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James A. Tindall, Andrew A. Campbell, and Edward H. Moran

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Water Security — A Synopsis

James A. Tindall, Andrew A. Campbell, and Edward H. Moran

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This report represents a summary overview or synopsis of the significant interdependencies in water security and its important role in the lives of people throughout the global community. What is water security? **"Water Security** is *the protection of adequate water supplies for food, fiber, industrial, and residential needs for expanding populations, which requires maximizing water-use efficiency, developing new supplies, and protecting water reserves in event of scarcity due to natural, [man-made], or technological hazards. [Eco-system functioning, environmental, social, and economic parameters are composite water-security components]."*[1]

By definition the subject is highly complex and covers many areas through interdependency with critical infrastructure — the systems that drive life and the economy, which include energy, transportation, agriculture and food, public health, defense industry, and others.[2] Water also is complexly interdependent with many other areas such as transboundary resources and political issues, national and international security, emergency preparedness and incident planning, policy, and many others. The security implications of water-related issues are fundamentally characterized by the uncertainty they introduce with respect to overall water availability, water security, food security, economic sustainability, and social stability. Terrorist, natural, and technological hazards also play an important role in mitigation of failure of water systems and how policy is implemented to account for these hazards. Although many countries such as the U.S. have invested and devoted substantial economic resources to dams, reservoirs, water conveyance systems, storage, flood control defenses, and other distribution systems, a growing population will inevitably increase this cost. Water is the primary driver that allows economic sustainability and has long been a source of conflict — from the Wild West days in the United States to current peace process endeavors in the Middle East. Aptly stated, nothing is more important than water and its security excepting life itself.

In this century new challenges to water security and national security will likely manifest themselves more frequently. Security convergence and operational resilience are examples of public and private sector components that will be vital for ensuring continuity of operations. In this sense, water security and other security measures should be thought of as sustainability, not merely physical elements — *there can be no security without sustainability*.[3] The fundamental key will be to maintain security processes that are flexible and adaptable and that incorporate continuity goals and strategies. These processes should be based on an all-hazards approach that considers disruption from the primary hazards — anthropogenic (terrorist or manmade), natural, and technological. There are four

[1] J. Tindall, and Campbell, A., "Water Security: Conflicts, Threats, Policies," 2010, DTP Publishing, Denver, 452 p.
[2] Ibid
[3] Ibid

major future security implications: (1) to hedge against uncertainty; (2) to curtail outdated and less useful security concepts; (3) to explore new security concepts and be rapidly adaptable; and (4) to adapt through time via changing technologies. These implications will be applied against relations with not only current security issues, but also far more significant issues that relate to water security and critical infrastructure, mass sustainability, and the primary hazards that can affect them. Addressing these issues requires a heightened flexibility and adaptability that could prove problematic for hierarchal organizations. Thus, water-security issues reflect much more than management, planning, and policy.

Both energy and water security has become a national and global priority. The continued security and economic health of a country depends on a sustainable supply of both because these two critical natural resources are so closely linked. The production of energy requires large volumes of water while the treatment and distribution of water is equally dependent upon readily available, low-cost energy. For example, electricity production accounts for over 40 percent of all daily freshwater withdrawals in the United States; the indirect use of water (home lighting and electric appliances) is approximately equal to direct use (watering lawns and taking showers).

Current trends of water use and availability indicate that meeting future water and energy demands to support continued economic development will require improved utilization and management of both resources. Primary concerns include (1) increasing populations that require more food and energy (which will cause direct competition between the two largest water users for limited water resources — energy and agriculture); (2) resource needs for economic expansion (projections indicate the U.S. will require an additional 393,000 MW of new generating capacity — equivalent to about 1,000 new 400 MW plants by the year 2020, which is unlikely to occur); (3) potential environmental and ecological restrictions on the use of water for various purposes; and (4) potential terrorist attacks on power grids and water-treatment and distribution systems. The ability to meet increasing demand for affordable water and energy is being seriously challenged by these and other emerging issues; this is true for almost all countries. As an example, a terrorist attack or other hazard occurrence against a national water supply could disrupt the delivery of vital human services, threaten both public health and the environment, potentially cause mass casualties, and likely weaken social cohesion and trust in government, resulting in grave public concern for national and/or homeland security. A threat to continuity of services is a potential threat to continuity of government since both are necessary for continuity of operations. To exacerbate matters, water infrastructure is difficult to protect — it extends over vast areas and ownership is overwhelmingly nonfederal (approximately 85 percent). Although counter measures are being established for enhanced physical security, improved coordination among stakeholders, and risk assessment and vulnerability analysis, the vastness of these systems leaves them weakened. A key issue is the proportionate additional resources directed at public and private sector specific priorities. A large portion of this work is focused on water quality and supply, which for some locations is errant.

Globally, unsafe water, inadequate sanitation, and improper hygiene cause illness and death from disease on a large scale. Improving these conditions can lead to better health, poverty reduction, and sustainable socio-economic development. However, many countries are challenged to provide these basic necessities, which have left and continue to leave people at risk for water, sanitation, and hygiene (WASH)-related diseases. Generally, water and public health revolve around safe water, good sanitation and hygiene and their education in six areas: (1) community systems (water safety plans, assessment and development); (2) sanitation and hygiene (toilets, hygiene, sewer and wastewater treatment); (3) diseases and contaminants (waterborne, sanitation, and hygiene related); (4) household treatment (safe water systems and storage); (5) travelers' health (safe drinking and recreational water and injury and illnesses); and (6) educational resources (publication, Internet, etc.). These are additional, yet significant aspects of water security.

A growing population is beginning to strain global resources, particularly water. Water stress affects 44 percent of the world's population. The United Nations Environment Programme (1999) projected that by 2050 nearly 5 billion people will be affected by freshwater scarcity. Currently, over one billion people in the world lack access to improved water supplies and 2.6 billion people lack adequate sanitation — the two issues are interdependent — water is needed for sanitation and lack of it promotes disease. On a global scale, the health burden accompanying these interdependent conditions results in about 5,000 child deaths daily, mostly from diseases associated with lack of access to good quality drinking water, sanitation, and good hygiene.[4] The disparate distribution of water also makes it difficult for resource and economic scarce areas such as the Middle East, Pakistan, Afghanistan, Northern Africa, and others to cope. The three general areas necessary for improved water-related public health problems include (1) good quality drinking water; (2) adequate quantities of water for food production, health, and hygiene; and (3) sustainable sanitation processes. Although these issues may seem trite, their effects on the local or regional area are a security concern and illustrated by the rising number of conflicts over water resources around the world.

For large cities, simultaneous shortages of food, water and power, created in large part by water shortages, could dramatically destabilize mass population sustainability, security, and governance, which make water security and supply issues a matter of national stability. The most pressing water-supply issues facing almost all cities are increasing population and urbanization — the primary causes of water shortages. Population growth in arid regions dramatically reduces available water supplies from both ground and surface waters. Examples include Phoenix, Las Vegas, and Denver in the U.S., as well as other cities that are located in semi-arid to desert conditions. Within the U.S., cities are short of water, especially in the arid West where the Colorado River supports about 22 million people, is drawn upon by seven states, supplies such cities as Los Angeles and San Diego, California; Las Vegas, Nevada; Phoenix, Arizona; and Denver, Colorado and also provides large volumes of water for agriculture. The situation is similar for the Indus River system that supplies parts of China, India, and Pakistan; the Jordan River supplying Israel, Jordan, and Syria; and other world regions. A worst case scenario is Lake Chad in Africa, which has been depleted 95 percent in the past 40 years.

The effects of global water and distribution shortages are potentially catastrophic, creating mass civil unrest, food shortages, and large-scale failure of industry and, thus, society. The end result could dramatically destabilize security and governance, especially if the current poor global economic outlook persists. Water supply is therefore a matter of national stability and security for all countries and is the reason most countries have sought to harness water and the energy it provides. As an example, construction of Hoover Dam was one of the greatest undertakings in human history considering its scale and scope, the manpower necessary to achieve the project, and its economic and social impacts. The waters impounded behind Hoover Dam in Lake Mead have played an integral role

[4] M. Schomaker, "Guidelines on Municipal Wastewater Management," ed. UNEO/WHO/HABITAT/WSSCC (The Hague: WSSCC, 2004).

in the burgeoning of agriculture and urban development in the American Southwest — providing water to about 22 million people and hydro power to about 7 million. The Colorado River is the lifeblood of this region and Hoover Dam is, quite literally, the heart of it. All of the major cities and the majority of the agricultural lands would not exist without the security of water reserved in Lake Mead. Therefore, management and mitigation of stored water will become increasingly significant as a function of rapidly increasing population and increasing demand.

The centralized nature of such projects, coupled with substantially increasing resources, needs to facilitate a viable and renewable source of water and power, and pose a liability to the future security and sustainability of a region. Total reliance on the entrapment of water in a hot and arid climate regime utilized by millions of people and large agricultural investments is generally not a sustainable endeavor. Additionally, these issues pose a significant threat to the security of critical resources (access to water, food, and power) due to a non-redundant water supply.

The zones most directly at risk from failure of such systems are those areas directly dependent on it for critical resources, regardless of geographic location. Examples could include Hoover Dam in the U.S., Three Gorges Dam in China, and Tarbela Dam in Pakistan. For agricultural areas that depend on these resources, a failure of the system would be catastrophic, causing simultaneous security risks to our basic needs as a society — water, food, and energy.[5] This would occur through failure to provide municipal and industrial water needs; agricultural water needs (loss of a reliable supply of resources would have both local and national impacts); clean electrical power; and economic losses (which would cause a significant downturn in production and loss of jobs with cascading failures into the supply chain and other critical infrastructure that would have a severe rippling effect through the nation). Failure also would affect energy, commodity, and food prices extensively, as well as have other unseen effects (not discussed here due to sensitivity and security issues).

The security risks to critical resources are overly relevant because of the number of people and agricultural lands that are directly and solely dependent on resources provided either directly or indirectly from large-scale water projects. Additionally, any clear and present resource security risks are likely to occur simultaneously to a large population, causing deprivation of critical resources with almost no alternatives available for substitution — posing a significant security risk to the entire population at large. As more people compete for finite resources, sustainability will likely fail at some juncture and many people will be unable to meet basic resource needs. However, it is difficult to predict and gauge the exact effects of such an event to the local and national environmental and economic landscape, generally because an event of this magnitude and scope has not yet been experienced. However, it could be assumed that this event would cause large-scale disruption, both locally and nationally — the duration of the residual effects of this event would not be short lived.

The major mechanisms of failure for large water projects, dams, etc., would include earthquakes and terrorist attacks, as well as technological failure. The likelihood of a terrorist attacks remains the highest probability of dam inoperability and would likely occur due to contamination from biological agents such as Anthrax, Botulism, or others, through chemical agents, such as Nerve (G and V agents), biotoxins (Ricin, Digitalis), etc. Bio-agents would cause the most immediate damage through poisoning water, especially an agricultural water supply. Other terrorist threats could potentially rely

[5] Tindall, J.A., and Campbell, A.A., 2010, Water security—National and global issues: U.S. Geological Survey Fact Sheet 2010–3106, 6 p.

on explosives of various types and/or technology such as cyber attacks of industrial control and Supervisory Control and Data Acquisition systems (SCADA).

Industrial control systems (ICS) that manage critical infrastructure such as flow of water, energy transmission, communications and so forth are moving to general-purpose computer hardware and software in ever increasing numbers for cost efficiency and centralization of control. Yet best practices for information technology that shares many of the same components do not always work for industrial control systems and in some cases can be harmful. Common products and practices such as the Java programming language, virtualization, desktop security tools, remote access, standard network topology, commercial off-the-shelf operating systems and lax password policy have the capability to cause more damage than good, creating increased vulnerability of these systems to hackers. Industrial control systems should defy information technology and embrace read-only operating systems, network segmentation, security through simplicity, and, above all, set higher standards for employees who manage and maintain computer systems. These control systems must have unique policies and procedures, patch procedures, security software, and employees who understand the differences between information technology and industrial control systems — all while working on the same general-purpose computer hardware. The information technology and industrial control system worlds should never come together. Their objectives, consequences, and fates are too far apart.

Natural and technological failures also represent dire threats to these systems and/or projects. Regardless, the shadow cast by the limited resources and growing populations poses an urgent dilemma to the future security of many nations and could have a profound effect on national security. For example, the importance of interdependencies among critical infrastructures is well recognized — the economic sustainability and prosperity, security, and social well being of countries depend on infrastructure reliability. Although the surface interdependencies are more easily understood, the complex underlying interdependencies are understood by a scant few. This failure to understand the complexities and the cascading failures and resulting disruptions among infrastructures will decrease the effectiveness of response and recovery efforts during man-made, natural, or technological hazards, or may result in common cause failures that leave planners and emergency response personnel unprepared to effectively deal with operational continuity and the impacts of these disruptions.

Interdependencies among infrastructure can generally be categorized into four components: (1) cyber; (2) physical; (3) logical; and (4) geographical. Additionally, water and wastewater systems have interdependencies with other infrastructure that are unique and that must be understood when developing and conducting vulnerability assessments, response and recovery plans, and security and sustainability.

Gaps in understanding the analytic capability of infrastructure and related systems are apparent in the context of analyzing multiple scenarios of possible events that involve interdependence between one or multiple infrastructure and related components within even one system. Each linkage between systems is important. The types of failure that can occur within infrastructure include (1) cascading; (2) escalating; and (3) common cause. Infrastructures are also linked to varying degrees, which influences vulnerability and response requirements, resiliency, and operational considerations. ICS, deregulation, business mergers, and related components can dramatically affect both the economic and business aspects of the infrastructure environment and have become an important part of infrastructure that is rarely discussed, even though these components can all significantly affect water security. Unfortunately ICS have also led to the introduction of new vulnerabilities, particularly cyber attack from both terrorist and criminal elements. Compounding these factors has been the increase of legal and regulatory issues, increased environmental regulations, government investment decisions, and public health and safety concerns. All have served to influence infrastructure operations and interdependence. The importance of the crucial role of water is profound. Water infrastructure and shortages have a cascading detrimental effect on all facets of economic, public health, social areas, the political arena, transportation, trade, and interdependencies between various industries — these are the non-surficial complexities that scant few understand.

Compounded with water is its requirement by agriculture to feed a growing population — without water, agriculture is impossible. Risks and vulnerabilities due to the three primary hazards also link directly to agriculture. For example, attacks against agriculture are not new, and have been conducted throughout history both by nation-states and by sub-state organizations utilizing biological weapons. At least nine countries (Canada, France, Germany, Iraq, Japan, South Africa, United Kingdom, United States and former USSR) have documented agricultural bioweapons programs during some part of the 20th century. Four other countries (Egypt, North Korea, Rhodesia and Syria) are believed to have or have had agricultural bioweapons programs.[6] Although individuals or sub-state groups have used bioweapons against agricultural or food targets, only a few can be considered terrorist in nature. In 1952, the Mau Mau (an insurgent organization in Kenya) killed 33 head of cattle at a mission station using African milk bush (a local plant toxin). In 1984, the Rajneesh cult spread salmonella in salad bars at Oregon restaurants to influence a local election.[7]

The most effective biological weapon agents would be highly infectious, communicable, and lethal; efficiently dispersible; easily produced in large quantities; stable in storage; resistant to environmental degradation; and lacking vaccines or effective treatments. Biological agents may be targeted directly against humans through injection or topical application; deployed against agricultural crops, livestock, poultry, and fish; applied as a contaminant of food or drinking water; disseminated as an aerosol; or introduced through a natural vector such as an insect.

Authorities may be persuaded that a disease outbreak is natural, providing cover or plausible deniability to biological terrorists. An example is the recent E-coli outbreak in Europe during May-June 2011 that spread to the U.S., which has thus far managed to control it. According to European scientists, the source of the outbreaks is unknown and potential causes have ranged from Spanish cucumbers to vegetables from other countries. At the time of this writing more than 2,400 people have become ill and 23 are dead.[8]

Linking water security to agriculture from an agroterrorism perspective, there are a number of threats to drinking water: improperly disposed chemicals; animal wastes; pesticides; human wastes; wastes injected deep underground; and naturally-occurring substances that can all contaminate drinking water and also food, either deliberately or accidentally. Likewise, drinking water that is poorly

[6] Jim Monke, "Agroterrorism: Threats and Preparedeness," ed. Congressional Research Service (Washington DC: Library of Congress, 2004).

[7] Ibid.

[8] Lisa Baertlein, "Major E.Coli Outbreaks Decline, Salmonella Up," *Reuters U.S. Edition*(2011), http://www.reuters.com/article/2011/06/07/us-ecoli-usa-idUSTRE75675K20110607.

treated or disinfected that travels through an improperly maintained or sabotaged distribution system can also pose a health risk.

Naturally occurring outbreaks of diseases signal the devastation that could result from a carefully choreographed intentional or accidental event. Examples include the recent Foot and Mouth disease epidemics in Taiwan and Great Britain, swine cholera in the Netherlands, and infection of Florida citrus trees with citrus canker, which aptly demonstrate the vulnerability of living targets to biological pathogens and the economic chaos that can result from an outbreak — intentional, accidental, or natural.

Distribution systems are among the most vulnerable physical components of a drinking-water utility, as well as the computer systems that manage critical utility functions; treatment chemicals stored on-site; and source water supplies. Two key factors appear to constitute overarching vulnerabilities: (1) a lack of the information individual utilities need to identify their most serious threats and (2) a lack of redundancy in vital system components, which increases the likelihood an attack or failure could render an entire utility inoperable.

In regard to anthropogenic threats to water security, supplies, and sustainability, the most serious terrorist threat to a water supply is the flight or sudden emergence of simultaneous and coordinated black-swan. A coordinated 'black swan' terrorist attack on the U.S. water supply, dependent on severity, could involve a reordering of defense priorities to the maintenance of civil order within the continental United States. Also, a paradigm case of a terrorist 'black swan attack' was the three day terror attack on Mumbai from 26-28 November 2008. In 1993, Bin Laden declared war on America and stressed his commitment to 'the defeat of the U.S. economy." By 14 September 2003, Bin Laden claimed the success of the 9/11 attacks. Not surprisingly, Al Qaeda and other terrorist group's psychological warfare strategists have an impressive sociological understanding of the vulnerabilities of western target societies, including the importance of the relationship between consent and legitimacy of government.

Since the 2001 terrorist attacks, the FBI has identified and interviewed Al Qaeda supporters who planned attacks against U.S. water supplies and plans, particularly Hoover and TVA Dams. A successful attack would potentially be catastrophic. It should also be presumed that the U.S. is not the only target country. A cascading attack on water infrastructure would disrupt and in some cases destroy key storage and distribution nodes. The chaotic consequences would ensure that government priorities would be diverted to terrorist induced socio-economic dislocation, a form of Al Qaeda induced Hurricane Katrina. Simultaneous co-coordinated attacks on targets across a country would complicate the attack picture. For example, in the U.S. alone there are over 5,700 facilities and structures vital to American national security and economic well being. A terrorist attack against a single vulnerable high-value infrastructure target of over 5,000 key nodes would exhibit many of the characteristics and consequences of a natural disaster, including social dislocation, disorientation and panic, widespread anomie and social disorganization, threats to public order, public health crises, and possible epidemics.

A water infrastructure attack would likely be executed in four stages: (1) intelligence collection; (2) distraction and diversion of security forces; (3) attack by U.S. indigenous person(s); and (4) use of bio-agents as weapon of choice to poison large supplies. Terrorists have demonstrated operational interests in various water systems around the world. The best tool to defeat them is likely counterintelligence. Internal counterintelligence (CI) programs are essential to counter a wide spectrum of insider threats ranging from targeted terrorist moles within the target infrastructure to employees, contractors, and sub-contractors who may have direct or indirect affiliations to foreign intelligence services, or terrorist patron states, and individuals with untraceable or unverifiable familial tribal ethnic connections to pro-terrorist groups, organizations, or regimes. As an example, a paradigm CI failure occurred in May 2009: a California Water Service Company (CWSC) employed Abdirahman Ismael Abdi, a non-U.S. citizen who was holding a British passport and working on a fraudulent H1B visa. Employed as an auditor at CWSC in San Jose, California, and using his electronic key card, he gained access to the secure electronic gate at the CWSC parking lot, and then used the computers of two CWSC employees to send over $9 million dollars to three separate accounts in Qatar. Terrorists are the primary counterintelligence threat to many countries. Such attacks on water systems have four operational advantages: (1) technical and human assets in the form of "home grown" jihadists; (2) secure human and technical clandestine communications; (3) clandestine assets in Islamic Diasporas; and (4) the ability of its engineering elite to inflict a single spectacular attack on water infrastructure, which could wreak massive damage to social cohesion and the economy. Terrorist threats exacerbate the already stretched thin lines of water security.

In addition to manmade threats, natural threats pose a significant problem for water security. An example is wildfires, which can cause major disruptions of the water supply for a city due to debris flow and other processes and thus play a major role in water security. The primary post-fire pathways for the transport of various constituents are mudslides and erosion — often termed debris flow. This flow carries nutrients down slope into streams and reservoirs to varying degree. The effects of wildfires should not be underestimated. In recent years a large number of fires have been anthropogenic (intentionally or accidentally lit). It should be noted that terrorists consider fire a strategy to achieve operational and economic objectives against their enemies. For example, although not known to be specifically terrorist associated, approximately half of Australia's 20-30,000 bush fires are deliberately lit; the same is true in the U.S. and other countries.

The effects of large wildfires can be catastrophic, costing millions of dollars in damage, destroying thousands of acres of land and the environment, and lasting effects on the economy, agriculture, the environment and other sectors. Wildfires can significantly affect water security through destruction and disruption of infrastructure, supply and distribution, rail and truck transportation, air traffic, power supply and transmission, and can cause public health and environmental hazards resulting in severe economic damage, loss of life, and loss of animal species. Additionally, timber exports and pharmaceutical supplies can be affected.

To further compound water-security concerns, there are other issues of equal or greater importance including transboundary, emergency preparedness and planning, water economics, and policy. Transboundary water resource issues and disputes are those that cross one or more international borders. The term '*water war*' has often been used to describe disputes regarding water use. The divergence between nations concerning economics, infrastructure, and political orientation has complicated transboundary water sharing. Poor use and management of already limited water resources provides evidence of problems at each level of government: (1) State level — lacking sufficient supplies; (2) National level — competing demands between sectors; and (3) International level — threats between nations sharing transboundary resources. Examples of transboundary water issues include multiple entity competition for water, the stronger antagonist controlling water resources (through military or economic means), use of propaganda to justify control, threat of water terrorism, and economic development disputes.

During transboundary disputes regarding the Danube River in Europe, it was discovered that the public consultation process and working with all stakeholders brought more rapid results. There appears to be several factors that have been the driving force for transboundary cooperation in Europe specifically including: (1) a large gradient in economic development; (2) major political changes in Central and Eastern Europe after 1991; (3) transformation of legislation and administration of former East Bloc countries; (4) water pollution and environmental degradation; and (5) International River, i.e., used for navigation. It remains to be determined whether or not China and its neighbors, Israel and its neighbors, and other regions can utilize the European model as a framework for their respective transboundary issues.

From a historical setting, the mode of cooperation has shifted from bilateral agreements to basin-wide agreements. For transboundary problems it is likely that water and environment relation actions will likely be based on implementation of precautionary principles, utilizing best available techniques and practices, controlling pollution at the source, requiring the polluter to pay, and regional cooperation and information sharing. For conflicting areas such as China and its relation with Pakistan and India, as well as Southeast Asia, and for the Middle East, water-security issues threaten basic national interests. Both the quantity and distribution of water throughout these countries and their neighbors represent significant challenges to social and economic sustainability. Population growth increases demands on water supply, causing problems with the environment, salt-water intrusion, economic development, public health, and other issues. All of these nations are already under some form of water stress that minimally threatens economic sustainability from the individual fisherman to the entire country, threatening disruption of economic and agricultural activity in the most vulnerable areas.

As a highlight, China's very survival, particularly its economic sustainability, is growingly threatened by water-security and water-supply issues. About 23 percent of its population lives in western regions where glacial melt provides the principal dry season water source. This continually diminishing resource is creating an emergent competition among users. Also, the Indus River system, with headwaters in Tibet, has become a significant problem that could potentially erupt into conflict with Pakistan and India. Because China, Pakistan, and India are nuclear armed, a solution to transboundary water issues for this area is critical. The Indus River has been a source of conflict between China, Pakistan, Nepal, Bangladesh, and India for centuries. The use and overuse of water, territorial claiming of water resources, damming and water distribution are resulting in more grievous water conflicts. Specific regions such as the Mekong, Indus, and Ganges also will likely be more severely impacted with time in regard to water stress, and being transboundary in nature will likely strain the capacity of Chinese institutions and policy frameworks. China's national security also will be in jeopardy in event of dire water stress, forcing greater cooperation or potential hostility with its surrounding neighbors and even the U.S. because of strategic concerns over water and food security as well as economic sustainability. Transboundary water issues seriously affect and impact water security and other global issues, especially sustainable economic development, human health, and food production.

Developing new water resources to help resolve transboundary water problems will require technological solutions that increase water supplies such as desalination, waste-water reuse, and so forth, but also, effective management of current resources such as transferring water from wet to dry zones. These types of measures will require significant financial investment.

Within-country water issues are just as important as transboundary issues, especially for emergency services and response, where different levels of government, public authorities, and private sector interests need to collaborate for the national good, i.e., most commonly during severe natural disasters. Generally, a lack of standards continues to undermine the vast majority of a nation's water systems and local government emergency planning and complicate water-security implementation. There is an obvious difference in a national approach to protecting water infrastructure compared to the approach of local and state governments — the low-probability high-consequence Federal approach and the high-probability low-consequence local approach complicates collaboration and response. However, this issue is more appropriately addressed through policy.

Water economics also is one of the greatest challenges to water security. The world is facing a global crisis for resources; energy prices are soaring, creating unexpected consequences for water-supply issues, commodity prices, and food production. When discussing water versus a national economy, it is important to understand three basic areas: (1) the relation between the overall economy and the water sector; (2) the physical, social, and economic nature of water; and (3) the pros and cons of alternative approaches to water policies for public use and policy issues related to an economic organization of water resources, such as water pricing, and their management.

Four primary types of economic benefits of water use include (1) commodity; (2) water assimilation; (3) aquatic and wildlife habitats; and (4) recreational. Also, individuals obtain commodity benefits from water through use for cooking, drinking, and sanitation. Agriculture and industry gain commodity benefits by using water for production for foodstuffs and manufacturing. This type of use represents private goods from water through production activities, but also represents rivals in consumption. An economic organization of the water sector has generally been split into either market or government entities. Along with attempts to organize have come many market and government failures, many of which have related to economic structure and irrigation. Almost every country relies on a mix of market policies and government interventions to manage water resources. In the U.S., while the free market competitive system is often viewed as the most efficient system for allocation of resources, market imperfections and fluctuations on occasion can accentuate income disparities.

The outputs of non-market activities for water are difficult to define and the inputs that produced them are difficult to measure. Regardless, water economics is complex; the resource is extremely interdependent with other sectors and due to scarcity in many areas around the globe, development of supplies and pricing are a primary focus. Because of these critical issues, water is a national-security problem.

Pricing water is also difficult, initially stemming from increasing populations that need more; concentration of these populations in locations that over time are further removed from the resource; increased pollution requiring more costly treatment; and industrialization that has led to the connection of all homes connected to public water and sewer systems. The pricing of water should consider both the level and structure of prices. A pricing structure should consider at least four requirements: (1) a price sufficient to recover costs; (2) a price fair to all users; (3) pricing that provides incentives for conservation; and (4) a price that is efficient and administratively feasible.

A primary principle in water economics is that there is a demand for water of differing qualities. Also, the largest costs in the water sector are borne by the development of storage, transportation, distribution, and treatment systems. Innovative and forward thinking approaches of water management are needed to ensure sustainability of such large systems. Economic principles also must be explicitly integrated into management. Development of a basic framework that could serve as a starting solution would include numerous parameters such as (1) recovering costs; (2) utilizing/developing tools for economic analysis; (3) putting costs and benefits into proportion; (4) implementing pricing policies for droughts and water scarcity; (5) implementing analysis of management and economics; and (4) assessing a 'true' value for water.

The shorter the supply of a natural resource, the more important it is to have an institutional structure for efficient allocation among stakeholders for current and future needs. The general economic system views water as either a common property resource to be freely shared or as a good to be priced and traded in the market. Neither approach ensures sound water management and economics because many functions, services, and values of water are not used or traded in the market. These include the value of aquatic environments (a habitat for biodiversity), recreational values of water, use as a transportation medium, role in waste treatment and manufacturing, role of water in displacing and transporting materials and contaminants, and more.

Because of these many issues, there has been much discussion about water being undervalued around the world. Although many nations are focused on water issues, many also lack the capital investment to develop and implement needed water systems for supply and treatment. Conceptually, water can be priced directly or indirectly. Direct pricing involves setting prices and charges payable from use, reuse, and disposal of water — by users. Indirect pricing relies on applying a wide variety of mechanisms that reveal the cost of using water and associated resources. The latter is more difficult, but compares interdependencies with other sectors and through economic analysis and other tools could suggest a more true value for water within a locale, region, or country.

It should be noted that externality (effects of an economic transaction that extends beyond the actors in the transaction) charges work in both political and social contexts when there is reasonable acceptance of the principle of 'polluters and users pay.' In a social climate that supports economic development regardless of impacts across the water cycle and sector, an externality charge is difficult to implement. Thus, within such a framework, it is important that externalities associated with potable water, reuse, and wastewater be treated consistently. Typically, any framework used would be designed to facilitate a rational investment in potable water, reuse water, and wastewater, which incorporates the full costs of production and effects of the environment into account. For large projects, public investment is likely always a requirement due to total cost and environmental consequences. Failure to adequately address water economics will imperil national security.

Finally, critical questions arise about water and other resource and policy issues regarding water security and use. What are the roles of local, state, Tribal, and Federal governments in water resources development and management? Who should pay, and how much? What agencies should be involved? Should existing projects be revamped or re-operated? What agency should be in oversight control for security from a sustainability perspective? The list is endless, but sound policies can alleviate major future problems.

Within a management context policy is generally presented as a formal, written statement. Policy analysis can aptly be defined as a systematic analysis of policy options. Alternately, policy management is a comprehensive umbrella that concerns a specific effort to improve capacity to manage policy, perform good policy analysis, and facilitate cooperation in policy processes. Generally, policy development can be improved in two ways: (1) upgrading policy-making processes, which can involve improved policy process management and restructuring organizations; and (2) establishing improved broad-scope policies that guide the substance of discrete policies. Regardless of policy type or approach, specific circumstances will likely need specific process requirements. A problem with many international type policy process models is that they provide for the policy analysis phase in great detail, not for guidance regarding events that lead up to the analysis phase.

A variety of underlying issues separate to the policy itself and should be recognized. These include policy reform, political processes, time-frame opportunities, internal processes, process development, forward thinking, involvement of multiple stakeholders and other criteria.

Atop a policy sets a governance cycle, generally a four-step process, but one that can be highly complex in relation to execution. Governance cycles generally follow (1) a review phase; (2) a policy development phase; (3) a reform phase; and (4) an implementation and control phase. When implementing functions of the governance cycle, it is important to emphasize, especially for sectors as complex as water, fit within the country's national development framework and thus, with governing laws consistent with the constitution. It is also important to begin with the macro level. Once the basic phases of policy development are accomplished, a review cycle must regularly monitor and evaluate implementation of policy, which may need to be adjusted through time in terms of legislation, resources management, etc., along with cross-cutting issues such as intra-governmental cooperation and interaction.

Inclusive within policy development is defining and having a clear understanding of what policy is and what it is not, that it is dynamic, requires political endorsement (particularly for a national policy), and that a specific process (and style) is necessary for writing policy. A policy will require an overall description and reference framework. Ideally, it will contain primary or main policy principles that provide an overall framework such as water use, water management, fostering participation, etc. The policy needs to be sufficiently detailed so that it covers a comprehensive range of issues that integrate the whole. It is also important to address global concerns such as water security and global systems for water-scarce regions.

Perceptions of natural resources have changed greatly since the 1990s. Consequently, fundamental economic measures taken by governments to meet their water deficits will differ widely from the water rhetoric and declared water policy. Interdependent within global perspectives is the fact that water is recognized as an economic resource, which contradicts user expectations and various religious claims that water should be a free entitlement. Within this environment, water that was free for agriculture is not based on user-pay scenarios. Two economic principles — allocation and productive efficiency — are particularly relevant to water allocation and management because they comply with the sound principle of increasing returns to water. Unfortunately, the subject of the reallocation of water generally results in intense political reaction from those who perceive they might lose by the change. However, these ultimately need to be reflected in policy.

Other factors that are of great importance in water security globally are the close relations between a national water gap and that nation's food gap. The greatest management challenge in attempting to steer the political economy of water is how to access sufficient water to meet staple food needs — a growing problem.[9] Water is a major factor of production in agriculture, and its relative availability in different climatic zones ensures that some economies have a significant advantage in food-staples production. The contrast in the capacities to produce food surpluses is given stark expression in the world trade figures. In the decades since the middle of the twentieth century, agricultural sectors of industrialized economies located in the temperate climatic regions have progressively increased their productivity in grain production.

All of these global issues, including environmental resources and development for sustainability, as well as legal issues (particularly transboundary water sharing) create growing complexities for water security in a real way that has significant ramifications to both national security and local to national resilience.

[9] Tindall, J.A., and Campbell, A.A., 2010, Water security—National and global issues: U.S. Geological Survey Fact Sheet 2010–3106, 6 p.