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Plum Run and its Watershed: A Short Course in Stream Ecology

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Plum Run and its Watershed: A Short Course in Stream Ecology

This tutorial is intended to introduce you to the ecology of Plum Run, a tributary of the Brandywine Creek. The information summarized in the tutorial was gathered by faculty and students in three academic departments at West Chester University (see Acknowledgements). Interactive maps are part of the tutorial and provide a basis for considering options in stream and watershed restoration. Small versions of these maps are referred to in the text. Click on these areas of the maps when instructed to view them in more detail. Fundamental concepts for stream ecology are described below, including geomorphology, biota, topography, land use and restoration.

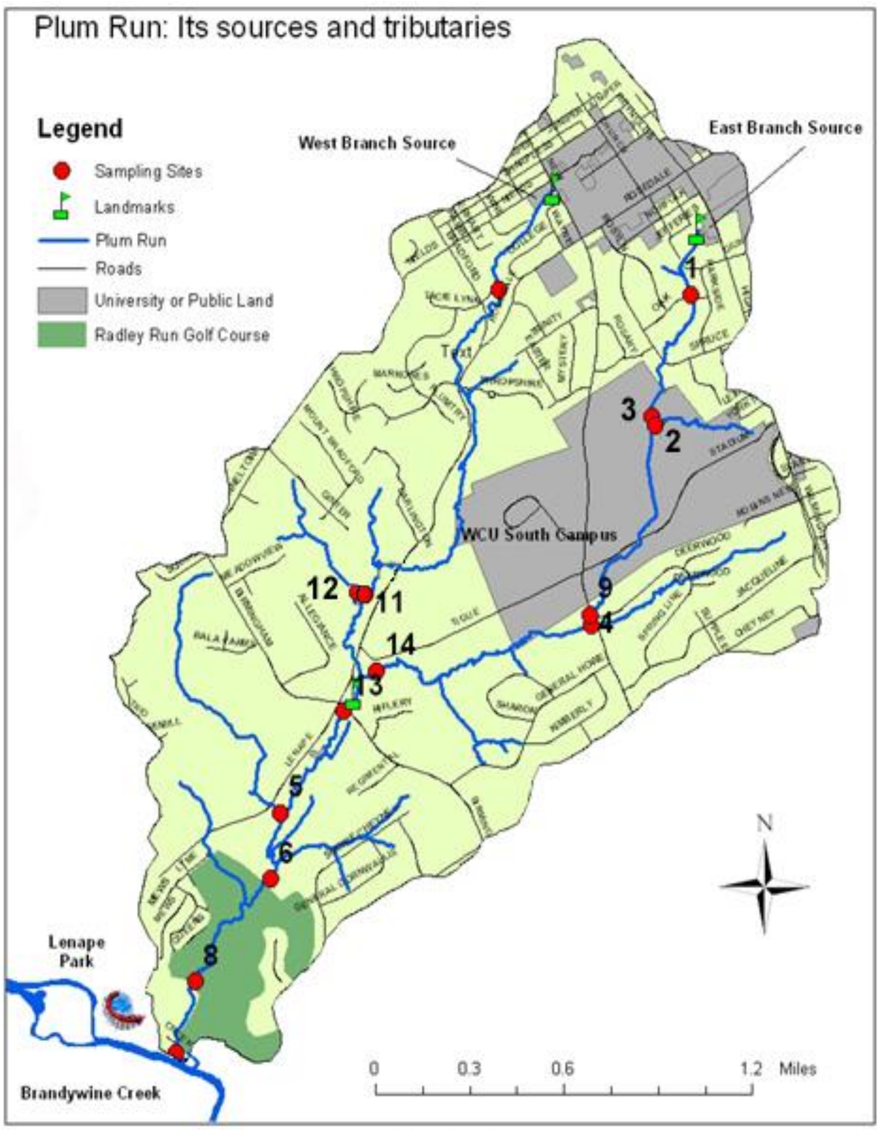


Figure 1

Landmarks and Sampling Sites

First you'll need to find some landmarks within the watershed and be aware of some general features of the stream network. To get your bearings, enlarge the map to view where the stream lies relative to roads within the watershed. Then return to this page.

Note that there are two main "branches" to Plum Run. The "East Branch" first surfaces just behind the High Street Texaco station. Click the  symbol in Figure 1 indicating the origin of the East Branch to see what the origin of the East Branch looks like in real life. Do the same for the "West Branch" (bearing the name "Plum Run") and note that it begins as a network of stormsewer pipes beneath West Chester University, and surfaces next to a university parking lot just west of New Street. The East Branch and West Branch join just north of the Strodes Mill Art Gallery near the junction of Rte 52 and Tigue Road (click on the symbol for a picture). The stream then passes southward through the Radley Run Country Club Golf Course and empties into the Brandywine Creek near the Lenape Picnic Park .

Some statistics of the Plum Run watershed (in acres): Total acres 2,308; Agriculture 275; Commercial 115; Parking 53; Recreationcre167; Residential-multi 105; Residential-single 1,156; Transportation 9; Vacant 60; Water 7; Wooded 361. The total length of the Plum Run is about 12 miles. Total lengths of roads in the watershed is 37 miles.

Geomorphology of the Stream Network

The term "geomorphology" is a composite description of stream size, shape, water flow and other physical characteristics. As you will see later, geomorphology is strongly influenced by topographic features of the watershed.

Stream Order

The calculation of "Stream Order" provides a rough indication of stream size and discharge (the amount of water passing a given point per unit time, often measured in "cfs" (cubic feet per second)). A first order stream segment, or "reach", is defined as having no tributaries. A second order stream or stream segment has at least 2 first-order tributaries. A third order stream has at least 2 second-order tributaries, etc. as shown in Figure 2.

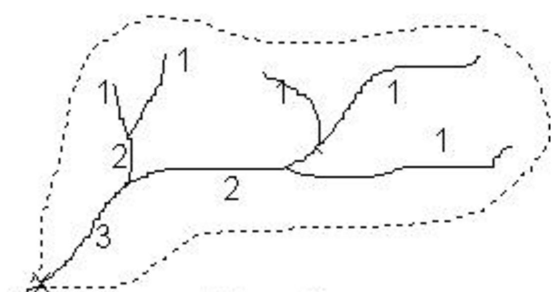


Figure 2

Fourteen sites within the Plum Run stream network were sampled during summer 2005. Figure 1 at the beginning of this tutorial shows all site locations and can be consulted if you get "lost" within the watershed. Below is a table of data collected for each site. Look for the stream order column in the table marked "STR_ORD". Examine the map area, and the theme table, to answer the following: (Use the numbers in the ID column to note which sampling sites correspond to 1st order streams)

Caption: Selected environmental and biological features of the 14 sampling sites, including discharge (L/sec) elevation gradient (m/m), invertebrate family biotic index, number of fish species, distance from the confluence with Brandywine Creek (ft), abundance of the stonefly family Leuctridae (LEU) and caddisfly family Hydrosychidae (HYD), presence of Rockbass and Blacknose Dace, and stream order (STR_ORD).

ID	DISCHARGE	PCY_RIF	GRADIENT	FBI	FISH SPECIES	DIST_FT	LEU	HYD	ROCKBASS	BNDACE	STR_(
1	0.2	33	0.017	6.2	1	20045.31	0	137	N	Y	2
2	1.2	78	0.032	2.8	1	17601.73	204	12	N	Y	1
3	16.3	50	0.009	5	2	17682.03	8	13	N	Y	2
4	5.1	67	0.038	5.2	2	13756.49	17	29	N	Y	1
5	3.4	23	0.014	4.4	9	5637.78	0	18	N	Y	2
6	31.7	17	0.004	4.7	9	4198.25	2	105	Y	Y	4
7	49.5	25	0.003	4.4	13	367.81	0	120	Y	N	4
8	52.8	26	0.004	5.1	11	1734.61	0	41	Y	N	4
9	11.6	34	0.012	4.4	6	13874.06	5	33	Y	Y	2
10	6.7	20	0.011	5.4	2	17691.3	0	38	N	Y	1
11	9.5	61	0.014	5.4	6	10312.27	0	65	Y	Y	2
12	4	72	0.047	5.7	2	10334.73	0	39	N	Y	2
13	35.7	79	0.012	4.8	6	7948.11	2	31	Y	Y	4
14	15	36	0.009	5	6	8940.48	4	12	N	Y	3

Sampling Sites Data Table: ID = Site Number

How many first-order stream segments occur in the Plum Run network? What stream order is **Site 7** (look under the column "ID" in the attribute table for site numbers) just before the stream enters the Brandywine Creek? Click on the image in Figure 2 for the answer.

Discharge

Stream discharge is highly variable, both in space (downstream locations experience greater discharge as a result of the greater accumulation of water from upstream) and over time (water supply varies predictably with season, and less predictably immediately following precipitation events. Changes in discharge over time constitute a "hydrograph" (Fig. 3). To view current daily discharge data go to the U.S.G.S. National Water Information web site for the Brandywine Creek..

The discharge information provided for Plum Run was obtained at 14 sites within the stream network. All of the estimates were taken during mid-summer under "base flow" conditions (the minimum discharge expected for that season, unaffected by rain). Discharge at base flow largely reflects the net seepage of groundwater into the stream from the surrounding soil. The much higher discharge immediately after rain events largely results from overland runoff into the creek (more

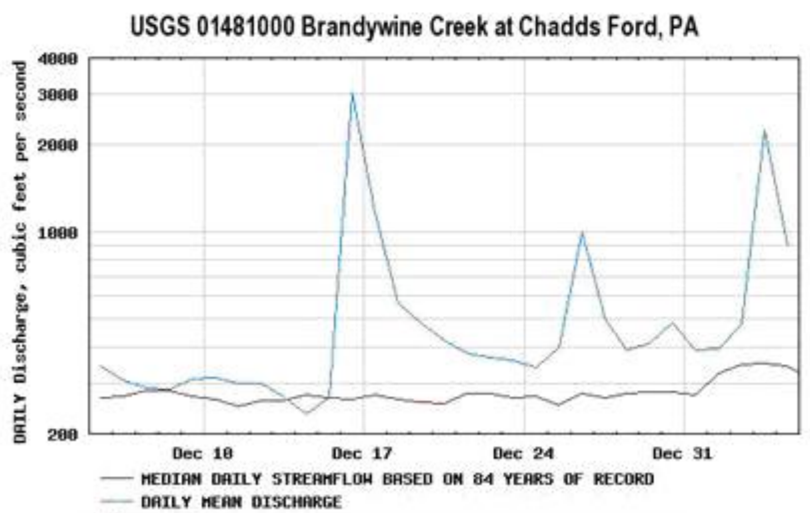


Figure 3: A hydrograph for the Brandywine Creek at Chadds Ford, courtesy of the USGS, which monitors stream flow in Chester County in cooperation with the Chester County Water Resource Authority.

about watershed effects on the stream later).

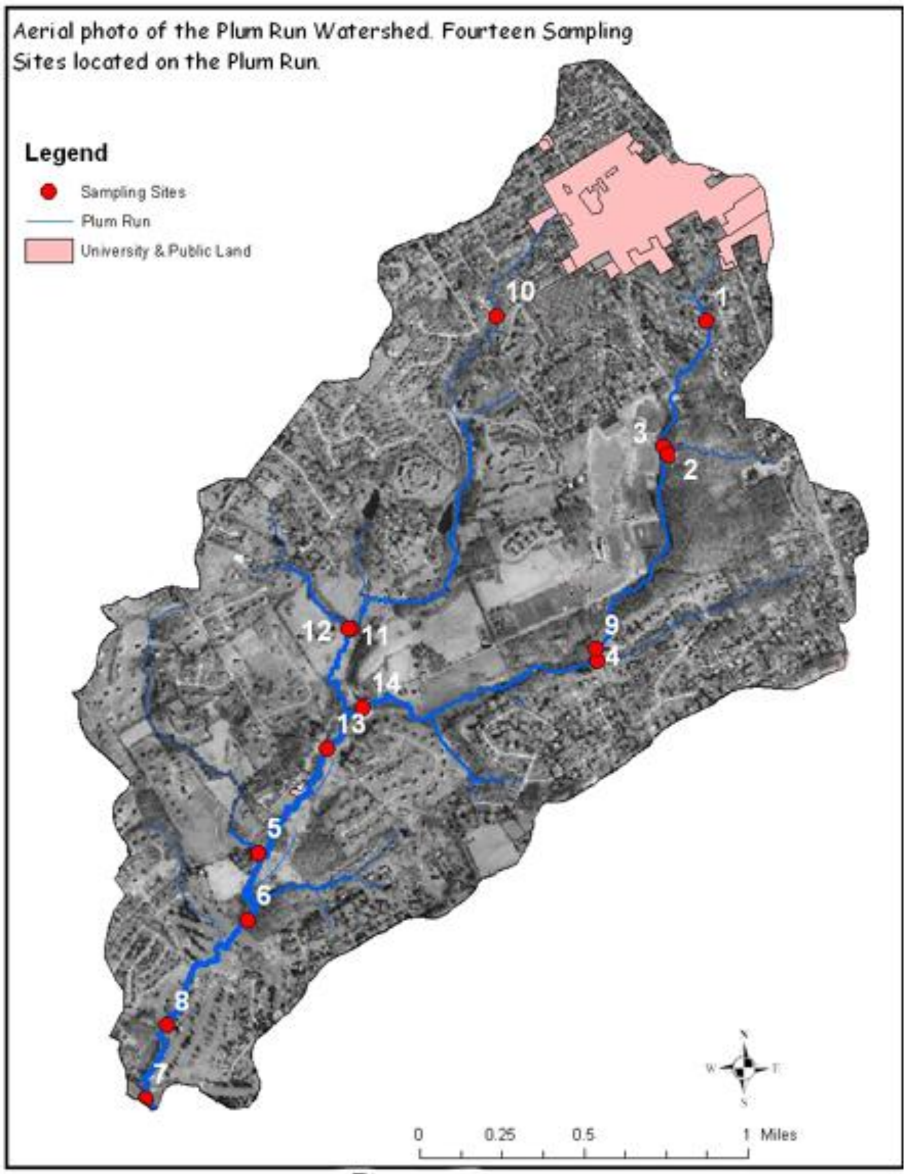
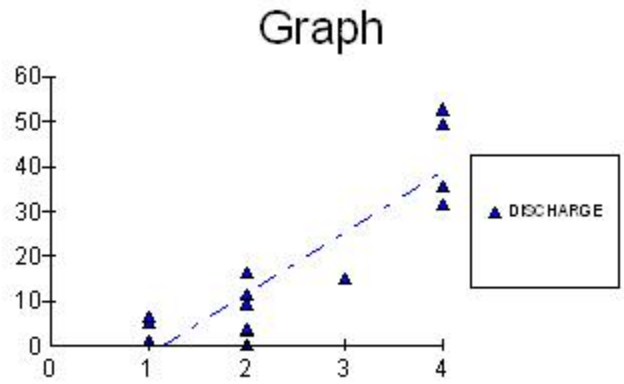


Figure 4

Figure 4 shows all fourteen Sampling Sites of the Plum Run watershed. An aerial photo outlines the watershed. To see pictures of each station click the respective number.

In the Sites theme table (above), look down under the column marked Discharge in the table to note the estimates of water flow (as liters/sec) for each of the 14 sites. Does the East Branch or West Branch appear to have higher flow? Compare site 14 on the East Branch (= _____L/sec) with site 11 on the West Branch (=______ L/sec). What was the discharge at site 7 where Plum Run enters the Brandywine ? ______ L/sec. Figure 5 is a chart showing the 14 relationship between stream order and the discharge values.



Relationship of discharge to stream order in the Plum Run

Figure 5

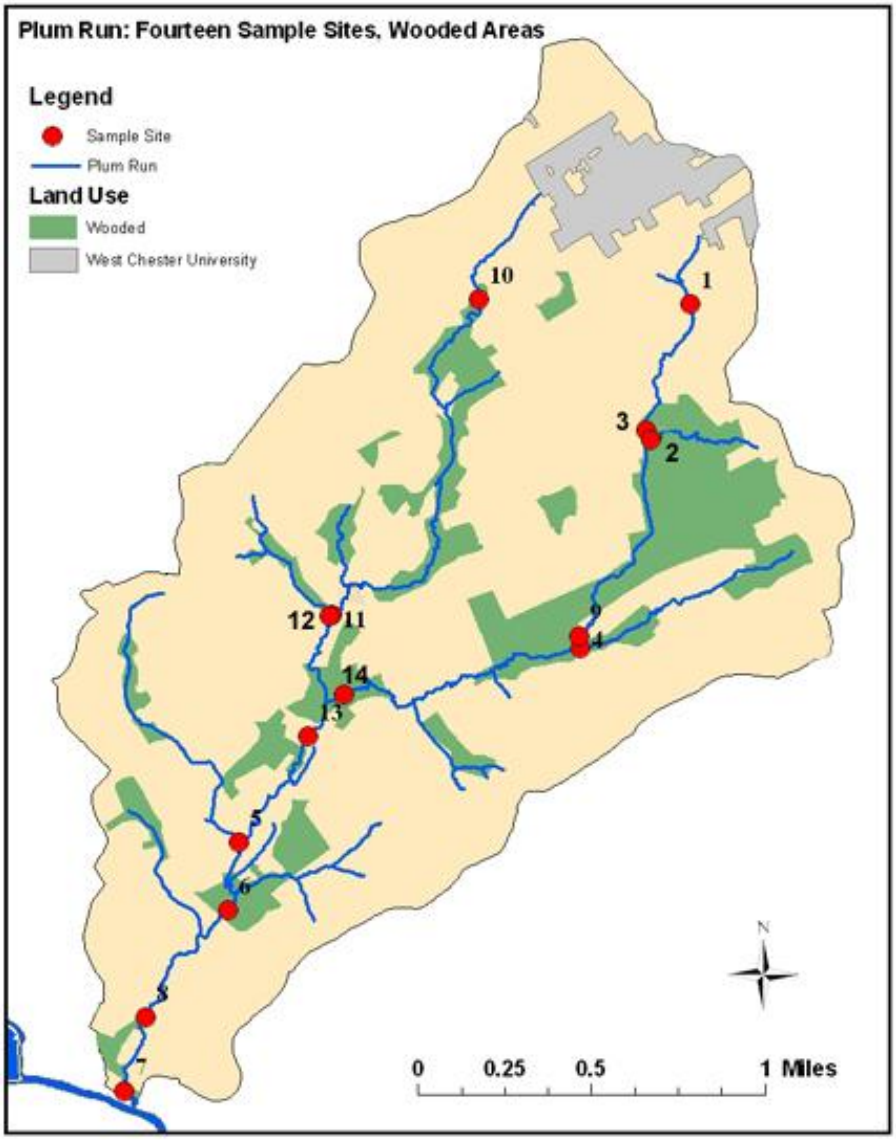


Figure 6

Effects of Streamside Vegetation

The kind of riparian vegetation immediately adjacent to the stream influences the stream biota in several ways. First, riparian forest canopies help shade the stream, particularly at lower order sites where stream branches may extend over the entire stream channel. Shading reduces stream water temperature, thereby increasing the capacity of the water to hold oxygen. Stream segments surrounded by meadow grasses or mowed lawns are typically warmer. Meadow streams are also narrower and more deeply "entrenched" (the stream lies within a deeply cut "U" shaped channel), as shallow rooted grasses do little to prevent the erosion of deeper soil layers. Whereas riparian forests provide nutrition to a stream in the form of fallen leaves and woody debris, meadow streams typically have higher rates of photosynthesis.

In the adjacent map (Figure 6)click on the number symbol for Site 5 to display a photograph of the stream segment with its riparian vegetation. What kind of vegetation borders the stream? Describe the degree of entrenchment (a cross sectional profile that crosses the stream in two places is shown in the graph at the lower right). In the same way take a look at the vegetation at sites 1, 10, and 11, which have similar streamside vegetation and cross-sectional profile. Now click on site 9 on the East Branch. What is the surrounding vegetation? What is the degree of entrenchment compared to site 5? Site 13 is similar to site 9 in its geomorphology. Click on the remaining Sampling Sites to view their streamside vegetation and cross sectional profiles.

The Stream Biota

Stream Invertebrates

Fig.7 a-b. Images of (a) a stonefly larva (http://www.nps.gov/olym/insect/plecoptera.htm) and (b) a net-spinning caddisfly larva (http://www.csuchico.edu).

The stream invertebrate community includes crustaceans such as crayfish and amphipods, snails and a wide variety of aquatic insects. Stream invertebrates respond either directly or indirectly to both the physical habitat and to water chemistry. "Bioassessment" of the numbers and kinds of species present can thus provide a valuable indication of environmental degradation at a site. For example, aquatic insects such as stonefly larvae (shown in Figure 7a), require cool water, and are likely to be found only in smaller (e.g., first order) stream segments surrounded by trees that shade the stream and maintain cool water temperatures. Cooler water also holds more oxygen, often required by invertebrates found in shallow streams. Most net-spinning caddisfly larvae (Figure 7b) are more tolerant of warmer water and are more typical of larger downstream sites.

To find out where individuals of the stonefly family Leuctridae were abundant in the Plum Run stream network, ask the question regarding its occurrence. To do so, refer to the sites data table below**.** Find the column heading "LEU" and look for those sampling sites (the ID column) where "LEU" is larger than 100. Site 2 contains more than 100 individuals of the stonefly family Leuctridae highlighted in light blue in this map. Based on the table below, what stream order is Site 2? Based on pictures of Site 2 what kind of vegetation surrounds the stream segment? It may not surprise you that a principal diet of these stonefly larvae is leaves that fall into the stream from the surrounding trees. To further test your understanding of invertebrate occurrence, determine which three sites have in excess of 100 individuals of the pollution-tolerant net-spinning caddisfly larvae (column: HYD). Where do these sites occur within the stream network? .

Caption: Selected environmental and biological features of the 14 sampling sites, including discharge (L/se gradient (m/m), invertebrate family biotic index, number of fish species, distance from the confluence with I Creek (ft), abundance of the stonefly family Leuctridae (LEU) and caddisfly family Hydrosychidae (HYD), pr Rockbass and Blacknose Dace, and stream order (STR_ORD).

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14	15	36	0.009	5	6	8940.48	4	12	N	

Sampling Sites Data Table: ID = Site Number

Known pollution tolerances (to inputs of nutrients and sediments) of the huge variety of invertebrates found in most streams may be used to construct a composite rating of stream habitat quality. For example, the **Family Biotic Index (FBI)** is a weighted average of the collective tolerances of the various kinds of invertebrates in the community. Tolerances range from 0 for invertebrates found in very clear streams to 10 for invertebrates that exist in highly degraded streams. FBI values are related to water quality in Table 2.

Table 2. Family Biotic Index values in relation to Water Quality in streams.

Family Biotic Index	Water Quality	Degree of Organic Pollution
0.00-3.75	Excellent	Organic pollution unlikely
3.76-4.25	Very Good	Possible slight pollution
4.26-5.00	Good	Some pollution probable
5.01-5.75	Fair	Fairly substantial pollution likely
5.76-6.50	Fairly Poor	Substantial pollution likely
6.51-7.25	Poor	Very substantial pollution likely
7.26-10.00	Very Poor	Severe organic pollution likely

Values for the Family Biotic Index (FBI) can be seen under the column "FBI" in the Sampling Sites Table. Based on the FBI results, which site has "Excellent" water quality, and where is it located? Which has the lowest water quality, and where is it located? Based on assessment of water chemistry, other habitat characteristics and especially the invertebrate community at site 7 in 1997 by personnel from the Pennsylvania Department of Environmental Protection, Plum Run is currently designated a "red" (impaired) stream on water quality maps of Chester County.

Fish

Fish communities, like invertebrates, respond to habitat degradation, but are also strongly organized by stream size. Downstream, higher-order, stream segments typically have more kinds of fish and include larger fish, many of them potential predators on smaller species. For example, most species of the family Centrarchidae (bass and sunfish) in Plum Run are confined to larger pools near the mouth of Plum Run, and actually leave Plum Run for the larger Brandywine Creek during winter. Rock bass (Fig. 8a) are found further upstream further than other centrarchids. To observe its distribution, view the map of the locations of sites with Rock bass (blue dots). How far up into the watershed does its distribution extend?

Fig.8a-b. Pictures of (a) Rock Bass and (b) Black Nose Dace.

By contrast, many of the smaller minnow species (family Cyprinidae) such as Blacknose Dace (Fig. 8b) are year-round residents. View the distribution map for the Black Nose Dace. At which sites is it NOT present?

Examine a chart showing the effect of distance ("DIST_FT" in the above table) from Brandywine Creek on total fish species richness ["Sp_Rich" in the above table]. What effect does distance upstream have on the total number of fish species? Basically, smaller upstream sites can't support larger fish species.

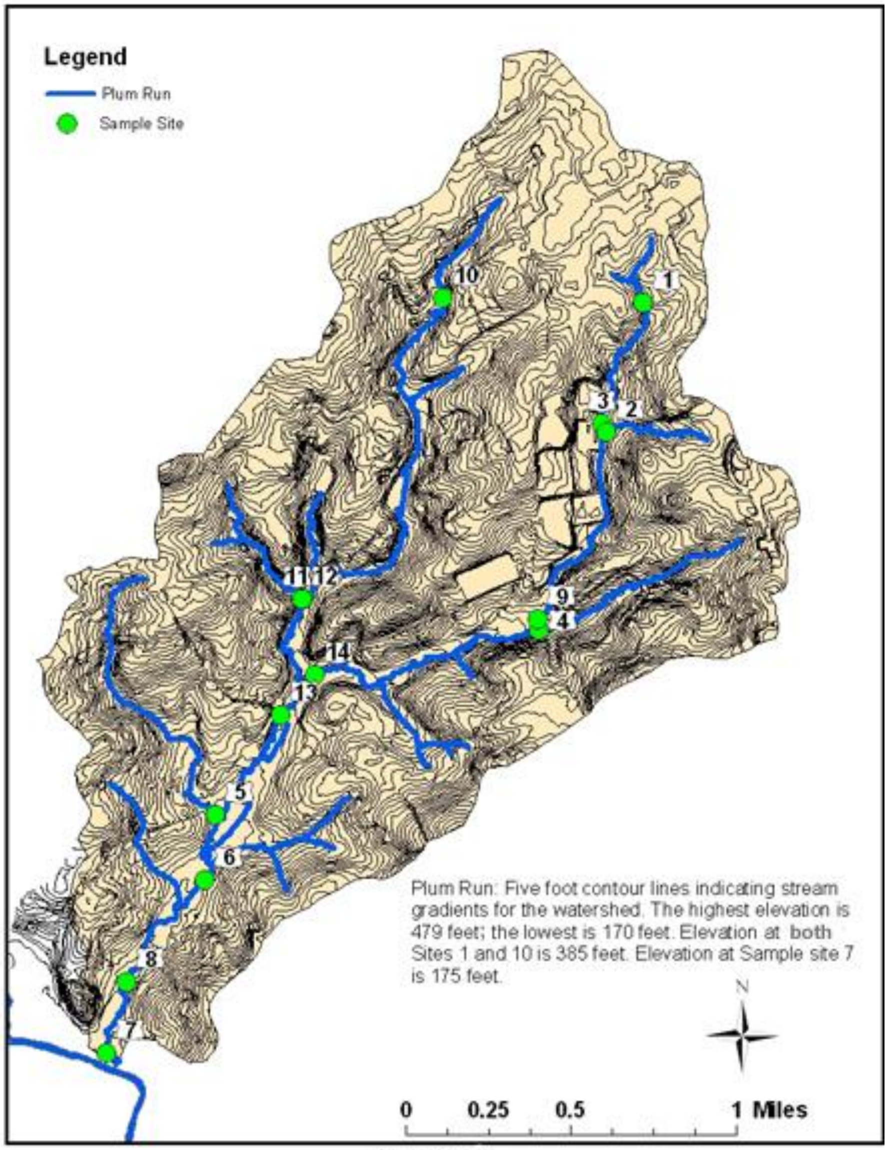


Figure 9

Topography, Soils and Bedrock of the Plum Run Watershed

Elevational Gradients

View the topographical map of Plum Run (Fig. 9). Each of the black curving lines (except the thicker blue line indicating the stream) consists of a series of locations with identical elevation. High points of ground often are surrounded by a series of concentric lines of progressively lower elevation. Each adjacent "isoline" represents a difference in elevation of 5 feet. Areas where the lines are close together have steep slopes. In the adjacent map click Sample site 5 to view the upper portion of the tributary stream that empties into Plum Run in the lower portion of the watershed. Note that the contour lines tend to form "V"s as they cross the stream. Does the tip (bottom) of the "V" point upstream or downstream in the tributary? What does this tell you about how the stream has modified the elevation of the land immediately surrounding it?

"Stream gradient" is often measured as the amount of altitudinal change per unit of stream distance. Headwater stream segments with steeper elevational gradients tend to have a) more riffle habitat, b) higher water velocities, c) substrates dominated by larger particles , and d) straighter channels with relatively little meandering (low sinuosity). Low-gradient downstream segments usually have more quiet water and show greater sinuosity. Most stream invertebrates are more abundant in riff les , where there are rocks to cling to, fast water to bring oxygen and food particles , and shallow water reducing the likelihood of being eaten by large fish.

In the adjacent map click on site 4, a tributary of the East Branch. Examine the picture and accompanying graph at the upper right. The researcher in the photo is Danielle Difederico, who completed her thesis on the fish and invertebrate communities of Plum Run. Based on the graph at the upper right, what channel distance was mapped (X axis)? What was the elevational change over that distance (Y axis)? The gradient (gradient = [elev. change] / [distance]) at site 4 is relatively steep (about 0.04 m/m). In the graph, note the absence of deep pools at this site (water level is shown as a blue line, whereas the elevation of the streambed is a black line).

For contrast, click on site 6, a downstream site. What horizontal distance was measured? What was the elevational change of the water level (blue line)? Was the gradient greater or less than at site 4? Based on the picture and graph, is the site dominated by riffles or pools?

Stream geomorphology can be altered by human activities. Click on site 8, where the mainstem passes through the Radley Run Country Club, and examine both the photo and graph at the upper right. How has the Country Club reduced streambank erosion? How has the pattern of elevational change at the site been altered? This section of the stream consists of long stretches of quiet water, interrupted occasionally by small vertical drops over rock dams.

Bedrock

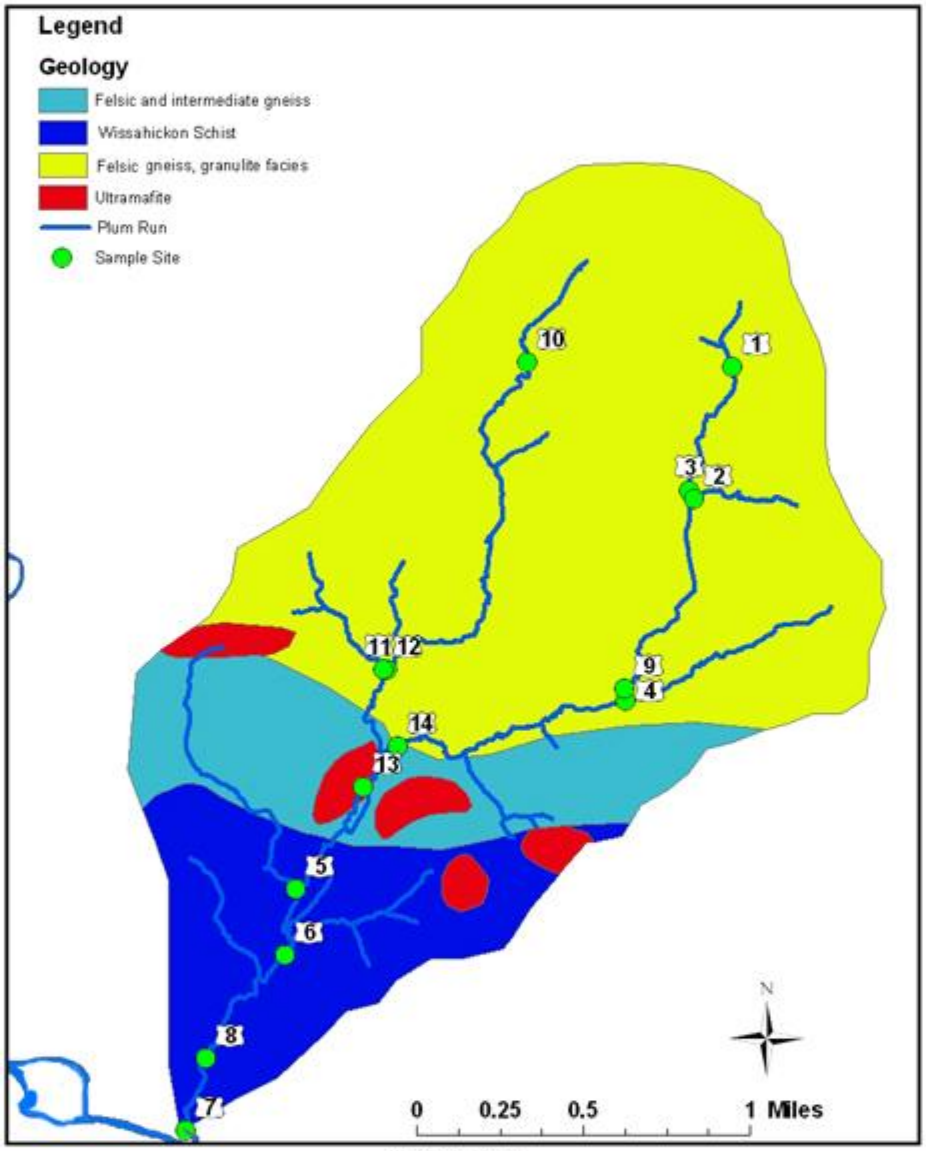


Figure 10

Elevational gradients often reflects weathering of the underlying bedrock (more easily weathered rock tends to be lower in elevation). The bedrock beneath the Plum Run watershed consists largely of "Wissahickon schist" and "felsic gneiss". View the adjacent Geology coverage of Plum Run (Figure 10). Based on their positions and relative elevations in the watershed, which of the two rock types, Wissahickon schist" or felsic gneiss, is likely the more easily weathered?

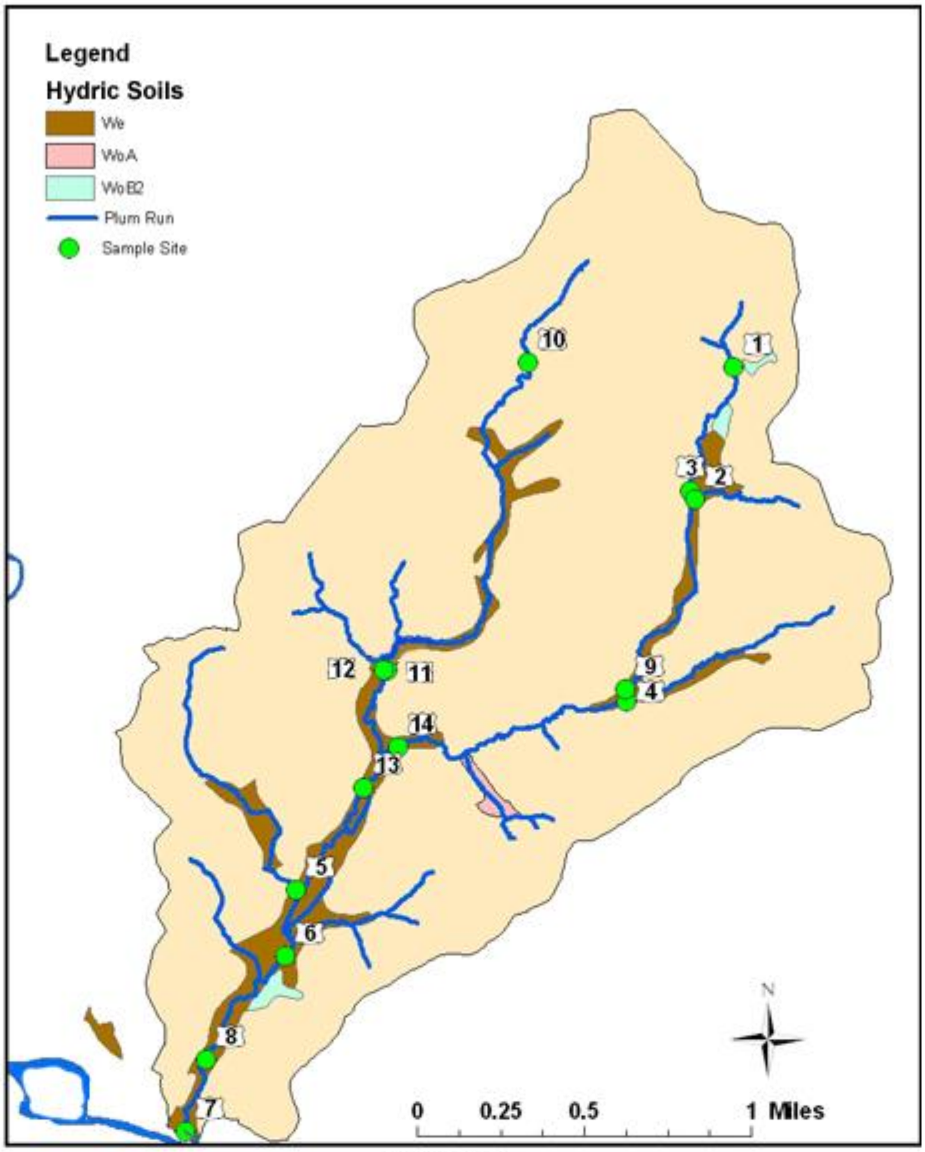


Figure 11

Soils

Soils may be classified in a number of ways, giving rise to a rather wide variety of names. The presence of poorly drained "hydric" soils, formed in part by the presence of groundwater close to the soil surface, is one criterion by which wetlands are identified and protected. In the adjacent Hydric soil map of Plum Run (Figure 11) three kinds of hydric soils are shown. Where are they located in relation to the stream? You will have a chance to observe the locations of wetlands in the watershed later.

Land Use within the Watershed

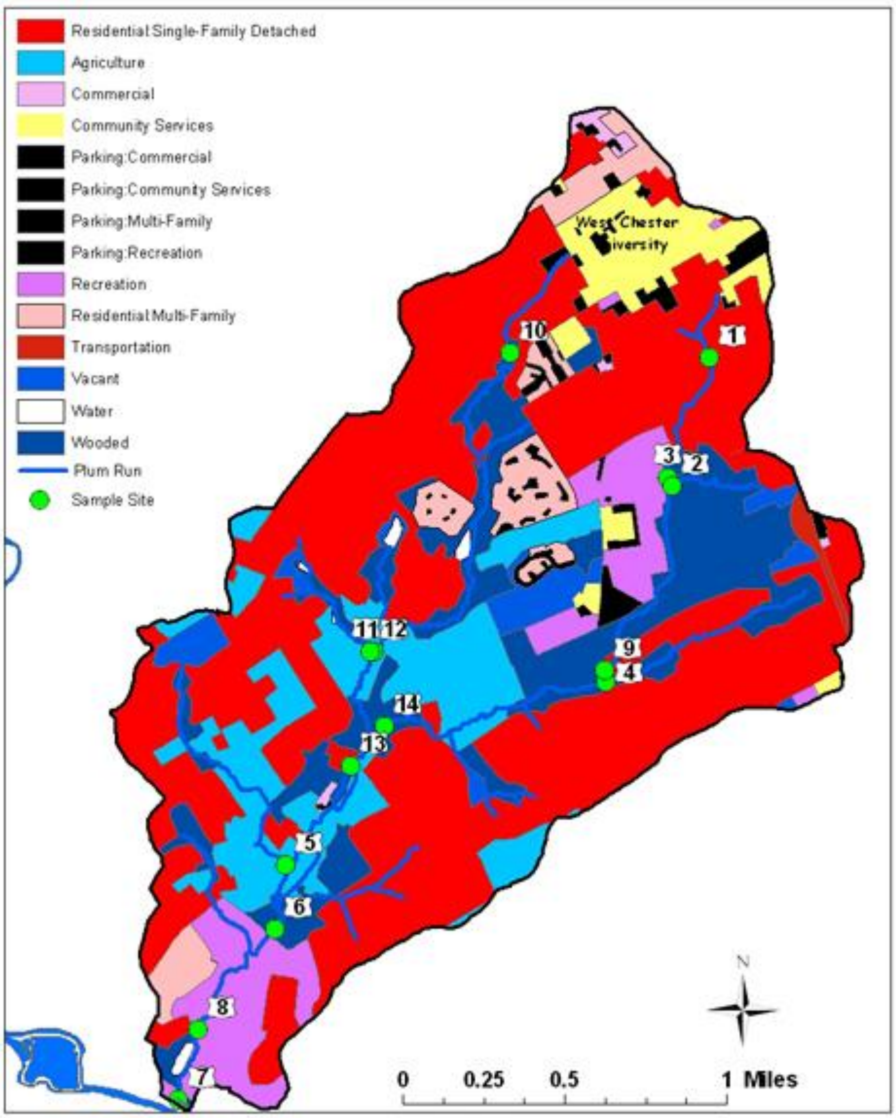
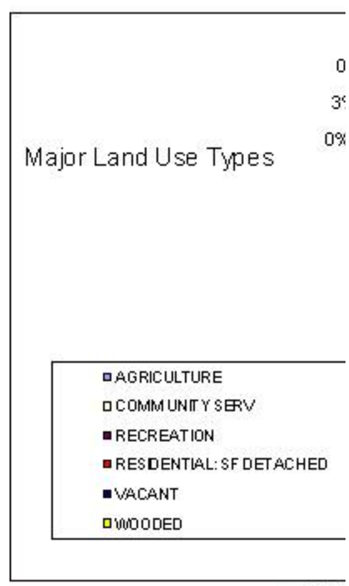


Figure 12

Current Land Use Patterns

In the adjacent [Land Use map](#) (Figure 12) find the polygon for West Chester University's North Campus. What is its land use description? Figure 13 summarizes the relative aerial proportions of the major land use types in the Plum Run watershed.



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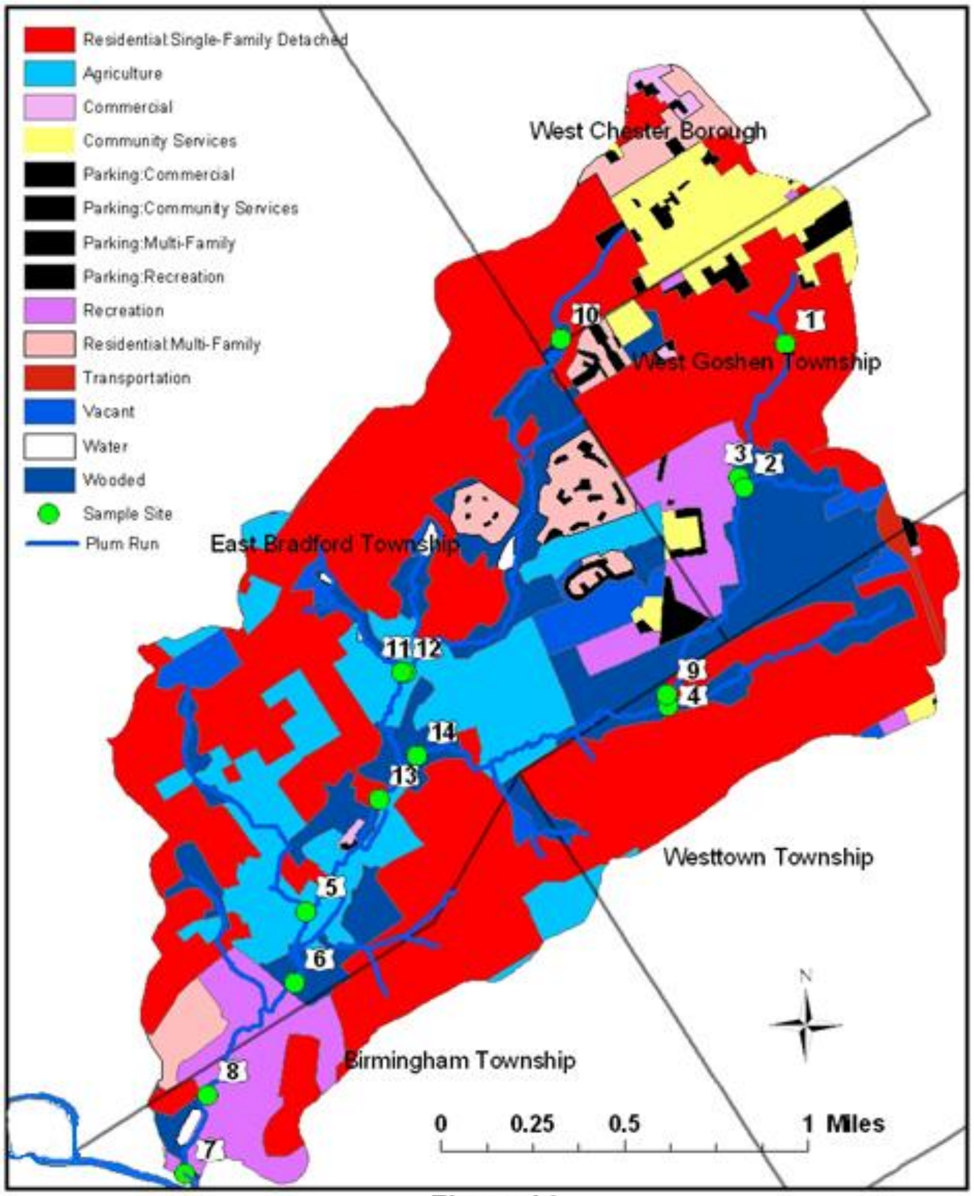

Figure 14

Some land uses have an abundance of impervious surfaces (e.g., roads and driveways, rooftops) and thus experience considerable stormwater runoff, whereas other land uses promote the retention of water and infiltration to the groundwater. View the adjacent LandUse and Municipal map (Figure 14) On the basis of the land uses shown, which of the municipalities (townships,West Chester Borough) contain a high proportion of high density housing and parking surfaces, and should thus likely to be particular concerned about controlling stormwater runoff?

Wetlands

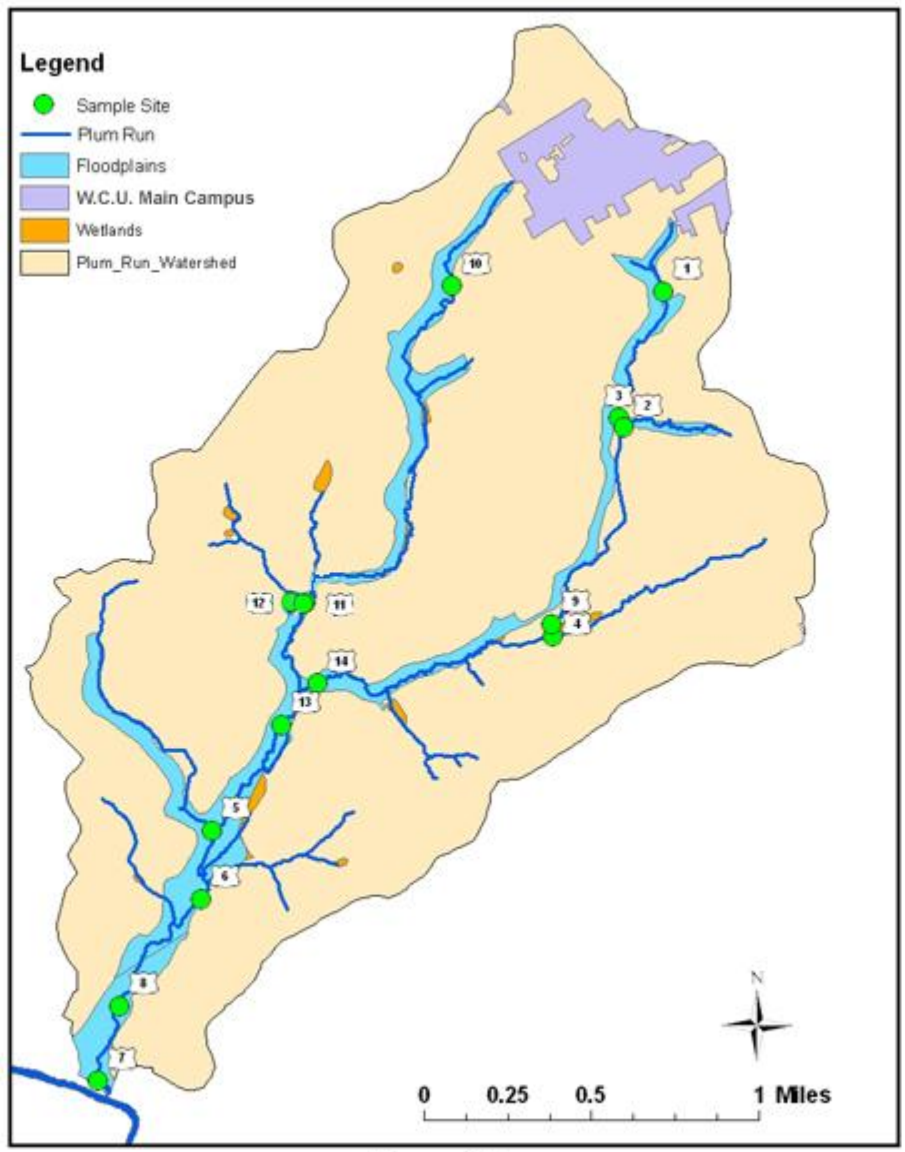

Figure 15

View the wetlands map (Figure 15) to look at the distribution of wetlands within the Plum Run drainage. Floodplains are also shown within the Plum Run drainage. The National Wetlands Inventory attempts to both identify the presence of wetlands (on the basis of characteristic vegetation, hydric soils and the presence of water at or near the surface), and to further classify them into general types. Compare the distribution of wetlands that still remain within the watershed to the extent of the floodplains within the watershed. Why might wetlands be expected to occur frequently within floodplains? (Think first about where houses are likely NOT to be built, then secondly about the definition of wetlands as occurring where the groundwater is close to the surface).

As wetlands within the watershed have been destroyed, their ability to reduce flooding has been proportionally reduced, leaving humans to increasingly shoulder that responsibility (see Stormwater Management below).

Options for Stream Restoration

Plum Run is currently designated as an impaired stream by the Pennsylvania Department of Environmental Protection (1997). The impairment is evidenced by frequent flooding events, severe bank erosion in many parts of the network, and by its depauperate invertebrate assemblage. This portion of the tutorial organizes the information needed to evaluate how and in what portions of the watershed stream restoration can best be accomplished. Because streamside vegetation is such a strong determinant of stream habitat quality, emphasis is placed on opportunities for improvement of the riparian corridor.

Flooding and Floodplains

Flooding is accentuated as land within the watershed becomes increasingly developed and impervious surfaces increasingly conduct overland runoff directly into the stream. During flood events, water velocities and discharge greatly exceed base flow conditions, and water spreads out over a portion of the stream's floodplain.

View the above map (Figure 15). Floodplains are delineated as light blue areas surrounding the stream, and indicate the likely areas of land which would be impacted by a 100-yr flood (likely to occur at an average frequency of 100 years; somehow major floods seem to happen more often than predicted if you're a streamside landowner!). These lands are typically restricted to development and also have natural plant communities which are adapted to periodic flooding.

Floodplain widths vary at each Sample Site. For example the width of the flood area for Sample Site 1 is 201 feet, 260 feet for Sample Site 14 and a whopping 760 feet at Sample Site 7. What happens to floodplain width with increasing stream order? Why?

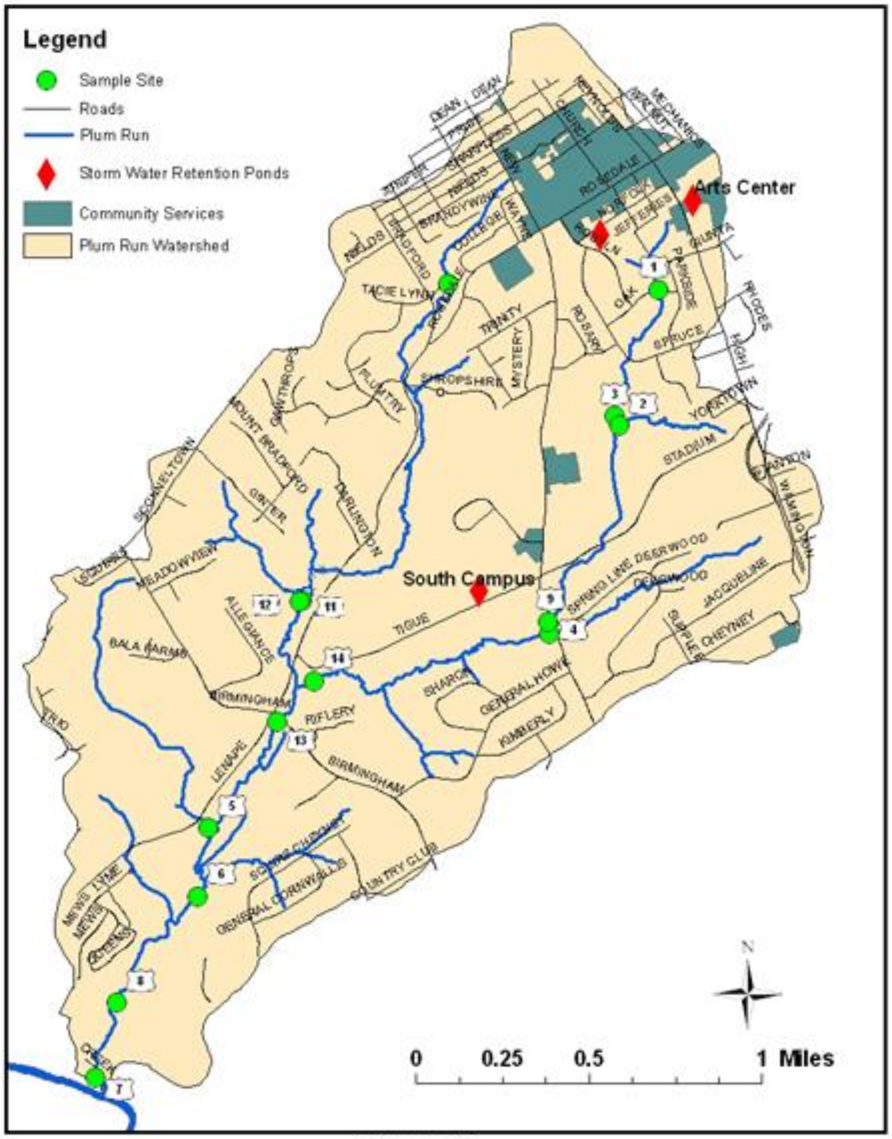

Figure 16

Stormwater Management

West Chester University maintains several stormwater retention basins within the Plum Run watershed. These are intended to limit peak flows in the stream, and to reduce the downstream transport of sediments. View the adjacent map (Figure 16). Click the " ♦ " symbol to view the retention basin adjacent to the new Performing Arts Center, labeled "Arts Center"., Also view the much older retention basin directly south of the Sykes Student Center, labeled "Student Center. . Trees have now overgrown the Sykes basin, which is currently in need of repair. Both retention basins are intended to maintain water quality and reduce erosion in the East Branch.

The locations of two additional retention basins and a "polisher", established in sequence to control runoff from new student housing on the university's South Campus, are shown by clicking on the " ♦ " symbol, labeled "South Campus". The polisher, at the lower right of the composite photo, is intended to allow further sediment retention before the water reaches Plum Run, and to spread water over a wide area to allow increased infiltration to the groundwater.

The Riparian Corridor

The corridor of riparian vegetation directly adjacent to Plum Run is particularly critical to the health of the stream, and a logical place to start in terms of managing stream water quality through improved land use within this riparian buffer. It is also likely that changes in land use can be best accomplished in public open space not controlled by individual landowners. Land use categories within the riparian buffer were assessed from aerial photography. Of these, forested land and wetlands may be considered to provide the maximum stream protection, while impervious surfaces provide the greatest threats to stream integrity.

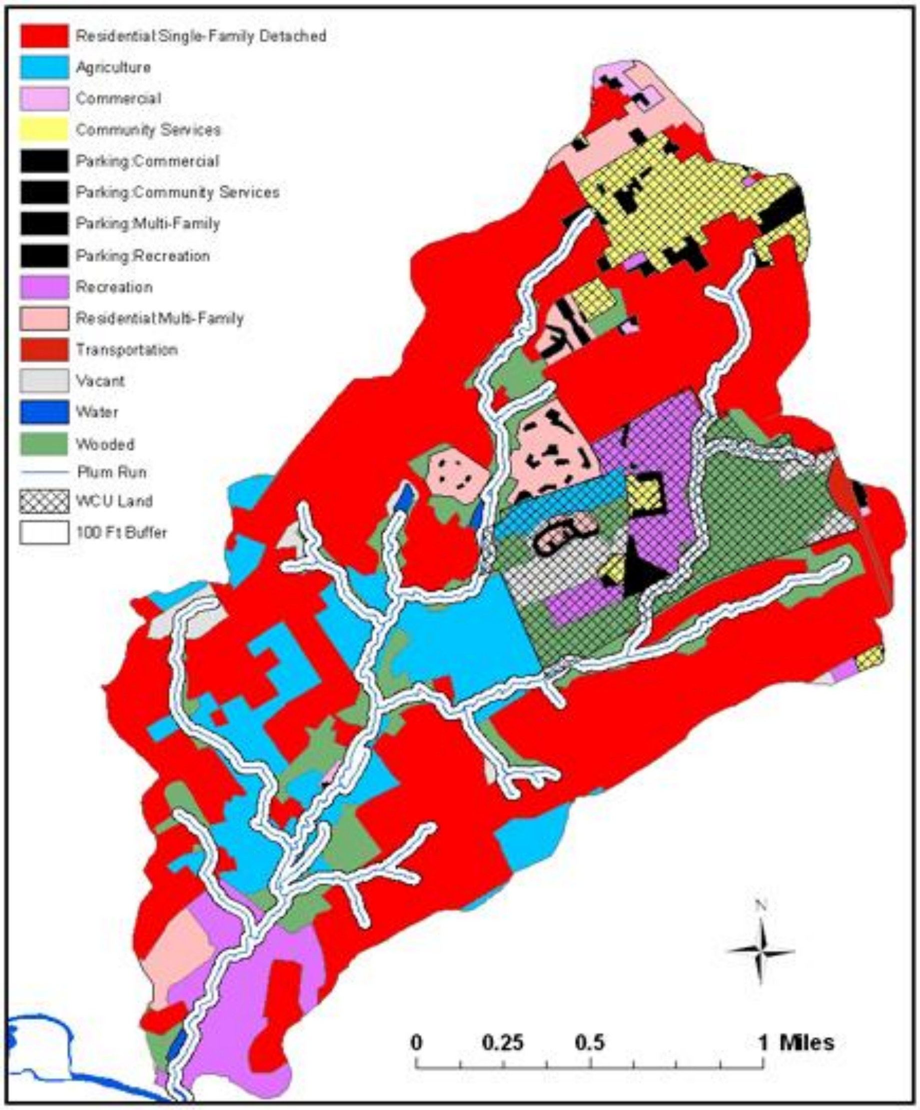

Figure 17

The adjacent map shows a 100 foot buffer area for both sides of the Plum Run and the land use within that buffer. Of the 272 acres within the buffer 43% is wooded, 27% is residential, 17% is farmland and 13% is comprised of other uses. The cross hatched area represents the buffered land that the University owns.

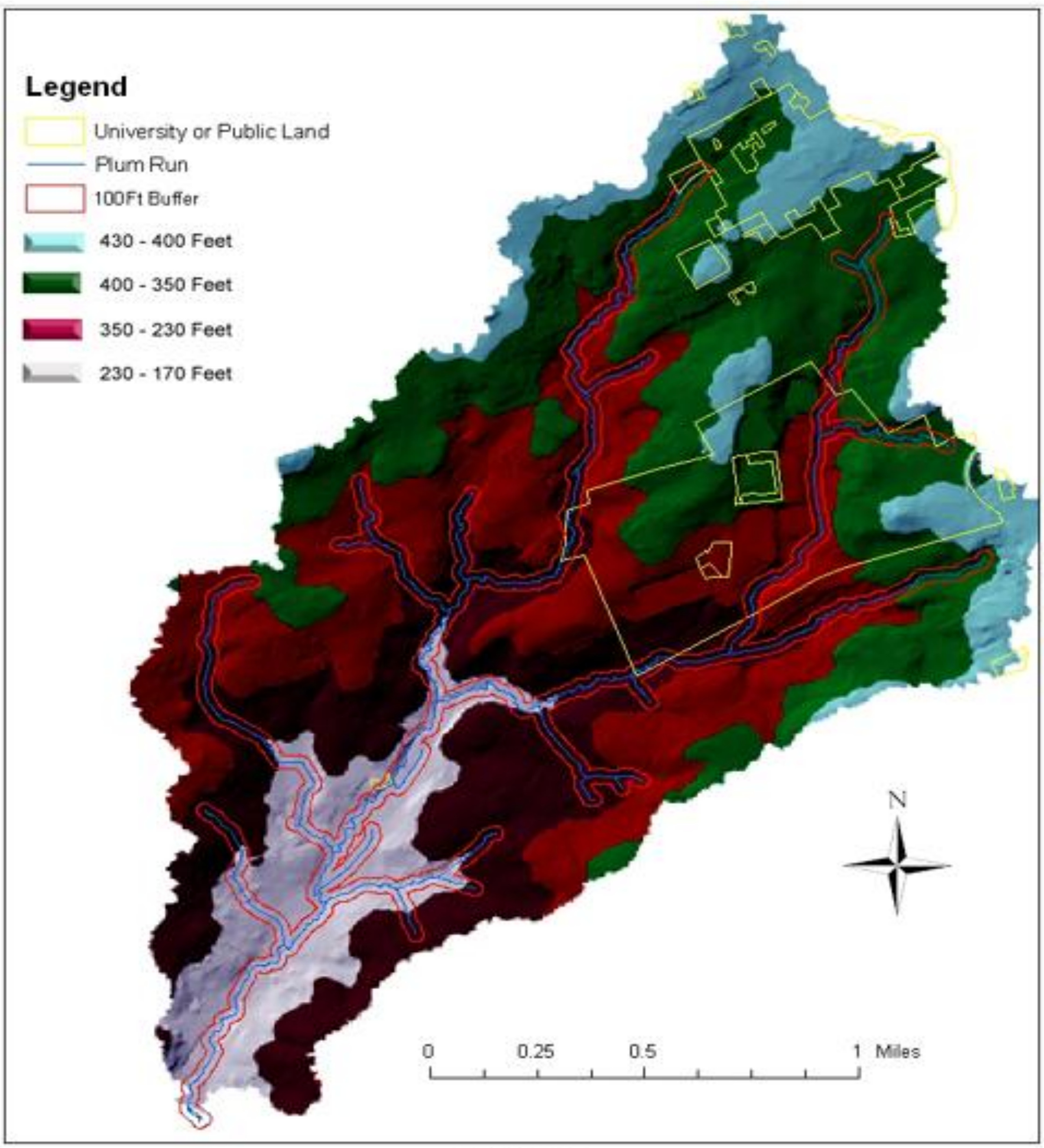

Figure 18

Question: Sources of stream impairment

As also shown in Figure 18, West Chester University occupies much of the "high ground" within the watershed, and also controls 32 acres (12%) within the 100 foot buffer, particularly along the East Branch. What is the University doing to protect the stream? What negative impacts may university property be having on the stream? How could the University help to restore the stream by changing current land use within the university--owned portion of the riparian buffer?

Acknowledgements

West Chester University faculty members Winfield Fairchild (Department of Biology), Timothy Lutz (Department of Geology and Astronomy) and Joan Welch (Department of Geography and Planning) jointly supervised the project. Graduate students Danielle Difederico and Mike McGeehin, and undergraduates Katherine Broadbent and Danielle Varnes performed much of the fieldwork, laboratory analyses, and assembly of GIS information. We thank the Pennsylvania Department of Environmental Protection for analysis of total phosphorus samples , and Jane Fava and Kathy Campbell of the Brandywine Valley Association for logistical support.

Interactive version of this short course can be found at
http://darwin.wcupa.edu/faculty/fairchild/plumrun/