Groundwater in the Midwest: Past, Present, and Future, and Implications for North America

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From a human perspective, water is the second most precious commodity, but its supply—across the face of the planet and on a per capita basis—is diminishing. This is particularly true for groundwater. Contrary to the perception of the general public, most of the world's freshwater does not in fact sit on the surface but is instead hidden in aquifers. It is that reservoir that I shall focus on here, beginning with the present but moving on to examine the past, and finally the future.

Groundwater is being mined from many major aquifers in the world. "Mined" is the correct descriptor to use given that the recharge rate is very often being exceeded by the extraction rate, in some well-known cases by orders of magnitude. Consider the following examples, each of which has analogous implications for North America:

1. The Sahara Desert:
As a direct result of the same long-term changes in the Earth's orbit about the sun that drive ice ages, the Sahara Desert was a lush grassland for a few millenia centred around roughly 8000 years ago. Heavy seasonal (monsoon) rains led to the accumulation of vast supplies of groundwater below what is now the desert. That ancient water is now being pumped at a furious rate to support agriculture and urban societies in northern Africa. Mohammar Gahdaffi's regime in Libya has provided the most egregious example. The coastal strip along the Mediterranean Sea hosts ninety per cent of the country's population and is the only region in Libya to receive sufficient rainfall to support agriculture. Rapid population growth and agricultural development has led to increasing scarcity of water. The response has been to undertake one of the largest engineering projects in the world: the " the Great Man-Made River", a 2000 km long, 4 m diameter water pipeline and viaduct system that transports some 4 million m^3 of water a day from the southern reaches of the country to northward to the Benghazi and Tripoli regions on the coast[1]. The water is pumped derived from hundreds of wells from aquifers under the Sahara in the southern half of the country. At current rates of extraction, some commentators suggest that the easily available (shallowest) supply can be maintained for several decades only but sufficient water exists at greater depths (500 to 2000 m) to meet anticipated demand for centuries, albeit with very high extraction costs. But a more important issue lurks in the background. Aquifers do not respect borders, and some of those now being tapped in Libya extend into—and are hydraulically connected with—the Sudan and Egypt. Will Libya's wholesale sequestration of the

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"clear gold" become a trilateral flashpoint as populations continue to grow and demand continues to rise?

2. Gujarat State, Northwestern India

Gujarat provides a classic example of what is happening with groundwater extraction in highly populated and drought-prone—thus particularly vulnerable—parts of the world. Ahmedabad is the largest city in Gujarat with a population that is approaching 4 million. Until recently, most of the domestic and irrigation supply for the city and surrounding agricultural region came from the underlying aquifer. But overextraction relative to very limited recharge has lowered the water table by about 3 metres per year in recent decades. This is a stunning rate of decline, and the phreatic surface now sits at minus 210 metres below the city. Not only is it very energy intensive to pump water from that depth, the extracted water is now increasingly saline. What Ahmedabad has done, in essence, is completely exhaust its "traditional" water supply. Like the Saharan case, that supply consisted of fossil water. Recharge occurs during the monsoon in the foothill regions in the eastern part of the state and drives flow in the aquifer from east to west. At its western extent, not far from Ahmedabad, the age of the groundwater is 40,000 years. Thus, water that accumulated over as many as 40 millenia has been exhausted in a little over a century.

What does the future hold? The short-term solution to Gujarat's water woes has been to build the very large and extremely contentious 138 m tall Sardar Sarovar Dam across the Narmada River to the southeast, and transport the water to the state via the 460 km long so-called Wonder Canal. Flooding behind the Sarovar will displace an estimated 200,000 people, contributing to the 21 or more million who have been displaced by dam construction in India since about 1950[2]. Is such a societal price worth it? Various commentators have made the point that the expected supply from the Narmada will be insufficient to meet demand. The districts of Kutch and Saurashtra at the western end of the canal network in particular are expected to receive little additional supply[3]. But another concern looms in the background. The modern climatic boundary conditions under which societies have expanded are not representative of longer term natural variability. This is particularly true of North America, as argued below, but it also applies to southern Asia. For example, the major El Nino event of 1789-1793 was associated with intense drought in India as the monsoon rains collapsed. Some 600,000 Indians died in the Madras region alone (Grove, 1998) as a direct result of the drought. Should such an event occur today, as it has repeatedly in the past, the impact could be muted if groundwater was available to be exploited. But in a state like Gujarat, this will no longer be an option. That region is now much more vulnerable to climate change than in the past. To paraphrase metaphorically, the savings account that Nature put aside for use on a non-rainy day has been squandered. We are now doing the same in North America, as argued in the next section.

3. Central North America

The High Plains or Ogallala Aquifer extends from South Dakota to northern Texas along the eastern front ranges of the Rocky Mountains. This single vast aquifer is hosted by the alluvial/eolian Ogallala Formation, and contained in 1850 a volume of water equivalent to that today in Lake Ontario. Since that time, it has being heavily exploited to support agriculture across a belt from northern Nebraska right into Texas. Roughly 30 % of American cereal grains are produced using groundwater taken from this aquifer.

Between 1850, when settlers put in the first windmills to drive groundwater extraction, to 1980, the groundwater table in the High Plains Aquifer between southern Kansas and northern Texas dropped by as much as 35 m. Since then, the decline has generally continued (Fig. 1), to the extent that the water table is now 45 metres below its 1850 level in parts of the Texas Panhandle and southwest Kansas. In 1997/l998 the water table dropped by another 1.5 metres at the southern end of the aquifer system. This is an important observation because precipitation was well above normal in that year. Even in a wet year, the demand is such that water is pulled from the ground at a rate much higher than recharge.

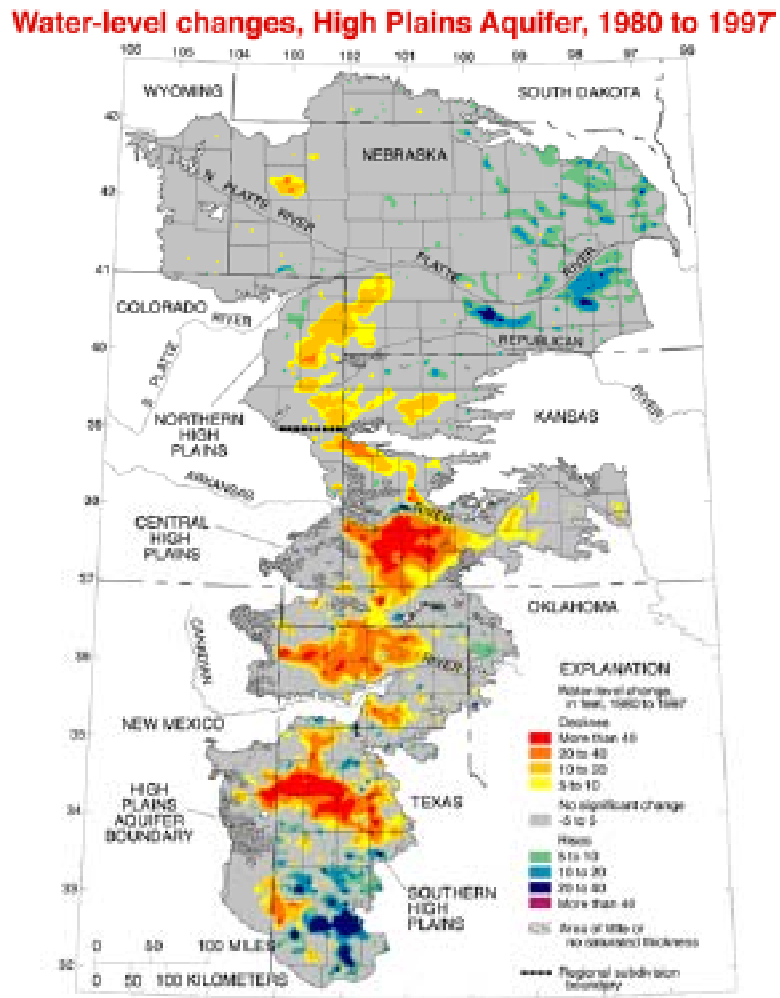

Figure 1. Water-level Changes, High Plains Aquifer, 1980 – 1997 (in feet). The red zones define declines >12 m (40 feet) during that period. Source: U.S. Geological Survey, Water Resources Branch.

Where does this leave us? Changes in erosion patterns over time have caused the Ogallala to be cut off from its original supply of water. Indeed, the southern portion of the aquifer in Texas and New Mexico is now a plateau, cut off on all sides[7]. Thus, even on long time scales, the groundwater in the High Plains Aquifer is a finite resource. In the Texas Panhandle there is an estimated 25-30 years of supply remaining, while in southwestern Kansas, current extraction rates will consume the available groundwater reservoir in less than 25 years. Like Gujarat, irrigated agriculture in the region is rather quickly heading toward unsustainability.

Let us now consider the longer term temporal framework. The past half century in the U.S. Midwest has been quite wet, although not continuously. Figure 2 shows the 1950s drought that swept across the United States between 1954 and 1956 before breaking in 1957. This was a severe drought, equivalent in impact on soil moisture content to the dust-bowl event of the 1930s. Since that time, it has been relatively wet.

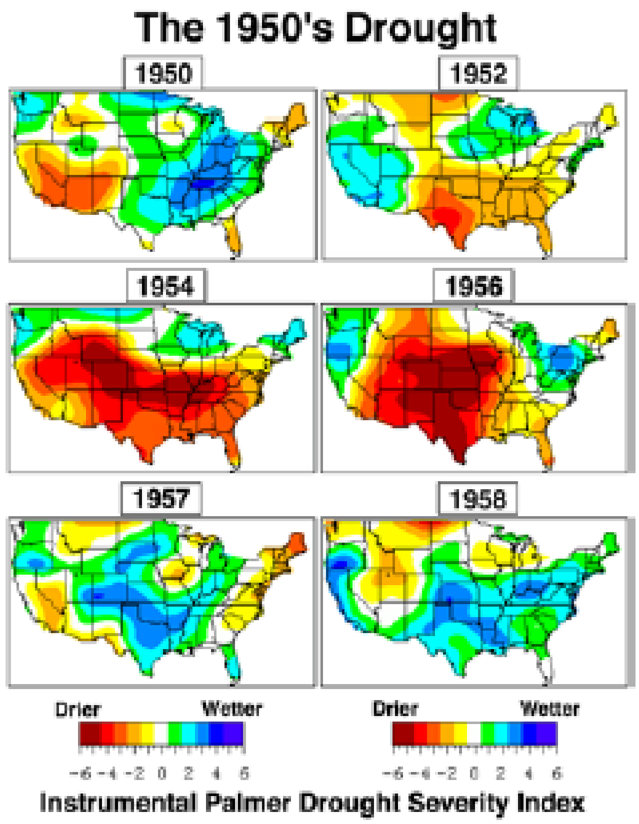

Figure 2. Annual-average snapshots showing the time-course of the 1950s Drought. The Palmer DSI is based on instrumental records. Compiled from figures developed by Connie Woodhouse (NOAA) and Ed Cook (Lamont-Doherty Tree Ring Observatory).

The 1950's drought wreaked havoc on agriculture in the region; during that time, farmers depended entirely on groundwater, the only water-supply buffer at hand. That buffer is now on the verge of being mined out, which becomes a particularly sobering consideration in view of both the longer-term past and the future. Earlier this month, Cook et al.[8] published a 1,200 year long record of drought history across the Midwestern United States (Figure 3). This work, based on the study of tree rings, shows that the aggregate drylands area waxed and waned, with long-lived megadroughts characterizing the 10th through the 13th Centuries. Over the last century, shorter dry episodes have been episodic but common, with severe drought being recorded in the 1930s, mid-1950s and the last five years. Since the agricultural infrastructure now in place in most of the midwest depends on groundwater, and given that in many key areas that subsurface reservoir is coming close to being drained, it must be concluded that agriculture in the region—*as we now practice it*— is increasingly vulnerable to natural climate variability. The next megadrought will have a crippling effect. But it gets worse. ***All*** climate models project a net decline in summertime soil moisture in the midwestern heart of North America as a consequence of progressive global warming and enhanced evaporation. Superimposing that trend on the natural variability in precipitation over the last millenium paints a picture that must give cause for serious concern.

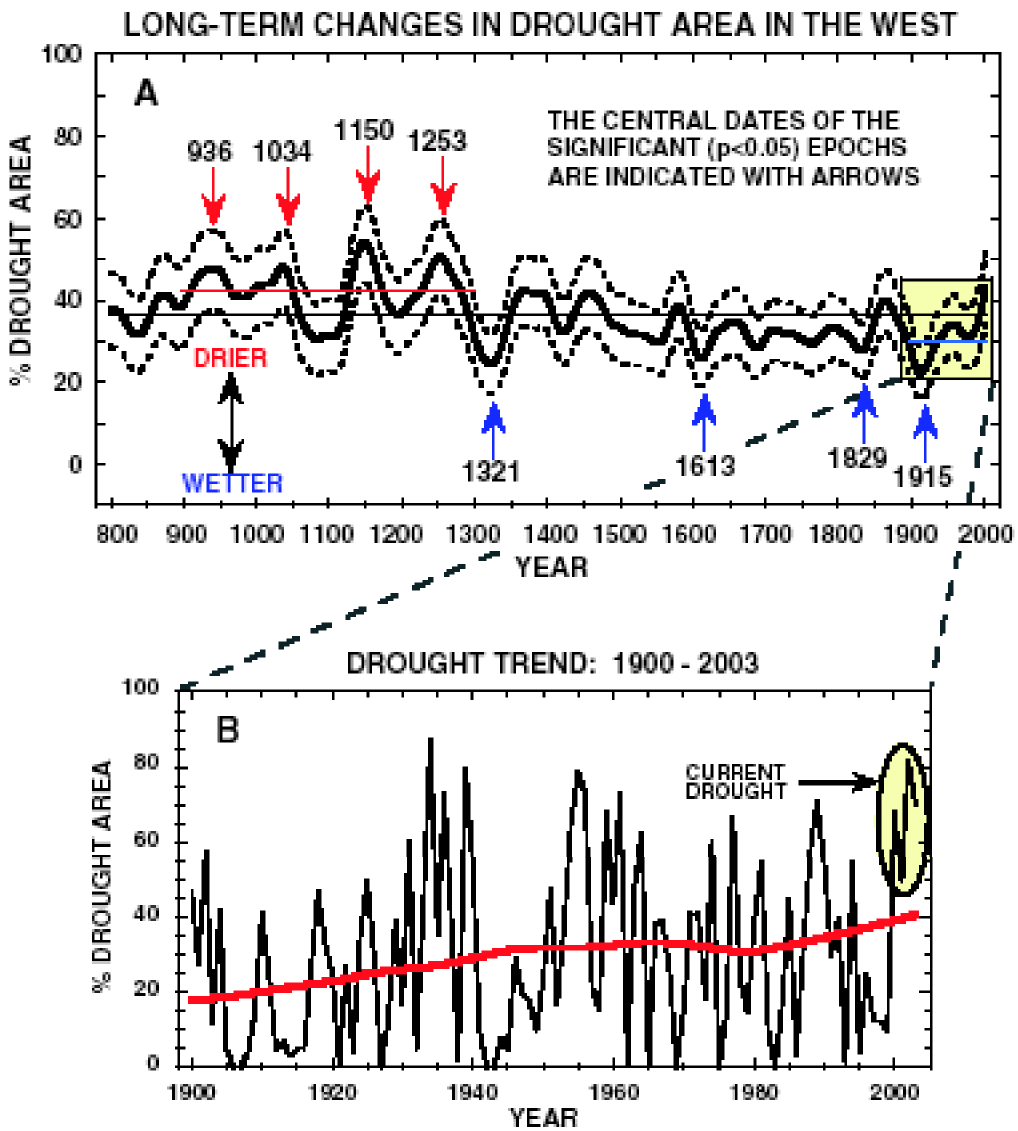

Figure 3. Estimation of relative area of drought in western North America between northern Mexico and southern Canada over the last 1,200 years. The compilation is based on the study of annual growth rings in drought-sensitive tree species. The upper curve has been smoothed with a 60-year running average to highlight long-term events. From Cook et al. (2004)[7].

Conclusion

The looming shortage of available water in the US Midwest is a serious issue in the United States and it must be of concern to Canada. There can be little doubt that the combination of future warming, depletion of the groundwater savings account, and episodic natural droughts are pushing agriculture in the breadbasket into an increasingly parlous state. It is unrealistic to think that this will not cause our southern neighbour to look north for salvation. The political implications are many, and both planning and policy need to consider them. The examples from other continents help frame the discussion. As described earlier, the Libyans exhausted their local groundwater along the Mediterranean coast and are now piping water 2000 km to the north; the Gujaratis exhausted their groundwater and are now transporting water long distances from the south; and most recently, increasing demand and regional salinization in the Perth area of western Australia are sparking contemplation of a similar scheme in that country. The state of Western Australia is now exploring the feasibility of constructing a 3,500 km canal—the world's longest—to carry water from the Kimberley region in the tropical north to Perth in the temperate south[8]. And finally, in China, construction is underway on an extension of the Grand Canal from the Yangzte basin in the South to the increasingly dessicated Yellow River basin in the north. This massive redistribution project is intended to mitigate the water crisis in the north which has seen groundwater tables fall by a meter or so per year in many areas and surface flows decline (as a result of both drought and diversion of water for irrigation) to the extent that the Yellow River has failed to reach its mouth roughly two-thirds of every year since the early 1970's[9].

Meanwhile, and closer to home, the 1950's drought is but a dim memory, and midwestern states continue to exhaust their groundwater. Will the response of our continent be different from the others? Will the South covet the water in the North? Or will we revert to dryland agriculture, severe conservation, full economic pricing and other management approaches? In the context of North American bilateralism, such questions warrant intense scrutiny.

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