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RC Gardner

E Okuno

et al

JE Perry
Virginia Institute of Marine Science

et al

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Advocating for Science: Amici Curiae Brief of Wetland and Water Scientists in Support of the Clean Water Rule

Royal C. Gardner[1] · Erin Okuno[1] · Steph Tai[2] · M. Siobhan Fennessy[3] · Carol A. Johnston[4] · Marinus L. Otte[5] · Margaret Palmer[6] · James E. Perry[7] · Charles Simenstad[8] · Benjamin R. Tanner[9] · Dan Tufford[10] · R. Eugene Turner[11] · Kirsten Work[9] · Scott C. Yaich[12] · Joy B. Zedler[2]

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Abstract
The Trump administration has proposed replacing the Clean Water Rule, a 2015 regulation that defined the statutory term "waters of the United States" to clarify the geographic jurisdiction of the Clean Water Act. Since its promulgation, the Clean Water Rule has been subjected to numerous judicial challenges. We submitted an amici curiae brief to the United States Court of Appeals for the Sixth Circuit, explaining why the Clean Water Rule, and its definition of "waters of the United States," is scientifically sound. The definition of "waters of the United States" is a legal determination informed by science. The best available science supports the Clean Water Rule's categorical treatment of tributaries because compelling scientific evidence demonstrates that tributaries significantly affect the chemical, physical, and biological integrity of traditional navigable waters (primary waters). Similarly, the best available science supports the Clean Water Rule's categorical treatment of adjacent waters based on geographic proximity. Compelling scientific evidence demonstrates that waters within 100 ft of an ordinary high water mark (OHWM) significantly affect the chemical, physical, and biological integrity of primary waters, as do waters within 100-year floodplains and waters within 1500 ft of high tide lines of tidally influenced primary waters or OHWMs of the Great Lakes. This review article is adapted from that amici brief.

Keywords Clean Water Act · Waters of the United States · Wetlands · Navigable waters · Significant nexus · Regulation

The Clean Water Act (CWA) (2018) is the primary wetland protection law in the United States (33 U.S.C. §1251 et seq.). If a wetland is considered to be "waters of the United States" under the CWA, then no one may discharge pollutants into that wetland without a federal permit. The geographic scope of the Clean Water Act—i.e., the extent of waters of the United States—has long been subject to controversy and litigation (Gardner 2011).

In 2015, the Obama administration issued the Clean Water Rule, a regulation that clarified the geographic scope of the CWA (U.S. Army Corps of Engineers and U.S. EPA 2015). This regulation was based upon an analysis of over 1200 scientific publications in *Connectivity of Streams and Wetlands to Downstream Waters: A Review and Synthesis of the Scientific Evidence* (U.S. EPA Office of Research and Development 2015). This analysis was performed to comply with the Administrative Procedure Act (2018), which prohibits federal agencies from acting arbitrarily or capriciously (5 U.S.C. §706). Courts have interpreted this language to require agencies to consider the scientific basis behind their decisions (*see,* e.g.,

Dan Tufford and Scott C. Yaich are both retired.

✉ Royal C. Gardner
gardner@law.stetson.edu

[1] Stetson University, Gulfport, FL, USA
[2] University of Wisconsin, Madison, WI, USA
[3] Kenyon College, Gambier, OH, USA
[4] South Dakota State University, Brookings, SD, USA
[5] North Dakota State University, Fargo, ND, USA
[6] University of Maryland, College Park, MD, USA
[7] College of William and Mary, Williamsburg, VA, USA
[8] University of Washington, Seattle, WA, USA
[9] Stetson University, DeLand, FL, USA
[10] University of South Carolina, Columbia, SC, USA
[11] Louisiana State University, Baton Rouge, LA, USA
[12] Ducks Unlimited, Memphis, TN, USA

Motor Vehicle Mfrs. Ass'n v. State Farm Mut. Auto. Ins. Co., 463 U.S. 29 (1983), which mandates that agencies "articulate a satisfactory explanation for [their] action[s]," provide a "reasoned analysis" for their decisions, consider all "relevant factors" in reaching their decisions, and explore "alternative ways of achieving" the purpose of their rules).

Nevertheless, the Clean Water Rule was immediately challenged by industry groups and others on procedural, statutory, and constitutional grounds. A major claim—raised under the Administrative Procedure Act—was that the U.S. Environmental Protection Agency (EPA) and the U.S. Army Corps of Engineers (Corps) failed to adequately provide scientific support for the regulation, thereby rendering it arbitrary and capricious.[1] In January 2017, the authors, a group of twelve wetland and water scientists and their attorneys, filed an amici curiae brief in the United States Court of Appeals for the Sixth Circuit in support of the scientific basis behind the Clean Water Rule. An objective of the amici brief was to educate the court about basic wetland and water science.

Since then, the debate over what constitutes waters of the United States has become more complicated through a series of Trump administration rulemakings and judicial decisions (Gardner and Okuno 2018). In February 2018, the Trump administration attempted to suspend the Clean Water Rule for 2 years and, in doing so, expressly refused to consider the scientific basis on the Clean Water Rule (U.S. Army Corps of Engineers and U.S. EPA 2018a). In December 2018, the Trump administration announced its intent to replace the Clean Water Rule with a more restrictive definition of waters of the United States, again diminishing the importance of science (U.S. Army Corps of Engineers and U.S. EPA 2018b). In this context, we believe it is critical to emphasize the importance of science in CWA rulemaking.

As professionals who have spent their careers studying streams, wetlands, and other aquatic ecosystems, the amici and their attorneys have long explored the ways in which human activities that affect one part of a watershed can also affect—and damage—other parts of that watershed. In doing so, the amici have applied the basic tools of the profession: literature review, on-site observations, measurements, experimental manipulations, studies of "natural experiments," and modeling based on observations and understanding of the physical sciences. Based upon these tools, we believe that current science provides sound support for the Clean Water Rule.

In this review, which is adapted from our brief (and supplemented with additional studies), we elaborate on the scientific basis behind efforts to address human activities that alter the integrity of aquatic ecosystems. Damage to these systems can affect society in a number of ways, including: harming human welfare and property via flooding; impairing human health and reducing recreational opportunities via water pollution; and threatening species, including commercial species harvested in fisheries, via water pollution and a loss of connectivity (Sarukhán et al. 2005; Pendleton 2008; Moreno-Mateos and Palmer 2016; Gardner and Finlayson 2018). We believe that the Clean Water Rule's definition of "waters of the United States" is a scientifically justified approach to address these impacts.

[1] The groups also argued that the EPA and the Corps, in promulgating the Clean Water Rule, violated the Administrative Procedure Act by acting "in excess of statutory jurisdiction, authority, or limitations, or short of statutory right," 5 U.S.C. §706. Such arguments were based on the claim that the Clean Water Rule contravened the jurisdiction set forth in the Clean Water Act, the statute upon which the Clean Water Rule was grounded. These more legal—versus scientific—arguments are beyond the scope of this article.

The Clean Water Rule Is Scientifically Sound

In drafting the Clean Water Rule, the EPA and the Corps utilized many methodologies commonly employed by wetland and water scientists. The agencies studied key chemical, physical, and biological features of water systems and relied upon studies that used rigorous and respected methodologies in researching aquatic ecosystems.

Key Chemical, Physical, and Biological Features Are Used to Study Water Systems

An early major National Research Council report, *Wetlands: Characteristics and Boundaries*, which amici Joy Zedler and Carol Johnston co-authored, outlined three structural components of wetlands that apply generally to all water systems: water, substrate (physical and chemical features), and biota (animals, plants, and microorganisms) (National Research Council 1995). Each component interacts with the others to shape the functions (services) of water systems. In the study underlying the Clean Water Rule, the EPA and the Corps examined connections among the three components to provide an integrated, scientific perspective on water systems (U.S. EPA Office of Research and Development 2015).

Rigorous Research Methods Are Used to Study these Attributes, and to Study Aquatic Ecosystems as a Whole

The study of water systems integrates several scientific disciplines. In the context of understanding wetlands, hydrology, geology, and chemistry are used to examine how wetlands regulate stream flow, filter pollutants and sediment, incorporate excess nutrients, act to control flooding, and connect to groundwater (*see,* e.g., Johnston 1991; Hey and Philippi 2006; Hancock et al. 2009). Ecological research can be used to examine the role of wetlands as habitats for fish and wildlife, and their support of food webs within and among interconnected water systems (*see,* e.g., Sierszen et al. 2012b; Gray et al. 2013). Underlying this cross-disciplinary approach is a focus on the various methodologies noted above. Scientists do not apply these methods independently of each other, but rather actively compare them to ensure that the results are robust and reproducible (cf. Goodstein 2011).

To study water systems, scientists use a wide range of sampling and analytical methods to make on-site observations and measurements (*see* DeLaune et al. 2013). These methods include examining the chemical and physical characteristics of the waters, characterizing soil and sediment samples, sampling plant and animal communities, and quantifying the direction and movement of water and materials (dissolved and particulate) in stream networks and to/from wetlands (*see generally* DeLaune et al. 2013; *see also* Kondolf and Piégay 2016). These sampling and analytical methods are well-established, rigorous, and refined over time; they are used to enhance scientific understanding of the relationships between the various components of water systems.

Watershed or hydrologic studies may make use of "natural experiments" (a form of observational study), which focus on comparing a natural event or feature with areas (or times) with and without the event or feature (Breyer et al. 2011; *see also* Layzer 2008). In studying developed and undeveloped watersheds, for example, the assignment of subjects (e.g., watersheds) to groups (e.g., developed or not) is akin to randomization. Such natural experiments are often necessary because ethical considerations (i.e., concerns of deliberately damaging those systems), size, and cost create barriers for actual experiments on existing systems (*see* Haack 2003). Rather than disrupting existing systems, scientists focus on variability to extrapolate the effects of differences on the overall water system. Scientists who study freshwater ecosystems also use naturally occurring and injected tracers that do not cause any harm to the system but move with the water and allow us to identify the direction and magnitude of water transport as well as the rates of many ecological processes (Mulholland et al. 1990; Bertrand et al. 2014; Martínez-Carreras et al. 2015). This has been increasingly important in documenting flow paths and connectivity and the role of systems in global biogeochemical cycles (Abbott et al. 2016). Leibowitz et al. (2018) provide an extensive review of hydrologic connectivity and describe field-based, modeling, and remote sensing methods to detect stream and wetland connectivity to downstream waters. Rinderer et al. (2018) provide a detailed overview of the mathematics and statistics useful for assessing connectivity from time-series of groundwater and streamflow.

Modeling approaches also enhance scientific understanding of the water-system relationships (*see* National Judicial College 2010, describing computer-based models as "essential" for understanding water systems). Models serve multiple purposes. First, they enable scientists to test their understanding of interrelationships between different components of a water system (National Judicial College 2010). Second, they enable scientists to predict the outcomes of potential human activities that may cause damage—without modifying those systems (National Judicial College 2010). Models also make it possible to study processes at scales ranging from watersheds to continents that are too extensive to be investigated by observations alone, and to simulate scenarios of hydrologic and other wetland/watershed processes drawn from the historical record (e.g., Wu and Johnston 2008). A number of modeling tools are directly relevant to advancing scientific understanding of hydrologic connectivity between isolated wetlands and surface waters (Golden et al. 2014; Jones et al. 2018).

As noted above, the Clean Water Rule was based on, inter alia, an analysis entitled *Connectivity of Streams and Wetlands to Downstream Waters: A Review and Synthesis of the Scientific Evidence* (U.S. EPA Office of Research and Development 2015), which considered over 1200 scientific publications. The Connectivity Report reached its conclusions using studies that applied all of these methodologies. Indeed, the EPA, in its Connectivity Report, compiled these studies in a manner to ensure the use of high-quality, relevant research (U.S. EPA Office of Research and Development 2015; *see also* U.S. EPA and U.S. Department of the Army 2015, describing the extensive process of peer review of the Connectivity Report itself, including the use of a panel of 27 technical experts from an array of relevant fields, as well as other public processes). Moreover, the Connectivity Report included only studies that were peer reviewed or otherwise verified for quality assurance (U.S. EPA Office of Research and Development 2015; U.S. EPA and U.S. Department of the Army 2015). The focus on high standards and verification through peer review means that the Connectivity Report used the best available science to develop the Clean Water Rule (*see* 80 Federal Register 37,054; *see also,* e.g., Sullivan et al. 2006, describing assurance of data quality and use of rigorous peer review as aspects of best available science).

"Waters of the United States" Is a Legal Determination Informed by Science

Jurisdiction under the CWA has both legal and scientific components. The CWA defines the term "navigable waters" as "waters of the United States," which has been further refined by case law, regulation, and agency guidance (Congressional Research Service 2019). There is no question that traditional navigable waters, such as rivers, lakes, and the territorial seas (hereinafter collectively referred to as "primary waters") are "waters of the United States." There is also no question that the chemical, physical, and biological integrity of these primary waters are affected by activities upstream (e.g., Zhang et al. 2012). As Congress recognized, "[w]ater moves in hydrologic cycles, and it is essential that discharge of pollutants be controlled at the source" (U.S. Senate 1972). Scientific research plays a critical role in determining how upstream tributaries and waters adjacent to those tributaries affect the integrity of primary waters, and thus whether these upstream waters should qualify for CWA protection.

As a Legal Matter, CWA Jurisdiction Requires a "Significant Nexus" to a Primary Water

Interpreting the CWA, the U.S. Supreme Court has observed that the "regulation of activities that cause water pollution cannot rely on ... artificial lines ..., but must focus on all waters that together form the entire aquatic system" (*United States v. Riverside Bayview Homes, Inc.*, 474 U.S. 121 (1985)). How far upstream from a traditional navigable water the EPA and the Corps may regulate has been controversial, in part because federalism concerns may be invoked (Owen 2017). Accordingly, while "waters of the United States" include more than primary waters, the CWA's jurisdictional scope has limits. In *Solid Waste Agency of Northern Cook County v. U.S. Army Corps of Engineers*, the U.S. Supreme Court noted that the term "navigable" has some import in CWA jurisdictional determinations (531 U.S. 159 (2001)). As a result, agencies and courts have employed the "significant nexus" analysis endorsed by Justice Kennedy in *Rapanos v. United States* (547 U.S. 715 (2006) (Kennedy, J., concurring in the judgment)) to assess whether an upstream water has a sufficient chemical, physical, or biological connection to a traditional navigable water to warrant asserting CWA jurisdiction. This approach recognizes that upstream waters must be protected to ensure the integrity of primary waters (*Rapanos v. United States*, 547 U.S. 715 (2006)).

As a Scientific Matter, the Clean Water Rule's Approach to "Significant Nexus" Is Sound

The Clean Water Rule relies on the best available science to establish criteria for the requisite "significant nexus" between primary waters and other waters. Primary waters do not exist in isolation (National Research Council 2001). Rather, they are heavily influenced by their interactions with streams, wetlands, and open waters within their watersheds. As the Connectivity Report correctly emphasizes:

> The structure and function of downstream waters highly depend on materials—broadly defined as any physical, chemical, or biological entity—that originate outside of the downstream waters. Most of the constituent materials in rivers, for example, originate from aquatic ecosystems located upstream in the drainage network or elsewhere in the drainage basin, and are transported to the river through flowpaths[.]

(U.S. EPA Office of Research and Development 2015). The Clean Water Rule appropriately defines "significant nexus" using scientifically supported functions to demonstrate strong chemical, physical, and biological connections between upstream waters and primary waters. Since the Clean Water Rule was developed, a number of reviews have been published that provide overviews and updates on these connections and their importance (e.g., Cohen et al. 2016; Fritz et al. 2018; Lane et al. 2018). Although these recent studies were not part of the scientific record that formed the basis of the Clean Water Rule, they demonstrate that accumulating scientific evidence continues to substantiate the Clean Water Rule.

Scientific literature strongly supports the nine functions listed in the Clean Water Rule's "significant nexus" definition, each of which relates to the chemical, physical, and/or biological integrity of primary waters. Wetlands enhance the chemical integrity of downstream waters through trapping, transforming, and filtering pollutants (*see* Johnston et al. 1990). Wetlands also recycle nutrients and export organic material important for downstream food webs (*see* McClain et al. 2003; Smucker and Detenbeck 2014). For example, streams that flow intermittently are critical to certain life history stages of fish, including coho salmon (Larsen and Woelfle-Erskine 2018) as well as many invertebrates (Schofield et al. 2018). Microbially available organic matter in stream networks can be traced to seasonally connected wetland sources based on the molecular composition of its carbon (Hosen et al. 2018).

Similarly, the functions of streams, wetlands, and open waters affect the physical integrity of downstream waters (*see,* e.g., Fletcher et al. 2014). These waters contribute flow to primary waters (*see,* e.g., Johnston and Shmagin 2008). Research has shown that many wetlands without a year-round surface connection to primary waters flow into perennial streams a significant amount of the time, thereby contributing water and other materials downstream (*see,* e.g., Golden et al. 2014; McDonough et al. 2015; Hosen et al. 2018; Epting et al. 2018; Evenson et al. 2018). For example, researchers used direct field measurements of connectivity to demonstrate that prairie pothole wetlands contribute significant amounts of water to receiving perennial streams through surface water connections (Brooks et al. 2018; Neff and Rosenberry 2018). Focusing on ten catchments across the United States, Thorslund et al. (2018) used chloride tracers to demonstrate that geographically isolated wetlands are hydrologically connected and integral elements in flow-generating networks. Recent advances in remote sensing have also allowed scientists to detect and quantify physical connections that provide temporally variable surface water flows between streams and wetlands that were previously considered isolated (Vanderhoof et al. 2016, 2017).

Wetlands also retain and attenuate floodwaters, as well as store runoff (*see* Ogawa and Male 1986; Johnston 1993). Hydrological modeling recently showed that depressional wetlands in the Prairie Pothole Region attenuate peak flows, thus decreasing the probability of downstream flooding (Evenson et al. 2018). In addition, wetlands trap sediment and nutrients, thereby substantially reducing the degradation of downstream water quality (*see* Johnston et al. 1984).

Extensive evidence demonstrates that wetlands act to remove nutrients, thereby regulating the movement of excess nitrogen and phosphorus to downstream waters (McClain et al. 2003; Jordan et al. 2011). As a recent study showed, at the catchment scale, geographically isolated wetlands can provide substantial water storage capacity that can optimize these wetland functions (Jones et al. 2018). Furthermore, research has confirmed that, like small streams in some regions (Alexander et al. 2000; Peterson et al. 2001), small wetlands play a disproportionately large role in landscape-scale nutrient processes (Cheng and Basu 2017). These are exactly the wetlands that are likely to be filled in and developed and thus are at greater risk without protection (Van Meter and Basu 2015).

The Clean Water Rule's definition of "significant nexus" also recognizes how streams, wetlands, and open waters affect the biological integrity of downstream waters. Such waters provide important foraging, nesting, breeding, spawning, and nursery habitat for species that occur in primary waters (*see* Semlitsch and Bodie 1998; Sheaves 2009; Pittman et al. 2014).

Connectivity refers to "the degree to which components of a watershed are joined and interact by transport mechanisms that function across multiple spatial and temporal scales" (U.S. EPA Office of Research and Development 2015). Whether the functions of a particular stream, wetland, or open water (or a group of "similarly situated" waters) satisfy the legal threshold of "significant nexus" depends on the extent of its connectivity with primary waters. We examine the Clean Water Rule's categorical application of the "significant nexus" test below.

Best Available Science Supports the Clean Water Rule's Categorical Treatment of Tributaries

Scientific research demonstrates extensive connections between tributaries and their downstream primary waters sufficient to warrant categorical inclusion under the Clean Water Rule (*see* Turner and Rabalais 2003). The U.S. Supreme Court has held that federal agencies may craft a categorical rule to assert CWA jurisdiction over certain waters (*United States v. Riverside Bayview Homes, Inc.*, 474 U.S. 121 (1985)). The Court noted that so long as "it is reasonable ... to conclude that, in the majority of cases" the category of waters has "significant effects on water quality and the aquatic ecosystem, its definition can stand" (*United States v. Riverside Bayview Homes, Inc.*, 474 U.S. 121 (1985)).

The Clean Water Rule's Definition of Tributary Is Scientifically Sound

The Clean Water Rule defines "tributary" in a manner consistent with scientific understanding. At its most basic level, a tributary is simply a waterbody that flows into a larger waterbody. From a scientific perspective, "a tributary is the smaller of two intersecting channels, and the larger is the main stem" (Benda et al. 2004). A standard stream ordering system classifies the smallest streams as first-order streams; when two streams meet, they form a second-order stream and so on (*see* Strahler 1957). The smaller waters are intrinsically linked to primary waters both structurally and functionally (*see* Whigham et al. 1988). Indeed, "[t]he great majority of the total length of river systems is comprised of lower-order or headwater systems" (Allan and Castillo 2007; *see also* Fritz et al. 2013).

Under the Clean Water Rule, a "tributary ... contributes flow, either directly or through another water" to primary waters and is "characterized by the presence of the physical indicators of a bed and banks and an ordinary high water mark" (80 Federal Register 37,054). The Clean Water Rule notes that tributaries may be natural or human-made and include "rivers, streams, [and] canals," as well as ditches that are not otherwise excluded by the Rule (80 Federal Register 37,054). From a scientific perspective, whether a tributary is natural or human-made is immaterial; what matters is whether the water contributes flow to another waterbody.

Under the Clean Water Rule, a water meets the definition of a tributary even if it contributes flow to a primary water through a non-jurisdictional water. This approach is also sound because the scientific definition of tributary focuses on the hydrologic connection between waters.

From a scientific perspective, the Clean Water Rule's definition of "tributary" could be considered conservative. In addition to requiring a bed and banks (channels), it also provides that a tributary must have an ordinary high water mark (OHWM). In comments to the EPA, however, the Scientific Advisory Board noted that not all tributaries have OHWMs (U.S. EPA Scientific Advisory Board 2014). The OHWM requirement (which is ultimately a limitation on what constitutes a water of the United States) is not dictated by science, but we recognize that the agencies must set boundaries along gradients to apply the CWA on a national basis.

Compelling Scientific Evidence Demonstrates that Tributaries Significantly Affect the Chemical, Physical, and Biological Integrity of Primary Waters

The National Academy of Sciences has extensively documented the connections between tributaries and downstream waters (*see,* e.g., National Research Council 2000, 2011a, b). Scientific studies demonstrate how tributaries significantly affect the functions and integrity of downstream waters through chemical, physical, and biological interrelationships, especially regarding how physical aspects (e.g., flow) can influence chemical processes (e.g., pesticide contamination), which in turn can affect the biological features (e.g., species) of a water. Below we highlight a few examples of connections between tributaries and primary waters.

Scientists find evidence of strong chemical connections between tributaries and downstream primary waters in the movement of contaminants and pathogens. Sediment-laden waters typically transport some contaminants (such as mercury) from tributaries to downstream waters (*see* Salomons and Förtsner 1984). Waterborne pathogens (such as bacteria and viruses) that originate from agricultural and municipal wastes are also transported to downstream waters through tributaries (*see* Jokinen et al. 2012; Pandey et al. 2014; Jalliffier-Verne et al. 2016). Pathogens may pose a risk to human health, highlighting the importance of regulating and protecting tributaries to ensure the integrity of primary waters.

Tributaries also have important physical connections with downstream primary waters. The water flow from tributaries helps to create and maintain river networks. Indeed, most of the water in most rivers comes from tributaries (*see,* e.g., Alexander et al. 2007).

Furthermore, tributaries support the metabolism of river ecosystems. For example, they export organic matter (dissolved and particulate) that is incorporated into the food webs of downstream waters (Hosen et al. 2018), and the resulting turbid water may shade and protect fish and amphibians from damage by ultraviolet radiation (e.g., Frost et al. 2006). Other biological connections relate to the passive and active transport of living organisms (*see* Meyer et al. 2007 (discussing how organisms rely on streams); Moreno-Mateos and Palmer 2016; Johnston 2017; Schofield et al. 2018).

Accordingly, the Clean Water Rule's categorical treatment of tributaries reflects scientific reality.

Best Available Science Supports the Clean Water Rule's Categorical Treatment of Adjacent Waters Based on Geographic Proximity

Scientific research demonstrates that adjacent waters warrant regulation under the Clean Water Rule because of their chemical, physical, and biological connections to downstream primary waters.

Compelling Scientific Evidence Demonstrates that Waters within 100 Ft of an OHWM Significantly Affect the Chemical, Physical, and Biological Integrity of Primary Waters

Waters, including wetlands, ponds, oxbows, and impoundments, within 100 ft of an OHWM are "hotspots" of species diversity with important ecological functions that affect the flux of materials (water, sediment, energy, organic matter, pollutants, and organisms) to primary waters (*see* Groffman et al. 2003). These adjacent waters affect the movement of pollutants from uplands into streams and rivers; regulate stream temperatures, light, and flow regimes; reduce downstream flooding; and provide nursery areas and critical habitat for aquatic biota, including threatened and endangered species (*see* Ward et al. 2002). Riparian wetlands act as buffers, effectively reducing concentrations of nutrients and other pollutants. For example, riparian wetlands may remove up to 100% of the nitrate-nitrogen that enters them (*see* Fennessy and Cronk 1997). Nitrate is a serious water pollutant and a major contributor to coastal algal blooms, such as the Gulf of Mexico's hypoxic "dead zone," as well as nuisance algal blooms in many other surface waters (*see* Mitsch et al. 2005; *see also* Kosten et al. 2012).

These adjacent waters can act as sources, sinks, or transformers of materials from upland habitats. As sources, adjacent waters contribute organic materials, such as leaf litter, that provide food (energy) for many in-stream species (*see* Vannote et al. 1980). They also carry woody debris, which increases habitat complexity and biodiversity (*see* Allan 1995; Ward et al. 2002).

Adjacent waters are also major sinks for materials. By capturing and storing sediment eroded from nearby uplands, they reduce downstream sediment transport and its negative effects on fish feeding and spawning, macroinvertebrate communities, and overall habitat quality (*see* Newcombe and MacDonald 1991). These adjacent waters convert materials from one form to another; plants and algae can can take up nutrients and bind them in their tissues, reducing the risk of downstream eutrophication. Wetlands in particular mitigate nonpoint source pollution, such as insecticides and fertilizers, thus protecting stream water quality and drinking water supplies (e.g., Mitsch et al. 2005; Everich et al. 2011). Adjacent waters also slow the movement of materials and biota by providing temporary storage of excess water during times of high precipitation; this storage dissipates the energy of flows (reducing erosion and soil loss) and attenuates flood peaks (*see* Mitsch and Gosselink 2015).

Hydrologic connections do not need to be continuous to have a substantial effect on downstream primary waters. Hydrologic connectivity involves longitudinal, lateral, and vertical exchange, and adjacent waters are intimately linked to streams and rivers both in space (i.e., proximity to the OHWM) and time (e.g., by means of high water and flood events). Seasonal high water levels increase connectivity, promoting the lateral movement of animals between lakes, wetlands, stream channels, and their adjacent waters. This movement facilitates use of critical spawning and nursery habitats by fish and supports the biological integrity of the system. Many fish are sustained by varied habitats dispersed throughout the watershed for spawning, nurseries, growth, and maturation (*see* Fausch et al. 2002).

Overall, the benefits of protecting waters within 100 ft of an OHWM accrue both locally (at that point on the river system) and cumulatively (at the watershed scale). The

Clean Water Rule's categorical inclusion of these adjacent waters reflects scientific reality.

Compelling Scientific Evidence Demonstrates that Waters within 100-Year Floodplains Significantly Affect the Chemical, Physical, and Biological Integrity of Primary Waters

The Clean Water Rule's coverage of waters within 100-year floodplains is based on scientific understanding of watershed dynamics. These dynamics include not only surface expressions of connectivity (floods), but also underlying hydrologic conditions.

Every primary water has a watershed, which can be described as the land area that drains into that primary water and its tributaries (*see* Bierman and Montgomery 2014). During any flood event, primary waters and their tributaries may overflow their banks (Bierman and Montgomery 2014). The proportion of land that becomes obviously flooded (the "floodplain") depends upon the rate and total amount of rainfall. The geographic extent of the floodplain also depends upon the watershed's topography, soil saturation, and geological characteristics (*see* Osterkamp and Friedman 2000). A landscape with more topographic relief (steeper) will have a smaller floodplain than a flatter landscape where floodwaters more readily spread outward (*see* Howard 1996).

Although every flood is unique in extent and duration, scientists describe floodplains statistically to characterize other hydrologic (non-flooding) features (*see* Pandey and Nguyen 1999). For example, the "100-year floodplain" represents the land area that has a 1% chance of being inundated by floodwaters in any given year (1/100 likelihood). This definition is entirely statistical; such floods can occur more often in a 100-year floodplain, even 2 years or more in a row. It is incorrect to conclude that waters on a 100-year floodplain have a connection with a primary water only once in a century because the hydrologic connections extend beyond surface flooding alone and into belowground material.

Furthermore, changes in land use can affect flood dynamics. Increasing the proportion of the landscape that is covered with impermeable surfaces (such as streets and roofs) may increase flood intensity and duration (*see* Bedan and Clausen 2009).

Floodwaters are only the surface expressions of a flood. Rainfall permeates into the soil and often moves underground toward open waterbodies, such as primary waters (*see* Alley et al. 2002; Malard et al. 2002). Groundwater movement also contributes to baseflow in the absence of a flood. This understanding results from tracer techniques that show large proportions of streamflow are derived from groundwater (e.g., Alley et al. 2002).

Factors other than surface flooding determine the actual extent of hydrologic connections between waters in a floodplain. The direction of movement and the rate at which the water moves depend upon topography, geology, and rainfall (*see* Stanford and Ward 1993; Alley et al. 2002). Impermeable subsurface layers, like clay layers, can reduce the downward movement of water and force it to move laterally (*see* Bush and Johnston 1988). Often subsurface impermeable (or semi-permeable) layers are not level; they may slope toward waterbodies, and this subsurface lateral flow may re-emerge in a surface waterbody, such as a primary water. However, subsurface lateral flow can occur even without sloping impermeable layers; when more water pools in a particular subsurface location, lateral flow will occur from areas of higher pressure to areas of lower pressure, which may be river channels, wetlands, or lakes (Bear 2012).

Many different types of waterbodies can occur in 100-year floodplains. Tributaries and other waters can be connected to a primary river in more than one way (*see* Amoros and Bornette 2002). Headwaters and tributaries may flow directly into primary waters, adding organic matter and constituents that create unique water chemistry in the primary water (*see* Gomi et al. 2002). Wetlands may border primary waters, buffering the input of floodwaters, altering the water chemistry of floodwaters and the primary water itself, and providing habitat and resources for local biota (*see* Zedler 2003).

Even other waterbodies with no obvious surface connections to primary waters may still be hydrologically connected to them. Lakes, ponds, wetlands, and streams that flow into these apparently isolated waterbodies may have no surface connections to the primary water but, in addition to storing water as previously described, can have subsurface connections through groundwater (Bear 2012). These subsurface connections can carry water to primary waters; for example, water seeping down out of an apparently isolated waterbody may hit an impermeable layer and move laterally until it emerges in the primary waterbody (*see* Poole 2002). Therefore, loss of a superficially isolated waterbody can reduce water volume and alter flow characteristics of a primary water.

Evidence for these connections can be observed in the physical and chemical properties of primary waters (*see* Malard et al. 2002). Temperature, alkalinity, salinity, nitrate, other chemicals and pollutants, and dyes have been used as tracers to show the impact of groundwater connections to surface waters (*see* Soulsby et al. 2007). Furthermore, additions of pollutants into apparently isolated waterbodies or disparate areas of the watershed can affect primary waters (*see* Lerner and Harris 2009). Tracer and stable isotope studies have established paths and rates of water movements, substantiating that a distant source can pollute primary waters (*see* Badruzzaman et al. 2012). These studies highlight the chemical, physical, and biological connections between a primary water and other waterbodies that are located within its 100-year floodplain, thus justifying the inclusion of these adjacent waters in the Clean Water Rule.

Compelling Scientific Evidence Demonstrates that Waters within 1500 Ft of High Tide Lines of Tidally Influenced Primary Waters or OHWMs of the Great Lakes Significantly Affect the Integrity of these Primary Waters

Scientific evidence strongly supports protecting waters located within 1500 ft of such primary waters. These waters have the same types of connections and functions as the tributaries and other adjacent waters discussed *supra*. Adjacent waters within 1500 ft of primary waters have important chemical connections to those waters. Adjacent waters that were thought to be isolated have become more saline, providing empirical data regarding the groundwater connection between adjacent waters and primary waters (*see,* e.g., Wood and Harrington 2014). In addition, adjacent waters in the 1500-ft zone may release freshwater into coastal waters, thereby reducing the salinity of these waters (*see,* e.g., Sklar and Browder 1998).

Indeed, the inputs of groundwater into coastal waters are quite large, and groundwater can contain high levels of dissolved solids and nutrients (*see,* e.g., Moore 1996; Krest et al. 2000; Charette et al. 2001). As in inland systems, coastal wetlands remove nutrients, such as nitrate, thereby reducing down-gradient eutrophication in primary waters (*see* Ardón et al. 2013). Thus, adjacent waters protect and improve the quality of primary waters by removing harmful contaminants or transforming and transporting nutrients to primary waters (*see* Dahm et al. 2016).

Adjacent waters also physically influence primary waters through surface and subsurface connections. Adjacent waters contribute flow to nearby primary waters and retain floodwaters and sediments (*see,* e.g., Barlow 2003). Further, adjacent waters have a significant impact on the biological integrity of primary waters. Wetlands near tidally influenced primary waters can serve as a critical source of freshwater for some species that use wetlands and coastal waters (*see* U.S. EPA and U.S. Department of the Army 2015). Adjacent wetlands, lakes, ponds, and other waters also provide important foraging and breeding habitat for coastal species and are an important refuge from predators (*see,* e.g., Jude and Pappas 1992; Sierszen et al. 2012a).

Distance is but one factor that affects the connectivity between waters, and as with the other geographical distance limitations discussed *supra*, the agencies' selection of 1500 ft as the distance limitation is conservative from a scientific perspective. Indeed, waters located beyond this threshold can be chemically, physically, and biologically connected to tidally influenced primary waters or the Great Lakes. While the categorical jurisdictional line could have been drawn farther from high tide lines, science supports connecting the majority of lakes, wetlands, ponds, and other waters located within this 1500-ft area to primary waters.

Once again, the Clean Water Rule's categorical inclusion of these adjacent waters reflects scientific reality.

Conclusion

The U.S. Supreme Court has held that federal agencies may protect waters on a categorical basis if most waters in that category have a significant effect on primary waters. The best available science overwhelmingly demonstrates that the waters treated categorically in the Clean Water Rule have significant chemical, physical, and biological connections to primary waters. Accordingly, we support the Clean Water Rule. Any effort to suspend or revise the Clean Water Rule must take into account this scientific record and explain how any proposed changes would contribute to furthering the goals of the Clean Water Act.

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