Exercise 4: Teacher Notes

Background Information

As we have already seen, watersheds vary in size and complexity and can be delineated based on the research that is being done or problem that is being addressed. For instance, Columbus, Ohio is part of the large Mississippi River watershed but also part of the Ohio River watershed and Scioto River watershed. If we prefer to look at a smaller scale, we can examine the watersheds of streams flowing into the Scioto River within Columbus.

Introduction

The previous exercises have built an understanding of where water goes once it falls to the soil as precipitation, how water flows over and through the soil on a table-top watershed, and scaled up this understanding through successively larger watersheds, first in a school yard and then along a stream. Exercise 4 will use the same approach utilized in Exercise 3 but look at a substantially larger watershed.

In this case, we have selected the Big Darby Creek watershed as an example. When considering watersheds to use, we looked for one that covered a large geographic area and was experiencing changes in land use. It is important to select the watershed appropriately as students will identify land use changes that are happening, discuss their causes, and suggest possible consequences. A local watershed currently going through transformation is highly relevant to students. In addition, you will need to select a second area (not necessarily an entire watershed) that has already gone through well-document changes in land use to frame the discussion. In this exercise, our second land area is shown on the USGS Northwest Columbus Quadrangle; the areas is bounded by the Olentangy and Scioto Rivers on the East and West respectively and encompasses a part of Central Ohio that saw dramatic urbanization between 1955 and 1995. We also have aerial photographs from a portion of this area, Worthington, Ohio, going back to 1938 to make the changes shown on the topographic maps more tangible.

Historical examples will inform students that land use changes are not new even if suburban sprawl is a more recent phenomenon. For instance, Ohio was at one time 95% forest. Then, almost all of the forest was cut down (largely for agriculture), but now approximately 33% of the state is forest again. Recently, a large amount of agricultural land outside the major cities in Ohio has been converted to residential and commercial property in suburbs. Most regions of the country experiencing growth will have locations with similar patterns. Students will use the large-scale watershed to model how land use changes could result in different hydrology in the future. This modeling of land use will connect with Exercise 5.

The unit will start with a review of aerial photographs from Worthington, progress to a comparison of two Northwest Columbus quadrangles, continue to a specific examination of a section of Big Darby Creek, and conclude by looking at documents showing the ongoing discussion about land use in the Big Darby Creek watershed. There has been much work done to preserve and restore various parts of the Darby Creek watershed. One resource, provided by The Nature Conservancy, documents efforts at the headwaters of the creek and is available online at http://www.nature.org/ourinitiatives/regions/northamerica/unitedstates/ohio/placesweprotect/big-darby-creek-headwaters-restoration.xml.

The model in this exercise accounts for the land area feeding into the Big Darby Creek Watershed above Darbyville, Ohio. Therefore, all water inputs in this model are treated as if they come from this land area. The reason we selected Darbyville as a convenient endpoint is that USGS measurements are taken there and available on USGS and NOAA websites. While we do not expect the numbers we calculate to identically match those of USGS measurements, it is rewarding for students to see if patterns (periods of increased and decreased flow) are consistent and calculations are on the same order of magnitude.

Once again, students will be using software that was created to mathematically model how water moves through and is stored in a watershed following a precipitation event. Models are simplifications of real systems, simplified because of limits in measurements to input into the model, computing power to run the model, or understanding of the science on which to base the model. But, we use models, however imperfect, because they provide us with insight about what will happen under given circumstances. We know that models are not perfect approximations of the real world, but they are useful nonetheless. This might be what led statistician George Box to comment, "All models are wrong; some models are useful."

Materials

- USGS Quadrangles for a Nearby Region That Has Experienced Growth (1955 & 1995 USGS Northwest Columbus Quadrangles)
- Historical Aerial Photographs of a the Site from USGS/Google Earth/Google Maps (Worthington, Ohio from 1939 to 1998)*
- Rulers and/or Transparency Grids
- Computers and Internet Access (if using digital tools)
- Computers Running Web Application (for computer modeling)
- Data from Two Storm Events from NOAA
- Maps, Aerial Photographs, Images, Newspaper Articles, or Planning Reports to Provide Information About Past and Current Land Use Changes to the Watershed and Adjacent Watersheds (Big Darby Accord, Big Darby Town Center Master Plan, various articles from the Columbus Dispatch)
- Information on Development Standards and Infrastructure to Mitigate Runoff

*Aerial photographs for most locations in the U.S. are available, free of charge, from USGS at http://earthexplorer.usgs.gov/. You need to have patience navigating the site. The best place to find instructions is online at https://lta.cr.usgs.gov/Single_Frame_Records where you will also find information on images that USGS has made available. You will need to setup an account before downloading images.

Exercise 4.1: Examination of Historical Aerial Photographs (Worthington, Ohio)

A series of aerial photos are provided for Worthington, Ohio (shown on the northeastern portion of the Northwestern Columbus Quadrangle); these photos were taken about once a decade and visually document changes that occur. For students, photographs are often easier to understand than maps and the visual appeal of these images is great. Students bring some familiarity to the exercise if they have experience using Google Maps and/or Google Earth.

Students should be asked to:

1. Place the images in order, from oldest to most recent.
2. Identify the evidence that allows you to place the images in order and explain why that evidence suggests an order to the photos.

Students should whiteboard their results to prepare for a subsequent discussion on the land features that have changed over time. First, students will need to determine a reference point that is the same on all of the aerial photographs (look for key crossroads, diagonal roads, and unique bends in the river). For younger classes, this part of the exercise can be frustrating and you might want to have a consensus on reference points before allowing students to look for differences and placing the photographs in order.

Students will notice rivers change, ponds appear, roads be built and structures constructed or expanded. Teams can share their whiteboards to compare the orders that various group arrived at for the photos. There will be general agreement, with the exception of the last two photographs as they are challenging. The most important part of the exercise is the discussion as it sets the stage for Exercise 4.2 with topographic map comparisons.

Exercise 4.2: Examination of Differences in Land Use and Hydrology (Northwest Columbus Quadrangles)

Students will use the two sets of Northwest Columbus Quadrangles to examine changes that have happened during a 40-year time period. The same topographic map from 1995 was used in the optional exercise on topographic maps. While it helps to be familiar with topographic maps, at least if you are going to use contour lines to get information about terrain, it is not critical.

Questions

1. Using the Northwest Columbus Quadrangles from 1955 and 1995, identify five major changes that have happened over the 40-year period.
2. What percentage of the map was build-up (pink) in 1955? In 1995? How many acres have gone through this change?

3. On average, how many acres have been built up per year?
4. Identify five areas that have not been built up and identify potential reasons why they have not been built up.
5. Identify five changes that have happened to water features over the 40-year interval. This could be the appearance, disappearance, or altered path of a water feature.

We recommend giving students question 1 and discussing the results before providing students with the remaining questions. Questions 2 and 3 are more mathematically based and can be adapted based on the abilities of students. Question 4 is a departure point for a class discussion about the reasons for certain locations being developed as they are. Geography and geology can play a role, but so can the interests of the owner of the land or historical patterns in the area. Question 5 is a departure point for a class discussion about changes that humans cause to watersheds. On the two maps, we see significant changes to the Olentangy River; many of these changes occurred when a highway was built alongside the river in the northern part of the quadrangle. We notice many small ponds near build-up areas on the second map where there had been none on the first map. These ponds are largely retention ponds to drain and delay water flow from paves surfaces. We notice ponds created in the quarry on the southwestern portion of the map. There is also a pond created in a park on the northeastern portion of the map. This pond, while currently in a park, was also the site of a quarry. Some smaller streams seem to disappear, largely by burying pipes carrying their water as areas are urbanized.

Exercise 4.3: Large-Scale Watershed Hydrology (Big Darby Creek Watershed)

Students are asked to apply the content knowledge and skills that they have developed in the unit thus far to investigate the Darby Creek watershed. Specifically, students are asked to determine:

1. What is the total length of Big Darby Creek watershed above Darbyville, Ohio? How did you determine this length?
2. What is the total surface area of this section of the Big Darby Creek watershed above Darbyville, Ohio? How did you determine this area? (Necessarily, students will need to select a way to determine the watershed boundaries.)
3. What are the current land uses? What percentage of the land is in each use? How did you determine these uses and percentages? (Students can be asked to print out a few images to visually show their method. Since the models limits us to four land uses, students should be limited to four land uses as well.)
4. Using the web application, determine the hydrograph for Big Darby Creek watershed with the precipitation event on July 9th. Include an image of your hydrograph.
5. Alter your land use by changing half of the agricultural lands to some other land use. What impact does it have on the hydrograph? Include an image of your hydrograph.
6. Would either situation, in questions 4 or 5, have resulted in flooding? (We will look at some online tools that provide information about flood stage.)

Questions 1 through 3 are relatively straightforward but require students to use aerial photographs without the benefit of being able to walk the area. They will also need to use estimation and calculations skills that they honed in Exercise 3.

Questions 4 and 5 draw on more recent skills, allowing students to look at changes in flow in the drainage and compare impacts of land uses. Remember, the concept of flow is abstract for students as it is a rate. If you have not run an example calculation of flow in the GeoSandbox or smaller drainages, you can use a stopwatch to time how long it takes to fill a 5-gallon bucket with a hose. This will allow students to calculate, using a proportion, the volume of water per second coming out of the hose and compare it with gallons of water per second flowing down the drainage. For example, "How many hoses worth of water are coming down Darby Creek each second?" Otherwise, the volume of water per second flowing down the drainage is unlikely to have any meaning to students.

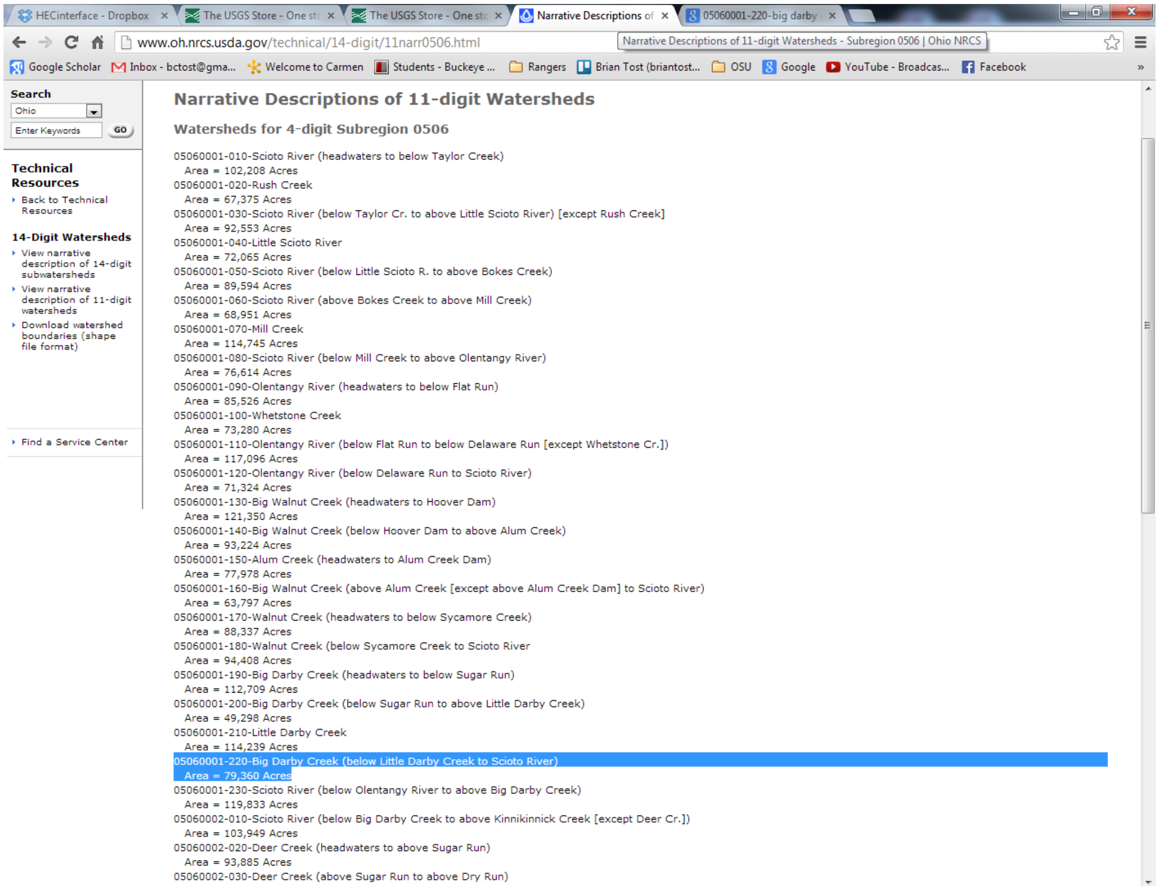
Question 6 is challenging and will require students to do some research or the teacher to provide some guidance. First, students will need to grapple with the definition of flooding that we discussed in Exercise 3. The government sets flood levels for each drainage and flood stage is generally defined as, "the level at which the surface of a river, stream, ocean, or other body of water has risen to a sufficient level to cause sufficient inundation of areas not normally covered by water to cause an inconvenience or a threat to life or property." USGS has created a website (http://waterwatch.usgs.gov/) that allows visitors to look at the current state of water in the country. By looking for Darbyville (a gauging station on Darby Creek a few miles above Circleville), you can find the current flow (in height or by volume), the flood stage, and additional historical information. The possibilities of the USGS website are endless as students can investigate watersheds anywhere in the country; for students, it is particularly exciting to investigate real time data for stations in a region over three to five days of a flooding event.

Advanced Preparation

You will need to decide how much to scaffold the activity and how many support materials you would like to print in advance. Younger students will need more support than older students.

Procedure

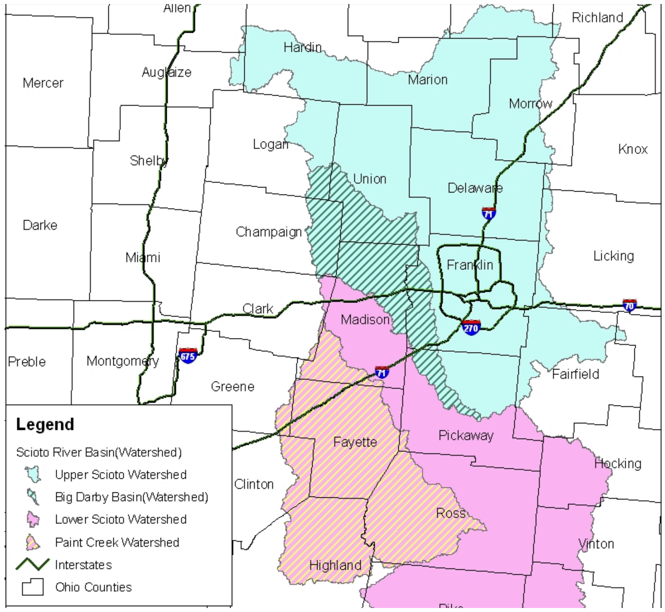
The US Department of Agriculture - Natural Resources Conservation Service provides information on watersheds: http://www.oh.nrcs.usda.gov/technical/14-digit/11narr0506.html



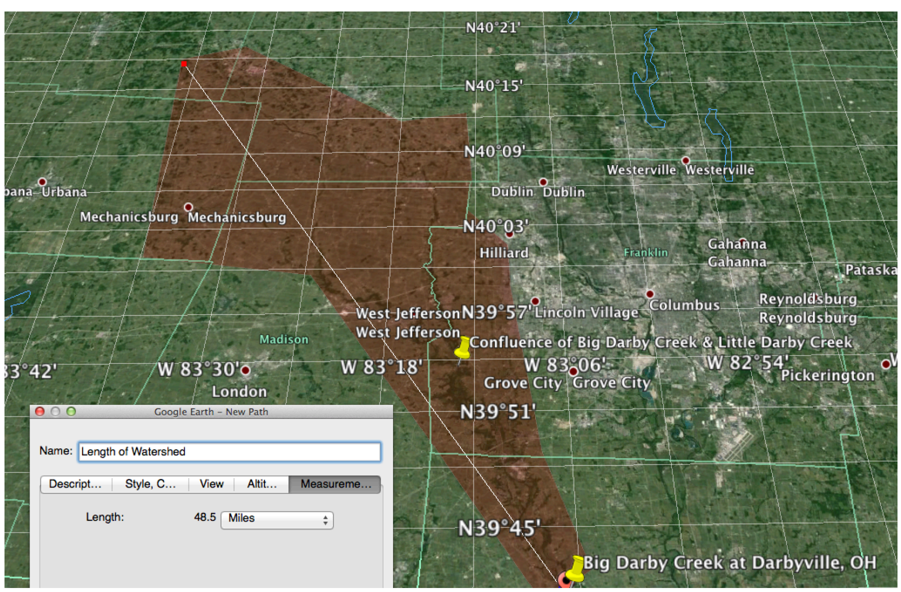
The Big Darby Creek watershed is divided into smaller basins. The specific area that will be modeled in this exercise is the run of the Big Darby Creek above Darbyville, Ohio. The surface area drained by this watershed is approximately 356,000 acres (we added the four area measurements for Darby Creek – this does include extra area downstream of Darbyville but we are looking for approximate values). If you use a watershed that is not listed on the website, you will need to find a credible resource with the area listed or calculate it using Google Earth. For example, Big Darby Creek has a Nature Conservancy website that lists its area as 560 square miles (http://www.nature.org/ourinitiatives/regions/northamerica/unitedstates/ohio/placesweprotect/darby-creek-watershed.xml).

If students are given a map with the boundaries of the Big Darby Creek watershed marked, they can trace the boundaries in GoogleEarth and calculate the area, length, and elevation change of the watershed using the tools shown in Exercise 3.

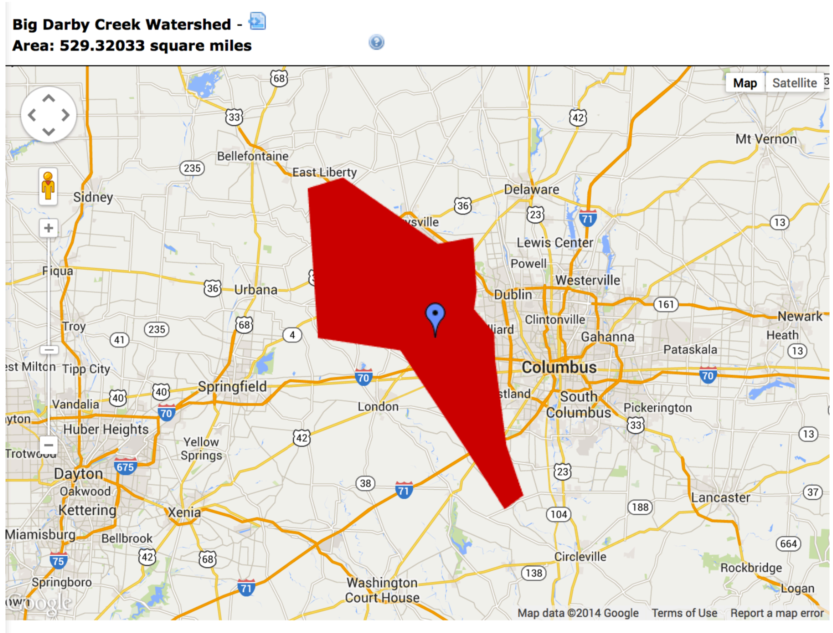
A map of the Big Darby Creek watershed is available with counties marked.



A polygon can be traced in Google Earth using cities or counties as reference points. The length of the watershed and elevation change can be determined using Google. For example, the flow length of the Big Darby Creek is approximately 48.5 miles. While the actual length is longer, because of bends, we are looking for an estimate of the length. The elevation at the start of the flow length is 1322 feet above sea level. The elevation at the end of the flow length is 728 feet. Thus, the change in elevation is the difference between these values, which is 594 feet.



The area of the watershed can be determined using the University of New Hampshire website from Exercise 3. The Big Darby Creek watershed is approximately 530 square miles.



The predominant land use in this watershed is agriculture crop land, with some small cities appears to be in good condition. Thus, the designated land use conditions and percentages will be:

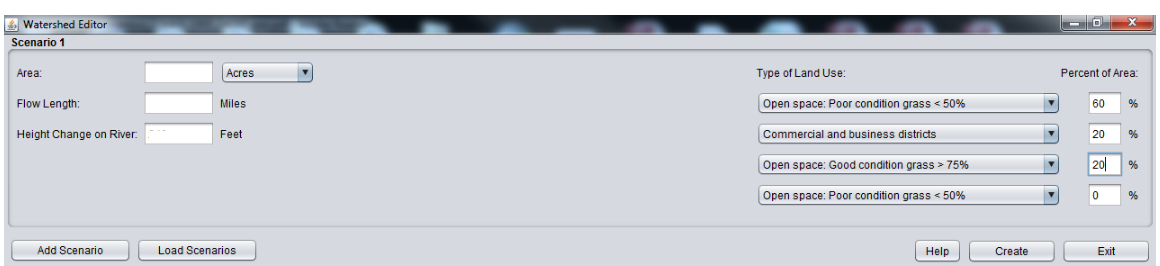
Open Space: Poor Condition Grass: 60% (for agricultural crop land)

Commercial and business districts: 20% (for small cities)

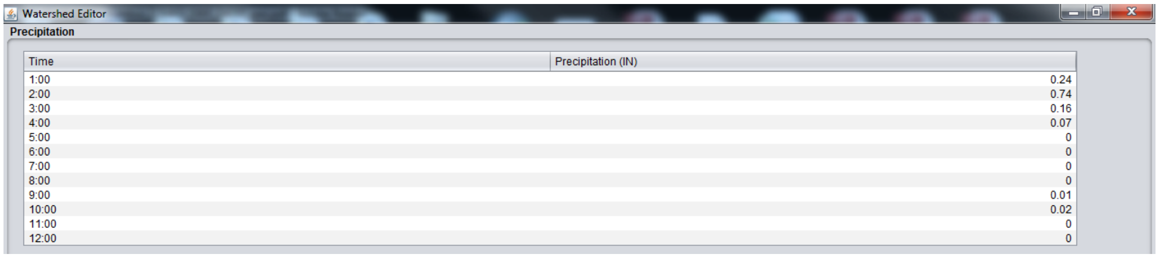
Open Space: Good Condition Grass: 20% (for creekside forests)

Students can be asked to make rough estimates of the land use percentages or transparency grids can be applied to make the estimation process more precise.

Inputs are entered into the web application interface.
***The appearance of this web application has been slightly altered, but all functions used throughout this exercise are still available.**



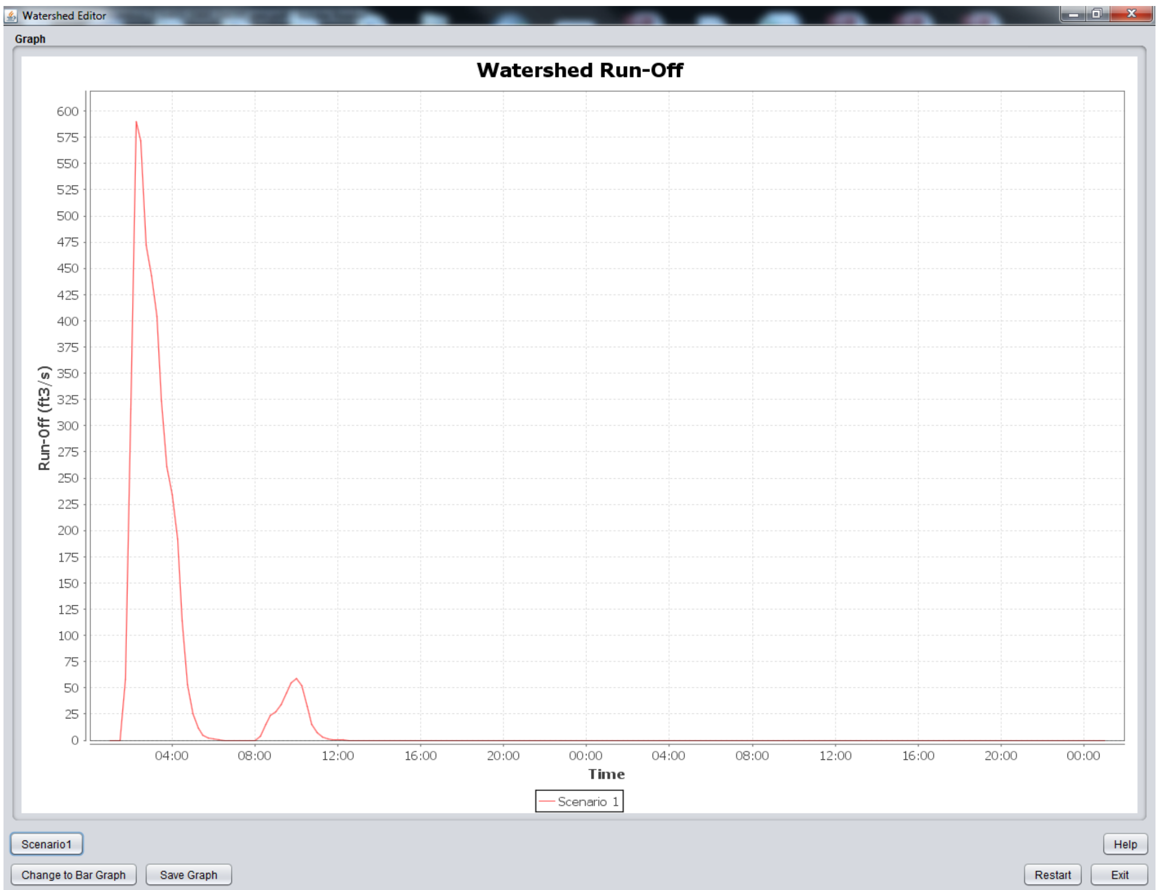
The first precipitation event used in Exercise 3 will be used in this exercise.


Watershed Editor

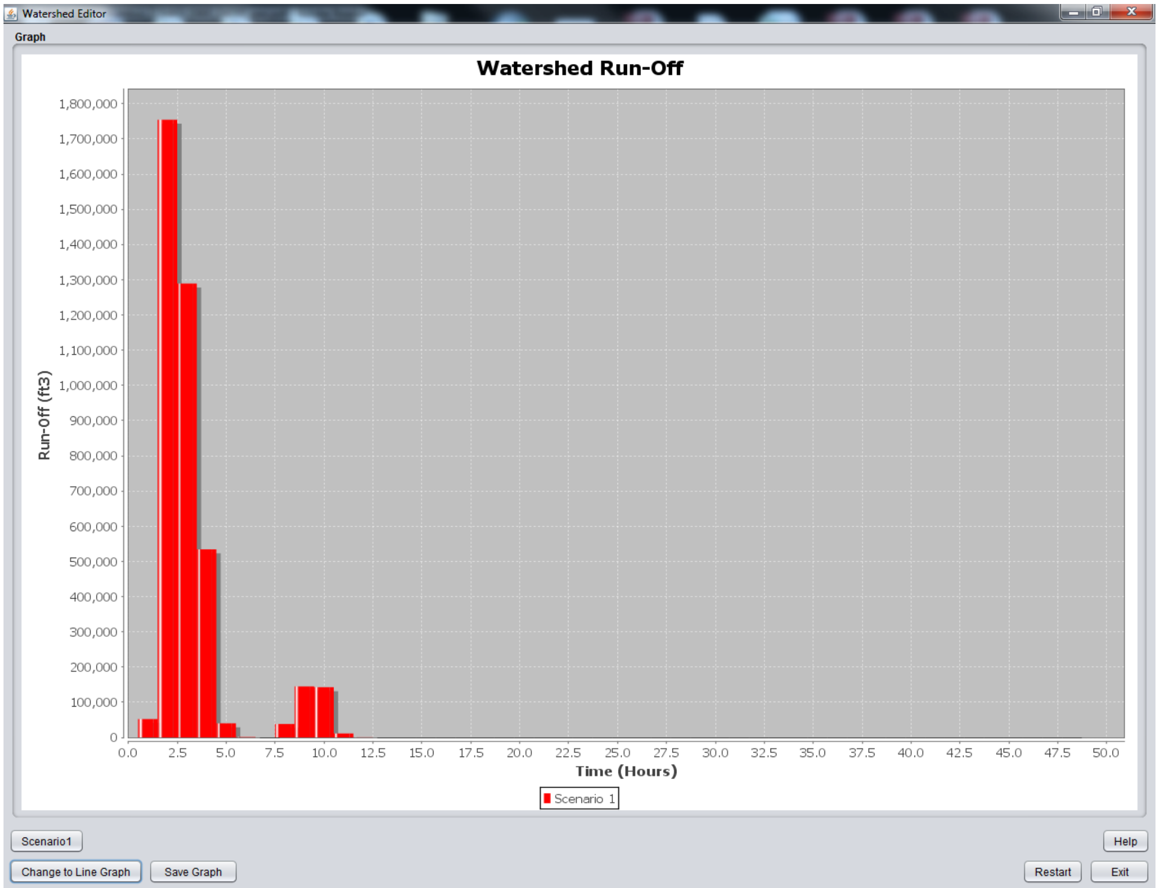
Precipitation

Time	Precipitation (IN)
1:00	0.24
2:00	0.74
3:00	0.16
4:00	0.07
5:00	0
6:00	0
7:00	0
8:00	0
9:00	0.01
10:00	0.02
11:00	0
12:00	0

Here is a hydrograph output for the Big Darby Creek Watershed.



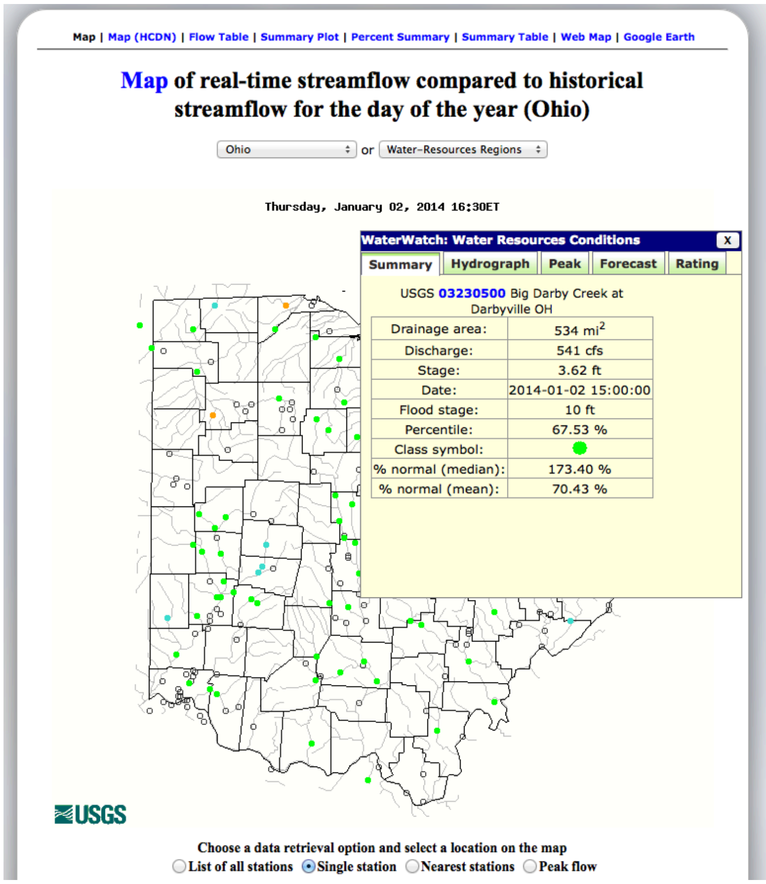
The hydrograph is shown in bar graph form.



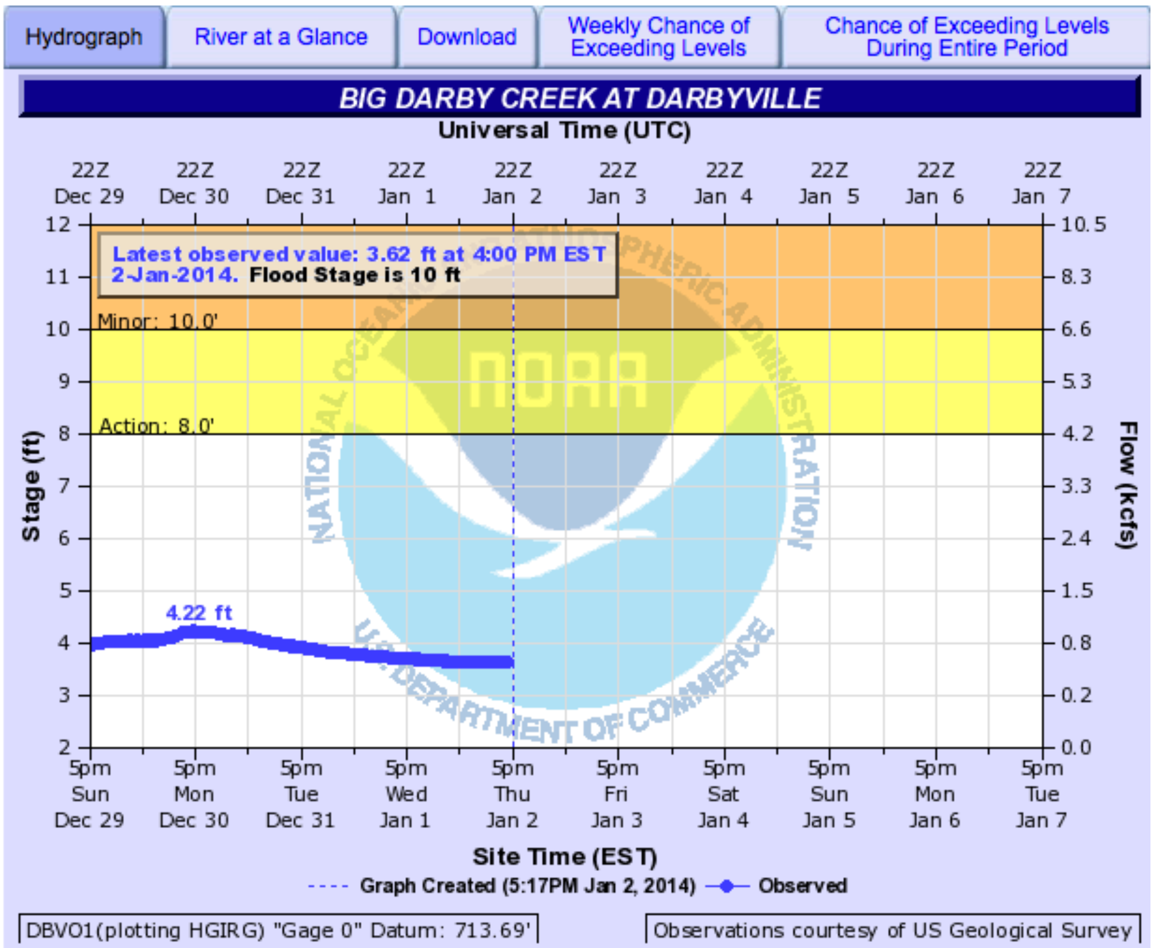
Run the same analysis for the second precipitation event in Exercise 3. What are the similarities between the two locations and the two events? The differences?

Save or note your settings as we will be using the Big Darby Creek data again for Exercise 4.6.

Below, a view of Ohio watersheds with gauging stations marked is provided by USGS's WaterWatch. If you select a gauging station, Darbyville in this case, a window opens with additional information (http://waterwatch.usgs.gov/?m=real&r=oh&w=map).



The forecast tab on the window allows you to see the current stage and flood stage in both height and flow. If you click on the hydrograph, it opens another window, shown below (http://water.weather.gov/ahps2/hydrograph.php?wfo=iln&gage=dbvo1), with additional tabs. You can find more information about the watershed at and above the gauging station using these tabs. You can also get this information and more from a National Weather Service website (water.weather.gov)



Exercise 4.4: Government and Planning Documents Related to Land Use (Big Darby Creek Watershed)

A number of supplemental materials have been provided to frame the discussion about past and future land use in the Big Darby Watershed and the impact of this land use on the watershed. An intergovernmental accord (Big Darby Accord) and planning document (Big Darby Creek Town Center Master Plan) have been included to explain the transformation occurring in the Big Darby Watershed and capture the ongoing community dialogue. These documents show how multiple jurisdictions work cooperatively to govern the watershed and implement policies. While the Big

Darby Accord is a large document, the Executive Summary and Introduction provide sufficient detail. The Big Darby Creek Town Center Master Plan shows development plans created after the accord was accepted that include features designed to protect the watershed. The town center document will serve as a platform for students to discuss differences in planning, development, and infrastructure now versus in the last century. While this document is also large, the Executive Summary and Ecology & The Environment sections are most relevant. It is important to note, the town center plan was shelved as the economic recession continued.

The Big Darby Accord Watershed Master Plan and Big Darby Town Center Plan are examples of government and private enterprise in action trying to balance competing needs and desires. The following questions allow student to delve into a portion of the documents (Executive Summary and Introduction sections of the Big Darby Accord Watershed Master Plan and Executive Summary and Ecology & The Environment sections of the Big Darby Town Center Plan). After their investigation into the questions below, a class discussion can further elucidate the situation.

Questions

1. What is the Big Darby Accord? Who are its members?
2. Why was it setup? What major issues does it hope to tackle?
3. How will it address these issues?
4. What is the Big Darby Town Center? Why is it being built?
5. What solutions has the developer proposed to address issues being tackled by the Big Darby Accord?

It is recommended that you read both documents in advance to better understand the complexities of the political arrangements, the nature of the planning process, and the infrastructure solutions that are proposed. Additional documents are included within the unit to provide an understanding for the legal protections and limitations afforded by state and federal scenic river status, how EPA regulatory procedures are established, and the basis for environmental impact statements.

Exercise 4.5: Media Coverage of Changing Land Use (Big Darby Creek Watershed)

Newspaper articles covering the creation of the Big Darby Accord and ongoing contention surrounding development in the Big Darby Watershed show how competing land use interests continue today. The Big Darby Accord and three newspaper articles allow students to better understand the structure of the Big Darby Accord, challenges of balancing landowner's rights and community desires with the need to protect the watershed, and compliance with the letter and spirit of the law.

Questions

1. How were the member jurisdictions of the Big Darby Accord selected?

2. Are the recommendations of the Big Darby Accord advisory board mandatory?
3. Does the developer of the Heritage Preserve project have approval to build? If so, which body has the ultimate authority to decide? Explain if any other body can make decisions that have an impact on the project.
4. What are some strengths and weaknesses of the Heritage Preserve project according to the articles?

Student can draw from knowledge they gained from the Big Darby Accord, Town Center Master Plan, and other documents about environmental regulations in Exercise 4.4. You should review these other documents as students often ask pointed questions for clarification. Exercise 4.5 can be completed even if Exercise 4.4 is skipped.

Exercise 4.6: Land Use Changes in a Large-Scale Watershed (Big Darby Creek Watershed)

Now that students understand how the Big Darby Creek watershed could undergo a significant change, they will alter the land use in the watershed. Students will use the same data they entered for the precipitation events and begin with the same land use percentages that they identified in Exercise 4.3. There are two ways to proceed with this exercise, a quick approach is to simply change the percentages from Exercise 4.1 from 60% open space (for agricultural land), 20% (small cities), and 20% (creek-side forests) to the numbers provided below. The first scenario assumes light-density development and the second assumes high-density development.

Land Use	Scenario 1 (Light-Density Development)	Scenario 2 (High-Density Development)
Open Space: Poor Condition Grass (<50%)	0%	60%
Commercial and business districts	80%	20%
Open Space: Good Condition Grass	20%	20%

The second way is to have students study the map on page 8 of the Big Darby Town Center Master Plan (easier if it is printed or displayed in color), and run a scenario or two based on how this plan changes use of the land. Remember, the master plan calls for a number of features that should reduce runoff (such as rain gardens and retention ponds) whereas the web application does not include these features. Much of the planting and infrastructure identified in the Ecology & The Environment section of the Big Darby Town Center document are specifically designed to mitigate this problem. Proper design and construction can result in minimal impact on the watershed; poor design and construction would result in significant damage to the watershed. The Big Darby Accord shows how governments are trying to coordinate their work to balance the desires of landowners to develop their land with the needs of the community to protect their watersheds.

Questions

1. In what ways did the flow of Big Darby Creek change with different levels of development?
2. Explain the underlying reasons for this change in flow based on what we have already observed in this unit.
3. What challenges could this change in flow present for Big Darby Creek?

It should be noted that, according to staff at Battelle Darby Creek Metro Park, one of the biggest threats to endangered mussel species in Big Darby Creek is sediment entering the creek during large rainfall events.

Summer workshop participants reviewing the Big Darby Accord and Big Darby Town Center Master Plan, sharing their findings, and hearing from a panel of geosciences professionals working in hydrology.