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Water Law and Climate Disasters

Robin Kundis Craig
S.J. Quinney College of Law, University of Utah, robin.craig@law.utah.edu

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ABSTRACT

Climate and water supply have always been intimately connected. As a result, a given society's water law generally reflects climatic realities, including its most common climate disasters. In the future, however, water-related climate disasters are likely to increase in frequency and perhaps even change in kind, because some of the most-predicted consequences of climate change are impacts on water supply, although those impacts will vary from region to region.

This chapter examines the roles of water law in addressing three different forms of water-related climate disasters: drought, flooding, and coastal inundation. Each discussion begins with a closer examination of the relevant water-related climate predictions. From a legal perspective, however, the subject of water law and climate disasters is made more complex by the fact that water law systems themselves vary considerably. As such, two issues regarding the role of water law in climate disasters are likely to emerge as most critical: the extent to which a given water law system provides for flexibility in how water supplies are allocated; and the extent to which a given water law system both can adapt existing water supplies to changing ecological realities and can increase the short-term and long-term resilience of the overall water supply to the impacts of climate disasters.

1.0 Introduction

"Water law," as used in this chapter, refers to the law that governs public and private fresh water supplies and how those resources are allocated among individual users and public priorities, such as ecological protection and public recreation. As such, this chapter treats water law as a different subject from water quality protection. In broad strokes, water law is about the *quantity* of water available for human and ecological use

* James I. Farr Presidential Endowed Professor of Law, University of Utah S.J. Quinney College of Law, Salt Lake City, UT USA. The author may be reached at robin.craig@law.utah.edu.

and about individual and public legal use rights, while water *quality* law is about water pollution and water treatment, including the public health ramifications of both.

Water-related climate disasters can occur, and certainly have occurred, without anthropogenic climate change. However, climate change is making these disasters more probable on a more frequent basis. The IPCC concluded in 2014 that:

> In many regions, changing precipitation or melting snow and ice are altering hydrological systems, affecting water resources in terms of quantity and quality (*medium confidence*). Glaciers continue to shrink almost worldwide due to climate change (*high confidence*), affecting runoff and water resources downstream (*medium confidence*).[1]

It also concluded with very high confidence that "[i]mpacts from recent climate-related extremes, such as heat waves, droughts, floods, [and] cyclones . . ., reveal significant vulnerability and exposure of . . . many human systems to current climate variability . . . ."[2] These vulnerabilities include disruption of water supply.[3] Finally, the IPCC reported with high confidence that "[d]irect and insured losses from weather-related disasters have increased substantially in recent decades, both globally and regionally."[4] Water-related climate disasters, in other words, are becoming increasingly costly but increasingly common risks, demanding an effective legal response.

Indeed, some of the most consistently predicted impacts of climate change directly affect fresh water supply. Climate scientists project that some regions of the world will become hotter and drier as a result of climate change, receiving less precipitation overall, shifting from snowpack to rainfall, experiencing earlier snowmelt, and experiencing more frequent and more severe periods of drought.[5] However, these same scientists also predict that other regions will become wetter overall,[6] which would

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[1] INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, CLIMATE CHANGE 2014: SYNTHESIS REPORT 51 (2014).

[2] 2014 IPCC SYNTHESIS REPORT, *supra* note 5, at 53.

[3] *Id*.

[4] *Id*.

[5] *Id.* at 2, 4 ("Northern Hemisphere spring snow cover has continued to decrease in extent (*high confidence*)."); 11 ("In many mid-latitude and subtropical dry regions, mean precipitation will likely decrease . . . ."); 12 fig. SPM.7(b); 13 ("Climate change is projected to reduce renewable surface water and groundwater resources in most dry subtropical regions (*robust evidence*, *high agreement*), intensifying competition for water among sectors (*limited evidence*, *medium agreement*).") (2014), *available at* https://www.ipcc.ch/pdf/assessment-report/ar5/syr/SYR_AR5_FINAL_full_wcover.pdf.

[6] *Id*. at 4 ("Averaged over the mid-latitude land areas of the Northern Hemisphere, precipitation has increased since 1901 (*medium confidence* before and *high confidence* after 1951). For other latitudes, area-averaged long-term positive or negative trends have *low confidence*."); 11 ("Changes in precipitation will not be uniform. The high latitudes and the equatorial Pacific are likely to experience an increase in annual

seem at first blush to be a boon from a water law perspective. However, the precipitation in wetter regions may often come in the form of more severe storm events, challenging communities' water storage capacities and leading to flooding disasters.[7] Finally, coastal communities face their own constellation of water-related climate disasters, as sea-level rise combines with increasing numbers of increasingly severe coastal storms to contaminate coastal streams, lakes, rivers, and aquifers.[8]

This chapter is organized around the three climate disasters to which water law is most relevant: drought, flooding, and coastal inundation. These climate disasters directly affect either the available sources of fresh water (rivers, lakes, aquifers) that supply human societies or the total quantity of water available for human use, or both.

For each type of climate disaster, this chapter begins by reviewing the current and future importance of each type of water-related climate disaster and exploring climate scientists' projections for them in more detail, relying primarily on the Intergovernmental Panel on Climate Change's most recent (2014) Fifth Assessment Report.[9] It then acknowledges that how water law mediates communities' responses to water-related climate disasters depends in large part on exactly what kind of water law system the community has in place. Water law systems vary tremendously around the world and

mean precipitation under the RCP8.5 scenario[,] . . . [and] in many mid-latitude wet regions, mean precipitation will likely increase under the RCP8.5 scenario."); 12 fig. SPM.7(b).

[7] *Id*. at 8 ("There are likely more land regions where the number of heavy precipitation events has increased than where it has decreased. Recent detection of increasing trends in extreme precipitation and discharge in some catchments implies greater risks of flooding at regional scale (*medium confidence*)."); 11 ("Extreme precipitation events over most of the mid-latitude land masses and over wet tropical regions will very likely become more intense and more frequent.").

[8] *Id*. at 4 ("Over the period 1901 to 2010, global mean sea level rose by 0.19 [0.17 to 0.21] m . . . . The rate of sea level rise since the mid-19th century has been larger than the mean rate during the previous two millennia (*high confidence*)."); 8 ("It is *likely* that extreme sea levels (for example, as experienced in storm surges) have increased since 1970, being mainly a result of rising mean sea level."); 13 ("Global mean sea level rise will continue during the 21st century, very likely at a faster rate than observed from 1971 to 2010. For the period 2081–2100 relative to 1986–2005, the rise will likely be in the ranges of 0.26 to 0.55 m for RCP2.6, and of 0.45 to 0.82 m for RCP8.5 (*medium confidence*) . . . . Sea level rise will not be uniform across regions. By the end of the 21st century, it is very likely that sea level will rise in more than about 95% of the ocean area. About 70% of the coastlines worldwide are projected to experience a sea level change within ±20% of the global mean.")

[9] The IPCC's Fifth Assessment Report consists of four documents: INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, CLIMATE CHANGE 2013: THE PHYSICAL SCIENCE BASIS (2013), *available through* https://www.ipcc.ch/report/ar5/wg1/ [hereinafter 2013 IPCC PHYSICAL SCIENCE REPORT]; INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, CLIMATE CHANGE 2014: IMPACTS, ADAPTATION, AND VULNERABILITY (2014), *available through* https://www.ipcc.ch/report/ar5/wg2/ [hereinafter 2014 IPCC ADAPTATION REPORT]; INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, CLIMATE CHANGE 2014: MITIGATION OF CLIMATE CHANGE (2014), *available through* https://www.ipcc.ch/report/ar5/wg3/ [hereinafter 2014 IPCC MITIGATION REPORT]; and INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, CLIMATE CHANGE 2014: SYNTHESIS REPORT (2014), *available through* https://www.ipcc.ch/report/ar5/syr/ [hereinafter 2014 IPCC SYNTHESIS REPORT].

even within nations; the states within the United States, for example, use at least three distinct legal regimes for surface water[10] and five legal regimes for groundwater.[11] Because a single chapter cannot explore all of these variations in any depth, this chapter instead highlights key features of water law systems in responding to each of the three types of climate disasters. These discussions address: (1) how water law has evolved in many places to respond to the key water-related climate threats of that region; (2) how much flexibility different water law systems allow in allocating and re-allocating available water supply; and (3) how different water systems promote or impede the short-term and long-term adaptability and resilience of available water supplies to climate disasters.

As is generally true in the laws relating to climate change, flexibility in the law usually increases a community's ability to adapt both to climate change impacts and to climate disasters, and some water law systems are inherently more flexible in this respect than others. Of course, a community's ability to adapt to water-related climate disasters is intimately dependent on ecological realities, including whether existing sources can be maintained in the face of a changing climate and whether other sources of fresh water are physically available in the region. In addition, many communities around the world lack the economic capacity to engage in source diversification or even protection. However, water law itself also can promote or inhibit both the resilience of existing sources to climate disasters and the development of alternative water supplies so that communities can adapt to and cope with climate disasters.

2.0 Drought and Water Law

2.1 Drought as a Climate Disaster

Drought is likely to become both an increasingly frequent and an increasingly widespread climate disaster in the remaining decades of the 21st century. "Drought," however, is a context-dependent term. According to the United States' National Weather Service, "Drought is a deficiency in precipitation over an extended period, usually a season or more, resulting in a water shortage causing adverse impacts on vegetation, animals, and/or people. It is a normal, recurrent feature of climate that occurs in virtually all climate zones, from very wet to very dry."[12] Importantly in a water law context, "[h]uman

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[10] The three general categories are common-law riparianism, prior appropriation, and regulated riparianism. ROBIN KUNDIS CRAIG, ROBERT W. ADLER, AND NOAH D. HALL, WATER LAW: CONCEPTS & INSIGHTS chaps. 2, 3, and 5 (2017).

[11] The five systems, as usually categorized, are the common-law rule of capture, the American reasonable use rule, the correlative rights doctrine, the Restatement (2d) of Torts, and prior appropriation. *Id*. chap. 4.

[12] National Weather Service, National Oceanic & Atmospheric Administration, *Drought: Public Fact Sheet* 1 (May 2008), *available at* http://www.nws.noaa.gov/om/brochures/climate/DroughtPublic2.pdf.

factors, such as water demand and water management, can exacerbate the impact that drought has on a region," and, as a result, "drought means different things to different people."[13] Meteorological droughts, for example, are defined by degree of dryness compared to normal and the duration of the dry period.[14] Agricultural droughts, in turn, "focus[] on precipitation shortages, soil water deficits, reduced ground water or reservoir levels needed for irrigation"—*i.e.*, a dry period's actual impacts on agriculture.[15] As a third category, "[h]ydrological drought usually occurs following periods of extended precipitation shortfalls that impact water supply (i.e., stream flow, reservoir and lake levels, ground water), potentially resulting in significant societal impacts."[16]

Droughts can be very expensive climate disasters. In the United States, for example:

> Droughts are among the most costly weather-related events, in terms of economics and loss of life. During the 25-year period from 1980 to 2005, the U.S. sustained nine drought events in which overall damages and costs reached or exceeded $1 billion at the time of the event. Of these, the most costly was the 1988-89 drought in the central and eastern U.S., which resulted in severe losses to agriculture and related industries, with an estimated loss of $15 billion just in agricultural output. According to the National Climatic Data Center (NCDC) the overall cost of the event was $39-40 billion (http:// www.ncdc.noaa.gov/oa/reports/billionz.html). In 1995, the Federal Emergency Management Agency (FEMA) estimated annual losses from drought to be $6-8 billion, which is higher than any other natural weather-related disaster, including hurricane and flood.[17]

More globally, "the World Economic Forum (WEF) says that drought across the globe costs six to eight billion dollars a year from losses in agriculture and related businesses."[18] However, this estimate is almost certainly conservative.[19]

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[13] *Id*.
[14] *Id*.
[15] *Id*.
[16] *Id*.
[17] *Id*. at 1-2.
[18] Mark Koba, "The High Cost of Droughts Around the World," *The Fiscal Times*, http://www.thefiscaltimes.com/Articles/2014/09/05/High-Cost-Droughts-Around-World (Sept. 5, 2014) (republished from CNBC).
[19] For example, in 2015, the May through October drought in China caused US$2.49 billion in economic damage, while the full-year drought in the United States caused US$1.82 billion—and these are just the top two of drought disasters that year. Statistica, *The ten natural disasters with the most economic damage in 2015 (in billion U.S. dollars*, https://www.statista.com/statistics/273895/natural-disasters-with-the-most-damage/ (as viewed Jan 22, 2017).

Increasing global atmospheric temperatures will play a significant role in promoting future droughts. The IPCC concluded in 2014 that

> Each of the last three decades has been successively warmer at the Earth's surface than any preceding decade since 1850. The period from 1983 to 2012 was very likely the warmest 30-year period of the last 800 years in the Northern Hemisphere, where such assessment is possible (*high confidence*) and likely the warmest 30-year period of the last 1400 years (*medium confidence*).[20]

Moreover, "[s]urface temperature is projected to rise over the 21st century under all assessed emission scenarios. It is very likely that heat waves will occur more often and last longer,"[21] and "[i]t is virtually certain that there will be more frequent hot and fewer cold temperature extremes over most land areas on daily and seasonal timescales, as global mean surface temperature increases."[22]

All of these projections suggest that the risk of drought will be increasing, as well, especially in the mid-latitude and subtropical dry regions where precipitation is likely to decrease.[23] However, it is currently very difficult to attribute drought events to anthropogenic climate change or to assess global drought trends because of a pervasive lack of long-term data, inconsistent definitions of "drought," and "geographical inconsistencies in drought trends."[24]

2.2 Drought, Water Supply, and Water Law

Drought has a fairly obvious connection to water supplies and hence to water law: Less precipitation means less water for human (and other) uses, and hence a need for law to prioritize uses and to allocate available water among those uses. Indeed, governments and communities often shape their water laws both in response to and in anticipation of drought. In the aftermath of its prolonged droughts, for example, California enacted a new groundwater law in 2015[25] to curb excessive groundwater pumping and then

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[20] 2014 IPCC SYNTHESIS REPORT, *supra* note 1, at 40.
[21] *Id*. at 58.
[22] *Id*. at 60.
[23] *Id*.
[24] *Id*. at 53.
[25] California Department of Water Resources, *Groundwater Information Center: Key Legislation*, http://www.water.ca.gov/groundwater/groundwater_management/legislation.cfm (last modified Dec. 29, 2015, and viewed Jan. 22, 2017).

legislation in 2016 that would impose financial penalties and public shaming on users who do not conserve water during drought.[26]

2.2.1 Allocation of water during times of shortage

In arid places where drought is a perpetual threat, the relevant water law often reflects that reality. Thus, a first important question regarding water law's relationship to drought is how the relevant water law system will allocate available water during dry periods.

Australia's and the U.S. western states' modifications of English common law provide good examples of how governments adapt water law to actual hydrological conditions. England traditionally has had sufficient rainfall and surface waters to accommodate most human needs, and English common law accorded legal rights to use surface water to landowners whose properties border a waterway, a system known as riparian rights or riparianism.[27] In most modern versions of riparianism, riparian landowners share rights to make reasonable use of the water resource, subject to the co-equal rights of all other riparian on the same waterbody to do the same.[28]

In parts of the British Empire where climatic and water-supply conditions are similar to those in England—New Zealand and Canada, for example—English riparianism could continue as the basis of water law.[29] In Australia and the arid western half of the United States, however, common-law riparianism simply could not function—there was too little water in too few waterways.[30]

The western states of the United States instead adopted prior appropriation, a system of water law based on "first in time, first in right"—i.e., the first person to take water from a particular source and apply it to a beneficial use has the strongest water right.[31] The system thus creates a time-based hierarchy of water rights, and in times of

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[26] Paul Rogers, "California drought: Water guzzlers to face new penalties, possible public disclosure of names," *The Mercury News*, http://www.mercurynews.com/2016/08/30/california-drought-water-guzzlers-to-face-new-penalties-possible-public-disclosure-of-names/ (Aug 30, 2016). *See also* Justice Greg Hobbs, Jr., *How Drought Shapes Colorado Water Law and Policy*, https://www.yourwatercolorado.org/headwaters-archive-template/279-how-drought-shapes-colorado-water-law-and-policy (as viewed Jan. 22, 2017).

[27] DANTE A. CAPONERA, PRINCIPLES OF WATER LAW AND ADMINISTRATION: NATIONAL AND INTERNATIONAL 73 (2d edition revised & updated by Marcella Nanni; Taylor & Francis 2007).

[28] ROBERT W. ADLER, ROBIN KUNDIS CRAIG, & NOAH D. HALL, MODERN WATER LAW: PRIVATE PROPERTY, PUBLIC RIGHTS, AND ENVIRONMENTAL PROTECTIONS 46-61 (Foundation Press 2013).

[29] CAPONERA, *supra* note 29, at 74.

[30] *Id*.

[31] ADLER, CRAIG, & HALL, *supra* note 30, at 87-89, 92, 106-07, 139-40.

drought, the more junior (later in time) rights yield entirely to the more senior rights.[32] For example, in 2015, after years of drought, the California Water Resources Control Board, which issues and manages prior appropriation rights in California, curtailed all water rights to the Merced River that had priority dates later than 1858.[33]

Nevertheless, prior appropriation's historic priority system can interfere with what many would consider "optimal" drought management. For example, during droughts in 2009 and 2012, the Texas Commission on Environmental Quality, the agency that manages surface water rights in Texas, opted to deny Dow Chemicals' and farmers' more senior rights to water from the Brazos River in favor of supplying water to cities and power plants, citing the necessity of protecting public health and safety.[34] However, in 2015 the Texas Court of Appeals ruled the decision illegal,[35] significantly limiting the Commission's flexibility to re-apportion water during droughts. This lack of flexibility in the prior appropriation system is exacerbated by the slow development of water markets that so far have high transaction costs[36] and a "use it or lose it" principle under which rights holders lose rights if they don't use the full amount of water appropriated,[37] disincentivizing water conservation.

Australia is the driest inhabited continent and has significant annual variation in precipitation,[38] also requiring a rejection of common-law riparianism. Nevertheless, states there took a different approach to water law than in the western United States, adapting English common-law riparianism rather than replacing it. Beginning early in the 20th century, each Australian state and territory adopted legislation that vested the primary ownership and control of water in the Crown, allowing private riparian rights to be displaced.[39] New South Wales, South Australia, Tasmania, and Victoria have abolished

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[32] *Id*. at 139-40.

[33] California Water Resources Control Board, Notice of Unavailability of Water and Need for Immediate Curtailment for Those Diverting Water in the Merced River Watershed with a Pre-1914 Appropriative Claim Commencing During or After 1858, at 1 (June 26, 2015), *available at* http://www.swrcb.ca.gov/waterrights/water_issues/programs/drought/docs/merced_2015curtltr.pdf.

[34] Jim Malewitz, "Water Ruling Cuts Texas' Power in Droughts," *The Texas Tribune*, http://www.governing.com/topics/transportation-infrastructure/tt-water-ruling-texas-drought.html (April 3, 2015).

[35] Texas Commission on Environmental Quality v. Texas Farm Bureau, 460 S.W.3d 264, 272-73 (Tex. Ct. App.—Corpus Christi 2015), *rev. denied* (Tex. Ct. App.—Corpus Christi 2016).

[36] *See generally* Zachary Donohue, *Property rights and western United States water markets*, 53 AUSTRALIAN J. AGRICULTURAL & RESOURCE ECONOMICS 85-103 (2009), *available at* http://www.perc.org/sites/default/files/Aust_Donohew.pdf (analyzing why water markets have been slow to develop in the United States).

[37] ADLER, CRAIG, & HALL, *supra* note 30, at 148-49.

[38] ALEX GARDNER, RICHARD BARTLETT, & JANICE GRAY, WATER RESOURCES LAW 4 (LexisNexis 2009).

[39] KATE STOEKEL, ROMANY WEBB, LUKE WOODWARD, & AMY HANKINSON, AUSTRALIAN WATER LAW 18 (Lawbook Co. 2012).

common-law water access rights entirely[40] and instead allocate water entitlements entirely through licenses. Moreover, while water rights in Australia originally remained tied to individual riparian properties, under the National Water Initiative water rights are being severed from the land to improve their marketability.[41]

Because water law in Australian states retains ties to riparianism, it remains grounded in principles of sharing water resources rather than prioritizing use.[42] As a result, Australian water users tend to "share the shortage" during drought, each reducing its water use to accommodate the available supply, and licensed water suppliers often have use reduction targets built into their licenses. For example, during Australia's "Millennium Drought" of 1997-2012,[43] Sydney Water was in some ways already prepared:

> Sydney Water's regulated operating license required it to achieve aggressive water efficiency targets, and these targets subsequently became a significant component of the Metropolitan Water Plan in 2004, 2006 and 2010. This is an example that shows how regulatory arrangements can strongly encourage investment in demand-side measures. As part of this arrangement Sydney Water publicly reported annually on its performance against the targets for water efficiency, reuse and leakage.[44]

Thus, government control over water resources, a legal regime of sharing shortages, and increasing marketability of water licenses has given Australian governments and communities significantly more legal flexibility to deal with droughts than in the western United States. Moreover, the "share the shortage" approach incentivizes water users to conserve water.

Many other arid nations in the world, particularly those in the Middle East and North Africa, follow versions of Islamic water law.[45] "The fundamentals of Islamic water law purport to ensure that water is available to all members of the Moslem community,"

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[40] *Id*. at 19.
[41] *Id.* at 20.
[42] GARDNER, BARTLETT, & GRAY, *supra* note 40, at 57.
[43] Alliance for Water Efficiency, Institute for Sustainable Futures, & Pacific Institute, *Managing Drought: Learning from Australia* 3 (Feb. 2016), *available at* http://www.allianceforwaterefficiency.org/uploadedFiles/Resource_Center/Library/drought/Managing-Drought-Report_2016-02-23-FINAL-US-Letter.pdf [hereinafter *Learning from Australia*].
[44] *Id*. at 9.
[45] These nations include Afghanistan, Iran, Pakistan, Saudi Arabia, Kuwait, Qatar, and the United Arab Emirates. CAPONERA, *supra* note 29, at 62. Less arid nations whose water law is also built upon Islamic water law principles include Bangladesh, Indonesia, and Malaysia. *Id*.

resulting in water law systems that view water as belonging to the entire community.[46] Islamic water law recognizes two basic water rights: The right of thirst (chafa), which is the right to take water to drink and to water animals; and the right of irrigation (chirb).[47] In addition, selling water from natural water sources is prohibited under Islamic tradition.[48]

The Ottoman Civil Code Mejelle codified these basic tenets of Islamic water law in the 1870s, spreading them throughout the Ottoman Empire.[49] Thus, under this Code, "all members of the community had the right of access, in instances of private necessity, to use water on private property for personal and domestic use"; "[d]uring times of public necessity, all sources of water, including privately-owned water sources, were taken for public use"; and private individuals were prohibited from selling water.[50] However, the Ottoman Empire refigured community ownership as sovereign ownership of water, and hence "[a]ll water resources, even water on private property and from man-made wells, was subject to government regulation and control."[51] As such, the state awarded water rights, and a concept of reasonable use developed.[52]

While the different Islamic schools (Shi'ite, Sunni, and Ibadite) have refined Islamic water law in different ways,[53] certain core concepts are still generalizable. For example, in times of shortage, Islamic water law prioritizes use by categories: "Top priority was given to water for drinking purposes, then for domestic purposes, including watering one's animals, and then for other uses. Upper riparians and upstream users had priority over lower riparians and downstream users."[54] This hierarchy remained essentially the same under the Mejelle Code.[55] Thus, countries still basing their water law in Islamic water law principles share shortages during drought, as in Australia, but based on categorical use priorities. While the system lacks some flexibility, it does help to ensure that no humans die of thirst.

2.2.2. Promotion of technology to meliorate the impacts of drought and to diversify sources of supply

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[46] *Id*.
[47] *Id*.
[48] *Id*.
[49] *Id*.
[50] Melanne Andromecca Civic, *A Comparative Analysis of the Israeli and Arab Water Law Traditions and Insights for Modern Water Sharing Agreements*, 26 DENV. J. INT'L L. & POL'Y 437, 444 (Spring 1998).
[51] *Id*. at 443.
[52] *Id*. at 444.
[53] CAPONERA, *supra* note 29, at 62-63.
[54] Civic, *supra* note 53, at 442.
[55] *Id*. at 444.

In all arid countries, technology can ameliorate the impacts of drought by allowing for storage of water during wet periods or by making new sources of water available. Thus, a second important aspect of water law with respect to drought disasters is the extent to which law and policy allow for and finance major water infrastructure that make communities more resilient to drought.

Dams and irrigation projects often serve to average out water supplies over multiple years, allowing communities to store water in wet years and to distribute the stored supplies during shortages and drought. In the United States, for example, Congress enacted the federal Reclamation Act of 1902 specifically to finance dams and reservoirs in the arid western half of the country to allow for reliable irrigation and settlement.[56] The laws of wealthier nations and communities may also allow investment in water transportation, resulting in long-distance pipelines and new sources of water supply.[57] As one example of many, the island of Cyprus is experiencing increasing water shortages as a result of over-pumping of groundwater, which is causing saltwater intrusion, increasing population growth and climate change.[58] Northern Cyprus seeks to solve its water problems through a water pipeline from Turkey that travels through the Mediterranean Sea and carries 19.8 billion gallons a year, at a financial cost of 1 billion Turkish lire (about US$550 million).[59]

Desalination is another expensive (financially and in terms of energy intensity) source of water supply that can nevertheless increase communities' resilience to drought disasters. For example, the energy-rich but water-poor nations of the Middle East have invested significantly in desalination and have installed over half the world's current desalination capacity.[60] Similarly, during the Millennium Drought, many Australian cities invested in desalination plants.[61] However, desalination can be a costly choice if implemented under political pressure, as reportedly was the case in Victoria and New South Wales in Australia,[62] and returning rains left many of the new Australian

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[56] 43 U.S.C. §§ 371-616yyyy.

[57] For a detailed description of these projects in the American West, see generally MARC REISNER, CADILLAC DESERT: THE AMERICAN WEST AND ITS DISAPPEARING WATER (1986).

[58] Erica Gies, "Northern Cyprus Sees Hope in Water Pipeline," *The New York Times*, http://www.nytimes.com/2013/04/04/world/europe/northern-cyprus-sees-hope-in-water-pipeline.html? (April 3, 2013).

[59] *Id*.

[60] Poseidon, Inc., *Desalination Worldwide*, fig. 1, http://hbfreshwater.com/desalination-101/desalination-worldwide (as viewed Jan. 27, 2017).

[61] Norimitsu Onishi, "Arid Australia Sips Seawater, but at a Cost," *The New York Times*, http://www.nytimes.com/2010/07/11/world/asia/11water.html (July 10, 2010).

[62] *Learning from Australia*, *supra* note 45, at 6 (noting that politics during a severe drought "can result in over-investment in large-scale infrastructure that is expensive, energy-intensive, subject to unfavorable contractual terms, and in many cases not actually used, resulting in costly stranded assets that will need to be paid for by the community for decades, well ahead of when they may be needed.").

desalination plants idle.[63] Nevertheless, in 2016 dry conditions returned, leaving cities like Melbourne with the decision of whether to restart these expensive water supply alternatives[64]—and renewing the debate over the long-term wisdom of these investments in water supply flexibility.

3.0 Floods and Water Law

3.1 Flood as a Climate Disaster

Floods, of course, are the opposite of a drought: too much water in too short a period of time. Like "drought," however, "flood" has a variety of definitions. Geoscience Australia, for example, notes that definitions of "flood" can be as general as "water where it is not wanted" or as precise as "[a] general and temporary condition of partial or complete inundation of normally dry land areas from overflow of inland or tidal waters from the unusual and rapid accumulation or runoff of surface waters from any source."[65]

Notably, while droughts are costly, of the ten most expensive natural disasters in 2015, three involved floods while only two involved droughts.[66] "Costs related to flood damage, worldwide, have been increasing since the 1970s, although this is partly due to the increasing exposure of people and assets."[67] Several floods in the United States in 2016 caused damage of more than US$1 billion, including March flooding in Texas and Louisiana (US$2.3 billion in five days), April flooding in Houston, Texas (US$2.7 billion in two days), June flooding in West Virginia (US$1 billion in three days), and August flooding in Louisiana (US$10 billion in four days).[68]

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[63] James Paton, "A Nice Glass of Seawater? Drought Forces Australia to Rethink Desalination," *Bloomberg News*, https://www.bloomberg.com/news/articles/2016-02-23/seawater-may-quench-australian-city-s-thirst-as-dams-decline (Feb. 23, 2016).
[64] *Id*.
[65] Geoscience Australia, *What is a Flood?*, http://www.ga.gov.au/scientific-topics/hazards/flood/basics/what (as viewed Jan. 22, 2017).
[66] Statistica, *The ten natural disasters with the most economic damage in 2015 (in billion U.S. dollars*, https://www.statista.com/statistics/273895/natural-disasters-with-the-most-damage/ (as viewed Jan 22, 2017). The three floods were a May flash flood in the United States (US$2.73 billion), a November flood in India (US$2.22 billion), and a June riverine flood in China (U.S$2.02 billion).
[67] 2014 IPCC Synthesis Report, *supra* note 1, at 53.
[68] National Centers for Environmental Information, *Billion-Dollar Weather and Climate Disasters: Table of Events*, https://www.ncdc.noaa.gov/billions/events (as viewed Jan. 27, 2017).

More importantly, flood disasters generally kill far more people than drought (and most other kinds of natural disasters except earthquakes).[69] Floods are also far more common, worldwide, than droughts,[70] and climate change will likely exacerbate that trend. As the IPCC concluded in 2014, "There are *likely* more land regions where the number of heavy precipitation events has increased than where it has decreased."[71] Moreover, over the course of the rest of the 21st century, it is very likely that "extreme precipitation events will become more intense and frequent in many regions,"[72] particularly in areas where precipitation is projected to increase overall—high latitudes, the equatorial Pacific, and mid-latitude and subtropical wet regions.[73] Globally, under all scenarios, it is likely that monsoons will affect more areas, that monsoon precipitation will intensify, and that the effect of the El Niño-Southern Oscillation (ENSO) on regional precipitation variability will intensify,[74] all of which would increase flooding risks around the globe. However, even more than with drought, it is difficult to attribute flood events to climate change, given both the lack of long-term records in many watersheds (catchments) and the ability of humans to significantly contribute to flooding.[75]

3.2 Floods, Water Supply, and Water Law

In many parts of the world—especially those parts subject to seasonal monsoons—floods are an annual threat. The most common impact of flooding on water supply is contamination, with consequent threats to public health. The World Health Organization, for example, detailed the water supply impacts of flooding in Ghana in 2000 as follows:

> In northern Ghana, clean drinking water became scarce three months after severe floods. Water sources had been polluted by tons of untreated human and industrial waste. More than 200 dams, wells and boreholes in the upper West Region were reported to be polluted with sewage and used engine oil. In addition, the floodwater had submerged refuse dumps due to rising river levels. The costs of the flooding raised dramatically due to

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[69] International Federation of Red Cross and Red Crescent Societies, *World Disasters Report 2014—Data*, tbl. 5, http://www.ifrc.org/en/publications-and-reports/world-disasters-report/world-disasters-report-2014/world-disasters-report-2014---data/ (2014).
[70] *Id*. tbl. 5.
[71] 2014 IPCC SYNTHESIS REPORT, *supra* note 1, at 53.
[72] *Id*. at 58.
[73] *Id*. at 60.
[74] *Id*.
[75] *Id*.

> the need to resettle people in other areas and to rehabilitate the polluted dams in the three northern regions.[76]

Such water contamination during flood events becomes the province of emergency response, water pollution, and drinking water laws.

Water law, in contrast, is often most relevant to attempts to control and mitigate flood events in the first place, especially by allowing the construction of water infrastructure (dams, reservoirs, and levees) that can capture and hold back flood waters until emergency conditions subside. However, water law operates differently at different scales of flood response. At the level of the individual, for example, water law often governs what a landowner can and cannot do to respond to flood waters. Common-law countries have had to wrestle with the legacy of the "common enemy doctrine," a traditional rule that viewed floodwaters as the "common enemy" of all humans and hence imposed no liability on landowners who directed the flow toward their neighbors.[77] The civil law tradition took the opposite approach, dictating

> that a property owner may not so interfere with the natural flow of surface waters as to cause an invasion of a neighboring owner's interest in the use and enjoyment of his land. The rule recognizes a servitude for natural drainage of surface water. An owner of lower property must accept the burden of surface water which naturally drains upon his land. Conversely, the owner of higher property cannot increase this burden by changing the natural system of drainage.[78]

Neither legal approach, it should be noted, operates to prevent flood disasters; moreover, neither legal rule represents an adequate response to flood disasters at the community or society level.

As a result, in most nations serious flood control emanates from a higher scale of water law, often the national scale. At this larger scale, however, nations vary widely in how they use their water law for flood control. In India, for example, flood control is generally not a specific subject of the law, and legal authorities over flood control are

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[76] World Health Organization, *Too much water: The health effects of floods*, http://www.who.int/water_sanitation_health/emergencies/floodrought/en/index1.html (as viewed Jan. 22, 2017).

[77] *E.g.*, Currens v. Sleek, 983 P.2d 626, 628-29 (Wash. 1999) (*en banc*) ("In its strictest form, the common enemy doctrine allows landowners to dispose of unwanted surface water in any way they see fit, without liability for resulting damage to one's neighbor. The idea is that "surface water ... is regarded as an outlaw and a common enemy against which anyone may defend himself, even though by so doing injury may result to others." (quoting Cass v. Dicks, 44 P. 113, 114 (Wash. 1896)).

[78] Smith v. King Creek Grazing Ass'n, 671 P.2d 1107, 1109 (Idaho 1983).

diffuse.[79] In the United States, in contrast, Congress has enacted a series of Flood Control Acts beginning in 1917, which generally empower the U.S. Army Corps of Engineers to engage in flood prevention activities in various watersheds.[80] In addition, Congress has also authorized numerous flood control projects through successive Water Resources Development Acts.[81]

Once Congress requires (and usually finances) a flood control project, it also usually delegates management to a federal agency. Agency flood management can become quite complex, especially in larger hydrological systems. For example, the Missouri River mainstem system spans 1,770 miles and includes six dams and reservoirs that the U.S. Army Corps of Engineers manages, pursuant to federal statutes, for eight potentially conflicting uses: "flood control, irrigation, navigation, hydroelectric power generation, water supply, water quality, recreation, and fish and wildlife enhancement."[82] Traditionally, the Army Corps' Master Manual for managing these dams has emphasized flood control, but a severe regional drought in 1988-1990—the first major drought that the Missouri River dam system had ever experienced—launched the Army Corps into a 14-year revision of that Master Manual, culminating in 2004.[83] In 2011, the Missouri River flooded severely, leading to public outcry against the Army Corps and its new Management Manual,[84] but the next year, severe drought returned to the region, taxing the Army Corps' management capabilities in the opposite direction.[85] Climate change is likely to make these whipsawing extremes of flood and drought more common,[86] challenging the law's and management's capacities to effectively manage rapidly fluctuating types of climate disasters.

The United States, of course, is a wealthy nation. In contrast, developing nations do not always have sufficient native adaptive capacity, legal support, and/or financial wherewithal to engage in significant flood control efforts. In such nations, international law and financing often become important. Bangladesh, for example, is subject to annual monsoons that bring heavy precipitation and flooding. "For months at a time, monsoon season brings heavy rainfall to the country. In fact, approximately 80% of Bangladesh's

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[79] Water Resources Information System of India, *Flood Management*, http://www.india-wris.nrsc.gov.in/wrpinfo/index.php?title=Flood_Management (as viewed Jan. 22, 2017).
[80] *E.g.*, Flood Control Act of 1917, Act of March 1, 1917, § 2, 39 Stat. 948 (authorizing the Army Corps to engage in flood control projects on the Mississippi River).
[81] *E.g.*, Water Resources Development Act of 2007, Pub. L. No. 110-114, §§ 1002, 2009, 2021, 3008, 3029, 3116, 4068, 4077, 5005, 5070, 5154, 5157, 121 Stat. 1041 (Nov. 8, 2007) (authorizing numerous flood control and flood recovery projects throughout the United States).
[82] ADLER, CRAIG, AND HALL, *supra* note 30, at 636-37.
[83] *Id*. at 637.
[84] *Id*. at 637-38.
[85] *Id*. at 638.
[86] *Id*.

yearly rainfall will occur from June to October, and by the end of monsoon season, almost one third of the country is underwater."[87] However, much of Bangladesh's flood response came courtesy of the United Nations:

> In response to severe flooding in 1954, 1955 and 1956, the United Nations came up with a plan to provide flood control and increase the amount of land available for rice cultivation by adopting the Dutch approach of building permanent embankments, or "polders," around a number of these islands. In the 1960's and 70's, 5,000 kilometers of earthen embankments were constructed around 126 islands covering a total of 8,000 square kilometers (3,100 square miles).
>
> The embankment system continued to expand through the 1970s. Despite a number of problems, the system largely succeeded in increasing food production and protecting the islands from storm surges, which encouraged more people to move to the still environmentally vulnerable islands.[88]

However, new research reveals that the polders also cut these islands off from sediment renourishment, with the result that the "protected" islands are now "more than a meter below the local high water level" and are "flooded by four times as much water as the adjacent [unprotected] Sundarbans . . . ."[89]

Like New Orleans, Louisiana,[90] therefore, Bangladesh is the victim of legal and well-intentioned flood control efforts that nevertheless undermined long-term natural land-building processes, ultimately increasing flooding vulnerability. Thus, to adequately deal with flood disasters, water law in many places needs to re-evaluate the long-term value of technological controls, especially when those controls result in the stagnation of dynamic natural processes.

4.0 Coastal Inundation

4.1 Coastal Inundation as a Climate Disaster

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[87] Plan International, *Life Underwater: When Monsoon Strikes in Bangladesh*, http://plancanada.ca/monsoon-season-in-bangladesh (as viewed Jan. 27, 2017).

[88] David Salisbury, *Flood control efforts in Bangladesh exacerbate flooding, threaten millions*, https://news.vanderbilt.edu/2015/01/05/flood-control-efforts-in-bangladesh-exacerbate-flooding-threaten-millions/ (Jan. 5, 2015).

[89] *Id*.

[90] Restore the Mississippi River Delta, *What Went Wrong*, http://www.mississippiriverdelta.org/discover-the-delta/what-went-wrong/ (as viewed Jan. 27, 2017).

Coastal communities face the combined climate challenges of rising seas, more severe storm surge, and increasing numbers of increasingly severe coastal storms, such as hurricanes and typhoons. Coastal storms are costly climate disasters, both economically and in terms of human lives. In 2016, Hurricane Matthew caused about US$6 billion in damage in the United States,[91] while a month later Tropical Storm Otto killed six people in Nicaragua and nine in Costa Rica, which had not experienced such a storm since at least 1851.[92] The Philippines is generally considered the most storm-exposed country on the planet, and "[t]he most expensive storm to have made landfall in the Philippines, December 2012's Typhoon Bopha, killed more than 1,900 people and cost the country some $1 billion."[93] Nevertheless, while "it is virtually certain that intense tropical cyclone activity has increased in the North Atlantic since 1970," scientists continue to have difficulty attributing coastal storm events to anthropogenic climate change.[94]

Rising seas make these storm events worse; indeed, the exacerbation of storm surge is the most immediate and significant consequence of sea-level rise. According to the IPCC, "it is likely that extreme sea levels (for example, as experienced in storm surges) have increased since 1970, being mainly the result of mean sea level rise."[95] The IPCC also concluded that:

> It is *very likely* that the mean rate of global averaged sea level rise was 1.7 [1.5 to 1.9] mm/yr between 1901 and 2010 and 3.2 [2.8 to 3.6] mm/yr between 1993 and 2010. Tide gauge and satellite altimeter data are consistent regarding the higher rate during the latter period. It is *likely* that similarly high rates occurred between 1920 and 1950.[96]

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[91] Doyle Rice, "Hurricane Matthew economic damage nears $6 billion," *USA Today*, http://www.usatoday.com/story/weather/2016/10/08/hurricane-matthew-economic-damage-cost-6-billion/91783304/ (Oct. 8, 2016).

[92] "Tropical storm Otto kills nine in Costa Rica," *BBC News*, http://www.bbc.com/news/world-latin-america-38103330 (29 Nov. 2016).

[93] Sophie Brown, "The Philippines Is the Most Storm-Exposed Country on Earth," *Time*, http://world.time.com/2013/11/11/the-philippines-is-the-most-storm-exposed-country-on-earth/ (Nov. 11, 2013).

[94] 2014 IPCC SYNTHESIS REPORT, *supra* note 1, at 53.

[95] *Id*. at 53.

[96] *Id*. at 42. "Since the early 1970s, glacier mass loss and ocean thermal expansion from warming together explain about 75% of the observed global mean sea level rise (*high confidence*). Over the period 1993–2010, global mean sea level rise is, with *high confidence*, consistent with the sum of the observed contributions from ocean thermal expansion, due to warming, from changes in glaciers, the Greenland ice sheet, the Antarctic ice sheet and land water storage. . . ." *Id*.

Sea-level rise will continue throughout the 21st century,[97] although its exact impact will vary considerably among coastal regions. For example, "[s]ince 1993, the regional rates for the Western Pacific are up to three times larger than the global mean, while those for much of the Eastern Pacific are near zero or negative."[98]

4.2 Coastal Inundation, Water Supply, and Water Law

Coastal inundation is often a similar type of climate disaster to flooding, with similar public health and water quality problems that must be addressed outside the province of water law. For example, in Europe,

> The most obvious impact of extreme sea levels is flooding. The most well-known coastal flooding event in Europe in living memory occurred in 1953 due to a combination of a severe storm surge and a high spring tide. The event caused in excess of 2 000 deaths in Belgium, the Netherlands and the UK, and damaged or destroyed more than 40 000 buildings. Currently around 200 million people live in the coastal zone in Europe, and insurable losses due to coastal flooding are likely to rise during the 21st century, at least for the North Sea region.[99]

Nevertheless, water law offers two critical responses to coastal inundation. First, water law supplies the rules for changing coastal property boundaries. Both international practice and domestic water law define the boundaries of littoral property (property bordering the ocean) to be ambulatory.[100] While the various doctrines governing this

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[97] *Id*. at 58.

[98] *Id*. at 42.

[99] European Environment Agency, *Global and European sea-level rise*, http://www.eea.europa.eu/data-and-maps/indicators/sea-level-rise-2 (Sept. 10, 2014).

[100] While the United Nations Convention on the Law of the Sea is silent on the subject of whether coastal baselines are ambulatory, international practice is that coastal property boundaries shift with the shifting coastline. L. Poe Leggett & Dimitri L. Seletzky, *The Outer Continental Shelf Lands Act Turns Fifty: A Premature Look at the First Half-Century of the OCSLA*, 2002-3 RMMLF Inst. 1, 12 (April 2002); Charles Di Leva & Sachiko Morita, The World Bank, Maritime Rights of Coastal States and Climate Change: Should States Adapt to Submerged Boundaries?, at 17-19 (2009), *available at* http://siteresources.worldbank.org/INTLAWJUSTICE/Resources/L&D_number5.pdf. The United States adopted this principle in the Submerged Lands Act. 43 U.S.C. § 1301(b).

mobility—accretion,[101] reliction,[102] erosion,[103] avulsion[104]—can become complex in application,[105] the more important point here is that the law recognizes that the coast changes and can redefine the boundaries of coastal properties in the face of coastal inundation.

Second, with respect to coastal water supplies, water law controls coastal groundwater use. "Groundwater is generally the most important freshwater resource in many coastal regions which are threatened by seawater intrusion . . . ."[106] Coastal inundation puts coastal freshwater aquifers at risk in ways that freshwater flooding does not, as a result of saltwater intrusion and seawater inundation.[107] "Sea intrusion, exacerbated by intensive exploitation, threatens coastal aquifers with large-scale and slow-to-reverse contamination: mixing 2% seawater (salinity 35000 ppm TDS [parts per million Total Dissolved Solids]) with freshwater makes the mixture non-potable (standard 500 ppm TDS) and 5%-mixing makes it unfit for irrigation."[108]

Overpumping of coastal aquifers already puts them at risk of saltwater intrusion, and a 2012 study in *Nature Climate Change* concluded that water extraction remains the major salinity risk for most coastal aquifers.[109] Thus, coastal communities can and should use their water law governing groundwater to account for saltwater intrusion, limiting pumping to levels that avoids such intrusion: "Human water use is a key driver in the hydrology of coastal aquifers, and efforts to adapt to sea-level rise at the expense of

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[101] "Accretions are additions of alluvion (sand, sediment, or other deposits) to waterfront land," and the littoral owner automatically takes title to accretions. Stop the Beach Renourishment, Inc. v. Florida Dept. of Envtl. Protection, 660 U.S. 702, 708-09 (2010). "In order for an addition to dry land to qualify as an accretion, it must have occurred gradually and imperceptibly—that is, so slowly that one could not see the change occurring, though over time the difference became apparent." *Id*. at 708.
[102] "[R]elictions are lands once covered by water that become dry when the water recedes." *Id*. at 708. Relictions are treated like accretions. *Id*.
[103] Erosion is the gradual wearing away of the land, and the property boundary follows the changing coast. Georgia v. South Carolina, 497 U.S. 376, 403-04 (1990).
[104] Avulsions are sudden and perceptible changes to littoral property, as during a hurricane. Stop the Beach Renourishment, 660 U.S. at 708-09.
[105] *See*, *e.g.*, *id*. at 709 (2010) (deciding the legality of Florida's beach renourishment statutes on the basis of the distinction between accretion and avulsion).
[106] Hameb Ketabchi, Davood Mahmoodzadeh, Behzad Ataie-Ashtiani, & Craig T. Simmons, *Sea-level rise impacts on seawater intrusion in coastal aquifers: Review and integration*, 535 J. HYDROLOGY 235, 235 (Feb. 2016).
[107] *Id*. at 253.
[108] Katerina Mazi, Antonis D. Koussis, & Georgia Destouni, *Tipping points for seawater intrusion for coastal aquifers under rising sea level*, 8 ENVTL. RESEARCH LETTERS 1, 2 (9 Jan. 2013).
[109] Grant Ferguson & Tom Gleeson, *Vulnerability of coastal aquifers to groundwater use and climate change*, 2 NATURE CLIMATE CHANGE 342, 342 (May 2012).

better water management are misguided."[110] Public interest considerations in water rights permitting or licensing could be evolved to address this issue.

Nevertheless, "aquifers with very low hydraulic gradients are more vulnerable to sea-level rise and these regions will be impacted by saltwater inundation before saltwater intrusion."[111] Moreover, sea-level rise and increasingly severe coastal storms can increase the vulnerability of coastal aquifers to salinity contamination,[112] even when aquifer pumping is the more important factor. Such vulnerabilities are arising in coastal nations around the world, from South Korea[113] to Egypt[114] to the southeastern United States.[115] Research also indicates that aquifers' responses to sea-level rise are nonlinear, indicating that they can cross thresholds or tipping points where the aquifer rapidly transforms from mild levels of salinity to complete saltwater intrusion.[116] This risk suggests that precautionary measures in coastal groundwater law and management are warranted. For example, the Orange County Water District in southern California uses treated wastewater to recharge coastal aquifers, in part to stop saltwater intrusion.[117]

5.0 Conclusion

Water law creates the foundational rules for how humans use and manage water. As such, it can play a significant—albeit never exclusive—role in avoiding and responding to water-related climate disasters such as drought, flooding, and coastal inundation. Flexibility is a key attribute of water law's effectiveness in responding to drought, whereas rules governing individuals' responses to floodwaters and use of coastal aquifers are more important in the other two types of disasters. Preventative measures, in contrast, often require significant investments in water infrastructure to capture and control water flow and to make alternative water supplies available. While such investments can save human lives and reduce economic damage from water-related climate disasters, they also often come with longer-term ecological costs, including increased energy demands. Climate

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[110] *Id.* at 344.
[111] *Id*. at 342.
[112] Ketabchi et al., *supra* note 109, at 253.
[113] Sung-Ho Song & Gil Zemansky, *Vulnerability of groundwater systems with sea-level rise in coastal aquifers, South Korea*, 65 ENVTL. EARTH SCIENCES 1865-76 (Mar. 2012).
[114] Adrian D. Werner & Craig T. Simmons, *Impact of Sea-Level Rise on Sea Water Intrusion in Coastal Aquifers*, 47:2 GROUND WATER 197, 198 (March-April 2009).
[115] U.S. Environmental Protection Agency, *Climate Impacts in the Southeast*, https://www.epa.gov/climate-impacts/climate-impacts-southeast (as updated Dec. 22, 2016, and viewed Jan. 27, 2017).
[116] Mazi, Koussis, & Destouni, *supra* note 111, at 6.
[117] Water Replacement District of Southern California, *Groundwater Recharge with Recycled Water*, http://www.wrd.org/water_quality/recycled-water-groundwater-recharge.php (as viewed Jan. 27, 2017).

change is likely only to increase the starkness of these trade-offs, and we will see whether the world's water law systems can adequately adapt to a more disaster-prone world.