topic VIII

TOPIC VIII - MOISTURE AND ENERGY BUDGETS AND ENVIRONMENT CHANGE

What Happens To Water And Energy Released From The Atmosphere?

Time Emphasis: 11 days

TOPIC OUTLINE

INVESTIGATION		A-1a	A-3a	A-3b	B-1a	B-2a	C-1a	LTI - #15	FEI - #3	FE - #5								
Estimated Time (Periods)		2	1	1	3	2	3											
A. Earth's water																		
A-1 Ground water		*How Does Water Move Into the Earth?*																
A-1.1 Infiltration	A-1.11																	
	A-1.12	■																
A-1.2 Permeability	A-1.21	■																
	A-1.22	■																
A-1.3 Porosity	A-1.31	■																
A-1.4 Capillarity	A-1.41	■																
A-2 Surface water		*How Does Water Move on the Surface of the Earth?*																
A-2.1 Runoff	A-2.11				■	■												
A-3 Pollution of the earth's water		*What Is Man's Effect on the Earth's Water?*																
A-3.1 Sources of pollutants	A-3.11		■						■									
A-3.2 Types of pollutants	A-3.21		■	■					■									
	A-3.22																	
A-3.3 Concentration of pollutants	A-3.31		■			■												
	A-3.32			■														
	A-3.33																	
A-3.4 Long-range effects	A-3.41									■								
	A-3.42			■														
B. The local water budget																		
B-1 Water budget variables		*How Is the Water Budget Influenced by the Environment?*																
B-1.1 Precipitation (P)	B-1.11				■			■										
B-1.2 Potential evapo-transpiration (Ep)	B-1.21				■													
B-1.3 Moisture storage (St)	B-1.31				■			■										
B-1.4 Moisture utilization	B-1.41				■													
B-1.5 Moisture deficit (D)	B-1.51				■													
B-1.6 Moisture recharge	B-1.61				■													
B-1.7 Moisture surplus (S)	B-1.71				■													
B-2 Streams		*How Is the Local Water Budget Related to Stream Discharge?*																
B-2.1 Stream discharge and the water budget	B-2.11					■												
	B-2.12																	
B-3 Climates and the local water budget		*How Is the Local Water Budget Related to Climate?*																
B-3.1 Climatic regions	B-3.11						■											

	INVESTIGATION	A-1a	A-3a	A-3b	B-1a	B-2a	C-1a	LTI - #15	FE - #3	FE - #5
	Estimated Time (Periods)	2	1	1	3	2	3			
TOPIC OUTLINE	C. Climate pattern factors									
	C-1 Factors — *What Factors Affect Climate Patterns?*									
	C-1.1 Latitude — C-1.11				■		■			
	C-1.2 Elevation — C-1.21						■			
	C-1.3 Large bodies of water and ocean currents — C-1.31						■			
	C-1.32						■			
	C-1.4 Mountain barriers — C-1.41						■			
	C-1.5 Wind belts — C-1.51						■			
	C-1.6 Storm tracks — C-1.61									
PROCESS OF INQUIRY OBJECTIVES	Mathematical Skill — PIO-1	■		■				■		
	Measurement Skill — PIO-2	■	■				■	■	■	■
	Creating Models — PIO-3	■			■	■	■			
	Analysis of Error — PIO-4				■					
	Data Analysis — PIO-5	■	■	■	■	■	■	■	■	■
TITLES		Soil Water Movement	Stream Pollution	Water Purification	The Local Water Budget	Stream Hydrograph	Climate of an Imaginary Continent	Soil Moisture	Stream	Beach

Multimedia: Check Multimedia Section of Supplement for reference to this topic.

Challenging (2)

VIII-A-1a: SOIL WATER MOVEMENT

QUESTION:

How does water move into the earth?

MATERIALS:

Ring stand and column clamp; plastic or glass column, at least 30 cm. long; column outlet with clamp fitting; wire screen in bottom of column; 100-ml. graduated cylinder; two 400-ml. beakers (larger, if available); sorted earth materials (sieved sand, gravel, etc.).

SUGGESTED APPROACH:

1. Keep prelab discussion brief. Review the hydrologic cycle, in general, and infiltration of water into soil, specifically.

   The following questions can be raised:

   a) What factors control the amount of water that a soil can hold?

   b) What factors control the rate at which water can seep into soil?

   c) What factors control the amount of water retained in a soil after it is drained?

   d) How does water move through soil?

   e) What direction does water move through soil?

   f) How could any or all of these factors be measured?

2. Have the students set up the apparatus, measure, and record data concerning each variable.

3. Conduct class demonstrations as follows:

   a) Place 100 ml. of loose soil consisting of a mixture of particle sizes in a plastic tube, and measure the amount of water necessary to just cover the upper surface of the particles.

   b) Set up three plastic tubes each about 3/4 filled with different-sized particles (i.e., fine sand, coarse sand, and gravel). Submerge the bases of the tubes equidistant into beakers of water leaving the clamp open so that the water is in contact with the base of the soil column. Mark the level to which the water has risen, with a grease pencil, using 2-minute time intervals. Allow the students to measure and record these measurements during the class period. The apparatus can be left on display for days with a new mark being made on a once or twice per day basis. The rate of rise will decrease rapidly after the first half hour.

4. Have the students graph their results and draw inferences from the graphs.

PRECAUTIONS:

1. Wet particles should be removed and tubes cleaned and dried before rerunning the investigation (push a paper towel wad through the tube with a long stick). If this is not done, allowances must be made for the water that is retained.

2. The larger the particles, the harder it is to estimate when the surface is <u>just</u> covered with water. Some approximating may be necessary.

3. No particle larger than 1/6 of the column diameter will work effectively because of poor packing.

TYPICAL RESULTS:

Student results will be quite varied, but you should expect the following:

1. There should be enough class data to convince the students that porosity is relatively independent of grain size.

2. The smaller the particles, the slower the rate of infiltration (low permeability).

3. The smaller the particles, the higher the rate (and amount) of capillarity.

4. The smaller the particles, the greater the amount of water retained.

MODIFICATIONS:

1. Whenever possible use earth materials; when unavailable, use beads, shot, etc.

2. Three or four tubes with different grain size soils can be set up with the bases of the tubes submerged in water and left for a couple of days to show how high the capillary water will rise if given time.

3. Water retention in soils is related to the surface tension of water. To demonstrate this phenomena, the following demonstration can be done. Fill two new test tubes (make certain lips of the tubes are not scratched) to level full with water and ethyl alcohol. The tubes must be level full. Drop BB's from a height of 1 cm. into each tube, and count the number dropped before the liquid begins to overflow the test tube.

   The higher surface tension in water should allow a considerably larger number of BB's to be dropped into the tube before overflow occurs.

REFERENCES:

Investigating the Earth, pp. 209-210; Teacher's Guide, pp. 258-260.
Ground Water in New York (1964).

VIII-A-1a: SOIL WATER MOVEMENT

QUESTION:

How does water move into the earth?

INTRODUCTION:

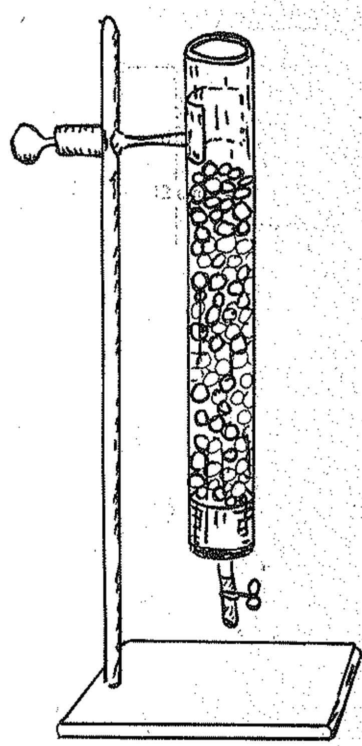
Have you ever seen water seeping or flowing from a hillside? How fast does ground water move through the pore spaces in earth materials? Can water move upward through soil? In this investigation you will find evidence to answer some of these questions and others by examining properties of earth materials that affect the flow of water through soil materials.

OBJECTIVES:

When you have finished this investigation, you should be able to:

1. describe the effects of a change in soil particle size on each of the following:
   a) porosity
   b) permeability
   c) water retention
   d) capillarity

METHOD:



1. Set up the column as shown in the diagram. You will be provided with quantities of different sized particles. Place 100 ml. of one of the sized particles in the column, making sure that the wire screen is in place to prevent the particles from running out.

2. Measure and record the amount of water needed to just cover the upper surface of the particles and the time necessary for the wetting front to reach the bottom of the tube. This will provide a relative measure of the infiltration rate.

3. Open the clamp and allow the water to drain into a clean dry beaker. Remove the beaker when the flow is reduced to dripping, and measure the volume. Calculate the amount of water that was retained by the particles.

4. Repeat the procedure, using as many different-sized particles as you are directed to do.

5. Make observations and measurements of the demonstrations that your teacher has prepared for:

   a) the amount of water necessary to just cover the upper surface of 100 ml. of a loose soil consisting of a mixture of particle sizes.

   b) the rates of capillary action in three soils consisting of different but uniform particle sizes.

6. Prepare graphs of each variable observed (i.e., amount of water needed to fill the pore spaces, time necessary for infiltration, amount of water retained in the soil and capillary movement) vs. time. Examine your graphs and draw inferences from them.

<u>QUESTIONS</u>:

(A-1.12) 1. What soil conditions are necessary for infiltration to occur?

(A-1.21) 2. Describe the relationship between the permeability of soil material and its particle size.

(A-1.22) 3. How far downward will a water molecule move after it infiltrated loose soil?

(A-1.31) 4. What factors influence the porosity of soil material?

5. Which soil particle size retains the greatest amount of water?

(A-1.41) 6. What is the relationship between the capillarity and soil particle size?

Challenging (1)

VIII-A-3a: STREAM POLLUTION

QUESTION:

What is man's effect on the earth's water?

MATERIALS:

Student handout sheets, including supplementary map and graph sheet.

SUGGESTED APPROACH:

1. Conduct a class discussion concerning water pollution, considering the following topics:
   a) How can you define water pollution?
   b) What are some common pollutants found in water?
   c) How could a study be conducted to determine the amount of water pollution existing in an area?
2. Assign the student handout sheets as a homework exercise (including the supplementary sheet).
3. After the students complete the exercise, conduct a brief concluding discussion during which you may want to consider the following:
   a) There are natural forms of pollution as well as manmade forms.
   b) Little can be done to prevent natural pollution, but to add to it unnecessarily is unjustifiable.

TYPICAL RESULTS:

1. Students should easily recognize the close correlation between quantity of dissolved solids in area streams and the bedrock types over which they flow.
2. They should recognize the sharp increase in dissolved solids on graph #1 as being a result of the Tonawanda Creek flowing across a boundary onto rock type B which is rich in dissolved solids.
3. Observations of graph #2 should result in the inference that the sharp increase in dissolved solids at Gowanda is most likely due to man's polluting the stream at that point since the stream flows over only one bedrock type.

BACKGROUND INFORMATION:

The total dissolved solids illustrated in graphs #1 and #2 include - SiO_2, Ca, Mg, Na, K, HCO_3, SO_4, Cl, and NO_3.

REFERENCES:

Erie-Niagara Basin, Chemical Quality of Streams, Basin Planning Report ENB-4, 1968, pp. 9, 29-32. Available from the State of New York Conservation Department, Water Resources Commission.

VIII-A-3a: STREAM POLLUTION

QUESTION:

What is man's effect on the earth's water?

INTRODUCTION:

Water pollution concern has increased greatly in recent years, probably due to the fact that increasing populations have greater needs for pure water. However, water pollution is not a new situation; in areas of high density population it has proven to be a problem through the ages. For example, one of the first recorded incidences, of large magnitude, occurred during the barbarian invasion of Rome during the fourth century A.D. The sewer system of Rome, clogged by silt and refuse, fell into ruin. Farmlands drained by the Cloaca Maxima reverted to a malarial swamp (the Pontine marshes). As a consequence, plagues and malaria debilitated thousands of Roman citizens when their services were needed to defend the Empire.

During the Civil War, water pollution probably resulted in deaths due to dysentery, typhoid, hepatitis, etc., and may have spelled the difference between victory and defeat in some crucial battles.

Long before man's existence, the environment was contaminated with natural undesirable ingredients. Examples of natural pollution might include dust, silt, volcanic products, and chemicals dissolved from rock and soil over which the water has passed. These forms of natural pollution are still in existence today and, with the addition of wastes by man, the problem is compounded.

OBJECTIVES:

When you have finished the investigation, you should be able to:

1. analyze maps and graphs of water quality data, and draw inferences concerning probable sources of pollution.

METHOD:

1. Study map #1, and make careful observations concerning: the area of New York State represented, the types of bedrock present and where they are exposed at the surface, the locations of Tonawanda and Cattaraugus creeks and the major population centers.

2. Compare map #2 with map #1 and draw inferences from your observations.

3. Observe graph #1, and compare it with map #1. Draw inferences

concerning the probable sources of the dissolved solids.

4. Observe graph #2 and compare it with map #1. Draw inferences concerning the probable sources of the dissolved solids.

QUESTIONS:

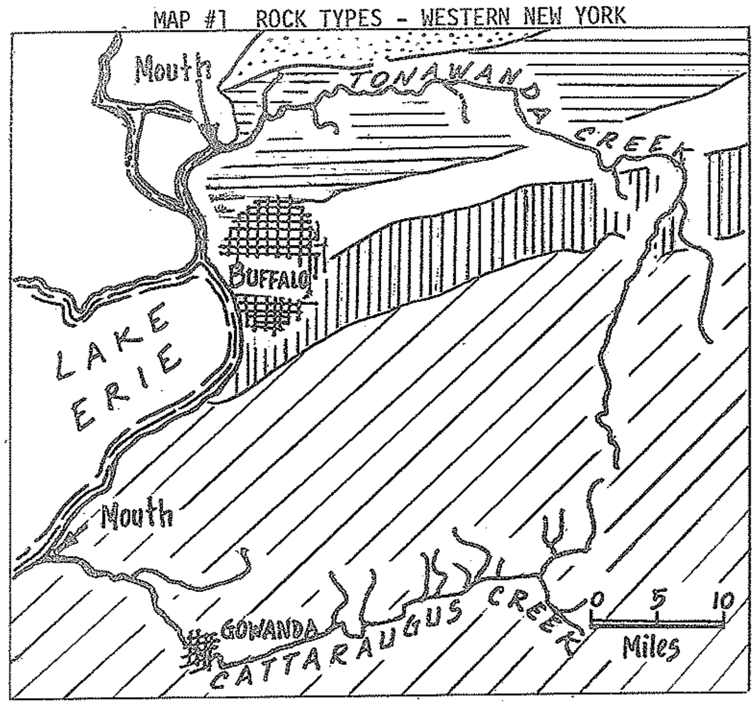
(A-3.11) 1. What are the probable sources of the pollutants found in both creeks?

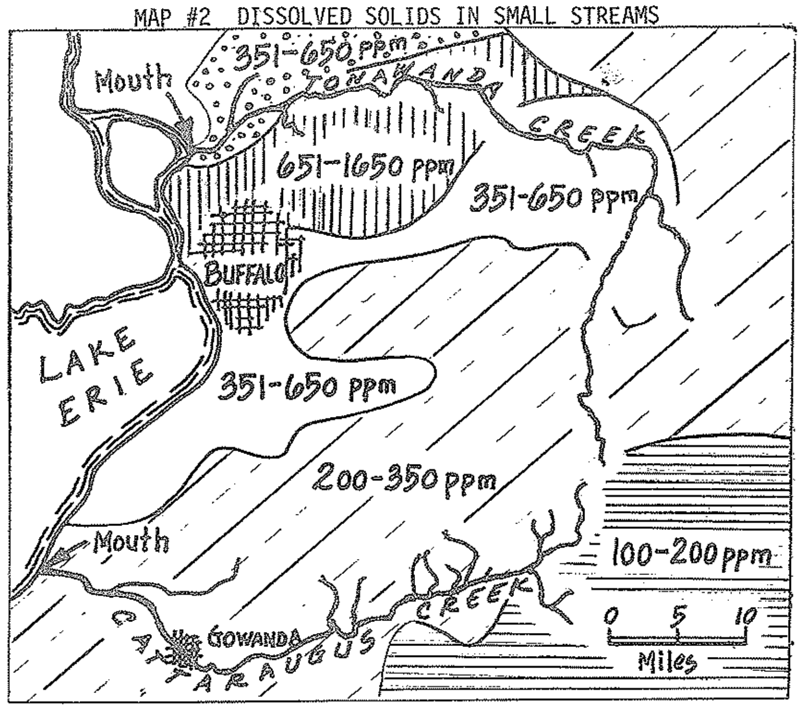
(A-3.21) 2. What kinds of pollutants are studied in this investigation?

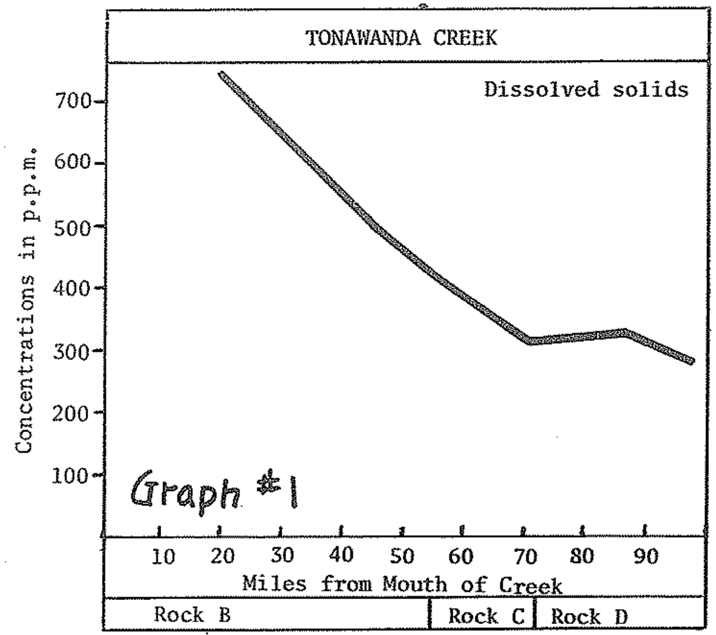
(A-3.31) 3. Where are the greatest increases in the amount of pollutants in the streams observed?

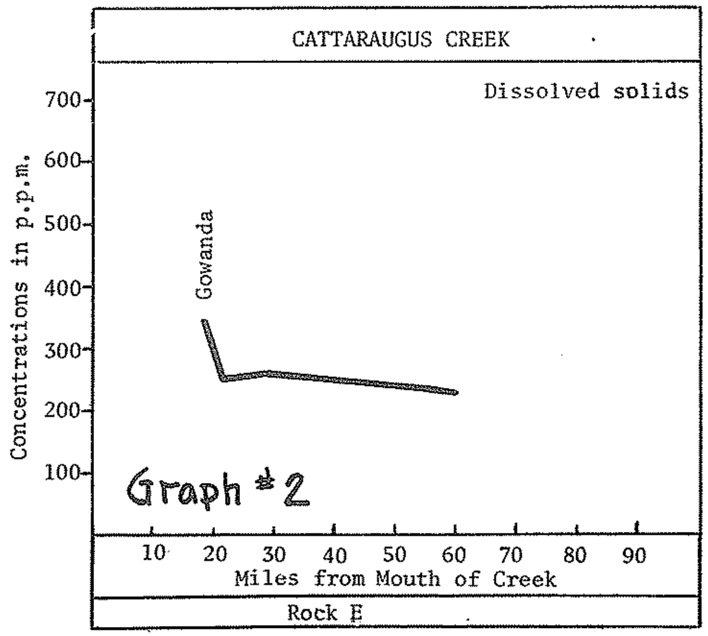
KEY

- Rock A — Low solubility
- Rock B — High solubility
- Rock C — High solubility
- Rock D — Low solubility
- Rock E — Low solubility









Easy (1)

VIII-A-3b: WATER PURIFICATION

QUESTION:

What is man's effect on the earth's water?

MATERIALS:

Large beaker, glass, or jar; muddy water (can be made from clay or soil and clear water); sodium bicarbonate; aluminum sulfate solution (most liquid deodorants and styptic pencils, used to stop bleeding from small cuts, contain aluminum sulfate).

SUGGESTED APPROACH:

1. Discuss with the students, problems in pure water shortages that exist today. Ask them to identify some solutions to these problems. Water recycling should be included in the discussion.

2. Discuss some of the problems faced in removing pollutants from water and making it usable for humans to drink.

3. Provide the necessary materials and have the students complete the laboratory part of the investigation.

PRECAUTIONS:

1. If the water is too muddy, it may take longer than a period to coagulate. It may be necessary to dilute the muddy water with some fresh water to speed up the process. You may want to find the right combination before the class tries the investigation.

TYPICAL RESULTS:

The muddy water should clear up in a matter of minutes after the chemicals have been added and stirring has taken place.

MODIFICATIONS:

1. Filtration and the purifying effect of biologic action can be demonstrated by using a large pipe. The pipe should be 4 to 6 inches in diameter and 8 to 12 feet long (e.g., plastic drain pipe). The pipe should be capped at one end with a fine screen and supported in a vertical or near vertical position. A pail of polluted water should be positioned above the pipe and siphoned into it. The siphon tube can be clamped so that the water enters at a rate less than the permeability rate of the sand. In a few days, the water should begin to trickle out of the lower end of the tube. This water can then be observed and tested for purity.

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VIII-A-3b: WATER PURIFICATION

QUESTION:

What is man's effect on the earth's water.

INTRODUCTION:

Man's population and water needs are both increasing. At the same time, he is continuing to pollute more of the hydrosphere. This set of conditions can only result in an eventual shortage of natural pure water. Because of this, more attention is being given to techniques of water purification.

The cost of purifying fresh (not waste) water ranges from a few pennies to seldom more than about twenty-five cents per thousand gallons. For purifying waste water, the cost will usually be greater, possibly as much as double.

The responsibility for designing and operating a water purifying plant is usually given to the chemist or chemical engineer. What are some ways in which waste water can be purified?

METHOD:

1. Place some muddy water in a beaker. Allow a few minutes for the heavy particles to settle to the bottom, then pour the partially settled water into another beaker.

2. To be sure that the water is sufficiently alkaline, dissolve a small amount of sodium bicarbonate in it.

3. Next, dissolve a small amount of aluminum sulfate in the water. (This can be accomplished by scraping the edge of a styptic pencil (which contains aluminum sulfate) with a sharp knife.)

4. Stir the mixture rapidly at first, to assure quick dispersion; then slowly, as a change begins to occur.

5. After stirring for 2 or 3 minutes, allow the mixture to stand.

6. Make careful visual observations of the changes that occur in the beaker, and record them.

QUESTIONS:

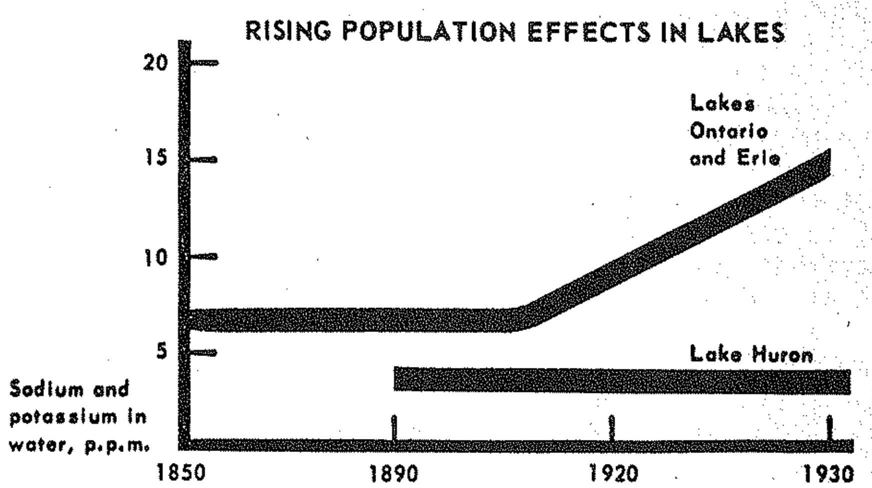
1. What change occurred in the beaker after the aluminum sulfate was added?

2. How does this change "purify" the water?

3. After the change has occurred, is the remaining water "pure"?

(A-3.21) 4. What are the characteristics of the pollutant that was removed from the water in this investigation?

(A-3.32) 5.



a) Which of the lake regions represented in the graph above would you expect to be most heavily populated? Explain.

b) On which of the lakes would you expect to find the greatest amount of industry? Explain.

c) What are some possible interpretations for the change in the graph of Lakes Ontario and Erie?

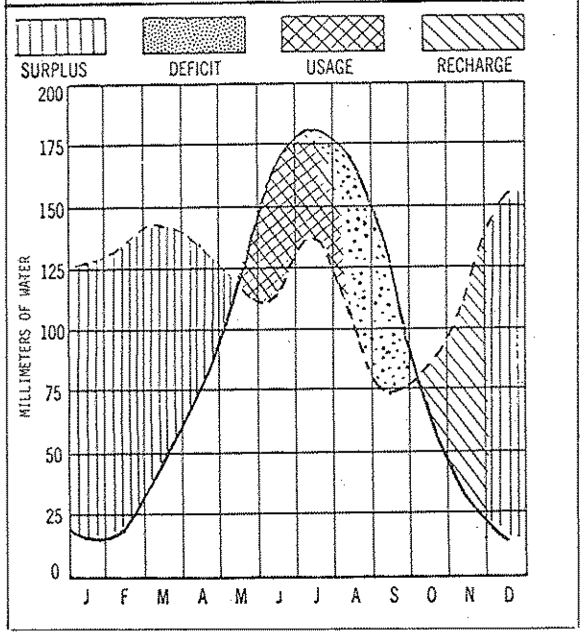
(A-3.42) 6. Assuming that each person uses about 100 gallons of water per day and the approximate cost of purifying water is twenty-five cents per thousand gallons, what is the annual cost to purify water for use by you as an individual and by your community?

TYPICAL RESULTS:

WATER BUDGET

FOR: Alexandria, Louisiana

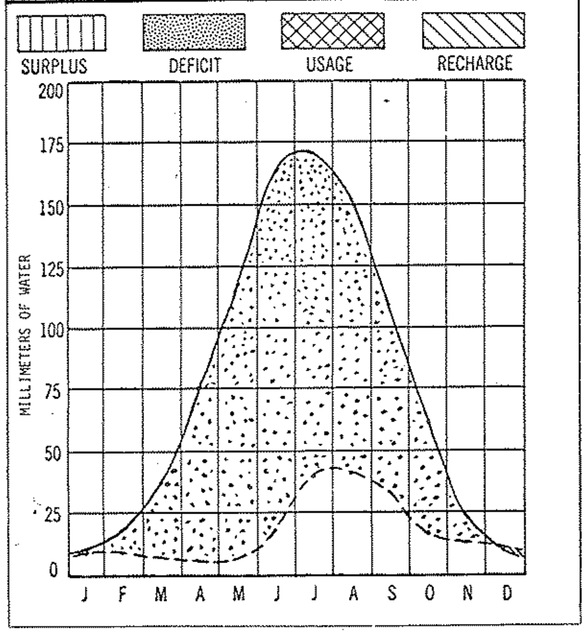
	J	F	M	A	M	J	J	A	S	O	N	D	Totals
P	127	133	142	134	119	115	136	106	73	85	111	152	1433
E_P	15	18	45	75	122	164	179	170	129	69	31	15	1032
$P-E_P$	112	115	97	59	-3	-49	-43	-64	-56	16	80	137	
ΔSt	0	0	0	0	-3	-49	-43	-5	0	16	80	4	
St	100	100	100	100	97	48	5	0	0	16	96	100	
E_A	15	18	45	75	122	164	179	111	73	69	31	15	917
D	0	0	0	0	0	0	0	59	56	0	0	0	115
S	112	115	97	59	0	0	0	0	0	0	0	133	516



WATER BUDGET

FOR: El Paso, Texas

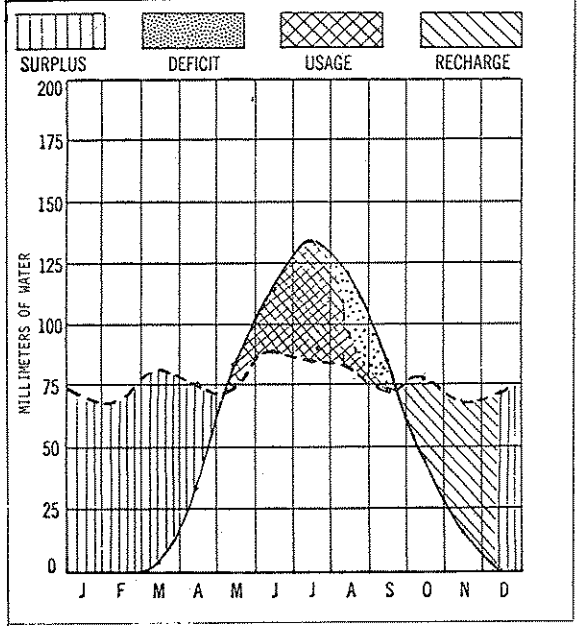
	J	F	M	A	M	J	J	A	S	O	N	D	Totals
P	10	11	8	7	8	18	40	41	33	17	13	12	218
E_P	11	18	37	75	117	163	171	152	111	62	24	10	951
$P-E_P$	-1	-7	-29	-68	-109	-145	-131	-111	-78	-45	-11	2	
ΔSt	-1	-1	0	0	0	0	0	0	0	0	0	2	
St	1	0	0	0	0	0	0	0	0	0	0	2	
E_A	11	12	8	7	8	18	40	41	33	17	13	10	218
D	0	6	29	68	109	145	131	111	78	45	11	0	733
S	0	0	0	0	0	0	0	0	0	0	0	0	0



WATER BUDGET

FOR: Syracuse, N. Y.

	J	F	M	A	M	J	J	A	S	O	N	D	Totals
P	72	68	81	75	74	87	84	82	72	76	68	72	911
E_P	0	0	3	34	83	115	134	122	84	46	15	0	636
$P-E_P$	72	68	78	41	-9	-28	-50	-40	-12	30	53	72	
ΔSt	0	0	0	0	-9	-28	-50	-13	0	30	53	17	
St	100	100	100	100	91	63	13	0	0	30	83	100	
E_A	0	0	3	34	83	115	134	95	72	46	15	0	597
D	0	0	0	0	0	0	0	27	12	0	0	0	39
S	72	68	78	41	0	0	0	0	0	0	0	55	314



Difficult (3)

VIII-B-1a: THE LOCAL WATER BUDGET

QUESTION:

How is the water budget influenced by the environment?

MATERIALS:

Student handout sheet (Supplementary Sheet), three copies for each student.

SUGGESTED APPROACH:

1. Hold a class discussion during which the terminology used can be explained as the need arises. Use the blackboard or overhead projector and work through the Alexandria, Louisiana Water Budget table with the students participating. It is best not to have it prepared on the board before class, but fill it in with student help. Prepare a water budget graph for Alexandria, Louisiana. Have students fill in their own table and graph on their lab handout sheets while you or a student fills in the one on the board.

2. The remainder of the handout sheets can be completed as a homework assignment.

3. When the assignment is completed, conduct a class discussion including the following topics:

   a) Hydrologic cycle, how it works.
   b) Factors that determine which will occur, infiltration or surface runoff.
   c) Factors that determine whether infiltrating water will stay in the rooting zone as stored capillary water or will continue downward to the water table.
   Note: For more information, refer to Background Information.
   d) How climate characteristics can be inferred from observations of water budgets.

PRECAUTIONS:

1. Students tend to get so involved in finding the right answer to the bookkeeping problems that they lose sight of the real purpose of the lab.

2. Students tend to conclude that soil saturation alone controls runoff.

3. This investigation should be completed before doing the stream hydrograph investigation.

TYPICAL RESULTS:

1. Many students will falter with the bookkeeping and graphing the first time through. Continue to work with them until they understand that the bookkeeping and graphing are only mechanisms which will help them understand the water income, storage, and outgo relationship in a particular area. Eventually, most of the students should recognize this. Concentrate on their understanding of this relationship, and the arithmetic should eventually make more sense to them.

2. See diagrams on next sheet for typical results of the three areas investigated.

MODIFICATIONS:

Water budgets are available for most areas in New York State. The teacher may want to include more local data, either in place of or in addition to the data given in this lab.

BACKGROUND INFORMATION:

1. The hydrologic cycle operates like a pumping system with solar energy and gravity acting as the driving force. The water comes to the earth from the atmosphere as precipitation and condensation, from the earth to the atmosphere as evaporation and transpiration.

2. Not all the water on the earth is in motion. At any given moment, only about 5 gallons of every 100,000 is in motion. The rest is stored in the oceans, glaciers, underground water, and surface water.

3. Areas having excess solar energy (dry areas) will evaporate most of the precipitation arriving in the area.

4. Areas having excess precipitation (moist areas) will not evaporate all the precipitation arriving. The excess precipitation will either leave the area as surface runoff, be stored as capillary water within the rooting zone of plants, or penetrate through to the water table.

   Factors determining which will occur, infiltration or surface runoff.

   A. Texture and structure of the soil - porosity and permeability.

   B. Thickness of the soil and water-absorbing characteristics of the bedrock underlying the soil.

   C. Slope of the land - steep slopes promote runoff; flat land promotes infiltration.

   D. Vegetative cover - vegetation decreases the velocity of raindrops and helps preserve the structure of the soil.

   E. Rate of precipitation - if the rate of precipitation exceeds the permeability rate of the soil, the surface zone will become saturated, encouraging runoff. (Relate this to Lab VIII-A-1a Water Movement Through Soils.)

5. Water that infiltrates into the soil may remain above the water table and within the root zone of plants as "capillary water," or it may continue to move downward as "gravity water" until it reaches the water table. This will depend on the dryness of the soil. The dryer the soil, the more water will be retained as capillary water. After the soil reaches a certain moisture content, the remainder of the infiltrating water will continue to move downward under the influence of gravity until it reaches the water table, or saturated zone.

   Note: Water budget computations consider only the "capillary water" stored above the water table and within the rooting zone of plants (this can extend downward from the surface 0-10 meters or more). Infiltrating water which passes through this zone and on to the water table is handled under the heading of surplus, since much of the excess will eventually seep back into stream beds and leave the area.

REFERENCES:

Investigating the Earth, pp. 218-223; Teacher's Guide, pp. 267-273.
The Earth Sciences, A. N. Strahler, Chapter 25.

VIII-B-1a: THE LOCAL WATER BUDGET

QUESTION:

How is the water budget influenced by the environment?

INTRODUCTION:

What happens to the precipitation and condensation that reaches the earth's surface? If we were to investigate this question in a local area, we would find that some water escapes from the region in stream flow, some evaporates or is transpired by plants, and some sinks into the ground.

This information may be summarized in the following equation: Precipitation = evapotranspiration + stream flow + infiltration, or in symbols:

$$P = Ea + S.F. + I.$$

In a local area drained by one stream, we could measure some of these variables. The total precipitation can be measured by using rain gauges placed randomly throughout the area. The stream flow can be measured by determining the volume of water passing through the stream channel at a point where it leaves the area. Infiltration can be determined by observing water level changes in dug wells where the porosity of the soil is known.

Evapotranspiration is not as easily measured because of interaction between variables such as: wind velocity, relative humidity, temperature, and various types of vegetation, each with a different transpiration rate. However, by rearranging the above equation to $Ea = P - S.F. - I$, we can solve for Ea.

This method is sometimes used to determine the input - output relationship of water in an area. Because of the expense involved in carrying out a prolonged investigation of this type, it is seldom done unless warranted by major projects such as vast irrigation systems, dam building, etc.

The water budget is a model which can be used to analyze the changes that occur within an area. The model is an approximation for a general area and does not always represent specific conditions at all points within the region.

The values that are derived in the table will help you determine probable periods of water runoff and water storage.

OBJECTIVES:

When you have finished this investigation, you should be able to:

1. when given the Ep and P data for a locality and the maximum soil storage in mm. of water, you should be able to:

   a) identify the climate as being moist or dry.

   b) identify months when maximum surface runoff will likely occur (flood potential).

   c) identify months when soil moisture storage is at a minimum and irrigation may be desirable.

   d) identify periods of soil moisture usage and recharge.

METHOD:

1. Complete the water budget table for Alexandria, Louisiana, and prepare a water budget graph.

2. Prepare a water budget graph for Syracuse, New York and El Paso, Texas.

   On each of the water budget graphs, label the following, if present:

   A. USAGE - months when stored moisture was withdrawn from the plant rooting zone of the soil by plants and evaporation.

   B. RECHARGE - months when the stored moisture within the rooting zone of plants was replenished.

   C. SURPLUS - months when storage within the rooting zone was at a maximum (100 mm.) and surface runoff or penetration through to the water table occurred.

   D. DEFICIT - months when solar energy is available to withdraw moisture but none is available either in the rooting zone moisture or as fresh precipitation.

QUESTIONS:

(B-1.11) 1. What is the moisture source for a water budget?

(B-1.21) 2. What factors determine the maximum evapotranspiration that can occur in an area?

(B-1.31) 3. What was assumed to be the maximum amount of water that could be stored within the rooting zone of plants as capillary water?

(B-1.41) 4. When precipitation is less than potential evapotranspiration, what is likely to happen to soil moisture storage?

(B-1.51) 5. When does a moisture deficit exist?

(B-1.61) 6. When precipitation is more than potential evapotranspiration, what will happen to soil moisture storage?

(B-1.71) 7. What are the conditions under which surplus moisture may exist?

(A-2.11) 8. What are some surface or near surface soil conditions that might lead to surface runoff?

9. Which climate is most desert-like, El Paso or Alexandria?

10. How does the climate of Syracuse compare to El Paso and Alexandria?

11. Why are the Ep values high in the summer and low in the winter?

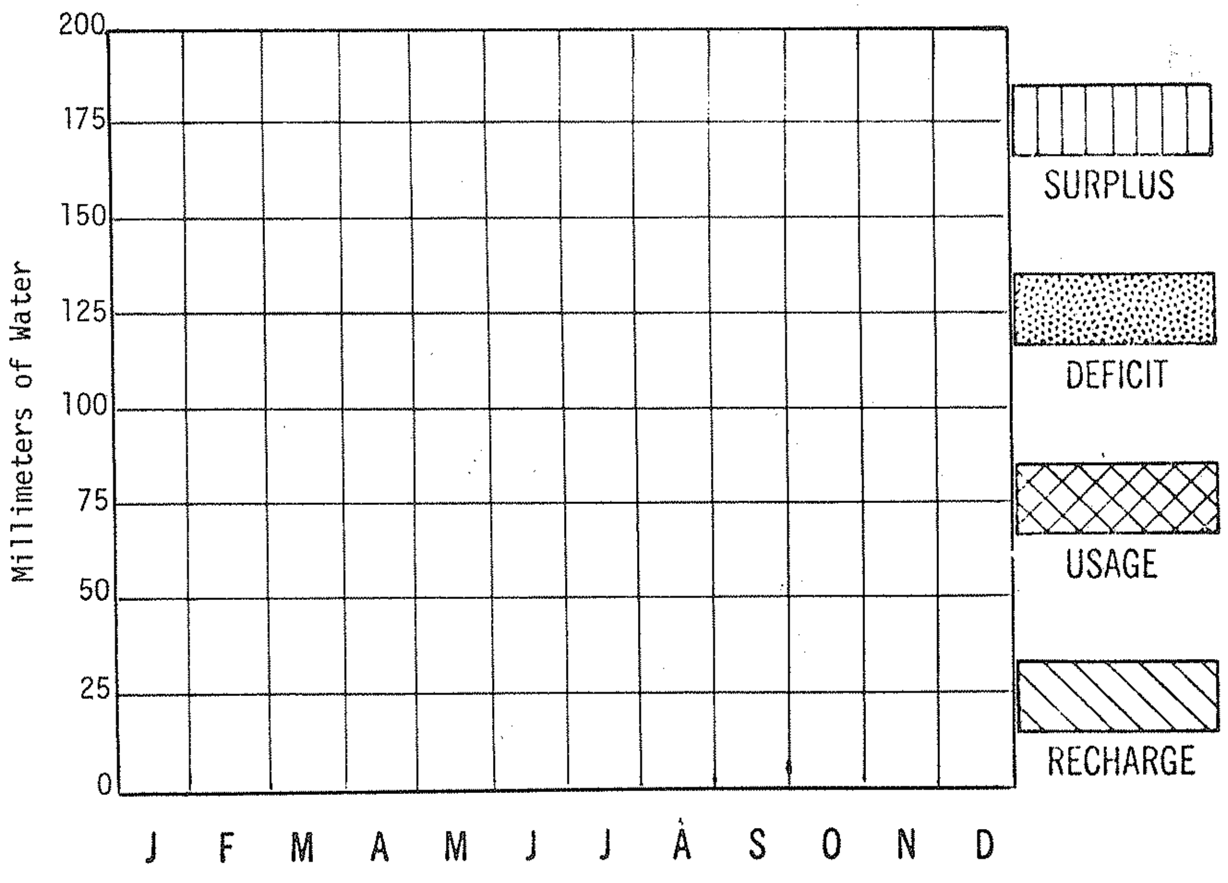
(C-1.11) 12. What factor probably accounts for the similarity between the Ea curves of El Paso and Alexandria and the dissimilarity of the Ea curve for Syracuse?

13. How does the water budget of an area where freezing winter temperatures are experienced differ from water budgets of an area where the temperature remains above freezing all year?

(Water Budget Table & Graph)

		J	F	M	A	M	J	J	A	S	O	N	D
Alexandria, Louisiana	P	127	133	142	134	119	115	136	106	73	85	111	152
	Ep	15	18	45	75	122	164	179	170	129	69	31	15
Syracuse, N.Y.	P	72	68	81	75	74	87	84	82	72	76	68	72
	Ep	0	0	3	34	83	115	134	122	84	46	15	0
El Paso, Texas	P	10	11	8	7	8	18	40	41	33	17	13	12
	Ep	11	18	37	75	117	163	171	152	111	62	24	10

	J	F	M	A	M	J	J	A	S	O	N	D	Totals
P													
E_P													
$P-E_P$													
ΔSt													
St													
E_A													
D													
S													



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Challenging (2)

VIII-B-2a: STREAM HYDROGRAPHS

QUESTION:

How is the local water budget related to stream discharge?

MATERIALS:

1. Tables of daily streamflow measurements for: Horsepen Creek, Harbor Brook, and Government ditch (supplementary sheets).
2. Completed copies of the local water budget investigation.

SUGGESTED APPROACH:

1. Review concepts of the water budget with the students. Place emphasis on conditions that result in surface runoff. Ask the students how information concerning runoff from an area could be measured.
2. Have the students graph data (see precaution #2). This can be accomplished as a homework assignment, providing a uniform graphing scale is agreed upon.
3. When the assignment is completed, have the students connect their sections of the graphs. Display the three completed graphs on the wall. Ask the students to observe and compare the stream hydrograph with the water budget from the same area and to defend their comparisons in each case.

PRECAUTIONS:

1. The water budget investigation should be completed before this investigation is begun.
2. Make the job of graphing brief. Expecting a student to graph an entire year by days, or even by weeks, is tedious. Have each student graph a small part, and then combine the parts for a large yearly graph. This way, many hydrographs can be easily completed.
3. Do not indicate the locations of these streams to the students until completion of the investigation.

BACKGROUND INFORMATION:

1. Horsepen Creek is located near Provencal, La. The measurement was made near the left bank on downstream side of bridge on State Highway 117, 3 1/2 miles south of Provencal. This location is approximately 50 miles NW. of Alexandria, Louisiana.
2. Harbor Brook is located near Syracuse, N.Y. The measurement was made on the right bank 145 feet downstream from bridge on Velasko Road at Syracuse, Onondaga County, and about 3 miles upstream from the mouth.
3. Government ditch is located near El Paso, Texas. The measurement was made at the intersection of Montana and Houston Streets, El Paso, Texas.

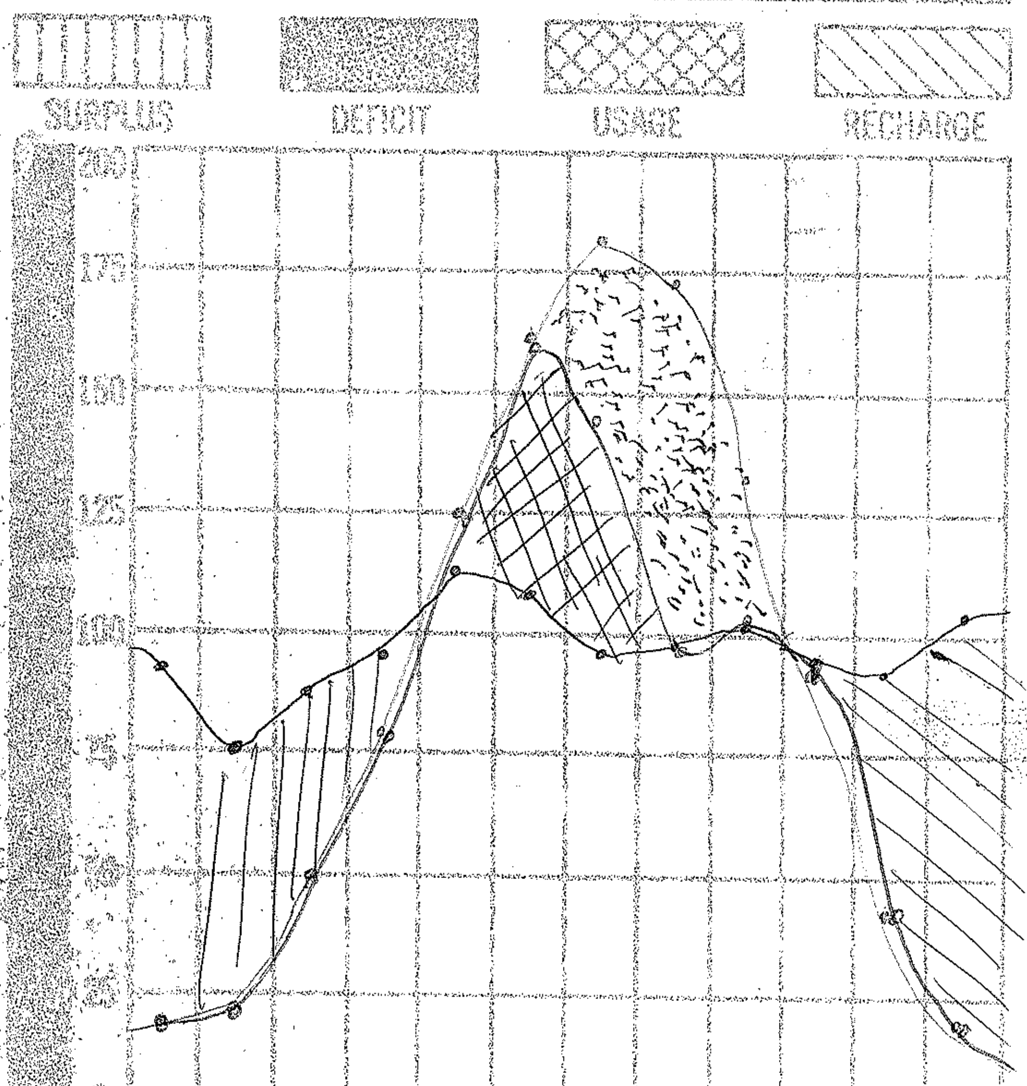
P 218 ESCP Text

P . Precipitation
PE Potential Evaporation
ΔST Change in Soil Moisture

WATER BUDGET

FOR: Houston, Texas

	J	F	M	A	M	J	J	A	S	O	N	D
P	89	75	85	92	119	116	98	99	103	95	89	108
PE	19	23	50	83	125	166	182	172	135	81	39	20
P-PE	70	52	35	9	-6	-50	-84	-73	32	14	50	88
ΔST	0	0	0	0	-6	-50	-44	0	0	14	50	36
ST	100	100	100	100	94	44	0	0	0	14	64	100
AE	19	23	50	83	125	166	142	99	103	81	39	20
D	0	0	0	0	0	0	40	73	32	0	0	0
S	70	52	35	9	0	0	0	0	0	0	0	52



REFERENCES:

Investigating the Earth, pp. 204-225, Teacher's Guide, pp. 255-279.
Water Resources Data for Texas - 1968, Part I, Surface Water Records.
Water Resources Data for Louisiana - 1968, Part I, Surface Water Records.
Water Resources Data for New York - 1968, Part I, Surface Water Records. This catalog of streamflow data can be obtained from the District Chief, Water Resources Division, U. S. Geological Survey, P. O. Box 948, Federal Building, Albany, New York.

VIII-B-2a: STREAM HYDROGRAPHS

QUESTION:

How is the local water budget related to stream discharge?

INTRODUCTION:

What is the pattern of streamflow throughout a year? How is the change in volume of a stream related to the water budget? Would you expect a seasonal pattern to exist in streamflow? In this investigation, you will analyze streamflow data and compare it with the water budget from the area.

OBJECTIVES:

When you have finished this investigation you should be able to:

1. identify the months during which maximum and minimum streamflow occurred when provided with a yearly hydrograph for a stream;

2. match a stream hydrograph of an area with a water budget from the same climatic region.

METHOD:

1. Graph the data provided in the manner explained by your teacher.

2. Compare your graph or graphs with the water budgets that are available to you.

3. The stream hydrographs you have prepared are for streams in the vicinity of each of the three water budget areas that you worked with in a previous lab. Observe the characteristics of both your water budgets and stream hydrographs, and attempt to match the hydrograph with the water budget area near which the stream is located.

QUESTIONS:

1. Compare the land area drained by each of these streams. Describe their sizes relative to some local streams with which you are familiar.

(A-2.11) 2. What is the relationship between streamflow and precipitation? Will this relationship be more pronounced in a small stream or in a very large stream? What factors other than precipitation might affect the rate of increase of stream discharge?

(A-3.31) 3. According to the "Remarks" concerning flow of Harbor Brook, what effect has man had on this stream? What density of human population would you expect to find near the gauging station in this stream.

(B-2.11) 4. What could be the source of the water that keeps streams flowing even during long periods of no precipitation?

(A-2.11) 5. What is the basis on which streamflow data can be matched with water budget data?

Horsepen Creek

Discharge, in cubic feet per second, water year Oct. 1967 to Sept. 1968

Day	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
1	.20	.43	.32	2.3	1.6	4.8	2.1	1.3	1.0	.32	.32	.80
2	.18	.32	.43	2.9	3.1	3.5	120	1.2	.92	2.1	.30	.80
3	.16	.30	.64	2.6	1.9	5.3	28	1.2	1.1	6.5	.30	1.1
4	.15	.24	.40	5.8	1.4	3.4	106	8.9	.96	1.1	.28	11
5	.14	.28	.32	31	1.1	2.9	32	2.8	.76	.61	.24	24
6	.14	.28	.32	44	.96	3.7	8.5	1.2	.88	.43	.22	11
7	.14	.28	.32	5.5	.88	3.4	4.2	1.1	1.1	.34	8.1	2.9
8	.16	.28	.32	3.0	.84	2.7	269	1.1	1.1	.30	20	1.4
9	.24	.28	.37	100	.88	2.5	280	2.9	.92	.30	1.4	1.2
10	.16	.28	.55	42	.88	2.4	48	119	.84	.34	5.5	1.1
11	.15	.26	.61	7.9	.88	9.5	21	42	.80	.32	108	1.1
12	.14	.26	.80	4.0	.84	19	14	31	.76	.32	159	1.0
13	.14	.28	.55	3.1	.84	4.4	12	9.3	.72	.37	105	.92
14	.14	.28	2.4	2.7	.88	3.0	9.7	4.5	.68	.37	21	.88
15	.13	.26	49	2.3	1.9	2.6	8.1	3.0	.64	.40	11	9.1
16	.43	.26	5.3	2.0	1.7	2.3	6.7	2.4	1.1	.37	7.5	5.8
17	.43	.28	8.9	1.9	1.3	2.0	6.0	48	.64	.37	5.7	6.0
18	.24	.26	3.8	1.7	1.3	1.9	5.3	79	.52	.52	4.7	4.4
19	.20	.28	1.3	1.6	1.3	1.7	4.8	9.3	.52	.80	3.3	1.2
20	.20	.30	.88	1.5	1.1	1.8	4.4	4.1	.49	.61	2.8	1.1
21	.20	.30	.80	1.4	1.1	6.7	5.1	2.9	.46	1.2	2.4	1.1
22	.20	.32	1.4	1.5	1.4	61	8.1	2.1	.52	11	2.0	1.0
23	.20	.34	.84	12	1.5	14	5.1	1.4	.76	112	1.6	.92
24	.18	.37	.64	7.1	1.6	5.3	4.0	1.2	.84	24	1.2	.88
25	.15	.32	.58	3.2	2.4	3.7	3.1	1.1	.92	6.0	1.2	.80
26	.15	.30	.52	2.3	1.6	3.0	2.8	16	6.3	1.8	1.1	.88
27	.15	.30	.55	1.8	1.2	2.7	2.6	4.4	1.2	1.1	1.1	.88
28	.15	.28	1.3	1.5	43	2.4	2.5	2.4	.68	.80	1.1	.76
29	.18	.30	.92	1.4	16	2.3	3.1	1.2	.49	.58	1.0	.72
30	2.6	.32	.80	1.3	----	2.1	2.5	1.1	.37	.52	.92	.68
31	.96	----	2.3	1.3	----	1.3	----	1.1	----	.40	.88	----
TOTAL	8.99	8.84	88.18	302.6	95.38	187.9	1,028.7	408.2	28.99	176.19	479.16	95.42

Drainage area.--5.27 sq. mi.

Remarks.--Records good.

Harbor Brook

Discharge, in cubic feet per second, water year Oct. 1967 to Sept. 1968

Day	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
1	6.1	3.1	7.1	7.1	22	5.5	26	5.7	5.0	18	5.5	3.7
2	5.5	48	6.4	6.8	40	5.5	16	5.5	4.8	15	5.1	3.8
3	5.5	24	11	6.4	25	5.4	14	5.7	4.7	13	5.0	3.7
4	4.7	12	7.7	6.1	18	5.4	19	5.5	4.5	11	4.7	3.7
5	4.3	9.0	7.1	6.1	17	5.4	17	5.2	4.5	12	5.0	3.8
6	4.2	6.8	6.8	5.8	15	5.4	14	5.2	4.5	14	5.8	5.1
7	4.1	5.5	6.8	5.8	14	5.2	13	5.1	4.4	11	9.3	3.9
8	4.3	5.2	7.4	5.7	13	5.8	13	5.1	4.4	10	4.7	3.6
9	4.5	5.1	6.4	5.5	13	8.0	11	5.2	4.4	20	4.8	3.6
10	3.8	5.2	6.1	5.4	12	13	11	6.4	4.4	28	4.7	4.7
11	3.1	5.1	13	5.1	11	22	10	5.2	4.3	11	4.5	14
12	3.1	8.1	23	4.7	11	8.4	9.8	6.8	6.1	10	4.3	5.0
13	3.1	12	14	4.5	11	5.0	9.0	5.5	4.7	9.0	4.3	4.0
14	3.2	8.4	11	4.5	10	4.3	8.7	5.2	4.4	8.4	4.1	3.9
15	3.2	7.1	8.7	5.2	10	5.2	9.0	5.0	4.7	8.0	4.0	3.9
16	3.4	6.8	8.0	5.1	9.8	18	8.0	5.7	4.4	7.4	4.2	3.8
17	3.6	6.1	7.7	5.1	9.4	44	7.4	5.2	4.4	7.4	4.1	3.8
18	7.0	14	17	5.2	9.0	21	8.0	5.7	4.2	71.	4.0	3.7
19	14	17	26	5.7	7.4	26	6.8	6.8	4.1	6.8	4.1	3.7
20	4.8	11	15	5.5	7.1	19	6.8	8.4	3.9	6.8	4.0	3.6
21	3.5	9.4	13	5.4	6.8	14	6.8	5.5	3.8	6.4	3.9	3.5
22	3.3	13	12	5.2	6.1	37	11	5.0	4.3	6.4	19	3.7
23	3.3	43	10	5.2	5.8	38	7.4	4.8	3.7	6.1	5.5	3.6
24	3.2	19	9.4	4.7	5.5	23	7.4	4.7	4.7	7.4	4.5	3.6
25	14	15	8.7	4.3	5.0	22	6.4	4.5	4.8	6.8	5.0	3.5
26	10	14	8.4	4.2	4.8	29	6.1	4.4	99	7.1	4.1	3.5
27	3.8	11	7.7	4.4	5.2	26	8.0	4.4	30	7.1	3.9	3.5
28	3.5	9.4	7.7	4.8	5.4	19	5.8	4.4	39	7.4	3.8	3.5
29	3.3	8.4	7.7	9.4	5.5	17	5.7	6.8	21	6.1	3.8	3.4
30	3.2	7.7	7.4	53	----	15	6.8	8.0	19	6.1	3.8	3.4
31	3.2	----	7.1	25	----	15	----	5.7	----	6.1	3.8	----
TOTAL	149.8	369.4	315.3	236.9	334.8	492.5	308.9	172.3	320.1	306.9	157.3	124.2

Drainage area.--9.63 sq. mi.

Remarks.--Records fair. Flow includes some sewage and storm sewer inflow, some originating outside the basin.

Government ditch

Discharge, in cubic feet per second, water year Oct. 1967 to Sept. 1968

Day	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
1	0	0	0	0	0	0	0	0	0	0	6.2	.06
2	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	.01	0	0	0	0	0	0	1.2	0	0
4	0	0	.01	0	0	0	0	0	0	8.0	0	0
5	0	0	0	0	0	0	0	0	0	17	1.6	0
6	0	0	0	0	0	0	0	0	.05	46	2.6	0
7	0	0	0	.02	.03	0	0	0	0	0	.58	0
8	0	0	0	.07	0	3.6	0	0	0	0	0	0
9	0	0	0	0	0	.84	0	0	0	0	0	0
10	0	0	0	0	.10	1.5	0	0	0	0	0	.05
11	0	0	0	0	0	.83	.06	0	0	0	0	0
12	0	0	0	0	1.8	0	0	0	0	0	0	0
13	0	0	0	0	1.1	0	0	0	0	0	.03	0
14	0	0	.02	0	.53	0	0	0	0	0	.05	0
15	0	0	.01	0	0	0	0	0	0	0	0	0
16	0	0	.26	0	0	0	0	0	0	0	0	0
17	0	0	.41	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	.05	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	.21	0
23	0	0	0	0	0	0	0	0	0	.21	0	0
24	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0
26	0	.07	0	0	0	0	0	0	0	0	0	0
27	0	.06	0	0	0	0	0	0	0	0	0	0
28	0	0	0	0	.87	0	0	0	0	0	.05	0
29	0	0	0	0	0	0	0	0	0	.01	.07	0
30	.11	0	0	0	----	0	0	0	0	0	0	0
31	0	----	0	0	----	0	----	0	----	5.3	0	----
TOTAL	0.11	0.13	0.72	0.14	4.43	6.77	0.06	0	0.05	77.72	11.39	0.11

Drainage area.--6.4 sq. mi., approximately.

Remarks.--Records good.

Challenging (3)

VIII-C-1a: CLIMATE OF AN IMAGINARY CONTINENT

QUESTION:

What factors affect climate patterns?

MATERIALS:

Student handout sheets including the supplementary sheet (map of an imaginary continent), completed water budget investigations, colored pencils or crayons, and optional photographs (magazine or 35 mm. slides) taken in various world climate areas.

SUGGESTED APPROACH:

Part I

A. Ask the students what kinds of relationships between precipitation and potential evapotranspiration they would expect to find in an arid region, and in a humid region. Could this relationship be expressed numerically as a ratio? What range of numbers would represent arid regions? humid regions?

B. Have the students prepare a P/Ep isoline map from the information plotted on the map of the imaginary continent. Have them shade arid regions in red and humid regions in blue. This can best be done as a homework assignment.

Part II

A. When part I has been completed, briefly discuss the P/Ep isoline map making certain that all students have identified the major arid and humid regions.

B. Ask the students if they could improve upon their maps by designating more accurate climatic regions, such as humid, subhumid, semiarid, arid, and mountain climate zones if they were to consider other factors (i.e., latitude, elevation, nearness to large bodies of water, ocean currents, mountain barriers, and planetary wind systems). In a class discussion, decide on the probable ocean current patterns and planetary wind systems that might be found on and around the imaginary continent (see map under Typical Results).

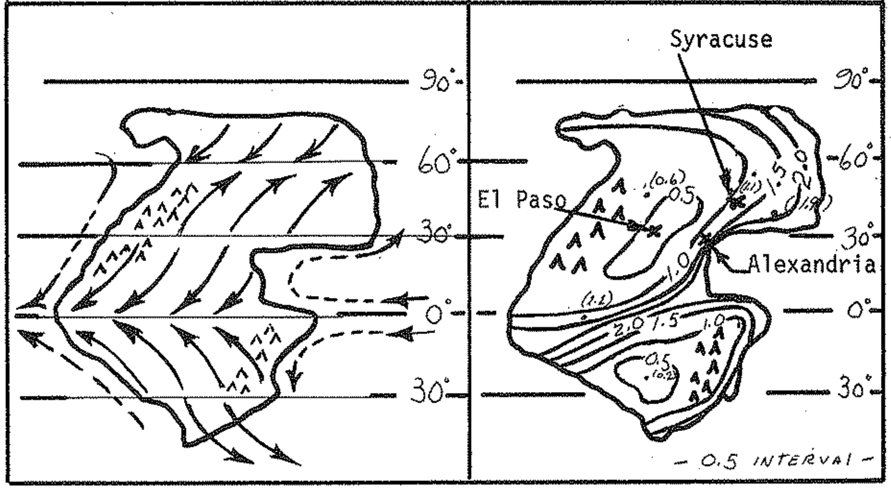
Allow the students to complete refinements on their maps as a homework assignment.

Part III

As a concluding class exercise, have the students refer to their water budget investigation and plot on the imaginary continent the most likely position for each of the three water budget locations. Have them study photographs, either projected on a screen or in magazines, taken in various world climatic regions and match these with their most probable location on the imaginary continent (see map under Typical Results).

TYPICAL RESULTS:

Probable Wind and Ocean Current Map	Isoline Map of P/Ep Values



BACKGROUND INFORMATION:

P/Ep Ratio	Climatic Type	Generalized Type
Greater than 1.2	Humid	Humid
0.8 - 1.2	Subhumid	
0.4 - 0.8	Semiarid	Arid
Less than 0.4	Arid	

REFERENCE:

Investigating the Earth, pp. 247-266; Teacher's Guide, pp. 299-327.
The Earth Sciences, Strahler, ch. 18.
Earth Science, The World We Live In, Namowitz and Stone, ch. 41 & 42.
Principles of Climatology, Neiberger and Cahir, Holt, Rinehart and Winston, 1969.

VIII-C-1a: CLIMATE OF AN IMAGINARY CONTINENT

QUESTION:

What factors affect climate patterns?

INTRODUCTION:

You are well aware that many areas of the world have unusual climates - deserts, tropical rain forests, polar ice caps, etc. What causes these differences? Are they predictable, knowing certain information? In this investigation, you will apply what you have learned about water budgets to locations on a continent to help answer these questions.

OBJECTIVES:

When you have finished this investigation you should be able to:

1. identify arid and humid regions when given yearly precipitation and potential evapotranspiration data for various points within an area.
2. outline climatic zones based on P & Ep data, latitude, elevation, nearness to large bodies of water, ocean currents, and planetary wind system information for an imaginary continent.
3. match a set of water budget graphs with their most probable location on an imaginary continent.
4. match a series of photographs taken in various world climatic regions with their most likely position on an imaginary continent.

METHOD:

Part I — On the outline map containing P/Ep ratio data for a number of locations within an imaginary continent, construct iso-P/Ep lines. When the lines are completed, color the humid regions blue and the arid regions red.

Part II A. Defend your classification of these regions in a class discussion and be prepared to outline other factors that would enable you to identify a more elaborate classification system.

B. As a result of your class discussion, outline as complete a climatic classification system as you are able, on a new imaginary continent map.

Part III A. Match the three localities for which water budget information was completed, in an earlier investigation, with their probable position on your completed climate map of the imaginary continent. Be prepared to defend your decision.

B. Match a series of photographs taken in various world climatic regions with their most likely position on your imaginary climate.

QUESTIONS:

(B-3.11) 1. How can precipitation and potential evapotranspiration data be used to identify climatic regions?

(C-1.11) 2. What relationship exists between latitude and climatic patterns?

(C-1.21) 3. Describe the effect of elevation on climatic patterns?

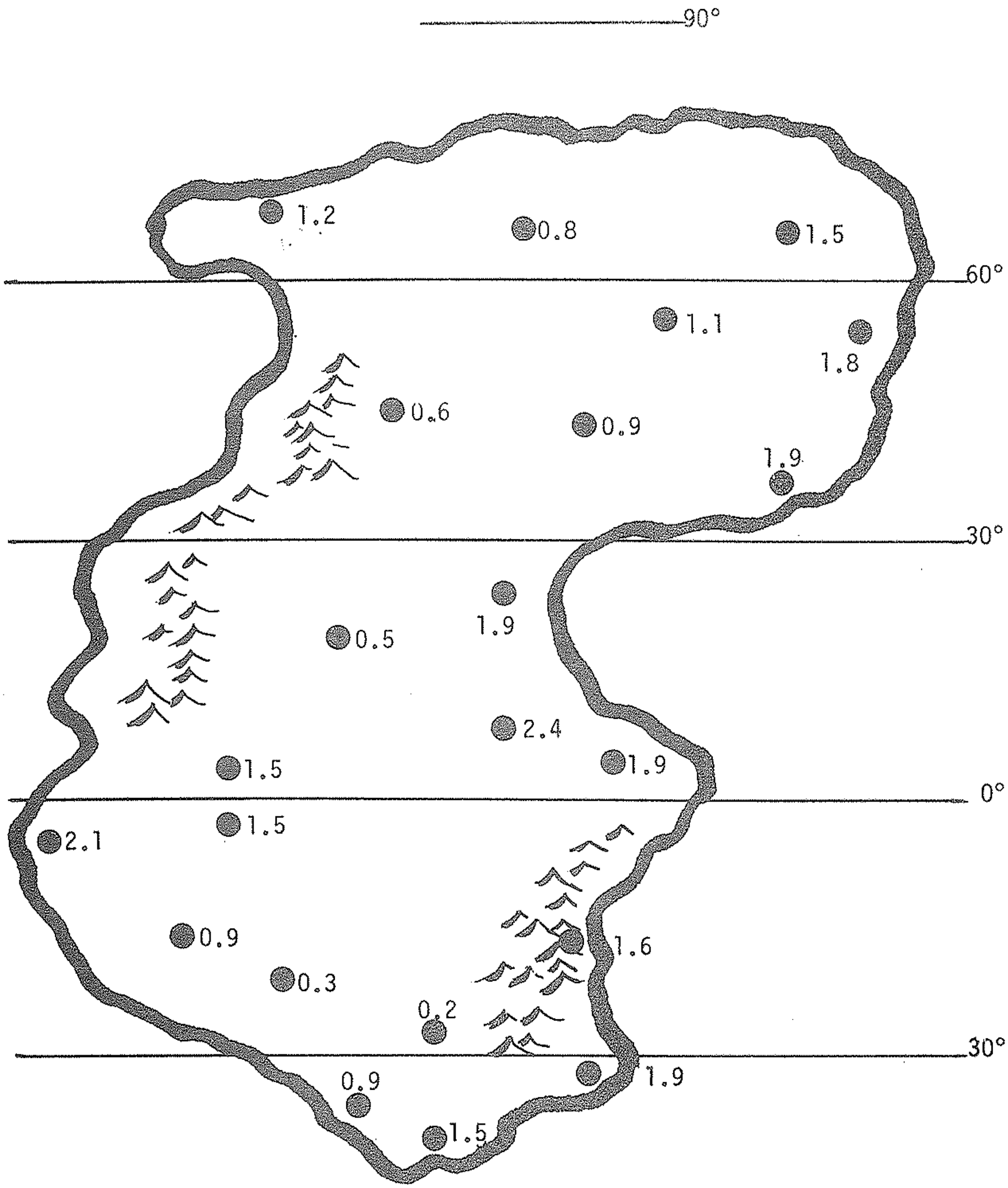
(C-1.31) 4. What effect does a large body of water have on the climate of a nearby landmass?

(C-1.32) 5. What effect does an ocean current have on the climate of a nearby landmass?

(C-1.41) 6. How do mountains affect the climate of a region?

(C-1.51) 7. How do planetary wind and pressure belts affect climate?

MAP OF AN IMAGINARY CONTINENT



<u>Adapted from:</u>

Investigating the Earth, Teacher's Guide.