EIR Science & Technology

World's Water Wells Are Drying Up!

Australian Professor Lance Endersbee reviews the disastrous state of world groundwater, and shows why it is not replenished by rainfall, contrary to the textbook models.[1]

Around the world, groundwater from deep wells is the main source of drinking water for over three billion people. In addition, a large proportion of the food supply in many poor countries is based on irrigation from wells. However, almost all of the world's wells have falling water levels, and declining yield, and already, many have run dry.

These deep water wells cannot be replenished from rainfall. The source of the groundwater that supports these three billion people lies in the interior of the Earth. There is a continuing release of water from the interior towards the surface of the Earth, and we see that in the steam of volcanoes, and the water gushing from deep ocean vents. Over geological time, some of the rising water was trapped in the path towards the surface of the Earth, and accumulated as underground reservoirs of water.

There are resources of groundwater underlying most of the flat lands of the world. From early times, men dug wells by hand, and lifted water in buckets for their needs. Many civilizations were established where groundwater was available at oases or in shallow wells. The ancient Romans built aqueducts to bring springs of groundwater to their many cities around the shores of the Mediterranean. Vitruvius, a Roman engineer and architect, describes in his book, written in the First Century B.C., the methods the Romans used to find and test underground sources of water. He tells of the adverse properties of some spring waters. There are cautionary tales about a little well at Susa, the capital of Persia, where those who drink of the water lose their teeth, and a well in the Alps where those who drink the water immediately fall lifeless. There are also wells with healing properties, such as the acid springs in Campania that have the power to break up stones in the bladder. Vitruvius advises on the tests for good water: The first test is to look at the physique of the people who dwell in the vicinity!

Today, in the United States, groundwater provides drinking water for over one half of the population. The same applies in much of Europe, India, China, and many other countries.

The pattern of dependence on groundwater that had continued for centuries began to change from about 1950. The population of the world was continuing to increase, there was growth of cities and expansion of city water supplies based on the use of groundwater, and in rural areas there was the introduction of mechanical pumps and commercial agriculture based on groundwater. As a consequence, there was a simultaneous and rapid growth in the use of groundwater all around the world. In countries like India and China, in North Africa and the Middle East, the use of shallow hand-dug wells, and hand lifting of water, was replaced by drilled bores

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1. Professor Lance Endersbee is a former Dean of Engineering and former Pro-Vice Chancellor of Melbourne's Monash University, and a world authority on rock behavior and tunnelling.

This article is adapted from the first chapter of his new book, *A Voyage of Discovery: A History of Ideas About the Earth, With a New Understanding of the Global Resources of Water and Petroleum, and the Problems of Climate Change,* which is available from the Monash University Bookstore website. It is used here with the permission of the author.

Courtesy of Lance Endersbee

A village water well in India. With the extraction of groundwater from deeper bores, the shallow village wells are drying up. Also, the deeper waters are more mineralized, with potentially poisonous levels of arsenic and fluoride.

and mechanical pumps. The use of fertilizers enabled a very great increase in yield, but that required much more water. There was a vast increase in the areas under irrigation from groundwater.

There was a rush to exploit the limited groundwater resources. The groundwater was freely available at the cost of a bore and a pump. There was competition to use more and more groundwater. Water tables dropped, and farmers drilled deeper bores, and installed more powerful pumps. Almost simultaneously, all around the world, the wells began to run dry, and governments were quite unable to control the extraction of groundwater, or protect the resources.

Most governments did not know where the wells were, or the depth of the wells. Governments did not record water levels, but were certainly informed when farmers complained when their wells ran dry. Farmers, governments, and their professional advisors, had all believed that the wells would flow forever.

The groundwater rush was like a gold rush; it was a great uncontrolled bonanza. The International Water Management Institute has estimated that the total global withdrawal of groundwater is now about 1,000 cubic kilometers each year, but it is quite unsustainable. This great global rush to exploit available groundwater resources in our time is a one-off extraction of a limited natural resource.

Groundwater has been, and in many areas still continues to be, the best and only readily available source of clean drinking water. This is because the groundwater may be just directly below the place of use, for agriculture, cities, factories, and mines. In most cases the groundwater is available at no cost, except for the cost of the well, and the pump.

The groundwater in these underground reservoirs has accumulated in geological time. The resource can be considered as a great reservoir of water that has been captured in open joints and fissures in the rock, and in pores in porous rocks. In the natural state, prior to intervention to exploit the resource, the underground reservoir was filled to the brim, and overflowed naturally at springs, and into lakes and streams.

Prior to 1950, most of the world's groundwater basins were in a condition close to a state where the rate of use of the groundwater was compatible with the sustainability of the resource. After over half a century of massive exploitation, far greater than any possible rate of recovery, most of the groundwater basins of the world are now close to the limits of the resource.

The consequences are now evident in many countries. In essence, the world has been exploiting the reserve bank of groundwater at a rate far greater than the rate of natural replacement, and the water bank is becoming insolvent. This excess use of water is a deficit that can never be repaid in our time.

The deficit in the groundwater bank is also being matched by a deficit in the food it provided. Thus the present prosperity in much of the world is based on *borrowing from the bank of water,* which is also, in essence, *the borrowing of food from the food bank,* neither of which can be repaid. As a consequence there has been an artificial stimulus of food production in many countries where groundwater enabled food production to be raised well above sustainable levels.

The UN Food and Agriculture Organization even suggested that the rapid exploitation of groundwater has *saved* the world from a food crisis. But if countries have been *borrowing water on credit,* and effectively, *borrowing food on credit,* it means that the world is facing the prospect of *an even more serious food crisis.* This prospect is already highly evident in some countries as they try to rapidly expand food production from resources of surface waters, especially in China, and India.

China's Water Crisis

China is heavily dependent on groundwater. Most of the flat areas of China overlay groundwater basins, and the groundwater is being extracted for water supply for cities, industries, and agriculture. The northern agricultural areas of China are virtually drying out: The major rivers have ceased to flow in the dry season. The water table under the North China Plain, which produces half of China's wheat, and a third of the corn, is falling at an alarming rate. Under Hebei Province, in the heart of the North China Plain, the water level in the deep aquifer is falling at a rate of 3 meters each year.

The decline of the water table has led to wells drying up, and to deeper wells being drilled. The consequent increase in pumping costs has forced some farmers off their land, while the demand for groundwater for cities and industries has continued to grow. In Beijing, the new wells for the city water supply now have to reach 1,000 meters to tap fresh water.

The pumping of groundwater in the North China Plain has resulted in the entire area subsiding, with many funnels and sinks appearing on the ground surface. Cities are reporting substantial subsidence, complicated by the consolidation of the ground under the new high-rise buildings.

Shanghai started pumping groundwater for the city water supply in 1860. The old city of Shanghai sank almost 2 meters in the period 1921-65. Subsidence is continuing, and the authorities are now trying to correct it by injecting water into the aquifers.

Such ground subsidence in densely populated cities has caused great economic losses, as well as presenting a hazard to buildings and people. It is reported that Shanghai has suffered economic losses estimated at $35 billion in the past 40 years due to destructive flooding and tidal effects caused by subsidence, probably mostly caused by groundwater extraction.

In the Pudong New Area of Shanghai there are a large number of new skyscrapers. Settlement of the new urban area is being recorded at about 3 centimeters a year. The foundation of the tallest building, at 420 meters high, sank by 6.3 centimeters in 2002. Most of that settlement is probably due to the great weight of the building, but extraction of groundwater would have contributed. It may be unfair of me to mention that during construction of a tower in Pisa in Italy, from the year 1173, it began to tilt in 1178, due to extraction of groundwater nearby. Construction continued intermittently in the tilted position until 1350. It became famous as the Leaning Tower of Pisa. I am pleased to note that the buildings in Shanghai appear to be subsiding without tilting.

The urgency of the need to control the use of groundwater, and to provide other sources of water and food, has been recognized by the Chinese government. They are planning to build several new water projects, including two very large projects, one in China, and one in South East Asia to provide a food bowl for China.

In November 2002, the Chinese Government authorized the construction of a hugely ambitious water diversion plan to take waters from the Yangtze River system to the Yellow River.

The aim of the project is to divert water from the south of the country, where the rivers flow from the Tibetan plateau, to the areas of water shortage in the North China Plain, and to Beijing and other industrial cities in the north. There are three separate diversion systems. Construction of the first diversion system began in 2002, and is estimated to cost $19 billion, and will divert 13.4 billion cubic meters per year to north China. There are two more similar diversions in the total project.

The population of China is about 1.3 billion, and still growing at about 0.8% each year. That means an increasing demand for food. Even with the proposed water projects in China, there will still be a need to import food.

One prospective source of food for export to China is the Mekong Basin in South East Asia. The Basin begins where the Mekong River leaves the mountains at the Thailand-Myanmar border, and comprises the flood plain of the Mekong River in parts of Thailand, Laos, Cambodia, and Vietnam.

In 1956, a Mekong Committee, comprising representatives of the four riparian countries, was established with a secretariat provided by the UN Economic Commission for Asia and the Far East (ECAFE), in Bangkok. They studied conceptual plans that had been developed by the riparian countries with significant input from expert engineers from U.S. Government agencies (Corps of Engineers, Bureau of Reclamation, and Tennessee Valley Authority).

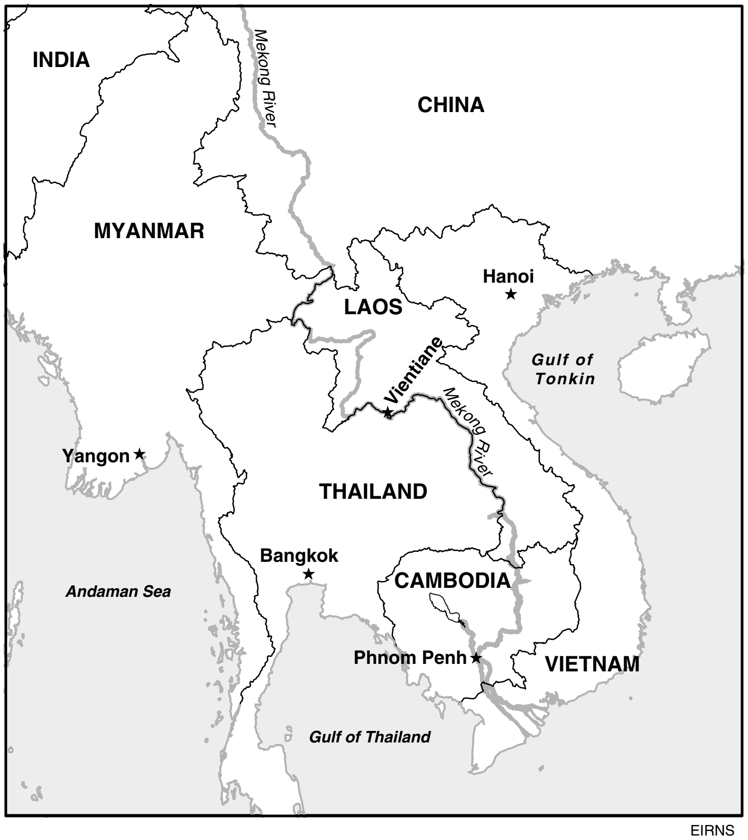
The conceptual plan was a vast scheme involving a cascade of seven dams on the Mekong River, associated hydro power, river navigation for 1,000 kilometers inland from the sea, the diversion of waters for extensive irrigation development throughout the Basin, the construction of many dams on tributary rivers, and water supply to cities and towns, and flood control.

In 1964, I became interested and involved in the Mekong Project when I went to Thailand as a UN advisor on dam design and hydropower. At the time, there was great enthusiasm to get on with the Mekong project, and wonderful international co-operation. Some excellent and extensive investigatory studies had been made on many aspects of the project by experts from friendly nations, all under the umbrella of the United Nations—for example: U.S.A, Japan, Israel, Australia, France, and other countries were active in programs of assistance in planning and evaluation. In addition, there were offers of support from many countries for participation in the construction of the project. Overall, it was a wonderful example of international co-operation in action. For my part, I was delighted to share in the work with my Thai colleagues, and to collaborate with experts from so many countries.

At the beginning of 1965, it all seemed to stop. The war in Vietnam halted any prospect of the project continuing, even on-site investigations on the main river dam sites. Shots were sometimes fired at the operators of drill rigs in the middle of the river, lessening enthusiasm for international cooperation. The World Bank was quite firm in refusing to fund any part of the project while hostilities continued.

Later, the terrible civil hostilities in Cambodia, especially the genocide, and the laying of a vast number of land mines, did not encourage any construction activity in that country for the foreseeable future. The effect was to stop all work on the key parts of the project—for 40 years.

Recently, the Chinese government announced an interest in funding and building the entire project, and sought the



The Mekong River rises in Tibet, and flows south through the four countries of the Indo-China peninsula, Thailand, Laos, Cambodia, and Vietnam. China has shown interest in reviving the Mekong Project, designed in the 1950s, which would build dams and hydro power plants to create a new food bowl for the world.

cooperation of the riparian countries. The Chinese were quite clear that they wanted to create a new food bowl for the world, and especially for China.

The Chinese government indicated that there would be no need for funding from international sources such as the World Bank, or the Asian Development Bank. The Chinese were prepared to fund the project and to undertake the design and supervision of construction of all the major dams and hydro power plants. The total cost of all those parts of the Mekong Project in the four riparian countries will probably be much more than $100 billion dollars. The offer of such large funds is a strong incentive to the riparian countries to accept the Chinese proposals. Of course the World Bank and the Asian Development Bank would also welcome the Chinese proposal, as it frees bank funds for other purposes.

Far upstream on the Mekong River, in China, near Tibet, the Chinese government is now constructing a 290 meter-high concrete arch dam project, which includes a large hydroelectric power plant. It will be the highest dam in the world. The project is likely to be followed by a cascade of hydropower dams down the river towards the Mekong Basin.

These two great projects to be funded by the Chinese Government, the south-north river diversions in China, and the Mekong Project, illustrate the urgent concern about future food supplies for China, and the magnitude of the extraordinary problems that have been created by the exploitation of the Chinese groundwater resources towards extinction.

India—'Where Has All the Water Gone?'

In India, there has been an enormous increase in irrigation from deep groundwater over the past 50 years. India is mining aquifer waters in virtually all states, and water tables are steadily falling, in some cases by 1 meter each year.

The population of India is well over one billion people, and increasing. There were 1 million wells with pumps in 1960. Now there are 21 to 26 million groundwater wells, with 55-60% of the population dependent on groundwater. The total use of groundwater is 200 cubic kilometers each year.

The Indian agricultural economy prospered from the benefits of this abundant, free, and clean groundwater. Groundwater irrigation expanded to create more agricultural wealth than any other irrigation source.

Irrigation from groundwater had many advantages. The farmers could use the groundwater when and where they needed it. The improved prosperity enabled them to use higher yielding crops, fertilizers, and pest control, making the use of groundwater far more productive, and thereby causing increasing dependence on groundwater. As a consequence, a great groundwater economy was created in India over the past 50 years. It has now reached its maximum level of development, and is starting to decline, rapidly in many cases.

The over-exploitation of groundwater has led to declining water levels, drying of shallow aquifers, and saline water intrusion. The deeper groundwater wells are highly mineralized, and in some parts of India, the population is now suffering fluoride poisoning and arsenic poisoning.

It is evident that India faces a terrible calamity as the groundwater economy limps to a standstill. Half of the country's traditional hand-dug wells have already run dry, as have millions of bored wells. Many farmers have borrowed money to spend on new wells, only to find that they did not flow. Because of the risks involved, the money had to be borrowed at high interest rates. The consequent inability to repay borrowings has led to suicides of farmers.

Urgent action is now planned by the Indian Government. They have approved a plan to use waters from the rivers flowing from the Himalayas for diversion south to replenish 17 southern rivers, and to be distributed over much of the Indian Peninsula. The project is based on using the waters of 14 tributaries of the Ganges and Brahmaputra Rivers.

The scheme involves some 300 reservoirs, 12,000 kilometers of canals, and will divert a total flow of 1,500 cubic meters/second. The estimated cost is from $70-200 billion. The proposed project has already caused tensions with Bangladesh, because it involves diverting rivers which flow through Bangladesh.

The Indian Government has formed a Task Force to implement the project, with a completion date of 2016. It will be an enormous task to complete the project in that time. On the other hand, the provision of a secure supply of water to the people of India is now a matter of crucial human and economic importance to the nation, and to the world.

Bangladesh—Arsenic Poisoning From Groundwater

Bangladesh has a population of 141 million, as of July 2004, and has the highest population density in the world, other than the city-states such as Hong Kong and Singapore. Yet Bangladesh is a rural economy with most of the people working in the agricultural sector. It is a low-lying country on the delta of the Ganges and Brahmaputra Rivers. About one-third of the country floods annually during the monsoon season.

Bangladesh came into existence originally as Bengali East Pakistan after the partition of India in 1950. It became a separate country in 1971, when it seceded from its union with West Pakistan. As an ethnic group the people are almost entirely Bengali, and 83% of the population is Moslem. Almost the entire land border is with India, and relations between the two countries are tense.

It is an extremely poor country. Until the 1970s, the people in the countryside were largely dependent for their water supply on surface water ponds and rivers. With increasing population, the surface ponds became highly polluted. Sewage bacteria unleashed water-borne diseases, which killed a quarter of a million children each year. The United Nations became concerned about this dreadful calamity, and the Children's Emergency Fund (UNICEF) sought to solve the problem by installing a great number of water wells in order to replace dangerous surface waters with clean groundwater.

The economic impact of the mass introduction of groundwater wells was quite dramatic. The contribution of groundwater to the total irrigated area increased from 4% in 1971 to 70% in 1999. Some 12 million wells were installed. Employment and output in agriculture increased, and poverty was reduced. The United Nations had saved the children.

The health problem seemed to be solved, but by 1985 the people were beginning to be diagnosed with arsenic poisoning. Arsenic is a slow killer, and the signs of poisoning are blisters on the palms of the hands and soles of the feet, which eventually become gangrenous and cancerous. Almost all the wells had traces of arsenic. . . . This means that virtually the entire population is now exposed to some degree to arsenic poisoning; almost every one of the 68,000 villages in Bangladesh is at risk.

Corrective action is slow. The population has now been alerted to the problem, and the authorities are trying to identify the most contaminated wells. But there are about 12 million wells, and testing all of these may take decades.

But the situation is actually much worse. Further testing has shown that arsenic is not the only toxic metal in the groundwater—it is just that arsenic poisoning was the first to be revealed in patients. There are also unsafe levels of manganese, lead, nickel, and chromium. And now it has been discovered that a proportion of wells also exceed World Health Organization limits for uranium. . . . An entire population of over 140 million is slowly being poisoned in Bangladesh, and it is time for effective action.

In June, 2004, the Board of the World Bank provided a grant of US $40 million to the Government of Bangladesh to expand the provision of safe drinking water to some rural areas by promotion of piped water supply, but that is a small amount for the task when there are about 100 million rural people at risk.

I recall that in the early days of the United Nations, there was a wonderful spirit of goodwill between nations, and nations were prepared to give generously to support worthy projects. The gifts were often support in kind, such as construction, plant, and equipment, or sending a team of experts, or making donations of food to regions stricken with famine.

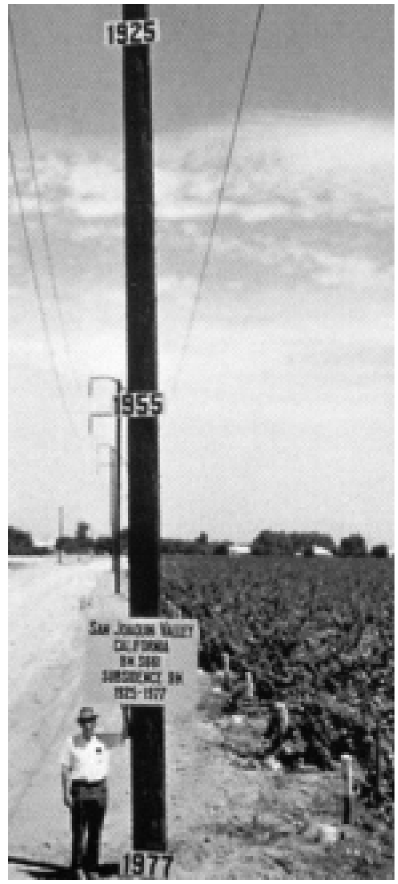
Bangladesh is in desperate need of international assistance if the problem of arsenic poisoning is to be corrected quickly. At present there is a tendency for the international community to stand back, and to fund *studies* of the problems, rather than intervening directly and solving the problems. . . .

U.S.A.: Groundwater and Market Forces

In the United States, the state governments retain residual responsibilities for such matters as land and water. All states maintain their own legislation on water. In the case of groundwater, the property owner has an absolute right of *capture* of the groundwater under his property. This means that the land owner may pump as much water as he wishes, without incurring any responsibility, if his actions are found to be detrimental to his neighbors or the community as a whole.

Under state environmental laws, a state may establish controls to maintain groundwater quality, and that may influence well spacing and disposal of waste into the groundwater. But overall, throughout the United States, the state legislatures treat groundwater as a basic property right, and there is no control over groundwater withdrawal. Because of problems of depletion of groundwater in some basins, many states have established local district conservancy boards, which are self-governing bodies of users of groundwater. The boards are charged with responsibility to deal with all property owners in the management of the water resources. It is hoped that the problems will be solved by mutual agreement. Nevertheless, in any dispute, the legislatures and the courts continue to treat groundwater as a basic property right.

Even with the conservancy boards, the consequence has



State of California

This telephone pole in the San Joaquin Valley in California shows the level of the land in 1925, 1955, and 1977. Such subsidence is caused by extraction of groundwater, and arises from the closure of fracture openings and pore spaces in the rock. It is essentially irreversible.

been a disastrous emptying of the nation's groundwater basins. In cases of dispute, the right of unlimited private use of groundwater is defended by the law!

Groundwater is the source of drinking water for about one-half of the U.S. population, including nearly all of the rural population. The pumps deliver in total about 50 billion U.S. gallons per day, or about 70 cubic kilometers per year. The problem is made worse by a continued quaint view in the groundwater profession that the aquifers are being recharged from surface rainfall. They use dubious mathematical models of groundwater flow to show farmers and cities where to drill more and deeper wells, but inevitably the new wells cause the water table to drop, while the wells decline in flow.

The reality is that the United States is coming to the end of the cowboy era of groundwater exploitation, and it is to be expected that the flow in all basins will gradually decline towards extinction. The evidence is clear.

There are reduced flows of water to springs, lakes, and streams. In the natural state, the small residual flow of groundwater came to the surface as springs, and as flow to streams, lakes, and wetlands. With the lowering of groundwater levels, the associated springs and streams cease to flow.

There is serious subsidence of land in many parts of the United States due to pumping of groundwater. In the area of Houston, Texas, groundwater pumping has led to subsidence at the surface of about 3 meters, together with a lowering of the groundwater level by about 120 meters.

In the desert state of Arizona, there have been water level declines of between 100 and 200 meters over much of the area, and associated subsidence of the ground of 5 meters and more. Unequal subsidence and deep land fissures are a serious problem. (The following internet reference is informative, http://ag.arizona.edu/AZWATER/arroyo/062land.html).

In 1952 I became familiar with problems being caused by land subsidence in the San Joaquin valley in California. I was with the Bureau of Reclamation in Denver, and the engineers in the Bureau were designing a canal system for the area to distribute surface water for irrigation. They had a problem with land subsidence that was being caused by extraction of groundwater. The land was subsiding at the rate of about 1 meter in three years, presenting major difficulties in the design of irrigation canals, which follow very flat grades. The subsidence continued for decades after, as the accompanying photo shows.

In Kansas, groundwater accounts for 90% of the total water supply. It is the principal source for 600 public water supply systems, and most rural-domestic supply. Most of the groundwater is used for irrigation. Groundwater levels have dropped substantially, in some areas by over 200 feet. There are many similar examples in other states.

Virtually all of the drinking water in Florida is supplied from groundwater. The Florida aquifer system extends across the entire state of Florida, southern Georgia, and adjoining parts of Alabama and South Carolina. A major concern is the increasing contamination of the aquifer system as the water levels decline. There is intrusion of seawater into the aquifers along the east coast, and on the south coast along the Gulf of Mexico.

In Texas and Arizona, there are proposals to privatize the groundwater aquifers. This would absolve governments from the responsibilities for management of groundwater, and leave the matter to the private sector and the people to sort out. This seems a dangerous proposal in a country where citizens may own guns.

Subsidence of lands due to groundwater extraction is a serious problem in several states of the United States. Differential settlement, sometimes with cracking of the ground surface, and sinkholes, can cause serious damage in built-up areas.

Throughout the United States, the common law right of capture of groundwater is firmly entrenched in the minds of the people, and in legislation. Landowners protect their claim to capture by pumping the water. Consequently, there has been a race to the pumphouse. The race is now ending. From now on, water supply will become a far more important issue for farms, cities, and states. Water supply for cities will become more expensive, and there will be pressures for transfer of water across state boundaries.

The rapid decline of groundwater resources in China and India has led to the governments of those countries moving

Government of Libya

Libya's great man-made river is one of the largest construction projects ever undertaken, with the objective of reducing dependence on food imports and employing people in modern agriculture and industry. These pipe sections are 4 meters in diameter, made of pre-stressed concrete, weighing up to 80 tons.

to construct huge projects for the transfer of water to their cities and farms. Similar actions may be needed in the United States.

Libya—The Man-Made river

In the 1960s, during the exploration for oil in the desert in Libya, vast deep reservoirs of groundwater were discovered. Four major underground basins have subsequently been identified, and estimated to contain over 35,000 cubic kilometers of water, a truly huge volume of groundwater, if the estimates turn out to be close. The groundwater is recognized to be fossil groundwater, and there will be no effective recharge as the resource is exploited.

In 1983, the Libyan Government created an Authority to plan and build a great project to take waters from the aquifers in the desert in the south to the coastal plain, along the Mediterranean Sea, for irrigation and public water supply. The project involves 270 deep wells, and 4,000 kilometers of large diameter pipe, over 4 meters in diameter, all buried under the desert sand.

The entire project will cost about $27 billion, funded entirely by the Libyan Government from its oil revenues. The project is described as the Great Man-Made River Project. By 1996, a key stage of the project was reached when water was delivered to Tripoli, the capital of Libya.

Libya covers a large area, but the population is little more than 5 million. The construction of this project, funded entirely without overseas borrowing, is a most remarkable achievement. It is one of the largest construction projects ever undertaken. It was intended that the project would make Libya self-sufficient in food. Libya imports about 75% of its food. Irrigated farmlands are now being developed along the coast towards this purpose of self-sufficiency. But self-sufficiency in most foods may not be the most efficient and economical way for Libya to use these abundant new resources of groundwater. For example, it may be a great waste of water for Libya to grow cereals such as wheat, barley, and rice. These crops have high water demands, and are best grown in areas of sufficient natural rainfall.

There may be far higher financial returns, and far more employment, if Libya uses its lands, sunshine, and high-value water to grow higher-value foods for export to world markets, such as fruit and vegetables, and to support new industries based on these new crops.

A Brief Review of Other Nations

Yemen is a rocky barren country, with very little arable land, and a population of 20 million people. Groundwater was developed in the last few decades to provide water for urban areas, and for limited agriculture. The water table is now falling at 2 meters each year in the agricultural areas. The capital is Sanaa, and its groundwater level has been falling at 6 meters each year. This presents a very serious problem as there are no other supplies of groundwater, and virtually no supplies of fresh surface water.

Iran is a rocky country with limited areas of soils suitable for agriculture, and a population of 69 million. Iran is facing an acute shortage of water. In eastern Iran, villagers are leaving the region as wells run dry. It has been reported that in the fertile plain in the northeast, the water table has been falling by 2 to 3 meters a year.

Mexico. There are serious problems of water supply in some states and several cities, as aquifers are pumped dry. Mexico has a population of 105 million people, growing by about 2 million each year. The agricultural lands are deteriorating, and there is a drift of people to the cities, but the cities also have serious water and pollution problems. The government considers that lack of clean water is a national security issue. There have been serious problems of land subsidence in Mexico City for a long time, simply due to the weight of monumental buildings on the underlying clays. The subsidence is aggravated by groundwater extraction.

The World Groundwater Deficit: How Did It Happen?

The great magnitude of the problems caused by the depletion of the world's groundwater resources is abundantly clear. Yet except for China and India, there has been very little action by governments. In Australia, the government has recently issued a report recommending the use of groundwater to supplement surface irrigation in the Murray-Darling Basin, a vast flat area that is the food-bowl of the nation. The decision seems to have been made with no consideration whatever of the prospect of very serious damage of irrigation areas, due to land subsidence caused by groundwater extraction, or increased salinity in low areas, or earth fissures as in Arizona, and a firm conviction that recharge from surface rainfall would maintain water levels.

I believe that one reason for this inability of most governments to comprehend the situation lies in the nature of the professional advice they receive. I note that in the scientific and professional journals of the world, there is never any mention of world groundwater problems. The professional groups most concerned with water resources and groundwater are all strangely silent about the worldwide decline of groundwater resources. The textbooks on groundwater hydrology appear to be part of the problem: They all show mathematical models of groundwater flow based on the key assumption that the groundwater is recharged from surface rainfall. As a consequence, the related computer models of groundwater flow are very seriously misleading.

These days it is so easy for professionals to share ideas with colleagues all around the world, and one would expect that the serious matter of the worldwide decline of groundwater resources would command attention. But it does not. It is apparent that the main cause of the silence is that the present understanding of the origin of groundwater by the professions involved, is not all consistent with what is actually happening. The theory is not working out in practice. There is a global disaster, and the key experts are silent.

There is clearly a need for a new understanding of the origin of deep groundwater. It is hoped that this book may be a step in that direction.

Solve the Water Crisis With Nuclear Desalination

Nuclear desalination, researched since the 1960s, is a technology ready for take-off as a clean, economical source for supplying safe drinking water from seawater. As Lance Endersbee makes clear, there is no time to waste in planning and building desalination plants that can meet the looming deficits of fresh water for the world's population.

Conventional desalination plants powered by the steam or electricity that is produced by gas or oil, have been operating for 50 years, and in 2001, there were 12,451 desalination plants worldwide. In the Gulf region and North Africa, desalination supplies about 1 million cubic meters per day of water, while Saudi Arabia, which is even more dependent on desalination, has a capacity of 4 million cubic meters per day. The Mideast and Gulf regions are the largest users, with more than 50% of the world's desalination capacity.

There are three main desalination technologies: reverse osmosis, or RO, which is used in nearly half of today's desalination plants; multi-effect distillation (MED); and multi-stage flash distillation (MSF). All three technologies are still undergoing research to improve efficiency and cost.

Nuclear Desalination Most Attractive

Any power plant—even a small diesel engine—can be coupled to a desalination facility. But nuclear plants are the most attractive power source for desalination, because they are more energy-intensive than plants fired by conventional fuels, and cleaner. Although almost any kind of nuclear plant could be used to power a desalination facility, the fourth-generation high-temperature nuclear reactors—which are 50% more efficient, modular, mass-producible, and super-safe—are ideal for the job. Because of its passive safety characteristics and smaller design, the new high temperature reactors (either the South African Pebble Bed or the prismatic core model of General Atomics), can be easily sited near the water-distribution systems.

Especially for developing-sector countries, which do not have large power grids, the small- to medium-size, fourth-generation reactors are economical, because they can be added to the grid module by module, as demand increases.

For industrialized countries, larger nuclear plants are appropriate. In fact, in the 1980s, the Metropolitan Water District of Southern California, which serves the large desert population of more than 15 million people, proposed building a large desalination facility powered by a high-temperature gas-cooled reactor of the General Atomics design. The desalination process was designed to directly use exhaust heat from the reactor. Although economically and technologically feasible, the project was killed by the environmental Malthusians.

The International Atomic Energy Agency has conducted research and feasibility studies on nuclear desalination since the Atoms for Peace days. In its recent studies, the IAEA has stressed that nuclear desalination is cost competitive against other energy sources; it has inherent advantages, such as no pollution, continuous operation, and a secured fuel supply; and that both the heat and/or the electricity produced by a nuclear reactor can be used for desalination, permitting flexible design concepts.

—Marjorie Mazel Hecht