Future-Proofing Critical Water Infrastructure from an Economic and Hazard Resilience Perspective

This paper examines different future-proofing options for increasing both the resilience and capabilities of Tijuana's critical infrastructure, using San Diego as a comparative control. It also examines the problems in effectively pricing water as a commodity, and the productivity impact of non-potable piped water on Tijuana's GDP. The system improvements being pursued by San Diego demonstrate the application of the Principles of Future-Proofing as guidance for infrastructure projects yielding a high ROI and offsetting potential economic losses.

BRIAN D. RICH
University of Washington

MEGHAN GATTUSO
University of Washington

INTRODUCTION

Tijuana and San Diego are two cities, separated by a border, but share critical components of their built environment. They share water sources, water infrastructure, and the same climate. They have similar populations and population growth patterns, yet their plans for dealing with water scarcity issues, and their planning for potential natural hazards vary widely. Tijuana's critical water infrastructure has much room for improvement, as well as a strong need for improvement.

This paper examines different future-proofing options for increasing both the resilience and capabilities of Tijuana's critical infrastructure, using San Diego as a comparative control. It also examines the problems in effectively pricing water as a commodity, and the productivity impact of non-potable piped water on Tijuana's GDP. High costs of water serve as an economic rationale and incentive for investing in Tijuana's critical water infrastructure system. Common vulnerabilities of water infrastructure systems are explored. The system improvements being pursued by San Diego demonstrate the application of the Principles of Future-Proofing as guidance for infrastructure projects yielding a high ROI and offsetting potential economic losses. Future-proofing is applicable to infrastructure systems as well as not only to existing and historic buildings.

PROBLEMS IN EFFICIENTLY AND EFFECTIVELY PRICING POTABLE WATER

The pricing of water is a complex question, taking into account infrastructure, social, economic and security factors. The issue of social equity is central to potable water supply: no matter the scarcity, potable water should be priced so as to be affordable for vulnerable, impoverished populations. The World Bank defines household potable water as affordable if it costs less than 5% of household expenditures (Wang, 2008).

Water Quality as a Basis of Cost

However, water for manufacturing and irrigation are not held to the same social equity standards. One of the main difficulties in the Continental Southwest region of North America is that water is considered and treated as a singular variety and quality—potable water. In reality, water, as a commodity, is much more complex and includes potable water, treated and reclaimed water as well as many grades of industrial water and wastewater. Potable water is considered a high value and increasingly scarce. Treated water can often be used for agriculture and energy resources, and reclaimed water can be used for recharging aquifers and rivers, along with commercial uses.

Hummels (2002) examined the importance of the extensive, intensive and quality margins in trade using the highly detailed 1995 United Nations data on traditional exported goods. If one considers water a traditional good, the extensive margin (variety and quality) should be the optimal way to consider water. However, water is not often considered a traditional good, and is not differentiated by quality or variety on the North American commodity market. Because the difference in water quality and variety levels can be substantial, there are different price points due to their supply side costs. The type of water a supplying nation must provide is often not mandated or specified in international water agreements.

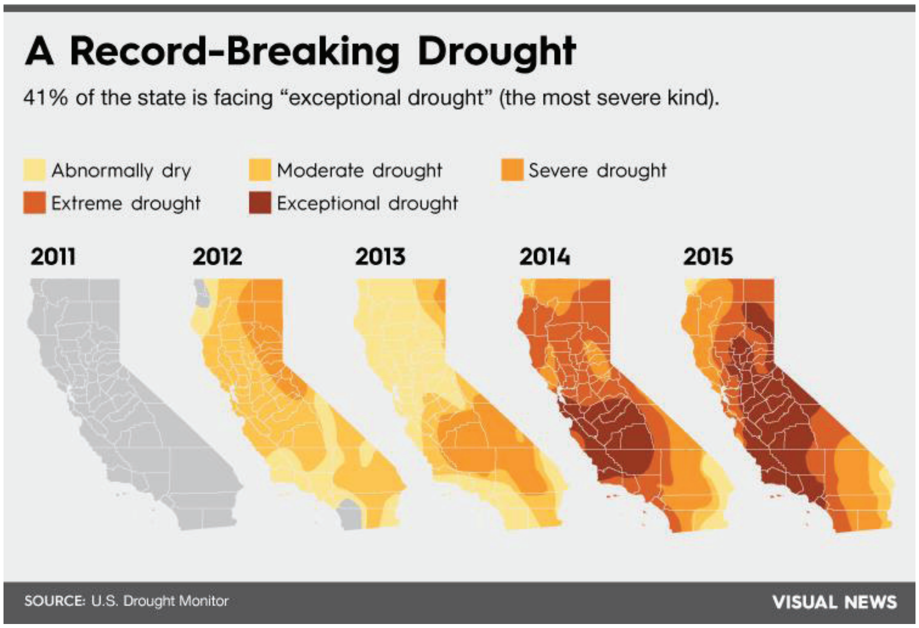
As water scarcity has become a widespread issue, many different methodologies and pricing structures for efficiently valuing water have been tried and discarded. Many countries have been testing using different types of water tariffs. Mexico uses block tariffs in many regions for water to encourage water conservation within the population. By contrast, The World Bank often establishes the value of water by using Willing-To-Pay (WTP), an economic measurement that determines the value of a commodity based on the demand for the commodity.

WTP uses the contingent valuation method (CVM), a method that bases the value and price of a commodity on the consumer demand for the commodity, and is usually accompanied by a regression variation. In essence, WTP is a measure of how much a household is willing to pay for that commodity. The weakness of CVM is in incomplete information on the part of the consumer. In reality, potable water is an inelastic good, meaning that WTP for potable water would be contingent on scarcity issues. CVM is actually questioning the WTP for the convenience of 24-hour potable water infrastructure. In a study by Van Houtven, et al, in 2006, the WTP for centralized piped water connections was examined and found to be connected to several factors: the consumer's access to other water sources, whether they were already connected to the government's critical water infrastructure, and, most importantly, how safe the consumers viewed their current water source.

This is but one direct connection to our built environment where the degree of resilience is important. Architects should strive to provide universally accessible potable water sources that are secure, reliable, and trustworthy. The facilities and infrastructure that architects design can help to ensure these goals are met by demanding infrastructure improvements, supporting minimum code requirements for water quality and quantity and legislation that secure water sources for the long term future, and by designing buildings that can purify contaminated water sources that may contaminate potable water systems.

Economic Considerations for Potable Water in Tijuana

Tijuana's water supply is considered by locals to be unsafe to drink. The local government does not perform spatial analysis of water-borne diseases (Calva 2012). Therefore the disease burden of water is a pervasive problem, though not included in public discourse. CESPT, the water utilities organization of Tijuana, is responsible for water services within Tijuana, and their only inter-governmental liaison is with the United States Department of Environmental Health. Tijuana is one of the largest consumers of private water in Mexico—more specifically, privately bottled water. The privately run water industry is not well regulated for quality on the local level, despite regulations. Often, the water trucks used by private companies unintentionally provide contaminated water, when contaminated, unsterile, and unclean equipment and practices are used (Calva 2012).



1

Figure 1: Map of the expanding drought area in California. *Credit: US Drought Monitor, National Drought Mitigation Center, 2015.*

Economic Rationale for Future-Proofing Water Infrastructure

To develop an economic rationale for the infrastructure improvements, a basic Ordinary Least Squares (OLS) regression could be run, incorporating the age, condition, and location of infrastructure, the incidence of waterborne illness in terms of its effect on productivity. Equating productivity with lost wages, we can use the minimum wage for Mexico, 70 pesos per day, as a quantitative measure of lost productivity (Harrup 2014). Assuming that obtaining clean water and water-borne illnesses cause lost productivity, we can assess the lost productivity, and thus, lost Gross Domestic Product (GDP) of Tijuana based on poorly maintained critical infrastructure.

The case in San Diego is similarly based in economics, but with less emphasis on health and welfare. The primary reason to future-proof the water infrastructure in San Diego is because of the economic loss that might be incurred due to reduced business volume. Water shortages or interruptions due to natural or man-made disasters can impact the region's economy severely. In addition, maintaining a ready supply of water is important to the long term economic health of the region. If there is not enough water available to sustain the population at an affordable price, people and businesses will leave the region for more affordable areas. These threats to water security in San Diego can be managed by future-proofing the infrastructure. This includes development of quantities of water that meet generously predicted growth in the region, strengthening water processing facilities and pipelines to resist natural hazards, and even providing private water treatment on our sites. Architects can further influence the situation by designing buildings for low water consumption, rainwater capture, and wastewater recycling. These methods of managing the threats to water security are based upon the Principles of Future-Proofing, as we shall see later.

Clearly, we can establish the economic value of potable water, though the exact value is not relevant in this context and is researched elsewhere. The Return on Investment (ROI) for future-proof improvements to water infrastructure systems can, therefore, also be established. How, then, can that value be used to improve the resilience of water infrastructure systems? The first step is to understand the vulnerabilities of water infrastructure system. Following that, the Principles of Future-Proofing can be applied to guide capital investments in the system for the greatest effect. The rest of this paper will further explore region-specific vulnerabilities of the infrastructure system and different future-proofing options that can be utilized to increase resilience not only in infrastructure systems, but other aspects of the built environment as well.

FUTURE-PROOFING: A NEW METHODOLOGY TO ADDRESS VULNERABILITIES

To increase resilience to vulnerabilities, there are four aspects related to critical water infrastructure resiliency that need to be addressed. As stated by John Matthews, the key aspects of underground water infrastructure resiliency include:

> (1) redundancy in the water distribution system, (2) storage capacity in the wastewater collection system, (3) structural integrity in the water distribution and wastewater collection systems, and (4) backup power to and structural stability of drinking water and wastewater treatment and pumping facilities (Matthews, 2015).

Vulnerabilities of Regional Water Systems

There are numerous potential vulnerabilities to the critical infrastructure systems for potable water. The San Diego and Tijuana regional water systems are an excellent example of these vulnerabilities as well as potential methods for future-proofing those systems. Potential vulnerabilities include levee failures, material deterioration, and climate change (CDWR, 2009, 2). With changes in the hydrologic conditions due to climate change (see Figure 1, below), there will be increased emphasis on ensuring that the water infrastructure systems continue to function after a natural hazard event where specific components or facilities in the system are compromised (RWMG, 2013). In addition to the aqueducts and pipelines, local or regional infrastructure such as reservoirs, dams, local pipeline systems, pump stations, water treatment, and desalination facilities could be impacted by any of several potential natural hazards.

Imported water via aqueducts and pipelines stands as the most significant vulnerability due to the high volumes required, the length of travel, and the nature of the delivery system. See Figure 2, above. "A seismic event is the single greatest risk to levee integrity in the Delta Region," a region in central California that is the "hub of California's water supply system" (CDWR, 2009, 2). Examining the combination of the vulnerabilities of water infrastructure and seismic events demonstrates the potential impacts in San Diego and Tijuana.

Conventional piping infrastructure is at risk for damage in a seismic event as the materials do not generally react well to the shear stresses brought upon by earthquakes. A 2012 article in the American International Journal of Contemporary Research by Robert Brears outlines the effect of a 6.3 earthquake that occurred 5 km below the surface on water systems in Christchurch, New Zealand (Brears, 2012). The city relied heavily on piped water from aqueducts, using 1500 km (932 miles) of pipe which were heavily damaged in the earthquake. It was estimated that the damage totaled $17 million and consisted of 150 km (10%) of pipe being damaged ($12 million), reservoirs cracked, and wells collapsed.

The City of San Diego has 3,250 miles of pipeline compared to 932 miles in Christchurch (City of San Diego, 2015b). Based upon the damage in Christchurch and the proportional differences in amount of pipeline supplying water to San Diego, the damage due to a seismic event would be more than three times larger.

By contrast, Tijuana has a shorter amount of pipeline than San Diego and approximately the same amount of reservoirs and wells as Christchurch (CDM, 2010). With twice as much pipe and approximately the same amount of reservoirs and wells as Christchurch, the damage could be about twice that in Christchurch (CDM, 2010).

2

Figure 2: A map of the aqueducts in California. *Credit: Shannon1 / Wikimedia Commons /CC-BY-SA-3.0.*

RESPONSE TO VULNERABILITIES AND SEISMIC IMPACTS

New Potable Water Technologies

There are a multitude of different technologies being pursued which will provide different options for new sources of potable water. There are two basic options: natural filtration or human filtration.

Natural filtration of water has been through the latter part of the 20th century by humans to provide safe sources of water. Typically, natural water is filtered through the ground to purify it. Only in the last century has ground water been treated by additional processes to comply with EPA and WHO potable water standards. Such naturally filtered water ends up in streams or rivers and underground aquifer systems and is often accessed through wells. Naturally filtered water sources are no longer sufficient to support our population and the natural ecosystems for a variety of reasons—overuse, pollution, climate changes.

Due to the ready availability of wastewater, however, there are several man-made water filtration systems that have been developed in search of the most efficient ways to create drinking water from contaminated wastewater. These include desalination, physical treatment, chemical treatment, and biological treatment systems.

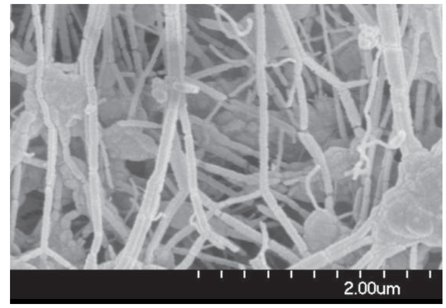
Desalination, the direct conversion of salt water to potable water, is achieved through reverse osmosis technology, eliminating salt and resulting in pure water that requires little additional treatment. Physical treatment includes different types of filtration of the contaminated water. Filtration media include sand or soil, and membrane filtration. Membrane filtration technologies include micro- or ultrafiltration and membrane bioreactor filtration (MBR) which uses combined biological treatment and membrane filtration to meet non-potable water use standards (Li, 2009). Chemical treatment can include "coagulation, photocatalytic oxidation, ion exchange, and granular activated carbon treatments" (Li, 2009). Biological treatment can include rotating biological contactor (RBC), sequencing batch reactor (SBR), anaerobic sludge blanket, and constructed wetland processes (Li, 2009).

These options are often used in combination since one particular treatment does not remove all contaminants. For instance, physical filtration systems are not adequate to remove all organics, nutrients or surfactants and chemical processes don't work well for highly contaminated greywater. In addition, anaerobic processes don't treat organic substances or surfactants, contrasting with aerobic biological processes will treat organics and surfactants, but still require filtration and ultraviolet light treatment (Li, 2009).

In the end, there are many technologies available for treatment of contaminated water, but there are few that are reasonable to pursue from the point of view of economics or energy consumption. Reasonable processes include a combination of aerobic processes, filtration, and disinfection or filtration membrane technologies. For example, the California Groundwater Replenishment System (GWRS) takes wastewater that has already been highly treated and further purifies it using microfiltration, reverse osmosis, and ultraviolet treatments to meet US and California drinking water standards (Bennett, 2011). In the San Diego and Tijuana region, additional potable water sources are being implemented to future-proof their water infrastructure system.

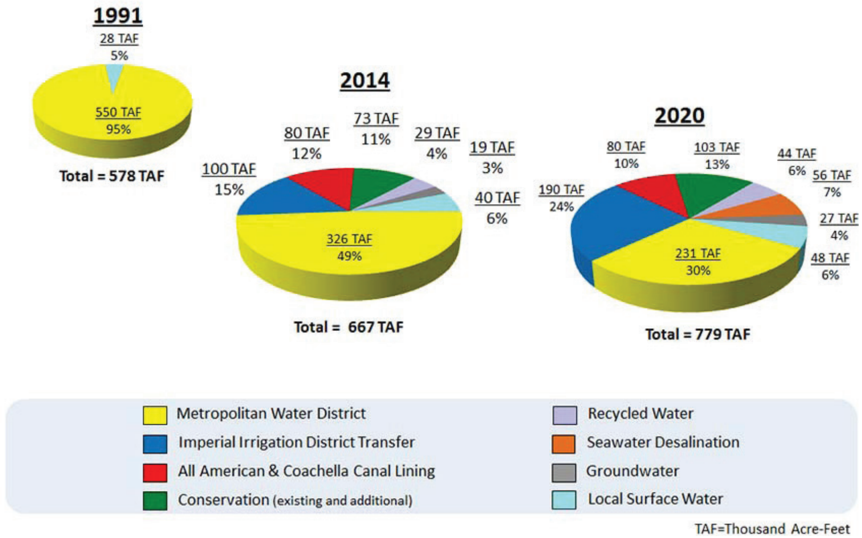
SAN DIEGO AND TIJUANA INFRASTRUCTURE VULNERABILITY RESPONSE

The San Diego Regional Water System has sought to ensure water sources for many decades into the future, assuring the region of secure water supplies and distribution. For emergencies, the Regional Water Management Group (RWMG) has developed an emergency storage program aimed at providing a 75% service level and includes several key elements of the regional water system (RWMG, 2013). The regional water authority is also in the middle of a



3

Figure 3: An electron microscope image of a membrane filter for water. *Credit: Joachim Koschikowski / Wikimedia Commons /CC-BY-SA-3.0.*



4

multi-decade long project to reline the existing pipeline system to increase their service life (Water-technology.net, 2012). In the Delta Region of Central California, the source of much of the water supplying San Diego, "state water representatives… …say they need to build the [water] tunnels to guard the water supply against" the impacts of catastrophic earthquakes (Madrigal, 2014). While these efforts continue, the region also seeks to supplement the water supply through diversification of sources of water which will support continued growth of the regional population. This diversification of water sources is illustrated in Figure 4 (below).

To address the critical shortfalls in the water supply for Tijuana and Playa de Rosarito, the Mexican government and US government have pursued several water infrastructure projects. Priorities for development of new water sources (in order of preference) are seawater desalination, indirect potable reuse (wastewater recycling), and additional water from the Colorado River (CDM, 2010). Alternative sources of water in the region are limited to optimization of the Colorado River supply, indirect potable use of effluent (wastewater recycling), and seawater desalination (CDM 2010). Capital improvement projects totaling more than $1 billion seek to construct a desalination plant, wastewater treatment plants, update the water and wastewater piping system, advanced treatment of wastewater, aquifer recharge, and aggressive industrial pretreatment programs (Calva, 2012). In 2012, 3 wastewater treatment plants generated a total of 55 million gallons per day (mgd) of potable and indirect potable water for the area (Calva, 2012).

The projects and improvements above are all examples of ways in which a water infrastructure system may be developed in a future-proof way while also addressing hazard mitigation concerns and the long term adaptive cycles of panarchy. Diversification of the water sources future-proofs the system by increasing ecological resiliency allowing for multiple states of equilibrium should one source fails. The bi-national support for wastewater treatment plants in the region helps to ensure that water sources are not polluted and easier to convert into potable water sources. Relining pipes is a clear effort to maintain and strengthen the pipeline infrastructure. Installation of additional wastewater treatment plants and other facilities helps to ensure not only an adequate volume of water will be available for current needs but also for future needs. Last, multiple facilities of each type create redundancy in the system so that at least partial service is more likely in the event of a natural disaster.

Figure 4: Diversification of the water sources for the San Diego County area shows increased diversification of metropolitan water district sources. *Credit: San Diego County Water Authority (SDCWA), 2015.*

THE PRINCIPLES OF FUTURE-PROOFING

The interventions in the water systems in San Diego and Tijuana above are examples of future-proofing the infrastructure and water sources to ensure that the region continues to be a viable location to live. The Principles of Future-Proofing established by Rich were originally written with a focus on historic buildings (2014). However, they are also excellent guidelines for increasing resilience in infrastructure systems with the addition of two principles that address the long timeline required to design and implement major infrastructure projects: Plan Ahead and Diversify. With these, the Principles of Future-Proofing are:

1. **Prevent decay.** Promote building materials, methods, maintenance, and inspections that prevent premature deterioration of our built environment rather than accelerate deterioration.
2. **Promote understanding.** Allow for understanding of the built environment and its place in our built heritage through minimal interventions that remain distinguishable from the original structure.
3. **Stimulate flexibility and adaptability.** Flexibility and adaptability of our built environment and our attitudes toward it are essential to retention of our built environment in a disposable society.
4. **Extend service life.** Extend the service life of our built environment through regular maintenance so it may continue to contribute to our economy, culture, and sustainable society.
5. **Fortify!** Fortify our built environment against climate change, extreme weather and natural hazards, and shortages of materials and energy.
6. **Increase durability and redundancy.** Interventions should use building materials of equal or greater durability than existing building fabric or design for disassembly and replacement. Redundant systems provide backup in the event that a primary system fails and allow a building to continue to function.
7. **Reduce obsolescence.** Don't accept planned obsolescence. Take a proactive approach to preventing physical, functional, aesthetic, and sustainable obsolescence.
8. **Consider life cycle benefits.** Consider the long-term life cycle benefits of interventions in our built environment as opposed to demolition and disposal of existing historic building fabric.
9. **Be local and healthy.** Incorporate non-toxic, renewable, local materials, parts, and labor into our built environment to ensure materials and manufacturing capabilities will be readily available in the future for efficient repairs.
10. **Take advantage of cultural heritage policy documents.** Cultural heritage policy documents provide excellent guidance for the long-term retention of an historic building.
11. **Plan Ahead.** Plan for optimum materials, construction phasing, and maintenance to prevent the need of major interventions.
12. **Diversify** Ecologically resilient systems allow for multiple stable states, including different sources, uses, capabilities, and economic models rather than on one dominant trait.

Analysis

It is immediately evident that many of the strategies being employed in San Diego and Tijuana are future-proofing their potable water infrastructure systems, in line with John Matthews' key aspects previously discussed. Architects, Urban Designers, and Planners are regularly involved with the design and implementation of infrastructure systems, including water systems. Even on a site by site basis, we can learn to design in future-proof measures such as seismic loops and flexible over-sized systems to prevent damage in seismic events as well as accommodate future changes in use and population growth.

ENDNOTES

1. Bennett, Anthony. Potable water: New technology enables use of alternative water sources. *Filtration and* Separation, 2011, Vol. 48 (2), pp.24–27. http://www.sciencedirect.com.offcampus.lib.washington.edu/science/article/pii/S0015188211700829#
2. Brears, Robert. 2012. "The Effects of the Earthquake on Urban Freshwater Resources in Christchurch." *American International Journal of Contemporary Research*. 2 (10): 145–149. http://www.aijcrnet.com/journals/Vol_2_No_10_October_2012/16.pdf
3. California Department of Water Resources (CDWR). 2009. "Delta Risk Management Strategy: Executive Summary." http://www.water.ca.gov/floodmgmt/dsmo/sab/drmsp/docs/drms_execsum_ph1_final_low.pdf.
4. Calva, Enrique Lopez. 2012. "Water, Wastewater, and Recycled Water Integration Plan for Tijuana, Mexico." *2012 Guidelines for Water Reuse*. Washington: United States Environmental Protection Agency. http://nepis.epa.gov/Adobe/PDF/P100FS7K.pdf.
5. CDM. 2010. "Section 3: Assessment of Current Conditions." "Section 5: Population, Growth and Land use Projections." Section 6: Water Demand Projections." "Section 9: Development of Water and Wastewater Alternatives." Comisión Estatal de Servicios Públicos de Tijuana. http://www.riversimulator.org/Resources/Mexico/TijuanaWaterSupply.pdf
6. Haas, Andrew, et al, thesis: Collective Ecology: An Integrated Hydrological System for Arid Climates. http://issuu.com/ncabargas/docs/collective_ecology
7. Harrup, Anthony. "Mexico Raises Minimum Wage For 2015 by 4.2%, In Line With Inflation." *Wall Street Journal*. Web. 27 Sep. 2015. <http://www.wsj.com/articles/mexico-raises-minimum-wage-for-2015-by-4-2-in-line-with-inflation-1419049866>
8. Hummels, D., & Klenow, P. (2002). *The Variety and Quality of a Nation's Trade*. NBER Working Paper Series, 8712.
9. Li, Fangyue ; Wichmann, Knut ; Otterpohl, Ralf. Review of the technological approaches for grey water treatment and reuses. *Science of the Total Environment*, 2009, Vol. 407 (11), pp. 3439–3449. http://www.sciencedirect.com.offcampus.lib.washington.edu/science/article/pii/S0048969709001594
10. Madrigal, Alexis C. 2014. "American Aqueduct: The Great California Water Saga." *The Atlantic*. February 24, 2014. http://www.theatlantic.com/features/archive/2014/02/american-aqueduct-the-great-california-water-saga/284009/.
11. Matthews, John C. "Disaster Resilience of Critical Water Infrastructure Systems." *Journal of Structural Engineering* (2015): C6015001. Web.

Diversification of the water sources and processing facilities most closely relates to Principle 12, but also increases redundancy (Principle 6). In San Diego, the long term plan includes several water sources including metropolitan water district sources, irrigation water transfer, canal lining to prevent leakage, conservation or reduced consumption, recycled wastewater, desalination, groundwater sources, and surface water sources.

The City of San Diego projects to reline water mains, branches, and canals demonstrates the implementation of Principle 4 to extend service life, Principle 5 to fortify and increase durability, and Principle 7 to reduce physical and functional obsolescence. Relining the water pipes is an example of Principle 1 preventing further deterioration of the infrastructure system and preventing obsolescence. Relining is also a result of life cycle analysis that includes cost and community impact considerations—Principle 8.

Recycling of wastewater sources, including industrial and greywater is a sustainable practice advocated by Principle 9 and also increases the diversity of water sources and building redundancy into the infrastructure system—Principles 9, 12, and 6 respectively. Developing use agreements with adjacent users such as Tijuana and the agricultural communities in central California demonstrate long term planning and diversification of water sources, exemplifying Principles 11 and 12.

New water tunnels are being built from northern California to the San Diego region, thus fortifying water supply systems against natural hazards, increasing capacity, and demonstrating long term planning, diversification of sources. The implementation of new water tunnels are examples of Principle 5 and 11. The emergency storage program under development for San Diego is an example of developing redundancy (Principle 6) and planning ahead (Principle 11).

The efforts that San Diego Regional Water management group are pursuing in relation to their local and regional water infrastructure exemplify nine of the twelve Principles of Future-Proofing. This suggests that when all of these projects are complete that they will have a far more future-proof water system than ever before. However, the current efforts should not be the end of the process. Ongoing maintenance, diversification efforts, capacity development, and planning for future requirements are necessary to ensure an ongoing future-proof supply of water for the region.

CONCLUSION

Water infrastructure, a component of our built environment, has important economic, social and health benefits. Application of the Principles of Future-Proofing to water infrastructure systems is critical in regions that are vulnerable to water scarcity, flooding, drought and earthquake hazards. The return on investment of future-proofing water infrastructure include productivity increases due to health and welfare benefits, effective water pricing, and a higher WTP price point for potable water. This will allow utility infrastructure managers to effectively create a portfolio of water infrastructure resilience options that fit their budget and needs.

Architects are involved on a regular basis to design secure water treatment facilities, secure water supply sources, and infrastructure systems for all scales of built environment from individual sites to regions of the country. Future-proofing infrastructure systems means durable and redundant systems that are flexible and adaptable to anticipate future needs and prevent obsolescence. Stringent maintenance regimens coupled with diversification of water sources extend the service life of infrastructure systems. These and other techniques founded on future-proof principles will help to develop a sustainable resilient built environment.

12. Rich, Brian. 2014. "The Principles of Future-Proofing: A Broader Understanding of Resiliency in the Historic Built Environment." *Journal of Preservation Education and Research*. Vol. 7. 31–49.

13. San Diego, City of. 2015b. "University Avenue Pipeline Replacement Project." http://www.sandiego.gov/cip/projectinfo/featuredprojects/universitypipeline.shtml

14. San Diego Regional Water Management Group (RWMG). 2013 San Diego Integrated Regional Water Management Plan: An Update of the 2007 IRWM Plan. http://sdirwmp.org/pdf/SDIRWM_Highlights_Sept2013.pdf and http://sdirwmp.org/pdf/SDIRWM_03_Region_Description_Sep2013.pdf

15. Van Houtven, George, Caroline van den Berg, Subhrendu K. Pattanayak and Jui-Chen Yang. 2006. "The Use Of Willingness To Pay Experiments: Estimating Demand For Piped Water Connections In Sri Lanka." *Policy Research Working Papers*. January 2006. http://doi.org/10.1596/1813-9450-3818

16. Water-technology.net. 2012. San Diego County Water Authority relining water mains to increase service life. http://www.water-technology.net/news/newssdcwa-relining-water-mains.

17. Wang, H., Li, Honglin, Xie, Jian, & World Bank. (2008). Domestic water pricing with household surveys : A study of acceptability and willingness to pay in Chongqing, China (Policy research working papers ; 4690). Washington, D.C.: World Bank.