The Age of Water Scarcity:

Understanding the future of water and controls

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Photo cover: Grand Ethiopia Dam is situated at the headwaters of the Nile River on the Blue Nile in Ethiopia.

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Executive Summary

Water scarcity has emerged as one of the most pressing global challenges of the 21st century. With over half of the world's population currently living under water-stressed conditions, the implications for global economics, industry, and food security are profound. This paper examines the multifaceted impacts of water scarcity, explores the legal and political ramifications of designating water as a global commons, and analyzes emerging technological and policy solutions. It also addresses some of the organizational and cultural challenges in the water industry that have allowed water crises to continue to worsen over time. Through a comprehensive review of current data and trends, the paper forecasts the short-term and long-term effects of water scarcity on societies worldwide, aiming to inform policymakers, industry leaders, and stakeholders about the critical decisions that lie ahead. As citizens and professionals responsible for our society, we must become the change agents needed for the transformations we need now.

Keywords: *Water scarcity, global commons, groundwater depletion, water rights, economic impact, renewable water technologies, agriculture, policy forecast.*

Introduction

In recent years, alarming reports have highlighted that more than two-thirds of the global population now lives under conditions of water scarcity (Mekonnen & Hoekstra, 2016). This is far from a trivial concern; water is fundamental to human survival, with life ceasing in just three days without it. The fragility of societies living on the brink of water-related catastrophes has far-reaching consequences, affecting everything from health and food security to economic stability and geopolitical relations.

Historically, access to secure water resources has been a cornerstone of social and political stability. Archaeologists and anthropologists point to water scarcity as a common thread in the collapse of civilizations throughout history (Diamond, 2005). Today, water directly supports an estimated 60-80-percent of global GDP through its essential role in agriculture, energy production, and industry (World Bank, 2016). Without water, commerce, and life as we know it would halt abruptly.

Despite Earth being a "blue planet," only about 2.5-percent of the world's water is freshwater, and less than 1-percent of that is readily accessible for human use (Gleick, 1993). The majority lies underground in aquifers, which are being depleted at alarming rates due to over-extraction and insufficient recharge—a process that can take decades to centuries. In North America, most of the aquafers were charged during the last ice age.

This report explores the prospective impact of designating underground water as a global commons and the implications of such a legal shift. It also examines the drivers pushing this movement forward and considers the potential second- and third-order effects on industries, economies, and societies. It makes potent recommendations as we are in a race against conditions.

Key Issues and Trends

The Importance of Water in Human Societies

Water is indispensable for life, economic development, and environmental sustainability. It is a critical resource that underpins agriculture, energy production, industry, and domestic use (United Nations, 2015). The historical significance of water is evident in the development of early civilizations along river valleys such as the Nile, Tigris-Euphrates, Indus, and Yellow River, where access to water facilitated agriculture, trade, and societal growth (Postel, 1999).

In modern times, water continues to be a fundamental driver of economic activities. Approximately 70-percent of global freshwater withdrawals are used for agriculture, 20-percent for industry, and 10-percent for domestic purposes (FAO, 2011). The World Bank (2016) highlights that water scarcity, exacerbated by climate change, could cost some regions up to 6-percent of their GDP by 2050 due to impacts on agriculture, health, and incomes. It is estimated that water underpins as much as 60-80-percent of the global GDP.

Gate Keepers and Disruptors

Notwithstanding water’s importance, since the 1960s with the creation of desalinization, the water industry has in many respects become stagnant, pushing forward only incremental advancements. Since antiquity, engineering and thinking about water have remained substantively unchanged.

The expectation of doing the same thing over and over while expecting a different outcome is clinically diagnosable. Around the world, the fallout arising from the inactions of the unyielding water industry fearful of adaption and change can be seen from Cape Town, South Africa to Lima, Peru. Planners and policymakers must think forward of old ideas – NOW. This effort begins first and foremost with intellectual honesty about where things are with respect to need, the urgency for change, and actions that speak louder than words. This self-appraisal must also be willing to look past professional dispositions as well. Such dispositions can be seen in industry where *old guard* members become the gatekeepers on new ideas, they fear more than understand. There are a variety of motives and drivers for such behaviors, but in the water industry, aversions to innovation are deeply pervasive and have long inhibited positive progress.

The persistence of industry gatekeepers means that innovators, disruptors, and change agents will play a more critical role in the advancement of new ideas than those of Edison and Westinghouse as their electric systems paved the way for societal transformation. While these pioneers faced fear and resistance, with the help of hero investors and financial backers, they broke down barriers and put the Second Industrial Revolution on the fast track.

Maturing Industries and Finance

After Westinghouse and General Electric began electrifying the United States, new industries were needed to supply and support growth. Turtle-Hughes company, more than 100 years after its founding, remains an exemplar of the kind of supports that helped mobilize nationwide efforts to make power and electricity ubiquitous from the home to industry. By supplying the parts and machinery needed to electrify the entire nation, Turtle-Hughe's role in maturing vision cannot be overstated. It is hard to estimate the impact on America's production capacity and GDP. The economic uplift was tremendous.

In like manner, as new and disruptive ideas and concepts mature across the water industry, financing and fundraising must come alongside. Without the convergence of growth and project capital, modernization efforts will continue to be slow and stifled. Thus, both maturing industries and finance are critical to advancing sustainability and growth efforts in water constructs from decentralization to Smart cities.

Global Water Scarcity: Current Status and Trends

The State of Global Water Resources

Global freshwater resources are under significantly increasing pressure from population growth, urbanization, industrialization, and climate change (UN-Water, 2021). While Earth's surface is covered by about 71-percent water, only 2.5-percent of this is freshwater, and less than 1-percent is readily accessible for direct human use (Gleick, 1993). The available freshwater is unevenly distributed, leading to regional disparities in water access (Vörösmarty et al., 2000).

Water is the economic potential energy of a nation. It is needed for food, manufacturing, resource exploration, industry, and all human and animal life. A nation's potential can be measured by the amount

"Water is the economic potential energy of a nation."

of water available for utilization. A nation's life without water can be measured in days. Notwithstanding this reality, the tendency of industry and governments to centralize and consolidate water systems has been nearly universal where budgets allow. Rather than building several systems that could function in part during an interruption, most centralized water systems can be broken by interrupting as little as one key node. This means a single domino can trip the rest of the systems causing water delivery to be interrupted for thousands and millions of people.

Such engineering puts populations, property, business, health, and safety at risk. Water systems should be resilient. Energy is important, but without energy, humans do not die in three days. Yet most key facilities have Uninterruptable Power Systems (UPS) to enable key operations and functions to continue. Such are said to be resilient as they can suffer an interruption but continue supporting production and key functions. In like manner, the water industry needs to begin engineering resilience into water planning and technologies. Uninterruptable Water Systems (UWS) should be a prime directive of modern supply-side water planning efforts.

Further to the need for UWS, military conflicts in Ukraine and recent cyber-attacks on the U.S. water system highlight the willingness of bad actors to target the lifeblood of a society – its water supply. In 2024, the largest water system in the U.S. was targeted by hackers; while in Ukraine, Russia targeted key critical infrastructure, specifically water. The recency of these attacks highlights the risks of taking water delivery for granted in any context. Planners have not used a security or resilience mindset, as they are usually focused on cost and efficiency. It is likely that over the next decade, efficiencies and cost will become secondary to all priorities with the central focus becoming, can water be supplied at all.

Depletion of Groundwater Aquifers

Groundwater aquifers account for about 30-percent of the world's freshwater resources and are a vital source of drinking water and irrigation (Margat & van der Gun, 2013). However, many major aquifers are being depleted faster than they can be replenished.

NASA's Gravity Recovery and Climate Experiment (GRACE), launched in 2002, has provided critical data on groundwater depletion globally (Tapley et al., 2004). GRACE data reveals significant declines in groundwater storage in key regions, including (see Figure 1):

- **North America:** Five of the world's largest aquifers are experiencing rapid depletion, notably the Ogallala Aquifer, which supports much of the U.S. agricultural heartland (Scanlon et al., 2012).
- **The Punjab Region (India and Pakistan):** Intensive irrigation has led to a dramatic decline in groundwater levels, threatening agricultural productivity and food security (Rodell et al., 2009).

- **Northern China:** Over-extraction of groundwater has resulted in land subsidence and reduced water availability (Feng et al., 2013).
- **Mexico City:** Excessive groundwater pumping has caused the city to sink, damaging infrastructure and exacerbating flood risks (Mejía et al., 2017).

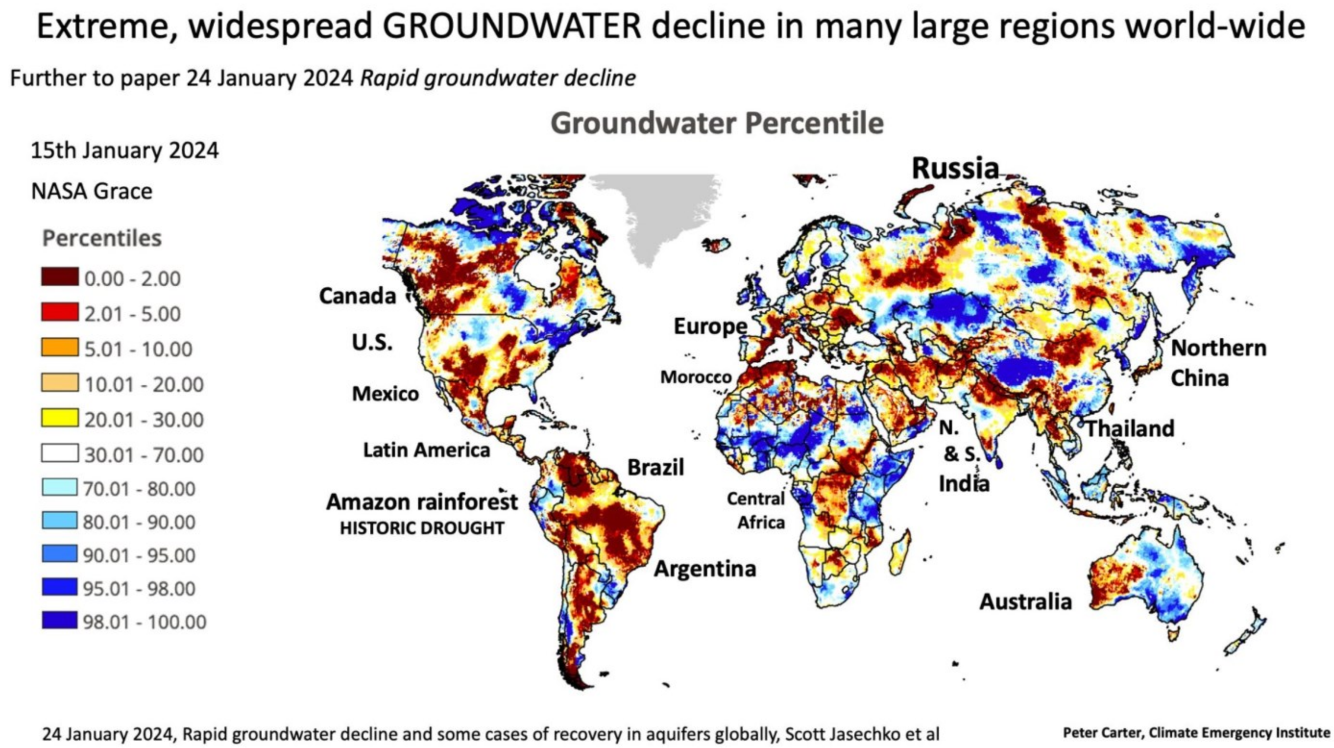

Figure 1. NASA's GRACE image of water scarcity:

Select Case Studies of Water Scarcity Impacts

North America

In the Western United States, prolonged droughts and over-extraction have led to significant water shortages. The Colorado River Basin, which supplies water to seven states and Mexico, is facing critical levels, with Lake Mead and Lake Powell at historic lows (Udall &; Overpeck, 2017). The depletion of aquifers is resulting in the loss of irrigated agricultural land at a rate of thousands of acres per year (Steward et al., 2013). For instance, the Ogallala Aquifer is being depleted at unsustainable rates, threatening the viability of agriculture in the region (McGuire, 2017). The U.S. Environmental Protection Agency has stepped up control.

The Indus River Basin

The Indus River supports millions of people in India and Pakistan. Intensive agriculture and population growth have stressed water resources, leading to conflicts over water allocation. Climate change impacts on glacial melt in the Himalayas further threaten water availability (Immerzeel et al., 2010). The region faces significant groundwater depletion, with studies indicating a loss of 18 km³ of groundwater per year between 2002 and 2008 (Rodell et al., 2009). A treaty on the use of water for multiple nations keeps the region's peace and stability in a fragile state.

The Nile River Basin

The construction of the Grand Ethiopian Renaissance Dam (GERD) on the Blue Nile (the headwaters of the Nile River) has heightened tensions between Ethiopia, Egypt, and Sudan. Egypt relies heavily on the Nile for its freshwater needs, and GERD operations could significantly impact downstream water availability (Cascão & Nicol, 2016). The dispute underscores the challenges of transboundary water management in regions where water scarcity is acute. Over the last 10 years, Egypt has threatened war if waters are stopped.

Mexico City

Mexico City faces severe water challenges due to over-extraction of groundwater, leading to land subsidence and infrastructure damage. The city is sinking at an alarming rate—up to 50 centimeters per year in some areas—exacerbating flood risks and water distribution issues (Mejía et al., 2017). The sinking has damaged buildings, roads, and pipelines, increasing the cost of maintenance and repairs. Changing hydrology and climate impacts in some areas, lead to more than 40-percent of disposable income is spent on fresh water.

The Legal Implications of Water Scarcity

Water as a Human Right and Global Commons

In 2010, the United Nations General Assembly recognized the human right to water and sanitation, acknowledging that clean drinking water is essential for the realization of all human rights (UN General Assembly, 2010). The recognition emphasizes that water should be accessible, safe, acceptable, and affordable for personal and domestic uses.

Designating water as a global commons has significant legal and political implications. It challenges traditional notions of sovereignty and property rights over water resources, potentially leading to conflicts between nations and stakeholders over access and control (Dellapenna & Gupta, 2009). This shift may necessitate new legal frameworks to balance the rights of individuals, communities, and nations with the collective need for sustainable water management.

Implications for Water Rights and Ownership

The concept of water as a global commons raises questions about water rights, private ownership, and management. It could lead to international regulations that supersede national laws, affecting industries,

> "…[M]ovements toward government control of water supplies could undermine the value of real-estate in water scarce areas."

agriculture, and individuals who rely on existing water rights (Schmidt, 2017). For example, the reallocation of water resources could impact farmers who depend on groundwater for irrigation, potentially leading to economic hardship and social unrest. Additionally, movements toward government control of water supplies could undermine the value of real estate in water-scarce areas.

In the Northern United States, the State of Utah Department of Natural Resources has learned of communities using more than their allocated annual water use. In some cases, the overuse has continued for decades. In response, Utah plans to revoke long-standing permits to take charge of water conservation. Situations such as this and other instances including crackdowns across the Western United States and as far South as Panama, indicate a trend. Legacy and long-standing water rights, even for communities will not guarantee continued water supply access – even for residential areas.

Economic Impacts of Water Scarcity

Impact on Global GDP

Water scarcity poses a significant risk to global economic stability. The World Bank (2016) estimates that water scarcity, exacerbated by climate change, could reduce GDP growth by up to 6-percent in some regions by 2050. Industries reliant on water for production, such as agriculture, energy, and manufacturing, are particularly vulnerable. Nearly all supply chains require reliable water to provide both materials and manufacturing.

Industry Implications

Industries face increasing operational risks due to water scarcity. A study by CDP (formerly the Carbon Disclosure Project) found that in 2016, water-related financial losses amounted to $14 billion among the companies surveyed (CDP, 2016). Data centers, essential for the digital economy, are experiencing increased water demands for cooling systems. The rise of artificial intelligence and large-scale computing has intensified this demand, with data centers consuming significant amounts of water for cooling (Masanet et al., 2020). In 2024, the overall water use in data centers jumped an estimated 17 percent due to the introduction of Large Language Models (or AI/GPTs). According to the United Nations, "Data Centers are large consumers of water, which is becoming scarce in many places. AI-related infrastructure may soon consume six times more water than Denmark—a country of 6 million—exacerbating global water scarcity where 25-percent of humanity already lacks water [note: in 2024, NATURE reported that 4.4 billion people live in water scarcity—more than half the world's population] (2024).

Food Production and Agriculture

Agriculture accounts for the largest share of global freshwater use. Water scarcity threatens food security by reducing crop yields and increasing production costs. In the Western United States, farmers are losing access to irrigation water as wells run dry, leading to a loss of arable land (Scanlon et al., 2012). Globally, water scarcity could lead to a 30-percent decline in food production by 2050 if current trends continue (FAO, 2011).

Livestock production is also under scrutiny for its higher water footprint. Producing one kilogram of beef requires approximately 15,400 liters of water, raising concerns about the sustainability of meat consumption (Mekonnen & Hoekstra, 2010).

Technological Responses to Water Scarcity

Desalination and Its Limitations

Desalination provides an alternative source of freshwater by removing salt from seawater. While it has expanded in regions like the Middle East and California, desalination is energy-intensive and produces brine that can harm marine ecosystems (Jones et al., 2019). Increasing salinity in bodies of water due to toxic brine discharge poses additional environmental challenges. For example, the Arabian Gulf has seen increased salinity levels, which can affect desalination plant efficiency and marine life (Lattemann & Höpner, 2008).

> "…[w]ithout significant investment and policy intervention, the age of free and abundant water may be coming to an end."

Renewable Water from Air (RWA)

Innovations in extracting water from atmospheric humidity offer promising solutions. Technologies such as atmospheric water generators (AWGs) can provide water in arid regions without relying on existing water sources or generating harmful byproducts (Fath et al., 2015). While still in development, these technologies have the potential to supplement water supplies, especially in remote or drought-stricken areas or those away from shorelines (oceans and other bodies of water). The U.S. military is already adopting RWA technologies along with state governments for use in deployments and disaster recovery. Hospitals with critical care facilities have used RWA systems to reduce risks from storm disruptions.

Innovations in Agriculture

Advancements in agricultural practices aim to increase water efficiency. Drip irrigation, hydroponics, and vertical farming reduce water usage by delivering water directly to plant roots and recycling water within closed systems (Despommier, 2013). Genetically modified (GMO) crops with enhanced drought tolerance are also being developed to maintain yields under water-stressed conditions (Nuccio et al., 2018). Notwithstanding, GMO threatens to extinct crop biodiversity and limit wild strains of genetic material. Over time, this crop monoculture reduces the ability of crops to resist pests, climate change, and man-made impacts.

Conclusion

Water scarcity represents a critical challenge with profound implications for global economics, industry, and food security. As the economic potential energy of nations, water availability and security are increasingly uncertain. Technological innovations offer promising solutions, but without significant investment and policy intervention, the age of free and abundant water may be coming to an end. One of the most significant challenges to industry and technology development is a continued focus on efficiency and incremental innovations rather than step-change improvements.

The potential designation of water as a global commons raises complex legal and political questions about rights and ownership. Balancing the need for collective stewardship with individual and national interests will require new frameworks and collaborative efforts. However, the need to revoke water rights and permitting on many existing sources will likely outpace the deployment and integration of breakthrough innovations such as RWA creating compound risks to industry and commerce in an effort to stave off health and community survival issues. The forecasts outlined in this paper highlight the urgency of addressing water scarcity through sustainable practices, technological innovation, and proactive policy measures. The often-irresponsible global water industry needs deliberate disruption, but the industry is insular and typically nested deep within large corporations or governments creating little incentive for change.

By understanding the interconnected impacts of water scarcity, stakeholders can make informed decisions to mitigate risks and navigate the challenges ahead. The future of water controls will shape the trajectory of human societies, economies, and the environment for decades to come. We are in a race against very dangerous conditions emerging globally.

Recommendations

Often planners, strategists, and others argue they are being asked to boil the ocean when tackling hard problems. Yet, the journey of a thousand miles must begin with humble first steps. Based on the trends and developments outlined in this work, it is imperative that humanity resist the tendency to admire the sheer magnitude of water issues. The scale of the problem must not become an excuse for inaction.

With the benefit of much deliberation over water during the 2023 UN Water Conference in New York City and the various climate forums globally, there is no lack of recognition as to the seriousness of water scarcity. There is, however, a paucity of action steps to take. The recommendations below are informed by more than 30 years of research and experience in water, business, and government:

- **The right people will solve humanity's greatest challenges by applying intellectual rigor and creativity; find them, and support them.** Intentionally back the disruptors and proven innovators (people); do not back incumbents who tend to perpetuate the *status quo*.

Entrenched industry is seldom able to turn fast, adapt, or overcome institutional inertias needed to do new, better, and different.

- **Think tanks are not the answer.** While this may be surprising coming from a think tank, ALPF is no ordinary think tank. Most think tanks accept funds from industry and compromise their research in order to prevent offending corporate donors. Corporations donate and provide endowments to think tanks to help them control the public narrative.
- **Truth will pave the way to new ideas.** The truth is, that the water industry has failed; the incumbents have failed; and the professionals managing the industry have failed. There is now a need to own failure and to develop and discover new thinking outside of an echo chamber of old tired ideas.
- **Innovation is the gateway to sustainable global water solutions.** In the movie, The Boy Who Harnessed the Wind, the story of a young boy in Africa showed how to use leftover machinery to operate a windmill for a village. Without the water, the village would have died of starvation. Innovation was the gateway to success. It takes relentless courage to innovate.
- **Community support is the force that keeps good ideas moving forward.** Too often ideas that do not originate with high titles and well-known individuals fail to gain traction. Innovators and disruptors need help to move their ideas forward. Needed help can range from encouragement to investment and partnership. If you want to go fast, go alone. If you want to go far, go together." – African Proverb.
- **Funding that takes chances is worth a hundred times more than over-managed funds.** There are billions of dollars presently waiting in funds, bonds, promissory notes, and pledges to solve water issues. Most of these programs are completely overmanaged and those who are innovating do not have time to pull funding from such sources – these programs are too rigid and difficult to navigate. Funds must be willing to take risks. Risk aversion kills the kind of funding needed to support innovation.
- **Know the difference between true innovation and innovation theater.** Innovation theater brings together CEOs and well-titled individuals to talk about new ideas in front of admiring audiences. But the higher the stool and the bigger the stage the less likely the chance there is an innovator on it. Innovators are not one-hit wonders. They are people who have made a habit of creating and they would rather be creating than explaining how their ideas are going to work.
- **Innovation is more precious than gold; it is not a commodity.** Innovation only thrives in an environment where risk-taking is welcome and where failure is embraced. Silicon Valley developed a unique culture that allowed certain adjacent talent to develop into a niche culture. Putting a sign on a building or an X in the name does not connote innovation. "Water is the new Silicon Valley, and it's early." Jay Heller, Head of Capital Markets, NASDAQ.
- **Windfall profits in the water industry are okay, but the promise of prosperity drives investment.**

  Many think tanks and industry experts believe water costs should be controlled. Yet, those who benefit the most from water investing will be those taking the biggest risks. These two schools of thought will always pull against one another. Profit motive is not a perverse incentive, it is the foundation of the free market and is a foundational driver in the global economic engine.
- **Not everyone speaking has something important to say – firebrands will lead the way.** While the tendency to filter ideas is toward those who are less known in the water industry, the most important filter is on ideas that promote the same thinking. The age of the old guard will never pass unless firebrands take them on. Find the firebrands and help them**!**

- **Innovators and firebrands will need hero investors.** Hero investors are more than entities with capital, or opportunistic ventures hoping to hit it and get a 100x return on investment. Hero investors are those willing to seek out quality individuals and partner with them to make their ideas a success. Hero investors help forge world changers. And they will reap the reward.

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