Land and Water Quality Protection in Northern Virginia: Phase 1

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Executive Summary

A major challenge facing the Northern Virginia region is the shift in land cover from pervious to impervious which has increased the volume of stormwater runoff. Stormwater runoff from urban areas has been determined to be a major cause of water quality impairment, including the inability of surface waters to meet their state-designated uses to support recreation and aquatic life. In addition to the degradation of streams and loss of property, the erosive forces of excessive runoff can put municipal infrastructure at risk such as sewer pipes.

The Chesapeake Bay Program recognizes that urban impervious land cover is a major contributor to the total load of Total Nitrogen (TN), Total Phosphourous (TP), and Total Suspended Solids (TSS). There exists the opportunity in local stormwater planning to incorporate strategies in urban and suburban areas of Virginia that could possibly include urban forest cover. This project identified if maintaining and/or increasing urban tree canopy might be a cost effective and meaningful tool to assist local governments with meeting water quality milestones in not only a complex regulatory environment, but also in the complex land use and development environment of Northern Virginia.

To answer the above question, four things were studied; 1) the current policies regarding urban tree canopy in northern VA, 2) the population projections in Tranpsortation Area Zones through 2040, 3) effects of those projections on land cover, and 4) the potential future effects on water quality from a. doing nothing and b. maximizing tree cover.

Many localities in Northern Virginia have adopted one or more ordinances governing tree management and care on development sites. Gaining credit in the Chesapeake Bay Model and VA BMP Clearinghouse for these locality's efforts to preserve, enhance, and maintain the existing urban tree canopy is potentially important since preservation and maintenance of existing canopy is less expensive than retrofits or other engineered solutions per-pound of Nitrogen reduced. The ordinances governing tree canopy vary significantly across the boundaries of Northern Virginia. Some have interpreted the Code of Virginia § 15.2-961 in different ways by either adhering to the minimum standards set forth or through much more prescriptive ways.

Build-out anlaysis derived from population projections indicated that impervious cover will continue to grow and tree canopy will decrease in the region and it varies by watershed. Streams in high growth watersheds will develop flashy characteristics that will increase erosion. Results indicate that retaining and increasing urban tree canopy provides significant runoff reduction benefits. Loads of TN and TP were reduced slightly but not at the same level as other types of retrofits such as bioretention.

1 Introduction

A major environmental challenge facing the Northern Virginia region is the shift in land cover from pervious to impervious which has increased the volume of stormwater runoff. Stormwater runoff from urban areas has been determined to be a major cause of water quality impairment, including the inability of surface waters to meet their state-designated uses to support recreation and aquatic life. Water pollution from runoff is due primarily to fertilizers, pesticides, sediment, and hydrocarbons. Sediment from roads and construction finds its way into the stream valleys during construction, especially if these soils are located on steep slopes next to streams. As the percentage of impervious cover increases, so does the volume of stormwater runoff. Excessive runoff overwhelms the capacity of a stream channel and results in downcutting and bank erosion. In addition to the degradation of streams and loss of property, the erosive forces of excessive runoff can put municipal infrastructure at risk such as sewer pipes (Figure 1).

Figure 1. Examples of an eroded stream bank and exposed infrastructure in Prince William County, Northern Virginia (photo credit: Potomac Local News)

The Chesapeake Bay Program recognizes that urban impervious land cover is a major contributor to the total load of Total Nitrogen (TN), Total Phosphourous (TP), and Total Suspended Solids (TSS). Table 1 shows the load of pollutants of concern generated from an acre of urban impervious and an acre of urban pervious.

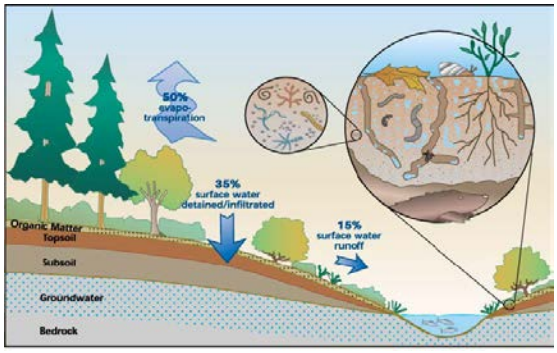
Table 1. CBP Annual Urban Runoff Loads per Acre of land cover

Parameter	Urban Impervious	Urban Pervious
TN (lbs)	16.86	10.07
TP (lbs)	1.62	0.41
TSS (lbs)	1,171.32	175.80

The EPA encourages the use of green infrastructure to help manage stormwater runoff. The Center for Watershed Protection defines green infrastructure as "natural systems that capture, cleanse and reduce stormwater runoff using plants, soils and microbes. On the regional scale, green infrastructure consists of the interconnected network of open spaces and natural areas (such as forested areas, floodplains and wetlands) that improve water quality while providing recreational opportunities, wildlife habitat, air quality and urban heat island benefits, and other community benefits. At the site scale, green infrastructure consists of site-specific management practices (such as tree planting and rain gardens) that are designed to maintain natural hydrologic functions by absorbing and infiltrating precipitation where it falls."

Many localities are realizing that green infrastructure can be a solution to the land use and water quality challenges including runoff reduction, however the exact extent is not always known. Currently, only those Best Management Practices (BMPs) that are included in the Virginia BMP Clearinghouse have approved pollutant removal efficiencies. Afforestation and/or urban canopy preservation is currently not credited as a BMP in the VA BMP Clearinghouse. Urban tree canopy is considered to be trees growing individually, in small groups, or under forest conditions on public and private lands in our cities, towns, and their suburbs. Tree canopy is the layer of tree leaves, branches, and stems that cover the ground when viewed from above.

The ecological benefits of urban forests are well documented and include nutrient reduction/uptake, stream bank stabilization, thermal buffering, wildlife habitat, carbon sequestration, erosion control, soil building, flood control, air filtration, and ground water recharge (Figure 2). Forests also provide an abundance of societal benefits: shade, open space, quality of life, aesthetics, and recreational opportunities.



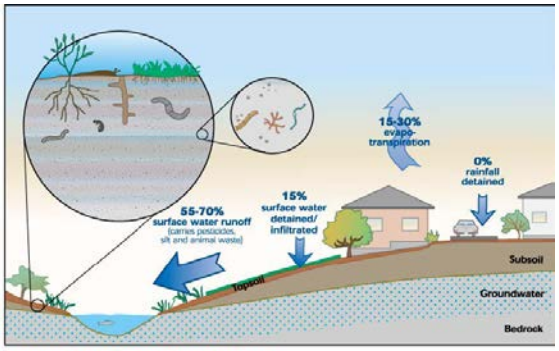


Figure 2. After construction, compacted soils make root growth and tunneling difficult and have fewer air and water pockets. Graphic From the Chesapeake Stormwater Network

There exists the opportunity in local stormwater planning to incorporate strategies in urban and suburban areas of Virginia that could possibly include urban forest cover. Many localities in Northern Virginia have tree preservation ordinances that value the environmental benefits associated with tree cover. Gaining recognition in the Chesapeake Bay Model and VA BMP Clearinghouse for these localities' efforts to preserve, enhance, and maintain the existing urban tree canopy is potentially important since preservation and maintenance of existing canopy is less expensive than retrofits or other engineered solutions per-pound of Nitrogen reduced.

Strategies that manage conservation of urban tree canopy and mitigate for loss of urban forest cover, particularly in headwaters portions of the region, could include identification of priority areas for retention, identifying areas that are vulnerable to canopy loss, developing tree preservations policies for development, and replanting cleared areas. Priority areas for canopy preservation would include flood plains, riparian areas, steep slopes, headwaters, and critical habitat. Areas vulnerable to canopy loss are those that are anticipated to experience high development pressure due to population growth or planned infill development. A robust urban and community forest retention plan that makes use of the above strategies may reduce the rate of tree canopy and urban forestland loss even as population growth increases.

In order to identify "regionally appropriate and cost effective Best Management Practices" for managing stormwater in Northern Virginia, a methodology for modeling impacts of various development scenarios on water quality is an essential tool. This project is an effort to identify if maintaining and/or increasing urban tree canopy might be a cost effective and meaningful tool to assist local governments with meeting water quality milestones in not only a complex regulatory environment, but also in the complex land use and development environment of Northern Virginia.

To answer the above question, four things were studied: 1) the current policies regarding urban tree canopy in northern VA, 2) the population projections in Tranpsortation Area Zones through 2040, 3) effects of those projections on land cover, and 4) the potential future effects on water quality from a. doing nothing, and b. maximizing tree cover.

2 Common Drivers and Regulatory Framework in Northern Virginia

2.1 Federal Stormwater Regulations

The Clean Water Act (CWA) of 1972 is the principal federal statute protecting navigable waters and adjoining shorelines from pollution. Since its enactment, the CWA has formed the foundation for regulations detailing specific requirements for pollution prevention and response measures. Section 402 of the Clean Water Act established the National Pollutant Discharge Elimination System to limit pollutant discharges into streams, rivers, and bays. In the Commonwealth of Virginia, DEQ administers the program as the Virginia Pollutant Discharge Elimination System (VPDES). Under the NPDES storm water program, publicly owned systems such as storm drains, storm sewers, pipes, ditches or swales that collect or move water to surface waters must obtain permit coverage and develop a stormwater management program.

Medium and large MS4 operators are required to submit comprehensive permit applications and are issued individual permits. Regulated small MS4 operators (serving populations less than 100,000) have the option of choosing to be covered by an individual permit, a general permit, or a modification of an existing Phase I MS4s individual permit.

There are three large MS4 operators in Northern VA; Fairfax County, Arlington County, and Prince William County. Numerous other medium and small operators are also regulated in Northern Virginia.

2.2 Commonwealth of Virginia Stormwater Regulations

DEQ is the lead agency for developing and implementing statewide stormwater management and nonpoint source pollution control programs to protect the Commonwealth's water quality and quantity.

Stormwater runoff from streets, lawns, parking lots, construction sites, industrial facilities and other impervious surfaces may enter surface waters directly or through natural and constructed channel systems. Activities occurring in developed and urban areas contaminate stormwater runoff with pollutants such as automobile oil, grease, metals, sediment, bacteria from animal waste, nutrients and pesticides, as well as deposits from airborne pollutants and those contaminants wind up in rivers and streams. Stormwater can also cause erosion and flooding.

As authorized under the State Water Control Law and the federal Clean Water Act, the Virginia Pollutant Discharge Elimination System (VPDES) permitting program regulates point source pollution. “Point source” is defined by the U.S. Environmental Protection Agency as “a source of pollution that can be attributed to a specific physical location – usually an identifiable, "end-of-pipe ‘point." This includes stormwater discharges from: MS4s; Construction activities; and Industrial discharges.

The Department of Environmental Quality, the Department of Conservation and Recreation, and the Chesapeake Bay Local Assistance Department coordinate three separate State programs that regulate the management of pollution carried by stormwater runoff:

• The federal Clean Water Act requires large cities and urbanized counties and cities to develop stormwater management plans and obtain discharge permits for stormwater outfalls. DEQ manages this aspect of the Virginia Pollutant Discharge Elimination System program through permits issued to localities, as well as to companies that directly discharge industrial wastewater into streams.

• The Virginia Stormwater Management Act enables local governments to establish management plans and adopt ordinances that require control and treatment of stormwater runoff to prevent flooding and contamination of local waterways. Locally administered programs are voluntary but must meet or exceed the minimum standards contained in the Act regulations.

• The Chesapeake Bay Preservation Act establishes requirements for stormwater management within designated Chesapeake Bay Preservation Areas that are within the Tidewater region of Virginia. Each local government enforces its own program, which has been based on a model developed by the Chesapeake Bay Local Assistance Board and Chesapeake Bay Local Assistance Department.

The Commonwealth has been utilizing MS4 permits as a vehicle to ensure BMP implementation on existing developed lands achieves nutrient and sediment reductions equivalent to Level 2 (L2) scoping run reductions by 2025. Level 2 implementation equates to an average reduction of 9 percent of nitrogen loads, 16 percent of phosphorus loads, and 20 percent of sediment loads from impervious regulated acres and 6 percent of nitrogen loads, 7.25 percent of phosphorus loads and 8.75 percent sediment loads beyond 2009 progress loads for pervious regulated acreage. These reductions are beyond urban nutrient management reductions for pervious regulated acreage. MS4 operators will be able to adjust the levels of reduction between pervious and impervious land uses within their service area, provided the total pollutant load reduction is met. For example, an MS4 could implement a five percent nitrogen load reduction on impervious land uses by implementing a reduction strategy sufficiently greater than six percent nitrogen load reduction on pervious land uses, provided the total loads from both land uses are met.

MS4 Permittees are also required to complete local Total Maximum Daily Load (TMDL) Action Plans (for local TMDL's established by July 2008) and Chesapeake Bay TMDL Action Plans. Action Plans were submitted to DEQ with the Annual Report for the reporting period of July 1, 2014 through June 30, 2015 on October 1, 2015. The Action Plans included an outline of the means and methods that will be utilized to meet the L2 level necessary for the permit. The MS4 operators also reviewed their authorities, adopted and modified ordinances, and enhanced their resources in order to implement the necessary reductions (e.g., develop design protocols, operation and maintenance programs, site plan review criteria, inspection standards, and tracking

systems). As a part of reapplication for the second cycle of permit coverage, the MS4 operator will provide a schedule of implementation of the means and methods to implement sufficient reductions to reach 35 percent of the L2 reductions. As a part of reapplication for the third cycle of permit coverage, the MS4 operator must provide a schedule of implementation of the means and methods to implement sufficient reductions to reach the remaining L2 reductions by the end of the third permit cycle.

DEQ intends for nonpoint source reductions recommended in TMDL's to be implemented through Best Management Practices (BMPs) and expect that implementation will occur in stages.

Land Use Change BMP's as a vehicle for Urban Forestry

One method of using urban forestry towards pollutant reductions required of MS4 operators is land use change. Permittees may receive credit towards their required reductions for land use change conversions based on the number of acres converted. Conversion efficiencies for land use change are dependent on basin and are listed in Table 2. Permittees may receive credit for converting:

1. Impervious to Forest – Permittees may receive credit for converting any Impervious Surface to Forest. To receive credit for the "Forest" land use, permittees should meet the tree density per acre described in the Virginia Department of Forestry's Land Use Tax Assessment Standards, which can be found on the Virginia Department of Forestry's website: http://www.dof.virginia.gov/land/usetax/assessment-standards.htm.

2. Impervious to Grass – Permittees may receive credit for converting any Impervious Surface to Grass. To qualify for this credit the "Grass" must be unmanaged (i.e. no nutrient application).

3. Impervious to Pervious – Permittees may receive credit for converting any Impervious Surface to a Pervious Surface other than Forest and/or Grass. Pervious surfaces might include: lawns, unimpacted gravel, etc. If a permittee is unsure if a surface is considered "pervious," the Department should be contacted for further guidance.

4. Pervious to Forest – Permittees may receive credit for converting any Pervious Surface, including unmanaged Grass, to Forest.

5. Pervious to Grass – Permittees may receive credit for converting any Pervious Surface, other than Forest, to unmanaged Grass.

Table 2. Pollutant load reductions resulting from land use changes in the Potomac Basin

Basin	**Land Use from**	**Conversion**	**Edge of Stream Reductions TN(lbs/ac/year)**	**Edge of Stream Reductions TP(lbs/ac/year)**	**Edge of Stream Reductions TSS(lbs/ac/year)**

Potomac	Impervious	Forest	13.91	1.80	1252.01
Potomac	Impervious	Grass	12.56	1.34	623.28
Potomac	Impervious	Pervious	6.75	1.42	1119.05
Potomac	Pervious	Forest	7.16	0.38	132.96
Potomac	Pervious	Grass	5.81	0.00	0.00

Riparian Forest Buffers can be credited as both a land use change and efficiency BMP. The efficiency is applied at up to a 2-to-1 ratio for upland acres that drain to the buffer as sheetflow (i.e. if a one acre buffer is installed, but only 1.5 upland acres drains to the buffer as sheetflow, the permittee may only receive the efficiency credit for 1.5 acres) (Table 3). The following established efficiencies for TP, TN, and TSS are used:

Table 3. Efficiencies for Forest Buffers Applied to Two Upland Acres per Acre of Buffer

Practice	TN	TP	TSS
Forest Buffer	25%	50%	50%

Although these options are available, land use conversions are not widely utilized in urban areas due to space constraints and property value/ownership considerations.

Another opportunity that includes planting trees to enhance water quality is the Virginia Nutrient Credit Trading Program. Tree planting projects on open land are recognized as a management practice that generates saleable credits. The plantings reduce nitrogen and phosphorus loading and, therefore, enhance water quality.

Urbanization and development is the single biggest factor in loss of forestland acreage. This is not from the cutting of trees for forest products such as lumber, paper, or firewood, but rather the conversion of forest to houses, roads, shopping centers, and other development. Since 2001, 484,965 acres of forested land has been lost to land use changes; 64% of this acreage was cleared for urban development, 30% to agricultural uses, and the balance to other land uses. Partially offsetting this loss were reversions and afforestation efforts that returned 354,381 non-forest acres to the forest land base (VDOF, Forest Facts http://www.dof.virginia.gov/stateforest/facts/forest-facts.htm).

This forestland loss impacts nutrient and sediment loads and overwhelms the ability of afforestation to keep pace with nutrient and sediment load reduction targets on a landscape scale. Developing strategies that reduce the rate of canopy loss is important in the context of protecting water quality particularly in suburban areas that are rapidly developing. The Code of Virginia allows local jurisdictions to develop tree canopy ordinances for development in accordance with § 15.2-961, *Replacement of tree during development process in certain localities*. All of the Counties and Cities of Northern Virginia have adopted one or more ordinances governing tree management and care on development sites. An analysis of selected local tree canopy ordinances was conducted for Northern Virginia.

A matrix of all the Northern Virginia tree canopy ordinances with links to the code is found in Appendix A. Below is a summary of the key findings.

Ordinances on Development: Most jurisdictions have ordinances which require new development projects to achieve a minimum percentage of a site to be covered with canopy in ten years. Developers can do this by retaining trees on site, planting new trees, or paying into a tree mitigation fund. The percentage typically varies by the zoning district. In Arlington County, for example, a site zoned business, commercial, or industrial is required to achieve ten percent (10%) coverage in ten years and a residential site zoned ten (10) units or less per acre is required to achieve twenty percent (20%). The Town of Herndon is significantly different in terms of its requirements for new development. Rather than requiring minimum percentage of coverage, the actual number and types of plants are specified for a particular use. For example, a single-family detached dwelling, two-family dwelling, group home, or quadruplex is required to plant 4 canopy trees, 3 evergreen trees, and at least 12 shrubs per dwelling unit. In short, the localities of Northern Virginia have interpreted the Code of Virginia § 15.2-961 in different ways by either adhering to the minimum standards set forth or through much more prescriptive ways.

Tree Canopy Goals: Most Northern Virginia localities have made enlarging the tree canopy by a certain timeframe a stated goal of their overall tree resource management plan. For example, the Fairfax County Board of Supervisors formally adopted a 30-year tree canopy goal to increase Fairfax County's tree cover from 40 percent to 45 percent by the year 2037. A plan exists to accomplish this, however since most of the land lies in the private sector, the County must rely heavily on landowners to voluntarily convert residential turf to trees. There is currently no incentive for a landowner to do this however, community tree planting groups such as Fairfax ReLeaf work with landowners to promote tree planting projects.

Tree Inventory: Some Northern VA jurisdictions maintain a detailed inventory of street or city-owned trees. For example the City of Alexandria has an inventory of street trees and has used the i-Tree software tools developed by the USFS to assess the value and benefits those trees bring to the community. For some jurisdictions, the scale and complexity involved in undertaking such a detailed task is too great given the amount of resources available relative to land area, so a lower resolution approach is taken using aerial photography, land use land cover

GIS data and modeling software. For example a number of these reports were prepared for Prince William County by American Forests and can be found on the Prince William Conservation Alliance website at http://www.pwconserve.org/issues/floraandfauna/Trees/ . Prince William County

3 Green Infrastructure Practices that Make Sense in Northern Virginia

3.1 Projected Growth

The population of Northern Virginia grew by over half a million between 2000 and 2010. The Northern Virginia population totaled 2.62 million in 2010, up from 2.12 million in 2000, reflecting an increase of 23.9 percent over the decade. Northern Virginia's population growth was 54.9 percent of the total growth in the state of Virginia over the decade.

The rate of population growth fuels a need for housing, transportation, schools, commercial services, and other development. As one might expect, there has been a shift in the land cover of the region from forest and fields to buildings and pavement which has increased impervious land cover in the region.

Growth is projected to continue in the region. Transportation area zones overlaid with population projection data were used to identify watersheds in the region that are projected to experience high pressure from new development over the next 35 years.

3.1.1 Neabsco Creek

Neabsco Creek in Prince William County was identified as a high growth watershed with an increase of up to 400% in households projected to occur primarily in the lower reaches of the watershed near the confluence of Neabsco Creek and the Potomac River (Figure 3).

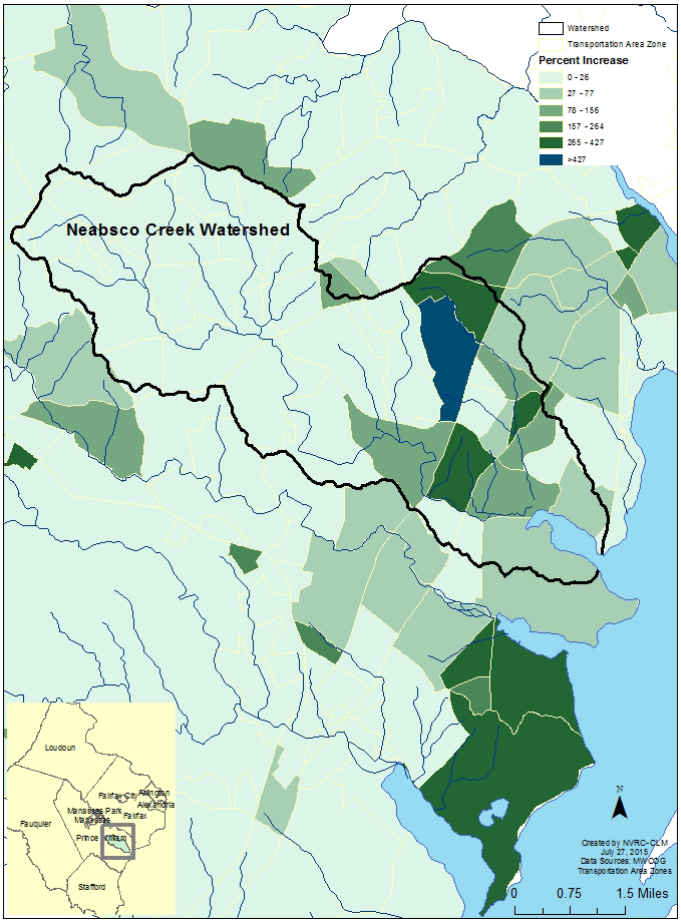


Figure 2. Projected Change in Households in Transportation Area Zones From 2015 to 2040 in the Neabsco Creek Watershed of Prince William County

The Neabsco Creek watershed is approximately 27 square miles (17,280 acres) and covers most of Dale City and portions of Woodbridge. Land use is predominately developed land (51 percent), forest (33 percent) and pastureland (15 percent). Development in the watershed spans the range of low density residential to high density commercial. Neabsco Creek routinely floods Route 1 and other areas in the watershed.

The Virginia Department of Environmental Quality (VADEQ) listed Neabsco Creek on Virginia's 2002 Section 303(d) List as being unable to attain its primary contact use due to violations of the bacteriological criteria. To address the pollution, drainage and erosion problems associated with the Neabsco Creek watershed, the Prince William County Government is in the process of undertaking a series of stream restoration and infrastructure protection practices along Cow Branch http://www.pwcgov.org/government/dept/budget/Documents/13CIP--05--Community%20Development--3WM--Neabsco%20Creek.pdf

3.1.2 Powell's Creek

The Powell's Creek watershed covers about 18 square miles (11,520 acres). Powell's Creek begins near Independent Hill and flows past the Prince William landfill on Rte 234/Dumfries Rd., then on through Montclair, where it is interrupted by Lake Montclair.

Powell's Creek crosses Route 1 just south of Cardinal Drive, flows through the Port Potomac subdivision and joins the Potomac River at Leeslyvania State Park. Near the Potomac River shoreline, the southern boundary for the Powell's Creek watershed generally follows Cherry Hill Road.

The upper third of the watershed is somewhat rural in nature, with low density residential and agricultural land uses alongside the County's large acreage landfill operation and Resource Protection Area (RPA) buffers. The trend in recent years for this portion of the watershed appears to be one of rezoning A-1 zones to residential and then sub-dividing the large agricultural tracts into higher density residential developments. This trend appears to be one that will continue into the future as large increases in the number of households is projected to occur (Figure 4).

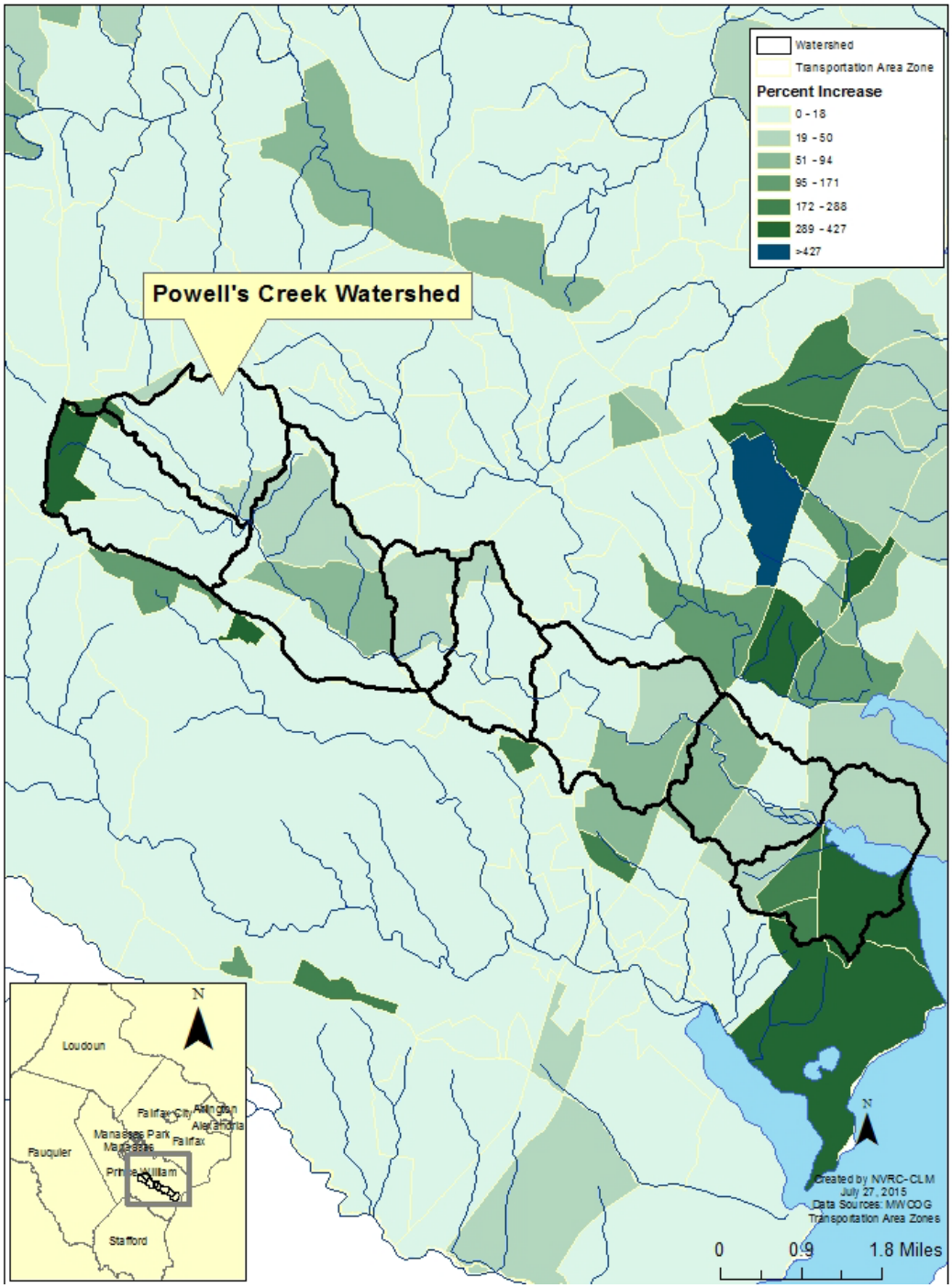


Figure 3. Projected Change in Households in Transportation Area Zones From 2015 to 2040 in the Powell's Creek Watershed of Prince William County

The middle third of this watershed is heavily developed with medium density residential neighborhoods that have been in place for many years and is not projected to have a large increase in new development. The residential area around Lake Montclair and the associated recreational areas dominate this region of the watershed.

The lower third of the watershed has a mix of large swaths of undeveloped, wooded land along with higher density development (i.e. apartments and townhouses). According to the Prince William County Powell's Creek Watershed Management Plan, large lot developments such as schools and high density residential development will significantly change the land use characteristics of this portion of the watershed in coming years. A 400% projected increase in new households through 2040 as shown in Figure 3 is predicted to occur in the lower third of the watershed.

At the confluence of Powell's Creek with the Potomac River, the Creek becomes tidal. The Virginia Institute of Marine Science's 1992 study of tidal tributary streams along the Potomac River described the wetlands in Powell's Creek as one, large creek marsh that is valuable as both a nursery and spawning area for anadromous fishes, as well as a habitat for many other fishes and wildlife.

Water quality in Powell's Creek is impaired and has a local TMDL for fecal coliform bacteria, polychlorinated biphenyls PCB's, and benzo(k)fluoranthene in fish tissue. Due to exceedances of the water quality standard criterion, the water in Powell's Creek is not supporting of the Recreation Use goal and not supporting of the Fish Consumption Use goal. The listing of this stream segment is based on data from the DEQ's ambient water quality monitoring and fish tissue/sediment monitoring.

3.1.3 Windy Run

The Windy Run watershed is located in north Arlington County. Windy Run drains directly into the Potomac River. The drainage area is one-half of a square mile, and 21% of the watershed is impervious. The land use in Windy Run watershed is largely single-family residential (74%) and is not projected to experience a large increase in households (Figure 6). Arlington County found Windy Run to be a priority stream for restoration given that almost 75 percent of the stream length was in an actively eroding state, with only 6 percent artificially stabilized.

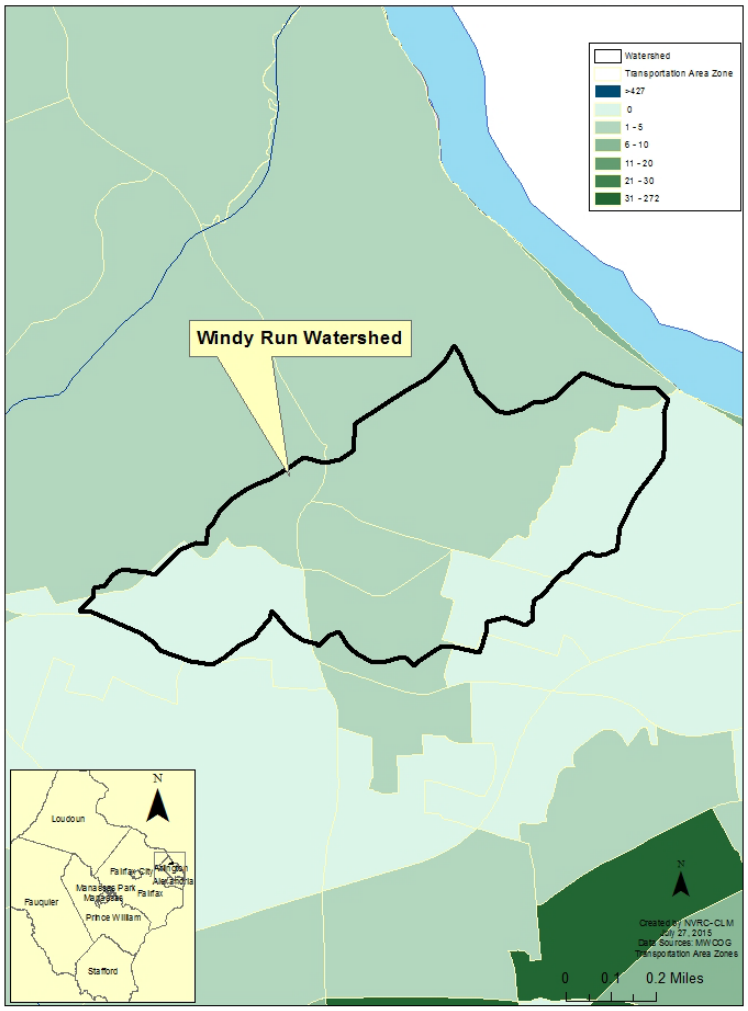


Figure 6. Projected Change in Households in Transportation Area Zones From 2015 to 2040 in the Windy Run Watershed of Arlington County

3.2 Build-out Description

A build-out analysis is an estimate of the amount and location of development that may ultimately occur in a specified area as permitted by current zoning code. A build-out analysis allows for evaluation of potential development impacts on land use. The build-out analysis is an estimate of future development and looks specifically at how zoning regulations enable and guide future development potential. The build-out estimates the amount of development permitted under the zoning in place at the time of the analysis and provides an estimate of the spatial distribution of such future development. However, as with all build-out methodologies, it is only an estimate of what is possible under current zoning. Many other factors, regulations, and economic decisions effect the development of property but, not all of these factors can be accounted for in the build-out analysis.

Most neighborhoods in Arlington County and City of Falls Church are already built out however; the demand for larger and more modern homes is high. These areas are undergoing infill development where older homes built in the 1950's and 1960's are torn down and replaced with much larger homes that maximize the buildable footprint of the parcel. From FY10 to FY13, the impervious footprint of single-family parcels increased by an average of 50 percent. In Arlington County, single-family residential development projects accounted for nearly 60 percent of the impervious cover increases associated with all regulated development activity (Arlington County Stormwater Mgmt Plan). New development and infill development practices will result in loss of urban tree canopy and an increase in impervious cover (Figure 7).

Figure 7. Example of infill redevelopment in Northern Virginia

New development is required to comply with stormwater regulations and most use BMP's capture and detain the first inch of runoff on site. However, the Bay TMDL and the MS4 permits required the permit holder to offset these pollutant load increases if each project does not do so. This places legal and fiscal risk on the permit holder.

3.2.1 General Procedure for Conducting the Build-out Analyses

Build-out analyses were conducted for the following watersheds that are projected to experience a high rate of new development or infill development between 2015 and 2014:

- Neabsco Creek, Prince William County,
- Powell's Creek, Prince William County, and
- Windy Run, Arlington County.

The build-out assumes that owners will make the highest and best use of their properties, maximizing the density of residential uses and maximizing the size of the structures allowed in the zone. The build-out does not account for relief to the density or dimensional standards resulting from discretionary decisions such as variances.

The build-out also does not account for potential accessory buildings that may be allowed under local ordinances, i.e. a shed or detached garage on a single family residential lot. The analysis is aimed at getting an estimate of the areal extent of land cover change that might occur as a result

of build-out so less emphasis was placed on the numbers of certain types of buildings that would occur at build-out. With those assumptions in mind, the following paragraphs summarize the general procedure that was followed.

Community Viz, which is a GIS extension to ESRI's ArcMAP, was used to run the build-out analyses. The program has the capability of calculating build-out based on a variety of inputs and assumptions about density and the estimated gross floor area.

Step 1: Assemble data. The most recent available GIS data was gathered to conduct the build-out analysis. Data sets gathered include zoning and updated parcel layers.

Step 2: Calculate input formulas. Each zoning designation is assigned either a density for residential development, or an Effective Floor Area Ratio (EffectiveFAR) for non-residential development, or both in the case of a mixed use category.

Step 3. Building Information. Enter maximum building footprints for each zone taking into account setbacks.

Step 4: Create a constraint layer. A constraint layer that includes all areas that are to be excluded from the analysis is created. This layer includes all permanently protected open space, wetlands, water bodies, rights-of-way/roads, parks, Resource Protection Areas (RPA), FEMA 100 year flood plains, and land owned by the county, state, or federal government. These were all excluded as they were unlikely to be developed in the planning horizon under consideration.

Step 5: Run Build-out. Community Viz is used to run the build-out analysis. Community Viz first calculates the potential development on each parcel (based on the density or Effective FAR) and then establishes the net additional development by subtracting the existing development from the maximum build-out potential. The results provide additional dwelling units and/or nonresidential square footage for each parcel (Figure 8).

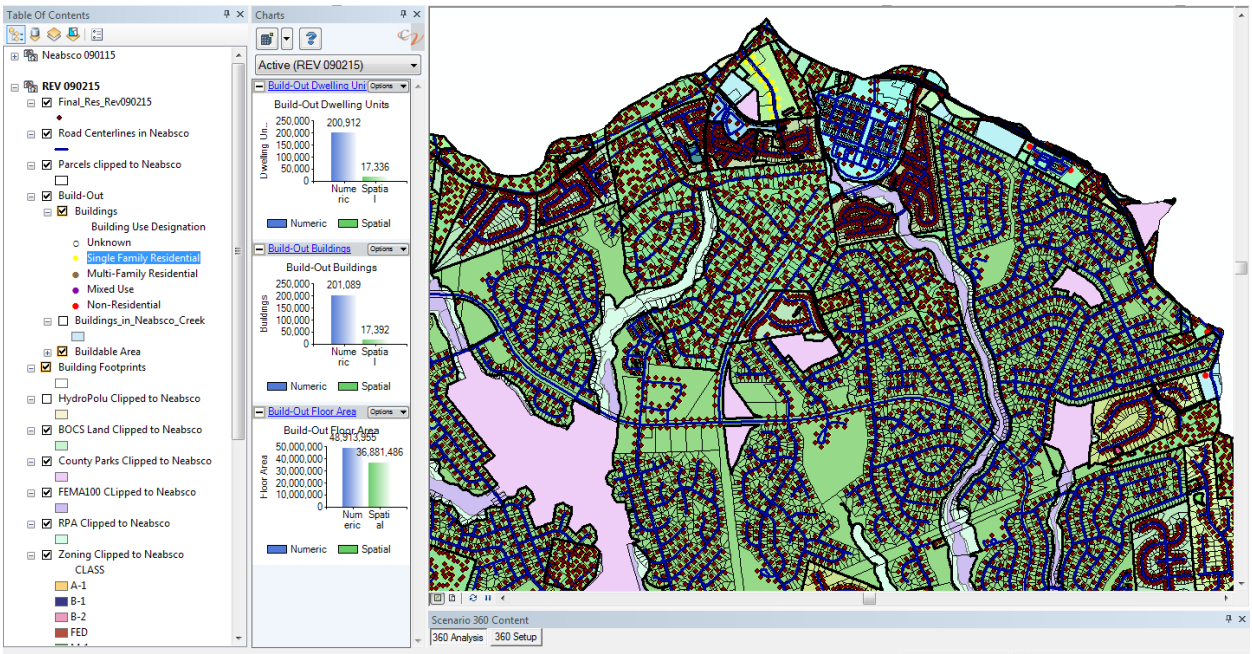


Figure 8. Screenshot of Neabsco Creek Build-out showing constraint layers and buildings.

3.3 Results of Build-out Analyses

3.3.1 Neabsco Creek

According to the Prince William County building footprint layer, the square footage of all residential and commercial existing building footprints in the Neabsco Creek watershed is 94,135,428 square feet. At full build-out, the square footage of residential and commercial buildings is estimated to be 111,642,065 square feet which is an increase of 17,506,637 square feet or 401.9 acres. The projected increase in impervious surface associated with new buildings is estimated to be approximately 2.3 percent of the watershed area (Table 4).

Table 4. Results of Neabsco Creek Build-out in square feet of new buildings

Existing Buildings (square feet)	Build-out Buildings (square feet)	Percent Change in square feet of Buildings	Percent change in the watershed area to buildings
94,135,428	111,642,065	18.5%	2.3%

3.3.2 Powell's Creek

According to the Prince William County building footprint layer, the square footage of all residential and commercial existing building footprints in the Powell's Creek watershed is 21,624,168 square feet. At full build-out, the square footage is estimated to be 52,749,653 square feet which is an increase of 31,125,485 square feet or 714.5 acres. At build-out, an additional 10 percent of the watershed area could potentially become impervious (Table 5).

Table 5. Results of Powell's Creek Build-out in square feet of new buildings

Existing Buildings (square feet)	Build-out Buildings (square feet)	Percent Change in square feet of Buildings	Percent of watershed area covered by buildings at build-out
21,624,168	52,749,653	69.5	10

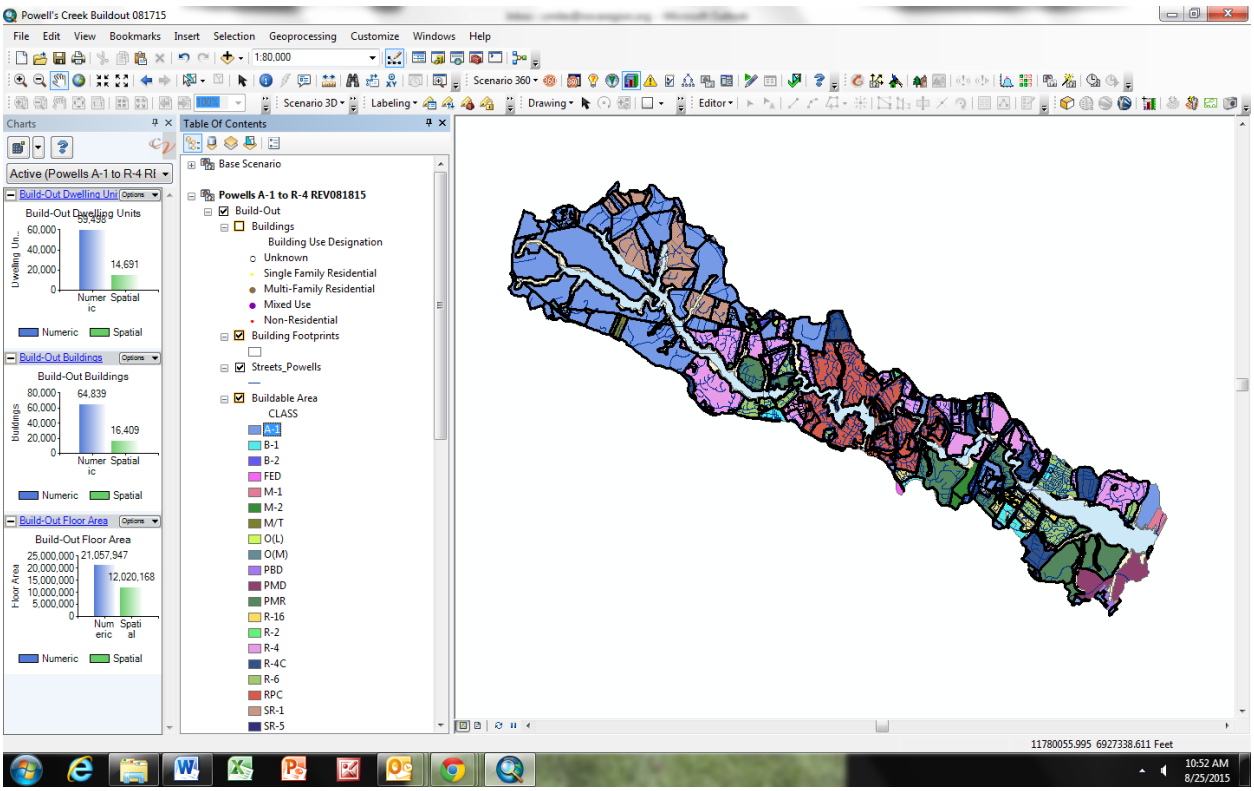


Figure 9. Powell's Creek Zoning

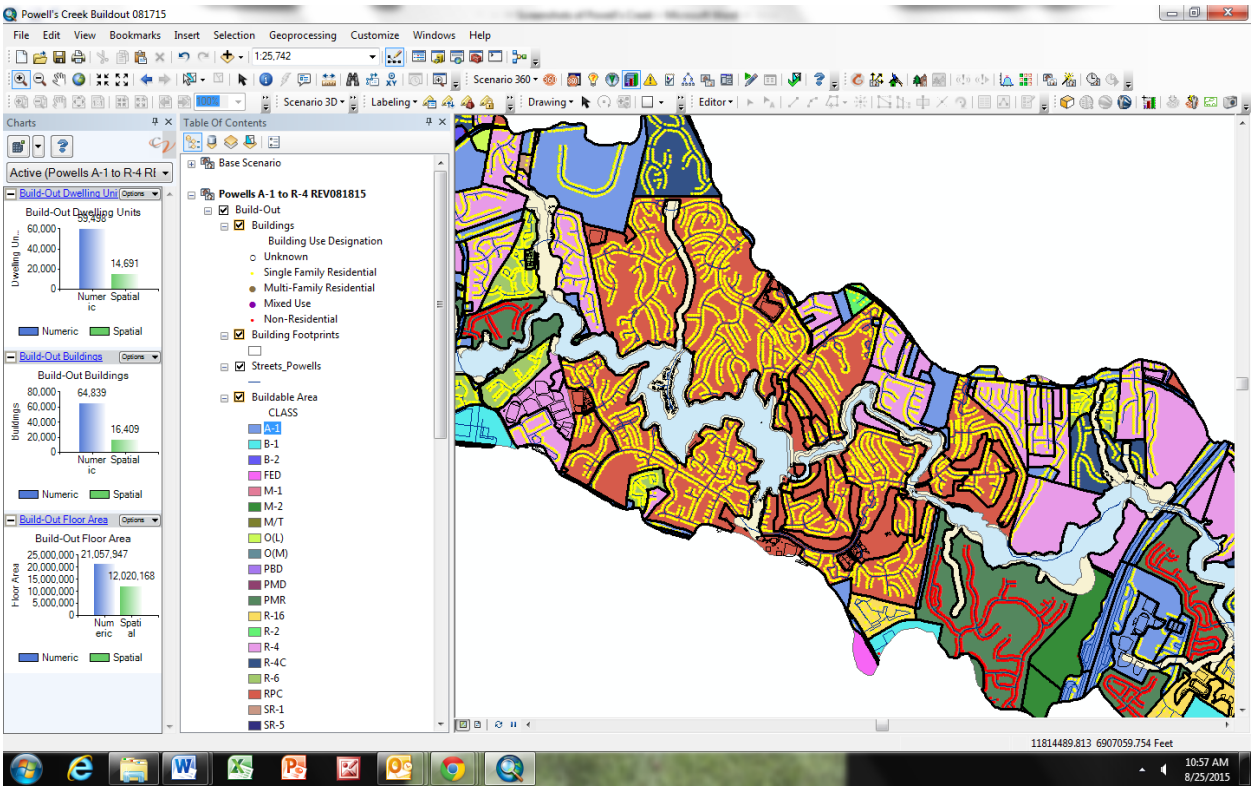


Figure 10. Southern Half of Powell's Watershed- Shows build-out of the base scenario which is build-out under current zoning

If A-1 parcels were to be rezoned to R-4 in the future, additional buildings would be placed in the watershed (Figure 11).

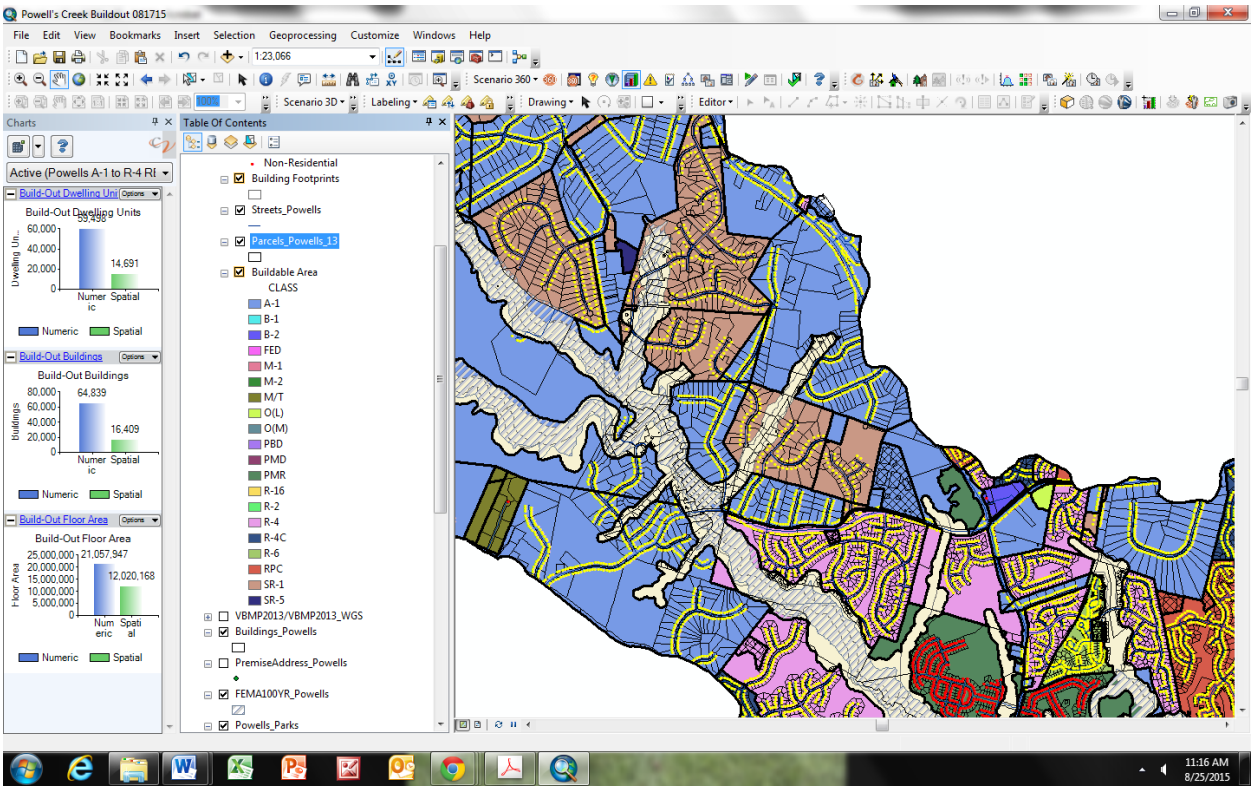


Figure 11. Screenshot of Northern Powell's Creek showing build-out with A-1 rezoned to R-4

3.4 Windy Run

Windy Run is approximately 316 acres (13,791,811 square feet). Residential buildings currently make up approximately 35.5 acres (1,957,064 square feet) of the watershed. At full residential build-out, residential buildings would comprise approximately 52 acres of the watershed; an increase in impervious acreage of approximately 13.4 acres. This is approximately four percent of the watershed area that could potentially transition to impervious cover (Table 6)

Table 6. Results of Windy Run Build-out in square feet of new buildings

Existing Buildings (square feet)	Build-out Buildings (square feet)	Percent Change in square feet of Buildings	Percent of watershed area covered by buildings at build-out
1,957,064	2,543,243	4.0	18.2

3.5 i-Tree Hydro Procedure

The goal of this project is to better understand the role of the urban forest –for stormwater management. In particular, how the presence or absence of trees and plants affect both stormwater runoff quantity and quality. The changes in land cover resulting from build-out were used as data input into a hydrologic simulation tool called i-Tree Hydro. The tool, i-Tree Hydro, is part of the i-Tree software suite from the USDA Forest Service that provides urban and community forestry analysis and benefits assessment tools. This suite of tools has gained popularity among planners in recent years because it is free, easy to use, and the results are useful and easy to understand.

i-Treen Hydro is "a stand-alone application designed to simulate the effects of changes in tree and impervious cover characteristics within a defined watershed on stream flow and water quality. It was designed specifically to handle urban vegetation effects so urban natural resource managers and urban planners can quantify the impacts of changes in tree and impervious cover on local hydrology to aid in management and planning decisions." The model was developed collaboratively among individuals from the U.S. Forest Service, SUNY College of Environmental Science and Forestry, Davey Institute, and Syracuse University.

i-Tree Hydro models runoff volume and water quality using inputs of elevation, land cover, weather, and various model parameters. It simulates precipitation, interception, infiltration, evaporation, transpiration, snowmelt, flow, and storage.

The accuracy of the model is checked by comparing estimated values with the actual values gathered from weather stations.

3.6 i-Tree Hydro Results

3.6.1 Neabsco Creek

The Base Case scenario was defined using current land cover conditions that were ascertained through a sampling of 500 points on satellite imagery with a resolution of at least one foot and categorized in i-Tree Canopy (Table 7).

Table 7. Neabsco Creek landcover from i-Tree Canopy Analysis

Neabsco Creek Watershed		
Landcover (Base Case)	Percent Cover (%)	Percent Error (±)
Tree Deciduous	40	2.19
Tree Evergreen	0	0
Shrub	4.2	0.9
Road	9.4	1.31
Canopy over Impervious	2	0.63
Grass	21.4	1.83
Bare Soil	2.2	0.66
Water	1.6	0.57
Building	7	1.14
Impervious Other	12.2	1.46

The Alternative Case scenario utilized the land cover conditions that were estimated from the build-out analysis. Under full build-out, the percentage of tree canopy decreased by 7 percent and the percentage of impervious cover increased by 7 percent. The change in land cover resulted in additional 1,982,858.2 cubic meters or 9 percent of total stream flow for the modeled time period (2012). The baseflow decreased by 1,033,410.4 cubic meters (13%). The pervious flow increased by 2,921,839.8 cubic meters (61%). The impervious flow increased by 1,832,328.3 cubic meters (16%). The number of flow events that result in above average flow increased and the number of events with below normal flow also increased. In general, the shift in proportions of types of flow will result in the stream developing more flashy flow characteristics (Table 8).

Table 8. Change in stream flow at build-out using i-Tree Hydro

Scenario	Baseflow (MG/YR)	Impervious (MG/YR)	Pervious (MG/YR)	Total Runoff (MG/YR)
Current	2,175	2,988	510	5,673
Build-out	1,902	3,472	823	6,197
% Change under Build-out Conditions	**-13%**	**16%**	**61%**	**9%**

The Event Mean Concentrations (EMC) for most pollutants also increased slightly particularly for Total Suspended Solids. Modest increases in Pollutants of Concern such as TN, TP, and TSS were also found.

Additional results of the i-Tree Hydro simulation can be found in Appendix B.

3.6.2 Powell's Creek

The Base Case scenario was defined using current land cover conditions that were ascertained through a sampling of 500 points on satellite imagery with a resolution of at least one foot and categorized in i-Tree Canopy (Table 9).

Table 9. Powell's Creek landcover from i-Tree Canopy Analysis

Powell's Creek Watershed		
Landcover (Base Case)	Percent Cover (%)	Percent Error (±)
Tree Deciduous	51.7	2.24
Tree Evergreen	0	0
Shrub	5.41	1.01
Road	7.62	1.19
Canopy over Impervious	2	0.63
Grass	15	1.6
Bare Soil	4.21	0.9

Water	2.2	0.66
Building	5.21	0.99
Impervious Other	6.61	1.11

The Alternative Case scenario utilized the land cover conditions that were estimated from the build-out analysis. Under full build-out, the percentage of tree canopy decreased by 5.3 percent and the percentage of impervious cover increased by 5.3 percent. The change in land cover resulted in additional 406,033.9 cubic meters of total stream flow for the modeled time period (2012). The baseflow decreased by 112 million gallons. The pervious flow increased by 2,921,839.8 cubic meters. The impervious flow increased by 1,832,328.3 cubic meters. The number of flow events that result in above average flow increased and the number of events with below normal flow also increased. In general, the shift in proportions of types of flow will result in the stream developing more flashy characteristics (Table 10).

Table 10. Results from i-Tree Hydro model showing the change in flow

Scenario	**Baseflow (MG/YR)**	**Impervious (MG/YR)**	**Pervious (MG/YR)**	**Total Runoff (MG/YR)**
Base Case	1,521	32.47	49.58	1,603
Build-out	1,409	40.15	47.02	1,496
% Change under Build-out Conditions	-7%	24%	-5%	-7%

The Event Mean Concentrations (EMC) for most pollutants also increased slightly particularly for Total Suspended Solids. The results of the simulation can be found in Appendix B.

3.6.3 Windy Run

The Base Case scenario was defined using current land cover conditions that were ascertained through a sampling of 500 points on satellite imagery with a resolution of at least one foot and categorized in i-Tree Canopy (Table 11).

Table 11. Windy Run landcover from i-Tree Canopy Analysis

Windy Run Watershed		
Landcover	Percent Cover (%)	Percent Error (±)
Tree Deciduous	42.7	2.21
Tree Evergreen	0	0
Shrub	1	0.45
Road	12.8	1.49
Canopy over Impervious	5.79	1.04
Grass	13.8	1.54
Bare Soil	0.6	0.35
Water	0	0
Building	14.2	1.56
Impervious Other	9.18	1.29

3.7 Leaf out Procedure

A 'Leaf Out' analysis was conducted to estimate the area for potential new urban tree canopy in the watershed and what effect that new canopy might have on runoff. The procedure entailed a process of elimination by first identifying areas that are unsuitable for planting. The following GIS layers were used to identify unsuitable planting areas. Unsuitable planting areas are:

- Existing Forest
- Current Trees
- Impervious Surface

- Buildings
- Roadways
- Water
- Utility Easements
- Railroads
- Power Lines

The remaining areas were considered suitable for planting. However, it is unlikely that trees would be planted right next to buildings, so in ArcView, buffer the plantable area by 10 feet to create separation from buildings, current forests and roads. The buffered plantable area is now the total area in which you can plant trees/have additional tree canopy.

The buffered plantable areas that are owned by the county were selected and colored red and the buffered plantable areas that are privately owned were colored green (Figure 12).

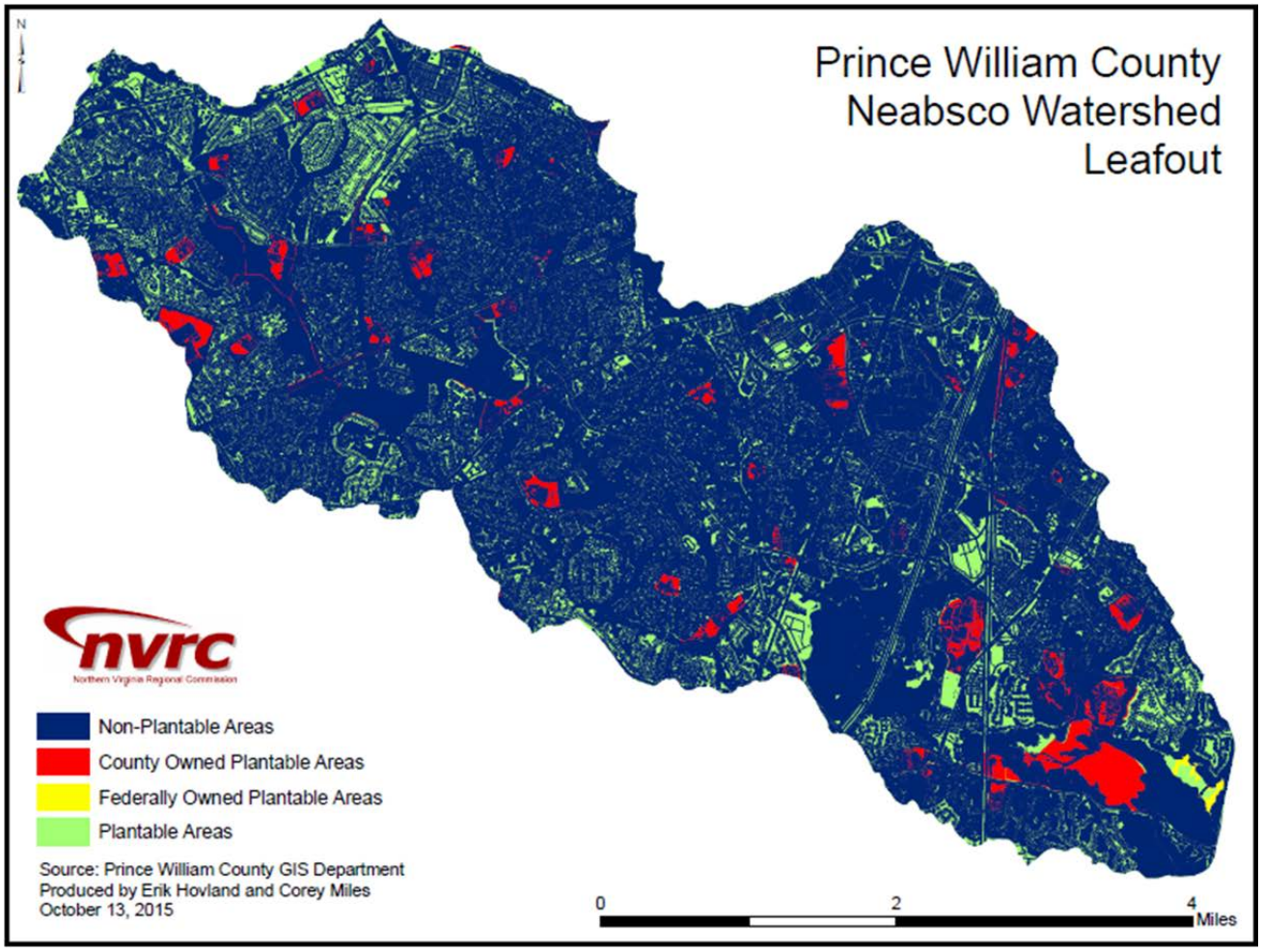


Figure 12. Map of Plantable and Non-plantable areas in Neabsco Creek.

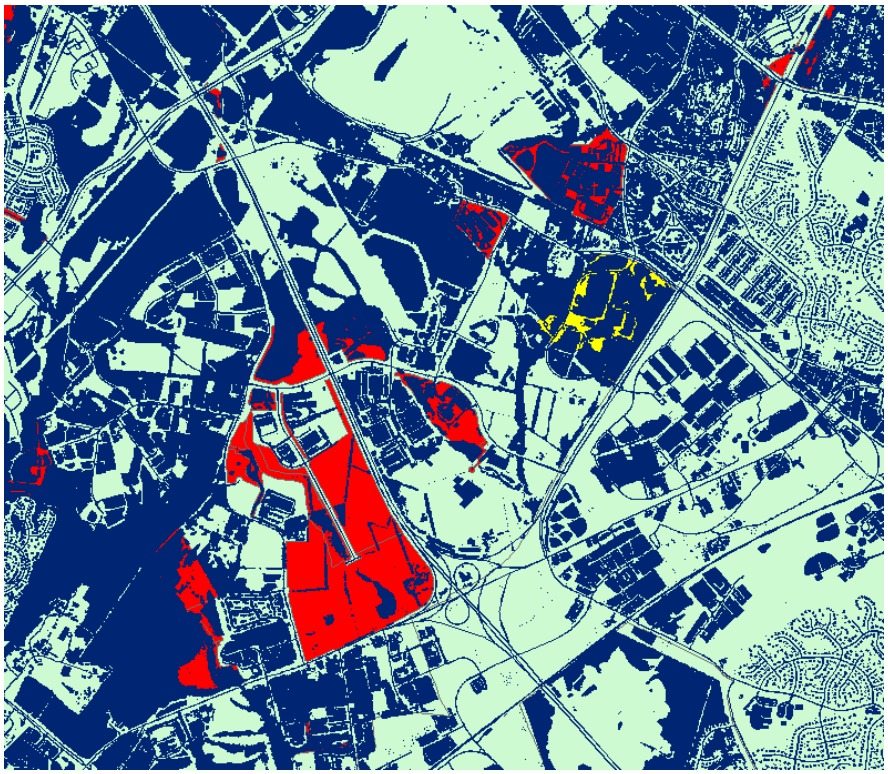


Figure 13. Screenshot of county owned plantable area shown in red

3.8 Leaf out Results

The area of the watershed associated various cover types under existing conditions compared to leafout conditions is shown in Table 12. If all plantable areas were planted with canopy trees, approximately 15% of the watershed land cover that is currently grass, shrubs, or bare soil, could be converted to urban tree canopy

Table 12 Percent change in land cover types under leaf-out scenario

Cover Type	Current Area (%)	Leaf-out Area (%)	Percent Change (%)
Buildings	8.6	8.6	0.0
Impervious	29.0	29.0	0.0
Tree	44.7	59.8	15.1
Shrub	2.5	0.0	-2.5
Herbaceous	12.7	0.5	-12.2
Water	10.7	10.7	0.0
Soil	0.4	0.0	-0.4

The Leaf-Out Scenario was then modeled in i-Tree Hydro for Neabsco Creek Watershed. The results of the Leaf-Out scenario were then compared to the Build-Out Scenario. The change in land cover under the leaf-out scenario resulted in a three percent decrease of total runoff. The impervious flow component decreased by 13 percent

Scenario	Baseflow (MG/YR)	Impervious (MG/YR)	Pervious (MG/YR)	Total Runoff (MG/YR)
Build-out	1,902	3,472	823	6,197
Leafout	1,994	3,037	950	5,981
% Change under Leafout Conditions	5%	-13%	13%	-3%

4 Policy and Implementation Strategy Recommendations

Tree canopy provides stormwater controls in urban areas where options and space are limited. Such controls through reductions to stormwater peak flow, velocity, and stream bank erosion show particular promise in the MS4 area where subsequent reductions in pollutant loadings could make progress toward meeting local and Bay TMDL requirements. Extensive use of on-site BMP's will be required to mitigate future impacts to stream channels and water quality in many watersheds throughout the region particularly those projected to experience heavy development pressure. Even though new development is required to retain the first inch of rain on site, flashy flows will continue to be a problem. According to the National Climate Assessment report, projections of future climate in Northern Virginia state that the recent trend towards increased frequency of heavy precipitation events will continue. Projections also suggest that future warming will cause tropical storms to be fewer in number globally, but stronger in force (National Climate Assessment, 2014). Urban tree canopy and forested buffer areas will necessary to reduce the flow of runoff and mitigate the erosive potential of high-flow events. This highlights the need for local governments and non-governmental organizations to actively and collaboratively work towards shared solutions where stormwater management is concerned. Taking action to identify legal risk and make appropriate decisions to minimize risk is particularly important in light of predicted changes in our climate.

4.1.1 Urban Canopy and Stormwater Recommendations

- Chesapeake Bay Program and the Commonwealth of Virginia should allow local governments TMDL credits for increasing forest canopy and for maintaining existing forests through an urban forest management plan. The high costs of meeting Bay water

quality goals through wastewater and stormwater BMP's could make maintenance and preservation of existing forest highly attractive - if counties can get proper credit for it.

- Examine every possibility, like large parking lots and residential lawns, as places to offset tree losses.
- Require tree preservation plans to be prepared by certified arborists as part of the Stormwater Pollution Prevention Plan (SWPPP) for development
- Utilize local Soil and Water Conservation District's to provide by-law guidance to HOA's to obtain consultation from a certified arborist when planning to remove trees greater than 10 inches dbh
- Develop a social marketing campaign aimed at promoting the preservation of existing trees in the landscape and the planting of new trees
- Develop a policy that requires tree companies to have a certified arborist on staff or develop a Voluntary Certification Program for Arborists in Virginia (examples include MD Licensed Tree Expert, New Hampshire Arborists Association Certification Program, Massachusetts Certified Arborist Program). This would reduce the number of companies promoting poor tree practices that ultimately result in the decline of a tree such as topping, spiking, and unnecessary removals.
- Counties could require three trees to be planted for every 5,000 square feet of disturbance
- Ensure that trees have a soil volume minimum by restricting impediments to root growth.

4.1.2 Planning and Zoning Recommendations

Northern Virginia has begun to experience the effects of suburban sprawl; traffic jams, air and water pollution, higher energy use etc. The following recommendations utilize local planning and zoning solutions that would preserve or increase urban tree canopy.

- Create town centers and cluster high density development around Encourage development in areas where public investments have already been made in public transportation, infrastructure, parks, schools, and other facilities,
- Use dimensional requirements such as lot size, frontage, and open space to encourage cluster developments.
- Utilize land use density transfers and transfer of development rights to achieve the same overall density in a site, but concentrate the development in less sensitive portions of watersheds.
- Increase minimum ten-year tree canopy percentages for developers who cut trees by five percent in all zones.

- Protect large contiguous patches of trees that were identified in the NVRC Conservation Corridors study from development through an overlay district or stormwater easement that requires developers utilize Conservation Subdivision Designs.
- Track the health of new trees and existing canopy through inventories.
- Dedicate a portion of tree mitigation funds to preservation and maintenance of city/county owned trees.
- Require a long-term tree preservation plan that will become part of the covenants or architectural guidelines for development of subdivisions that result in formation of new Homeowner's Associations; i.e. the new homeowner must provide adequate provision of staking, watering, and maintenance to ensure long-term survival.

5 Conclusion and Next Steps

The results show that a reduction of tree canopy leads to an increase in stormwater volume and flow rates, and a gain in canopy leads to a decrease in stormwater volume and flow rates. Increasing tree canopy cover over a watershed mitigates stormwater pollution loading modestly. The percentages of increase and decrease are consistent with other studies of similar nature and were expected (Filipovic et al., 2015). One outcome that is important to note is the particular effect on stream flow components. The results show that the component of flow that is most affected by the changing landcovers is impervious surface runoff. The large amount of pavement in urban watersheds retains a lot of heat in the summer, so the flashy flows that follow heavy rains inundate the streams with pulses of warm water. This outcome is consistent with other literature that states that the amount of impervious surface especially directly connected impervious surface is actually more important to changes in urban hydrology than the size of the tree canopy. For places in Northern Virginia that are actively restoring stream channels at a cost of up to $700 per linear foot, the results show that these restoration efforts should also be coupled with much larger afforestation efforts in the drainage area. Even a small increase in canopy (3-5%) upstream of a stream restoration project can alleviate effects of future large pulses in impervious flow that may occur as a result of build-out and help to ensure that stream restoration efforts are successful over time.

6 References

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Appendix A- Local Codes Pertaining to Tree Canopy and Development

Table of Contents:

Arlington

Alexandria

Fairfax County

Fairfax City

Falls Church

Herndon

Prince William

Arlington:

Minimum tree canopy requirements

a. Ten percent (10%) tree canopy for a site zoned business, commercial, or industrial

b. Ten percent (10%) tree canopy for a residential site zoned twenty (20) or more units per acre

c. Fifteen percent (15%) tree canopy for a residential site zoned more than ten (10) but less than twenty (20) units per acre;

d. and, Twenty percent (20%) tree canopy for a residential site zoned ten (10) units or less per acre.

Arlington County Code § 61-10. General Performance Standards for Development in Chesapeake Bay Preservation Areas

http://arlingtonva.s3.amazonaws.com/wp-content/uploads/sites/22/2014/01/County-Code-61-Chesapeake-Bay-Preservation-Ordinance.pdf

Alexandria:

- **7-2507 - Tree coverage requirement.**

(A)

For all construction that requires a grading plan, trees must be planted or existing trees preserved to provide a minimum of 25 percent canopy cover over the site. Refer to the City of Alexandria Landscape Guidelines to determine tree crown coverage allowances.

(B)

The director shall approve this requirement as part of the grading plan.

(Ord. No. 4556, § 1, 6-24-08; Ord. No. 4653, § 2, 4-17-10; Ord. No. 4724, § 1, 6-25-11)

https://www.municode.com/library/va/alexandria/codes/zoning?searchRequest=%7B%22searchText%22:%22canopy%22,%22pageNum%22:1,%22resultsPerPage%22:25,%22booleanSearch%22:false,%22stemming%22:true,%22fuzzy%22:false,%22synonym%22:false,%22contentTypes%22:%5B%22CODES%22%5D,%22productIds%22:%5B%5D%7D&nodeId=ARTVIISUZORE_7-2507TRCORE

Fairfax County:

- **Section 122-2-1. - Ten-year Tree Canopy Requirements.**

  (a) All land development requiring the submission of a site plan, preliminary subdivision plan, subdivision construction plan, conservation plan, grading plan, or a rough grading plan shall provide for the conservation of trees on the site such that, after ten (10) years, minimum tree canopy is projected to be as follows:

- **Table 1 10-Year Tree Canopy Requirements**

Use or Zoning District	**Percentage of site to be covered by tree canopy in 10 years**
Dedicated school, athletic field, nonwooded active recreation area	Ten percent (10%)
Commercial Revitalization District	See Note Below
Commercial; Industrial; PDC; R-20; R-30; PDH-20; PDH-30; PDH-40; PRM; R-MHP; medium and high-density areas of a PRC District	Ten percent (10%)
R-12; R-16; PDH-12; PDH-16	Fifteen percent (15%)
R-5; R-8; PDH-5; PDH-8	Twenty percent (20%)
R-3; R-4; PDH-3; PDH-4	Twenty-five percent (25%)
R-A; R-P; R-C; R-E; R-1; R-2; PDH-1; PDH-2; and low-density areas of a PRC District	Thirty percent (30%)
Note: In Commercial Revitalization Districts the above requirements shall apply to the extent feasible for expansion or enlargement of existing developments and shall be applicable for redevelopment and new developments. Expansion, enlargement, redevelopment and new	

Use or Zoning District	Percentage of site to be covered by tree canopy in 10 years
development shall be as defined by the Zoning Ordinance.	

-

(b)

For purposes of administering the above requirement, land development does not include: construction of additions to existing residential structures; construction of residential accessory structures; demolition of existing residential structures; reconstruction of residential structures on existing foundations; construction associated with minor site plans; construction of trails, sidewalks, sanitary sewers, storm sewers, and other public improvements of a linear nature not included as part of a larger common plan of development; and, other land disturbing activities that present a minor threat to existing tree resources as determined by the Director.

(64-08-122; 32-10-122)

- **Section 122-2-2. - Standards for 10-year Tree Canopy Requirements.**

(a)

The 10-year tree canopy requirement may be met through the preservation or planting of trees. However, when existing trees meet standards of health, condition, and suitability, and when it is feasible to preserve those trees within the framework of permissible uses, densities, design standards, and construction practices, all efforts shall first be made to meet the tree canopy requirement through the preservation of trees before tree planting is allowed to meet any portion of the tree canopy requirement.

(b)

Tree canopy credit shall be given to existing areas of trees and forested areas designated to be preserved on plans and comprised of self-supporting and woody plant material exceeding five feet in height at time of plan submission provided that the trees and forested areas meet standards for health, condition, and suitability.

(c)

Any portion of the tree canopy requirement that cannot first be met through the preservation of trees as provided for in § 122-2-3 shall be provided through tree planting.

(d)

Tree canopy credits for trees and plant material used to satisfy 10-year tree canopy requirements shall be determined in accordance with the provisions of the Public Facilities Manual (PFM). (64-08-122.)

- **Section 122-2-3. - Tree Preservation Requirements.**

(a)

Except as provided for in § 122-2-3(b), the percentage of the development site covered by tree canopy at the time of plan submission shall equate to the minimum portion of the total 10-year tree canopy requirement of § 122-2-2(a) that should be met by means of tree preservation. This minimum portion shall be identified in plats and plans as the "tree preservation target."

(b)

Deviations, in whole or part, from the tree preservation target may be requested under the following conditions:

1.

Meeting the tree preservation target would prevent the development of uses or densities otherwise allowed by the Zoning Ordinance;

2.

Meeting the tree preservation target would require the preservation of trees and forested areas that do not meet standards for health, structural condition, and other vegetation and risk management requirements.

3.

Construction activities could be reasonably expected to impact existing trees or forested areas used to meet the tree preservation target to the extent they would not likely survive in a healthy and structurally sound manner for a minimum of ten (10) years in accordance with the post-development standards for trees and forested areas.

(c)

Deviations from the Tree Preservation Target shall be granted for any of the justifications listed above provided that a written request is submitted and approved by the Director.

(d)

The Director may grant additional canopy credits in order to encourage the preservation of forest communities that provide valuable environmental, ecological, and wildlife conservation benefits.

(e)

The Director may grant additional tree canopy credits in order to encourage developers to preserve trees for official designation as heritage, memorial, specimen and street trees as provided in Chapter 120 (Heritage, Memorial, Specimen and Street Tree Ordinance).

(f)

All tree and forested areas designated to be preserved on plans shall be protected and managed during all phases of construction. (64-08-122.)

- **Section 122-2-4. - Tree Planting Requirements.**

(a)

Tree canopy credit shall be given to areas of planted tree canopy based on the projected 10-year tree canopy calculation as set forth in the PFM, provided that the proposed tree species meets standards established to manage proper levels of biodiversity and the spread of invasive plants, pests, and diseases.

(b)

Tree canopy credits shall be given to tree seedlings, shrubs and woody seed mix planted in large open spaces, low-density residential settings, or in low-impact development projects.

(c)

Additional tree canopy credits shall be granted for the planting of trees that will provide air quality, energy conservation, water quality, wildlife conservation benefits.

(d)

Additional tree canopy credits shall be granted for the use of native tree species, and the use of cultivars or varieties that develop desirable growth and structural patterns, resist decay organisms and the development of cavities, show high levels of resistance to disease or insect infestations, and, exhibit high survival rates in harsh urban environments.

(e)

In order to provide higher levels of biodiversity and to minimize the spread of pests and diseases, or to limit the use of species that cause negative impacts to native plant communities, cause damage to nearby structures, or possess inherent physiological traits that prone trees to structural

failure, the PFM designates trees that cannot be planted to meet tree canopy requirements or that shall only receive partial tree canopy credits.

(f)

All plant materials used to satisfy 10-year tree canopy requirements shall be selected, located, handled and installed in accordance with the PFM. (64-08-122.)

- **Section 122-2-5. - Use of Tree Banking and Tree Preservation and Planting Fund.**

  (a) Where it can be demonstrated to the satisfaction of the Director that the tree canopy requirements set forth in § 122-2-1 cannot be met on-site, the portion of the requirement that cannot be met on-site may be met through the use of off-site tree banking or through a pro rata payment into the Tree Preservation and Planting Fund. (64-08-122.)

- **Section 122-2-6. - Exemptions and Modifications.**

  (a) The following uses are exempt from the requirements of this Chapter: bona fide silvicultural activity as defined by Va. Code Ann. § 10.1-1181.1 and the areas of sites included in lakes, ponds, and the normal water elevation area of stormwater retention facilities.

  (b) Deviations of the overall canopy requirements set forth in § 122-2-1 may be granted by the Director to allow for the preservation of wetlands, the development of farm land or other areas previously devoid of healthy and/or suitable tree canopy, or where the strict application of the requirements would result in unnecessary or unreasonable hardship to the developer. (64-08-122.)

Fairfax City:

Each subdivision or development shall provide for the planting or retention of trees on the site to the extent that, at a maturity of ten years, the minimum lot coverage of the tree canopy shall be as follows:

(1) Ten percent for a lot within any office, commercial or industrial zoning district;

(2) Fifteen percent for a site zoned RM or any other residential site zoned greater than ten units per acre;

(3) Twenty percent for a site zoned R-2, R-3, R-T6, RT or any other residential site zoned three to ten units per acre; and

(4) Twenty-five percent for a site zoned R-1 or any other residential site zoned less than three units per acre.

(Code 1978, § 26-65)

Falls Church:

- **Sec. 48-1180. - Tree canopy coverage required for single-family residential development.**

  (a) It is the intent of this section to regulate existing and replacement trees and/or shrubs to provide tree canopy coverage on developing and/or redeveloping residential lots zoned R1-A, low density residential and R1-B, medium density residential.

(b)Trees designated by the city as historic, specimen, street, park, memorial and other public trees shall be regulated pursuant to chapter 44, article II, pertaining to trees and shrubs.

(c) All developments, redevelopments, and/or land disturbing activities that are located in R1-A and R1-B zones that will disturb greater than or equal to 2,500 square feet of land shall provide for the preservation and/or planting of trees on the lot to the extent that, at a maturity of ten years, the minimum lot coverage of the tree canopy shall be 20 percent.

(d) Tree canopy coverage includes all areas within a lot's property lines beneath the dripline of vegetation. Calculation of the tree canopy coverage shall be the sum total of the existing vegetation and replacement vegetation.

(1)

Preserved tree canopy coverage vegetation shall include the dripline beneath trees that measure no less than two inches in diameter at breast height (DBH) six inches above ground level and shrubs that measure no less than five feet in height.

(2)

Replacement tree canopy coverage shall be as calculated by the most recent standards for tree canopy coverage by the Virginia Nursery and Landscape Association. Vegetation that is not included in this list may be substituted for vegetation of similar growth rate, type and form.

(e) Existing vegetation that shall be credited towards the required tree canopy coverage includes:

(1)

Existing or relocated trees and/or shrubs that have been preserved in accordance with a landscape conservation plan, pursuant to article IV, division 16 of this chapter, pertaining to Chesapeake Bay preservation area overlay district.

(2)

Canopy coverage from existing trees and/or shrubs shall be multiplied by 1.25 to determine the total tree canopy from preserved trees and shrubs. This is to encourage the preservation of existing vegetation and to recognize the additional environmental benefits that mature trees provide.

(f) Existing vegetation that shall not be credited towards the required tree canopy coverage include:

(1)

Trees with a rating of fair to poor and with a life expectancy less than ten years, as calculated by the city arborist using the most recent edition of the Guide for Plant Appraisal, published by the International Society of Arboriculture.

(2)

Undesirable and/or invasive vegetation, as published by the Virginia Department of Conservation and Recreation (DCR) and the Virginia Native Plant Society (VNPS).

(g) Replacement vegetation is required on lots that do not meet the minimum tree canopy coverage requirements either through the preservation of existing vegetation or due to the absence of tree canopy coverage present at the time of development or redevelopment.

(1)

Replacement vegetation should be chosen from the Recommended List of Trees and Shrubs to Plant in the City of Falls Church.

(2)

Substitute vegetation may be considered, provided it does not negatively impact native plant communities, cause damage to nearby structures and infrastructure, or possess inherent physiological traits that cause such trees to structurally fail.

(3)

Size, planting and installation specifications of the required replacement vegetation shall be pursuant to this section.

(h) In addition to the quantity of the replacement vegetation, its quality shall be encouraged through providing tree canopy coverage credit. Credit shall be given for the following types of vegetation that are selected and planted on the lot so that it improves the overall health and condition of the urban tree canopy and provides for additional environmental benefits.

(1)

A best management practice (BMP) credit of 25 percent of the tree canopy of the individual tree shall be given for those trees that are used in rain gardens, bio-retention areas or other vegetative best management practices.

(2)

An energy conservation credit of 25 percent of the tree canopy of the individual tree shall be given for those types of trees that are an approved species for energy conservation. Trees shall be located 20 to 35 feet from the edge of a building and shade its western, southwestern or northern exposure from 2:30 p.m. to 7:30 p.m. from May through September.

(3)

A species diversity credit of an additional ten percent shall be given for the use of not more than 20 percent of the trees to be of the same species.

(4)

A utility line compatibility credit of the average of the listed shade trees shall be given for trees that are an approved species that do not conflict with overhead utility lines. This credit applies when site constraints do not allow for the planting of shade trees elsewhere on the lot.

(i) Installation and bonding requirements of replacement vegetation shall be regulated pursuant to article V, division 7 of this chapter, pertaining to site plans.

(j) Where areas to be preserved (as designated on an approved landscape conservation plan) are encroached upon, the city arborist may require the replacement of any vegetation damaged or destroyed. The size, species and quantity of these replacements shall be determined by the city arborist based on the value of the vegetation removed as calculated by the latest formula published by the International Society of Arboriculture.

(k) Modifications to the tree canopy coverage requirement in this section may be permitted when in the professional opinion of the city arborist, a lot's unique physical constraints will not allow for the planting of the replacement vegetation. Only in these cases, the city arborist may allow a cash contribution to the tree canopy coverage fund or off-site mitigation fund whereby a portion of a lot's tree canopy coverage requirements may be met from off-site mitigation planting or replanting at locations at the direction of the city arborist.

(l) The tree canopy coverage fund or off-site mitigation fund shall be established for the deposit of cash contributions and mitigation fees, when necessary, and administered by the city arborist. This fund shall be utilized to plant trees on public and/or private properties within the city boundaries.

(1)

Cash contribution shall be based upon the replacement cost of the vegetation. The replacement cost shall be the sum total of all costs to purchase, transport, plant and guarantee the tree for one year from the date of planting.

(2)

Requests for tree plantings on private property shall be prioritized based on the lot's location in the sub watershed, existing tree canopy coverage and other site conditions that would improve the urban tree canopy. The commitment of the homeowner to provide longterm care for the planting shall be required.

(3)

Tree plantings shall be contracted out yearly and documentation provided to the tree commission and/or other interested parties as to the fund's administration, and the locations and types of trees planted.

(Code 1982, § 38-30(b); Ord. No. 1766, 9-13-2004)

https://www.municode.com/library/va/falls_church/codes/code_of_ordinances?nodeId=PTIICOOR_CH48ZO_ARTVSURE_DIV8LA_S48-1180TRCACORESIMIREDE

Herndon:

- **Sec. 78-503.6. - Landscaping for site areas not otherwise contained in perimeter buffers and vehicular use areas.**
- (a) *Standards.*
- (1) *Amount of landscaping*. Landscaping for site areas not otherwise contained in perimeter buffers and vehicular use areas shall be required for all development, except as otherwise stated in section 78-503.6(a)(3) below, and shall be supplied in the amounts identified in Table 78-503.6, required site landscape plantings, and shall meet the minimum size standards in section 78-503.9, Other landscape standards.
- TABLE 78-503.6: REQUIRED SITE LANDSCAPE PLANTINGS

Type of Use	Required Plantings*
Single-family detached dwelling, two-	4 canopy trees, 3 evergreen trees, and at least 12

family dwelling, group home, or quadruplex	shrubs per dwelling unit
Townhouse dwelling	1 canopy tree, 1 evergreen tree, and at least 10 shrubs per dwelling unit lot
Townhouse development common area	16 canopy trees + 10 evergreen trees per acre, and at least one shrub per each 5 feet of outer building perimeter
Multiple-family dwelling, and home for the elderly	12 canopy trees + 7 evergreen trees per acre, and at least 1 shrub per each 5 feet of outer building perimeter
Public and institutional uses	16 canopy trees + 10 evergreen trees per acre, and at least 1 shrub per each 5 feet of outer building perimeter
Business uses	16 canopy trees + 10 evergreen trees per acre, and at least 1 shrub per each 5 feet of outer building perimeter
*For purposes of calculating required plantings, the acreage of the entire site shall be used.	

https://www.municode.com/library/va/herndon/codes/code_of_ordinances?searchRequest=%7B%22searchText%22:%22canopy%22,%22pageNum%22:1,%22resultsPerPage%22:25,%22booleanSearch%22:false,%22stemming%22:true,%22fuzzy%22:false,%22synonym%22:false,%22contentTypes%22:%5B%22CODES%22%5D,%22productIds%22:%5B%5D%7D&nodeId=PTIICOOR_CH78ZO_ARTVDEST_S78-503.6LASIARNOOTCOPEBUVEUSAR

Prince William:

-Residential developments where density does not exceed 10 units/acre: 20% of Area of Site

-Residential developments with density over 10 units/acre but less than 20 units/acre: 15% of Area of Site

-Residential developments with density of 20 units/acre or higher: 10% of Area of Site

-Commercial, industrial, and institutional developments: 10% of Area of Site

Section 802.20

http://www.pwcgov.org/government/dept/planning/Documents/DCSM_Section-800.pdf

	Use or Zoning District	Minimum percentage of site to be covered in ten years	Ordinance Number	Link	Current Canopy Coverage	Source for Coverage	Tree Canopy Targets	Source for Targets
Arlington County	Site zoned business, commercial, or industrial	Ten percent (10%)	Arlington County Code § 61-10.	http://arlingtonva.s3.amazonaws.com/wp-content/uploads/sites/22/2014/01/County-Code-61-Chesapeake-Bay-Preservation-Ordinance.pdf	As of December 21, 2009, 6353 acres or 43.5% of total land	https://arlingtonva.s3.amazonaws.com/wp-content/uploads/sites/13/2013/10/2008-assessment-of-tree-canopy-cover.pdf		
	Residential site zoned twenty (20) or more units per acre	Ten percent (10%)						
	Residential site zoned more than ten (10) but less than twenty (20) units per acre;	Fifteen percent (15%)						
	Residential site zoned ten (10) units or less per acre	Twenty percent (20%)						
Alexandria	All construction that requires a grading plan	Trees must be planted or existing trees preserved to provide a minimum of 25 percent canopy cover over the site	(Ord. No. 4556, § 1, 6-24-08; Ord. No. 4653, § 2, 4-17-10; Ord. No. 4724, § 1, 6-25-11)	https://www.municode.com/library/va/alexandria/codes/zoning?searchRequest=%7B%22searchText%22:%22canopy%22,%22pageNum%22:1,%22resultsPerPage%22:25,%22booleanSearch%22:false,%22stemming%22:true,%22fuzzy%22:false,%22synon	In 2007, cover was approximately 30% of the city. Northridge: 57%, Del Ray East: 27%, Del Ray West: 39%	https://www.alexandriava.gov/uploadedFiles/recreation/info/UFMP%20Final.pdf	Reccomendations from the American Forests group: Increase coverage to 40% of the city and develop a strategy to meet said goal.	https://www.alexandriava.gov/uploadedFiles/recreation/info/UFMP%20Final.pdf

				ym%22:false,%22contentTypes%22:%5B%22CODES%22%5D,%22productIds%22:%5B%5D%7D&nodeId=ARTVIISUZORE_7-2507TRCORE				
Fairfax County	**Use or Zoning District**	**Percentage of site to be covered by tree canopy in 10 years**	(64-08-122; 32-10-122)	http://www.fairfaxcounty.gov/dpwes/publications/pfm/chapter2.pdf				
	Dedicated school, athletic field, nonwooded active recreation area	Ten percent (10%)						
	Commercial; Industrial; PDC; R-20; R-30; PDH-20; PDH-30; PDH-40; PRM; R-MHP; medium and high-density areas of a PRC District	Ten percent (10%)			In 2007, 40% of land was covered with tree canopy.	http://www.fairfaxcounty.gov/dpwes/environmental/30year.htm	Goal: Increase to 45% by 2037	http://www.fairfaxcounty.gov/dpwes/environmental/30year.htm
	R-12; R-16; PDH-12; PDH-16	Fifteen percent (15%)						
	R-5; R-8; PDH-5; PDH-8	Twenty percent (20%)						
	R-3; R-4; PDH-3; PDH-4	Twenty-five percent (25%)						

	R-A; R-P; R-C; R-E; R-1; R-2; PDH-1; PDH-2; and low-density areas of a PRC District	Thirty percent (30%)							
Fairfax City	A lot within any office, commercial or industrial zoning district;	Ten percent (10%)	Sec. 110-255. (Code 1978, § 26-65)	https://www.municode.com/library/va/fairfax/codes/code_of_ordinances?searchRequest=%7B%22searchText%22:%22tree%20canopy%22,%22pageNum%22:1,%22resultsPerPage%22:25,%22booleanSearch%22:false,%22stemming%22:true,%22fuzzy%22:false,%22synonym%22:false,%22contentTypes%22:%5B%22CODES%22%5D,%22productIds%22:%5B%5D%7D&nodeId=PTIICO_CH110ZO_ARTIIDIDESTREGE_DIV10TRPRLASC_S110-255CACORE					
	A site zoned RM or any other residential site zoned greater than ten units per acre;	Fifteen percent (15%)							
	A site zoned R-2, R-3, R-T6, RT or any other residential site zoned three to ten units per acre	Twenty percent (20%)							
	A site zoned R-1 or any other residential site zoned less than three units per acre.	Twenty-five percent (25%)							
Falls Church	**Type of Use**	**Minimum coverage at ten years**	Code 1982, § 38-30(b); Ord. No. 1766, 9-13-2004	https://www.municode.com/library/va/falls_church/					

	Single-family residential development lots, R1-A, R1-B	Twenty percent (20%)		codes/code_of_ordinances?nodeId=PTIICOOR_CH48ZO_ARTVSURE_DIV8LA_S48-1180TRCACORESIMIREDE	In 2012, 35% of land was covered. (VA Tech). The U of Vermont estimated that there was 45% around this time.			
Herndon	**Type of Use**	**Required Plantings***	Sec. 78-503.6	https://www.municode.com/library/va/herndon/codes/code_of_ordinances?searchRequest=%7B%22searchText%22:%22canopy%22,%22pageNum%22:1,%22resultsPerPage%22:25,%22booleanSearch%22:false,%22stemming%22:true,%22fuzzy%22:false,%22synonym%22:false,%22contentTypes%22:%5B%22CODES%22%5D,%22productIds%22:%5B%5D%7D&nodeId=PTIICOOR_CH78ZO_ARTVDEST_S78-503.6LASIARNOOTCOPEBUVEUSAR				
	Single-family detached dwelling, two-family dwelling, group home, or quadruplex	4 canopy trees, 3 evergreen trees, and at least 12 shrubs per dwelling unit						
	Townhouse dwelling	1 canopy tree, 1 evergreen tree, and at least 10 shrubs per dwelling unit lot						

	Townhouse development common area	16 canopy trees + 10 evergreen trees per acre, and at least one shrub per each 5 feet of outer building perimeter							
	Multiple-family dwelling, and home for the elderly	12 canopy trees + 7 evergreen trees per acre, and at least 1 shrub per each 5 feet of outer building perimeter							
	Public and institutional uses	16 canopy trees + 10 evergreen trees per acre, and at least 1 shrub per each 5 feet of outer building perimeter							
	Business uses	16 canopy trees + 10 evergreen trees per acre, and at least 1 shrub per each 5 feet of outer building perimeter							
	*For purposes of calculating required plantings, the acreage of the entire site shall be used.								
Prince William	**Type of Use**	**Required Canopy at Ten Year Maturity**	Section 802.20	http://www.pwcgov.org/government/dept/planning/Documents/DCSM_Section-800.pdf		http://www.pwconserve.org/issues/floraandfauna/Trees/			
	Residential developments where density does not exceed 10 units/acre	Twenty percent (20%)							
	Residential developments with density over 10 units/acre but less than 20 units/acre	Fifteen percent (15%)							

	Residential developments with density of 20 units/acre or higher	Ten percent (10%)				
	Commercial, industrial, and institutional developments	Ten percent (10%)				

Appendix B - Build-out Reports

Build-Out Report

Analysis Name: Neabsco 090115

Wednesday, September 02, 2015, 8:05 PM

Report Contents

Numeric Build-Out
Settings
Spatial Build-Out Settings
Results

Report Summary

This report gives details about a single run of the Build-Out Wizard for this scenario.

☑ Numeric Build-Out has been run

☑ Spatial Build-Out has been run

☒ Visual Build-Out has not been run

Numeric Build-Out Settings

Land Use Layer

Layer containing land-use information	Zoning Clipped to Neabsco
Attribute specifying land-use designation	CLASS
Attribute specifying unique identifier of each land-use area	FID

Density Rules

Land-Use Designation	Dwelling Units	Floor Area	Efficiency Factor (%)
A-1	4 DU per acre		100
B-1		0.85 FAR	100
B-2		0.8 FAR	100
FED			100
M-1		0.85 FAR	100
M-2		0.8 FAR	100
O(F)		0.8 FAR	100
O(H)		1.25 FAR	100
O(L)		0.8 FAR	100
O(M)		0.8 FAR	100
PBD	30 DU per acre		100
PMD	30 DU per acre		100
PMR	6 DU per acre		100
R-16	16 DU per acre		100

R-2	2 DU per acre		100
R-2C	2 DU per acre		100
R-30	30 DU per acre		100
R-4	4 DU per acre		100
R-4C	4 DU per acre		100
R-6	6 DU per acre		100
RPC	30 DU per acre		100
SR-1	1 DU per acre		100

Building Information

Land-Use Designation	DU per Building	Area (sq feet)	Floors
A-1	1	4000	1
B-1	1	0	1
B-2	1	0	1
FED	1	0	1
M-1	1	0	1
M-2	1	0	1
O(F)	1	0	1
O(H)	1	0	1
O(L)	1	0	1
O(M)	1	0	1
PBD	1	20000	1
PMD	1	12000	1
PMR	1	2250	1
R-16	1	10000	1
R-2	1	6000	1
R-2C	1	5250	1
R-30	1	15000	1
R-4	1	4000	1
R-4C	1	3375	1
R-6	1	2250	1
RPC	1	12000	1
SR-1	1	10890	1

Constraints to Development

Constraint Layer	Can density be transferred?
County Parks Clipped to Neabsco	no
FEMA100 CLipped to Neabsco	no
HydroPolu Clipped to Neabsco	no
RPA Clipped to Neabsco	no

Spatial Build-Out Settings

Settings				
Land-Use Designation	**Minimum Separation Distance(feet)**	**Layout Pattern**	**Road or Line Layer**	**Setback (feet)**
A-1	70	Random	Road Centerlines in Neabsco	71
B-1	200	Follow Roads	Road Centerlines in Neabsco	96
B-2	200	Follow Roads	Road Centerlines in Neabsco	132
FED	0	Follow Roads	Road Centerlines in Neabsco	32
M-1	200	Follow Roads	Road Centerlines in Neabsco	96
M-2	200	Follow Roads	Road Centerlines in Neabsco	50
O(F)	30	Follow Roads	Road Centerlines in Neabsco	132
O(H)	100	Follow Roads	Road Centerlines in Neabsco	112
O(L)	80	Follow Roads	Road Centerlines in Neabsco	82
O(M)	80	Follow Roads	Road Centerlines in Neabsco	32
PBD	150	Follow Roads	Road Centerlines in Neabsco	79
PMD	150	Follow Roads	Road Centerlines in Neabsco	72
PMR	50	Follow Roads	Road Centerlines in Neabsco	55
R-16	150	Follow Roads	Road Centerlines in Neabsco	80
R-2	100	Follow Roads	Road Centerlines in Neabsco	77
R-2C	80	Follow Roads	Road Centerlines in Neabsco	75
R-30	150	Follow Roads	Road Centerlines in Neabsco	97
R-4	70	Follow Roads	Road Centerlines in Neabsco	71
R-4C	60	Follow Roads	Road Centerlines in Neabsco	65
R-6	50	Follow Roads	Road Centerlines in Neabsco	55
RPC	150	Follow Roads	Road Centerlines in Neabsco	72
SR-1	100	Follow Roads	Road Centerlines	112

			in Neabsco	

Results

Dwelling Unit Quantities

Land-Use Designation	Numeric Build-Out	Spatial Build-Out	Difference	Existing Dwelling Units
A-1	7601	4930	2671	0
B-1	0	0	0	0
B-2	0	0	0	0
FED	0	0	0	0
M-1	0	0	0	0
M-2	0	0	0	0
O(F)	0	0	0	0
O(H)	0	0	0	0
O(L)	0	0	0	0
O(M)	0	0	0	0
PBD	7487	151	7336	0
PMD	3946	86	3860	0
PMR	620	358	262	0
R-16	6882	268	6614	0
R-2	740	588	152	0
R-2C	240	198	42	0
R-30	810	15	795	0
R-4	4949	2745	2204	0
R-4C	604	387	217	0
R-6	3080	2148	932	0
RPC	163905	5416	158489	0
SR-1	48	46	2	0
Total	**200912**	**17336**	**183576**	**0**

Commercial Floor Space

Land-Use Designation	Numeric Build-Out Floor Area(sq. feet)	Spatial Build-Out Floor Area(sq. feet)	Difference	Existing Floor Area
A-1	0	0	0	0
B-1	35867271.337	28306191.22	7561080.117	0
B-2	546749.559	471482.834	75266.725	0
FED	0	0	0	0
M-1	695805.488	95169.242	600636.246	0
M-2	2164875.425	923808.945	1241066.48	0
O(F)	250366.749	250366.749	0	0

O(H)	6545377.153	5641897.066	903480.087	0
O(L)	1570414.403	1170176.588	400237.815	0
O(M)	1273095.158	22392.88	1250702.278	0
PBD	0	0	0	0
PMD	0	0	0	0
PMR	0	0	0	0
R-16	0	0	0	0
R-2	0	0	0	0
R-2C	0	0	0	0
R-30	0	0	0	0
R-4	0	0	0	0
R-4C	0	0	0	0
R-6	0	0	0	0
RPC	0	0	0	0
SR-1	0	0	0	0
Total	**48913955.271**	**36881485.524**	**12032469.747**	**0**

Building Quantities

Land-Use Designation	Numeric Build-Out Units	Spatial Build-Out Units	Difference	Existing Buildings
A-1	7601	4930	2671	0
B-1	110	30	80	0
B-2	4	2	2	0
FED	0	0	0	0
M-1	10	1	9	0
M-2	15	4	11	0
O(F)	3	3	0	0
O(H)	6	3	3	0
O(L)	23	12	11	0
O(M)	6	1	5	0
PBD	7487	151	7336	0
PMD	3946	86	3860	0
PMR	620	358	262	0
R-16	6882	268	6614	0
R-2	740	588	152	0
R-2C	240	198	42	0
R-30	810	15	795	0
R-4	4949	2745	2204	0
R-4C	604	387	217	0
R-6	3080	2148	932	0
RPC	163905	5416	158489	0
SR-1	48	46	2	0
Total	**201089**	**17392**	**183697**	**0**

Buildable Area

Land-Use Designation	Gross Area (sq feet)	Net Buildable Area (sq feet)	Difference (sq feet)
A-1	103940917.257	83615150.868	20325766.389
B-1	48031428.805	42196789.809	5834638.996
B-2	769333.062	683436.949	85896.114
FED	1478113.933	99551.734	1378562.199
M-1	820248.759	818594.691	1654.068
M-2	3271661.255	2706094.281	565566.974
O(F)	317606.143	312958.436	4647.706
O(H)	5407520.836	5236301.722	171219.114
O(L)	1963018.003	1963018.003	0
O(M)	1594461.272	1591368.948	3092.324
PBD	12554889.347	10882299.028	1672590.319
PMD	6231927.158	5734491.135	497436.023
PMR	5077288.243	4523914.695	553373.549
R-16	20878683.632	18757035.181	2121648.452
R-2	18024118.959	16184473.884	1839645.076
R-2C	5597989.424	5268014.386	329975.038
R-30	1374819.633	1178172.819	196646.814
R-4	63061847.975	54101781.586	8960066.389
R-4C	7160515.748	6628888.696	531627.052
R-6	25892596.59	22415846.071	3476750.519
RPC	283331901.877	238002274.172	45329627.705
SR-1	2194295.105	2186211.651	8083.453
Total	**618975183.018**	**525086668.745**	**93888514.272**

Exceptions

Land-Use Designation	Number of dwelling units that couldn't be placed because of space constraints	Number of buildings that couldn't be placed because of space constraints	Number of polygons where number of existing buildings exceeds build-out limit
A-1	2671	2671	0
B-1	0	80	0
B-2	0	2	0
FED	0	0	0
M-1	0	9	0

M-2	0	11	0
O(F)	0	0	0
O(H)	0	3	0
O(L)	0	11	0
O(M)	0	5	0
PBD	7336	7336	0
PMD	3860	3860	0
PMR	262	262	0
R-16	6614	6614	0
R-2	152	152	0
R-2C	42	42	0
R-30	795	795	0
R-4	2204	2204	0
R-4C	217	217	0
R-6	932	932	0
RPC	158489	158489	0
SR-1	2	2	0
Total	**183576**	**183697**	**0**

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Build-Out Report - Base Scenario

Analysis Name: Powell's Creek Build-out 081715

Monday, August 17, 2015, 6:00 PM

Report Contents

Numeric Build-Out Settings
Spatial Build-Out Settings
Results

Report Summary

This report gives details about a single run of the Build-Out Wizard for this scenario.

☑ Numeric Build-Out has been run

☑ Spatial Build-Out has been run

☒ Visual Build-Out has not been run

Numeric Build-Out Settings

Land Use Layer	
Layer containing land-use information	Zoning_Powells
Attribute specifying land-use designation	CLASS
Attribute specifying unique identifier of each land-use area	FID

Density Rules

Land-Use Designation	Dwelling Units	Floor Area	Efficiency Factor (%)
A-1	0.1 DU per acre		100
B-1		0.4 FAR	100
B-2		0.3 FAR	100
FED			100
M/T		0.75 FAR	100
M-1		0.5 FAR	100
M-2		0.5 FAR	100
O(L)		0.35 FAR	100
O(M)		0.65 FAR	100
PBD		0.3 FAR	100
PMD		0.3 FAR	100

PMR		0.3 FAR	100
R-16	16 DU per acre		100
R-2	2 DU per acre		100
R-4	4 DU per acre		100
R-4C	4 DU per acre		100
R-6	6 DU per acre		100
RPC	30 DU per acre		100
SR-1	1 DU per acre		100
SR-5	0.2 DU per acre		100

Building Information

Land-Use Designation	DU per Building	Area (sq feet)	Floors
A-1	1	6000	1
B-1	1	0	1
B-2	1	0	1
FED	1	0	1
M/T	1	0	1
M-1	1	0	1
M-2	1	0	1
O(L)	1	0	1
O(M)	1	0	1
PBD	1	0	1
PMD	1	0	1
PMR	1	2250	1
R-16	1	1875	1
R-2	1	6000	1
R-4	1	4000	1
R-4C	1	3375	1
R-6	1	2250	1
RPC	1	1500	1
SR-1	1	10890	1
SR-5	1	54450	1

Constraints to Development

Constraint Layer	Can density be transferred?
FEMA100YR_Powells	no
Powells_Parks	no
RPA_Powells	no

Spatial Build-Out Settings

Settings				
Land-Use Designation	**Minimum Separation Distance(feet)**	**Layout Pattern**	**Road or Line Layer**	**Setback (feet)**
A-1	100	Follow Roads	Streets_Powells	97
B-1	0	Follow Roads	Streets_Powells	132
B-2	0	Follow Roads	Streets_Powells	132
FED	0	Follow Roads	Streets_Powells	0
M/T	0	Follow Roads	Streets_Powells	47
M-1	0	Follow Roads	Streets_Powells	132
M-2	0	Follow Roads	Streets_Powells	47
O(L)	0	Follow Roads	Streets_Powells	82
O(M)	0	Follow Roads	Streets_Powells	72
PBD	0	Follow Roads	Streets_Powells	107
PMD	0	Follow Roads	Streets_Powells	45
PMR	50	Follow Roads	Streets_Powells	57
R-16	150	Follow Roads	Streets_Powells	60
R-2	100	Follow Roads	Streets_Powells	97
R-4	60	Follow Roads	Streets_Powells	72
R-4C	60	Follow Roads	Streets_Powells	67
R-6	50	Follow Roads	Streets_Powells	42
RPC	60	Follow Roads	Streets_Powells	60
SR-1	100	Follow Roads	Streets_Powells	97
SR-5	100	Follow Roads	Streets_Powells	97

Results

Dwelling Unit Quantities

Land-Use Designation	Numeric Build-Out	Spatial Build-Out	Difference	Existing Dwelling Units
A-1	374	295	79	0
B-1	0	0	0	0
B-2	0	0	0	0
FED	0	0	0	0
M/T	0	0	0	0
M-1	0	0	0	0
M-2	0	0	0	0
O(L)	0	0	0	0
O(M)	0	0	0	0
PBD	0	0	0	0
PMD	0	0	0	0
PMR	0	0	0	0
R-16	2211	128	2083	0
R-2	16	11	5	0
R-4	5992	3345	2647	0
R-4C	1698	1181	517	0
R-6	3160	2719	441	0
RPC	33310	3762	29548	0
SR-1	599	524	75	0
SR-5	1	0	1	0
Total	**47361**	**11965**	**35396**	**0**

Commercial Floor Space

Land-Use Designation	Numeric Build-Out Floor Area(sq. feet)	Spatial Build-Out Floor Area(sq. feet)	Difference	Existing Floor Area
A-1	0	0	0	0
B-1	2354314.403	2301600.466	52713.938	0
B-2	138191.986	138191.986	0	0
FED	0	0	0	0
M/T	1183517.426	768230.847	415286.579	0
M-1	202723.003	202723.003	0	0
M-2	1646031.885	1203008.477	443023.408	0
O(L)	79268.271	79268.271	0	0
O(M)	320353.736	320353.736	0	0
PBD	293384.272	293384.272	0	0
PMD	2892907.105	2892907.105	0	0

PMR	11947254.695	3820500	8126754.695	0
R-16	0	0	0	0
R-2	0	0	0	0
R-4	0	0	0	0
R-4C	0	0	0	0
R-6	0	0	0	0
RPC	0	0	0	0
SR-1	0	0	0	0
SR-5	0	0	0	0
Total	**21057946.783**	**12020168.163**	**9037778.62**	**0**

Building Quantities

Land-Use Designation	Numeric Build-Out Units	Spatial Build-Out Units	Difference	Existing Buildings
A-1	374	295	79	0
B-1	11	9	2	0
B-2	2	2	0	0
FED	0	0	0	0
M/T	3	1	2	0
M-1	2	2	0	0
M-2	3	1	2	0
O(L)	1	1	0	0
O(M)	2	2	0	0
PBD	1	1	0	0
PMD	1	1	0	0
PMR	5315	1698	3617	0
R-16	2211	128	2083	0
R-2	16	11	5	0
R-4	5992	3345	2647	0
R-4C	1698	1181	517	0
R-6	3160	2719	441	0
RPC	33310	3762	29548	0
SR-1	599	524	75	0
SR-5	1	0	1	0
Total	**52702**	**13683**	**39019**	**0**

Buildable Area

Land-Use Designation	Gross Area (sq feet)	Net Buildable Area (sq feet)	Difference (sq feet)
A-1	187552960.773	136736887.374	50816073.399
B-1	6412361.952	5885786.009	526575.943
B-2	460639.953	460639.953	0
FED	523275.286	49929.089	473346.197
M/T	1578023.235	1578023.235	0

M-1	2125305.437	405446.006	1719859.43
M-2	3512695.353	3292063.769	220631.583
O(L)	226480.774	226480.774	0
O(M)	492851.902	492851.902	0
PBD	1114807.481	977947.574	136859.907
PMD	11366149.824	9643023.682	1723126.141
PMR	52535269.115	39824182.318	12711086.797
R-16	8776270.425	6026671.456	2749598.969
R-2	381529.516	381529.516	0
R-4	79169877.476	65481664.272	13688213.204
R-4C	21478249.411	18533650.814	2944598.597
R-6	27773743.51	22981710.773	4792032.737
RPC	67353771.818	48370530.433	18983241.385
SR-1	29361294.511	26451862.887	2909431.624
SR-5	242374.022	242374.022	0
Total	**502437931.772**	**388043255.859**	**114394675.913**

Exceptions

Land-Use Designation	Number of dwelling units that couldn't be placed because of space constraints	Number of buildings that couldn't be placed because of space constraints	Number of polygons where number of existing buildings exceeds build-out limit
A-1	79	79	0
B-1	0	2	0
B-2	0	0	0
FED	0	0	0
M/T	0	2	0
M-1	0	0	0
M-2	0	2	0
O(L)	0	0	0
O(M)	0	0	0
PBD	0	0	0
PMD	0	0	0
PMR	0	3617	0
R-16	2083	2083	0
R-2	5	5	0
R-4	2647	2647	0
R-4C	517	517	0
R-6	441	441	0
RPC	29548	29548	0
SR-1	75	75	0

SR-5	1	1	0
Total	**35396**	**39019**	**0**

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WINDY RUN, Arlington County, VA

Build-Out Report - WindyRun_Build-out

Monday, July 27, 2015, 10:41 AM

Report Summary

This report gives details about a single run of the Build-Out Wizard for this scenario.

☑ Numeric Build-Out has been run

☑ Spatial Build-Out has been run

☒ Visual Build-Out has not been run

Numeric Build-Out Settings

Land Use Layer	
Layer containing land-use information	Res_Zone
Attribute specifying land-use designation	ZONE
Attribute specifying unique identifier of each land-use area	FID

Density Rules

Land-Use Designation	**Dwelling Units**	**Floor Area**	**Efficiency Factor (%)**
R-10	4.36 DU per acre		100
R-20	2.18 DU per acre		100

R-5	8.71 DU per acre		100
R-6	7.26 DU per acre		100
R-8	5.45 DU per acre		100

Building Information

Land-Use Designation	DU per Building	Area (sq feet)	Floors
R-10	1	3920	1
R-20	1	5320	1
R-5	1	2590	1
R-6	1	2772	1
R-8	1	3136	1

Constraints to Development

Constraint Layer	Can density be transferred?
RPA_poly	no
Windy_Parks2	no

Spatial Build-Out Settings

Settings

Land-Use Designation	Minimum Separation Distance(feet)	Layout Pattern	Road or Line Layer	Setback (feet)

R-10	80	Follow Roads	Windy_Streets2	77
R-20	100	Follow Roads	Windy_Streets2	87
R-5	50	Follow Roads	Windy_Streets2	62
R-6	60	Follow Roads	Windy_Streets2	67
R-8	70	Follow Roads	Windy_Streets2	72

Results

Dwelling Unit Quantities

Land-Use Designation	Numeric Build-Out	Spatial Build-Out	Difference	Existing Dwelling Units
R-10	308	174	134	0
R-20	65	28	37	0
R-5	66	38	28	0
R-6	615	317	298	0
R-8	272	146	126	0
Total	**1326**	**703**	**623**	**0**

Commercial Floor Space

Land-Use Designation	Numeric Build-Out Floor Area(sq. feet)	Spatial Build-Out Floor Area(sq. feet)	Difference	Existing Floor Area
R-10	0	0	0	0
R-20	0	0	0	0
R-5	0	0	0	0
R-6	0	0	0	0
R-8	0	0	0	0
Total	**0**	**0**	**0**	**0**

Building Quantities

Land-Use Designation	Numeric Build-Out Units	Spatial Build-Out Units	Difference	Existing Building
R-10	308	174	134	0
R-20	65	28	37	0
R-5	66	38	28	0
R-6	615	317	298	0
R-8	272	146	126	0
Total	**1326**	**703**	**623**	**0**

Buildable Area

Land-Use Designation	Gross Area (sq feet)	Net Buildable Area (sq feet)	Difference (sq feet)
R-10	3324109.537	3086952.07	237157.467

R-20	1432759.191	1310314.504	122444.687
R-5	339614.284	339614.284	0
R-6	3739860.773	3685253.72	54607.053
R-8	2185395.997	2175114.898	10281.099
Total	**11021739.783**	**10597249.476**	**424490.307**

Exceptions

Land-Use Designation	Number of dwelling units that couldn't be placed because of space constraints	Number of buildings that couldn't be placed because of space constraints	Number of polygons where number of existing buildings exceeds build-out limit
R-10	134	134	0
R-20	37	37	0
R-5	28	28	0
R-6	298	298	0
R-8	126	126	0
Total	**623**	**623**	**0**

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Appendix C – i-Tree Hydro Reports

Neabsco Creek i-Tree Hydro Reports

Figure A-1compares the total volume of observed discharge (if provided as an input) to the total volume of predicted streamflow, in cubic meters or cubic feet. It doesn't account for the distribution of the flows in time; the Water Flow Reports or Calibration Comparison plot the flows (discharge) across the modeled time period.

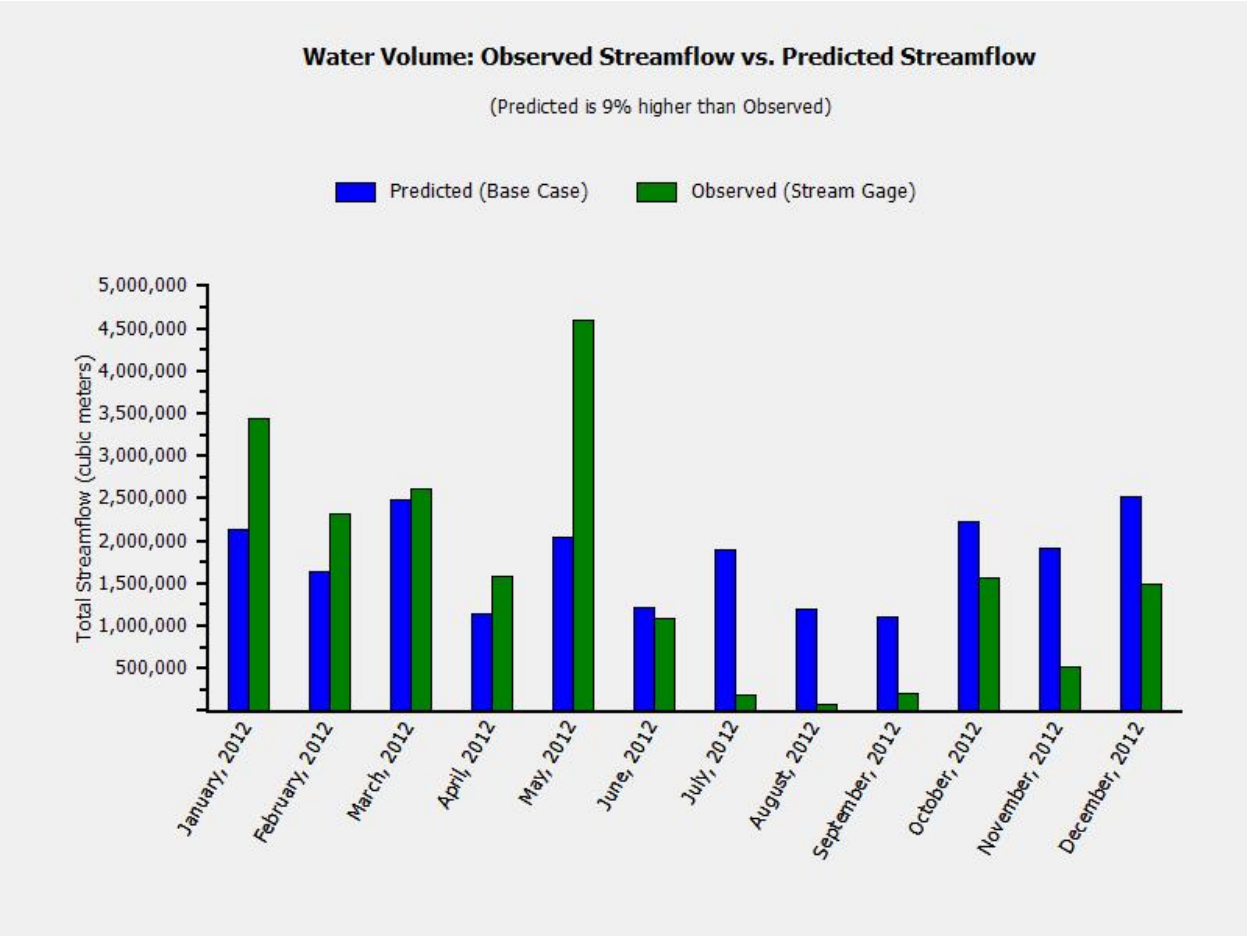


Figure C-1. Water Volume Observed vs. Predicted

Figure A-2 displays the breakdown of the predicted streamflow of the Base Case according to the three types of streamflow the model predicts: Pervious area runoff (surface flow generated by infiltration or saturation excess), Impervious area runoff (surface flow generated by precipitation on impervious surfaces), and Baseflow (subsurface flow generated through infiltration of precipitation). The ratio of Pervious area runoff to Impervious area runoff will shift as the ratio of pervious area to impervious area changes; if pervious area (as a percentage of the watershed) increases, pervious area runoff may increase while impervious area runoff decreases, and vice versa. Also, as pervious area increases or decreases, baseflow should increase or decrease, since

increasing or decreasing the pervious area (as a percentage of the watershed) will affect the amount of infiltrated water which in turn affects the amount of baseflow generated.

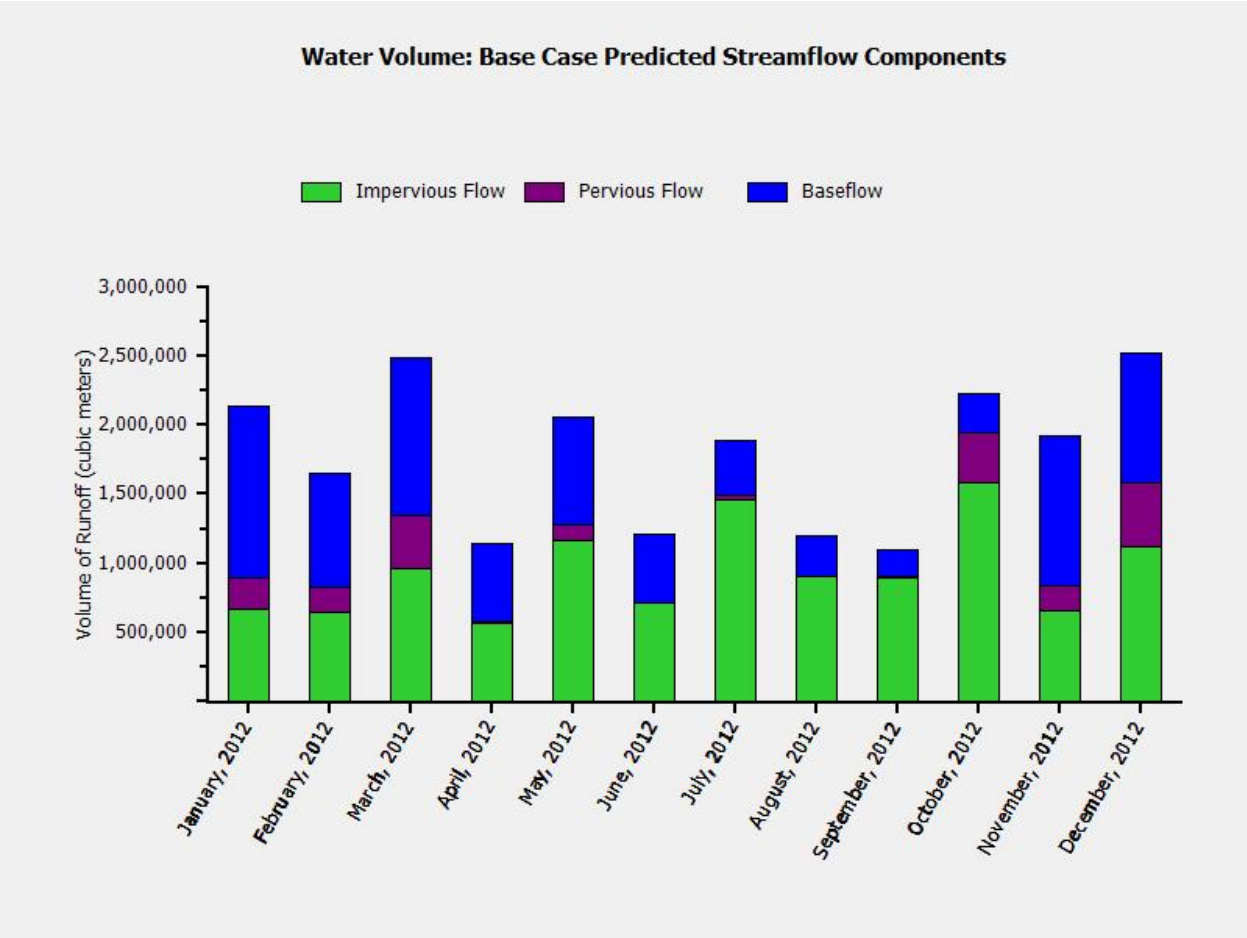


Figure A-2. Components of streamflow under existing conditions (base case)

Figure A-3 compares the total volume of predicted discharge of the Base Case and Alternative Case, in cubic meters or cubic feet. It doesn't account for the distribution of the flows in time; the Water Flow Reports or Calibration Comparison plot the flows (discharge) across the modeled time period.

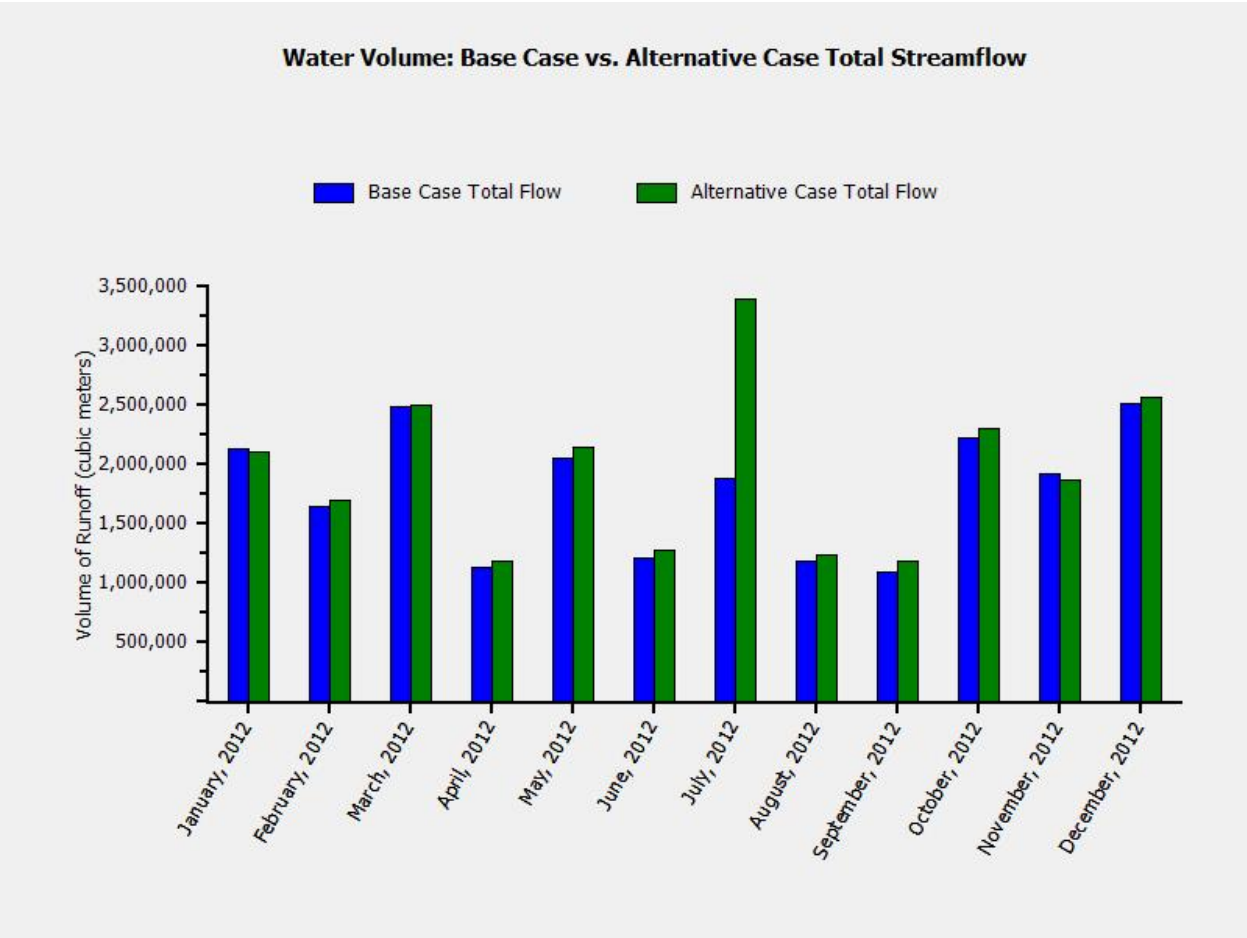


Figure A-3. Total volume of predicted discharge of the Base Case and Alternative Case

Figure A-4 compares the breakdown of the predicted streamflow of the Base Case and Alternative Case according to the three types of streamflow the model predicts: Pervious area runoff (surface flow generated by infiltration or saturation excess), Impervious area runoff (surface flow generated by precipitation on impervious surfaces), and Baseflow (subsurface flow generated through infiltration of precipitation). The ratio of Pervious area runoff to Impervious area runoff will shift as the ratio of pervious area to impervious area changes; if pervious area (as a percentage of the watershed) increases, pervious area runoff may increase while impervious area runoff decreases, and vice versa. Also, as pervious area increases or decreases, baseflow should increase or decrease, since increasing or decreasing the pervious area (as a percentage of the watershed) will affect the amount of infiltrated water which in turn affects the amount of baseflow generated. **Solid colors represent Base Case values and the hatched pattern indicates Alternative Case values.**

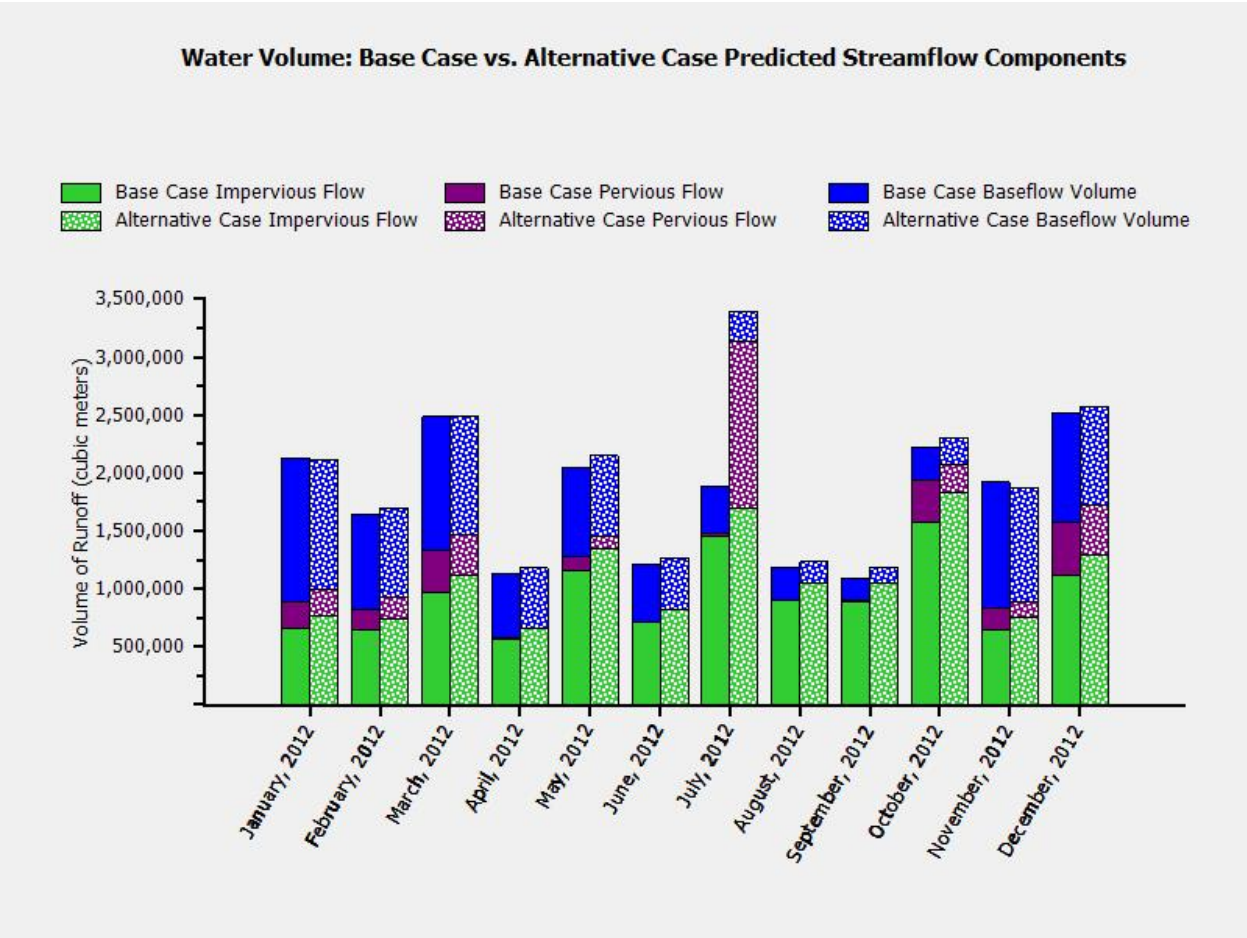


Figure A-4. Comparison of streamflow components of the existing conditions and build-out conditions.

Figure A-5 displays pollutant load (kg) for the modeled watershed. The different pollutant loads are the predicted model outputs for the Base Case.

The pollutant load measurements are displayed on the bottom of the graph and correspond to the left-side axis.

An event mean concentration (EMC) value represents the flow-proportional average concentration of a given pollutant during a storm event and is measured in units of mass per volume, usually milligrams per liter. EMC can be multiplied by actual flow to estimate the mass of pollutants entering a body of water. Changes in flow owing to changes in cover and tree canopy will therefore be reflected in changes in pollutant load. These are the results that Hydro presents. Site-specific EMCs data collection can be cost-prohibitive, so regional or national averages can be used. The EMC values used within Hydro are explained further and referenced in Appendix 3 of the manual.

Total suspended solids: TSS

Biochemical oxygen demand: BOD

Chemical oxygen demand: COD

Total phosphorus: TP

Soluble phosphorus: soluble P

Total Kjeldhal nitrogen: TKN

Nitrite and nitrate: NO2 and NO3

Copper: Cu

Lead: Pb

Zinc: Zn

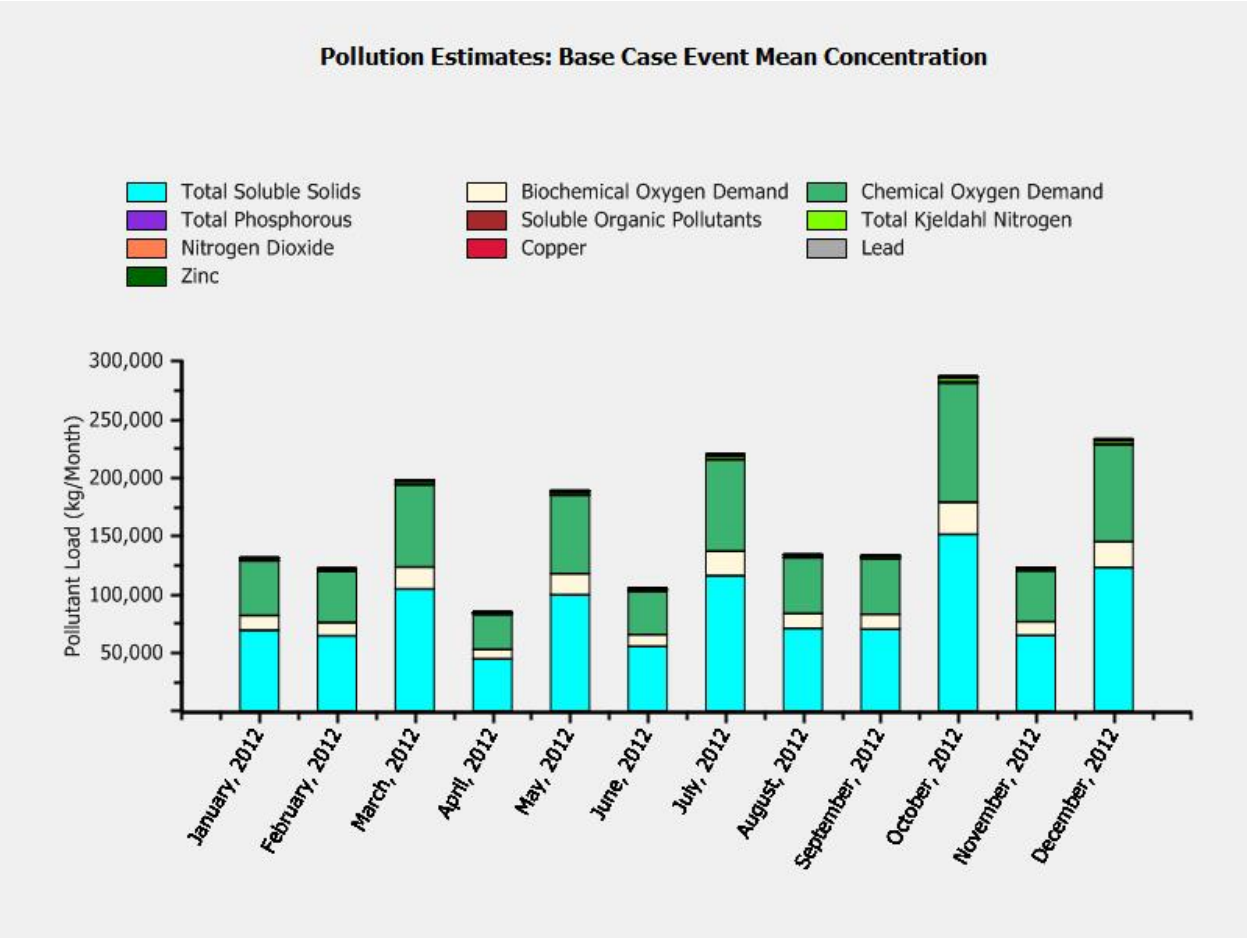


Figure A-5. Predicted pollutant loads (kg) for the for the existing conditions.

Figure A-6 displays pollutant load (kg) for the modeled watershed. The different pollutant loads are the predicted model outputs for both the Base Case and Alternative Case.

The pollutant load measurements are displayed on the bottom of the graph and correspond to the left-side axis.

An event mean concentration (EMC) value represents the flow-proportional average concentration of a given pollutant during a storm event and is measured in units of mass per volume, usually milligrams per liter. EMC can be multiplied by actual flow to estimate the mass of pollutants entering a body of water. Changes in flow owing to changes in cover and tree canopy will therefore be reflected in changes in pollutant load. These are the results that Hydro presents. Site-specific EMCs data collection can be cost-prohibitive, so regional or national averages can be used. The EMC values used within Hydro are explained further and referenced in Appendix 3 of the manual. Solid colors display Base Case values while the hatched pattern displays Alternative Case values.

Total suspended solids: TSS

Biochemical oxygen demand: BOD

Chemical oxygen demand: COD

Total phosphorus: TP

Soluble phosphorus: soluble P

Total Kjeldhal nitrogen: TKN

Nitrite and nitrate: NO2 and NO3

Copper: Cu

Lead: Pb

Zinc: Zn

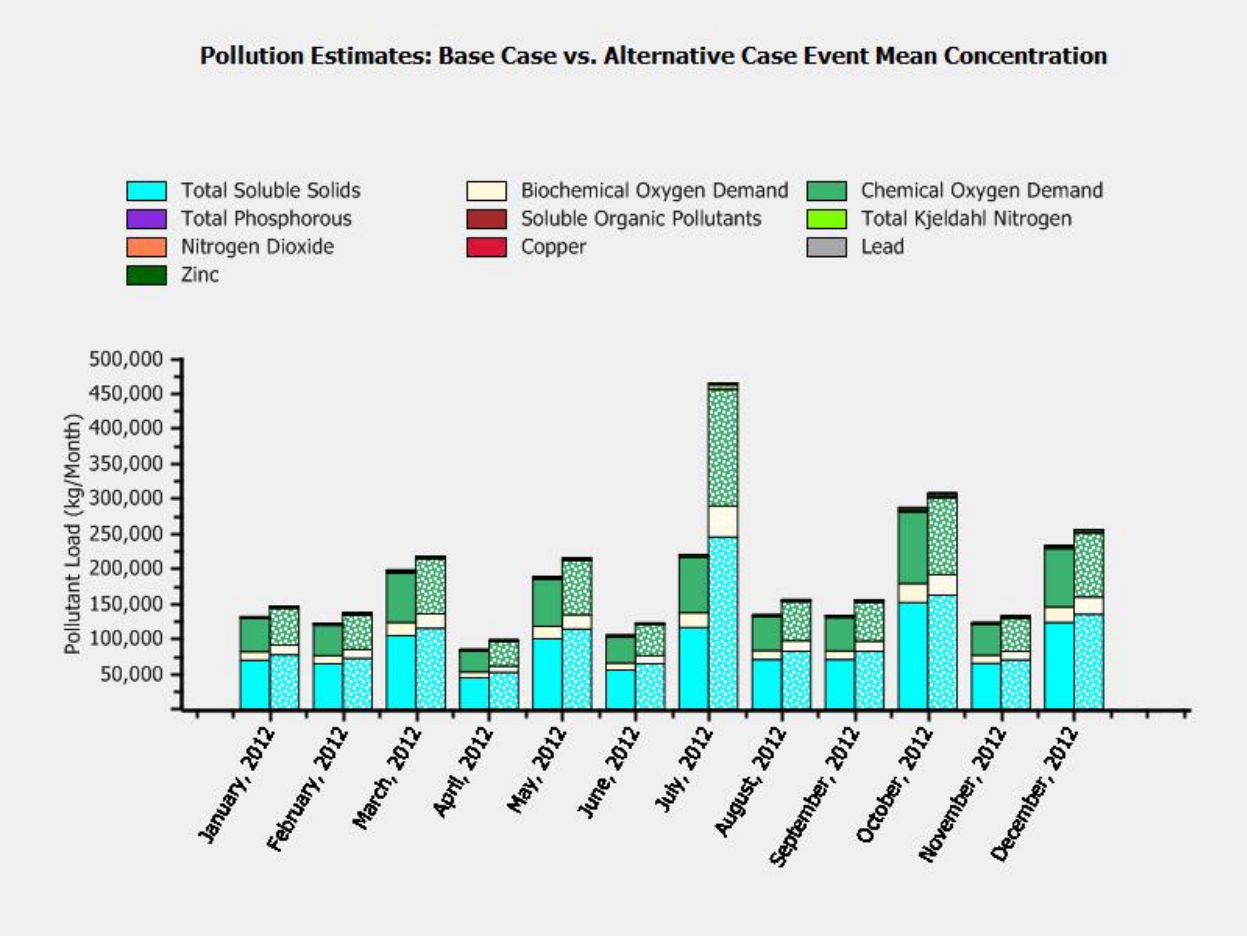


Figure A-6. Predicted pollutant loads for both the existing conditions and build-out scenario.

Figure A-7 displays rainfall (mm/h) and total flow (m^3/h) for the modeled watershed. The rainfall values are the recorded measurements that were inputs to the model. If the supplied 2005-2012 data sets were used, the weather data is from the National Climactic Data Center (part of the NOAA). The total flow (discharge) and total flow components (Base Flow, Pervious Flow, and Impervious Flow) are the predicted model outputs for the Current Base Case.

Rainfall is displayed on the top of the graph, with larger rainfall events stretching towards the bottom of the graph; the rainfall rates correspond to the right-side axis.

Total flow (discharge) and component flow measurements are displayed on the bottom of the graph and correspond to the left-side axis. Displaying the total flow and its components allows the user to observe how the individual flow component's contribution to the total flow (discharge) hydrograph changes during and after a precipitation event.

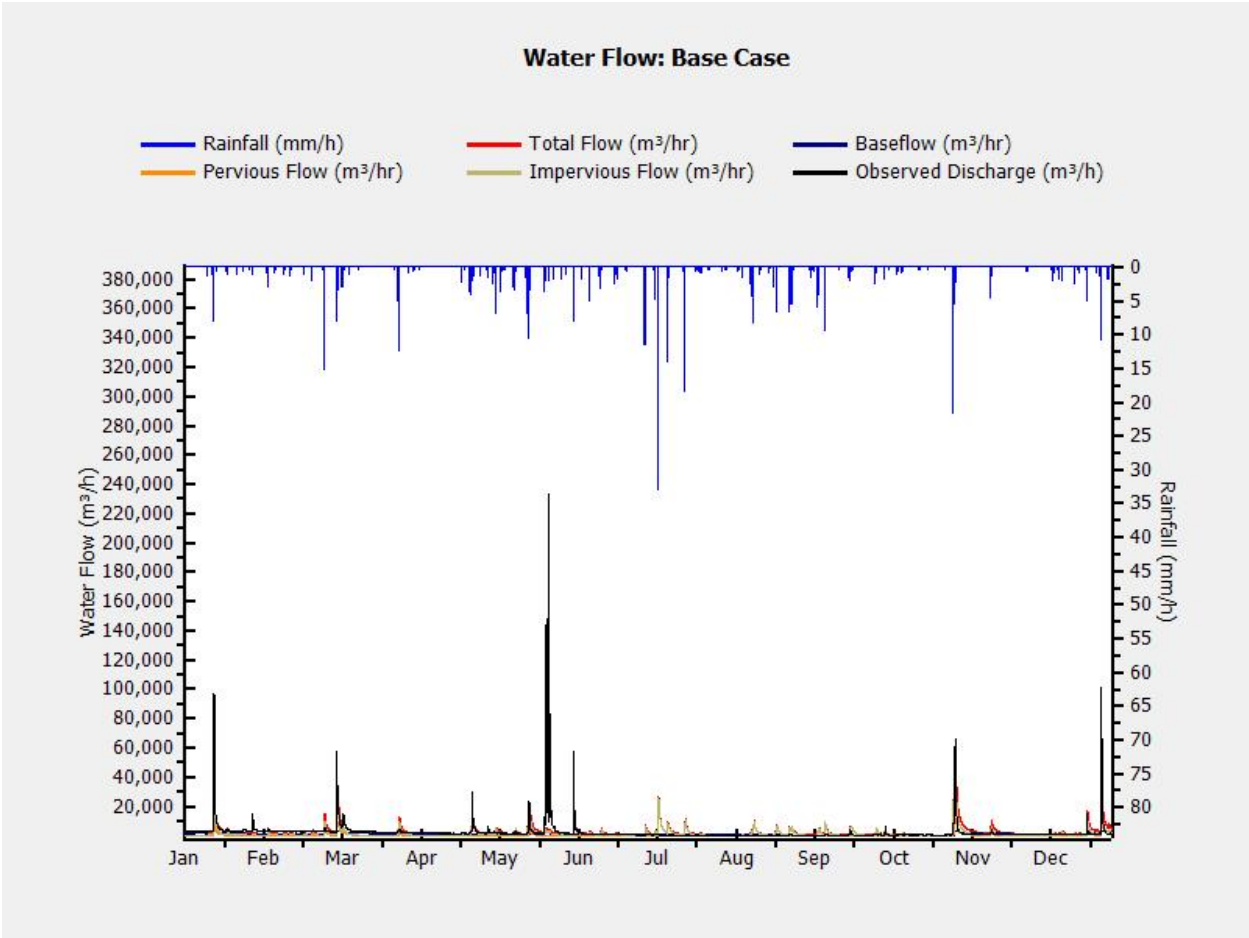


Figure A-7. Rainfall (mm/h) and total flow (m^3/h) under existing conditions

Figure A-8 displays rainfall (mm/h) and total flow (m^3/h) for the modeled watershed. The rainfall values are the recorded measurements that were inputs to the model. If the supplied 2005-2012 data sets were used, the weather data is from the National Climactic Data Center (part of the NOAA). The total flow (discharge) and total flow components (Base Flow, Pervious Flow, Impervious Flow) are the predicted model outputs for the future Alternative Case.

Rainfall is displayed on the top of the graph, with larger rainfall events stretching towards the bottom of the graph; the rainfall rates correspond to the right-side axis.

Total flow (discharge) and component flow measurements are displayed on the bottom of the graph and correspond to the left-side axis.

Displaying the total flow and its components allows the user to observe how the individual flow component's contribution to the total flow (discharge) hydrograph changes during and after a precipitation event.

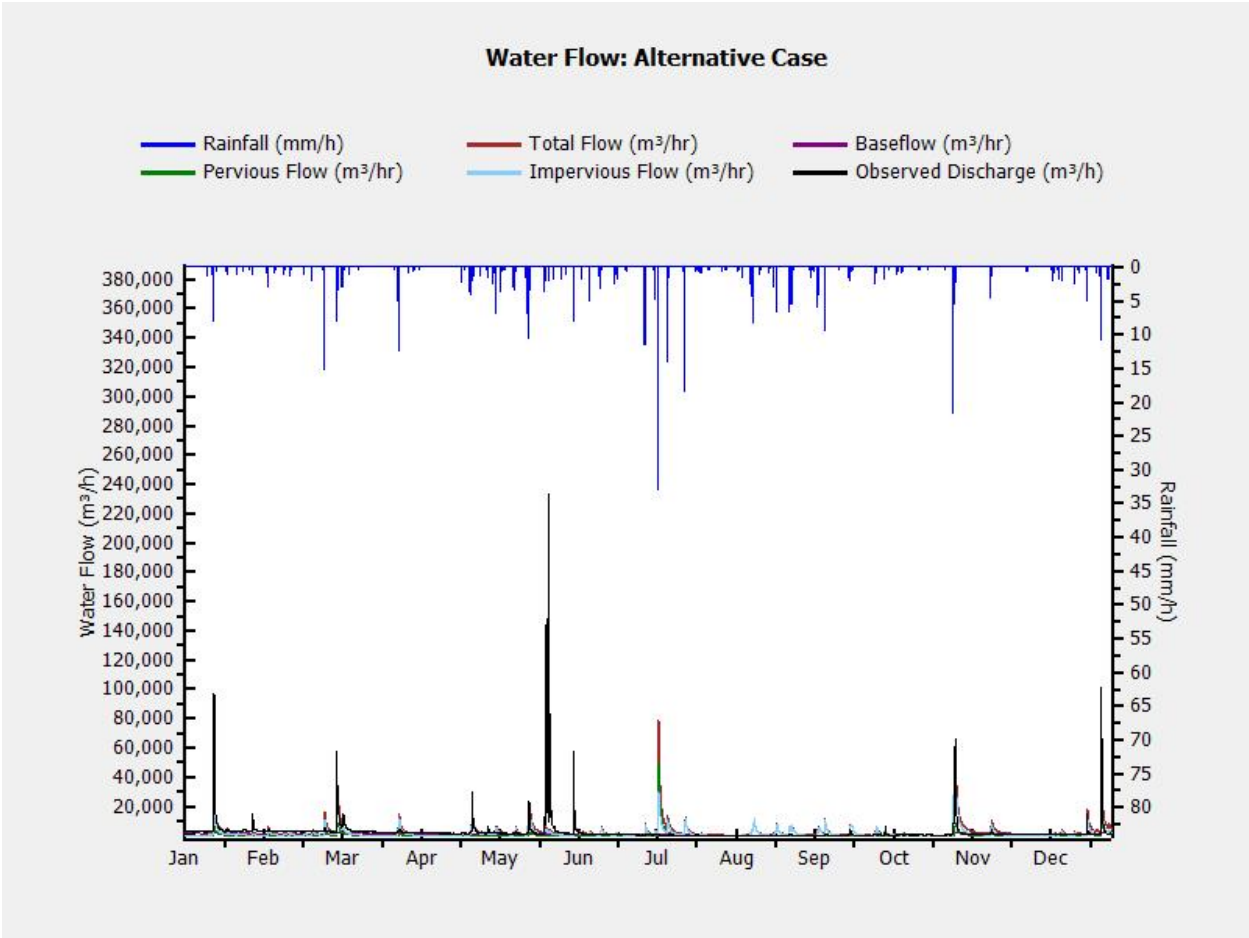


Figure A-8. Rainfall (mm/h) and total flow (m^3/h) under build-out conditions

Figure A-9 displays rainfall (mm/h) and total flow (m^3/h) for the modeled watershed. The rainfall values are the recorded measurements that were inputs to the model. If the supplied 2005-2012 data sets were used, the weather data is from the National Climactic Data Center (part of the NOAA). The total flow (discharge) and total flow components (Base Flow, Pervious Flow, Impervious Flow) are the predicted model outputs for both the Base Case and future Alternative Case.

Rainfall is displayed on the top of the graph, with larger rainfall events stretching towards the bottom of the graph; the rainfall rates correspond to the right-side axis.

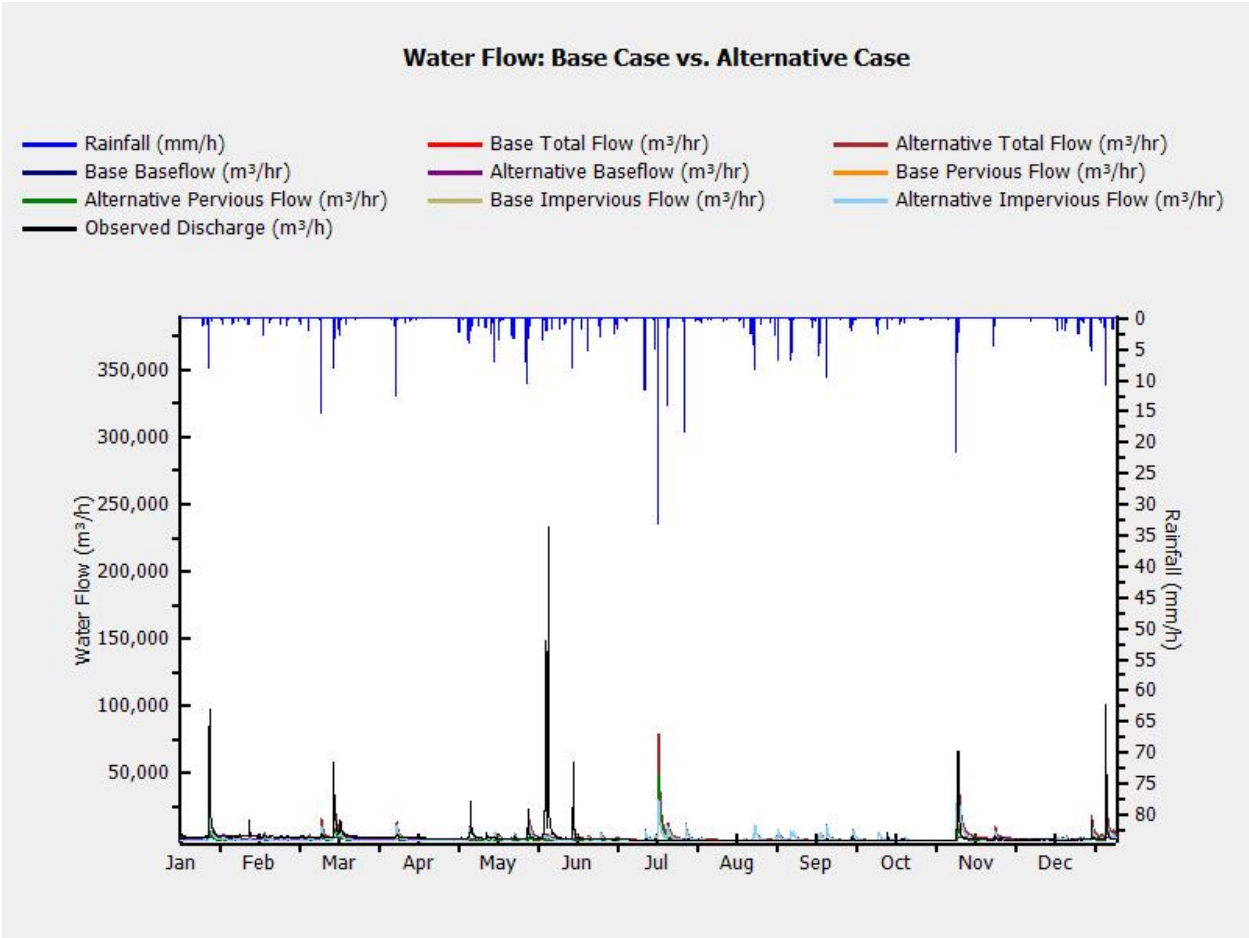


Figure A-9. Comparison of rainfall (mm/h) and total flow (m^3/h) under existing and build-out conditions

Figure A-10 displays rainfall (mm/h) and the result of the predicted Alternative Case flows minus the predicted Base Case flows (in m^3/h) for the modeled watershed. The rainfall values are the recorded measurements that were inputs to the model. If the supplied 2005-2012 data sets were used, the weather data is from the National Climactic Data Center (part of the NOAA). The total flow (discharge) and total flow components (Base Flow, Pervious Flow, Impervious Flow) are the predicted model outputs for both the Base Case and future Alternative Case.

Rainfall is displayed on the top of the graph, with larger rainfall events stretching towards the bottom of the graph; the rainfall rates correspond to the right-side axis.

The results of subtracting the predicted current base case flows from the predicted future (proposed) alternative case flows are displayed to demonstrate the increase or decrease in the flows (total and component) due to the changes proposed by the future alternative case.

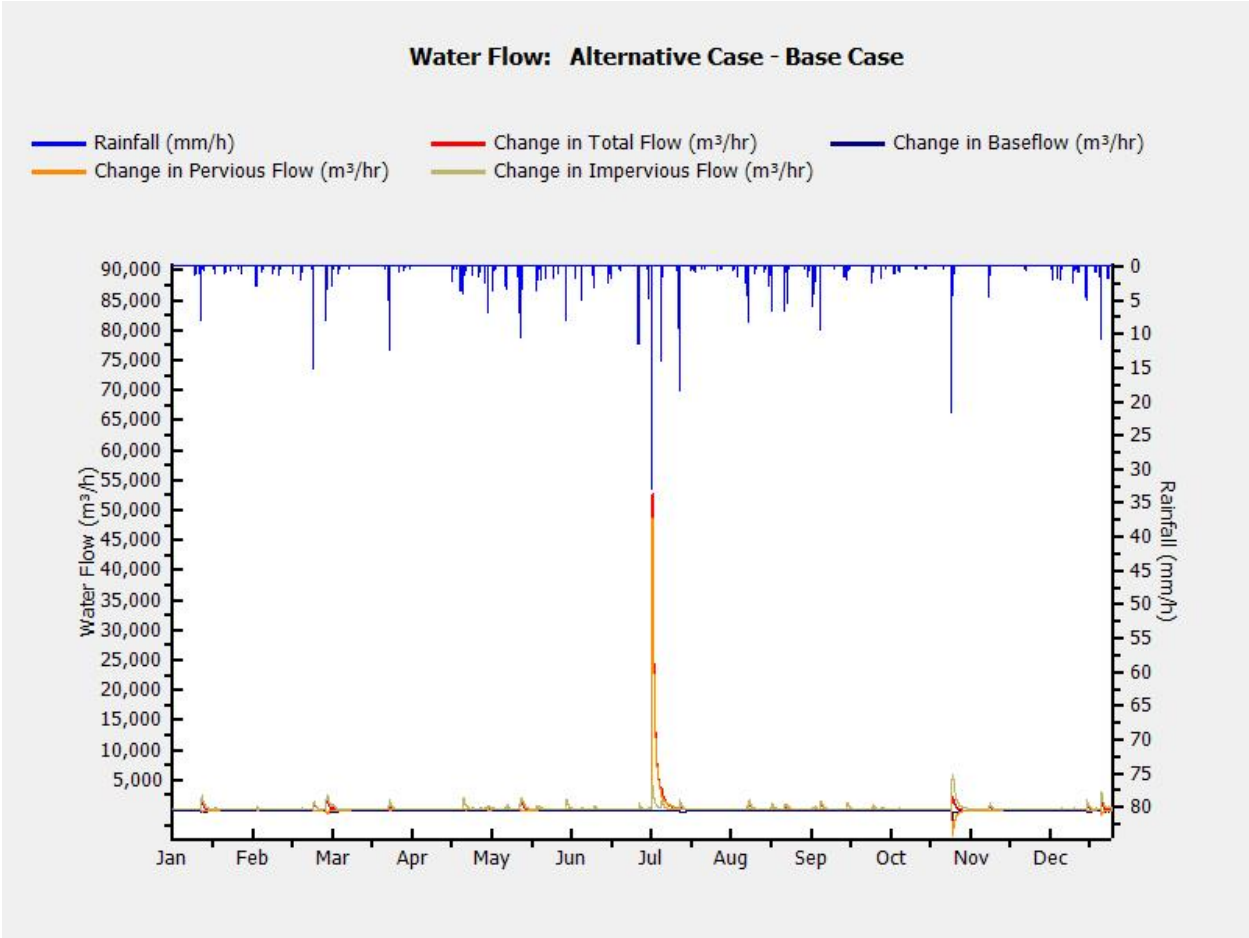


Figure A-10. The delta in flow between build-out conditions and existing conditions

Figure A-11 displays pollutant load (kg/h) for the modeled watershed. The different pollutant loads are the predicted model outputs for the Base Case.

The pollutant load measurements are displayed on the bottom of the graph and correspond to the left-side axis.

An event mean concentration (EMC) value represents the flow-proportional average concentration of a given pollutant during a storm event and is measured in units of mass per volume, usually milligrams per liter. EMC can be multiplied by actual flow to estimate the mass of pollutants entering a body of water. Changes in flow owing to changes in cover and tree canopy will therefore be reflected in changes in pollutant load. These are the results that Hydro

presents. Site-specific EMCs data collection can be cost-prohibitive, so regional or national averages can be used. The EMC values used within Hydro are explained further and referenced in Appendix 3 of the manual.

Total suspended solids: TSS

Biochemical oxygen demand: BOD

Chemical oxygen demand: COD

Total phosphorus: TP

Soluble phosphorus: soluble P

Total Kjeldhal nitrogen: TKN

Nitrite and nitrate: NO2 and NO3

Copper: Cu

Lead: Pb

Zinc: Zn

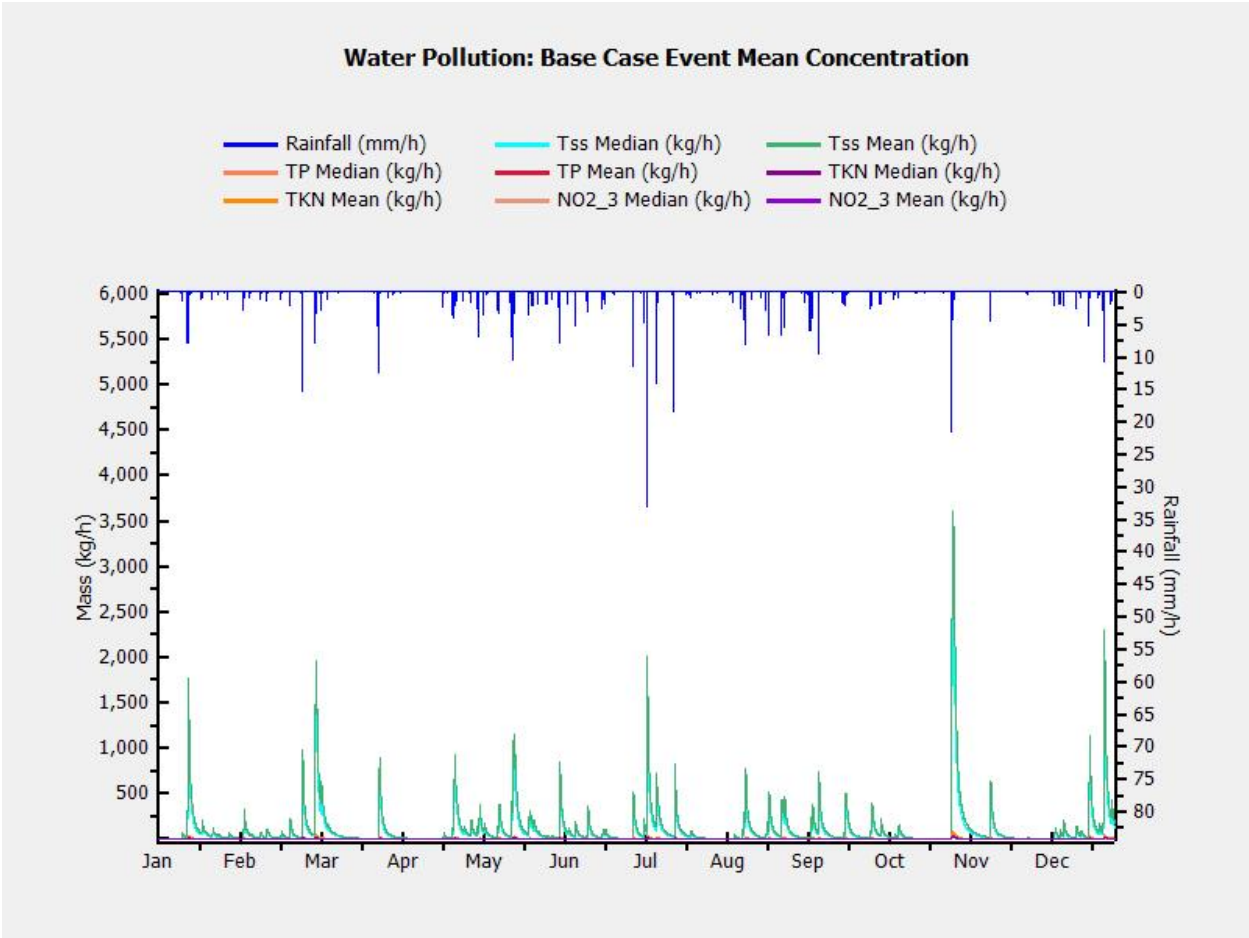


Figure A-11. Predicted pollutant loads compared to rainfall under existing conditions

Figure A-12 displays rainfall (mm/h) and pollutant load (kg/h) of the Alternative Case for the modeled watershed. The rainfall values are the recorded measurements that were inputs to the model. If the supplied data sets were used, the weather data is from the National Climactic Data Center (part of the NOAA). The different pollutant loads are the predicted model outputs for the Future (proposed) Alternative Case. The EMC values used within Hydro are explained further and referenced in Appendix 3 of the manual.

Rainfall is displayed on the top of the graph, with larger rainfall events stretching towards the bottom of the graph; the rainfall rates correspond to the right-side axis.

The pollutant load measurements are displayed on the bottom of the graph and correspond to the left-side axis.

Displaying the pollutant loads with rainfall allows the user to observe changes in the magnitude of the predicted pollutant loads during and after a precipitation event.

Total suspended solids: TSS

Biochemical oxygen demand: BOD

Chemical oxygen demand: COD

Total phosphorus: TP

Soluble phosphorus: soluble P

Total Kjeldhal nitrogen: TKN

Nitrite and nitrate: NO2 and NO3

Copper: Cu

Lead: Pb

Zinc: Zn

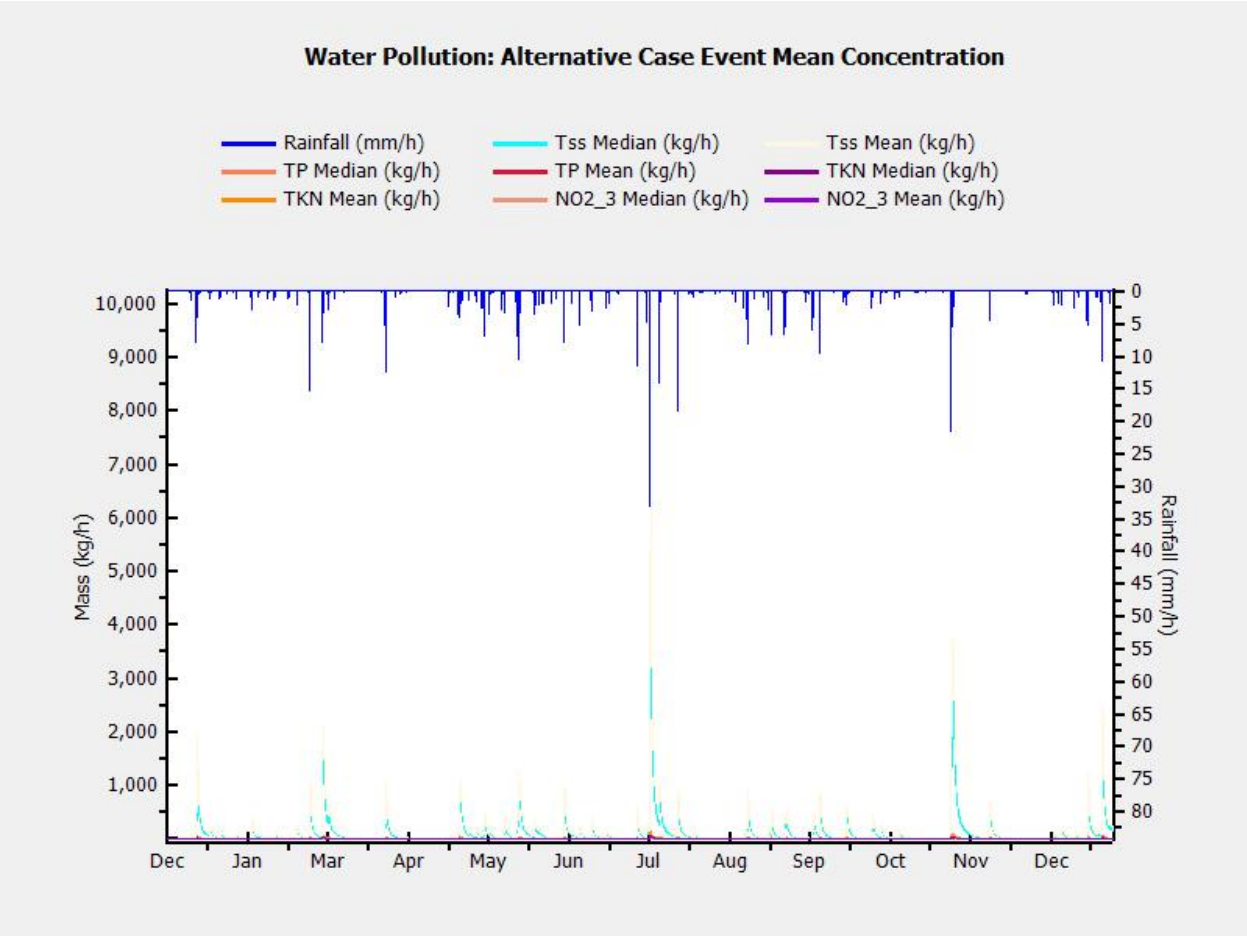


Figure A-12. Predicted pollutant loads compared to rainfall under build-out conditions

Figure A-13 displays the change in rainfall (mm/h) and pollutant load (kg/h) between the Base Cae and Alternative Case for the modeled watershed. The rainfall values are the recorded measurements that were inputs to the model. If the supplied data sets were used, the weather data is from the National Climactic Data Center (part of the NOAA). The pollutant loads are the predicted model outputs for both the current Base Case and future Alternative Case. Rainfall is displayed on the top of the graph, with larger rainfall events stretching towards the bottom of the graph; the rainfall rates correspond to the right-side axis.

The pollutant load measurements are displayed on the bottom of the graph and correspond to the left-side axis. Displaying the pollutant loads against the rainfall allows the user to observe how the pollutant load(s) change(s) during and after a precipitation event. This graph allows a user to compare the pollutant loads of the current Base Case against the pollutant loads of a future (proposed) Alternative Case. This allows for observation of the effects (positive or negative) on the pollutant load present in the total flow (discharge) associated with the proposed changes to tree cover, land cover, etc. The EMC values used within Hydro are explained further and referenced in Appendix 3 of the manual.

Total suspended solids: TSS

Total phosphorus: TP

Total Kjeldhal nitrogen: TKN

Nitrite and nitrate: NO2 and NO3

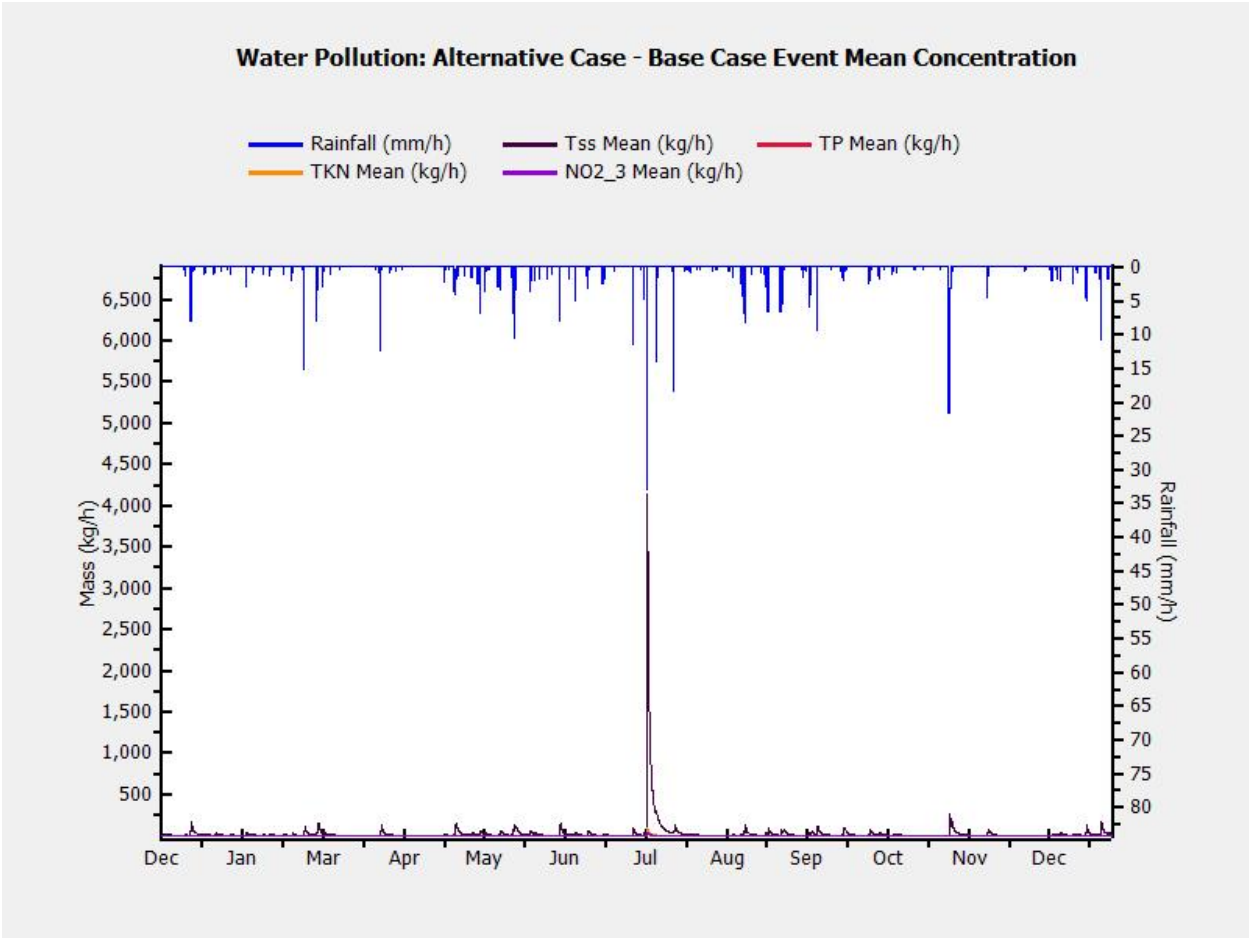


Figure A-13. The delta in pollutant loads between existing conditions and build-out conditions compared to rainfall

6.1 Powell's Creek i-Tree Hydro Results

i-Tree Hydro Executive Summary

Project Location: Montclair, Virginia
Project Time Span: 01/01/2012 - 12/30/2012

Model Parameters

Watershed Area	Rainfall	Total Runoff	Stream Gage	Weather Station
square kilometers	*millimeters*	*cubic meters*		
19.88	781.30	6,067,604.09	01658500	724035-13773

Land Cover	*Base*	*Alternative*		*Base*	*Alternative*	LC beneath Tree Cover	*Base*	*Alternative*
Tree Cover %	53.7	48.4	Tree LAI	5.0	5.0	Soil Cover %	96.1	95.0
Shrub Cover %	5.4	5.4	Shrub LAI	2.2	2.2	Impervious Cover %	3.9	5.0
Herbaceous Cover %	15.0	15.0	Herbaceous LAI	1.6	1.6			
Water Cover %	2.2	2.2						
Impervious Cover %	19.5	24.8	Directly Connected Impervious Cover (%)	40.0	40.0			
Soil Cover %	4.2	4.2						

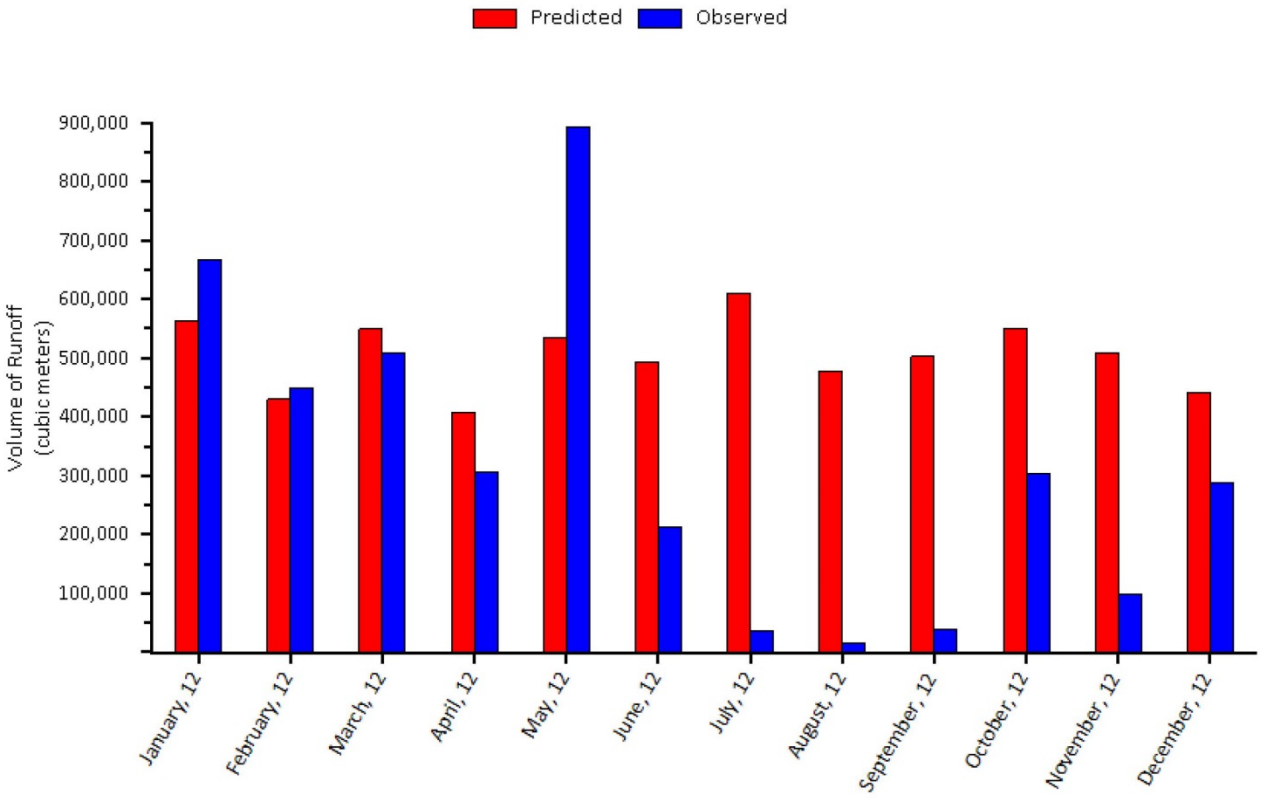
Streamflow Predictions

	Total Runoff		Baseflow		Pervious Flow		Impervious Flow	
	Base	*Alternative*	*Base*	*Alternative*	*Base*	*Alternative*	*Base*	*Alternative*
Total Flow (cubic meters)	6,067,604.1	5,661,570.2	5,757,062.5	5,331,572.2	187,673.3	178,013.8	122,868.3	151,984.2
Highest Flow (cubic meters / hour)	22,648.3	23,850.0	932.5	863.8	15,788.0	15,659.1	5,928.0	7,327.3
Lowest Flow (cubic meters / hour)	433.0	398.2	433.0	398.2	0.0	0.0	0.0	0.0
Highest Flow Date	07/05/12	07/05/12	07/05/12	07/05/12	07/05/12	07/05/12	07/05/12	07/05/12
Lowest Flow Date	10/29/12	10/29/12	10/29/12	10/29/12	01/01/12	01/01/12	01/01/12	01/01/12
Median Flow (cubic meters / hour)	645.8	599.1	642.0	595.2	0.0	0.0	0.0	0.0
Number of flow events ABOVE median flow	73.0	75.0	21.0	20.0	40.0	40.0	49.0	49.0
Average length of flow events with flow ABOVE median (hours)	59.3	57.7	213.5	224.7	79.2	79.0	81.5	81.5
High Flow: Number of flow events ABOVE 1 standard deviation	32.0	32.0	8.0	8.0	26.0	26.0	45.0	45.0
Average length of flow events ABOVE 1 standard deviation (hours)	128.8	128.7	469.1	468.3	81.3	81.2	82.7	82.7
Number of flow events BELOW median flow	72.0	74.0	20.0	19.0	0.0	0.0	0.0	0.0
Average length of events BELOW median (hours)	60.8	59.2	219.0	230.5	0.0	0.0	0.0	0.0

i-Tree Hydro Executive Summary

Project Location: Montclair, Virginia
Project Time Span: 01/01/2012 - 12/30/2012

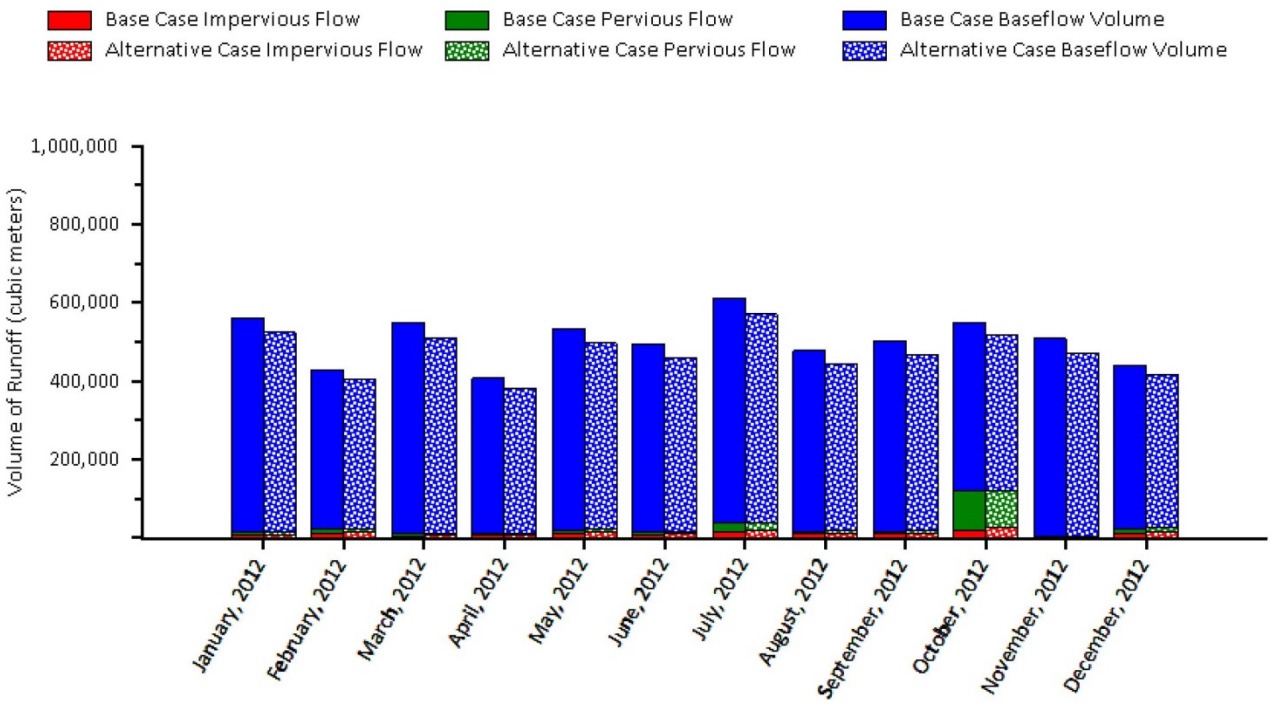
Water Volume: Observed Streamflow vs. Predicted Streamflow
(Predicted is 59% higher than Observed)



i-Tree Hydro Executive Summary

Project Location: Montclair, Virginia
Project Time Span: 01/01/2012 - 12/30/2012

Base Case vs. Alternative Case Predicted Streamflow Components

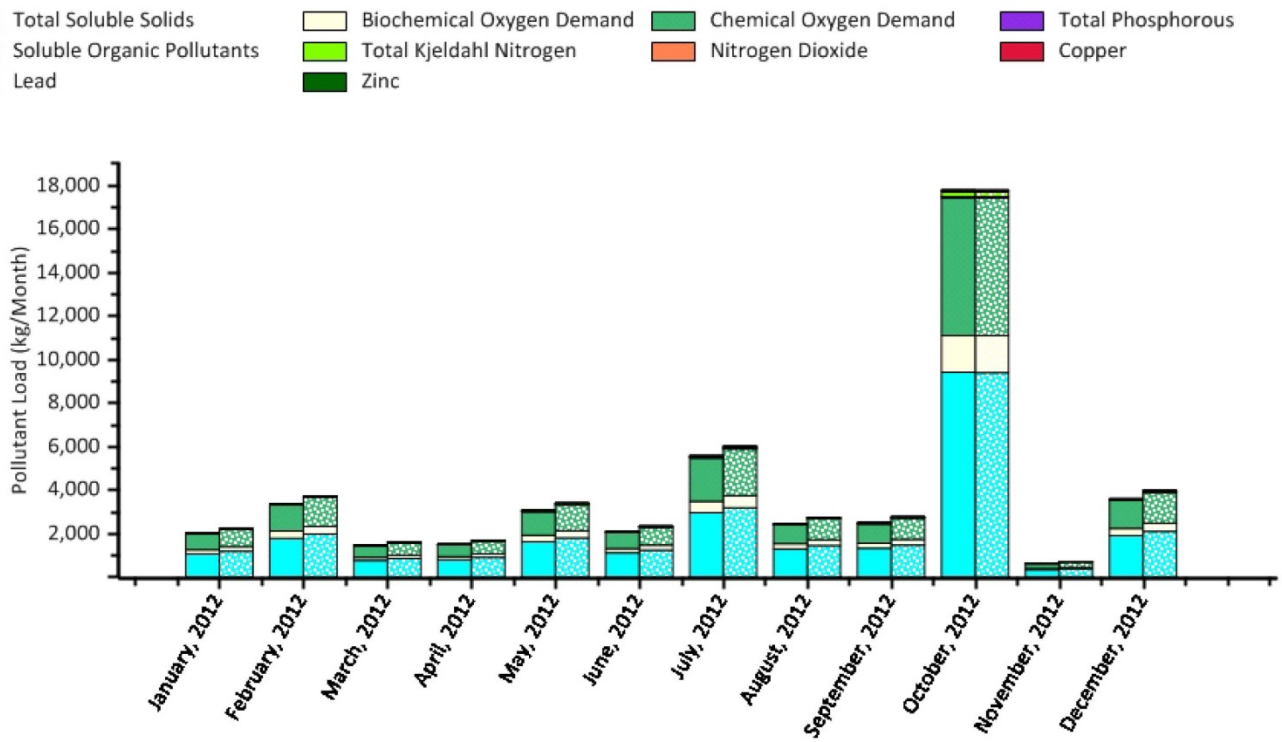


Note: Solid colors represent Base Case values while the hatched pattern indicates Alternative Case values

i-Tree Hydro Executive Summary

Project Location: Montclair, Virginia
Project Time Span: 01/01/2012 - 12/30/2012

Pollutants: Base Case vs. Alternative Case Event Mean Concentration



Note: Solid colors represent Base Case values while the hatched pattern indicates Alternative Case values

i-Tree Hydro Executive Summary

Project Location: Montclair, Virginia
Project Time Span: 01/01/2012 - 12/30/2012

Glossary of Key Terms

Base Case – The original modeled scenario defined by the initial land cover values (e.g. tree cover, herbaceous cover, impervious cover, etc.).

Alternative Case – The modeled scenario contrasted with the base case. It is defined by changes in the initial land cover values representing an increase in development (e.g. increase in impervious cover or decrease in vegetative cover) or an increase in vegetative cover (e.g. increase in tree cover or herbaceous cover).

Baseflow – The stream flow from groundwater and no recent storm runoff. Baseflow is generated from the saturated soil zone within i-Tree Hydro.

Impervious Flow – The predicted overland surface runoff generated from impervious cover areas, which may be impervious cover with or without vegetative canopies. The model first checks that impervious cover specific depression storage is filled and evaporation from this storage is accounted for, before generating impervious flow. Impervious flow either passes directly to the outlet through directly connected impervious cover area (DCIA) or runs on to neighboring pervious cover areas where infiltration may occur.

Pervious Flow – The predicted overland surface runoff generated from pervious cover areas, which include bare soil and soil areas under herbaceous cover and vegetative canopies. The model uses first checks that pervious cover specific depression storage is filled and evaporation from this storage is accounted for, then uses saturation excess and infiltration excess routines to calculate the total amount of pervious flow. Pervious cover surface runoff generates run-on to neighboring impervious areas, where DCIA transports a portion of the runoff to the outlet, or onto neighboring pervious cover areas where infiltration may occur.

Total Flow volume (cubic meters) – This is the total amount of streamflow (baseflow plus pervious and impervious surface runoff) for the modeled time period. To arrive at this number, the predicted total streamflow rate for each timestep (typically m/hr) is multiplied by the watershed area represented by each landcover type and the total number of modeled timesteps (typically hr).

Highest Flow rate (cubic meters / hour) – The largest predicted peak streamflow rate during the modeled period.

Lowest Flow rate (cubic meters / hour) – The lowest predicted peak streamflow rate during the modeled period.

Highest Flow Date – The date of the largest predicted peak streamflow rate.

Lowest Flow Date – The date of the lowest predicted peak streamflow rate.

Average Flow rate (cubic meters/hour) – The average predicted streamflow rate during the modeled period.

Number of flow events ABOVE average flow – The number of continuous periods (timesteps) where the predicted streamflow rate is above the average streamflow rate.

Average length of flow events ABOVE average (hours) – The average length in hours of the continuous periods (timesteps) where the predicted streamflow rate is above the average streamflow rate.

6.2 Windy Run i-Tree Hydro Results

i-Tree Hydro Executive Summary

Project Location: Arlington, Virginia
Project Time Span: 01/01/2005 - 12/30/2005

Model Parameters

Watershed Area	Rainfall	Total Runoff	Stream Gage	Weather Station
square kilometers	*millimeters*	*cubic meters*		
1.28	901.19	395,711.82	01652500	724050-13743

Land Cover	*Base*	*Alternative*		*Base*	*Alternative*	LC beneath Tree Cover	*Base*	*Alternative*
Tree Cover %	48.5	44.5	Tree LAI	5.0	5.0	Soil Cover %	93.9	90.0
Shrub Cover %	1.0	1.0	Shrub LAI	2.2	2.2	Impervious Cover %	6.1	10.0
Herbaceous Cover %	13.8	13.8	Herbaceous LAI	1.6	1.6			
Water Cover %	0.0	0.0						
Impervious Cover %	36.1	40.2	Directly Connected Impervious Cover (%)	40.0	40.0			
Soil Cover %	0.6	0.6						

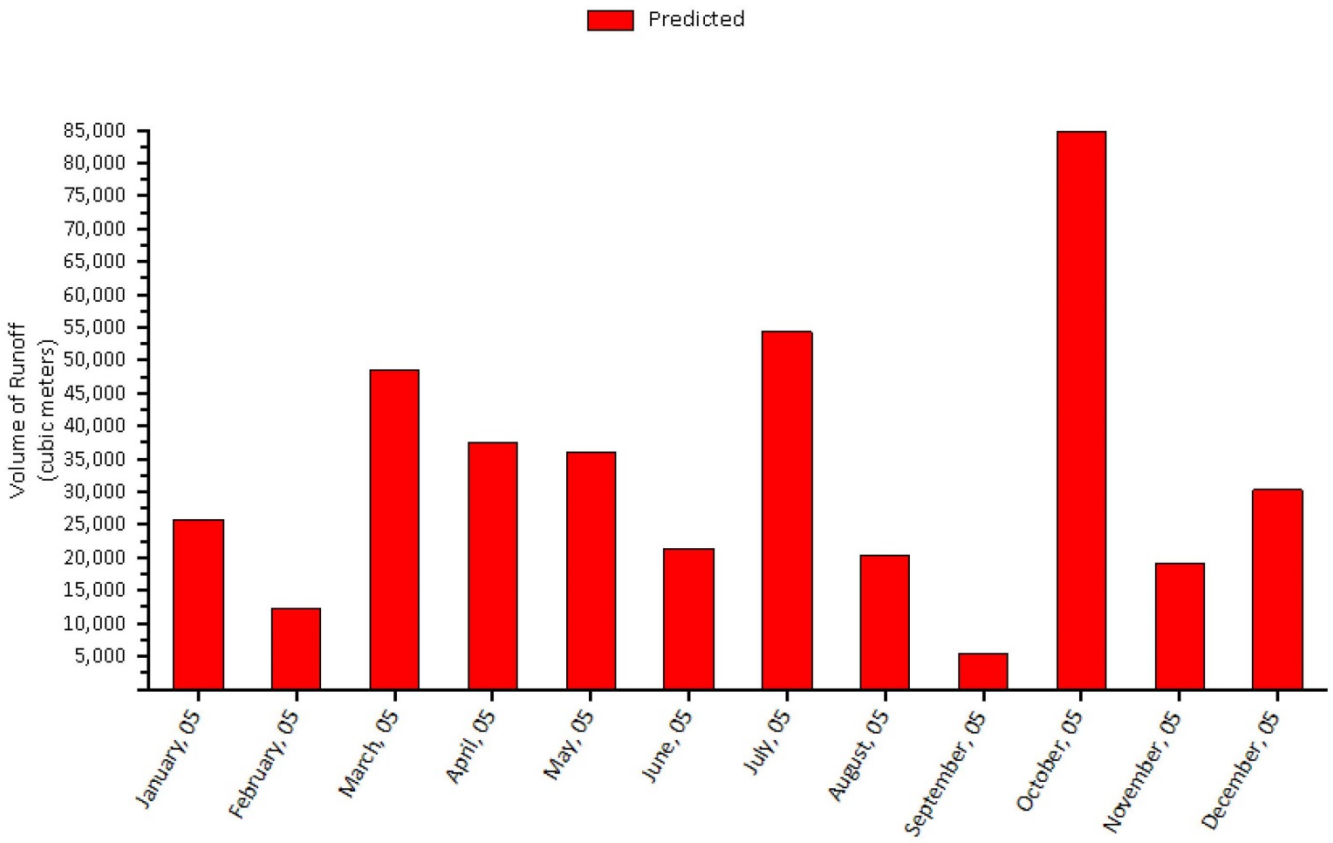
Streamflow Predictions

	Total Runoff		Baseflow		Pervious Flow		Impervious Flow	
	Base	*Alternative*	*Base*	*Alternative*	*Base*	*Alternative*	*Base*	*Alternative*
Total Flow (cubic meters)	395,711.8	397,552.1	102,422.9	93,329.6	137,871.3	127,169.6	155,417.6	177,053.0
Highest Flow (cubic meters / hour)	9,562.5	9,739.7	14.9	13.6	6,231.6	5,940.1	3,435.1	3,920.9
Lowest Flow (cubic meters / hour)	6.2	5.6	6.1	5.6	0.0	0.0	0.0	0.0
Highest Flow Date	07/08/05	07/08/05	07/15/05	07/15/05	07/08/05	07/08/05	07/15/05	07/15/05
Lowest Flow Date	10/07/05	10/07/05	10/07/05	10/07/05	01/01/05	01/01/05	01/01/05	01/01/05
Median Flow (cubic meters / hour)	12.3	11.2	12.0	10.9	0.0	0.0	0.0	0.0
Number of flow events ABOVE median flow	46.0	45.0	10.0	10.0	23.0	22.0	32.0	32.0
Average length of flow events with flow ABOVE median (hours)	76.0	77.8	380.8	380.6	149.5	151.5	136.6	136.6
High Flow: Number of flow events ABOVE 1 standard deviation	20.0	21.0	9.0	9.0	18.0	19.0	29.0	29.0
Average length of flow events ABOVE 1 standard deviation (hours)	170.8	162.5	420.6	420.5	159.3	156.9	139.5	139.5
Number of flow events BELOW median flow	45.0	44.0	9.0	9.0	0.0	0.0	32.0	32.0
Average length of events BELOW median (hours)	97.0	99.3	485.3	484.9	0.0	0.0	136.5	136.5

i-Tree Hydro Executive Summary

Project Location: Arlington, Virginia
Project Time Span: 01/01/2005 - 12/30/2005

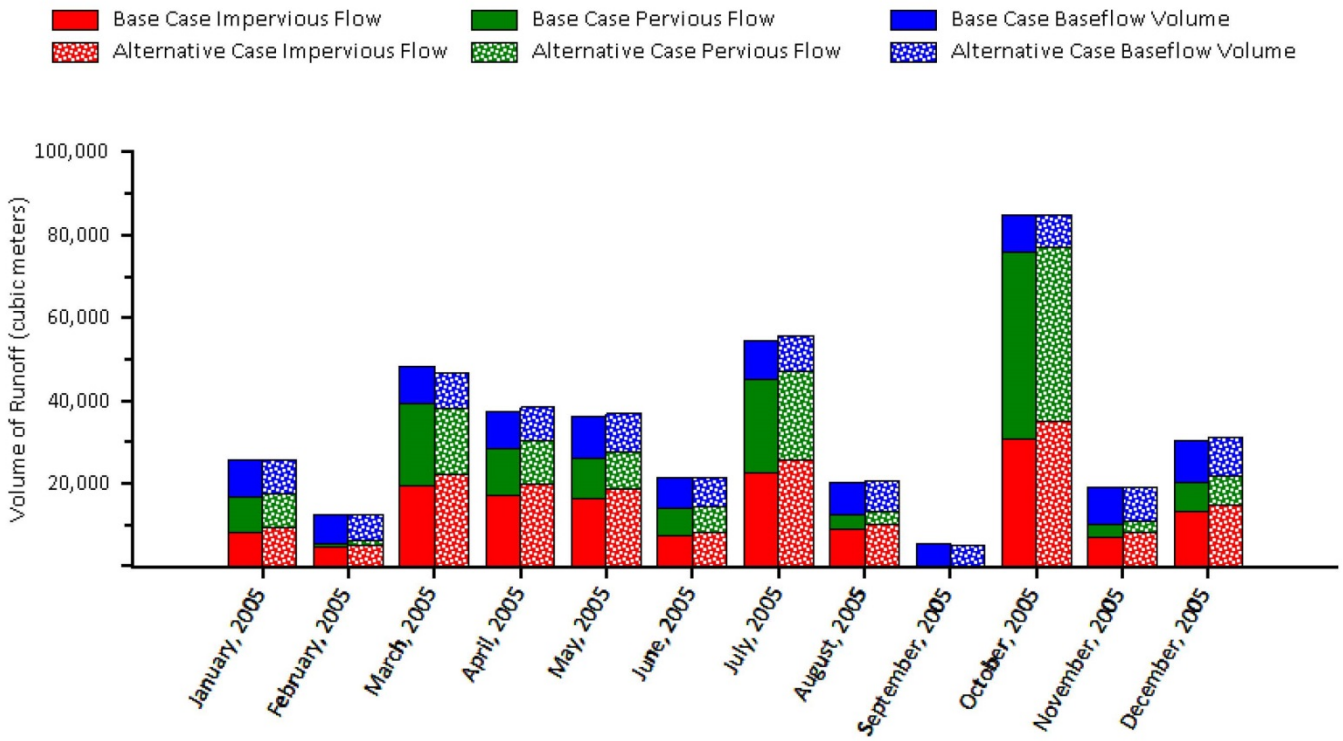
Water Volume: Predicted Streamflow



i-Tree Hydro Executive Summary

Project Location: Arlington, Virginia
Project Time Span: 01/01/2005 - 12/30/2005

Base Case vs. Alternative Case Predicted Streamflow Components

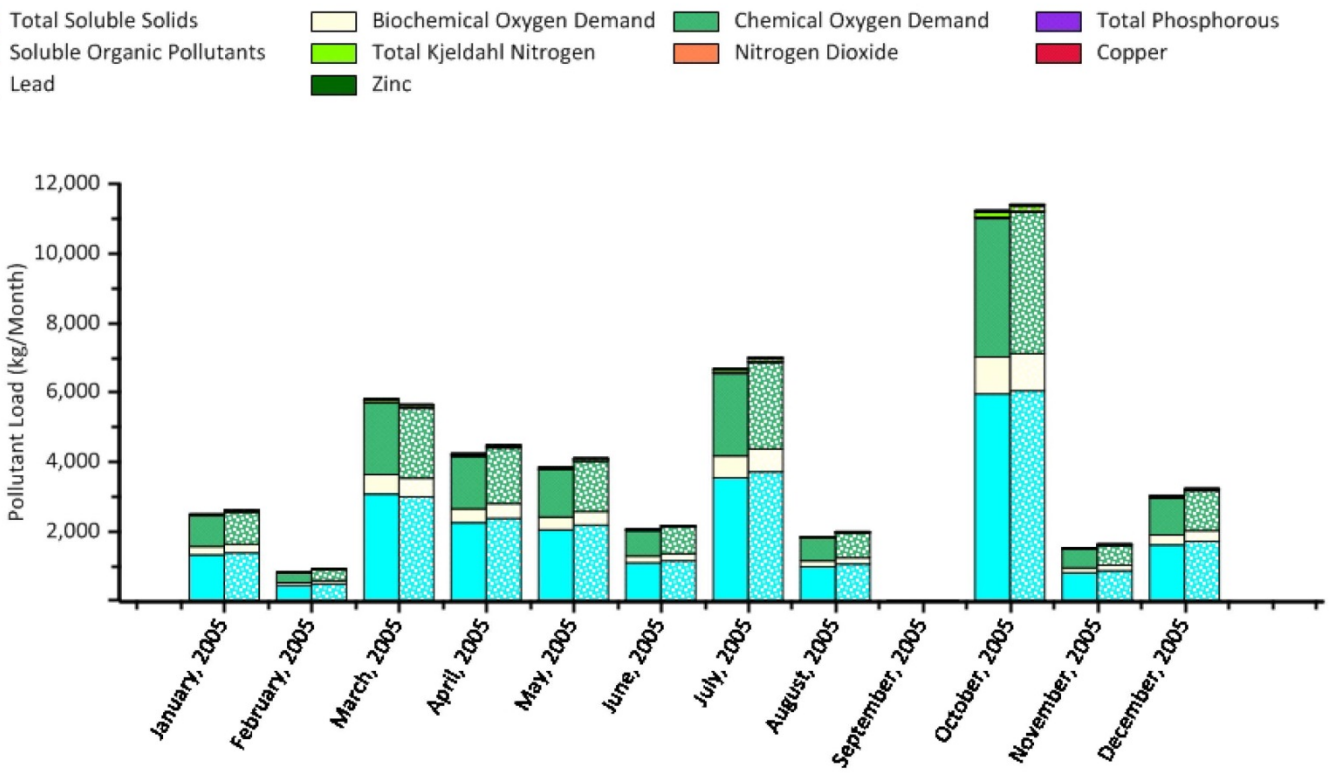


Note: Solid colors represent Base Case values while the hatched pattern indicates Alternative Case values

i-Tree Hydro Executive Summary

Project Location: Arlington, Virginia
Project Time Span: 01/01/2005 - 12/30/2005

Pollutants: Base Case vs. Alternative Case Event Mean Concentration



Note: Solid colors represent Base Case values while the hatched pattern indicates Alternative Case values

i-Tree Hydro Executive Summary

Project Location: Arlington, Virginia
Project Time Span: 01/01/2005 - 12/30/2005

Glossary of Key Terms

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Total Flow volume (cubic meters) – This is the total amount of streamflow (baseflow plus pervious and impervious surface runoff) for the modeled time period. To arrive at this number, the predicted total streamflow rate for each timestep (typically m/hr) is multiplied by the watershed area represented by each landcover type and the total number of modeled timesteps (typically hr).

Highest Flow rate (cubic meters / hour) – The largest predicted peak streamflow rate during the modeled period.

Lowest Flow rate (cubic meters / hour) – The lowest predicted peak streamflow rate during the modeled period.

Highest Flow Date – The date of the largest predicted peak streamflow rate.

Lowest Flow Date – The date of the lowest predicted peak streamflow rate.

Average Flow rate (cubic meters/hour) – The average predicted streamflow rate during the modeled period.

Number of flow events ABOVE average flow – The number of continuous periods (timesteps) where the predicted streamflow rate is above the average streamflow rate.

Average length of flow events ABOVE average (hours) – The average length in hours of the continuous periods (timesteps) where the predicted streamflow rate is above the average streamflow rate.