Color Me A Watershed

What might make a watershed blue . . . or brown . . . or green?

Summary

Through interpretation of maps, students observe how land use and development can affect a watershed.

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Subject Areas:
Environmental Science, Mathematics, History

Duration:
Preparation time:
Option 1: 10 minutes
Option 2: 10 minutes
Option 3: 10 minutes
Activity time:
Option 1: 40 minutes
Option 2: 50 minutes
Option 3: 40 minutes

Setting:
Classroom

Skills:
Gathering information (calculating); Analyzing (comparing); Interpreting (identifying cause and effect)

Vocabulary::
discharge, watershed, runoff

Objectives

Students will:

- recognize that population growth and settlement cause land-use changes.
- analyze how land-use variations in a watershed can affect surface-water runoff.

Materials

- *Maps and photographs of local community, past and present* (optional)
- *Copies of* ***Maps A, B*** *and* ***C***

For Option 1

- *Colored pencils*

For Options 2 and 3

- *Calculator*
- *Copies of the* ***Area of Land Coverage*** *chart*
- *Copies of the* ***Volume of Rain and Volume of Runoff*** *chart*

Making Connections

Learning about the past refines our current perspectives and helps us plan for the future. Historical, sequential maps can provide graphic interpretations of watershed history. By comparing past and current land-use practices, students can recognize development trends. This knowledge can help them appreciate the importance of watershed management.

Background

Resource managers and policy-makers use maps to monitor land-use changes that could contribute to increased surface water runoff into a river, pond, lake or wetland. Monitored land uses include, but are not limited to: urban (e.g., residential, parks and businesses); agriculture (e.g., pastures and corn, soybean, wheat, sugar cane, rice, pineapple and lettuce production); industry; transportation systems (e.g., roads, railroads and trails); and public lands (e.g., refuges, parks and monuments).

Land-use changes can significantly impact a region's water resources. Streams, lakes, wetlands and other bodies of water collect surface water from the surrounding land, called a watershed, drainage basin or catchment. After periods of precipitation or during snowmelt, some surface water is captured by the soil and vegetation, stored in ground water and plants, and may be slowly released into a collection site (e.g., a stream). Some evaporates or remains as ground water.

Resource managers use Geographic Information Systems (GIS) to store data and generate land-use maps electronically. Although the data collection process can be tedious, the ease of generating usable maps and map overlays is significant.

For example, water managers generate maps that show a river's watershed and major tributaries, its floodplains, and the location of urban dwellings (homes, businesses and factories) likely to be


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impacted by floods. This information is valuable to local governments, planners, homeowners, insurers and others. This map also could be compared to land-use maps from 10, 20, or 30 years ago.

One way water managers study drainage basins is by measuring streamflow. Determining how much water is discharged in a watershed involves measuring the amount of water (volume) that flows past a certain point over time. Streamflow is measured in cubic meters per second (m^3/s) or cubic feet per second (cfs).

Scientists calculate average streamflow by measuring the amount of water flowing through a stream channel over years. When streamflow changes significantly from its normal quantities, water managers investigate reasons for this anomaly.

The amount of water discharged in a watershed is influenced by a complex set of factors. Those include upstream human releases of water from reservoirs; availability of snow and ice cover in the upper reaches of the watershed; development of river engineering works, such as dams and levees; rainfall and soil conditions; vegetative coverings; and human settlement patterns.

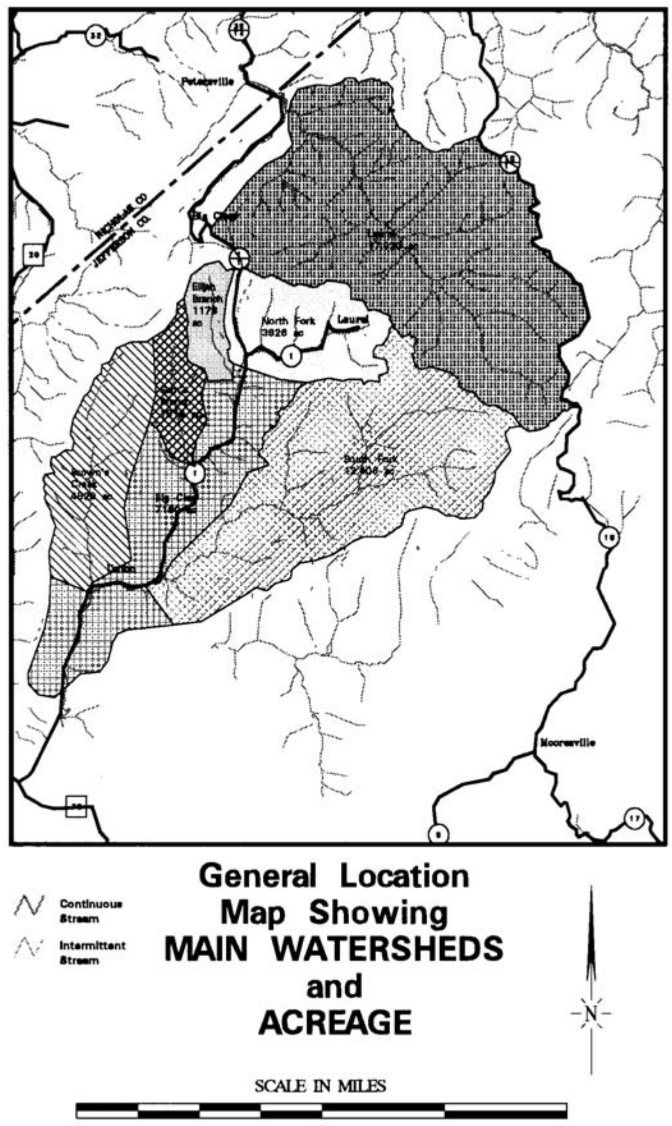
Wetlands, forests, and prairies capture and store more water than paved roads and parking lots. So, urban areas will have more runoff than areas covered with vegetation.

Floodplain managers seek to manage the natural resources there to maximize society's benefits from their long-term use. Floodplain maps from different areas can show development of flood defenses. This may include transportation infrastructure and power plants, agricultural and residential development, and nature reserves benefiting society. Comparing floodplain maps over time can be valuable to community development planners designing strategies for safe, healthy growth of towns and cities.

Water managers assess land-use changes and encourage corresponding development policy. Water managers also seek to cooperate with land-use planners and other local government officials to coordinate planning between land and water development.

For example, in areas susceptible to erosion, soil conservation measures (e.g., planting cover crops on farmland and establishing grassed waterways) can significantly reduce erosion and stream sediment load. Managers may designate lands so susceptible to erosion that landowners are required to plant vegetation. In urban areas, local governments may set aside natural areas as filters for storm-water runoff, based on runoff data and stream-water quality problems. In each situation, water managers can use maps to understand past and present land use to better predict future problems.

Sample GIS map



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Procedure

Warm Up

What did your community's land and water resources look like 50 or 100 years ago? How has growth changed your community?

Ask students to imagine their community 100 years ago. They may want to refer to photographs or news stories. Did the school exist? What happened when precipitation fell then, compared to now? What happened when the floodplain was inundated and what would happen now? If a body of water is near the school, have the years altered its appearance and condition?

Tell students that maps can teach us about the past and possibly answer questions such as these.

The Activity

Provide students with copies of *Maps A, B* and *C*. Explain that they represent aerial views of a watershed taken at different times. To simplify map interpretation, watershed borders coincide with edges of the grid. Also, outlines of land areas (e.g., wetlands, forests) align with grid lines.

Following are three options for interpreting changes in the watershed presented on the maps. The first option may be more appropriate for younger students, but can help all students complete ***Options 2*** and ***3***. Students should be able to multiply and calculate percentages to complete the second and third options.

Option 1

1. **Tell students to look at *Maps A, B* and *C*.** Explain that they represent changes in land use over a 100-year period. Have students review each map key. Instruct them to designate each land area with a different color (e.g., color all forest areas green). Use the same color scheme for all maps.

2. **When students finish coloring, have them compare the sizes of the different areas on each map and among maps**. Ask them to compare plant cover and land-use practices during the 100-year period. They may note changes in crop lands, forests, grasslands, wetlands, urban land uses, etc.

3. **Discuss one or more of the following questions:**

- What happens to the amount of forested land as you go from ***Map A*** to ***Map C***?
- Which map has the most land for human settlements?
- Where are most human settlements located? What benefits or risks do you see in placing those settlements there?
- What effect might these human settlements have on the watershed?
- Would you have directed development differently?

Option 2

1. **Have students determine each map's land area**. Each unit in the grid represents one square kilometer; there are 360 square kilometers (or 360,000,000 m^2) on each map.

2. **For each map, have students determine how much area is occupied by each type of land coverage (e.g., forest, wetland and farmland).** Responses can be guesses or exact calculations. For example, for ***Map A***, 17 of the grid units are occupied by wetlands. By dividing 17 by the total number of units (360), students should calculate that 4.7% of the land area is wetlands.

The land allotted to wetlands, forests, etc. will change for each map, but the stream coverage (111 squares or 30.8%) will remain constant. Students should record their answers in the ***Area of Land Coverage*** chart.

3. **Tell students that the watershed has received 5 cm (0.05 m) of rain.** (Although rain does not normally fall evenly over a large area, assume that the 5 cm of rain fell evenly over the entire

watershed.) By converting both the rainfall and the land area to meters, students can calculate the amount of water (m^3) which fell on the land.

About 18,000,000 m^3 of rain fell on the watershed (0.05 m x 360,000,000 m^2 = 18,000,000 m^3). Of this, 5,550,000 m^3 landed on the stream (111,000,000 m^2 x 0.05 m = 5,550,000 m^3). This might seem like a large quantity, but if 5 cm of rain fell evenly on a watershed of this size, the stream would receive this volume of water. (**Note:** 100 cm = 1 m; 1,000,000 m^2 = 1 km^2.)

4. Ask students to estimate the amount of water that would be drained from the land into the stream. Tell students that for the watershed represented by ***Map A***, 2,767,500 m^3 of rain was runoff (i.e., the water flowed into the stream and did not soak into the ground, did not evaporate and was not used by plants or animals). Runoff volumes are provided in the *Answer Key*. In ***Option 3***, students can calculate runoff for each land area.

5. Discuss land coverage changes represented in *Maps A* through *C*. Ask students if they think the amount of runoff would increase or decrease?

6. Tell students that when 12,450,000 m^3 of rain fell on the land represented by *Map A*, 2,767,500 m^3 was runoff. For *Map B*, 3,102,500 m^3 was runoff. For *Map C*, 4,797,500 m^3 was runoff. Discuss the following questions in addition to those listed in ***Option 1***.

- Which absorbs more water, concrete or forest?
- Which map represents the watershed capable of capturing and storing the most water?
- What problems could result if water runs quickly over surface material, rather than moving slowly or soaking in?
- Look at Map C and note Community A and Community B toward the bottom of the map. What could happen if, due to increased runoff and river discharge, Community A decides to build a levee on its side of the river to reduce the likelihood of flooding? What would happen to Community B that does not have a levee? (People along the Mississippi River in the U.S. had this problem in the 1800s. Each levee district tried to build their levee a little bit higher than the levee on the other side of the river. They would even cross the river in a boat, very quietly at night, and use dynamite to make a hole in the levee across the river. That would relieve the flood water pressure on their levee as floodwaters pored through the hole on the other side of the river. Levee board members on both sides of the river often stayed on their levee all night to protect it from midnight attacks.)
- What solutions may work for the benefit of both communities? (Cooperation and teamwork are required to protect both communities. As long as Community A tries to keep its levee at a higher elevation than Community B, flood disasters will occur on one side of the river or the other. This is unacceptable. Communities must work together, and agree to an equal elevation mark for the top of both levees. This will make the two communities equal partners to protect themselves against flood disasters. On the Mississippi River, the U.S. Army Corps of Engineers eventually took over construction of the levees, and made sure they were the same elevation on both sides of the river.)
- How might the stream's water quality be affected by watershed land-use changes?

Option 3

Have students determine how the figures in *Option 2* were obtained. In the chart ***Volume of Rain*** and ***Volume of Runoff***, each land area has been assigned a proportion of the water not absorbed or that runs off its land surface. Using information from this chart and from the *Area of Land Coverage* chart, have students calculate the amount of water each land area does not absorb.

For example, for the forested land in ***Map A***, 189 km^2 x 1,000,000 m^2/km^2 = 189,000,000 m^2 of land. Multiply this by the amount of rainfall (189,000,000 m^2 x 0.05 m = 9,450,000 m^3). Since 20% of the rainfall was runoff, 1,890,000 m^3 of water drained into the stream from the forested land (9,450,000 m^3 x .20).

Note: Percent runoff figures are based on hypothetical data. To determine how much water is absorbed by surface material requires knowing soil type and texture, slope, vegetation, intensity of rainfall, etc. In addition, many farms and urban areas practice water conservation measures that help retain water and prevent it from streaming over the surface. The information in the chart is intended only for practice and comparisons.

ANSWER KEY: AREA OF LAND COVERAGE

	MAP A 100 years ago		MAP B 50 years ago		MAP C Present	
Land coverage	**km^2**	**%**	**km^2**	**%**	**km^2**	**%**
Forest	189	52.5	162	45	111	30.8
Grassland	20	5.6	14	3.9	6	1.7
Wetland	17	4.7	13	3.6	5	1.4
Residential	13	3.6	33	9.2	58	16.1
Agriculture	10	2.8	27	7.5	69	19.2
Stream	111	30.8	111	30.8	111	30.8

Wrap Up

Have students summarize how land-use changes affect a watershed's quantity and quality of surface-water runoff. Discuss community land-use practices and how they may affect water discharge in the watershed.

Take students on a walking tour of the school and community, and note areas that contribute to or reduce storm runoff. For example, parking lots, paved roads and sidewalks promote runoff; parks, wetlands and trees capture water.

Students could attend a public meeting where community land-use changes are being discussed.

If students were to draw a fourth map of the same area 100 years from now, how would it appear? Have students plan a city that contributes to a watershed's health. They should contact city planners or conduct library research to support their projections.

Assessment

Have students:

- compare land area occupied by farms, towns, and natural areas in a watershed during different time periods (***Options 1*** and ***2***).
- describe how surface-water runoff is influenced by changes in land use (***Option 2***).
- calculate quantities of runoff from different land areas in a watershed (***Option 3***).

Extensions

NOTE: The exercise including the answer key are simplified examples that do not necessarily reflect all physical processes in the catchment. For example, in semi-arid areas the losses from evapotranspiration may increase with increasing forest cover. This can reduce streamflows in the lean season. Similarly the role of wetlands can be very different depending on how much water they already took up from previous rainfall events.

Some caution may also be due concerning the role of forests on flood peaks. For extreme flood events and larger catchments the influence of forest cover on reducing flood peaks may be minimal. One issue that is, however, fairly well established is that deforestation can lead to larger sediment yields in the river. This can cause massive problems for flood managers and river engineers, especially where those sediments are deposited. In those places the flood protection levels may become insufficient over time as the riverbed rises in relation to the adjacent land, or the river takes a different course.

Such questions could be raised and discussed with older students.

Provide discharge values for a specific point on the stream corresponding to

ANSWER KEY: VOLUME OF RAIN AND VOLUME OF RUNOFF

	MAP A 100 years ago		MAP B 50 years ago		MAP C Present	
Land coverage and % runoff	**volume m^3**	**runoff m^3**	**volume m^3**	**runoff m^3**	**volume m^3**	**runoff m^3**
Forest 20% runoff	(9.45×10^6) 9,450,000	(1.89×10^6) 1,890,000	(5.55×10^6) 5,550,000	(1.11×10^6) 1,110,000	(5.55×10^6) 5,550,000	(1.11×10^6) 1,110,000
Grassland 10% runoff	(1.0×10^6) 1,000,000	($.1 \times 10^6$) 100,000	($.7 \times 10^6$) 700,000	($.07 \times 10^6$) 70,000	($.3 \times 10^6$) 300,000	($.03 \times 10^6$) 30,000
Wetland 5% runoff	($.85 \times 10^6$) 850,000	($.425 \times 10^6$) 42,500	($.65 \times 10^6$) 650,000	($.0325 \times 10^6$) 32,500	($.25 \times 10^6$) 250,000	($.0125 \times 10^6$) 12,500
Residential 90% runoff	($.65 \times 10^6$) 650,000	($.585 \times 10^6$) 585,000	(1.65×10^6) 1,650,000	(1.485×10^6) 1,485,000	(2.9×10^6) 2,900,000	(2.61×10^6) 2,610,000
Agriculture 30% runoff	($.5 \times 10^6$) 500,000	($.15 \times 10^6$) 150,000	(1.35×10^6) 1,350,000	($.405 \times 10^6$) 405,000	(3.45×10^6) 3,450,000	(1.035×10^6) 1,035,000
Total runoff		**2,767,500**		**3,102,500**		**4,797,500**
Total runoff plus stream discharge (5,550,000 m^3)		(8.32×10^6) 8,317,500		(8.652×10^6) 8,652,500		(10.347×10^6) 10,347,500

the three runoff values provided under point 6. Have students indicate flood-hazard areas corresponding to those discharge values, (i.e., possible extent of flooding should discharge occur). Discuss the consequence of a levee that could safely discharge the amount of water provided under scenario B (50 years ago) for scenario C (the present).

With land-use changes and resulting streamflow increases, the old levee may not be sufficient to protect the community. If the levee is overtopped under scenario C, a larger area will be covered by water than under scenario B. In addition, constructing a levee provides incentive for increased investment and development of the protected area. Due to increased investment in the community because of the levee's assumed protection, more value is concentrated in the flooded area and damage potential is higher.

Have students explore changes in their community. Usually, maps are available at local, state and federal land and water agencies. Libraries have historical, hand-drawn maps. Employees there also will have information about past, present and future water use.

Students may want to conduct a more accurate analysis of the degree to which different surface areas are permeable to water. Contact community conservation agencies to learn how different soil types affect runoff.

Students can use Geographic Information Systems (GIS) computer technology to better understand geographic features.

Resources

Baker, Jeannie. 1991. *Window*. New York: Greenwillow Books.

Guling, Cynthia L., and Kenneth I. Helphand. 1994. *Yard Street Park*. New York: John Wiley & Sons.

Huff, Barbara A. 1990. *Greening the City Streets: The Story of Community Gardens*. St. Louis, MO.: Clarion.

Leopold, Luna B. 1974. *Water: A Primer*. San Francisco, CA: W. H. Freeman.

Patterson, Mark, and Ron Mahoney. 1993. *Environmental Education Software and Multimedia Source Book*. Moscow, ID: University of Idaho Agricultural Publications.

Hellmund. 1993. *Ecology of Greenways*. Minneapolis: University of Minnesota Press.

e-Links

World Meteorlogical Organization, 2004, Integrated Flood Management Concept Paper, Geneva, available at http://www.apfm.info/pdf/concept_paper_e.pdf

Photo Resources

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Name: ______________________________ Date: ______________

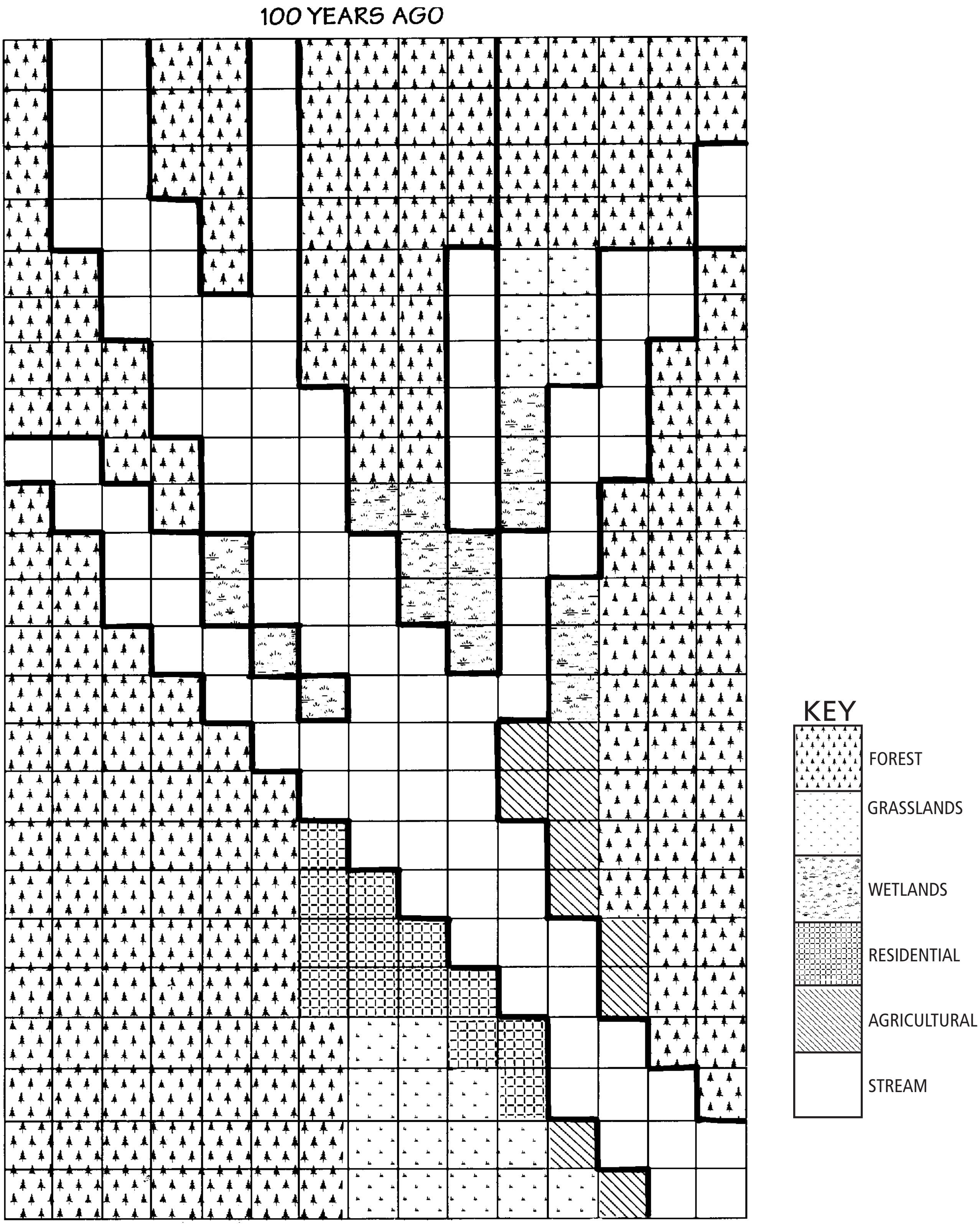
Chart for Option 2 AREA OF LAND COVERAGE

	MAP A 100 yrs. ago		MAP B 50 yrs. ago		MAP C Present	
Land coverage	**km^2**	**%**	**km^2**	**%**	**km^2**	**%**
Forest						
Grasslands						
Wetlands						
Residential						
Agricultural						
Stream						

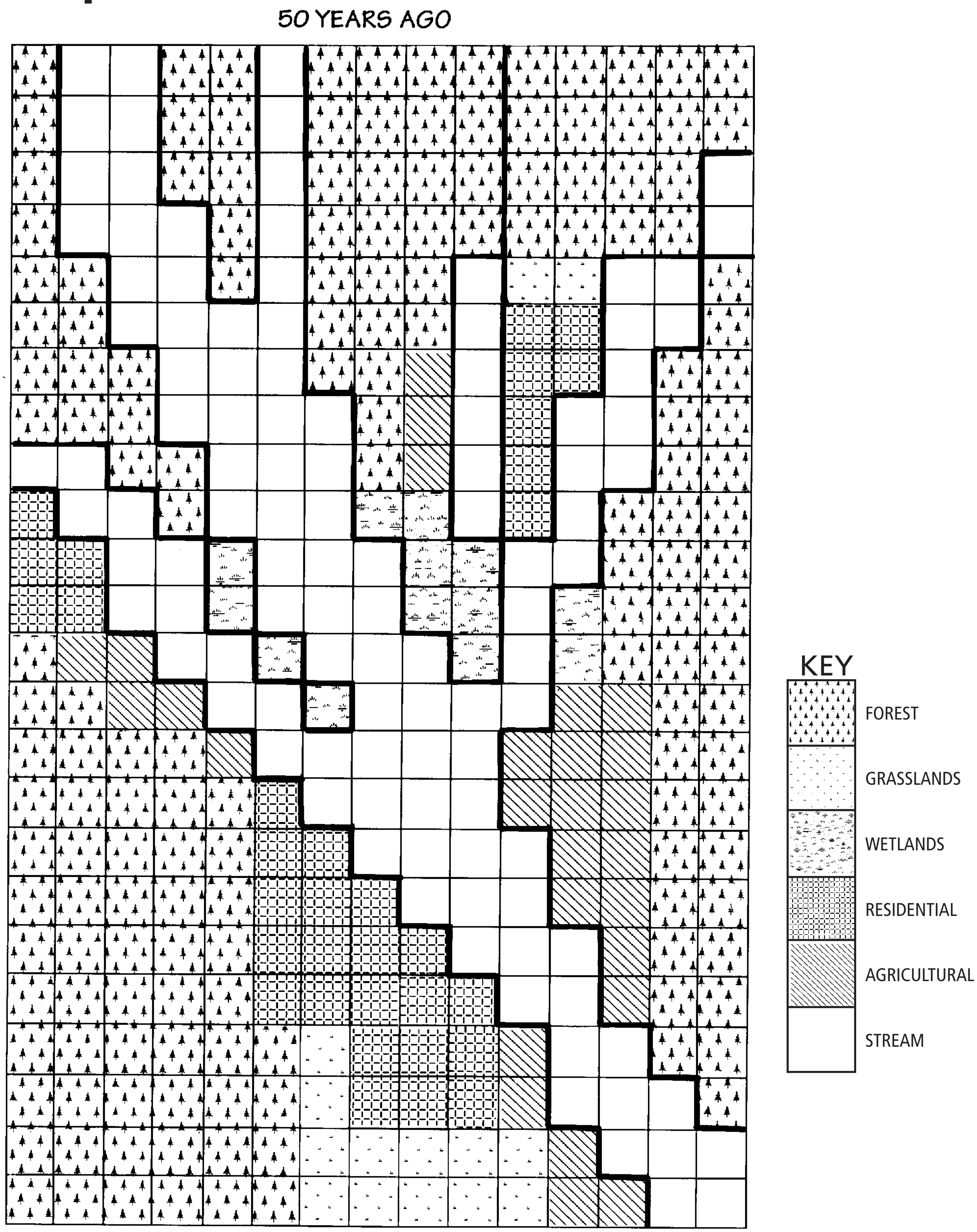
Chart for Option 3 VOLUME OF RAIN AND VOLUME OF RUNOFF

	MAP A 100 years ago		MAP B 50 years ago		MAP C Present	
Land coverage and % runoff	**volume m^3**	**runoff m^3**	**volume m^3**	**runoff m^3**	**volume m^3**	**runoff m^3**
Forest 20% runoff						
Grasslands 10% runoff						
Wetlands 5% runoff						
Residential 90% runoff						
Agricultural 30% runoff						
Total runoff						
Total runoff plus stream discharge (5,550,000 m^3)						

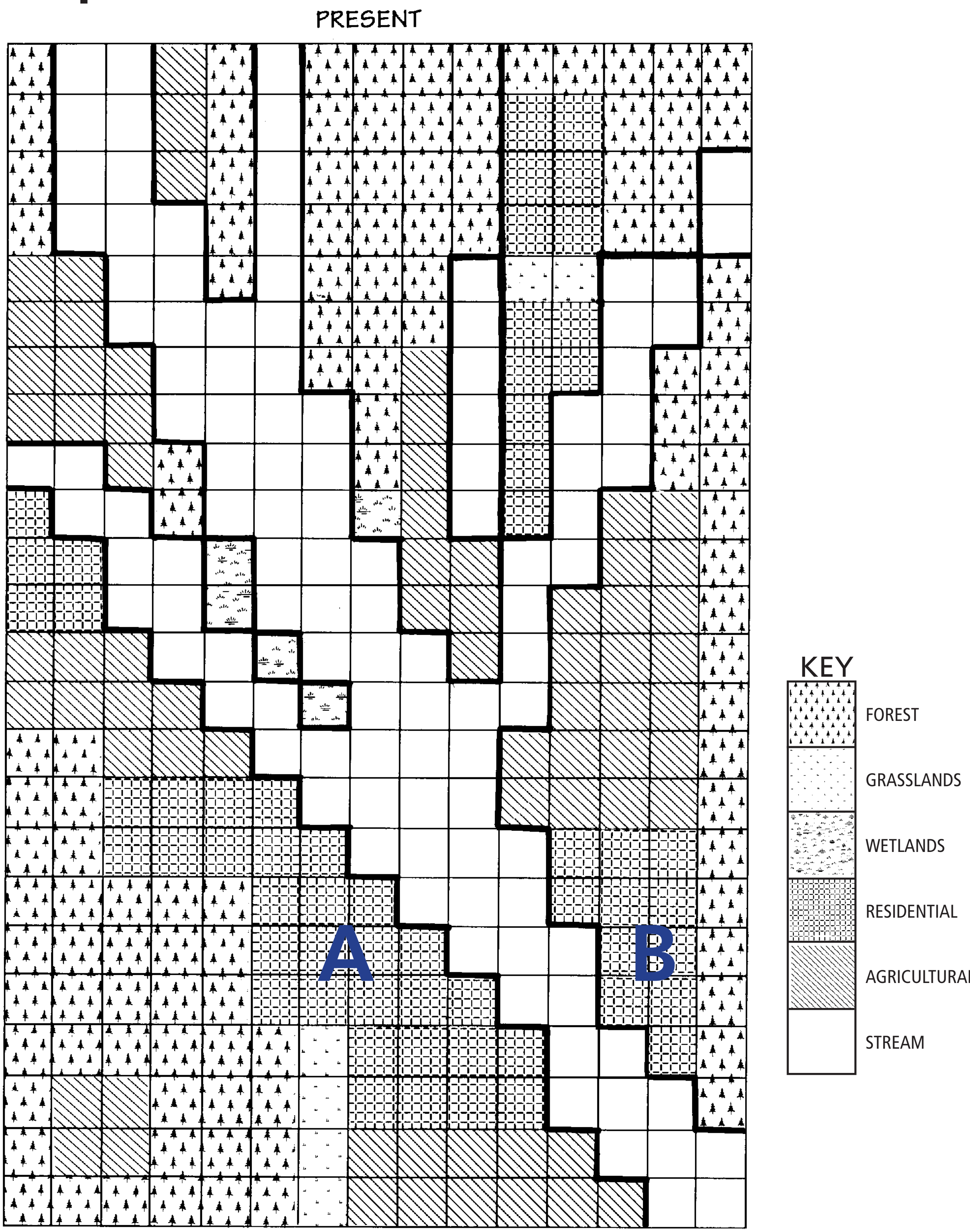
Map A


100 YEARS AGO
KEY
FOREST
GRASSLANDS
WETLANDS
RESIDENTIAL
AGRICULTURAL
STREAM

Map B


50 YEARS AGO
KEY
FOREST
GRASSLANDS
WETLANDS
RESIDENTIAL
AGRICULTURAL
STREAM

Map C


PRESENT
A
B
KEY
FOREST
GRASSLANDS
WETLANDS
RESIDENTIAL
AGRICULTURAL
STREAM