2.0 Watershed Study Methodology

2.1 Watershed Management Areas and Subwatersheds

Fairfax County contains 30 watersheds, including the Nichol Run and Pond Branch Watersheds. A watershed is the land area where all of the water that is under it or drains off of it goes into the same place. They are defined by the topography of the area and do not follow county, state or national boundaries. The size of a watershed can vary from a few acres for a small stream to many square miles for a large river. The watersheds within Fairfax County are part of the larger Potomac River basin. The Potomac River, in turn, is part of the even larger Chesapeake Bay Watershed, which drains 64,000 square miles and extends from New York through Pennsylvania, Delaware, West Virginia, Maryland, Virginia and the District of Columbia.

For management and planning purposes, watersheds are further broken down into watershed management areas (WMAs) and subwatersheds. A WMA is generally four square miles (2,560 acres) in size and is the contributing drainage area to a major tributary or a group of subwatersheds with similar characteristics. A subwatershed ranges in size from 100 to 300 acres. Due to their smaller size, WMAs and subwatersheds are easier to target for specific watershed management and restoration strategies. The WMAs in the Nichol Run and Pond Branch watersheds are shown in Figure 2.1.

2.2 Existing and Future Land Use

One of the leading causes of stream degradation, including water quality impairments and habitat decline, is changes in land use. As shown in Figure 1.3 in Chapter 1, the Nichol Run and Pond Branch watersheds are moderately developed. Monitoring changes in land use will provide critical information to the overall health of the watersheds. For example, high density residential, commercial and industrial land uses generally produce higher stormwater runoff volumes and pollutant loads, whereas open space and estate residential land uses have a much lower impact on the health of the watershed.

For this study, the existing and future land use within the Nichol Run and Pond Branch watersheds were analyzed to assist with the selection of areas for field reconnaissance. The open space land use was compared to the buildings layer using the county's Geographic Information System (GIS) to determine areas of new construction. The areas thought to be newly constructed were field-verified to ensure accuracy. The land use GIS was updated to reflect changes found during the field reconnaissance. The land use GIS was also used to identify neighborhoods and other development areas for the Neighborhood Source Assessments (NSA), which are described further in Chapters 3 and 4. At least one representative neighborhood was chosen per WMA, based upon the land use within the area. The existing and future land use data will be further utilized to identify current and future management opportunities and project areas to better achieve the county's goals and objectives.

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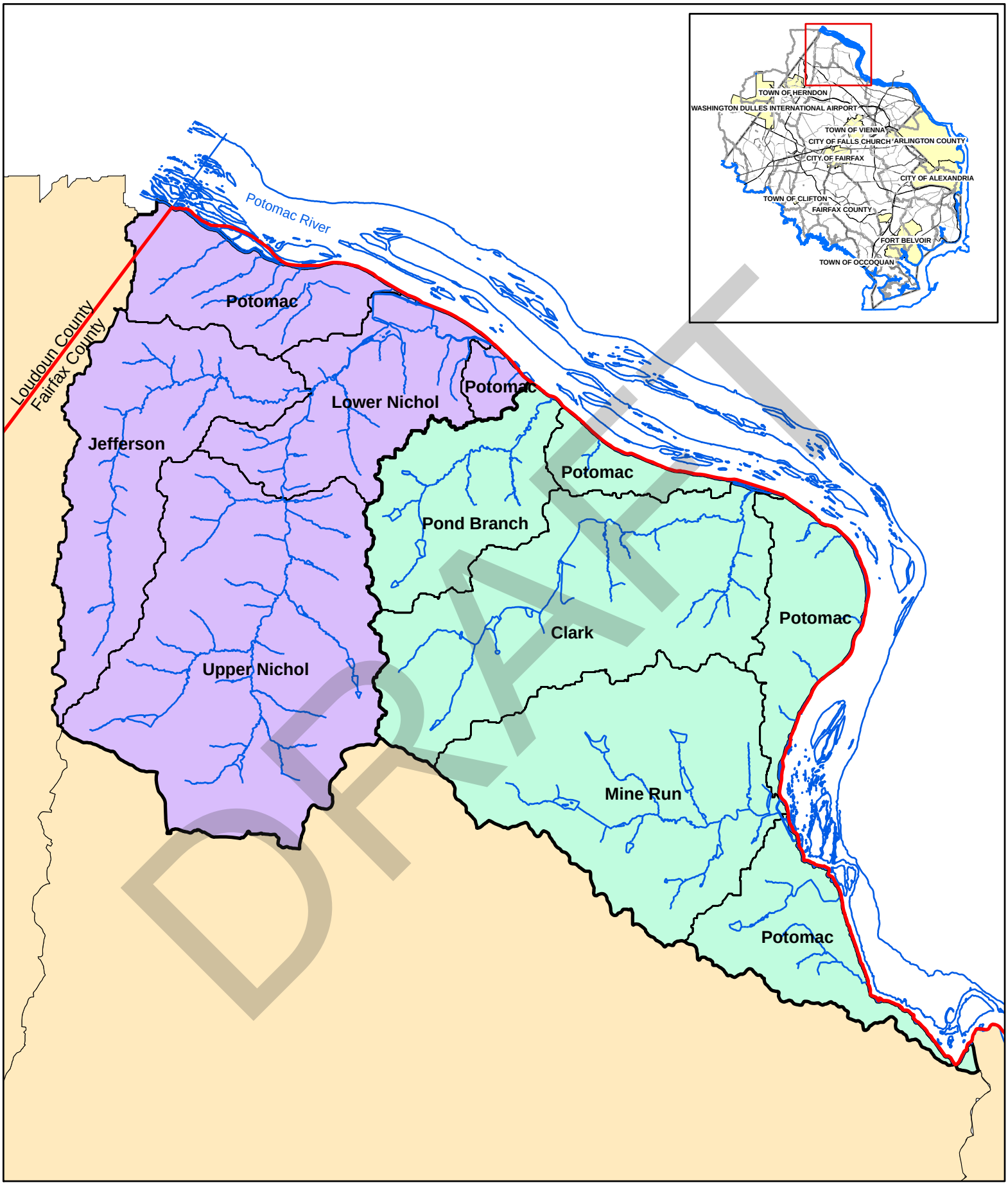

N

0 0.15 0.3 0.6 Miles

Perennial Streams
Nichol Run Watershed
Pond Branch Watershed
Other Fairfax County Watersheds
Fairfax County Boundary

Figure 2.1
Nichol Run and Pond Branch WMAs

2.3 Field Reconnaissance and Stream Physical Assessment

Field reconnaissance was conducted to update and supplement existing Fairfax County GIS data so current field conditions were accurately represented. Once these data were acquired, spatial analysis was performed to characterize county watersheds as they currently exist using the county's GIS. The reconnaissance effort included the identification of pollution sources, current stormwater management practices and potential restoration opportunities across the various watersheds.

Fairfax County conducted a physical stream assessment in 2005 to obtain baseline data for the County's streams, as described in Chapter 1. A supplemental physical stream assessment was completed during the summer of 2008. Approximately three miles of stream within the Nichol Run and Pond Branch watersheds were surveyed. The assessment included portions of Nichol Run, Harkney Branch and Mine Run Branch. The original physical stream assessment protocol was followed which included a habitat assessment, an infrastructure inventory, stream characterization, and a Channel Evolution Model assessment. The infrastructure inventory identified and characterized the following:

- Ditches
- Dump sites
- Erosion areas
- Head cuts
- Obstructions
- Pipes
- Road and other stream crossings
- Utility lines

The habitat assessment and stream characterization served to document the stream physical conditions, while the Channel Evolution Model assessment evaluated the stability of the stream. The Channel Evolution Model can define the stages the stream channel geomorphology will take after a disturbance, and can be used to predict future conditions. Geomorphology is the process by which stream channels adjust to changes within the associated watershed. Stream geomorphology is a natural process that occurs slowly over time. The features of a stream channel are determined by the type of soil, the slope, and the flow experienced by the channel. Alterations to the watershed will lead to changes in the stream channel; the channel will rework itself to meet the new watershed conditions. Figure 2.2 shows the five stages of geomorphic condition in the Channel Evolution Model.

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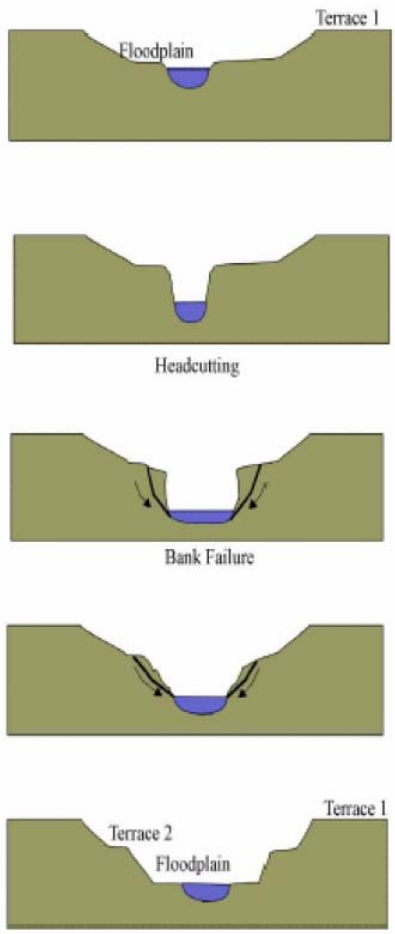

Type 1: Well-developed base flow and bankfull channel; consistent floodplain features easily identified; one terrace apparent above active floodplain; predictable channel morphology; floodplain covered by diverse vegetation; stream banks less than or equal to 45°

Type 2: Head cuts; exposed cultural features (along channel bottom); sediment deposits absent or sparse; exposed bedrock (parts of reach); stream bank slopes greater than 45°

Type 3: Stream bank sloughing, sloughed material eroding; stream bank slopes greater than 60° or vertical/undercut; erosion on inside of bends; accelerated bend migration; exposed cultural features (along channel banks); exposed bedrock (majority of reach)

Type 4: Stream bank aggrading; sloughed material not eroded; sloughed material colonized by vegetation; base flow, bankfull, and floodplain channel developing; predictable channel morphology developing; stream bank slopes less than or equal to 45°

Type 5: Well-developed base flow and bankfull channel; consistent floodplain features easily identified; two terraces apparent above active floodplain; predictable channel morphology; stream banks less than or equal to 45°

Figure 2.2 Channel Evolution Model Stages (Schumm, et al., 1984)

Along with habitat assessments, the stream reaches were placed in one of five stages of geomorphic condition in the Channel Evolution Model (CEM). Approximately 91 percent of the Nichol Run Watershed was in Evolutionary Stage 3. This is the widening stage and is characterized by streambank sloughing, erosion on insides of bends, accelerated bed migration, and exposed bedrock. The majority of channels in the Pond Branch Watershed were also determined to be in Evolutionary Stage 3 (Fairfax County, 2001).

2.4 Watershed Characterization

Successful management of a watershed requires the assessment of the interactions between pollutant sources, watershed stressors, and conditions within streams and other waterbodies. The goal is to identify existing and potential problem areas and evaluate subwatershed restoration opportunities. This requires a direct evaluation of the existing stream conditions and stormwater infrastructure, streambank erosion, flooding, unique watershed conditions, water quality problems, and other factors relating to the ecosystem and stormwater drainage network.

The watershed characterization data obtained from previous studies and provided by the county were used to create maps to characterize the watersheds. Two types of maps were developed: stream condition maps and stormwater infrastructure maps. The stream condition maps display the overall health and stability of the streams within the watersheds and the stormwater infrastructure maps display the extent and type of stormwater management facilities within the watersheds. Chapters 3 and 4 provide more detailed information on a WMA scale.

2.5 Modeling

Storm events are classified by the amount of rainfall, in inches, that occurs over the duration of a storm. The amount of rainfall depends on how frequently the storm will statistically occur and how long the storm will last. Based on many years of rainfall data collected, storms of varying strength have been established based on the duration and probability of that event occurring within any given year. In general, smaller storms occur more frequently than larger storms of equal duration. Hence, a 2-year, 24-hour storm (having a 50% chance of happening in a given year) has less rainfall than a 10-year, 24-hour storm (having a 10% chance of happening in a given year). Stormwater runoff (which is related to the strength of the storm) is surplus rainfall that does not soak into the ground. This surplus rainfall flows (or 'runs off') from roof tops, parking lots and other impervious surfaces and is ultimately received by storm drainage systems, culverts and streams.

Modeling is a way to mathematically predict and spatially represent what will occur with a given rainfall event. There are two primary types of models that are used to achieve this goal; hydrologic and hydraulic:

- Hydrologic models take into account several factors: the particular rainfall event of interest, the physical nature of the land area where the rainfall occurs and how quickly the resulting stormwater runoff drains this given land area. Hydrologic models can describe both the quantity of stormwater runoff and the resulting pollution, such as nutrients (nitrogen and phosphorus) and sediment that are transported by the runoff.

- Hydraulic models represent the effect the stormwater runoff from a particular rainfall event has on both man-made and natural systems. Hydraulic models can predict both the ability of man-made culverts/channels to convey stormwater runoff and the spatial extent of potential flooding.

Table 2.1 shows three storm events and the rationale for modeling.

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Table 2.1 Rationale for Storm Event Modeling

Storm Event	Rationale for Modeling
2-year, 24-hour	Represents the amount of runoff that defines the shape of the receiving streams.
10-year, 24-hour	Used to determine which road culverts will have adequate capacity to convey this storm without overtopping the road.
100-year, 24-hour	Used to define the limits of flood inundation zones

For this study, the Storm Water Management Model (SWMM), a hydrologic model developed by the U. S. Environmental Protection Agency (EPA), was used to quantify stormwater runoff. SWMM is a dynamic rainfall-runoff simulation model that can simulate runoff quantity and quality for single rain event or long-term conditions in primarily urban areas. It was used in this project to estimate the quantity of stormwater runoff at specific pre-determined locations within the watershed and calculate the peak rate of those flows at these locations as well. Specifically, the runoff component of SWMM operates on a collection of treatment areas within subwatersheds on which rain falls and runoff is generated. The routing portion of SWMM transports this runoff through a conveyance system of pipes, channels and storage/treatment devices. SWMM tracks the quantity of runoff generated within each treatment area, and the flow rate and flow depth of water in each pipe and channel during a simulation period comprised of multiple time steps.

The Spreadsheet Tool for Estimating Pollutant Loading (STEPL) developed by the U. S. EPA Office of Water is another hydrologic model used to estimate the quantity of pollution and sediment transported by stormwater runoff. The STEPL model employs simple algorithms to calculate nutrient and sediment loads from different land uses and the load reductions that would result from the implementation of various best management practices. The nutrient loading is calculated based on the runoff volume and the pollutant concentrations in the runoff water as influenced by factors such as the land use distribution and management practices. Sediment loads are calculated based on the Universal Soil Loss Equation (USLE) and the sediment delivery ratio. The sediment and pollutant load reductions that result from the implementation of BMPs are computed using known BMP efficiencies.

The hydraulic model used in this project is the Hydrologic Engineering Centers River Analysis System (HEC-RAS) model developed by the United States Army Corps of Engineers (USACE) to manage rivers and harbors under their jurisdiction. The model is a one dimensional program that provides no direct modeling of the hydraulic effect of cross section shape changes, bends, and other two- and three-dimensional aspects of flow. Aside from this limitation, the model has found wide acceptance in simulating the hydraulics of water flow through natural and/or manmade channels and rivers. HEC-RAS is commonly used for modeling water flowing through a system of open channels with the objective of computing water surface profiles. The computed surface profiles are then used to predict and evaluate conveyance capability of culverts and bridges and determine the spatial extent of potential flooding dependent on the specific topography in the area of interest.

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2.6 Subwatershed Ranking

The purpose of the subwatershed ranking is to provide a systematic means of compiling available water quality and natural resources information. Ranking subwatersheds based on watershed characterization and modeling results provides a tool for planners and managers to set priorities and to use as they consider which subwatersheds should undergo further study.

Three basic indicator categories are used to rank subwatershed conditions including watershed impact indicators, source indicators, and programmatic indicators. These indicator categories are described below.

Watershed impact composite scores are calculated by analyzing a variety of indicators including channel morphology, flooding hazards, aquatic/terrestrial habitat and water quality.

Source indicator composite scores were calculated by analyzing a variety of pollutant sources and environmental stressors, including urban land cover, channelized streams, industrial and stormwater outfalls, septic systems and water quality. They provide information on the source of watershed impacts and stressors.

Programmatic indicators describe the existence or benefits of stormwater management facilities and programs. There is no scoring associated with programmatic indicators; however, a data inventory will be compiled in order to help determine where stormwater management is needed most during candidate project identification.

The scores from these indicators are rolled up into composite scores which are used in the prioritization and subwatershed ranking process. In cases where a subwatershed did not have any reported data for a particular indicator, or data was only geographically available for a portion of the subwatershed (e.g., headwaters only), the metric value from another subwatershed with reported data ("reference subwatershed") was used. Several factors were considered when assigning surrogate metric values. These factors are listed in priority order below.

1. Land use and land cover distribution based on the Virginia Department of Forestry's 2005 Virginia Forest Cover Map.
2. Location of reference subwatershed (within the same WMA was preferable).
3. Similar drainage area.
4. Proximity of reference subwatershed.
5. Similar stream order (e.g., headwater, major waterway stem, main stem outlet).
6. Hydrologic connectivity.

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