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ARIZONA'S GROUNDWATER MANAGEMENT ACT AT FORTY:
TACKLING UNFINISHED BUSINESS

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Abstract

Forty years ago, motivated by dropping water tables and land subsidence, Arizona lawmakers enacted the 1980 Groundwater Management Act. At the time, the Act was hailed as the most far-reaching state legislation to control rampant groundwater depletion ever enacted. Despite the rhetoric, however, the Act never dealt with Arizona's groundwater usage in a comprehensive manner and today its shortcomings are starkly apparent. The Act addressed the groundwater crisis only in the State's most populous areas, leaving the remainder of the State to the unregulated Wild West of groundwater use, a veritable "tragedy of the commons" perpetuated by the lax "reasonable use" doctrine. Furthermore, it left untouched in the law the hydrologic fallacy that ground and surface waters are distinct. The result is as predictable as it is tragic; plunging water tables in many of Arizona's rural areas are forcing homeowners and businesses to either drill deeper wells or

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relocate. Riparian areas are being lost, and with them, Arizona's unique desert ecosystems.

This Article argues that Arizona lawmakers must return to the drafting table to complete the work they started in 1980—the creation of a groundwater management code, based in science, that will ensure the equitable and sustainable use of groundwater across the entire State for current and future generations. It suggests two options for such future legislation, one embodying a property rights approach and the other a government regulation approach. Under the former, legislation would establish the framework for a groundwater market according to which existing and future groundwater users could purchase and trade the right to pump groundwater. Under the latter, Arizona could balance the powerful state and local interests in groundwater management through an expanded Act that follows "cooperative localism," a term coined in this Article to refer to a division of governing authority between state and local government in which local governments plan and implement state-imposed groundwater protection requirements. Cooperative localism would provide for local planning in pursuit of a statewide safe yield goal implemented on a basin-by-basin basis.

Today's groundwater crisis comes at a time when scientists warn that climate change will likely exacerbate current drought conditions, thus placing additional pressure on Arizona's declining groundwater resources. It also comes at a time when Arizona can expect future reductions in Colorado River supplies as a result of the recently enacted multistate Drought Contingency Plan.

I. Introduction

On June 12, 2020, Arizona's Groundwater Management Act (GMA) will turn forty. Hailed as "the most comprehensive groundwater code in the nation,"[2] the Act was described at the time as a "far-reaching" effort to address the diminishing supply of groundwater resulting from the explosion of development across the State.[3] This explosion had resulted in withdrawals within the State's populated areas vastly exceeding recharge rates,[4] dropping water tables and associated subsidence (including fissures),[5] and major cities such as Tucson buying nearby farmland in order to transport water once used for irrigation to thirsty city-dwellers.[6] The Arizona legislature, threatened with the prospect that all funding for the Central Arizona Project would be forfeited if no action was taken, passed the GMA in a single day.[7]

The conditions in the State's most populous areas that triggered the GMA's enactment are not unlike those occurring across the State today. Groundwater aquifers are experiencing rapid depletion across the State, especially those underlying Arizona's rural areas in the southeastern and northwestern

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[2] Robert Clark, Rocky Mtn. Min. L. Foundation, *Arizona Enacts Groundwater Management Law*, 13 WATER L. NEWSL. 1 (Nov. 3, 1980).

[3] Jon L. Kyl, *The 1980 Arizona Groundwater Management Act: From Inception to Current Constitutional Challenge*, 53 U. COLO. L. REV. 471, 472 (1982).

[4] According to the Groundwater Management Study Commission charged with developing a state groundwater code, in 1977 Arizona was consuming 2.5 million acre feet more groundwater than was being replenished in the state's aquifers. ARIZ. GROUNDWATER MGMT. STUDY COMM'N, DRAFT REPORT OF TENTATIVE RECOMMENDATIONS I-2 (July 1979) (on file with author).

[5] Scientific reports published during the 1970s found that the water table had dropped by as much as 100 feet during the previous ten years. Lawrence McBride, Comment, *Arizona's Coming Dilemma: Water Supply and Population Growth*, 2 ECOLOGY L.Q. 357, 361 (1972).

[6] BONNIE G. COLBY, DANA R. SMITH & KATHERINE PITTENGER, *Water Transactions: Enhancing Supply Reliability during Drought*, *in* ARIZONA WATER POLICY: MANAGEMENT INNOVATIONS IN AN URBANIZING, ARID REGION 81 (Bonnie G. Colby & Katharine Jacobs, eds., 2007) (Between 1971-79, Tucson purchased over 13,000 acres of irrigated farmland in Avra Valley to the west of the City and installed infrastructure so as to transport the water to city customers). *See also* Kyl, *supra* note 3, at 473 (Tucson, at the time reportedly the largest city in the nation entirely dependent upon groundwater, was experiencing difficulty obtaining new water supplies).

[7] Kyl, *supra* note 3, at 472.

portions of the State.[8] The rate of groundwater withdrawal in even those populated areas subject to groundwater regulation is outpacing the rate by which the aquifer is being replenished.[9] Only one such area, the broader Tucson area, is considered to be in a state of "safe yield" where the rate is roughly co-equal,[10] but this is likely attributed largely to recharge of the local aquifer with Colorado River water.[11]

The impacts of rapid groundwater declines are both immediate and long-term. In some areas of the State, groundwater tables have dropped below ordinary well depths, forcing residents to choose between abandoning their homes or paying the high cost of drilling a deeper well. Riparian areas, once flush with water, are drying up in part due to nearby groundwater withdrawals. As a result, habitat for Arizona's unique desert flora and fauna is disappearing.[12] Groundwater supplies 40 percent of the water used across the State. Cities, towns, agriculture, ranching, mining and commercial and industrial users all heavily rely upon groundwater. And yet the State projects water supply deficits in 30 out of 46 groundwater basins by 2035 and 36 by 2110.[13] A future with less groundwater is definitely a different future, and many would argue, a less prosperous and ecologically healthy future.

That these conditions are occurring now, a full 40 years after the enactment of the GMA, begs the question why the Act has failed to prevent the current groundwater crisis. While there is no one answer to an issue as complex as

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[8] Based upon an examination of more than 33,000 wells and over 250,000 well-drilling records, the Arizona Republic recently reported that water levels in more than 2,000 groundwater wells have dropped more than 100 feet since they were first drilled. Ian James & Rob O'Dell, *Amid unregulated pumping, Arizona's water tables are falling*, ARIZ. REPUBLIC (Dec. 6, 2019), https://www.azcentral.com/in-depth/news/local/arizona-environment/2019/12/05/unregulated-pumping-arizona-groundwater-dry-wells/2425078001/. "Moreover, the same report finds that "The number of newly constructed wells is accelerating, and wells are being drilled deeper and hitting water at lower levels." *Id.*

[9] ARIZ. DEP'T OF WATER RES., MANAGEMENT PLANS WORKGROUP PRESENTATION, Slide 25 (Aug 20, 2019), https://new.azwater.gov/sites/default/files/media/2019-08-20MPWG-Data.pdf.

[10] *Id.* (showing that groundwater overdrafts in the Tucson Active Management Area have been at zero since 2015).

[11] *See* VIOLETA CABELLO ET AL., *Implications of spatially neutral groundwater management: Water use and sustainability in the Tucson basin*, *in* WATER BANKRUPTCY IN THE LAND OF PLENTY 310-311 (2015) (stating the total combined volume of artificial recharge groundwater stored in the Tucson Active Management Area consisting of Central Arizona Project Colorado River water and wastewater is three times that of natural recharge and concluding that the increase in recharge capacity and concluding that the increase in capacity for recharge together with other factors is responsible for the achievement of safe yield in the Tucson AMA).

[12] A recent national study demonstrates this is unfortunately not unique to Arizona because groundwater pumping in the last century has contributed as much as 50 percent to stream flow declines in some U.S. rivers. Laura E. Condon & Reed M. Maxwell, *Simulating the sensitivity of evapotranspiration and streamflow to large-scale groundwater depletion*, 5 SCI. ADVANCES 6 (2019).

[13] GOVERNOR'S WATER AUGMENTATION, INNOVATION, AND CONSERVATION COUNCIL, NON-AMA GROUNDWATER COMM., AN ADWR PRESENTATION TO THE COMMITTEE ON GROUNDWATER IN ARIZONA, Slides 25-26 (Sept. 23, 2019), https://new.azwater.gov/sites/default/files/20190923Non AMA-GWpresentation.pdf.

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that of groundwater depletion, this Article will focus on the impacts of important gaps in the 1980 Act. The reality is that, despite being hailed as a "comprehensive" answer to Arizona's groundwater problems, the Act is anything but. The Act addressed the groundwater crisis in the State's most populated areas but actually weakened the system of private remedies for excessive groundwater pumping that otherwise applies throughout the remainder of the State. It also left untouched the bifurcation in the legal doctrines that control surface water appropriation from that governing groundwater use and management despite the widespread scientific understanding of their connection.[14] The associated weak system of coordination between the two has enabled decision makers to ignore the impacts of pumping upon surface waters and their associated ecosystems.

This Article argues that the 1980 GMA, or rather the GMA's *incompleteness*, is at least partially to blame for Arizona's current groundwater crisis. This is not because of the Act's regulatory provisions, but instead because the legislature applied them to just the State's most populated areas. In the rest of the State, groundwater withdrawals need adhere only to the lax "reasonable use" standard. This standard essentially allows unlimited withdrawals tempered only by the requirement that the water be put to a beneficial use on the land from which it is withdrawn. The Act's uneven regulation arguably impacts the effectiveness of the Act even in the populated areas that are subject to the Act's regulatory provisions. Consistent with efforts to protect businesses within regulated areas from competition from businesses that may relocate or locate in areas not subject to regulation (whether instate or out of state), the State's implementation of the Act in the regulated areas has been marred by delays and concessions to larger water users.[15]

Arizona's experience hides a larger lesson. Natural resource managers have long argued for uniformity in the legal framework applicable to all users of a geographically distinct common pool resource, but Arizona's experience indicates that this may not be adequate. Instead, attention must be paid to the uniformity of regulation across users not only of the target natural resource, but also resources that are likely to become substitutes when restrictions upon the targeted natural resource are imposed. Comprehensive regulation of users within an entire region or state may yield underappreciated benefits.

So what to do? This Article argues that Arizona lawmakers should return to the drafting table to complete the work they started in 1980—the creation of a groundwater management code, based in science, that will ensure the equitable and sustainable use of groundwater across the entire State for current and future generations. Additionally, it examines two options under which Arizona might do so, one embodying a property rights approach and the other a government regulation approach. Under the former, legislation would establish the framework

[14] Robert J. Glennon & Thomas Maddock III, *The Concept of Capture: The Hydrology and Law of Stream/Aquifer Interactions*, 43 RMMLF-INST 22, 22.02-22.03 (1997).
[15] *See infra* text accompanying notes 85-89.

for a groundwater market according to which existing and future groundwater users could purchase and trade the right to pump groundwater. Under the latter, Arizona could balance the powerful state and local interests in groundwater management through an expanded Act that follows "cooperative localism," which would provide for local planning in pursuit of a statewide safe yield goal implemented on a basin-by-basin basis.

Today's groundwater crisis comes at a time when scientists warn that climate change will likely exacerbate current drought conditions, thus placing additional pressure on Arizona's declining groundwater flows. It also comes at a time when Arizona can expect future reductions in Colorado River supplies as a result of Congress's recent enactment of the multistate Drought Contingency Plan.[16] In addition to greater reliance on groundwater, less Colorado River water will mean a smaller supply of renewable water that can be used to recharge groundwater aquifers. Indeed, today significant quantities of Colorado River water allocated through the Central Arizona Project are used to recharge groundwater aquifers on either a temporary or permanent basis.[17]

II. Arizona's Double-Bifurcated System of Groundwater Management

Arizona established its regulatory scheme for groundwater in the 1980 Groundwater Management Act.[18] Although hailed as a comprehensive treatment of groundwater management, it is limited in its application. In 1980 as well as in the State's prior 1948 Groundwater Code, the legislature restricted its regulatory efforts to the areas of the State experiencing the greatest groundwater overdraft, leaving groundwater exploitation in most of the remainder of the State essentially untouched. Both times the legislature limited its regulatory hand to areas that already exhibited groundwater mining, ignoring those that were yet to be significantly impacted. Today, however, areas of the State exhibiting severe groundwater overdraft are not limited only to those regulated under the Groundwater Management Act but include some of the State's most rural areas.

A. The Limited Scope of the Groundwater Management Act

In Arizona, whether the extraction of groundwater is regulated and if so, to what degree, depends almost entirely upon the location of the groundwater user. Very few requirements apply across the State. Instead, under the Groundwater Management Act, groundwater use is restricted within five "Active Management Areas"[19] (AMAs) and, to a lesser degree, within the three irrigation non-

[16] Colorado River Drought Contingency Plan Authorization Act, Pub. L. No. 116-14, 133 Stat. 850 (2019).

[17] *See* Sharon B. Megdal, Peter Dillon & Kenneth Seasholes, *Water Banks: Using Managed Aquifer Recharge to Meet Water Policy Objectives*, 6 WATER 1500, 1503-07 (2014).

[18] ARIZ. REV. STAT. ANN. §§ 45-401 to 636 (2020).

[19] The five AMAs consist of the four originally established by the Act in 1980, *see id.* § 45-111, and which surround the metropolitan areas of Phoenix, Tucson, Prescott as well as part of the intensively farmed areas of Pinal County residing between Phoenix and Tucson. A fifth AMA, the

expansion areas. Outside those areas, groundwater use is essentially unregulated, subject only to a slightly modified version of the common law "reasonable use" doctrine. After explaining Arizona's bifurcated groundwater regulatory structure, this Part draws upon the theoretical literature to discuss the implications of this system for limiting groundwater withdrawals to sustainable levels.

B. Within Active Management Areas

The GMA essentially divided the State into three regions: Active Management Areas (AMAs), Irrigation Non-Expansion Areas (INAs) and every place else. AMAs are areas where groundwater was considered "imperiled" in 1980 and the Act reserves its regulatory firepower for groundwater withdrawals in these areas. The boundaries of the AMAs are roughly coterminous with those of existing groundwater basins.

Because the Act's regulatory scheme is explained in easily accessible sources,[20] the following summary will be brief. In broad outline, the Act did three things: it created a new state-level department—the Arizona Department of Water Resources (ADWR)—to regulate ground and surface water within the State, it limited all future groundwater withdrawals within AMAs to only those specifically authorized by the Act and, importantly, capped the expansion of agricultural acreage. Finally, it created goals for the intensity of groundwater withdrawals within the AMAs and specified a suite of conservation measures, which, when rolled out in progressively more stringent formats found in the once-every-ten-years state-issued management plans, were intended to achieve the water withdrawal intensity goal by 2025.[21]

The Act prohibits future groundwater withdrawals in AMAs but includes important exceptions. Most significantly, within AMAs and "Irrigation Non-Expansion Areas" (INAs), the Act freezes the number of acres that can be irrigated.[22] After passage of the Act, within AMAs and INAs only lands that had been irrigated at some point between 1975 and 1979 could continue to be used for irrigated agriculture.[23] At the time of the GMA's enactment, agriculture was using

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Santa Cruz AMA, was created by the legislature in 1994 by carving an area out of the larger Tucson AMA. *Id.* § 45-111.03.

[20] For an excellent summary, see William Staudenmaier, *Arizona Groundwater Law*, 33 WATER REP. 1, 2 (Nov. 15, 2006), https://www.swlaw. com/assets/pdf/publications/2006/11/15/TheWater Report_ArizonaGroundwaterLaw_StaudenmaierWEB.pdf.

[21] SHARON B. MEGDAL, ZACHARY A. SMITH & AARON M. LIEN, EVOLUTION AND EVALUATION OF THE ACTIVE MANAGEMENT AREA MANAGEMENT PLANS 1, 5-6 (2008) ("The framers of the Act wanted to improve the groundwater situation, but also did not want to disproportionately harm water users by requiring rapid reductions in water use. The management plans provided a means for a gradual transition.").

[22] § 45-416.

[23] *Id.* § 45-462. For INAs, this restriction upon new acreage being subject to irrigation is the only restriction imposed by the GMA. The 1980 Act established two INAs: the Joseph City and the

a full 89 percent of all water in the State, so reducing this percentage was a top objective of the law's drafters.[24] Under the original Act, the amount of water that can be used to irrigate cropland was subject to increasing reductions with each successive 10 year state-issued management plan. The GMA permits continued groundwater withdrawals by cities, towns, private water companies, and irrigation districts.[25] Finally, the State can by special permit specifically authorize groundwater withdrawals for a variety of uses, including industrial use and mining.[26]

The GMA imposes goals and a planning and implementation scheme designed to bring most of the State's AMAs into a state of equilibrium such that the rate of groundwater withdrawals does not exceed the rate of recharge. This is known as "safe yield." With the exception of the Pinal AMA, each AMA is subject to the goal of safe yield. The Santa Cruz AMA is subject to both the safe yield goal and a goal of preventing the further decline of area water tables. Safe yield is defined as the balance between the amount of groundwater going in and the amount being withdrawn.[27] The goal for two of the AMAs is slightly different; the goal for the Pinal AMA incorporates the concept of "optimal yield"[28] whereby agriculture is maintained for as long as is feasible, considering the necessity of reserving future water supplies for non-irrigation uses.[29] In the Santa Cruz AMA, safe yield is defined as that which also protects the water tables of nearby surface waters.[30] Under the Act, each AMA is to achieve its goal by 2025 after the implementation of five successive state management plans which impose increasingly stringent water conservation measures.[31] These include a

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Douglas INAs. *Id.* § 45-431. The Harquahala INA was subsequently established in 1981 by the Director of ADWR pursuant to title 45, section 432 of the Arizona Revised Statutes. *Id.* § 45-432.

[24] ARIZ. GROUNDWATER MGMT. STUDY COMM'N, *supra* note 4, at I-3. Today, agriculture uses approximately 74 percent of Arizona's water. *Conservation, Agriculture*, ARIZ. DEP'T OF WATER RES., https://new.azwater.gov/ conservation/agriculture (last visited Mar. 1, 2020).

[25] §§ 45-492, 494.

[26] *Id.* § 45-515 (listing the types of uses for which the state may issue a special permit). Industrial and mining uses may also use a grandfathered right which is the right to withdraw water that was lawfully withdrawn prior to the designation of the area as an Active Management Area. *Id.* § 45-402. The GMA recognizes two types of grandfathered rights that can be used for non-irrigation purposes, Type 1 and Type 2, and either could be used for mining or industrial purposes. *Id.*

[27] § 45-561(12) (defining "safe yield" as a long-term balance between the annual amount of groundwater withdrawn in an active management area and the annual amount of natural and artificial recharge in the active management area.").

[28] This is the characterization provided in one report and seems accurate considering the goal asks for balancing two objectives – the preservation of agriculture as long as possible, and the reservation of sufficient water for future municipal and industrial uses. *See* KAREN L. SMITH, GRAND CANYON INST., GROUNDWATER: GETTING TO SAFE YIELD BY 2025 1, 3 (2015) https://grandcanyoninstitute.org/wp-content/uploads/2015/06/GCI_Policy_GroundwaterGettingto SafeYieldby2025_February2015.pdf.

However, the Pinal AMA goal is often referred to as "planned depletion" though that wording neither appears in the statute and nor is it consistent with the statutory directive to preserve future water supplies for future non-irrigation uses. *See, e.g.*, *id.* at 32.

[29] § 45-562(B).

[30] *Id.* § 45-562(C).

[31] *Id.* § 45-562.

ramping down in the amount of water that can be pumped under a given grandfathered irrigation right, per capita reductions upon municipal water users, and requirement that water users adopt best available technology. Additionally, since the second management plan, all AMAs must have an Augmentation and Recharge program to fund measures to facilitate natural recharge of groundwater and which are supported through a groundwater withdrawal fee.[32]

For many, however, the cornerstone of the 1980 GWA is the Assured Water Supply (AWS) program which attempts to prevent future growth that cannot be supported by available water supplies. Under the AWS, in order for any developer to sell subdivision lots, the developer must assure that water of adequate quality is available to future subdivision lot owners for 100 years.[33] The AWS requirement is satisfied if the subdivision is located within the service territory of a city, town or private water company that has been designated by ADWR to itself have a sufficient water supply.[34] Otherwise, the developer must obtain a Certificate of Assured Water Supply from ADWR. A Certificate is granted only after ADWR determines that sufficient supplies of adequate water quality are continuously, legally, and physically available for at least one hundred years.[35] While the AWS program applies within AMAs, individual counties can opt into the program, in which case a similar but more skeletal regime of "adequate" water supply requirements apply.[36]

Under the original GMA, a city or a developer could only satisfy the AWS requirement with demonstrated access to surface water supplies. Since 1995, however, a subdivision developer or city or town may satisfy AWS requirements with demonstrated access to groundwater, provided the developer or city or town is enrolled in the Central Arizona Groundwater Replenishment District (CAGRD).[37] CAGRD is an authority that, in exchange for the payment of ongoing fees, will replenish, with surface water, any excess groundwater pumped by the subdivision to satisfy its water needs.[38] CAGRD operates within three of the five AMAs: the Phoenix, Pinal, and Tucson AMAs.[39] While the AWS is considered a bulwark against unsustainable growth, the ability to satisfy AWS with groundwater is revealing new threats to groundwater supplies. Imprecision in estimating available groundwater supplies has led to a substantial over-

[32] *Id.* §§ 45-564 to 568.
[33] *Id.* § 45-576.
[34] *Id.*
[35] *Id.*; *see also* ARIZ. ADMIN. CODE § 12-15-7 (2020).
[36] ARIZ. REV. STAT. ANN. § 45-108. *See also Assured and Adequate Water Supply*, ARIZ. DEP'T OF WATER RES., https://new.azwater.gov/aaws (last visited Apr. 13, 2020).
[37] § 45-576.
[38] For a recent and eye-opening expose of the potential unsustainability of the Central Arizona Groundwater Replenishment District, see KATHLEEN FERRIS & SARAH PORTER, KYL CTR. FOR WATER POL'Y AT MORRISON INST., THE ELUSIVE CONCEPT OF AN ASSURED WATER SUPPLY (Fall 2019), https://morrisoninstitute.asu.edu/content/elusive-concept-assured-water-supply.
[39] *See What is CAGRD?*, CENT. ARIZ. PROJECT (May 31, 2017), https://www.cap-az.com/cap-currents/679-what-is-cagrd-3-31.

commitment of the supply available in at least one county, Pinal,[40] and the permissiveness in the rules for where CAGRD must replenish excess groundwater—anywhere in the AMA even if far from the point of the excess withdrawal—is risking serious harm to groundwater aquifers.[41]

C. Outside Active Management Areas

Outside the AMAs, none of these restrictions apply. In fact, the only provisions of the GMA that apply to the remainder of Arizona are those requiring wells be registered with the State and those prohibiting certain groundwater transfers.[42] Instead, groundwater withdrawals are governed by the common law doctrine of "reasonable use" codified in state statute.[43] According to the standard articulation of the "reasonable use" doctrine (also known as the "American rule"), landowners are entitled to withdraw percolating groundwater beneath their property in any amount so long as they apply it to the land from which it is extracted for a reasonable and beneficial use.

As other commentators have pointed out, the reasonable use doctrine provides scant protection against excessive groundwater pumping.[44] The doctrine does not provide a cap upon the total amount of water that a landowner can pump other than that imposed indirectly as a result of limitations upon the transfer of water. So long as the landowner puts the water to a reasonable and beneficial use upon the land itself, the amount she can withdraw is essentially unlimited.[45] This is true regardless of whether the owner's pumping deprives neighboring landowners of water needed to satisfy their land uses[46] or adversely affects the

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[40] Audio recording: Thomas Buschatzke, Director, Ariz. Dep't of Water Res., Ad Hoc Comm. on Groundwater Supply to Pinal Cty., Ariz. House of Representatives (Oct. 11, 2019), http://azleg.granicus.com/MediaPlayer.php?clip_id=23327&autostart=0 (approximately 2 million acre feet out of the 8.1 million acre feet of unmet groundwater demand in Pinal County over the next 100 years predicted by ADWR is associated with assured water supply determinations previously made by ADWR based upon earlier groundwater supply modeling that has since been replaced with more accurate modeling).

[41] FERRIS & PORTER, *supra* note 38, at 28-29.

[42] The Act prohibits groundwater from being transported between groundwater basins outside of AMAs and, with the exception of certain grandfathered transfers, also prohibits groundwater transfers from a groundwater basin outside an AMA into an AMA. ARIZ. REV. STAT. ANN. §§ 45-544, 45-551 to 555.

[43] *Id.* § 45-453.

[44] *See, e.g.*, Robert J. Glennon, *Water Exchanges: Arizona's Most Recent Innovation in Water Law and Policy*, 8 ARIZ. J. ENVTL. L. & POL'Y 1, 3 (2018) ("An oxymoron, this doctrine allows for the drilling of new wells with essentially no limits on pumping, setting the stage for uncontrolled pumping and plummeting water tables."); L. William Staudenmaier, *Between a Rock and a Hard Place: The Rural Water Supply Challenge in Arizona*, 49 ARIZ. L. REV. 321, 325-26 (2007) ("So long as a landowner withdraws groundwater in order to make reasonable use of the landowner's property, neighboring landowners have no claim for damages even if the groundwater withdrawals adversely affect water levels under the neighbor's property.").

[45] Bristor v. Cheatham, 255 P.2d 173, 180 (Ariz. 1953) (Bristor II).

[46] *Id.*; *See also* ROBERT J. GLENNON, WATER FOLLIES: GROUNDWATER PUMPING AND THE FATE OF AMERICA'S FRESH WATERS 8 (2004) ("[L]andowners may pump as much water as they want, so long as the pumping does not unreasonably harm adjoining landowners."); William Staudenmaier,

height of the groundwater table beneath neighboring property. In a particularly telling case, the Ninth Circuit Court of Appeals, applying Arizona law, reversed an award of damages to a pecan orchard owner whose trees had died due to the groundwater pumping activity of a neighboring landowner.[47] The court held that damages were unwarranted where the pumping was performed as part of an expansion of the neighbor's manufacturing facilities which was a reasonable and beneficial use of its land.[48]

Contrary to one's likely first impression, Arizona's adoption of the reasonable use doctrine is comparatively recent. The Arizona Supreme Court did not formally adopt the doctrine until 1953 in a second opinion in the case of *Bristor v. Cheatham* (*"Bristor II"*).[49] The historical context of the case is instructive as it came at a time when Arizona's groundwater supplies were clearly in deep trouble. So much trouble, in fact, that the Secretary of the Department of Interior had previously threatened to cancel plans for construction of the Central Arizona Project to bring a large fraction of Arizona's Colorado River allocation to the central part of the State unless the State acted to conserve its groundwater.[50]

In *Briston II*,[51] the Arizona Supreme Court reversed a short-lived majority opinion in the same case holding that access to the percolating ground waters were subject to the doctrine of prior appropriation, the same rules that applied at the time and still do to this day, to surface waters. The court found the adoption of prior appropriation to be inconsistent with precedent holding access to groundwater to be a private property right of surface owners[52] and, in any case, to lack a statutory foundation. The court then engaged in a debate over what doctrine should control the rights of a surface owner to underlying groundwater. With respect to this question, the court considered whether Arizona should follow the English common law rule of "correlative rights" or the American rule of reasonable use. The court chose the latter, primarily based upon its finding that a "great majority" of states had recently adopted the doctrine, a view contested by later commentators.[53]

Over the years, the Arizona legislature has weakened the doctrine of reasonable use to permit more groundwater extraction. Under the common law,

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Arizona Groundwater Law, 33 WATER REP. 1, 2 (Nov. 15, 2006), https://www.swlaw.com/assets/pdf/publications/2006/11/15/TheWaterReport_ArizonaGroundwaterLaw_StaudenmaierWEB.pdf ("So long as a landowner withdraws groundwater to make reasonable and beneficial use of the landowner's property, neighboring landowners have no claim for damages even if the groundwater withdrawals adversely affect water levels under the neighbors' property.").

[47] Brady v. Abbott Laboratories, 433 F.3d 679 (9th Cir. 2005).

[48] *Id.* ("Abbott withdrew the groundwater for the purpose of expanding its manufacturing facilities, which was an improvement of the land from which the water was withdrawn; therefore, it was a permitted beneficial use under Arizona law.")

[49] *Bristor II*, 240 P.2d at 185.

[50] DEAN MANN, THE POLITICS OF WATER IN ARIZONA (1963).

[51] *Bristor II*, 240 P.2d at 185.

[52] *Id.* at 175.

[53] *Id.* at 178.

the reasonable use doctrine came with an important caveat: it was limited to the reasonable and beneficial use of the pumped groundwater upon the landowner's *own land.* Landowners were prohibited from transporting any water they pumped on their own land for use on other lands.[54] In 1980, though less so today,[55] this rule contained an inherent limitation upon the quantity of water used, as there is only so much water that can be used on a single parcel of land.[56] This rule limited the amount of water in another important respect: the use was logically limited to the quantity needed to sustain local land uses and would last only so long as that local land use continued to be sustainable. Thus for example, if the local economy supported water-thirsty agriculture, then use of that quantity of water necessary to grow those crops would be consistent with the reasonable use doctrine. But if the local economy supported only lower-water intensity crops or housing rather than agriculture, the water available under the reasonable use doctrine would be substantially less as it could be no more than that which could reasonably be used on the land from which it was pumped. Finally and importantly, a violation of the prohibition was a basis for injunctive relief.

Nevertheless, these restrictions inherent in the common law reasonable use doctrine were gradually relaxed by the courts and the legislature not long after the reasonable use doctrine was adopted. In a 1970 decision, the Arizona Supreme Court amended a prior injunction against the City of Tucson which had prohibited it from pumping groundwater from land outside the city boundaries and within the confines of a critical Groundwater Management Area.[57] Tucson proposed to transport the water for municipal uses to the city, a distance of fifteen or so miles. The city's plan was challenged by farmers in the area from which Tucson proposed to transport the water who claimed that Tucson's plan would deprive them of water on which they relied. In the court's original opinion, it held that both the restrictions upon the export of water under the reasonable use doctrine as well as the legislature's action of developing critical groundwater areas required that the city's transport plan be enjoined.[58] But in the subsequent 1970 decision, the court stepped away from that hard line and used the "legislative priority scheme" in the 1948 Groundwater Act to amend the injunction to allow Tucson to buy up farms in the very same area—the critical groundwater protection area—and to transport water from those irrigated lands in amounts equal to the water that had been used for cultivation.[59]

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[54] *See also* Jarvis v. State Land Dept., 479 P.2d 169 (Ariz. 1970) (Jarvis II) (citing a long line of cases adhering to this restriction upon a landowner's use rights pursuant to the reasonable use doctrine).

[55] *See, e.g.*, large industrial farming and ranching operations today using huge quantities of water on their own property.

[56] *See* Melissa K. Scanlan, *Droughts, Floods and Scarcity in a Climate-disrupted Planet: Understanding the Legal Challenges and Opportunities for Groundwater Sustainability*, 37 VA. J. ENVTL. L. 52, 63 (2016) (noting this aspect of the reasonable use doctrine "provides an enforceable way to limit pumping to on-tract use").

[57] *See Jarvis II*, 479 P.2d 169.

[58] Jarvis v. State Land Dep't, 456 P.2d 385 (1969).

[59] *Jarvis II*, 479 P.2d at 174.

By expanding the market for water transfers, the court began to chip away at the inherent limitations in the reasonable use doctrine. Importantly, Tucson was afforded the right to pump, indefinitely, a specified amount of water that had previously been pumped on the land when it was under agricultural use, but to transport it to its customers living elsewhere for municipal purposes. The case destroyed the inherent limitations upon groundwater extraction imposed by the common law limitation that any water pumped must be for a reasonable and beneficial use of the overlying property.[60]

The legislature has subsequently amended the rules for water transfers. Unlike the common law rule, groundwater can be transferred within a sub-basin without restriction and between sub-basins upon the payment of any damages incurred. Only the transfer of groundwater between basins that are not otherwise grandfathered in the law is protected by the property rule entitling the complaining party to an injunction.[61] Like the court decisions, this loosening of the traditional common law rule that the water extracted had to be used *on the very property* from which it was pumped enables greater groundwater extraction.

III. Of Common Pools and Tragedies

A. Groundwater as a Common Pool Natural Resource

Many commentators consider groundwater to be a "common pool" natural resource similar to the common pool resources frequently mentioned in the economics literature such as fishing grounds and grazing pastures.[62] According to Elinor Ostrom, Nobel Laureate economist and expert on the dynamics of the maintenance or depletion of natural resource commons, "a common pool resource is a natural or man-made resource from which it is difficult to exclude or limit users once the resource is provided by nature or produced by humans."[63] Unlimited access to the good nevertheless threatens to degrade or deplete the good. In this way, a common pool is different from a public good where the enjoyment the good by one person does not diminish the enjoyment of the good by others.[64]

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[60] In a subsequent proceeding in the same case, Tucson's extraction was limited to the prior "consumptive use" of groundwater when it was subject to agricultural use. Jarvis v. State Land Dept., 550 P.2d 227, 230 (Ariz. 1976) (Jarvis III).

[61] ARIZ. REV. STAT. ANN. §§ 45-451 to 459 (2020).

[62] *See, e.g.*, Alan E. Friedman, *The Economics of the Common Pool: Property Rights in Exhaustible Resources*, 18 UCLA L. REV. 855, 855 (1971) (groundwater is a classic common pool resource); Jennifer L. Harder, *Unlimited Rights in a Water Scarce World*, 48 TEX. TECH. L. REV. 719, 723 (2016) ("Groundwater is one of the most recognizable examples of a common pool resource").

[63] Elinor Ostrom, *Coping with Tragedies of the Commons*, ANN. REV. POL. SCI. 493, 497 (1999).

[64] *Id.*

In order to define a rate of replenishment, a renewable common pool resource can be broken down into two components: a "stock" component and a "flow" component.[65] The stock component is the aspect or amount of the resource needed to maintain the common pool whereas the flow component is that which can be consumed without threatening the ability of the resource to regenerate. According to commons economist Elinor Ostrom, so long as the rate of withdrawal does not exceed the rate of replenishment, a renewable resource can be sustained into the future.[66] With respect to a fishing bed, for example, the stock component would be the number of fish needed to maintain a healthy fish population, and with respect to groundwater it would be the amount of water needed to maintain a healthy aquifer. The "flow" on the other hand is the rate at which units of the resource can be removed without harming the stock or the resource system. This would be the rate at which fish may be harvested or water might be withdrawn without harming a fishing bed or a groundwater aquifer.

To some, groundwater is not just an ordinary commons resource, but something of an "uber" common resource. M. Alexander Pearl has termed groundwater a "vital commons" to distinguish it from other common pool natural resources.[67] According to this terminology, a vital commons is a critically important resource whose benefits and externalities impact great numbers of people, are necessary for sustenance, and whose depletion would be extremely difficult to remediate.[68]

B. Groundwater Depletion Outside the AMAs as a Tragedy of the Commons

The dynamics of the collapse of an open access common pool is well-traveled ground in the law and economics literature. Likely the best known explanation is that of Garrett Hardin, who likens the users of such resources to prisoners in a Prisoner's Dilemma drawn from non-cooperative game theory.[69] Just like the prisoner who, driven by greed and self-interest, refuses to cooperate with prosecutors and, as a result, ends up with a harsher sentence, a herder, driven by the prospect of greater profits, will add more and more cattle to his herd grazing on a common pasture with the ultimate result that the pasture will collapse from overgrazing. The result is the tragedy attributable to the fact the herder is left worse off than had he worked with others to limit the total number of grazing cattle. The *Tragedy of the Commons* has been employed to explain the collapse of open access commons in the absence of restrictions upon use imposed either through a system of private property rights or government regulation.

Commentators since Hardin penned his famous essay have imposed important qualifications upon the circumstances that trigger a tragedy of the

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[65] ELINOR OSTROM, GOVERNING THE COMMONS: THE EVOLUTION OF INSTITUTIONS FOR COLLECTIVE ACTION 30 (1990).
[66] *Id.*
[67] M. Alexander Pearl, *Tragedy of the Vital Commons*, 45 ENVTL. L. 1021, 1021 (2015).
[68] *Id.* at 1041.
[69] Garrett Hardin, *The Tragedy of the Commons*, 162 SCI. 1243 (1968).

commons. One of the most important is Ostrom, whose scholarship identifies many long-enduring common pool resources in which users have failed to fall victim to the "tragedy" of rational selfishly-motivated overuse.[70] Instead, where users of the commons share social norms and an interdependent future, they are able to self-regulate so that even in the absence of a system of property rights or regulation, they do not overuse the commons to a point that it collapses.[71]

Hardin's metaphorical open access pastures bear many similarities to Arizona's groundwater aquifers located outside the State's Active Management Areas. Groundwater basins across the southern part of the State show steep declines in groundwater tables.[72] According to the United States Geological Survey (USGS), due to increased groundwater pumping throughout the south central parts of the State, water table levels have dropped by 300-500 feet in many areas.[73]

Arizona's aquifers are not exactly "open access" commons like Hardin's pasture.[74] Instead, access is limited to surface owners. Furthermore, because aquifers more resemble an underground labyrinth of interconnected rock pockets and pores filled with water, it is not always certain what will be the impacts of groundwater pumping from one part of an aquifer upon groundwater levels in other parts of the same aquifer. Nevertheless, because a surface owner's pumping is limited only by the weak reasonable use doctrine, groundwater basins have many similarities to an open access commons. While Arizona's groundwater aquifers are a commons open to a few, those few can essentially take however much they want, limited only by certain restrictions upon their ability to transfer the water for use on other property.

From all appearances, the trajectory of groundwater use outside AMAs is trending toward the tragedy of the commons predicted by Hardin and others. In an unprecedented investigation of Arizona groundwater, journalists from the State's largest media outlet examined data for more than 33,000 wells and 250,000 well-drilling records throughout Arizona, some going back over 100 years.[75] The results are striking; more than one in four wells have dropped over 100 feet and the problem is worst in rural areas outside the reach of the Groundwater Management Act. In the Wilcox basin, outside an AMA, wells in 2018 were being drilled over 358 feet deeper than they were in 2010.[76] In the Welton-Mohawk

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[70] OSTROM, *supra* note 65, at 61-102.
[71] *Id.*
[72] *Groundwater Depletion and Decline*, USGS, 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. 2, 2020).
[73] *Groundwater Depletion Across the Nation*, USGS (Nov. 2003), https://pubs.usgs.gov/fs/fs-103-03/; *Aquifers: Map of the Principal Aquifers of the United States*, USGS, https://water.usgs.gov/ogw/aquifer/map.html (last visited Mar. 2, 2020).
[74] Hardin posits a pasture "open to all." Hardin, *supra* note 69, at 1244-45.
[75] James & O'Dell, *supra* note 8.
[76] *Id.*

basin, that figure is 741 feet deeper, and in the Hualapai Valley in Mohave County, also outside an AMA, that number is 280 feet deeper.[77] In Mohave County, the problem is particularly acute. Large alfalfa and nut growers have purchased thousands of acres there for water-thirsty crops.[78] Using satellite imagery, the Arizona Department of Water Resources predicts that in just two years pumping for agriculture has quadrupled from 8,000 acre feet in 2014 to 32,000 acre feet a year in 2016, drastically shortening earlier predictions of how long water in the aquifer will last from 400 years to just 40 years.[79]

Nearby LaPaz County has seen the same exploitation of lax groundwater regulations outside AMAs. For instance, in 2014 a Saudi Arabian-owned company, the Almarai Corporation, bought 10,000 acres in the town of Vicksburg, Arizona, to plant the water intensive crop alfalfa, which it then ships back to Saudi Arabia to feed cattle.[80] It is known that a United Arab Emirates farming corporation, Al Dahra, is currently farming several thousand-acre farms along both sides of the Arizona-California border.[81] But the list of large landowners who are located in Arizona's rural area outside the reach of the GMA is not limited to foreign corporations. In the agricultural area of Cochise County in the southeastern portion of the State, Riverview LLP, a dairy and beef conglomerate headquartered in Morris, Minnesota, has purchased 20,000 acres of land outside an AMA for its industrial feedlot operation.[82]

The impact of these large industrial agricultural operations upon groundwater levels is significant. Wells drilled in the area of Riverview's operations averaged 270 feet twenty years ago, but more recently the cattle operation has drilled wells deeper than 1,000 feet.[83] The deeper the well, the more expensive the well and the more costly it is to pump water. Other local landowners, residents using well water simply for domestic purposes or smaller farming operations, can often not afford to dig deeper wells, the result being that their wells are going dry while the big industrial agricultural operations, who have invested in deeper wells, are continuing to pump the aquifer.

There is some evidence of a current transition away from an earlier era during which members of the county's tight-knit traditional farmer community exercised self-regulation to reduce the intensity of their aggregate groundwater use. The newcomers are not only larger users of groundwater, but they lack the social and professional ties that bound the prior agricultural community.[84] Current levels of excessive groundwater withdrawals might reflect a community of users that now lack the shared social norms and interdependent future that

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[77] *Id.*

[78] Jeremey P. Jacobs, *It was the 'Land of the Free.' Then the water disappeared*, E & E NEWS (Dec. 27, 2018), https://www.eenews.net/stories/1060110247.

[79] *Id.*

[80] Noah G. Shannon, *The Water Wars of Arizona*, N.Y. TIMES (July 19, 2018), https://www.nytimes.com/2018/07/19/magazine/the-water-wars-of-arizona.html.

[81] *Id.*

[82] Jacobs, *supra* note 78.

[83] *Registry of Wells in Arizona (Wells55)*, ARIZ. DEP'T OF WATER RES., https://gisweb2.azwater.gov/WellReg# (last visited Mar. 4, 2020).

[84] Shannon, *supra* note 80.

Elinor Ostrom identified as key to preventing the tragedy of the commons with respect to a common pool resource.

C. Unrealized Goals of Water Sustainability Within Active Management Areas

But what about the status of groundwater within the boundaries of Arizona's AMAs—areas where groundwater withdrawals are subject to the full force of the GMA's regulatory provisions? Unfortunately, although not so bleak as the situation in many areas of the State outside of the AMAs, problems are apparent throughout the administration of the GMA's regulatory regime. First and foremost, out of the four AMAs with safe yield-related goals, only one, Tucson, is meeting the goal. None of the others have, or in all likelihood will, meet the goal by 2025.[85] In addition, the process of developing and implementing management plans every ten years for the purpose of bringing the AMAs into safe yield has been wracked by delays, missed deadlines, and the over-estimation of available groundwater supplies.

D. The Tragedy of a Geographically Limited Groundwater Regulatory Scheme

The incomplete nature of Arizona's groundwater regulation can lead to a "tragedy" for those inhabiting the regulated areas. The tragedy consists of losing economic activity that thrives on readily available groundwater. All else being equal, demand for economic activities that consume large quantities of water—agriculture primarily, but also housing, mining, other commercial and industrial activities, can be expected to shift, or "leak" to firms located in areas where groundwater is comparatively unregulated, meaning areas outside AMAs. Lack of regulation in non-AMA areas will result in the cheaper production of goods and services.[86] The tragedy is thus that areas subject to regulation suffer economically for adhering to a regulatory regime; they may be deprived of the economic benefits that would otherwise accompany water-dependent production activities within their boundaries. This loss may or may not be compensated for in the economic benefits accompanying less-intensive water uses that may take the place of those which are lost as a result of regulation.

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[85] *See* MANAGEMENT PLANS WORKGROUP PRESENTATION, *supra* note 9, at Slide 25.

[86] The problem of a partial geographic regulatory regime is well-known in the scholarly literature, especially with respect to the problem of pollution. Economists have shown that if production from unregulated firms can be easily substituted for production from regulated firms, the amount of emissions reductions achieved by regulated producers "may be substantially offset, or even eliminated, by increases in emissions among unregulated producers." Meredith Fowlie, *Incomplete Environmental Regulation, Imperfect Competition and Emissions Leakage* 1-2 (Nat'l Bureau of Econ. Research Working Paper Series, Paper No. 14421, 2008), https://www.nber.org/papers/w14421.pdf.

A well-studied response to concerns over these potential negative impacts of regulation is a "race to the bottom," loosely used here to refer to efforts to relax the stringency of regulation in an effort to compete for the location of mobile industry.[87] Such relaxation can take many forms, from delays in the implementation of regulation, to lax enforcement, to policies that run counter to, or undercut, the regulatory regime. While the "race to the bottom" phenomenon is most often discussed in the context of interstate (or even international) competition, there is some evidence of the weakening of groundwater regulation within AMAs that is at least consistent with being motivated by a desire to stem the location or relocation of economic activity to areas outside AMAs. An early example is provided by the legislature's establishment of the CAGRD and its role in facilitating developers' compliance with the Assured Water Supply program. Rules enabling CAGRD to replenish groundwater extracted by developers located in AMAs with surface water help ensure that new subdivisions will continue to be sited within AMAs and not just in areas outside the AMAs. In the absence of the CAGRD, to comply with the AWS, new subdivisions within the AMAs would need to secure renewable water supplies in quantities sufficient to satisfy the 100 year water supply requirement. As this was an all but impossible hurdle within an AMA, the effect of the AWS would be to push new developments to locate outside AMAs. Legislation enabling developers to use groundwater to meet the 100 year supply requirement backed up by CAGRD's replenishment of that groundwater, somewhere within the same AMA, with surface water supplies, enabled new developments to locate within AMAs.

More recent examples provide further evidence of the weakening the GMA's groundwater regulatory regime within AMAs in a manner that would assist them in attracting or keeping economic activities that might otherwise locate outside the AMAs. One such example is passage of a 2002 amendment to the GMA that allows agricultural entities to implement “best management practices” (BMPs) for groundwater use during the 3rd, 4th, and 5th management periods rather than abide by a quantitative restriction upon the amount of water that could be used on acreage subject to grandfathered irrigation rights.[88] Data collected indicates that many growers participating in the program are using more water than they would otherwise be allocated were they limited to the water duty provided under the applicable management plan.[89]

Still further evidence is found in the funding cuts and missed deadlines that have plagued the administration of the GMA within the AMAs. The legislature has failed to return the Arizona Department of Water Resources to the

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[87] *See, e.g.*, Richard B. Stewart, *Pyramids of Sacrifice? Problems of Federalism in Mandating State Implementation of National Environmental Policy*, 86 YALE L.J. 1196, 1211-12 (1977) (presenting the theoretical basis for a race to the bottom in state environmental standard-setting as a rational for uniform national environmental regulation); s*ee also* Kirsten Engel, *State Environmental Standard-Setting: Is there a "Race" and is it "to the bottom?"*, 48 Hastings L. J. 271, 271 (1997) (presenting empirical basis for finding a race to the bottom in state environmental standard-setting exists).

[88] ARIZ. REV. STAT. ANN. §45-566.02(F) (2020).

[89] Smith, *supra* note 28, at 6-7.

level at which it was funded pre-recession, nor have staffing levels returned to pre-recession levels. In another example, whether due to staffing shortages or to other "political" factors, today the ADWR is over a decade late in completing a statutorily required plan for bringing the State's four Active Management Areas into safe yield status. [90] Lax administration is found not just in these delays but also in the system for accounting for water within the AMAs. In one example, the state water agency recently announced that, "[l]ooking out 100 years, there is insufficient groundwater in the Pinal Active Management Area to support all existing uses and issued assured water supply determinations."[91]

So what to do? Hardin famously gave society a choice for preventing tragedy of the commons: provide for property rights in the common pool resource or authorize government to allocate rights to use the resource.[92] The following will discuss both of these options with respect to the future of groundwater management in Arizona.

E. Property Rights

Not long ago, the Arizona Supreme Court rejected property rights as the basis for the reasonable use doctrine. In the 2009 case of *Davis v. Agua Sierra Resources*,[93] the court rejected the right of a grantor to reserve rights to the commercial use of percolating groundwater beneath land that the grantor no longer owned. The court stated, "'there can be no ownership in seeping and percolating waters until they are reduced to actual possession and control by the person claiming them because of their migratory character.'" The court furthermore stated, "'[l]ike wild animals free to roam as they please, they are the property of no one.'"[94] The court held that Arizona's groundwater is a "critical

[90] *See* Warren Tenney, Blog, *Arizona's Overdue Water Plans Must be a Priority,* AMWUA (Oct. 14, 2019), https://www.amwua.org/blog/arizonas-overdue-water-plans-must-be-a-priority. In order to achieve the water sustainability management goal established for the active Management Areas, the 1980 Act requires that the State Water Department issue plans for each AMA every ten years designed to move the area to the achievement of the safe yield goal by 2025. The plans were to include measures of increasingly greater stringency applicable to the broad variety of water users within the AMA, including cities, private water providers, mines, farmers, golf course and power plants. The idea was that, by 2025, the plans would ensure that the "gap" between the rate of water withdrawals and water replenishment would be closed and each AMA would reach its goal. While the state agency issued the first three management plans on time, today it is over a decade late completing the Fourth Management Plan and has just started to consider the elements of the Fifth Management Plan.

[91] *ADWR Posts Pinal Model Run Information,* ARIZ. DEP'T OF WATER RES. (Nov. 7, 2019), https://new.azwater.gov/news/articles/2019-07-11-0.

[92] Hardin, *supra* note 69, at 1245 ("What shall we do? We have several options. We might sell them off as private property. We might keep them as public property, but allocate the right to enter them….But we must choose-or acquiesce in the destruction of the commons that we call our National Parks.").

[93] Davis. v. Agua Sierra Res., 203 P.3d 506, 509 (Ariz. 2009).

[94] *Id.* at 510 (quoting *Chino Valley II*, 131 Ariz. at 82, 638 P.2d at 1328).

public resource" and that "Arizona law does not recognize a real property interest in the potential future use of groundwater that has never been captured and applied to reasonable use."[95]

Arizona's rejection of a property right in uncaptured groundwater does not preclude the legislature's creation and allocation of transferable rights to capture extracted groundwater. This is precisely what was done recently by California when it adopted a cap and trade regime for groundwater pumping rights. Under California's recently adopted Sustainable Groundwater Management Act (SGMA), local management agencies must adopt measures to bring each of the State's 127 groundwater basins into safe yield. For two basins underlying the heavily-agricultural Ventura County, getting to safe yield may require up to a 40 percent reduction in groundwater pumping.[96] The local agency is addressing this task through first establishing a declining cap upon the total amount of groundwater that can be pumped in the basin. Each existing grower and pumper will be allocated a right to pump a certain portion of that capped amount, an allocation that, like the cap, will also decrease over time. They can use the whole amount of their allocation to water their crops, or they can reduce their water use by switching to less water-intensive crops, installing drip irrigation, or fallowing their fields, and they can sell their allocation, or a portion of it, to another grower. Farmers have agreed to install metering technology on their wells to ensure the integrity of the pumping rights that are traded.

The cap and trade regime being implemented in Ventura County, California, could serve as a model for regulation of groundwater in the areas currently left unregulated in Arizona.[97] The advantages and disadvantages of a cap and trade regime are many and are well-analyzed in the literature of their use to address climate change, conventional air pollution problems, and the loss of wetlands.[98] With proper monitoring, cap and trade regimes can provide an efficient pathway to the achievement of an environmental goal such as safe yield. Cap and trade can also be susceptible to "hot spots," and "paper trades," and rests upon the commodification of a life-sustaining resource, water, which many might find objectionable. As in California, trading would best be limited to users within a single groundwater basin. This might raise the question of whether there is a sufficient number of pumpers to create a competitive market. Nevertheless, despite these questions, California is demonstrating that a cap and trade program in a rural area is a viable option for efforts to achieve safe yield, and thus this option should be considered by Arizona lawmakers.

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[95] *Id.*

[96] Jeremy P. Jacobs, *Farmers tap free market ideas in bid to rescue aquifer,* EENEWS (Aug 6, 2018), https://www.eenews.net/special_reports/when_the_wells_run_dry/stories/1060092819.

[97] *See* Sarah Heard, et al., The Nature Conservancy, *SGMA's First Groundwater Market* (May 2019) https://groundwaterresourcehub.org/public/uploads/pdfs/TNC_FoxCanyon_GroundwaterMarketCaseStudy.pdf.

[98] *See, e.g.*, Robert N. Stavins, *A Meaningful Cap and Trade System to Address Climate Change,* 32 HARV. ENVTL. L. REV. 293 (2008); Sonya Dewan, *Emissions Trading: A Cost-Effective Approach to Reducing Non-point Source Pollution,* 15 FORDHAM ENVTL. L. REV. 233 (2004).

F. Government Regulation

Alternatively, Arizona could enact a regulatory scheme that expands the coverage of the Groundwater Management Act to include the rural areas of the State. However, any regulatory regime going forward must accommodate the competing claims to groundwater management by the state and local governments.

The cooperative federalism framework found in many federal environmental laws may provide a model for the balance between the competing claims for state and local control that are needed. Cooperative federalism grew out of conflicts over state and federal authority, similar to those stymieing progress on rural groundwater management: strong claims to state control bundled with federal distrust of state control in view of the worsening condition of the environment. The solution to this in cooperative federalism is shared authority between the federal and state governments, though always recognizing the preeminence of federal authority. States are allowed to plan and administer programs, but always in compliance with minimum federal standards.[99] The federal Clean Air Act in particular provides a model for many of the potential features of an expanded Groundwater Management Act. In this Article we label the approach "cooperative localism."

1. Cooperative Federalism

Cooperative federalism refers to an arrangement of power sharing seen in many federal laws, but especially environmental laws,[100] where Congress, in the exercise of its Commerce Clause authority, provides for federal regulation of a given area but offers the states the power to implement federal standards and, in many situations, to exercise significant control over the means by which they implement federal standards. In cooperative federalism, roles are distributed between the federal government and the states according to their respective strengths. For instance, consistent with the rationale for federal as opposed to state-level environmental policymaking, the federal government is given the role

[99] We owe the inspiration for this idea to the well-argued opinion piece by two leaders in Arizona Groundwater policy, former Arizona Governor and Secretary of Interior, Bruce Babbitt and former Arizona Department of Water Resources Director and current Kyl Center Fellow, Kathy Ferris. *See* Bruce Babbitt & Kathleen Ferris, Opinion, *Water Shortages are a real threat for rural Arizona: Can we stop them?*, AZ CENT. (June 21, 2019), https://eu.azcentral.com/story/opinion/op-ed/2019/06/21/water-shortages-real-threat-rural-arizona-can-we-stop-them/1505992001/.

[100] *See* New York v. United States, 505 U.S. 144, 167 (1992) (defining cooperative federalism as a system whereby Congress provides states with the power to regulate an area according to state standards rather than preempting a given area). For statutes incorporating a cooperative federalism approach, see Clean Air Act, 42 U.S.C. § 7401 (2018); Clean Water Act, U.S.C. §§ 1251-1387 (2018); Occupational Safety and Health Act of 1970, 29 U.S.C. § 651 (2018); Resource Conservation and Recovery Act of 1976, 42 U.S.C. § 6901 (2018).

of carrying out and communicating scientific research, establishing minimum environmental quality regulations, protecting states from interstate spillovers, and serving as a back-up for the states when enforcing rules, regulations, and permit violations.[101] In contrast, given states' broad police powers and traditional role in land use, cooperative federalism schemes give states the role of planners, permit-issuers, and first-line enforcers. Cooperative federalism has its proponents and its detractors, some finding it causes delays and blame-shifting and others finding it too coercive.[102]

2. "Cooperative Localism"

Similar to the existence of claims for both a federal and a state role in comprehensive environmental statutes, there are claims to both a strong state, local, and even federal role in Arizona's groundwater management. With respect to local governments, water is by far the most important natural resource in the West. There are likely few resources as important to the local rural economy as groundwater, not to mention the health and biodiversity of local ecosystems. On the local level, Arizona has 65 irrigation districts authorized by state statute to, among other things, "acquire water rights, real estate and personal property; construct or acquire canals, water, water rights, rights-of-way and other irrigation works."[103] A belief in the importance of strong local control over water management runs deep and has been a persistent feature of contemporary Arizona water policy. On the other hand, the state role has been preeminent. Groundwater and its use are defined by state law. Indeed, the State has never delegated authority to local governments to manage their groundwater resources; water has always been considered an issue of state control. When massive over depletion of Arizona's aquifers could no longer be denied (and the federal government threatened to pull funding from the Central Arizona Project), the State stepped in to enact the regulatory program of the Groundwater Management Plan and to create an Arizona Department of Water Resources with broad powers to regulate groundwater use within the Active Management Areas and to require the registration of all water wells across the State.

The Clean Air Act's cooperative federalism construct for the promulgation and attainment of the National Ambient Air Quality Standards (NAAQs) could serve as a model for a new regulatory regime for groundwater management in Arizona's rural areas. Under this scheme, the Environmental Protection Agency is required to complete the scientific research that serves as a basis for nationally-

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[101] For the classic treatment of the rationale for a federal role in environmental policy, see Richard B. Stewart, *Pyramids of Sacrifice? Problems of Federalism in Mandating State Implementation of Federal Environmental Policy*, 86 YALE L.J. 1196, 1211-12 (1977).

[102] For the former perspective, see Rena I. Steinzor, *Devolution and the Public Health*, 24 HARV. ENVTL. L. REV. 351, 367-69 (2000). For the latter, see Jonathan Adler & Nathaniel Stewart, *Is the Clean Air Act Unconstitutional Coercion, Cooperative Federalism and Conditional Spending after NFIB v. Sebelius*, 43 Ecology L.Q. 671 (2016).

[103] *See, eg., About Us*, CENT. ARIZ. IRRIGATION DIST., https://www.ed4.biz/view/43/ (last visited Mar. 8, 2020).

uniform health-based ambient air quality standards. The agency is also delegated the authority to promulgate and continually update those standards. Nevertheless, the states are provided the opportunity to develop and implement, in basically whatever fashion they choose, the NAAQs through State Implementation Plans (SIPs). The Plans must be approved by the EPA and once approved, operate as federal law and hence are fully enforceable by the federal government.

Applied to Arizona's groundwater management scheme and substituting state and local government for the federal and state roles, the Clean Air Act's cooperative federalism structure would seem well-suited to the balance needed to make a regulatory regime work. Rather than cooperative federalism, this scheme might be referred to as cooperative localism. According to this framework, the State would be charged with information-gathering and scientific research as well as the development of uniform state standards. In turn, county, or even existing local groundwater management units, would be charged with developing plans to implement the state standards that must be approved by the State.

G. Components of a Comprehensive Groundwater Management Act

1. Information Gathering and Scientific Research: The Critical Role of Metering

Management of groundwater resources outside the State's Active Management Areas is currently hampered by the lack of good information on exactly how much water is being pumped from aquifers. While owners of non-exempt wells in AMAs must regularly report their groundwater usage, no such requirement applies outside AMAs.[104] As a result, the State is severely hampered in its efforts to understand the current rate of groundwater usage and associated impacts and to model future groundwater use and impacts as well as aquifer health. Better information on well pumping levels would result in a better understanding of groundwater situation and better models for future groundwater use.[105] In the absence of a metering requirement, the State is limited to modeling current and future groundwater use based upon such information as the known pumping capacity of wells in a given area, electricity usage, and Geographic

[104] The amount of groundwater currently being pumped but not currently being tracked or monitored is potentially extremely large. According to an ADWR Report in September 2019, Arizona has a total of 37,000 non-exempt wells (wells pumping over 35 gallons of groundwater per minute) which represents 95 percent of all groundwater being pumped in the state. While only 13 percent of those are located outside an AMA or an INA, those 13 percent are responsible for roughly half the total pumping capacity of all non-exempt wells. GOVERNOR'S WATER AUGMENTATION, INNOVATION, AND CONSERVATION COUNCIL, *supra* note 13, at Slide 7.

[105] According to Thomas Buschatzke, Director of Arizoa's Department of Water Resources, the absence of a metering requirement is a major gap in Arizona's groundwater laws and the Department has proposed mandatory water-use reporting by well owners in unregulated areas. James & O'Dell, *supra* note 8.

Information System (GIS) data.[106] Closing this information gap, whether through a requirement that larger well owners meter their wells or provide other information sufficient to meet the State's needs to accurately model groundwater use, must be a top priority for a new statutory scheme for groundwater use outside existing AMAs.

Consistent with the breakdown of state and local roles according to tradition, law, and expertise, the State should have the authority to develop information-gathering requirements applicable to well owners and to use that information to generate publicly-available information on current and future groundwater use. Certainly local entities should be able to provide input to the State on how the information is collected as well as the specifics on additional information they may wish to be collected.

2. Establishing and Attaining a Statewide Sustainable Groundwater Management Regime

i. State Sustainability Targets and Local Planning

The framework for revisions to the Groundwater Management Act would be a state-local process for achieving and maintaining water sustainability across the State. Using the Clean Air Act's NAAQ-SIP framework as a model, such a process would include sustainability targets, a planning process for meeting the sustainability targets, and a system of accountability whereby a failure to meet the targets has consequences that trigger an area into a more stringent regime of requirements designed to bring the area into compliance with the sustainability targets.

ii. A Statewide Safe Yield Goal

The heart of a groundwater management scheme applicable to non-AMA areas are the "safe yield" goals standards for the governance of groundwater withdrawals. The safe yield goal is a widely accepted metric for the sustainable use of a natural resource, and in broad outlines would make sense to be applied to govern the acceptable level of groundwater withdrawals across the State.[107] Safe yield derives from the concept of sustainability and refers to the maximum pumping rate for which the consequences for water table-level declines, reduced

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[106] According to ADWR, the accuracy of the models used to characterize groundwater use and its impacts is much less than if the state had reported data. Audio recording: Thomas Buschatzke, Director, Ariz. Dep't of Water Res., Presentation to Ariz. House Comm. on Nat'l Res., Energy and Water (Mar. 5, 2019), http://azleg.granicus.com/MediaPlayer.php?clip_id=22349&autostart=0.

[107] It is conceivable that it may be impossible to achieve the safe yield goal in some areas outside an AMA without shutting down current agriculture due to the rate by which groundwater is currently being pumped in those areas. If this is the case, an alternative to the safe yield goal, perhaps one that tries to get as close as possible to safe yield, would need to be developed.

stream flow, and degradation of water quality are considered acceptable[108] Sustainability reflects concepts of intergenerational justice; the environmentally impactful actions of current generations will not deprive future generations of their enjoyment of the environment.[109] Safe yield is a more specific application of the concept of sustainability in use and has been applied as a guiding concept in natural resources nationally and internationally, from fisheries to timber harvesting.

The goal of safe yield should, at a minimum, apply throughout the State. The need to ensure sufficient quantities of groundwater, a life-giving, nonrenewable natural resource, are available for future generations is just as important for Arizona's rural areas as it is for Arizona's populated areas. With the help of groundwater metering data, the state officials should be able to track outflows from groundwater basins to know whether the safe yield goal is being met or exceeded.

In amending the Groundwater Management Act to apply across the State, the legislature, working through the Arizona Department of Water Resources, has the opportunity to address shortcomings in the current safe yield regime applicable in AMAs. First off, the State should address the sufficiency of the safe yield concept to maintaining a healthy aquifer. Given the many variables that go into this goal, many hydrologists question the sufficiency of the mass-balance approach in protecting an aquifer.[110] Climate change is an additional reason to review the sufficiency of the mass balance approach to safe yield as warmer temperatures and drought conditions can alter groundwater hydrology.[111]

Second, and more importantly, this is an opportunity to address the longstanding disconnect between groundwater and surface water that has plagued Arizona water law for decades. As is widely recognized, groundwater pumping near surface waters is quite literally draining those surface waters and drying up ecologically critical riparian areas. Nevertheless, adherence to the legal fiction that surface and groundwater are distinct has stood in the way of efforts to prevent groundwater withdrawals that are currently draining surface waters. Despite

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[108] William M. Alley, Thomas E. Reilly & O. Lehn Franke, *Sustainability of Groundwater Resources*, U.S. GEOLOGICAL SURV. CIRCULAR 1186 at 4 (1999), https://pubs.usgs.gov/circ/circ1186/pdf/circ1186.pdf.

[109] World Comm'n on Env't and Dev., *Our Common Future*, U.N. Doc. A/42/427 (1987) ("Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs.").

[110] *See, e.g.*, Yangxiao Zhou, *A critical review of groundwater budget myth, safe yield and sustainability*, 370 J. HYDROLOGY 208, 209 (2009); *See also* Cabello, *supra* note 11, at 291 (criticizing the concept of safe yield as "reductionist" because it fails to take into account other hydrogeological, socioeconomic, and ecological criteria affecting aquifer health, referring exclusively to the relationship between the quantity of flows in and out of an aquifer).

[111] *See* C.P. Kumar, *Climate Change and its Impact on Groundwater Resources*, 1 INT'L J. ENGIN. & SCI. 43, 44-45 (2012) (climate change can affect groundwater quantity and quality through changes to soil moisture and characteristics, the dynamics of recharge and, in coastal areas, salt water intrusion).

repeated invitations by the courts to the legislature to do so,[112] the legislature has so far failed to remedy this problem.

iii. Attainment or Nonattainment Designation

With respect to determining compliance with the safe yield within AMAs, the current GMA somewhat tracks the Clean Air Act's scheme for determining compliance with National Ambient Air Quality Standards. Currently, the State determines compliance with the safe yield goal on an AMA-by-AMA basis, much like EPA determines compliance with NAAQs in each Air Quality Control region within individual states. Nevertheless, in extending the safe yield standard to apply to groundwater resources throughout the entire State of Arizona, and not just within the AMAs, the legislature would need to elaborate upon the current AMA-only structure of the GMA. First, the legislature would need to determine the scope of the geographic area that would be appropriate for measuring attainment with the safe yield goal. Here it would seem to make most sense to determine attainment on a basin-by-basin basis, as groundwater basins represent distinct areas where groundwater recharges. According to the Arizona Department of Water Resources, Arizona has 36 groundwater basins. Groundwater basins might thus be analogized to an air quality control region under the Clean Air Act, the geographic area used to determine the attainment of the NAAQs. These regions roughly follow the boundaries of air sheds and are thus precedents for using natural boundaries to determine compliance with an environmental quality goal.

For each groundwater basin, and again, much like the regime that currently exists under the GMA with respect to each AMA, the State would be charged with the duty to determine each basin's attainment with the safe yield goal. The revised GMA could take a chapter from the Clean Air Act in further refining the degree of nonattainment. In the 1990 amendments to the Clean Air Act, Congress specified that when designating an area in nonattainment with either ozone for example, EPA was to determine whether the area was in "moderate," "serious," "severe," or "extreme" nonattainment, depending upon the degree to which concentrations of ozone in the area exceeded maximum ozone concentration levels. More finely-tuned nonattainment designations are used under the Clean Air Act to trigger the applicability of more extensive or more stringent pollution controls for more polluted areas and, correspondingly, to incentivize efforts to reduce emissions in an effort to avoid harsher pollution control measures. Use of more than one level of nonattainment with safe yield might be employed in furtherance of the same goal.

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[112] Among jurisdictions following prior appropriation, Arizona is an outlier in this respect. John D. Leshy & James Belanger, *Arizona Law Where Ground and Surface Water Meet*, 20 ARIZ. ST. L.J. 657, 659-60 (1988) ("most prior appropriation jurisdictions by now have abandoned the bifurcated treatment of ground and surface waters and undertaken unitary management of water supplies.").

iv. Local Planning to Achieve Safe Yield

The most novel aspect of this proposed scheme for a statewide groundwater management code is the use of local planning to achieve the safe yield goal in each groundwater basin. This would be a departure from the allocation of decision-making power under the current GMA, which leaves the process of planning to achieve safe yield within the AMAs entirely to the state water agency, albeit with local input through the administrative process. Not surprisingly, this reliance on state planning has led to claims that the State is dictating water management and not taking local conditions sufficiently into account. An expanded GMA could avoid this by relying upon local government for groundwater management planning in the first instance, only to be backed up by state oversight and enforcement.

Arizona lacks an independent framework for governing groundwater management at the local level.[113] Although the State has designated twenty-two local water planning areas across the State,[114] no separate governing has been created for these areas and their boundaries are not co-terminus with that of the county governments.[115] While planning at the level that corresponds to the geographic boundaries of the resource at issue makes sense, existing county governments will need to be employed to develop and implement plans to attain state standards. However, in their planning, counties should seek to take advantage of the work being done to fashion solutions in the twenty-two planning areas.

Under the cooperative localism framework suggested here, with the exception of certain minimum state programs applicable to all local groundwater planning units, local governments would be responsible for developing plans to attain safe yield within each groundwater basin. If the basin is out of attainment, the county would be obligated to develop a plan to bring it into attainment within a certain period of time, much like the State is currently obligated to develop management plans for AMAs designed to bring the AMA into attainment with the AMA-specific safe yield goal. Similarly, if the basin is in attainment, the county would be obligated to develop a plan to ensure safe yield continued to be

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[113] *See, e.g.*, Babbit & Ferris, *supra* note 99 ("The Legislature has never given county governments jurisdiction to regulate groundwater. Groundwater management has traditionally been an exclusive state function.").

[114] ARIZ. DEP'T OF WATER RES., ARIZONA'S NEXT CENTURY: A STRATEGIC VISION FOR WATER SUPPLY SUSTAINABILITY 9 (Jan. 2014), https://new.azwater.gov/sites/default/files/media/ArizonaStrategicVisionforWaterResourcesSustainability_May2014%20%2817%29.pdf.

[115] While the exact rationale for the boundaries of the planning areas is not clear (they are also not coterminous with the boundaries of the state's approximately thirty-six groundwater basins), they seem to have been designed to take advantage of potential long and short-term strategies to meet projected water imbalances. *Id.* at 17 ("These Planning Areas . . . have been identified based on possible short-term and long-term strategies available to meet the projected water supply imbalances.").

maintained. Furthermore, consistent with the principles of cooperative localism, should a county decline to develop or implement a plan, the State would be authorized to step in and develop or implement the plan in its stead.

v. Components of Local Safe Yield Plans

Optimally, a local safe yield plan would consist of certain minimum state requirements applicable throughout the State together with a suite of local programs that reflect unique aspects of the groundwater resource or the preferences and needs of the local economy and community. This would be much like State Implementation Plans under the Clean Air Act, which consist of certain nationally-uniform minimum standards, such as best available technology standards for emissions of pollutants from certain categories of facilities to unique SIP controls upon certain sources specifically targeted in the plan.

An example of a statewide standard could be the assured water supply requirements for new residential housing developments that currently apply to AMAs under the GMA. These requirements ensure that new source of long-term water use, such as a housing development, is not built unless there exists sufficient water to support that use long-term, or 100 years. It also protects consumers who invest in such subdivisions, ensuring that their investment does not turn out to be worthless due to lack of sufficient water supplies.

Other than the statewide components, a local plan could consist of measures chosen by the local government to attain or maintain safe yield. An example of such a measure could be a water offset program. Generally, offset programs, such as those applicable to air pollution, consist of caps upon an activity that can be overridden through measures that offset the same activity elsewhere. An example of a water offset program that might serve as a model for what could be incorporated into a local safe yield plan on a voluntary or mandatory basis is the Verde River Exchange Water Offset Program. This is a voluntary program designed to reduce the impacts of groundwater pumping upon the Verde River ecosystem.[116] Under the program, groundwater users are encouraged to offset their impacts upon the River by purchasing mitigation certificates from existing surface water or groundwater users in the same mitigation zone who agree to reduce their preexisting water use.[117] The Verde River Program is not as effective as it could be because participation is voluntary and there is no regulatory cap upon water use that would create corresponding

[116] For an excellent analysis of the program, see Lauren Podgorski, *From Wine to Water: Wet Markets for Dry Times*, 51 ARIZ. ST. L.J. 821, 822 (2019).
[117] *Id.* at 837-38.

market value for mitigation certificates. Nevertheless, it serves as an example of a local planning effort that is helping to reduce the impacts of groundwater pumping and could be copied and strengthened in local plans under a revised GMA.

IV. Conclusion

Forty years after the enactment of the Groundwater Management Act, it has become clear that Arizona's statute is not sufficiently protective of Arizona's groundwater. Despite claims of its comprehensiveness upon enactment, the GMA has always been only a partial plan for groundwater management. Left outside the protections provided by the Act's regulatory provisions are the State's rapidly developing rural areas, many of which are today grappling with the problem of diminishing groundwater. Furthermore, the 1980 Act never addressed the problems resulting from the State's adherence to the legal fiction that ground and surface waters are distinct. Today we are seeing the harmful impacts of this oversight: riparian areas that are being drained by groundwater pumping. It is time to expand the scope of the GMA to make the comprehensive groundwater management statute that the State needs to ensure groundwater will continue to be available to future generations. This will mean replacing the "reasonable use" doctrine applicable outside the Active Management Areas with a statutory scheme that regulates groundwater use.

Contrary to initial impressions, scrapping the reasonable use doctrine is less radical than might first appear. Arizona's reasonable use standard is not the recognition of venerable common law standards consistently applied by the courts since time immemorial. Instead, the reasonable use doctrine in Arizona is of comparatively recent origin and stood from the start on a questionable property rights foundation that the Arizona Supreme Court has now thoroughly abandoned. Finally, the conditions of extreme groundwater overdraft justifying the doctrine's replacement by a regulatory regime in the State's most populated areas now apply in many areas of the State. Hence the 1980 Act itself, as well as the case law supporting it, serve as precedents for a broad-based repeal of the doctrine in favor of a truly comprehensive regulatory program.

There are many ways of structuring a regulatory program that would apply to safeguard groundwater across the State. This Article has suggested two: a property rights approach that employs a cap and trade regime to achieve safe yield in individual groundwater basins, and a more traditional regulatory scheme that balances the competing interests of the state and local government in groundwater regulation. The latter, labeled here as "cooperative localism," would require minimum state standards for attaining and maintaining safe yield conditions in all of Arizona's aquifers but would enable local governments to develop plans to meet those safe yield conditions. Whichever option Arizona chooses, forty years is not too late to craft a solution that fulfills the GMA's promise of providing comprehensive protection to Arizona's groundwater resources.