Section 2: Watershed Characteristics and Runoff

The hydrology of the Wissahickon Creek and its tributaries varies greatly from place to place within the larger watershed. Stormwater management planning must take numerous surface features into account, including topography, soils, land use, and impervious cover, as well as existing stormwater collection and discharge. This section describes the primary factors defining the storm runoff in the watershed. In addition, because of the close linkage between land cover and runoff, an analysis of land development alternatives to meet projected future growth is provided.

2.1 Precipitation

For the 30 year period from 1981 to 2010, precipitation at the National Weather Service (NWS) rain gage at Springhouse, PA, in the north-central portion of the Wissahickon Watershed averaged 47.4 inches.[1] Similar annual totals were recorded for NWS stations near the watershed at Norristown (48.4 inches) and Conshohocken (48.7 inches). Additionally, a water budget analysis performed by the U.S. Geological Survey for the period 1987-1998 reported an average annual total for the watershed of 47.2 inches.[2] This annual total, however, is not uniformly distributed over time, and extreme events can produce 8 inches of rain or more in a single day. Flood events occur at any time of year, and may be caused by different types of weather events including severe thunderstorms, tropical storms, or even colder weather events when heavy rains can combine with snowmelt. Rainfall during individual storms is generally not distributed evenly across the watershed, and rarely occurs at a constant rate. Because of its location immediately northwest of the Coastal Plain, the watershed is vulnerable to heavy rainfall from tropical weather events. Damaging tropical storms in recent years have included Floyd (1999), Allison (2001), Ivan (2004), Irene (2011), and Lee (2011).

Table 2.1.A lists design rainfall totals that have been applied to the hydrologic analyses in this study. The design events are based on the PennDOT Intensity-Duration-Frequency (IDF) data for regions in Pennsylvania. This data was developed from the latest NOAA Atlas 14 precipitation frequency data. The precipitation totals for the various design events are weighted averages because the Wissahickon Watershed is situated at the boundary of PennDOT IDF Regions 4 and 5. Approximately 40% of the Wissahickon Watershed is in Region 4 and 60% in Region 5.

In terms of probability, the meaning of design storm frequency is as follows: a 5-year event would have a 20 percent chance of occurring in a given year; a 10-year event would have a 10 percent chance of occurring in a given year, etc. The rainfall totals in the table provide a means of predicting the magnitude of storms for planning and design purposes. They are a statistical product based on the population of events that have occurred in the past. They are not predictive of the timing or sequence of individual storm events or their rainfall distribution in the watershed. For example, the extreme precipitation events caused by tropical storms Floyd and Allison occurred less than two years apart.

In addition to total rainfall, the timing of rain during an event affects peak runoff rates. The design storms applied in this study include a period of heavy rain in the middle of the event. This is done

[1] NOAA, National Climatic Data Center, 1981-2010 Normals Data Access, http://www.ncdc.noaa.gov/land-based-station-data/climate-normals/1981-2010-normals-data.
[2] Sloto, R. A., and Buxton, D. E., Scientific Investigations Report 2005-5113, U.S. Geological Survey, 2005.

to mimic the flashy runoff conditions that are usually a part of flood events in watersheds the size of the Wissahickon and its tributaries. Additionally, the same rainfall total and timing of rain is applied to the entire watershed simultaneously in the modeling. While this does not replicate any single historic event, it provides a means of evaluating the watershed under a range of runoff conditions and gives a measure of the effectiveness of potential stormwater improvements.

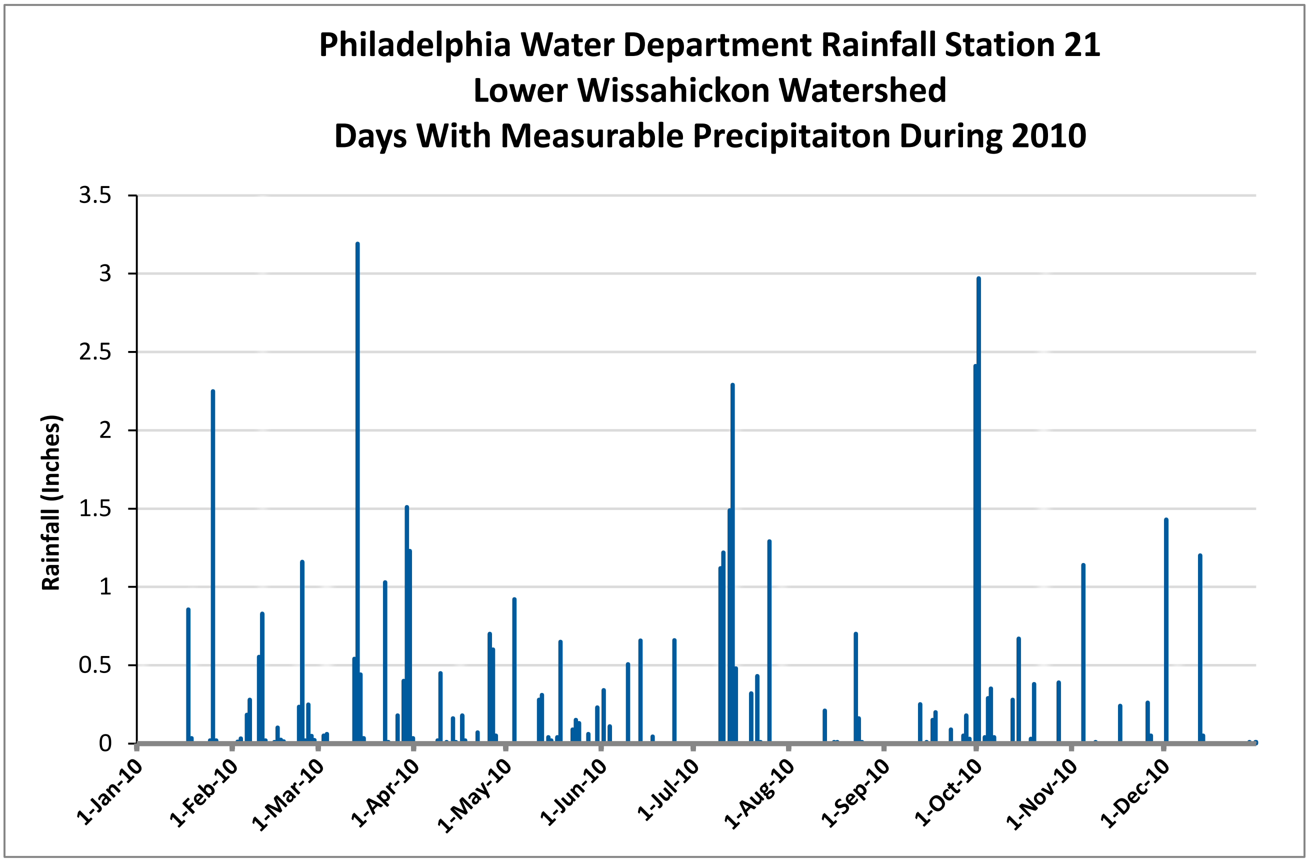
Although extreme storm events trigger the most damaging flooding in the Wissahickon Watershed, most storms produce less than one inch of rainfall. These smaller storms produce a significant portion of annual runoff. For this reason, stormwater management measures designed for infiltration or extended detention of these smaller runoff events are effective in reducing non-point pollution loadings and stream erosion. Daily precipitation data for 2010 at the Philadelphia Water Department's rain gage No. 21 in the lower portion of the Wissahickon Watershed is presented in Figure 2.1.A. Of the 69 days when more than 0.1 inch of precipitation occurred, only 16 (23 percent) produced total rainfall exceeding one inch.

Table 2.1.A Rainfall Totals for 24-Hour Design Storms

Based on PennDOT Intensity-Duration-Frequency (IDF) data for Regions 4 and 5 in Pennsylvania.

Storm Frequency	Total Precipitation (in)
1-Yr	2.75
2-Yr	3.30
5-Yr	4.10
10-Yr	4.80
25-Yr	5.90
50-Yr	6.91
100-Yr	8.11
500-Yr	11.83

Figure 2.1.A   Precipitation Events in the Wissahickon Watershed



2.2 Surface Features

The Wissahickon Watershed is characterized by gently rolling terrain in the headwaters, a moderately sloping valley in the central part of the watershed, and the relatively steep terrain of Wissahickon Valley Park in the lower watershed. The elevations over the watershed range from 12 feet at the mouth of Wissahickon Creek in Philadelphia to 488 feet in Montgomery and Upper Gwynedd Townships. Portions of Roxboro and Chestnut Hill in Philadelphia have elevations of over 400 feet, as well as sections of Cheltenham, Montgomery, and Springfield Townships and North Wales and Lansdale Boroughs.

Figure 2.2.A provides a graphical presentation of elevation from a Digital Elevation Model or DEM. The DEM was created from 2008 LIDAR flown for the PAMAP program of the Pennsylvania Department of Conservation and Natural Resources, and was downloaded from the Pennsylvania Spatial Data Access website.[3] It includes high resolution, high quality data with two-foot contours.

Based on their runoff characteristics, soils of the U.S. are classified by the Natural Resource Conservation Service (NRCS) into four hydrologic groups A, B, C, D. Group A soils have low runoff potential with high infiltration rates, while Group D soils have high runoff with very slow infiltration

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[3] Pennsylvania State Data Access, Penn State Institutes of Energy and the Environment, Penn State University

rates. The other two groups are in between. Runoff characteristics of various land uses vary with the underlying hydrologic soil group designation, and information on the location of hydrologic soils groups was used in the hydrologic modeling for this study. As noted on Figure 2.2.B, hydrologic soils in the Wissahickon Watershed are predominately groups B and C with some D soils.

Group B soils have moderate infiltration rates even when thoroughly wetted and consist chiefly of moderately deep to deep, moderately well drained to well drained soils with moderately fine to moderately coarse textures.

Group C soils have slow infiltration rates even when thoroughly wetted and consist chiefly of soils with a layer that impedes downward movement of water, or soils with moderately fine to fine textures.

Group D soils have the slowest infiltration rates of the four groups. Movement of water through this soil type is highly restricted due to the soil composition which generally more than 40 percent clay. All soils with a water table within 2 feet of the surface are included in Group D.[4]

Soil erodibility in the Wissahickon Watershed is depicted in Figure 2.2.C. Soil erodibility in the watershed ranges from slight in most upland areas to severe in riparian areas along the lower main stem of the Wissahickon Creek in the City of Philadelphia.

Current land use in the Wissahickon Watershed is shown in Figure 2.2.D. The watershed has been heavily developed with residential use, and includes areas of commercial and manufacturing use along with highway and rail corridors. Despite the high degree of development, lands in Wissahickon Valley Park in Philadelphia and lands preserved through efforts of the Wissahickon Valley Watershed Association have preserved long reaches of the main stem stream corridor as open space. Had these lands been developed to the degree of many other riparian stream reaches in urban areas, the flood damage potential would be much higher.

As of 2005, approximately 46 percent of the Wissahickon Watershed was in single-family residential use, with an additional 5 percent used for multi-family residences. Commercial and industrial use comprised 3 percent and 1 percent of the watershed, respectively. Parking to support commercial, residential and community activities comprised an additional 3 percent of the land use. Woodland covered 17 percent of the watershed, agriculture covered 7 percent , and recreational space occupied an additional 8 percent. The remaining land use (10 percent) was comprised of transportation, community services, water, utility operations, and vacant properties. A detailed analysis of alternative land use scenarios to meet projected future growth in the Wissahickon watershed is provided in Section 2.3. A summary of a hydrologic model evaluation of the two scenarios is presented in Section 4.

Taken together, the surface features of the Wissahickon Watershed, along with antecedent soil moisture conditions, define how it responds to rainfall. In order to provide more precise information about potential for flash flooding in small watersheds, the National Weather Services' Mount Holly Weather Forecast Office has conducted a GIS-based analysis of flash flood potential for its forecast area. The product of the analysis is the map shown in Figure 2.2.E, which shows

[4] U.S. Department of Agriculture, Natural Resources Conservation Service, National Engineering Handbook, Part 630 – Hydrology, Chapter 7, pp. 7-2-7-3.

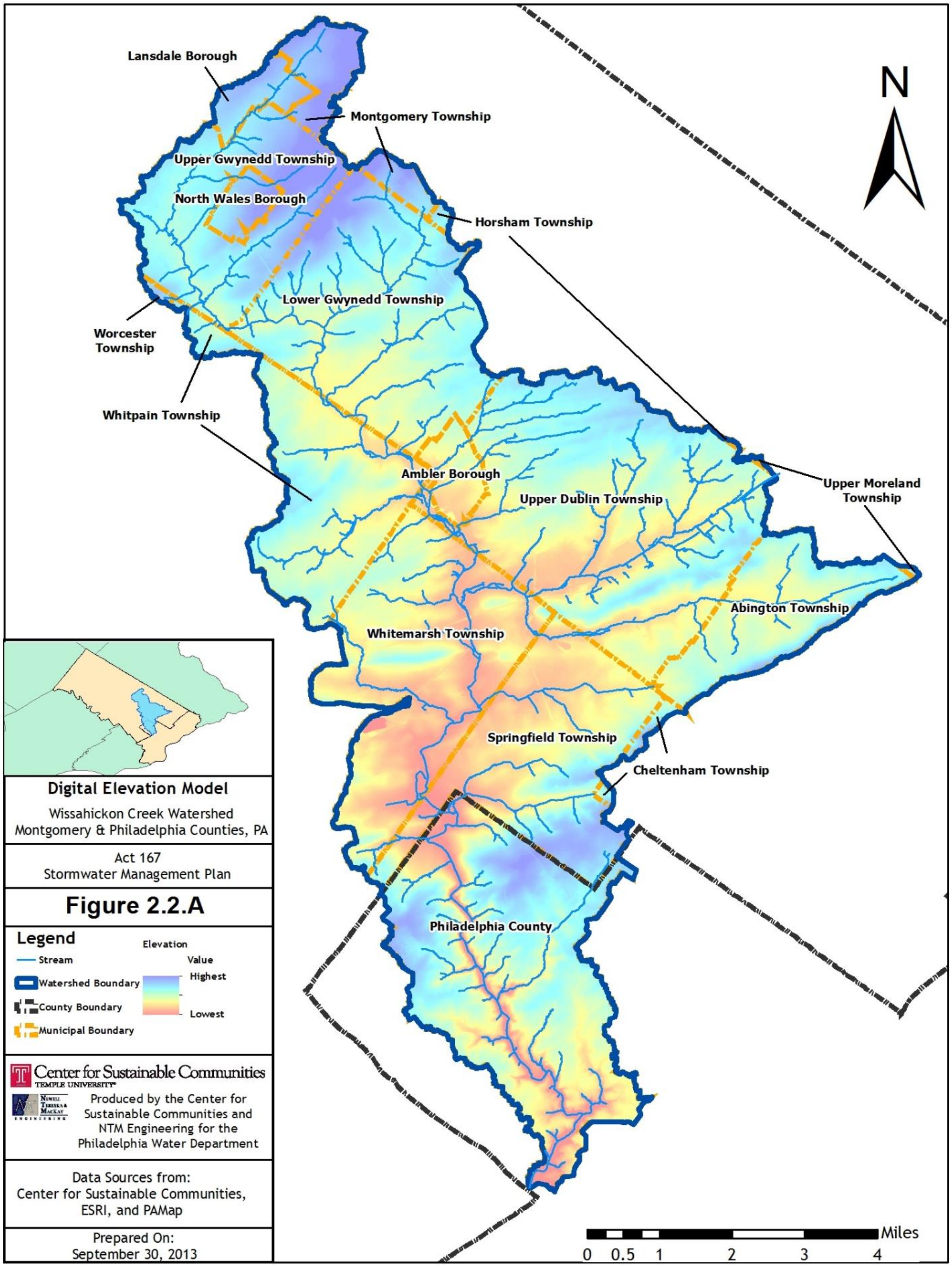
relative flash flood potential in the Wissahickon Watershed based on digital data available for soils, slope, forest density, and land use. The map shows an index of the combined potential for these land-based parameters to generate flash flooding, with the highest index numbers representing the areas of highest flood potential. Comparison of this map with Figure 2.2.D shows the close agreement with flash flood potential and land uses associated with impervious cover. The map provides a good picture of the areas in the watershed that would be expected to generate the largest runoff volumes, and is consistent with the representation of surface conditions by the hydrologic model described in Section 4.

Once runoff occurs, constructed surface storage that intercepts and holds the runoff can delay flow and lower flood peaks. For this study, the Philadelphia Water Department provided an inventory with 185 existing detention basins in the watershed. This was supplemented by data collected by the CSC during field inspections of additional detention facilities and ponds. Figure 2.2.F shows the distribution of these facilities in the watershed. The majority are located in the upper half of the watershed where there has been more development subsequent to the implementation of stormwater management regulations. The storage provided by these facilities was estimated and totals for each modeled subbasin were included in the hydrologic model. The estimated total storage of all existing facilities is approximately 380 acre-feet. Most are local facilities designed to control site runoff from specific development sites. If spread over the entire area of the Wissahickon Watershed, this storage total amounts to the equivalent of 0.11 inches of runoff. Many existing facilities are not designed for extended detention, and runoff from smaller storms passes directly through the facility. These structures represent opportunities for retrofitting to provide additional storage and extended detention.

Stormwater collection, piping, and discharge through outfalls affect the pathway and timing of runoff in developed watersheds such as the Wissahickon. Stormwater collection systems are located in each of the municipalities in the Wissahickon Watershed. The collection systems are located primarily in the residential, commercial, and industrial areas served by curbed streets, and along arterial and secondary roadways. Although a detailed survey of stormwater piping was not conducted as part of this study, estimates of the extent of coverage were made based on field observations, orthophotography, land use data, and outfall and drainage shed data provided by the Philadelphia Water Department. Based on this information, it is estimated that stormwater collection systems of various capacities have been installed in approximately 60 percent of the Wissahickon Watershed.

The single largest land use category in the Wissahickon Watershed is single-family residential. In most residential areas, only a portion of the water falling on roofs and properties enters the street, and subsequently the storm inlets, depending on the slope of the property and gutter drainage onto the property. The remainder of roof and property drainage infiltrates into the soil, and as the soil becomes saturated, runoff flows at an increasing rate to the street or to other drainage basins offsite. As housing density increases, a larger proportion of each property's drainage enters storm inlets. In the developed sections of the watershed with curbed roadways, the roadways channel runoff to the storm inlets during smaller storm events, and become stormwater channels once runoff exceeds the capacity of the inlets and/or pipe capacities. Development alters the local runoff pathway, particularly for smaller storms, and the runoff to stream channels is often controlled by the location of stormwater inlets, piping, detention basins, and outfalls. This situation is depicted in Figure 2.2.G. For the portion of the watershed within the Philadelphia city limits, stormwater shed boundaries were used to delineate subareas for modeling, due to the modification of drainage caused by streets, inlets and piping. The watershed boundaries and outfall locations also were used as guidance in delineating subareas outside of the City limits. A map showing outfall locations in the watershed is shown in Figure 2.2.H. In addition, an example of a municipal stormwater system map, with stormwater piping, inlet and outlet locations provided by Upper Dublin Township, is shown in Figure 2.2.I.

Based on the analysis of future land use presented in Section 2.3, and as shown on Figure 2.3.A, scattered areas of new residential and non-residential development are projected in each of the watershed's municipalities. Future stormwater collection modifications or expansions would be most likely in these areas.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Worcester Township
Whitpain Township
Ambler Borough
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Upper Moreland Township
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Digital Elevation Model
Wissahickon Creek Watershed
Montgomery & Philadelphia Counties, PA
Act 167
Stormwater Management Plan
Figure 2.2.A
Legend
Stream
Watershed Boundary
County Boundary
Municipal Boundary
Elevation
Value
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Center for Sustainable Communities
TEMPLE UNIVERSITY
Produced by the Center for Sustainable Communities and NTM Engineering for the Philadelphia Water Department
Data Sources from:
Center for Sustainable Communities, ESRI, and PAMap
Prepared On:
September 30, 2013
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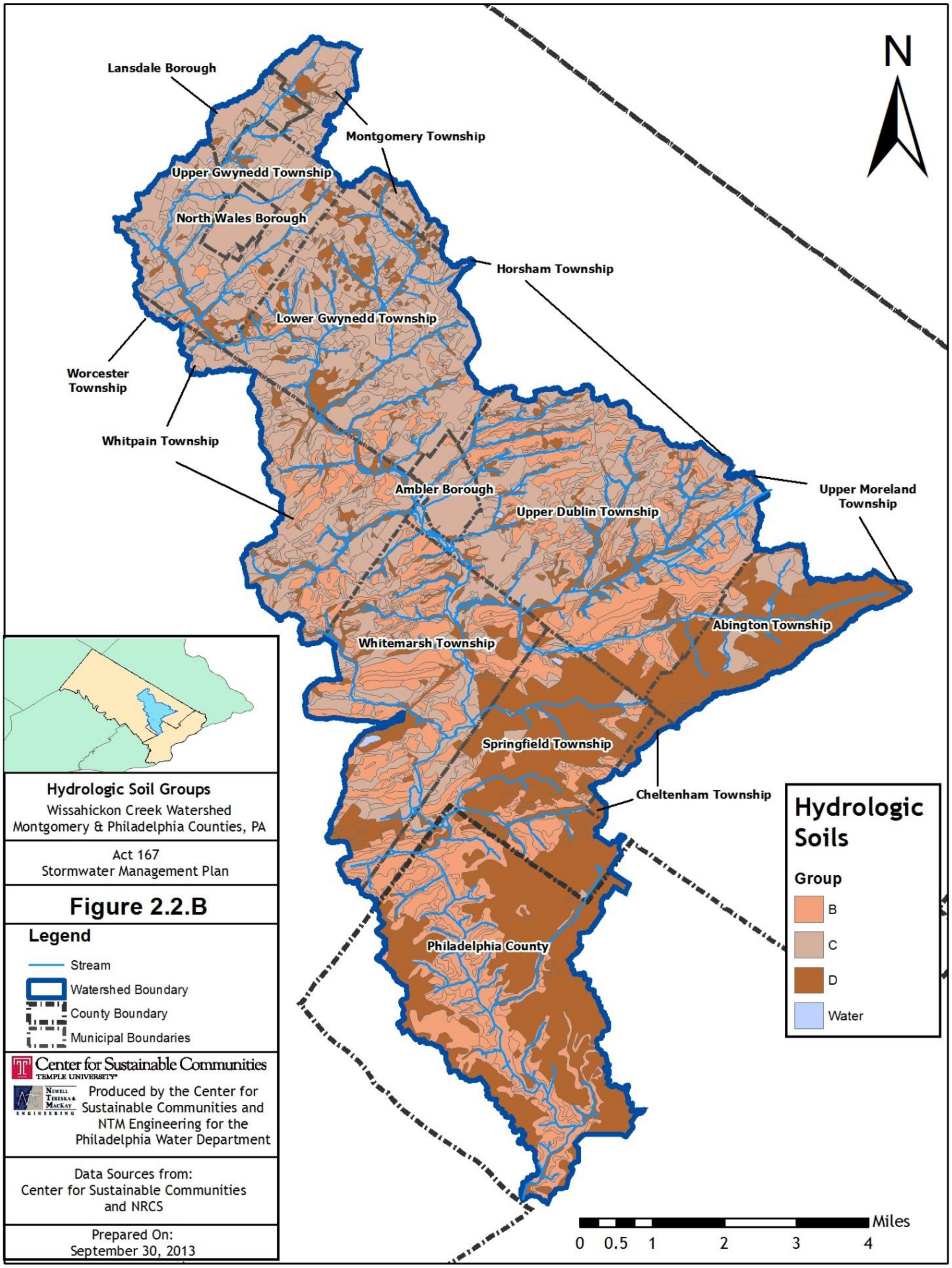
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Montgomery & Philadelphia Counties, PA
Act 167
Stormwater Management Plan
Figure 2.2.B
Legend
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Watershed Boundary
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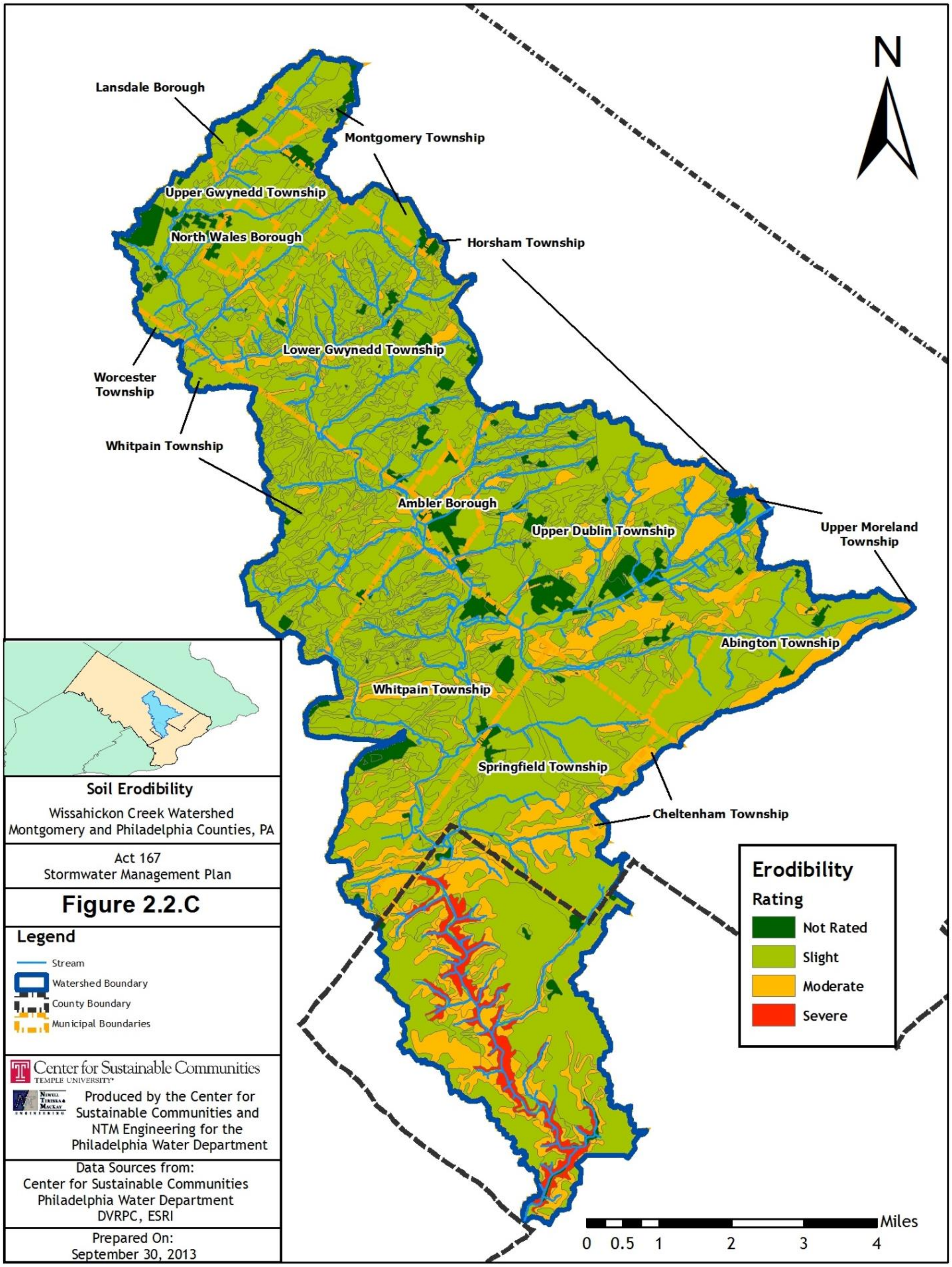
Data Sources from:
Center for Sustainable Communities and NRCS
Prepared On:
September 30, 2013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Montgomery and Philadelphia Counties, PA
Act 167
Stormwater Management Plan
Figure 2.2.C
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Municipal Boundaries
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Produced by the Center for Sustainable Communities and NTM Engineering for the Philadelphia Water Department
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Center for Sustainable Communities
Philadelphia Water Department
DVRPC, ESRI
Prepared On:
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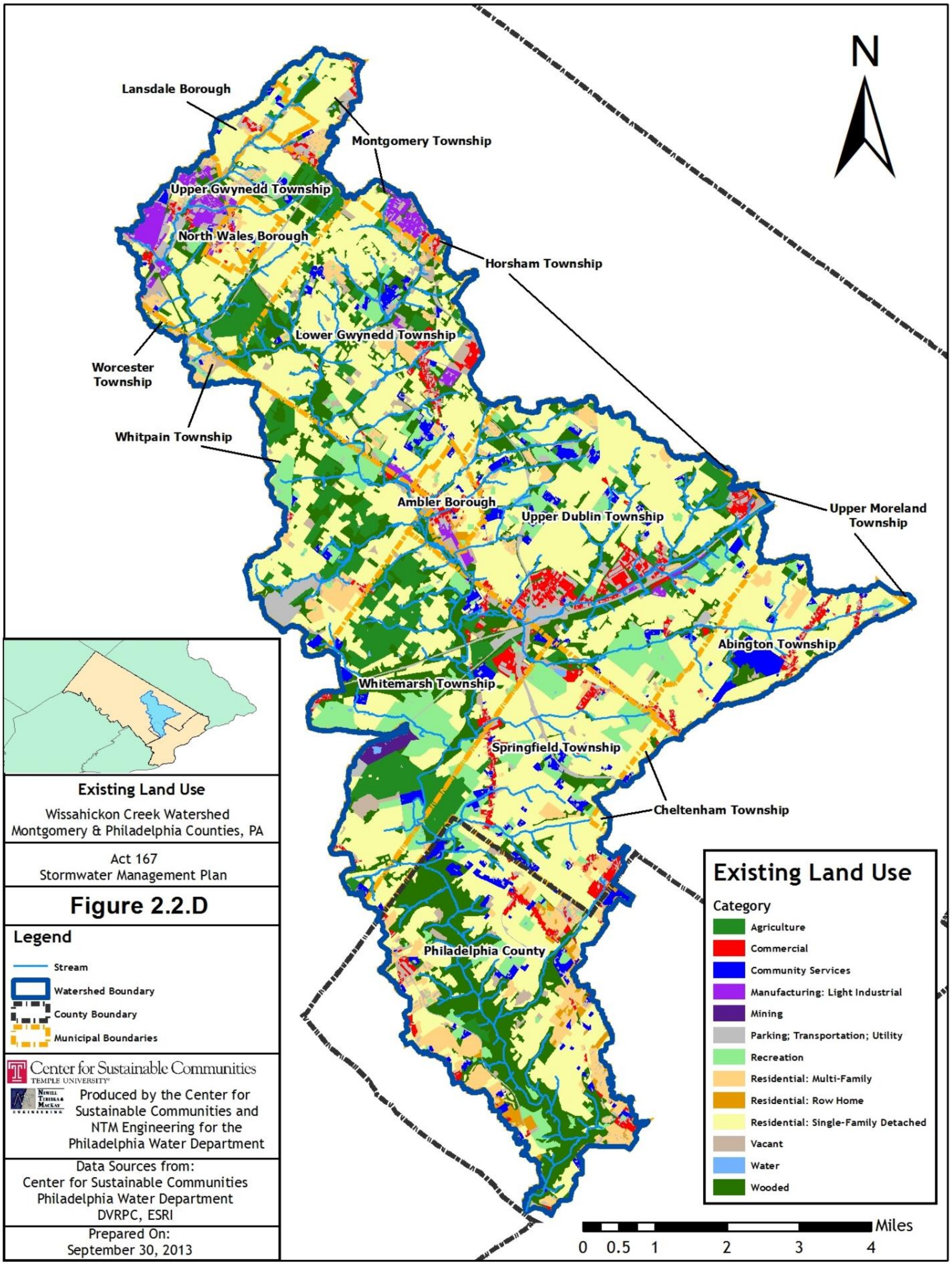
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Act 167
Stormwater Management Plan
Figure 2.2.D
Legend
Stream
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Produced by the Center for Sustainable Communities and NTM Engineering for the Philadelphia Water Department
Data Sources from:
Center for Sustainable Communities
Philadelphia Water Department
DVRPC, ESRI
Prepared On:
September 30, 2013
Existing Land Use
Category
Agriculture
Commercial
Community Services
Manufacturing: Light Industrial
Mining
Parking; Transportation; Utility
Recreation
Residential: Multi-Family
Residential: Row Home
Residential: Single-Family Detached
Vacant
Water
Wooded
Miles
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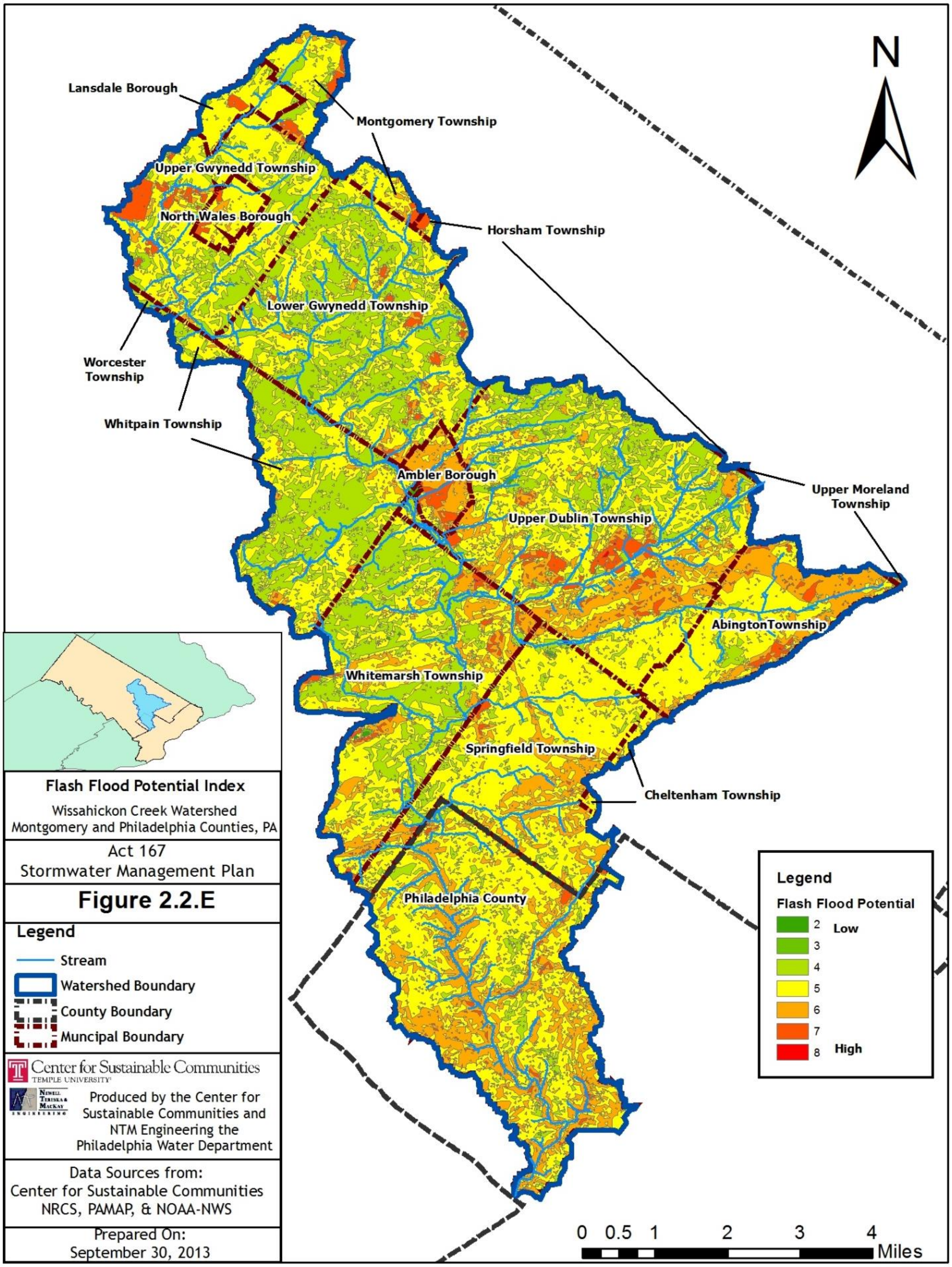

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Flash Flood Potential
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Flash Flood Potential Index
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Montgomery and Philadelphia Counties, PA
Act 167
Stormwater Management Plan
Figure 2.2.E
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Produced by the Center for Sustainable Communities and NTM Engineering the Philadelphia Water Department
Data Sources from:
Center for Sustainable Communities
NRCS, PAMAP, & NOAA-NWS
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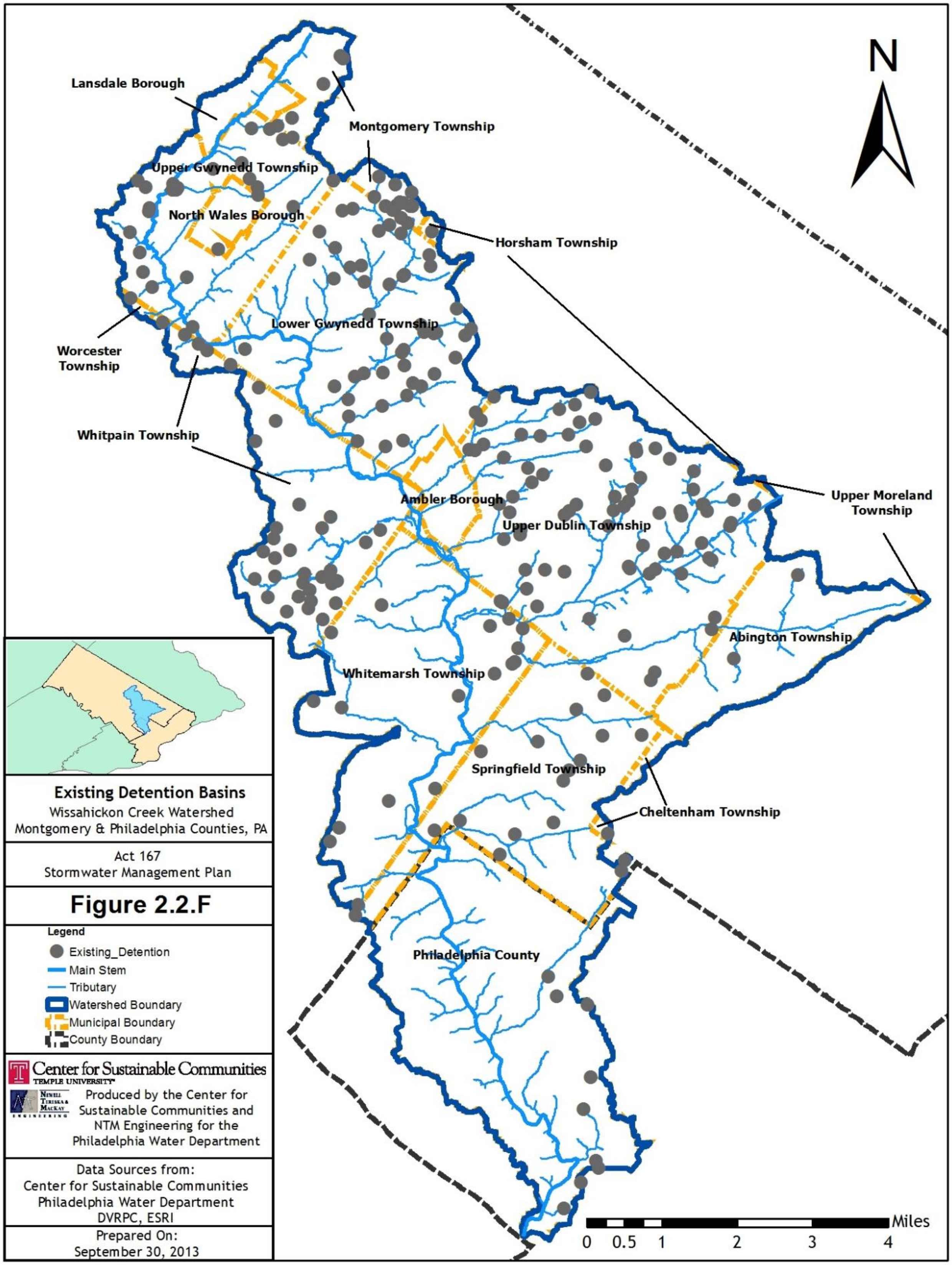

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Springfield Township
Cheltenham Township
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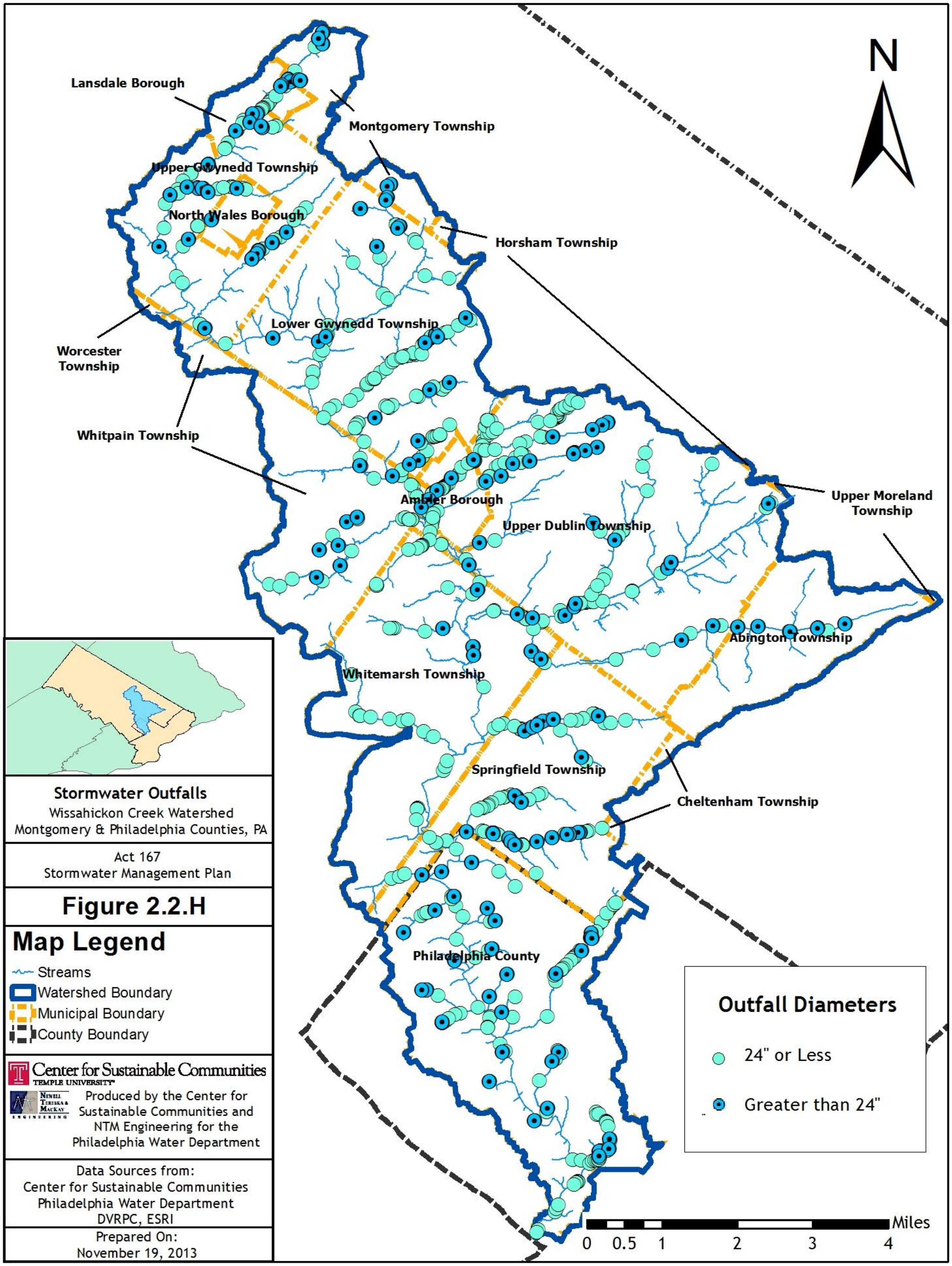
Existing Detention Basins
Wissahickon Creek Watershed
Montgomery & Philadelphia Counties, PA
Act 167
Stormwater Management Plan
Figure 2.2.F
Legend
Existing_Detention
Main Stem
Tributary
Watershed Boundary
Municipal Boundary
County Boundary
Center for Sustainable Communities
TEMPLE UNIVERSITY
Produced by the Center for Sustainable Communities and NTM Engineering for the Philadelphia Water Department
Data Sources from:
Center for Sustainable Communities
Philadelphia Water Department
DVRPC, ESRI
Prepared On:
September 30, 2013

Figure 2.2.G   Stormwater Collection and Outfalls



Lansdale Borough
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North Wales Borough
Horsham Township
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Whitpain Township
Ambler Borough
Upper Dublin Township
Upper Moreland Township
Abington Township
Whitemarsh Township
Springfield Township
Cheltenham Township
Philadelphia County
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Outfall Diameters
24" or Less
Greater than 24"
Miles
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Stormwater Outfalls
Wissahickon Creek Watershed
Montgomery & Philadelphia Counties, PA
Act 167
Stormwater Management Plan
Figure 2.2.H
Map Legend
Streams
Watershed Boundary
Municipal Boundary
County Boundary
Center for Sustainable Communities
TEMPLE UNIVERSITY
Produced by the Center for Sustainable Communities and NTM Engineering for the Philadelphia Water Department
Data Sources from:
Center for Sustainable Communities
Philadelphia Water Department
DVRPC, ESRI
Prepared On:
November 19, 2013

Figure 2.2.I Stormwater Collection System for a Portion of Upper Dublin Township, Montgomery County, PA

Section 2.3 Projected Growth and Land Use Projections

The project team evaluated the potential impacts of projected land use changes on stormwater runoff. Specifically, this study developed and compared two projected future land use scenarios in the Wissahickon Watershed. The projected "trend" scenario considered the continuation of current land use practices throughout the watershed. The alternate scenario was a "green" scenario, incorporating a wide variety of sustainable planning and development practices. This land use projection analysis looked only at the effects of land use change at the watershed scale in order to isolate the impact that land use decisions alone can have on watershed hydrology. The combined effect of potential stormwater control measures and sustainable development practices on future conditions is presented in Section 4.

Population forecasts were used to generate future land use demand for the watershed. The most recent official population forecasts were obtained from the Delaware Valley Regional Planning Commission (DVRPC), the designated regional and metropolitan planning organization covering the WCW area. The official population forecasts are used by DVRPC for transportation planning and modeling, and serve as an objective source of population forecasts. The study team used projections for the year 2040 that were developed in 2012.

The population forecasts for each of the 16 municipalities, either partially or completely located with the Wissahickon Watershed, were used to determine the proportion of the housing and population growth needs for those portions of the municipalities within the boundaries of the watershed. Using the land use and demographic data, the project team determined how much of a municipality's population and land area were within the Wissahickon Watershed's boundary using the area weighted-average technique. These percentages were used to apportion future population growth targets to the appropriate watershed. For example, if a weighted average of 30 percent of a municipality's land area was within the watershed, then 30 percent of the forecasted population growth rates were apportioned to future growth within the WCW. One of the difficulties in watershed planning and land use forecasting within smaller watersheds in Pennsylvania is that fundamental land use decisions are made by municipalities and the boundaries of municipalities do not conform to watershed boundaries. Municipalities are generally required to make adequate provision in their zoning for their projected population growth, but predicting into which watershed the growth will be directed is difficult.

Table 2.3.A presents the projected population growth for Wissahickon Watershed municipalities, representing only the future growth assigned to areas within the Wissahickon Watershed. The fifth column represents the population growth estimates for 2040 for each municipality. U.S. Census data was used to project the additional housing that will be associated with the population growth. First, the population of each municipality was divided by the total number of households in each municipality in order to calculate occupancy rates. Occupancy rates are listed in column 2. Within the municipalities in the Wissahickon watershed, the average household size is 2.56 persons per household, ranging from a low of 2.42 persons per household in Upper Moreland Township to a high of 2.74 persons per household in Worcester Township. Housing unit needs were also adjusted to account for each municipality's vacancy rate. The vacancy rates in column 3 were calculated by dividing the number of vacant housing units by the total number of housing units.

The last column of Table 2.3.A presents the number of housing units, which would need to be constructed during the planning horizon to maintain the same household size for the increase of population. These figures were determined by dividing the expected population increase inside the watershed by the current occupancy rate plus the vacancy rate.

Overall, the results of the demographic analysis forecast a slow growth rate in the Wissahickon Watershed. The suburban watershed's population is expected to grow from approximately 109,200 in 2010 to slightly over 116,900 by the year 2040, a total increase of 7.0 percent. A similar increase is forecast for the City of Philadelphia. A total of 5,826 new housing units in a 30-year time period would be needed to accommodate the overall population growth, with about half of the units located within Philadelphia. The amount of undeveloped land used to provide for new housing demand was different in the "trend" and "green" scenarios evaluated for this study.

Table 2.3.A Population Growth and Housing Needs in the Wissahickon Watershed

Municipality	2010 Census Occupancy Rate (Persons per Occupied Housing Unit)	Vacancy Rate (Vacant units per Total Units)	Occupancy Rate + Vacancy Rate (Persons per unit)	Change in Population in Watershed 2010 to 2040	**2040 Housing Units Needed**
Abington Township	2.5868	0.0441	2.6309	281	**107**
Ambler Borough	2.4643	0.0589	2.5232	556	**221**
Cheltenham Township	2.5431	0.0611	2.6041	14	**6**
Horsham Township	2.7325	0.0481	2.7806	31	**12**
Lansdale Borough	2.4446	0.0701	2.5148	482	**192**
Lower Gwynedd Township	2.4307	0.0436	2.4744	851	**344**
Montgomery Township	2.6925	0.0275	2.7200	346	**128**
North Wales Borough	2.5031	0.0430	2.5461	112	**44**
Philadelphia County	2.5445	0.1051	2.6496	7,680	**2,899**
Springfield Township	2.5719	0.0347	2.6066	539	**207**
Upper Dublin Township	2.7210	0.0261	2.7471	1,975	**719**
Upper Gwynedd Township	2.4935	0.0385	2.5320	768	**304**
Upper Moreland Township	2.4175	0.0603	2.4778	3	**2**
Whitemarsh Township	2.5725	0.0508	2.6233	1,092	**417**
Whitpain Township	2.5295	0.0598	2.5893	591	**229**
Worcester Township	2.7411	0.0575	2.7986	18	**7**

Scenario 1: Trend Development

Table 2.3.B represents the land use analysis associated with Scenario 1: Trend Development. In this scenario, each new housing unit was assumed to consume the same amount of land as the existing year 2010 average housing unit land consumption, for each municipality. That is, in this scenario current densities (reflecting current zoning and current development practices) were assumed to predict future densities. This assumption is still somewhat conservative in terms of land consumption, because newer housing units generally are produced at densities lower than existing average densities.

Table 2.3.B   Land Consumption Rates: Trend Development Scenario

Municipality	2040 Residential Need	2040 Non-Residential Need	2040 Acreage Need
Montgomery County			
Abington Township	29.6	12.9	42.5
Ambler Borough	26.9	25.5	52.4
Cheltenham Township	1.4	0.6	2.0
Horsham Township	4.7	1.4	6.1
Lansdale Borough	29.1	22.1	51.2
Lower Gwynedd Township	220.5	39.1	259.6
Montgomery Township	45.6	15.9	61.5
North Wales Borough	9.1	5.1	14.2
Springfield Township	71.1	24.8	95.9
Upper Dublin Township	361.6	90.7	452.3
Upper Gwynedd Township	114.3	35.3	149.6
Upper Moreland Township	0.5	0.1	0.6
Whitemarsh Township	195.5	50.1	245.6
Whitpain Township	120.2	27.1	147.3
Worcester Township	6.7	0.8	7.5
Philadelphia County	157.6	352.6	510.2
TOTAL	**1394.4**	**704.1**	**2098.5**

Note: all figures expressed in acres

Using the high-resolution digital land data in this study, the project team determined gross residential housing unit densities, defined for each municipality as number of housing units divided by land classified as in residential use. Thus, the estimate of gross residential housing unit densities was a good estimate of the amount of land consumed per housing unit. Using the figures from 2010, aggregate residential land use consumption was projected in Table 2.3.B, shown in column 1. Development densities across the suburban portion of the Wissahickon Watershed ranged from a low of 1.05 housing units per acre in Worcester Township to a high of 8.2 housing units per acre in Ambler Borough. Philadelphia had the highest density of residential housing density with 18.4 units per acre.

Estimates of the amount of land needed for non-residential development (including commercial, industrial, office, utility, and transportation land use needs) can be estimated with detailed employment growth forecasts to convert employment needs into space requirements. In this case, per capita demand projected for non-residential land under the trend development scenario was approximately 2000 square feet. The analysis in Table 2.3.B indicates that, at current trend densities, the Wissahickon Watershed would see a total of 2,098 additional acres converted to urban development between now and 2040, of which almost 1394 acres (66 percent) would be residential, while 704 acres would be non-residential.

For this scenario, in order to apportion future land use growth in, the suitability and capability of current land uses was analyzed to accommodate future land development, redevelopment, and growth. The first step was to create a GIS layer that included all land uses identified as not "potentially developable." This included known permanently-preserved open space and conservation land (state, county and municipal parks, riparian corridors, etc.). The project team restricted areas within the Wissahickon Creek floodway, the 100-year floodplain, and an additional 50-foot buffer around the creek and its tributaries. Finally, wetland areas were also deemed not suitable for development. All remaining land is considered "potentially developable."

Within the land classified as potentially developable, four criteria were applied to identify the areas most suitable for development. The first criterion was the derived slope of the land, calculated in 100 square feet cells. Slope values over 25% were given a score of 0, while values from 15% to 25% were given a score of 4, and values under 15% were given a perfect score of 10. Accordingly, for the trend scenario, steep slope areas were scored lower than flat areas, but development was not prohibited in these areas except in special cases.

The second and third criteria used were proximity to major roads and schools. For each of these, a half-mile buffer was added around major arterial roads and highways, and public and private schools in the watershed. Areas within the half-mile buffer for roads and schools received a score of 10, while areas outside the school buffer area scored a 7 and areas outside the road buffer area scored a 5, on the grounds that developers are more likely to prefer proximity to arterial roads than schools for their development, be it residential or non-residential.

The final criterion accounted for the land use currently in place across the watershed. Agricultural and wooded areas were given scores of 10, based on an analysis of land use from 1990 to 2005 across the watershed, showing that agriculture and wooded lands decreased in coverage across the watershed, suggesting that these areas were most attractive to developers. Vacant areas were given a score of 3, balancing the availability of land for development with the general willingness of developers to use "virgin" land over previously developed areas for their projects. All current residential and commercial areas were given a score of 2, while all other land uses (including industrial, parking, community services, recreation, military, and utility) were given a score of 0, reflecting that it is still technically possible to use these areas for new development or redevelopment, but they should not be preferred.

Each criterion was combined to create a single raw score for all areas deemed "potentially developable", with a perfect score being 10. This layer with the raw score is then subdivided into municipalities within the watershed for purposes of analysis and assigning development areas. These subdivided layers were assigned to have "residential" or "non-residential" development based on the combined suitability score as well as the acreage of the continuous area receiving the same score; larger areas were given preference over smaller areas. Needed residential acreage was assigned to the high-scoring parcels first, followed by non-residential acreage. Areas were chosen to add up to the required acreage for each municipality, but overrun was permitted if the result would mean concentrating development in fewer areas. Area selection using the trend scenario ended up exceeding the projected need by 1.62 acres across the entire watershed, or 0.07% of the projected need.

Out of the 2,100 acres assigned for development, 1591 acres (76%) is in areas that received a perfect score of 10, meaning that the area has a slope of under 15%, is within a half-mile of a major arterial road and a school, and is currently classified as agriculture or wooded. Another 22% of the needed land was chosen from areas that scored a 9, and a further 2% of the needed land scored an 8. Overall, 73% of the land chosen for development in the trend scenario is currently agriculture or wooded areas. Thus, one of the planning challenges facing the watershed is balancing the growth needs with preserving agricultural and forested landscapes. Even if an area in this analysis is classified as potentially suitable for development, it does not mean that development of these landscapes is the most appropriate policy choice. See Table 2.3.C below for a chart of how land was allocated to the individual municipalities based on suitability score.

Table 2.3.C Trend Scenario Land Allocation

Municipality	NEED - Trend Scenario Residential (Acres)	NEED - Trend Scenario Non-Residential (Acres)	NEED - Trend Scenario Total (Acres)	Trend Scenario Land Allocation Scores (AC)			Total Allocated	Difference from Need
				10	9	8		
Abington Township	29.62	12.90	42.53	42.55	0.00	0.00	42.55	-0.02
Ambler Borough	26.94	25.53	52.47	3.24	8.71	40.53	52.48	-0.01
Cheltenham Township	1.42	0.64	2.06	3.19			3.19	-1.13
Horsham Township	4.68	1.42	6.10		6.11		6.11	-0.01
Lansdale Borough	29.07	22.13	51.20	34.80	4.63	12.10	51.53	-0.33
Lower Gwynedd Township	220.52	39.07	259.60	201.38	58.22		259.60	0.00
Montgomery Township	45.56	15.89	61.45	19.98	41.52		61.50	-0.05
North Wales Borough	9.15	5.14	14.29	14.32			14.32	-0.03
Philadelphia County	157.60	352.62	510.22	491.12	19.10		510.22	0.00
Springfield Township	71.14	24.75	95.89	95.89			95.89	0.00
Upper Dublin Township	361.58	90.68	452.26	287.68	164.59		452.27	-0.01
Upper Gwynedd Township	114.29	35.26	149.55	106.61	42.94		149.55	0.00
Upper Moreland Township	0.52	0.14	0.66	0.63			0.63	0.03
Whitemarsh Township	195.47	50.14	245.61	134.42	111.19		245.61	0.00
Whitpain Township	120.18	27.13	147.31	147.38			147.38	-0.07
Worcester Township	6.68	0.83	7.50	7.49			7.49	0.01
TOTALS	1394.43	704.27	2098.70	1590.68	457.01	52.63	2100.32	-1.62
				75.74%	21.76%	2.51%		

In this scenario, each municipality accommodates its own projected land development needs and there is no sharing of uses among municipalities. In many ways, this represents the trend in Pennsylvania land use planning by municipalities, as each municipality is under an affirmative obligation to "accommodate reasonable overall community growth, including population and employment growth" (cf. 53 P.S. § 10604 [5]) absent a shared land-use agreement within a multi-municipal plan.

Figure 2.3.A shows the projected land use in 2040 under the Trend Development scenario. Much of the undeveloped land near the various streams of the watershed is protected in this scenario from development because of their environmental constraints. Most of the land conversion under this scenario occurs in the currently less developed townships in the northern portion of the watershed.

Scenario 2: "Green" Development

In this land use future scenario, municipalities accommodated their forecasted population growth needs, but accommodated the residential portion of that population growth at significantly higher gross residential housing unit densities and the non-residential portion of that development at slightly increased intensities. In order to illustrate this scenario, the project team chose to simulate new residential development in the less dense municipalities as occurring at densities of six units per gross residential acre. Existing densities were maintained in those municipalities where the current density is higher than six units per acre.

Depending on the planning decisions of these municipalities in accommodating growth at higher densities in terms of housing mix and design standards (e.g. cluster subdivisions), some of these housing units could be townhouses and others would be cluster houses on smaller lots (<8,000 square feet). Further, in this scenario, we assumed only 1,500 square feet of non-residential land per new resident, in that commercial and other uses are developed at higher intensities. The results are shown in Table 2.3.D below. The last column of Table 2.3.D indicates that, in comparison with the trend development scenario illustrated in Table 2.3.B, the total area of land required for new residential and non-residential development under the green scenario is 936 acres (45 percent) less.

Table 2.3.D Land Consumption Rates: Green Development Scenario

Municipality	2040 Residential Need	2040 Non-Residential Need	2040 Acreage Need	Acreage Saved vs. Trend
Montgomery County				
Abington Township	17.8	9.7	27.5	15.0
Ambler Borough	26.9	19.2	46.1	6.4
Cheltenham Township	1.0	0.5	1.5	0.6
Horsham Township	2.0	1.1	3.1	3.0
Lansdale Borough	29.1	16.6	45.7	5.5
Lower Gwynedd Township	57.3	29.3	86.6	173.0
Montgomery Township	21.3	11.9	33.2	28.2
North Wales Borough	7.3	3.9	11.2	3.1
Springfield Township	34.5	18.6	53.1	42.8
Upper Dublin Township	119.8	68.0	187.8	264.4
Upper Gwynedd Township	50.7	26.4	77.1	72.4
Upper Moreland Township	0.3	0.1	0.4	0.2
Whitemarsh Township	69.5	37.6	107.1	138.5
Whitpain Township	38.2	20.4	58.6	88.8
Worcester Township	1.2	0.6	1.8	5.7
Philadelphia County	157.6	264.5	422.1	88.2
TOTAL	**634.6**	**528.2**	**1162.8**	**935.9**

Note: all figures expressed in acres

The factors that were used to craft the green scenario suitability score were developed by the Center for Sustainable Communities with assistance from a survey of Environmental Advisory Committee members and other officials from municipalities in the Pennypack watershed. The Pennypack and Wissahickon watersheds have experienced similar land use development, so it is reasonable to apply the Pennypack survey results to the Wissahickon. After combining survey input with CSC decisions, the final decisions on scoring for land use types are as follows (scores out of 10):

- Agriculture: 3
- Commercial: 8
- Community Services: 5
- Light Industrial: 4
- Military: 10
- Mobile Home Residential: 3
- Multi-Family Residential: 6
- Parking: 8
- Recreation: 2
- Row Home Residential: 6
- Single Family Residential: 8
- Transportation: 6
- Utility: 5
- Vacant: 10
- Water: 0
- Wooded: 1

In addition to existing land use type, suitability of land in the green scenario was scored based on additional physical characteristics and proximity factors.

Scores based on proximity to train stations, bus routes, open space and institutions were based one-quarter mile distances. For example, areas within a quarter-mile of a train station were given a score of 10. Areas that were between a quarter-mile and a half-mile of a train station were given a score of 9 and so on. Slope values over 25% were given a score of 0, while values from 15% to 25% were given a score of 4, and values under 15% were given a perfect score of 10. Areas that contain wetlands, were in the floodway, or within a 60-foot buffer of the stream or its tributaries were restricted. Areas within the 100-year flood plain were given a score of 0. Areas within the 500-year flood plain were given a score of 5. The relative weightings for all criteria, including land use type was as follows:

- 17%: Water (areas outside of floodplain, wetlands, ponds, streams)
- 15%: Current Land Use
- 15%: Slope

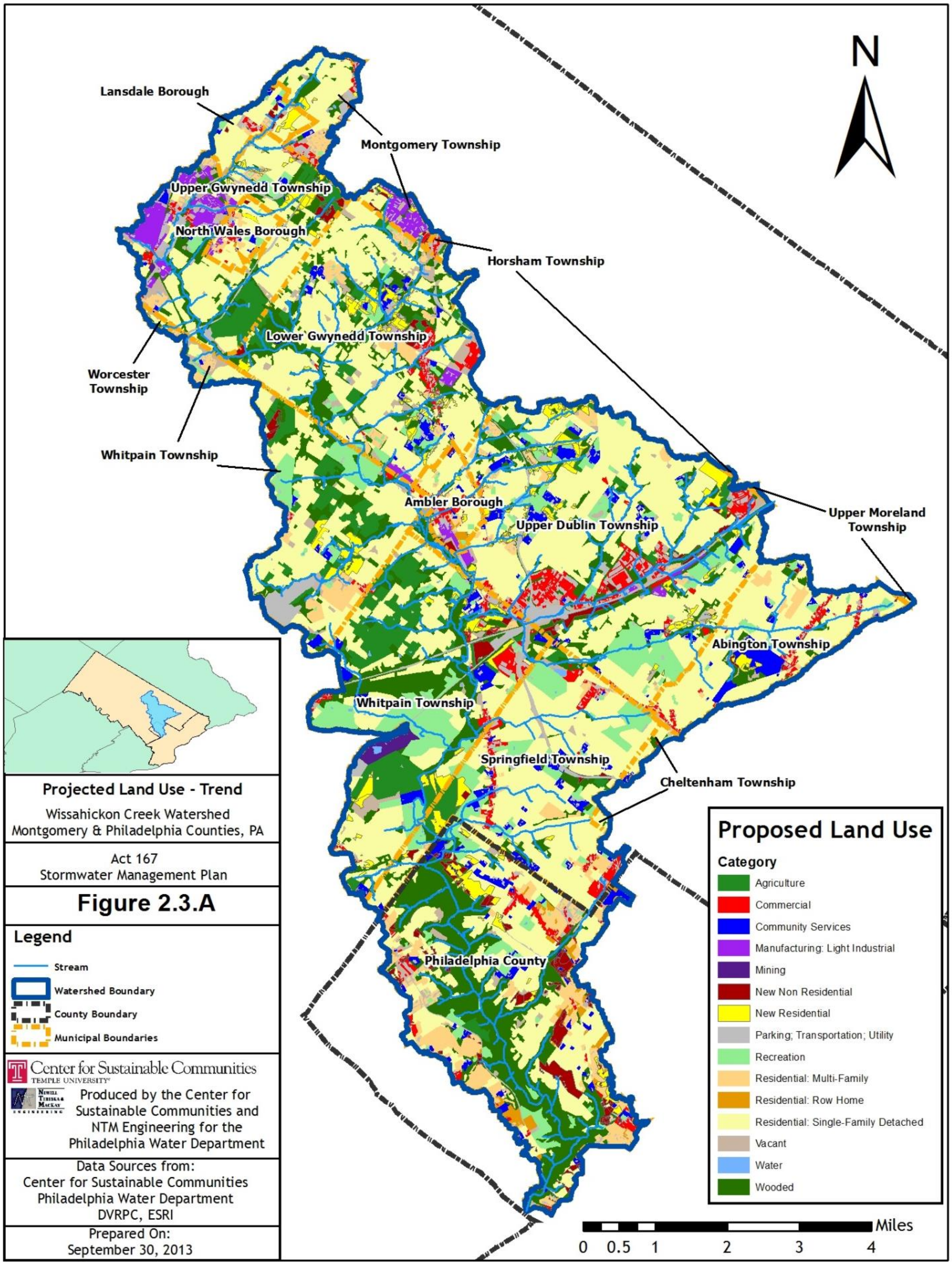
  Proximity to:
- 12%: Bus Routes
- 12%: Rail Stations
- 12%: Institutions (schools, hospitals, employment centers, religious sites)
- 17%: Open Space (includes trails)

The scoring factors and relative weightings were combined with the maximum suitability score being 10. Table 2.3.E shows how the development required for each municipality was allocated to land in accordance with suitability scores.

Table 2.3.E Green Scenario Land Allocation

Municipality	NEED - Green Scenario Residential	NEED - Green Scenario Non-Residential	NEED - Green Scenario Total (Acres)	Green Scenario Land Allocation Scores (AC)			Total Allocated	Difference from Need
				9	8	7		
Abington Township	17.83	9.68	27.51	1.72	25.75		27.47	0.04
Ambler Borough	26.94	19.15	46.09		46.21		46.21	-0.12
Cheltenham Township	1.00	0.48	1.48		1.55		1.55	-0.07
Horsham Township	2.00	1.07	3.07		0.02	3.14	3.16	-0.09
Lansdale Borough	29.07	16.60	45.67		45.83		45.83	-0.16
Lower Gwynedd Township	57.33	29.30	86.64	0.45	86.30		86.75	-0.11
Montgomery Township	21.33	11.91	33.25		33.37		33.37	-0.12
North Wales Borough	7.33	3.86	11.19		11.22		11.22	-0.03
Philadelphia County	157.60	264.46	422.07	1.97	420.55		422.52	-0.45
Springfield Township	34.50	18.56	53.06	5.22	47.91		53.13	-0.07
Upper Dublin Township	119.83	68.01	187.84	11.32	176.57		187.89	-0.05
Upper Gwynedd Township	50.67	26.45	77.11	0.15	77.03		77.18	-0.07
Upper Moreland Township	0.33	0.10	0.44		0.47		0.47	-0.03
Whitemarsh Township	69.50	37.60	107.10	10.64	96.47		107.11	-0.01
Whitpain Township	38.17	20.35	58.52		58.52		58.52	0.00
Worcester Township	1.17	0.62	1.79			1.85	1.85	-0.06
TOTALS	634.61	528.20	1,162.82	31.47	1,127.77	4.99	1,164.23	-1.41
				2.70%	96.87%	0.43%		

Figure 2.3.B shows the projected land use futures for 2040 under the green scenario.
The green scenario is a concept which allows for the use of developed land to accommodate additional growth. Many of the areas designated as new residential or non-residential development are already developed in some fashion, as the suitability decision was driven by many factors, not just existing land use. For most of these areas, including already existing commercial, community services, manufacturing, parking, utility, and transportation land uses, it may be possible to "stack" land uses through mixed-use development by adding another floor (or multiple floors) to existing buildings. In this way, a 2 acre commercial area could accommodate an additional 2 acres of residential development if, for example, apartments were added on top of stores or in parking areas. This would require changes in how land is developed, especially in the suburban municipalities, but it would result in a reduced requirement for the development of open land.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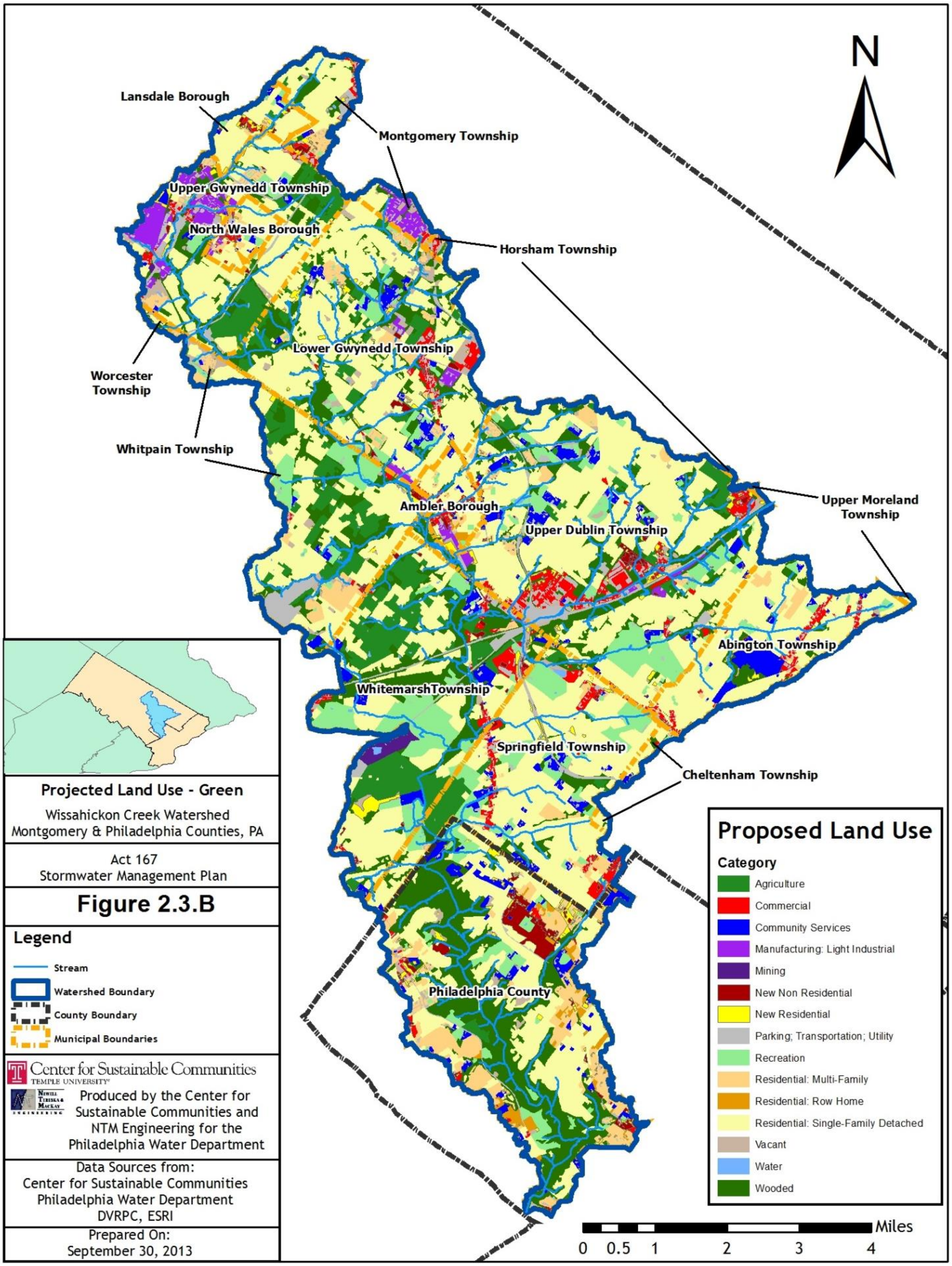
Lansdale Borough
Montgomery Township
Upper Gwynedd Township
North Wales Borough
Horsham Township
Lower Gwynedd Township
Worcester Township
Whitpain Township
Ambler Borough
Upper Dublin Township
Upper Moreland Township
Abington Township
Whitpain Township
Springfield Township
Cheltenham Township
Philadelphia County
Projected Land Use - Trend
Wissahickon Creek Watershed
Montgomery & Philadelphia Counties, PA
Act 167
Stormwater Management Plan
Figure 2.3.A
Legend
Stream
Watershed Boundary
County Boundary
Municipal Boundaries
Center for Sustainable Communities
TEMPLE UNIVERSITY
Produced by the Center for Sustainable Communities and NTM Engineering for the Philadelphia Water Department
Data Sources from:
Center for Sustainable Communities
Philadelphia Water Department
DVRPC, ESRI
Prepared On:
September 30, 2013
Proposed Land Use
Category
Agriculture
Commercial
Community Services
Manufacturing: Light Industrial
Mining
New Non Residential
New Residential
Parking; Transportation; Utility
Recreation
Residential: Multi-Family
Residential: Row Home
Residential: Single-Family Detached
Vacant
Water
Wooded
Miles
0 0.5 1 2 3 4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Montgomery Township
Upper Gwynedd Township
North Wales Borough
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