Land and people : Finding a Balance

Cape Cod

U.S. Department of the Interior
U.S. Geological Survey

Finding a Balance **is an environmental study project that allows you and a group of your classmates to consider real environmental dilemmas concerning water use and to provide solutions to these dilemmas. The student packet gives you most of the information you'll need to answer the Focus Question, information like maps, data, background, a reading about the region, and a description of the "Interested Parties," or the various interest groups that have a stake in the outcome of the Focus Question. While you are working on this project, each member of your group will take a role or become one of the interested parties. Your teacher will guide you through a series of discussions, activities, calculations, and labs. At the end of this project, your group will be asked to present and justify a solution to the environmental dilemma.**

The following excerpt from a book published by the Association for the Preservation of Cape Cod, an environmental group, explains the problem from the viewpoint of the people who live and work around the contaminated area.

Reading

From *The Enemy Within: The Struggle to Clean Up Cape Cod's Military Superfund Site* by Seth Rolbein. *Chapter 1: A Watershed Place, A Watershed Moment, 1995.*

"July 7, 1994. The dignitaries were seated under a blazing sun, the flat, broad landscape of the Massachusetts Military Reservation [MMR] broken by a small building behind them. Inside that building was the only respite from the heat, because huge tanks holding underground water stood in the shade, acting as air conditioners.

That wasn't why they were there, of course, to serve as multi-million-dollar air conditioners. Their purpose was something else entirely:

The water is being pumped out of the ground and held in these tanks so it can be treated. This water bears telltale remnants of pollution dumped decades ago. This water must now be filtered to remove poisons left from the past.

It was a fitting place to hold this ceremony, between hot sun and cool groundwater, beside the first small treatment plant on the giant base. The chairs and tables where politicians and military brass sat side by side, where community activists, newspaper reporters and television cameramen focused their attention, were all directly above one of many so-called "plumes" buried deep underground, a spreading pool of contamination no longer ignored or denied, one of many invisible catastrophes which have caused so much concern for thousands of people who live and work around Camp Edwards and Otis Air National Guard Base. This was the appropriate place because after more than a decade of study, argument, delay and frustration, Cape Cod was about to hear a promise: the federal government will spend hundreds of millions of dollars to try to stop these plumes from reaching even farther into the neighborhoods of Falmouth, Bourne, Mashpee, and Sandwich...

...Some of the people who have dedicated years to this effort, spent countless hours in meetings, labored over thousands of pages of documents, done everything from digging wells to lobbying officials to getting arrested, were sitting in the hot sun that July day... many of them seem to have vivid memories of their first steps down this long road, when they first realized that something was wrong at Cape Cod's military base:

Dr. Joel Feigenbaum, a mathematics professor at Cape Cod Community College, says that moment came in the early 1980s as he watched smoke and debris from a huge fire blowing over Sandwich, a fire caused by artillery shells exploding on a dry, windy day. He stood with a hose in his hand, protecting his house from sparks. He wondered why this was happening, and what else was going on inside the borders of the base...

For Bob Kreykenbohm, manager of the Sandwich Water District, the moment came later, in 1990. Water pumped from deep underground, below what looked like a pristine forest, foamed as it came to the surface. There was enough fuel coming out of the pipe to make a lit match flame. It didn't take long for him to suspect that the only thing that could have caused something so big, so disastrous, was the old pipeline that carried fuel through his town, from Cape Cod Canal to the base...

...For Ralph Marks, who now runs the Bourne Water District, the moment came as he pulled the plug and stopped Falmouth's public supply well from pumping water in the late 1970s. Even back then, he figured he knew where the contamination was coming from. It was coming from the same place where he had been serving his National Guard duty...

...For Denis LeBlanc [a hydrologist with the U.S. Geological Survey], who studies geology and underground water movement, the moment came more than 15 years ago, when he sank a test well into the sandy soil on the southern side of the base. As it turned out, he had put his first dart into the bulls eye: thousands of test wells and samples later, the Ashumet Valley plume would become studied, analyzed, and charted with more detail than virtually any other plume in the country...

...And so Cape Cod finds itself in the vanguard of what will be one of the most important environmental issues to face this country as we move into the next century..."

Focus Question

Cape Cod has a serious problem with its ground water. During the past six decades, activities of the Massachusetts Military Reservation (MMR) — formerly known as Camp Edwards, then Otis Air Force Base — on the Upper Cape have resulted in contamination of billions of gallons of underground water. (The Upper Cape is the western part of Cape Cod, including the following towns: Bourne, Sandwich, Barnstable, Mashpee, and Falmouth.)

You and your group are members of a blue-ribbon panel that has been formed to present a plan for providing safe, drinkable water to the Upper Cape for the next 10 years. You know of the contamination problem of the underground water supply. You also know how many Cape Cod residents will require water; your panel has been given data that describe the predicted increase in the region's population. Now, you and the members of your panel must figure out how the Upper Cape will meet its need for safe ground water in spite of the vulnerability of its water supply to contamination.

The Interested Parties

Many groups and individuals are affected by water-quality issues on Cape Cod and are interested in the answer to the Focus Question. As your group works to answer the Focus Question, each person will take one of the following roles:

The Military

Military officials, including the Air Force, Army, and National Guard, are responsible for the cleanup of ground water contaminated by activities at the base and for prevention of additional ground-water pollution. The U.S. Environmental Protection Agency classified the MMR as a Superfund site in 1989. When a military site is classified as a Superfund site, the Department of Defense MUST carry out the cleanup under the oversight of the U.S. Environmental Protection Agency. However, ground-water cleanup is expensive and difficult. The Department of Defense must remedy the problem, but responsibility for the cleanup is complicated because the base has changed hands and functions several times in the last generation.

Regulatory Agencies

Regulatory officials from the U.S. Environmental Agency and the Massachusetts Department of Environmental Protection who oversee the cleanup want to restore and protect water quality in the aquifer. As "public servants," they must balance the difficult task of cleanup and associated costs with the public demand for action. They are working closely with the Department of Defense to find a solution that is quick, effective, and affordable.

Municipal Water Managers

Officials responsible for providing town residents with a clean, safe supply of water want to do all they can to protect the Cape Cod aquifer. And if a town's water supply becomes contaminated by ground-water plumes, water supply officials want action to restore the lost supply. In fact, when underground contamination closed supply wells in Mashpee and Falmouth, the military base paid most of the costs of building new public water systems.

Cancer Victims' Rights Group

As a member of the Cape Cod chapter of the Massachusetts Breast Cancer Coalition, you are concerned about how contaminated ground water might be affecting cancer rates on the Upper Cape. Between 1982 and 1988 the incidence of cancer was 22 percent greater in the five towns that make up the Upper Cape than in the rest of the state. You want to know — is polluted ground water causing cancer?

Environmentalists

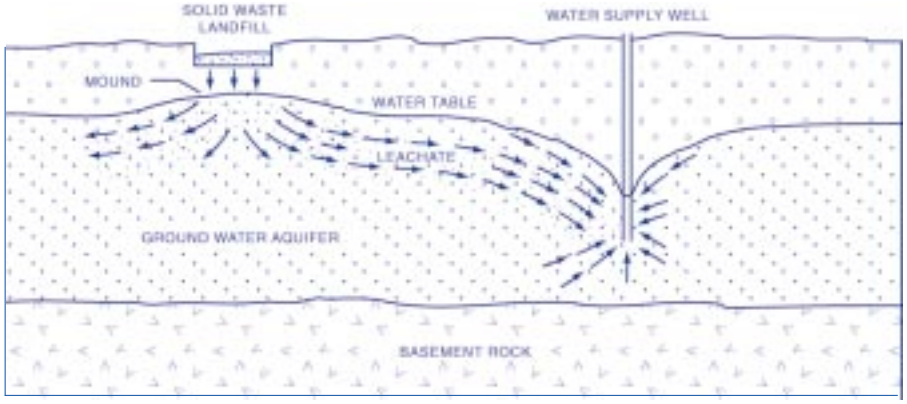
Environmentalists celebrate Cape Cod's unique geology, protected seashores, native plants, and crystal ponds. Generations of naturalists, including Henry David Thoreau, have celebrated Cape Cod's beauty. People have protected the Cape's dunes, grasses, and coastline for many years. Now they need to turn their attention to protecting an important unseen player in the environmental balance — the Cape Cod aquifer.

Homeowners

Residents on the Upper Cape are afraid. They worry that the water they drink and bathe in is unsafe. They worry about getting cancer. They worry that the value of their property will plummet if the ground-water problems are not fixed. If the contaminated ground-water plumes aren't stopped, will the tourists stop coming? How would Cape Cod survive without tourist dollars?

Cape Cod's Unique, "Absorbent" Geology

Cape Cod, a sandy peninsula formed mostly during the Ice Age, sticks out into the Atlantic, looking from above like a bodybuilder's flexed arm. Cape Cod is particularly interesting, geologically speaking, because it was formed by glaciers very recently in terms of geologic time. The geologic history of Cape Cod mostly involves the last advance and retreat of glacial ice in southern New England and the rise in sea level that followed the melting of the ice. These events occurred within the



How leachate from a solid waste disposal site contaminates a well. From the *Environmental Impact of Ground Water Use on Cape Cod.* (Strahler, 1972).

last 25,000 years. Sometime between 18,000 and 23,000 years ago, the Wisconsin ice sheet (large glacier that completely covers the terrain) that had been moving southeast across all of New England reached its maximum advance. About 18,000 years ago, the glacial ice started to recede rapidly northward by melting; within about 4,000 years, the ice sheet front had retreated to just north of Boston.

As it retreated, the glacier deposited rock debris, called drift. On Cape Cod, drift overlies a surface of much older rock. This older rock is buried by drift 200-600 feet thick. Most of the drift on Cape Cod has been fashioned into either moraines or outwash plains. Both features mark the various positions of the front of the glacier as it moved. Moraines are ridges of rock debris formed by moving ice. In a moraine, rock fragments carried by the ice are piled up along the ice front. Moraines may also form when the ice front advances and bulldozes the sand and gravel of an outwash plain into a ridge. The moraines on Cape Cod were formed by a combination of these processes. Outwash plains make up most of the landscape of Cape Cod. They were built by meltwater streams flowing from the glacier margin that deposited sand and gravel to form a broad, flat, porous plain.

Cape Cod's landscape is defined by the glacier's deposition of loose material. These porous, sandy soils are highly absorbent. Such soils have a profound effect on the quality of underground water. Sandy soils make the underground water supply vulnerable to contamination — toxic substances on the surface can travel through the soil quickly and can move great distances underground.

Where Do Cape Codders Get Their Water?

Cape Cod has what is called a sole-source aquifer. An aquifer is an underground rock or sand body that permits water to move through with ease. This ground water is the only source of drinking water for residents of western Cape Cod. Aquifers are classified as confined or unconfined. Confined aquifers are overlain by materials that have low permeability and receive little or no direct recharge from rainfall. The movement of water into and out of confined aquifers is slow. Unconfined aquifers are exposed to the atmosphere and are continually recharged by the percolation of rainfall, snowmelt, or water from streams or rivers. Recharge rates vary with the seasons and from year to year. Under natural conditions, discharge, or water flowing out of the aquifer, is balanced by recharge.

The unconfined Cape Cod aquifer is segmented into six sections called lenses. The upper limit of the lenses, or the water table, has about the same shape as the land above. The largest lens is on the Upper Cape. The highest point of this lens is right under the MMR. Ground water flows perpendicular to the contours of the water table, much like rainwater would flow down hillsides above ground. It moves at the rate of about a foot a day until it reaches the sea.

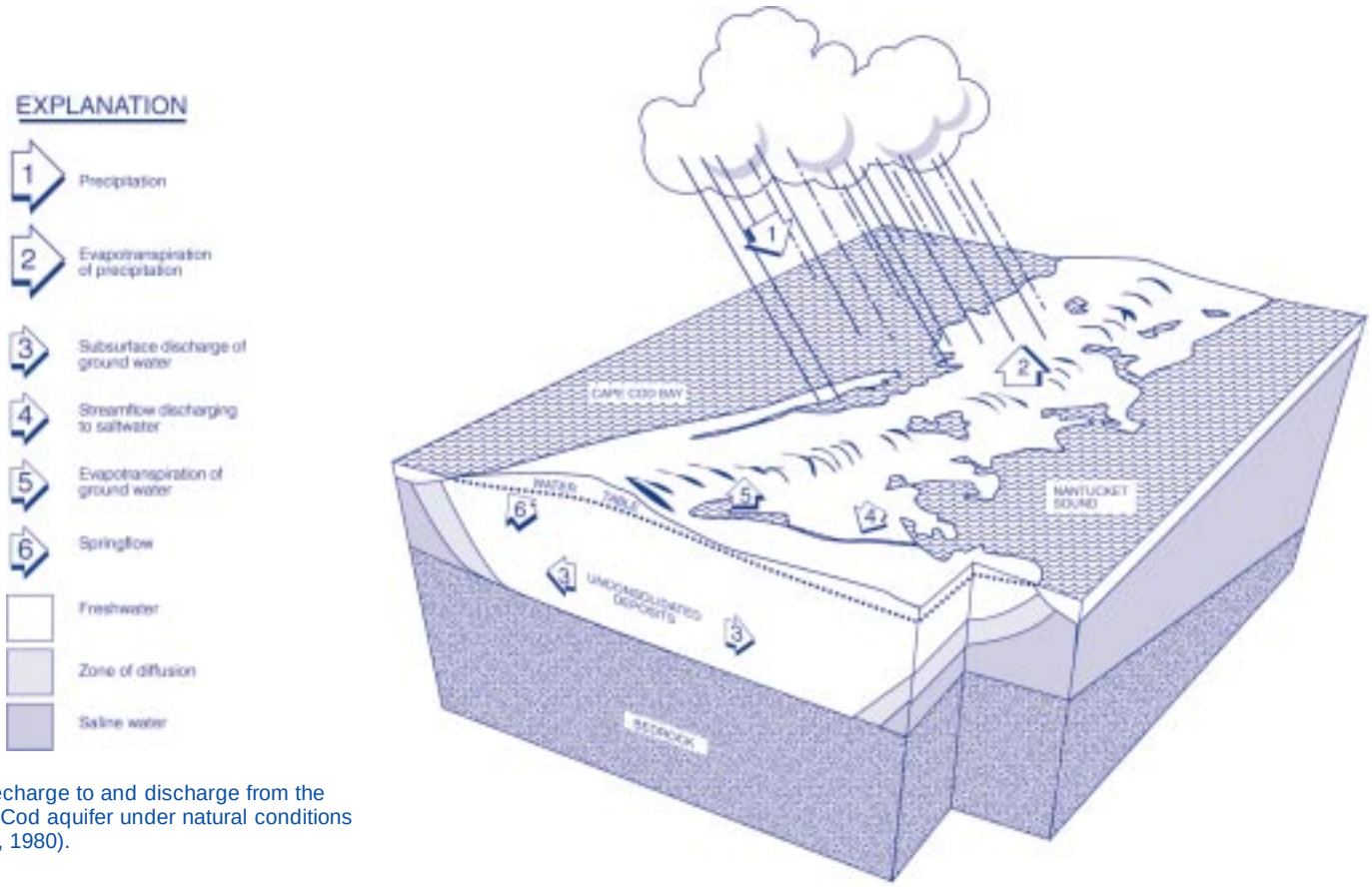
Cape Codders get their drinking water from the aquifer. Public water supply systems bring drinking water to about 70 percent of the population of the MMR and the towns of Bourne, Sandwich, Mashpee, and Falmouth. The other 30 percent of the population use domestic wells to supply their drinking water. The total average daily water demand on western Cape Cod is about 6.4 million gallons per day. This figure was calculated on an average of the amounts of water used during the vacation season and during the off season. During the summer season, water demand rises to 10.1 million gallons per day; during the off season, demand is at 5.2 million gallons per day.

Here's a paradox — ground water is the primary drinking supply for the Cape, but it is also the primary disposal area for wastewater generated by the population of the Cape.

Porosity, Permeability, and Ground Water

To discuss water-supply issues, you must understand how ground water moves through or is contained by rock underground. Ground water is stored in small cracks and voids in soil and bedrock. Porosity is the proportion of a volume of rock or soil that consists of open spaces. Igneous and metamorphic rocks, such as granite and schist, have low porosities unless they are fractured. However, many sedimentary rocks can be quite porous. Loose sediments, such as Cape Cod's glacial deposits, can be highly porous: 40 percent in sand, and even 90 percent in clay.

Porosity tells us how much water rock or soil can retain. Permeability is a measure of how easily water can travel through porous soil or bedrock. Soil and loose sediments, such as sand



The recharge to and discharge from the Cape Cod aquifer under natural conditions (Ryan, 1980).

and gravel, are porous and permeable. They can hold a lot of water, and it flows easily through them. Although clay and shale are porous and can hold a lot of water, the pores in these fine-grained materials are so small that water flows very slowly through them. Clay has a low permeability.

Remember these water-holding and water-moving characteristics when you do Activity 1 — A Model Aquifer.

The Massachusetts Military Reservation – An Environmental Dilemma

The story of the Cape Cod aquifer in the 20th century is the story of a plot of land now identified as the Massachusetts Military Reservation (MMR). The MMR on western Cape Cod covers an area of about 34 square miles. It includes parts of the towns of Bourne, Sandwich, Mashpee, and Falmouth. The present MMR area has been in existence since 1912. Over the years, it has been occupied by many tenants and been called by many names. In the 1940's, it was Camp Edwards. From 1948 until 1973, it was Otis Air Force Base. Since 1973, the MMR has been used primarily by the Massachusetts National Guard and the U.S. Coast Guard.

During the late 1970's and early 1980's, Upper Cape residents began to discover how the long history of the MMR had affected the land it occupied and the area around it. They discovered that activities at the MMR have contaminated the ground water. Over the years, those using the MMR have dumped or disposed of many toxic substances, including jet fuel, solvents, and industrial chemicals. Most of these substances were disposed of during the last 50 years and have been percolating down through the Cape's sandy soil ever since. These chemicals dissolved into and moved with the ground water; contaminant plumes formed, much like the plumes coming from smokestacks.

One of the earliest casualties of the contaminant plume from the reservation was a public water-supply well in Falmouth.This large well was pumped strongly enough to draw a plume of treated sewage from the base into its intake pipe, while individual household wells continued to tap the clean water above the plume.The town of Falmouth lost 25 percent of its water supply when the sell was shut down in 1975.

After much alarm and much civic action, a report on the extent of the contamination on the MMR was published in 1986. The report listed many areas with many problems and used abbreviations to describe them:

- SD sites were storm drainage ditches that caught the contaminated runoff, which then seeped into the ground water.
- LF stood for landfills that had been used for disposing of everything from household waste to explosives to entire trucks.
- CS meant chemical spill — including fuels, battery acid, and unburned gunpowder.
- FS sites were fuel spills, such as the runways where planes tested their fuel-dump valves.

- FTA's were fire training areas, which are large, squared-off patches of ground where fuels and other chemicals were spilled and then burned to give firefighters practice in extinguishing fires.

Each of the kinds of sites listed above has contributed to the spread of plumes of underground contamination. Almost a decade of study has led to the documentation of 11 major contaminant plumes that move off the base. These plumes threaten ponds, beaches, individual wells, and town water supplies alike. The plumes are large and have traveled far because the sandy soil allows the ground water to move quickly. Although parts of the plumes are very dilute, with small "hot spots" that contain high levels of contaminants, large volumes of water can be rendered unfit for drinking and sensitive ecosystems can be harmed by contact with small amounts of the industrial solvents and other organic chemicals contained in the plumes. The plumes are now well documented, but many problems remain to be resolved: demand for water continues to increase, and plumes move more than a foot a day and contaminate additional acres of aquifer each day. Other unknown contamination sites may exist, waiting to be discovered. New methods are needed to clean up the plumes in accordance with stringent water-quality standards.

In 1996, the U.S. Air Force Center for Environmental Excellence (AFCEE) assumed responsibility for cleanup of ground water at the MMR. By late 1996, dozens of pumping wells were being drilled to stop the advance of the plumes, the base landfill had been capped to stop leachate from reaching the ground water, and contaminated soils at several sources had been treated to remove solvents and fuels. A long-term plan is being developed by AFCEE, the U.S. Environmental Protection Agency, and the Massachusetts Department of Environmental Protection to clean up the plumes and to provide safe drinking water to the base and surrounding communities. Additional information about the plan can be obtained from the Installation Restoration Program (IRP).

The Facts About Septic Tanks, and Other Threats to the Cape's Ground–Water Quality

Another cause of ground-water contamination on the Upper Cape is effluent, or outflow, from septic tanks and cesspools. A majority of the homes on the Cape have septic systems.

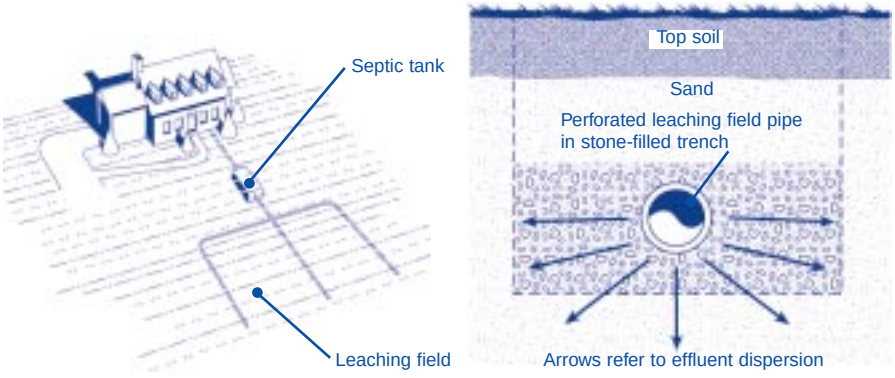
During the operation of a septic system, domestic sewage is flushed into a large underground tank. The solids settle to the bottom of the tank and accumulated septage is pumped out every 2 years or so. The effluent flows out of the tank and into a series of underground trenches filled with gravel. The effluent trickles through the gravel into the soil where the organic matter decomposes.

For purification to work, however, effluent must move slowly through aerated soil or rock. That way, organisms can feed on the sewage and make it harmless before it moves very far. If the polluted water moves through the soil or rock too quickly, the organisms cannot decompose it, and the polluted water can contaminate the aquifer underneath. Geologic conditions on the Cape — the sandy, permeable soil and unconfined aquifer — make the ground water highly susceptible to septic-tank effluent contamination. The Cape's sand filters bacterial contamination well, but it allows other household toxins, such as paint thinner, to move straight through to the aquifer from which the drinking water supply is drawn.

In addition to septic tank systems, other sources of ground-water contamination in Cape Cod include wastewater treatment facilities; landfills; underground tank storage of fuel oil and home-heating oil in addition to gasoline; pesticide, herbicide, and fertilizer application in agricultural areas as well as salt application in residential areas; deicing salt-storage areas and salt application on highways; waste from industrial parks, leaking sewer lines, and so forth. Information on additional sources of ground-water contamination in Cape Cod is described by Frimpton and Horsley (1993).

Ground-Water Cleanup – No Easy Task

Restoring ground water is not easy, it's not cheap, and it's not always effective. The two most common approaches are containment and extraction. Containment keeps the polluted water away from the rest of the aquifer. If the residents of the Upper Cape want to contain their polluted water, they could have under-



A septic tank holds solid waste and releases wastewater into a leaching field that contains stone-filled trenches. On Cape Cod, septic tank wastewater frequently percolates to the aquifer below.

ground retaining walls built or have the water's natural flow direction altered by pumps. The downside of containment? It doesn't do anything to purify the water — it just keeps the contaminated water from moving into the rest of the aquifer. Extraction involves getting the water out of the ground, cleaning it by aeration and filtration, and then returning it to the aquifer. The downside of extraction — it requires a long time, even decades. A final option is to do nothing — just let the contamination flow into the ocean. The downside? You decide.

The USGS's Toxic Substances Hydrology Program, or "How We Learned About the Ashumet Valley Sewage Plume"

Government and university scientists are using the sewage plume created by the MMR sewage treatment plant on Cape Cod as a field laboratory. They are studying how toxic chemicals move in ground water. For 50 years, treated sewage disposed on the reservation has leached into the sand and gravel aquifer below. To figure out how and where this sewage affects the quality of the ground water, scientists have drilled a "well field" or set of narrow wells. These wells enable them to pump ground-water samples for examination.

To study the Ashumet Valley plume, the USGS scientists have dug more than 300 sampling wells. They began the study after State and Federal officials became concerned that sewage disposal was contaminating shallow aquifers. At one of their first test wells, dug in 1979, 10,000 feet away from the sewage treatment plant, water foamed when it came out of the ground. The USGS scientists knew they had discovered a problem.

To decide where to place the sampling wells, they had to hypothesize about what chemicals in the treated sewage would move in the aquifer and where the contaminated ground water would move. Then, using topographic and water table contour maps to guide them, they dug wells downgradient — along the downward slope of the water table — below the suspected source of contamination. To gather information about the shape, content, and movement of the plume, they kept digging groups of

Tying theory to reality: the USGS uses experimental wells in the area of the Ashumet Valley sewage plume, (Photo by D. LeBlanc, USGS, 1985).

Source of water samples taken in 1979	Chemical Concentration		
	Chloride (milligrams/liter)	Boron (micrograms/liter)	Nitrogen (milligrams/liter)
Treated sewage released at the MMR	33	510	19
Contaminated ground water 3,000 feet from the sewage disposal site	28	280	16
Uncontaminated ground water in the area	8	7	0.4

This table shows the levels of ground-water contamination caused by sewage. Soils may be able to trap some contaminants, but they cannot turn sewage into pristine ground water.

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Year-Round Population, 1980-2010, by Community*

Community	Federal Census Year-Round Population		Projected Population		
	1980	1990	1994 (est.)	2000	2010
Barnstable	30,698	40,949	42,579	46,417	51,684
Bourne	13,874	16,064	16,646	17,891	19,061
Falmouth	23,640	27,960	28,949	30,157	31,701
Mashpee	3,700	7,884	9,540	10,945	14,088
Sandwich	8,727	15,489	17,755	19,587	23,720
TOTAL	80,639	108,346	115,469	124,997	140,254

* From Cape Cod Commission, Barnstable County Population 1980-2010.

Use these data to help you answer the Focus Question. By what percentage is the total population of the Upper Cape likely to increase during the next decade? Where will the population jumps be the largest? How are the areas with the fastest growing demand for clean water affected by the ground-water contaminant plumes?

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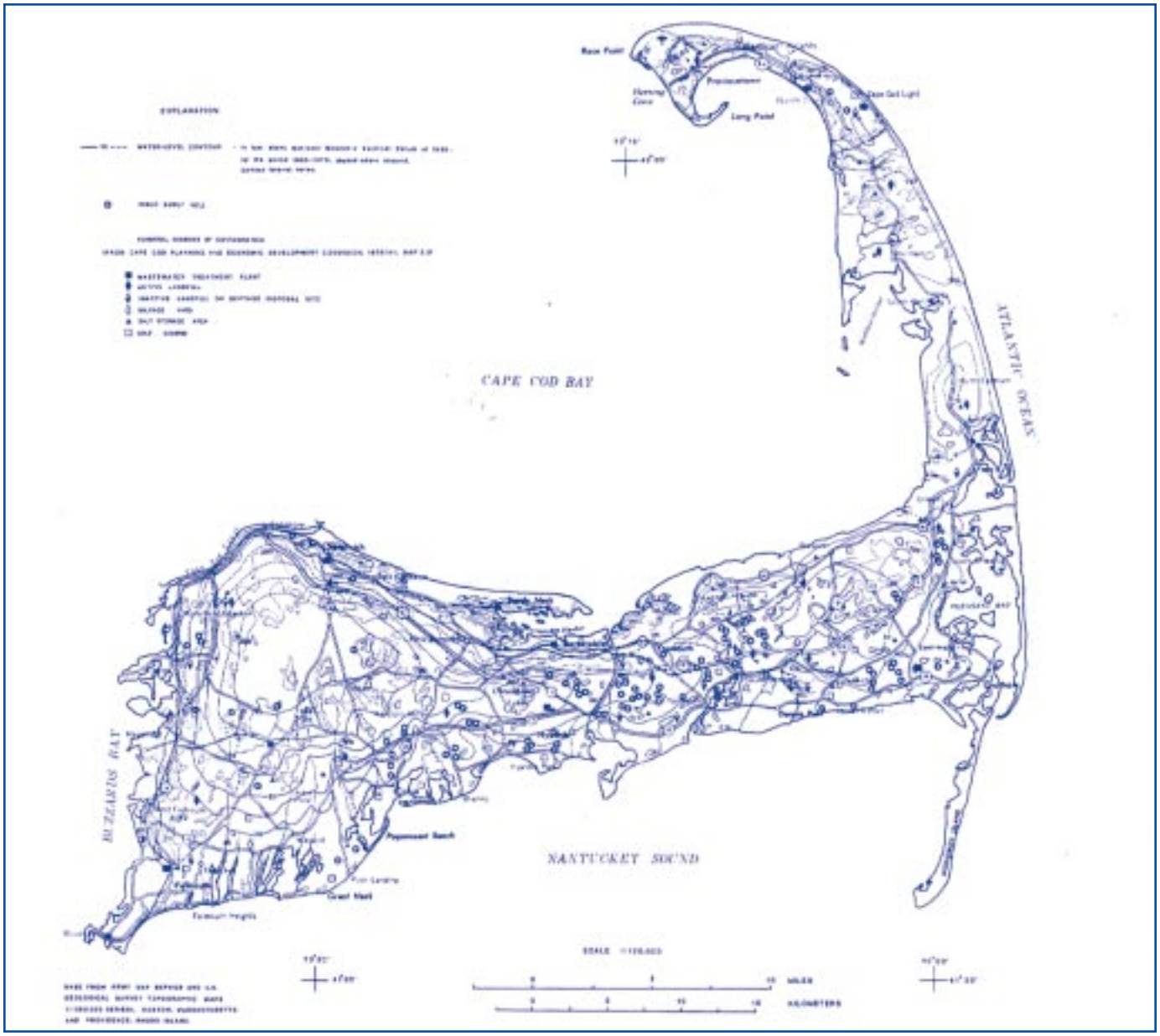
Community	1990 Federal Census Year-Round Population*	Projected Peak Summer Population*
Barnstable	40,949	81,800
Bourne	16,064	37,900
Falmouth	27,960	69,300
Mashpee	7,884	25,800
Sandwich	15,489	29,200
TOTAL	108,346	244,000

*From Cape Cod Commission (Cape Trends, 3rd edition, 1996).

By what percentage does the Upper Cape's population increase during the summer? How many ways does the increase in population affect the water supply? How does the increase in population change the quantity or the effects of contamination in the ground water?



Use this map as a decisionmaking tool as your group identifies potential ground-water contamination sources (Ryan, 1980).

sampling wells until they found clean, uncontaminated water.

By sampling ground water in the area for several years, scientists have been able to describe accurately the sewage plume. The Ashumet Valley plume is more than 2 miles long. However, the plume is only 75 feet thick. It is overlain by as much as 40 feet of uncontaminated ground water. The plume moves 0.9 to 1.5 feet per day southward toward Nantucket Sound. The plume contains high concentrations of boron (found in household cleaners), chloride, nitrogen (a byproduct of decomposing organic material), and detergents, which cause the water to foam. Approximately 2.6 billion cubic feet of the Cape Cod sole-source aquifer have been contaminated by the treated sewage from the MMR.

Can the Ashumet Valley plume story have a happy ending? Perhaps. In late 1996, proposals were being prepared to contain the Ashumet Valley plume and other plumes on the MMR with extraction wells.

The Harwich Solar Aquatic Septage Treatment Plant — the Neighbors May Have One Answer

About 20 miles from the MMR, the community of Harwich is treating its septage in a greenhouse. The facility treats 5,000 gallons of septage per day and returns sewage-free water to the aquifer. To begin the process, trucks bring the septage from homes and businesses to the greenhouse, situated near the Harwich town dump. The septage moves through large, transparent tanks that are full of bacteria, algae, water

hyacinths, and trees that put down roots in the sludge. All these help break down the sludge; roots absorb some of the toxins while bacteria consume others.

The effluent from these tanks then goes on through an artificial marsh that contains gravel, grasses, and small flowers. The filtering process continues with more tanks and more marshes until at last the water is clean enough to be returned to the aquifer.

The greenhouse is a warm, pleasant, leafy place to enjoy a picnic lunch, which many people do. There's no bad smell, and Harwich residents enjoy the greenhouse's mix of lush plant life and environmental responsibility.

Glossary

Use these definitions of important terms as you answer the Focus Question.

AQUIFER- A geologic formation that contains sufficient saturated permeable material to yield economically significant quantities of water to wells and springs.

EFFLUENT- Something that flows out, such as the discharge of a pollutant from an industrial plant or a septic tank into surface or ground water.

LEACHATE- The soluble product obtained from the action of percolating liquid on the soil or landfill waste.

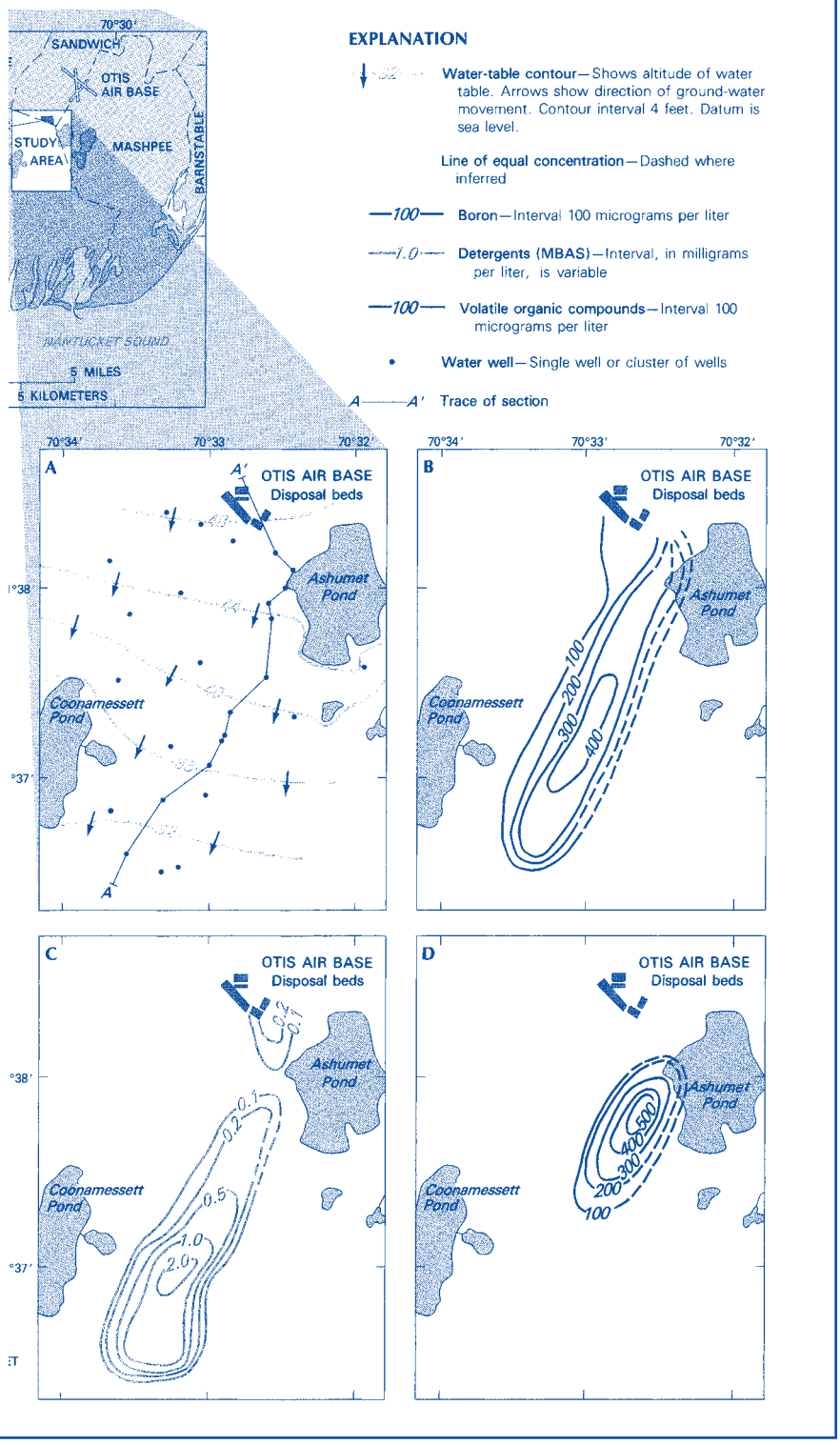
PERMEABILITY- The measure of the ability of porous material to transmit fluid.

PLUME- A zone of ground water that is contaminated by various chemicals and that often has an elongated shape, much like a smokestack plume.

POROSITY- The proportion of the volume of a material that consists of open spaces.

SEPTAGE- Effluent from septic tanks.

SOLUBILITY- The amount of a substance that can be dissolved in a liquid at a given pressure and temperature.



Sewage plume in ground water downgradient from Otis Air Force Base in 1983. **A** shows the water-table contours and the location of sampling wells. **B** shows the distribution of boron, in micrograms per liter. **C** shows the distribution of detergents, in milligrams per liter. **D** shows the distribution of volatile organic compounds, in micrograms per liter (Hess, 1986).

Why did different contaminants have different concentrations in the plume? Consider such factors as the solubility of the contaminants and when they were released. For example, in 1964 new biodegradable detergents replaced the nonbiodegradable detergents being used at the time.