Appendix D -
Watershed Modeling Process

January 25, 2008

Final

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Table of Contents

List of Figures

List of Tables

1.0 Introduction

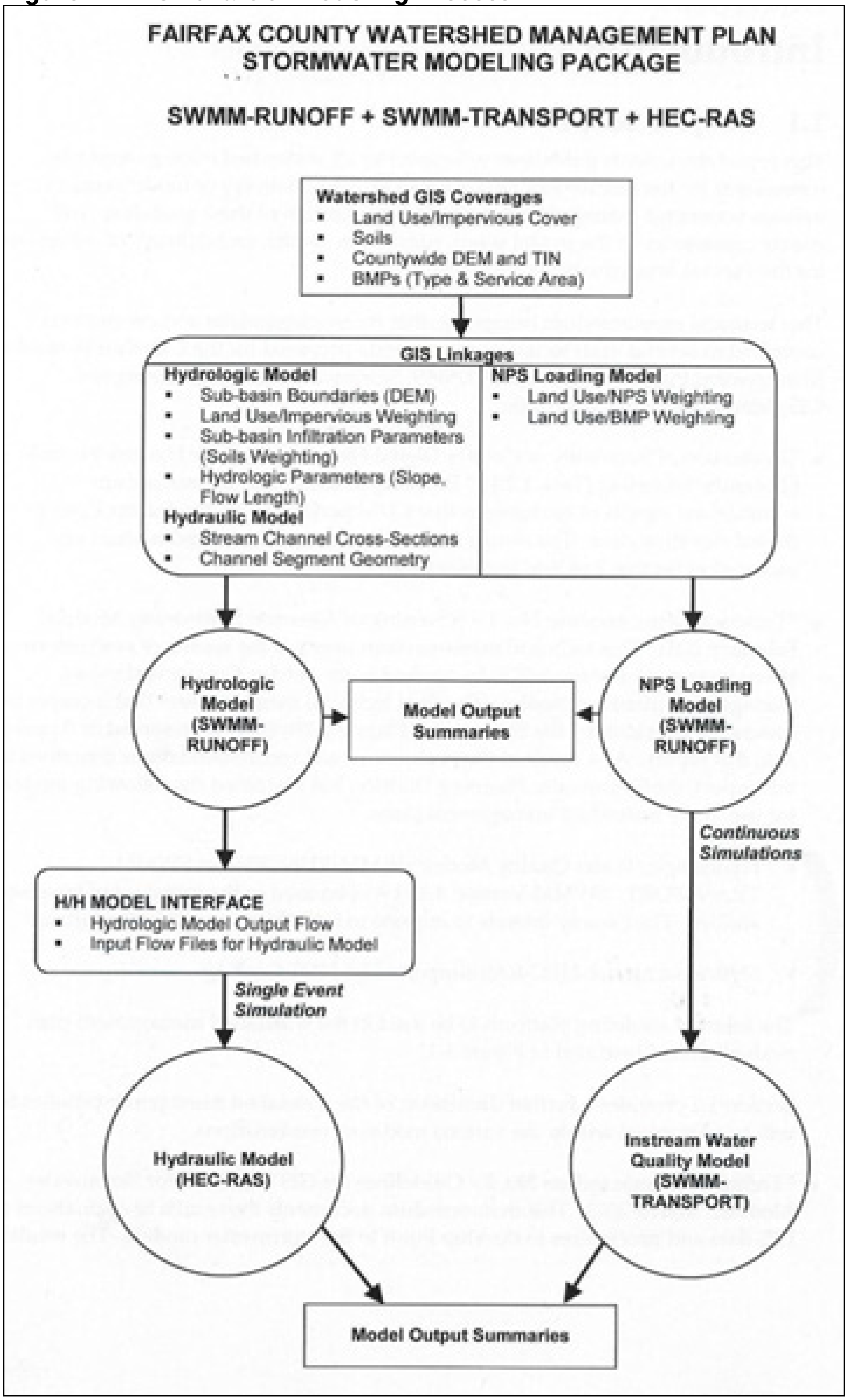
Hydrologic, water quality, and hydraulic models were developed to simulate the existing and future development conditions in the watershed and to evaluate the benefits of proposed BMPs on the watershed runoff and water quality. The county provided guidelines for the modeling process which were outlined in the document *Technical Memorandum No. 3, Stormwater Model and GIS Interface Guidelines,* June 2003 (TM3). This document supplements the information found in TM3 and explains some of the specific parameters and procedures used to model the Middle Potomac Watersheds.

The goals established by the county for the modeling process are as follows:

- Predict the existing water quality and flow conditions in the watershed
- Determine the impacts of development projected to occur in the watershed
- Quantify the benefits provided by various stormwater management measures
- Identify stream crossing flooding and improvements
- Justify the overall benefits of watershed management planning alternatives

Two separate computer models, a hydrologic/water quality model and a hydraulic model, were used to predict the existing and future conditions in the watershed and to evaluate the proposed alternatives. The hydrologic/water quality model was used to calculate the stormwater runoff flows and to estimate amount of pollutants in the runoff. The hydraulic model was used to simulate the stream hydraulics to predict the in-stream velocities and water surface elevations. The modeling process is illustrated in Figure 1.1 as described in TM3.

Figure 1.1 Flowchart of Modeling Process



Source: Technical Memorandum No. 3 (June 2003)

2.0 Hydrologic Model

The hydrologic model was used to calculate stormwater runoff for each subbasin in the watershed. The software used for the hydrologic model was XP-SWMM V10.5, which was chosen for the ease of use when importing and exporting GIS files and the ability to modify a model-generated .dat file within EPA-SWMM 5.0h.

2.1 Development of Hydrologic Parameters

For calculating runoff within SWMM, there were four key parameters; the area, the width (a parameter that affects the peak runoff rate and the shape of the runoff hydrograph), the slope, and the percent imperviousness of the ground surface.

2.1.1 Subbasin Delineation and DEM Based Parameters

The first step in the modeling process was to create the digital elevation model (DEM) for the watershed. Using ArcGIS, the DEM for the Middle Potomac Watersheds was clipped from the Fairfax County DEM using a buffer of 1,000 feet outside of the original Middle Potomac Watersheds boundary that was provided by the county. The Pimmit Run Watershed includes a portion of Arlington County which was also added to the DEM. After the DEM was clipped, ArcHydro Tools for Arc 8 were used to complete the following tasks:

- Create the stream centerline using “Stream Definition”
- Create the stream sections using “Stream Segments”
- Create subbasins for each watershed
- Create outlets for the subbasins which were adjusted for the location of the crossings and the reach data

The 16,672-acres of the Middle Potomac Watersheds were divided into the five major watersheds: Pimmit Run, Scotts Run, Bull Neck Run, Dead Run, and Turkey Run. Each watershed was then divided into smaller subbasins with areas ranging between 100 and 300 acres with an average subbasin size of 194 acres. The subbasins were created automatically using the DEM and ArcGIS. There were a total of 86 subbasins delineated within the Middle Potomac Watersheds as presented in Table 2.1. After the automatic delineation, the subbasin boundaries were manually checked by comparing the boundary with the location of the drainage system and the boundary lines were adjusted as necessary. The StormNet inventory was compared with the subbasin delineation to ensure accuracy and the subbasins were updated as necessary.

Table 2.1 Number of Subbasins per Watershed

Watershed Name	Acreage of Subwatershed (ac)	No. of Subbasins	Average Acreage of Subbasins (ac)
Pimmit Run	8,083	37	218
Bull Neck Run	1,559	11	142
Scotts Run	3,860	20	193
Dead Run	1,922	11	175
Turkey Run	1,248	7	178
Total	**16,672**	**86**	**194**

After the initial delineation, the outlet points or pour points for the subbasins were adjusted to ensure that the cross sections for HEC-RAS were upstream of a crossing or stream junction. Other tasks for delineation included:

- Adjusting the subbasin boundaries to the stream reach locations
- Adjusting the subbasin boundaries to the stream crossing locations
- Checking for one-to-one relationships between drainage outlet points and subbasins

The subbasin delineations were then finalized and submitted to the county for final approval. Map 2.4 displays the final delineation as approved by the county and is provided at the end of Chapter 2.

After the final subbasin delineation was approved by the county, the following steps were performed:

- Subbasin IDs were generated for all subbasins in accordance with Appendix C of TM3. For subbasin PM-PM-001, the first two letters denote the watershed name is Pimmit Run Watershed, the second two letters denote the stream name is the main stem of Pimmit Run, and the last three numbers denote the subbasins numbered from downstream to upstream.
- Subbasin IDs were applied to the drainage points of subbasins for the XP-SWMM RUNOFF nodes

2.1.2 Stormwater Management Subareas

Each of the 86 subbasins was divided into three separate subareas based on the parcel control GIS data provided by the county. The subareas were created in order to simulate areas with stormwater management controls. The three areas within each subbasin were labeled A, B, and C, with the A subareas representing those areas which drain to a peak-shaving detention storage facility, the B subareas representing those areas which drain to a water quality and peak-shaving detention storage facility, and the C subareas representing those areas which are uncontrolled. Duplicate parcels occupying the same horizontal location were deleted using the “remove duplicates” command within ArcGIS.

Using the parcel control file provided by the county, the parcels were intersected with the subbasin boundaries and the parcels were designated as an “A”, “B”, or “C” type. The parcel control data was compared to the BMP inspection database to verify the location of the controlled parcels. The StormNet inventory of stormwater management facilities was also reviewed to check the parcel control designation.

The parcel control designation was based on the following parameters:

- The "A" subarea parcels included "Det1", "Det2", and "Det3" attributes which included all parcels that were developed between 1972 and 1994.
  - DET1: Detention only, parcel is residential (detached/townhome), post 1978 parcel creation, < five acres
  - DET2: Detention only, parcel is residential, 1972-1978 build date, < five acres
  - DET3: Detention only, parcel is not residential, post 1972 build date
- The "B" subarea parcels included "DetBMP1" and "DetBMP2" attributes which included parcels developed after 1994 and were mandated to incorporate both detention and water quality control BMPs.
  - DETBMP1: Detention and water quality control, parcel is residential, post 1994 parcel creation, < five acres
  - DETBMP2: Detention and water quality control, parcel is not residential, post 1994 build date
- The "C" subarea value was assigned to those parcels that did not have any stormwater management controls, such as roadways.

2.1.3 Subbasin Width

The subbasin width represents the average width of overland flow in a subbasin and affects the shape of the hydrograph. The width of each subbasin was calculated using the formula from the SWMM User's Manual. The skew factor was determined by taking the area on one side of the main channel and subtracting it from the area on the other side of the main channel. This difference in the area was then divided by the total area. The skew is then subtracted from two, which should produce a number between zero and two and multiplied by the basin length. The basin flow path length is the difference between the most hydrologically distant part of the watershed and the most downstream point in the watershed located in the channel. This flow path was visually determined from the contours and the stormwater system tiff images. The formulas for the width calculations are as follows:

$$W = (2 - S_k) \times l$$

$$S_k = {(A_2 - A_1)}/{A_{Total}}$$

W = Subcatchment Width

l = Length of Main Channel

S_k = skew factor, $0 < S_k < 1$

A_1 = Area to one side of channel

A_2 = Area to other side of channel

A_{Total} = Total Area

2.1.4 Subbasin Slope

The slope of the subbasin was determined by subtracting the farthest downstream elevation from the farthest upstream elevation along the flow path of each subbasin and dividing by the length of the flow path. The upstream and downstream elevations were obtained from the county's GIS data.

2.2 Soil Infiltration Parameters

2.2.1 Digital Soils Data

The soils GIS data was used to calculate each of the subbasins' infiltration parameters for the pre-development, existing, and future development conditions. The two sources of data were the:

- Fairfax County GIS soils mapping
- Natural Resource Conservation Service (NRCS) STATSGO soils mapping

The primary source of data used for the infiltration parameters was the Fairfax County soils database and mapping. The NRCS State Soils Geographic (STATSGO) database and mapping was used to supplement the watershed areas that lacked coverage by the county soils information. The steps for formatting the soil data were as follows:

1. The Fairfax County soils data and the NRCS data were clipped from the countywide maps with a boundary of 2,000 feet around the Middle Potomac Watersheds.
2. For the county mapping, each soils polygon was assigned a number from 1 through 4, with 1 assigned to Hydrologic Soils Group (HSG) "A" and 4 assigned to HSG "D". The NRCS soils data already contained the HSG value within the database.
3. The county soils map and NRCS soils map were intersected. Where the county soils and the NRCS data overlapped, the county data replaced the NRCS soils data.
4. The weighted HSG for the entire subbasin was calculated by multiplying the area of the soil polygon by the assigned HSG number. The HSG area value was then divided by the entire area of the subbasin to calculate the weighted HSG number

2.2.2 Infiltration Parameters

The Horton method was used to simulate infiltration as described in TM3. Three infiltration parameters were required for each subbasin:

- WLMAX – maximum infiltration capacity of the soil (inches/hour)
- WLMIN – minimum infiltration capacity of the soil (inches/hour)
- DECAY – exponential decay coefficient for infiltration capacity (sec^{-1})

The REGEN parameter was used during the continuous simulation to determine the rate at which the infiltration capacity regenerates after a storm has ended. The value for REGEN was 0.01. The SWMM program regenerates the infiltration capacity by setting the Horton type exponential rate constant equal to REGEN*DECAY, where the DECAY value was 0.0009 sec^{-1}.

The Horton infiltration parameters were based on the Hydrologic Soils Group (HSG) value for the soils polygon. Using the values as shown in Table 2.2, the Horton parameters WLMAX and WLMIN were interpolated using the weighted HSG value for each subbasin.

Table 2.2 Relationship between the Horton Model Parameters and the Hydrologic Soil Group

Horton Parameters	Hydrologic Soil Group			
	A	B	C	D
Weighting Value	1	2	3	4
WLMAX (inches/hour)	6	4	3	2
WLMIN (inches/hour)	0.25	0.10	0.05	0.03
DECAY (sec^{-1})	0.0009	0.0009	0.0009	0.0009

The interpolated WLMAX and WLMIN values were adjusted within ArcGIS to account for the impervious area that is not directly connected to the storm drain system (NDCIA). Each parameter was adjusted by multiplying a factor that was calculated using the equation:

Factor = PERVA / (PERVA + NDCIA)

The pervious area, PERVA, was calculated by subtracting the total impervious area from the total area of each subbasin. The NDCIA and the directly connected impervious, DCIA, were calculated as described in Section 2.4.1.

2.3 Land Use Parameters

The land use within the Middle Potomac Watersheds was used for the following tasks:

- To estimate the directly connected and not directly connected impervious area for the future conditions
- To determine the water quality parameters
- To estimate the overland flow roughness coefficients

2.3.1 Existing Land Use

The county's GIS data was used to identify the land use for the existing developed conditions. Not all of the land area was included in the county's GIS land use data. A portion of the Pimmit Run Watershed was supplemented with Arlington County's GIS data. The roadway right-of-way was another area that was not included in the land use data, and this area was assigned a land use proportional to the land uses for the parcel area in the subbasin for the water quality simulation. In the Tysons Corner region, ROW with roadway interchanges comprises a large portion of the land use. Therefore, in subbasins PM-BR-002, SC-SC-007, SC-SC-008, SC-SC-010, SC-UN-004, and SC-UN-005, the ROW was assigned to industrial (IND) land use to simulate the amount of pollutants generated from roadways instead of being assigned the land uses for the parcels in the subbasins.

2.3.2 Future Land Use

The county's GIS data was used to identify the land use for the future conditions. It was assumed that there were no underutilized or vacant parcels in the future conditions. For the underutilized and vacant parcels, the existing land use was replaced by either the planned land use or zoning land use, whichever land use represented a greater density. For the Tysons Corner area, the future land use was updated using data from the Fairfax County presentation to the Tysons Corner Coordinating Committee on July 6, 2005. All mixed land use for the Tysons Corner area was assumed to be either commercial (LIC or HIC) or industrial (IND).

2.4 Percent Impervious Parameters

The percent impervious was calculated for each of the 197 subareas of the Middle Potomac Watersheds and was based on the impervious areas of the buildings, roads, paved parking lots, unpaved parking lots, sidewalks, and driveways. The percent impervious was calculated for the existing and future development conditions. The county's GIS shapefiles that were used to calculate the impervious area included the following:

- Buildings
- Sidewalks
- Roads (Transmajor and Transminor)
- Land use (included CLU and PLU)

The percent impervious was divided between the directly connected impervious areas (DCIA) and not directly connected impervious areas (NDCIA) based on the type of land use. The directly connected impervious surface is defined as the impervious surface that directly drains to the storm drain system. An example of a DCIA would be a roadway draining directly to an inlet that is part of the storm drain system. The NDCIA is the impervious surface where water would run off the surface and infiltrate into the ground. An example of NDCIA is a residential rooftop that has a downspout where runoff discharges onto the lawn. Only the area that was directly connected to the storm drain system was included in the determination of the impervious surface for the runoff calculations. The percent DCIA for the various impervious surface types in the subbasins was assigned as listed in Table 2.3.

Table 2.3 Assigned Percent DCIA for Impervious Surface Types

Impervious Surface	Percent DCIA
Building Type	
Commercial	100%
Industrial	95%
Multi-Family Residential	90%
Non-enclosed	85%
Other	85%
Public	85%
Single Family Residential	50%
Roads	100%
Paved Parking Lots	100%

Impervious Surface	Percent DCIA
Unpaved Parking Lots	50%
Sidewalks	85%
Driveways	100%

2.4.1 Existing Conditions

The steps for determining the directly connected and not-directly connected impervious area for existing conditions were as follows:

1. Each impervious shapefile (buildings, roads, sidewalks) was intersected with the subareas which were previously assigned an A, B, or C parcel control designation. This intersection resulted in each subarea having a polygon with an A, B, or C attribute as well as the impervious area for that feature (buildings, roads, and sidewalks).
2. The driveway impervious area was calculated by multiplying the number of single family residential buildings for each subbasin by a driveway area determined by the land use. The estimated driveway area for an estate residential or low density residential building was 2,500 square feet. A medium density residential building was estimated to have a driveway area of 1,000 square feet. High density residential and Arlington County driveways were included in the roads shapefile. Single family buildings smaller than 500 square feet were excluded from the driveway area calculation since these buildings would either have been non-residential buildings that would not have driveways or would be a portion of a divided building that had been accounted for in another subarea.
3. Directly Connected Impervious Area (DCIA): The DCIA was calculated for each impervious feature (buildings, paved roads, etc.) within a subarea by multiplying the feature's impervious area by the percent DCIA, see Table 2.3.
4. Not Directly Connected Impervious Area (NDCIA): The NDCIA was calculated in the same way as the DCIA except that each impervious feature was multiplied by the percent NDCIA.
5. Within the Microsoft Access database, the DCIA for each subarea impervious feature was summed to calculate the total impervious surface for the entire subarea.
6. Lastly, the percentage of total DCIA was calculated for each subarea and this data was imported into XPSWMM.

2.4.2 Future Conditions

With the exception of the parcels identified as underutilized or vacant, the method of calculating the future impervious area remains the same as the method used for calculating the existing impervious area. For the underutilized and vacant parcels, the existing land use (CLU) was replaced by the planned land use (PLU) or the zoning land use, whichever land use represented a greater impervious area.

The following steps were used to determine the future impervious area for the watershed:

1. The first task was to create a map of the underutilized parcels. This was accomplished by combining the following two sources of data:
   - The underutilized GIS parcel data file provided by the county, which mainly contained the residential land use.

- For the non-residential areas, the land use was evaluated by comparing the percent impervious of the existing and planned generalized land uses. Where the existing land use was industrial or low intensity commercial, which both have a total imperviousness of 80 percent, and the planned land use was high intensity commercial, which was assigned an imperviousness of 90 percent, the area was identified as underutilized and the parcels were clipped from the impervious shapefiles. No other non-residential areas were identified as underutilized.

2. The impervious area that was within the underutilized and vacant parcel areas was clipped from the existing impervious features (roads, buildings, and sidewalk). The clipped features were then subtracted from the total existing impervious surface for each subarea for the total, DCIA, and NDCIA impervious areas.
3. Next, the underutilized parcels were assigned a percent DCIA and NDCIA based on their planned land use (PLU) or the planned zoning, whichever had the greater percent imperviousness. The values for DCIA for the land uses are shown in Table 2.4. Using the descriptions for the zoning code and descriptions for the generalized planned land use, the zoning was classified as a land use type in order to determine which feature represented the greater percent impervious, the zoning or the planned land use. The zoning code descriptions are listed in Table B-3 of the TM3 and the generalized planned land use code descriptions are listed in the TM3 on page 4-25. Table 2.5 describes the land use assigned to the zoning code.

Table 2.4 Summary of Impervious Surfaces

Land Use Group	DCIA Percent	NDCIA Percent	Total Percent Impervious
OS – Open Space	1%	2%	3%
ESR – Estate Residential	7%	2%	9%
LDR – Low Density Residential	10%	5%	15%
MDR – Medium Density Residential	25%	15%	40%
HDR – High Density Residential	45%	15%	60%
LIC – Low Intensity Commercial	70%	10%	80%
HIC – High Intensity Commercial	80%	10%	90%
IND – Industrial	70%	10%	80%
Other	-	-	-

Table 2.5 Comparative Planned Land Uses

Zoning Code	Comparative Planned Land Use
C-2	LIC
C-3	LIC
C-5	LIC
C-6	LIC
C-8	LIC
R-1	LDR

Zoning Code	Comparative Planned Land Use
R-2	LDR
R-3	MDR
R-4	MDR
R-5	MDR
R-8	HDR
R-12	HDR
R-20	HDR
R-MHP	MDR

4. After subtracting the existing impervious road, parking lot, sidewalk, and driveway impervious areas calculated in step 2 from the existing impervious area, the DCIA for the underutilized and zoning parcels, which was calculated in step 3, was added into the revised DCIA for future development.

2.4.3 Mansionization

This section explains the procedure Woolpert used for estimating the amount of impervious area that will be added in the future due to mansionization in the Middle Potomac Watersheds. We used parcel information from the county that included the parcel identification number and the year a building addition was added to the structure. Table 2.6 describes the trend in the additions in the Middle Potomac Watershed in five year increments. The average add-on size also includes the area from second story additions.

Table 2.6 Middle Potomac Watersheds Add-Ons by Year

Year of Addition	Number of Additions	Total Addition Area (sq ft)	Average Addition Size (sq ft)
1980 - 1984	163	142,429	874
1985 – 1989	239	259,136	1,084
1990 - 1994	418	441,932	1,057
1995 - 1999	692	658,027	951
2000 - 2004	919	873,137	950

It is anticipated that the number of additions in the five years from 2000 to 2005 will closely reflect the additions that will occur in the next 25 years, with some years having more or fewer additions than other years depending on the economic climate. The last three years have shown a greater number of add-ons than the previous years, however, the rate of first floor add-on construction is not predicted to continue for the older medium density neighborhoods because of the building limits due to the parcel size. First floor add-ons will probably continue at a high rate in the low density and estate residential neighborhoods. Second story add-ons that match the foot print of the existing structure do not increase the amount of impervious area on the lot.

All single family residential parcels that were either estate, low, or medium density residential and had an addition added to the property in or after 1980 were identified. This did not consider tear downs and rebuilds, which were not included in the add-on data provided by the county. The number of parcels with additions within the past five years were counted by subarea, which was divided into A, B, and C areas. We used an estimated average add-on area of 1,000 square feet and the number of parcels was multiplied by 1,000 square feet.

In order to verify the estimated average add-on area, the footprint of the new addition was determined from the county's aerial mapping for a sample number of homes. The outline of the home, which was created based on a 1997 aerial photograph, was overlaid on top of a 2003 aerial photograph. Any new addition outside of the existing 1997 footprint of the home could be identified and measured. From this area, the additions constructed between 1997 and 2003 were noted and the square footage was determined for seven homes.

For the sample seven homes, Table 2.7 shows the year built, the land use, and the year added-on. The add-on year and square footage for each parcel was obtained from the county's data. This area was the exact add-on square footage and it contained add-on area from second story additions which should not be included in the impervious area calculations.

Table 2.7 Middle Potomac Watersheds Sample Add-Ons

PIN	Add-On Area (sq ft)	Add-On Area Measured from Map (sq ft)	Year Built	Year Added-On	Land Use
0401 11 0055	884	593	1953	1999	MDR
0302 17 0047	1,886	0	1959	1999	MDR
0311 12 0020	952	419	1966	2002	MDR
0311 17 0020	690	556	1981	2001	MDR
0223 04 0127	1,192	671	1981	2003	LDR
0212 05 0003A	1,015	1,097	1961	2001	LDR
0292 03 0409	1,298	650	1967	2002	MDR
Average	1,131	569	-	-	-

The average of the seven map measurements shown in Table 2.7 was 569 square feet, while the average total addition area from the parcel information was 1,131 square feet. A conservative estimate of 1,000 square feet was used for the average add-on area.

The increase in the total impervious area due to mansionization for the next 25 years is estimated at approximately 106 acres, or a one percent increase in impervious area over the Middle Potomac Watersheds. In the hydrologic model, half of the impervious area was assigned to directly connected impervious area and half to not directly connected impervious area.

2.5 Overland Flow Roughness Coefficient Parameters

The overland flow roughness coefficient is used in the runoff calculations in XP-SWMM and is different for impervious and pervious surfaces. The overland flow roughness coefficients for pervious surfaces were calculated based on the type of land use as shown in Table 2.8. For impervious surfaces, the overland flow roughness coefficient is the same for all types of land use.

Table 2.8 Overland Flow Roughness Coefficients

Land Use Type	Overland Flow Roughness Coefficient	
	Impervious	Pervious
OS - Open Space	0.015	0.35
ESR- Estate Residential	0.015	0.30
LDR – Low Density Residential	0.015	0.25
MDR – Medium Density Residential	0.015	0.25
HDR – High Density Residential	0.015	0.25
LIC – Low Intensity Commercial	0.015	0.25
HIC – High Intensity Commercial	0.015	0.25
IND – Industrial	0.015	0.25
OTHER	0.015	0.25

For pre-developed conditions, the pervious surface overland flow roughness coefficient was set to 0.35 for all subbasins, which corresponds to the open space land use type. The pervious surface overland flow roughness coefficient for existing and future land use conditions was developed by using a weighted average based on land use for each subbasin.

2.6 Depression Storage Parameters

The depression storage parameter represents the water that is stored in depressions on the land surface and neither runs off the land nor is infiltrated. This parameter was established as 0.10 inches for impervious surfaces and 0.20 inches for pervious surfaces. Another parameter assigns the percentage of impervious area that contains zero depression storage and simulates immediate runoff. The percentage of impervious area with zero depression storage was set to 25 percent as recommended in TM3.

3.0 Water Quality Model

The water quality model simulates the amount of pollutants washed off of the land. The water quality pollutants modeled for future and existing conditions included the following:

- 5 Day Biochemical Oxygen Demand (BOD5)
- Chemical Oxygen Demand (COD)
- Total Suspended Solids (TSS)
- Total Dissolved Solids (TDS)
- Dissolved Phosphorus (DP)
- Total Phosphorus (TP)
- Total Nitrogen (TN)
- Total Kjeldahl Nitrogen (TKN)
- Total Cadmium (TCd)
- Total Copper (TCu)
- Total Lead (TPb)
- Total Zinc (TZn)

3.1 Buildup and Washoff Parameters

The water quality model simulates the buildup and washoff of the pollutants from the land surface. The parameter values were provided by the county in the document titled *Development of SWMM Water Quality Model Inputs for Fairfax County, Virginia*, March 2004 and TM3.

The water quality parameter values were weighted for the following land use types: estate residential, low density residential, medium density residential, high density residential, industrial, open space, low intensity commercial and high intensity commercial. When estimating the existing and future land use area for each subarea, the area within the watershed that was not included in the parcel mapping was apportioned to the parcel land use based on percentage of the overall subarea. The area outside of the parcels predominantly included roadway right of way.

The parameters used to represent pollutant build up on the land surface were as follows:

- QFACT(1) represents the maximum pollutant accumulation on the land in pounds per acre and values are shown in Table 3.1.
- QFACT(2) is an exponential factor that determines the accumulation rate and how quickly the surface pollutant mass recovers after a storm has washed pollutants off the land surface. QFACT(2) was set to a standard value of 0.15/year for all land use types.

Table 3.1 QFACT(1) Values by Pollutant and Land Use (lb/acre)

Water Quality Parameter	Land Use Type							
	OS	ESR	LDR	MDR	HDR	LIC	IND	HIC
Biochemical Oxygen Demand (BOD5)	0.4	0.6	1.2	2.4	4.5	2.7	5.5	5.6
Chemical Oxygen Demand (COD)	3.1	3.2	6.7	13.5	36.5	16.2	21.5	21.5
Total Suspended Solids (TSS)	2.0	1.7	3.6	7.3	12.8	16.7	17.7	20.7
Total Dissolved Solids (TDS)	5.2	2.3	4.8	9.7	21.2	16.6	23.6	21
Dissolved Phosphorus (DP)	0.005	0.028	0.035	0.039	0.046	0.042	0.045	0.045
Total Phosphorus (TP)	0.0075	0.04	0.05	0.055	0.065	0.06	0.065	0.065
Total Kjeldahl Nitrogen (TKN)	0.04	0.23	0.26	0.32	0.36	0.36	0.30	0.30
Total Nitrogen (TN)	0.055	0.30	0.35	0.425	0.55	0.55	0.65	0.65
Total Cadmium (TCd)	0.000025	0.000025	0.000026	0.00003	0.00004	0.000025	0.000011	0.000024
Total Copper (TCu)	0.0006	0.0003	0.0006	0.0011	0.0096	0.0074	0.0075	0.0048
Total Lead (TPb)	0.00032	0.00009	0.0002	0.0004	0.0008	0.00049	0.00155	0.00143
Total Zinc (TZn)	0.0025	0.0016	0.0034	0.0068	0.0197	0.0369	0.0476	0.0297

The pollutant washoff parameters for the wet weather events were RCOEFF and WASHPO. The following describes the parameters:

- RCOEFF, a washoff coefficient, was set to a standard 4.6 inches^{-1}.
- WASHPO, an exponential rate factor that is applied to the calculated surface runoff

rate, was set to a recommended standard of 1.0 inches.

3.2 Peak-Shaving Facilities and Water Quality BMPs

As discussed previously, the subbasins were divided into three subareas categorizing parcels that have a stormwater management facility controlling runoff or treating water quality or not having any stormwater management controls.

3.2.1 Peak Shaving Detention Storage

For the parcels controlled by a stormwater detention basin, an allowable discharge versus storage rating curve was created. Points on the rating curve were developed for the two-year, ten-year, and 100-year storm events. The peak discharge from the detention basin was set to the pre-developed peak flow rate and the storage in the detention basin at that flow rate was calculated as the difference in volume from the existing runoff and the pre-developed runoff. For the subareas with BMP controls, which included parcels developed after 1994, a 48-hour drawdown period was simulated for the water quality treatment volume in addition to the peak discharge control for the two-year and ten-year storm events.

3.2.2 Structural BMPs for Water Quality Control

Structural BMPs with pollutant removal efficiencies were modeled for those areas identified with BMP controls. The primary type of structural BMP in the Middle Potomac Watersheds is an extended dry detention basin. The average pollutant removal efficiencies for the modeled pollutants for extended dry detention basins were obtained from TM3 and other sources such as the *Stormwater Treatment Practice Pollutant Performance Database*, Schueler, 1997 for stormwater dry ponds, and *A Current Assessment of Urban Best Management Practices*, Metropolitan Washington Council of Governments. The pollutant removal efficiencies used in the model are shown in Table 3.2.

Table 3.2 Average Pollutant Removal Efficiency Percentage

Water Quality Parameter	Average Removal Efficiency
Biochemical Oxygen Demand (BOD)	30%
Chemical Oxygen Demand (COD)	17%
Total Suspended Solids (TSS)	80%
Total Dissolved Solids (TDS)	61%
Dissolved Phosphorus (DP)	0%
Total Phosphorus (TP)	40%
Total Kjeldahl Nitrogen (TKN)	15%
Total Nitrogen (TN)	30%
Total Cadmium (TCd)	50%
Total Copper (TCu)	50%
Total Lead (TPb)	80%
Total Zinc (TZn)	50%

3.3 Continuous Rainfall Data

For the water quality model, continuous rainfall was simulated in order to develop an average annual pollutant loading rate for the subbasins. The continuous rainfall data used for the model was from the Sislers rain gauge station located near Falls Church for a seven year period from 1995 to 2001. The rainfall gauge data was obtained from the county.

3.4 Pollutant Loading Results

The water quality model calculated the amount of pollutants generated and washed off of the drainage subareas for the continuous rainfall simulation period. The average amount of each pollutant in the runoff per year for each subbasin was calculated. This average annual pollutant amount was divided by the subbasin area to determine the loading rate in pounds per acre per year. The loading rates for future and existing land use conditions for each watershed's subbasins are provided in Chapters 4 through 8 of the *Middle Potomac Watersheds Management Plan.*

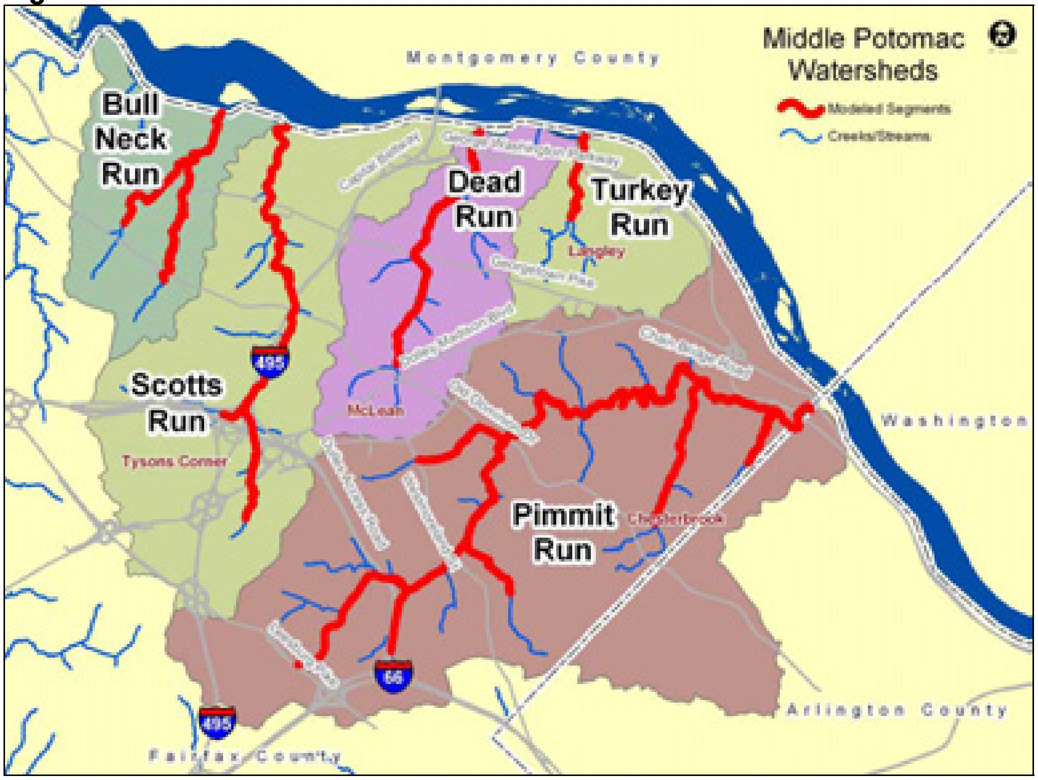
4.0 Hydraulic Model

The hydraulic model, HEC-RAS, was used to simulate the stream flow in the Middle Potomac Watersheds streams and tributaries. The hydraulic model was specifically established to evaluate the following:

- Flood water overtopping at road crossings
- Extent of predicted flooding
- Erosive velocities for selected design storms
- Benefits of proposed new LID measures, new BMPs, and BMP retrofits on the hydraulic conditions of the streams

Information that was used to develop the hydraulic model included the stream network obtained from the countywide hydrography dataset, the cross section data points developed from the county's digital elevation data, and the runoff hydrographs obtained from the XP-SWMM runoff model. Not all of the streams in the watersheds were modeled because of the size requirements for the subbasin areas in TM3. The streams modeled in the Pimmit Run Watershed included the main stem of Pimmit Run, Little Pimmit Run, Strohmans Branch, Saucy Branch, Bridge Branch, and Darrell Branch. The streams modeled in the Scotts Run Watershed included the main branch of Scotts Run and one unnamed tributary to Scotts Run. The streams modeled in the Bull Neck Run Watershed included the main branch of Bull Neck Run and one unnamed tributary to Bull Neck Run. In the Dead Run and Turkey Run Watersheds, only the main stems were included in the hydraulic models. The modeled portions of these streams are shown in Figure 4.1 on the next page.

Figure 4.1 Modeled Portions of Streams in Middle Potomac Watersheds



A major part of the hydraulic model development was creating the cross sections along each stream segment. Cross sections are lines of points that represent a section of the stream and the floodplain and contain specific characteristics of the streambed and floodplain. These cross sections, which were drawn perpendicular to the stream flow, were located between 200 and 1,000 feet apart from each other, with a typical distance of 300 feet. The characteristics determined for each cross section included the channel roughness, the location of stream banks, and areas of ineffective flow. The elevation of the cross section points was obtained from the county's digital terrain mapping using ArcGIS and the program HEC-GeoRAS.

Once the stream segments and cross sections were created in the hydraulic model, the stream crossings data were entered. The crossings information was collected in the field by survey crews and included the number and configuration of the stream culverts, details and configuration for bridges, roadway information, and culvert data such as diameter, material, and length. There were 36 crossings included in the hydraulic model and the number of crossings located in each watershed was as follows:

- Sixteen crossings in Pimmit Run
- Five crossings in Bull Neck Run
- Eleven crossings in Scotts Run
- Three crossings in Dead Run
- One crossing in Turkey Run

The survey crossing elevation data was compared to the county TIN data and the survey elevation data was adjusted to match the stream profile.

The hydraulic model was run for the two, ten, and 100-year storm events. The results of the existing land use, future land use, and proposed alternatives conditions were evaluated and compared in order to determine the effects on the stream stage and velocity.

5.0 Model Flow Calibration

After the initial hydrologic and hydraulic models were completed, the hydraulic model road flooding locations for the two and ten-year storm events were compared to the known road flooding locations. The road flooding locations were determined from information from the public, county data, and road flooding signage. No flow meter data was available for model flow comparison for any of the streams in the watersheds.

Some of the hydrologic model parameters for some of the watersheds were adjusted to decrease the peak flow amounts so that the road flooding locations in the hydraulic model matched the known road flooding locations.

5.1 Pimmit Run Watershed

The model results for a two-year storm event showed road flooding at the crossing at Kirby Road. The widths of the subbasins were decreased by 70 percent, the directly connected impervious area (DCIA) was decreased by 55 percent, the maximum infiltration rate (WLMAX) and the depression storage were both doubled to reduce the peak flows so that the crossing at Kirby Road did not flood the road for the two-year storm event.

5.2 Bull Neck Run Watershed

There were no changes to the modeling variables for the Bull Neck Run Watershed.

5.3 Scotts Run Watershed

The model results for a two-year storm event showed road flooding at the crossing at Georgetown Pike. The widths of the subbasins were decreased by 50 percent and the directly connected impervious area (DCIA) was decreased by ten percent in order to reduce the peak flows. The maximum infiltration rate (WLMAX) and the depression storage were both doubled. The peak flow at the storage node for subbasin SC-SC-008 was limited to a maximum flow of 3,100 cfs based on culvert hydraulic calculations at the Lewinsville Road and I-495 culvert.

5.4 Dead Run Watershed

The model results for a two-year storm event showed road flooding at the crossing at Georgetown Pike. In the hydrologic model, the widths of the subbasins were decreased by 80 percent, the directly connected impervious area (DCIA) was decreased by 25 percent, the maximum infiltration capacity (WLMAX) was increased by 80 percent and the depression storage was doubled in order to reduce the peak flows so that no roadway flooding occurred at Georgetown Pike for the two-year storm.

5.5 Turkey Run Watershed

There were no changes to the modeling variables for the Turkey Run Watershed.

6.0 Proposed Alternatives

Woolpert developed alternative strategies to mitigate existing and potential stormwater related problems and to meet the goals and objectives for the watershed management plan, which were developed by the Middle Potomac Watersheds Steering Committee as part of the public involvement process. The alternative strategies with the top priority rankings were modeled in SWMM and the pollutant removal and stream flow impacts were assessed.

The structural practices that were modeled include the following:

- Retrofit of existing BMPs
- Construction of new BMPs
- New low-impact development (LID) measures
- LID zones

The specific parcels located in the drainage areas of the proposed structural strategies were identified and this information was entered in the GIS.

New BMPs and BMP Retrofits were modeled by simulating a one-year extended detention basin. For areas with existing stormwater management facilities that do not provide water quality treatment, a pollutant removal efficiency percentage was added for the BMP retrofit project to add water quality enhancements.

The new low impact development measures proposed for individual sites and zones were modeled as infiltration measures as described in TM3. Just as runoff from an area served by a biofiltration facility (rain garden) drains to a depression where it infiltrates into the ground, the hydrologic model redirects flow to a node that is 100 percent pervious and infiltrates flow up to a maximum volume. After the maximum amount of infiltration is exceeded the rainfall becomes runoff and flows to the storm drain system. The maximum amount of flow was calculated to be the first half inch of runoff from the impervious surface in the LID drainage area.

Results of the SWMM modeling can be found in Sections 2.6, 3.3, 4.1.7, 5.1.7, 6.1.7, 7.1.7, and 8.1.7.