Introduction

Over the past twenty-five years the United States has made considerable progress in cleaning up our rivers, lakes and coastal waters by controlling pollution from industry and sewage treatment plants. Why then does so much of our water remain too dirty for swimming, fishing or drinking? And why are many species of plants and animals disappearing from our waters? The problem, it now appears, is that we have not done enough to stop storm water pollution, or non-point source pollution, that runs off the land every time it rains.

Imagine the path that a drop of rain takes from its arrival on the ground to the time it reaches a river, lake or the ocean. Any pollutant that it picks up along the way may get deposited in nearby bodies of water unless the raindrop soaks into the ground before it reaches its destination. Even then, runoff can create a problem for ground water that, in many areas, is used for drinking.

1. What kinds of pollutants may be carried to our rivers and oceans by storm water run-off? List at least 3 different pollutants.

   - Start ArcView. Open the Stormh2o.apr project.
   - From the project window, select the California coast view and click Open. The view will open showing the California coastline, sanctuary boundary, the major islands within the sanctuary, and the topography and bathymetry of the area.
   - Zoom in on the coastline surrounding Santa Barbara.
   - Investigate the change in elevation. Activate the Topography theme and click on the Info tool. Click on the highest spots (displayed as light colors) around Santa Barbara. Each time you click on a location, the elevation will be displayed in meters on the right side of the Identify Results window.

2. How high are the mountains surrounding Santa Barbara? Record the highest elevation you found.

   - Turn on the Rivers theme by clicking in the box in front of its name.
   - How do the mountains surrounding Santa Barbara effect run-off following storm events? Where does the storm water end up?

   - Turn off the Topography and Rivers themes.
   - Zoom out so you can see the California coast and sanctuary boundaries.

Each year winter storms wash excess nutrients, microorganisms, hazardous chemicals, sediments and debris into our coastal waters. This discharge enters the ocean as buoyant freshwater plumes which spread out over the ocean's surface. In February 1998, storms generated by El Niño resulted in two-thirds of the Santa Barbara Channel being inundated with freshwater run-off.
It spread across the ocean surface forming a large sediment plume, affecting both biological and chemical processes in the channel. Large amounts of mud and terrestrial sediments in the plume reflected the sunlight, reducing the amount of light available to algae on the sea floor.

Turn on and activate the Turbidity 2/9/98 theme. Turbidity is a measure of water clarity.

High amounts of suspended soil, plankton, and small fragments of dead plant material increase the turbidity and change the color of the water. The turbidity data was collected by a satellite with SeaWiF (Sea-viewing Wide Field-of-View) sensors as it passed over the California coast. The SeaWiF sensors measure the amount of light reflectance. Deeper shades of orange indicate higher levels of suspended sediments.

Outline the areas of the sediment plume with values higher than 10, shown in orange. Reveal the theme legend by selecting Theme/Hide/Show Legend from the menu bar.

- Click and hold the draw tool, to display the drop-down list of tools. Select the draw line tool.
- Click once to start the line and again to change directions.
- Double click to end the line when you have finished. If you don’t like your line, hit the delete key and begin again.

Measure the width of the plume at its widest point from Santa Barbara towards Santa Cruz. For our purposes, use the line you just drew, showing the areas with sediment values higher than 10.

4. Measuring just the areas with sediment values higher than 10, how wide was the sediment plume on February 9, 1998? Which islands were most affected by the run-off?

Follow the growth and decline of the sediment plume. One by one, turn on the remaining turbidity themes. Note: only one turbidity theme is visible at a time. The top-most turbidity theme that is turned on will cover the other themes.

5. What happens to the sediment plume in April, after the winter storms subside?

6. Imagine you are a mussel, living attached to the bottom of the sea floor. What effect might the sediment from the plume have on you?

Turn off all of the Turbidity themes.

In April 1998, after the sediments had settled out of the water column and the water temperature began to rise, excess nutrients left behind by the sediment plume triggered a rapid growth of single-celled algae, called a phytoplankton bloom.

One by one, turn on the Chlorophyll themes. These images were also captured by the SeaWiF sensors. Oranges and reds indicate high concentrations of chlorophyll, a photosynthetic pigment used by plants and algae. Yellows and greens indicate low concentrations of chlorophyll.

7. Did the phytoplankton bloom grow or shrink between February and April? How do you know?
8. What effect would a large phytoplankton bloom have on the ecosystem? Consider food, dissolved nutrients and oxygen availability initially and after a few weeks.

**Urban Pollution**

Much of the sediment seen in the SeaWiF images resulted from agricultural, forestry and land development practices in the regions surrounding Santa Barbara. Clear cutting forests, grating land for development projects, and plowing under agricultural fields, all remove natural vegetation and increase erosion. Without plants to anchor the topsoil, it can wash or blow away during storm events and increase sedimentation in our rivers and oceans. Excess sediments are also problematic because they provide a substrate to which pollutants may adhere.

In the city, storm water run-off is likely to encounter and pick up a pollutant, such as motor oil, household chemicals, pet wastes, etc. Excess sediments and nutrients (from lawn fertilizers) are also pollutants. If the water encounters a patch of lawn to soak into, the pollutant might not reach a nearby creek. But if the run-off doesn’t flow across any soil or grass along the way, because it keeps encountering hard, *impervious* surfaces, it may well make its way into a storm drain and then all the way from the creeks into the ocean. When all the drops of polluted water from our urban areas are added up, the problem becomes immense. Urban storm water runoff in the United States carries the equivalent of ten supertankers full of oil into our oceans every year, a drop at a time!

Urban areas contribute greatly to water pollution problems because of the higher concentration of hazardous chemicals and other contaminants (more people, cars, factories, etc.) and the greater proportion of impervious surfaces. (In rural areas, the majority of the pollutants are from agricultural sources such as fertilizers or manure.) In urban areas, impervious surfaces first collect pollutants and then allow the pollutants to wash off and to enter our waterways during rainstorms.

9. In a city, common surfaces include asphalt streets, concrete sidewalks, landscaped medians, bricked walkways, dirt patches, grass filled parks, tarred roof tops, and marble walkways. Decide if each represents a pervious (water can penetrate and soak through to the ground) or an impervious surface (impermeable to water) and complete the chart.

In the remainder of this lesson we will show how GIS technology can be used to identify areas that are contributing the most to the problem and look at one way we might reduce storm water pollution in urban areas.

**Santa Barbara: A Case Study**

Santa Barbara is a small city along the California coast. Santa Barbara’s economy depends on the health of the ocean along its beaches and piers to support outdoor recreation and a very large tourist industry. Most of the time when it rains in Santa Barbara, the beaches have to be closed because of high levels of bacteria in the water, a strong indication that the ocean is being seriously affected by pollution coming off the land.
Rainstorms in Santa Barbara are intense, and rainfall can be too high for the impervious surfaces to handle. Storm water pools on the sidewalk before it flows down the streets and into a storm drain along the curb. From there the water enters a network of pipes that deliver it directly to the creeks which empty into the ocean. Unless it soaks into the ground along the way, storm water in Santa Barbara is not filtered. We have to watch polluted storm water flow by and put up with the damage it causes. Or do we?

10. Suggest 3 things city officials could do to keep polluted storm water from reaching the ocean.

One easy thing to do would be if we could sweep all the streets in town just before a heavy rain. While we might not remove all the pollutants, at least we could remove some of the surface contaminants that would otherwise flow into the storm drains. But there is generally not enough money or time to sweep all the streets before every storm. In this exercise we will use GIS and satellite imagery to focus our efforts and decide which streets should be swept to remove the most contaminants.

Looking at Santa Barbara from Space

Landsat, a satellite with a large array of sensors on board, passes over every part of the earth every few days. Its sensors can detect the color of the earth’s surface, heat and infrared radiation. An image analyst can use combinations of these sensors to pick out features in the land cover such as types of crops, wetlands and even the intensity of development.

From the Stormh2o.apr project window, click on the Views button and select Santa Barbara, then Open. The view opens showing the city limits of Santa Barbara, California.

Shown on the left side of the Santa Barbara view are several themes showing various land cover types, they represent various components of the Landsat image and are not the true colors of the original features. An image analyst examined the satellite data and painstakingly classified every pixel in the image.

Display each theme to reveal the composite image of Santa Barbara, viewed according to land cover.

11. How much of the ground cover in Santa Barbara is vegetation or natural surfaces? Where are these areas generally found?

Turn off all of the colored themes except for the following: Santa Barbara Streets, Santa Barbara City Limits and Highly Developed areas.

The red areas shown on the screen are areas that Landsat “sees” as made up almost entirely of concrete, asphalt and rooftops, almost all man-made hard surfaces. Each pixel in the image represents an area 30 meters x 30 meters, an area about the size of a small house. These are the areas of greatest concern for sources of urban storm water pollution.

12. Which parts of Santa Barbara are the most highly developed?

If we are only able to sweep some streets before it rains, we want to concentrate on the highly developed areas and their surroundings first. Using GIS,
we can figure out which streets to sweep and create maps for the street sweepers to follow. First, let’s expand the red areas a little bit to account for the fact that storm water is going to runoff these areas and flow down the street before it runs into a storm drain. Polluted water from the red, “highly developed areas” may flow into a neighboring area before entering a storm drain. We can create a 100 foot buffer around each red area to make sure we sweep all the streets around the areas where the pollution is going to be the greatest.

Create a 100 foot buffer around the highly developed areas, by first selecting the **Highly Developed** theme to buffer.

Select the distance to be buffered (100 feet) around the theme.

Complete the buffering process and wait for the new theme to be created and added to the top of the theme menu.

Click on the **Highly Developed** theme by to activate it.
- Select Theme/Create Buffers...
- Click the in front of “The features of a theme”.
- From the pull down menu, select **Highly Developed**.
- Click Next.

Make sure the radio box next to “At a specified distance” is selected.
- Change the buffer distance to 100.
- Set the distance units to “feet”.
- Click Next.

Answer each of the following questions in the Create Buffer window.
- “Dissolve barriers between buffers?”, click Yes.
- “Create buffers so they are”, click only outside the polygon(s).
- “Where do you want the buffers to be saved?”, click the radio button next to “in a new theme”.
- Click on the open folder button, navigate to the YourName folder on your computer. Name the file 100ftbuf.shp.
- Click Finish.
Student Activity

 Rename the new theme “H. Developed - 100 ft. Buffer”.

13. How does the areas shown in the buffered theme compare with the original highly developed theme?

14. Why did we want to “buffer” the highly developed areas?

Let’s see how the streets lay out with respect to this new theme.

 Move the Santa Barbara Streets theme to the top of the list so that it is drawn on top of the H. Developed 100 ft. Buffer theme and turn it on.

Now we’re ready to make a map for the street sweepers. We want them to know where the most important areas are to be cleaned before the rains come.

 Turn on the Geoprocessing extension. From the project window, select File/Extensions... Select the Geoprocessing extension and click OK.

 Open the GeoProcessing Wizard…

 Select “Clip one theme base on another”, then click Next.

 Update the GeoProcessing Wizard window with your preferences and wait for the new theme to be created.

 Turn on the StrClip.shp and the Santa Barbara Streets themes.

 Change the color of the new theme to red.

You have just created a map showing the city street network and the areas that we would like swept before a storm (shown in red). The street sweepers would also like a list of the streets and specific blocks that they need to sweep.

 Activate the StrClip.shp theme and open its associated table file.

A list of the streets in the highly developed areas will appear. This list can be printed out to be used by the street sweepers to do their job.

 Print the list of streets to be swept and attach them to your data sheet.

 Save your project and close ArcView.

15. What is the advantage of providing a prioritized list of critical streets to the City Council?
16. What other things might the City Council consider doing to minimize the effects of storm water pollution?

17. Write a paragraph describing what you learned about storm pollution. Where is it the greatest problem? How does the ground cover affect runoff? What can we do to minimize the effect of storm water runoff?

**Extension Activities**


- Find out how storm water is managed in your community. Are the storm drains in your region fitted with filters? Does storm water runoff enter the sewer system for processing? Or does storm water flow directly from storm drains to a nearby pond, river, or the ocean?

- Obtain land cover images and Census Bureau street data for your own community. Investigate storm water pollution locally using techniques presented in this lesson. Use hand-help GPS receivers to locate the storm drains in your community. Enter your data into ArcView (see Environmental Monitoring for details on how to enter your own data and create shape files). Determine which storm drains are near highly developed areas and should be monitored for pollutants.

- Start a local water monitoring project or adopt a beach or river. See Environmental Monitoring for background information and tips on how to get started.

- Increase community awareness of water quality issues. Participate in local beach or river clean up efforts to help pick up and remove trash and other debris before it enters our oceans. If you live near the coast, identify the storm drains near highly developed areas. Next to each, stencil a reminder “Storm Drain flows to the Ocean.”
1. What kinds of pollutants may be carried to our rivers and oceans by storm water run-off? List at least 3 different sources.

2. How high are the mountains surrounding Santa Barbara?

3. How do the mountains surrounding Santa Barbara effect run-off following storm events? Where does the storm water end up?

4. Measuring just the areas with sediment values higher than 10, how wide is the plume? Which islands are most affected by the run-off?

5. What happens to the sediment plume in April, after the winter storms subside?

6. Imagine you are a mussel, living attached to the bottom of the seafloor. What effects might the sediment from the plume have on you?

7. Did the phytoplankton bloom grow or shrink between February and April? How do you know?

8. What effect would have a phytoplankton bloom have on a marine ecosystem? Consider the effects initially and after a few weeks as the phytoplankton die off.
9. Decide if each surface represents a pervious (water can penetrate and soak through to the ground) or an impervious surface (impermeable to water) and complete the chart.

<table>
<thead>
<tr>
<th>Surface</th>
<th>Impervious or Pervious?</th>
</tr>
</thead>
<tbody>
<tr>
<td>a) concrete walkways</td>
<td>________________________</td>
</tr>
<tr>
<td>b) buildings</td>
<td>________________________</td>
</tr>
<tr>
<td>c) roads</td>
<td>________________________</td>
</tr>
<tr>
<td>d) grassy parks</td>
<td>________________________</td>
</tr>
<tr>
<td>e) parking lots</td>
<td>________________________</td>
</tr>
</tbody>
</table>

10. Suggest 3 things city officials could do to keep polluted storm water from reaching the ocean.

11. How much of the ground cover in Santa Barbara is vegetation or natural surfaces? Where are these areas generally found?

12. Which parts of Santa Barbara are the most highly developed?

13. How does the areas shown in the buffered theme compare with the original highly developed theme?

14. Why did we want to “buffer” the highly developed areas?

15. What is the advantage of providing a prioritized list of critical streets to the City Council?

16. What other things might the City Council consider doing to minimize the effects of storm water pollution?

17. Write a paragraph describing what you learned about storm water pollution. Be sure to address the following issues: Where is it the greatest problem? How does the ground cover affect runoff? What can we do to minimize the effect of storm water pollution?