CARLOS C. HUERTA

RUNNING SILENT

Acknowledged Hebrew University expertise in the exploration, exploitation and management of underground water resources has drawn hundreds of water professionals from abroad to an annual international course on the subject. Dr. Eli Wakshal heads the course. Geologist Dr. Ronit Nativ is an expert on deep aquifers who has been called upon to prepare reports and evaluations for the government

WITH THE AFFLUENCE OF the 1980s and the emergence of Yuppies, it became very fashionable to drink water from a bottle. No respectable Yuppie would be caught drinking tap water. Now in the '90s, with many of our taps running dry and bottled water being the primary drinking water in some countries, it is becoming fashionable to see if we can get water from a rock. Not just any rock, but special types of rocks called aquifers. Some of this water was deposited recently, and some of it has been lying in the rock for thousands of years. Some of the water is fresh drinking water, and some of it is more than nine times saltier than sea water. Just what are these aquifers, and how do we use the water they contain, wisely? How big are they? How did the water in some of them get so salty? Are they replenishable, that is, if we use them are they refilled, or is that all

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A water-drilling installation near Beersheba, with students of the international groundwater course on a field trip

RUNNING DEEP

there is, forever? These are some of the questions that scientists at the Seagram Center for Soil and Water Sciences at the University's Faculty of Agriculture in Rehovot have been asking. We will look at some of the results of their efforts in dealing with what many consider to be the major problem not only of the Middle East, but of much of the world.

The solid crust of our globe is composed of different types of rock. There are, for example, granitic rocks (as in the Sierra Nevada), volcanic rocks (as in Hawaii), limestone (as there is in Florida), sandstone, gravel, gypsum, and clay. Those rocks, which have the ability to hold water (porosity), and let water move in them (transmissivity), are called aquifers. Rocks that lack or have very low values of porosity and transmissivity are called aquicludes. It must be admitted that what makes rocks aquifers or aquicludes is relative. Shale and clay, because of their low permeability (the inability of water to enter and move in them), and massive chalk, composed of fine carbonate particles, tightly packed and therefore not very permeable, are two examples of aquicludes. Aquifers can be divided into two general groups, magmatic rocks and sedimentary rocks. Granites, an example of magmatic rocks, are formed when the molten magma deep in the Earth's crust is cooled. Sedimentary rocks are those produced by the action of water, wind or both. Carbonates (limestone, dolomite), sandstone, and gravel are examples of sedimentary rocks.

Going far back through the geological time scale, we would see quite a different environment from the one we have today. The climates in many of our presently arid zones would be far more humid; some of today's continental landscapes would be under marine domain, and vice versa. The rocks we call aquifers would have small fissures and cracks in them, due to mechanical and chemical action brought about by the countless number of earthquakes and tension or pressure forces formed by the crashing together of ancient continents. Sometimes, the cracks would be due to the tremendous thermal and mechanical activity produced by the impact of numerous large meteors from outer space.

On the continents, the ancient rains would start to seep down into these fissures and cracks making them bigger, and would slowly, through time, start to dissolve some of the rock making large holes, caves, and caverns. This type of action is particularly important in carbonate rocks, such as might be found in Pennsylvania, Florida, or the Yucatan. Some of these caves and caverns would be rather spectacular like the Carlsbad Caverns in the United States. Others would just be little ones not worth mentioning, except for their number. The importance of the formation of these millions of channels in the rock of the aquifers cannot be overstressed. It is these many channels, fissures, caves, and caverns formed millions of years ago that hold the water we find so important today.

We should not think of this groundwater as underground stagnant pools. The water in the aquifers is rather a living, flowing entity. Its rate of flow is dependent on the degree of transmissivity, and like all water it flows to its base level, generally the lowest topographical level the water can find. In the United States, the major base levels are those of the Pacific Ocean, the Atlantic Ocean, and the Gulf of Mexico.

There are numerous local base levels as well, the most famous being

aq-ui-fer n: a water-bearing stratum of permeable rock, sand, or gravel (*Webster*) the Great Lakes between the United States and Canada. Israel has three major base levels. All aquifers on the coastal plain have the Mediterranean Sea for their base level. That is, all groundwater in the coastal aquifers flows towards the Mediterranean. To the south, the base level for many of the aquifers in the Negev is the Gulf of Eilat, and in the middle of the country much of the groundwater has the Dead Sea as its base level. The most famous local base level in Israel is the Sea of Galilee. It is only a local base level because eventually much of its water flows south, ending in the Dead Sea. If, as in the case of the Dead Sea, base level is an enclosed basin with no outlet except evaporation, the result will be salt lakes.

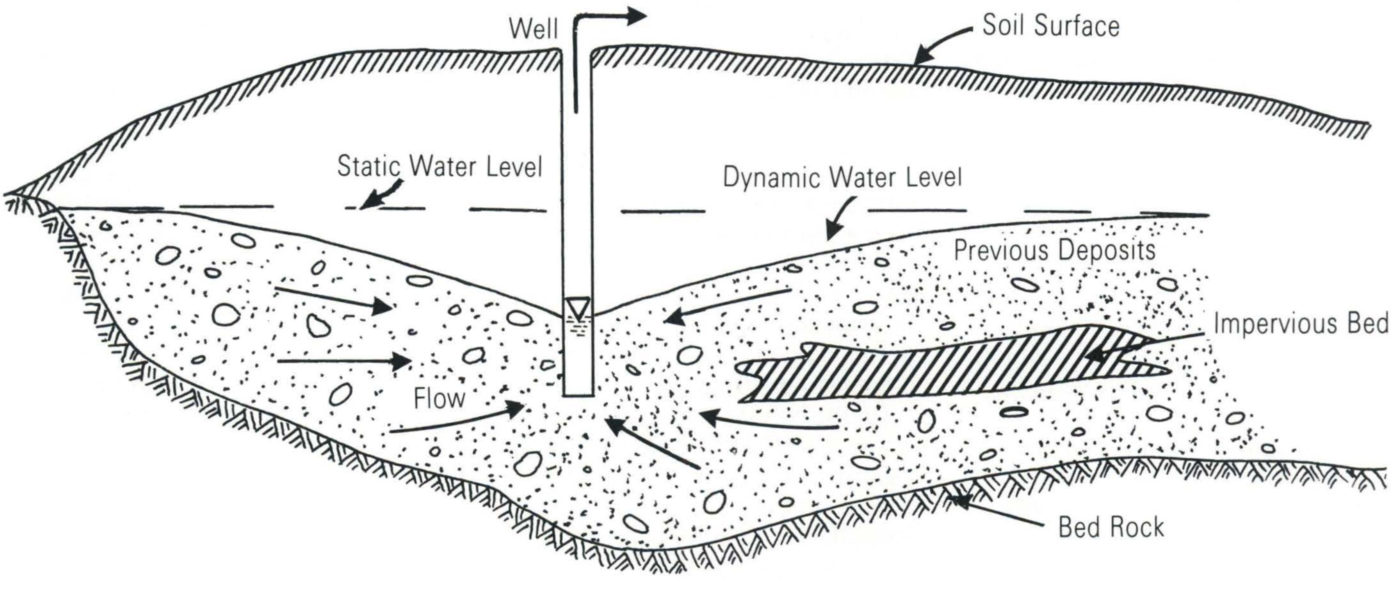
This flow of groundwater to its base level has rather important implications. Imagine a farmer pumping water from the coastal aquifers for his crops. He is so successful that in time he expands his farm and pumps out tremendous amounts of water. What actually can happen, due to his overpumping, is that the base level water, in this case the Mediterranean Sea, starts to flow eastward into the aquifers. The result is a reverse flow of saline sea water into the freshwater land aquifers, causing irreparable damage to the aquifers. This scenario is presently being played out in parts of Mexico.

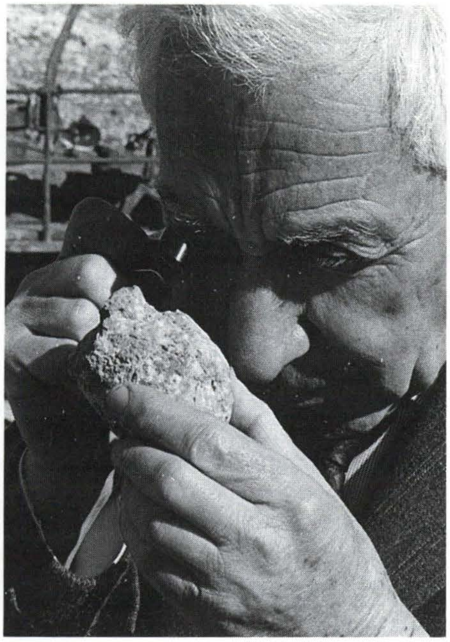
Knowing where the base level is, the rate of transmissivity, and the amount of water in the aquifer can be rather important knowledge for water management. Imagine again that the topography of the land is such that the land goes below the watertable of the groundwater in the aquifer. In such a situation we would get springs as we find around Jerusalem. If the terrain permits, we can get spectacular falls like those at Ein Gedi in the Dead Sea area. The transmissivity for all these aquifers is different. The rate of flow is very dependent on the type of aquifer and its characteristics.

ISRAEL CAN be divided into four main aquifer groups. In the north (Mount Hermon, the Galilee region, Mount Gilboa, Judea and Samaria) there are mainly carbonate aquifers. These are composed mostly of limestone and dolomite and were formed in the Jurassic Upper Cretaceous and Lower Tertiary ages, 200 million to 40 million years ago. It is these aquifers that form the sources of the Jordan River and also feed the Yarkon and Taninim Springs, along the western slope of Judea and Samaria.

All along the coastal plain is the

SUBSURFACE FLOW OF GROUND WATER TO A PUMPING WELL





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MISTER WATER

The man for whom the Groundwater Research Center is named, Prof. Emeritus Leo Picard, achieved renown for his discovery of groundwater resources in the northern part of the Land of Israel in the 1920s. Following his surveying methods, groundwater was discovered in the Jezreel and Hefer valleys and in the Galilee. He also developed the scientific principles for water exploration in arid zones.

Prof. Picard has had a part in helping Third World nations discover water and has insisted repeatedly that there was more water to be found in Israel - and was repeatedly proved right. He had a decisive hand in siting the wells that provide Jerusalem's water supply and even today, vibrant at 90, he urges that a search be made for deep groundwater sources in the upper Galilee. He says that although this water may not be of the best quality, it would be cheaper to purify such water than to think of importing water from other countries -- a solution which has actually been proposed in Israel.

Prof. Leo Picard examining a rock sample

sandstone aquifer that in most places goes to a depth of 150 meters. This sandstone, which has accumulated on the coast from the Mediterranean, was brought into the Mediterranean by the Nile River. The quartz grains that dominate this sandstone, which the Nile carried, came from the weathering and disintegration of granitic rocks in Central Africa. This coastal aquifer was laid down by submarine currents, which carried the quartz grains from the Nile delta to the coast of Israel over two million years ago. In looking at a geological map of Israel and Lebanon we can see that the coastal aquifer is widest in southern Israel, extending a distance of 30 miles inland in some places. As we move northward, it significantly narrows down to where it extends to a maximum of three miles inland north of Haifa and continues to narrow to the point where it does not exist or is insignificant in southern Lebanon. This is because the currents that carry these grains of sand deposit them as soon as possible.

In the Golan Heights and north of the Sea of Galilee we find some small aquifers composed mostly of basalt. In the Jordan Rift Valley all the way down to Gulf of Eilat we find gravel, sand and sandstone aquifers. This gravel and sand accumulated in the Jordan Rift Valley over the last 13 million years because of runoff into the valley due to its low topography relative to its surroundings. A measure of just how valuable these water resources are is the length of time it took nature to fill all these natural water jugs. The exact time is difficult to know, but a conservative estimate puts it in the order of tens of thousands of years.

When we look at what happens to rain and rain patterns we can begin to understand why it took and takes so long to fill these aquifers. In some arid zones the rains only come once or twice a year. In extremely arid areas rainfall comes only once or twice every five or ten years. The first thing that happens to rain water when it hits the ground is that the soil takes its share. The soil absorbs all it can until it is saturated. Some of the water also goes into runoff. Only after the surface is saturated does the water, assuming there is enough of it, begin its long trip downward into the aquifers. What is interesting here is that the water continues its downward journey until it hits a non-permeable layer like an aquiclude, and then starts collecting. Now imagine that the aquifer is filled and something happens in nature, such as an earthquake or flood, that deposits a non-permeable layer (aquiclude) on top of the aquifer. Then, with the same event or even a later one, more porous type rock is deposited on top of the recently deposited aquiclude forming, in time, a new aquifer on top of the old one. Such events and forces were not uncommon millions of years ago, and we see their results in the form of stacked aquifers separated by layers of aquicludes.

The water in the lowest aquifer can be very old. Perhaps more important is the fact that the water in the lower aquifers is not replenishable. Once it is used or mined, it is gone forever. The present rain can only fill the highest aquifer because it cannot penetrate past the aquiclude layer that separates the aquifers. The water in the deep aquifers is called *fossil water.* One cannot help but notice the similarity between the terms used for water and those used for oil, coal, or gas. The reason is that the processes described for water are also applicable for the fossil fuels, oil, coal, or gas. That is, instead of trapping water in our rocks, under the right prehistoric conditions like our neighbors in Kuwait or Saudi Arabia had, we could have trapped oil or gas.

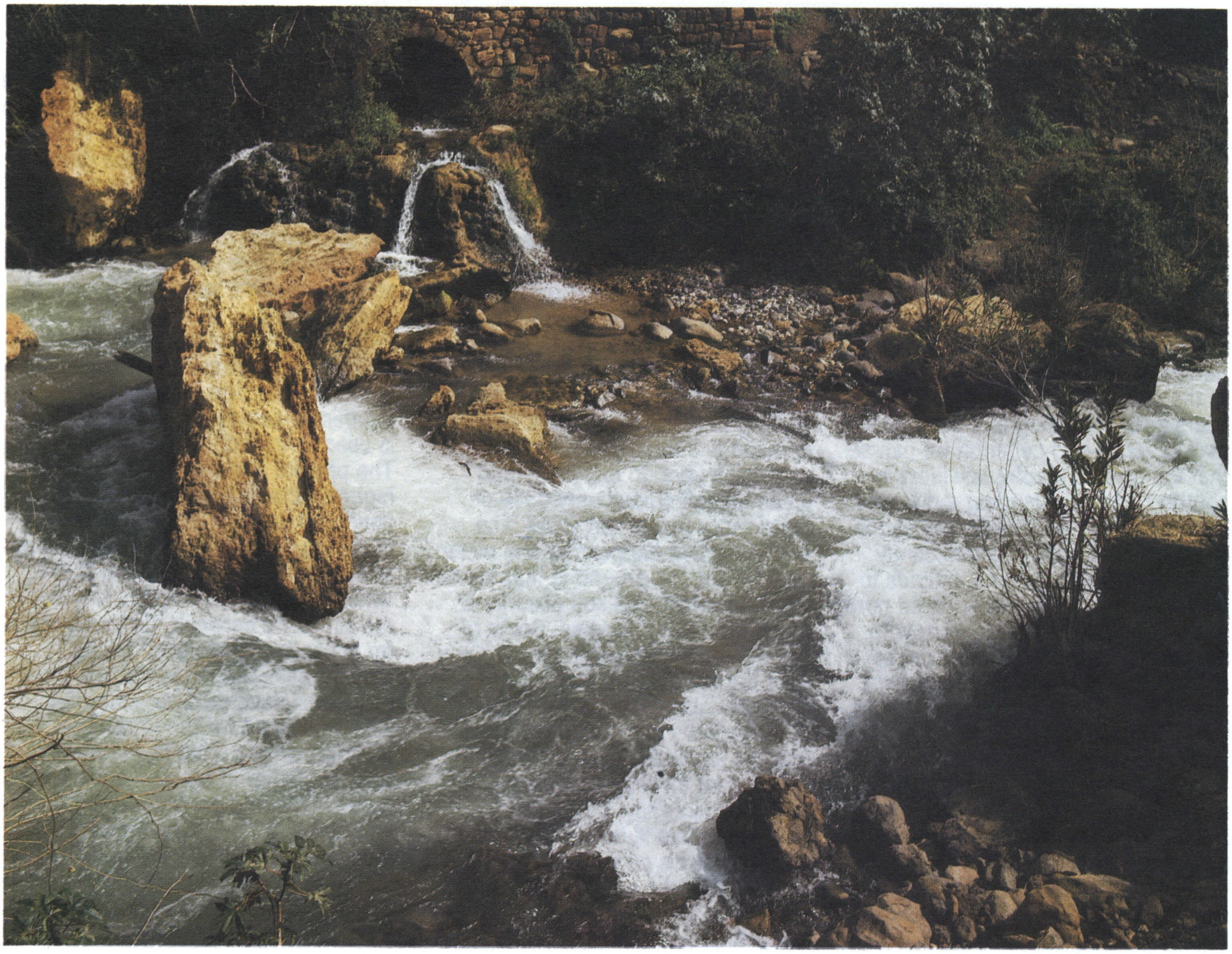
But today we are beginning to realize that water is just as important, if not more important, a natural resource as oil. We always thought that our water supply replenished itself every year or so. Now we are realizing that this might not be the case. It was thought that it was only arid countries like those in the Middle East that had to worry about water. The people in the Bay Area of San Francisco, California who started to ration water this year know better. We are beginning to understand that the use of water must be managed and managed wisely. Wise management, though, is a function of knowledge. We need to know the answers to basic questions about our aquifers. Just how big are they? Those aquifers that replenish themselves, how fast do they replenish themselves? Just where are all the aquifers? It is questions like this that Dr. Eliyahu Wakshal and other scientists in the University's Leo Picard Center for Groundwater Research in Rehovot are trying to answer.

DR. WAKSHAL considers that one of the most important things he does is to help organize an international post-graduate course in the exploration, exploitation and management of groundwater resources for students and professionals who come from countries abroad to learn and gain from the Israeli experience in groundwater science and management. The students come from five continents, and over thirty countries, to learn what Israel and the Hebrew University have to offer. By this year, over 230 students will have participated in the course, which is held in cooperation with the Ministry of Foreign Affairs.

The Groundwater Research Center, which conducts the course, was established in 1967 by the Swiss Friends of the Hebrew University, at the initiative of the geologist Prof. Leo Picard, who directed the Center until 1973. Prof. Shmuel Mandel was the director from 1973 to 1981.

Teaching water management and exploitation might appear to be easy, but when the shots have to be called out in the field, complexities arise. A good example of this is that unreplenishable water we find in the deep aquifers, the fossil water. The salinity of water is a major factor

The Banias Spring, one of the underground sources of the Jordan River



Werner Braun

in determining its use. One way to measure salinity is determining how much chloride ion the water contains. As we remember, common table salt is composed of sodium and chloride. To get a feel for the numbers involved, seawater has 19,000 milligrams of chloride per liter. Potable drinking water can have up to 300 milligrams per liter, and at the other extreme, the Dead Sea has about 218,000 milligrams of chloride per liter. Dead Sea water is more than ten times as salty as normal seawater.

AS IT TURNS out, one of the greatest reserves of fossil water is found in the Israeli Negev. The aquifer there is part of a tremendous aquifer that starts in North Africa under the Sahara Desert and runs under Libya, Egypt, the Sinai, the Negev, and continues to Jordan and Saudi Arabia. The fact that it is a single aquifer does not mean that if we draw water in the Negev we can deplete the water under Jordan or Egypt. After this huge aquifer was formed it was geologically bisected by the Gulf of Suez and the Red Sea on one side, and the Jordan Rift Valley on the other. The water found in this aquifer ranges from being slightly saline, 500 milligrams of chloride per liter, to brine water, 100,000 milligrams of chloride per liter. This brine water is about five times more saline than seawater.

Now the communities of the Negev import a large part of the water they use from different places in Israel. Some water comes from the coastal aquifers, some from the Sea of Galilee via the National Water Carrier. Of all the water that is imported, less than five percent is used as drinking water. The remainder is used for industry and agriculture. *Looking at present water consumption in the Negev and projecting into the future, forecasts are that there is enough fossil water to meet the water needs of the Negev for over a hundred years!*

You are the water manager, what do you recommend? As you quickly realize, there are tremendous ramifications in using the fossil water. Once you use it, it is gone forever, but so are oil, gas, and coal and we still use them at ever-increasing rates.

A student in the International Course in Groundwater Research, Udom Kompayak of Thailand, tasting water from a newly drilled borehole near the Dead Sea

The advantage of using the fossil water is that the water we import from the rest of the country can be used in other places that do not have this tremendous potential. Then again, getting to the fossil water can be a problem. The depth from which fossil water can be pumped with current techniques ranges from 50 to over 800 meters below land surface, and some of this fossil water is over 2,000 meters deep. Then there is the problem of salinity. Of course one could introduce crops into the region that are not sensitive to the salinity of some of the water. Good candidates would be celery and tomatoes. Then there is the psychological problem of convincing people to live in an area whose water they know will run out in 100 years or so. If Israel does decide to exploit the fossil water she will not be the first. Egypt and Libya started to mine their fossil water years ago. So what is the solution, water manager?

These are some of the problems that Dr. Ronit Nativ of the Seagram Center is trying to deal with. After extensive research, her recommendation is to use it. Not to use it blindly with no eye to the future, but use it while developing alternate sources of water for the region. Actually her reasoning is along the same lines as the argument for using fossil fuels. Who would not recommend using them? Then again, who would not recommend pursuing the development of other sources of energy at the same time?

Water management is not easy in Israel, California, or any other place where water is a scarce commodity. New techniques are constantly being developed and tried in Israel. If necessity is the mother of invention then the scientists at the University will continue to be on the cutting edge of groundwater management and exploitation for many years to come. ■