Trans-Basin Pipelines as a Solution to Water Resources
A Network for Water Resilience and Economic Vitality

by Maury D. Gaston

Abstract

For several years, much of the country struggled with stubborn drought. Then, floods came to Texas, and California had a generationally-high snowpack. The problems and wide variations between water demand and water supply are well known.

Not as well known outside our industry is that per capita water consumption is down 38 percent since 1980. Conservation is working, but it's time we took a serious and open-minded look at augmenting water resource resilience by construction of an integrated system of trans-basin pipelines.

Fortunately, our nation is blessed with an abundance of water. While we speak of water shortages in times of drought, when considered globally and even to some degree with respect to our continent, we actually have all the water we have ever had, and we also have all the water we will ever have. Our water supply problem is that our water and our people are often separated. Our water supply problem is further magnified when our water and our agriculture are also separated. Fortunately, recent awareness of the water-energy-food nexus has brought this issue more to the public arena.

We have the means to address this by moving our water from where we have it abundantly to where we need it badly. Australia has done this, and some areas of North America have begun to. Other areas can benefit from what has been learned in these places.

Eight of the American Public Works Association's top ten projects of the 20th century involved water. Let's have another innovative public works project, strengthen the resilience of our water resources, put hundreds of thousands of Americans to work in dozens of fields, strengthen our economy, and ensure our future economic vitality with respect to water resource resilience.

This topic and author received an ASCE Innovative Thinking award in 2016.

Our water, engineering, and public service professionals are challenged like never before. This paper presents an opportunity for leadership.

Progress thus Far

Water industry leaders have significantly reduced per capita water consumption from its peak. In 1980, our population was 230 million and our daily water withdrawals were 430 billion gallons, or 1,869 gallons per person per day. This includes water for energy production, agriculture, and household use, the water-energy-food nexus. In 2010, our population had increased to 309 million and our total water withdrawals fell to 355 billion gallons per day. This is a 38 percent reduction in per capita water use and shown graphically in Figure 1. (J. F. Kenny, 2009)

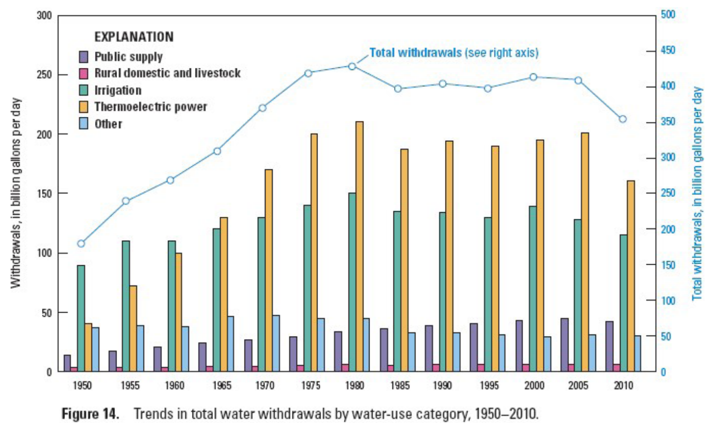


Figure 1. Water use by sector since 1950.

When considering only domestic household use, the USGS reports a reduction between 2010 and 2015 from 88 gallons to 82 gallons per person per day, a significant continuation. (Jerome, 2018) There may be additional per capita savings to be had, but given our current national infrastructure discussion, now is a great opportunity to present the game-changer of augmenting our nation's water supply. This paper presents a plan for that including benefits of flood control, drought relief, economic security, jobs, and much more.

Parallels in other Infrastructure

Figure 2. The United States rail network is a public-private partnership success.

As background, let's briefly review the history and development of our transportation, electrical, and energy infrastructure. Today's interstate highway system has its origin in local trails that became county roads, which became a state road network, which grew into the U.S. highway system. Short line and local railroads grew to the transcontinental railroad, a public-private partnership that spurred unprecedented economic growth. (Admin, 2013). Today's rail network is shown in Figure 2.

Early on, local steam plants produced electricity for cities and small towns and were soon connected to one another and have since grown to various investor-owned, connected power grids utilizing numerous fuel sources. Most of these were built and are operated through the private sector. The power to burn a bulb or heat a home in Minnesota may well have been generated by a hydroelectric facility in Alabama or a solar farm in Nevada. (Southern Company, 2016) All of these utilities are generally investor-owned private entities serving the public with essential services.

Our vast petroleum network is privately owned and operated and makes possible the free trade and movement of valuable energy resources from their source to the refineries through an extensive privately-owned pipeline network, and then to consumers.

Water, on the other hand, has largely remained a local and sometimes regional service usually provided at a service rate far below its value. Given the current imbalances in water supply and demand and the lack of public capital, it's time to rethink both policy and funding and consider an integrated water network financed through public-private partnerships. When the cost of water more closely reflects its value, investment in water supply will be attractive. As an example, a $3.4 billion water supply project in Texas has been privately funded. (Price, 2015) The Trump administration has brought more attention to the potential of private funding for previously public projects. (Walton, 2017)

Water and Economic Development

We all know water is essential for life, but the ***economic*** value of water is often not as well understood by the general public. The residents in Texas and California and the farmers and ranchers in the Great Plains however, have more recently developed a keen understanding of these issues at this defining time.

Even in the midst of record-setting droughts, our nation was blessed with an abundance of water; and that abundance unfortunately soon manifested itself with flooding. Our abundant water supply has been necessary for and contributed to our prosperity and growth. Our coastlines and waterways have contributed to our nation's strength and growth and fostered our expansion from sea to shining sea. Simply put, economic development has always followed water supply. Laurent Auguste, President and CEO of Veolia Water Americas, wrote about the crucial role water plays in economic development and security. (Auguste, n.d.)

While the extremes of drought and flood draw our attention, we actually have all the water we have ever had, and we also have all the water we will ***ever*** have. After all, it's called a hydrological cycle for a reason. That hydrological cycle is shown in Figure 10.

As recently as 2010, following a year of above-average rainfall, the Tennessee River had an excess flow of 45 billion gallons each day. All reservoirs were full, and 29 hydroelectric dams were generating at full capacity, yet excess flow still escaped downstream. (Rome News Tribune, 2010)

The story of mankind is the story of water. The Tigris and Euphrates rivers are the cradle of civilization. The Nile River made the rise of Egypt possible. Roman aqueducts, shown in Figure 3, secured the empire's water supply and together with the Roman roads ensured her power. Moving water from areas of abundance to areas of need is as old as civilization itself.

Figure 3. Roman aqueducts were necessary for the growth and security of the Empire.

In 1982, studies were being done related to collecting flood waters from the Missouri and Mississippi Rivers and using them to slake the thirst of the Colorado River basin. (U. S. Army Corp of Engineers, 1982) More recently, the seven Colorado River Basin states commissioned a study concerning augmentation of their water supply. (United States Bureau of Reclamation, 2016) Figure 4 shows a proposed component from the Missouri River.

After years of drought, the 2015 floods in Texas quickly filled low or empty reservoirs, and then billions more gallons freely flowed into rivers, over many miles of riverbanks into our communities and homes causing unmeasured damage, and was eventually given up to the sea. If volume and elevation gauges had been in place, the rising rivers could have been drawn from and those precious yet dangerous gallons transferred away from the immediate area to a system of reservoirs or into a network through which it could be directed to where it was needed. With such a network, pervasive flood damage can be avoided and water supply needs can be met. We can regulate rail, air traffic, and electrical demand in real time throughout the day and all year long. Why not do the same with water?

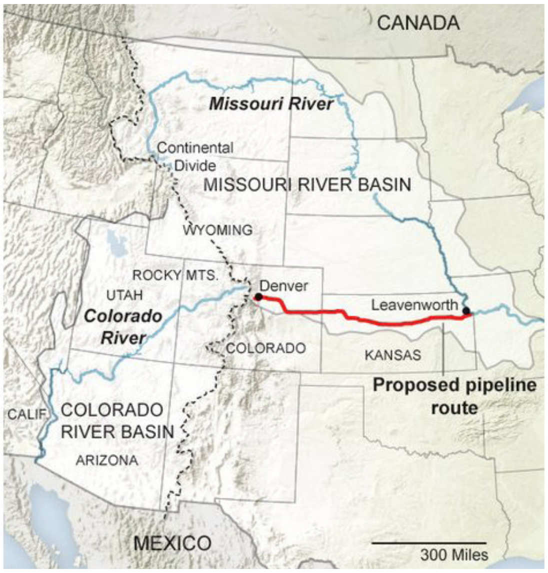


Figure 4. A plan is on the table that would move Missouri River water across Kansas and Colorado.

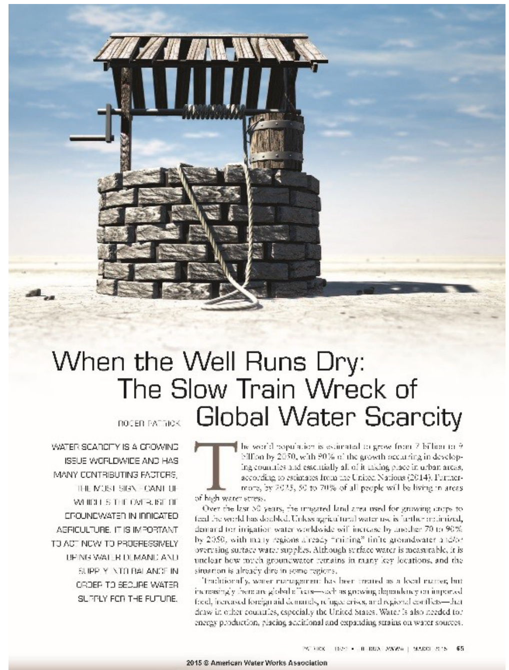
Our problem is that our water supply and our water demand are often separated. This water supply vs. water demand problem is bad enough when only population centers are considered, but it is exacerbated when our agricultural water supply and agricultural water demand are also widely separated. Conservation in all areas of water use has helped; however, given the current circumstances, especially the recent droughts, and given future projections, augmented water supply for parched regions is increasingly seen as necessary.

Water scarcity around the world and here in the United States was chronicled in the March 2015 edition of Journal AWWA by Roger Patrick, shown in Figure 5. (Patrick, 2015)

Given the geographic dichotomy of our water supply and our water demand; given our current, multiple droughts; given the cost of damaging floods; and given our public funding environment today; the discussion of an expanded and integrated water network funded through public-private partnerships is an idea whose time has come.

In December of 2015, the previous White House announced a program to investigate just that. (WhiteHouse.Gov, 2015) One of the plan's three main points called for trans-basin water exchanges. The program also called for innovative financing to fund new water infrastructure. More recently and at the time of this writing in January 2018, an infrastructure bill is eagerly anticipated; and those in the water industry are working for underground buried water pipelines to get more attention than in the past. (G. Tracey Mehan, 2016)

The Water Dichotomy



When the Well Runs Dry: The Slow Train Wreck of Global Water Scarcity

ROGER PATRICK

WATER SCARCITY IS A GROWING ISSUE WORLDWIDE AND HAS MANY CONTRIBUTING FACTORS, THE MOST SIGNIFICANT OF WHICH IS THE OVERUSE OF GROUNDWATER IN IRRIGATED AGRICULTURE. IT IS IMPORTANT TO ACT NOW TO PROGRESSIVELY BRING WATER DEMAND AND SUPPLY INTO BALANCE IN ORDER TO SECURE WATER SUPPLY FOR THE FUTURE.

The world population is estimated to grow from 7 billion to 9 billion by 2050, with 90% of the growth occurring in developing countries and essentially all of it taking place in urban areas, according to estimates from the United Nations (2014). Furthermore, by 2025, 50 to 70% of all people will be living in areas of high water stress.

Over the last 50 years, the irrigated land area used for growing crops to feed the world has doubled. Unless agricultural water use is further optimized, demand for irrigation water worldwide will increase by another 70 to 90% by 2050, with many regions already "mining" finite groundwater and/or overusing surface water supplies. Although surface water is measurable, it is unclear how much groundwater remains in many key locations, and the situation is already dire in some regions.

Traditionally, water management has been treated as a local matter, but increasingly there are global effects—such as growing dependency on imported food, increased foreign aid demands, refugee crises, and regional conflicts—that draw in other countries, especially the United States. Water is also needed for energy production, placing additional and expanding strains on water sources.

65

2015 © American Water Works Association

Figure 5. "When the Well Runs Dry."

A Bold and Innovative Vision

An expanded and integrated water supply system as suggested here provides an innovative vision for building a water augmentation network to move our water from where we have it abundantly — and maybe even suddenly and dangerously — to where we need it badly.

Eight of the American Public Works Association's top 10 projects of the 20th century involve water. (APWA.Net, n.d.) Let's have a 21st century innovative, forward-thinking, bold and visionary public works project, address flood-control on one hand and water shortages on the other, put hundreds of thousands of Americans to work, strengthen our economy, and ensure our future economic vitality with respect to water supply, and do it with public-private partnerships.

Benefits of this Insightful and Innovative Undertaking

Private investment in infrastructure has increased and has sustainable potential. (Kuchel, 2017) The increase was 50 percent in the 12 months prior to September 2014. (Cit.Com, n.d.) Many organizations, including the Brookings Institution, have documented the impact of infrastructure investment on the American economy in general and job creation in particular. Infrastructure jobs are not limited to short-term construction. In fact, there are more jobs in long-term infrastructure finance, design, operation, and governance than in hands-on construction. (Kane, 2015)

In the manufacturing and construction sectors, the building of trans-basin pipelines would be a tremendous boost to iron and steel, aggregates, concrete, transportation, welding, heavy equipment, valves, pumps, and power suppliers, among other industrial and economic sectors.

The United States Geological Survey has a network of more than 7,500 stream gages to monitor stream and river flow and provide flood-prediction data, shown in Figure 6. (USGS.Gov, 2018)

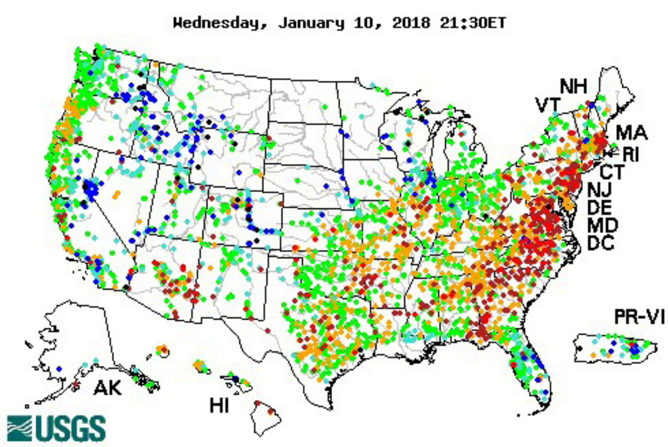


Figure 6. The USGS stream gage network.

This information can be used to activate pumps to move valuable water before it becomes destructive floodwater, transfer it to areas of drought, fill depleted reservoirs, and recharge falling aquifers. This may strike some as far-fetched, but the nation's electrical grid works that way, moving electrons in real time from where they are to where they are needed. (Conca, 2015)

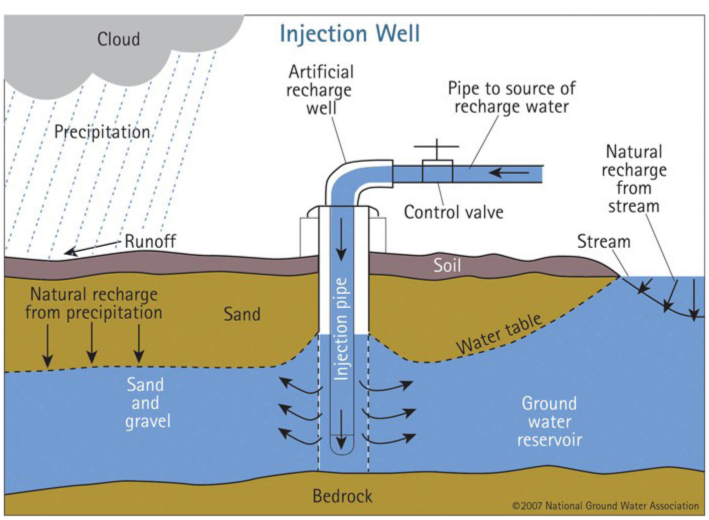


Figure 7. Artificial groundwater recharge with injection wells.

Groundwater replenishment, pumping surface water into the aquifer, illustrated in Figure 7, is more economical than construction of new reservoirs, more economical than desalination, and more acceptable to activists. (Janny Choy, 2014) Projected costs vary widely depending on many variables, but the average of the 25th and 75th percentiles for aquifer recharge is $595 per acre-foot compared to $2,200 for reservoir construction and more than $2,450 for desalination. Groundwater recharge would face significantly less opposition, if any, as compared to additional reservoirs; and while very expensive, desalination's opportunities and benefits are mostly along the coasts.

Challenges and their Solutions

The needs and benefits are obvious, but what are the obstacles to super-regional or even a nationwide water supply network?

Cost is always an issue. Perhaps surprisingly, the cost per mile of a 72-inch diameter pipeline is one-quarter the cost of a mile of interstate highway, graphed in Figure 8. (Cobin, 2000)

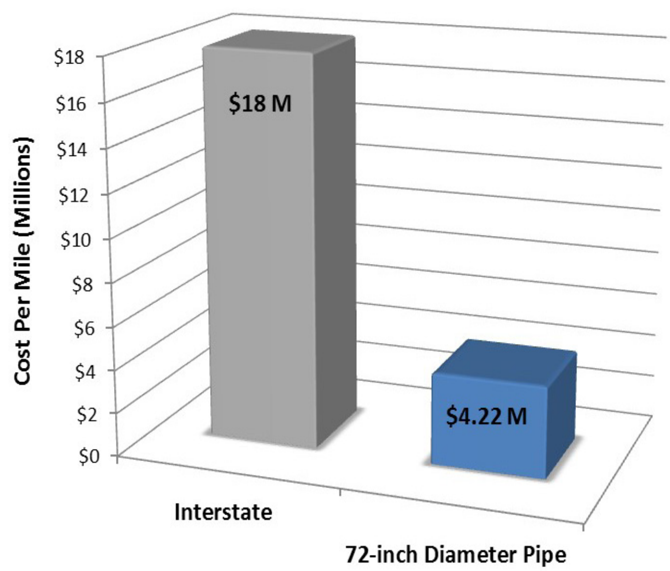


Figure 8. Relative costs of a mile of interstate highway and a mile of 72-inch diameter pipe.

A 72-inch diameter pipeline flowing at 4 feet per second can deliver 50,000 gallons per minute, 73 million gallons per day, 26 billion gallons or 80,000 acre-feet each year. (Icenta.Co.UK, n.d.) Such a pipeline would move significant volumes of water from where we have it abundantly from strong river flows, from good rainfall, and from springtime floods to where we need it badly to sustain the water-energy-food nexus. Maintenance costs of an underground pipeline are less than those of a surface highway, but operational costs such as pump station construction and electricity for pumping will be substantial.

The economic value of the interstate highway system is well accepted. We also build long and expensive pipelines for oil and gas as shown in Figure 9 because we understand the economic benefits of such projects.

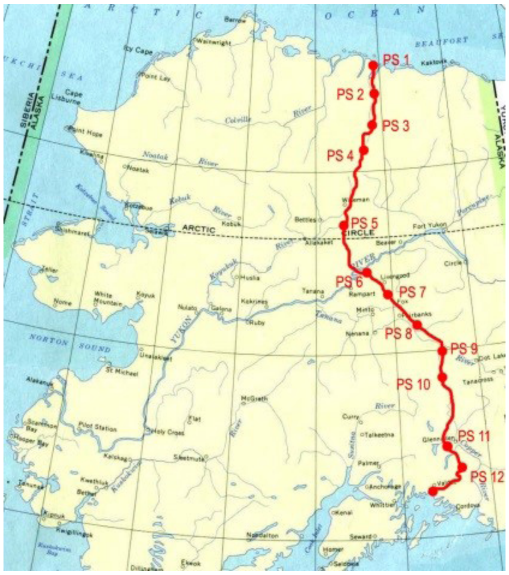


Figure 9. The Alaskan pipeline is 800 miles long, the same distance as Atlanta, Georgia, to Dallas, Texas; and from Seattle, Washington, to the San Joaquin Valley.

The value of an expanded and integrated water network will be no less beneficial because the real value and necessity of water far exceeds its cost. As the cost of water approaches the value of water, such projects become more economically viable to public-private partnerships. The previously noted $3.4-billion project in Texas is an example. It is projected to deliver 50,000 acre-feet per year. Revenue to pay 4 percent interest is only $85 per 10,000 gallons delivered, a typical household volume of both use and cost of water.

Another obstacle to an expanded and integrated water supply is age-old objection to inter-basin transfers. Why not consider contiguous basins as a single super-basin? One may extrapolate this line of thought to our having two basins in North America – one on each side of the continental divide. Interestingly, transfers across that divide are being made now because they must be. A recent Denver Post article cited six different trans-mountain diversions across the Rockies. A Bureau of Reclamation-sponsored project in 2011 resulted in numerous trans-basin suggestions, many across the continental divide, the largest basin boundary. (USBR.Gov, 2012) Inter-basin transfers are currently being constructed in Texas because of the extreme dichotomy between water supply and water demand.

At the end of the day, the hydrological cycle transfers water across river basins, and with reasonable planning and safeguards, we can do the same through an integrated water network with no negative ecological impact.

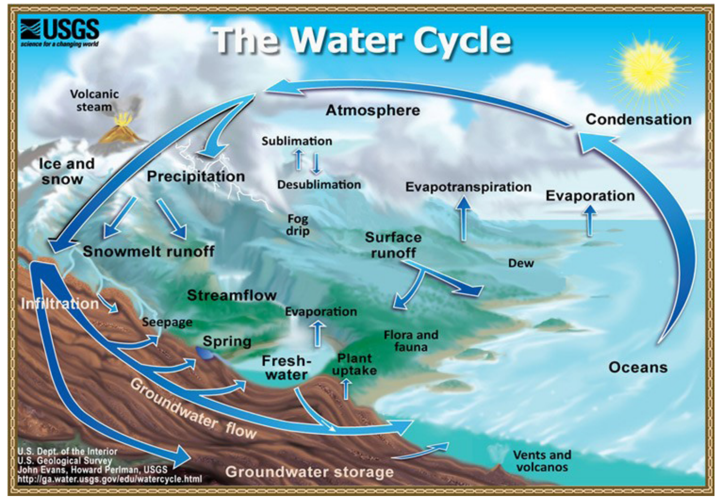


Figure 10. The water cycle moves water all around the earth through the atmosphere, rivers, lakes, and the ground.

Another issue to be dealt with is that of ecological balance, organism transfer, and related topics. A sufficient level of treatment can ensure that unacceptable microbial contamination will not occur between basins. Treatment to potable standards is not necessary, but some level of treatment to prevent unwanted biological transfers is readily available and easily enough accomplished. Providing such a level of treatment to ensure no ecological problems from these transfers would actually improve the quality of surface water and ground water supplies, much like wastewater treatment standards have improved the quality of many previously polluted waterways.

As illustrated in Figure 11, the purpose of the expanded and integrated water network will be to fill reservoirs and replenish diminishing groundwater. It is significant to understand in this discussion that downstream infrastructure to collect, treat, and deliver drinking water to the tap and irrigation supplies to agriculture is already in place. The purpose will be to simply move water from where it is abundantly to where it is needed badly. One of the most well-known reservoirs in need of additional supply is Lake Mead, behind Hoover Dam. Lake Mead is part of the water supply for more than 25 million Americans, one in 14; and even many more when agriculture is considered. (Plumer, 2016) The opportunity for positive impact is great.

Figure 11. The purpose of the integrated water network is to fill drying reservoirs and charge falling aquifers, using in-place infrastructure downstream from there through treatment and to the tap and the agricultural fields.

A major obstacle to a super-regional or national integrated water network is the concept of states' rights and water law. Generally speaking, the more arid areas in the western United States use prior appropriation water law and the more water-rich states in the east use riparian law. (NationalAgLawCenter.Org, n.d.).

Another challenge is the acquisition of rights-of-way necessary for construction. This is a common requirement and easily enough addressed. In fact, existing road and railroad rights-of-way may very well be utilized. For example, the Colorado River Basin augmentation project proposes use of the I-70 right-of-way. More than one electric generating company has suggested using transmission line rights-of-way to move water. (SouthernCompany.Com, 2014).

Broad Problems Require Broad Solutions

Recognizing our drought, our threat of flooding, and our water supply and demand issues as a single national problem and opportunity rather than multiple local and regional disparate problems will help us arrive at various super-regional or even a national solution. For example, struggling agriculture above the Ogallala aquifer is not an isolated Midwestern problem. It's a national problem because stress on our nation's breadbasket will raise prices across the country for all types of food and can even develop into a security issue as it ultimately did for Rome. (Dermody, 2014). A parched farm is shown in Figure 12.

The economic health and vitality of California and Texas, and the entire nation for that matter, depend on water; and that makes water a national problem calling for a national solution. If an electrical power plant goes down, or a fleet of aircraft are stranded in a storm, we move our supply to meet our demand. We can and should do the same with water.

Figure 12. Our nation's food supply is threatened by drought in agricultural areas.

Our electrical grid, illustrated in Figure 13, is privately funded and provides a public service. Our nation's air transportation system is a partnership between publicly funded airports and privately owned airlines. The railroads are an example of how a profitable nationwide infrastructure network can be built and operated. (AAR.Org, 2017). Private funds are increasingly being viewed as part of the highway infrastructure solution. (Kile, 2014).

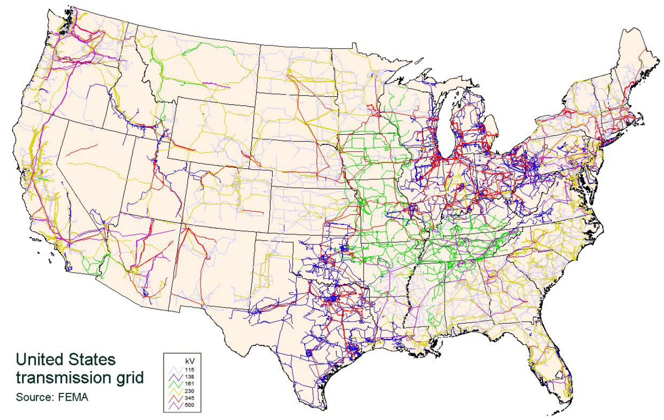


Figure 13. Electricity produced at an investor-owned Alabama hydroelectric dam may burn a light bulb in Minnesota.

Water is no less important than electricity, airports, railroads, and highways, and we have the precedence and means to share our water resources in real time for the economic benefit of everyone.

A public-private partnership approach ensures local control, local authority, and local decision making – all consistent with the culture and tradition of the water industry. Such a partnership is also more politically acceptable in today's environment of deficit spending and revenue shortfall. Public-private partnerships address both funding and governance issues and are gaining popularity and being employed more frequently for more infrastructure needs and solutions.

Call to Action

Let's take a big leadership step forward in the water industry to address our demand and supply imbalance, prevent future flooding, solve our persistent water woes, and do it with innovative public-private partnership financing.

Prior establishment of agriculture in arid regions, migration of people and industries into those areas, multiple and persistent droughts, and devastating floods have placed tremendous local and regional strain on America's water agencies. Meanwhile, many parts of our rich nation have vast and abundant water supplies that are not being used and oftentimes experience seasonal flooding that can be tapped. We can bring these water resources and water needs together with an expanded and integrated water network, provide flood protection, create economic growth and opportunity, and ensure the future supply of dependable water resources.

Certainly, there are obstacles and challenges as noted and addressed above, and there are also tremendous benefits. With courage, innovation, and focus, pipeline engineers, water professionals, and the American people can solve this problem, rebalance our water supply and water demand, lessen the impact of flooding, and grow the American economy. As an engineering professional, make this part of your legacy for the betterment of mankind.

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About the Author

Maury D. Gaston is a 36-year veteran of the water industry and a member of the American Water Works Association and American Society of Civil Engineers. Within AWWA, he is a member of the A21 committee concerning ductile iron pipe products and chairs sub-committee 1 dealing with design and manufacturing standards of ductile iron pipe. In April of 2016, ASCE recognized Gaston with an innovative thinking award for his writings on trans-basin pipelines. He has presented a number of papers on a variety of topics at various conferences.

Mr. Gaston has held numerous sales and marketing responsibilities across the country during his career at AMERICAN, and is currently Manager of Marketing Services for AMERICAN Ductile Iron Pipe and AMERICAN SpiralWeld Pipe.

Mr. Gaston is presently serving as Vice Chairman of the Alabama Iron and Steel Council, a council of Manufacture Alabama. He is also a Director and past Chairman of the state of Alabama Engineering Hall of Fame, and has served as Chairman of the Auburn University Alumni Engineering Council. He was recognized as Auburn's 2014 Mechanical Engineering Alumnus of the Year.

Mr. Gaston may be contacted at mgaston@american-usa.com and 205-325-7803.