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Principles for Water and Development

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Water is a stable, versatile molecule. Many organisms live in it, all require it, and most, including humans, are largely made of it. We use water for agriculture, industry, power, retail, residential needs, and direct consumption. About 75 percent of the water we extract from ground and surface is used for irrigation. Water is renewable. It remains in the river after moving the turbines of a hydropower dam, and remains in the soil, air or crops after use in irrigation. It passes through people and animals when they drink it, and through the leaves of plants that pull it up through their roots. Water naturally recycles into the atmosphere and back to the surface through precipitation, and it is cleaned by evaporation and sublimation from surfaces, by plant transpiration, and by respiration. Water also cycles to sugar and back to water again through photosynthesis and respiration.

The Earth has lots of water on its surface and in the ground just below - 1.4 billion cubic kilometers in total, amounting to 52 billion gallons per person. About 97 percent is seawater, and about 2 percent is locked in ice. Less than one percent is liquid freshwater. Nearly 99 percent of that is groundwater, with a small remainder in lakes and much smaller amounts parceled out to soil moisture, the atmosphere, swamps, rivers, streams, and the bodies of living things. About 400 million gallons of liquid freshwater is present on Earth for each person living - a million times the amount that people use daily. In overall quantity, we have more than enough water.

The devil is in the details. Seawater is, of course, salty and, unless treated, can't be consumed by humans or most of the animals and plants that people eat. Seawater can't sustain the bacteria conventionally employed in wastewater treatment, and many industrial processes can't use it. On the other hand, seawater can substitute for some uses that depend typically on freshwater, like cooling power plants and Google's new data factory in Finland.

Freshwater isn't pure either, and securing adequate freshwater quality is the focus of laws and programs such as the Clean Water Act and the Safe Drinking Water Act in the United States. The Clean Water Act includes a national goal "that the discharge of pollutants into the navigable waters be eliminated by 1985." That goal proved to be ambitious, but federal and state laws have made freshwater cleaner, if not always clean enough to drink, and the Safe Drinking Water Act and other laws have produced eminently potable water in the U.S. The same is true for much of the developed world, however that is often not the case elsewhere where pollution degrades watershed ecology and diseases from contaminated drinking water are common. The World Health Organization (WHO) reports that about 1 billion people (over 14 percent of the world population) lack access to "improved" water supplies, defined as the availability of at least 20 liters per person, per day, from a source within 1 kilometer of the user's dwelling that is likely to provide safe water. The WHO also reports that 2.6 billion people (over 37 percent of the world population) lack access to "improved" sanitation, meaning a connection to a public sewer or a septic system or access to a well-placed and well-designed private latrine. Lack of sanitation translates to contaminated watersheds and groundwater. The majority of people without improved water supplies or sanitation live in Asia and Africa. Not every apparent solution to these problems works. For example, in Bangladesh, more than 4 million tube wells were installed in an effort to provide safe drinking water to 95 percent of the population, but high concentrations of arsenic found in the wells caused the largest mass arsenic poisoning in history. Clean water is a global priority, but not easily within grasp.

The challenge with water, of course, is not just quality, but having adequate quality and quantity at the places and times needed. The current average freshwater availability is about 6,000 gallons per person per day, varying with location. The United Nations (U.N.) describes "water stressed" nations as those whose freshwater availability is less than 1,230 gallons per person per day and "water scarce" nations are those whose availability is less than 724 gallons. Availability in the Middle East and North Africa, where water storage is limited, is about 1,000 gallons, and most water scarce nations are located there. Current global freshwater usage is about 400 gallons per person per day, falling to a low in Sub-Saharan Africa of 110 gallons. In other words, although stress and scarcity exist, both the global and national populations typically have amounts of available water on an order of magnitude greater than the amounts actually used.

But availability varies widely with year, season and weather. Somalia is now enduring a famine because of drought, and droughts occur episodically in many places including Northern Africa, the Middle East, Australia, China, India, and the Southwest U.S. Furthermore, growing populations and economies are narrowing the band between use and availability. Some questionable responses involve domestic reallocation. The Yellow River watershed in northern China is oversubscribed by multiple uses, and the Yangtze watershed to the south is being tapped through massive new channels and infrastructure to shift water to the north - with potentially acute adverse effects in the Yangtze basin. Some 260 rivers cross the international boundaries of 90 percent of the world's nations. Many of these, including the Nile, Indus, and Mekong, are being tapped by upstream nations for their needs, which takes water away from nations downstream. These demands and impacts are compounded by "mining" groundwater taking more water out than is being recharged back in which compromises future delivery. Such groundwater overdrafts are widespread, including in the High Plains Aquifer of the Central United States, India, North Africa , Yemen, and elsewhere in the Middle East. It is the poor who depend on wells that will suffer the most when they go empty.

At first blush, climate change could look like an ally. The atmosphere of a warming Earth will hold more water and give more water back to the ground. Average global precipitation will increase several percent for each degree Celsius increase in temperature. One might think that will raise surface flow, recharge groundwater, and help respond to growing demand. Unfortunately, the opposite is more likely. Growing extremes of rain and shine are forecasted and concomitant floods and droughts will occur in many of the places most stressed today, like the African Sahel, Southwest U.S., and the Indus watershed. Rising sea levels and increased coastal storm surge is predicted to turn some coastal freshwater sources saline. Overlaying this are predictions that regions of the world will differ in average precipitation change, with some increasing and other decreasing. Average precipitation is expected to increase over most of northern Europe, the Arctic, Canada, the northeastern United States, tropical and eastern Africa, the northern Pacific, Antarctica, northern Asia, and the Tibetan Plateau in winter. On the other hand, average precipitation is forecasted to decrease in most of the Mediterranean, northern Africa, Central America, the American Southwest, the southern Andes, and southwestern Australia during winter. All in all, climate change is an adversary, not an ally, in the quest for water security, and adaptation to climate change will require measures to lessen negative impacts on water resources.

So what should be done? Many ideas have been proposed and many tried, but the obvious good steps are often ignored through competing politics, economics or lack of thought. The nine principles below offer steps forward for water initiatives of government, industry and civil society. The principles are also recommended for deliberation by participants in international conferences considering water, including those discussing adaptation to climate change at the upcoming 17th Conference of the Parties to the Framework Convention on Climate Change, in Durban, South

Africa, and participants discussing overall global environmental priorities at the Rio+20 World Summit on Sustainable Development scheduled for Rio de Janeiro in June 2012. The principles recommended here are in addition to more general principles suggested in Global Environmental Quality: Recommendations for Rio+20 and Beyond (Brown, 2011). Those principles - assessment, measurement, reporting, organization, education in general and for women, research, and infrastructure - apply to water just as they apply to other natural resource use and conservation.

Principles

1. **Engage communities and the private sector openly and early in planning, construction, and operation of water facilities.** Large-scale water projects have too often been set on course without significant, early public participation or sophisticated, competitive involvement of the private sector. The current Three Gorges Dam in China and the proposed, but recently suspended, Irrawaddy Dam in Myanmar illustrate that rule, with public involvement coming as an after-thought in the form of protests and with the selection and specific plans of the private sector not transparent. The World Bank and regional and national development agencies concerned with water now take a different stance, promoting early community involvement and private sector competition, but the reality on the ground still often reflects less open attitudes of national and local governments and the seductive power of project funding. Those with influence in water project development should redouble efforts to end this shortcoming. Early community involvement broadens knowledge of needs and perspectives and strengthens political support. In the U.S., valuable public engagement is provided through the policies of the National Environmental Policy Act (NEPA) and state analogues. These laws prescribe steps to scope project purpose and alternatives and to assess the environmental impact of alternatives as well as impacts of the action tentatively proposed. A process of this kind should be employed universally.

The private sector should be brought in to participate actively from the beginning along with civil society and community representatives. The first questions for water projects are need and purpose, followed by performance objectives. Companies that want project business should be invited to compete with proposals that seek to meet the need, without project managers determining the solution beforehand. For example, if the need is irrigation, the private sector should be asked to propose and cost-out concepts for providing irrigation, rather than be asked for a proposal to build a dam. If the need is to provide drinking water for a population, companies should be asked to submit innovative proposals considering any means to achieve that end, rather than being asked for proposals to build a drinking water facility or to drill certain kinds of wells. Too often private sector creativity is short-circuited and better alternatives missed. There are options at more specific levels too. These include innovations like smaller, "decentralized" water and wastewater treatment facilities, improved membranes for filtering, new treatment technologies, and vastly improved information technology for managing and monitoring operations to improve efficiency. Obviously, it is crucial to have an open and fair bidding process. If no one bids, or no bid is acceptable, that comments on whether the project needs to be re-thought fundamentally or is feasible at all.

2. **Preserve watersheds ecosystems.** History is replete with lessons where trees were leveled and land was plowed or turned to settlements on the banks of rivers and lakes, resulting in destroyed ecology, floods, reduced groundwater recharge, and lack of water. This occurred in Haiti and is a central obstacle to improving living standards in that country. The first lesson of water is to preserve the river, lake and wetland ecosystems that are sources of clean water, slow runoff to allow groundwater recharge, support native biota, and sustain the lives of local peoples. This preservation is no less important to the water supply than installing pipes and treatment facilities, and its cost should be included in clean water funding. Many municipalities - including New York City - have successfully applied a portion of water bill payments to watershed protection, but many have not despite universal recognition of value. Effective watershed protection should be a priority for all agencies supplying water

to populations.

3. **Invest in more efficient water use.** An enormous amount of water is wasted through inefficient irrigation and other uses. It's an old but continuing story, and not limited to developing nations. Earlier this year, for example, an agency report to the State of California took issue with the practices of delivering water to fields on a pre-set schedule, rather than delivering water based on need. A comprehensive new report supports this conclusion on a global scale. The report, released on 26 September 2011 by the Challenge Program on Water and Food of the Consultative Group on International Agricultural Research, reflects five years of study of 10 major river basins in 30 countries. It finds that despite many water-related conflicts, there is "clearly sufficient water" to sustain needs through the 21st century. The 'sleeping giant' of water challenges is said to be not scarcity, but the inefficient use and inequitable distribution of the massive amounts of water that flow through the breadbaskets of key river basins such as the Nile, Ganges, Andes, Yellow, Niger and Volta. With modest improvements in water efficiency and distribution, food production can be increased two to three times. Africa offers the greatest potential for increase, but Asia and Latin America offer significant potential too. A key point noted for improvement in the report is investment in rain-fed agriculture - to collect and use for crops and livestock the huge amounts of untapped rainwater runoff.

Another priority for municipalities is maintenance and upgrades to existing water and wastewater treatment facilities and the infrastructure of pipes and drains that feed to and from them. Although the cost of this is daunting, even in developed nations such as the U.S., addressing deferred maintenance is typically a fraction of the cost of installing new capital.

4. **Build few, and only the very best, dams.** There will never be a consensus on dams. They provide storage capacity that can mitigate flooding and provide water for irrigation and other uses during dry periods. Nations that could afford to have built thousands of dams since the 1950s. China leads with about 22,000, and the United States is a distant second at over 6,500. The U.S. and Europe have the greatest surface water reservoir storage capacity per capita, and the world's poorest nations trail far behind. By many calculations, dams have saved lives and supported a level of agricultural production not possible without them.

Dams also provide hydropower without generating significant carbon emissions. Average global hydropower generation is roughly 342,200 MW. Assuming that coal-fired power plants would be generating this power alternatively, the avoided carbon emissions are about 834 million tons per year. A recent National Research Council report estimates that the global average temperature rises about 1.75oC for every trillion tons of carbon added to the atmosphere. If this is accurate, each year of current hydropower in lieu of coal is preventing global temperature from rising about one-thousandth of one degree Celsius. Significant, but not a huge number.

Dams harm as well as benefit. Sometimes they rupture. Over 200,000 people were killed by dam failures in China in 1975. Dams can fill up with sediment and consequently hold less water in reservoirs and generate less power. They trap silt and organics, which will then not reach the downstream deltas where they sustain key habitats and provide food for fish and other biota on which people depend. Dams stop fish from reaching breeding grounds upstream and they convert flooded ecosystems into different, less diverse places, displacing natural species. Flood control through dams, dikes and reservoirs can reduce groundwater recharge. Dams displace people, sometimes in large numbers, like the Three Gorges Dam and the proposed Belo Monte Dam in Brazil. Millions have moved for dams in China, and thousands have moved elsewhere. Furthermore, some benefits provided by dams can be achieved without them. Groundwater may provide all the storage capacity needed in some areas, and maintaining watershed ecology and vegetation may sometimes be a better means of flood control, especially if combined with policies to kept people and structures away from places prone to floods. Smaller dams with little reservoirs are much less damaging and can provide some storage and hydropower. There will be more dams, and the objective should be to test their costs and benefits in analysis and public debate to make those few that advance be the best that they can be - in safety, environmental and cultural impact, performance, and sustainability.

5. **Invest in sustainable use of groundwater.** Tapping groundwater is a priority - it accounts for nearly all liquid freshwater and can provide storage reservoirs that surface waters can't match in quantity. It can be accessible in locations far from surface waters or municipal sources, sometimes in places with little precipitation, including the Sahara, Gobi, and Sonoran Deserts. It often does not require treatment before use - even human consumption. Furthermore, shallow wells can be inexpensive - wells 30 meters deep can sometimes be drilled manually for less than $1,000. But, with the exception of fossil groundwater sealed in geologic structures, groundwater take should not exceed recharge. Water tables in many locations have dropped from overdraft, over 10 meters since 1979 in the Punjab region of India. The number of groundwater wells in India increased from less than 100,000 in 1960 to about 12 million in 2006. Whether by regulation or voluntary effort, groundwater budgets should be balanced or the populations relying on groundwater will face an unpleasant reckoning when wells run dry. Recharge isn't necessarily passive - faced with its problems, India is capturing rainwater and feeding it into aquifers through wells designed for recharge, with assistance from the International Water Management Institute. Such efforts should be encouraged.

6. **Treat and use more wastewater.** Conventional municipal wastewater treatment facilities typically use bacteria to digest organic material, including feces, and then discharge treated water into rivers or the sea. However, with additional treatment, the wastewater can be made ready for other uses, even direct human consumption. This reclaimed water is currently applied in agriculture, and can be used for other purposes with adequate planning and investment in distribution. Wastewater has a stigma, magnified by outbreaks of diseases associated with bacteria from waste, but with proper treatment the risks are low and value high. Used in irrigation, the organic material is a nutrient for crops. In places where freshwater is very scarce, an investment to treat wastewater to meet drinking standard would have high value.

7. **Use more seawater, desalted and raw.** About 40 percent of Earth's people live within 100 kilometers from the sea and over half of the U.S. population is within 50 miles of the coast. Hence, desalination and direct use of seawater are a priority. Desalination facilities have become widespread and effective. As of 2009, over 14,000 plants were operating and collectively produced 15.8 billion gallons of desalinated water daily. Most plants use one of two technologies: vacuum distillation - lowering pressure so that seawater boils at a low temperature - or reverse osmosis - pressurizing seawater so that pure water flows through a membrane, leaving brine behind. The two largest plants are in the United Arab Emirates and Israel and have maximum capacities of about 220 million gallons per day. The Israeli plant provides 5 to 6 percent of the country's water needs at about $1 cost per 500 gallons produced. Cost can be reduced in vacuum distillation through cogeneration with power. Currently this is mostly done by using seawater to cool nuclear and fossil fuel power plants in the Middle East and Africa and desalinating the water at the same time.

Seawater is also directly used for needs such as cooling power plants and providing ballast for ships. Although no major crops can be irrigated with undiluted seawater at this time, a number of institutions are investigating the potential for "seawater agriculture," involving new crops adapted to salty environments and combining a mix of sea and freshwater for irrigation. Another interesting technology is the "seawater" greenhouse that relies on solar energy to produce freshwater for irrigation of greenhouse plants. Clearly, many interesting and promising options exist for greater use of seawater. Higher relative cost currently limits their utility, but that should change for the better over time as technology advances, and support for research and development of those technologies is a priority.

8. **Engineer crops for drought and flooding.** Drought and flooding challenge agriculture, and these extremes are expected to increase with climate change. Genetic engineering offers ways to improve the ability of crops to cope. For example, flood-tolerant transgenic rice varieties have been developed that can survive underwater where others die. Dry spells can inhibit plant growth, and a range of transgenic crops, including peas and corn, are being engineered for continued, fast growth with less water. Tomatoes have been engineered to resist frost and to grow in salty, inhospitable soils. Research and development on crop resistance to drought and flooding is bearing fruit and will bear more. Investment in this field is critical.

9. **Change agricultural products if needed.** Some crops and livestock require far more water to grow than others for the same amount of energy and biochemicals produced for consumption. Cattle, for example, are a well-studied case of food requiring high water consumption. Beans require less water than cotton and alfalfa. Edible cacti, marketed in Israel, have particularly high "water efficiencies." More water-efficient species of crops and livestock, combined with breeding and genetic engineering to enhance efficiency, offer great potential for sustaining human populations.

The good news is that our planet has more than enough water overall to sustain the human population for the foreseeable future. The challenge is to deliver water in the quality and quantities people need and to protect the environment at the same time. These nine principles are offered to help meet that challenge. The solution is within our reach if we try.