No. 18-260

In The
Supreme Court of the United States

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COUNTY OF MAUI,

Petitioner,

v.

HAWAIʻI WILDLIFE FUND; SIERRA CLUB – MAUI GROUP; SURFRIDER FOUNDATION; WEST MAUI PRESERVATION ASSOCIATION,

Respondents.

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On Writ Of Certiorari To The United States Court Of Appeals For The Ninth Circuit

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BRIEF FOR AQUATIC SCIENTISTS AND SCIENTIFIC SOCIETIES AS *AMICI CURIAE* IN SUPPORT OF RESPONDENTS

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QUESTION PRESENTED

Whether the Clean Water Act requires a permit for the discharge of pollutants when the pollutants travel through groundwater from a point source to navigable waters.

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INTERESTS OF *AMICI CURIAE*[1]

Amici curiae[2] are four scientists and eight national and international scientific societies, all actively involved in research, education, and the conservation and restoration of aquatic ecosystems and resources in the United States. *Amici* have an interest in this case because of its impact on the integrity of those ecosystems and resources. The Clean Water Act's objective can only be achieved by considering the science behind the ways in which groundwater connects point sources and surface waters.

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[1] In accordance with this Court's Rule 37.3(a), all parties have provided written consent to the filing of this brief. In a letter submitted to this Court on April 4, 2019, counsel for respondents provided blanket consent to the filing of *amici curiae* briefs in support of either or neither party, filed within the time allowed by this Court's rules. Counsel for petitioner provided written consent to the filing of this brief on July 3, 2019.

Additionally, pursuant to this Court's Rule 37.6, *amici curiae* state that no counsel for a party authored this brief in whole or in part, that no party or party's counsel made a monetary contribution intended to fund the preparation or submission of this brief, and that no person—other than *amici curiae*, their members, or their counsel—made a monetary contribution intended to fund the preparation or submission of this brief.

[2] *Amici curiae* are Dr. Thomas Harter, Dr. David Kaplan, Dr. Mark Rains, Dr. Andrew Reeve, American Fisheries Society, Association for the Sciences of Limnology and Oceanography, Coastal and Estuarine Research Federation, Freshwater Mollusk Conservation Society, International Association for Great Lakes Research, Phycological Society of America, Society for Freshwater Science, and Society of Wetland Scientists. Biographies of the scientists and descriptions of the scientific societies are provided in the Appendix to this brief.

The legal and policy decisions at issue in this case must be based on sound science. As Justice Breyer noted, "[t]he law must seek decisions that fall within the boundaries of scientifically sound knowledge." Fed. Judicial Ctr. & Nat'l Research Council, *Reference Manual on Scientific Evidence* 4 (3d ed. 2011). Scientists can measure the interactions between surface waters and groundwater using robust methods, including physical measurements, chemical tracers, and computer models. These methods can be used to determine when point source discharges of pollutants adversely affect surface waters, including navigable waters, via groundwater. The Clean Water Act was intended to—and indeed, must—regulate such point source discharges of pollutants to maintain the chemical, physical, and biological integrity of the Nation's waters. This brief highlights the important scientific reality of the connections between point sources and surface waters via different types of groundwater pathways, as well as the scientific tools used to ascertain those connections.

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SUMMARY OF ARGUMENT

A proper interpretation of the Clean Water Act requires a basic understanding of hydrology, the science of water on and below the Earth's surface. Groundwater can connect point sources and surface waters. Thus, pollutants discharged into groundwater may contaminate surface waters, including navigable waters.

The vast majority of groundwater is stored in aquifers. Scientists generally classify aquifers as unconfined, confined, or perched, depending on the groundwater's interaction with subsurface geology. Groundwater flow through these aquifers varies based on hydraulic gradient and hydraulic conductivity. Connectivity between groundwater and surface waters is a function of hydrology, landscape topography, aquifer conditions, surface water and groundwater management, and climate.

Multiple scientific methods exist to estimate and empirically quantify the magnitude and timing of groundwater connections between point sources and surface waters. These methods include physical measurements, chemical tracers, and groundwater models. These methods can also be used to determine if, and to what extent, pollutants discharged from point sources contaminate surface waters through groundwater.

The Clean Water Act's mandate of restoring and maintaining the chemical, physical, and biological integrity of the Nation's waters is based on science and thus can only be achieved through the consideration of science. Furthermore, Congress's use of the terms "well" and "discrete fissure" in the definition of point source establishes an intent to regulate discharges that travel through groundwater; as a scientific matter (and as a matter of common sense), wells and fissures can only discharge into groundwater. The Ninth Circuit's approach, which considers whether pollutants in a navigable water are fairly traceable from a point source, is consistent with the science discussed in this brief. In contrast, petitioner's means-of-delivery test blithely disregards hydrogeologic reality, ignoring the science behind the connections between point sources and surface waters through groundwater, as well as established scientific methods used to track pollutants through these pathways.

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ARGUMENT

Well-established scientific methods are used to assess whether and how much particular point sources and surface waters are connected by groundwater. Like surface water, groundwater occurs in several forms. The flowpaths of groundwater, including pollutants contained therein, can be traced through physical measurements (*e.g.*, groundwater levels, flow meters), chemical measurements (*e.g.*, forensic analysis of water quality, tracer studies), and numerical modeling (*e.g.*, USGS MODFLOW). These scientific methods can establish the hydrological connection between particular point sources and surface waters via groundwater (and, in the present case, they were used to conclusively establish the hydrological connection between the Lahaina Wells and the nearby Pacific coastal waters). The Clean Water Act's text makes clear that Congress intended the Act to regulate the discharges of pollutants from point sources when those pollutants are conveyed via groundwater to surface waters that are waters of the United States. The Clean Water Act's mandate to restore and maintain the chemical, physical, and biological integrity of the Nation's waters, 33 U.S.C. § 1251(a), can only be met if the scientific reality of connections between point sources and surface waters through groundwater is taken into account.

I. INTRODUCTION TO HYDROLOGIC CONCEPTS AND GROUNDWATER

To understand how groundwater conveys pollutants from point sources to surface waters, one must understand several basic hydrologic principles. Groundwater plays an important role in overall surface water quantity and quality. Indeed, groundwater flow significantly contributes to annual streamflow. While highly variable across the country, approximately 55% of annual streamflow nationwide is provided by groundwater. Thomas C. Winter et al., *Ground Water and Surface Water: A Single Resource* 12 (U.S. Geological Survey Circular 1139, 1999). This hydrological connection includes the transfer of anything transported by the groundwater, such as pollutants. The precise nature of how groundwater flow can connect a particular point source to a surface water depends on a variety of factors, but this fact remains unassailable: groundwater can create a hydrological connection between a particular point source and a surface water. *See generally* Brewster Conant Jr. et al., *A Framework for Conceptualizing Groundwater-Surface Water Interactions and Identifying Potential Impacts on Water Quality, Water Quantity, and Ecosystems*, 574 J. Hydrology 609 (2019).

Several factors influence the nature of groundwater connections between point sources and surface waters. A basic tenet of freshwater ecology is that hydrological connections consist of four dimensions: longitudinal (*e.g.*, along the stream system), lateral (*e.g.*, stream-landscape), vertical (*e.g.*, stream-groundwater), and temporal. J. V. Ward, *The Four-Dimensional Nature of Lotic Ecosystems*, 8 J. N. Am. Benthological Soc'y 2, 2–6 (1989). These dimensions operate from local to landscape scales. *Id.* Fluxes of water along hydrological flowpaths occur at varying frequencies, magnitudes, timings, durations, and rates, which are primarily determined by topography, geology, and climate. Thomas C. Winter, *The Concept of Hydrologic Landscapes*, 37 J. Am. Water Resources Ass'n 335, 336–39 (2001); David M. Wolock et al., *Delineation and Evaluation of Hydrologic-Landscape Regions in the United States Using Geographic Information System Tools and Multivariate Statistical Analyses*, 34 Envtl. Mgmt. S71, S72–S73, S80–S81 (2004); K. Devito et al., *A Framework for Broad-Scale Classification of Hydrologic Response Units on the Boreal Plain: Is Topography the Last Thing to Consider?*, 19 Hydrological Processes 1705, 1708–11 (2005); Parker J. Wigington et al., *Oregon Hydrologic Landscapes: A Classification*

Framework, 49 J. Am. Water Resources Ass'n 163, 164, 172 (2013). Collectively, these factors control the physical integrity of downgradient waters. Tracie-Lynn Nadeau & Mark Cable Rains, *Hydrological Connectivity Between Headwater Streams and Downstream Waters: How Science Can Inform Policy*, 43 J. Am. Water Resources Ass'n 118, 122–24 (2007); Mark Cable Rains et al., *The Role of Perched Aquifers in Hydrological Connectivity and Biogeochemical Processes in Vernal Pool Landscapes, Central Valley, California*, 20 Hydrological Processes 1157, 1157 (2006). In essence, these factors can shape the ways in which the downgradient waters are affected by the other waters (including groundwater) to which they have connections.

A. Groundwater Storage

Groundwater systems have a number of characteristics that affect their storage and flows and thus the ways in which a particular groundwater system can convey pollutants from an individual point source to surface waters. The vast majority of groundwater flow occurs in aquifers, geological formations made up of permeable materials (*i.e.*, soil and rock) saturated with water. S. W. Lohman et al., *Definitions of Selected Ground-Water Terms—Revisions and Conceptual Refinements* 2 (Geological Survey Water-Supply Paper 1988, 5th prtg. 1983). Water in aquifers is stored in pores and fractures, the spaces between sediment particles and rock surfaces, respectively. The collective behavior of pores or fractures in a soil or rock medium is referred to as porosity, which is the volume fraction of pore space relative to the total volume of the medium. J.R. Nimmo, *Porosity and Pore Size Distribution* 1–3 (Reference Module in Earth Sys. & Envtl. Scis., 2013). The soil and rocks that make up aquifers are thus referred to as porous media, and the higher the porosity, the more water a porous medium can hold.[3] The size, shape, and connectivity of pores within the medium help define the aquifer storage capacity, aquifer hydraulic conductivity (rate at which water can move through the aquifer), and the type and rate of surface water-groundwater interactions.

In turn, aquifers are classified into three primary categories based on their interaction with subsurface geology: unconfined, confined, and perched. Colo. Geological Survey, *Ground Water Atlas of Colorado*, http://coloradogeologicalsurvey.org/wp-content/uploads/water atlas/chapter2page2.html (last visited July 8, 2019); *see also* Vedat Batu, *Aquifer Hydraulics: A Comprehensive Guide to Hydrogeologic Data Analysis* 22–24 (1998). Unconfined aquifers (Figure 1), also referred to as water table aquifers or surficial aquifers, extend from near the land surface down to some constraining

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[3] The porous media that make up aquifers can include unconsolidated (individual) soil particles, ranging in size from sand grains (approximately 0.1 to 2 mm) to gravel (2 to 64 mm) to large cobbles and boulders (>64 mm), S. Jeffress Williams et al., *Surficial Sediment Character of the New York-New Jersey Offshore Continental Shelf Region: A GIS Compilation* 11–12 (U.S. Geological Survey Open-File Report 2006-1046, 2007), as well as consolidated porous rocks like sandstone, and fractured porous rocks like basalt and limestone. R. Allan Freeze & John A. Cherry, *Groundwater* 152–63 (1979).

geological unit (a low-permeability soil or rock layer, such as clay or some types of bedrock). Unconfined aquifers are closely connected to the land surface and atmosphere, and the level of water in an unconfined aquifer, often referred to as the water table, is the top of the groundwater system. Confined aquifers (Figure 1) are fully saturated zones that are separated from the land surface and atmosphere by one or more confining layers or units, which are geological formations with relatively low hydraulic conductivity (permeability). Because confined aquifers are separated from the atmosphere, they are often under considerable pressure from water recharging (infiltrating into/filling up) the aquifer at higher elevations, meaning that water in a well placed in the confined aquifer will rise above the confining unit (Figure 1). Finally, perched aquifers are small and localized mounds of groundwater that accumulate on top of discontinuous patches of low-permeability geologic units (Figure 2). The volume of water in perched aquifers is generally small and varies with climate, but they can be important for supporting groundwater-dependent ecosystems, such as wetlands and ephemeral streams. Mark M. Brinson, *A Hydrogeomorphic Classification for Wetlands* 35 (Wetlands Research Program Tech. Report WRP-DE-4, 1993); Richard G. Niswonger & Graham E. Fogg, *Influence of Perched Groundwater on Base Flow*, 44 Water Resources Res. W03405, at 1 (2008). Thus, each type of aquifer can bear a different relationship to surface waters, based on its different interactions with surface topography and subsurface geology.

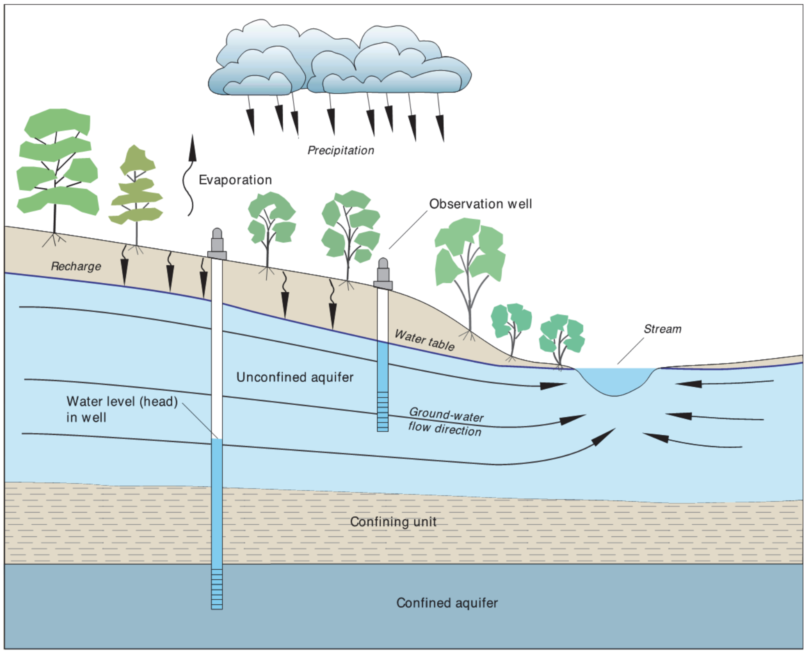

Figure 1. Cross section of an aquifer system with both unconfined and confined units. Source: Charles J. Taylor & William M. Alley, *Ground-Water-Level Monitoring and the Importance of Long-Term Water-Level Data* 4 fig.A–2 (U.S. Geological Survey Circular 1217, 2001).

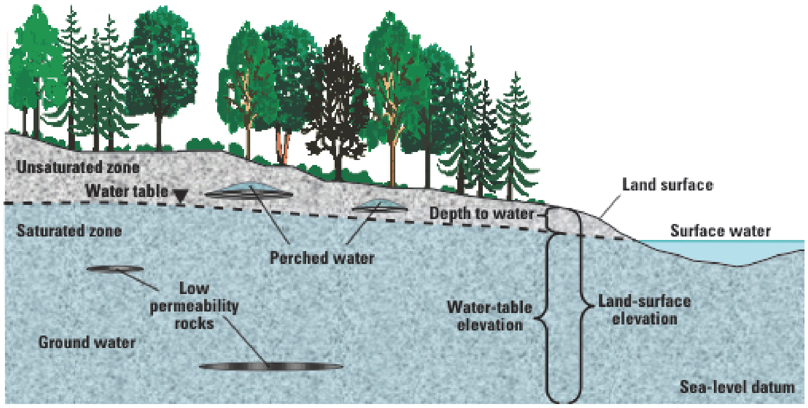

Figure 2. Cross section of an aquifer system with both unconfined and perched units. Source: Daniel T. Snyder, *Estimated Depth to Ground Water and Configuration of the Water Table in the Portland, Oregon Area* 4 fig.2 (U.S. Geological Survey Sci. Investigations Report 2008–5059, 2008).

B. Groundwater Flows

The science behind groundwater flows is key to understanding how groundwater can transport discharges of pollutants from point sources to surface waters. In general, groundwater flow is much slower than flow in surface water systems. S. Ge & S.M. Gorelick, *Groundwater and Surface Water*, *in* 3 *Encyclopedia of Atmospheric Sciences* 209, 210 (Gerald R. North et al. eds., 2d ed. 2015). For example, groundwater flow in the High Plains aquifer has been estimated to be about 1 foot (0.3 meters) per day. James A. Miller & Cynthia L. Appel, *Segment 3: Kansas, Missouri, and Nebraska*, *in* U.S. Geological Survey, *Ground Water Atlas of the*

United States ch. 730-D, at D13 (1997). This is not the case, however, for all groundwater systems. Flow velocities in karst (limestone) aquifers and in some volcanic aquifers, where water is moving through fractures and conduits, can approach or exceed those in surface water systems. For example, Kincaid et al. observed groundwater flow velocities of up to 15,000 feet (approximately 4,500 meters) per day. Todd R. Kincaid et al., *Quantitative Groundwater Tracing and Effective Numerical Modeling in Karst: An Example from the Woodville Karst Plain of North Florida* (2012).

Across all groundwater system types and materials, groundwater flow rates are controlled by two fundamental quantities: hydraulic gradient and hydraulic conductivity. Hydraulic gradient is the difference in hydraulic head between two points divided by the distance between them (*e.g.*, the slope of the water table). Hydraulic head (sometimes referred to as total head) at any point in a groundwater system is the sum of two elements: (1) the elevation head, which is equal to the elevation of the point above a vertical reference datum, such as mean sea level; and (2) the pressure head, which is equal to the height of a water that can be supported by the pressure at the point.[4] Groundwater flows from areas of high hydraulic head to areas of low hydraulic head; critically, this includes flow from groundwater systems to surface water bodies and vice versa. Hydraulic conductivity can be thought of as the ease with which water flows through a porous or

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[4] A third component, the velocity head, is extremely small and usually not taken into account. Lohman et al., *supra*, at 7.

fractured medium. Ralph C. Heath, *Basic Ground-Water Hydrology* 10, 12, 25 (U.S. Geological Survey Water Supply Paper No. 2220, 10th prtg. 2004).

The physical law that describes groundwater flow is Darcy's Law, which states that flow through a porous medium is the mathematical product of the hydraulic gradient and hydraulic conductivity. Henry Darcy, *Les Fontaines Publiques de la Ville de Dijon: Exposition et Application des Principes à Suivre et des Formules à Employer dans les Questions de Distribution d'Eau* (Victor Dalmont ed., 1856). Larger values of hydraulic gradient or hydraulic conductivity equate directly to larger groundwater flow volumes and velocities. For example, if the hydraulic gradient is doubled (*i.e.*, by increasing the water table slope) and the hydraulic conductivity stays the same, the groundwater flow rate will double. Similarly, if the hydraulic conductivity is halved (*i.e.*, a less transmissive geologic medium), but the hydraulic gradient remains the same, the groundwater flow rate will be halved. Groundwater flow rates can be high in areas where the hydraulic gradient, hydraulic conductivity, or both are high.

II. ROBUST SCIENTIFIC METHODS CAN MEASURE THE EXTENT TO WHICH GROUNDWATER CONNECTS POINT SOURCES TO SURFACE WATERS

Hydrogeologists have developed a robust set of tools for measuring the extent to which point sources are connected to surface waters through groundwater.

Multiple direct and indirect approaches have been developed to measure groundwater flow speed and direction, surface water-groundwater interactions, and contaminant transport in the subsurface. These approaches include physical measurements, chemical tracer methods, and groundwater models. They rely on field, laboratory, or remote sensing measurements, and on knowledge of the geology, hydrology, land use, and climate. The choice of measurement will depend on local conditions, funding, available data, and time available for data collection and analysis.[5]

A. Physical Measurements

First, groundwater connections between a point source and a surface water can be measured via physical measurement, the most direct approach to quantifying groundwater flow speed and direction. Measuring hydraulic heads in multiple locations allows hydrogeologists to understand general groundwater flow direction (*i.e.*, from areas of high to low head) and estimate flow rates. Maps of hydraulic heads across a region are called potentiometric surfaces (sometimes referred to as piezometric surfaces) and are analogous to topographic maps, but instead of

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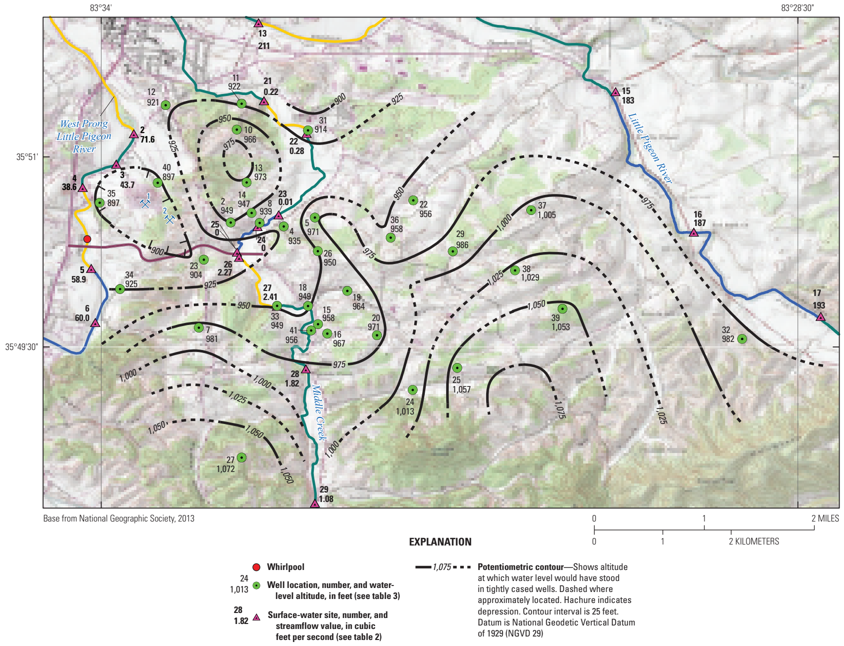
[5] Like any tool, each approach is subject to limitations, which may include time constraints, lack of data, and uncertainty regarding future conditions. *See*, *e.g.*, Mary P. Anderson et al., *Applied Groundwater Modeling: Simulation of Flow and Advective Transport* 11–13 (2d ed. 2015). In such cases, pollutants in a surface water may not be "fairly traceable" to a particular point source.

illustrating how land surface elevation varies across a landscape, they show spatial variation in hydraulic heads of groundwater (Figure 3). Potentiometric maps are thus useful both for representing spatiotemporal variation in aquifer storage and for visually illustrating patterns of groundwater flow direction. Difference in hydraulic heads between points allows for the estimation of groundwater velocity using Darcy's Law with information about aquifer hydraulic conductivity and porosity. Under some circumstances, groundwater flow speed and direction can also be measured directly in the aquifer using several different types of groundwater flow meters (*e.g.*, heat-pulse, acoustic Doppler, and fluid-conductivity) deployed in wells. E.R. Bayless et al., *Accuracy of Flowmeters Measuring Horizontal Groundwater Flow in an Unconsolidated Aquifer Simulator*, 31 Ground Water Monitoring & Remediation 48, 49 (2011); *see also* Donald O. Rosenberry et al., *Combined Use of Thermal Methods and Seepage Meters to Efficiently Locate, Quantify, and Monitor Focused Groundwater Discharge to a Sand-Bed Stream*, 52 Water Resources Res. 4486 (2016) (use of seepage meters to quantify groundwater-surface water exchange).

Groundwater storages can be estimated as the product of aquifer area, specific yield (the volume of water that can be pumped out of an aquifer relative to its total volume), and thickness (the height or length of the saturated aquifer media); this information comes from geological surveys, aquifer mapping efforts, and measurements of groundwater levels from observation and pumping wells. *See generally* U.S. Geological Survey, *Ground Water Atlas of the United States* (James A. Miller ed., 2000); Kevin F. Dennehy et al., *Groundwater Availability in the United States: The Value of Quantitative Regional Assessments*, 23 Hydrogeology J. 1629 (2015). Groundwater storage changes are typically measured using a network of wells that track changes in water levels over time. More recently, satellite-based remote sensing technology has been used to estimate groundwater storage volumes over large groundwater basins by detecting changes in gravity. J.S. Famiglietti et al., *Satellites Measure Recent Rates of Groundwater Depletion in California's Central Valley*, 38 Geophysical Res. Letters L03403, at 1–2 (2011); B. R. Scanlon et al., *Ground Referencing GRACE Satellite Estimates of Groundwater Storage Changes in the California Central Valley, USA*, 48 Water Resources Res. W04520, at 2–5 (2012). Measurements of water levels, hydraulic conductivity, and estimates of groundwater storage are often coupled with mathematical models of groundwater hydrology (discussed *infra* Section II(C)) to understand changes over time and guide more sustainable groundwater management. James McPhee & William W-G. Yeh, *Multiobjective Optimization for Sustainable Groundwater Management in Semiarid Regions*, 130 J. Water Resources Plan. & Mgmt. 490, 491–93 (2004); Saber Farhadi et al., *An Agent-Based-Nash Modeling Framework for Sustainable Groundwater Management: A Case Study*, 177 Agric. Water Mgmt. 348, 350–53 (2016). Critically, groundwater storage is not a static quantity but a result of the balance of dynamic flows among atmosphere (precipitation and evapotranspiration), surface waters (lakes, rivers, and oceans), and groundwater systems.



Base from National Geographic Society, 2013

Figure 3. Potentiometric surface showing contour lines (lines of equal hydraulic head), from which flow direction (from high to low head) can be derived. Adapted from: John K. Carmichael & Gregory C. Johnson, *Groundwater/Surface-Water Interaction in Central Sevier County, Tennessee, October 2015–2016*, at 18 fig.7 (U.S. Geological Survey Open-File Report 2017–1147, 2017).

B. Chemical Tracer Methods

Next, hydrogeologists can use various chemical tracer methods to derive additional detailed information about groundwater flow and thus the hydrological connection between a particular point source and surface waters. These types of measurements can be subdivided into two categories: artificial and natural, both of which can be useful for quantifying surface water-groundwater interactions. Ross Brodie et al., *An Overview of Tools for Assessing Groundwater-Surface Water Connectivity* 86–90, 95–98 (2007). Artificial tracer studies consist of injecting a conservative solute (*e.g.*, a salt, dye, or dissolved gas that does not react or bind to the aquifer material) into the aquifer in one location and measuring tracer concentrations over time in the groundwater at downgradient (downhill) wells. Stanley N. Davis et al., *Ground-Water Tracers—A Short Review*, 18 Ground Water 14, 14 (1980). Because they are non-reactive, injected tracers move with the water, allowing for the mapping of flow paths and calculation of groundwater flow speed (*i.e.*, the time from injection at one point to detection at another, divided by the distance between them). Tracer studies are widely applied to confirm flow directions and speeds inferred from measured hydraulic heads, *see*, *e.g.*, Paul W. Reimus & Bill W. Arnold, *Evaluation of Multiple Tracer Methods to Estimate Low Groundwater Flow Velocities*, 199 J. Contaminant Hydrology 1 (2017), and are especially useful for mapping specific flow paths, Douglas A. Burns & Long Nguyen, *Nitrate Movement and Removal Along a Shallow Groundwater Flow Path* *in a Riparian Wetland Within a Sheep-Grazed Pastoral Catchment: Results of a Tracer Study*, 36 N.Z. J. Marine & Freshwater Res. 371, 376–80 (2002). Importantly, artificial tracer methods characterize both the average and variation in groundwater flow speed, since groundwater in the same aquifer can move at vastly different speeds (*i.e.*, quickly through large pores or conduits and slowly through small pores and consolidated rock). This variation in flow speed is referred to as velocity distribution but is often reported in terms of the inverse, called residence time distribution, which quantifies the range of times that groundwater remains in a particular section of the aquifer. F. Cornaton & P. Perrochet, *Groundwater Age, Life Expectancy and Transit Time Distributions in Advective-Dispersive Systems: 1. Generalized Reservoir Theory*, 29 Advances in Water Resources 1267, 1269 (2006). Put simply: high velocity means low residence time and vice versa.

In contrast to artificial tracer methods, natural tracer methods use naturally occurring water quality properties of surface waters and/or groundwater to understand water sources, travel paths, and interactions. Helmut Elsenbeer et al., *Chemical Fingerprints of Hydrological Compartments and Flow Paths at La Cuenca, Western Amazonia*, 31 Water Resources Res. 3051 (1995). Natural tracer studies are sometimes referred to as "fingerprinting" since they seek to use unique physical, chemical, or biological "fingerprints" or "signatures" of particular water types. *Id.* Some studies also use the term "fingerprinting" when looking to identify waters contaminated with specific wastes. *See*, *e.g.*, Paulo Lojkasek-Lima et al., *Fingerprinting TCE in a Bedrock Aquifer Using Compound-Specific Isotope Analysis*, 50 Ground Water 754 (2012). Some common natural tracers include heat, Mary P. Anderson, *Heat as a Ground Water Tracer*, 43 Ground Water 951 (2005); dissolved solutes and isotopes, *Environmental Tracers in Subsurface Hydrology* 2–5 (Peter G. Cook & Andrew L. Herczeg eds., 2d prtg. 2001); atmospheric gases, Sebastian Bauer et al., *A Multi-Tracer Study in a Shallow Aquifer Using Age Dating Tracers ^{3}H, ^{85}Kr, CFC-113 and SF_6—Indication for Retarded Transport of CFC-113*, 248 J. Hydrology 14, 23–26 (2001); and even microorganisms, Ronald W. Harvey, *Microorganisms as Tracers in Groundwater Injection and Recovery Experiments: A Review*, 20 FEMS Microbiology Reviews 461, 463–67 (1997). Natural tracers can be particularly useful for surveying surface water-groundwater interactions. Brodie et al., *supra*, at 86–90; *see*, *e.g.*, David P. Genereux & Harold F. Hemond, *Naturally Occurring Radon 222 as a Tracer for Streamflow Generation: Steady State Methodology and Field Example*, 26 Water Resources Res. 3065, 3066–67 (1990) (use of the radon-222 isotope for quantifying streamflow generation from groundwater); Jaye E. Cable et al., *Estimating Groundwater Discharge into the Northeastern Gulf of Mexico Using Radon-222*, 144 Earth & Planetary Sci. Letters 591, 592–93 (1996) (use of the radon-222 isotope for quantifying submarine groundwater flow to the coast); Christina Schornberg et al., *Simulating the Effects of Geologic Heterogeneity and Transient Boundary Conditions on Streambed Temperatures—Implications for*

Temperature-Based Water Flux Calculations, 33 Advances in Water Resources 1309, 1311–13 (2010) (use of temperature-based measurements of surface water-groundwater interactions in streams); P.G. Cook et al., *Determining Natural Groundwater Influx to a Tropical River Using Radon, Chlorofluorocarbons and Ionic Environmental Tracers*, 277 J. Hydrology 74, 78 (2003) (combining radon, chlorofluorocarbons, and dissolved ions to estimate groundwater influx to a tropical river). Finally, natural and artificial tracer methods are sometimes combined to elucidate different components of groundwater flow. Ute Lauber & Nico Goldscheider, *Use of Artificial and Natural Tracers to Assess Groundwater Transit-Time Distribution and Flow Systems in a High-Alpine Karst System (Wetterstein Mountains, Germany)*, 22 Hydrogeology J. 1807, 1811–13 (2014).

In the present case, a multi-faceted study was conducted by researchers from the U.S. Environmental Protection Agency, the Hawai‘i Department of Health, the U.S. Army Engineer Research and Development Center, and the University of Hawai‘i. Part of the study involved using a fluorescent tracer dye, which was added to the effluent before it was injected into the Lahaina Wells. Craig R. Glenn et al., *Lahaina Groundwater Tracer Study—Lahaina, Maui, Hawai'i, Final Report* 4-1 (2013) [hereinafter Glenn et al., *Lahaina Study*]. The study found “a hydrogeologic connection” between the Lahaina injection wells “and the nearby coastal waters of West Maui.” Pet. App. 9 (internal quotation marks omitted); Glenn et al., *Lahaina Study*, *supra*, at ES-3. The study was conducted using methods consistent with the principles described in this brief and was an application of sound science.

C. Groundwater Models

Both physical and chemical measurements of groundwater storage and flow are often coupled with groundwater models to understand groundwater flow systems and predict how they will change under different conditions. Mich. Dep't of Envtl. Quality, *RRD-RESOURCE MATERIALS-25-2013-01, Groundwater Modeling: Remediation and Redevelopment Division Resource Materials* 14–15 (2014). Groundwater models provide tools to determine the manner by and degree to which point source pollution would be conveyed to a surface water. *See generally* Thomas Harter et al., *Adjudicating Groundwater: A Judge's Guide to Understanding Groundwater and Modeling* (2018). There are many types of groundwater models, *see* Ward Sanford, *Recharge and Groundwater Models: An Overview*, 10 Hydrogeology J. 110 (2002), but all apply Darcy's Law and the principle of the water balance concept[6] to mathematically represent groundwater storage changes and flows in a specific place over a specified time period, *see*, *e.g.*, Emin C. Dogrul et al., *Groundwater Modeling in Support of Water Resources Management and Planning Under Complex Climate, Regulatory,*

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[6] The volume of water in an aquifer at any time is driven by the water balance, or the sum of all water inflows and outflows, including inflows from and outflows to surface waters. Tom Gleeson et al., *Water Balance of Global Aquifers Revealed by Groundwater Footprint*, 488 Nature 197, 197 (2012).

and Economic Stresses, 8 Water 592 (2016) (applying model to simulate groundwater and surface water flow dynamics within the California Central Valley). Groundwater models can be coupled with transport models to simulate the movement of reactive and non-reactive solutes (such as contaminants) through the aquifer.

The most common groundwater modeling tools, particularly in the applied setting, are numerical groundwater models, such as the USGS MODFLOW model, Arlen W. Harbaugh, *MODFLOW-2005, The U.S. Geological Survey Modular Ground-Water Model—the Ground-Water Flow Process* (U.S. Geological Survey Techniques & Methods 6-A16, 2005), which is often coupled with the MT3DMS groundwater transport model, H. Prommer et al., *MODFLOW/MT3DMS-Based Reactive Multicomponent Transport Modeling*, 41 Ground Water 247 (2003). Numerical groundwater models represent the groundwater system through a network or grid of cells (small elements or grid blocks), each of which represents the aquifer properties and hydraulic head in that location (similar to a TV monitor that represents an image through a large number of discrete pixels, each with one specific color). Each groundwater model cell interacts with neighboring cells such that water and associated solutes flow from cells with high head to those with low head (consistent with physical laws). Model cells extend laterally and vertically to a specified model boundary. Such groundwater modeling was used in the Lahaina Study to aid in the design of the tracer test by estimating the dilution of the dye during the test and the time it would take for the dye to appear in the ocean. The Lahaina model incorporated the USGS MODFLOW model and MT3DMS groundwater transport model, as well as the MODPATH transport model, to track the movement of particles and to simulate the transport of the dyes. Glenn et al., *Lahaina Study*, *supra*, at ES-18–ES-19.

Developing a spatially distributed groundwater model generally requires at least three sources of information: (1) spatial variation in aquifer hydrogeological characteristics (*e.g.*, porosity, specific yield, hydraulic conductivity); (2) information or assumptions about model boundary conditions (known or assumed aquifer heads or flows and solute concentrations at the model boundary); and (3) climate/weather data that, together with information about land cover, drive aquifer recharge. Depending on the specific application, information about groundwater pumping for human use and surface water-groundwater interactions also may be important. The groundwater model uses this information to solve for hydraulic heads within each cell.[7] Model outputs can include time series of hydraulic heads at any or all locations in the aquifer system, spatiotemporal variation in groundwater flow speed and direction, and the speed and magnitude of any solute transport.

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[7] To solve numerically, groundwater models use a groundwater flow equation (a water balance based on Darcy's Law over a specified time step (*e.g.*, hourly, daily, monthly)) and a groundwater transport equation over the timeline of the model run (the temporal duration of the model).

Model simulations are most often compared to observations (*i.e.*, data) to determine how well the model represents the real world. Most often, models go through an iterative process of model calibration and validation, which consists of adjusting model parameters within their uncertainty limits until model outputs best match observed data. Thomas E. Reilly & Arlen W. Harbaugh, *Guidelines for Evaluating Ground-Water Flow Models* 23–24 (U.S. Geological Survey Sci. Investigations Report 2004–5038, 2004); Mary C. Hill & Claire R. Tiedeman, *Effective Groundwater Model Calibration: With Analysis of Data, Sensitivities, Predictions, and Uncertainty* 213–27 (2007). Just as there are many types of groundwater models, there are many model calibration and validation approaches and techniques. Chin-Fu Tsang, *The Modeling Process and Model Validation*, 29 Ground Water 825, 829 (1991); Ahmed Hassan, *A Validation Process for the Groundwater Flow and Transport Model of the Faultless Nuclear Test at Central Nevada Test Area* 8–17 (U.S. Dep't of Energy Pub. No. 45197, 2003).[8]

Once calibrated and validated, groundwater models can be used for a variety of applications, including quantifying surface water-groundwater interactions. Alida Cantor et al., *Navigating Groundwater-Surface Water Interactions Under the Sustainable*

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[8] The Lahaina model, for example, was calibrated and modified using actual tracer data. The Lahaina model was then used to test various hydrogeologic processes to determine which processes may have been affecting the transport of the tracer dye. Glenn et al., *Lahaina Study*, *supra*, at ES-18–ES-19.

Groundwater Management Act 8–10 (2018) (discussing tools and methods for monitoring and measuring surface water-groundwater dynamics); Kimberly A. Rhodes et al., *The Importance of Bank Storage in Supplying Baseflow to Rivers Flowing Through Compartmentalized, Alluvial Aquifers*, 53 Water Resources Res. 10,539, 10,551–54 (2017) (examining interaction of Brazos River Alluvium Aquifer and Brazos River). Additionally, as explained below, models can be used to estimate where and how quickly pollutants will flow through groundwater systems. *See*, *e.g.*, Anderson et al., *supra*; George P. Karatzas, *Developments on Modeling of Groundwater Flow and Contaminant Transport*, 31 Water Resources Mgmt. 3235 (2017).

D. Applying Robust Scientific Methods to Track Pollutants in Groundwater

The groundwater measurement and modeling tools described above can be used to track pollutants as they flow though groundwater systems and interact with surface water bodies. William G. Reay et al., *Groundwater Discharge and Its Impact on Surface Water Quality in a Chesapeake Bay Inlet*, 28 Water Resources Bull. 1121, 1122 (1992). This process is often referred to as contaminant fate and transport modeling, where fate refers to any alteration of contaminants via chemical or biological processes and transport refers to movement of contaminants with groundwater flow. Contaminant fate and transport are generally modeled using a calibrated groundwater flow model (like those described above), but they can also be modeled using measurements of flow velocity if they are available from physical measurements or tracer studies. Ohio Envtl. Prot. Agency, *Ground Water Flow and Fate and Transport Modeling*, *in Technical Guidance Manual for Ground Water Investigations* 14-25 to 14-26 (revision 1, 2007). Contaminant fate and transport models generally simulate the following: (1) movement of contaminants by advection (flow) and dispersion (spreading due to velocity variation and concentration differences); (2) sorption and desorption (attachment and release) of contaminants from aquifer materials; and (3) contaminant transformations due to biological processes (*e.g.*, microbial degradation) or chemical reactions (*e.g.*, oxidation-reduction reactions). *Id.* at 14-3.

As with groundwater flow models, groundwater fate and transport models are calibrated and validated using measured data. Once calibrated, they can be used to predict the magnitude and timing of contaminant flow between different aquifer regions, *see* Susan E. Powers et al., *The Transport and Fate of Ethanol and BTEX in Groundwater Contaminated by Gasohol*, 31 Critical Reviews in Envtl. Sci. & Tech. 79, 114–15 (2001); Claudette Spiteri et al., *Modelling the Geochemical Fate and Transport of Wastewater-Derived Phosphorus in Contrasting Groundwater Systems*, 92 J. Contaminant Hydrology 87, 105–06 (2007), as well as to simulate the transport of contaminants through groundwater to surface water systems. For example, McKnight et al. developed a groundwater fate and transport model for a trichloroethylene (TCE)-contaminated groundwater plume discharging to a stream and found that, without cleanup, TCE would be discharging from the groundwater to the stream for multiple decades. Ursula S. McKnight et al., *An Integrated Model for Assessing the Risk of TCE Groundwater Contamination to Human Receptors and Surface Water Ecosystems*, 36 Ecological Engineering 1126, 1136 (2010). In a recent study, Sullivan et al. simulated nitrate transport through a karst aquifer, finding that anthropogenic sources such as fertilizers and wastewater applied to the land surface were primary sources of contamination to the aquifer and associated surface water springs. T.P. Sullivan et al., *Nitrate Transport in a Karst Aquifer: Numerical Model Development and Source Evaluation*, 573 J. Hydrology 432, 446 (2019).

III. THE CLEAN WATER ACT REQUIRES THE CONSIDERATION OF THE SCIENCE REGARDING GROUNDWATER AND SURFACE WATER CONNECTIONS

While the degree of hydrological connectivity may be a function of a variety of factors, the measurement and flow of groundwater to surface waters can be scientifically ascertained as described above. As Justice Breyer observed, "[judicial] decisions should reflect a proper scientific and technical understanding so that the law can respond to the needs of the public." Fed. Judicial Ctr. & Nat'l Research Council, *supra*, at 2. Thus, when a pollutant discharges to a navigable water via a scientifically ascertained groundwater connection, the Clean Water Act requires a permit for that discharge. *See* 33 U.S.C. §§ 1311(a), 1342(a). Indeed, the mandate of the Clean Water Act—to restore and maintain the chemical, physical, and biological integrity of the Nation's waters—can only be met by taking into account the above-described scientific reality of the hydrological connection between surface waters and groundwater, including the conveyance of pollutants.

A. The Clean Water Act Requires Consideration of Science to Meet Its Objective

Science is critically important to make the necessary empirical determinations about the chemical, physical, and biological integrity of our waters to achieve the Clean Water Act's objective. This Court has noted that the Act "incorporated a broad, systemic view of the goal of maintaining and improving water quality: as the House Report on the legislation put it, 'the word "integrity" . . . refers to a condition in which the natural structure and function of ecosystems [are] maintained.'" *United States v. Riverside Bayview Homes, Inc.*, 474 U.S. 121, 132 (1985) (citing H.R. Rep. No. 92-911, at 76 (1972)). The scientific principles and methods described in this brief are routinely used to empirically track contaminants and assess water quality.

Courts regularly rely on physical measurements, chemical tracer methods, and groundwater modeling in Clean Water Act cases. *See*, *e.g.*, *Assateague*

Coastkeeper v. Alan & Kristin Hudson Farm, 727 F. Supp. 2d 433, 439 (D. Md. 2010) (relying on piezometers to show that concentrated animal feeding operation was source of pollution); *Cmty. Ass'n for the Restoration of the Env't v. Nelson Faria Dairy, Inc.*, No. CV-04-3060-LRS, 2011 WL 6934707, at *9–10 (E.D. Wash. Dec. 30, 2011) (relying on groundwater monitoring wells to show that manure management practices were source of pollution); *United States v. Donovan*, 661 F.3d 174, 186–88 (3d Cir. 2011) (upholding grant of summary judgment where scientific evidence, including dye tracer studies showing hydrological connection, established Clean Water Act violations); *United States v. Acquest Transit LLC*, No. 09-CV-00055S(F), 2018 WL 3861612, at *17–19 (W.D.N.Y. Aug. 14, 2018) (denying motion to preclude dye-tracer study); *Greater Yellowstone Coal. v. Larson*, 641 F. Supp. 2d 1120, 1139 (D. Idaho 2009) (holding that no Clean Water Act section 401 certification is required when "modeling predicted that it would take between 60 and 420 years for peak concentrations of selenium to arrive at the surface waters" and the concentrations would not exceed acceptable limits). Indeed, this Court has deferred to agency judgments when agencies base their decisions on sound science. *See*, *e.g.*, *Baltimore Gas & Elec. Co. v. Nat. Res. Def. Council, Inc.*, 462 U.S. 87, 103 (1983).[9]

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[9] Rules, however, that ignore science run counter to the objectives of the Clean Water Act and should not be given deference. In 2016, the EPA submitted an *amicus* brief to the Ninth Circuit, siding with the environmental groups in the instant action, acknowledging that the Lahaina Study had determined that a direct hydrological connection existed between the Lahaina Wells

B. Congress's Inclusion of the Terms "Well" and "Discrete Fissure" in the Definition of Point Source Demonstrates Its Intent that the Clean Water Act Regulates Discharges of Pollutants to Groundwater

The fact that Congress included the terms "well" and "discrete fissure" in the definition of point source cannot be ignored. A cardinal rule of statutory interpretation is that it is a court's "duty to give effect, if possible, to every clause and word of a statute." *Duncan v. Walker*, 533 U.S. 167, 174 (2001) (citations and internal quotation marks omitted). Courts "are thus 'reluctan[t] to treat statutory terms as surplusage' in any setting." *Id.* (alteration in original) (quoting *Babbitt v. Sweet Home Chapter of Communities for a Great Or.*, 515 U.S. 687, 698 (1995)); *see also United States v. Jicarilla Apache Nation*, 564 U.S. 162, 185 (2011). The Clean Water Act defines a "point source" as

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and the ocean, and consequently arguing the wells should be regulated under the Clean Water Act. Br. United States as Amicus Curiae in Supp. of Pls.-Appellees 27–32, May 31, 2016, No. 15-17447. The EPA's brief acknowledged and was supported by sound science. In a 180-degree reversal, the EPA issued its April 2019 Interpretive Statement that categorically excludes all discharges to groundwater from the NPDES permit program. *See* U.S. Envtl. Prot. Agency, Interpretive Statement on Application of the Clean Water Act National Pollutant Discharge Elimination System Program to Releases of Pollutants from a Point Source to Groundwater, 84 Fed. Reg. 16,810, 16,810 (Apr. 23, 2019). This statement is bereft of any scientific analysis, referring only to a nearly three-decades-old EPA publication, U.S. Envtl. Prot. Agency, *Citizen's Guide to Ground-Water Protection* (1990). Accordingly, the statement should be afforded no deference. *Cf.* Br. Resp'ts 42, July 12, 2019 (explaining why the Interpretive Statement should not receive *Chevron* deference).

> any discernible, confined and discrete conveyance, including but not limited to any pipe, ditch, channel, tunnel, conduit, *well, discrete fissure*, container, rolling stock, concentrated animal feeding operation, or vessel or other floating craft, from which pollutants are or may be discharged.

33 U.S.C. § 1362(14) (emphasis added). A "well" in this context includes injection wells, such as those at issue in this case, which are expressly used to dispose of waste. Geologists define deep-well injection or disposal as "[d]isposal of liquid waste by injection into wells, usually constructed especially for the purpose, that penetrate deep, porous and permeable formations that are confined vertically by relatively impermeable beds." Klaus K.E. Neuendorf et al., *Glossary of Geology* 167 (5th ed. 2005). A "fissure" is a geologic term meaning a "surface of fracture or a crack in a rock along which there is a distinct separation." *Id.* at 239. As a scientific matter, indeed as a matter of common sense, pollutants from these types of point sources can only discharge into groundwater. As the Arizona Geological Survey notes, "fissures are a direct path to the groundwater table, so pollutants and contaminants could potentially flush down the fissure into a groundwater aquifer." Univ. of Ariz., Ariz. Geological Survey, *Earth Fissures—Natural Hazards in Arizona Viewer*, http://azgs.arizona.edu/earth-fissures-ground-subsidence/earth-fissures-natural-hazards-arizona-viewer (last visited July 8, 2019).

Many of the briefs in the instant case supporting petitioner and opposing Clean Water Act regulation do not even touch on the fact that wells and discrete fissures are explicitly listed as point sources. Petitioner's means-of-delivery test conveniently ignores the inclusion of "well" and "discrete fissure" in the definition of point source. There is simply no logical explanation offered for why Congress included terms like "well" and "discrete fissure" if it did not intend to regulate discharge from those point sources that make their way to navigable surface waters through groundwater.[10]

Furthermore, the legislative history of the Safe Drinking Water Act ("SDWA"), 42 U.S.C. § 300f et seq., strongly indicates that Congress understood that certain discharges of pollutants to groundwater were already regulated under the Clean Water Act. A report from the House of Representatives explained that a primary reason for enacting the SDWA was because "it appears that the Federal Water Pollution Control Act [later, Clean Water Act] may not authorize any regulation of deep well injection of wastes *which is not* carried out in conjunction with a discharge into navigable

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[10] While much is made of Congress's rejection of the so-called Aspin Amendment, which called for regulating *all* groundwater (*see*, *e.g.*, Br. United States as Amicus Curiae Supporting Pet'r 27–28, May 16, 2019; Br. Amicus Curiae for Agricultural Business Organizations Supporting Pet'r 19, May 15, 2019), these arguments fail to take into account Aspin's full speech, which makes clear that, at a bare minimum, all injection wells were meant to be fully regulated under the Clean Water Act, with a limited exception for wells used by the oil industry. 1 Cong. Research Serv., *A Legislative History of the Water Pollution Control Act Amendments of 1972*, at 589–90 (1973).

waters." H.R. Rep. No. 93-1185, at 4 (1974) (emphasis added) (citing U.S. Envtl. Prot. Agency, Op. of Acting Deputy Gen. Counsel No. 590 (Dec. 13, 1973)). The clear inference taken from this report is that at the time the SDWA was enacted, Congress understood the Clean Water Act to cover groundwater that flows into navigable waters.

C. The Science Behind the Hydrological Connectivity of Groundwater and Surface Waters Supports the Ninth Circuit's Fairly Traceable Test, Whereas the Petitioner's Means-of-Delivery Test Is Not Workable and Is Not Supported by Science

The approach taken by the Ninth Circuit—one that considers whether the pollutants in a navigable water are fairly traceable from a point source—is consistent with the science discussed in this brief. This approach recognizes the intrinsic connections between surface waters and groundwater, and it recognizes that scientists have developed robust methods to measure groundwater flow and track contaminants. In some cases, like the one currently before this Court, because of the hydrological connection, a discharge of a pollutant to groundwater is the functional equivalent of a discharge into the navigable water.

In contrast, the petitioner's means-of-delivery test blithely disregards hydrogeologic reality. It ignores all surface water and groundwater connections, as well as the scientific methods used to track pollutants. Such a simplistic interpretation of the Clean Water Act is inconsistent with Congress's intent (as evinced by the use of the terms "well" and "discrete fissure" in the definition of point source) and the overall purpose of the Act.

Several briefs in the instant case erroneously suggest that the fairly traceable test offers no logical stopping point. There are, however, at least three such limiting principles. First, the test itself articulates a limiting principle. The scientific methods used to measure groundwater flow and track pollutants—physical measurements, chemical tracers, and groundwater modeling—may not be able to "fairly trace" a surface water pollutant back to a particular point source due to time, data, or other constraints. *See supra* note 5. Second, the scientific methods may show that the particular point source is not or is not projected to be the source of surface water contaminants. *See Greater Yellowstone Coal.*, 641 F. Supp. 2d at 1139. Third, the principle of proximate cause may serve as a limiting principle. *Babbitt*, 515 U.S. at 709 (O'Connor, J., concurring) (noting that Endangered Species Act regulation "is limited by ordinary principles of proximate causation, which introduce notions of foreseeability"). Accordingly, even if a scientific method does establish that it is more likely than not that a particular point source is the cause in fact of the pollution, a court may decide that the connection is too remote in time or distance to warrant Clean Water Act regulation. In the instant case, however, the scientific methods used conclusively established that the Lahaina

Wells are the source of pollution in the nearby Pacific coastal waters.

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CONCLUSION

The Clean Water Act's mandate can only be met by considering science, which can be used to assess the extent to which point sources are connected to surface waters through groundwater. The Ninth Circuit's fairly traceable test reflects the scientific reality of surface water-groundwater connections. Accordingly, *amici curiae* respectfully request that this Court affirm the Ninth Circuit's decision.

Respectfully submitted,

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