Description:	■ Replacement of the existing double-barrel culvert with a reinforced concrete single-cell box culvert ■ H&H analysis indicates an 11' x 3' opening will convey the 100-year storm event and mitigate flooding along Forest Lane at the crossing
Benefits:	■ Reinforced concrete has a longer life span than corrugated metal ■ Mitigate flooding at Forest Lane ■ Mitigate sediment and debris clogging at the culvert ■ May be designed to convey the 500-year storm event; cost will increase
Challenges:	■ Need to confirm increased hydraulic capacity of culvert will not affect downstream rates ■ May need to restore with a similar brick/historic wall at culvert faces ■ Requires Chapter 105 Permit for Water Obstructions and Encroachment ■ Adjacent trees may need to be removed ■ Temporary easements may be needed
Opinion of Probable Cost:	$330,000 to $800,000 Depends on culvert and wall type, and if downstream mitigation is required for higher flows
Estimated Design and Construction Time:	6 months to 1 year Depends on type of culvert, permitting, contractor and material supplier availability

SITE CONDITIONS

Figure 5: View of upstream face of culvert

Figure 6: Debris build-up noted during inspection

Figure 7: View of Crum Creek, downstream of culvert

6.2 PA-3 SPRING ROAD CONCEPT

GENERAL HIGHEST PRIORITY AREA INFORMATION	
Location:	Spring Road
Description:	Double-barrel culvert (2 elliptical 34” x 56” pipes) at Spring Road crossing of Crum Creek
Drainage Area:	775 acres
Land Cover:	Majority is low density residential or recreational greenspace
Drainage Area Map:	 *Figure 8: Drainage area map of PA-3*
Primary Flow Paths:	Flow conveyed from upper area of watershed through Crum Creek to the culvert
Drainage Issues:	■ Severe flooding at the culvert crossing/roadway overtopping resulting in road closures ■ Deteriorating pavement; erosion of road bank ■ Debris build-up upstream of culvert ■ Failing corrugated metal pipe (field investigation assessment)
Cause of Problem:	■ Failing and undersized culvert pipe; pipe capacity issues ■ Debris build-up at culvert; flow-blockage ■ Sediment build-up within culvert; flow-blockage ■ Lack of upstream stormwater management features; minimal stormwater controls

RECOMMENDED MITIGATION SOLUTION	
Description:	■ Replacement of the existing double-barrel culvert with a reinforced concrete single-cell box culvert ■ H&H analysis indicates a 12' x 5' opening will convey the 100-year storm event and mitigate flooding along Spring Road at the crossing
Benefits:	■ Reinforced concrete has a longer life span than corrugated metal ■ Mitigate flooding at Spring Road ■ Mitigate sediment and debris clogging at the culvert ■ May be designed to convey the 500-year storm event; cost will increase
Challenges:	■ Need to confirm increased hydraulic capacity of culvert will not affect downstream rates ■ Requires Chapter 105 Permit for Water Obstructions and Encroachment ■ Adjacent trees may need to be removed ■ Temporary easements may be needed
Opinion of Probable Cost:	$350,000 to $850,000 Depends on culvert and wall type, and if downstream mitigation is required for higher flows
Estimated Design and Construction Time:	6 months to 1 year Depends on type of culvert, permitting, contractor and material supplier availability

SITE CONDITIONS

Figure 9: Upstream view of culvert with debris

Figure 10: Erosion of roadside swale

Figure 11: Downstream view of culvert

6.3 PA-4 CHETWYND ROAD CONCEPT

GENERAL HIGHEST PRIORITY AREA INFORMATION	
Location:	Chetwynd Road
Description:	Double inlet draining to single 24" RCP that drains the development
Drainage Area:	36 acres
Land Cover:	Primarily residential development and roadway
Drainage Area Map:	 *Figure 12: Drainage area map of PA-4*
Primary Flow Paths:	Flow conveyed from Wistar and South Cedar Hollow Roads down concrete drainage swales and by gutter flow down Chetwynd Road where it enters the inlets and drains through the existing pipe out of the development
Drainage Issues:	■ Flooding ■ Township has attempted to resolve the issue through installation of a swale to capture drainage overflow from the roadway, which has helped convey stormwater overflow from the roadway to safely discharge away from residential properties that are impacted in the area, however roadway flooding remains a concern.
Cause of Problem:	■ Lack of adequate inlet collection system ■ Pipe capacity issues (i.e. undersized, concrete swales increase flow rates and runoff volume). Note: storm sewer pipe network downstream of Problem Area was not locatable during field data collection due to dense vegetation. ■ Lack of upstream and downstream stormwater management features; minimal stormwater controls

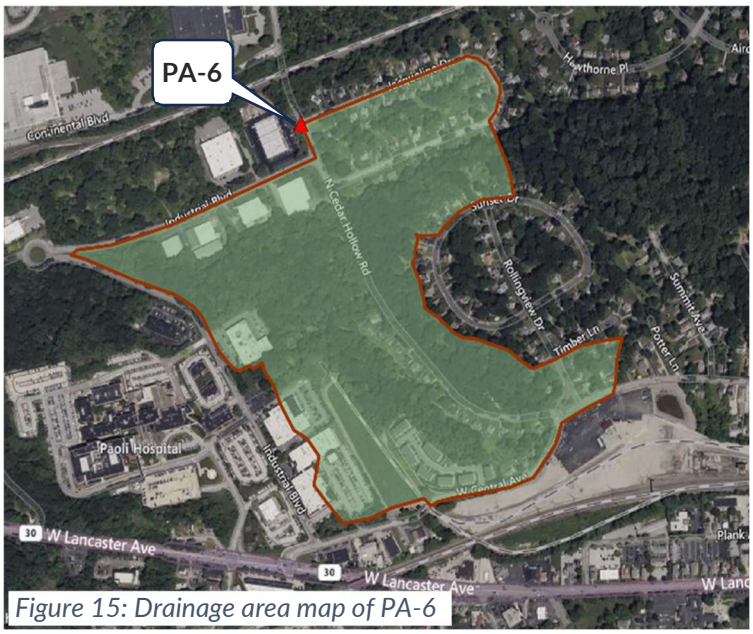
RECOMMENDED MITIGATION SOLUTION	
Description:	■ Detailed feasibility study ■ Drainage improvements throughout the contributory drainage basin: – New storm sewer infrastructure – Rate control structures – consider inline storage ■ Removal of concrete swale and replace with bioinfiltration swale
Benefits:	■ Reduce peak runoff rates ■ Reduce volume/flooding ■ Potential PRP benefits from bioinfiltration swale ■ Potential MS4 pollutant reductions benefits depending on inline storage and inlet designs
Challenges:	■ Utility conflicts ■ Excessive disturbance/noise within neighborhood ■ Neighborhood traffic will be impacted ■ Permanent and temporary easements will be needed
Opinion of Probable Cost:	$270,000 to $1,800,000 Depends on extents of sewer installations/drainage improvements and if MS4 goals are integrated
Estimated Design and Construction Time:	2 to 4 years Depends on extents of sewer installations/drainage improvements, results of utility and geotechnical analysis, permitting requirements, easement acquisitions

SITE CONDITIONS

Figure 13: Inlet and swale at location of flooding on Chetwynd Road

Figure 14: Existing concrete swale draining to cul-de-sac

6.4 PA-6 NORTH CEDAR HOLLOW ROAD CONCEPT

GENERAL HIGHEST PRIORITY AREA INFORMATION	
Location:	North Cedar Hollow Road
Description:	Single 30" RCP draining inlets in intersection of Industrial Boulevard and Jacqueline Drive in addition to conveying tributary to Little Valley Creek
Drainage Area:	59 acres
Land Cover:	Primarily forested, with some industrial development and a portion of the development along Jaqueline Drive
Drainage Area Map:	 *Figure 15: Drainage area map of PA-6*
Primary Flow Paths:	Flow conveyed from a drainage tributary of Little Valley Creek approximately 500' along North Cedar Hollow Road through a 30" RCP. Approximately nine (9) stormwater inlets capture runoff and discharge to the 30" RCP. Existing stormwater inlets located in the upper portion of North Cedar Hollow Road convey flow to the upstream section of the tributary.
Drainage Issues:	■ Flooding; H&H analysis indicates Problem Area floods for storm events at or greater than the 5-year rainfall return period.
Cause of Problem:	■ Pipe capacity issues (i.e., undersized system) ■ Steep topography ■ Lack of stormwater management features; minimal stormwater controls; lack of energy dissipation ■ Increases in runoff associated with urbanization ■ Disconnected sub-drainage basins ■ Sediment build-up within inlets; flow-blockage ■ Eroded outlet structure (Note: During field inspection, it was observed that a conveyance channel to the outlet structure, conveying discharge from a privately-owned upstream stormwater facility, has eroded on steep sloped area with severe undercutting adjacent to the outlet – future studies should consider investigation of this facility)

RECOMMENDED MITIGATION SOLUTION	
Description:	■ Detailed feasibility study ■ Integrate solutions with adjacent ongoing project at Jaqueline Drive ■ Drainage improvements throughout the contributory drainage basin: – New storm sewer infrastructure – Rate control structures
Benefits:	■ Reduce peak runoff rates ■ Reduce volume/flooding ■ Potential MS4 pollutant reductions benefits from channel stabilization and basin enhancements
Challenges:	■ PennDOT coordination/collaboration required (This activity is ongoing by Township for stormwater issues in the area) ■ PennDOT HOP permit required ■ Potential Chapter 105 permit (for channel stabilization) ■ Utility conflicts & extensive coordination ■ Excessive disturbance/noise within neighborhood ■ Permanent and temporary easements will be needed ■ Privately-owned stormwater basin maintenance issues
Opinion of Probable Cost:	$400,000 to $3,300,000 Depends on extents of sewer installations/drainage improvements
Estimated Design and Construction Time:	3 to 5 years Depends on extents of sewer installations/drainage improvements, timeline of adjacent Jaqueline Drive project implementation, analysis of potential reduced impacts to Problem Area from Jaqueline Drive project, results of utility and geotechnical analysis, permitting requirements, and easement acquisitions

SITE CONDITIONS

Figure 16: Connection from Tributary of Little Valley that overflows directly to North Cedar Hollow Road

Figure 17: Severely eroded channel leading from private outfall to Little Valley Tributary

6.5 PA-7 BRYAN AVENUE CONCEPT

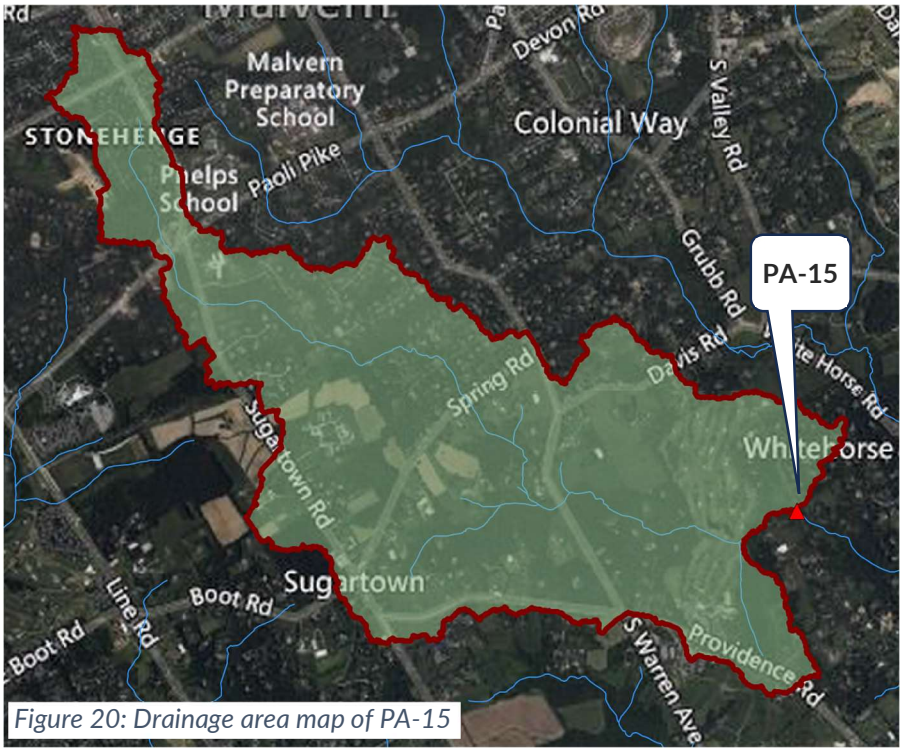
GENERAL HIGHEST PRIORITY AREA INFORMATION	
Location:	Bryan Avenue
Description:	Double inlet draining to single 24” RCP that drains the development
Drainage Area:	16 acres
Land Cover:	Primarily residential development and roadway
Drainage Area Map:	 *Figure 18: Drainage area map of PA-7*
Primary Flow Paths:	Flow conveyed through the drainage basin, discharging to double inlets and a 24” RCP via gutter flow, ultimately discharges to a tributary of the Crum Creek on the northeast section of the residential development.
Drainage Issues:	■ Flooding ■ Township has attempted to resolve the issue through installation of a swale to capture drainage overflow from the roadway, which has helped convey stormwater overflow from the roadway to safely discharge away from residential property that are impacted in the area, however roadway flooding remains a concern.
Cause of Problem:	■ Lack of adequate inlet collection system ■ Pipe capacity issues (i.e. undersized, concrete swales increase flow rates and runoff volume). Note: storm sewer pipe network downstream of Problem Area was not locatable during field data collection due to dense vegetation. ■ Lack of upstream and downstream stormwater management features; minimal stormwater controls

RECOMMENDED MITIGATION SOLUTION	
Description:	■ Detailed feasibility study ■ Drainage improvements throughout the contributory drainage basin: – New storm sewer infrastructure – Rate control structures – consider inline storage
Benefits:	■ Reduce peak runoff rates ■ Reduce volume/flooding ■ Potential MS4 pollutant reductions benefits depending on inline storage and inlet designs
Challenges:	■ Existing 24" RCP discharge pipe abuts residential property; any disturbance associated with this pipe may have the potential to impact resident – consideration should be made to minimize impacts to residential property ■ Utility conflicts ■ Excessive disturbance/noise within neighborhood ■ Neighborhood traffic will be impacted ■ Permanent and temporary easements will be needed
Opinion of Probable Cost:	$340,000 to $3,300,000 Depends on extents of sewer installations/drainage improvements and if MS4 goals are integrated
Estimated Design and Construction Time:	2 to 4 years Depends on extents of sewer installations/drainage improvements, results of utility and geotechnical analysis, permitting requirements, and easement acquisitions

SITE CONDITIONS

Figure 19: Double inlets at the lowest point of Byran Avenue

6.6 PA-15 HILLVIEW ROAD CONCEPT

GENERAL HIGHEST PRIORITY AREA INFORMATION	
Location:	Hillview Road
Description:	Double-barrel CMP culvert (2 semi-elliptical 36” x 58” pipes) and single span stone box culvert (approximately 12” x 30”) at Hillview Road crossing of Crum Creek
Drainage Area:	1,930 acres
Land Cover:	Majority is low density residential or recreational greenspace
Drainage Area Map:	 *Figure 20: Drainage area map of PA-15*
Primary Flow Paths:	Flow conveyed from upper area of watershed through Crum Creek to the culvert
Drainage Issues:	■ Flooding at the culvert crossing/roadway overtopping regularly resulting in road closures ■ Deteriorating pavement ■ Failing corrugated metal pipe (field investigation assessment)
Cause of Problem:	■ Failing and undersized culvert pipes; pipe capacity issues ■ Sediment build-up within culvert; flow-blockage ■ Lack of upstream stormwater management features; minimal stormwater controls

RECOMMENDED MITIGATION SOLUTION	
Description:	■ Replacement of the existing CMP double-barrel and stone box culvert with a reinforced concrete single-cell box culvert ■ Vertical alignment adjustment of Hillview Road by approximately 1' ■ H&H analysis indicates a 15' x 5' opening will convey the 50-year storm event and mitigate flooding along Hillview Road at the crossing
Benefits:	■ Reinforced concrete has a longer life span than corrugated metal ■ Mitigate regular flooding at Hillview Road ■ Mitigate sediment and debris clogging at the culvert
Challenges:	■ Need to confirm increased hydraulic capacity of culvert will not affect downstream rates ■ Requires Chapter 105 Permit for Water Obstructions and Encroachment ■ Adjacent wetlands will require extra permitting and mitigation ■ Temporary easements may be needed
Opinion of Probable Cost:	$600,000 to $1,300,000 Depends on culvert and wall type, and if downstream mitigation is required for higher flows
Estimated Design and Construction Time:	3 to 5 years Depends on type of culvert, permitting, contractor and material supplier availability

SITE CONDITIONS

Figure 21: Upstream view of dual culvert

Figure 22: View of flattened foliage on downstream side of road indicating recent road flooding

Figure 23: View of road crossings where stream recombines

6.7 CONCLUSION

The Planning-Level Concept analysis summarized Priority Areas and associated conceptual Mitigation Solutions. The recommendations in this Section are intended to provide the Township with information necessary for stormwater capital improvement project planning related to implementation of these Priority Area projects. Upon completion of the analysis of each Priority Area and through discussions with the Township, a Recommended Implementation Schedule was developed and is provided in Table 10.

Table 10 – Recommended Implementation Schedule

Problem Area ID	Schedule	Reason
PA- 1 Forest Lane	Immediate	Lower costs, less constraints, build off previous planning efforts, design can initiate right away, shorter design & construction period
PA-3 Spring Road	Immediate	Lower costs, less constraints, build off previous planning efforts, design can initiate right away, shorter design & construction period
PA-4 Chetwynd Road	2-4 years	Longer design period, more constraints (utility, easement), no previous planning to build from
PA-7 Bryan Avenue	2-4 years	Longer design period, more constraints (utility, easement), no previous planning to build from
PA-6 North Cedar Hollow Road	3-5 years	Significant coordination with multiple stakeholders and regulators (PennDOT, private property, utilities), expensive construction for mitigation, longer design period
PA-15 Hillview Road	3-5 years	Significant permitting requirements due to potential threatened and endangered species, significant coordination with multiple stakeholders and regulators (PADEP, private property)

6.8 FUNDING STRATEGIES

A range of potential funding sources have been identified, encompassing state, federal, and local programs that support stormwater infrastructure improvements. While timing and subject matter will dictate each of these programs' applicability to the Township's needs, these sources may provide funding alternatives to financially assist with project implementation. The Priority Area projects include the PA-1 Forest Lane, the PA-3 Spring Road, and the PA-15 Hillview Road box culvert replacements, all of which are essential for mitigating flooding and enhancing the Township's stormwater management capabilities. Mitigation solutions for PA-4 Chetwynd Road and PA-7 Bryan Avenue focus on drainage improvements to alleviate localized flooding issues, while PA-6 North Cedar Hollow Road requires further investigation to determine the best course of action for consistent flooding at the base of a large hill.

Grants are a tool that can leverage the Township's budgeted stormwater funds. However, grants can delay a project, prolonging the time of construction for several months to a year, until after grant awards are announced, paperwork executed, and projects designed. Two (2) of the culvert projects are proposed for implementation over the next two (2) years and this tight schedule does not coincide with utilizing grant funds. While it is possible to pursue grants, at least one of the two (2) culverts would ideally move forward in 2024 with only budgeted funds.

The two (2) stormwater infrastructure extension and storage projects (PA-4 Chetwynd Road and PA-7 Bryan Avenue) are proposed for two (2) to four (4) years out, a timeline more conducive to exploring, applying for,

and utilizing grants in conjunction with a strategic use of the Township's budgeted funds. With these projects, grants may be able to fill funding gaps or augment existing funding streams, helping to ensure a more comprehensive and impactful project can be constructed and saving the Township money that can be redirected to future stormwater projects.

The Commonwealth Financing Authority's Local Share Account – Statewide program provides the greatest flexibility in use of the funding, with project eligibility broadly defined as projects "in the public interest" or ones that will "improve the quality of life of citizens in the community." Applicants may receive only partial funding from what they requested. In this context, it is a sound strategy to apply for a project scope that could be reduced or phased if necessary, depending on the amount of funding granted.

The PA Small Water & Sewer and H20 PA Water & Sewer Programs are fitting funding considerations. While both programs provide grants for water, sewer, or stormwater projects – the latter requires a heftier match but will also fund larger projects (over $500,000). Unfortunately, these two (2) programs are not funded annually in the state budget, so funding rounds are open on an inconsistent basis.

Regarding the PA-6 North Cedar Hollow Road and PA-15 Hillview Road projects, additional studies are necessary to determine the scope and magnitude of this work. Anticipated to carry a more significant multi-million-dollar price tag, loan options – particularly PENNVEST – may be a logical consideration to explore for implementation, to provide the financial means to complete all the stormwater components of the project in one (1) phase, under a single construction contract. PENNVEST is a popular program that provides low-interest, 20-year financing for water, sewer, or stormwater projects. While some communities may be grant eligible, PENNVEST primarily provides loans.

Appendix E contains a list of potential grant programs that the Township may consider for stormwater projects – with a range of priorities and eligibility, from water management to water quality. As the Township's MS4 Stormwater Program and Pollutant Reduction Plan evolves, there may be opportunities to combine stormwater and other infrastructure projects together to creatively pair municipal and state dollars to accomplish more projects. The CFA's Watershed Restoration Program, DEP's Growing Greener program, and National Fish & Wildlife grants are reasonable funding mechanisms to explore more and would be targeted to green infrastructure and watershed protection elements of the Township's stormwater program.

In addition to grant funding, as the Township's water quality and control strategies come together, the implementation of a Stormwater Utility Program is also a consideration as an additional funding mechanism. Creating a utility may ensure a steady and predictable revenue stream, enabling more effective planning for capital improvement projects. Typically, the average residential property owner receives a savings of 30% to 70% when paying for stormwater through a fee as compared to a tax.

7. STORMWATER PROGRAM CONSIDERATIONS

A review of existing the Township Municipal Separate Stormwater Sewer System (MS4) Program and Township ordinances for the identification of the potential modifications and/or recommendations for revisions was conducted. This Section is a summary of these assessments and potential programmatic and ordinance modifications to increase the effectiveness and resiliency of the Township's stormwater and flood mitigation system.

7.1 MS4 PROGRAM REVIEW

The Pennsylvania Department of Environmental Protection (PADEP) issued an NPDES Permit to Willistown Township for the discharge of stormwater to regulated waters. The current MS4 Permit (PAI130521) became effective July 1, 2022 and expires June 30, 2027. In addition to Part A (Effluent Limitations,

Reporting and Recordkeeping Requirements), Part B (Standard Conditions), and Part C (Special Conditions) of the Permit, the Township is responsible for meeting the requirements imposed by Appendix B (Pollutant Control Measures for Waters Impaired by Pathogens), Appendix C (Pollutant Control Measures for Waters Impaired by Priority Organic Compounds), and Appendix E (Pollutant Reduction Plan Requirements for Discharges to Waters Impaired for Nutrients and/or Sediment).

The Annual MS4 Status Report submitted to PADEP for activities from July 1, 2022 through June 30, 2023 was reviewed to determine compliance with the requirements noted. Willistown Township appears to be meeting, or exceeding, requirements in some areas; however, additional review is required to determine full permit compliance. A full review of previous MS4 permit activities and Township MS4 Program was outside the scope of this study. Primary objective for this study is to document programmatic areas for improvement as well as list potential projects that may be implemented towards compliance with the MS4 permit. The compliance determination and recommendations included in this study are subject to change based on additional review.

7.1.1 Minimum Control Measures

A cursory review of the Township's compliance with the six (6) Minimum Control Measures (MCMs) was completed based on the information included in the Annual MS4 Status Report. The Township is required to comply with the following six (6) MCMs over the course of each permit cycle:

1. Public Education and Outreach on Stormwater Impacts
2. Public Involvement/Participation
3. Illicit Discharge Detection and Elimination
4. Construction Site Stormwater Runoff Control
5. Post-Construction Stormwater Management
6. Pollution Prevention/Good Housekeeping

Based on the review of the documentation included in the Annual MS4 Status Report, it appears the Township is in compliance with the six (6) MCMs.

7.1.2 Pollutant Reduction Plan

A cursory review of the Township's Pollutant Reduction Plan (PRP) was completed. The PRP utilized the Simplified Method to calculate the Township's sediment load. The Township's PADEP-approved PRP, outlines a plan to meet the 10% reduction in sediment load, required by Appendix E of the approved MS4 Permit. As documented in the PRP, to achieve compliance with this 10% reduction goal, a combination of the following projects are planned for implementation by 2027.

Ridley Creek

- Rita Reves Park Basin Retrofit
- Nine (9) Inlet Sediment Filter Bags
- Troutbeck Farm Subdivision Riparian Forest Buffer
- Willistown Point Subdivision Tree Plantings

Crum Creek

- Greentree Park Basin Retrofit
- Mill Road Park Basin Retrofit
- Eisenhower Road Stream Bank Stabilization
- Three (3) Inlet Sediment Filter Bags
- Stonehenge Subdivision Stream Restoration

Little Valley Creek

- Four (4) Inlet Sediment Filter Bags
- Industrial Boulevard Bioretention Basin

Determining sediment load and 10% reduction values from the PRP requires extensive H&H analysis, and inaccuracies may exist depending on the modeling parameters and methodologies. The Annual Report states a required reduction higher than the values stated in the PRP and should be evaluated for future Annual Reports. The MS4 Permit requires the reduction goals be met by June 30, 2027. The Annual Report indicates no projects had been completed as of June 30, 2023. Through discussions with the Township, it was determined the following have been completed, and should therefore be included in the next Annual Report:

- Eight (8) inlet sediment filter bags have been installed.
- Troutbeck Farm Subdivision Riparian Forest Buffer
  - Riparian forest buffer plantings have been completed (30 dogwoods may still need to be replaced as they were located in a saturated area)
  - Tree tubes have been placed
  - Riparian buffer seed mix remains to be applied
- Willistown Point Subdivision Tree Plantings
  - Majority of trees have been planted with the exception of lots 22-27, interior of basin, and bio-retention area
  - Planted trees have been mulched and have deer protection
  - Riparian buffer seed mix remains to be applied

The Township should be aware that regular maintenance and measuring/documentation of sediment removed from filter bags are critical to their effectiveness and to receive MS4 credit for installation of this Best Management Practice (BMP). The Township should also be aware that ensuring the full maturation of the trees and replacing any that fail to thrive are required in order to receive MS4 credit for those BMPs.

Implementation of basin retrofit and stream restoration projects require substantial planning, design, and permitting. Anticipated construction dates may be impacted and could be a concern for meeting the June 30, 2027 deadline.

7.1.3 MS4 Permit Compliance/Programmatic Recommendations

Based on the review of the current MS4 permit and latest MS4 Status Report, the following recommendations are provided for compliance and programmatic improvements:

- An additional in-depth review of the MS4 Program is necessary to accurately determine full compliance. A thorough review of the Stormwater Program's written plans should occur, updating as appropriate. All reviews and revisions should be documented and tracked for inclusion in future Annual Reports.
- Stormwater system map updates utilizing GIS should be completed for clarity and ease of use. Map updates should be utilized for Post Construction Stormwater Management (PCSM) Best Management Practice (BMP) list review and revisions. Similarly, mapping should be utilized for Outfall list review and revisions.
- The Annual Report indicates that the mapping requirements have been completed, however, does not indicate anticipated completion dates for inventory development or inspections. It is recommended that a Pollutant Control Measure (PCM) plan and schedule be developed to ensure forthcoming requirements are met.

- Development of inspection schedules for PCSM BMPs and Outfalls are recommended practices; inspection results should be included in the Annual Report.
- Appendices B and C require the development of storm sewershed maps (due September 30, 2024), an inventory of suspected and known sources of Pathogens and Priority Organic Compounds (due September 30, 2025), and investigation of suspected sources (due September 30, 2026). Recommend Township build upon the Stormwater GIS Database provided through this study to develop the required maps and create inventory of any source of Pathogens and Priority Organic Compounds.
- In the 2024 Annual MS4 Status Report, the Township should report development of a Stormwater GIS Database and completion of the Stormwater Master Plan.
- HRG recommends a more thorough review of the PRP be completed, and an updated PRP be developed if warranted. Township loading rates should be reviewed and additional opportunities for parsed areas evaluated. The current project list should be reviewed for feasibility and reviewed against other potential projects not currently included in the PRP. Long-term maintenance, project cost effectiveness (cost per pound of reduction), and opportunities to address areas of concern should be considered. A schedule for implementation, including all required design and permitting requirements, should be developed.
- To ensure the Township receives MS4 credit for installation of inlet filter bags, we include a reminder that maintenance of these BMPs are critical. Recommended maintenance of the inlet filter bags includes emptying when half full of sediment/trash and cleaning twice a year. In general, the more frequently filter bags are cleaned, the more effective they are.
- HRG recommends a more thorough review of the activities associated with MCM compliance. While it appears the Township is complying with these requirements, there may be opportunities to improve implementation and efficiencies associated with these activities.

7.2 ORDINANCE AND POLICY RECOMMENDATIONS

Regulations are an important tool to help mitigate the impacts of stormwater and flooding. Stormwater and floodplain regulations exist at federal, state and local levels. Generally, state and local regulations have the greatest impact on a community, as federal regulations often have a broader focus. Many municipalities throughout Pennsylvania enforce stormwater and floodplain regulations through their Zoning Ordinance, Subdivision and Land Development Ordinance (SALDO), and sometimes separate Floodplain and/or Stormwater Management Ordinances (SWMO). Willistown Township has a Zoning Ordinance, SALDO, Environmental Protection Ordinance, Flood Hazard Area Ordinance, and Soil Erosion and Sedimentation Control Ordinance. The following is an overview of a review of the Township's existing regulations related to flooding and stormwater and some recommendations to consider.

7.2.1 Township Ordinance Review

As part of this study, the project team reviewed existing ordinance regulations related to stormwater management, floodplain management, and environmental protection. Through this analysis, recommendations related to flooding and stormwater management for Township consideration have been developed. This section summarizes topics that were reviewed.

The Township adopted an amended Stormwater Management Ordinance in December 2022, which incorporated PADEP's 2022 Model Stormwater Management Ordinance. The Township's current land use standards include stormwater management provisions that can support water quality and quantity control through the development process. In general, the Township includes the necessary requirements for stormwater management in their ordinance.

The following are recommendations for improvements that could provide the Township additional water quality and flood mitigation benefits and improve the development plan submission/review process:

- Consider increasing the 2-year design storm value to the NOAA Atlas 14% Upper 90% confidence interval as recommended in the forthcoming revised PADEP PCSM design manual (Note: Manual is currently in Draft format but has been made available for public comment).
- Consider increasing the volume control/groundwater recharge volume requirements (10% to 20% suggested). Increasing the recharge volume aids with reduction of downstream flooding and erosion.
- Consider adding provisions to utilize the managed release concept (MRC) in-lieu of infiltration facilities where it is not feasible to infiltrate stormwater on a particular site.
- Consider going above and beyond current peak rate control requirements by adding a percentage to the design storm requirements in the ordinance. This will help reduce flooding.
- Consider increasing the required percentage of impervious area (minimum requirement is 20%) that is assumed meadow in pre-developed calculations. Incorporation of additional percentage requirements helps offset the deficiencies in older stormwater management facilities installed prior to current standards.
- Consider including requirement for sump pumps to discharge to infiltration or vegetative BMPs where feasible.
- Consider including specific Stormwater Management Plan (SWP) and Report requirements in the Stormwater Ordinance. Including this in the ordinance provides clear guidance for applicants on requirements for Stormwater Permit approval.
- The Township already has regulations and an approval process in place for construction within the floodplain. However, since any construction, reconstruction, and/or elevation may result in disturbances to the floodplain and increase downstream flooding, it is recommended to consider additional regulation that prohibits new construction within the floodplain.

7.2.2 Additional Items for Stormwater Management Consideration

1. **Floodplain Management Policies** - Floodplain management helps to decrease and mitigate the impacts of wet weather events, including flooding, while having policy focused on future development and reducing the possibility of increased flooding. Floodplain management serves as a tool used to limit the impacts of flooding by mitigating the conflicts of land use within the floodplain. To have effective floodplain management policy, it needs to focus on both preventative provisions as well as corrective measures. Both preventative and corrective policies help restrict future development within the floodplain and reduce the impacts of flooding within the floodplain and problem areas.

   Recommendations to improve and strengthen the Township's existing Floodplain Management Policies include:

   - The Township should consider participating in FEMA's Community Rating System (CRS) to exceed the minimum requirements of the National Flood Insurance Program (NFIP). CRS communities can reduce flood insurance premium rates by addressing the three program goals of reducing and avoiding flood damage to insurable properties, strengthening and supporting the insurance aspects of the NFIP, and fostering comprehensive floodplain management.
   - Develop and implement a maintenance program for the Township's stormwater drainage system. Regular maintenance of stormwater drainage infrastructure is important, as they are designed to operate at full conveyance, but when they become clogged, the system is no longer working at full capacity. Therefore, it is important that municipalities have a plan in place for the inspection and maintenance of channels as well as conveyance and storage facilities.

2. **Riparian Buffer Protection –** Riparian buffers, the areas between the aquatic zone and the adjacent uplands, provide benefits related to flood protection and water quality. Riparian buffers provide a temporary storage area that allows water velocities to be reduced and allow for infiltration of some water. Through the slowing of the waters and infiltration, pollutants are filtered out and helps to reduce streambank erosion, which decreases sedimentation in the water channels. Severe flooding is becoming more frequent due to more extreme weather events, leading to a greater risk of destructive impacts to properties and residents in riparian areas. Riparian buffer restoration, protection, and sustainable management in still functioning riparian areas helps mitigate flooding adjacent to and downstream of those areas.

   The Township includes provisions and regulations related to riparian buffers in their Environmental Protection Ordinance. Recommendations for additional Riparian Buffer Area Protection include:

   - Adopt stream specific guidelines in areas where flooding problems have been identified, and a riparian buffer is identified as a potential solution. One way to determine guidelines is through the preparation of a stream corridor study to help designate riparian buffers within the study area, as these buffers range from 75 to 1,000 feet. Variable riparian buffer widths may be based on a specific flood event.
   - Encourage collaboration with upstream municipalities to strengthen riparian buffer protection.

3. **Limiting Impervious Cover** - Studies have found that once 10% of the land area within a watershed is impervious, the waterways begin to show signs of degradation. Through the limitation of impervious cover, the impacts that impervious area have on the hydrologic cycle may be reduced.

   Recommendations to help decrease impervious land cover include:

   - Parking Requirements and Dimensions: The Township could consider re-evaluating the minimum and maximum number of parking spaces required for land use types, based on societal changes in recent years. The Township could also look at the parking space size and set the requirements at 8’ x 18’ long to help reduce impervious area. Lastly, within parking lots the Township should have requirements in place to require minimum green space or permeable pavement within parking lots that allow for run off infiltration.
   - Total impervious coverage on a lot: The Township could consider reducing the percentage of impervious land coverage that is permitted on a lot. Similarly, the Township could look to require permeable pavement or green space minimums based on land use types.

4. **Overlay Zoning** - Overlay districts add an additional layer of regulatory standards, permitted uses, or applies specific development criteria onto existing zoning regulations. The Township already has a Floodplain and Riparian Buffer Overlay District, but the Township could add an Impervious Overlay District in areas with documented stormwater problems to help set maximums for impervious area coverage.

8. RECOMMENDATIONS

The Willistown Stormwater Master Plan is a comprehensive effort to assist the Township to implement a set of prioritized projects and strategies. The project team was assigned to perform the study and identify actionable steps and recommendations. This Section summarizes strategic recommendations and prioritized projects. This includes items such as recommendations for projects, programmatic improvements, and areas for further evaluation. The recommendations in this Section are intended to provide Township officials with the information to prioritize next steps for increasing Willistown's stormwater and flood mitigation efforts. Table 11 provides the summary of early or short-term recommendations, items that could be completed in the next 12 to 36 months. Table 12 provides the summary of medium-term recommendations, items that could be completed within the next 3 to 6 years. Table 13 provides a summary of additional items for the Township to consider, but do not have a recommended timeline.

Table 11 – Short-Term Recommendations (1-3 years)

Item	Description
A1	Implement Priority Area PA-1 Forest Lane Mitigation Solution project.
A2	Implement Priority Area PA-3 Spring Road Mitigation Solution project.
A3	Investigate the condition of the eroded outlet structure identified within the North Cedar Hollow Road watershed, which was identified during field inspections as eroding on a steep slope.
A4	Use the results of the stormwater infrastructure conditions assessment to address those assets that are in most severe, failing condition.
A5	Build upon the Stormwater GIS Database developed through this study for asset management, capital improvement project planning and tracking, NPDES MS4 mapping and project tracking, logging residential stormwater concerns, operation & maintenance tracking, hazardous spill response, etc. Training may be provided to Township staff on use of the GIS field collection methods. An asset management database may be developed by staff/consultants.
A6	Capital improvements planning to identify stormwater capital projects, planning schedule, and finance options to realize the plan. This type of planning will put the Township in the position to identify grant opportunities well in advance.
A7	Review the MS4 Permit PRP, and update if necessary. Recommend reviewing loading rates areas and additional opportunities for water quality projects. The current project list should be reviewed for feasibility and reviewed against other potential projects not currently included in the PRP.
A8	Utilize the Stormwater GIS Database developed through this study for MS4 mapping and compliance tracking (e.g., BMP inspections, operations & maintenance, etc.)

Table 12 – Medium-Term Recommendations (3-6 years)	
Item	**Description**
B1	Implement Priority Area PA-4 Chetwynd Road Mitigation Solution project. Feasibility study recommended.
B2	Implement Priority Area PA-6 North Cedar Hollow Road Mitigation Solution project. Feasibility study recommended.
B3	Implement Priority Area PA-7 Bryan Avenue Mitigation Solution project. Feasibility study recommended.
B4	Implement Priority Area PA-15 Hillview Road Mitigation Solution project. Feasibility study recommended.

Table 13 – Additional Items to Consider	
Item	**Description**
X1	It is recommended that a study be performed on all creek crossings within Township boundaries to understand and address any future impacts to adjacent roadways.
X2	While elevation (Z) data was collected during field data collection with one (1) centimeter accuracy, they are typically less accurate than horizontal (X,Y) data. The data collected for this study is sufficient for planning purposes, however it is recommended that a field survey be conducted for higher level of accuracy in more detailed studies and designs.
X3	Closed Circuit Television (CCTV), is recommended of the storm sewer system for a more accurate understanding of the asset condition and for prioritization of rehabilitation and replacement projects. Corrugated metal pipe (CMP) has a shorter useful life than concrete pipe, and as such, it is recommended that the Township consider rehabilitation (e.g., Cured-in-place pipe, pipe-bursting) or replacement of CMP within the drainage system.
X4	It is recommended that planning and design of mitigation projects include H&H analysis of simulated high-intensity rainfall events to assess the feasibility of mitigating for larger rainfall events.
X5	It is recommended that the Township consider the additional suggestions for MS4 Permit Compliance and Programmatic Improvements included in Section 7.1.
X6	It is recommended that the Township consider the suggestions for ordinance and policy improvements included in Section 7.2.

9. REFERENCES

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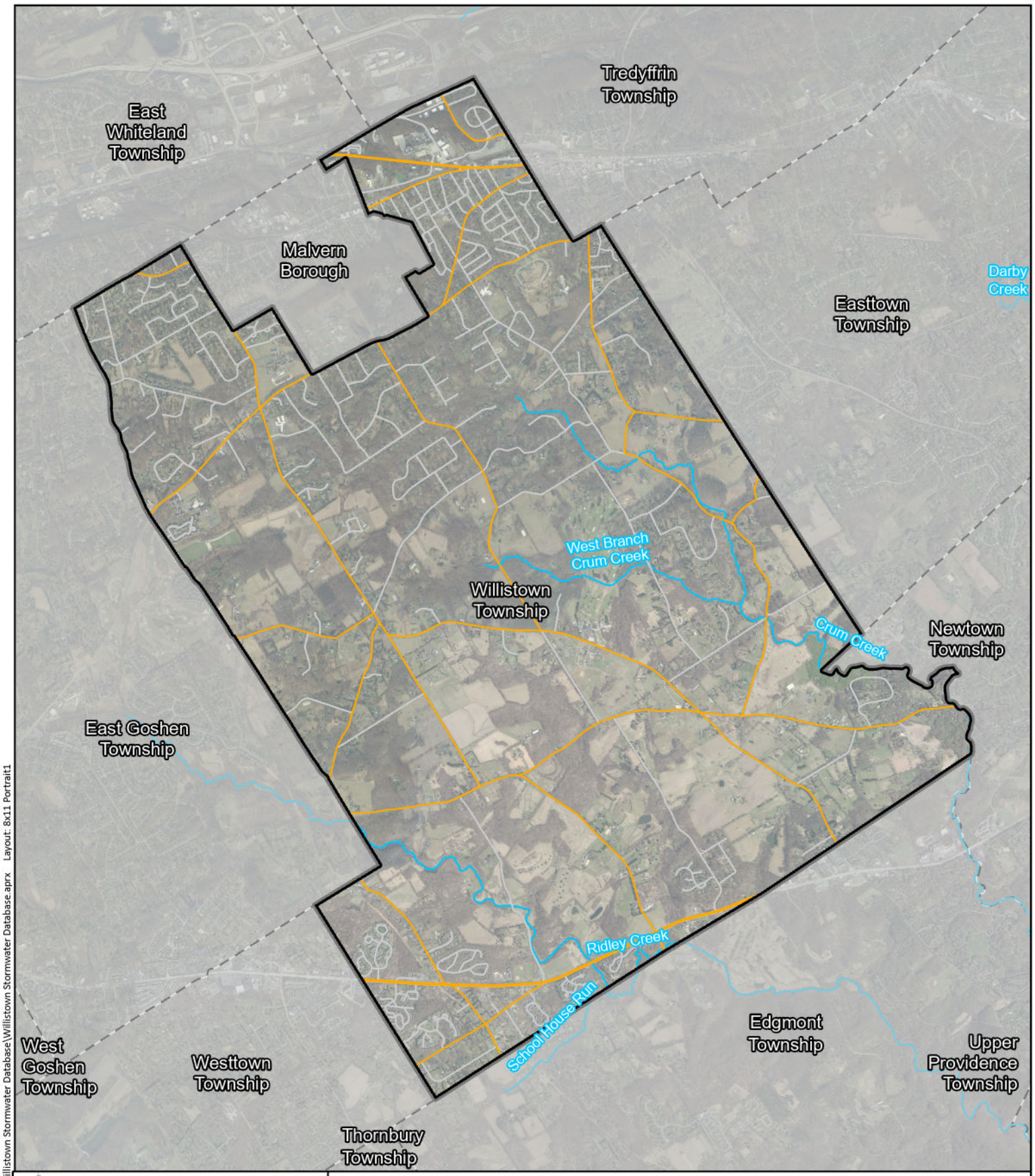
APPENDIX A: EXISTING CONDITIONS



N

0 0.5 1 Miles

Mapping derived from data provided by ESRI, PennDOT, and USGS.

4/15/2024	PM: JA	GIS: RBG	QA: MV	R012018.0425

HRG

501 Allendale Road
Suite 203
King of Prussia, PA 19406
484.460.7050 [phone]
www.hrg-inc.com

State Roads
Local Roads
PA Rivers and Creeks
Municipal Boundaries
Willistown Boundary

Map 1 - Existing Conditions

Willistown Township
Chester County, Pennsylvania

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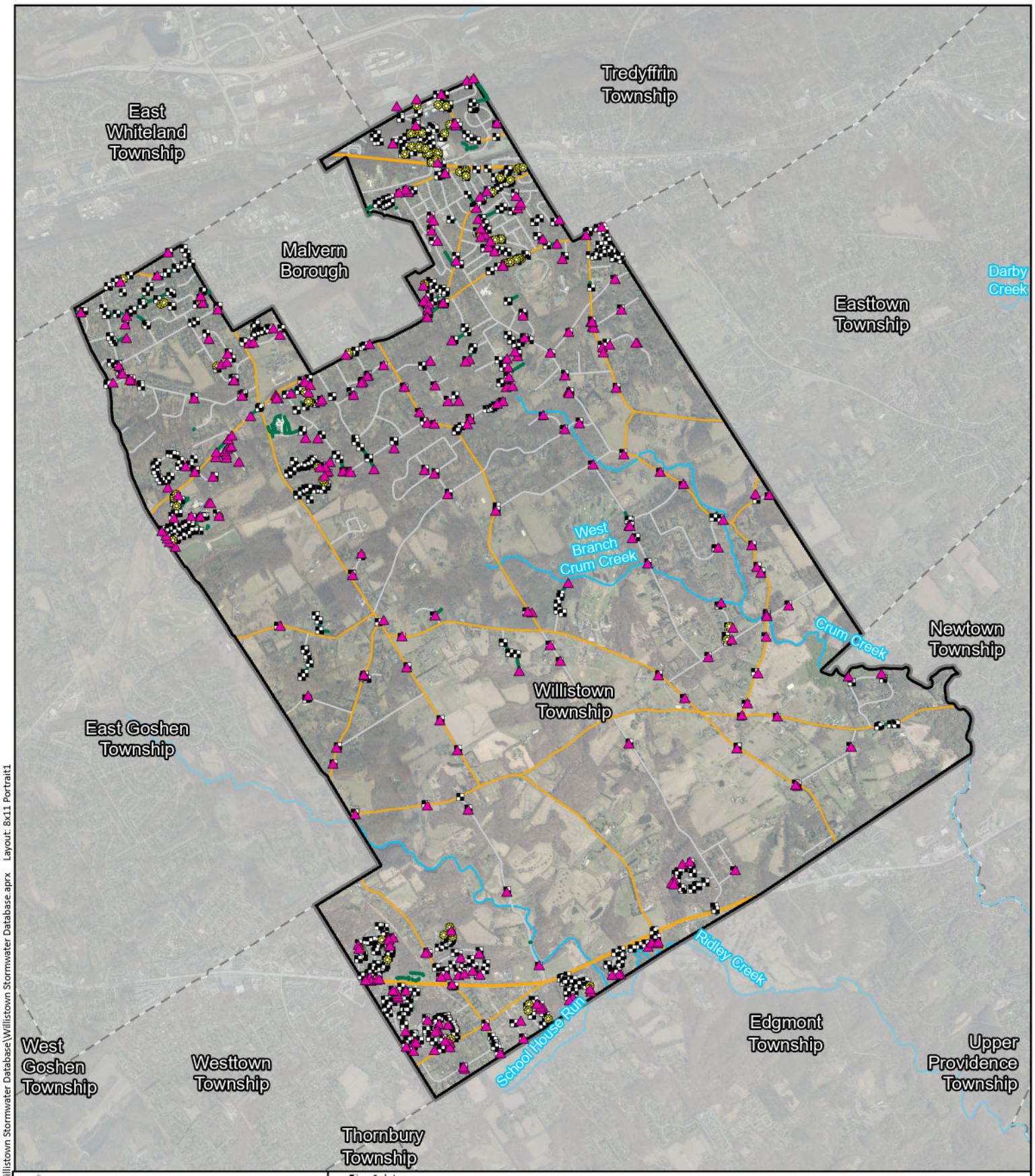

Map 2 - Existing Stormwater Infrastructure

Willistown Township
Chester County, Pennsylvania

4/15/2024	PM: JA	GIS: RBG	QA: MV	R012018.0425

HRG
501 Allendale Road
Suite 203
King of Prussia, PA 19406
484.460.7050 [phone]
www.hrg-inc.com

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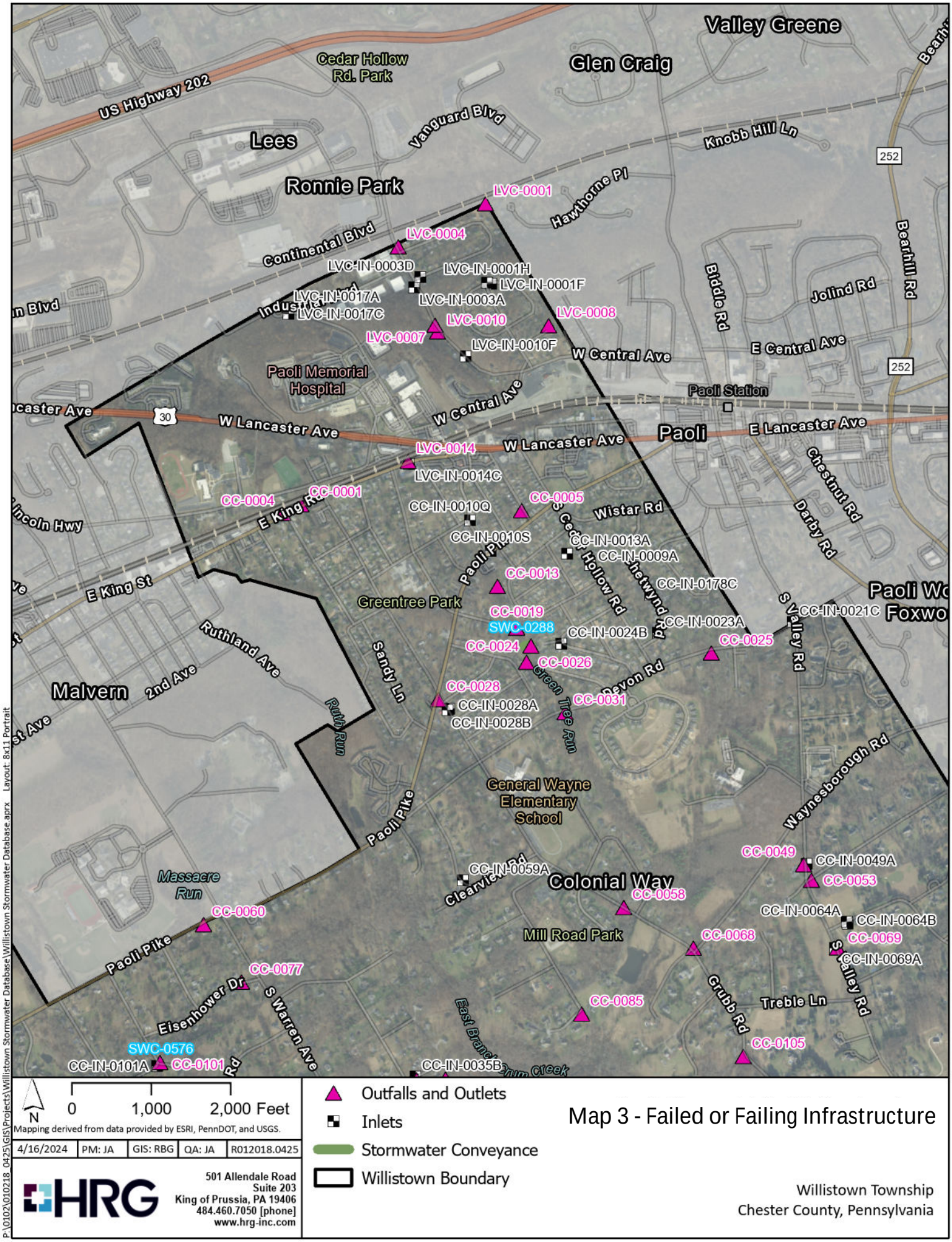
APPENDIX B: CONDITIONS ASSESSMENT OF POOR INFRASTRUCTURE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Glen Craig
Cedar Hollow Rd. Park
US Highway 202
Lees
Vanguard Blvd
Knobb Hill Ln
Ronnie Park
LVC-0001
Hawthorne Pl
LVC-0004
Continental Blvd
LVC-IN-0003D
LVC-IN-0001H
LVC-IN-0001F
LVC-IN-0003A
LVC-IN-0017A
LVC-IN-0017C
LVC-0010
LVC-0008
LVC-0007
LVC-IN-0010F
Biddle Rd
Jolind Rd
Bearhill Rd
E Central Ave
W Central Ave
Paoli Memorial Hospital
Paoli Station
W Lancaster Ave
Paoli
E Lancaster Ave
LVC-0014
LVC-IN-0014C
Chestnut Rd
Darby Rd
CC-0004
CC-0001
E King Rd
CC-IN-0010Q
CC-0005
Wistar Rd
CC-IN-0010S
CC-IN-0013A
CC-IN-0009A
Paoli Pk
Cedar Hollow Rd
Whetwynd Rd
CC-0013
CC-IN-0178C
E King St
Greentree Park
CC-0019
SWC-0288
CC-IN-0024B
CC-IN-0023A
CC-IN-0021C
S Valley Rd
CC-0024
CC-0025
CC-0026
Ruthland Ave
Sandy Ln
Devon Rd
Malvern
2nd Ave
CC-0028
CC-IN-0028A
CC-IN-0028B
CC-0031
Green Tree Run
Ruth Run
Waynesborough Rd
General Wayne Elementary School
Paoli Pike
CC-0049
CC-IN-0049A
CC-0053
CC-IN-0059A
Clearview Rd
Colonial Way
CC-0058
Massacre Run
CC-0060
CC-IN-0064A
CC-IN-0064B
Mill Road Park
CC-0068
CC-0069
CC-IN-0069A
Paoli Pike
CC-0077
Eisenhower Dr
S Warren Ave
CC-0085
Grubb Rd
Treble Ln
SWC-0576
CC-IN-0101A
CC-0101
Rd
CC-IN-0035B
CC-0105
East Branch Crum Creek
0
1,000
2,000 Feet
N
Mapping derived from data provided by ESRI, PennDOT, and USGS.
4/16/2024
PM: JA
GIS: RBG
QA: JA
R012018.0425
Outfalls and Outlets
Inlets
Stormwater Conveyance
Willistown Boundary
Map 3 - Failed or Failing Infrastructure
Willistown Township
Chester County, Pennsylvania
HRG
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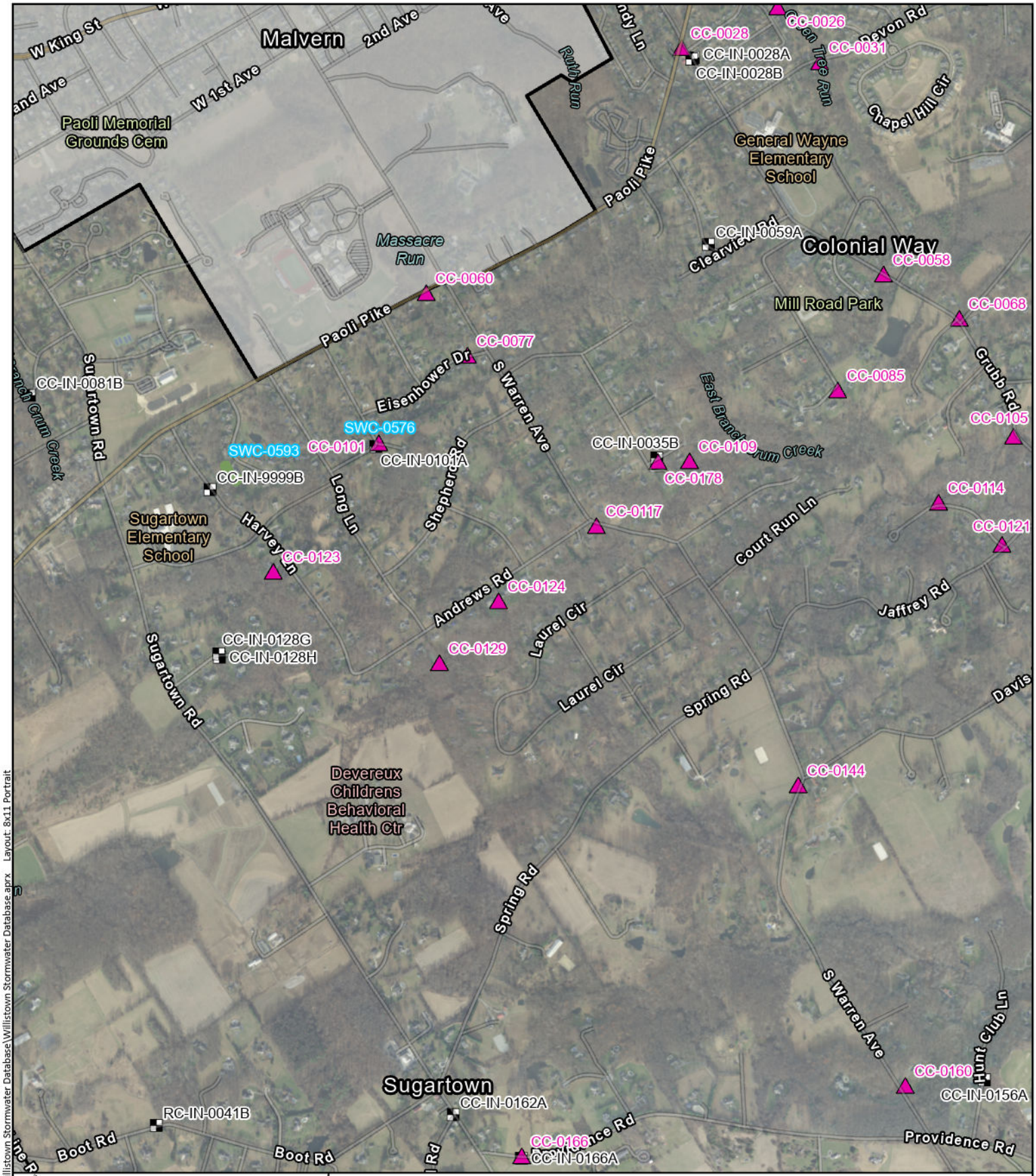
P:\0102\010218_0425\GIS\Projects\Willistown Stormwater Database\Willistown Stormwater Database.aprx Layout: 8x11 Portrait


Malvern
W King St
2nd Ave
W 1st Ave
Paoli Memorial Grounds Cem
Ruth Run
Massacre Run
Paoli Pike
CC-0028
CC-IN-0028A
CC-IN-0028B
CC-0026
CC-0031
Devon Rd
Chapel Hill Cir
General Wayne Elementary School
CC-IN-0059A
Clearview Rd
Colonial Way
CC-0058
CC-0060
Mill Road Park
CC-0068
CC-0077
Eisenhower Dr
S Warren Ave
Grubb Rd
CC-0085
CC-IN-0081B
Sugartown Rd
Crum Creek
SWC-0576
SWC-0593
CC-0101
CC-IN-0101A
CC-IN-9999B
Long Ln
Shepherd Rd
CC-IN-0035B
CC-0109
CC-0178
CC-0105
CC-0114
CC-0117
Court Run Ln
Sugartown Elementary School
Harvey Ln
CC-0123
CC-0121
Andrews Rd
CC-0124
Jaffrey Rd
Laurel Cir
CC-IN-0128G
CC-IN-0128H
CC-0129
Spring Rd
Davis
CC-0144
Devereux Childrens Behavioral Health Ctr
S Warren Ave
Hunt Club Ln
CC-0160
CC-IN-0156A
Sugartown
CC-IN-0162A
RC-IN-0041B
Boot Rd
CC-0166
CC-IN-0166A
Providence Rd
0
1,000
2,000 Feet
N
Mapping derived from data provided by ESRI, PennDOT, and USGS.
Outfalls and Outlets
Inlets
Stormwater Conveyance
Willistown Boundary
Map 4 - Failed or Failing Infrastructure
Willistown Township
Chester County, Pennsylvania
4/16/2024
PM: JA
GIS: RBG
QA: JA
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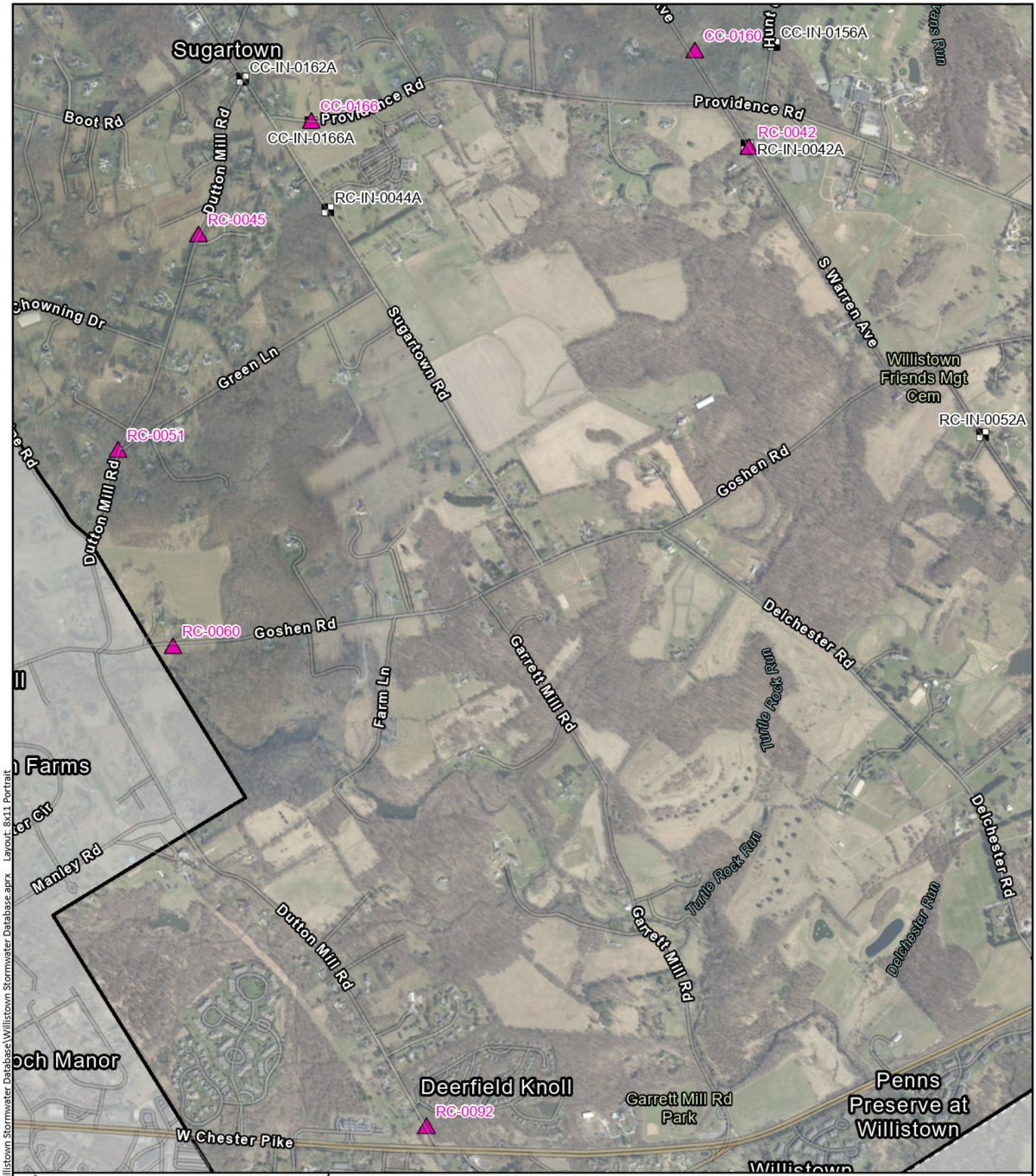
Sugartown
CC-IN-0162A
CC-0160
CC-IN-0156A
Providence Rd
RC-0042
RC-IN-0042A
Boot Rd
Dutton Mill Rd
CC-0166
CC-IN-0166A
RC-IN-0044A
RC-0045
Chowning Dr
Green Ln
Sugartown Rd
S Warren Ave
Willistown Friends Mgt Cem
RC-IN-0052A
RC-0051
Goshen Rd
Delchester Rd
RC-0060
Farm Ln
Garrett Mill Rd
Turtle Rock Run
Maniey Rd
Deerfield Knoll
RC-0092
Garrett Mill Rd Park
Penns Preserve at Willistown
W Chester Pike
0
1,000
2,000 Feet
N
Mapping derived from data provided by ESRI, PennDOT, and USGS.
Outfalls and Outlets
Inlets
Stormwater Conveyance
Willistown Boundary
Map 5 - Failed or Failing Infrastructure
Willistown Township
Chester County, Pennsylvania
4/16/2024
PM: JA
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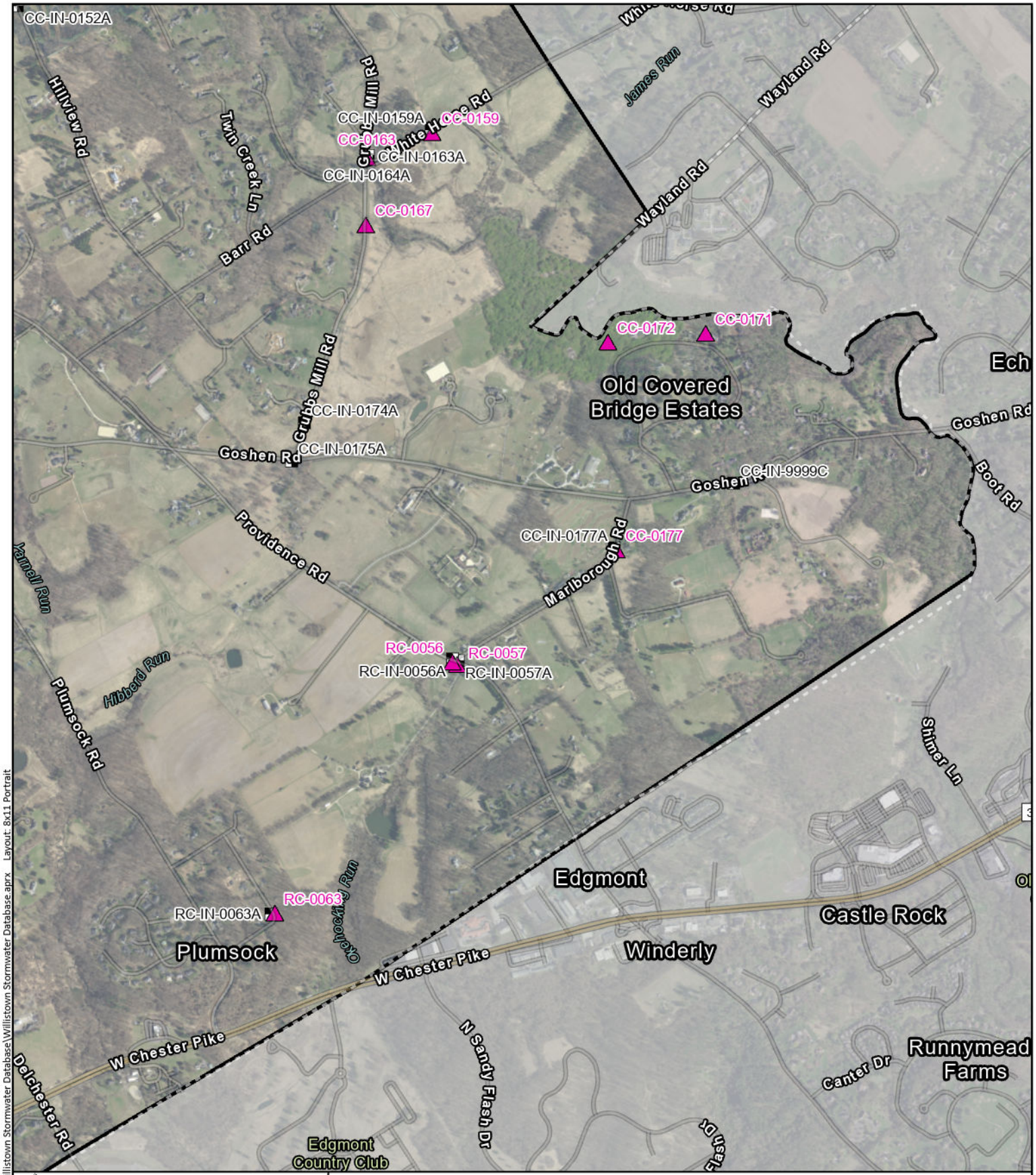

Map 6 - Failed or Failing Infrastructure

Willistown Township
Chester County, Pennsylvania

4/16/2024	PM: JA	GIS: RBG	QA: JA	R012018.0425

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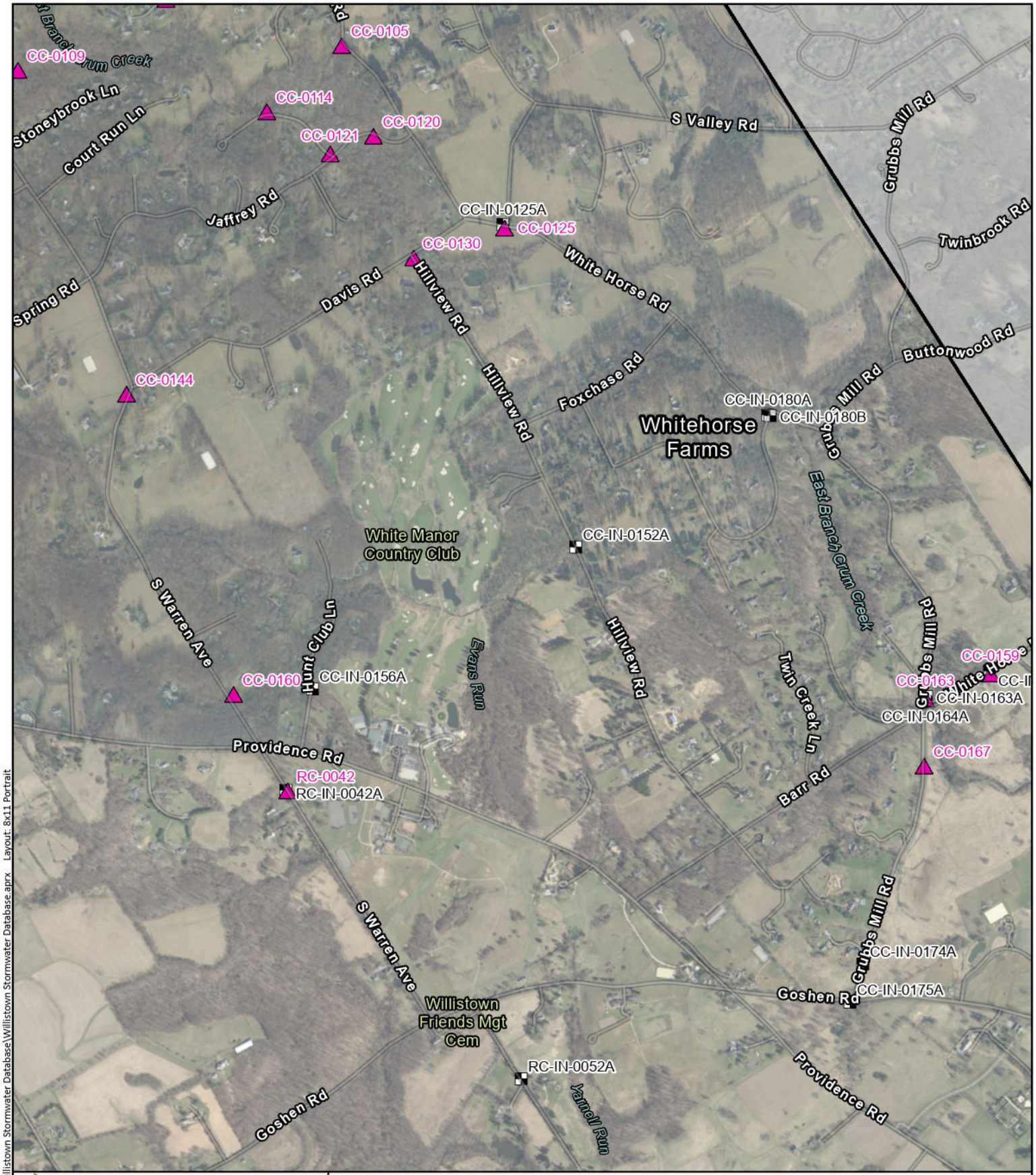

N

0 1,000 2,000 Feet

Mapping derived from data provided by ESRI, PennDOT, and USGS.

4/16/2024	PM: JA	GIS: RBG	QA: JA	R012018.0425

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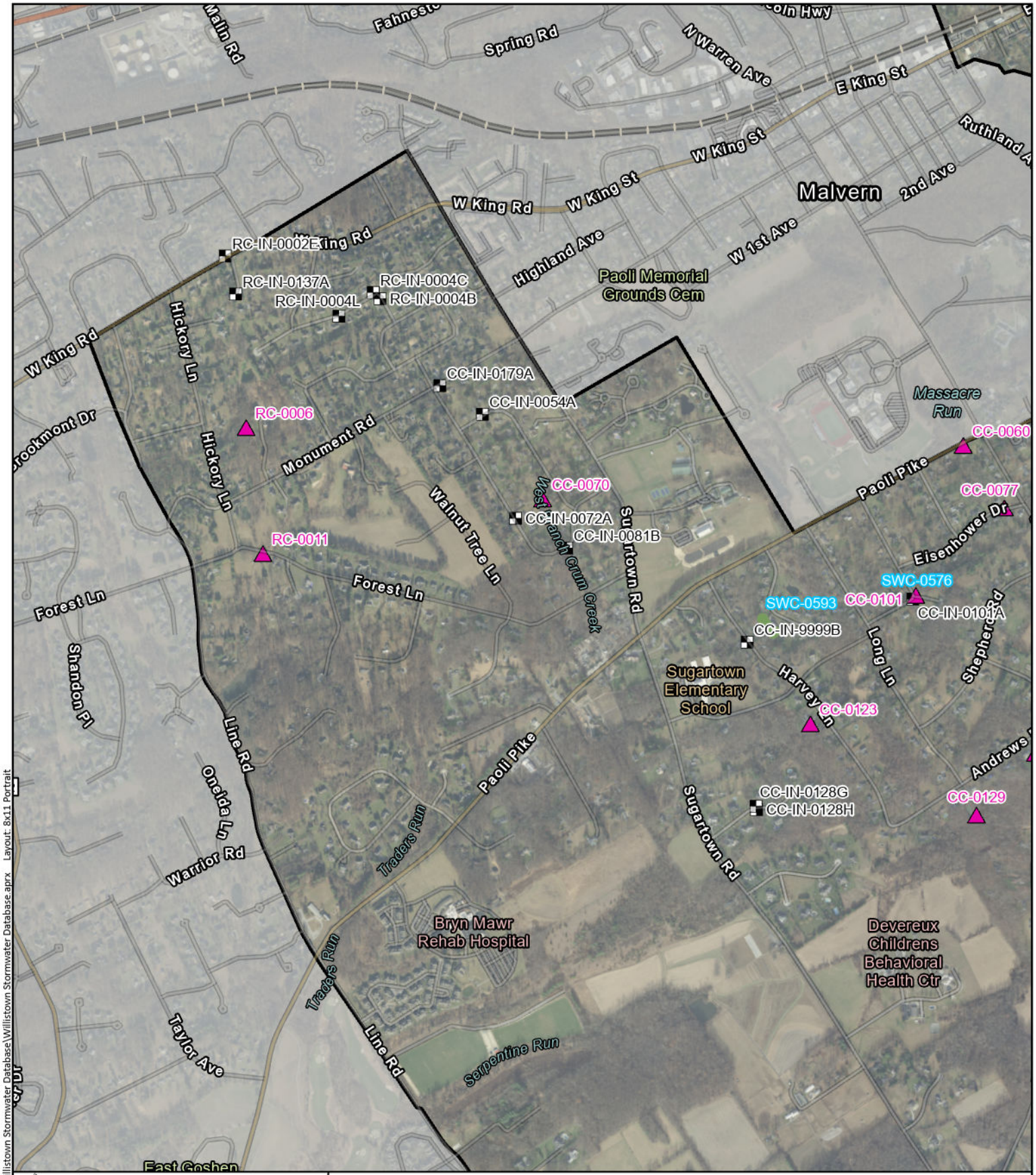
Outfalls and Outlets
Inlets
Stormwater Conveyance
Willistown Boundary

Map 7 - Failed or Failing Infrastructure

Willistown Township
Chester County, Pennsylvania

P:\0102\010218_0425\GIS\Projects\Willistown Stormwater Database\Willistown Stormwater Database.aprx Layout: 8x11 Portrait



N

0 1,000 2,000 Feet

Mapping derived from data provided by ESRI, PennDOT, and USGS.

4/16/2024	PM: JA	GIS: RBG	QA: JA	R012018.0425

Outfalls and Outlets

Inlets

Stormwater Conveyance

Willistown Boundary

Map 8 - Failed or Failing Infrastructure

Willistown Township
Chester County, Pennsylvania

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CONDITIONS ASSESSMENT SUMMARY			
Asset Type	**Asset ID**	**Condition**	**Notes**
Outfall	CC-0001	Failed	15” x 27” CMP outfall
Outfall	CC-0004	Failed	-
Outfall	CC-0025	Failed	Unable to tell if actual outlet. Covered by debris.
Outfall	CC-0028	Failed	Outfall area is sunk below road grade
Outfall	CC-0053	Failed	Pipe buried cannot determine size
Outfall	CC-0058	Failed	-
Outfall	CC-0070	Failed	Endwall is collapsing onto pipe.
Outfall	CC-0077	Failed	-
Outfall	CC-0085	Failed	-
Outfall	CC-0114	Failed	-
Outfall	CC-0117	Failed	Pipe completely silted in
Outfall	CC-0125	Failed	Pipe size and shape unknown
Outfall	CC-0129	Failed	18” x 29” arch
Outfall	CC-0163	Failed	Outlet fully blocked by soil
Outfall	CC-0166	Failed	-
Outfall	CC-0177	Failed	-
Outfall	LVC-0001	Failed	21 inch RCP
Outfall	LVC-0004	Failed	-
Outfall	LVC-0010	Failed	Last pipe section disconnected from rest of pipe. Two pipes at this outfall.
Outfall	RC-0042	Failed	Could not locate assumed to be buried
Outfall	RC-0045	Failed	-
Outfall	RC-0051	Failed	-
Outfall	RC-0056	Failed	Heavy siltation, outfall information unknown
Outfall	RC-0057	Failed	-
Outfall	RC-0060	Failed	-
Outfall	CC-0005	Near Failure	-

CONDITIONS ASSESSMENT SUMMARY			
Asset Type	**Asset ID**	**Condition**	**Notes**
Outfall	CC-0013	Near Failure	-
Outfall	CC-0019	Near Failure	Dry weather flow origin unknown
Outfall	CC-0024	Near Failure	-
Outfall	CC-0026	Near Failure	-
Outfall	CC-0031	Near Failure	Severe undercutting of foundation
Outfall	CC-0068	Near Failure	20" CMP
Outfall	CC-0105	Near Failure	-
Outfall	CC-0109	Near Failure	-
Outfall	CC-0011	Near Failure	-
Outfall	CC-0120	Near Failure	Pipe size unknown
Outfall	CC-0121	Near Failure	-
Outfall	CC-0123	Near Failure	Pipe partially collapsed endwall beginning to fail. Two pipes in outlet.
Outfall	CC-0124	Near Failure	-
Outfall	CC-0130	Near Failure	-
Outfall	CC-0144	Near Failure	Pipe heavily silted size unknown
Outfall	CC-0159	Near Failure	-
Outfall	CC-0167	Near Failure	10 x 17 elliptical outlet
Outfall	CC-0171	Near Failure	-
Outfall	CC-0172	Near Failure	-
Outfall	CC-0178	Near Failure	HRG created name 3/15/2024, Western Outfall on Creek Road
Outfall	LVC-0007	Near Failure	Rusty and heavily silted.
Outfall	LVC-0008	Near Failure	10” PVC
Outfall	LVC-0014	Near Failure	-
Outfall	RC-0006	Near Failure	-
Outfall	RC-0063	Near Failure	-
Outfall	RC-0092	Near Failure	Pipe is exposed, and water is under cutting road

CONDITIONS ASSESSMENT SUMMARY			
Asset Type	**Asset ID**	**Condition**	**Notes**
Inlet	CC-IN-0021C	Failed	-
Inlet	CC-IN-0024B	Failed	Incoming pipe blocked with asphalt and debris
Inlet	CC-IN-0028A	Failed	-
Inlet	CC-IN-0064A	Failed	-
Inlet	CC-IN-0064B	Failed	-
Inlet	CC-IN-0101A	Failed	Curb cut street inlet to swale
Inlet	CC-IN-0159A	Failed	Original invert, has separated from rest of pipe
Inlet	CC-IN-0162A	Failed	Inlet is not draining water. Standing water above the frame. Unable to determine any characteristics.
Inlet	CC-IN-0163A	Failed	Inlet completely full of sediment
Inlet	CC-IN-0166A	Failed	-
Inlet	CC-IN-0174A	Failed	Two 15 x 20 elliptical pipes
Inlet	CC-IN-0175A	Failed	-
Inlet	CC-IN-0177A	Failed	-
Inlet	CC-IN-9999D	Failed	Inlet is also the outlet no bottom (Placeholder name unknown pipe connections Goshen Road)
Inlet	LVC-IN-0010F	Failed	Filled to grate with silt unable to determine pipe info and inlet box information
Inlet	RC-IN-0002E	Failed	-
Inlet	RC-IN-0044A	Failed	Headwall has deteriorated blocking entrance to culvert
Inlet	RC-IN-0052A	Failed	-
Inlet	RC-IN-0056A	Failed	Grate size is 3‘ x 3‘
Inlet	RC-IN-0063A	Failed	Bottom of pipe rusted out, Its marked as RC 30?
Inlet	CC-IN-0009A	Near Failure	-
Inlet	CC-IN-0013A	Near Failure	-
Inlet	CC-IN-0023A	Near Failure	-

CONDITIONS ASSESSMENT SUMMARY			
Asset Type	**Asset ID**	**Condition**	**Notes**
Inlet	CC-IN-0028B	Near Failure	-
Inlet	CC-IN-0035B	Near Failure	-
Inlet	CC-IN-0054A	Near Failure	Brick falling off wall
Inlet	CC-IN-0059A	Near Failure	-
Inlet	CC-IN-0059B	Near Failure	-
Inlet	CC-IN-0072A	Near Failure	-
Inlet	CC-IN-0081B	Near Failure	-
Inlet	CC-IN-0125A	Near Failure	-
Inlet	CC-IN-0128G	Near Failure	-
Inlet	CC-IN-0128H	Near Failure	-
Inlet	CC-IN-0152A	Near Failure	-
Inlet	CC-IN-0156D	Near Failure	Brick wall, on verge of collapsing
Inlet	CC-IN-0164A	Near Failure	-
Inlet	CC-IN-0178C	Near Failure	-
Inlet	CC-IN-0179A	Near Failure	Bottom failed in multiple locations
Inlet	CC-IN-0179B	Near Failure	Bottom failed in multiple locations
Inlet	CC-IN-0180A	Near Failure	-
Inlet	CC-IN-0180B	Near Failure	-
Inlet	CC-IN-9999B	Near Failure	Place holder name (Harvey Lane)
Inlet	LVC-IN-0001F	Near Failure	-
Inlet	LVC-IN-0001H	Near Failure	Combination inlet
Inlet	LVC-IN-0003A	Near Failure	-
Inlet	LVC-IN-0003D	Near Failure	Part of corner wall missing

CONDITIONS ASSESSMENT SUMMARY			
Asset Type	**Asset ID**	**Condition**	**Notes**
Inlet	LVC-IN-0014C	Near Failure	-
Inlet	LVC-IN-0017A	Near Failure	-
Inlet	LVC-IN-0017C	Near Failure	-
Inlet	RC-IN-0004B	Near Failure	-
Inlet	RC-IN-0004C	Near Failure	-
Inlet	RC-IN-0004L	Near Failure	-
Inlet	RC-IN-0041B	Near Failure	-
Inlet	RC-IN-0042A	Near Failure	-
Inlet	RC-IN-0057A	Near Failure	-
Inlet	RC-IN-0137A	Near Failure	-
Stormwater Conveyance	SWC-0288	Needs Repair	-
Stormwater Conveyance	SWC-0576	Needs Repair	Slate landscaping stones
Stormwater Conveyance	SWC-0593	Needs Repair	-

CC-0001

CC-0004

CC-0005

CC-0011

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DESIGN N/A
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SCALE N/A
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CC-0013

CC-0019

CC-0024

CC-0025

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CC-0026

CC-0028

CC-0031

CC-0053

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				DRAWN N/A
				SCALE N/A
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CC-0058

CC-0068

CC-0070

CC-0077

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				SCALE N/A
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CC-0085

CC-0105

CC-0109

CC-0114

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CC-0117

CC-0120

CC-0121

CC-0123

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CC-0124

CC-0125

CC-0129

CC-0130

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CC-0144

CC-0159

CC-0163

CC-0166

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SCALE	N/A
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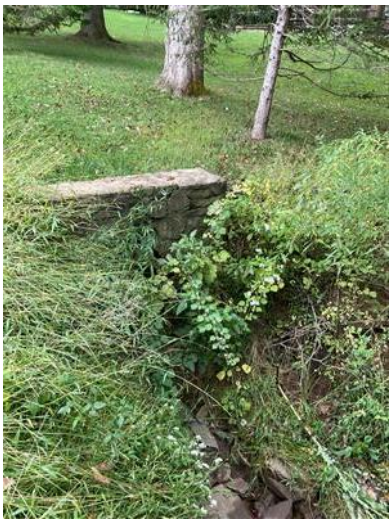
CC-0167



CC-0171

CC-0172

CC-0177

SHEET: 9	OF: 27	DATE: 3.14.2024

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SCALE N/A
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CC-0178

LVC-0001

LVC-0004

LVC-0007

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LVC-0008

LVC-0010

LVC-0014

RC-0006

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RC-0042

RC-0045

RC-0051

RC-0056

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RC-0057

RC-0060

RC-0063

RC-0092

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DESIGN N/A
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SCALE N/A
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CC-IN-0009A

CC-IN-0013A

CC-IN-0021C

CC-IN-0023A

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				SCALE N/A
SHEET: 14	OF: 27	DATE: 3.14.2024		PROJECT R010218.0425

CC-IN-0024B

CC-IN-0028A

CC-IN-0028B

CC-IN-0035B

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SCALE N/A
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CC-IN-0054A

CC-IN-0059A

CC-IN-0059B

CC-IN-0064A

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CC-IN-0064B

CC-IN-0072A

CC-IN-0081B

CC-IN-0101A

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CC-IN-0125A

CC-IN-0128G

CC-IN-0128H

CC-IN-0152A

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CC-IN-0156D

CC-IN-0159A

CC-IN-0162A

CC-IN-0163A

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CC-IN-0164A

CC-IN-0166A

CC-IN-0174A

CC-IN-0175A

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				DRAWN N/A
				SCALE N/A
SHEET: 20	OF: 27	DATE: 3.14.2024		PROJECT R010218.0425

CC-IN-0177A

CC-IN-0178C

CC-IN-0179A

CC-IN-0179B

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CC-IN-0180A

CC-IN-0180B

CC-IN-9999B

CC-IN-9999D

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LVC-IN-0001F

LVC-IN-0001H

LVC-IN-0003A

LVC-IN-0003D

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LVC-IN-0010F

LVC-IN-0014C

LVC-IN-0017A

LVC-IN-0017C

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RC-IN-0002E

RC-IN-0004B

RC-IN-0004C

RC-IN-0004L

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RC-IN-0041B

RC-IN-0042A

RC-IN-0044A

RC-IN-0052A

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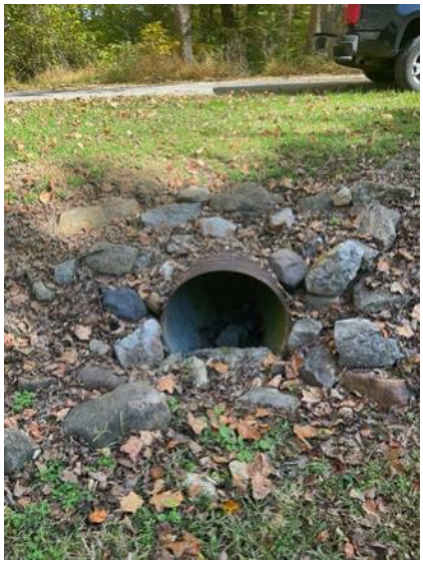
RC-IN-0056A

RC-IN-0057A



RC-IN-0063A

RC-IN-0137A

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				SCALE N/A
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APPENDIX C: CORRUGATED METAL PIPE INVENTORY

CORRUGATED METAL PIPE INVENTORY	
Asset ID	**Length of Pipe***
SWC-0006	27
SWC-0015	21
SWC-0017	84
SWC-0022	63
SWC-0033	40
SWC-0037	49
SWC-0039	3
SWC-0040	41
SWC-0042	64
SWC-0047	477
SWC-0090	69
SWC-0097	241
SWC-0112	59
SWC-0114	58
SWC-0116	40
SWC-0118	35
SWC-0123	72
SWC-0124	33
SWC-0129	66
SWC-0133	48
SWC-0134	47
SWC-0135	67
SWC-0136	127
SWC-0137	51
SWC-0138	114
SWC-0139	26
SWC-0140	65
SWC-0143	45
SWC-0169	258
SWC-0175	45
SWC-0188	41
SWC-0189	63
SWC-0190	78
SWC-0191	57
SWC-0192	230
SWC-0193	63

CORRUGATED METAL PIPE INVENTORY	
Asset ID	**Length of Pipe***
SWC-0194	8
SWC-0195	135
SWC-0196	51
SWC-0197	49
SWC-0198	37
SWC-0200	97
SWC-0201	105
SWC-0202	51
SWC-0203	87
SWC-0204	31
SWC-0206	67
SWC-0207	340
SWC-0208	116
SWC-0210	30
SWC-0211	464
SWC-0212	59
SWC-0215	32
SWC-0221	31
SWC-0226	26
SWC-0229	36
SWC-0230	63
SWC-0233	20
SWC-0238	152
SWC-0240	190
SWC-0243	21
SWC-0246	61
SWC-0247	23
SWC-0248	133
SWC-0251	205
SWC-0253	20
SWC-0255	24
SWC-0261	23
SWC-0278	21
SWC-0281	183
SWC-0287	124
SWC-0289	34

CORRUGATED METAL PIPE INVENTORY	
Asset ID	**Length of Pipe***
SWC-0301	70
SWC-0303	28
SWC-0305	235
SWC-0311	28
SWC-0323	120
SWC-0325	13
SWC-0328	16
SWC-0332	9
SWC-0337	11
SWC-0341	55
SWC-0349	31
SWC-0358	117
SWC-0360	176
SWC-0361	45
SWC-0363	252
SWC-0365	51
SWC-0386	131
SWC-0398	17
SWC-0417	11
SWC-0420	25
SWC-0421	20
SWC-0422	7
SWC-0423	554
SWC-0429	46
SWC-0433	25
SWC-0449	63
SWC-0451	49
SWC-0468	14
SWC-0471	31
SWC-0474	102
SWC-0477	60
SWC-0480	52
SWC-0482	26
SWC-0488	200
SWC-0489	26
SWC-0491	90

CORRUGATED METAL PIPE INVENTORY	
Asset ID	**Length of Pipe***
SWC-0492	27
SWC-0494	184
SWC-0495	77
SWC-0496	61
SWC-0497	86
SWC-0498	11
SWC-0499	90
SWC-0501	168
SWC-0502	50
SWC-0503	32
SWC-0504	25
SWC-0509	72
SWC-0522	37
SWC-0532	47
SWC-0534	26
SWC-0535	25
SWC-0536	33
SWC-0537	31
SWC-0541	89
SWC-0542	202
SWC-0545	87
SWC-0546	25
SWC-0550	201
SWC-0552	41
SWC-0554	20
SWC-0558	42
SWC-0561	17
SWC-0562	57
SWC-0564	188
SWC-0565	14
SWC-0567	48
SWC-0569	167
SWC-0571	79
SWC-0572	5
SWC-0573	28
SWC-0574	25

CORRUGATED METAL PIPE INVENTORY	
Asset ID	**Length of Pipe***
SWC-0579	30
SWC-0583	31
SWC-0588	20
SWC-0589	12
SWC-0591	193
SWC-0592	107
SWC-0594	95
SWC-0596	25
SWC-0597	90
SWC-0598	143
SWC-0603	46
SWC-0605	21
SWC-0613	37
SWC-0614	86
SWC-0615	42
SWC-0628	19
SWC-0630	19
SWC-0656	158
SWC-0659	17
SWC-0660	23
SWC-0664	228
SWC-0671	35
SWC-0673	105
SWC-0674	10
SWC-0675	99
SWC-0678	251
SWC-0679	37
SWC-0680	36
SWC-0684	125
SWC-0686	253
SWC-0687	64
SWC-0689	119
SWC-0690	93
SWC-0691	24
SWC-0692	393
SWC-0698	24

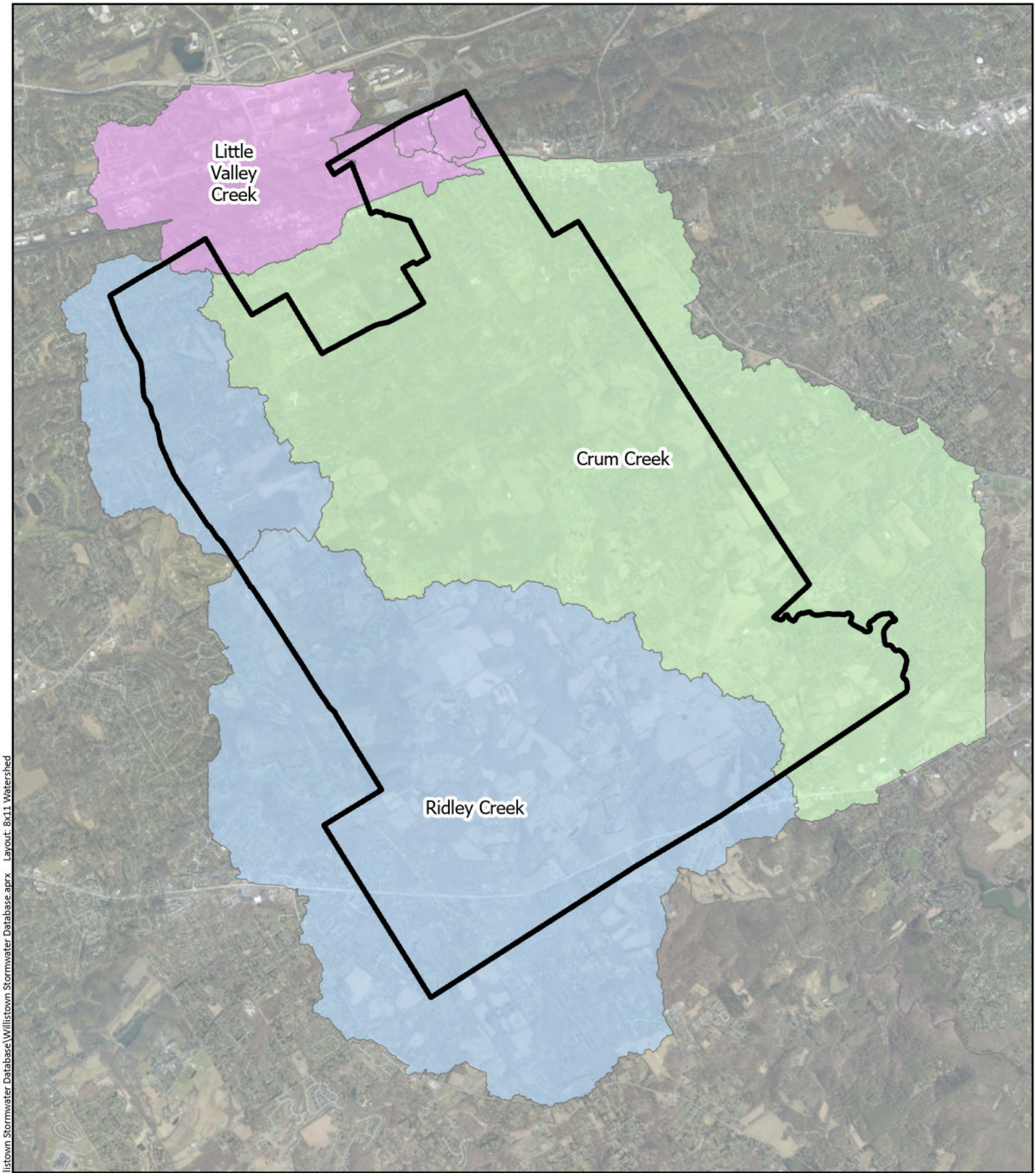
CORRUGATED METAL PIPE INVENTORY	
Asset ID	**Length of Pipe***
SWC-0699	143
SWC-0700	34
SWC-0703	57
SWC-0705	82
SWC-0714	152
SWC-0715	200
SWC-0718	16
SWC-0721	19
SWC-0723	48
SWC-0727	105
SWC-0728	48
SWC-0731	156
SWC-0734	164
SWC-0735	133
SWC-0736	78
SWC-0737	24
SWC-0738	24
SWC-0739	155
SWC-0743	203
SWC-0767	223
SWC-0806	174
SWC-0807	269
SWC-0812	29
SWC-0814	77
SWC-0817	23
SWC-0823	162
SWC-0830	30
SWC-0891	471
SWC-0892	109
SWC-0893	235
SWC-0897	236
SWC-0898	36
SWC-0901	93
SWC-0904	41
SWC-0905	3
SWC-0906	3

CORRUGATED METAL PIPE INVENTORY	
Asset ID	**Length of Pipe***
SWC-0907	196
SWC-0908	3
SWC-0911	341
SWC-0912	24
SWC-0914	18
SWC-0915	22
SWC-0916	128
SWC-0917	34
SWC-0919	31
SWC-0920	40
SWC-0922	161
SWC-0924	32
SWC-0925	21
SWC-0926	426
SWC-0927	8
SWC-0928	17
SWC-0930	32
SWC-0931	125
SWC-0932	113
SWC-0935	28
SWC-0937	572
SWC-0940	96
SWC-0941	34
SWC-0944	70
SWC-0946	121
SWC-0948	38
SWC-0959	29
SWC-0968	31
SWC-0969	24
SWC-0970	61
SWC-0973	34
SWC-0974	26
SWC-0976	36
SWC-0980	30
SWC-0985	47
SWC-1041	24

CORRUGATED METAL PIPE INVENTORY	
Asset ID	**Length of Pipe***
SWC-1057	22
SWC-1077	45
SWC-1085	22
SWC-1092	59
SWC-1093	75
SWC-1099	18
SWC-1105	166
SWC-1144	20
SWC-1330	240
SWC-1339	65
SWC-1377	143
SWC-1386	20
SWC-1392	124
SWC-1395	18
SWC-1398	58
SWC-1400	31
SWC-1402	110
SWC-1403	100
SWC-1404	35
SWC-1410	159
SWC-1411	164
SWC-1412	23
SWC-1413	25

*Length of pipe is estimated based on ArcGIS connections, not field verified

APPENDIX D: H&H ANALYSIS SUPPORTING DOCUMENTS



N

0 0.5 1 Miles

Mapping derived from data provided by ESRI, PennDOT, and USGS.

4/16/2024	PM: JA	GIS: RBG	QA: JA	R012018.0425

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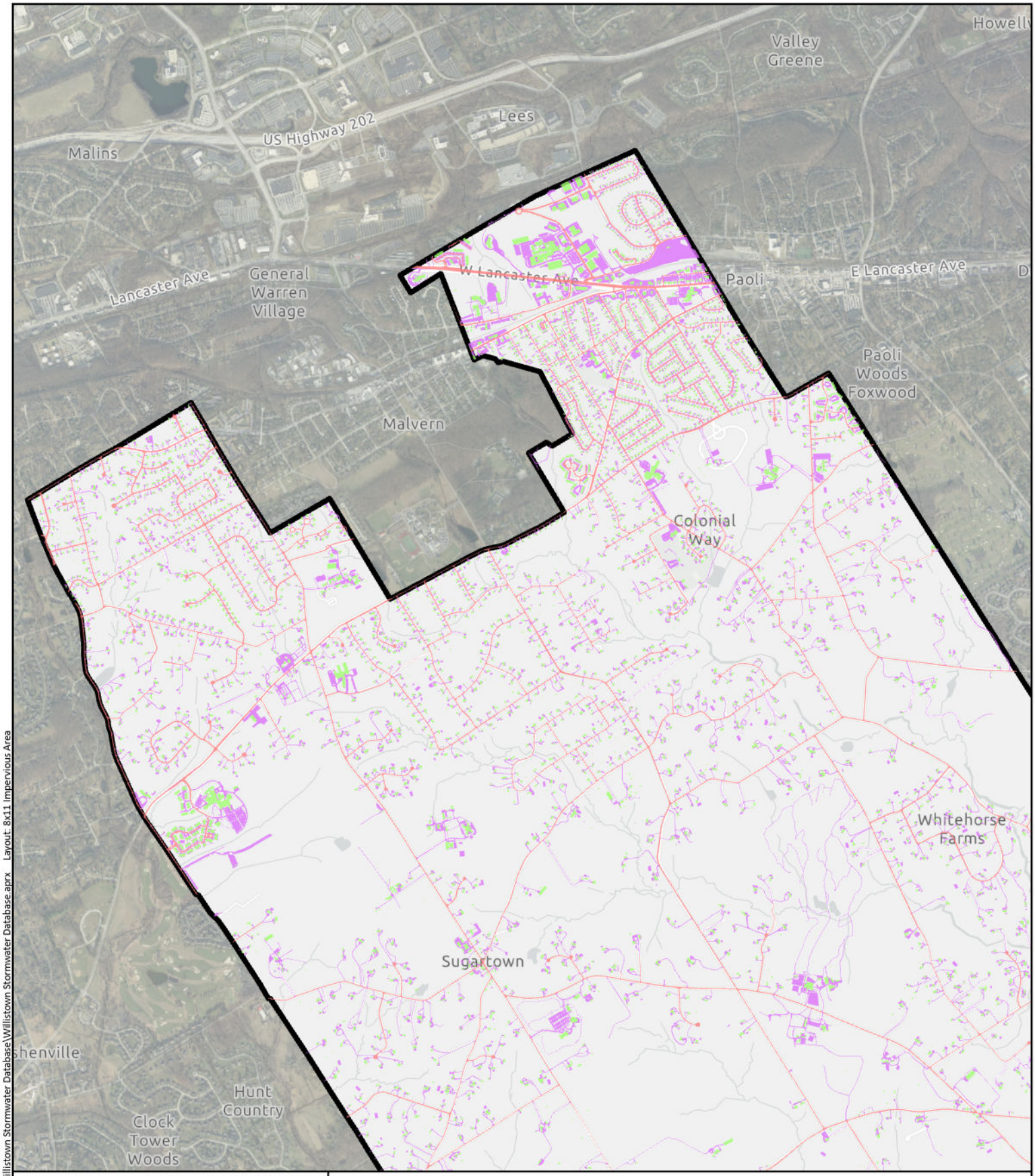
- Willistown Boundary
- Crum Creek
- Little Valley Creek
- Ridley Creek

Map 9 - Willistown Watersheds

Willistown Township
Chester County, Pennsylvania

P:\0102\010218_0425\GIS\Projects\Willistown Stormwater Database\Willistown Stormwater Database.aprx Layout: 8x11 Watershed



0 0.35 0.7 Miles

N

Mapping derived from data provided by ESRI, PennDOT, and USGS.

4/16/2024	PM: JA	GIS: RBG	QA: JA	R012018.0425

Building
Other
Road
Willistown Boundary

Map 10 - Impervious Areas (North)

Willistown Township
Chester County, Pennsylvania

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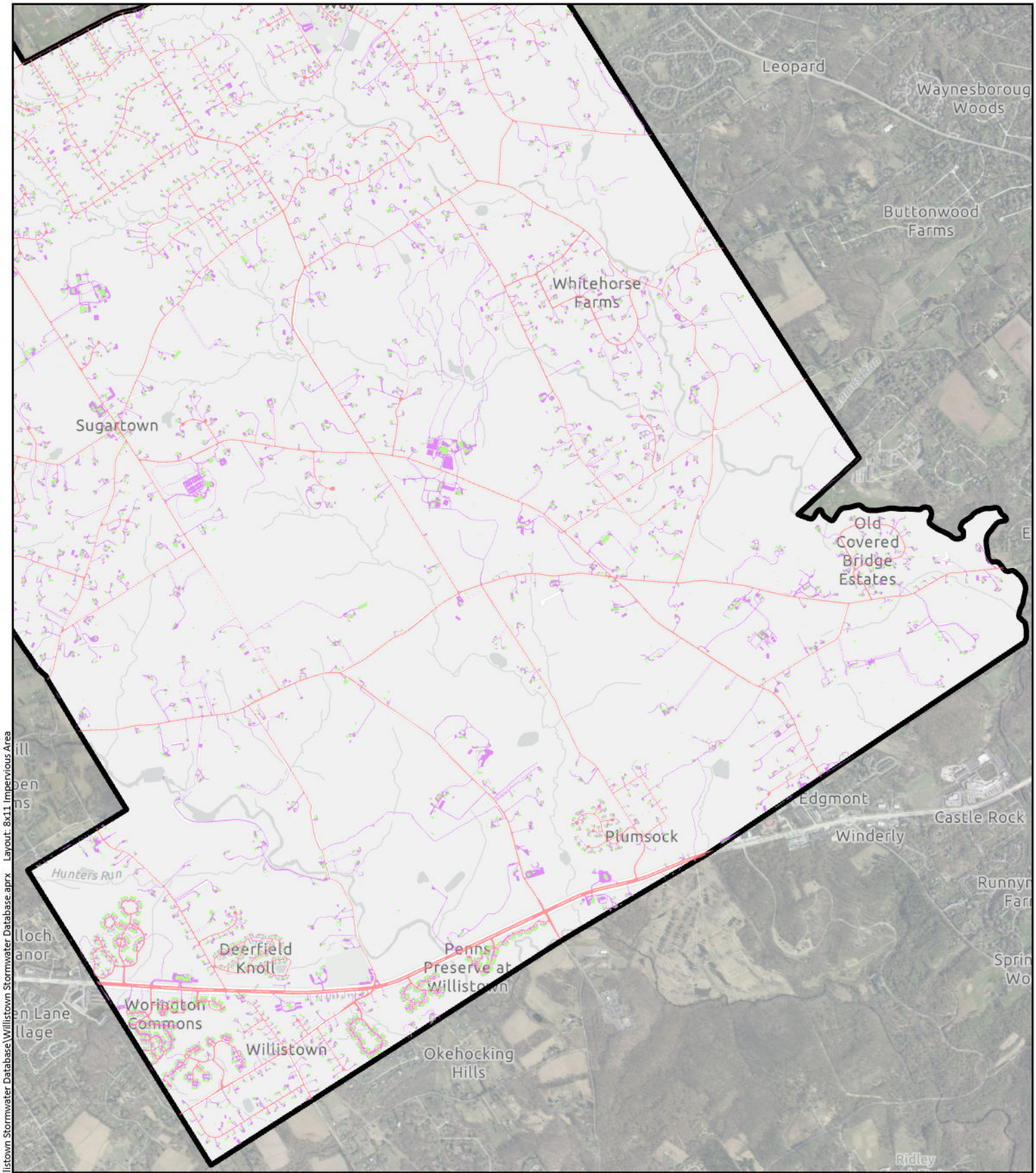
P:\0102\010218_0425\GIS\Projects\Willistown Stormwater Database\Willistown Stormwater Database.aprx Layout: 8x11 Impervious Area



0 0.35 0.7 Miles

N

Mapping derived from data provided by ESRI, PennDOT, and USGS.

4/16/2024	PM: JA	GIS: RBG	QA: JA	R012018.0425

Building
Other
Road
Willistown Boundary

Map 11 - Impervious Areas (South)

Willistown Township
Chester County, Pennsylvania

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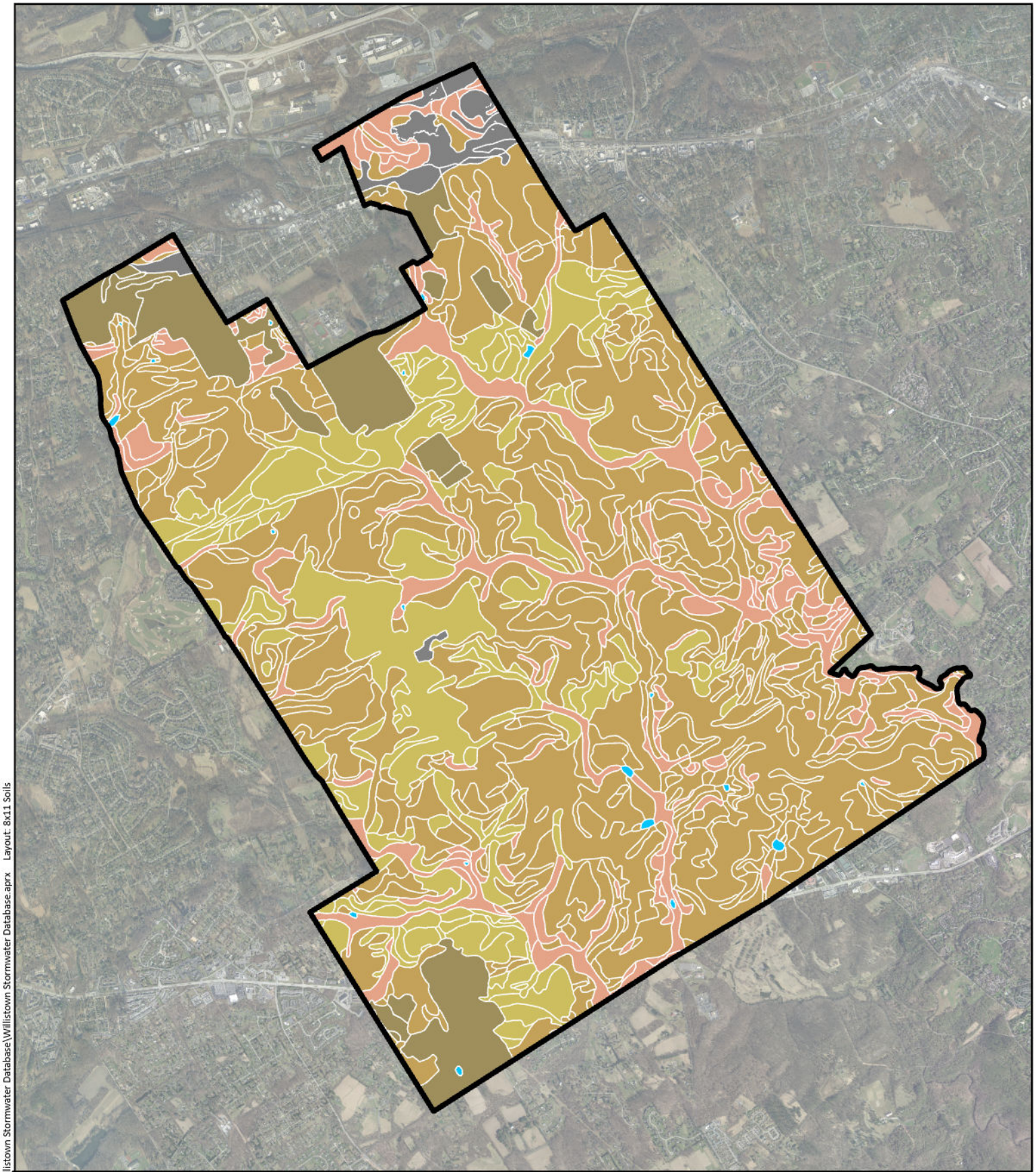
P:\0102\010218_0425\GIS\Projects\Willistown Stormwater Database\Willistown Stormwater Database.aprx Layout: 8x11 Impervious Area



N

0 0.5 1 Miles

Mapping derived from data provided by ESRI, PennDOT, and USGS.

4/16/2024	PM: JA	GIS: RBG	QA: JA	R012018.0425

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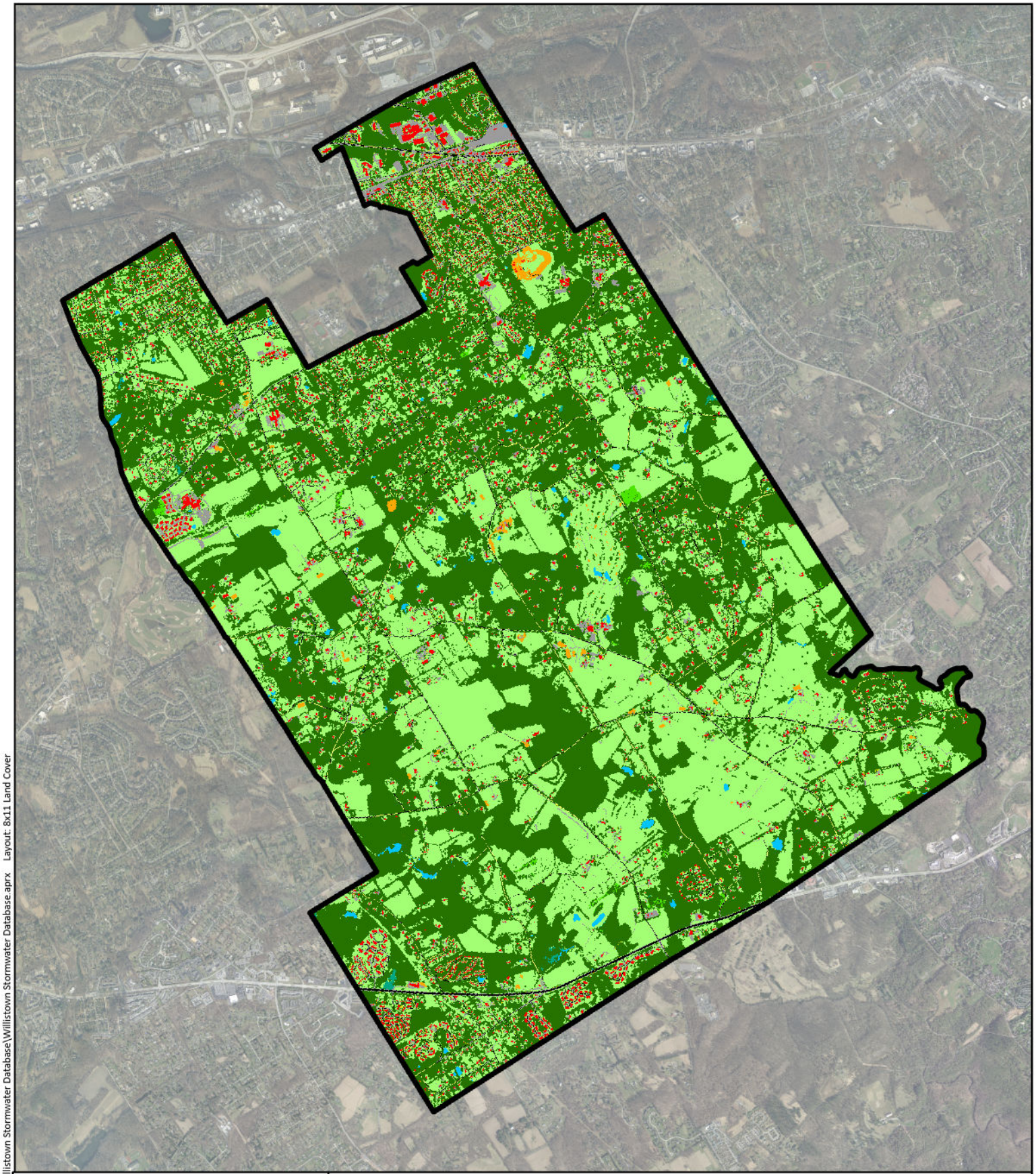
Map 12 - Hydrologic Soil Cover

Willistown Township
Chester County, Pennsylvania

P:\0102\010218_0425\GIS\Projects\Willistown Stormwater Database\Willistown Stormwater Database.aprx Layout: 8x11 Soils



N

0 0.5 1 Miles

Mapping derived from data provided by ESRI, PennDOT, and USGS.

4/16/2024	PM: JA	GIS: RBG	QA: JA	R012018.0425

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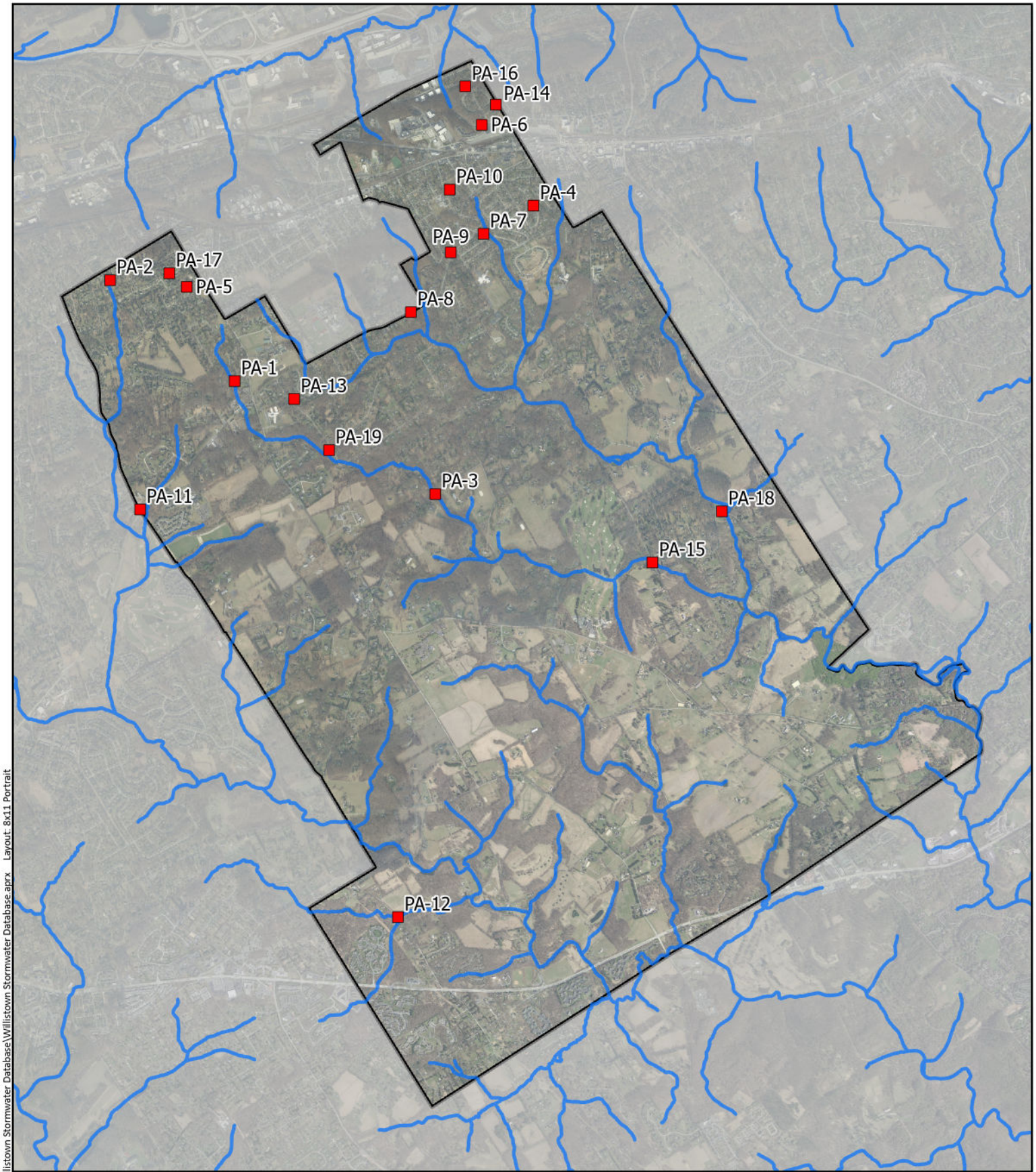
- Willistown Boundary
- Water
- Emergent Wetlands
- Tree Canopy
- Scrub\Shrub
- Herbaceous
- Barren
- Structures
- Other Impervious
- Roads
- Tree Canopy over Structures
- Tree Canopy over Other Impervious
- Tree Canopy over Roads

Map 13 - Land Cover (2017/2018)

Willistown Township
Chester County, Pennsylvania

P:\0102\010218_0425\GIS\Projects\Willistown Stormwater Database\Willistown Stormwater Database.aprx Layout: 8x11 Land Cover



N

0 2,500 5,000 Feet

Mapping derived from data provided by ESRI, PennDOT, and USGS.

4/15/2024	PM: JA	GIS: RBG	QA: JA	R012018.0425

Stormwater Concerns

Chapter 93 Streams

Willistown Boundary

Map 14 - Known Problem Areas

Willistown Township
Chester County, Pennsylvania

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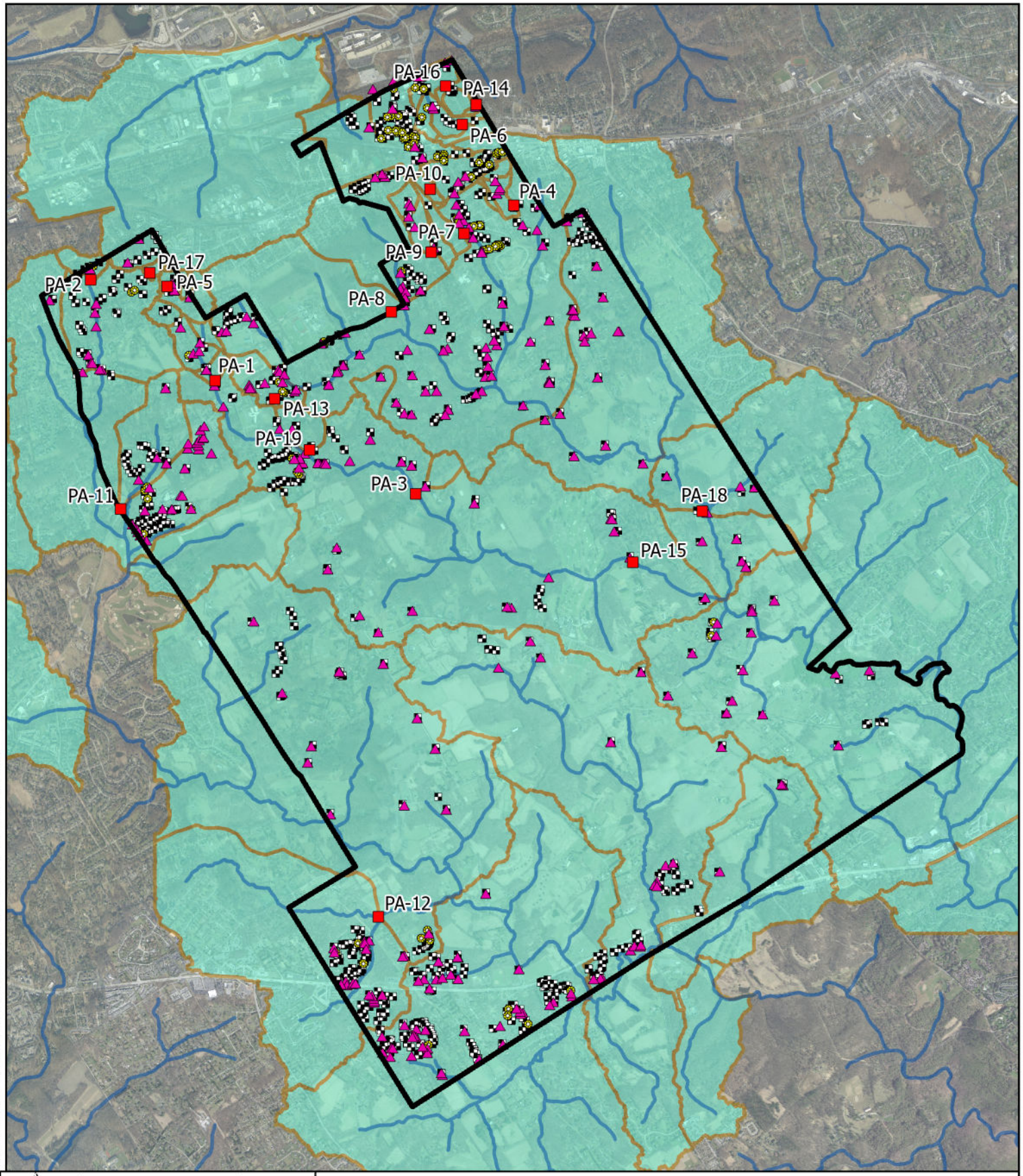
P:\0102\010218_0425\GIS\Projects\Willistown Stormwater Database\Willistown Stormwater Database.aprx Layout: 8x11 Portrait



N

0 0.5 1 Miles

Mapping derived from data provided by ESRI, PennDOT, and USGS.

4/16/2024	PM: JA	GIS: RBG	QA: JA	R012018.0425

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- Outfalls and Outlets
- Manholes
- Inlets
- Stormwater Concerns
- Chapter 93 Streams
- Willistown Boundary
- Problem Area Drainage Basins

Map 15 - H&H Base and Problem Areas Models

Willistown Township
Chester County, Pennsylvania

P:\0102\010218_0425\GIS\Projects\Willistown Stormwater Database\Willistown Stormwater Database.aprx Layout: 8x11 H&H Model

APPENDIX E: FUNDING MATRIX

STORMWATER MITIGATION FUNDING SOURCES				
AGENCY	PROGRAM NAME	GRANT (% FUNDED) OR LOAN	BRIEF DESCRIPTION	OPEN FUNDING ROUND (TYPICAL)
Commonwealth Financing Authority (CFA)	Local Shae Account (LSA) – Statewide	Grant (100%)	Provides funding for projects that improve the quality of life in the community	September – November
Commonwealth Financing Authority (CFA)	Flood Mitigation Program	Grant (85%)	Projects authorized by a flood protection authority, DEP, the ACOE, NCRS, or identified by a local government for flood mitigation	Due in May
Commonwealth Financing Authority (CFA)	Watershed Restoration and Protection Program	Grant (85%)	Construction, improvement, expansion, repair, maintenance, or rehabilitation of new or existing watershed protection BMPs, as well as improving impairs streams	Due in May
Commonwealth Financing Authority (CFA)	PA Small Water and Sewer Program	Grant (85%)	Construction, improvement, expansion, repair, or rehabilitation of water/sewer system	Varies
Commonwealth Financing Authority (CFA)	H2O PA – Flood Control Projects	Grant	Construction, improvement, expansion, repair, or rehabilitation of all or part of a flood control system.	Varies
Commonwealth Financing Authority (CFA)	H2O PA – Water Supply, Sanitary Sewer and Storm Water Projects	Grant (50%)	Acquisition, construction, improvement, expansion, or rehabilitation of drinking water, sanitary sewer, and storm sewer projects	Varies
PA Dept. of Environmental Protection (DEP)	Growing Greener Plus	Grant (85%)	Watershed protection and restoration, abandoned surface mine reclamation, and abandoned oil and gas well plugging projects	Due in June
PA Infrastructure Investment Authority (PENNVEST)	Clean Water State Revolving Fund	Loan	Affordable financing for wastewater, drinking water, or stormwater projects throughout PA	Quarterly

AGENCY	PROGRAM NAME	GRANT (% FUNDED) OR LOAN	BRIEF DESCRIPTION	OPEN FUNDING ROUND (TYPICAL)
U.S. Environmental Protection Agency (EPA)	Sewer Overflow and Stormwater Reuse Municipal Grants Program	Grant (80%)	For planning, design, and construction of critical stormwater infrastructure projects	Varies
Federal Emergency Management Agency (FEMA)	Flooding Mitigation Assistance Grant Program	Grant (75%)	Implement measures that reduce or eliminate the long-term risk of repetitive flood damage to buildings, homes, or other structures insured under NFIP	Varies
National Fish & Wildlife Foundation (NFWF)	Delaware River Program	Grant	Conserve and restore fish and wildlife habitat and water quality in the Delaware River watershed as well as benefit the quality of life and economic vitality of its communities	Due in March
Delaware Valley Regional Planning Commission	Transportation and Community Development Initiative	Grant (100%)	Supports smart growth initiatives that implement the 2050 Plan for Greater Philadelphia	Due in March