Alpheus Water Blog

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October 2016

Depleting Aquifers: The End Game for Cheap Water

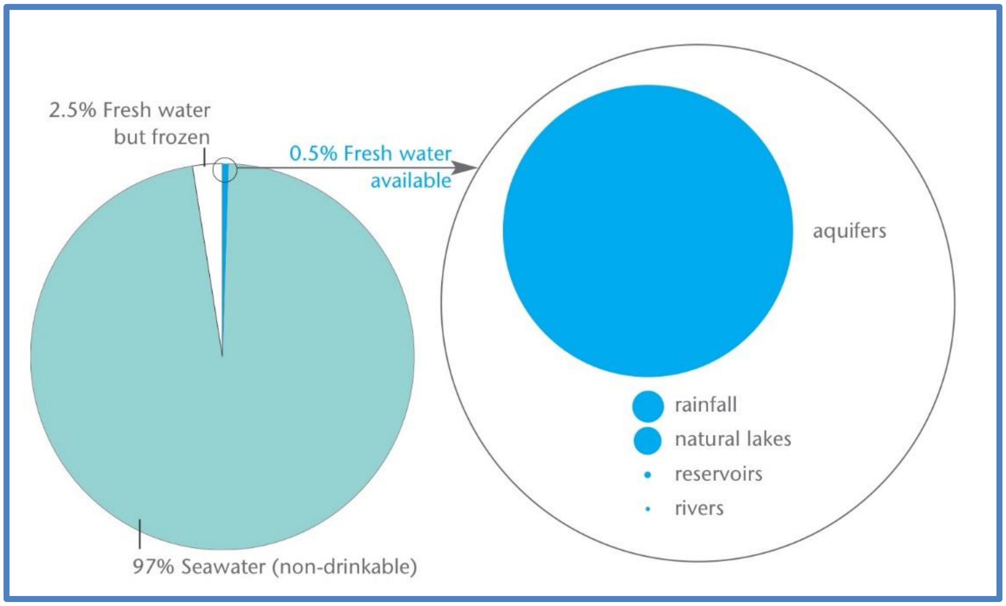
Summary

The world's depleting underground aquifers are the most unmistakable leading indicator of a global water crisis. As the ultimate renewable resource, rainfall replenishes fresh water in rivers and lakes. However, as above-ground water supplies diminish, civilizations have drilled deeper and deeper into the huge underground lakes that were formed over thousands, if not millions, of years.

Almost 96% of the world's fresh water is stored in aquifers.[1] (See Figure 1.[2]) While aquifers naturally replenish with seepage, about 57% of the world's largest aquifers are being depleted at a rate that is faster than replenishment. Most of these depleting aquifers support the world's largest populations and economic zones. This trend is clearly unsustainable, as this "borrowed," practically free water will eventually need to be replaced with costly desalination and aqueducts.

Adding to these costly supply-side investments is the similarly "past-due" debt of treating polluted water and replacing a dilapidated existing infrastructure. Yet another unintended consequence is sinking land in many of the world's largest cities and agricultural centers.[3] The "perfect storm" of all of these deferred investments will ultimately lead to a much higher cost of water.[4]

Figure 1: Fresh Water Available Worldwide



[1] "Deep Waters, Slowly Drying Up," *The Economist*, October 7, 2010.
[2] "Water Facts and Trends," World Business Council for Sustainable Development, August 2005.
[3] "Rising Tides, Sinking Cities," TRTWorld, August 10, 2016, www.trtworld.com/in-depth/rising-tides-sinking-cities-161804.
[4] "The United Nations World Water Development Report 2015: Water for a Sustainable World," United Nations World Water Assessment Program, 2015.

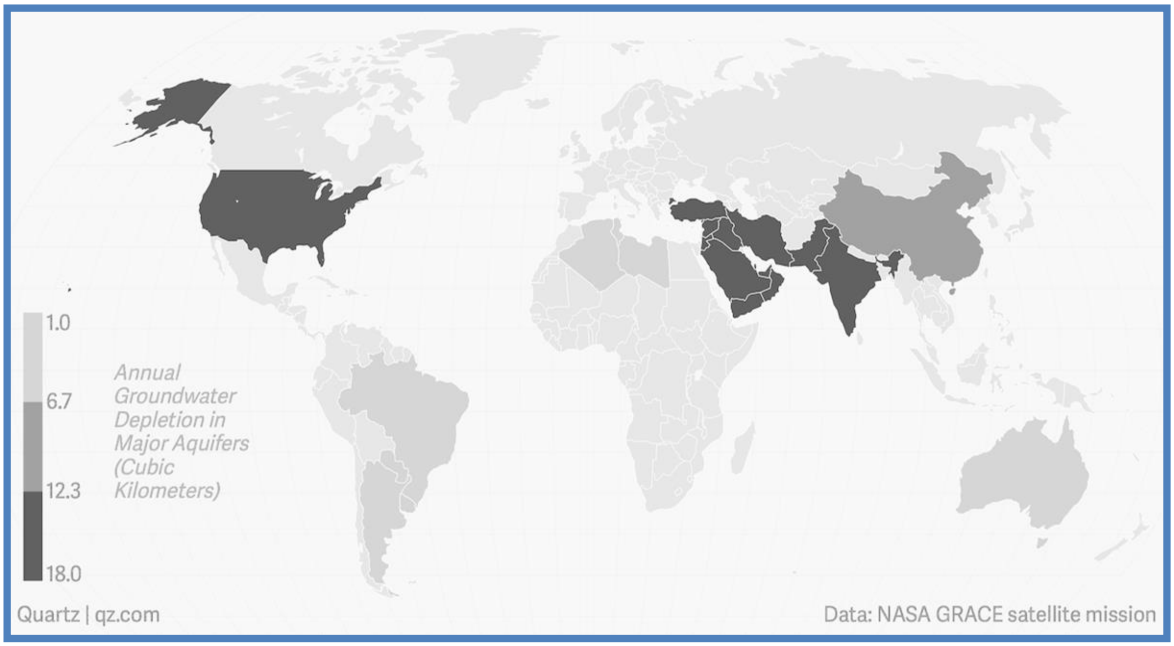
Depletion Centralized in the World's Economic and Food Breadbaskets

In a 2015 survey by the World Economic Forum, water was listed as the #1 risk to the world's socioeconomic stability, ahead of other more traditional risks such as pandemics, weapons of mass destruction, climate change, cyber-attacks, and war. Today, approximately 2.5 billion people, nearly 40% of the world's grain production, and approximately 25% of global GDP are "at risk" because of non-sustainable water use.[5]

Not surprisingly, the areas of greatest aquifer depletion are in the most populated, warmest, and most agriculturally driven areas of the world. Some of these economic zones are of particular concern, bearing in mind that agribusiness represents 71% and the energy sector adds another 15%[6] of all water demand.

The correlation of declining aquifers and high agricultural productivity is particularly clear. As indicated in Figure 2[7] below, the top three global grain producing countries—China (#1), India (#2), United States (#3)—are all in areas where aquifers are being depleted. Note also that the main Southern Hemisphere agricultural producers—Brazil (#4), Argentina (#11), Australia (#12)—are also drawing down their aquifer water.[8]

Figure 2: The Global Groundwater Crisis



[5] International Food Policy Research Institute; Growingblue.com.

[6] Ellina Livina and Takashi Hattori, "Round Table on the Water-Energy-Food Nexus," IEA, September 25, 2014.

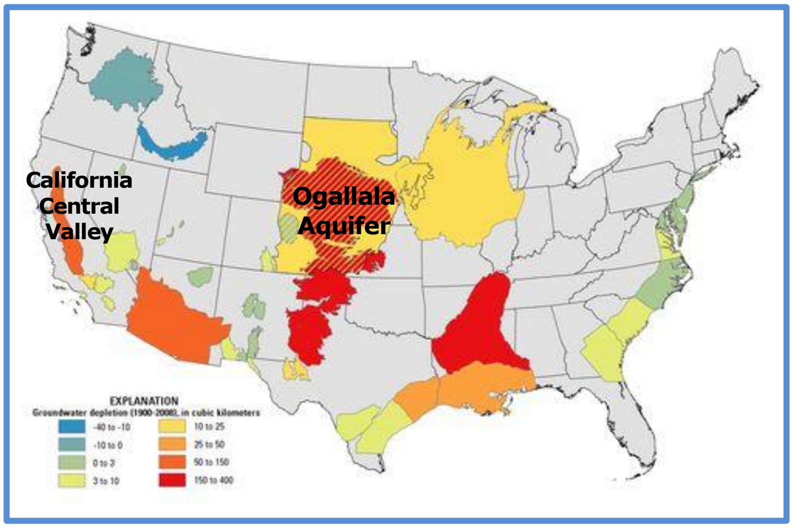
[7] "This Map Shows How Fast the World Is Depleting Irreplaceable Groundwater Reserves," takepart.com, November 4, 2014, www.takepart.com/article/2014/11/04/map-shows-how-dangerously-fast-world-draining-its-groundwater

[8] "List of Countries by GDP Sector Composition," StatisticsTimes.com, The World Factbook, June 14, 2015.

United States

In the United States, groundwater is the source of water for about half of the urban population, nearly all of the rural population, and 42% of agribusiness.[9] The United States has two of the largest agricultural zones in the world, and both are dependent on rapidly declining aquifers.

Figure 3: U.S. Aquifer Depletion

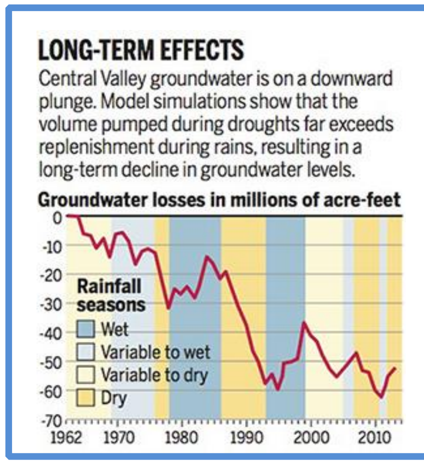


1. Ogallala

- **Location and Size:** Ogallala is the largest known aquifer in the world, stretching over 174,000 square miles, from South Dakota to Texas (see Figure 3[10]). The aquifer was initially formed a million years ago, but then was filled 10,000 years ago during the last ice age.
- **Importance:** The farmland over Ogallala is the most productive agricultural zone in the world, providing nearly one-fifth of the wheat, corn, cotton, and cattle produced in the United States.[11] Nearly 2 million people rely on Ogallala for their drinking water.
- **Condition:** As of 2010, about 30% of Ogallala's water had been tapped, with the water table going dry in some areas, declining by more than 300 feet in others, and/or becoming too expensive to pump.[12]

2. California

Figure 4: California Aquifer Depletion



- **Importance:** If the Midwest (supported by Ogallala) is the grain breadbasket for the United States, California (and the Central Valley aquifer) is the center for fruits, nuts, and vegetables, producing nearly half of the U.S. total.[13] California leads the United States in 74 of the country's top 89 agricultural products[14] and is by far the largest exporter. Over time, California's scarce water will shift to higher value-added and less water-intensive crops (and even solar farms); however, the state remains the #1 grower of alfalfa—one of the most water-intensive and lowest revenue-per-acre crops.[15]
- **Condition:** California's dependence on aquifer pumping has been increasing rapidly, and this now supplies over one-third of freshwater.[16] At the same time, an increasing number of wells are going dry and others keep going deeper. With this depletion (Figure 4[17]), the land in much of the Central Valley has sunk by as much as

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[9] USGS, Water Scinece School: water.usgs.gov/edu/gwdepletion.html and water.usgs.gov/edu/wuir.html.

[10] Konikow, Leonard F., *Groundwater Depletion in the United States* (1900–2008), U.S. Department of the Interior, U.S. Geological Survey. Modified and updated to 2013 in *Assessment of Trends in* Groundwater *Levels Across the United States,* Columbia Water Center, Earth Institute, Columbia University, March 2014.

[11] USDA website, "The Ogallala Aquifer Initiative."

[12] "Aquifers: Underground Sources of Fresh Water," *Live Science* magazine, September 18, 2016, Kansas State University.

[13] "California Agricultural Statistics Review, 2014–2015," p. 5–12.

[14] Ibid.

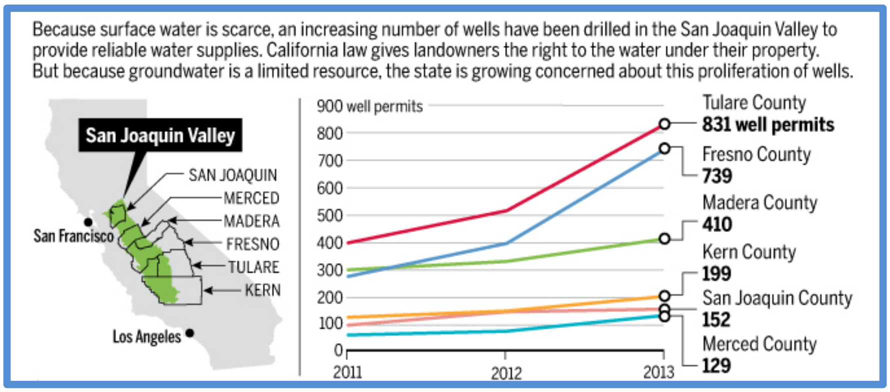
[15] USDA.

[16] "California Water Action Plan 2016 Update," p. 2.

[17] Krieger, Lisa M., "California Drought: San Joaquin Valley Sinking as Farmers Race to Tap Aquifer," Bay Area News Group, August 12, 2016. Analysis by Jay Famiglietti, US Center for Hydrolic Modeling, US Irvine, USGS, NASA, National Center for Atmospheric Research.

12 feet and continues to sink almost a foot per year. As a result, while most of the water for agribusiness is practically free for those that have legacy water rights, the cost of water for the state's largest water distribution company has increased at a 7.2% CAGR over the past ten years.[18] Consequently, much of California's farm acreage—particularly the immature permanent crops and water-intensive seasonal crops—are no longer able to afford their water (if they can get it at all). While some of this accelerated drilling reflects the state's four-year drought (Figure 5[19]), we note that drilling has been increasing since it began in the 1940s through many drought periods.

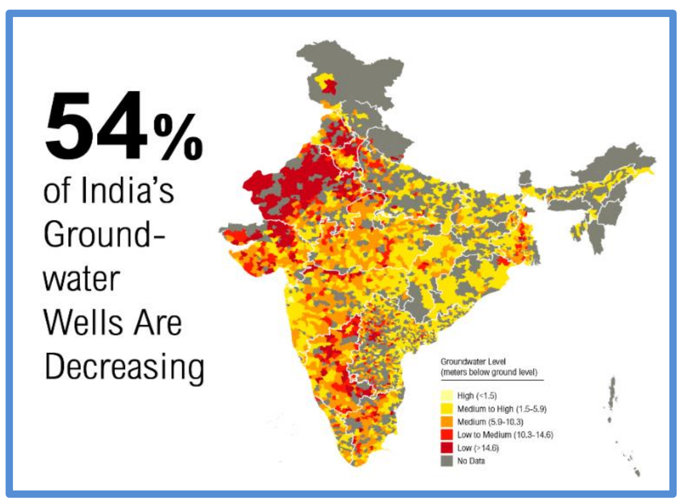
Figure 5: California's Rush to Drill Water Wells



India and Central Asia

- **Importance:** With 1.1 million people and an agriculturally driven economy, India relies on aquifers for an extraordinary two-thirds of its agricultural water and three-quarters of its drinking water.[20]
- **Condition:** India has 30 million wells and pumps, nearly two-thirds of which are at levels that are below their ten-year average[21] (see Figure 6[22]). Northern India has been particularly hard hit, with many farmers now migrating further south after wells have gone dry.

Figure 6: India's Water Depletion



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[18] i.e., 2006–2015. Annual Report of the Metropolitan Water District of Southern California, 2015. Tariff calculated includes all revenue (i.e., capacity, sewage, etc.) divided by total volume delivered.

[19] Krieger, Lisa M., "California Drought: San Joaquin Valley Sinking as Farmers Race to Tap Aquifer," Bay Area News Group, August 12, 2016.

[20] "Unholy Woes: India's Water Nightmare," *The Economist*, May 14, 2016, p. 29–30.

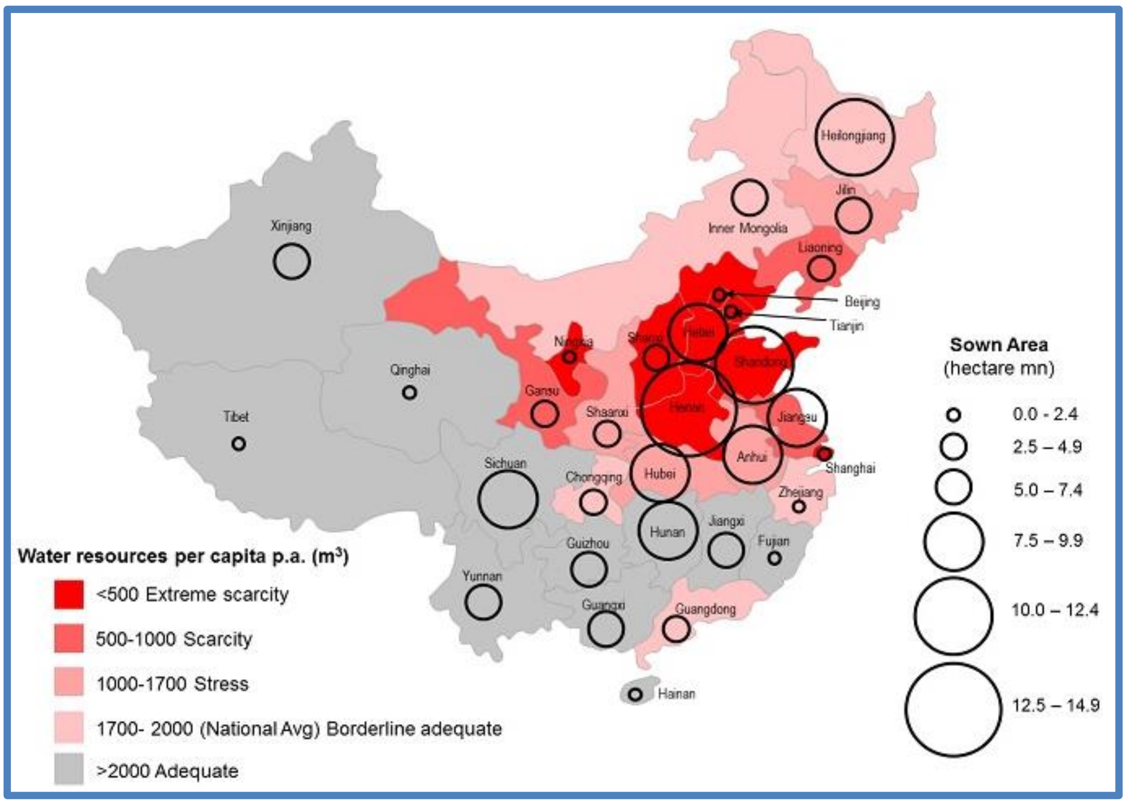
[21] Ibid.

[22] "3 Maps Explain India's Growing Water Risks," World Resources Institute, www.wri.org/blog/2015/02/3-maps-explain-india%E2%80%99s-growing-water-risks.

China and Southeast Asia

- **Importance:** China has 20% of the world's population but only 5–7% of freshwater resources. Aquifer groundwater is used for 40% of China's farmland and supplies about 70% of drinking water in the northern and northwest regions.[23]
- **Condition:** Water is already classified as "scarce" for two-thirds of China's largest 660 cities. In addition, the seepage from Chinese above-ground water has led to 90% of groundwater being polluted, 60% of which is considered "severe."[24]
- **Geopolitical Significance:** The Chinese government is in constant disputes with contiguous countries (particularly India, Thailand, and Vietnam) over water rights from the Tibetan Plateau aquifer and related rivers. This is a result of China's decades of over-pumping and large aqueducts that deplete the aquifers (see Figure 7[25]) and divert rivers away from other downstream countries. Several books[26] have even predicted the next war in Southeast Asia will be over water rights.

Figure 7: China Aquifer Depletion vs. Primary Agricultural Areas



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[23] "Opportunities and Challenges in the Chinese Groundwater Science," sponsored by China's National Natural Science Foundation and China's Geological Survey, 2009.

[24] Ministry of Water Resources survey, 2009.

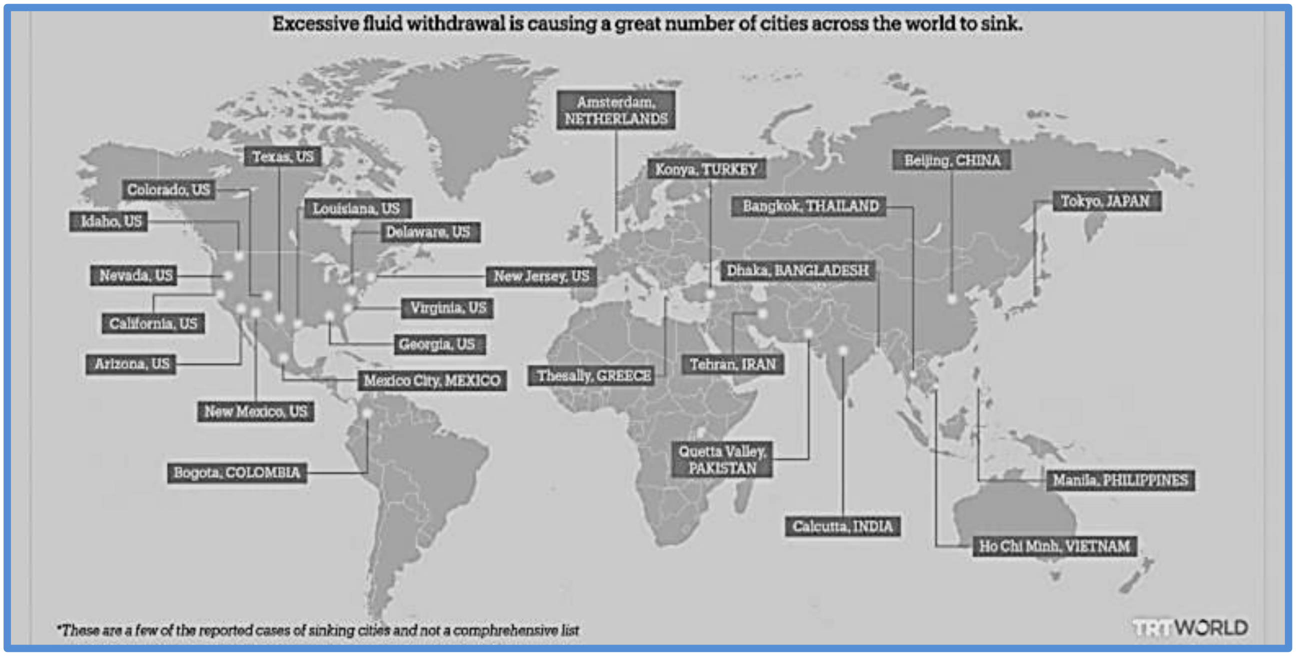
[25] "The State of China's Agriculture," China Water Risk, April 9, 2014, chinawaterrisk.org/resources/analysis-reviews/the-state-of-chinas-agriculture.

[26] For example: Robert G. Working, David C. Stole and Christopher Jasparro, *International Conflict over Water Resources in Asia,* Palgrave Macmillan, St. Maarten's Press, 2013; and Brahma Chellaney, *Water: Asia's New Battleground*, Washington, D.C.: Georgetown University Press, 2011.

Sinking Cities

Another unintended consequence of depleting aquifers is sinking cities and farm acreage. The California Central Valley is sinking about 1 foot per annum, and some geologists are linking this to increased regional earthquakes.[27] Some cities, such as Jakarta, Indonesia, have sunk so far that they must spend billions ($50 billion in this case) to install new dikes and levees. Many other global examples are highlighted in Figure 8.[28]

Figure 8: World's Sinking Cities



Aquifer Water Quality Also Declining

A surprising final piece of the "perfect storm" for aquifers is contamination, including seawater intrusion and manmade pollution.

Seawater intrusion occurs as the coastal freshwater aquifers are depleted, allowing ocean water to fill the void. The effect is significant as more than half (and rising) of the world's population lives within 60 kilometers (37.3 miles) of the ocean[29] and many coastal aquifers have become too salty to be useable.

Further inland, many of the bottled water companies boast of "spring" water as being inherently pure due to the very old age of the water (i.e., pre-manmade pollution) and being insulated by hundreds of feet of sediment. Nevertheless, pollution is now seeping into some of the largest aquifers, with some of these resources now completely unusable, even for agribusiness. Some examples:

- **Bangladesh:** In what has been called the world's "largest mass poisoning ever," extremely high arsenic levels have seeped into main aquifers that provide water to about 85–90% of the population.[30] An estimated 30–35 million of the country's 160 million people have been poisoned by the aquifer water, and an estimated 20% of all deaths in Bangladesh are attributed to arsenic.[31]
- **China:** Like many emerging and frontier economies, the Chinese have historically not lined their landfills with plastic. Until recently, there has been little regulation on what can be dumped into landfills, rivers, or streams. Hence, as rainfall seeped through the landfills, both the ground and many

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[27] Krieger, Lisa M., "California Drought: San Joaquin Valley Sinking as Farmers Race to Tap Aquifer," Bay Area News Group, August 12, 2016.
[28] "Rising Tides, Sinking Cities," TRTWorld, August 10, 2016, www.trtworld.com/in-depth/rising-tides-sinking-cities-161804.
[29] Abdou, Carnegie, Mathews, McCarthy, O'Keefe, Raghuraman, Wei, Xian, "Finding Value in Formation Water," *Oilfield Review*, Spring 2011.
[30] "Water Pollution Facts," Conserve Energy Future.org.
[31] "Water in Crisis: Spotlight on Bangladesh," by Saima Hedrick as guest author to The Water Project, Inc.

of the aquifers became toxic. As a result, China's aquifer water is even worse than above ground water: 60% of groundwater is Tier III (considered unsafe to drink) versus "only" 50% of lake water and 33% of river water.[32]

Conclusion: Scarcity is the Mother of Invention

In most parts of the world, water from aquifers is nearly free, or at most priced at the cost of energy to pump the water out of the ground. As such, it is no surprise that there are more water pumps being added every year, reaching ever deeper into the aquifers. In some areas, the dramatic rise in pumps has been called "akin to an arms race."[33]

Clearly, water crises begin when the aquifers are fully depleted or become so deep that the pumping costs become "uneconomic." When this tipping point is reached for the largest agricultural and economic zones of the world, the crisis becomes global.

Aquifer depletion will likely be one of the strongest catalysts for a dramatic increase in the "price signal" of water. Higher prices are already stimulating huge efficiency gains, particularly in agribusiness where "crops per drop" is becoming a key metric for such technologies as center-pivot, drip irrigation, and new drought-tolerant seeds and fertilizers. Higher prices will also stimulate many new water technologies that will be the marginal cost producers. However, nearly all of these promising technologies will cost at least double the average price of water now. Three of the most promising new technologies are:

1. **Water Reuse:** The basic technologies for treating sewage have been around a long time, and, unbeknownst to most of the public, have been used even to support drinking water for decades. However, there also many new technologies, both chemical and mechanical, for treating grey and sewage water, and water reuse will likely be the greatest growth area in absolute terms.
2. **Desalination:** Reverse osmosis is both very capital intensive and energy intensive, and most desalination plants can only produce at double the price of water in the majority of locations (ideally, cheap solar energy) where they are located. In addition, there are various environmental concerns for "desal," and intuitively this technology will only work for demand that is close to an ocean and not a country's interior.
3. **Atmospheric Generation:** The technology to separate water from air is improving, but the energy cost per gallon is still significantly higher than most consumers' water cost, even when excluding the up-front capital of each machine. Hence, for now, this "distributed water" technology is not scalable and is only being used in niche markets where there are no other short term alternatives. However, this science is improving, and the combination of distributed water that uses electricity from distributed solar (which has practically no variable cost) will likely lead to significant growth for atmospheric generation in niche markets.

The higher costs of "new water" will clearly create a conundrum for regulators and politicians. A price too low will not provide a "price signal" for new supply. A price too high would lead to political unrest, if not a collapse in local economies that are dependent on cheap water. Perhaps two-tiered "wholesale" water pricing will be the result, with "old" water-right-protected water continuing to have lower prices and any "new" water carrying a much higher price. In any scenario, the average cost of water will likely rise faster than any other commodity.

The era of "cheap water" is over; the era of water innovation is just beginning.

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[32] Chen, Trina, Credit Suisse First Boston, "China Environment Sector," Aug. 14, 2014, p. 18.

[33] Krieger, Lisa M., "California Drought: San Joaquin Valley Sinking as Farmers Race to Tap Aquifer," Bay Area News Group, March 29, 2014.