
Built infrastructure is essential

By Mike Muller,^{1*} Asit Biswas,^{2,3} Roberto Martin-Hurtado,⁴ Cecilia Tortajada^{2,3}

¹School of Governance, University of the Witwatersrand, Johannesburg, South Africa. ²Lee Kuan Yew School of Public Policy, Singapore, Singapore. ³Cofounder, Third World Centre for Water Management, Atizapán, Mexico. ⁴Alboran Consulting, London, UK. *Corresponding author. E-mail: mike.muller@wits.ac.za

Built water infrastructure supported the evolution of all human societies and will remain an integral part of socioeconomic development and modernization. Some postindustrial societies not only seek to “preserve” existing aquatic ecosystems in their otherwise transformed landscapes but also insist that others do the same. They suggest that “green infrastructure” can provide “equivalent or similar benefits to conventional (built) ‘gray’ water infrastructure” (1).

Fast developing countries have a different perspective. For them, built infrastructure underpins “water security”: enough water of adequate quality, reliably available to meet health, livelihoods, ecosystems, and production needs, as well as protection from water's destructive extremes (2). Their challenge is to enable an expanding global population, seeking a better quality of life, to determine the nature of their new environment, not simply to preserve the old.

21ST-CENTURY CHALLENGES. By 2050, water systems will have to support a global population of 9.6 billion, up from 7.2 billion in 2013 (3), most in expanding cities far larger than those of Europe and North America. More people and property will need infrastructure for services far beyond the capacity of “green

infrastructure,” based on natural ecosystems, to provide.

The OECD estimates (4) that global water abstraction for domestic and industrial purposes will more than double by 2050. Improved efficiencies may help (a 14% reduction in agricultural demand is forecast on this basis), but the world in 2050 will need more water infrastructure.

Large conurbations have long exceeded the capacity of local sources, and extensive infrastructure is required to capture, store, transmit, treat, and distribute water to them. Even a mature society like the USA needs to invest almost \$400 billion in its existing built infrastructure between 2011 and 2030 just to sustain drinking water supplies (5). The urban populations of China and India are expected to grow by 292 million and 404 million people, respectively, between 2014 and 2050 (6), with Africa and Latin America not far behind. These populations have access to better technologies and information, but their climate variability and extremes limit the potential contribution of “green” infrastructure and require built infrastructure to achieve water security.

Interventions needed to achieve water security depend not just on local specifics of topography and climate but also on institutional capacities, policies, economics, and politics. Global warming will reduce flows from water

stored in Andean glaciers. So trans-Andean transfers through short tunnels from high-level dams in the Amazon and Orinoco basins are logical responses for growing cities along South America's arid Pacific coastal region.

The 10 major rivers flowing from the Hindu Kush Himalayas underpin water, energy, food, and ecological security for 1.3 billion people. Only carefully judged infrastructure investments can provide water security for, for instance, the 50 million people in Bangladesh vulnerable to the calamitous coincidence of river flooding and storm surges.

SHIFTING CHALLENGES. Despite obvious needs, water projects are often opposed because they threaten poor people's livelihoods and the environment (7). In societies with water security, this opposition reflects changing social priorities. But "green infrastructure" often fails to achieve its goals.

In Britain, proposals to reduce sewage spillages into the Thames river using "green engineering" techniques were "not considered to be technically feasible" (8, 9). Instead, a massive 25-km tunnel is being built to contain contaminated stormwater and divert it for treatment.

Controversy surrounded South Korea's Four Rivers Restoration project; although promoted as a "green economy" project, it was criticized as "an ecological disaster" (10). Yet only a package of dams, dykes, and hydropower plants could reduce deadly flooding and sustain land and water availability.

Environmental concerns halted a century of infrastructure development in Spain. A transfer from the Ebro River to water-short areas, proposed by the 1998 National Hydraulic Plan, was later rejected on economic, environmental, and political grounds (11). But when drought struck in 2008, Barcelona had to import water by ship, and farmers refused to pay for desalination plants, built as an alternative.

Australia suffered similarly, and both countries are now analyzing the limitations of green infrastructure and the "dams versus desalination" dilemma (12).

Rapidly growing developing countries cannot afford risky experiments or high-cost alternatives. Although potable water needs are being met in most urban areas, sanitation and wastewater treatment are daunting tasks requiring even more investment.

These countries have followed precedent and public preferences, giving initial priority to infrastructure for water supply, irrigation, energy, and flood protection, followed by investments in wastewater management and, finally, other environmental improvements.

This sequence makes sense, given the vicious cycle of water insecurity, in which national economies cannot support the infrastructure investments needed, in part, because water security has not yet been achieved (13). In Africa, demands from water-secure communities elsewhere for green alternatives have delayed economic growth and social development (14). Economic water scarcity (15) is exemplified by the city of Cherrapunji, India, which, despite an annual rainfall of 12,000 mm, suffers severe water shortages during dry months because of inadequate storage.

CHANGING CLIMATES AND PRIORITIES. Over time, societies' needs for water infrastructure change. The Netherlands, whose existence depends on built water infrastructures, can now make "more room for the rivers," including flooding reclaimed polders, because agricultural intensification reduced the demand for agricultural land.

China's Three Gorges Dam symbolizes the infrastructure required to sustain prosperous large societies in the 21st century. It had social and environmental costs but protects millions of

people from floods; supports economic development through improved inland navigation; and generates more emission-free electricity than most European countries (16). It also helps to integrate wind and solar power into China's electric grids, building resilience while mitigating climate change.

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In this Anthropocene world, the primary concern should be to ensure that infrastructure interventions are part of a broader process of "ecological modernization" (17) that meets people's aspirations within an altered but sustainable and socially acceptable ecological framework.