Dividing the Waters: Focus on States' Approaches to Groundwater and Recent Developments

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Table of Contents

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TABLE OF CONTENTS

High-Capacity Wells: A Survey of Groundwater Withdrawal Rights and Regulations

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INTRODUCTION

Although out of sight, groundwater represents a critical portion of the world's freshwater supply. Approximately 30% of the world's freshwater is groundwater,[6] and 2.5 billion people depend solely on groundwater to satisfy their daily water consumption needs.[7] In the United States, approximately 20% of total freshwater withdrawals come from groundwater sources.[8] Historically, these extractions occurred through crude devices that limited efficiency[9] This changed in 1937 with the invention of the high-speed centrifugal pump, which drastically increased the rate at which groundwater could be extracted.[10] Current practices in many regions of the United States permit groundwater withdrawals that exceed the rate at which the aquifers naturally replenish, leading to sustained and long-term depletion.[11]

Agricultural irrigation accounts for the single largest use of groundwater in the United States.[12] Satisfying this demand often requires utilizing high-capacity wells, which are wells that, together with all other wells on a property, have the ability to withdraw water over an established daily threshold.[13]

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[6] Deepak Khare, Manesh Kumar Jat & P.K. Minshra, *Groundwater Hydrology: An Overview*, *in* SUSTAINABLE HOLISTIC WATER RESOURCES MANAGEMENT IN A CHANGING CLIMATE 4-1 (2017).

[7] Jenny Grönwall & Kerstin Danert, *Regarding Groundwater and Drinking Water Access through a Human Rights Lense: Self-Supply as a Norm*, 12 Water 419, 419 (2020).

[8] Jacob D. Peterson-Perlman et al., *Critical Issues Affecting Groundwater Quality Governance and Management in the United States*, 10 Water 735, 735 (2018).

[9] BARTON H. THOMPSON, JR. ET AL., LEGAL CONTROL OF WATER RESOURCES: CASES AND MATERIALS 447 (6th ed. 2018).

[10] *Id.*

[11] Leonard F. Konkikow, *Long-Term Groundwater Depletion in the United States*, 53 Groundwater 2, 2-4 (2015).

[12] Agriculture accounts for approximately 80% of the nation's consumption of surface and ground water. U.S. DEP'T OF AGRIC. ECON. RESCH. SERV., *Irrigation & Water Use*, https://www.ers.usda.gov/topics/farm-practices-management/irrigation-water-use/ (last updated Sept. 23, 2019).

[13] *See High-Capacity Wells*, WIS. DEP'T OF NAT. RES., https://dnr.wisconsin.gov/topic/Wells/HighCap (last visited Mar. 3, 2021).

High-capacity wells have the ability to reach withdrawal rates that exceed natural groundwater recharge and disrupt the hydrological cycle as a result.[14] Unlimited and unregulated groundwater withdrawals through the use of high-capacity wells are not sustainable.

Absent an overarching federal framework to avoid depleting underground aquifers, the regulation of high-capacity wells is left largely to the separate states. Groundwater and surface water supplies are part of a single hydrological system, but the law of groundwater rights does not recognize this relationship.[15] While surface water is covered by two common law doctrines (riparianism and prior appropriation), five groundwater doctrines have some acceptance (absolute ownership, American reasonable use, correlative rights, the Restatement (Second) of Torts, and prior appropriation).[16] However, few states apply any one of these doctrines in a uniform way.[17] Furthermore, state regulatory frameworks reflect varying degrees of scientific understanding of hydrology.[18] As a result, groundwater management in the United States has been highly fragmented.[19]

An inefficient and piecemeal regulatory framework at the state level can have consequences, including: overallocation of groundwater, reduction in levels of surface waters that are supplied by the groundwater, agricultural supply problems, impaired water quality, and land subsidence.[20] Furthermore, mismanagement can have economic consequences because of the expenses associated with drilling deeper wells in response to dropping water table levels and costs that must be expended to remediate declining water quality.[21] There may be additional consequences of over-appropriating aquifers with high-capacity wells that are "not yet apparent because the processes of groundwater movement occur slowly and the effects of capture are not always immediately visible."[22] Groundwater is a shared resource, and the consequences of improper or inefficient regulation of wells withdrawing large quantities of water are both localized and far-reaching.

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[14] ROBERT GLENNON, WATER FOLLIES: GROUNDWATER PUMPING AND THE FATE OF AMERICA'S FRESH WATERS 2 (2002).

[15] *Id.*

[16] *Id.* at 449.

[17] *Id.*

[18] Melissa K. Scanlan, *Droughts, Floods, and Scarcity on a Climate-Disrupted Plante: Understanding the Legal Challenges and Opportunities for Groundwater Sustainability*, 37 Va. Envtl. L.J. 52, 88 (2019).

[19] *Id.* ("While individuals are focused on specific 'rights' to withdraw water, there is a need for an overarching holistic management of the entire common pool resource as an integrated system where ground and surface waters, and the quality and quantity of these waters, are viewed together.")

[20] *Groundwater Decline and Depletion*, U.S. GEOLOGICAL SURV., https://www.usgs.gov/special-topic/water-science-school/science/groundwater-decline-and-depletion?qt-science_center_objects=0#qt-science_center_objects (last visited Mar. 5, 2021).

[21] GLENNON, *supra* note 13, at 32.

[22] *Id.* at 77.

This report proceeds as follows. Part I discusses the limited role of the federal government plays in managing groundwater resources. Part II provides an overview of the legal rights and obligations pertaining to the use of groundwater and examines the regulatory frameworks in place for groundwater withdrawal via high-capacity wells. Part III offers a brief conclusion.

I. FEDERAL LAW

The federal government is generally authorized to act in the public's interest to protect the *quality* of the nation's waters. In 1972, Congress passed the Federal Water Pollution Control Act, which is commonly referred to as the Clean Water Act (CWA).[23] Designed "to restore and maintain the chemical, physical, and biological integrity of the Nation's waters,"[24] regulates discharges of pollutants from point sources.[25] The CWA defines the phrase "discharge of a pollutant" to mean "any addition of any pollutant to navigable waters from any point source."[26] A "point source," is "any discernible, confined, and discrete conveyance from which pollutants are or may be discharged."[27] Historically, the CWA has not been applied to protect groundwater.[28] However, the Supreme Court recently held that indirect discharges of pollutants to groundwater are subject to the CWA if they are the "functional equivalent" of a direct discharge.[29] Uncertainty surrounding the definition of key terms in the CWA has resulted in a patchwork regulatory framework.[30]

The federal government's role in managing and allocating groundwater resources (*quantity*) is much more limited. While the federal government generally does not have direct authority to monitor

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[23] *History of the Clean Water Act*, U.S. ENV'T PROT. AGENCY, epa.gov/laws-regulations/summary-clean-water-act (last updated Jun. 15, 2020).

[24] 33 U.S.C. § 1251 *et seq.*

[25] For an overview of events leading up to the CWA, see William L. Andreen, *The Evolution of Water Pollution Control in the United States—State, Local, and Federal Efforts*, 1789-1972: Part I, 22 Stanford Envtl. L. J. 145 (2003), and *Part II*, 22 Stanford Envtl. L. J. 215 (2003). For a retrospective of the CWA and a discussion of its limitations see William L. Andreen, *Success and Backlash: The Remarkable (Continuing) Story of the Clean Water Act,* 4 Geo. Wash. J. of Energy & Envtl. L. 25 (Winter 2013).

[26] 33 U.S.C. § 1362(12).

[27] *Id.* § 1362(14).

[28] DAVID H. GETCHES ET. AL., WATER LAW IN A NUTSHELL 272 (5th ed. 2015). Some courts have held that the NPDES permit program covers discharges of pollutants to groundwater that is hydrologically connected to surface waters. *See, e.g.,* Idaho Rural Council v. Bosma, 143 F. Supp. 2d 1169 (D. Idaho 2001); Sierra Club v. Colorado Refining Co., 838 F. Supp. 1428 (D. Colo. 1993). However, most courts have held that the statute does not reach that far. See, e.g., Village of Oconomowoc Lake v. Dayton Hudson Corp., 24 F. 3d 962 (7th Cir.1994); Exxon Corp v. Train, 554 F.2d 1310 (5th Cir. 1977).

[29] County of Maui, Hawaii v. Hawaii Wildlife Fund, 140 S. Ct. 1462, 1468 (2020). For a discussion of the implications of the Court's decision, see Rachel L. Wagner, County of Maui, Hawaii v. Hawaii Wildlife Fund, 0 Pub. Land & Res. L. Rev. 9 (2020).

[30] Brigit Rollins, *Waters of the United States: Timeline of Definitions*, NAT'L AGRIC. L. CTR. 1 (Apr. 21, 2020), https://nationalaglawcenter.org/wp-content/uploads//assets/articles/WOTUS-Timeline.pdf.

and manage groundwater, several federal agencies help to inform state decision-making by providing assessments and information on groundwater trends.[31] Beyond this limited role, the responsibility for managing groundwater belongs to the states. The exception to this pertains to groundwater on land reserved to the federal government.[32] The Supreme Court stated that this exception is rooted in "Congress's explicit deference to state water law in other areas."[33] Thus, the default is that the authority to manage issues related to groundwater quantity, such as the use of high-capacity wells, is deferred to the states.

II. STATE LAW

The rules and regulations for the allocation, withdrawal, and use of groundwater are made by the governments of the several states, as opposed to by the federal government.[34] States regulate groundwater rights through application of common law, state statutes and regulations, or judicial precedent.[35] The rules that states adopt tend to incorporate more than one theory of groundwater rights.[36] As a result of these state-by-state differences, the regulatory framework for the nation's groundwater is complicated and often contradictory.

A. GROUNDWATER AS A PROPERTY RIGHT

A water right authorization is the right to use groundwater in a prescribed manner. States differ in who they consider to be the legal owner of the water right authorization. The right to withdraw and use groundwater is owned either by: (1) the overlying landowner, or (2) the public, held by the state. According to the Water Systems Council, there is a clear trend of increasing conflict between private property rights in groundwater and public rights in groundwater.[37]

While the Supreme Court has recognized a limited form of property rights in groundwater use, a state may still regulate this right. However, governmental regulation that goes "too far" by denying a landowner of the "economically viable use" of their property may be considered a

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[31] U.S. Geological Survey (USGS), NASA, National Oceanic and Atmospheric Administration (NOAA), U.S. Department of Agriculture (USDA); PETER FOLGER, ET AL., CONG. RSCH. SERV., R425259 THE FEDERAL ROLE IN GROUNDWATER SUPPLY: OVERVIEW AND LEGISLATION IN THE 115TH CONGRESS 16 (2018).

[32] Winters v. United States, 207 U.S. 564, 575-77 (1908).

[33] United States v. New Mexico, 438 U.S. 696 (1978).

[34] John D. Leshy, *Interstate Groundwater Resources: The Federal Role*, 14 Hastings W-Nw. J. Envtl. L. & Pol'y 1475, 1480 (2008).

[35] ALEXANDER BENNET ET AL.., GROUNDWATER LAWS AND REGULATIONS: A PRELIMINARY SURVEY OF THIRTEEN U.S. STATES 7 (2d. ed 2020).

[36] GETCHES ET AL., *supra* note 27, at 226.

[37] *Who Owns the Water?*, WATER SYSTEMS COUNCIL 3, http://nationalaglawcenter.org/wp-content/uploads/2017/03/Who-Owns-the-Water-2016-Update-FINAL.pdf (last updated Aug. 2016).

"regulatory taking."[38] The Constitution provides that the government may not take private property for public use without just compensation.[39] While the regulatory authority of a state over groundwater is not unlimited, the overall trend appears to be toward increased state regulation of groundwater resources.[40] This generally requires a prospective user to comply with applicable state procedures to obtain a groundwater right authorization. This process does not result in the user obtaining ownership of the actual groundwater, but the right to use the groundwater in a way that is consistent with limitations imposed by the state.

1. Overlying Common Law Doctrines Governing the Right to Withdraw and Use Groundwater

Common law principles serve as the foundation for how a water use right is obtained in each state. Common law is "[t]he body of law derived from judicial decisions, rather than statutes or constitutions."[41] While not a groundwater management law, common law serves as the theoretical basis used for managing groundwater withdrawals and uses in each state.

States generally follow one of five groundwater law doctrines:

(a) **Absolute ownership.** The oldest and simplest doctrine, it gives landowners an unlimited right to withdraw any water beneath their land for any purpose.[42] Also referred to as "capture" or the English Rule.[43]

(b) **Reasonable use.** The predominant groundwater doctrine in the United States, it is a modified version of absolute ownership wherein groundwater must be put to a reasonable use and must be used on the overlying land.[44] Also referred to as the "American Rule."[45]

(c) **Correlative rights.** Described as "riparianism on its side,"[46] it requires that groundwater be shared among overlying landowners.[47] In times of shortage, overlying owners must limit withdrawals to a "fair and just proportion" of the supply."[48]

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[38] Lucas v. South Carolina Coastal Council, 505 U.S. 1003 (1992).
[39] U.S. CONST. amend. V.
[40] GLENNON, *supra* note 13, at 219.
[41] *Common law*, BLACK'S LAW DICTIONARY (11th ed. 2019).
[42] THOMPSON ET AL., *supra* note 8, at 472.
[43] *Id.*
[44] Linda A. Malone, *The Necessary Interrelationship Between Land Use and Preservation of Groundwater Resources*, 9 UCLA J. J. Envtl. L. & Pol'y 1, 6 (1990).
[45] Adams v. Lang, 553 So.2d 89, 91 (Ala. 1989).
[46] THOMPSON ET AL., *supra* note 8, at 472.
[47] *Id.*
[48] Katz v. Walkinshaw, 74 P. 766, 772 (Cal. 1903).

(d) **Restatement of Torts Reasonable Use.** A combination of the English and American rules,[49] it imposes liability for withdrawals that cause unreasonable harm to others.[50] The Restatement "attempts to balance equities and hardships among competing users.[51]

(e) **Prior Appropriation.** A "first in time, first in right" system of ownership.[52] The first landowner to put a water source to beneficial use is granted a priority right.[53]

A common thread running through these doctrines is an emphasis on individualism.[54] "That is, like the common law of torts, the doctrines contemplate 'freedom of action where the effects of individual action cannot be demonstrated with specific proof.'"[55] Additionally, each doctrine is a variation on reasonableness as it relates to the withdrawal and use of groundwater. However, reasonableness is defined in various ways as it relates to each doctrine. Moreover, a state may modify a doctrine from its traditional form or combine aspects from multiple systems.[56] Thus, a prospective groundwater user should consult with the relevant agency or department in their state to ensure that they properly secure a groundwater use right.

Table 1 summarizes the distribution of the different approaches to groundwater rights across the United States.

[49] *Who Owns the Water?*, *supra* note 36, at 5.
[50] RESTATEMENT (SECOND) OF TORTS § 858 (1979)
[51] GETCHES ET AL., *supra* note 27, at 236.
[52] THOMPSON ET AL., *supra* note 8, at 472.
[53] Malone, *supra* note 43, at 8.
[54] THOMPSON ET AL., *supra* note 8, at 473.
[55] *Id.*
[56] THOMPSON ET AL., *supra* note 8, at 449.

Table 1: Summary of Groundwater Rights in the United States

Groundwater Allocation	States	Total
Absolute Ownership	CT, GA, IN, LA, ME, MA, MS, RI, TX	9
Reasonable Use	AL, AZ, AR, FL, IL, KY, MD, MO, NH, *NJ, NY, NC, PA, VA, WV	*15
Correlative Rights	DE, HI, IA, MN, *NJ, VT	*6
Restatement (Second) of Torts Reasonable Use	MI, OH, WI	3
Prior Appropriation	AK, CO, ID, KS, MT, NV, NM, ND, OR, SD, UT, WA, WY	14
Reasonable Use/Correlative Rights	CA, OK, NE, TN	4
No Common Law	SC	1

**New Jersey common law as it pertains to groundwater is unclear. We included it in both the Reasonable Use and Correlative Rights totals.*

It is also important to note that while withdrawing large amounts of groundwater from underground aquifers may impact surface waters, many states use a different common law water rights system to regulate groundwater allocations and uses than the one used for surface water.[57] The application of different common law rules likely originated from a misunderstanding of the connection between surface and ground waters. However, some states have begun to consider the connectivity of surface water and groundwater by applying the same common law concept to each and managing them in an integrated manner. States that are most effective in regulating groundwater withdrawals and uses tend to consider the interconnection with surface waters.

a. Absolute Ownership

Under the absolute ownership rule, an overlying landowner can withdraw an unlimited amount of groundwater from the aquifer below their land and put it to any use. Under this rule, a groundwater use right is a property right. Thus, the landowner may "intercept the groundwater which would otherwise have been available to a neighboring water user and may even monopolize the yield of an aquifer without incurring liability."[58]

[57] *Id.*

[58] Teresa N. Lukas, *When the Well Runs Dry: A Proposal for Change in the Common Law of Ground Water Rights in Massachusetts*, 10 B.C. Envtl. Aff. L. Rev. 455, 469 (1982).

The doctrine originates from the English rule set forth in *Acton v. Blundell*.[59] In *Acton*, the Court of Exchequer held that a landowner has a property interest in groundwater, and what is "his is his alone from the heavens to the depths of the earth."[60] This property interest gave the landowner the legal right to take and use as much groundwater as they wanted without incurring liability. As a result, there was very little government regulation over the diversion and use of groundwater.

The absolute ownership rule was initially used in a majority of states prior to the early 1900s.[61] However, the absolute ownership rule posed challenges by threatening the groundwater supply and leaving landowners without legal remedies for harms suffered by unlimited pumping by a neighboring landowner.[62] As a result, many states have moved away from the absolute ownership rule in its traditional form, instead opting for the reasonable use rule or correlative rights approach.[63] States that do continue to adhere to the absolute ownership rule have generally modified it to create an exception where an overlying landowner is liable for pumping groundwater in a willfully malicious or injurious manner.[64] Additionally, many of these states have enacted some type of registration or permitting system to prevent unregulated withdrawals. Texas is the only state that continues to follow the rule of capture in its traditional form (applies outside of special management areas).

States following: CT, GA, IN, LA, ME, MA, MS, RI, TX

b. Reasonable Use (American Rule)

More than a dozen states modified the rule of capture by adding "reasonable use" criteria to resolve conflicts between competing well owners.[65] A series of conflicts between cities that sunk high-capacity wells in rural areas to extract groundwater for use in the city led to the creation of the reasonable use rule.[66] Courts imposed a reasonableness restriction on all pumpers to protect farmers from unfair competition.[67]

Under the reasonable use doctrine, an overlying landowner may withdraw an unlimited amount of groundwater from beneath their land, even if to the detriment of a neighboring landowner,

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[59] 152 Eng. Rep. 1223 (Ex. Chamb. 1843).

[60] Acton v. Blundell, 12 M. & W. 324 (1843).

[61] *Who Owns the Water?*, *supra* note 36, at 4.

[62] GETCHES ET AL., *supra* note 27, at 228 (noting that the absolute ownership doctrine "leads to premature depletion of the resource and leaves groundwater users at the mercy of nearby high-capacity pumpers.").

[63] *Who Owns the Water?*, *supra* note 36, at 1.

[64] *Id.* at 4.

[65] Ronald Kaiser & Frank F. Skiller, *Deep Trouble: Options for Managing the Hidden Threat of Aquifer Depletion in Texas*, 32 Tex. Tech. L. Rev. 249, 266 (2001).

[66] DAN TARLOCK, LAW OF WATER RIGHTS AND RESOURCES § 4:8 (2020)

[67] *Id.* (citing Volkmann v. City of Crosby, 120 N.W.2d 18 (N.D. 1963) and Martin v. City of Linden, 667 So.2d 732 (Ala. 1995)).

qualified by the requirement that the use of the groundwater be "reasonable."[68] Traditionally, groundwater use is *per se* reasonable if it is made on the overlying land.[69] "The rule is essentially the rule of absolute ownership with exceptions for wasteful and off-site use."[70]

This provides a right holder with a legal remedy for harm suffered from the pumping of a neighboring landowner if the withdrawal and use is found to be unreasonable. "Reasonableness" is broadly construed and generally means that pumping can be done for any "beneficial use," meaning any use that is not wasteful and that has a reasonable relationship to the overlying land.[71] However, because land ownership is the source of the use right under this rule, off-site uses are categorically deemed unreasonable, regardless of how beneficial the use is.[72]

With a few exceptions, this doctrine is predominantly applied in the eastern United States[73] Many of the states that adhere to this doctrine have enacted some registration or permitting system to monitor withdrawals and ensure that the subsequent use is reasonable.

States following: AL, AZ, AR, **CA, FL, IL, KY, MD, MO, NE, NH, *NJ, NY, NC, **OK, PA, **TN, VA, WV

**Common law unclear*
***Also follows Correlative Rights*

c. Correlative Rights

The correlative rights doctrine allocates the use of groundwater based on land ownership of land above a basin or aquifer.[74] However, owners of land over a single aquifer or basin are each limited to a reasonable share of the total supply.[75] This rule was first recognized in *Katz v. Walkinshaw*, where the California Supreme Court held that in times of shortage, the amount of groundwater that an overlying landowner can withdraw is limited to a "fair and just proportion of the underlying supply."[76] The "fair and just proportion" of an overlying owner has traditionally been determined by the ratio of land owned overlying the aquifer[77]

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[68] THOMPSON ET AL., *supra* note 8, at 472.

[69] *See, e.g.,* Martin v. City of Linden, 667 So.2d 732 (Ala. 1995); Higday v. Nickolaus, 469 S.W.2d 859 (Mo. Ct. App. 1971); Finley v. Teeter Stone, Inc., 248 A.2d 106 (Md. 1968); Willis v. City of Perry, 60 N.W. 727, 730 (Iowa 1894).

[70] Lukas, *supra* note 57, at 484.

[71] THOMPSON ET AL., *supra* note 8, at 472.

[72] Corwin W. Johnson, *What Should Texas Do About the Rule of Capture?*, *in* 100 YEARS OF THE RULE OF CAPTURE: FROM EAST TO GROUNDWATER MANAGEMENT 12 (2004).

[73] GLENNON, *supra* note 13, at 30.

[74] GETCHES ET. AL, *supra* note 27, at 229.

[75] *Id.*

[76] 74 P. 766, 772. (Cal. 1903).

[77] Tehachapi-Cummings Water Dist v. Armstrong, 122 Cal. Rptr. 918, 924-25 (Ct. App. 1975).

In California surplus groundwater may be used on lands that do not overlie the aquifer.[78] The doctrine of prior appropriation governs conflicts between non-overlying users.[79] However, a non-overlying user is subordinate to an overlying owner regardless of priority relative to the non-overlying user.[80] However, this aspect of California's allocation scheme has been rejected by other jurisdictions adopting correlative rights.[81]

In contrast with reasonable use and absolute ownership, the correlative rights doctrine does not vest ownership rights in the water or recognize an unlimited right to pump.[82] Rather, the correlative rights doctrine maintains that the power to allocate water resources is held by the courts.[83] Therefore, overlying owners and non-overlying users have co-equal or correlative rights in the reasonable, beneficial use of groundwater.[84] "The most important distinguishing feature of the correlative rights doctrine, however, is its recognition that adjoining lands may be underlain by a common, shared aquifer."[85]

States following: **CA, DE, HI, IA, **NE, MN *NJ, **OK, **TN, VT

**Common law unclear*
***Also follows Reasonable Use Rule*

d. Restatement (Second) Of Torts Reasonable Use

The Restatement (Second) of Torts approach to groundwater management combines the traditional English rule of absolute ownership with the American reasonable use rule.[86] However, the Restatement considers the nature of the competing uses and the relative burdens imposed upon each user and it attaches no special significance to the use of the water on overlying land.[87] It attempts to provide specific criteria for comparing the reasonableness of competing uses of groundwater.[88] Under the doctrine, a well owner is not liable for withdrawal of groundwater unless the withdrawal:

(a) unreasonably causes harm to a neighbor by lowering the water table or reducing artesian pressure;

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[78] *See* Santa Maria v. Adam, 149 Cal. Rptr. 3d 491, 502 (Cal. Ct. App. 2012).
[79] TARLOCK, *supra* note 65, at § 4:14.
[80] *Katz*, 74 P. at 772.
[81] GETCHES ET. AL, *supra* note 27, at 229.
[82] Steven J. Levine, *Ground Water: Louisiana's QuasiFictional and Truly Fugacious Mineral*, 44 La. L. Rev. 1123, 1135 (1984).
[83] *Id.*
[84] *Id.*
[85] *Id.*
[86] Water Systems Council, *supra* note 36, at 5.
[87] GETCHES ET AL., *supra* note 27, at 236.
[88] Kaiser & Skiller, *supra* note 61 at 264.

(b) exceeds the owner's reasonable share of the annual supply or total score of groundwater; or
(c) has a direct and substantial effect upon a watercourse or lake and unreasonably causes harm to a person entitled to the use of its water.[89]

"Reasonableness" is determined using a balancing test weighing a number of factors.[90] For example, "[i]t seems to require that a[n] [owner's] well be reasonably efficient in light of the type of use."[91] The second restriction employs a correlative rights concept as another foundation of liability.[92] The final restriction considers administration of groundwater use along with surface appropriation frameworks.[93]

States following: MI, OH, WI

e. Prior Appropriation

Under the doctrine of prior appropriation, a groundwater user acquires the legal right to use groundwater by being the first to divert it and put it to a (broadly defined) "beneficial use" in a manner consistent with state rules.[94] The hallmark of this doctrine is "first in time, first in right."[95] Once the user has made a diversion and puts the water to beneficial use, the user has a perfected water use right. Prior appropriation protects investments in wells and other businesses that are based on an expectation of a water supply.[96]

A pumper's place in the priority system is determined by the date of withdrawal. Many states use a registration or permitting system to formally establish a user's position. The right holder is generally permitted to pump as much groundwater as can be put to beneficial use, subject to their place in the priority system. However, the right does not extend to amounts of groundwater that exceed what can be beneficially used.[97] In times of shortage when there is not enough groundwater to

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[89] RESTATEMENT (SECOND) OF TORTS § 858 (1979).

[90] Section 850A of the Restatement (Second) of Torts provides:

[f]actors that affect the determination [of reasonableness] include the following: (a) The purpose of the use, (b) the suitability of the use to the watershed or lake, (c) the economic value of the use, (d) the social value of the use, (e) the extent and amount of harm it causes, (f) the practicality of avoiding the harm by adjusting the use or method of use of one proprietor or the other, (g) the practicality of adjusting the quantity of water used by each proprietor, (h) the protection of existing values of water uses, land, investments, and enterprises, and (i) the justice of requiring the user causing harm to bear the loss.

[91] GETCHES ET AL., *supra* note 27, at 237.

[92] *Id.*

[93] *Id.*

[94] GLENNON, *supra* note 13, at 16.

[95] Chennat Gopalkrishnan, *The Doctrine of Prior Appropriation and Its Impact on Water Development: A Critical Survey*, Am. J. Econ. & Soc. 61, 67 (1973).

[96] GETCHES ET AL., *supra* note 27, at 231 (citing *Farmers Inv. Co. v. Bettwy*, 558 P.2d 14, 21 (Ariz. 1976))

[97] Kaiser & Skiller, *supra* note 61 at 263-64.

satisfy the needs of all users, the appropriator who later acquired the water right (junior appropriator) must yield to the right holder who made the diversion first (senior appropriator).[98]

Under this approach to groundwater management, the groundwater belongs to the state. The trend has been to recognize groundwater as a public resource, as opposed to private property. [99] The state then places rules, requirements, limits, and conditions on groundwater withdrawals and uses to protect groundwater supplies and the other users' rights. States are increasingly replacing common law procedures for determining groundwater use rights with legislative processes, such as registration schemes and permitting systems.[100]

The doctrine of prior appropriation tends to be adhered to in western states, where the climate is more arid and fewer tracts of land are adjacent to bodies of surface water. The comparative scarcity of groundwater in the west makes this system attractive because it provides users with "secure property rights."[101] In reality, however, these states' systems are "prior appropriation in name only."[102] A strict application of prior appropriation is unworkable and inconsistent with the nature of the resource.[103] Under a pure prior appropriation system "a senior groundwater appropriator theoretically could demand that no pumping be allowed because virtually any new pumping causes some effect on existing wells."[104]

States following: AK, CO, ID, KS, MT, NV, NM, ND, OR, SD, UT, WA, WY

[98] GLENNON, *supra* note 13, at 16.
[99] Johnson, *supra* note 68, at 14.
[100] WILLIAM GOLDFARB, WATER LAW 45 (2d ed. 1988).
[101] GLENNON, *supra* note 13, at 19.
[102] Dan Tarlock, *An Overview of the Law of Groundwater Management*, 21 Water Res. Rsch 1751, 1752 (1985).
[103] *Id.*; GETCHES ET AL., *supra* note 27, at 231.
[104] GETCHES ET AL., *supra* note 27, at 231.

Table 2 summarizes key aspects of the groundwater allocation doctrines.

Table 2: Key Aspects of Groundwater Allocation Doctrines

Groundwater Allocation	Basis of Right	Withdrawal Amount	Liability	Off-tract Use
Absolute Ownership	Land ownership	Unlimited	No, unless malicious or wasteful	Yes
Reasonable Use	Land ownership	"Reasonable" for beneficial use	Yes, if unreasonable amount or off-tract use	No
Correlative Rights	Land ownership	Proportional share based on ratio of land owned overlying aquifer	Yes, if exceeding share and injurious	No, unless surplus
Restatement of Torts Reasonable Use	Land ownership	"Reasonable" for beneficial use	Yes, if unreasonable amount and injurious	Yes, if reasonable and no harm
Prior Appropriation	"First in time, first in right"	Specific amount based on priority for beneficial use	No, unless interfering with reasonable pumping level of other users	Yes

B. MANAGING GROUNDWATER WITHDRAWALS

While there has been a trend towards legislative reform in groundwater management policies, commentators have noted that the process has been disorganized.[105] Groundwater statutes evolved independently from surface water statutes due to the complexity of groundwater as a resource[106]. Furthermore, groundwater statutes differ from state to states.[107]

1. Legal Source of Authority

The legal source of authority for securing a water use right varies by state. Some states allow for a property right to use groundwater to arise largely from common law principles (ex: CA and TX). However, in most states, a pumper must comply with the state's comprehensive statutory and regulatory schemes in order to obtain a use right. A minority of states take a hybrid approach, where

[105] THOMPSON ET AL., *supra* note 8, at 495 (citing Joseph W. Dellapenna, *Legal Classifications*, *in* 2 WATERS AND WATER RIGHTS § 19.05 (Amy K Kelley Ed., 3rd ed. 2017).

[106] *Id.*

[107] *Id.*

a pumper obtains a use right under common law principles but must follow statutory procedures to exercise that right (ex: CO and AZ).

2. Managing Agency/Regulatory Department

While each state is ultimately authorized to manage the groundwater within its boundaries, each state differs in how they allocate that authority. In some states, groundwater is managed entirely at the state level. In other states, the authority to regulate groundwater withdrawals and uses is allocated to local governments and agencies.

3. Special Management Areas

Many states have designated certain areas as "special management areas" (label differs by state). Groundwater withdrawals and uses in these areas are generally subject to different procedures or more stringent standards. These are generally areas that the state legislature has set aside to allow for more localized control in order to protect the aquifers from being over-appropriated.

Special management areas are prevalent in the western U.S., where groundwater is less available. In all southwestern states, groundwater that is withdrawn from a special permitting area must be put to beneficial use. However, what constitutes "beneficial use" varies by state. Some states provide a broad definition, while others expressly articulate uses that are considered "beneficial." Additionally, some state laws in special management areas require that the use of the groundwater be "reasonable." Most states will consider an existing user's rights when determining whether to permit a proposed withdrawal in these areas. A minority of southwestern states with special management areas require a determination of the impact that a proposed withdrawal would have on an ecosystem before issuing a use right.[108]

There are 12 states without any type of special management designation or with designations only applicable to protecting the groundwater quality and preventing pollution (GA, IL, KY, MA, ME, MI, MO, ND, NH, RI, TN, VT).

4. Management of Wells

Each state has different rules and procedures that allow a groundwater user to obtain the right to divert and use groundwater. This is most often accomplished through one or a combination of the following: registration, permitting, and adjudication.

[108] For example, in Utah, the State Engineer is directed to consider the impact that a proposed withdrawal will have on "the natural streams and environment" (§ 73-3-8(1)(b)).

a. Registration

In total, there are 30 states that have some type of registration requirement: AL, AR, CT, HI, IL, IN, KY, LA, MA, MI, MO, MT, NE, NV, NH, NJ, NY, NC, OH, OR, PA, RI, SC, SD, TN, TX, VA, WV, WI, WY. Of these states, only 5 have some type of registration requirement, but no permitting requirements (AL, LA, MO, TN, WV).

Breakdown by common law doctrine:

Absolute dominion: 6 states
Reasonable use: 13 states
Correlative rights: 2 states
Restatement of Torts (Second) § 858: 3
Prior appropriation: 5
Reasonable use/correlative rights: 1
States without common law: 1

Some of these states require a groundwater facility or withdrawal to be registered with the regulating agency if it has the *capacity* to withdraw a certain amount over a threshold amount. The applicable threshold varies by state. Several states with registration systems in place, all of which are east of the Mississippi River, set the threshold at a capacity to divert groundwater at a rate of 100,000 gallons/day, regardless of whether an actual diversion of that amount is made (AL, IL, IN, MO, NJ, NH, WI). Other states have lower thresholds (in descending order, based on threshold):

- Louisiana, Arkansas: wells with a capacity to pump 50,000 gallons/day (Arkansas exempts any well below this from its registration process)
- Montana: wells exempt from the permitting process with a maximum pump rate of 35 gallons/minute and maximum volume of 25 acre-feet/year
- Kentucky: exempts withdrawals made at a constant rate with an average withdrawal rate of 10,000 gallons/day

Other states require registration for wells that make *actual* diversions above a certain threshold.

North Carolina and Tennessee require registration based on an amount withdrawn in a day (at least 100,000 gallons/day, and at least 10,000 gallons/day, respectively). Other states require a well to be registered if it withdraws either a certain amount of groundwater in a given month or averages a certain rate. These states are (in ascending order, based on threshold):

- Michigan: withdrawals of more than 100,000 gallons/day averaged over any 30-day period
- West Virginia: withdrawals of more than 300,000 gallons/day averaged over any 30-day period
- South Carolina: withdrawals of more than 3 million gallons/month

New Hampshire merges the two by requiring a well to be registered if it withdraws over 20,000 gallons/day, or 600,000 gallons over 30 days.

Several states require registration for certain existing diversions, potentially exempting these wells from other permitting and reporting requirements (CT, HI, MA, OR).

Some states either specifically require registration in special management areas or have the potential to require registration if the need arises (TX, NV, OH, VA, WI).

States with different registration rules include: New York, where agricultural withdrawals can either be registered or reported; Rhode Island, where registration is required for the installation of the well, but not for the withdrawal; and South Dakota, where wells that are exempt from the permitting process have the option to register in order to document the location of their well and its output.

i. Exemptions/Exceptions

Most states exempt wells withdrawing groundwater for certain uses from registration requirements. Some of the more common exempted uses include:

- Agricultural uses (KY, NJ, NC,[109] TN, WV)
- Domestic uses: This typically requires that the well be on a property that serves a single family, or a small number of families, and that the water be used for non-commercial purposes (AR, KY, MI, SC)
- Existing uses (AR, NE, NJ, NY)
- Emergency uses (NH, NY, SC, TN)
- Temporary withdrawals (AL, MI, NH, TN)

Wyoming is the only state that does not exempt any wells or groundwater uses from its registration procedures.

b. Permitting

The majority of states (44) have some type of permitting scheme in place (all except AL, LA, MO, RI, TN, WV).

A groundwater withdrawal permitting regime requires a would-be user to obtain a permit before constructing the well or diverting groundwater. The state legislature may specify whether compliance with the permitting regime is mandatory or discriminatory. The majority of western states use a permit system where a prospective user must submit an application for the right to divert and use groundwater. Permit requirements differ by state. Some states require a user to have a permit

[109] Withdrawal must be less than 1 million gallons/day. N.C. GEN. STAT. § 143-215.22H(b1).

before making a withdrawal anywhere in the state, while others require a user to have a permit only in a special management area.

Many states require a groundwater user to have a permit if they are extracting groundwater from a well in an amount or at a rate above a certain threshold, regardless of what the water will be used for. This can be done either by only regulating withdrawals over a threshold amount or by exempting users withdrawing groundwater in amounts below the threshold. States differ in the duration of time that the amount of water withdrawn is measured over.

- Gallons/day
    - 5,000 gallons/day: AK, MD, WA
    - 10,000 gallons/day: KY,[110] MN[111]
    - 25,000 gallons/day: IA
    - 50,000 gallons/day: AR, CT, DE, ME[112]
    - 57,600 gallons/day (equals 40 gallons/minute): NH, VT
    - 100,000 gallons/day: GA, MA, NJ, NY, WI
    - 144,000 gallons/day: ME[113]
    - 2 million gallons/day: MI
- Gallons/minute
    - 15 gallons/minute: CO
    - 18 gallons/minute: SD
    - 35 gallons/minute: AZ, MT
- Gallons/month
    - 2 million gallons/month: WI

Some states require a groundwater user to have a permit in a legislatively designated special management area, regardless of the amount withdrawn (AZ, AR, HI, IL, NM, SC). Other states require a prospective user to obtain a permit in special management areas when the user withdraws an amount or at a rate above a certain threshold.

- Gallons/day
    - 10,000 gallons/day: PA
    - 20,000 gallons/day: MS
    - 100,000 gallons/day: IN, NC
- Gallons/minute
    - 20 gallons/minute: MT
    - 50 gallons/minute: CO, NE

[110] Note: withdrawal must be made at "a relatively constant rate." 401 KY. ADMIN. REGS. 4:010(2).

[111] Appropriation cannot total over 1 million gallons/year. Minn. Stat. § 103G.271(4)(a).

[112] If withdrawal is within 500 feet of a body of water or at least 75,000 gallons during any week. ME. STAT. TIT. 38, § 480-B(9-A)(A)(1).

[113] If withdrawal is over 500 feet from a body of water, or at least 216,000 gallons during any week ME. § 480-B(9-A)(A)(2).

- Gallons/month
    - 300,000 gallons/month: VA

Some states give local agencies in special management areas the authority to impose permit requirements or more stringent permit requirements (CA, MN, TX). Additionally, groundwater pumpers in states that are part of the Great Lakes Compact may be subject to additional permitting requirements. Finally, a state may subject a user to its permitting regime based on how the groundwater will be used. For example, both Nebraska and New York require that a pumper have a permit when the water will be used for irrigation, regardless of how much will be withdrawn.

i. Exemptions/Exceptions

A state may choose for wells withdrawing certain amounts of groundwater or putting the withdrawn water to certain uses to be exempt from standard permitting requirements. Exempt groundwater uses vary by state. Utah and Wyoming are the only two states that require a permit for all withdrawals, without exception. Common exemptions include:

- Withdrawals for domestic purposes[114]
- Withdrawals for agricultural purposes[115]
- Emergency withdrawals[116]
- Temporary or nonrecurring withdrawals[117]
- Certain existing water rights may be grandfathered in so as to not require a permit[118]

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[114] Examples include: AK (ALASKA ADMIN. CODE TIT. 11, § 93.040(D)), AR (ARIZ. REV. STAT. § 15-22-302(A)), CO (2 COLO. CODE REGS. § 4.2.18 SAYS THAT A PERMIT IS NEEDED UNLESS IT'S FOR A SMALL CAPACITY WELL; COLO. REV. STAT. § 37-90-105(1)(A) DEFINES A DOMESTIC WELL AS A SMALL CAPACITY WELL), FL (FLA. STAT. § 373.219(1)), HI (HAW. REV. STAT. § 174C-48(A)), ID (IDAHO CODE § 42-227), KS (KAN. STAT. ANN. § 82A-705), KY (KY. REV. STAT. ANN. § 151.140), ME (ME. STAT. TIT. 38, § 470-C(2)), MD (MD. CODE ANN., ENVIR. § 5-502(B)(1)), MI (MICH. COMP. LAWS § 324.32727(1)(H)), MN (MINN. STAT. § 103G.271 SUBD. 1 (B)(1)), MS (MISS. CODE ANN. § 51-3-7(1)), NV (NEV. REV. STAT. § 534.315(1)), ND (N.D. CENT. CODE § 61-04-02), OK (OKLA. STAT. TIT. 82, § 1020.3), OR (OR. REV. STAT. § 537.545(1)(D)), SC (S.C. CODE ANN. § 49-5-70(A)(4)), SD (S.D. CODIFIED LAWS § 46-5-8), TX (TEX. WATER CODE ANN. § 36.117(B)(1)), VT (VT. STAT. ANN. TIT. 10, § 1418(B)(2)), WA (WASH. REV. CODE § 90.44.050).

[115] Examples include: CO (2 COLO. CODE REGS. § 4.2.18 says that a permit is needed unless it's for a small capacity well; COLO. REV. STAT. § 37-90-105(1)(b) defines a domestic well as a small capacity well), KY (KY. REV. STAT. ANN. § 151.140), ME (ME. STAT. TIT. 38, § 470-C(10)), MD (MD. CODE ANN., ENVIR. § 5-502(b)(2)), NJ (N.J. STAT. ANN. § 7:19-1.4(a)(1) states that this chapter does not apply to agriculture and horticulture uses), NY (N.Y. ENVTL. CONSERV. LAW § 1501(7(E)), NC (N.C. GEN. STAT. § 143-215.22H(B1)), VT (VT. STAT. ANN. TIT. 10, § 1418(B)(3)).

[116] Examples include: CO (in designated basins: 2 Colo. Code Regs. § 4.2.18 says that a permit is needed unless it's for a small capacity well; Colo. Rev. Stat. § 37-90-105(1)(b) defines a well used exclusively for firefighting purposes as a small capacity well), NH (N.H. Rev. Stat. Ann. § 488:11 states that this chapter doesn't apply to a discrete withdrawal arising from an emergency event), NY (N.Y. Envtl. Conserv. Law § 15-1501(7)(a)), SC (S.C. Code Ann. § 49-5-70(A)(1)), VT (Vt. Stat. Ann. tit. 10, § 1418(b)(1)).

[117] Examples include: KY (401 Ky. Admin. Regs. 4:010 sec. 1 (3): permit may be required if withdrawal is made at irregular basis at irregular rate and the water withdrawn represents a significant portion of the available water supply), MI (Mich. Comp. Laws § 324.32723(13)(b)), NH (N.H. Rev. Stat. Ann. § 485-C:2(IX-a) exempts short-term withdrawals from being classified as a "large groundwater withdrawal").

[118] Examples include: AZ (Ariz. Rev. Stat. § 45-462), AR (Ark. Code Ann. § 15-22-905(1)(A)), CT (Conn. Gen. Stat. § 22a-368(b)), MT (Mont. Code Ann. § 85-2-306(4)-(5)).

Interestingly, in determining the amount of groundwater that a user withdraws and whether it is sufficient to warrant a permit, at least one eastern state (Massachusetts) exempts nonconsumptive uses from these calculations.[119]

c. Adjudication

Vested rights typically require adjudication, where the court decrees the existence of the right. This process results in the definition and confirmation of an existing water right. Adjudication was typically how an appropriator obtained a water use right prior to the establishment of specific agencies that were tasked with defining water rights. One issue with this approach is that the decision of a court applies only to the individual litigants and not to the entire water system.

5. Continued Compliance (Monitoring and Reporting)

Once a pumper obtains the right to appropriate groundwater, there are typically continuing obligations on the user. Some states require groundwater uses to be reported for all groundwater users (AR and HI).

a. For Registered Wells

The vast majority of states with registration procedures require that registrants submit reports. The contents of these reports and the frequency of reporting varies by state. States that require some type of reporting for all registrants include: AL, AR, CT, HI, IL, IN, MA, MO, NH, NC, OH, PA, SC, TN, WV, WI. A small number of states have no reporting requirements for registered wells (RI, SD, WY). Some states require reporting for registered wells in special management areas or give the local regulating department the authority to require users to submit reports (LA, NE, SC, TX). Virginia and West Virginia have thresholds for which a registrant withdrawing groundwater in amounts that exceed must submit information. Michigan has a threshold below which a registrant is subject to less stringent requirements. Finally, Montana requires the well driller to submit a report, not the groundwater user.

b. For Permitted Wells

Some states require all groundwater users who have obtained a permit and are not exempt from the permitting process to report certain information, regardless of the amount of groundwater withdrawn or the use to which it was put.[120] Additionally, a state may choose to vest local agencies

[119] Mass. Gen. Laws ch. 21G, § 4 ("for purposes of determining whether a withdrawal is in excess of the threshold volume, any withdrawal of water for a nonconsumptive use. . . shall not be counted in the volume of water withdrawn.")

[120] Examples include: DE (7 Del. Admin. Code § 5.5.3), GA (GA. CODE ANN. § 12-5-987: every person required to get a permit shall file a certified statement of quantities of water used and withdrawn; GA. COMP. R. & REGS. 391-3-2-.08(1)), KY (KY. REV. STAT. ANN. § 151.160(1)), ME (if within 500 feet of a lake or pond) (ME. STAT. TIT. 38 § 470-B),

with the authority to impose reporting requirements on permits.[121] Other states may require certain uses to be reported, such as groundwater used for agricultural purposes.[122] Finally, some states impose thresholds that differ from the threshold requiring a permit and mandate that groundwater users that exceed the threshold limits report their uses:

- 10,000 gallons/day: MD, VA
- 20,000 gallons/day: MS
- 30,000 gallons/day: AK
- 50,000 gallons/day: ME (if more than 500 feet from a lake or pond)
- 100,000 gallons/day: FL

A state may also choose to exempt certain uses from being subject to its reporting requirements, such as groundwater used for domestic uses, farm uses, or irrigation.

6. State Regulation of Large Groundwater Withdrawals

There are a variety of ways that states regulate wells that withdraw large quantities of groundwater. Below are summaries of the rules and regulations that each state has in place regarding large groundwater withdrawals. These summaries are not a comprehensive collection of a state's rules and are meant to serve as a starting point.

Alabama (Reasonable Use): Alabama employs a system of registration and reporting for withdrawals exceeding a certain threshold. Any well with a capacity to withdraw at least 100,000 gallons/day is required to register and report their withdrawals.[123] Additional limitations are imposed in capacity stress areas as to the maximum amount of groundwater that can be withdrawn.[124]

Alaska (Prior Appropriation): Alaska has a permitting system for wells exceeding certain statutory thresholds. A groundwater use permit is required for any withdrawal of a "significant" amount of groundwater.[125] A significant withdrawal is statutorily defined as: (1) more than 5,000 gallons in one day from a single source, (2) the regular use of more than 500 gallons/day from a single source for more than 10 days/year, (3) more than 30,000 gallons/day for non-consumptive use from a single source, or (4) any other use that may affect the rights of other appropriators.[126] The DNR is required to issue notices when considering applications for appropriations of 5,000 gallons/day or more.[127]

MA (Mass. Gen. Laws ch. 21G, § 11), MI (MICH. COMP. LAWS § 324.32707(1)), MN (MINN. STAT. § 103G.281 subd. 3), NJ (N.J. STAT. ANN. § 58:1A-8(d); N.J. ADMIN. CODE § 7:19-2.14(a)(3)), NY (N.Y. ENVTL. CONSERV. § 15-1501(6)), OH (OHIO REV. CODE ANN. § 1521.30), OK (OKLA. STAT. TIT. 82, § 1020.12; OKLA. ADMIN. Code § 785:30-5-9), SC (S.C. CODE ANN. § 49-5-90(A)), WI (WIS. STAT. § 281.34(5)(E)).

[121] California is an example (local agencies administer permits and impose conditions, such as reporting, into them).

[122] Examples include: MD (MD. CODE REGS. 26.17.06.06(D)(1)), NY (N.Y. ENVTL. CONSERV. LAW § 15-1504(1)(B)).

[123] ALA. CODE § 9-10B-20.

[124] § 9-10B-21.

[125] 11 ALASKA ADMIN. CODE § 93.035(A).

[126] § 93.035(b).

[127] *Fact Sheet: Water Rights in Alaska*, ALA. DEP'T OF NAT. RES. (July 2018), http://dnr.alaska.gov/mlw/factsht/wtr_fs/Fact-Sheet-Water-Rights-in-Alaska.pdf.

Arizona (Reasonable Use): Arizona regulates groundwater withdrawals in special management areas by requiring that all wells obtain a permit, subject to certain exemptions.[128] Exemptions include withdrawals for non-irrigation use[129] from wells with a maximum pump capacity not exceeding 35 gallons/minute.[130] However, exempted withdrawals may not exceed 10 acre-feet/year, unless the groundwater is used for domestic purposes or stock watering.[131] Arizona allows special management areas to set the maximum withdrawal amount (the goal of most is "safe yield") through the use of local management plans.[132] Reporting is required for all non-exempt wells in special management areas.

Arkansas (Reasonable Use): Arkansas regulates large quantity withdrawals as the rule, and exempts low-capacity wells. Registration is required for wells with a maximum potential flow rate of more than 50,000 gallons/day, excluding individual wells exclusively used for domestic purposes.[133] These wells must then report their usage.[134] A permitting scheme is used in the state's special management areas for withdrawals in excess of 50,000 gallons/day.[135]

California (Reasonable Use/Correlative Rights): California has delegated regulatory authority over groundwater withdrawals to local groundwater sustainability agencies.[136] These local agencies then adopt groundwater management plans, which provide for the regulation of groundwater withdrawals.

Colorado (Prior Appropriation): Colorado manages large-scale groundwater withdrawals geographically, based on where the groundwater is located. In designated basins, a permit is needed for large capacity wells.[137] A large capacity well is defined as "any well which is permitted to put designated groundwater to beneficial use provided the said permit is not for a small capacity well."[138] A small capacity well is exempt, and includes: (1) wells with a withdrawal rate not exceeding 50 gallons/minute and used for no more than three single-family dwellings (exception: does not include irrigation on more than one acre of land), (2) livestock wells not exceeding 50 gallons/minute, (3) wells used in one commercial business not exceeding 50 gallons/minute, (4) certain wells used for observation purposes, (5) wells used exclusively for firefighting purposes, and (6) certain monitoring

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[128] ARIZ. REV. STAT. § 45-152(A).

[129] Non-irrigation is defined to include growing crops on 2 acres of land or less. § 45-402(23)(a).

[130] § 45-454(A) and (B).

[131] § 45-454(B)(2).

[132] JANICK F. ARTIOLA AND KRISTINE UHLMAN, ARIZONA WELL OWNER'S GUIDE TO WATER SUPPLY 9 (2009), https://wrrc.arizona.edu/sites/wrrc.arizona.edu/files/az1485.pdf.

[133] *Water-use Registration*, ARK. DEP'T OF AGRIC., https://www.agriculture.arkansas.gov/natural-resources/divisions/water-management/groundwater-protection-and-management-program/water-use-registration/ (last visited Mar. 7, 2021).

[134] ARK. CODE § 15-22-302(a).

[135] § 15-22-905(3).

[136] *See* Cal. Water Code § 10720.

[137] COLO. DIV. OF WATER RES, SYNOPSIS OF COLORADO WATER LAW 3 (2016).

[138] 2 COLO. CODE REGS. § 4.2.18.

wells.[139] In non-designated basins, a prospective user must apply for a permit to appropriate groundwater from a non-exempt well.[140] An exempt well is one with flow rates of 15 gallons/minute or less for in-house use and outside use only for domestic animals.[141] In both designated and non-designated basins, wells must report if they are not exempt from permitting requirements.

Connecticut (Absolute Dominion): Connecticut employs a permitting and reporting scheme for wells above a certain threshold. A permit is required for withdrawals of more than 50,000 gallons/day.[142] Annual reporting is required for consumptive uses of water by permit holders.[143]

Delaware (Correlative Rights): Delaware regulates groundwater withdrawals through the use of a permitting scheme, applicable to wells exceeding a statutorily prescribed threshold. All withdrawals over 50,000 gallons/day must obtain a permit.[144] Annual reporting is required by permit holders.[145] The state can control the amount of water that is withdrawn by setting a maximum allowable withdrawal rate in the permit.[146] The maximum amount of groundwater that a permit holder can withdraw is 20 acre-inches/year, but not more than 10 acre-inches/month.[147]

Florida (Reasonable Use): The state has delegated its regulatory authority to local agencies. Florida is divided into five water management districts (WMDs), with each district having the authority to administer state water law. A WMD may require that an appropriator acquire a permit, subject to reasonable conditions.[148] However, a WMD is restricted from imposing its permitting requirements on wells that provide for the domestic consumption of water by individual users.[149] Each WMD has imposed a permitting regime in its district, so each appropriator must have a permit.[150] Each WMD is authorized to impose reasonable conditions as to the amount and rate of groundwater withdrawn. Annual reporting is required for permit holders who are authorized to withdraw more than 100,000 gallons/day.[151]

Georgia (Absolute Dominion): Georgia subjects wells above a certain threshold to its permitting and reporting requirements. A permit is required for any user who withdraws more than 100,000 gallons/day for any purpose.[152] Annual reporting is required for permit holders.[153]

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[139] COLO. REV. STAT. § 37-90-105(1).
[140] § 37-90-137(1).
[141] § 37-92-602.
[142] *See* CONN. GEN. STAT. §§ 22a-368, 22a-377(a)(1).
[143] § 22a-368a(b).
[144] 7 DEL. ADMIN. CODE § 1.2.
[145] § 5.5.3
[146] § 5.5.2.
[147] Del. Code Ann. tit. 7, § 6010(h)(1).
[148] Fla. Stat. § 373.219(1).
[149] § 373.219(1).
[150] Northwest Florida WMD: Fla. Stat. § 40A-2.041(1), Suwannee River WMD: § 40B-2.041(1), St. Johns River WMD: § 40C-1.602, Southwest Florida WMD:§ 40D-2.04, South Florida WMD: § 40E-2.041(1).
[151] § 373.223(6).
[152] Ga Code Ann. § 12-5-96.
[153] § 391-3-2-.04(11)(i).

Hawaii (Correlative Rights): Hawaii regulates all groundwater withdrawals in special management areas, subject to certain exceptions. In general, a water use permit is required to extract groundwater in designated water management areas.[154] However, no water use permit is needed for individual domestic users.[155]

Idaho (Prior Appropriation): Subject to certain exceptions, all groundwater users must obtain a permit prior to making a withdrawal.[156] Domestic users are exempted from the permitting process.[157] A "domestic purpose" is statutorily defined as withdrawal for individual use, irrigation of less than half an acre of land, and any other associated purpose so long as the withdrawal is not more than 13,000 gallons/day, and any other use so long as the total use is not more than .04 cubic-feet/second or 2,500 gallons/day.[158] Unlike other western states, exempt uses in Idaho are also exempt from reporting requirements.[159]

Illinois (Reasonable Use): Illinois uses the term "high-capacity well" to encompass large-scale withdrawals of groundwater. A high-capacity well is statutorily defined as a well "located on property where the rate or capacity of groundwater withdrawal of all wells on the property is at least 100,000 gallons during any 24-hour period."[160] When a user "proposes to develop a new point of withdrawal that is a high capacity well, the land occupier or person must notify the District before beginning construction on the well. The District then must notify other local units of government with water systems who may be impacted by the proposed withdrawal. The District then reviews . . . the proposed point of withdrawal's effect upon other uses of the water."[161] Registration with the local District is required for high-capacity wells.[162] These wells must participate in the Illinois Water Inventory Program and submit an annual report.[163] A maximum withdrawal amount may be placed upon high-capacity wells by the Department of Agriculture if the District has investigated and recommended a limit.[164]

Indiana (Absolute Dominion): A significant water withdrawal facility (SWWF) is defined as any well, or combination of wells, capable of pumping at least 100,000 gallons/day, regardless of how much water is actually pumped.[165] A SWWF must be registered[166] and must report groundwater

[154] Haw. Rev. Stat. § 174C-48.
[155] § 174C-84.
[156] Idaho Code § 42-217.
[157] § 42-227.
[158] § 42-111.
[159] §§ 42-221(K)(1), 42-701(7).
[160] 525 Ill. Comp. Stat. § 45/4.
[161] § 45/5.
[162] § 45/5.1.
[163] § 45/5.3.
[164] § 45/5.1.
[165] Ind. Code § 14-25-7-15(a).
[166] § 14-25-7-15(c).

usage.[167] An additional permitting regime is imposed in special management areas. A permit is required in restricted use areas for all new users or those withdrawing more than 100,000 gallons/day.[168] Liability is imposed on the owner of an SWWF, as state statute requires that the owner provide "timely and reasonable compensation to persons who own nonsignificant groundwater withdrawal facilities if there's failure or substantial impairment of those facilities" that can be tied to the SWWF.[169]

Iowa (Correlative Rights): In Iowa, a permit is required for withdrawals that exceed 25,000 gallons/day.[170] Additional permitting requirements are imposed on high-capacity wells and wells used for irrigation purposes.[171] Iowa uses the term "high-capacity well" to encompass any well expected to have a pump capacity at or above 500 gallons/minute.[172] The state allows for a degree of local control, as each aquifer has a different limit on the amount of groundwater that can be withdrawn or the rate that it can be withdrawn at.

Kansas (Prior Appropriation): Kansas regulates large-scale groundwater withdrawals by exempting smaller uses. All wells, except for domestic uses on 2 acres of land or less, are required to obtain a permit.[173] Permit holders must report their usage.[174]

Kentucky (Reasonable Use): Kentucky regulates large groundwater withdrawals by using a permitting and reporting regime for withdrawals above a certain threshold, subject to certain exemptions. A permit is required for facilities with a withdrawal rate of more than 10,000 gallons/day.[175] A permit may be required if the withdrawals are made on an "irregular basis and at an irregular rate" "if the water withdrawn represents a significant portion of the available water supply or collection of data is necessary for water resource planning purposes."[176] The quantity of groundwater to be withdrawn is managed by setting a maximum quantity and rate in the permit.[177] Exempt uses include domestic and agricultural uses (including irrigation).[178] Permit holders must submit reports regarding their water usage.[179]

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[167] § 14-25-7-15(e).

[168] Governed by IND. CODE § 14-25-3-6.

[169] § 14-25-4-17.

[170] *See* IOWA ADMIN. CODE R. 567-50.2.

[171] Iowa Source Link, *Private Water Well Construction Permit,* https://www.iasourcelink.com/licensing/detail/private-water-well-construction-permit.

[172] Water Use/Allocation Permitting – High Capacity Well – 2015, Technical Bulletin 23.1.

[173] KAN. STAT. ANN. §§ 82a-705, 82a-728 (Domestic rights, defined as "those held for household purposes" do not require a permit).

[174] § 82a-732.

[175] KY. REV. STAT. ANN. § 151.140; 401 KY. ADMIN. REGS. 4:010.

[176] 401 KY. ADMIN. REGS. 4:010.

[177] KY. REV. STAT. ANN. § 151.170(1).

[178] § 151.140.

[179] § 151.160.

Louisiana (Absolute Dominion): Registration is required for all wells that withdraw more than 50,000 gallons/day.[180] Users must provide usage information.[181] A large volume well is defined as a well "with an 8 inch or greater diameter screen size or a well that by itself or in conjunction . . is capable" of withdrawing 1,500 gallons/minute."[182] It is not immediately clear if there are specific rules or regulations applicable to large volume wells.

Maine (Absolute Dominion): Maine legislation requires a "significant groundwater user" to obtain a permit.[183] A significant groundwater user is one withdrawing at least 75,000 gallons/week or 50,000 gallons/day if the withdrawal is located within 500 feet of a body of water, or a withdrawal of at least 216,000 gallons/week or 144,000 gallons/day if the withdrawal is over 500 feet away from a body of water.[184] Additionally, "if a proposed activity includes a significant groundwater well, the applicant must demonstrate that the activity will not have 'an undue unreasonable effect on waters of the State.'"[185] Annual reporting is required for withdrawals exceeding the statutorily prescribed thresholds.[186]

Maryland (Reasonable Use): Subject to certain exceptions, every groundwater user must obtain a permit in Maryland.[187] Certain domestic uses, agriculture uses of less than 10,000 gallons/day (with some exceptions), and withdrawals of less than 5,000 gallons/day (not including use for a public water system, or uses within a water management strategy area) are exempted.[188] Semi-annual reporting is required for permit holders when a permit is issued for an average withdrawal of more than 10,000 gallons/day.[189]

Massachusetts (Absolute Dominion): In Massachusetts, a permit is required for withdrawals over 100,000 gallons/day.[190] These users may then be required to report their groundwater withdrawals.[191]

Michigan (Restatement Second of Torts § 858): Michigan requires that large quantity water withdrawals be registered.[192] A large quantity withdrawal is defined as a withdrawal with an average totaling over 100,000 gallons/day in any consecutive 30-day period.[193] Registration is not required for owners of a noncommercial well on certain residential properties (either a single-family residential property, or a multi-family residential property not exceeding four residential units on three acres or

[180] LA. STAT. ANN. § 3094(A)(1)-(2) (*see* § 3092(5) for definition of ground water user).
[181] §§ 38:3091-3097.
[182] LA. ADMIN. CODE. TIT. 43, § 103.
[183] ME. STAT. TIT. 38, § 480-C(4).
[184] § 480-B, 9-A(1)-(2).
[185] § 480-D(1).
[186] § 470-D.
[187] MD. CODE ANN. ENVIR. § 5-502.
[188] MD. CODE ANN. ENVIR. § 5-502.
[189] MD. CODE REGS. 26.17.06.07.
[190] MASS. GEN. LAWS CH. 21G, §§ 4, 7.
[191] MASS. GEN. LAWS ch. 21G, § 11.
[192] MICH. COMP. LAWS § 324.32705(1).
[193] § 324.32701(aa).

less) and seasonal withdrawals of 2 million gallons/day in any consecutive 90-day period to supply a common distribution system.[194] Compliance with a permitting system is required for users proposing to withdraw over 2,000,000 gallons/day, and certain other large withdrawals that will be used to supply a common distribution system.[195] Reporting is required for registered users and permit holders.[196] However, the reporting requirements are less stringent for registered users withdrawing less than 1,500,000 gallons/year.[197] If a groundwater dispute has been declared, liability is imposed on the owner of a high-capacity well, in which case, the owner must provide compensation "if there is a failure or substantial impairment of a small-quantity well" and either "the failure or substantial impairment was caused by the groundwater withdrawals of the high-capacity well" or if the small-quantity well was constructed before or after a certain date.[198] A high-capacity well is defined as "1 or more water wells associated with an industrial or processing facility, an irrigation facility, or a farm that, in the aggregate from all sources and by all methods, have the capability of withdrawing 100,000 or more gallons of groundwater in 1 day."[199] A small-quantity well is defined as "1 or more water wells of a person at the same location that, in the aggregate from all sources and by all methods, do not have the capability of withdrawing 100,000 or more gallons of groundwater in 1 day."[200]

Minnesota (Correlative Rights): Minnesota uses a permitting and reporting system to manage groundwater withdrawals, subject to certain exemptions. Under the minimum use exemption, a permit is not needed for withdrawals of less than 10,000 gallons/day, so long as the amount withdrawn does not exceed 1 million gallons/year.[201] Additionally, a well is exempt if the water is used to supply the domestic needs of less than 25 people.[202] However, an exempt well may still be required to obtain a permit if it is located in a groundwater management area.[203] A permit holder must annually report the total amount of water that was appropriated.[204] Additional requirements are placed on proposed withdrawals that will exceed 2 million gallons/day for consumptive use. Legislative approval is needed, along with a determination from DNR that there are adequate resources.

Mississippi (Absolute Dominion): A permit is required for all withdrawals,[205] except those made for domestic uses.[206] However, the Board may require permits for exempt wells in a water caution area for withdrawals of water in excess of 20,000 gallons/day.[207] Annual reporting is required for owners and operators of wells that withdraw over 20,000 gallons/day.[208]

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[194] *See* § 324.32705(2).
[195] § 324.32723(1)(a).
[196] § 324.32702(1).
[197] § 324.32707(8).
[198] § 324.31706.
[199] § 324.31701(k).
[200] § 324.31701(q).
[201] MINN. STAT. § 102G.271.
[202] § 102G.271.
[203] § 103G.281.
[204] *Id.*
[205] MISS. CODE ANN. § 51-3-5.
[206] § 51-3-7.
[207] § 51-3-7.
[208] 11-1 MISS. CODE R. § 1.4(E)(2).

Missouri (Reasonable Use): Missouri regulates "major water users." State statute defines a major water user as one with a capacity to withdraw at least 70 gallons/minute or 100,000 gallons/day.[209] These users must register their wells prior to making a withdrawal.[210] Reporting is required for registered wells. The failure of a major water user to register their withdrawals is a nuisance under state law.[211]

Montana (Prior Appropriation): Montana regulates withdrawals of large quantities of groundwater by exempting smaller withdrawals. Every new use is required to obtain a permit prior to construction.[212] Exempt wells are defined as those outside of a stream depletion zone with a maximum pumping rate of 35 gallons/minute and a maximum volume of 10 acre-feet/year,[213] so long as the water is used for domestic, irrigation, stock, or industrial purposes.[214] However, exempt wells may still need a permit to appropriate groundwater in a controlled groundwater area.[215] The combined appropriation by multiple wells exceeding 10 acre-feet/year requires permit, regardless of flow rate.[216] Additional requirements are imposed on appropriations of 4,000 or more acre-feet/year and 5.5 or more cubic-feet/second. These appropriators must prove the regular permit criteria,[217] and that the use of water is reasonable.[218] Appropriations greater than 3,000 acre-feet/year require legislative approval, unless the water will be used for irrigating croplands owned and operated by the applicant.[219]

Nebraska (Reasonable Use/Correlative Rights): Nebraska only regulates large quantity groundwater withdrawals in special management areas. All wells in these areas must have a permit, except for single water wells designated and built to pump 50 gallons/minute or less.[220]

Nevada (Prior Appropriation): Nevada regulates large quantity groundwater withdrawals through a permitting process by exempting certain smaller wells. Unless exempt, a permit is required for all groundwater withdrawals.[221] An exempt well is a domestic well diverting less than 2 acre-feet/year, with a flow rate below 1,800 gallons/day, and serving not more than three single-family dwellings.[222]

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[209] MO. REV. STAT. § 256.400(4).
[210] § 256.410.
[211] § 256.415.
[212] MONT. CODE ANN. § 85-2-301(1).
[213] § 85-2-306(3)(a)(iii).
[214] Water Policy Interim Committee, Jason Mohr, Final Report to the 66th Montana Legislature (Draft), *The Exemption at 45: A Study of Groundwater Wells Exempt From Permitting* 2 (July 2018).
[215] § 85-2-306(2).
[216] § 85-2-306(3)(a)(iii).
[217] § 85-2-311(3)(a).
[218] Factors to consider when evaluating reasonableness can be found at § 85-2-311(3)(b).
[219] § 85-2-317.
[220] NEB. REV. STAT. § 46-735(1).
[221] NEV. REV. STAT. § 533.325.
[222] § 534.315(8).

New Hampshire (Reasonable Use): New Hampshire uses a registration and reporting system to regulate smaller groundwater withdrawals,[223] but imposes an additional permitting scheme on large groundwater withdrawals. A large groundwater withdrawal is statutorily defined as any withdrawal of 57,600 gallons/day, except for short-term uses.[224] Approval from the Board is needed for large groundwater withdrawals.[225] Notice of these withdrawals must be provided to "the governing bodies of each municipality and each supplier of water within the potential impact area of the proposed withdrawal."[226] The Board is required to ensure that the proposed withdrawal will not have an "unmitigated impact."[227] Many of the factors that the Board is required to analyze involve consideration of the interconnection between groundwater and surface flows.

New Jersey (Reasonable Use or Correlative Rights): New Jersey regulates groundwater withdrawals that exceed a certain threshold. Registration is required for any well with the capacity to divert over 100,000 gallons/day, but that diverts less.[228] A permit is required for users withdrawing over 100,000 gallons/day for a period of more than 30 days in a 365 consecutive day period.[229] The maximum diversion quantity will be specified in the permit.[230] Both registered users and permit holders must report.[231]

New Mexico (Prior Appropriation): New Mexico regulates groundwater withdrawals by designating areas as declared groundwater basins, and then by imposing a permitting scheme in these areas.[232] The entire state has been designated as a declared groundwater basin. While permit applications are presumptively granted for minimal domestic uses, these uses are not exempted from complying with the state's permitting requirements.[233] A domestic use is defined as the irrigation of one acre or less of non-commercial land and other domestic uses.[234]

New York (Reasonable Use): New York regulates withdrawals over a certain threshold with a permitting system. A permit is required for all wells with a capacity to withdraw at least 100,000 gallons/day.[235] Annual reporting is required for permit holders and for any user withdrawing groundwater for agriculture purposes at an average rate of over 100,000 gallons/day in any consecutive 30-day period.[236]

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[223] Registration and reporting are required for users withdrawing over 20,000 gallons/day (averaged over a 7-day period) or over 600,000 gallons over any 30-day period. N.H. REV. STAT. ANN. § 488:3 (registration). § 488:6 (reporting).

[224] § 485-C:2(IX-a). Short-term use is defined as "the temporary, non-routine withdrawal of groundwater at a specific geographical location over a period of one year or less." § 485-C:2(IXIII-b).

[225] § 485-C:21(II).

[226] § 485-C:14-a.

[227] Factors found at § 485-C:32(V-c).

[228] N.J. ADMIN. CODE § 7:19-2.18.

[229] N.J. STAT. ANN. §§ 58:1A-5(a), 58-1A-6, 58:1A-7(a).

[230] § 58:1A-8(b).

[231] *See* §§ 58:1A-8(d) 7:19-2.14(a) for permits and § 7:19-2.18(b) for registered wells.

[232] N.M. STAT. ANN. § 72-12-3(A).

[233] N.M. CODE R. § 19.27.5.9(D).

[234] N.M. STAT. ANN. § 72-12-1.1.

[235] N.Y. ENVTL. CONSERV. § 15-1501.

[236] § 15-1504.

North Carolina (Reasonable Use): All withdrawals of at least 100,000 gallons/day must be registered.[237] A permit is required in order to make withdrawals in excess of 100,000 gallons/day in a capacity use area.[238] The groundwater user is then subject to more frequent reporting requirements. If an area is designated as a capacity use area, the Commission is required to adopt "provisions establishing a range of prescribed pumping levels or maximum pumping rates."[239]

North Dakota (Prior Appropriation): A permit is required for all withdrawals, unless exempted.[240] Exempt uses include: domestic uses of less than 12.5 acre-feet/year;[241] livestock uses of less than 12.5 acre-feet/year; and fish wildlife, or other recreational uses of less than 12.5 acre-feet/year.[242] Annual reporting is mandatory.[243]

Ohio (Restatement Second of Torts § 858): Registration is required for all facilities with a capacity to withdraw at least 100,000 gallons/day.[244] A permit is required for withdrawals resulting in the consumptive use of an average of more than 2 million gallons/day over a 30-day period.[245] Annual reporting is required for both registered users[246] and permit holders.[247]

Oklahoma (Reasonable Use/Correlative Rights): Oklahoma regulates large withdrawals by requiring a permit for all withdrawals, and by then exempting smaller amounts for certain uses.[248] Domestic uses are exempted,[249] defined as uses for household purposes, for farm and domestic animals up to normal grazing capacity of the land and for irrigation of three acres or less.[250] The maximum amount of groundwater that can be withdrawn is the user's proportionate share of the maximum annual yield (MAY)[251] allocated to the landowner on a per-acre basis.[252] An annual report of the amount used is required for all permit holders.[253]

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[237] N.C. GEN. STAT. § 143-215.22H.

[238] § 143-215.15.

[239] § 143-215.14.

[240] N.D. CENT. CODE § 61-01-03.

[241] A domestic use is defined as a use of water by a single individual, family, or household (includes irrigation of land not exceeding 5 acres) for non-commercial purposes. § 61-04-01.1(4).

[242] § 61-04-02.

[243] John Patch, *North Dakota Water Rights Administration*, N.D. STATE WATER COMM'N, https://westernstateengineers.files.wordpress.com/2015/10/patch2014fall.pdf (last visited Mar. 7, 2021).

[244] OHIO REV. CODE ANN. § 1521.23(A).

[245] § 1521.23.

[246] § 1521.23(C).

[247] § 1521.30.

[248] OKLA. STAT. TIT. 82, § 1020.7; OKLA. ADMIN. CODE § 785:30-1 and -2.

[249] § 1020.3; *see* OKLA. ADMIN. CODE § 785:30-1 and -2 for what uses are included.

[250] § 1020.1(2).

[251] *See* § 1020.5.

[252] *Id.*

[253] § 1020.12; OKLA. ADMIN. CODE § 785:30-5-9.

Oregon (Prior Appropriation): Oregon regulates large withdrawals by requiring a permit for all withdrawals,[254] and then by exempting smaller amounts and certain uses. Exemptions from the permitting process include: domestic uses up to 15,000 gallons/day, stock watering, lawn watering up to half an acre, and small industrial or commercial uses up to 5,000 gallons/day.[255] The Department may require any groundwater user, either permitted or exempt, to submit information about the well use.[256]

Pennsylvania (Prior Appropriation): Pennsylvania uses a registration and reporting system to track large quantity withdrawals. Registration is required for all facilities that withdraw or use more than 10,000 gallons/day over a 30-day period.[257] Additionally, registration is required for users of any amount of groundwater in critical water planning areas.[258] Registered users must annually report their withdrawals and use.[259] A permit is required for all new or increased withdrawals of 10,000 gallons/day in the Delaware or Susquehanna River basins.

Rhode Island (Absolute Dominion): Registration is required for the construction of the well, but not for the withdrawal. Wells constructed for domestic consumption or personal farming use are exempt.

South Carolina (no common law): South Carolina generally requires all wells to register and report.[260] Additionally, South Carolina imposes a permitting scheme in capacity use areas for withdrawals over 3,000,000 gallons/month.[261]

South Dakota (Prior Appropriation): A permit is required for any well, with certain exemptions.[262] Domestic uses are exempted,[263] defined as a withdrawal that does not exceed 18 gallons/minute or a peak diversion rate of 25 gallons/minute for individual farm/household use, or irrigation of a non-commercial area of one acre or less.[264] An application for a "large scale appropriation" (withdrawal of groundwater in excess of 10,000 acre-feet/year) must be presented to the legislature by the Board for approval.[265] No volume of groundwater withdrawn may be greater than three acre-feet/year (does not apply to permits to appropriate water for irrigation from the Missouri River). Limits have been set for certain uses. If water is to be used for irrigation, the rate cannot exceed one cubic-foot/second for

[254] OR. REV. STAT. § 537.140 says what must be included in permit application. *See* § 537.615 for permit application requirements.
[255] § 537.545.
[256] § 537.543(3).
[257] 25 PA. CONS. STAT. § 110.201.
[258] *Id.*
[259] § 110.301.
[260] S.C. CODE ANN. § 49-5-20.
[261] § 49-5-60.
[262] S.D. CODIFIED LAWS § 46-1-15.
[263] § 46-5-8.
[264] § 46-1-6(7).
[265] § 46-5-20.1.

each 70 acres, and the volume can't exceed two acre-feet/acre on land for a specified time each year.[266] For domestic uses, the rate cannot exceed 25 gallons/minute.[267]

Tennessee (Reasonable Use and/or Correlative Rights): Registration is required for withdrawals of 10,000 gallons or more on any day from any water source.[268] Certain groundwater uses are exempted (agriculture, emergency uses, nonrecurring uses, or water bought from a utility/industry).[269] Registered users must report their withdrawals.

Texas (Absolute Dominion): Texas has allocated the authority to manage large groundwater withdrawals to local groundwater conservation districts (GCDs). A permit is required for large withdrawals in these areas. However, GCDs cannot regulate wells extracting less than 25,000 gallons/day, wells supplying the domestic needs of 10 or less families on more than 10 acres, among other exceptions.[270] Otherwise, there are no state-wide registration, permitting, or reporting requirements. Texas is the only state (outside of GCDs) that still adheres to the English rule of absolute ownership in its traditional form. Thus, an appropriator can take as much water as they'd like and put it to any use without incurring liability, regardless of any harmful effects that the pumping may have on a neighboring landowner.[271] This is problematic because it results in practically unregulated pumping, which could potentially undercut conservation efforts in other states. Furthermore, the inability of GCDs to regulate smaller withdrawals could result in detrimental effects on the groundwater if the impact of those wells are considered in the aggregate.

Utah (Prior Appropriation): Without exception, a permit is required for all groundwater withdrawals in Utah.[272] The State Engineer can set limits on maximum annual withdrawals in areas where water management plans have been issued.[273]

Vermont (Correlative Rights): Vermont regulates groundwater withdrawals over a certain threshold by using a permitting and reporting system. A permit is required for withdrawals over 57,600 gallons/day (40 gallons/minute for 24 hours). Annual reporting is required for permit holders and for commercial and industrial uses that have a monthly average of 20,000 gallons/day.

Virginia (Reasonable Use): Virginia has enacted a permitting system in groundwater management areas for withdrawals of at least 300,000 gallons in any 30-day period.[274] Every user withdrawing an

[266] § 46-5-6.
[267] § 46-1-6(7).
[268] TENN. CODE ANN. § 69-7-304.
[269] *ID.*
[270] TEX. WATER CODE ANN. § 36.117(B).
[271] Sipriano v. Great Springs Water of America, 1 S.W.3d 75 (Tex. 1999).
[272] UTAH CODE ANN. § 73-3-1.
[273] § 73-5-15.
[274] VA. CODE ANN. § 62.1-258.

average of 10,000 gallons/day (or who withdraws over one million gallons/month for irrigation) must submit an annual report.[275]

Washington (Prior Appropriation): Washington regulates groundwater withdrawals by requiring that every appropriator apply for and receive a permit,[276] subject to certain exemptions. Permit holders must then report their usage. Exemptions from the permitting process include domestic and industrial uses of less than 5,000 gallons/day, groundwater used for irrigating non-commercial areas less than half an acre, and stock watering.[277] However, the Department of Ecology may still require exempt users to submit information about their water usage.

West Virginia (Reasonable Use): West Virginia requires all large quantity users to register their withdrawals.[278] A large quantity user is defined as "any person who withdraws over 300,000 gallons of water in any 30-day period," excluding water withdrawn for farm use.[279]

Wisconsin (Restatement of Torts § 858): There is a general set of requirements for all wells, and additional requirements imposed on high-capacity wells in Wisconsin. A high capacity well either has the capacity to withdraw more than 100,000 gallons/day or, when taken with all of the other wells on the same property, has a capacity to withdraw more than 100,000 gallons/day.[280] Residential wells and fire protection wells are excluded from this definition,[281] with residential wells being those with a pump capacity of 100,000 gallons/day or less and used primarily to supply water to a single-family or multifamily home.[282] Registration is required for new and existing high capacity wells.[283] Additionally, high capacity wells "with a water loss of more than two million gallons per day must also comply with the standards in Wis. Stat. § 281.35."[284] A permit is required for a well that proposes to make consumptive withdrawals at an average of more than two million gallons/day in any 30-day period.[285] Annual reports are required for high capacity wells.[286] For high capacity wells that are located in a groundwater protection area, have a water loss of more than 95% of the amount of water withdrawn, or potentially have a significant environmental impact on a spring, the DNR must review the application for the well.[287] In 2011 Wisconsin Supreme Court held that Wisconsin's permitting framework "provides the DNR with the discretion to undertake the environmental review it deems necessary for all proposed high capacity wells, including the authority and a general duty to consider

[275] 9 VA. ADMIN. CODE §§ 25-200-30, 25-200-40.
[276] WASH. REV. CODE § 90.44.050.
[277] § 90.44.050.
[278] W. VA CODE § 22-26-3(C).
[279] § 22-26-2.
[280] WIS. STAT. § 281.34(1)(B).
[281] *Id.*
[282] WIS. STAT. § 281.34(1)(EM).
[283] PAUL G. KENT, WISCONSIN WATER LAW IN THE 21ST CENTURY: UNDERSTANDING WATER RIGHTS AND REGULATIONS 177 (2013).
[284] *Id.* at 181.
[285] § 281.35.
[286] WIS. ADMIN. CODE NR § 856.30(2).
[287] WIS. STAT. § 281.34(4)(A).

the environmental impact of a proposed high capacity well on waters of the state" under Wisconsin's public trust doctrine."[288] However, there is a conflict between the implied duties of environmental protection stated by the Wisconsin Supreme Court in *Lake Beula* and Wisconsin Act 21, which was enacted just prior to the *Lake Beula* decision.[289] In 2016, Wisconsin Attorney General Brad Schimel issued an opinion stating that the Wisconsin Supreme Court in *Lake Beula* did not interpret or apply Act 21 and "much of the Court's reasoning in *Lake Beula*. . . is no longer controlling."[290] In 2020, the current Wisconsin Attorney General, Josh Kaul, rescinded Schimel's 2016 opinion,[291] after a circuit court held *Lake Beulah* still governed DNR review of high-capacity well permit applications.[292] The circuit court's decision is currently pending before the Wisconsin Supreme Court for resolution.[293]

Wyoming (Prior Appropriation): Registration and permitting procedures must be followed, without exception. Wells for stock and domestic uses may not withdraw at a rate greater than 25 gallons/minute.[294] The State Board of Control may designate areas and impose water restrictions where: (1) the use of groundwater is approaching a use equal to the current recharge rate; (2) groundwater levels are declining or have declined excessively; (3) conflicts between users are occurring or are foreseeable; (4) waste is occurring or may occur; or (5) other conditions exist or may arise that require regulation to protect the public interest.[295]

Great Lakes Compact: In addition to state laws, large quantity groundwater withdrawals in certain states may be subject to additional regulations based on the state's status as a party to the Great Lakes-St. Lawrence River Basin Compact (Public Law 110-342). The Compact is a legally binding agreement among the eight states that border the Great Lakes (Illinois, Indiana, Michigan, Minnesota, New York, Ohio, Pennsylvania, and Wisconsin) and two Canadian provinces (Ontario and Quebec).[296] Each of the state legislatures has ratified the compact, and it was signed into federal law in 2008.[297]

The Great Lakes Compact is an international agreement as to how new or increased surface water or groundwater withdrawals from the Great Lakes basins will be regulated. The Compact recognizes that "the landscape . . . constitute[s] a single system that must be managed as such" in order to preserve the Great Lakes.[298] Under the Compact, each party has signaled their commitment to "manage water

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[288] Lake Beulah Management District v. DNR, 2011 11 54, ¶ 39

[289] 2011 Wisconsin Act 21 states that "No agency may implement or enforce any standard, requirement, or threshold, including as a term or condition of any license issued by the agency, unless that standard, requirement or threshold is explicitly required or explicitly permitted by statute or by a rule that has promulgated."

[290] State of Wis. Dep't of Justice, OAG-01-16, Opinion Letter on the Application of Wis. Stat. § 227.10(2m) to the Issuance of High-Capacity Groundwater Well Withdrawal Permits ¶ 16 (May 10, 2016).

[291] State of Wis. Dep't of Justice, Opinion Letter on the Continuing Validity of OAG-01-16 (May 1, 2020).

[292] *See* Clean Wisconsin, Inc. v. DNR, No.16-CV-2817 (Wis. Cir. Ct. Dane Cty.) (consolidated).

[293] *See* Clean Wisconsin, Inc. v. DNR, Nos. 2016AP1688, 2016AP2502, unpublished certification (WI App Jan. 16, 2019).

[294] WYO. STAT. § 41-3-907.

[295] WYO. STAT.§ 41-3-912(A).

[296] *Who Owns the Water?*, *supra* note 36, at 9.

[297] *Id.*

[298] *Water Law Explanation*, MICH. DEP'T. OF ENV'T. QUALITY, https://www.michigan.gov/documents/deq/Water_Law_Explanation_626093_7.pdf (updated June 22, 2018).

within their jurisdictions similarly and annually report their water use and regulation to a central body."[299] The default threshold for regulating withdrawals is set at 100,000 gallons/day, averaged over a 90-day period.[300] Council approval is required for any new or increased consumptive use of 5 million gallons/day or greater averaged over a 90-day period.[301]

III. CONCLUSION

Withdrawing large amounts of groundwater is essential for agricultural irrigation. However, these large withdrawals have the potential to over appropriate the underlying aquifer. With regulatory authority over groundwater allocated to the several states, a piecemeal framework works to protect the aquifers. Several states have enacted comprehensive regulatory regimes over these high-capacity wells. With varying degrees of efficacy, these frameworks help the state to manage and track large quantity withdrawals. Protection of groundwater supplies from over appropriation by high-capacity wells is a collective concern and responsibility.

[299] *Id.*
[300] *Who Owns the Water?*, *supra* note 36, at 9.
[301] *Id.*

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High-Capacity Wells: A Survey of Groundwater Withdrawal Rights and Regulations

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Water365, LLC.

Groundwater represents roughly 30% of the world's freshwater supply, and 2.5 billion people depend solely on groundwater to meet their daily water needs. In the United States, around 20% of total freshwater withdrawals come from groundwater sources. Agricultural irrigation is currently the largest use of groundwater in the United States. To satisfy demand, high-capacity wells that have the ability to withdraw water over an established daily threshold are often employed. These wells are capable of achieving withdrawal rates that exceed natural groundwater recharge rates and can disrupt the hydrological cycle as a result. Therefore, unregulated groundwater withdrawals through the use of high-capacity wells can become unsustainable.

Like the regulation of rights to use surface water, regulation of groundwater rights and high-capacity wells has largely been left to states. Although states typically regulate surface water according to two common law doctrines (riparianism and prior appropriation), the regulations of groundwater has been more complex. Currently, there are five common law doctrines that states have used to regulate groundwater: absolute ownership, American reasonable use, correlative rights, the Restatement (Second) of Torts, and prior appropriation. However, few states apply any of these doctrines in a uniform way. As a result, groundwater management in the United States has been highly fragmented.

The following chart provides a brief summary of the common law doctrine applied to groundwater management in each state, and the regulatory frameworks in place for groundwater withdrawal through the use of high-capacity wells. Note, that the common law doctrine that some states adhere to is unclear. Furthermore, some states are not able to be neatly categorized as following a single doctrine. We selected the doctrine(s) that were most clear in the state's legislation and case law. The applicable common law doctrine may differ in special management areas.

State	Regulating Agency/Department	Groundwater Common Law Doctrine	Special Management Areas for Groundwater Supply	Maximum Withdrawal Amount	Registration	Permitting	Exceptions to Registration/Permitting	Reporting	Exceptions to Reporting Requirements	Footnotes
Alabama										
Alabama Water Resources Act (Ala. Code § 9-10B)	Alabama Office of Water Resources (within the Department of Economic and Community Affairs)	Reasonable Use	Capacity stress area	No limit (exception = capacity stress areas)	All public water systems Users with a capacity to withdraw at least 100,000 gallons/day	N/A	Temporary withdrawals may be eligible to be exempt from registering	Registered user must submit annual report	Users outside of capacity stress areas with a withdrawal capacity of less than 100,000 gallons/day	
Alaska										
Alaska Water Use Act (Alaska Stat. § 46.15) *Water Management Act (Alaska Admin. Code tit. 11, § 93)*	Alaska Department of Natural Resources	Prior Appropriation	Critical water management area	N/A	N/A	Permit required when withdrawal is a "significant amount"	(1) 5,000 gallons for 1 day from a single source (2) 500 gallons from a single source for more than 10 day/year (3) 30,000 gallons/day non-consumptive use from a single source	Well meters generally required for large commercial wells (greater than 30,000 gallons/day)	Smaller domestic wells	
Arizona										
Arizona Groundwater Management Act (Ariz. Rev. Stat. Ann. tit. 45)	Arizona Department of Water Resources	Reasonable Use[1]	Active management areas (AMA) Irrigation non-expansion areas (INA)[2]	AMA/INA: see local water management plan for amount (goal of most is "safe yield")	N/A	Permit required for any withdrawal in an AMA or INA	Special management areas: Exempt wells (withdrawal for non-irrigation use from a well with a pump capacity of less than 35 gallons/minute), certain existing irrigation uses grandfathered in	Required for non-exempt wells in special management areas AMA: required (see AMA water management plan for specific requirements) INA: required for all users using water for irrigation purposes, and required for all users withdrawing more than 10 acre-feet/year	Exempt wells (pump capacity of more than 35 gallons/minute) AMA: see local land management plan INA: irrigators of 10 acres or less	[1] Exception = doesn't apply in special management areas. [2] INAs subject to either the specific rules of the basin or all irrigation is prohibited unless the area was irrigated within 5 years before the adoption of the rule.
Arkansas										
Arkansas Ground Water Management and Protection Act (Ark. Code Ann. § 15-22: Water Resources)	Arkansas Natural Resources Commission	Reasonable Use[1]	Critical groundwater areas	Amount that can be beneficially used on one's own property	Required for all withdrawals	May be required in critical groundwater areas	Withdrawals for domestic uses Withdrawals from wells with a maximum potential flow rate of less than 50,000 gallons/day Certain existing uses grandfathered in (exception = an equally or less costly substitute exists)	Annual reports on the water usage from October 1st to September 30th of the next year required for all users	None	[1] There is also support for Correlative Rights in the state's common law. The eastern version of Correlative Rights differs from the doctrine as it was originally developed in California. In Arkansas, "reasonableness" is determined with respect to other landowners. A water right gives "each riparian owner . . . an equal right to make reasonable use of water subject to the equal rights of other owners to make reasonable use." Lingo v. City of Jacksonville, 258 Ark. 63, 65 (Ark. 1975).
California										
Cal. Water Code[1]	Groundwater is managed at the local level and no single state agency has authority	Reasonable Use and Correlative Rights	State divided into 515 basins (larger areas classified as medium or high priority basins)	Courts can limit the rights of a pumper to extract groundwater in order to protect the water supply and prevent overdraft	N/A	No default state groundwater withdrawal permitting requirements (see the permitting regime established for a particular basin by the local groundwater sustainability agency)	N/A	No statewide reporting requirements	N/A	[1] *See generally* Division 2: Water, Division 6: Conservation, Development, and Utilization of State Water Resources.

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Colorado Colorado Groundwater Management Act (Colo. Rev. Stat. Ann. § 37-90)	Colorado Division of Water Resources Colorado Ground Water Commission (regulates groundwater within designated basins)	Cal. Water Code [FN = *See generally* Division 2: Water, Division 6: Conservation, Development, and Utilization of State Water Resources]	Designated basins	Amount specified in permit[2]	N/A	Permit required regardless of where the well is located[3, 4]	Designated basins = Small capacity wells: (1) Wells not exceeding 50 gallons/minute and used for no more than 3 single-family dwellings (exception = does not include irrigation on more than 1 acre of land) (2) Livestock wells not exceeding 50 gallons/minute and used for watering livestock (3) Wells used in 1 commercial business not exceeding 50 gallons/minute (4) Certain wells used for observation purposes (5) Wells used exclusively for firefighting purposes (6) Certain monitoring wells Nondesignated basin = Exempt wells: flow rates of 15 gallons/minute or less for in-house use and outside use only for domestic animals	Reporting required	N/A	[1] Colorado has complicated water system, with rights and procedures differing based on how the groundwater is classified and where it is located. Groundwater classifications are: (1) Tributary groundwater: This is the "default" and is groundwater that is tributary to a natural stream. (2) Designated groundwater: This is groundwater in areas that have been declared "designated basins." (3) Nontributary groundwater: Groundwater that is located deep in an aquifer that is outside of a designated basin, that is not tributary to surface flows. (4) Not nontributary groundwater: Groundwater in the Denver Basin aquifers with slightly more connection to surface water than nontributary groundwater, but not located within a designated basin. [2] For nontributary groundwater, the State Engineer allocates the total available groundwater based on the 100-year aquifer life, with each permit holder being allowed to deplete the aquifer by 1% each year. [3] In a non-designated basin, the permit is a "non-exempt well permit." In a designated basin, it is a "large capacity well permit." [4] For tributary groundwater, the water right must first be adjudicated in Water Court.
Connecticut Conn. Gen. Stat. tit. 22a, ch. 446i (Water Resources)	Connecticut Department of Energy and Environmental Protection	Absolute Dominion	Aquifer protection areas[1]	N/A	Required for certain existing diversions (diversions maintained prior to or on July 1, 1982)	Required for all withdrawals over 50,000 gallons/day	Well(s) where withdrawal will not exceed 50,000 gallons during any 24-hour period Certain existing diversions grandfathered in (diversions existing and registered before July 1, 1983)[2]	Annual reporting required for registered wells Annual reporting required for permit holders putting water to consumptive use (non-consumptive use permit holders should consult their permit for reporting requirements)	None	[1] Focused on groundwater quality/pollution. [2] § 22a-377(a) for other exemptions.
Delaware Del. Code Ann. tit. 7 (Conservation), ch. 60 (Environmental Control) Del. Admin. Code tit. 7 (Natural Resources and Environmental Control), § 7303 (Regulations Governing the Allocation of Water)	Delaware Division of Water Resources	Correlative Rights	Groundwater management zones[1]	For permitted new withdrawals, a pumper can use up to 20 acre-inches/year, but not more than 10 acre-inches/month *See* Del. Admin. Code § 7303 for groundwater withdrawal rate limits	N/A	Required for all withdrawals over 50,000 gallons/day	N/A	Annual reports on water usage required for permit holders	Permit holders for irrigation only need to report from Mar. to Nov.	[1] Focused on groundwater quality/pollution.

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Florida Florida Water Resources Act of 1972 (Amended by 1997 Water Act) (Fla. Stat. §§ 373.302 - 373.342: Regulation of Wells) Fla. Admin. Code ch. 40A-E (Water Management Districts)	Water Management Districts (5 local governing bodies), with the Florida Department of Environmental Protection providing general supervision and oversight	Reasonable Use	Water resource caution areas (in some WMDs)	"Reasonable-beneficial use" ("use of water in such a quantity as necessary for economic and efficient utilization for a purpose and in such a manner that is both reasonable and in the public interest") Permit may contain limits on withdrawal amounts if the aquifer level time table is below that set by the Department of Environmental Protection	N/A	Every WMD requires groundwater users to obtain a permit for consumptive uses of water	Domestic consumption of water by individual users Additional exemptions vary based on WMD[1]	Annual reporting required for permit holders authorized to withdraw more than 100,000 gallons/day	Groundwater users exempt from permitting requirements Permit holders authorized withdraw 100,000 gallons/day or less	[1] *See* Fla. Admin. Code 40 A-E
Georgia Groundwater Use Act of 1972 (Ga. Code Ann. § 12-5-90) Ga. Comp. R. & Regs 12-5-3 (Wells and Drinking Water)	Georgia Environmental Protection Division (within the Georgia Department of Natural Resources)	Absolute Dominion	N/A	N/A	N/A	Required for any user who withdraws more than 100,000 gallons/day for any purpose Note: special permitting rules apply to farms	Withdrawals of less than 100,000 gallons/day	Permittees must submit a semiannual statement on the nature and quantity of their use, an annual report of their water use, and a progress report every 5 years that details water conservation techniques and supplemental information ;	Farm uses (includes irrigation for farm purposes)	
Hawaii State Water Code (Haw. Rev. Stat. ch. 174C)	Hawaii Commission on Water Resources Management	Correlative Rights	Water management areas	N/A	Required for wells in existence before State Water Code was adopted	Well construction permit required everywhere Water *use* permit required in water management areas	Domestic consumption for individual users	Monthly reports required for all wells[1]	None	[1] Salt water wells can report annually
Idaho Ground Water Act of 1951, as amended (Idaho Code tit. 42: Irrigation and Drainage - Water Rights and Reclamation) Idaho Admin. Code tit. 37: Dept. of Water Resources	Idaho Department of Water Resources	Prior Appropriation	Critical groundwater areas	Amount that can be beneficially used Note: Irrigation greater than 1 cubic-foot/second per 50 acres is prohibited without approval from IDWR	N/A	Required for all withdrawals	Domestic wells: use of water for individual use, irrigation of less than 1/2 acre of land, and any other associated purpose, so long as not more than 13,000 gallons/day, and any other use so long as the total use is not more than .04 cubic-feet/second or 2,500 gallons/day	Required for permittees	Exempt uses	
Illinois Illinois Water Use Act (1983) (525 Ill. Comp. Stat. 45)	County Soil and Water Conservation Districts (overseen by the Illinois Department of Agriculture)	Reasonable Use	Regulated recharge areas[1]	Limits may be placed upon wells with a capacity of 100,000 gallons/day or more if the District has investigated and recommended a limit State regulators may restrict withdrawals in certain counties	Required for high capacity wells (facilities with a capacity to withdraw at least 100,000 gallons/day)	Required for special jurisdictions (any town where the Iroquois River flows, or any town with more than 100,000 people where the Mackinaw River flows)	High capacity wells	Annual report to the Illinois Water Inventory Program for high capacity wells	Wells with pump capacity of less than 100,000 gallons/day	[1] Focused on groundwater quality/pollution.
Indiana Ind. Code § 14-25-3 (Water Rights; Ground Water)	Indiana Department of Natural Resources	Absolute Dominion	Restricted use areas	May be limits if the Director declares a groundwater emergency if small quantity users (less than 100,000 gallons/day) have a cause of action	Required for all facilities with a capacity to withdraw at least 100,000 gallons/day	Required in restricted use areas for all new users or those withdrawing more than 100,000 gallons/day	Wells with a pump capacity of less than 100,000 gallons/day	Annual reporting required for owners of registered facilities	None	

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Iowa Iowa Code ch. 455A (Water Rights), ch. 455E (Groundwater Protection) Iowa Admin. Code tit. 567 (Environmental Protection Commission)	Iowa Department of Natural Resources	Correlative Rights	Protected source areas	Each aquifer has a different limit on the amount or rate of withdrawal	N/A	Required for withdrawals that exceed 25,000 gallons/day[1]	Withdrawals less than 25,000 gallons/day	Annual reporting required	None	[1] Additional permitting requirements for high-capacity wells that have an expected pump capacity of 500 gallons/minute or more.
Kansas Kansas Water Appropriation Act (Kan. Stat. Ann. § 82a-701 *et seq*.) Kan. Admin. Regs. tit. 28 (Dept. of Human Health and Env.)	Division of Water Resources (within the Kansas Department of Agriculture)	Prior Appropriation	Intensive groundwater use control areas Local enhanced management areas	Annual authorized quantity (cannot be increased) Local groundwater management districts can impose additional limitations	N/A	Required for all withdrawals	Domestic uses (2 acres or less) Certain existing uses grandfathered in	Annual reporting required	Domestic users	
Kentucky Ky. Rev. Stat. ch. 151 (Geology and Water Resources)	Division of Water (within the Kentucky Energy and Environment Cabinet)	Reasonable Use	N/A	Quantity and rate specified in permit	N/A	Required for facilities with a withdrawal rate of more than 10,000 gallons/day	Domestic uses Agricultural uses (includes irrigation) Withdrawals made at a constant rate with an average withdrawal rate of 10,000 gallons/day or less[1]	Monthly reporting required for permitted withdrawals	Withdrawals exempt from the permitting process	[1] Permit may be required if the withdrawals are made on an irregular basis and at an irregular rate if the water withdrawn represents a significant portion of the available water supply.
Louisiana Water Control Law (La. Stat. Ann. §§ 30:2071 *et seq*.) La. Admin. Code tit. 43 (Natural Resources), Part VI (Water Resources Management), Subpart 1 (Ground Water Management)	Office of Conservation (within the Louisiana Department of Natural Resources)	Absolute Dominion	Areas of groundwater concern	No limit	Required for all wells (new wells and those that have been re-worked) producing more than 50,000 gallons/day	N/A	Wells pumping less than 50,000 gallons/day (owner is not considered a "user")	Monthly reporting required for owners of non-domestic water wells in an area of groundwater concern DNR can require registered wells to submit information	None	
Maine Me. Stat. tit. 38 (Waters and Navigation), ch. 3 (Protection and Improvement of Waters) See specifically: Art. 1-B (Ground Water Protection Program) § 404 Ground Water Rights Art. 4-B (Water Withdrawal Reporting Program) Art. 5-A (Natural Resources Protection Act)	Maine Department of Environmental Protection	Absolute Dominion	N/A	Amount needed for beneficial domestic use at single family home, so long as it doesn't cause harm to another beneficial user	N/A	If withdrawal is within 500 feet of a body of water: withdrawal of at least 75,000 gallons/week or 50,000 gallons/day If withdrawal is over 500 feet from a body of water: withdrawals of at least 216,000 gallons/week or 144,000 gallons/day Required for withdrawal from a significant groundwater well	Public water systems Home domestic supply Agricultural use	Annual usage reports required for those withdrawing more than threshold amount (varies depending on the location of nearby lakes/ponds)[1] Required for withdrawals from certain groundwater sources within 500 feet of a lake or pond Required if the withdrawal is from groundwater greater than 500 feet from certain water bodies and is 50,000 gallons or more on any day (exception = the person making the withdrawal demonstrates that it won't impact any adjacent surface water body)	Proven to the Department's satisfaction that the withdrawal won't impact the adjacent surface water body Nonconsumptive uses Household uses Emergencies	[1] § 470-B for threshold volumes for reporting annually.

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Maryland										
Md. Code Ann., Envir. tit. 5 (Water Resources)	Maryland Department of the Environment	Reasonable Use	Water management strategy areas	Administrative decisions suggest that the Department has an unwritten rule limiting withdrawals to an amount it calculates that belongs to the land or to land under the user's control	N/A	Required for all withdrawals	Certain domestic uses (other than heating/cooling) Agriculture use less than 10,000 gallons/day (with some exceptions) Groundwater withdrawals of less than 5,000 gallons/day (does not include use for public water systems, or uses within a water management strategy area)	Semi-annual reporting required for permit holders when permit is issued for an average withdrawal of more than 10,000 gallons/day Annual reporting required for agricultural uses	Users exempt from permitting process	
Massachusetts										
Massachusetts Water Management Act (Mass. Gen. Laws ch. 21G)	Massachusetts Department of Environmental Protection	Absolute Dominion	N/A	No limit	Users withdrawing over 100,000 gallons/day on average during the 5 years prior to January 1986	Required for withdrawals over 100,000 gallons/day	Nonconsumptive uses not factored into calculating the volume withdrawn	Annual reporting required for registered users and permit holders	None	
Michigan										
Natural Resources and Protection Act (Mich. Comp. Laws ch. 324 (Act 451 of 1994))	Michigan Department of Natural Resources	Restatement (Second) of Torts § 858 (Beneficial Purpose Doctrine)	N/A	A reasonable amount up to the point of interfering with a neighbor's reasonable use	Required for owners of prospective new or increased "large quantity water withdrawals" (1 or more cumulative withdrawals of over 100,000 gallons/day average in any consecutive 30-day period)	Required for users proposing to withdraw over 2,000,000 gallons/day	Owners of a noncommercial well on certain residential properties (either a single family residential property, or a multi-family residential property not exceeding 4 residential units on 3 acres or less) (exception = well is a lake augmentation well) Seasonal withdrawal of 2,000,000 gallons/day in any consecutive 90-day period to supply a common distribution system	Annual reporting required for registered users and permit holders	Owner of a farm who submits a water conservation plan under § 32708 User who withdraws less than 1,500,000 gallons in any year is subject to less stringent reporting requirements	
Minnesota										
Minn. Stat. ch. 103A - 114B	Minnesota Department of Natural Resources	Correlative Rights	Groundwater management areas	Non-essential uses may be limited if governor declares a critical water deficiency	N/A Note = Legislative approval is needed if a user plans to appropriate more than 2,000,000 gallons/day for a consumptive use, along with a determination from DNR that there are adequate resources	Facilities that withdraw at least 10,000 gallons/day or 1,000,000 gallons/year (exception = Commissioner can require a permit for wells with a capacity less than this in groundwater management areas)	Water is used to supply less than 25 people's domestic uses	Annual report tracking monthly withdrawals required for permit holders	None	
Mississippi										
Mississippi Commission on Environmental Quality Regulation LW-2 (Surface Water and Groundwater Use and Protection) Miss. Code Ann. tit. 51 (Water, Water Resources, Water Districts, Drainage, and Flood Control) Miss. Admin. Procedures Act Rules tit. 11 (Mississippi Department of Environmental Quality)	Office of Land and Water Resources (within the Mississippi Department of Environmental Quality)	Absolute Dominion[1]	Water use caution area	No limit	N/A	Required for all withdrawals[2]	Water for domestic uses (ordinary household purposes, livestock watering, and irrigation of non-commercial lands) Water withdrawn from a well with a surface casing diameter of less than 6 inches Existing water rights before grandfathered in Note = Board may require permits for exempt wells in in a water caution area for withdrawals in excess of 20,000 gallons/day	Annual reporting required on volume withdrawn over the year for owners of wells that withdraw over 20,000 gallons/day	None	[1] In *Bd. of Supervisors v. Miss. Lumber Co.*, 31 So. 905 (Miss. 1902), Mississippi was categorized as an absolute ownership state, but the court indicated that if faced with the appropriate case, it would instead apply reasonable use rule. [2] Additional permit requirements for wells with a withdrawal capacity in excess of 20,000 gallons/day.

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Missouri Mo. Rev. Stat. § 256.400 *et seq*.	Missouri Department of Natural Resources	Reasonable Use[1]	N/A	No limit	Required for "major water users" (owners of wells with a capacity to withdraw at least 70 gallons/minute or 100,000 gallons/day)	N/A	Water pumped from mines and quarries	Registered users must submit an annual report on their withdrawal/use May be required in water quality protection areas if the State Water Resource Plan requires reporting	None	[1] Missouri follows a modified version of the Reasonable Use rule called Comparative Reasonable Use, which is determined on case-by-case basis and takes into account all relevant facts/circumstances. See *Higday v. Nickolaus*, 469 S.W.2d 859 (Mo. App. 1971).
Montana Montana Water Use Act (Mont. Code Ann. § 85-2-5)	Montana Department of Natural Resources and Conservation	Prior Appropriation	Controlled ground water areas	No limit (exception = may be limits in controlled groundwater areas)	Required for wells that are exempt from the permitting process	Permit required for withdrawals over 35 gallons/minute or that exceed 10 acre-feet/year[1] Note = Appropriations greater than 3,000 acre-feet/year requires legislative approval (exception = appropriations for irrigating croplands owned and operated by applicant.]	Exempt well: well outside of a stream depletion zone with a maximum pumping rate of 35 gallons/minute and a maximum volume of 10 acre-feet/year[2], well in a stream depletion zone with a pumping rate of 20 gallons/minute or less, and a volume less than 2 acre-free/year[3] Existing water rights (appropriations put to beneficial use between 1962-1973) do not require a permit	Well log report must be filed by the driller	N/A	[1] Appropriations of 4,000 or more acre-feet/year and 5.5 or more cubic-feet/second of water may not get permit without proving the regular criteria and that that use of water is reasonable. [2] Permit may still be required to appropriate water in a controlled groundwater area, even if ordinarily exempt. [3] Combined appropriation by 2 or more wells exceeding 10 acre-feet/year requires permit, regardless of flow rate.
Nebraska Groundwater Management and Protection Act (1975) (Neb. Rev. Stat. §§ 46-701, *et seq*.) Neb. Rev. Stat. ch. 61 (Natural Resources)	Natural Resources Districts (local entities, supervised by the Nebraska Department of Natural Resources)	Reasonable Use (Correlative Rights in times of shortage)	Management areas	No limit	Required for all wells constructed after July 1, 2001	Required when pumping will be done for irrigation purposes Required in management areas	No registration required for domestic wells (wells used solely for domestic purposes and built before Sept. 9, 1993) No permit needed in management areas for single water wells designed and built to pump 50 gallons/minute or less (certain other exceptions)	Requirements differ based on the groundwater management plan for each Natural Resources District	N/A	
Nevada Nev. Admin. Code ch. 533 (Adjudication of Vested Water Rights; Appropriation of Public Waters), ch. 534 (Underground Water and Wells)	Nevada Division of Water Resources (within the Department of Conservation and Natural Resources)	Prior Appropriation	Designated basins (State Engineer can further designate areas within these basins as critical management areas)[1]	Withdrawals in designated basins generally limited to "safe yield" (State Engineer may limit to less)	State Engineer has authority to require registration of exempt domestic uses in certain water basins	Required before well is drilled in a designated basin Required before water is used outside of designated basins	Domestic wells (diverts less than 2 acre-feet/year and has a flow rate below 1,800 gallons/day, serving not more than 3 single-family dwellings) Wells existing before July 1, 1983	N/A	N/A	[1] Designation status of basins divided into general categories: (1) Designated areas, where order does not define administrative control (2) Designated, irrigation denied areas (irrigation is not a preferred use in the basins) (3) designated, prefered use areas (certain types of preferred uses) (4) designated preferred uses, irrigation denied areas (orders designate certain uses as preferred, but not irrigation)
New Hampshire Groundwater Protection Act (N.H. Rev. Stat. Ann. ch. 385-C)	New Hampshire Department of Environmental Services	Reasonable Use (the rights are correlative)	N/A	N/A	Users withdrawing over 20,000 gallons/day averaged over a 7-day period or over 600,000 gallons over any 30-day period (registration is in addition to any required permits)	Large groundwater withdrawal (any withdrawal of 57,600 gallons or more in any 24-hour period at a single property)	Emergency withdrawals Withdrawals associated with short-term use	Registered users must report their monthly water use on a quarterly basis	None	

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New Jersey Water Supply Management Act (N.J. Stat. Ann. tit. 58)	New Jersey Department of Environmental Protection	Reasonable Use or Correlative Rights[1]	Areas of critical water supply concern	Maximum diversion quantity set in permit (can modify conditions of existing diversion permit to limit or reduce the quantity of water to the safe or dependable yield)	Required for any user with the capacity to divert over 100,000 gallons/day, but who diverts less	Required for users withdrawing over 100,000 gallons/day for a period of more 30 days in a 365 consecutive day period	Agriculture uses Aquaculture or horticulture uses Certain existing uses grandfathered in	Registered users must annually report their monthly water use Permittees must submit monthly diversion amounts on a quarterly basis	None	[1] New Jersey common law as it pertains to groundwater remains unclear.
New Mexico New Mexico Groundwater Code (N.M. Stat. Ann. § 31-12)	New Mexico Division of Water Resources	Prior Appropriation	Declared groundwater basins (entire state)	Unclear: the rules have been changing and challenged	N/A	*Not required (*See exception)	Required if in declared groundwater basin (*entire state is a declared groundwater basin, so technically yes, a permit is required for all withdrawals) Certain existing uses grandfathered in and have to fill out a form (vested rights with priority dates prior to 1907 as long as they have been for a continuous use and not a 1 time diversion)[1]	Must *meter* if well serves more than 1 household	N/A	[1] Permit applications presumptively granted for minimal domestic uses, but they aren't technically exempted. A domestic use is irrigation of 1 acre or less of non-commercial land and other domestic uses.
New York Water Resources Law (N.Y. Envtl. Conserv. § 15: Water Resources) N.Y. Stat. tit. 6 (Department of Environmental Conservation), ch. V (Resource Management Services), Subchapter E (Water Regulation) Great Lakes Water Conservation and Management Act of 1989 imposes certain additional requirements to water users in the Great Lakes Basin	New York Department of Environmental Conservation	Reasonable Use	Special groundwater protection areas	Permit holders can withdraw amounts that are reasonable to meet proposed use of water	Anyone making a withdrawal of water for agricultural purposes must annually register or report the withdrawal Required in the Great Lakes Basin for withdrawals of 100 gallons/day averaged over a 30-day period or 3,000,000 gallons in a 30-day period	Required for wells with a pump capacity of at least 100,000 gallons/day Required for agricultural irrigation[1]	Withdrawals for fire/public emergency Withdrawals approved from a compact basin commission Existing registered withdrawals for agricultural purposes[2]	Annual reporting required for permit holders, detailing water usage and conservation measures Anyone who withdraws for agricultural purposes over an average of 100,000 gallons/day in any consecutive 30-day period must annually report	None	[1] Certain counties or areas may have imposed more stringent thresholds. [2] *See* § 15-1501 for other exceptions
North Carolina Water Use Act of 1967 (N.C. Gen. Stat. §§ 143-215.11, *et seq.*)	North Carolina Environmental Management Commission (within the Department of Environmental Quality) Division of Water Resources (issues permits) (within the North Carolina Department of Natural Resources and Community Development)	Reasonable Use	Capacity use areas	Limits must be set in capacity use areas on quantity and rate (*see* § 143-215.14)	Required for any withdrawal of at least 100,000 gallons/day	Required for any withdrawal of at least 100,000 gallons/day in capacity use areas	Agricultural-related withdrawals of less than 1,000,000 gallons/day Certain other uses exempt	Registrants required to update withdrawal information every 5 years Permittees must submit a statement on quantity, sources, and nature of use no more frequently than every 30 days Users in capacity use areas must submit monthly reports	None	

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North Dakota N.D. Cent. Code tit. 61 (Waters) N.D. Admin. Code tit. 89 (Water Commission)	State Engineer (assisted by the Water Appropriation Division of the North Dakota State Water Commission)	Prior Appropriation	Source water protection areas[1]	Amount that can be beneficially used (permit cannot be issued in an amount that is more than this) Conditions may be imposed on the permit by State Engineer	N/A	Required for all withdrawals	Domestic uses of less than 12.5 acre-feet/year (use of water by a single individual, family, or household (includes irrigation of land not exceeding 5 acres for non-commercial purposes)[2] Livestock uses of less than 12.5 acre-feet/year Fish, wildlife, or other recreational uses of less than 12.5 acre-feet/year Certain historical uses grandfathered in	Annual reporting required for permit holders	None	[1] Focused on groundwater quality/pollution. [2] Watering a large garden is a domestic use, but it's irrigation when watering more than 5 acres of land. A permit is then needed.
Ohio Ohio Rev. Code Ann. ch. 1521 (Division of Water Resources)	Division of Water Resources (within the Ohio Department of Natural Resources)	Restatement (Second) of Torts § 858 (Beneficial Purpose Doctrine)	Groundwater stress areas	A reasonable amount[1]	Required for all facilities with a capacity to withdraw at least 100,000 gallons/day Required for all water users in a capacity stress area that withdraw more than the amount set by the Division	Required if a facility plans to increase their withdrawal by more than 2,000,000 gallons/day over a 30 day period	Certain registration exceptions applying mostly to public water suppliers	Annual water use reporting required for owners of registered facilities and permit holders	None	[1] *See* § 1521.17 for factors to be considered when making a reasonableness determination
Oklahoma Okla. Stat. § 82-11 (Oklahoma Groundwater Law)	Oklahoma Water Resources Board	Reasonable Use and Correlative Rights	Sensitive sole source groundwater basin	Proportionate share of the maximum annual yield (MAY) allocated to the landowner on a per-acre basis[1]	N/A	Required for all withdrawals[2]	Domestic uses (household purposes, for farm and domestic animals up to normal grazing capacity of the land and for irrigation of land not more than 3 acres)	Annual reporting required for permit holders	None	[1] Maximum annual yield: a determination of total groundwater that can be produced from a basin maintaining safe yield. There are different types of permits, so the maximum amount depends on the type of permit. [2] Different requirements apply based on the type of permit: regular, temporary, provisional temporary, special, limited quantity.
Oregon Or. Rev. Stat. tit. 45, ch. 536 (Water Resources Administration), ch. 537 (Appropriation of Water Generally) Ground Water Act of 1955 (Or. Rev. Stat. § 537.505, *et seq.*)	Oregon Water Resources Department Oregon Water Resources Commission	Prior Appropriation	Groundwater management area	Beneficial use, without waste Permit may impose conditions May be limits in critical groundwater management areas	Required for a pre-Aug. 3, 1955 right	Required for all withdrawals	Domestic uses up to 15,000 gallons/day Stock watering Lawn watering up to 1/2 an acre Small industrial or commercial uses up to 5,000 gallons/day Note = exempt uses still require a permit in designated groundwater management areas[1]	On an honor system not to use more than permit allows Must complete a pump test every 10 years and report results to Commission	None	[1] *See* § 537.545 for other exempt uses
Pennsylvania No statute directly on regulation of the allocation of groundwater resources (*See generally*, Pa. Cons. Stat. § 25-110) Water Rights Act (PL 842, No. 365)	Pennsylvania Department of Environmental Protection	Reasonable Use	Critical water planning areas	N/A	Required for all facilities and operations that withdraw or use more than 10,000 gallons/day over a 30-day period	Required for all new or increased withdrawals of 10,000 gallons/day in the Delaware or Susquehanna River basins	Domestic wells	Registered users must annually report their withdrawals and use	None	

State	Regulating Agency/Department	Groundwater Common Law Doctrine	Special Management Areas for Groundwater Supply	Maximum Withdrawal Amount	Registration	Permitting	Exceptions to Registration/Permitting	Reporting	Exceptions to Reporting Requirements	Footnotes
Utah Utah Code Ann. tit. 73 (Water and Irrigation)	Utah Department of Natural Resources	Prior Appropriation	Critical management areas	Withdrawing large volumes of groundwater that have a certain chemical makeup making it suitable for irrigation is permitted only in certain basins State Engineer can set limits on maximum annual withdrawals in areas where water management plans have been issued Conditions may be placed on permit	N/A	Required for all withdrawals	None	N/A	N/A	
Vermont Vt. Stat. Ann. tit. 10 § 37 (Water Resources Management) (*See* specifically Act 250: ch. 151 of tit. 10)	Vermont Department of Environmental Conservation	Correlative Rights	N/A	N/A	N/A	Required for withdrawals over 57,600 gallons/day (40 gallons/minute for 24 hours)	Emergencies Domestic uses Farming Public water systems Waterworks enhancements that don't expand facilities capabilities by more than 10%	Annual report on water usage required for permit holders Required for commercial and industrial uses that have a monthly average of 20,000 gallons/day	None	
Virginia Ground Water Management Act of 1992 (Va. Code Ann. § 62.1-25) 9 Va. Admin. Code § 25-610 (Groundwater Withdrawal Regulations)	State Water Control Board (within the Virginia Department of Environmental Quality)	Reasonable Use	Ground water management areas	Board may include conditions or limits necessary to protect public welfare, health, and safety	Required for each private well constructed in a groundwater management area by the certified water well systems provider within 30 days of completion of construction	Required for withdrawals of at least 300,000 gallons in any 30-day period in ground water management areas	Withdrawals of groundwater in any area not declared a ground water management area Withdrawals less than 300,000 gallons/month in a groundwater management area Withdrawals related to the exploration/production of oil, gas, coal or other materials if the withdrawal won't injure another landowner Temporary withdrawals associated with state-approved groundwater remediation Certain existing rights grandfathered in	Every user withdrawing an average of 10,000 gallons/day must submit an annual report on their withdrawals Required for users withdrawing 1,000,000 gallons/month for irrigation	None	
Washington Groundwater Code (Wash. Rev. Code § 90.44) Wash. Admin. Code tit. 173 (Department of Ecology)	Washington State Department of Ecology	Prior Appropriation	Groundwater management areas	Beneficial use Department may approve an application for less than the full amt	N/A	Required for withdrawals greater than 5,000 gallons/day	SIngle or group domestic uses less than 5,000 gallons/day Industrial uses of less than 5,000 gallons/day Irrigation of non-commercial area less than 1/2 acre Stock watering	Department may still require exempt users to submit information about water use	N/A	

State	Regulating Agency/Department	Groundwater Common Law Doctrine	Special Management Areas for Groundwater Supply	Maximum Withdrawal Amount	Registration	Permitting	Exceptions to Registration/Permitting	Reporting	Exceptions to Reporting Requirements	Footnotes
West Virginia Groundwater Protection Act (W. Va. Code § 22-12) Water Resources Protection Act (W. Va. Code § 22-26)	West Virginia Division of Environmental Protection	Reasonable Use	Critical planning areas	N/A	Required for "large-quantity users" (withdraw more than 300,000 gallons in a 30 day period)	N/A	Note = "Large-quantity users" excludes farm use Large-quantity users who are buying water from a public or private water utility or other service that is reporting its total withdrawal	Registrants must submit annual reports, but agricultural users can voluntarily submit their use Required for "large quantity users (any person withdrawing more than 750,000 gallons in any month)	None	
Wisconsin Wis. Admin. Code Natural Resources ch. 811 (Requirements for the Operation and Design of Community Water Systems), ch. 812 (Well Construction and Pump Installation), ch. 856 (Water Use Registration and Report) and 812 Wis. Stat. § 281.34 (HCW statute) Wis. Stat. § 281.35 (HCW must comply with this if it has water loss of more than 2 million gallons/day) 2003 WI Act 310 (groundwater protection law)	Wisconsin Department of Natural Resources	Restatement (Second) of Torts § 858 (Beneficial Purpose Doctrine)	Water management areas	Additional requirements for wells withdrawing 2,000,000 or more gallons/day Wells of 5,000,000 gallons/day in Great Lakes Basin need prior notification and comment by the governors of states/provinces in the basin	Required for new and existing high-capacity wells (facilities with the capacity, from all wells on a property, to withdraw at least 100,000 gallons/day or more in any 30-day period) Certain registration requirements as a result of being part of GLC	Required for high-capacity wells (facilities with the capacity, from all wells on a property, to withdraw at least 100,000 gallons/day or more in any 30-day period) Additional requirements for wells within the Great Lakes Basins (individual permit required for withdrawals of at least 1,000,000 gallons/day for any 30 consecutive days) Required for certain water users, including diversion for stream level maintenance, agriculture and irrigation Required for for a system or plan which consumptive withdraws an average of more than 2,000,000 gallons/day in any 30-day period	DNR can waive the requirement to obtain coverage under the general permit for a person that makes a withdrawal for purpose of agriculture or irrigation in Great Lakes Charter basins	Annual reports are required for facilities that withdraw an average of at least 100,000 gallons/day in any 30-day period	None	
Wyoming Wyo. Stat. Ann. ch. 3 (Water Rights; Administration and Control)	Wyoming Department of Natural Resources	Prior Appropriation	Control areas	25 gallons/minute for domestic and stock uses (domestic use: household use where the area to be irrigated is not greater than 1 acre, supplying not more than 3 single family homes) May enact temporary corrective measures in groundwater control area	Required for all withdrawals	Required for all withdrawals	None	Owner must continue to ensure that the well is maintained so that it does not pollute the groundwater	N/A	

The Federal Role in Groundwater Supply

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CRS REPORT
Prepared for Members and
Committees of Congress

Summary

Groundwater, the water in aquifers accessible by wells, is a critical component of the U.S. water supply. It is important for both domestic and agricultural water needs, among other uses. Nearly half of the nation's population uses groundwater to meet daily needs; in 2015, about 149 million people (46% of the nation's population) relied on groundwater for their domestic indoor and outdoor water supply. The greatest volume of groundwater used every day is for agriculture, specifically for irrigation. In 2015, irrigation accounted for 69% of the total fresh groundwater withdrawals in the United States. For that year, California pumped the most groundwater for irrigation, followed by Arkansas, Nebraska, Idaho, Texas, and Kansas, in that order. Groundwater also is used as a supply for mining, oil and gas development, industrial processes, livestock, and thermoelectric power, among other uses.

Congress generally has deferred management of U.S. groundwater resources to the states, and there is little indication that this practice will change. Congress, various states, and other stakeholders recently have focused on the potential for using surface water to recharge aquifers and the ability to recover stored groundwater when needed. Some see aquifer recharge, storage, and recovery as a replacement or complement to surface water reservoirs, and there is interest in how federal agencies can support these efforts. In the congressional context, there is interest in the potential for federal policies to facilitate state, local, and private groundwater management efforts (e.g., management of federal reservoir releases to allow for groundwater recharge by local utilities).

The two primary federal water resources agencies are the U.S. Bureau of Reclamation (Reclamation) and the U.S. Army Corps of Engineers (USACE). No significant federal restrictions apply to Reclamation's authorities to deliver water for purposes of aquifer recharge, storage, and recovery. USACE authorities also do not restrict nonfederal entities from using water stored or released from USACE reservoirs for groundwater recharge. Both agencies acknowledge that some state restrictions affect the use of the delivered or stored waters for groundwater activities. Reclamation, the U.S. Department of Agriculture (USDA), and the U.S. Environmental Protection Agency also provide some forms of financial assistance that could be used for enhancing groundwater supplies.

Other federal agencies support activities that inform groundwater management. For example, the U.S. Geological Survey monitors and reports groundwater conditions across the country, develops groundwater models and software tools for characterizing aquifers, and provides long- and short-term forecasts of changing groundwater conditions as part of local and regional groundwater studies. The National Aeronautics and Space Administration and the National Oceanic and Atmospheric Administration also make observations and collect data that are relevant to groundwater monitoring and assessment. USDA collects groundwater data related to irrigation.

Long-term changes to the climate affecting the United States, particularly rising temperatures and changes in the patterns, quantities, and type of precipitation (i.e., rain versus snow), could affect the availability of groundwater in the future. Other factors, such as changes to land use, irrigation practices, and patterns of water consumption, also may influence future changes to groundwater supplies.

Contents

Figures

Contacts

Groundwater, the water in aquifers accessible by wells, is a critical component of the U.S. water supply. It serves as a water source for domestic use and as irrigation water for agriculture, and it is used in mining, oil and gas development, industrial processes, livestock production, and thermoelectric power generation, among other uses. Managing groundwater resources largely has been the purview of states rather than the federal government. How each state manages its groundwater resources differs and depends on a mix of common law emerging from the 19th century, state law, court decisions, water settlements, and, to a lesser extent, federal law. The federal role in managing groundwater includes activities under federal trust responsibilities to Indian tribes and reservations.[1] It also includes management responsibilities for certain federal reservations if the purposes of those reservations require water, such as some national monuments, national forests, military bases, and other federal land holdings. In addition, the federal government is involved in groundwater monitoring and assessment and in aspects of groundwater recharge, storage, and recovery. Much of the recent congressional interest in groundwater has been broadly related to policies for increasing water supplies generally, as a response to recent droughts, and in preparation for future droughts.

In recent Congresses, some Members have introduced legislation that could affect how groundwater resources may be managed to better ensure a sufficient and reliable supply, and several such bills (or portions of such bills) have been enacted into law. Drought conditions and constrained supplies of surface water have helped to spur legislative action.[2] These conditions continue to affect many regions in western states, although droughts can occur anywhere in the nation.[3] Congress could continue to explore its authority to shape policy, conduct oversight, and provide appropriations for federal activities that influence groundwater supply management in the United States. This report is intended to provide context and a broad summary of federal authorities and activities affecting the supply and use of groundwater resources.

Whereas the states primarily manage groundwater *supply*, the federal government plays a more direct role in managing the nation's groundwater *quality*. For example, the Comprehensive Environmental Response, Compensation, and Liability Act (42 U.S.C. §§9601 et seq.) authorizes federal cleanup and enforcement actions to respond to releases of hazardous substances to the environment, including groundwater. In addition, the Safe Drinking Water Act (42 U.S.C. §§300f et seq.) authorizes the U.S. Environmental Protection Agency (EPA) to regulate underground injection activities to protect underground sources of drinking water, including injection wells used for aquifer recharge. This report focuses on issues related to groundwater supply, not groundwater quality.[4]

This report is divided into two parts. The first part provides an overview of groundwater supply and management, including selected major issues before Congress. The second part provides a more detailed primer on groundwater resources, including relevant federal activities and authorities.

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[1] Unless otherwise noted, the terms *Indian*, *Indian tribes*, and *tribal reservations* refer to the approximately 1.9 million American Indians and Alaska Natives, the more than 570 federally recognized Indian tribes, and tribal land within reservation boundaries.

[2] Surface water includes streams, rivers, lakes, ponds, and is not groundwater or atmospheric water like rain or snow.

[3] For a general overview of drought in the United States, see CRS Report R43407, *Drought in the United States: Causes and Current Understanding*, by Peter Folger.

[4] Many CRS resources address issues of groundwater quality, including CRS Report R41039, *Comprehensive Environmental Response, Compensation, and Liability Act: A Summary of Superfund Cleanup Authorities and Related Provisions of the Act*, by David M. Bearden; and CRS Report RL31243, *Safe Drinking Water Act (SDWA): A Summary of the Act and Its Major Requirements*, by Mary Tiemann.

Overview

Who Relies on Groundwater?

Nearly half of the U.S. population relies on groundwater to meet their everyday needs. In 2015, groundwater was the primary source of water for domestic indoor and outdoor water uses for about 149 million people (46% of the U.S. population).[5] Most U.S. citizens (approximately 282 million people, or 87%) depended on public water supplies in 2015.[6] The remaining 13% (approximately 42.5 million people) supplied their own water, and nearly all of these citizens (98%, or about 42 million) pumped the water from their private wells. About 38% of public supply water is groundwater, and about 107 million people used groundwater from public water supplies.[7] Combined with the 42 million people pumping groundwater from their private wells, an estimated 149 million people relied on groundwater in 2015.

Groundwater and Irrigation

The greatest *volume* of groundwater used is for agriculture, nearly entirely for irrigation. In 2015, irrigation accounted for over 69% of all fresh groundwater withdrawals in the United States,[8] which corresponded to about 57.2 billion gallons per day (bgpd) in irrigation withdrawals as compared to 18.4 bgpd in withdrawals for domestic use (both public supply and self-supplied groundwater—in total, about 22% of all fresh groundwater withdrawals).[9] Among all states, California uses the most groundwater for irrigation, withdrawing 13.9 bgpd in 2015. Arkansas is second, withdrawing 9.28 bgpd in the same year, followed by Nebraska (5.42 bgpd), Idaho (4.9 bgpd), Texas (4.48 bgpd), and Kansas (2.56 bgpd).[10] Overall, groundwater withdrawals for irrigation in 2015 accounted for 48% of the total water withdrawn for irrigation, an increase of 16% compared to 2010.[11] In comparison, surface water sources supplied 52% of total irrigation withdrawals, a decrease of about 8% from 2010.[12]

Figure 1 illustrates the amount of groundwater withdrawn for irrigation by state. Generally, western states tend to use the most groundwater, due in part to hydrology and other surface water supply constraints.

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[5] Cheryl A. Dieter and Molly A. Maupin, *Public Supply and Domestic Water Use in the United States, 2015*, U.S. Geological Survey (USGS), Open-File Report 2017-1131, 2017, at https://doi.org/10.3133/ofr20171131. (Hereinafter, Dieter and Maupin, 2017.)

[6] *Public water supply*, as used in USGS reports and herein, refers to water withdrawn by public and private water suppliers that provide water to at least 25 people or have a minimum of 15 connections. It excludes self-supplied domestic withdrawals.

[7] Dieter and Maupin, 2017.

[8] Cheryl A. Dieter et al., *Estimated Use of Water in the United States in 2015*, USGS, Circular 1441, 2018, at https://pubs.er.usgs.gov/publication/cir1441. (Hereinafter, Dieter et al., 2018.) 2015 is the most recent year for which these data are available. Nearly all groundwater withdrawals in 2015 were freshwater (about 97%); the remainder (3%) were saline water withdrawals.

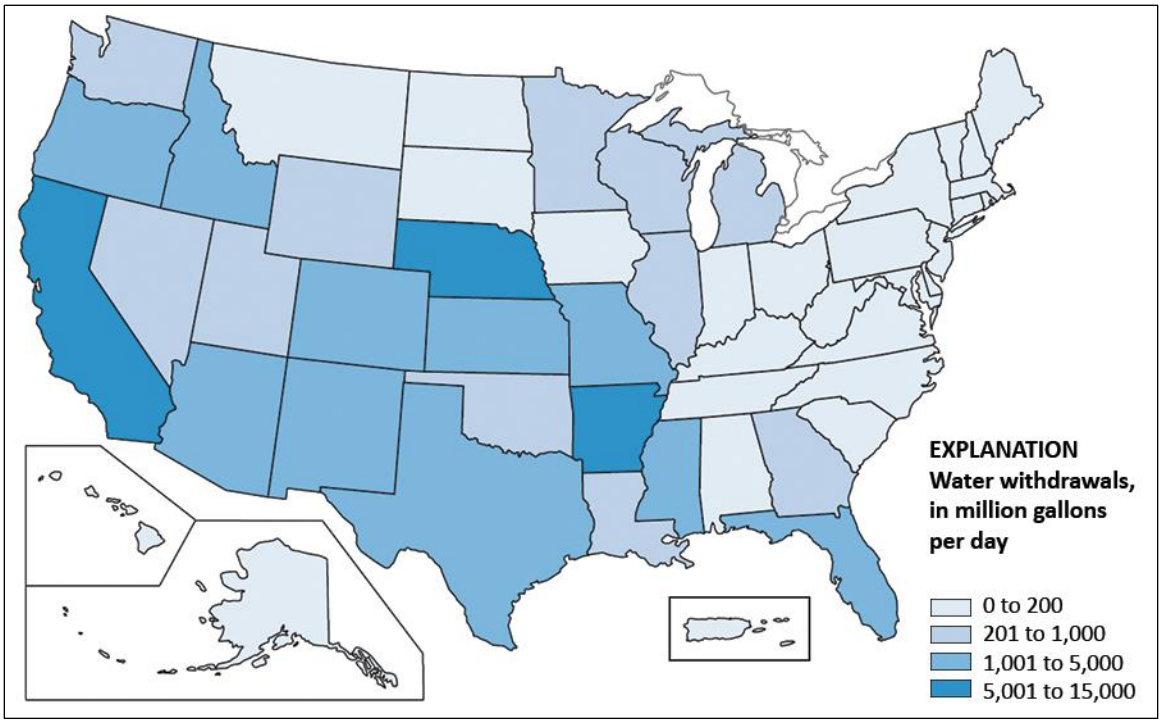
[9] Irrigation, public supply, and self-supplied groundwater withdrawals accounted for about 92% of the total fresh groundwater pumped in 2015. The remaining 8% included uses for livestock, aquaculture, industrial, mining, and thermoelectric power. Dieter et al., 2018, Table 4a.

[10] Dieter et al., 2018, Table 7.

[11] Dieter et al., 2018, p. 28.

[12] Dieter et al., 2018, p. 28.

Figure 1. Groundwater Withdrawals for Irrigation (2015)



Source: Cheryl A. Dieter et al., *Estimated Use of Water in the United States in 2015*, USGS, Circular 1441, 2018, at https://pubs.er.usgs.gov/publication/cir1441, p. 29, figure 7. (Modified by CRS.)

The Federal Role in Groundwater Supply

The federal government directly and indirectly influences how groundwater is managed in the United States. Several federal agencies monitor groundwater directly or with partners—through measurements at wells and springs—and remotely, using satellites or other remote sensing devices to provide information on groundwater flow, storage, depletion, and other characteristics that help inform state and local groundwater management. These include the U.S. Geological Survey (USGS), the National Aeronautics and Space Agency (NASA), the National Oceanic and Atmospheric Administration (NOAA), and the U.S. Department of Agriculture (USDA).[13] Congress has provided other federal agencies with the authority to make available some water delivered from or stored at federal water resource projects available for groundwater recharge, storage, and recovery. These agencies include the two principal federal water resources agencies: the U.S. Army Corps of Engineers (USACE, which operates nationwide) and the U.S. Bureau of Reclamation (Reclamation, which operates in the 17 coterminous states west of the Mississippi River). Additionally, courts have found that when the federal government reserves lands for a particular purpose (such as for a tribal reservation or national monument), it impliedly reserves a right to water necessary to accomplish the purposes for which the reservation was created. Thus, federal land management agencies and the Bureau of Indian Affairs often are involved in water rights issues. Federal reserved water rights doctrine has long been recognized for surface water; more recently, it is also being considered for groundwater.

[13] For more information on the roles of the agencies, see the below section, "Federal Activities and Authorities."

Congressional Interest

In recent years, congressional interest in groundwater has generally been in three major areas:

- aquifer storage, recharge, and recovery;
- groundwater rights (including among other issues, groundwater/surface water interaction and federal reserved water rights); and
- groundwater supply monitoring and assessment.

In some cases, these issues overlap.

Groundwater Recharge, Storage, and Recovery

Background

Historically, the federal government, through USACE and Reclamation, has played a prominent role in constructing infrastructure related to surface water resource management (e.g., storage, control, or delivery). At the same time, the federal government has played a comparatively smaller role in creating infrastructure to develop groundwater storage, which is commonly conducted as aquifer storage, recovery, and/or recharge.[14] The reasons for the differing levels of federal involvement are complex, tied to the long and complicated history of common law water rights, state water law, legal adjudication, federal deference to states on water supply issues, and a historically cruder understanding of how groundwater occurs and moves underground compared to surface water.

Both public and congressional focus on groundwater storage has sharpened in recent years, particularly in reaction to recent major drought events. Congressional interest has increased in the potential for the federal government to assist with state, local, and private groundwater management efforts, including efforts to use surface water to recharge and/or store water in aquifers and to recover (i.e., pump to the surface) the stored groundwater when needed. Some see aquifer recharge, storage, and recovery as potentially complementary to existing surface water storage; some also see these projects as possible alternatives to building new surface water reservoirs that may prove less costly and/or pose fewer environmental issues.[15]

Federal law authorizes Reclamation to provide water for irrigation and USACE to store water for various purposes. These authorities provide some opportunities for the federal government to promote aquifer recharge, storage, and recovery (see below section, “Federal Authority Related to Groundwater Recharge, Storage, and Recovery”). Currently, there are no general federal restrictions on the nonfederal use of water delivered by Reclamation or stored by USACE for aquifer recharge, storage, and recovery purposes; however, some state restrictions and federal environmental protection laws may affect the use of these waters for groundwater recharge.[16]

[14] For more background on this concept, see the below section, “Federal Authority Related to Groundwater Recharge, Storage, and Recovery.”

[15] An example of a major aquifer storage project currently operating within a larger water storage framework is the Kern Water Bank, a water storage bank that operates on about 20,000 acres southwest of Bakersfield, California. As of 2018, the bank could store about 1.5 million acre-feet of readily available water underground, with the ability to recover approximately 240,000 acre-feet within a 10-month period. Since its construction in 1996, the bank has formed an important component of California’s water storage network. For more information, see http://www.kwb.org/index.cfm/fuseaction/Pages.Page/id/330.

[16] For example, injection wells used for aquifer recharge or aquifer storage and recovery require a permit under the federal Safe Drinking Water Act (42 U.S.C. §300h). For further information, see https://www.epa.gov/uic/aquifer-

Although Congress has authorized aquifer storage, recharge, and/or recovery for some individual projects, general congressional guidance in this area has been limited. Under the Water Infrastructure Improvements for the Nation Act (WIIN Act; P.L. 114-322), Congress provided general authority for Reclamation to support new and enhanced federal and state surface and groundwater storage projects under certain, limited circumstances.[17] Reclamation, USDA, and EPA also provide some forms of financial assistance that could support aquifer recharge, storage, and recovery.

Groundwater Rights

Background

Groundwater and Surface Water Interaction

One reason often cited for the evolution of different legal frameworks for groundwater and surface water in most states is the relative lack of understanding of groundwater occurrence and movement in the 19th and early 20th centuries, when states and courts first established laws and rules allocating groundwater. Surface water was more readily understood, being in plain view, but groundwater was considered different and mysterious, being largely unobservable except at the bottom of a well. One commentator noted that the development of groundwater common law in England and the United States in the 19th century was "steeped in ignorance,"[18] as groundwater hydrology and hydraulics were virtually unknown compared to surface water. Citing a legal case from 1861 referring to groundwater, the commentator said,

> the existence, origin, movement and course of such waters, and the causes which govern and direct their movements, are so secret, occult and concealed, that an attempt to administer any set of legal rules in respect to them would be involved in hopeless uncertainty, and would be, therefore, practically impossible.[19]

Groundwater science has made significant strides in the interim, particularly in establishing the interconnected nature of surface water and groundwater in many instances, especially for shallow aquifers. Some observers argue that groundwater law has not kept pace in some cases, in part because of the courts' reluctance to unsettle a system of common law established under the principle of property rights; observers note that a disruption of this system could result in legal chaos.[20]

The complicated nature of groundwater laws and practices is noteworthy because any new executive branch action or federal legislation authorizing action that affects groundwater resources may perturb long-established state and local groundwater management regimes. The practice of managing groundwater and surface water together, termed *conjunctive management*, better reflects the intertwined nature of groundwater and surface water in many situations and is

recharge-and-aquifer-storage-and-recovery.

[17] For more information, see below section, "Reclamation Authority to Provide Financial Support for Groundwater Storage."

[18] Joseph W. Dellapenna, "A Primer on Groundwater Law," *Idaho Law Review*, vol. 49, no. 265 (2013), p. 267. Hereinafter Dellapenna, 2013.

[19] Dellapenna, 2013, citing Frazier v. Brown, 12 Ohio St. 294, 311 (1861).

[20] Dellapenna, 2013, p. 268.

generally recognized as an effective management approach, especially for shallow aquifers. Yet, groundwater law sometimes does not reflect or address that surface-groundwater interconnection.

Federal Reserved Water Rights

Federal reserved water rights doctrine is an important concept in groundwater law. This doctrine holds that when the federal government reserves lands for a particular purpose (such as for a tribal reservation or national monument), the government impliedly reserves a right to water necessary to accomplish the primary purpose for which the reservation was created.[21] Since 1908, when the Supreme Court established the doctrine in *Winters v. United States*, courts have applied this doctrine to surface waters.[22] A March 2017 decision of the U.S. Court of Appeals for the Ninth Circuit (Ninth Circuit) held, for the first time, that the doctrine can encompass groundwater as well.[23]

Congress has recently been involved in Indian water rights settlements, chiefly regarding tribal rights to surface water supplies and the appropriation of funds for enacted settlement agreements. The importance of groundwater to tribal water supplies is increasingly being discussed, and tribal rights to groundwater are the subject of ongoing litigation.[24]

Groundwater Monitoring

Background

Although the states have assumed primary responsibility for groundwater management, several federal agencies monitor, forecast, and assess groundwater conditions in the United States.[25] One agency, USGS, within the Department of the Interior (DOI), is a science agency with no regulatory or management responsibilities for water resources. For decades, USGS has monitored and reported groundwater conditions across the country; developed groundwater models and software tools for characterizing aquifers; and provided long- and short-term forecasts of changing groundwater conditions as part of local and regional groundwater studies.[26] The information is used to support federal, state, and local decisionmakers, and the research is often conducted in collaboration with federal, state, and local partners. For example, USGS makes data from its distributed water database available to stakeholders. The database is a locally managed network of stations that monitor surface-water flow, groundwater levels, and water quality across

[21] See, for example, the U.S. Department of Justice, "Federal Reserved Water Rights and State Law Claims," at https://www.justice.gov/enrd/federal-reserved-water-rights-and-state-law-claims. The nature of the water right for a specific federal reservation depends on various aspects of the reservation, such as its purpose and the mechanism for the reservation; the discussion herein is intended to introduce the topic of groundwater rights related to federal reservations generally and is not intended to clarify how the specific rights related to a reservation are determined. For example, in some cases, Congress has expressly not reserved water rights.

[22] Winters v. United States, 207 U.S. 564, 575-77 (1908).

[23] Agua Caliente Band of Cahuilla Indians v. Coachella Valley Water District, No. 15-55896 (9th Cir. 2017).

[24] See, for example, CRS Insight IN10857, *Federal Reserved Water Rights and Groundwater: Quantity, Quality, and Pore Space*, by Peter Folger.

[25] For more information on the roles of the agencies, see the below section, "Federal Activities and Authorities."

[26] USGS, "USGS Groundwater Information: USGS Groundwater Science for a Changing World," at https://water.usgs.gov/ogw/about/.

the nation. The database includes long- and short-term records from more than 850,000 groundwater measurement sites.[27]

Other agencies, such as NASA and NOAA, make observations and collect data that also are relevant to groundwater monitoring and assessment. Earth-observing satellites that detect changes in gravity, for example, can help link those changes to losses or gains in the volume of groundwater due to pumping or recharge. NOAA's estimation of drought severity throughout the country, as expressed in the U.S. Drought Monitor,[28] includes the estimation of the effects of drought on groundwater supplies. Also, USDA collects irrigation data, including information on wells, characteristics of aquifers used for irrigation supply, and quantities of water applied from wells.[29]

Primer on Groundwater

Groundwater science has advanced markedly in the last century; this primer presents an introduction to fundamental concepts relevant to groundwater use, management, and recharge.

Groundwater is found in aquifers. An aquifer is composed of (1) solid materials, such as rocks and mineral grains; (2) interconnected spaces or openings (*pore space*); and (3) groundwater, which completely fills the pore space (**Figure 2**). Strictly speaking, an aquifer is sufficiently permeable (i.e., groundwater can move readily through the interconnected pores) to transmit economic quantities of water to wells or springs.[30] In other words, if a farmer drills a well into a water-bearing layer of rock or sediments (sometimes called a *formation*) and can pump sufficient quantities of groundwater to irrigate crops, water livestock, or use for drinking water and washing, then that formation can be considered an aquifer. If the same farmer drilled a well but could not pump enough water to satisfy any needs, then the formation would not be considered an aquifer.

Types of Aquifers

There are two principal types of aquifers: unconfined and confined. An *unconfined aquifer* is one in which the water table moves up and down freely without an overlying confining layer (see **Figure 2**).[31]

[27] See, for example, USGS, "USGS Groundwater Watch," at https://groundwaterwatch.usgs.gov/.

[28] See United States Drought Monitor at http://droughtmonitor.unl.edu/.

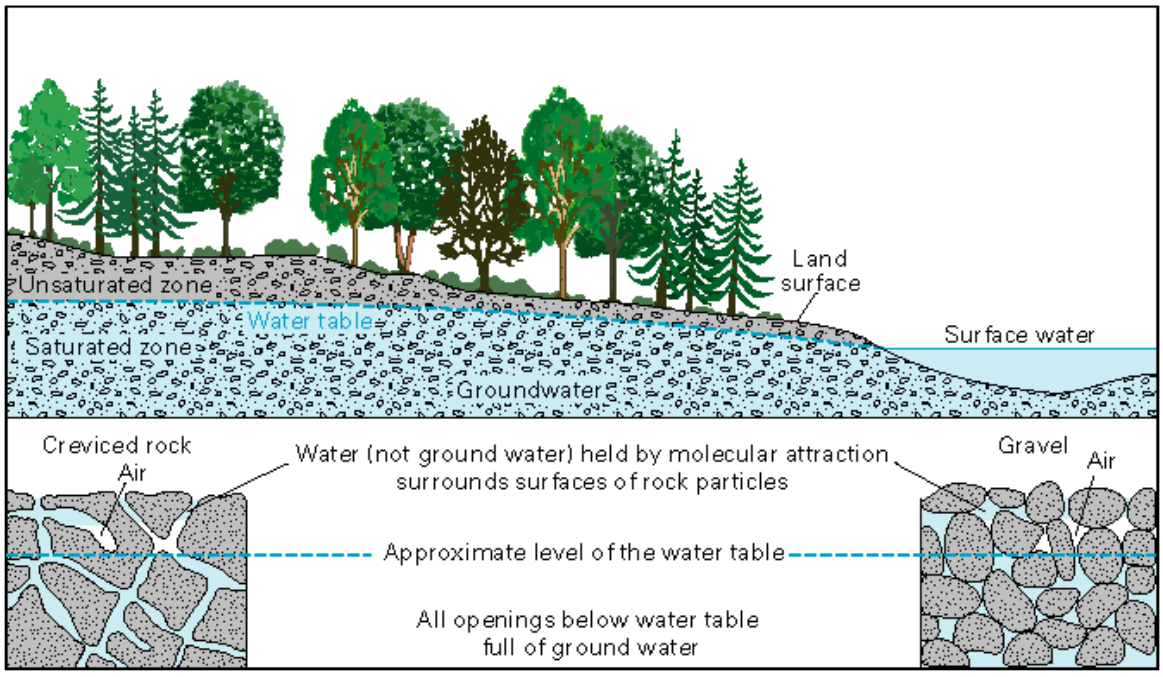
[29] The U.S. Environmental Protection Agency (EPA) plays a significant role in matters related to groundwater quality. Such EPA authorities and activities are beyond the scope of this report.

[30] C. W. Fetter, "Glossary," in *Applied Hydrogeology*, 2nd ed. (Columbus, OH: Merrill Publishing Company, 1988), p. 565.

[31] A *confining layer* is a bed or strata composed of relatively impermeable materials, such as clay, so that groundwater flow through the layer is impeded or significantly restricted. The ability of a bed or strata to conduct groundwater flow is referred to as *hydraulic conductivity*. A confining layer would have a low hydraulic conductivity compared to an aquifer.

Figure 2. Unconfined, or Water Table, Aquifer

(illustrating two types of pore space)

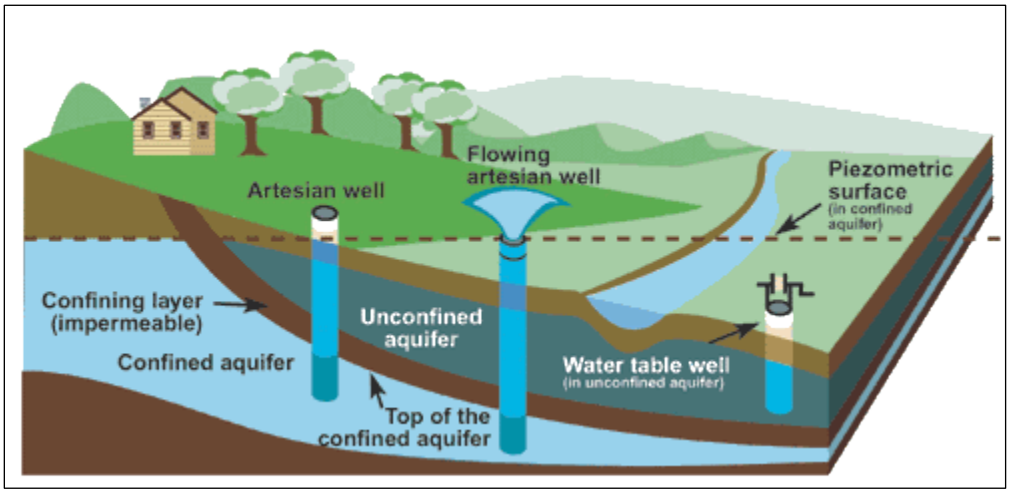


Source: USGS, USGS Water Science School, "Aquifers and Groundwater," at https://water.usgs.gov/edu/earthgwaquifer.html. (Modified by CRS.)

Notes: Above the water table, the pores may contain water but are not completely full. Only the saturated zone below the water table is considered the aquifer.

A *confined aquifer*, in contrast, is an aquifer overlain (and sometimes underlain) by an impermeable or confining layer that the water does not freely move above. The confining beds cause the aquifer to be under pressure. As a result, when a well penetrates a confined aquifer, the water will rise above the top of the aquifer, sometimes all the way to the land surface (the latter case is referred to as an *artesian aquifer*), as shown in **Figure 3**.

Figure 3. Different Types of Aquifers and Wells



Source: Government of Canada, Environment and Natural Resources, "Water Sources: Groundwater," at https://www.canada.ca/en/environment-climate-change/services/water-overview/sources/groundwater.html.

Notes: The piezometric surface in the figure refers to an imaginary line that corresponds to where the water level in the confined aquifer would rise if not for the impermeable confining layer. It also corresponds to the water level in the artesian wells shown in the figure.

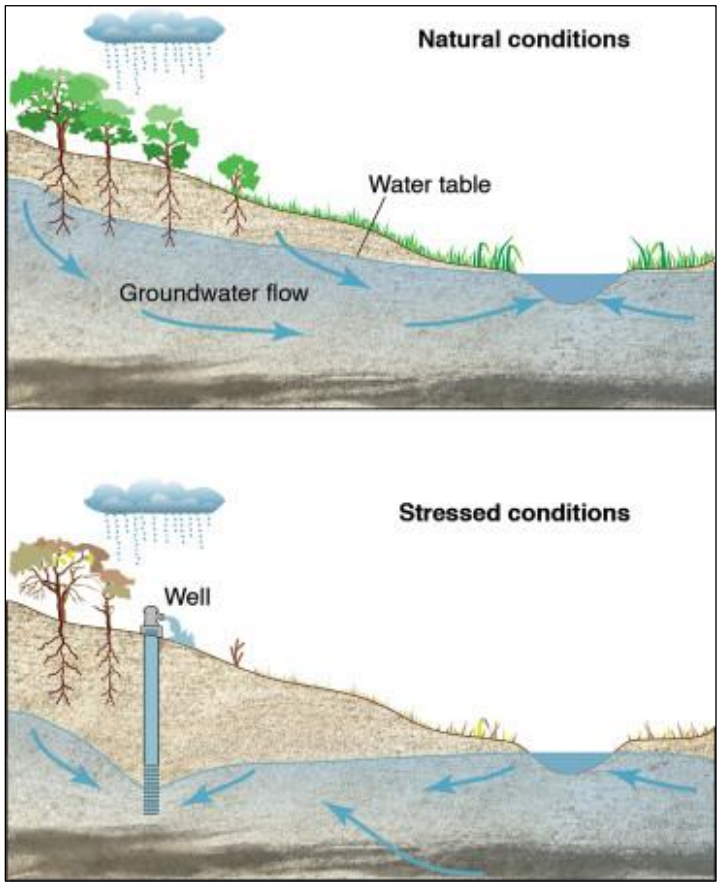
The distinction between unconfined and confined aquifers is important for this discussion, as the technique of groundwater recharge, storage, and recovery differs depending on what kind of aquifer is involved. Because a confining layer or layers separates a confined aquifer from surface water bodies, the degree of connection between surface water and groundwater is not as direct or distinct as it is for unconfined aquifers.[32] Groundwater recharge can occur naturally in confined and unconfined aquifers as water moves downward from the land surface into the aquifer from rain and melting snow, lakes, river, and streams. For unconfined aquifers, other sources of recharge water can include built impoundments, such as reservoirs; unlined irrigation ditches and canals; and applied irrigation water not consumed by crops. In a system of managed *artificial recharge*, water can be added deliberately to a confined or unconfined aquifer by using an injection well; by spreading water across the land surface, where it can trickle down into an unconfined aquifer; or by building an impoundment to temporarily store water and allow it to leak through the bottom down to an unconfined aquifer.

The distinction between an unconfined and a confined aquifer also is important for understanding the connection between surface water and groundwater. In **Figure 3**, the confined aquifer is separated from the river by a confining layer, so that changes in river flow will not directly affect groundwater in the confined aquifer and flow from the artesian wells will not directly affect flow in the river. In **Figure 4**, by contrast, the unconfined aquifer is connected directly to the stream. Under natural conditions, the groundwater will flow toward and feed the stream (top panel) because the slope of the water table is toward the top of the stream level. However, sometimes when aquifers are subject to excessive pumping—during drought conditions, for example, or because of a lack of surface water availability—they are said to be under stress. Under stressed conditions (bottom panel of **Figure 4**), pumping from a well will cause the water table to slope

[32] Decades of groundwater development involving hundreds or thousands of wells in some agricultural regions of the United States, such as California's Central Valley, sometimes have led to interconnections between the unconfined and confined aquifers. Wells penetrating the confining layer above the confined aquifers can serve as conduits for groundwater to flow up or down. See, for example, Claudia C. Faunt et al., *Groundwater Availability of the Central Valley Aquifer, California*, USGS, Professional Paper 1766, 2009, pp. 85-86.

away from the top of the stream. In that case, the water in the stream will leak through the stream bottom and flow into the aquifer, toward the pumping well.

Figure 4. Unconfined Aquifer Without Pumping (top) and With Pumping (bottom)

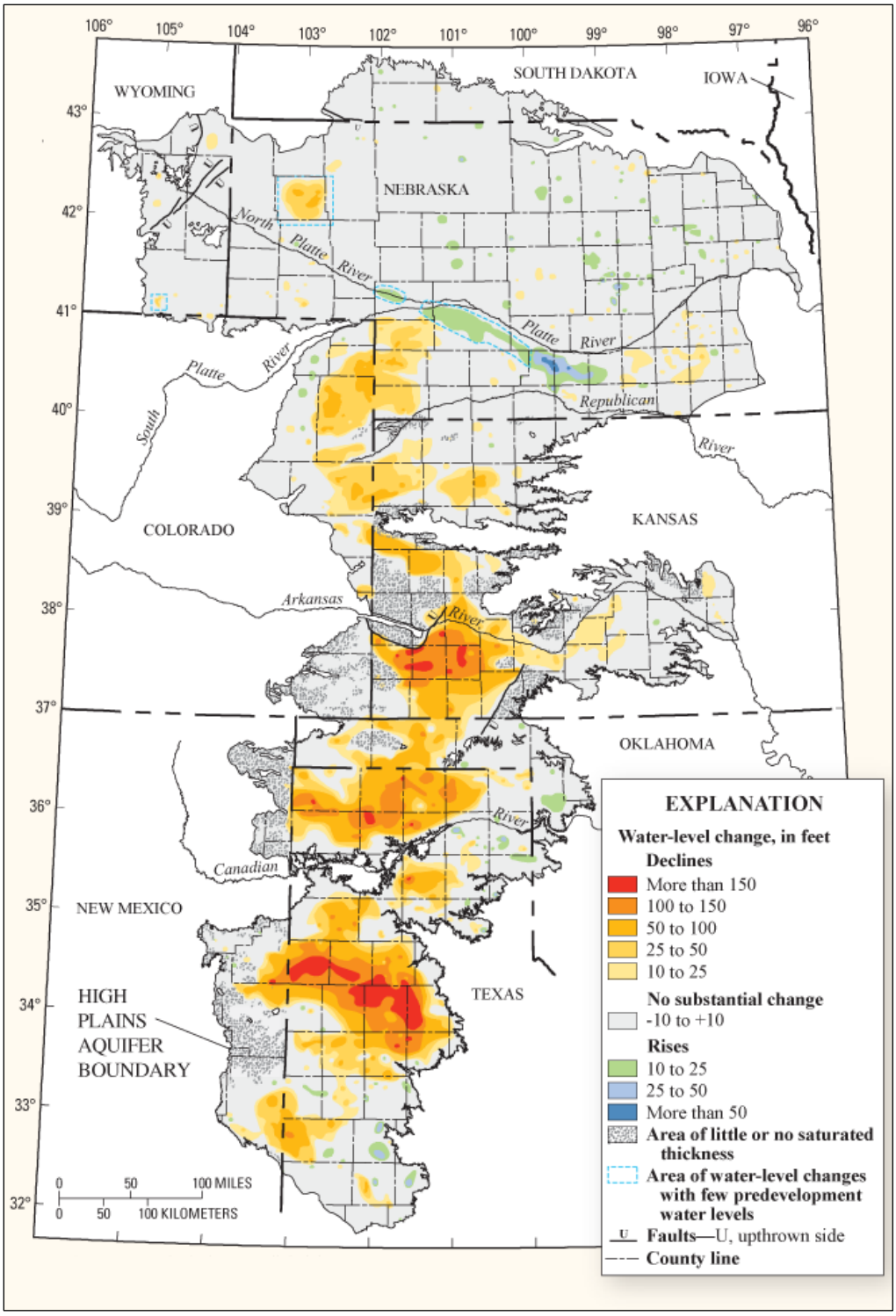


Source: Steven M. Gorelick and Chunmiao Zheng, "Global Change and the Groundwater Management Challenge," Water Resources Research, vol. 51, March 28, 2015 (with permission).

Notes: Under natural conditions in this particular case, groundwater flows toward the stream (arrows indicate direction of groundwater flow) and the water table is high enough to be accessible to trees and plants. During pumping, when the aquifer is stressed, water flows from the stream into the aquifer and toward the well. Also, the water table under stressed conditions drops below the roots of trees and plants depicted in the figure, affecting their growth.

Consistently stressed conditions can have dramatic long-term effects on groundwater. If pumping continues in excess of recharge, increasing stress on the aquifer, the water table may drop tens to hundreds of feet (**Figure 5**). This situation has occurred in many regions of the United States, including the Ogallala aquifer (also called the High Plains aquifer) underlying several Midwest and Great Plains states and in California's Central Valley. In the Central Valley, historical levels of pumping caused the water table to drop so far in some areas that it caused the land surface to drop, or subside, nearly 30 feet (**Figure 6**). Excessive land subsidence can harm surface structures, such as canals and levees.

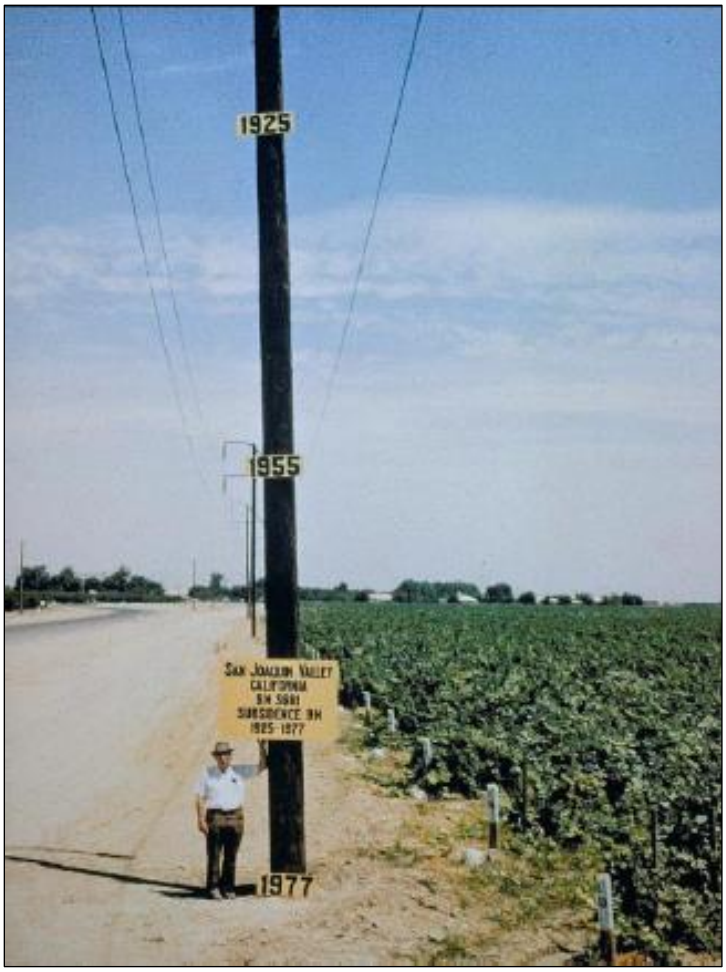
Figure 5. Water Level Changes in the High Plains Aquifer, Predevelopment to 2007



Source: V. L. McGuire, "Changes in Water Levels and Storage in the High Plains Aquifer, Predevelopment to 2007," USGS, Fact Sheet 2009-3005, February 2009. (Modified by CRS.)

Note: *Predevelopment* refers to approximately 1950.

Figure 6. Land Subsidence in the San Joaquin Valley Southwest of Mendota Between 1925 and 1977



Source: Devin Galloway et al., "Land Subsidence in the United States," USGS Circular 1182, 1999, p. 23, at http://pubs.usgs.gov/circ/circ1182/pdf/06SanJoaquinValley.pdf.

Note: Approximate location of the maximum land subsidence in the United States, showing the approximate relative position of the land surface in 1925, 1955, and 1977.

Federal Activities and Authorities

The federal government directly and indirectly influences how groundwater is managed in the United States. Several federal agencies monitor groundwater directly or with partners—through measurements at wells and springs—and remotely, using satellites or other remote sensing devices to provide information on groundwater flow, storage, depletion, and other characteristics that help inform state and local groundwater management. These agencies include the USGS, NASA, the National Oceanic and Atmospheric Administration, and USDA. Congress has provided other federal agencies with the authority to make water delivered from or water stored at federal water resource projects available for groundwater recharge, storage, and recovery. These include the two principal federal water resources agencies: USACE (which operates nationwide) and Reclamation (which operates in the 17 coterminous states west of the Mississippi River). Reclamation, USDA, and EPA also provide some forms of financial assistance that could support groundwater storage, recharge, and recovery.

Additionally, when the federal government reserves lands for a particular purpose (such as for a tribal reservation or national monument), it impliedly reserves a right to water necessary to accomplish the purposes for which the reservation was created. That federal reserved water rights doctrine has long been recognized for surface water; more recently, it is also being considered for groundwater. (See discussion under "Groundwater Rights.")

Groundwater Monitoring and Assessment

Several federal agencies that have no regulatory role in managing groundwater are authorized to collect data, make observations and assessments, and provide information on groundwater supplies that supports decisionmakers at the state and local levels. USGS likely provides the most direct groundwater information and support for groundwater management among the federal agencies, although NASA and NOAA also make pertinent observations and distribute groundwater-relevant information. USDA also collects groundwater data related to irrigation. Selected activities within those four agencies are briefly summarized below.

U.S. Geological Survey

The Groundwater and Streamflow Information Program, within the USGS water resources mission area, funds activities that provide information directly relevant to groundwater management. About 10% ($7.5 million in FY2019) of the approximately $74 million program is directed at groundwater-related activities, including the National Groundwater Monitoring Network (NGWMN).[33] The NGWMN is a compilation of selected groundwater monitoring wells from federal, state, and local monitoring networks across the country. Data from the network are accessible through a portal that contains current and historical data.[34] USGS administers the program through cooperative agreements with state and local water resource agencies; in FY2020, Congress provided $3.9 million to USGS to fund the network, the same as the enacted amounts for the previous four years.[35]

USGS also maintains a distributed groundwater database, the USGS Groundwater Watch. It is locally managed and contains data from more than 850,000 wells compiled over the past 100 years. The long-term and distributed nature of the data is valuable to groundwater managers seeking information about regional groundwater trends over time. **Figure 7** shows an example of one of the products updated daily from groundwater well information within the database.

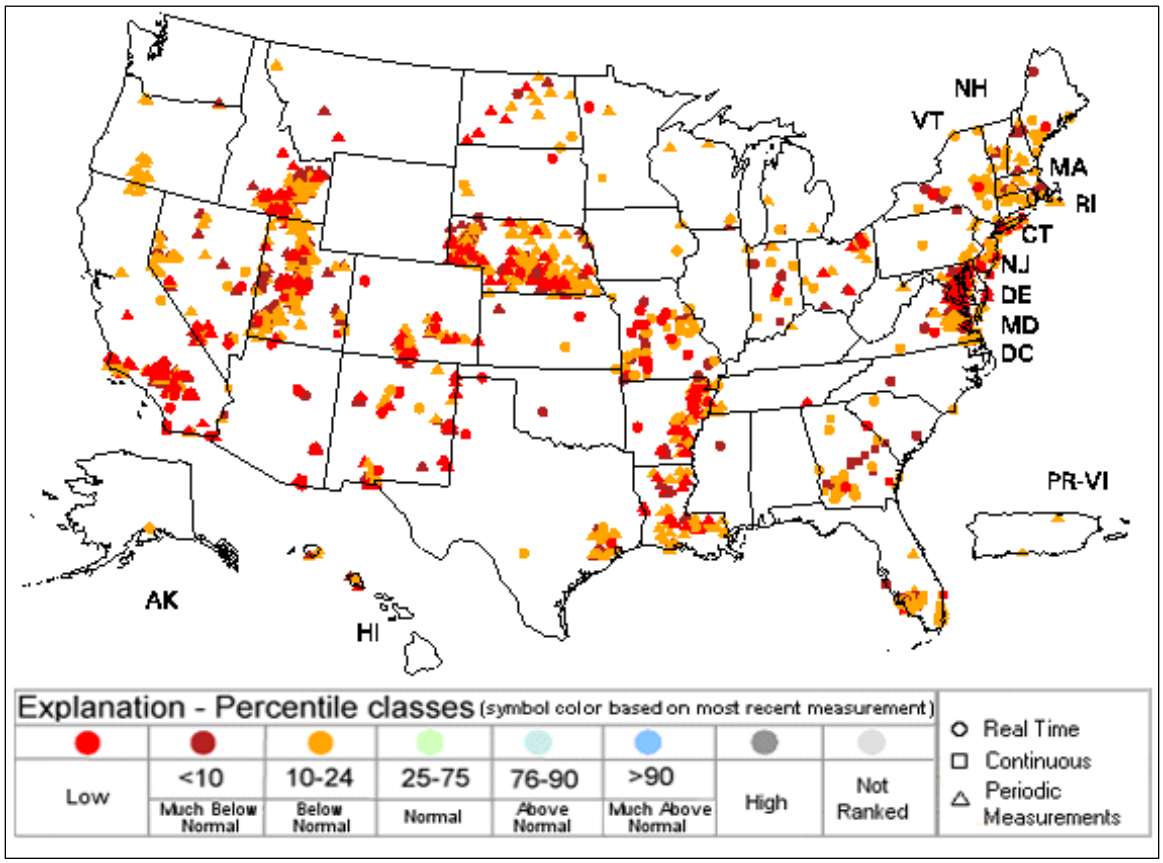
[33] Email from Jeffrey Onizuk, USGS Congressional Affairs, March 19, 2020.

[34] Advisory Committee on Water Information, "National Ground-Water Monitoring Network," at https://cida.usgs.gov/ngwmn/index.jsp.

[35] Email from Jeffrey Onizuk, USGS Congressional Affairs, March 19, 2020.

Figure 7. Below-Normal Groundwater Levels for Actively Monitored Wells

(data from 3,855 wells)



Source: USGS, "Groundwater Watch," at https://groundwaterwatch.usgs.gov/net/ogwnetwork.asp?ncd=lwl. (Modified by CRS.)

Notes: Below-normal means that the wells shown in red or orange had groundwater levels at the 24th percentile or lower for the month the well was measured, compared to the entire period of record for the well. In other words, if the well has been measured for 50 years, it would be shown on this map if the water level was lower than 75% of the measurements taken over the past 50 years. Red dots indicate wells lower than the 10th percentile; orange shows wells at the 10th-24th percentile.

In addition to collecting and providing data, USGS conducts regional groundwater studies, such as assessing the groundwater availability in the Central Valley aquifer in California,[36] and national overviews, such as the *Ground Water Atlas of the United States*.[37] Several observers have suggested that although groundwater generally is locally managed in the United States, regional studies (such as those conducted by USGS) are important for documenting the status and trends of groundwater availability, as these trends affect local groundwater resources, particularly when changes in an aquifer occur beyond the local or state political boundaries.[38]

[36] C. C. Faunt et al., *Groundwater Availability of the Central Valley Aquifer, California*, USGS, USGS Professional Paper 1766, 2009, at https://pubs.usgs.gov/pp/1766/.

[37] James A. Miller et al., *Ground Water Atlas of the United States*, USGS, 2000, at https://water.usgs.gov/ogw/aquifer/atlas.html.

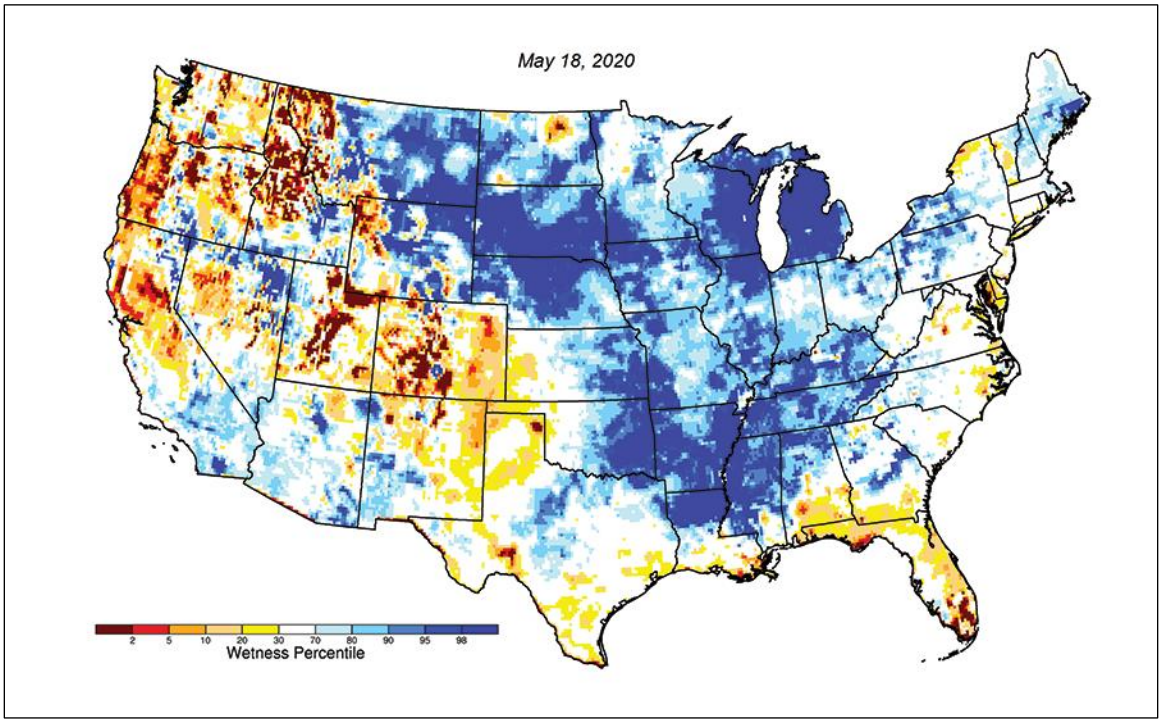
[38] See, for example, K. F. Dennehy, T. E. Reilly, and W. L. Cunningham, "Groundwater Availability in the United States: The Value of Quantitative Regional Assessments," *Hydrogeology Journal*, vol. 23, no. 8 (December 2015), pp.

NASA

Earth-observing satellites can provide information to assess changes in the amount of groundwater stored in large aquifers, variations in the amount of soil moisture, and tiny fluctuations in land elevation that reflect how the water table is moving up and down.

Using data from NASA's GRACE and SMAP satellites,[39] integrated with other observations, scientists can analyze shallow groundwater and soil moisture levels that reflect drought conditions across the United States (**Figure 8**).

Figure 8. Shallow Groundwater and Soil Moisture Comparison from NASA Satellite Data



Source: The National Drought Mitigation Center, "Groundwater and Soil Moisture Conditions from GRACE Data Assimilation," at http://nasagrace.unl.edu/Default.aspx. (Modified by CRS.)

Notes: Map shows wet or dry conditions relative to the probability of occurrence using the baseline period from 1948 to 2012, expressed as a percentile. The lower values in the warmer colors indicate drier-than-normal conditions (30th percentile or less), and the cooler colors indicate wetter-than-normal conditions (70th percentile or more). Areas in white express 31st-69th percentile, spanning the midpoint of 50th percentile (the 50th percentile indicates that half the values are higher and half are lower). The map is available for the contiguous United States from the data source and does not include Alaska and Hawaii.

Data from the GRACE satellite also have been interpreted to show changes in the amount of groundwater held in storage in large, regional aquifers, such as the Central Valley aquifer in California, the High Plains aquifer underlying several states in the Midwest and Great Plains, and

1629-1632; and Roland Barthel, "A Call for More Fundamental Science in Regional Hydrogeology," *Hydrogeology Journal*, vol. 22, no. 3 (May 2014), pp. 507-510.

[39] GRACE stands for Gravity Recovery and Climate Experiment satellite (see https://www.nasa.gov/mission_pages/Grace/index.html); SMAP stands for Soil Moisture Active Passive satellite (see https://smap.jpl.nasa.gov/).

other large aquifers around the world.[40] One study using GRACE data indicated that the volume of groundwater in the Central Valley aquifer pumped out over a 78-month period was equivalent to nearly the capacity of Lake Mead.[41]

Scientists can use a special type of radar data collected by satellites using a technique called synthetic aperture radar interferometry to detect minute changes in the land-surface elevation caused when the water table moves up and down. In one study, NASA scientists and others used the technique to track how the aquifer in the Santa Clara Valley, California, recovered following depletion during a drought when conservation measures were put in place to limit groundwater pumping.[42] In that study, a cluster of Italian satellites provided the radar data. NASA is planning a joint mission with the Indian Space Research Organisation in 2021 that would collect radar imagery of nearly every major aquifer in the world.[43]

NOAA

NOAA coordinates and integrates drought research and forecasting from federal, state, tribal, local, and academic sources through the National Integrated Drought Information System. NOAA uses data from these and other sources to create drought maps, seasonal outlooks, and other drought indicators, including effects of drought on groundwater.[44] A typical U.S. Drought Monitor map, for example, indicates which regions of the country are experiencing short- and long-term impacts from drought. Long-term-impacted regions mean that drought has affected the region's hydrology, including groundwater resources.

NOAA's constellation of both geostationary and polar-orbiting weather satellites provides real-time atmospheric weather data that can be used to better understand the hydrologic cycle in regions across the country. The satellite data contribute to short- and long-term forecasts of precipitation that, for example, can inform groundwater models and other tools about water available for groundwater recharge. NOAA data from satellites and ground-based observing systems also feed into longer-term climate forecasts and climate models, which can be used to help understand the potential effects of climate change on groundwater supplies.

USDA

The Census of Agriculture is required by law and authorizes the Secretary of Agriculture to conduct surveys deemed necessary to furnish annual or other data on the subjects covered by the census.[45] The census is a broad survey that includes questions about irrigation and water use, and is conducted every five years. A more detailed national assessment of irrigated agriculture in the

[40] See, for example, NASA, Jet Propulsion Laboratory, "GRACE Tellus: Groundwater," at https://grace.jpl.nasa.gov/applications/groundwater/.

[41] About 31 cubic kilometers, or 6.8 trillion gallons. See J. S. Famiglietti et al., (2011), *Satellites Measure Recent Rates of Groundwater Depletion in California's Central Valley*, Geophys. Res. Lett., 38, L03403, at doi:10.1029/2010GL046442.

[42] Estelle Chaussard et al., "Remote Sensing of Ground Deformation for Monitoring Groundwater Management Practices: Application to the Santa Clara Valley During the 2012-2015 California Drought," *Journal of Geophysical Research-Solid Earth*, vol. 122, no. 10 (September 21, 2017), pp. 8566-8582.

[43] See, for example, NASA, Jet Propulsion Laboratory, "Satellites See Silicon Valley's Quick Drought Recovery," October 3, 2017, at https://www.jpl.nasa.gov/news/news.php?feature=6962.

[44] See National Integrated Drought Information System (NIDIS), "What Is NIDIS?," at https://www.drought.gov/drought/what-nidis.

[45] 7 U.S.C. 2204g et seq.

United States is the Irrigation and Water Management Survey (formally the Farm and Ranch Irrigation Survey), also conducted every five years, and usually two or three years after the general census and under the same authority.[46] The most recent Irrigation and Water Management Survey (2018), conducted by the National Agricultural Statistics Service in USDA, supplemented the basic irrigation data collected from all farm and ranch operators in the 2017 census.[47]

Federal Authority Related to Groundwater Recharge, Storage, and Recovery

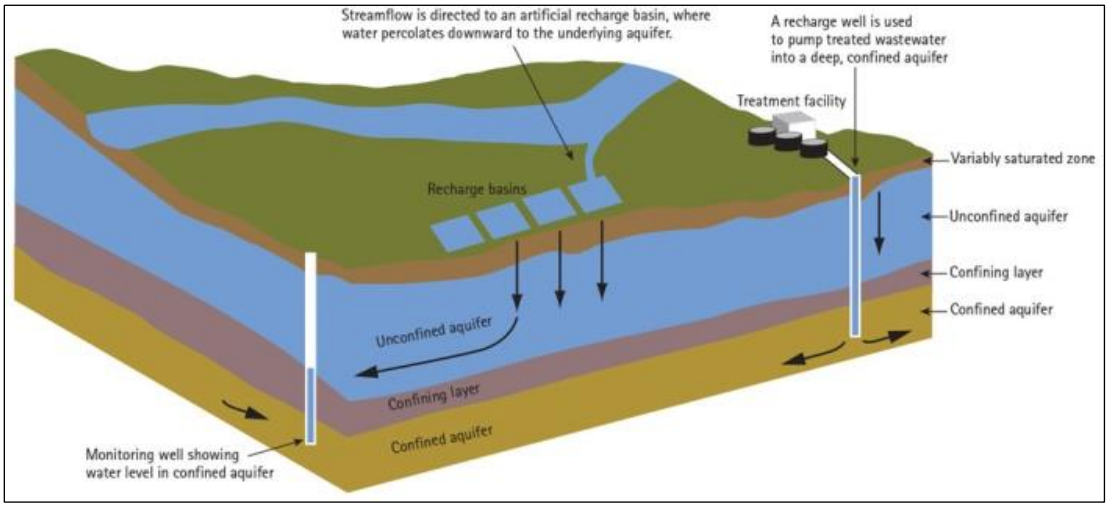
Recharging groundwater artificially with surface water is not a new concept, but interest in the practice is growing at the local, state, and federal levels for several reasons. When surface water supplies are curtailed because of drought, diversion for other uses, regulatory constraints, or other reasons, groundwater is often used to meet the demand. In addition, if demand for water supplies increases and additional surface water is not available, consumers may turn to groundwater. Along the coastline, groundwater extraction and the lowering of the water table sometimes have resulted in saltwater intrusion into the aquifer. Groundwater recharge may be used in those cases to replenish the aquifer and create a freshwater barrier to prevent seawater encroachment. Groundwater recharge, storage, and recovery also may be part of a conjunctive water management strategy in which both surface and groundwater are used, recharging groundwater in times of surface water surplus and extracting groundwater when surface water is in short supply.

Typically, groundwater recharge, storage, and recovery involves either injecting water into the aquifer through a well or allowing water to recharge from an impoundment (e.g., a pond) or a spreading basin (water is spread on the ground to percolate down to the aquifer). The water is stored in the aquifer until it is recovered by a pumping well for freshwater supply. **Figure 9** illustrates the process.

[46] For more information on the most recent Irrigation and Water Management Survey, see U.S. Department of Agriculture, Census of Agriculture, "2018 Irrigation and Water Management Survey," at https://www.nass.usda.gov/Publications/AgCensus/2017/Online_Resources/Farm_and_Ranch_Irrigation_Survey/index.php.

[47] The USDA Irrigation and Water Management Survey differs from the USGS water use estimates report in methodologies and reporting schedules and should not be compared directly. See footnote 6.

Figure 9. Groundwater Recharge, Storage, and Recovery



Source: National Groundwater Association (NGWA), "Managed Aquifer Recharge: A Water Supply Management Tool," NGWA Information Brief, 2014 (with permission). (Modified by CRS.)

Notes: The figure shows how the aquifer is recharged using a recharge well (on the right) and from recharge basins (middle of the figure). The recharge well is recharging a confined aquifer, and the recharge basins are recharging an unconfined aquifer.

According to several sources, more than 1,000 aquifer recharge wells and aquifer storage and recovery wells, along with many recharge basins, have been constructed across the nation.[48] In addition to technical, economic, and regulatory issues, identifying and providing a source of water for these activities is critical. Increasingly, federal water resource projects, such as those managed by Reclamation and USACE, are being considered as potential sources of recharge water. Reclamation, USDA, and EPA are also potential sources of financial assistance for supporting aquifer recharge, storage, and recovery projects. This section identifies various federal authorities for groundwater storage, recharge, and recovery.

Bureau of Reclamation

Reclamation, a federal agency of the Department of the Interior, owns and operates hundreds of dams and water diversion structures projects in the 17 coterminous U.S. states west of the Mississippi River. Reclamation was created by Congress in the Reclamation Act of 1902,[49] which authorized the Secretary of the Interior to construct irrigation works in western states. In addition to water supply, Reclamation facilities also provide flood control, recreation, and fish and wildlife benefits.[50] Reclamation cites several authorities for groundwater activities, including the authority to deliver project and excess water for aquifer storage and recharge and the authority to provide financial support for these activities. These authorities are discussed below.

[48] See, for example, U.S. Environmental Protection Agency, Underground Injection Control, "Aquifer Recharge and Aquifer Storage and Recovery," at https://www.epa.gov/uic/aquifer-recharge-and-aquifer-storage-and-recovery#inventory; and National Groundwater Association, "Aquifer Storage and Recovery: Need for Critical Analysis of the Technical, Economic, and Regulatory Issues," at http://www.ngwa.org/Media-Center/issues/Pages/Aquifer-storage-and-recovery.aspx.

[49] Act of June 17, 1902 (ch. 1093, 32 Stat. 388).

[50] For a brief synopsis of Reclamation project authorization and financing, see CRS In Focus IF10806, *Bureau of Reclamation Project Authorization and Financing*, by Charles V. Stern.

Reclamation Authority to Deliver Project or Excess Water for Groundwater Use

Overall, Reclamation reports no federal restrictions on its authority to deliver project or excess water to contractors for groundwater recharge, and contractors using these waters for groundwater recharge are not required to seek any special approvals beyond what is normally required by Reclamation. However, DOI officials also have acknowledged that Reclamation's existing authorities for groundwater use are general in nature, and increased specificity of these authorities may be useful.[51] For example, some aquifers underlie both project and non-project areas, with non-project areas being the preferable delivery location for groundwater uses due to one or more factors (e.g., land use, geology). However, under Reclamation's existing authorities, the delivery of "project waters" (i.e., waters for which Reclamation holds water rights) for groundwater uses may be limited to lands within a Reclamation project's authorized boundaries. As a result, some have urged Congress to clarify Reclamation authorities to deliver project water for groundwater recharge outside of project boundaries.[52] Reclamation also reports that some state restrictions affect the use of these waters for groundwater activities. In general, Reclamation does not track the use of project or excess water for groundwater recharge, although these uses appear to be occurring in at least a few places. The following authorities have been or may be used by Reclamation for groundwater storage:

- Section 9 of the Reclamation Project Act of 1939 (43 U.S.C. §485) is the general authority by which Reclamation is authorized to enter into contracts to furnish water for irrigation, municipal, and miscellaneous water supply purposes. Reclamation interprets the purposes of deliveries under this section to include groundwater recharge.
- Section 1 of the Warren Act of February 21, 1911 (43 U.S.C. §523), authorizes Reclamation to enter into contracts for the conveyance and storage of non-project water through the federal reclamation project, when the water is to be used for irrigation purposes and excess capacity exists. This authority has in some cases been used for groundwater recharge.[53]
- Section 215 of the Reclamation Reform Act of 1982 (P.L. 97-293) is the authority Reclamation uses to enter into temporary water service contracts for un-storable or excess flood flows. Reclamation indicates that it has no restrictions on using these waters for groundwater recharge.
- Section 101(d) of the Reclamation States Emergency Drought Relief Act of 1991 (P.L. 102-250) authorizes Reclamation to participate in state-established *water banks* to respond to drought.[54]

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[51] Statement of Timothy Petty, Assistant Secretary for Water and Science, U.S. Department of the Interior, before the U.S. Congress, Senate Committee on Energy and Natural Resources, *Full Committee Hearing to Examine the 2018 Western Water Supply Outlook and Bills Related to Water Infrastructure and Drought Resiliency*, 115th Cong., 2nd sess., March 22, 2018.

[52] See, for example, U.S. Congress, Senate Committee on Energy and Natural Resources, *Aquifer Recharge Flexibility Act*, Report to Accompany S. 1570, 116th Cong., 1st sess., October 29, 2019, S.Rept. 116-155 (Washington: GPO, 2019). Hereinafter, "S. Rept. 116-155."

[53] In its report accompanying S. 1570, the *Aquifer Recharge Flexibility Act*, the Senate Committee on Energy and Natural Resources noted that the ability to enter into a Warren Act contract for groundwater recharge has been "unevenly" applied by Reclamation. See S.Rept. 116-155.

[54] *Water banking* generally means the temporary storage of water in an aquifer for later extraction and use. See U.S. Bureau of Reclamation, *Groundwater Banking Guidelines for Central Valley Project Water* (under P.L. 102-575 §3408(d)), November 12, 2014, at https://www.usbr.gov/mp/waterbanking/docs/water-banking-guidelines.pdf.

- Section 3408((c), (d), and (e)) of the Central Valley Project (CVP) Improvement Act of 1992 (P.L. 102-575) authorize the *banking* of CVP water, consistent with and subject to state law.

Reclamation Authority to Provide Financial Support for Groundwater Storage

- Title IX, Subtitle F (Secure Water), Section 9504 (Water Management Improvement) of the Omnibus Public Land Management Act of 2009 (P.L. 111-11) authorizes Reclamation to provide financial assistance through the WaterSMART program for groundwater projects.[55]
- Title III, Section 4007(c) of the Water Infrastructure Improvements for the Nation Act (WIIN Act; P.L. 114-322) authorizes Reclamation to participate in state-led storage projects, which are defined to include groundwater storage facilities, among other facility types.
- Title III, Section 4009(a) of the WIIN Act amended the Water Desalination Act of 1996 (P.L. 104-298) to authorize Reclamation to provide financial support for projects that involve the desalination of brackish groundwater.
- Reclamation's Title XVI program (Title XVI of P.L. 102-575) provides Reclamation with the authority to implement water recycling and reuse projects, which may include projects that recycle and reuse impaired groundwater.

U.S. Army Corps of Engineers

USACE, an agency within the Department of Defense, has both military and civil works responsibilities. Congress directs USACE's civil works activities through authorizations, appropriations, and oversight of the agency's study, construction, and ongoing operations of water resource projects. Its civil works responsibilities are to support coastal and inland commercial navigation, reduce riverine flood and coastal storm damage, and protect and restore aquatic ecosystems in U.S. states and territories. In undertaking projects for these purposes, USACE also may pursue additional project benefits related to water supply, hydropower, recreation, fish and wildlife enhancement, and other purposes. That is, USACE projects typically have navigation, flood control, and/or aquatic ecosystem restoration as a primary purpose; other purposes and benefits are generally secondary or incidental. Therefore, USACE projects may support groundwater recharge, but generally recharge is not the primary purpose or justification for the projects. Moreover, USACE activities generally are in support of, rather than a direct performance of, aquifer recharge; that is, how USACE operates its projects may affect how others perform groundwater recharge or may affect the water demand that is met by water stored at USACE reservoirs or by groundwater pumping.[56]

USACE water resource projects typically are for nonconsumptive water uses (e.g., dams that store water to reduce the peak flow of a river during flood conditions), with a few specifically authorized exceptions; thus, the federal government generally has not acquired water rights from states for USACE projects. To access project water for water supply purposes, including groundwater recharge activities, nonfederal entities are responsible for securing any water rights

[55] For more information on the WaterSMART program, see U.S. Bureau of Reclamation, "WaterSMART (Sustain and Manage America's Resources for Tomorrow)," at https://www.usbr.gov/watersmart/.

[56] The effect that USACE projects may have on altering hydrology in a basin, including natural recharge in the floodplain, is beyond the scope of this report.

pursuant to state law. USACE generally does not deliver water under contract, in contrast to Reclamation. Instead, USACE provides storage at its reservoirs as a nonconsumptive service. USACE has some, albeit constrained, flexibility and authorities to operate its projects to benefit groundwater recharge.[57] That is, for projects with purposes of *water conservation* or *water supply storage*, USACE may be able to operate them in ways that support recharge.[58]

Prior to the WIIN Act in 2016, USACE had no general authority to include storage space in USACE projects for seasonal operations (i.e., short-term retention of water for a few months if storage space is available based on seasonal hydrologic patterns) for water conservation that would benefit municipal and industrial (M&I) water supply.[59] Notwithstanding those projects with specific authorization for water conservation, USACE policy and procedures indicated that seasonal operations for water supply could be conducted insofar as they were consistent with authorized project purposes and law, and subject to hydrologic and hydraulic capability of the project. Nonfederal entities could use the water supply to enhance groundwater replenishment, to increase downstream flow, or to otherwise enhance the general usage of the project for M&I purposes. Also, USACE has two long-standing general authorities related to M&I water supply: a surplus water authority and a water supply authority for permanent reallocations of storage at a reservoir.[60]

Title I of the WIIN Act addressed seasonal operation for water conservation and groundwater recharge in three sections[61]

- **Section 1116**: In a state with a drought emergency between December 2015 and December 2016, the Secretary of the Army is authorized to evaluate and carry out water supply conservation measures, including releases for groundwater replenishment or aquifer storage and recovery.
- **Section 1117**: In a state with a drought emergency between December 2015 and December 2016, upon the request of the governor, the Secretary of the Army is authorized to prioritize the updating of the water control manuals for control structures in the state and incorporate into the manuals seasonal operations for water conservation and water supply for such control structures.
- **Section 1118**: At the request of a nonfederal interest, the Secretary of the Army may review proposals (except those involving a few excluded river basins) to

[57] CRS did not identify any federal restrictions on the use of water released from or water withdrawn from USACE reservoirs for groundwater recharge, as long as that use is consistent with state law (i.e., the entity capturing the water has a right to use the water pursuant to state law) and federal environmental protection laws (e.g., the Safe Drinking Water Act). USACE does not track whether water released from or water withdrawn from USACE reservoirs is used for recharge.

[58] Some USACE aquatic ecosystem restoration projects may have components that relate to groundwater (e.g., aquifers may provide minimum flows into certain streams during low-water conditions). Given this report's focus on the consumptive social uses of groundwater, USACE groundwater-related ecosystem restoration projects and authorities are not discussed further in this report.

[59] USACE Institute for Water Resources, *Comprehensive Water Supply Study*, September 2001, at http://www.iwr.usace.army.mil/Portals/70/docs/iwrreports/01-PS-1.pdf;USACE, *Planning Guidance Notebook*, ER 1105-2-100, April 22, 2000, at http://www.publications.usace.army.mil/Portals/76/Publications/EngineerRegulations/ER_1105-2-100.pdf.

[60] For more on these authorities and how they are used, see CRS Report RL30478, *Federally Supported Water Supply and Wastewater Treatment Programs*, coordinated by Jonathan L. Ramseur.

[61] USACE has published implementation guidance for each of the WIIN Act provisions discussed below; they are available at http://www.usace.army.mil/Missions/Civil-Works/Project-Planning/Legislative-Links/wrda2016/wrda2016_impguide/.

> increase the quantity of available water supplies at a federal water resources development project by modifying the project, modifying how the project is managed, or accessing water released from the project. Among other things, proposals may include diversion of water released or withdrawn from the project to recharge groundwater or for aquifer storage and recovery.

As with other aspects of USACE reservoir operations, the storage or release of water to support nonfederal recharge activities pursuant to these authorities is to be consistent with the USACE project's congressionally authorized project purposes and subject to the project's capability.

In September 2019, EPA released a draft national action plan for water reuse that included the following recommended action on incorporating water reuse into USACE projects:

> Civil Works projects are developed, implemented, and operated with non-federal sponsors for flood risk management, commercial navigation, ecosystem restoration, recreation, and environmental stewardship. Clarification on how the civil works project development process can directly include water reuse considerations could enable better incorporation of such reuse features in projects authorized by Congress.[62]

In particular, interest has been growing regarding how to capture and use floodwaters to enhance groundwater recharge on agricultural lands and in urban areas. One method is to reestablish more natural floodways rather than confined channels transporting flood flows. Congress has authorized USACE to evaluate more nature-based approaches in legislation.[63] Among the challenges for reestablishing wider floodplains are real estate-related property rights and maintaining flood risk reduction in developed areas.[64]

USDA

USDA does not have a federal mandate to control groundwater use, recharge, storage, or recovery on private agricultural lands. The disproportionate percentage of groundwater usage by agriculture relative to other industries, however, has led USDA to take an active role in research, conservation, and education related to groundwater and its agriculturally connected uses.

Conservation of Groundwater

USDA provides agricultural producers with financial and technical assistance, as well as research to conserve on-farm water use. A number of USDA agencies provide support through education, outreach, and research in addition to providing direct federal assistance for adoption of on-farm irrigation best management practices. For more information on irrigation in the United States and related best management technologies, see CRS Report R44158, *Irrigation in U.S. Agriculture: On-Farm Technologies and Best Management Practices*.

Financial assistance for irrigation conservation practice adoption is primarily authorized through omnibus farm bills. Most recently, the 2018 Agriculture Improvement Act (2018 farm bill; P.L. 115-334) authorized a number of programs that provide cost-share assistance to private farm and

[62] U.S. Environmental Protection Agency, *National Water Reuse Action Plan Draft*, September 2019, p. 21, at https://www.epa.gov/sites/production/files/2019-09/documents/water-reuse-action-plan-draft-2019.pdf.

[63] For example, see Section 1184 of WIIN Act, as amended (33 U.S.C. §2289a), and Sections 1176 and 1183 of WIIN Act.

[64] Thomas Jacobson, "Too Much Water, Not Enough Water: Planning and Property Rights Considerations for Linking Flood Management and Groundwater Recharge," *Water International*, vol. 4, no. 5 (September 2019).

ranch land owners to adopt water conserving practices.[65] Technical assistance, which includes planning and design of on-farm water conservation measures, can be provided either in connection with financial assistance or through a separate irrigation water management plan.[66] The primary USDA agency administering both financial and technical assistance is the Natural Resources Conservation Service.

USDA also conducts research into groundwater-related areas, such as irrigation technologies, plant water use efficiency, hydrologic connectivity, and source water protection, to name a few. Primary research activities are conducted either through the Agricultural Research Service, USDA's intramural research agency, or the National Institute of Food and Agriculture, which administers extramural funding to support agriculture-related science and research, primarily at state universities.

U.S. Environmental Protection Agency[67]

To promote development of and private investment in water infrastructure projects, the 113th Congress authorized the Water Infrastructure Finance and Innovation Act (WIFIA) in the Water Resources Reform and Development Act of 2014 (P.L. 113-121, Title V; 33 U.S.C. §§3901-3914). WIFIA authorizes EPA and USACE to provide credit assistance—secured or direct loans—for a range of water infrastructure projects. EPA is implementing a WIFIA program.

Categories of projects eligible for assistance from EPA's WIFIA program include aquifer recharge or development of alternative water supplies to reduce aquifer depletion, among others. Activities eligible for WIFIA assistance include project development and planning, construction, acquisition of real property, and carrying costs during construction. WIFIA credit assistance is available to a number of entities, including private entities, some of which may be interested in aquifer recharge, storage, and recovery projects.[68]

Projects carried out by private entities are required to have a public sponsor to be eligible for WIFIA assistance. WIFIA requires private entities to demonstrate to EPA that the affected state, local, or tribal government supports the project. The maximum amount of a loan is 49% of eligible project costs, but the act authorizes EPA to make available up to 25% of available funds each year for credit assistance in excess of 49% of project costs. Except for certain projects, the total amount of federal assistance (i.e., WIFIA and other sources combined) may not exceed 80% of a project's cost.[69]

[65] For example, the Environmental Quality Incentives Program (EQIP) provides financial assistance to address natural resource concerns, including water conservation, under the general authorities established in §§1240-1240G of the Food Security Act of 1985 (P.L. 99-198), as amended (16 U.S.C. 3839aa et seq.).

[66] Most conservation technical assistance is provided by USDA under the general authorities of the Soil Conservation and Domestic Allotment Act (P.L. 74-46), as amended (16 U.S.C. §590a et seq.).

[67] This section was contributed by Elena H. Humphreys, Analyst in Environmental Policy.

[68] The eligible entities include state infrastructure financing authorities; a corporation; a partnership; a joint venture; a trust; or a federal, state, local, or tribal government, or consortium of tribal governments.

[69] For more information on WIFIA, see CRS Report R43315, *Water Infrastructure Financing: The Water Infrastructure Finance and Innovation Act (WIFIA) Program*, by Jonathan L. Ramseur, Mary Tiemann, and Elena H. Humphreys. For an example of a groundwater project funded in part under WIFIA, see the Pure Water Monterey Groundwater Replenishment Project, at https://www.epa.gov/wifia/pure-water-monterey-groundwater-replenishment-project.

Federal Reserved Rights to Groundwater

The federal government typically defers to states to allocate water resources within the state.[70] An exception has been the right to regulate water supplies on federal reservations, stemming from the U.S. Supreme Court decision in *Winters v. United States*.[71] Under the *Winters* doctrine, when Congress reserves land (e.g., for an Indian reservation), Congress also reserves water sufficient to fulfill the purpose of the reservation.[72] The *Winters* case specifically addressed the priority and extent of Indian reserved water rights, but the Supreme Court also recognized these rights in non-Indian contexts. In 1976, the Court noted that it "has long held that when the Federal Government withdraws its land from the public domain and reserves it for a federal purpose, the Government, by implication, reserves appurtenant water then unappropriated to the extent needed to accomplish the purpose of the reservation."[73]

Although the *Winters* doctrine has been applied to federal reserved water rights generally, the federal reserved rights for groundwater are more ambiguous than the rights for surface water. Tribal rights to groundwater, for example, have not been legally established to the same extent as rights to surface water (and other natural resources, such as timber, oil and gas, and minerals).[74] However, an ongoing legal case involving a Southern California Indian tribe's rights to groundwater under the *Winters* doctrine may establish those rights more specifically.[75]

Climate Change and Other Long-Term Influences on Groundwater Supply

Long-term changes to the climate affecting the United States, particularly rising temperatures and changes in the patterns, quantities, and type of precipitation (i.e., rain versus snow), could affect the availability of groundwater in the future. Changes in temperature and precipitation could affect the amount of water that recharges aquifers and therefore could shape how much groundwater is available for irrigation, domestic water supply, and other uses. However, the amount of natural recharge is just one variable (albeit an important one) influencing groundwater supply (i.e., its amount and availability). In some important aquifers, such as the Central Valley aquifer in California, the largest portion of recharge comes from irrigation return flow—excess water applied to the crops that is not lost to evapotranspiration or runoff.[76] Changes in irrigation

[70] Some legal scholars observe that the federal government has authority to regulate water resources, based on the Commerce Clause and the Property Clause of the U.S. Constitution. For further discussion, see, for example, John D. Leshy, "The Federal Role in Managing the Nation's Groundwater," *Hastings West-Northwest Journal of Environmental Law and Policy*, vol. 11, no. 1 (Fall 2004), p. 2.

[71] Winters v. United States, 207 U.S. 564, 575-77 (1908). Also, in United States v. New Mexico, the Supreme Court noted that "the 'reserved rights doctrine' is a doctrine built on implication and is an exception to Congress's explicit deference to state water law in other areas." United States v. New Mexico, 438 U.S. 696 (1978).

[72] For more information on rights stemming from Winters v. United States, see CRS Report RL32198, *Indian Reserved Water Rights Under the Winters Doctrine: An Overview*, by Cynthia Brown (available to congressional clients upon request).

[73] See Cappaert v. United States, 426 U.S. 128, 138 (1976).

[74] For more information on Indian water rights and water settlements, see CRS Report R44148, *Indian Water Rights Settlements*, by Charles V. Stern.

[75] See CRS Insight IN10857, *Federal Reserved Water Rights and Groundwater: Quantity, Quality, and Pore Space*, by Peter Folger.

[76] Thomas Meixner et al., "Implications of Projected Climate Change for Groundwater Recharge in the Western United States," *Journal of Hydrology*, vol. 534 (January 4, 2016), p. 127. Evapotranspiration is the combination of evaporation

practices and technology could significantly alter irrigation return flow in the Central Valley. For example, more efficient irrigation would use less water for the same yield yet conversely would contribute less return flow as recharge to the aquifer.

Policies that would enable greater artificial recharge, such as current authorities at Reclamation and USACE or new authorities that Congress may introduce, also may create long-term changes to groundwater supply and availability. In addition, broad changes in water demand, such as a transition to less irrigation and more municipal use, could influence how groundwater is used. All of these factors complicate any precise projection of changes to U.S. groundwater supply. Data collected and distributed by the USGS, NASA, NOAA, and the USDA will likely improve the understanding of long-term trends in groundwater storage and use. The long-term trends can be assessed against the effects of climate change in the future.

Climate Change and Groundwater Recharge

Intense global interest in greenhouse gas-influenced climate change prompted a number of studies investigating how a changing climate could affect groundwater, particularly affecting groundwater depletion and the amount of water available for recharging aquifers.[77] These studies have helped identify the many complexities involved in forecasting long-term consequences of climate change on groundwater supplies. Two broad review studies published in 2016 and 2017 are summarized below.

One study (by Meixner et al., 2016) synthesized the results of several other studies in an attempt to gauge the impacts of future climate change on the western United States (states west of the 100th meridian).[78] The study focused at the scale of major aquifers (specifically, eight aquifers),[79] because the study authors considered that global-scale studies are too broad to inform policymaking and that local-scale studies do little to illuminate potential changes across larger regions, such as states, which are important for setting water policy. The authors selected the western United States because of the importance of groundwater in that area relative to the more humid east, with its more abundant supplies of surface water.[80]

A conclusion from the study is that a "wet gets wetter, dry gets drier" scenario may prevail in the West, meaning generally that the already arid southwest is predicted to become drier, reducing the availability of precipitation for recharge, and the northern portion of the western United States may get wetter, increasing the availability of water for recharge. However, even for regions experiencing wetter conditions, higher average temperatures in the future could cancel out some of the gains, because of higher evaporation and other effects. Mountain systems, in which snowpack plays an important role in water supply and recharge, are likely to provide less water because of lower precipitation (in the south, particularly) and because of a transition to less snow and more rain in the northern ranges. However, the study notes that the impacts of expected

and respiration by plants. Hereinafter, Meixner et al., 2016.

[77] See USGCRP, Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II, 2018, U.S. Global Change Research Program, Chapter 3: Water, *Key Message 1*, https://nca2018.globalchange.gov/chapter/3/. See, also, the 2014 National Climate Assessment, U.S. Global Change Research Program, *Key Message 4: Groundwater Availability*, at https://nca2014.globalchange.gov/report/sectors/water.

[78] Meixner et al., 2016.

[79] These included the Ogallala (or High Plains aquifer; NE, CO, KA, TX, NM, AZ), San Pedro (AZ), Death Valley (NV, CA), Wasatch Front (UT), Central Valley (CA), Columbia Plateau (WA, OR, ID), Spokane Valley-Rathdrum Prairie (WA), and Williston Basin (ND, MT) aquifers.

[80] Meixner et al., 2016, p. 125.

snow-to-rain shifts on groundwater are uncertain due to a lack of robust knowledge about mountain system aquifers.[81]

A finding in the Meixner, et al. study was that knowledge gaps in forecasting changes in the frequency and intensity of future precipitation events will translate into uncertainty in predicting changes to recharge. **Figure 10** captures possible broad changes indicated in the study between current conditions and potential future climate conditions for the western United States under a greenhouse gas-induced global warming scenario.[82]

Another study (Smerdon, 2017) provides a broad synopsis of the published science. It summarized six review articles published between 2011 and 2016 on groundwater and climate change, noting common conclusions on aspects related to predicting changes in groundwater recharge.[83] The study noted that varying predictions of future recharge result from uncertainty inherent in the distribution and trend of future precipitation as predicted in climate change models (also called *general circulation models*, or GCMs). The study reported additional uncertainty in groundwater recharge forecasts because of uncertainties in downscaling GCM results from the global to the regional scale, similar to the findings in the paper discussed above.

One of the articles reviewed suggests "the role of vegetation is shown to be paramount for the recharge process, where change in precipitation could be accommodated by natural adjustment in evapotranspiration in some cases."[84] The finding implies that making predictions of recharge could be difficult because the water consumed by vegetation would not be available to recharge an aquifer. Other articles reviewed in the Smerdon study pointed out that GCMs do not directly incorporate changes in groundwater; in other words, groundwater recharge was not directly modeled in the GCM approach, so changes to groundwater can only be inferred from other model results.

One conclusion from the study is that forecasting future groundwater supplies requires better long-term groundwater observations to match the long-term changes in climate to investigate their relationship. The Smerdon study notes that given all the uncertainties, several of the articles reviewed indicate that even the direction and magnitude of change to groundwater recharge is difficult to predict; some GCM modeling results suggest recharge could decrease, whereas other GCM results suggest the opposite for similar regions. Mountainous regions likely will be the most sensitive to changes in climate, according to the review.[85]

[81] Meixner et al., 2016, p. 136.

[82] Meixner et al., 2016, figure 1, p. 126.

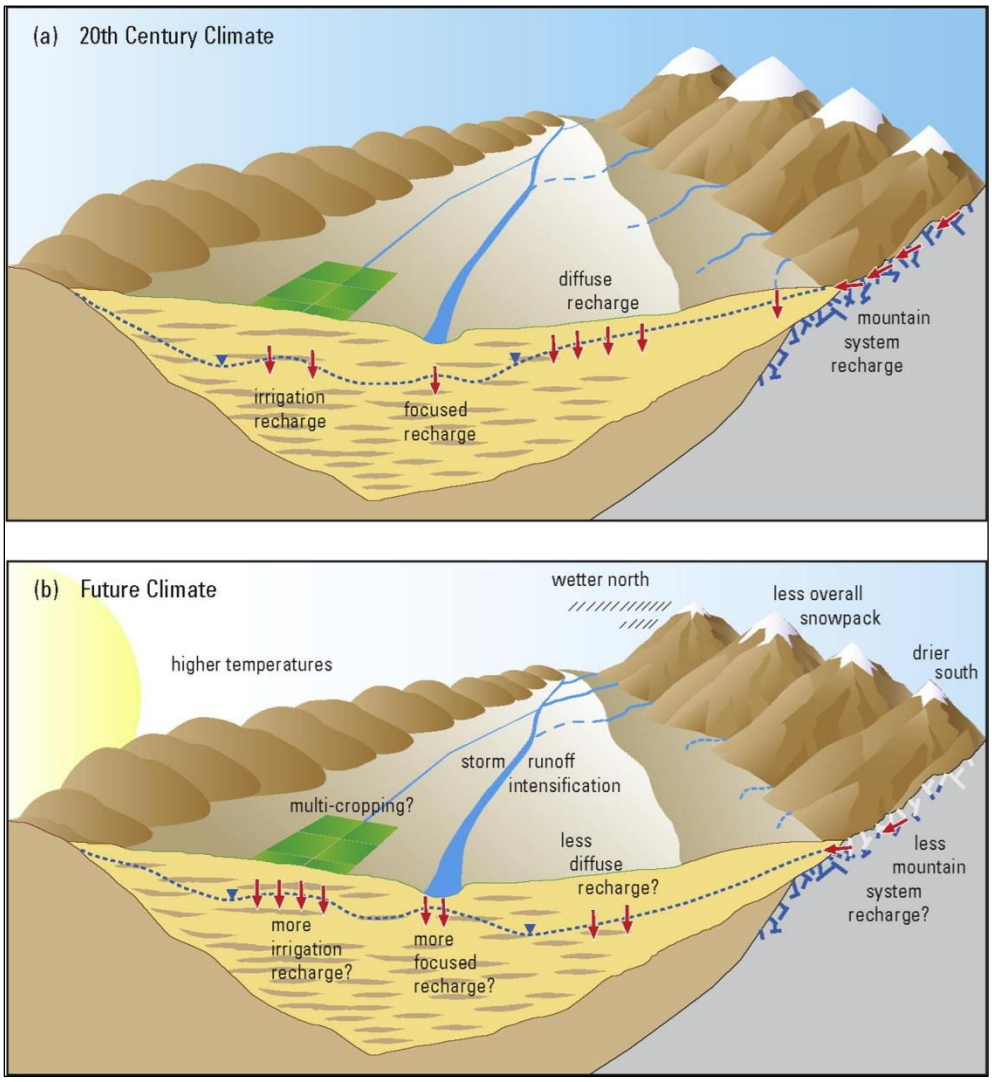
[83] Brian D. Smerdon, "A Synopsis of Climate Change Effects on Groundwater Recharge," *Journal of Hydrology*, vol. 555 (September 28, 2017). Hereinafter, Smerdon, 2017. (One of the six reviewed articles in the Smerdon synopsis is the Meixner et al., 2016, study discussed in this section.)

[84] Smerdon, 2017, p. 126.

[85] Smerdon, 2017, p. 127.

Figure 10. Conceptual Illustration of Recharge Mechanisms Under Two Different Climate Scenarios

(for the western United States)



Source: Thomas Meixner et al., "Implications of Projected Climate Change for Groundwater Recharge in the Western United States," *Journal of Hydrology*, vol. 534 (January 4, 2016), p. 126, figure 1, (with permission).

Notes: Four different recharge mechanisms are illustrated: *diffuse recharge*—resulting from infiltration of precipitation and direct recharge of the aquifer; *focused recharge* from rivers, streams, and lakes; *mountain system recharge* from where snow melts and infiltrates at the mountain front; and *irrigation recharge* from excess irrigation water that infiltrates the ground and reaches the water table. Under a greenhouse gas-induced warming climate (b), some of the recharge mechanisms may be diminished (such as mountain system recharge) and some may be enhanced (such as focused recharge) compared to 20th century conditions (a).

Other Factors

Other factors may also have profound influence on groundwater recharge and groundwater supply. For example, the Intergovernmental Panel on Climate Change Fifth Assessment noted that

changing land use is expected to affect freshwater systems globally, including groundwater.[86] The report noted that increasing urbanization, for example, may decrease groundwater recharge.[87] How irrigation practices evolve likely will influence the use and availability of groundwater, particularly for regions of the country where surface water supplies may decrease due to increasing aridity over the long term and where groundwater would substitute for surface water supplies during short-term droughts, much as it does today. Alternatively, regions experiencing wetter conditions could see reduced demand for groundwater if surface water supplies become more abundant. Because most groundwater in the United States is used for irrigation, more efficient irrigation practices may reduce overall water demand, which could place less stress on groundwater resources. A possible exception would be for aquifers that depend on excess irrigation flows for aquifer recharge (e.g., the Central Valley aquifer).

Summary and Conclusions

Congress generally has deferred management of U.S. groundwater resources to the states, and that practice appears likely to continue. Severe and widespread droughts over the last 10 years in California, the Midwest, and Texas and a longer period of drier-than-normal conditions in the Southwest have contributed to increasing congressional attention to the effects of drought on increased groundwater pumping and the depletion of groundwater supplies. These events have led to congressional interest in policies that would support augmentation of water supplies by enhanced aquifer recharge and the ability to store groundwater in an aquifer for later recovery when surface water supplies are curtailed by drought. Existing authorities for Reclamation and USACE allow federal projects to be involved in aquifer recharge, storage, and recovery in some way. Reclamation, USDA, and EPA also provide some forms of financial assistance that could support aquifer recharge, storage, and recovery.

A connection between federal water projects and groundwater enhancement already exists in Arizona, as part of the Central Arizona Project, and activities are being implemented via state law. More recently, California enacted three groundwater laws known collectively as the Sustainable Groundwater Management Act (SGMA), which directed the California Department of Water Resources to identify water available for replenishing groundwater in the state. Because the water provided by the Central Valley Project is integral to the water supply and delivery infrastructure of the state,[88] it is also recognized as part of the surface water resources potentially available for recharging aquifers as the SGMA is implemented.[89] Other western states with significant Reclamation water infrastructure also may look to enhance their sources of water for aquifer recharge by tapping the federal projects.

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[86] Jimenez Cisneros et al., "Freshwater Resources," Intergovernmental Panel on Climate Change, in *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects*, contribution of Working Group II to the *Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, 2014, p. 240.

[87] Increasing urbanization may include more covered surfaces, such as roads, parking lots, and other types of materials that are less permeable to precipitation than natural surfaces and could decrease the amount of water that infiltrates the ground and reaches the water table.

[88] For more information, see CRS Report R44456, *Central Valley Project Operations: Background and Legislation*, by Charles V. Stern and Pervaze A. Sheikh.

[89] See California Department of Water Resources, Sustainable Groundwater Management Program, *Water Available for Replenishment*, April 2018, at https://water.ca.gov/News/News-Releases/2018/April-18/Innovation-Investment-and-Infrastructure-Needed-to-Replenish-Groundwater-Basins.

Further technological developments in desalinating brackish or saline groundwater could help make those water supplies available for domestic, agricultural, or other uses.[90] Congress authorized an assessment of brackish groundwater in Section 9507(c) of P.L. 111-11 in 2009, and USGS released its assessment report in 2017.[91] In general, the assessment found that deeper wells had more brackish groundwater than shallower wells. Seventy percent of wells between 1,500 feet and 3,000 feet below the surface were brackish or highly saline, whereas less than 20% of wells 50 feet deep or shallower were brackish.

USGS reports that many water providers are turning to brackish groundwater to augment or replace freshwater for drinking and other uses, such as power generation, irrigation, aquaculture, and uses in the oil and gas industry (e.g., hydraulic fracturing).[92] For greater use of this potential resource, more detailed evaluations of specific aquifers likely are required. Technological and economic analyses would be needed to determine if brackish groundwater, especially from the deeper wells, could be used economically on a greater scale in the future.

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[90] Brackish water generally is more saline than fresh groundwater but less saline than seawater, containing total dissolved solids in concentrations ranging between 1,000 and 10,000 milligrams per liter (mg/l). Water with less than 1,000 mg/l is considered fresh; water with more than 10,000 mg/l is considered highly saline. Seawater is about 35,000 mg/l on average.

[91] Jennifer S. Stanton et al., *Brackish Groundwater in the United States*, USGS, Professional Paper 1833, 2017, at https://pubs.er.usgs.gov/publication/pp1833.

[92] Jennifer S. Stanton and Kevin F. Dennehy, "Brackish Groundwater and Its Potential to Augment Freshwater Supplies," USGS, Fact Sheet 2017-3054, July 2017, at https://pubs.er.usgs.gov/publication/fs20173054.

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