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Evaluating Groundwater Conveyance of Point Source Pollution to a Navigable Water as Functionally Equivalent to Direct Discharge

Introduction

In 2020, the Supreme Court of the United States (SCOTUS) issued its opinion in County of Maui v. Hawaii Wildlife Fund (No. 18-260) addressing functionally equivalent discharges through groundwater to jurisdictional waters. The case examined whether the Clean Water Act (CWA) requires a National Pollutant Discharge Elimination System (NPDES) permit when pollutants are conveyed from a point source to waters of the United States (WOTUS) by groundwater. NPDES permits are required by the CWA for facilities such as wastewater treatment plants that discharge directly into waterways. The SCOTUS ruling concluded that the CWA NPDES permitting requirements apply when conveyance by groundwater provides "the functional equivalent of a direct discharge" (FEDD) of a point source into jurisdictional waters under the Clean Water Act.

Purpose and Scope

This paper describes key scientific and policy processes in developing approaches for assessing functional equivalency by state and local agencies, potential dischargers, and technical evaluators of groundwater pollutant transport. A group of National Ground Water Association (NGWA) volunteers experienced in groundwater/surface-water evaluation, impacts, and policy prepared the paper. The group sought input from the U.S. Environmental Protection Agency (EPA), state organizations, state and local agencies, the regulated industry, and other interested parties.

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This paper is not a prescriptive or technical "how to" document. Its purpose is to provide a perspective on general approaches that might be taken to evaluate the possibility of conveyance of pollution release via groundwater being the functional equivalent of the direct conveyance of a point source discharge to jurisdictional waters. In developing this perspective, the paper outlines some of the basic considerations and industry standard techniques that could be used to address this complex issue. The science of groundwater and its interactions with surface water is well established, but the failWure to collect sufficient data using best practices and the limitations presented by data sparsity commonly results in many challenges in quantitatively predicting groundwater/surface-water interactions, particularly with respect to water quality, the paramount statutory and regulatory factor in this matter. The degree of certainty and confidence in predicting these interactions relies upon using best practices and multiple lines of evidence at the right resolution.

Given the many ways that groundwater and the subsurface environment can serve as a conveyance from point source discharges to surface water, and the lack of experience in applying the FEDD concept, states and other regulators may initially use a variety of different methods to develop regulations and guidelines. Case law that further elaborates on the FEDD construct will likely increase in the courts as litigation continues to be a means to address disputes over functionally equivalent discharges to jurisdictional waters. In some instances, existing programs and regulations of discharges to groundwater may already address these issues.

Overview of the Supreme Court Decision

The case examined by SCOTUS involves the operation of a wastewater reclamation facility on the island of Maui, Hawaii. The facility collects sewage from the surrounding area, partially treats it, and disposes the treated water through four injection wells at depths of 180 to 255 feet below ground level at a combined rate of about four million gallons per day. The permit for the injected wastewater is required under the Underground Injection Control Program of the Safe Drinking Water Act (SDWA). Investigations discovered that the injected wastewater travels a half mile or so through groundwater in porous basalt to the ocean, which is considered jurisdictional water.

In the Maui case, SCOTUS ruled that an NPDES permit is required not only when there is a direct discharge of a pollutant from a point source into a jurisdictional water, but also when the manner in which the discharge reaches the jurisdictional water (in this case through groundwater) is the functional equivalent of it being directly discharged from the point source into the jurisdictional water. SCOTUS further articulated the importance of time and distance and provided some endpoints to consider, stating: "Where a pipe ends a few feet from navigable waters and the pipe emits pollutants that travel those few feet through groundwater (or over the beach), the permitting requirement clearly applies. If the pipe ends 50 miles from navigable waters and the pipe emits pollutants that travel with groundwater, mix with much other material, and end up in navigable waters only many years later, the permitting requirements likely do not apply." [SCOTUS No. 18-260] SCOTUS further opines that functional equivalency also depends on whether pollutants that arrive at jurisdictional waters after traveling through groundwater are compositionally similar to (or different from) that which would occur by direct point-source discharge.

In its ruling, SCOTUS recognized that the courts could provide guidance on the matter through individual cases (some already in process) and resultant case law. The Maui ruling further recognized that the EPA also could provide guidance in the matter by granting individual permits, the promulgation of general permits, or the development of rules.

The majority Supreme Court opinion listed seven factors that may be considered when determining if a discharge is a functional equivalent of direct discharge, stating that the most important are (1) time and (2) distance "in most cases, but not necessarily every case." Additional factors that might be considered include: (3) the nature of the material through which the pollutant travels, (4) the extent to which the pollutant is diluted or chemically changed as it travels, (5) the amount of pollutant entering the jurisdictional waters relative to the amount of the pollutant that leaves the point source, (6) the manner by or area in which the pollutant enters the jurisdictional waters, and (7) the degree to which the pollution (at the discharge point) has maintained its specific identity.

SCOTUS did not rule out other factors and recognized that situations may occur that are easily recognizable as either a functional equivalent of direct discharge or not. The less obvious cases in the middle ground may be difficult to resolve with these stated factors.

Of additional importance to note is that the Maui case provides limited clarity on each of the seven factors, and how weighting of these factors may be appropriately applied. For example, the consultants on all sides of the Maui case agreed that *100 percent of the pollutants released* eventually reach the ocean, a navigable water of the U.S. The court recognized that less than two percent of the total discharge was detected at monitoring points on the ocean floor, within a few miles of the ocean-bed discharge zone, but that this is still a large amount of a pollutant to be released to the ocean, emphasizing in this case the amount of pollutant entering navigable waters. The court also highlighted that the pollutant maintained its specific identity even with less nitrogen when it reached the ocean. Yet, to the contrary, the court also found that the wastewater mixed with other waters, flowed through rocks, and possibly became diluted, but then acknowledged that "the precise manner by which all the wastewater entered the ocean was unclear," and that this "may not add much to the other factors in the circumstances of this case," thus giving no additional weight to this factor in the analysis. Balancing the seven Maui factors "as well as the additional volume factor that the court added," the court granted Hawaii Wildlife Fund's motion for summary judgment on their CWA claim that an NPDES permitting requirement applies (SCOTUS 2019).

Overview of Post SCOTUS Maui Case: Black Warrior Riverkeeper v. Drummond Company

Black Warrior Riverkeeper (BWR) sued Drummond Company under the CWA for ongoing and continuous discharges of acid mine drainage (AMD) from an abandoned underground mine and coal processing waste disposal area in U.S. District Court, Alabama, Southern Division. The case was settled after the SCOTUS Maui case and included addressing the relevant FEDD factors. The evidence presented demonstrates that AMD discharges continuously to tributaries of the Locust Fork via surface water and interconnected groundwater. Time and distance were key factors in deciding the case, with plaintiffs presenting evidence that groundwater carrying AMD traveled a short distance into the Locust Fork through and under a dam: Seeps cover a distance of 10 to 30 feet, while bed seepage travels 100 to 300 feet. BWR also presented evidence that groundwater discharges of pollutants to the jurisdictional surface water satisfy the remaining five factors relevant to the functional equivalent test under Maui, including that the pollutant maintains its AMD identity, and that 100 percent of the polluted groundwater from the site enters the Locust Fork. Drummond argued unsuccessfully that the groundwater discharges have no more than a de minimis impact on the Locust Fork, without citing legal authority supporting this position, and acknowledging that the Maui case failed to address this issue. Finally, Drummond asserted that the groundwater system is small or not robust, suggesting that the fifth factor, the "amount of pollutant entering the navigable water relative to the amount of pollutant leaving the point source," weakened but did not sway the decision, as the other six factors were considered indisputable.[1]

Overview of the National Pollutant Discharge Elimination System

The CWA regulations for the NPDES program apply to pollutant discharges to jurisdictional waters of the United States, including streams, lakes, wetlands, and coastal waters, but do not include groundwater in the definition of federal jurisdictional waters.[2] A functional equivalence of a direct discharge to jurisdictional waters by way of groundwater should address the technical means by which pollutants may reach jurisdictional waters through groundwater conveyance. The CWA prohibits a direct discharge of

[1] Black Warrior River-Keeper, Inc. v. Drummond Co., Civil Action 2:16-CV-01443-AKK (N.D. Ala. Jan. 12, 2022)

[2] 40 CFR § 120.2 Definitions (1) Jurisdictional waters and (2) Non-jurisdictional waters

"pollutants" through a "point source" into a "water of the United States" unless it is conducted under a NPDES permit. The permit contains limits on what can be discharged, monitoring and reporting requirements, and other provisions to ensure that the discharge does not degrade water quality so that designated use standards (such as fishable, swimmable, or high-quality aquatic habitat) are not met in the jurisdictional water (USEPA 2010).

An application for an NPDES permit requires providing information about the discharge, pollutants, analytical methods used, and test results of pollutant concentrations in waste streams, and other pertinent information (USEPA 2019a, b). The term "point source" is defined as any discernible, confined, and discrete conveyance, such as a pipe, ditch, channel, tunnel, conduit, well, discrete fissure, or container from which pollutants are or may be discharged. It does not include discharges of agricultural stormwater or return flows from irrigated agriculture (USEPA 2021).

Connections to the Underground Injection Control Program

In addition to the Clean Water Act, the Underground Injection Control (UIC) program established under the authority and standards of the Safe Drinking Water Act (SDWA) of 1974 is relevant to FEDD determinations. The UIC program focuses on the effective isolation of fluids injected into the subsurface through a wellbore. The UIC program requirements are designed to prevent contamination of Underground Sources of Drinking Water (USDWs). A USDW is defined as an "aquifer or its portion which supplies any public water system or contains a sufficient quantity of groundwater to supply a public water system, and either currently supplies a public water system, or contains less than 10,000 milligrams per liter of total dissolved solids and is not an exempted aquifer." The USEPA has given primary enforcement authority, called primacy, over underground injection wells to those state agencies that have demonstrated an ability to implement a UIC program meeting SDWA's requirements. While the focus of the UIC program is on the direct effects on groundwater, injection wells that might be the focus of a FEDD analysis (including the Maui case) would be subject to evaluation under the UIC program.

Functional Equivalence Decision Framework

In general, calculations and modeling programs can be used to evaluate the concentration or mass of pollutants reaching an aquifer and transported by groundwater to the discharge point in the channel or bed of jurisdictional waters. A conceptual framework for evaluation and decision-making to guide the process of determining whether the releases from groundwater are functionally equivalent to a direct discharge to jurisdictional waters is discussed below. A flowchart (Figure 1) and an associated cross-section of an aquifer-jurisdictional water system (Figure 2) are presented to describe a generalized perspective and decision-making process. Other conditions and factors not included in the figures may apply to particular cases.

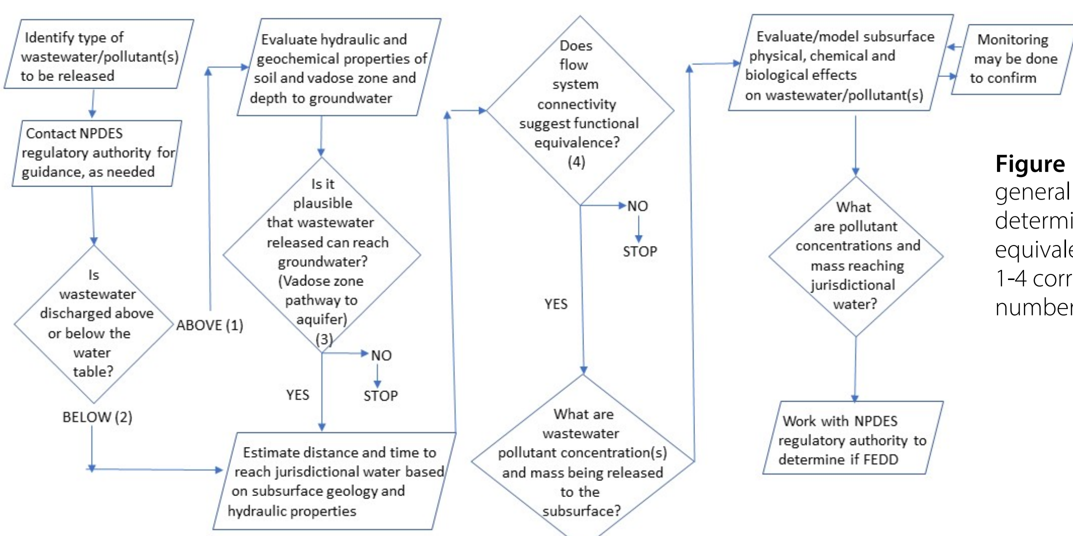

Figure 1. Flowchart of general approach to determining functional equivalence. Numbers 1-4 correspond to numbers in Figure 2.

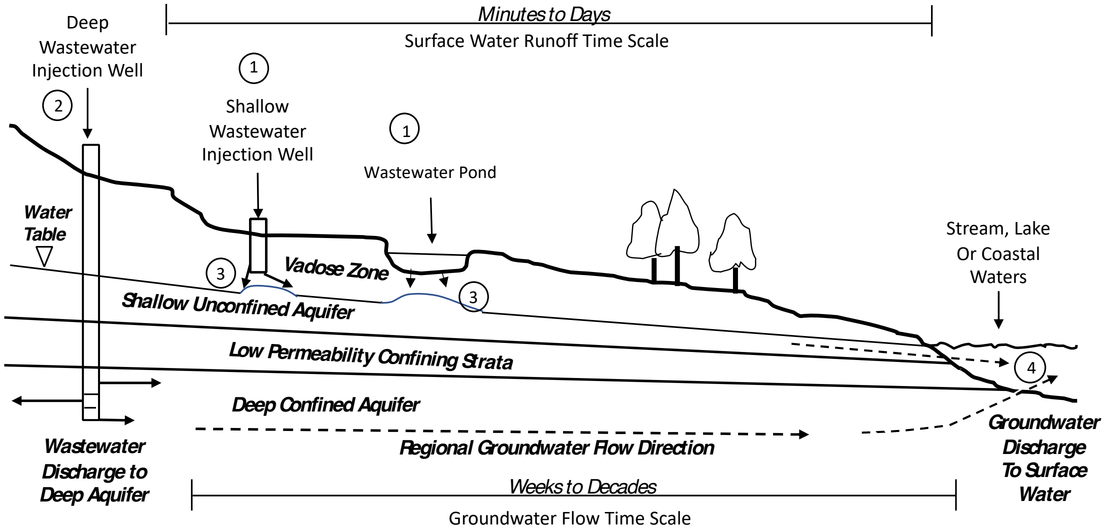

Figure 2. Hypothetical wastewater release to subsurface depicting functional equivalent discharge to surface water. Other variations of wastewater release may apply.

The flowchart indicates a very general approach that might be taken for a FEDD analysis. It starts with identification of the pollutant(s) to be released and notes that it may be advisable to contact the NPDES regulatory authority for guidance at this point. A series of questions and evaluations follow. First, is the pollutant released above the water table to the vadose zone (Figure 2, points "1")? If it is released above the water table, then an evaluation of hydraulic and geochemical properties of the soil and vadose zone and depth to groundwater should be conducted. If it is plausible that the wastewater can reach groundwater (Figure 2, points "3"), an estimate of distance and time to reach jurisdictional water based on subsurface geology and hydraulic properties, including the vadose zone, is made. If the pollutant is released below the water table directly to either a shallow or deep aquifer zone (Figure 2, point "2"), then estimation of distance and time to reach surface water should be made based on subsurface geology and hydraulic properties, but reactions and time of travel in the vadose zone do not need to be considered. (Note that pollutant releases to the soil/vadose zone near jurisdictional waters might travel to surface water without passing below the water table through the groundwater.)

If the flow system analysis indicates possible discharge of the pollutant to a jurisdictional water (Figure 2, point "4"), contaminant transport in the subsurface needs to be considered. This requires evaluation (and commonly modeling) of subsurface physical, chemical, and biological effects on pollutant concentrations and mass reaching jurisdictional water. Monitoring through monitoring wells in the watershed or piezometers in the jurisdictional water bed may be done to verify the analysis. The final step is working with the NPDES regulatory authority to determine if FEDD applies to the case.

As with other assessments of flow and transport, a combination of field investigations, data collection and analysis, and modeling is relied upon to enhance understanding. Groundwater scientists and engineers routinely select from a wide array of models to calculate the flow and transport of water and associated substances in the subsurface. Which model to select and what specific inputs are needed are decisions made on a site-specific and project-specific basis. There is no step-by-step guidance on how to do a FEDD analysis. In the following sections, we briefly review approaches for flow path analysis and pollutant load determination as two major components of a FEDD analysis. This is followed by a discussion of the role of models. Sites will vary from those that are relatively data poor to those with substantial field data, existing conceptual site models, and flow and/or transport models.

Flow Path Analysis

Analysis of the groundwater flow system is a logical starting point for evaluating the potential for contaminants released from a point source to reach jurisdictional waters. It is often prudent to undertake a flow path analysis using more than one method and at multiple scales. This analysis may rely on existing data. The analysis can also guide whether and where more data are needed.

Groundwater flow systems are largely a function of climate, landscape, and geology (Winter et al. 1998; Neff et al. 2020). For example, discharge from groundwater to surface water often takes place at a change in slope from an upland area to a lower area. In addition, the groundwater table is commonly a subdued reflection of the land surface topography. Thus, topography can provide initial insights on the potential flow paths of contaminants. Care is needed in making such interpretations, particularly for deeper groundwater or complex geology. Groundwater flow systems are three dimensional and geology often exerts greater influence than topography on flow paths. It is also important to recognize that surface-water and groundwater flow divides may differ.

Geologic setting is centrally important when evaluating flow and transport of pollutants in either surface or subsurface waters. The range of geologic materials and settings is vast, including unconsolidated/consolidated media, porous/fractured rocks, unsaturated/saturated conditions, and arid/wet climates. Interactions of groundwater and surface water also differ among physiographic landscapes, including mountainous, riverine, coastal, glacial, volcanic, and karst terrains.

At locations with highly developed preferential groundwater flow paths, such as karst and volcanic conduits or fractures in geologic media, the determination of flow at points of groundwater discharge to surface water (i.e., spring outflow) is necessary when characterizing the groundwater flow regime and the nature in which pollutants discharge to jurisdictional water. Volume average approximations of the flow regime may be used when actual preferential flow paths (such as subsurface karst channels) are not known. Rapid flow along preferential flow paths may justify recognizing discharge as the functional equivalent of direct discharge over greater distances.

When available, measurements of water levels in well networks can be used to determine groundwater gradients, relative to adjacent surface water, which in turn can indicate the direction and rate of flow between the aquifer and jurisdictional water. Other field methods to analyze connectivity at this scale include dye-tracer tests (in karst terrain), age-dating and other chemical tracers, and remote sensing, such as geophysics and aerial infrared photography/imagery. The latter can detect groundwater discharging to surface water based on differences in temperature.

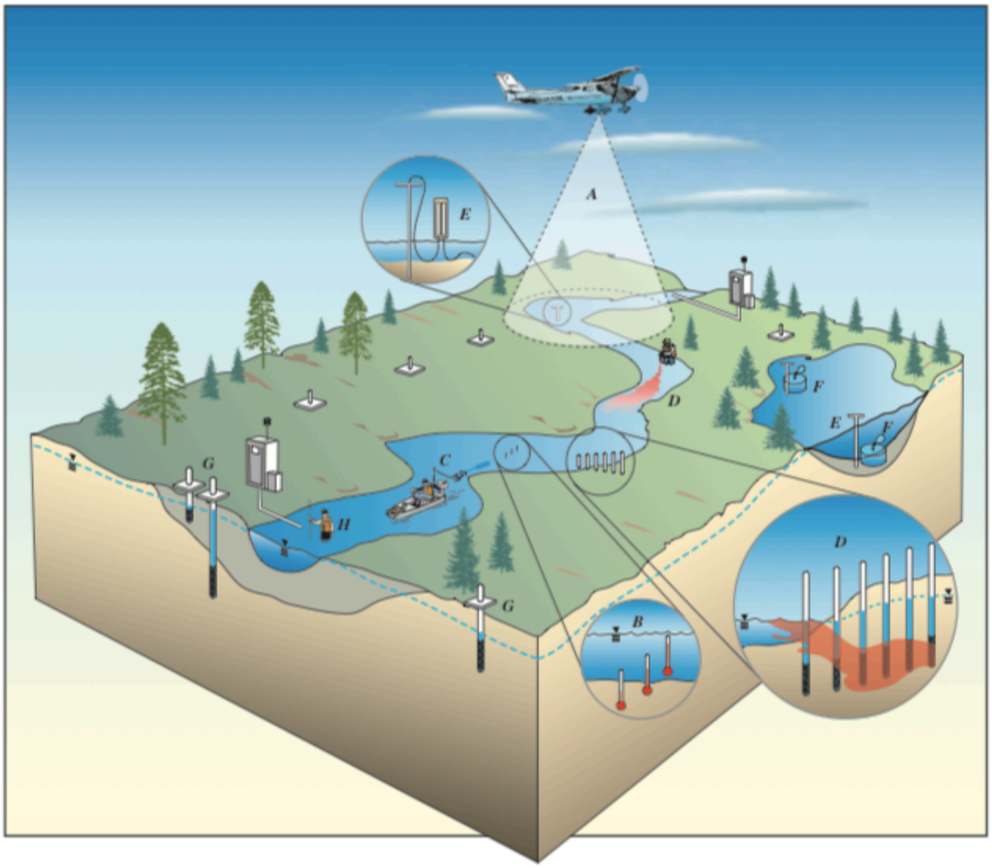

Figure 3. Summary of techniques that have been used for the measurement or estimation of water fluxes between groundwater and surface water. Techniques illustrated include: (A) aerial infrared photography and imagery, (B) thermal profiling, (C) the use of temperature and specific-conductance probes, (D) dyes and tracers, (E) mini-piezometers, (F) seepage meters, (G) well networks, and (H) streamflow measurements. (Rosenberry and LaBaugh 2008)

Smaller-scale studies to identify and delineate potential areas of flow of groundwater to surface water often focus on the jurisdictional water (see Figure 3). Measurements of streamflow at two or more locations along a stream segment are commonly used to estimate streamflow gains and losses of groundwater influent to or effluent from the stream. Local interaction of groundwater with surface water can be measured by placing devices such as thermistors, mini-piezometers, and seepage meters in the sediment to monitor temperature gradients, hydraulic gradients, or quantity of flow. Measurement of sediment temperature or specific conductance along transects within a surface-water body or use of dyes or other tracers to indicate the direction and rate of water movement may be useful.

A large array of geophysical techniques can be applied to indirectly determine the nature of the subsurface. Commonly applied surface geophysical methods include electrical resistivity, seismic methods, ground-penetrating radar, and ground-based and airborne time-domain electromagnetic methods (Parker et al. 2022). Examples of characteristics determined by geophysical methods include the thickness of unconsolidated surficial materials, depth to the water table, location of subsurface faults, and location, thickness, and extent of subsurface features such as clay layers or gravel deposits. Correlation of geophysical data with well logs or test-boring data is typically done to enhance the reliability of the geophysical interpretations.

Pollutant Load Determination

Release of pollutants from a point source to groundwater can occur by downward percolation from a land-surface or shallow subsurface source or by direct injection through wells. Different pollutants react differently with soil, sediments, and other geologic materials and commonly travel at different velocities. A wide array of physical, chemical, and biological reactions affects the transport of pollutants in the subsurface, including dilution, dispersion, sorption, ion exchange, oxidation-reduction (redox) reactions, and biodegradation.

Pollutant transport differs among the soil/vadose zone, the groundwater flow system, and the near-surface release location. When water infiltrates from the land surface, microorganisms in the soil have a particularly significant effect on the evolution of the water chemistry. Transport of dissolved pollutants is dependent on several factors, such as soil pH, soil vapor concentrations (oxygen, carbon dioxide, etc.), redox conditions, biotic action, and the amount of water percolating through the soil. Pollutants that are highly soluble may move readily from surface soils to saturated materials below the water table. Those contaminants that are not highly soluble may have considerably longer residence times in the soil zone.

Once in the saturated zone, pollutants are subject to dispersion (mechanical mixing with groundwater) and diffusion (transport and dilution by concentration gradients). These factors, and others such as sorption and precipitation on the aquifer matrix material, may increase or decrease the rate of pollutant transport.

A zone of enhanced biogeochemical activity surrounding and extending beyond the channel or bed of a surface-water body commonly develops as shallow groundwater mixes with surface water (see Figure 4). This zone, known as the hyporheic zone, can exert major controls on the pollutant concentrations and mass that enter jurisdictional water. Many solutes are highly reactive as water moves into and out of the streambed and carries dissolved gas and solutes, microorganisms, and particles with it. Depending on the underlying geology and topography, the hyporheic zone can range from several centimeters to tens of meters in thickness.

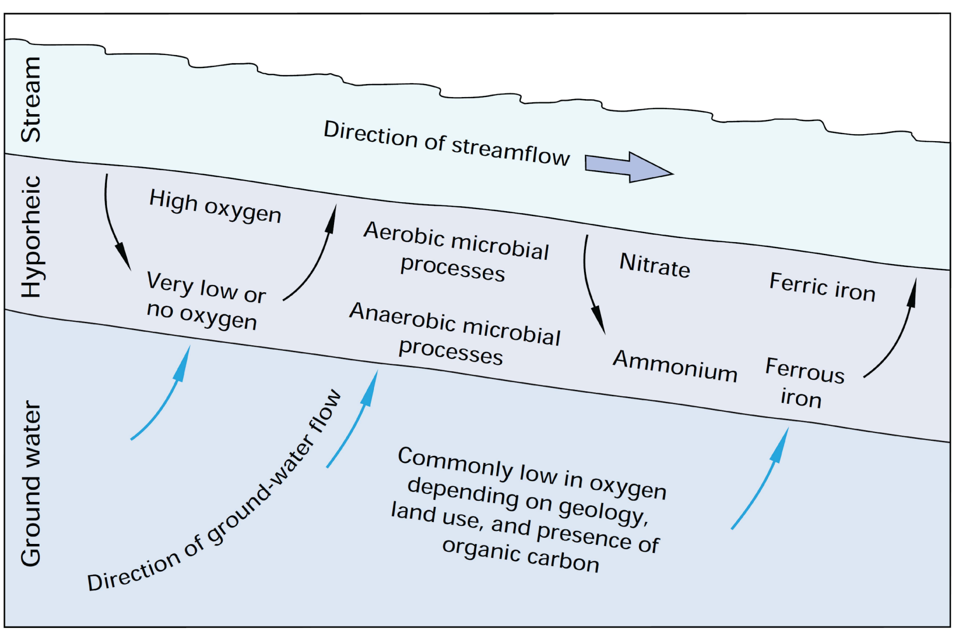

Figure 4. Microbial activity and chemical transformations commonly are enhanced in the hyporheic zone compared to those that take place in groundwater and surface water. (Winter et al. 1998)

The Role of Models

Groundwater scientists and engineers have developed a substantial set of modeling tools, many of which would benefit FEDD analyses. For FEDD analyses, four general classes of questions may benefit from the use of models. The four classes of questions and the types of models that address them are:

1) What are the directions and rates of flow and associated transport from the land surface to underlying groundwater? Models of flow and transport from the land surface to underlying groundwater are typically called vadose zone models. They range from simple equations to full numerical simulation codes.

2) What are the directions and rates of groundwater flow and associated transport between a release location and a surface-water body? As with vadose zone models, groundwater flow and transport models range from simple equations to fully numerical simulation codes. Many numerical simulation codes can do both the vadose zone and groundwater calculations. Some numerical simulation codes can also do simple surface-water flow and transport calculations.

3) What are the rates and distributions of the emergence of groundwater and associated pollutants and other constituents into surface-water bodies? These models, which focus on the hyporheic zone, also range from simple to fully numerical simulations.

4) Although the SCOTUS ruling does not explicitly consider surface-water processes, analyses after the FEDD determination may consider the question: What are the rates and locations of mixing, dispersion, and reactions within surface-water bodies? Models of surface water include flow and transport and are primarily used to calculate the mixing of water entering a surface-water body and the resulting reductions in concentration. Surface-water body mixing calculations can range from simple mixing cell calculations to full flow and transport simulations.

All of the above types of models have been widely accepted, applied, and improved by scientists and engineers in the private and public sectors for several decades. General approaches that might be used to address the seven FEDD factors identified by the U.S. Supreme Court are described in Table 1.

As a final note, there has been a recent increase in the application of Machine Learning, Deep Learning, Artificial Neural Networks, and other data-driven analysis methods. These techniques find and then employ empirical, rather than physical, mathematical relationships among selected variables. Some analysts have announced that these are the new and better way to model any relationship. For calculation of material flows in subsurface hydrology, this is not the case (Anderson, Woessner, and Hunt 2015, page 6). Subsurface hydrology has acquired and refined a set of physical laws for flow and transport that are very reliable for representing cause and effect relationships as expressed in algebraic equations and statistical calculations. Successful data-driven applications are characterized by relationships without reliable physical laws but a tremendous number of data points. In general, subsurface hydrologic assessments typically have few data points to work with. Data-driven analysis may assist in a FEDD analysis where many data points are available, such as when tens to hundreds of high-resolution satellite images (many small pixels may cover the area of interest) could be searched for high moisture content which may potentially be groundwater discharge to surface water.

Table 1. General approaches that might be used to address the seven FEDD factors identified by the U.S. Supreme Court

FEDD Factor	General Approach
1 - Transit Time	Assess groundwater flow direction and rates along identified flow paths using a conceptual site model (CSM) that may be existing or developed/refined for this work. The CSM is a written and/or illustrative description of the hydrogeologic system that draws on and summarizes the available geologic and hydrologic data, such as surface mapping, drilling observations, geophysical data, etc. The CSM is subject to reasoned and supported refinement over time. A first estimate of travel time for each identified pathway can be made from a simple 1D fate and transport model based on the CSM. Additional estimates of travel time for each identified pathway may employ particle tracking performed with a numerical groundwater model (if available). A range of estimated results can be provided.
2 - Distance Traveled	The approach for FEDD Factor 1 is the same foundation for assessing this FEDD Factor, but also estimates the distance traveled along each identified pathway. Again, simple 1D particle-tracking/fate and transport and/or numerical model-based particle-tracking/fate and transport can be used to estimate the distance traveled along each identified pathway. A range of estimated results can be provided.
3 - The Nature of the Material Through Which the Pollutant Travels	The nature of material along the preferred pathways is available as a primary part of the foundational CSM but may be further refined for this assessment based typically on data such as drilling returns, geophysical logging, and hydraulic testing of the subsurface.
4 - The Extent to Which the Pollutant Is Diluted or Chemically Changed as It Travels	The available geochemical site data, applied to water, pollutants, and other relevant chemicals flowing in the identified pathways from the CSM can be evaluated as to fate using simplified transport and reaction calculations or simulations with a complex numerical reactive transport model (if available). A range of estimated results can be provided.

5 - The Amount of Pollutant Entering the Navigable Waters Relative to the Amount of the Pollutant That Leaves the Point Source	The results of assessing FEDD Factor 4 (and FEDD Factor 6) are input used to estimate the amount of pollutant exiting the identified flow paths (entering navigable waters). This can be compared to the amount entering the identified flow paths to complete assessment of this FEDD Factor. Unique local processes not addressed in the assessments of the identified flow paths, if significant, can be evaluated using simplified transport and reaction calculations or simulations with a complex numerical reactive transport model (if available). A range of estimated results can be provided.
6 - The Manner by or Area in Which the Pollutant Enters the Navigable Waters	This assessment is needed as input to the assessment of FEDD Factor 5. It is the identification and quantification of the key processes controlling exit from the identified flow paths, which in turn are based on the CSM, but also on simplified transport and reaction calculations or simulations with a complex numerical reactive transport model (if available).
7 - The Degree to Which the Pollution (at the Point Where It Enters the Navigable Water) Has Maintained Its Specific Identity	This assessment is another result of the simplified transport and reaction calculations or simulations with a complex numerical reactive transport model (if available). That is, if transformations are predicted to be significant, such as natural degradation to non-pollutants or change to other chemicals, those changes are identified and quantified specifically for this FEDD Factor.

Summary and Conclusions

The SCOTUS Maui case ruled that the NPDES permitting requirements apply to facilities releasing or injecting wastewater to the subsurface when conveyance by groundwater provides "the functional equivalent of a direct discharge" of a point source into jurisdictional waters. The ruling identified seven factors that may be considered when making this determination:

(1) the time it takes for a pollutant to move to jurisdictional waters
(2) the distance it travels
(3) the nature of the material through which the pollutant travels
(4) the extent to which the pollutant is diluted or chemically changed as it travels
(5) the amount of pollutant entering the jurisdictional waters relative to the amount of the pollutant that leaves the point source
(6) the manner by or area in which the pollutant enters the jurisdictional waters
(7) the degree to which the pollution (at that point) has maintained its specific identity.

The court indicated that the two most important factors are time and distance in most cases, but not necessarily in every case. The high court did not rule out that additional factors may apply and acknowledged that situations may occur that are easily recognizable as either a functional equivalent of direct discharge or not.

The SCOTUS ruling in the Maui case provides limited guidance on each of the seven factors, and how weighting of these factors may be appropriately applied. It notes the difference between a pipe that emits pollutants that travel a few feet through groundwater to a jurisdictional water ("permitting requirement clearly applies") and a pipe that ends 50 miles from navigable waters ("permitting requirements likely do not apply"). Direction on how to evaluate cases between these two extremes is not provided by the Maui case but is addressed in the generalized approach presented above.

Given the many ways that groundwater can serve as a conveyance from point source releases or injection to surface water, and the lack of experience in applying the new FEDD concept, states and other regulators may initially use a variety of different methods to develop regulations and guidelines. The courts will likely provide additional guidance through decisions in individual cases.

This paper outlines some of the basic considerations and techniques that could be used to address this complex issue. The science of groundwater and its interactions with surface water is well established, but the failure to collect sufficient data using best practices and the limitations presented by data sparsity commonly result in many challenges in quantitatively predicting groundwater/surface-water interactions, particularly with respect to water quality and implications for discharge permits. Among the factors emphasized here are:

- Groundwater flow systems are three dimensional and geology often exerts greater influence than topography on flow paths of pollutants in the subsurface environment.
- Subsurface pollutant transport varies among the soil/vadose zone, the groundwater flow system, and the near-surface discharge location.
- A range of proven groundwater analytical techniques may be applied to estimate whether the point source pollutant may reach jurisdictional waters via groundwater and in what amount.
- Analysis may range from simple screening and modeling to sophisticated field monitoring, testing, and complex model development and application, depending on the pollutant characteristics and subsurface conditions.

In essence, the tools and underlying scientific understanding are available to address questions of the functional equivalency of a direct discharge under the CWA, but the use of these techniques to address the SCOTUS decision is, as of yet, largely untested.

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