Technical Support Document for the Final “Revised Definition of ‘Waters of the United States’” Rule

U.S. Environmental Protection Agency

and

Department of the Army

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This Technical Support Document addresses in more detail the existing scientific literature and technical information in support of the final rule of the U.S. Environmental Protection Agency (EPA) and U.S. Department of the Army's ("the agencies") which revises the definition of "waters of the United States."[1] The Preamble, the 2015 report *Connectivity of Streams and Wetlands to Downstream Waters: A Review and Synthesis of the Scientific Evidence*, this Technical Support Document, and the rest of the administrative record provide the basis for the definition of "waters of the United States" established in the final rule. Where this Technical Support Document does not reflect the language in the preamble and final rule, the language in the preamble and final rule controls and should be used for purposes of understanding the scope, requirements, and basis of the final rule.

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[1] The *Technical Support Document for the Proposed "Revised Definition of 'Waters of the United States' Rule"* contained a legal background section and an Appendix D, "Traditional Navigable Waters." Those sections have been moved from this Technical Support Document for the final rule to the response to comments documents or to separate documents that have been added to the docket for this rule. This includes section 6 of the agencies' response to comments document and "History of the Effects of Litigation over Recent Definitions of 'Waters of the United States" (formerly contained in the legal background section) and "Waters that Qualify as 'Traditional Navigable Waters' Under Section (a)(1) of the Agencies' Regulations" (formerly contained in Appendix D of the Technical Support Document for the Proposed Rule).

Supplementary Materials

Supplementary Materials are separate

Supplementary Material A: Scientific Papers Selected for Forward-Citation Mapping

Supplementary Material B: Papers Screened Early to Expediate Machine-Learning Model Building

Supplementary Material C: Questions Answered from Each Included Scientific Paper's Abstract

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Abbreviations

2020 NWPR	Navigable Waters Protection Rule
AJD	Approved jurisdictional determination
Army	U.S. Department of the Army
CFR	Code of Federal Regulations
Corps	U.S. Army Corps of Engineers
CWA	Clean Water Act
DEM	Digital elevation model
DOC	Dissolved Organic Carbon
EA	Economic analysis
E.O.	Executive Order
EPA	U.S. Environmental Protection Agency
FEMA	Federal Emergency Management Agency
FR	*Federal Register*
GIS	Geographic information systems
HAWQS	Hydrologic and Water Quality System
HUC	Hydrologic unit code
HUC4	4-digit hydrologic unit code
HUC12	12-digit hydrologic unit code
JD	Jurisdictional determination
LIDAR	Light detection and ranging
NASA	National Aeronautical and Space Administration
NFW	Non-floodplain wetland
NHD	National Hydrography Dataset
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NRCS	Natural Resources Conservation Service
NWI	National Wetlands Inventory
OCN	Optimal climate normals
ORM2	Operation and Maintenance Business Information Link, Regulatory Module
PJD	Preliminary jurisdictional determination

Rapanos	*Rapanos v. United States*, 547 U.S. 715 (2006)
RHA	Rivers and Harbors Act
Riverside Bayview Homes	*United States v. Riverside Bayview Homes Inc.*, 474 U.S. 121 (1985)
RPA	Resource and Programmatic Assessment
RPWWN	Wetlands adjacent to but not directly abutting relatively permanent waters
SAB	Science Advisory Board
Science Report	*Connectivity of Streams and Wetlands to Downstream Waters: A Review and Synthesis of the Scientific Evidence*
SWANCC	*Solid Waste Agency of Northern Cook County v. U.S. Army Corps of Engineers*, 531 U.S. 159 (2001)
SWAT	Soil and Water Assessment Tool
TAS	Treatment in a Manner Similar as a State
TMDL	Total Maximum Daily Load
TNW	Traditional navigable waters
U.S.C.	United States Code
USDA	U.S. Department of Agriculture
USFS	U.S. Department of Agriculture Forest Service
USGS	U.S. Geological Survey
U.S. FWS	U.S. Fish and Wildlife Service
WATERS	Watershed Assessment, Tracking and Environmental Results System
WMO	World Meteorological Organization
WOTUS	Waters of the United States

I. Science Report, More Recent Literature, and Other Scientific Support

EPA's 2015 report *Connectivity of Streams and Wetlands to Downstream Waters: A Review and Synthesis of the Scientific Evidence* (hereafter the Science Report) summarizes and assesses relevant scientific literature that is part of the administrative record for this final rule. In addition, the agencies considered other sources of scientific information and literature, particularly for topics that were not addressed in the Science Report. This includes peer-reviewed literature, federal and state government reports, and other relevant information. The agencies also conducted a literature search for scientific literature that had been published since the Science Report's publication, which is described in more detail in section I.C. Section I.A.i of this document provides the major conclusions of the Science Report. Section III provides additional detail of the scientific literature and the agencies' reasoning in support of the rule. The agencies' interpretation of the Clean Water Act's scope in this final rule is guided by the best available peer-reviewed science, including on the connectivity and effects that streams, wetlands, and open waters have on the chemical, physical, and biological integrity of traditional navigable waters, the territorial seas, or interstate waters.

A. Science Report: Synthesis of Peer-Reviewed Scientific Literature

The Science Report provides much of the technical support for this final rule. The Science Report is based on a review of more than 1,300 peer-reviewed publications. EPA's Office of Research and Development prepared the Science Report, a peer-reviewed synthesis of published peer-reviewed scientific literature discussing the nature of connectivity and effects of tributaries and wetlands on downstream waters. The Science Report was directly considered in the development of this final rule, as was the peer review of the Science Report led by EPA's Science Advisory Board (SAB), and is available at http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=296414. The SAB's comprehensive peer review of the Science Report is discussed in detail in section I.B. The Science Report also underwent an earlier external independent peer review, and the results of both peer reviews are available in the docket for the final rule. Prior to the earlier peer review, the Science Report also underwent a peer consultation.

The Science Report reviews and synthesizes the peer-reviewed scientific literature on the connectivity or isolation of streams and wetlands relative to large water bodies such as rivers, lakes, estuaries, and oceans. The purpose of the review and synthesis is to summarize current scientific understanding about the connectivity and mechanisms by which streams and wetlands, singly or in aggregate, affect the physical, chemical, and biological integrity of downstream waters. Specific types of connections considered in the Science Report include transport of physical materials and chemicals such as water, wood, and sediment, nutrients, pesticides, and mercury; movement of organisms or their seeds or eggs; and hydrologic and biogeochemical interactions occurring in surface and groundwater flows, including hyporheic zones and alluvial aquifers. A hyporheic zone is the area next to and beneath a stream or river in which hyporheic flow (water from a stream or river channel that enters subsurface materials of the stream bed and bank and then returns to the stream or river) occurs. Science Report at A-6. An alluvial aquifer is an aquifer with geologic materials deposited by a stream or river (alluvium) that retains a hydraulic connection with the depositing stream. *Id.* at A-1.

The final Science Report states that connectivity is a foundational concept in hydrology and freshwater ecology. Connectivity is the degree to which components of a system are joined, or connected, by various transport mechanisms and is determined by the characteristics of both the physical landscape and the biota of the specific system. Connectivity for purposes of interpreting the scope of "waters of the United States" under the Clean Water Act serves to demonstrate the "nexus" between upstream water bodies and the downstream traditional navigable water, the territorial seas, or interstate water and the strength of those connections. The scientific literature does not use the term "significant" as it is used in the context of the geographic scope of the Clean Water Act, but it does provide information on the strength of the effects on the chemical, physical, and biological functioning of traditional navigable waters, the territorial seas, and interstate waters from the connections among tributaries, adjacent wetlands, and intrastate waters that do not meet the criteria for jurisdiction under other categories of the rule and those fundamental waters. The scientific literature also does not use the terms traditional navigable waters, the territorial seas, or interstate waters. However, evidence of strong chemical, physical, and biological connections to larger rivers, estuaries, and lakes applies to that subset of rivers, estuaries, and lakes that are traditional navigable waters, the territorial seas, or interstate waters.

The agencies reiterate their previous conclusion that determining the presence of a significant nexus is not a purely scientific inquiry. This section reflects the scientific consensus on the connections and the strength of the effects that upstream tributaries, adjacent wetlands, and intrastate waters that do not meet the criteria for jurisdiction under other categories of the rule can and do have on traditional navigable waters, the territorial seas, or interstate waters. However, a significant nexus determination requires legal, technical, and policy judgment, as well as scientific considerations, for example, to assess the significance of any effects.

The Science Report presents evidence of those connections from various categories of waters, evaluated singly or in combination, which affect downstream waters and the strength of that effect. The objectives of the Science Report are (1) to provide a context for considering the evidence of connections between downstream waters and their tributary waters, and (2) to summarize current understanding about these connections, the factors that influence them, and the mechanisms by which the connections affect the function or condition of downstream waters. The connections and mechanisms discussed in the Science Report include transport of physical materials and chemicals such as water, wood, sediment, nutrients, pesticides, and mercury; functions that adjacent wetlands perform, such as storing and cleansing water; movement of organisms or their seeds and eggs; and hydrologic and biogeochemical interactions occurring in and among surface and groundwater flows, including hyporheic zones[2] and alluvial aquifers.

The Science Report consists of six chapters. Chapter 1 outlines the purpose, scientific context, and approach of the report. Chapter 2 describes the components of a river system and watershed; the types of physical, chemical, and biological connections that link those components; the factors that influence connectivity at various temporal and spatial scales; and methods for quantifying connectivity. Chapter 3

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[2] The hyporheic zone is the subsurface area immediately below the bed of intermittent and ephemeral streams that remains wet even when there is no surface flow. These areas are extremely important to macro-benthic organisms critical to the biochemical integrity of streams.

reviews literature on connectivity in stream networks in terms of physical, chemical, and biological connections and their resulting effects on downstream waters. Chapter 4 reviews literature on the connectivity and effects of nontidal wetlands and certain open waters on downstream waters. Chapter 5 applies concepts and evidence from previous chapters to six case studies from published literature on Carolina and Delmarva bays, oxbow lakes, prairie potholes, prairie streams, southwestern streams, and vernal pools. Chapter 6 summarizes key findings and conclusions, identifies data gaps, and briefly discusses research approaches that could fill those gaps. A glossary of scientific terms used in the report and detailed case studies of selected systems (summarized in Chapter 5) are included in Appendix A and Appendix B of the Report, respectively.

Since its publication in 2015, the scope, findings, and conclusions of the Science Report have at times been misconstrued as inclusive of all waters and all types of interconnections, regardless of their relevance to the Clean Water Act. This is not the case. As explained in the Executive Summary and Introduction of the Report, the scope of the Science Report was clearly restricted to specific types of surface waters, and considered only those connections having clearly documented scientific effects on the integrity of larger downstream waters.

i. Summary of Major Conclusions of the Science Report

Based on the review and synthesis of more than 1,300 publications from the peer-reviewed scientific literature, the evidence supports the Science Report's five major conclusions. Citations have been omitted from the text to improve readability; please refer to the Executive Summary and individual chapters of the Science Report for supporting publications and additional information.

Conclusion 1: Streams

The scientific literature unequivocally demonstrates that streams, individually or cumulatively, exert a strong influence on the integrity of downstream waters. All tributary streams, including perennial, intermittent, and ephemeral streams, are physically, chemically, and biologically connected to downstream rivers via channels and associated alluvial deposits where water and other materials are concentrated, mixed, transformed, and transported. Streams are the dominant source of water in most rivers, and the majority of tributaries are perennial, intermittent, or ephemeral headwater streams. Headwater streams also convey water into local storage compartments such as ponds, shallow aquifers, or stream banks, and into regional and alluvial aquifers; these local storage compartments are important sources of water for maintaining baseflow in rivers. In addition to water, streams transport sediment, wood, organic matter, nutrients, chemical contaminants, and many of the organisms found in rivers. The literature provides robust evidence that streams are biologically connected to downstream waters by the dispersal and migration of aquatic and semiaquatic organisms, including fish, amphibians, plants, microorganisms, and invertebrates, that use both upstream and downstream habitats during one or more stages of their life cycles, or provide food resources to downstream communities. In addition to material transport and biological connectivity, ephemeral, intermittent, and perennial flows influence fundamental biogeochemical processes by connecting channels and shallow ground water with other landscape elements. Physical, chemical, and biological connections between streams and downstream waters interact via integrative processes such as nutrient spiraling, in which stream communities assimilate and chemically transform large quantities of nitrogen and other nutrients that otherwise would be transported directly downstream, increasing nutrient loads and associated impairments due to excess nutrients in downstream waters.

Conclusion 2: Riparian/Floodplain Wetlands and Open Waters

The literature clearly shows that wetlands and open waters in riparian areas and floodplains are physically, chemically, and biologically integrated with rivers via functions that improve downstream water quality, including the temporary storage and deposition of channel-forming sediment and woody debris, temporary storage of local ground water that supports baseflow in rivers, and transformation and transport of stored organic matter. Riparian/floodplain wetlands and open waters improve water quality through the assimilation, transformation, or sequestration of pollutants, including excess nutrients and chemical contaminants such as pesticides and metals, that can degrade downstream water integrity. In addition to providing effective buffers to protect downstream waters from point source and nonpoint source pollution, these systems form integral components of river food webs, providing nursery habitat for breeding fish and amphibians, colonization opportunities for stream invertebrates, and maturation habitat for stream insects. Lateral expansion and contraction of the river in its floodplain result in an exchange of organic matter and organisms, including fish populations that are adapted to use floodplain habitats for feeding and spawning during high water, that are critical to river ecosystem function. Riparian/floodplain wetlands and open waters also affect the integrity of downstream waters by subsequently releasing (desynchronizing) floodwaters and retaining large volumes of stormwater, sediment, and contaminants in runoff that could otherwise negatively affect the condition or function of downstream waters.

Conclusion 3: Non-Floodplain Wetlands and Open Waters

Wetlands and open waters in non-floodplain landscape settings (hereafter called “non-floodplain wetlands”) provide numerous functions that benefit downstream water integrity. These functions include storage of floodwater; recharge of ground water that sustains river baseflow; retention and transformation of nutrients, metals, and pesticides; export of organisms or reproductive propagules (*e.g.*, seeds, eggs, spores) to downstream waters; and habitats needed for stream species. This diverse group of wetlands (*e.g*., many prairie potholes, vernal pools, playa lakes) can be connected to downstream waters through surface-water, shallow subsurface-water, and groundwater flows and through biological and chemical connections.

In general, connectivity of non-floodplain wetlands occurs along a gradient (Conclusion 4), and can be described in terms of the frequency, duration, magnitude, timing, and rate of change of water, material, and biotic fluxes to downstream waters. These descriptors are influenced by climate, geology, and terrain, which interact with factors such as the magnitudes of the various functions within wetlands (*e.g.*, amount of water storage or carbon export) and their proximity to downstream waters to determine where wetlands occur along the connectivity gradient. At one end of this gradient, the functions of non-floodplain wetlands clearly affect the condition of downstream waters if a visible (*e.g.*, channelized) surface-water or a regular shallow subsurface-water connection to the river network is present. For non-floodplain wetlands lacking a channelized surface or regular shallow subsurface connection (*i.e.*, those at intermediate points along the gradient of connectivity), generalizations about their specific effects on downstream waters from the available literature are difficult because information on both function and connectivity is needed. Although there is ample evidence that non-floodplain wetlands provide hydrologic, chemical, and biological functions that affect material fluxes (as of publication of the Science Report in 2015), few scientific studies explicitly addressing connections between non-floodplain wetlands and river networks have been published in the peer-reviewed literature. Even fewer publications specifically focus on the frequency, duration, magnitude, timing, or rate of change of these connections. In addition, although areas that are closer to rivers and streams have a higher probability of being connected than areas farther away when conditions governing the type and quantity of flows—including soil infiltration rate, wetland storage capacity, hydraulic gradient, etc.—are similar, information to determine if this similarity holds is generally not provided in the studies we reviewed (for the Science Report). Thus, current science (as of the Report's publication in 2015) does not support evaluations of the degree of connectivity for specific groups or classes of wetlands (*e.g.,* prairie potholes or vernal pools). Evaluations of individual wetlands or groups of wetlands, however, could be possible through case-by-case analysis.

Some effects of non-floodplain wetlands on downstream waters are due to their isolation, rather than their connectivity. Wetland "sink" functions that trap materials and prevent their export to downstream waters (*e.g.,* sediment and entrained pollutant removal, water storage) result because of the wetland's ability to isolate material fluxes. To establish that such functions influence downstream waters, we also need to know that the wetland intercepts materials that otherwise would reach the downstream water. The literature reviewed does provide limited examples of direct effects of wetland isolation on downstream waters, but not for classes of wetlands (*e.g.*, vernal pools). Nevertheless, the literature reviewed supports the conclusion that sink functions of non-floodplain wetlands, which result in part from their relative isolation, will affect a downstream water when these wetlands are situated between the downstream water and known point or nonpoint sources of pollution, and thus intersect flowpaths between the pollutant source and downstream waters.

Conclusion 4: Degrees and Determinants of Connectivity

Watersheds are integrated at multiple spatial and temporal scales by flows of surface water and ground water, transport and transformation of physical and chemical materials, and movements of organisms. Although all parts of a watershed are connected to some degree—by the hydrologic cycle or dispersal of organisms, for example—the degree and downstream effects of those connections vary spatially and temporally, and are determined by characteristics of the physical, chemical, and biological environments and by human activities.

Stream and wetland connections have particularly important consequences for downstream water integrity. Most of the materials—broadly defined as any physical, chemical, or biological entity—in rivers, for example, originate from aquatic ecosystems located upstream or elsewhere in the watershed. Longitudinal flows through ephemeral, intermittent, and perennial stream channels are much more efficient for transport of water, materials, and organisms than diffuse overland flows, and areas that concentrate water provide mechanisms for the storage and transformation, as well as transport, of materials.

Connectivity of streams and wetlands to downstream waters occurs along a continuum that can be described in terms of the frequency, duration, magnitude, timing, and rate of change of water, material, and biotic fluxes to downstream waters. These terms, which are referred to collectively as connectivity descriptors, characterize the range over which streams and wetlands vary and shift along the connectivity gradient in response to changes in natural and anthropogenic factors and, when considered in a watershed context, can be used to predict probable effects of different degrees of connectivity over time. The evidence unequivocally demonstrates that the stream channels and riparian/floodplain wetlands or open waters that together form river networks are clearly connected to downstream waters in ways that profoundly influence downstream water integrity. The connectivity and effects of non-floodplain wetlands and open waters are more variable and thus more difficult to address solely from evidence available in peer-reviewed studies.

Variations in the degree of connectivity influence the range of functions provided by streams and wetlands, and are critical to the integrity and sustainability of downstream waters. Connections with low values of one or more descriptors (*e.g.*, low-frequency, low-duration streamflows caused by flash floods) can have important downstream effects when considered in the context of other descriptors (*e.g.*, large magnitude of water transfer). At the other end of the frequency range, high-frequency, low-magnitude vertical (surface-subsurface) and lateral flows contribute to aquatic biogeochemical processes, including nutrient and contaminant transformation and organic matter accumulation. The timing of an event can alter both connectivity and the magnitude of its downstream effect. For example, when soils become saturated by previous rainfall events, even low or moderate rainfall can cause streams or wetlands to overflow, transporting water and materials to downstream waters. Fish that use nonperennial or perennial headwater stream habitats to spawn or rear young, and invertebrates that move into seasonally inundated floodplain wetlands prior to emergence, have life cycles that are synchronized with the timing of flows, temperature thresholds, and food resource availability in those habitats.

Conclusion 5: Cumulative Effects

The incremental effects of individual streams and wetlands are cumulative across entire watersheds and therefore must be evaluated in context with other streams and wetlands. Downstream waters are the time-integrated result of all waters contributing to them. For example, the amount of water or biomass contributed by a specific ephemeral stream in a given year might be small, but the aggregate contribution of that stream over multiple years, or by all ephemeral streams draining that watershed in a given year or over multiple years, can have substantial consequences on the integrity of the downstream waters. Similarly, the downstream effect of a single event, such as pollutant discharge into a single stream or wetland, might be negligible but the cumulative effect of multiple discharges could degrade the integrity of downstream waters.

In addition, when considering the effect of an individual stream or wetland, all contributions and functions of that stream or wetland should be evaluated cumulatively. For example, the same stream transports water, removes excess nutrients, mitigates flooding, and provides refuge for fish when conditions downstream are unfavorable; if any of these functions is ignored, the overall effect of that stream would be underestimated.

ii. Discussion of Major Conclusions

The Science Report synthesized a large body of scientific literature on the connectivity and mechanisms by which streams, wetlands, and open waters, singly or in aggregate, affect the physical, chemical, and biological integrity of downstream waters. The major conclusions reflect the strength of evidence available at that time in the peer-reviewed scientific literature for assessing the connectivity and downstream effects of water bodies identified in Chapter 1 of the Science Report.

The conclusions of the Science Report were corroborated by two independent peer reviews by scientists identified in the front matter of the Science Report and discussed in section I.B of this document.

The term connectivity is defined in the Science Report as the degree to which components of a watershed are joined and interact by transport mechanisms that function across multiple spatial and temporal scales. Connectivity is determined by the characteristics of both the physical landscape and the biota of the specific system. ORD's review found strong evidence supporting the central roles of the physical, chemical, and biological connectivity of streams, wetlands, and open waters—encompassing varying degrees of both connection and isolation—in maintaining the structure and function of downstream waters, including rivers, lakes, estuaries, and oceans. ORD's review also found strong evidence demonstrating the various mechanisms by which material and biological linkages from streams, wetlands, and open waters affect downstream waters, classified here into five functional categories (source, sink, refuge, lag, and transformation; discussed below), and modify the timing of transport and the quantity and quality of resources available to downstream ecosystems and communities. Thus, the literature available at the time of its publication in January 2015 provided a large body of evidence for assessing the types of connections and functions by which streams and wetlands produce the range of observed effects on the integrity of downstream waters.

ORD identified five categories of functions by which streams, wetlands, and open waters influence the timing, quantity, and quality of resources available to downstream waters:

- Source: the net export of materials, such as water and food resources;
- Sink: the net removal or storage of materials, such as sediment and contaminants;
- Refuge: the protection of materials, especially organisms;
- Transformation: the transformation of materials, especially nutrients and chemical contaminants, into different physical or chemical forms; and
- Lag: the delayed or regulated release of materials, such as stormwater.

These functions are not mutually exclusive; for example, the same stream or wetland can be both a source of organic matter and a sink for nitrogen. The presence or absence of these functions, which depend on the biota, hydrology, and environmental conditions in a watershed, can change over time; for example, the same wetland can attenuate runoff during storm events and provide groundwater recharge following storms. Further, some functions work in conjunction with others; a lag function can include transformation of materials prior to their delayed release. Finally, effects on downstream waters should consider both actual function and potential function. A potential function represents the capacity of an ecosystem to perform that function under suitable conditions. For example, a wetland with high capacity for denitrification is a potential sink for nitrogen, a nutrient that becomes a contaminant when present in excessive concentrations. In the absence of nitrogen, this capacity represents the wetland's potential function. If nitrogen enters the wetland (*e.g.*, from fertilizer in runoff), it is removed from the water; this removal represents the wetland's actual function. Both potential and actual functions play critical roles in protecting and restoring downstream waters as environmental conditions change.

The evidence unequivocally demonstrates that the stream channels and riparian/floodplain wetlands or open waters that together form river networks are clearly connected to downstream waters in ways that profoundly influence downstream water integrity. The body of literature documenting connectivity and downstream effects was most abundant for perennial and intermittent streams, and for riparian/floodplain wetlands. Although less abundant, the evidence for connectivity and downstream effects of ephemeral streams was strong and compelling, particularly in context with the large body of evidence supporting the physical connectivity and cumulative effects of channelized flows that form and maintain stream networks.

As stated in Conclusion 3, the connectivity and effects of wetlands and open waters that lack visible surface connections to other water bodies were more difficult to address solely from evidence available in the peer-reviewed literature at the time of publication of the Science Report. The limited evidence available at the time showed that these systems have important hydrologic, water-quality, and habitat functions that can affect downstream waters where connections to them exist; the literature also provided limited examples of direct effects of non-floodplain wetland isolation on downstream water integrity. The available peer-reviewed literature, however, did not identify which types or classes of non-floodplain wetlands had or lacked the types of connections needed to convey the effects on downstream waters of functions, materials, or biota provided by those wetlands.

iii. Key Findings for the Science Report's Major Conclusions

This section summarizes key findings for each of the five major conclusions, above and in Chapter 6 of the Science Report. Citations have been omitted from the text to improve readability; please refer to individual chapters of the Science Report for supporting publications and additional information.

Conclusion 1, Streams: Key Findings

- Streams are hydrologically connected to downstream waters via channels that convey surface and subsurface water either year-round (*i.e.*, perennial flow), weekly to seasonally (*i.e.*, intermittent flow), or only in direct response to precipitation (*i.e.*, ephemeral flow). Streams are the dominant source of water in most rivers, and the majority of tributaries are perennial, intermittent, or ephemeral headwater streams. For example, headwater streams, which are the smallest channels where streamflows begin, are the cumulative source of approximately 60% of the total mean annual flow to all northeastern U.S. streams and rivers.

- In addition to downstream transport, headwaters convey water into local storage compartments such as ponds, shallow aquifers, or stream banks, and into regional and alluvial aquifers. These local storage compartments are important sources of water for maintaining baseflow in rivers.

Streamflow typically depends on the delayed (*i.e.*, lagged) release of shallow ground water from local storage, especially during dry periods and in areas with shallow groundwater tables and pervious subsurfaces. For example, in the southwestern United States, short-term shallow groundwater storage in alluvial floodplain aquifers, with gradual release into stream channels, is a major source of annual flow in rivers.

- Infrequent, high-magnitude events are especially important for transmitting materials from headwater streams in most river networks. For example, headwater streams, including ephemeral and intermittent streams, shape river channels by accumulating and gradually or episodically releasing stored materials such as sediment and large woody debris. These materials help structure stream and river channels by slowing the flow of water through channels and providing substrate and habitat for aquatic organisms.

- There is strong evidence that headwater streams function as nitrogen sources (via export) and sinks (via uptake and transformation) for river networks. For example, one study estimated that rapid nutrient cycling in small streams with no agricultural or urban impacts removed 20−40% of the nitrogen that otherwise would be delivered to downstream waters. Nutrients are necessary to support aquatic life, but excess nutrients lead to eutrophication and hypoxia, in which over-enrichment causes dissolved oxygen concentrations to fall below the level necessary to sustain most aquatic animal life in the stream and streambed. Thus, the influence of streams on nutrient loads can have significant repercussions for hypoxia in downstream waters.

- Headwaters provide habitat that is critical for completion of one or more life-cycle stages of many aquatic and semiaquatic species capable of moving throughout river networks. Evidence is strong that headwaters provide habitat for complex life-cycle completion; refuge from predators, competitors, parasites, or adverse physical conditions in rivers (*e.g.*, temperature or flow extremes, low dissolved oxygen, high sediment); and reservoirs of genetic- and species-level diversity. Use of headwater streams as habitat is especially critical for the many species that migrate between small streams and marine environments during their life cycles (*e.g.*, Pacific and Atlantic salmon, American eels, certain lamprey species). The presence of these species within river networks provides robust evidence of biological connections between headwaters and larger rivers; because these organisms also transport nutrients and other materials as they migrate, their presence also provides evidence of biologically mediated chemical connections. In prairie streams, many fishes swim upstream into tributaries to release eggs, which develop as they are transported downstream.

- Human alterations affect the frequency, duration, magnitude, timing, and rate of change of connections between headwater streams, including ephemeral and intermittent streams, and downstream waters. Human activities and built structures (*e.g.*, channelization, dams, groundwater withdrawals) can either enhance or fragment longitudinal connections between headwater streams and downstream waters, while also constraining lateral and vertical exchanges and tightly controlling the temporal dimension of connectivity. In many cases, research on human alterations has enhanced our understanding of the headwater stream-downstream water connections and their consequences. Recognition of these connections and effects has encouraged the development of more sustainable practices and infrastructure to reestablish and manage connections, and ultimately to protect and restore the integrity of downstream waters.

Conclusion 2, Riparian/Floodplain Wetlands and Open Waters: Key Findings

- Riparian areas and floodplains connect upland and aquatic environments through both surface and subsurface hydrologic flowpaths. These areas are therefore uniquely situated in watersheds to receive and process waters that pass over densely vegetated areas and through subsurface zones before the waters reach streams and rivers. When pollutants reach a riparian or floodplain wetland, they can be sequestered in sediments, assimilated into wetland plants and animals, transformed into less harmful or mobile forms or compounds, or lost to the atmosphere. A wetland's potential for biogeochemical transformations (*e.g.*, denitrification) that can improve downstream water quality is influenced by local factors, including anoxic conditions and slow organic matter decomposition, shallow water tables, wetland plant communities, permeable soils, and complex topography.

- Riparian/floodplain wetlands can reduce flood peaks by storing and desynchronizing floodwaters. They can also maintain river baseflows by recharging alluvial aquifers. Many studies have documented the ability of riparian/floodplain wetlands to reduce flood pulses by storing excess water from streams and rivers. One review of wetland studies reported that riparian wetlands reduced or delayed floods in 23 of 28 studies. For example, peak discharges between upstream and downstream gaging stations on the Cache River in Arkansas were reduced 10−20% primarily due to floodplain water storage.

- Riparian areas and floodplains store large amounts of sediment and organic matter from upstream and from upland areas. For example, riparian areas have been shown to remove 80−90% of sediments leaving agricultural fields in North Carolina.

- Ecosystem function within a river system is driven in part by biological connectivity that links diverse biological communities with the river system. Movements of organisms that connect aquatic habitats and their populations, even across different watersheds, are important for the survival of individuals, populations, and species, and for the functioning of the river ecosystem. For example, lateral expansion and contraction of the river in its floodplain result in an exchange of matter and organisms, including fish populations that are adapted to use floodplain habitats for feeding and spawning during high water. Wetland and aquatic plants in floodplains can become important seed sources for the river network, especially if catastrophic flooding scours vegetation and seed banks in other parts of the channel. Many invertebrates exploit temporary hydrologic connections between rivers and floodplain wetland habitats, moving into these wetlands to feed, reproduce, or avoid harsh environmental conditions and then returning to the river network. Amphibians and aquatic reptiles commonly use both streams and riparian/floodplain wetlands to hunt, forage, overwinter, rest, or hide from predators. Birds can spatially integrate the watershed landscape through biological connectivity.

Conclusion 3, Non-floodplain Wetlands and Open Waters: Key Findings

- Water storage by wetlands well outside of riparian or floodplain areas can affect streamflow. Hydrologic models of prairie potholes in the Starkweather Coulee subbasin (North Dakota) that drains to Devils Lake indicate that increasing the volume of prairie pothole storage across the subbasin by approximately 60% caused simulated total annual streamflow to decrease 50% during a series of dry years and 20% during wet years. Similar simulation studies of watersheds that feed the Red River of the North in North Dakota and Minnesota demonstrated qualitatively comparable results, suggesting that the ability of prairie potholes to modulate streamflow could be widespread across eastern portions of the prairie pothole region. This work also indicates that reducing water storage capacity of wetlands by connecting formerly isolated prairie potholes through ditching or drainage to the Devils Lake and Red River basins could increase stormflow and contribute to downstream flooding. In many agricultural areas already crisscrossed by extensive drainage systems, total streamflow and baseflow are increased by directly connecting prairie potholes to stream networks. The impacts of changing streamflow are numerous, including altered flow regime, stream geomorphology, habitat, and ecology. The presence or absence of an effect of prairie pothole water storage on streamflow depends on many factors, including patterns of precipitation, topography, and degree of human alteration. For example, in parts of the prairie pothole region with low precipitation, low stream density, and little human alteration, hydrologic connectivity between prairie potholes and streams or rivers is likely to be low.

- Non-floodplain wetlands act as sinks and transformers for various pollutants, especially nutrients, which at excess levels can adversely impact human and ecosystem health and pose a serious pollution problem in the United States. In one study, sewage wastewaters were applied to forested wetlands in Florida for 4.5 years; more than 95% of the phosphorus, nitrate, ammonium, and total nitrogen were removed by the wetlands during the study period, and 66−86% of the nitrate removed was attributed to the process of denitrification (chemical and biological processes that remove nitrogen from water). In another study, sizeable phosphorus retention occurred in marshes that comprised only 7% of the lower Lake Okeechobee basin area in Florida. A non-floodplain bog in Massachusetts was reported to sequester nearly 80% of nitrogen inputs from various sources, including atmospheric deposition, and prairie pothole wetlands in the upper Midwest were found to remove >80% of the nitrate load via denitrification. A large prairie marsh was found to remove 86% of nitrate, 78% of ammonium, and 20% of phosphate through assimilation and sedimentation, sorption, and other mechanisms. Together, these and other studies indicate that onsite nutrient removal by non-floodplain wetlands is substantial and geographically widespread. The effects of this removal on rivers were generally not reported in the literature as of the 2015 publication date of the Scientific Report.

- Non-floodplain wetlands provide unique and important habitats for many species, both common and rare. Some of these species require multiple types of waters to complete their full life cycles, including downstream waters. Abundant or highly mobile species play important roles in transferring energy and materials between non-floodplain wetlands and downstream waters.

- Biological connections are likely to occur between most non-floodplain wetlands and downstream waters through either direct or stepping stone movement of amphibians, invertebrates, reptiles, mammals, and seeds of aquatic plants, including colonization by invasive species. Many species in those groups that use both stream and wetland habitats are capable of dispersal distances equal to or greater than distances between many wetlands and river networks. Migratory birds can be an important vector of long-distance dispersal of plants and invertebrates between non-floodplain wetlands and the river network, although their influence has not been quantified. Whether those connections are of sufficient magnitude to impact downstream waters will either require estimation of the magnitude of material fluxes or evidence that these movements of organisms are required for the survival and persistence of biota that contribute to the integrity of downstream waters.

- Spatial proximity is one important determinant of the magnitude, frequency and duration of connections between wetlands and streams that will ultimately influence the fluxes of water, materials and biota between wetlands and downstream waters. However, proximity alone is not sufficient to determine connectivity, due to local variation in factors such as slope and permeability.

- The cumulative influence of many individual wetlands within watersheds can strongly affect the spatial scale, magnitude, frequency, and duration of hydrologic, biological and chemical fluxes or transfers of water and materials to downstream waters. Because of their aggregated influence, any evaluation of changes to individual wetlands should be considered in the context of past and predicted changes (*e.g.*, from climate change) to other wetlands within the same watershed.

- Non-floodplain wetlands can be hydrologically connected directly to river networks through natural or constructed channels, nonchannelized surface flows, or subsurface flows, the latter of which can travel long distances to affect downstream waters. A wetland surrounded by uplands is defined as “geographically isolated.” Our review found that, in some cases, wetland types such as vernal pools and coastal depressional wetlands are collectively—and incorrectly—referred to as geographically isolated. Technically, the term “geographically isolated” should be applied only to the particular wetlands within a type or class that are completely surrounded by uplands. Furthermore, “geographic isolation” should not be confused with functional isolation, because geographically isolated wetlands can still have hydrologic, chemical, and biological connections to downstream waters.

- Non-floodplain wetlands occur along a gradient of hydrologic connectivity-isolation with respect to river networks, lakes, or marine/estuarine water bodies. This gradient includes, for example, wetlands that serve as origins for stream channels that have permanent surface-water connections to the river network; wetlands with outlets to stream channels that discharge to deep groundwater aquifers; geographically isolated wetlands that have local groundwater or occasional surface-water connections to downstream waters; and geographically isolated wetlands that have minimal hydrologic connection to other water bodies (but which could include surface and subsurface connections to other wetlands). This gradient can exist among wetlands of the same type or in the same geographic region.

- Caution should be used in interpreting connectivity for wetlands that have been designated as “geographically isolated” because (1) the term can be applied broadly to a heterogeneous group of wetlands, which can include wetlands that are not actually geographically isolated; (2) wetlands with permanent channels could be miscategorized as geographically isolated if the designation is based on maps or imagery with inadequate spatial resolution, obscured views, etc.; and (3) wetland complexes could have connections to downstream waters through stream channels even if individual wetlands within the complex are geographically isolated. For example, a recent study examined hydrologic connectivity in a complex of wetlands on the Texas Coastal Plain. The wetlands in this complex have been considered to be a type of geographically isolated wetland; however, collectively they are connected both geographically and hydrologically to downstream waters in the area: During an almost 4-year study period, nearly 20% of the precipitation that fell on the wetland complex flowed out through an intermittent stream into downstream waters. Thus, wetland complexes could have connections to downstream waters through stream channels even when the individual wetland components are geographically isolated.

Conclusion 4, Degrees and Determinants of Connectivity: Key Findings

- The surface-water and groundwater flowpaths (hereafter, hydrologic flowpaths), along which water and materials are transported and transformed, determine variations in the degree of physical and chemical connectivity. These flowpaths are controlled primarily by variations in climate, geology, and terrain within and among watersheds and over time. Climate, geology, and terrain are reflected locally in factors such as rainfall and snowfall intensity, soil infiltration rates, and the direction of groundwater flows. These local factors interact with the landscape positions of streams and wetlands relative to downstream waters, and with functions (such as the removal or transformation of pollutants) performed by those streams and wetlands to determine connectivity gradients.

- Gradients of biological connectivity (*i.e.*, the active or passive movements of organisms through water or air and over land that connect populations) are determined primarily by species assemblages, and by features of the landscape (*e.g.*, climate, geology, terrain) that facilitate or impede the movement of organisms. The temporal and spatial scales at which biological pathways connect aquatic habitats depend on characteristics of both the landscape and species, and overland transport or movement can occur across watershed boundaries. Dispersal is essential for population persistence, maintenance of genetic diversity, and evolution of aquatic species. Consequently, dispersal strategies reflect aquatic species' responses and adaptations to biotic and abiotic environments, including spatial and temporal variation in resource availability and quality. Species' traits and behaviors encompass species-environment relationships over time, and provide an ecological and evolutionary context for evaluating biological connectivity in a particular watershed or group of watersheds.

- Pathways for chemical transport and transformation largely follow hydrologic flowpaths, but sometimes follow biological pathways (*e.g.*, nutrient transport from wetlands to coastal waters by migrating waterfowl, upstream transport of marine-derived nutrients by spawning of anadromous fish, uptake and removal of nutrients by emerging stream insects).

- Human activities alter naturally occurring gradients of physical, chemical, and biological connectivity by modifying the frequency, duration, magnitude, timing, and rate of change of fluxes, exchanges, and transformations. For example, connectivity can be reduced by dams, levees, culverts, water withdrawals, and habitat destruction, and can be increased by effluent discharges, channelization, drainage ditches and tiles, and impervious surfaces.

Conclusion 5, Cumulative Effects: Key Findings

- Structurally and functionally, stream-channel networks and the watersheds they drain are fundamentally cumulative in how they are formed and maintained. Excess water from precipitation that is not evaporated, taken up by organisms, or stored in soils and geologic layers moves downgradient by gravity as overland flow or through channels carrying sediment, chemical constituents, and organisms. These channels concentrate surface-water flows and are more efficient than overland (*i.e.*, diffuse) flows in transporting water and materials, and are reinforced over time by recurrent flows.

- Connectivity between streams and rivers provides opportunities for materials, including nutrients and chemical contaminants, to be transformed chemically as they are transported downstream. Although highly efficient at the transport of water and other physical materials, streams are dynamic ecosystems with permeable beds and banks that interact with other ecosystems above and below the surface. The exchange of materials between surface and subsurface areas involves a series of complex physical, chemical, and biological alterations that occur as materials move through different parts of the river system. The amount and quality of such materials that eventually reach a river are determined by the aggregate effect of these sequential alterations that begin at the source waters, which can be at some distance from the river. The opportunity for transformation of material (*e.g.*, biological uptake, assimilation, or beneficial transformation) in intervening stream reaches increases with distance to the river. Nutrient spiraling, the process by which nutrients entering headwater streams are transformed by various aquatic organisms and chemical reactions as they are transported downstream, is one example of an instream alteration that exhibits significant beneficial effects on downstream waters. Nutrients (in their inorganic form) that enter a headwater stream (*e.g.*, via overland flow) are first removed from the water column by streambed algal and microbial populations. Fish or insects feeding on algae and microbes take up some of those nutrients, which are subsequently released back into the stream via excretion and decomposition (*i.e.*, in their organic form), and the cycle is repeated. In each phase of the cycling process—from dissolved inorganic nutrients in the water column, through microbial uptake, subsequent transformations through the food web, and back to dissolved nutrients in the water column—nutrients are subject to downstream transport. Stream and wetland capacities for nutrient cycling have important implications for the form and concentration of nutrients exported to downstream waters.

- Cumulative effects across a watershed must be considered when quantifying the frequency, duration, and magnitude of connectivity, to evaluate the downstream effects of streams and wetlands. For example, although the probability of a large-magnitude transfer of organisms from any given headwater stream in a given year might be low (*i.e.*, a low-frequency connection when each stream is considered individually), headwater streams are the most abundant type of stream in most watersheds. Thus, the overall probability of a large-magnitude transfer of organisms is higher when considered for all headwater streams in a watershed—that is, a high-frequency connection is present when headwaters are considered cumulatively at the watershed scale, compared with probabilities of transport for streams individually. Similarly, a single pollutant discharge might be negligible but the cumulative effect of multiple discharges could degrade the integrity of downstream waters. Riparian open waters (*e.g.*, oxbow lakes), wetlands, and vegetated areas cumulatively can retain up to 90% of eroded clays, silts, and sands that otherwise would enter stream channels. The larger amounts of snowmelt and precipitation cumulatively held by many wetlands can reduce the potential for flooding at downstream locations. For example, wetlands in the prairie pothole region cumulatively stored about 11−20% of the precipitation in one watershed.

- The combination of diverse habitat types and abundant food resources cumulatively makes floodplains important foraging, hunting, and breeding sites for fish, aquatic life stages of amphibians, and aquatic invertebrates. The scale of these cumulative effects can be extensive; for example, coastal ibises travel up to 40 km to obtain food from freshwater floodplain wetlands for nesting chicks, which cannot tolerate salt levels in local food resources until they fledge.

iv. Science Report: Framework for Analysis

In support of the conclusions addressed above in this section, Chapter 2 of the Science Report essentially provides the framework for the analysis by describing the components of a river system and watershed; the types of physical, chemical, and biological connections that link those components; the factors that influence connectivity at various temporal and spatial scales; and methods for quantifying connectivity. In addition, Chapter 1 of the Science Report introduces the approach used for the analysis of the peer-reviewed literature.

Justice Kennedy’s opinion in *Rapanos v. United States*, 547 U.S. 715 (2006) (*Rapanos*) established the framework for a significant nexus analysis that mirrors the framework through which scientists assess a river system – examining how the components of the system (*e.g.*, wetlands), in the aggregate (in combination), in the region, contribute and connect to the river (significantly affect the chemical, physical, or biological integrity of traditional navigable waters, the territorial seas, or interstate waters). In implementing the significant nexus standard under this rule for tributaries and adjacent wetlands, all tributaries and adjacent wetlands within the catchment area (*i.e.*, watershed) of the tributary of interest will be analyzed as part of the significant nexus analysis. The watershed scale is a scientifically valid scale for considering cumulative effects, including at the various levels of the watershed scale (*e.g.*, small watersheds, the catchment level for an individual stream reach, the watershed that drains to the next named stream, etc.). Watershed position influences function (*e.g.*, storage or groundwater recharge or surface outflow to other features), so it is defensible to allow for wetlands adjacent to the same tributary reach to be aggregated together with that tributary reach at the catchment level to assess the functions that work in concert to influence the traditional navigable water, the territorial seas, or the interstate water. Density is another important factor, but the effects of functions of remaining wetlands in formerly-dense wetland landscapes could become more important in light of cumulative losses.

To identify connections and effects of streams, wetlands, and other water bodies on downstream waters, the Science Report used two types of evidence from peer-reviewed, published literature: (1) direct evidence that demonstrated a connection or effect (*e.g.*, observed transport of materials or movement of organisms from streams or wetlands to downstream waters) and (2) indirect evidence that suggested a connection or effect (*e.g.*, presence of environmental factors known to influence connectivity, a gradient of impairment associated with cumulative loss of streams or wetlands). In some cases, an individual line of evidence demonstrated connections along the entire river network (*e.g.*, from headwaters to large rivers). In most cases, multiple sources of evidence were gathered and conclusions drawn via logical inference—for example, when one body of evidence shows that headwater streams are connected to downstream segments, another body of evidence shows those downstream segments are linked to other segments farther downstream, and so on. This approach, which borrows from weight-of-evidence approaches in causal analysis is an effective way to synthesize the diversity of evidence needed to address questions at larger spatial and longer temporal scales than are often considered in individual scientific studies. Science Report at 1-14, 1-16 (citing Suter *et al*. 2002; Suter and Cormier 2011).

A river is the time-integrated result of all waters contributing to it, and connectivity is the property that spatially integrates the individual components of the watershed. In discussions of connectivity, the watershed scale is the appropriate context for interpreting technical evidence about individual watershed components. Science Report at 2-1 (citing Newbold *et al.* 1982b; Stanford and Ward 1993; Bunn and Arthington 2002; Power and Dietrich 2002; Benda *et al*. 2004b; Naiman *et al*. 2005; Nadeau and Rains 2007; Rodriguez-Iturbe *et al*. 2009). Such interpretation requires that freshwater resources be viewed within a landscape—or systems—context. *Id.* (citing Baron *et al*. 2002). Addressing the questions asked in the Science Report, therefore, requires an integrated systems perspective that considers both the components contributing to the river and the connections between those components and the river.

Components of the River System

In the Science Report, the term river refers to a relatively large volume of flowing water within a visible channel, including subsurface water moving in the same direction as the surface water and lateral flows exchanged with associated floodplain and riparian areas. *Id.* at 2-2 (Naiman and Bilby 1998). Channels are natural or constructed passageways or depressions of perceptible linear extent that convey water and associated materials downgradient. They are defined by the presence of continuous bed and bank structures, or uninterrupted (but permeable) bottom and lateral boundaries. Although bed and bank structures might in places appear to be disrupted (*e.g.*, bedrock outcrops, braided channels, flow-through wetlands), the continuation of the bed and banks downgradient from such disruptions is evidence of the surface connection with the channel that is upgradient of the perceived disruption. Such disruptions are associated with changes in the gradient and in the material over and through which the water flows. If a disruption in the bed and bank structure prevented connection, the area downgradient would lack a bed and banks, be colonized with terrestrial vegetation, and be indiscernible from the nearby land. The concentrated longitudinal movement of water and sediment through these channels lowers local elevation, prevents soil development, selectively transports and stores sediment, and hampers the colonization and persistence of terrestrial vegetation. Streams are defined in a similar manner as rivers: a relatively small volume of flowing water within a visible channel, including subsurface water moving in the same direction as the surface water and lateral flows exchanged with associated floodplain and riparian areas. *Id.* (citing Naiman and Bilby 1998).

A river network is a hierarchical, interconnected population of channels that drains surface and subsurface water from a watershed to a river and includes the river itself. Watershed boundaries traditionally are defined topographically, such as by ridges. These channels can convey water year-round, weekly to seasonally, or only in direct response to rainfall and snowmelt. *Id.* (citing Frissell *et al*. 1986; Benda *et al*. 2004b). The smallest of these channels, where streamflows begin, are considered headwater streams. Headwater streams are first- to third-order streams, where stream order is a classification system based on the position of the stream in the river network. *Id.* (citing Strahler 1957; Vannote *et al.* 1980; Meyer and Wallace 2001; Gomi *et al*. 2002; Fritz *et al*. 2006; Nadeau and Rains 2007). The point at which stream or river channels intersect within a river network is called a confluence. The confluence of two streams with the same order results in an increase of stream order (*i.e.*, two first-order streams join to form a second-order stream, two second-order streams join to form a third-order stream, and so on); when streams of different order join, the order of the larger stream is retained.

Terminal and lateral source streams[3] typically originate at channel heads, which occur where surface-water runoff is sufficient to erode a definable channel. *Id.* at 2-3 (citing Dietrich and Dunne 1993). The channel head denotes the upstream extent of a stream's continuous bed and banks structure. Channel heads are relatively dynamic zones in river networks, as their position can advance upslope by overland or subsurface flow-driven erosion, or retreat downslope by colluvial infilling. Source streams also can originate at seeps or springs and associated wetlands.

When two streams join at a confluence, the smaller stream (*i.e.*, that with the smaller drainage area or lower mean annual discharge) is called a tributary of the larger stream, which is referred to as the mainstem. A basic way of classifying tributary contributions to a mainstem is the symmetry ratio, which describes the size of a tributary relative to the mainstem at their confluence, in terms of their respective discharges, drainage areas, or channel widths. *Id.* at 2-4 (citing Roy and Woldenberg 1986; Rhoads 1987; Benda 2008).

Surface-water hydrologic connectivity within river network channels occurs, in part, through the unidirectional movement of water from channels at higher elevations to ones at lower elevations—that is, hydrologic connectivity exists because water flows downhill. In essence, the river network represents the aboveground flow route and associated subsurface-water interactions, transporting water, energy, and materials from the surrounding watershed to downstream rivers, lakes, estuaries, and oceans (The River Continuum Concept). *Id.* (citing (Vannote *et al.* 1980).

Streamflow and the quantity and character of sediment—interacting with watershed geology, terrain, soils and vegetation—shape morphological changes in the stream channel that occur from river network headwaters to lower rivers. *Id.* (citing Montgomery 1999; Church 2002). Headwater streams are typically erosion zones in which sediment from the base of adjoining hillslopes moves directly into stream channels and is transported downstream. As stream channels increase in size and decrease in slope, a mixture of erosion and deposition processes usually is at work. At some point in the lower

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[3] Mock (1971) presented a classification of the streams comprising stream or river networks. He designated first-order streams that intersect other first-order streams as sources. We refer to these as terminal source streams. Mock defined first-order streams that flow into higher order streams as tributary sources, and we refer to this class of streams as lateral source streams.

portions of river networks, sediment deposition becomes the dominant process and floodplains form. Floodplains are level areas bordering stream or river channels that are formed by sediment deposition from those channels under present climatic conditions. These natural geomorphic features are inundated during moderate to high water events. *Id.* (citing Leopold 1994; Osterkamp 2008). Floodplain and associated river channel forms (*e.g.*, meandering, braided, anastomosing) are determined by interacting fluvial factors, including sediment size and supply, channel gradient, and streamflow. *Id.* (citing Church 2002; Church 2006).

Both riparian areas and floodplains are important components of river systems. Riparian areas are transition zones between terrestrial and aquatic ecosystems that are distinguished by gradients in biophysical conditions, ecological processes, and biota. They are areas through which surface and subsurface hydrology connect water bodies with their adjoining uplands, and they include those portions of terrestrial ecosystems that significantly influence exchanges of energy and matter with aquatic ecosystems. *Id.* (citing National Research Council 2002). Riparian areas often have high biodiversity. *Id.* (citing Naiman *et al*. 2005). They occur near lakes and estuarine-marine shorelines and along river networks, where their width can vary from narrow bands along headwater streams to broad zones that encompass the floodplains of large rivers.

Floodplains are also considered riparian areas, but not all riparian areas have floodplains. All rivers and streams within river networks have riparian areas, but small streams in constrained valleys are less likely to have floodplains than larger streams and rivers in unconstrained valleys. The “100-year floodplain” is the area with a one percent annual chance of flooding. *Id.* at 2-5; USGS c. The 100-year floodplain can but need not coincide with the geomorphic floodplain.

Wetlands are transitional areas between terrestrial and aquatic ecosystems. Wetlands include areas such as swamps, bogs, fens, marshes, ponds, and pools. Science Report at 2-6 (citing Mitsch *et al.* 2009).

Many classification systems have been developed for wetlands. *Id.* (citing Mitsch and Gosselink 2007). These classifications can focus on vegetation, hydrology, hydrogeomorphic characteristics, or other factors. *Id.* (citing Cowardin *et al*. 1979; Brinson 1993; Tiner 2003a; Comer *et al*. 2005). Because the Science Report focuses on downstream connectivity, it considered two landscape settings in which wetlands occur based on directionality of hydrologic flows. Directionality of flow also is included as a component of hydrodynamic setting in the hydrogeomorphic approach and as an element of water flowpath in an enhancement of National Wetlands Inventory data (the National Wetlands Inventory is a mapping dataset of the U.S. Fish and Wildlife Service regarding the extent and types of wetlands and deepwater habitats across the country) that provides descriptors for landscape position, landform, water flow path, and waterbody type (LLLW). *Id.* (citing Brinson 1993; Smith *et al.* 1995, Tiner 2011); *see also* U.S. FWS 2010. This emphasis on directionality of flow is necessary because hydrologic connectivity plays a dominant role in determining the types of effects wetlands have on downstream waters.

A non-floodplain wetland setting is a landscape setting where a potential exists for unidirectional, lateral hydrologic flows from wetlands to the river network through surface water or ground water. Such a setting would include upgradient areas such as hillslopes or upland areas outside of the floodplain. A floodplain is the level area bordering a stream or river channel that was built by sediment deposition from the stream or river under present climatic conditions and is inundated during moderate to high flow events. Floodplains formed under historic or prehistoric climatic conditions can be abandoned by rivers and form terraces. Any wetland setting where water could only flow from the wetland toward a river network would be considered a non-floodplain setting, regardless of the magnitude and duration of flows and of travel times. The Science Report refers to wetlands that occur in these settings as non-floodplain wetlands.

A riparian/floodplain wetland setting is a landscape setting (*e.g.*, floodplains, most riparian areas, lake and estuarine fringes) that is subject to bidirectional, lateral hydrologic flows. Wetlands in riparian/floodplain settings can have some of the same types of hydrologic connections as those in non-floodplain settings. In addition, wetlands in these settings also have bidirectional flows. For example, wetlands within a riparian area are connected to the river network through lateral movement of water between the channel and riparian area (*e.g.*, through overbank flooding, hyporheic flow). Given the Science Report's interest in addressing the effects of wetlands on downstream waters, it focused in particular on the subset of these wetlands that occur in riparian areas with and without floodplains (collectively referred to hereafter as riparian/floodplain wetlands); the Science Report generally does not address wetlands at lake and estuarine fringes. Riparian wetlands are portions of riparian areas that meet the Cowardin *et al*. (1979) three-attribute wetland criteria (*i.e*., having wetland hydrology, hydrophytic vegetation, or hydric soils); floodplain wetlands are portions of the floodplain that meet these same criteria. *Id.* at 2-7. Given that even infrequent flooding can have profound effects on wetland development and function, the Science Report considers such a wetland to be in a riparian/floodplain setting.

Note that the scientific definition of "wetland" used in the Science Report is not the same as the longstanding Clean Water Act regulatory definition of "wetlands," retained in the final rule at paragraph (c)(1)[4]. Only aquatic resources that meet the regulatory definition of "wetlands" at paragraph (c)(1) are considered to be wetlands for Clean Water Act purposes under the final rule. The agencies are not changing their longstanding regulation that requires that an aquatic resource must meet all three parameters under normal circumstances to be considered a wetland in the regulatory sense. Cowardin wetlands do not need to have all three parameters.[5] FGDC 2013. Conclusions in the Science Report apply to the Cowardin wetlands, and the Cowardin definition of wetlands encompasses a larger universe of wetlands than the regulatory definition. Therefore, the Science Report conclusions regarding Cowardin wetlands apply to the wetlands meeting the regulatory definition because those wetlands are a subset of the Cowardin wetlands. All wetlands that meet the regulatory definition also meet the Cowardin definition of wetlands. Because wetlands under the regulatory definition of "wetlands" must meet all three parameters under normal circumstances, it is even more likely that they provide the many functions described in the Science Report due to the conditions in the waters that make them wetlands – that is, their hydric soils (inundated or saturated soils), hydrophytic vegetation (plants that thrive in wet

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[4] The final rule at paragraph (c)(1) states, "*Wetlands* means those areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs, and similar areas." *See also* 33 CFR 328.3(b) (1987); 33 CFR 328.3(c)(16) (2021); 40 CFR 230.3(t) (1988); 40 CFR 120.2(3)(xvi) (2021).

[5] The Federal Geographic Data Committee (FGDC) (2013, p. 7) noted that "three (3) indicators – hydrophytic vegetation, undrained hydric soil, and wetland hydrology; two (2) indicators—hydrophytic vegetation and wetland hydrology or undrained hydric soil and wetland hydrology; and one (1) indicator—wetland hydrology, respectively, would be used to make the identification [that a feature meets the Cowardin "wetland" definition], based on the features available at the particular site."

conditions), and wetland hydrology (inundation or saturation at the surface at some time during the growing season). In addition, many of the Cowardin wetland types are in fact open waters, as the Cowardin definition encompasses open waters like ponds, and the Science Report utilizes many references that include such open waters when discussing floodplain and non-floodplain wetlands. Thus, open waters also provide the many functions described in the Science Report and throughout this document. The Science Report acknowledges that its conclusions apply to open waters as well as wetlands, stating, "although the literature review did not address other non-floodplain water bodies to the same extent as wetlands, our overall conclusions also apply to these water bodies (*e.g.*, ponds and lakes that lack surface water inlets) because the same principles govern hydrologic connectivity between these water bodies and downstream waters." *Id.* at 4-41. Wetlands and open waters are only jurisdictional when they meet the definition of "waters of the United States."

A major consequence of the two different landscape settings (non-floodplain versus riparian/floodplain) is that waterborne materials can be transported only from the wetland to the river network for a non-floodplain wetland, whereas waterborne materials can be transported from the wetland to the river network and from the river network to the wetland for a riparian/floodplain wetland. In the latter case, there is a mutual, interacting effect on the structure and function of both the wetland and river network. In contrast, a non-floodplain wetland can affect a river through the transport of waterborne material, but the opposite is not true. Note that the Science Report limits use of riparian/floodplain and non-floodplain landscape settings to describe the direction of hydrologic flow; the terms cannot be used to describe directionality of geochemical or biological flows. For example, mobile organisms can move from a stream to a non-floodplain wetland. *Id*. at 2-8 (citing, *e.g.*, Subalusky *et al.* 2009a; Subalusky *et al.* 2009b).

Both non-floodplain and riparian/floodplain wetlands can include geographically isolated wetlands, or wetlands completely surrounded by uplands. *Id.* (citing Tiner 2003b). These wetlands have no apparent surface-water outlets, but can hydrologically connect to downstream waters through spillage or groundwater. The Science Report defines an upland as any area not meeting the Cowardin *et al.* (1979) three-attribute wetland criteria, meaning that uplands can occur in both terrestrial and riparian areas.[6] *Id.* Thus, a wetland that is located on a floodplain but is surrounded by upland would be considered a geographically isolated, riparian/floodplain wetland that is subject to periodic inundation from the river network. Although the term "geographically isolated" could be misconstrued as implying functional isolation (*see* Mushet *et al*. 2015), the term has been defined in the peer-reviewed literature to refer specifically to wetlands surrounded by uplands. Furthermore, the literature explicitly notes that geographic isolation does not imply functional isolation. *Id.* (citing Leibowitz 2003; Tiner 2003b). Discussion of geographically isolated wetlands is essential because hydrologic gradients of connectivity in these systems support a wide range of functions that can benefit downstream waters.

River System Hydrology

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[6] Note that this definition of upland is the one that is used in the Science Report. The agencies are not promulgating a definition of upland in the rule. In addition, while the agencies consistently use the phrase "dry land" in the regulatory text to provide clarity to the public, the preamble and this Technical Support Document use the phrases "dry land" and "upland" interchangeably.

River system hydrology is controlled by hierarchical factors that result in a broad continuum of belowground and aboveground hydrologic flowpaths connecting river basins and river networks. *Id.* (citing Winter 2001; Wolock *et al.* 2004; Devito *et al*. 2005; Poole *et al*. 2006; Wagener *et al*. 2007; Poole 2010; Bencala *et al*. 2011; Jencso and McGlynn 2011). At the broadest scale, regional climate interacts with river-basin terrain and geology to shape inherent hydrologic infrastructure that bounds the nature of basin hydrologic flowpaths. Different climate-basin combinations form identifiable hydrologic landscape units with distinct hydrologic characteristics. *Id.* at 2-8 to 2-9 (Winter 2001; Wigington *et al*. 2013). Buttle (2006) posited three first-order controls of watershed streamflow generated under specific hydroclimatic conditions: (1) the ability of different landscape elements to generate runoff by surface or subsurface lateral flow of water; (2) the degree of hydrologic connectivity among landscapes by which surface and subsurface runoff can reach river networks; and (3) the capacity of the river network itself to convey runoff downstream to the river-basin outlet. *Id.* at 2-9. River and stream waters are influenced by not only basin-scale or larger ground-water systems, but also local-scale, vertical and lateral hydrologic exchanges between water in channels and sediments beneath and contiguous with river network channels. *Id.* at 2-9 (citing Ward 1989; Woessner 2000; Malard *et al*. 2002; Bencala 2011). The magnitude and importance of river-system hydrologic flowpaths at all spatial scales can radically change over time at hourly to yearly temporal scales. *Id.* (citing Junk *et al*. 1989; Ward 1989; Malard *et al*. 1999; Poole *et al*. 2006).

Because interactions between groundwater and surface waters are essential processes in rivers, knowledge of basic groundwater hydrology is necessary to understand the interaction between surface and subsurface water and their relationship to connectivity and effects within river systems. Subsurface water occurs in two principal zones: the unsaturated zone and the saturated zone. *Id.* (citing Winter *et al.* 1998). In the unsaturated zone, the spaces between soil, gravel, and other particles contain both air and water. In the saturated zone, these spaces are completely filled with water. Ground water refers to any water that occurs and flows (saturated groundwater flow) in the saturated zone beneath a watershed surface. *Id.* (citing Winter *et al*. 1998). Rapid flow (interflow) of water can occur through large pore spaces in the unsaturated zone. *Id.* (citing Beven and Germann 1982).

Other hydrologic flowpaths are also significant in determining the characteristics of river systems. The most obvious is the downstream water movement within stream or river channels, or open-channel flow. River water in stream and river channels can reach riparian areas and floodplains via overbank flow, which occurs when floodwaters flow over stream and river channels. *Id.* at 2-12 (citing Mertes 1997). Overland flow is the portion of streamflow derived from net precipitation that flows over the land surface to the nearest stream channel with no infiltration. *Id.* (citing Hewlett 1982). Overland flow can be generated by several mechanisms. Infiltration-excess overland flow occurs when the rainfall rates exceed the infiltration rates of land surfaces. *Id.* (citing Horton 1945). Saturation-excess overland flow occurs when precipitation inputs cause water tables to rise to land surfaces so that precipitation inputs to the land surfaces cannot infiltrate and flow overland. *Id.* (citing Dunne and Black 1970). Return flow occurs when water infiltrates, percolates through the unsaturated zones, enters saturated zones, and then returns to and flows over watershed surfaces, commonly at hillslope-floodplain transitions. *Id.* (citing Dunne and Black 1970).

Alluvium consists of deposits of clay, silt, sand, gravel, or other particulate materials that running water has deposited in a streambed, on a floodplain, on a delta, or in a fan at the base of a mountain.

These deposits occur near active river systems but also can be found in buried river valleys—the remnants of relict river systems. *Id.* (citing Lloyd and Lyke 1995). The Science Report was concerned primarily with alluvium deposited along active river networks. Commonly, alluvium is highly permeable, creating an environment conducive to groundwater flow. Alluvial groundwater (typically a mixture of river water and local, intermediate, and regional groundwater) moves through the alluvium. Together, the alluvium and alluvial ground water comprise alluvial aquifers. Alluvial aquifers are closely associated with floodplains and have high levels of hyporheic exchange. *Id.* (citing Stanford and Ward 1993; Amoros and Bornette 2002; Poole *et al*. 2006). Hyporheic exchange occurs when water moves from stream or river channels into alluvial deposits and then returns to the channels. *Id.* at 2-12, 4-8 (citing Sjodin *et al*. 2001; Bencala 2005; Gooseff *et al*. 2008; Leibowitz *et al*. 2008; Bencala 2011). Hyporheic exchange allows for the mixing of surface water and groundwater. It occurs during both high- and low-flow periods, and typically has relatively horizontal flowpaths at scales of meters to tens of meters and vertical flowpaths with depths ranging from centimeters to tens of meters. Science Report at 2-12 (citing Stanford and Ward 1988; Woessner 2000 and references therein; Bencala 2005).

Riparian areas and floodplains can have a diverse array of hydrologic inputs and outputs, which, in turn influence riparian/floodplain wetlands. Riparian areas and floodplains receive water from precipitation; overland flow from upland areas; local, intermediate, regional ground water; and hyporheic flows. *Id.* at 4-14 (National Research Council 2002; Richardson *et al*. 2005; Vidon *et al*. 2010). Water flowing over the land surface in many situations can infiltrate soils in riparian areas. *Id.* If low permeability subsoils or impervious clay layers are present, water contact with the plant root zone is increased and the water is subject to ecological functions (*e.g.*, sink or transformation) such as denitrification before it reaches the stream channel. *Id.* (citing National Research Council 2002; Naiman *et al*. 2005; Vidon *et al*. 2010).

The relative importance of the continuum of hydrologic flowpaths among river systems varies, creating streams and rivers with different flow duration (or hydrologic permanence) classes. Perennial streams or stream reaches typically flow year-round. They are maintained by local or regional ground-water discharge or streamflow from higher in the stream or river network. Intermittent streams or stream reaches flow continuously, but only at certain times of the year (*e.g.*, during certain seasons such as spring snowmelt); drying occurs when the water table falls below the channel bed elevation. Ephemeral streams or stream reaches flow briefly (typically hours to days) during and immediately following precipitation; these channels are above the water table at all times. Streams in these flow duration classes often transition longitudinally, from ephemeral to intermittent to perennial, as drainage area increases and elevation decreases along river networks. Many headwater streams, however, originate from permanent springs and flow directly into intermittent downstream reaches. At low flows, intermittent streams can contain dry segments alternating with flowing segments. Transitions between flow duration classes can coincide with confluences or with geomorphic discontinuities within the network. *Id.* at 2-14 (citing May and Lee 2004; Hunter *et al*. 2005). Variation of streamflow within river systems occurs in response to hydrologic events resulting from rainfall or snowmelt. Stormflow is streamflow that occurs in direct response to rainfall or snowmelt, which might stem from multiple groundwater and surface-water sources. *Id.* (citing Dunne and Leopold 1978). Baseflow is streamflow originating from groundwater discharge or seepage (locally or from higher in the river network), which sustains water flow through the channel between hydrologic events. Perennial streams have baseflow year-round; intermittent streams have baseflow seasonally; ephemeral streams have no baseflow. All three stream types convey stormflow.

Thus, perennial streams are more common in areas receiving high precipitation, whereas intermittent and ephemeral streams are more common in the more arid portions of the United States. *Id.* (citing NHD 2008). The distribution of headwater streams (perennial, intermittent, or ephemeral) as a proportion of total stream length is similar across geographic regions and climates.

Similar to streams, the occurrence and persistence of riparian/floodplain wetland and non-floodplain wetland hydrologic connections with river networks, via surface water (both channelized and nonchannelized) or groundwater, can be continuous, seasonal, or ephemeral, depending on the overall hydrologic conditions in the watershed. For example, a non-floodplain wetland might have a direct groundwater connection with a river network during wet conditions but an indirect regional ground-water connection (via groundwater recharge) under dry conditions. Another non-floodplain wetland might have direct surface water connections during wet periods (*e.g.*, fill and spill) and groundwater connections during drier periods. *See, e.g.*, Rains *et al.* 2008; Leibowitz and Vining 2003; Leibowitz *et al.* 2016. Geographically isolated wetlands can be hydrologically connected to the river network via nonchannelized surface flow (*e.g*., swales or overland flow) or groundwater.

The portions of river networks with flowing water expand and contract longitudinally (in an upstream-downstream direction) and laterally (in a stream channel-floodplain direction) in response to seasonal environmental conditions and precipitation events. *Id.* at 2-18 (citing Hewlett and Hibbert 1967; Gregory and Walling 1968; Dunne and Black 1970; Day 1978; Junk *et al*. 1989; Hunter *et al*. 2005; Wigington *et al*. 2005; Rains *et al*. 2006; Rains *et al*. 2008). The longitudinal expansion of channels with flowing water in response to major precipitation events represents a transient increase in the extent of headwater streams. Intermittent and perennial streams flow during wet seasons, whereas ephemeral streams flow only in response to rainfall or snowmelt. During dry periods, flowing portions of river networks are limited to perennial streams; these perennial portions of the river network can be discontinuous or interspersed with intermittently flowing stream reaches but may be flowing in the hyporheic zone for thousands of meters before emerging. *Id.* (citing Stanley *et al.* 1997; Hunter *et al*. 2005; Larned *et al*. 2010). Thus, stream reaches can be perennial even if the entire stream channel is not. As discussed previously, perennial streams typically flow year-round, intermittent streams flow continuously only at certain times of the year (*e.g.*, when they receive water from a spring, groundwater source, or surface snow such as melting snow), and ephemeral streams flow briefly in direct response to precipitation. In perennial streams, baseflow (the portion of flow contributed by groundwater) is typically present year-round. The definition of "perennial" allows for infrequent periods of severe drought to cause some perennial streams to not have flow year-round. Leopold 1994. Some studies have noted that perennial flow is present greater than 90% of the time, except in periods of severe drought, or greater than 80% of the time, and these definitions are consistent with the one used in the Science Report. Hedman and Osterkamp 1982; Hewlett 1982.

The dominant sources of water to a stream can shift during river network expansion and contraction. *Id.* (citing Malard *et al*. 1999; McGlynn and McDonnell 2003; McGlynn *et al.* 2004; Malard *et al.* 2006). Rainfall and snowmelt cause a river network to expand in two ways. First, local aquifers expand and water moves into dry channels, which increases the total length of the wet channel; the resulting intermittent streams will contain water during the entire wet season. *Id.* (citing Winter *et al*. 1998). Second, stormflow can cause water to enter ephemeral and intermittent streams. The larger the rainfall or snowmelt event, the greater the number of ephemeral streams and total length of flowing channels that occur within the river network. Ephemeral flows cease within days after rainfall or snowmelt ends, causing the length of wet channels to decrease and river networks to contract. The flowing portion of river networks further shrinks as the spatial extent of aquifers with ground water in contact with streams contract and intermittent streams dry. In many river systems across the United States, stormflow comprises a major portion of annual streamflow. *Id.* (citing Hewlett *et al*. 1977; Miller *et al*. 1988; Turton *et al*. 1992; Goodrich *et al*. 1997; Vivoni *et al*. 2006). In these systems, intermittent and ephemeral streams are major sources of river water. When rainfall or snowmelt induces stormflow in headwater streams or other portions of the river network, water flows downgradient through the network to its lower reaches. As water moves downstream through a river network, the hydrograph for a typical event broadens with a lower peak. This broadening of the hydrograph shape results from transient storage of water in river network channels and nearby alluvial aquifers. *Id.* (citing Fernald *et al*. 2001).

During very large hydrologic events, aggregate flows from headwaters and other tributary streams can result in overbank flooding in river reaches with floodplains; this occurrence represents lateral expansion of the river network. *Id.* (citing Mertes 1997). Water from overbank flows can recharge alluvial aquifers, supply water to floodplain wetlands, surficially connect floodplain wetlands to rivers, and shape the geomorphic features of the floodplain. *Id.* at 2-18 to 2-19 (citing Wolman and Miller 1960; Hammersmark *et al*. 2008). Bidirectional exchanges of water between ground water and river networks, including hyporheic flow, can occur under a wide range of streamflows, from flood flows to low flows. *Id.* at 2-19 to 2-20 (citing National Research Council 2002; Naiman *et al*. 2005; Vivoni *et al*. 2006).

Many studies have documented the fact that riparian/floodplain wetlands can attenuate flood pulses of streams and rivers by storing excess water from streams and rivers. Bullock and Acreman (2003) reviewed wetland studies and reported that wetlands reduced or delayed floods in 23 of 28 studies. *Id.* at 2-21. For example, Walton *et al*. (1996) found that peak discharges between upstream and downstream gaging stations on the Cache River in Arkansas were reduced 10–20% primarily due to floodplain water storage. *Id.* Locations within floodplains and riparian areas with higher elevations likely provide flood storage less frequently than lower elevation areas.

The interactions of high flows with floodplains and associated alluvial aquifers of river networks are important determinants of hydrologic and biogeochemical conditions of rivers. *Id.* at 2-21 (citing Ward 1989; Stanford and Ward 1993; Boulton *et al*. 1998; Burkart *et al*. 1999; Malard *et al*. 1999; Amoros and Bornette 2002; Malard *et al*. 2006; Poole 2010). Bencala (1993; 2011) noted that streams and rivers are not pipes; they interact with the alluvium and geologic materials adjoining and under channels. *Id.* In streams or river reaches constrained by topography, significant floodplain and near-channel alluvial aquifer interactions are limited. In reaches with floodplains, however, stormflow commonly supplies water to alluvial aquifers during high-flow periods through the process of bank storage. *Id.* at 2-22 (citing Whiting and Pomeranets 1997; Winter *et al*. 1998; Chen and Chen 2003). As streamflow decreases after hydrologic events, the water stored in these alluvial aquifers can serve as another source of baseflow in rivers.

In summary, the extent of wetted channels is dynamic because interactions between surface water in the channel and alluvial ground water, via hyporheic exchange, determine open-channel flow. The flowing portion of river networks expands and contracts in two primary dimensions: (1) longitudinally, as intermittent and ephemeral streams wet up and dry; and (2) laterally, as floodplains and associated alluvial aquifers gain (via overbank flooding, bank storage, and hyporheic exchange) and lose (via draining of alluvial aquifers and evapotranspiration) water. Vertical ground-water exchanges between streams and rivers and underlying alluvium are also key connections, and variations in these vertical exchanges contribute to the expansion and contraction of the portions of river networks with open-channel flow. Numerous studies have documented expansion and contraction of river systems; the temporal and spatial pattern of this expansion and contraction varies in response to many factors, including interannual and long-term dry cycles, climatic conditions, and watershed characteristics. *Id.* (citing Gregory and Walling 1968; Cayan and Peterson 1989; Fleming *et al*. 2007).

Influence of Streams and Wetlands on Downstream Waters

The structure and function of rivers are highly dependent on the constituent materials stored in and transported through them. Most of these materials, broadly defined here as any physical, chemical, or biological entity, including water, heat energy, sediment, wood, organic matter, nutrients, chemical contaminants, and organisms, originate outside of the river; they originate from either the upstream river network or other components of the river system, and then are transported to the river by water movement or other mechanisms. Thus, the fundamental way in which streams and wetlands affect river structure and function is by altering fluxes of materials to the river. This alteration of material fluxes depends on two key factors: (1) functions within streams and wetlands that affect material fluxes, and (2) connectivity (or isolation) between streams and wetlands and rivers that allows (or prevents) transport of materials between the systems. *Id.*

Streams and wetlands affect the amounts and types of materials that are or are not delivered to downstream waters, ultimately contributing to the structure and function of those waters. Leibowitz *et al*. (2008) identified three functions, or general mechanisms of action, by which streams and wetlands influence material fluxes into downstream waters: source, sink, and refuge. *Id.* at 2-22 to 2-23. The Science Report expanded on this framework to include two additional functions: lag and transformation. These five functions provide a framework for understanding how physical, chemical, and biological connections between streams and wetlands and downstream waters influence river systems.

These five functions are neither static nor mutually exclusive, and often the distinctions between them are not sharp. A stream or wetland can provide different functions at the same time. These functions can vary with the material considered (*e.g.*, acting as a source of organic matter and a sink for nitrogen) and can change over time (*e.g.*, acting as a water sink when evapotranspiration is high and a water source when evapotranspiration is low). The magnitude of a given function also is likely to vary temporally; for example, streams generally are greater sources of organic matter and contaminants during high flows. *Id.* at 2-24.

Leibowitz *et al*. (2008) explicitly focused on functions that benefit downstream waters, but these functions also can have negative effects—for example, when streams and wetlands serve as sources of chemical contamination. *Id.* In fact, benefits need not be linear with respect to concentration; a beneficial material could be harmful at higher concentrations due to nonlinear and threshold effects. For example, nitrogen can be beneficial at lower concentrations but can reduce water quality at higher concentrations. Although the Science Report focused primarily on the effects of streams and wetlands on downstream waters, these same functions can describe effects of downstream waters on streams and wetlands (*e.g.*, downstream rivers can serve as sources of colonists for upstream tributaries). *Id.*

Because many of these functions depend on import of materials and energy into streams and wetlands, distinguishing between actual function and potential function is instructive. For example, a wetland with appropriate conditions (*e.g.*, a reducing environment and denitrifying bacteria) is a potential sink for nitrogen: If nitrogen applied to the land is imported into the wetland, the wetland can remove it by denitrification. The wetland will not serve this function, however, if nitrogen is not imported. Thus, even if a stream and wetland do not currently serve a function, it has the potential to provide that function under appropriate conditions (*e.g.*, when material imports or environmental conditions change). These functions can be instrumental in protecting those waters from future impacts. Ignoring potential function also can lead to the paradox that degraded streams and wetlands (*e.g*., those receiving nonpoint-source nitrogen inputs) receive more protection than less impacted systems. *Id.* (citing Leibowitz *et al*. 2008).

Three factors influence the effect that material and energy fluxes from streams and wetlands have on downstream waters: (1) proportion of the material originating from (or reduced by) streams and wetlands relative to the importance of other system components, such as the river itself; (2) residence time of the material in the downstream water; and (3) relative importance of the material. *Id.* In many cases, the effects on downstream waters need to be considered in aggregate. For example, the contribution of material by a particular stream and wetland (*e.g*., a specific ephemeral stream) might be small, but the aggregate contribution by an entire class of streams and wetlands (*e.g*., all ephemeral streams in the river network) might be substantial. Similarly, the functions of a given non-floodplain wetland relative to nitrogen removal may be small, but the cumulative effects of nitrogen removal by the extant wetland on the landscape will be substantive. *See, e.g.*, Evenson *et al.* 2018; Evenson *et al.* 2021. Integrating contributions over time also might be necessary, taking into account the frequency, duration, and timing of material export and delivery. Considering the cumulative material fluxes that originate from a specific stream and wetland, rather than the individual materials separately, is essential in understanding the effects of material fluxes on downstream waters. Science Report at 2-26.

In general, the more frequently a material is delivered to the river (*i.e*., high connectivity), the greater its effect. The effect of an infrequently supplied material, however, can also be large if the material has a long residence time in the river and wetlands. *Id.* (citing Leibowitz *et al.* 2008). For example, woody debris might be exported to downstream waters infrequently but it can persist in downstream channels. In addition, some materials are more important in defining the structure and function of a river. For example, woody debris can have a large effect on river structure and function because it affects water flow, sediment and organic matter transport, and habitat. *Id.* (citing Harmon *et al*. 1986; Gurnell *et al*. 1995). Another example is salmon migrating to a river: They can serve as a keystone species to regulate other populations and as a source of marine-derived nutrients. *Id.* (citing Schindler *et al*. 2005). For functions relating to sinks and transformations, often the less frequently a material is delivered to the river (*i.e.*, high disconnectivity), the greater the effect. More examples of disconnectivity via sink functions are provided at the end of this section.

The functions discussed above represent general mechanisms by which streams and wetlands influence downstream waters. For these altered material and energy fluxes to affect a river, however, transport mechanisms that deliver (or could deliver) these materials to the river are necessary. Connectivity describes the degree to which components of a system are connected and interact through various transport mechanisms; connectivity is determined by the characteristics of both the physical landscape and the biota of the specific system. *Id.* This definition is related to, but is distinct from, definitions of connectivity based on the actual flow of materials between system components. *Id.* (citing, *e.g.*, Pringle 2001). That connectivity among river-system components, including streams and wetlands, plays a significant role in the structure and function of these systems is not a new concept. In fact, much of the theory developed to explain how these systems work focuses on connectivity and linkages between system components. *Id.* (citing, *e.g.*, Vannote *et al.* 1980; Newbold *et al*. 1982a; Newbold *et al*. 1982b; Junk *et al*. 1989; Ward 1989; Benda *et al*. 2004b; Thorp *et al*. 2006).

In addition to its central role in defining river systems, water movement through the river system is the primary mechanism providing physical connectivity both within river networks and between those networks and the surrounding landscape. *Id.* (citing Fullerton *et al*. 2010). Hydrologic connectivity results from the flow of water, which provides a "hydraulic highway" along which physical, chemical, and biological materials associated with the water are transported (*e.g.*, sediment, woody debris, contaminants, organisms). *Id.* (citing Fausch *et al*. 2002).

Ecosystem functions within a river system are driven by interactions between the river system's physical environment and the diverse biological communities living within it. *Id.* (Wiens 2002; Schroder 2006). Thus, river system structure and function also depend on biological connectivity among the system's populations of aquatic and semiaquatic organisms. Biological connectivity refers to the movement of organisms, including transport of reproductive materials (*e.g*., seeds, eggs, genes) and dormant stages, through river systems. *Id.* at 2-26 to 2-27. These movements link aquatic habitats and populations in different locations through several processes important for the survival of individuals, populations, and species. *Id.* at 2-27. Movements include dispersal, or movement away from an existing population or parent organism; migration, or long-distance movements occurring seasonally; localized movement over an organism's home range to find food, mates, or refuge from predators or adverse conditions; and movement to different habitats to complete life-cycle requirements. Biological connectivity can occur within aquatic ecosystems or across ecosystem or watershed boundaries, and it can be multidirectional. For example, organisms can move downstream from perennial, intermittent, and ephemeral headwaters to rivers; upstream from estuaries to rivers to headwaters; or laterally between floodplain wetlands and open waters, non-floodplain wetlands and open waters, rivers, lakes, or other water bodies.

As noted above, streams, rivers, wetlands, and open waters are not pipes; they provide opportunities for water to interact with internal components (*e.g.*, alluvium, organisms) through the five functions (*i.e.*, sink, source, lag, transformation, and refugia) by which streams, wetlands, and open waters alter material fluxes. *Id.* (citing Bencala 1993; Bencala *et al*. 2011). Connectivity between streams and wetlands provides opportunities for material fluxes to be altered sequentially by multiple streams and wetlands as the materials are transported downstream. The aggregate effect of these sequential fluxes determines the proportion of material that ultimately reaches the river. The form of the exported material can be transformed as it moves down the river network, however, making quantitative assessments of the importance of individual stream and wetland resources within the entire river system difficult. For example, organic matter can be exported from headwater streams and consumed by downstream macroinvertebrates. Those invertebrates can drift farther downstream and be eaten by juvenile fish that eventually move into the mainstem of the river, where they feed further and grow.

The assessment of stream and wetland influence on rivers also is complicated by the cumulative time lag resulting from these sequential transformations and transportations. For example, removal of nutrients by streambed algal and microbial populations, subsequent feeding by fish and insects, and release by excretion or decomposition delays the export of nutrients downstream.

Although the Science Report primarily focused on the benefits that connectivity can have on downstream systems, isolation (or more accurately, degrees of "disconnectivity") also can have important positive effects on the condition and function of downstream waters, especially when considered in the aggregate. Nevertheless, the literature reviewed supports the conclusion that sink functions of non-floodplain wetlands, which result in part from their relative isolation, will affect a downstream water when these wetlands are situated between the downstream water and known point or nonpoint sources of pollution, and thus intersect flowpaths between the pollutant source and downstream waters. For example, waterborne contaminants that enter a non-floodplain wetland (*e.g.*, excessive nitrate) are processed through transformations or sink functions and hence are not transported to a river system because the wetland is on the "less frequently connected" side of the aquatic connectivity continuum (*i.e.*, if the wetland is hydrologically isolated from the river, except by non-hydrologic pathways. *Id.* at 2-28 to 2-29). Furthermore, increased hydrologic isolation, again when considered in the aggregate, can attenuate stormflows, decoupling storm peaks and decreasing flood risks to downgradient communities (*e.g.*, Golden *et al.* 2021b). Increased isolation can also decrease the spread of pathogens and invasive species, and increase the rate of local adaptation. *Id.* at 2-29 (citing, *e.g.*, Hess 1996; Bodamer and Bossenbroek 2008; Fraser *et al*. 2011). Thus, both connectivity and isolation should be considered when examining material fluxes from streams and wetlands, and biological interactions should be viewed in light of the natural balance between these two factors.

Spatial and Temporal Variability of Connectivity

Connectivity is not a fixed characteristic of a system, but varies over space and time. *Id.* (citing Ward 1989; Leibowitz 2003; Leibowitz and Vining 2003). Variability in hydrologic connectivity results primarily from the longitudinal and lateral expansion and contraction of the river network and transient connection with other components of the river system. The variability of connectivity can be described in terms of frequency, duration, magnitude, timing, and rate of change. When assessing the effects of connectivity or isolation and the five general functions (sources, sinks, refuges, lags, and transformations) on downstream waters, dimensions of time and space must be considered. *Id.* Water or organisms transported from distant headwater streams or wetlands generally will take longer to travel to a larger river than materials transported from streams or wetlands near the river. This can introduce a lag between the time the function occurs and the time the material arrives at the river. In addition, the distribution of streams and wetlands can be a function of their distance from the mainstem channel. For example, in a classic dendritic network, there is an inverse geometric relationship between number of streams and stream order. In such a case, the aggregate level of function could be greater for terminal source streams, compared to higher order or lateral source streams. This is one reason why watersheds of terminal source streams often provide the greatest proportion of water for major rivers. Connectivity, however, results from many interacting factors. For example, the relationship between stream number and order can vary with the shape of the watershed and the configuration of the network.

The expansion and contraction of river networks affects the extent, magnitude, timing, and type of hydrologic connectivity. For example, intermittent and ephemeral streams flow only during wetter seasons or during and immediately following precipitation events. Thus, the spatial extent of connectivity between streams and wetlands and rivers increases greatly during these high-flow events because intermittent and ephemeral streams are estimated to account for 59% of the total length of streams in the contiguous United States. *Id.* (citing Nadeau and Rains 2007). Changes in the spatial extent of connectivity due to expansion and contraction are even more pronounced in the arid and semiarid Southwest, where more than 80% of all streams are intermittent or ephemeral. *Id.* at 2-29 to 2-30 (citing Levick *et al*. 2008). Expansion and contraction also affect the magnitude of connectivity because larger flows provide greater potential for material transport. *Id.* at 2-30.

Besides affecting the spatial extent and magnitude of hydrologic connectivity, expansion and contraction of the stream network also affect the duration and timing of flow in different portions of the network. Perennial streams have year-round surface water connectivity with a downstream river, while intermittent streams have seasonal connectivity. The temporal characteristics of connectivity for ephemeral streams depend on the duration and timing of storm events. Similarly, connectivity between wetlands and downstream waters can range from permanent to seasonal to episodic.

The expansion and contraction of river systems also affect the type of connectivity. For example, during wet periods when input from precipitation can exceed evapotranspiration and available storage, non-floodplain wetlands could have connectivity with other wetlands or streams through surface spillage. *Id.* (citing Leibowitz and Vining 2003; Rains *et al*. 2008). When spillage ceases due to drier conditions, hydrologic connectivity could only occur through groundwater. *Id.* (citing Rains *et al*. 2006; Rains *et al*. 2008).

When the flow of water mediates dispersal, migration, and other forms of biotic movement, biological and hydrologic connectivity can be tightly coupled. For example, seasonal flooding of riparian/floodplain wetlands creates temporary habitat that fish, aquatic insects, and other organisms use. *Id.* (citing Junk *et al*. 1989; Smock 1994; Tockner *et al*. 2000; Robinson *et al*. 2002; Tronstad *et al*. 2007). Factors other than hydrologic dynamics also can affect the temporal and spatial dynamics of biological connectivity. Such factors include movement associated with seasonal habitat use and shifts in habitat use due to life-history changes, quality or quantity of food resources, presence or absence of favorable dispersal conditions, physical differences in aquatic habitat structure, or the number and sizes of nearby populations. *Id.* (citing Moll 1990; Smock 1994; Huryn and Gibbs 1999; Lamoureux and Madison 1999; Gibbons *et al*. 2006; Gamble *et al*. 2007; Grant *et al*. 2007; Subalusky *et al*. 2009a; Schalk and Luhring 2010). For a specific river system with a given spatial configuration, variability in biological connectivity also occurs due to variation in the dispersal distance of organisms and reproductive propagules. *Id.* (citing Semlitsch and Bodie 2003).

Finally, just as connectivity from temporary or seasonal wetting of channels can affect downstream waters, temporary or seasonal drying also can affect river networks. Riverbeds or streambeds that temporarily dry up are used by aquatic organisms that are specially adapted to alternating flowing and dry conditions, and can serve as egg and seed banks for several organisms, including aquatic invertebrates and plants. *Id* at 2-30 (citing Steward *et al*. 2012). These temporary dry areas also can affect nutrient dynamics due to reduced microbial activity, increased oxygen availability, and inputs of terrestrial sources of organic matter and nutrients. *Id.* (citing Steward *et al*. 2012).

Numerous factors affect physical, chemical, and biological connectivity within river systems. These factors operate at multiple spatial and temporal scales, and interact with each other in complex ways to determine where components of a system fall on the connectivity-isolation gradient at a given time. *Id.* at 2-30 to 2-31. The Science Report focused on five key factors: climate, watershed characteristics, spatial distribution patterns, biota, and human activities and alterations. *Id.* at 2-31. These are by no means the only factors influencing connectivity, but they illustrate how many different variables shape physical, chemical, and biological connectivity.

Climate-watershed Characteristics

The movement and storage of water in watersheds varies with climatic, geologic, physiographic, and edaphic characteristics of river systems. *Id.* (citing Winter 2001; Wigington *et al*. 2013). At the largest spatial scale, climate determines the amount, timing, and duration of water available to watersheds and river basins. Key characteristics of water availability that influence connectivity include annual water surplus (precipitation minus evapotranspiration), timing (seasonality) of water surplus during the year that is heavily influenced by precipitation timing and form (*e.g.*, rain, snow), and rainfall intensity.

Annual runoff generally reflects water surplus and varies widely across the United States. Seasonality of water surplus during the year determines when and for how long runoff and ground-water recharge occur. Precipitation and water surplus in the eastern United States is less seasonal than in the West. *Id.* (Finkelstein and Truppi 1991). The Southwest experiences summer monsoonal rains, while the West Coast and Pacific Northwest receive most precipitation during the winter season. *Id.* (citing Wigington *et al*. 2013). Throughout the West, winter precipitation in the mountains occurs as snowfall, where it accumulates in seasonal snowpack and is released during the spring and summer melt seasons to sustain streamflow during late spring and summer months. *Id.* (citing Brooks *et al*. 2012). The flowing portions of river networks tend to have their maximum extent during seasons with the highest water surplus, when conditions for flooding are most likely. Typically, the occurrence of ephemeral and intermittent streams is greatest in watersheds with low annual runoff and high water surplus seasonality but also is influenced by watershed geologic and edaphic features. *Id.* (citing Gleeson *et al.* 2011).

Rainfall intensity can affect hydrologic connectivity in localities where watershed surfaces have low infiltration capacities relative to rainfall intensities. Infiltration-excess overland flow occurs when rainfall intensity exceeds watershed surface infiltration, and it can be an important mechanism in providing water to wetlands and river networks (Goodrich *et al*. 1997; Levick *et al*. 2008). Overland flow is common at low elevations in the Southwest, due to the presence of desert soils with low infiltration capacities combined with relatively high rainfall intensities. The Pacific Northwest has low rainfall intensities, whereas many locations in the Mid-Atlantic, Southeast, and Great Plains have higher rainfall intensities. The prevalence of impermeable surfaces in urban areas can generate overland flow in virtually any setting. *Id.* (citing Booth *et al*. 2002).

River system topography and landscape form can profoundly influence river network drainage patterns, distribution of wetlands, and ground-water and surface-water flowpaths. Winter (2001) described six generalized hydrologic landscape forms common throughout the United States. *Id.*

Mountain Valleys and Plateaus and High Plains have constrained valleys through which streams and rivers flow. *Id.* at 2-31, 2-33. The Mountain Valleys form has proportionally long, steep sides with narrow to nonexistent floodplains resulting in the rapid movement of water downslope. In contrast, Riverine Valleys have extensive floodplains that promote strong surface-water, hyporheic water, and alluvial ground-water connections between wetlands and rivers. *Id.* at 2-33 to 2-34. Small changes in water table elevations can influence the water levels and hydrologic connectivity of wetlands over extensive areas in this landscape form. Local ground-water flowpaths are especially important in Hummocky Terrain. Constrained valleys, such as the Mountain Valley landform, have limited opportunities for the development of floodplains and alluvial aquifers, whereas unconstrained valleys, such as the Riverine Valley landform, provide opportunities for the establishment of floodplains. Some river basins can be contained within a single hydrologic landscape form, but larger river basins commonly comprise complexes of hydrologic landscape forms. For example, the James River in Virginia, which flows from mountains through the Piedmont to the Coastal Plain, is an example of a Mountain Valley-High Plateaus and Plains-Coastal Terrain-Riverine Valley complex.

Floodplain hydrologic connectivity to rivers and streams occurs primarily through overbank flooding, shallow ground-water flow, and hyporheic flow. Water-table depth can influence connectivity across a range of hydrologic landscape forms, but especially in floodplains. Rivers and wetlands can shift from losing reaches (or recharge wetlands) during dry conditions to gaining reaches (or discharge wetlands) during wet conditions. Wet, high water-table conditions influence both ground-water and surface-water connectivity. When water tables are near the watershed surface, they create conditions in which swales and small stream channels fill with water and flow to nearby water bodies. *Id.* at 2-34 (citing Wigington *et al*. 2003; Wigington *et a*l. 2005). Nanson and Croke (1992) noted that a complex interaction of fluvial processes forms floodplains, but their character and evolution are essentially a product of stream power (the rate of energy dissipation against the bed and banks of a river or stream) and sediment characteristics. *Id.* They proposed three floodplain classes based on the stream power-sediment characteristic paradigm: (1) high-energy noncohesive, (2) medium-energy noncohesive, and (3) low-energy cohesive. The energy term describes stream power during floodplain formation, and the cohesiveness term depicts the nature of material deposited in the floodplain. In addition, hyporheic and alluvial aquifer exchanges are more responsive to seasonal discharge changes in floodplains with complex topography. *Id.* (citing Poole *et al*. 2006).

Within hydrologic landscape forms, soil and geologic formation permeabilities are important determinants of hydrologic flowpaths. Permeable soils promote infiltration that results in ground-water hydrologic flowpaths, whereas the presence of impermeable soils with low infiltration capacities is conducive to overland flow. In situations in which ground-water outflows from watersheds or landscapes dominate, the fate of water depends in part on the permeability of deeper geologic strata. The presence of an aquiclude (a confining layer) near the watershed surface leads to shallow subsurface flows through soil or geologic materials.

These local ground-water flowpaths connect portions of watersheds to nearby wetlands or streams. *Id.* at 2-35. Alternatively, if a deep permeable geologic material (an aquifer) is present, water is likely to move farther downward within watersheds and recharge deeper aquifers. *Id.* at 2-35 to 2-36. The permeability of soils and geologic formations both can influence the range of hydrologic connectivity between non-floodplain wetlands and river networks. *Id.* at 2-36.

Climate and watershed characteristics directly affect spatial and temporal patterns of connectivity between streams and wetlands and rivers by influencing the timing and extent of river network expansion and contraction. *Id.* at 2-38. They also influence the spatial distribution of water bodies within a watershed, and in particular, the spatial relationship between those water bodies and the river. *Id.* (citing, *e.g.*, Tihansky 1999)

Hydrologic connectivity between streams and rivers can be a function of the distance between the two water bodies. *Id.* (citing Bracken and Croke 2007; Peterson *et al*. 2007). If channels functioned as pipes, this would not be the case, and any water and its constituent materials exported from a stream eventually would reach the river. Because streams and rivers are not pipes, water can be lost from the channel through evapotranspiration and bank storage and diluted through downstream inputs. *Id.* (Bencala 1993). Thus, material from a headwater stream that flowed directly into the river would be subject to less transformation or dilution. On the other hand, the greater the distance a material travels between a particular stream reach and the river, the greater the opportunity for that material to be altered (*e.g.*, taken up, transformed, or assimilated) in intervening stream reaches; this alteration could reduce the material's direct effect on the river, but it could also allow for beneficial transformations. For example, organic matter exported from a headwater stream located high in a drainage network might never reach the river in its original form, instead becoming reworked and incorporated into the food chain. Similarly, higher order streams generally are located closer to rivers and, therefore, can have higher connectivity than upstream reaches of lower order. Note that although an individual low-order stream can have less connectivity than a high-order stream, a river network has many more low-order streams, which can represent a large portion of the watershed; thus, the magnitude of the cumulative effect of these low-order streams can be significant.

The relationship between streams and the river network is a function, in part, of basin shape and network configuration. Elongated basins tend to have trellis networks where relatively small streams join a larger mainstem; compact basins tend to have dendritic networks with tree-like branching, where streams gradually increase in size before joining the mainstem. This network configuration describes the incremental accumulation of drainage area along rivers, and therefore provides information about the relative contributions of streams to downstream waters. Streams in a trellis network are more likely to connect directly to a mainstem, compared with a dendritic network. The relationship between basin shape, network configuration, and connectivity, however, is complex. A mainstem in a trellis network also is more likely to have a lower stream order than one in a dendritic network. *Id.* at 2-38 to 2-39.

Distance also affects connectivity between non-floodplain and riparian/floodplain wetlands and downstream waters. *Id.* at 2-39. Riverine wetlands that serve as origins for lateral source streams that connect directly to a mainstem river have a more direct connection to that river than wetlands that serve as origins for terminal source streams high in a drainage network. This also applies to riparian/floodplain wetlands that have direct surface-water connections to streams or rivers. If geographically isolated non-floodplain wetlands have surface-water outputs (*e.g.*, depressions that experience surface-water spillage or ground-water seeps), the probability that surface water will infiltrate or be lost through evapotranspiration increases with distance. This is a beneficial function in attenuating storm flows and providing area (and time) for biogeochemical processing. Golden *et al.* 2021b; Evenson *et al*. 2018. For non-floodplain wetlands connected through ground-water flows, less distant areas are generally connected through shallower flowpaths, assuming similar soil and geologic properties. These shallower groundwater flows have the greatest interchange with surface waters and travel between points in the shortest amount of time. Although elevation is the primary factor determining areas that are inundated through overbank flooding, connectivity with the river generally will be higher for riparian/floodplain wetlands located near the river's edge compared with riparian/floodplain wetlands occurring near the floodplain edge.

Distance from the river network also influences biological connectivity among streams and wetlands. For example, mortality of an organism due to predators and natural hazards generally increases with the distance it has to travel to reach the river network. The likelihood that organisms or propagules traveling randomly or by diffusive mechanisms such as wind will arrive at the river network decreases as distance increases.

The distribution of distances between wetlands and river networks depends on both the drainage density of the river network (the total length of stream channels per unit area) and the density of wetlands. Science Report at 2-40. Climate and watershed characteristics influence these spatial patterns, which can vary widely.

Biota

Biological connectivity results from the interaction of physical characteristics of the environment—especially those facilitating or restricting dispersal—and species' traits or behaviors, such as life-cycle requirements, dispersal ability, or responses to environmental cues. *Id.* Thus, the types of biota within a river system are integral in determining the river system's connectivity, and landscape features or species traits that necessitate or facilitate movement of organisms tend to increase biological connectivity among water bodies.

Diadromous fauna (*e.g.*, Pacific and Atlantic salmon, certain freshwater shrimps and snails, American eels), which require both freshwater and marine habitats over their life cycles and therefore migrate along river networks, provide one of the clearest illustrations of biological connectivity. Many of these taxa are either obligate or facultative users of headwater streams, meaning that they either require (obligate) or can take advantage of (facultative) these habitats; these taxa thereby create a biological connection along the entire length of the river network. *Id.* (citing Erman and Hawthorne 1976; Wigington *et al*. 2006). For example, many Pacific salmon species spawn in headwater streams, where their young grow for a year or more before migrating downstream, living their adult life stages in the ocean, and then migrating back upstream to spawn. Many taxa also can exploit temporary hydrologic connections between rivers and floodplain wetland habitats caused by flood pulses, moving into these wetlands to feed, reproduce, or avoid harsh environmental conditions and then returning to the river network. *Id.* at 2-40, 2-43 (citing Copp 1989; Junk *et al*. 1989; Smock 1994; Tockner *et al*. 2000; Richardson *et al*. 2005).

Biological connectivity does not solely depend on diadromy, however, as many non-diadromous organisms are capable of significant movement within river networks. *Id.* at 2-40. For example, organisms such as pelagic-spawning fish and mussels release directly into the water eggs or larvae that disperse downstream with water flow; many fish swim significant distances both upstream and downstream; and many aquatic macroinvertebrates move or drift downstream. *Id.* at 2-40 (citing, *e.g.*, Elliott 1971; Müller 1982; Gorman 1986; Brittain and Eikeland 1988; Platania and Altenbach 1998; Elliott 2003; Hitt and

Angermeier 2008; Schwalb *et al*. 2010). Taxa capable of movement over land, via either passive transport (*e.g*., wind dispersal or attachment to animals capable of terrestrial dispersal) or active movement (*e.g*., terrestrial dispersal or aerial dispersal of winged adult stages), can establish biotic linkages between river networks and wetlands, as well as linkages across neighboring river systems. Science Report at 2-40 (citing Hughes *et al*. 2009).

Gradients of biological connectivity (*i.e.*, the active or passive movements of organisms through water or air and over land that connect populations) are determined primarily by species assemblages, and by features of the landscape (*e.g.*, climate, geology, terrain) that facilitate or impede the movement of organisms. Science Report 6-10. For example, mass river insect migrations into headwater streams provide food subsidies to support young-of-year fish (Uno and Power 2015), including diadromous salmon (Bramblett *et al.* 2002). On the other hand, lower rates of movement between more isolated habitats can decrease the spread of pathogens (*e.g.*, Hess 1996) and invasive species (*e.g.*, Bodamer and Bossenbroek 2008) and increase regional biodiversity through adaptation to local conditions, (*e.g.*, Fraser *et al.* 2011), increasing resiliency of aquatic species to changing landuse and climate.

Human Activities and Alterations

Human activities frequently alter connectivity between headwater streams, riparian/floodplain wetlands, non-floodplain wetlands, and downgradient river networks. *Id.* at 2-44. In doing so, they alter the transfer and movement of materials and energy between river system components. In fact, the individual or cumulative effects of headwater streams and wetlands on river networks often become discernible only following human-mediated changes in degree of connectivity. These human-mediated changes can increase or decrease hydrologic and biological connectivity (or, alternatively, decrease or increase hydrologic and biological isolation). *Id* at 2-44 to 2-45. For example, activities and alterations such as dams, levees, water abstraction, piping, channelization, and burial can reduce hydrologic connectivity between streams and wetlands and rivers, whereas activities and alterations such as wetland drainage, irrigation, impervious surfaces, interbasin transfers, and channelization can enhance hydrologic connections. *Id.* at 2-45. Biological connectivity can be affected similarly: For example, dams and impoundments might impede biotic movement, whereas nonnative species introductions artificially increase biotic movement. Further complicating the issue is that a given activity or alteration might simultaneously increase and decrease connectivity, depending on which part of the river network is considered. For example, channelization and levee construction reduce lateral expansion of the river network (thereby reducing hydrologic connections with floodplains), but might increase this connectivity downstream due to increased frequency and magnitude of high flows.

The greatest human impact on riparian/floodplain wetlands and non-floodplain wetlands has been through wetland drainage, primarily for agricultural purposes. Estimates show that, in the conterminous United States, states have lost more than half their original wetlands (50%), with some losing more than 90%; wetland surface areas also have declined significantly. *Id.* (citing Dahl 1990).

Drainage causes a direct loss of function and connectivity in cases where wetland characteristics are completely lost. *Id.* at 2-45. In the Des Moines lobe of the prairie pothole region, where more than 90% of the wetlands have been drained, a disproportionate loss of smaller and larger wetlands has occurred. Accompanying this loss have been significant decreases in perimeter area ratios—which are associated with greater biogeochemical processing and groundwater recharge rates—and increased mean distances between wetlands, which reduces biological connectivity. *Id.* at 2-45 to 2-46 (citing Van Meter and Basu 2015). Wetland drainage also increases hydrologic connectivity between the landscape—including drained areas that retain wetland characteristics—and downstream waters. Effects of this enhanced hydrologic connectivity include (1) reduced water storage and more rapid conveyance of water to the network, with subsequent increases in total runoff, baseflows, stormflows, and flooding risk; (2) increased delivery of sediment and pollutants to downstream waters; and (3) increased transport of water-dispersing organisms. *Id.* at 2-46 to 2-47 (citing Babbitt and Tanner 2000; Baber *et al*. 2002; Mulhouse and Galatowitsch 2003; Wiskow and van der Ploeg 2003; Blann *et al*. 2009). Biological connectivity, however, also can decrease with drainage and ditching, as average distances between wetlands increase and limit the ability of organisms to disperse between systems aerially or terrestrially. *Id.* at 2-47 (citing Leibowitz 2003). Groundwater withdrawal also can affect wetland connectivity by reducing the number of wetlands. Of particular concern in the arid Southwest is that ground-water withdrawal can decrease regional and local water tables, reducing or altogether eliminating ground-water-dependent wetlands. *Id.* (citing Patten *et al*. 2008). Groundwater withdrawal, however, also can increase connectivity in areas where that ground water is applied or consumed.

B. Peer Review of Report

The process for developing the Science Report followed standard information quality guidelines for EPA. In September 2013, EPA released a draft of the Science Report for an independent SAB review and invited submissions of public comments for consideration by the SAB panel. In October 2014, after several public meetings and hearings, the SAB completed its peer review of the draft Science Report (*hereafter*, “SAB 2014a”). The SAB was highly supportive of the draft Science Report’s conclusions regarding streams, riparian and floodplain wetlands, and open waters, and recommended strengthening the conclusion regarding non-floodplain waters to include a more definitive statement that reflects how numerous functions of such waters sustain the integrity of downstream waters. SAB 2014a. The final peer review report is available on the SAB website, as well as in the docket for this final rulemaking. EPA revised the draft Science Report based on comments from the public and recommendations from the SAB panel.

The SAB was established in 1978 by the Environmental Research, Development, and Demonstration Authorization Act (ERDDAA), to provide independent scientific and technical advice to the EPA Administrator on the technical basis for Agency positions and regulations. Advisory functions include peer review of EPA’s technical documents, such as the Science Report. At the time the peer review was completed, the chartered SAB was comprised of more than 50 members from a variety of sectors including academia, non-profit organizations, foundations, state governments, consulting firms, and industry. To conduct the peer review, EPA’s SAB staff formed an ad hoc panel based on nominations from the public to serve as the primary reviewers. The panel consisted of 27 technical experts in an array of relevant fields, including hydrology, wetland and stream ecology, biology, geomorphology, biogeochemistry, and freshwater science. Similar to the chartered SAB, the panel members represented sectors including academia, a federal government agency, non-profit organizations, and consulting firms. The chair of the panel was a member of the chartered SAB.

The SAB process is open and transparent, consistent with the Federal Advisory Committee Act, 5 U.S.C., App 2, and agency policies regarding Federal advisory committees. Consequently, the SAB has an approved charter, which must be renewed biennially, announces its meetings in the *Federal Register*, and provides opportunities for public comment on issues before the Board. The SAB staff announced via the *Federal Register* that they sought public nominations of technical experts to serve on the expert panel: SAB Panel for the Review of the EPA Water Body Connectivity Report (via a similar process the public also is invited to nominate chartered SAB members). 78 FR 15012 (March 8, 2013). The SAB staff then invited the public to comment on the list of candidates for the panel. Once the panel was selected, the SAB staff posted a memo on its website addressing the formation of the panel and the set of determinations that were necessary for its formation (*e.g.*, no conflicts of interest). In the public notice of the first public meetings interested members of the public were invited to submit relevant comments for the SAB Panel to consider pertaining to the review materials, including the charge to the Panel. Over 133,000 public comments were received by the Docket. Every meeting was open to the public, noticed in the *Federal Register*, and had time allotted for the public to present their views. In total, the Panel held a two-day in-person meeting in Washington, DC, in December 2013, and three four-hour public teleconferences in April, May, and June 2014. The SAB Panel also compiled four draft versions of its peer review report to inform and assist the meeting deliberations that were posted on the SAB website. In September 2014, the chartered SAB conducted a public teleconference to conduct the quality review of the Panel's final draft peer review report. The peer review report was approved at that meeting, and revisions were made to reflect the chartered SAB's review. The culmination of that public process was the release of the final peer review report in October 2014. All meeting minutes and draft reports are available on the SAB website for public access.

C. Updates to the Literature Since Publication of the Science Report

The agencies requested that EPA's Office of Research and Development (ORD) prepare an updated summary of the scientific evidence on the connectivity and downstream effects of streams (ephemeral, intermittent, and perennial) and both floodplain wetlands and open waters and non-floodplain wetlands and open waters since the publishing of the Science Report. The major conclusions of the Science Report are discussed in section I.A.i above.

The goal of this update was to analyze and synthesize the peer-reviewed scientific literature published in or after 2014, the year determined to correspond with the finalization of the Science Report, and summarize the updated "scientific understanding about the connectivity and mechanisms by which streams and wetlands, singly or in aggregate, affect the physical, chemical, and biological integrity of downstream waters." Science Report at ES-1.

As discussed in this section, since the publication of the Science Report in 2015, the published literature has supported the conclusions of the Science Report and has expanded scientific understanding and quantification of functions that ephemeral streams and non-floodplain waters perform that affect the integrity of larger downstream, particularly in the aggregate. *See also* Sullivan *et al*. 2019a, 2019b, 2020; CASS 2021. For example, the more recent literature (*i.e.*, 2014-present) has strengthened the scientific evidence underpinning the findings that non-floodplain wetlands have demonstrable hydrologic and biogeochemical downstream effects, such as decreasing peak flows, maintaining baseflows, and performing nitrate removal, particularly when considered cumulatively.

In addition to the screening process discussed in this section, the agencies also reviewed additional peer-reviewed literature published in or after 2014, including scientific references that were provided to the agencies as part of the public comment process for the proposed rule. The review of this additional literature is discussed in section I.C.vi. below. EPA's Science Advisory Board (SAB) also chose to review the proposed rule, including aspects of the Technical Support Document, for technical and scientific accuracy. The SAB's review is discussed in section I.G.

i. Update Process

The specific charge questions addressed in this update are the same as the Science Report (p. 1-1) report, namely:

A. What are the physical, chemical, and biological connections to and effects of ephemeral, intermittent, and perennial streams on downstream waters (*e.g.*, rivers, lakes, reservoirs, estuaries)?

B. What are the physical, chemical, and biological connections to and effects of riparian or floodplain wetlands and open waters (*e.g.*, riverine wetlands, oxbow lakes) on downstream waters?

C. What are the physical, chemical, and biological connections to and effects of wetlands and open waters in non-floodplain settings (*e.g.*, most prairie potholes, vernal pools) on downstream waters?

Definitions used in this analysis follow the glossary available in the Science Report (*i.e.*, at A-5 onwards) and Appendix B of this document.

ORD subject-matter scientists identified an initial database of 553 scientific peer-reviewed papers relevant to the specific charge questions (*i.e.*, questions related to the connectivity and/or effects of (a) ephemeral, intermittent, and perennial streams, (b) floodplain wetlands and open waters, or (c) non-floodplain wetlands and open waters) (Supplementary Material A). The focal paper citation database (n=553) was screened for duplicates and provided to EPA's Health and Environmental Research Online (HERO) library research service. HERO library science staff conducted a 'forward-citation mapping' analysis within the Web of Science (WoS) global citation database for the 553-forward citation-mapping papers that had identifiers within the WoS. There were 17,044 peer-reviewed scientific papers published from 2014 onwards within WoS that had cited one or more of the 553 relevant papers provided by ORD. These 17,044 papers were the set from which all three evidentiary reviews were conducted.

To analyze the updated scientific evidence within the available time frame, ORD scientists determined to include or exclude articles based on the paper's relevance to the specific charge questions through a review of the title and abstract of the scientific articles within the SWIFT-Active Screener environment (v. 1.061.0514 through v. 1.061.0527, Sciome, LLC., Research Triangle Park, NC). SWIFT-Active Screener is a software program designed to facilitate collaborative systematic reviews through application of a machine-learning algorithm that incorporates reviewer feedback (*i.e.*, include/exclude) to prioritize a population of articles for screening (Howard *et al.* 2020). Concurrently, a separate model within SWIFT-Active Screener estimates how many relevant articles remain in the screening pool; ORD established a target of 95% recall, or "…the percentage of truly relevant documents [to be] discovered during screening." Howard *et al*. 2020 at 4. These two models within SWIFT-Active Screener provide the opportunity to rapidly identify and screen the relevant articles from a dataset, in this case 17,044 scientific papers.

ORD identified 15-20 papers from the 17,044 that were selected as an initial training set for each of the evidentiary reviews (*i.e.*, ephemeral, intermittent, and perennial streams; floodplain wetlands and open waters; and non-floodplain wetlands and open waters; Supplementary Material B). These 15-20 papers were identified through preliminary screening as likely relevant (*i.e.*, likely to be included) in the active learning model, and these papers were moved to the top of the screening prioritization (*i.e.*, screened within the 30 papers presented to reviewers). This initiated the model building within SWIFT-Active Screener; this model was retrained after every 30 papers were screened. Howard *et al.* 2020. Three ORD scientists independently screened at least 1,000 scientific papers each for the evidentiary review on the connectivity and downstream effects of ephemeral, intermittent, and perennial streams. A separate ORD screening team independently screened at least 1,000 scientific papers each focusing on floodplain wetlands and open waters; that same team of three also independently screened at least 1,000 scientific papers each on non-floodplain wetlands and open waters.

During the screening process, ORD scientists read and reviewed the title and abstract (hereafter abstract) of each paper presented and determined if the paper was relevant to the appropriate charge question noted above. If papers were determined to be relevant, several additional questions were presented to the screener to extract further information associated with the charge questions (*e.g.*, the types of aquatic systems studied, etc.) and the ORD reviewer checked the appropriate boxes based on knowledge gleaned from the abstract. Importantly, a question specific to the major conclusions of the Science Report (*see* sections I.A.i and I.A.ii) was asked of each included paper. For instance, the screeners assessed abstracts for included papers and considered the following statements for each paper, having re-familiarized themselves with the full-text major conclusions of the Science Report. Note that five of the six screeners were co-authors of the Report, and the remaining screener has worked as a Research Ecologist on this topic since 2012. Thus, the ORD scientists who served as screeners were subject-matter experts and well-versed in the Science Report and its conclusions, as well as literature that has been published since the Report's release. The Report's conclusions were as follows:

> Streams: *The scientific literature unequivocally demonstrates that streams, individually or cumulatively, exert a strong influence on the integrity of downstream waters. All tributaries, regardless of size or flow duration, are physically, chemically, and biologically connected to downstream waters and strongly influence their function*.
>
> Floodplain Wetlands and Open Waters: *Wetlands and open waters in riparian areas and floodplains are physically, chemically, and biologically integrated with rivers via functions that improve downstream water quality. These systems buffer downstream waters from pollution and are essential components of river food webs*.
>
> Non-Floodplain Wetlands and Open Waters: *Wetlands and open waters located outside of riparian areas and floodplains, even when lacking surface water connections, provide numerous functions that could affect the integrity of downstream waters. Some benefits of these wetlands are due to their relative isolation rather than their connections*.

For this particular question, screeners chose from the following answers: supports findings, refutes findings, cannot be discerned. The full list of questions asked and possible answers for selection are listed in Supplementary Material C.

ii. Results

1. *Process*

ORD subject-matter experts screened the abstracts of 12,659 scientific papers across the three aquatic system topic areas. Papers were assessed on connectivity and downstream effects of ephemeral, intermittent, and/or perennial streams (total papers screened = 4,194, 24.6% of the scientific literature published in or after 2014), floodplain wetlands and open waters (total screened = 4,183, 24.5% of the presented scientific literature), and non-floodplain wetlands and open waters (total screened =4,282, 25.1% of the presented scientific literature). The total number of papers screened by each reviewer varied by aquatic system, with stream screeners ranging from 1,200-1,527 papers screened (average = 1,398), floodplain wetland and open water screeners ranging from 1,273-1,600 (average = 1,394), and non-floodplain wetlands and open waters ranging from 1,080-2,100 (average = 1,427). ORD screeners did not reach their SWIFT-Active Screener informed discovery and review target of 95% of the relevant literature (Howard *et al*. 2020) for any of the three aquatic systems analyzed. When the SWIFT-Active Screener recursive model-rebuilding ended for stream systems, 986 of 1,225.5 papers were included for a recall value of 80.5%. Floodplain wetland and open water systems screeners included 660 papers of a predicted 813.8, a recall value of 81.1%. The calculated non-floodplain wetlands and open water systems recall value was 89.6%, with 491 papers of 547.8 included.

The vast majority of the relevant papers were found earlier in the process, with fewer and fewer relevant papers found towards the end (*e.g.*, frequently dozens to hundreds of papers screened prior to finding a relevant paper to include as the screening process neared completion).

The ratio of included to excluded papers varied between screeners and across the three systems analyzed. The total included (n=2,137) to excluded (n=10,522) resulted in a ratio of 0.20; the include:exclude ratio was lowest for non-floodplain wetlands and open waters (0.13, indicating fewer papers were included), 0.19 for floodplain wetlands and open waters, and 0.31 for stream systems. The include:exclude ratio across screeners ranged from 0.10 to 0.34. Of the 2,137 total papers included, there were 2,022 unique papers, as 115 papers were relevant to multiple systems. The 2,022 unique papers are listed in Appendix C1.

2. *Analysis and Synthesis*

a. Ephemeral, Intermittent, and/or Perennial Streams

Nine hundred and eighty-six (986) scientific papers published in or after 2014 were included by the screeners. *See* Appendix C1. The stream type(s) (*e.g.*, ephemeral, intermittent, perennial, headwater [first- to third-order streams, can be ephemeral, intermittent, or perennial] for included papers was discernable in 38% of the papers (n=379; further analyzed below), with 607 papers not sufficiently descriptive to determine the stream type.

Across all screened and included papers (n=986), biological connectivity and effects was the most commonly reported type (n=344, or 35%), followed by physical (n=200, 20%) and chemical (n=163, 17%). Multiple types of connectivity and effects were noted in 265 (27%) papers, with physical and biological (n=122, 12%) and physical and chemical (n=101, 10%) more commonly found than chemical and biological (n=10, 1%). All three connectivity and effects types were reported in 32 papers (3%). Thirteen papers were noted as "connection and effects type[s]" could not be discerned, and one paper was marked as chemical connectivity and effects as well as "effect type cannot be discerned." The plurality of the papers were marked as addressing watershed-scales (*e.g.*, cumulative connections and effects; n=379 or 38%), followed by reach-scale studies (n=360, 37%), and "scale not discernable" in 211 papers (21%). Both reach and watershed scales were marked in 32 papers (4%). The location of most studies (n=613, 62%) was not discernible from the abstract (*e.g.*, a specific geographic location was not given in the abstract) or noted as outside of the United States. The balance was noted as having sufficient information in the abstract, such as a place name, to select occurring in the United States or parts thereof (n=373, 38%). The contributions of climate change, land use, or water use on connectivity and effects of the aquatic systems were analyzed for each paper. Most papers screened were noted as having no interacting effects (n=581, 59%), though climate interactions (n=167, 17%) and land use (n=132, 13%) were frequently noted, as was a combination of interacting effects (n=78, 8%). Water use was noted as an interacting effect in 28 papers (3%).

The screeners assessed whether the abstract contained sufficient information to support or refute the major conclusions on stream systems from the Science Report (discussed in sections I.A.i and I.A.ii). Forty-eight percent (n=471) of the papers were determined to lack sufficient information to assess their support or refutation vis-à-vis the conclusions. Of the remaining 515 papers, 506 (98%) were found to support the physical, biological, and chemical connectivity and effects of stream systems on downgradient waters. Four papers (1%) were marked as refuting the findings, while two were marked as both supports and refutes the findings. Three additional papers were marked as both supports the findings and support or refutation "cannot be discerned."

Analyzing a subset of papers where stream type was discernable to the screeners (379 of 986 papers, or 38%), the majority of the papers with indicated stream type(s) identified headwaters (n=179, 47%). Screeners noted ephemeral in 26 papers (7%), intermittent in 44 (12%), and perennial in 22 (6%), with the balance of papers a combination of types. Analyzing the 379 papers with known stream types, biological connections and/or effects were the most commonly reported (n=111, 29%), followed by physical (n=77, 20%), then chemical (n=73, 19%). Fifty-three papers (14%) were noted to have both physical and biological connections and/or effects, 38 (10%) had physical and chemical, and 21 (6%) had all three connectivity and effects types. Watershed-scale connectivity and effects were most commonly marked (n=166, 44%) followed by reach-scale (n=147, 39%) and both reach-scale and watershed-scale (n=16, 4%). The scale of the study could not be discerned in 50 of the screened papers with a known stream type denoted (13%). Forty percent of the studies (n=151) were noted as occurring in the United States or parts of the United States, whereas the location could not be discerned or did not encompass the United States in 60% (n=228) of the papers. Climate (n=80, 21%) and land use (n=53, 14%) were the most commonly occurring interactions noted, along with water use (n=11, 3%) and any combination of interacting effects (n=32, 8%).

Of the included papers with a known stream type marked (n=379), whether the conclusions supported or refuted the Science Report could be discerned in 224 of the papers (59%). Based on the abstracts read, the scientific papers reviewed with known types denoted unequivocally supported the connectivity and effects of ephemeral, intermittent, perennial, and headwater stream systems with 219 (98%) supporting the major conclusions of the Science Report and one paper noted as refuting the findings. Three papers were marked as supports and “cannot be discerned” and one paper was marked as both supports and refutes.

A further analysis was conducted on two smaller paper subsets on ephemeral streams (n=28) and both ephemeral and intermittent streams (n=70). Twenty-eight were marked as focusing on ephemeral streams (n=28, *i.e.*, marked as ephemeral [n=26], ephemeral and headwater [n=1], and ephemeral and “stream type not discernable [n=1]). Of these, 22 papers were noted as supporting the Science Report major conclusions and zero papers were marked as refuting the findings. Two additional papers noted as both supporting and “cannot be discerned.” Support or refutation could not be discerned in an additional four papers.

An additional 70 papers (19%) were demarcated as ephemeral and intermittent (n=14), intermittent (n=44), headwater and intermittent (n=11), and headwater plus ephemeral and intermittent (n=1). Support or refutation was discerned in 35 of those papers. The data presented to the screeners in the abstracts were sufficient for all 35 (100%) to be denoted as supporting the major conclusions of the Science Report, namely that these systems were physically, chemically, and/or connected to and exerted a strong influence on downgradient waters.

b. Floodplain Wetlands and Open Waters

Based on the content of the abstracts read by the screeners, six hundred and sixty (660) scientific papers published in or after 2014 were included for analyses. Of these, 62% (n=406) were noted as focusing specifically on floodplain (or riparian) wetlands and open waters (further analyzed below), 31 (5%) on riverine (*i.e.*, within channel) systems, 92 (14%) addressed multiple wetland types (*e.g.*, riverine, floodplain wetlands, non-floodplain wetlands, etc.), and 33 (5%) lacked sufficient information to discern the aquatic system.

Biological connections and effects were noted as the most commonly occurring in the papers reviewed (n=195, 30%), followed by chemical (n=144, 22%) and physical (n=143, 22%). Multiple connections and effect types were frequently noted, with both physical and chemical most common (n=103, 16%), followed by physical and biological (n=34, 5%), and chemical and biological (n=10, 2%). Eighteen papers (3%) were marked as having all three types of connections and effects, and 13 papers (2%) were noted as connection and/effect type could not be discerned.

The scale of most screened and included papers were individual functions, connections, and effects (n=174, 26%) and landscape-scale analyses (n=162, 25%); 123 papers were marked as addressing both scales (19%). Fifty-three papers (8%) focused on watershed-scale analyses, while 57 (9%) noted both an individual and watershed-scale focus, 57 (9%) addressed landscape- and watershed-scales, and 14 (2%) addressed all three listed scales. Twenty-six papers (4%) lacked sufficient information for screeners to note scale, and one paper noted both landscape-scale and “scale not discernable.” Thirty-nine percent (n=254) of the papers emanated from studies in the United States, whereas the balance (n=406) either were outside of the United States or the study location could not be discerned from the abstract. Most papers did not have interacting effects noted (n=567, 86%), though 34 papers noted climate and 33 land use (5% each). Both water use and any combination of the three interacting effects were noted to occur in 13 papers (2% each).

The Science Report concludes that wetlands and open waters in riparian areas and floodplains are physically, chemically, and biologically integrated with rivers through functions that affect downstream water quality. Based on the abstracts reviewed from scientific papers published in or after 2014, 449 papers presented sufficient material in the abstract relative to this finding. Of those papers, 95% (n=427) supported the conclusion, with another 3% (n=12) marked as supports and cannot be discerned. Seven papers (2%) were noted as both supporting and refuting, two papers were marked as refutes and cannot be discerned, and one paper was marked as refuting the major conclusions.

Focusing specifically on a subset of papers with the aquatic system type noted as floodplain wetlands and open waters (n=406), these focal aquatic systems were found to mainly connect and/or affect flowing waters through biological connections and effects (n=123, 30%), followed by physical (n=85, 21%) and chemical (n=81, 20%) connections and effects. Both physical and chemical connections were noted on 76 papers (19%), followed by physical and biological (n=25, 6%), and chemical and biological (n=5, 1%). All three connectivity and effects types (n=7, 2%) were found infrequently, and connection and effect type were not discernable in four papers (1%).

Individual system-scales of analyses was the most commonly selected scale (n=121, 30%), followed by landscape-scale (n=76, 19%); both were pipped in 96 papers (24%). Watershed-scale studies were noted in 29 cases (7%), and both individual and watershed-scales in 41 papers (10%), and landscape- and watershed-scales in 22 papers (5%). All three scales of analysis were denoted in nine papers (2%), whereas no scale was discernable in twelve papers (3%).

Findings related to the major conclusions of the Science Report were discerned in 298 of the 406 papers that focused on floodplain wetlands and open waters (74%). Of those 298 papers, 98% were found to support the findings on the interrelatedness and connectivity of floodplain wetlands and open waters with rivers. Four papers (1%) were marked as both supporting and “cannot be discerned.” Two papers (1%) were noted as both supporting and refuting the major conclusions.

c. Non-Floodplain Wetlands and Open Waters

Four-hundred and ninety-one (491) scientific papers published in or after 2014 were included by the screeners, and 51% (n=250, further analyzed below) were marked as explicitly focusing on known non-floodplain wetland types. A further 113 (23%) were marked as either multiple wetland types and spatial locations, and 20 (4%) had both “explicitly about known non-floodplain wetland type” and “multiple wetland types” marked. Six papers were marked as both multiple wetland types and wetlands type not discernable (1%). Wetland type was not discernable in 102 included papers (21%).

Physical connectivity and/or effects were most commonly noted (n=160, 33%), followed by biological connectivity and/or effects (n=147, 30%), and chemical connectivity and/or effects (n=90, 18%). Multiple connectivity and/or effects were frequently marked (n=82, 17%), with all but four (1% noted as chemical and biological) including physical connectivity and/or effects (*e.g.*, 48 papers marked as addressing physical and chemical effects, 12 papers addressing physical and biological, and 18 papers including all three connectivity types). The frequency of physical connectivity and effects was likely a result of surface, shallow subsurface, or groundwater serving as the physical medium directly connecting non-floodplain wetlands to downgradient systems. Surface water, shallow subsurface water, or groundwater also serves to functionally connect non-floodplain wetlands, for instance by mobilizing dissolved or entrained materials into non-floodplain wetlands whereby lags, transformation, or sink functions affecting downgradient systems occur. Leibowitz *et al*. 2018.

The plurality of papers (n=182, 37%) addressed landscape-scale types of connections and effects (*e.g.*, connections, functions, and/or effects on other features, such as a stream). One hundred and two papers (21%) focused on watershed-scale downgradient or downstream cumulative connections, functions, and/or effects, while 75 papers (15%) were noted as addressing functions or scales associated with individual wetland and open waters. Fifty-seven (12%) addressed individual and landscape scales while 40 were marked as both landscape and watershed connections (8%). Twelve were marked as individual and watershed scales (2%), five were noted as a combination of all three scales (1%), and 18 (4%) did not have scale discernible from the abstracts. Fifty-two percent (n=257) were marked as being conducted in the US or parts thereof. Sixty-five percent (n=317) lacked interacting effects while 17% (n=81) involved climate effects and 12% (n=61) addressed land use effects. Seventeen papers (n=4%) addressed water use and fifteen papers (3%) addressed some combination of the three effects.

Two hundred and thirty papers (47%, n=230) of included scientific papers (n=491) presented sufficient information in the abstract to assess findings vis-à-vis the major conclusions from the Science Report. Of the 230 papers assessed, 97% (n=223) were marked as supporting the findings of the Science Report. Three papers (1%) were noted as refuting the findings, two papers (1%) were noted as both supporting and refuting, and two papers (1%) were noted as supporting and "cannot be discerned."

There were 250 papers (51% of 491 included papers) marked as explicitly focusing on known non-floodplain wetland and open water types. Of these papers, most were noted as having physical connectivity and effects (n=89, 36%) followed by biological (n=68, 27%), and chemical (n=53, 21%); connection and/or effect type(s) were not discernable in seven papers (3%). Twenty papers were noted as addressing physical and chemical connectivity and effects (8%), with two each of physical and chemical or biological and chemical (1% each). Nine papers (4%) addressed all three connectivity and effects types. The scale of the included studies specific to non-floodplain wetland types tended towards landscape-scale papers (n=86, 34%), followed by watershed-scale papers (n=46, 18%), and individual wetlands and waters were noted as the paper focus in 45 instances (18%); 10 papers were marked as "scale not discernable" by the screeners (4%). Thirty-six papers (14%) were noted as addressing both individual and landscape-scale analyses, while 15 (6%) were marked as both landscape- and watershed-scale, and eight (3%) marked as individual and watershed-scale. Four papers (2%) were noted to be a combination of all three scales. Sixty percent (n=149) of the papers noted research was conducted in the United States or parts of the United States. Most papers (n=154, 62%) did not include an interacting effect. Forty-five papers addressed climate interactions (18%), 35 addressed land use (14%), six addressed water use (2%), and 10 papers had a combination of interacting effects.

Major conclusions from the Science Report on the connectivity and effects of non-floodplain wetlands and open waters on downstream waters state that these systems provide numerous functions that could affect the integrity of downstream waters, and that some benefits of these wetlands emerge from their relative isolation (or disconnectivity) rather than their connections. The finding was supported when sufficient information was available in the abstract to assess. Across papers marked as explicitly focusing on known non-floodplain wetland types and sufficiently descriptive to assess the findings vis-à-vis the major conclusions (n=133 of 250), 99% of all papers (n=131) were found to support the findings, with one paper marked as both supporting and refuting the findings, and one paper noted to refute the findings.

iii. Discussion

The goal of this summary review of the scientific evidence was to analyze and synthesize the peer-reviewed scientific literature (published in or after 2014) and to provide updates on the "…scientific understanding about the connectivity and mechanisms by which streams and wetlands, singly or in aggregate, affect the physical, chemical, and biological integrity of downstream waters." Science Report at ES-1. As noted, the summarized state-of-the-science in the Science Report is given in sections I.A.i and I.A.ii; updated assessments of the state of the science were peer-reviewed and published as a Featured Collection in the *Journal of the American Water Resources Association*. Alexander *et al.* 2018; Fritz *et al.* 2018; Goodrich *et al*. 2018; Lane *et al.* 2018, Leibowitz *et al.* 2018; Schofield *et al.* 2018.

The analysis by ORD subject-matter experts summarized in this document was conducted over a six-week period and consisted of reviewing the titles and abstracts of identified peer-reviewed literature published in or after 2014. The resulting citation database, with analysis of trends and illustrative summaries of abstracts for papers published since 2014, confirm that recent research reinforces the major conclusions of the Science Report, and that this report remains the authoritative standard regarding the connections, disconnections, and resulting effects between the nation's streams, rivers, lakes, estuarine systems and seas, and the focal aquatic systems summarized here: (a) ephemeral, intermittent, and perennial streams, (b) riparian or floodplain wetlands and open waters, and (c) wetlands and open waters in non-floodplain settings.

The screening process recovered a number of papers that directly addressed data gaps or needs identified in the Science Report and identified meaningful trends in the scientific literature published in or after 2014. For instance, the scientific literature published in or after 2014 on the downgradient connectivity and effects of non-floodplain wetlands and open waters has notably and markedly expanded the total available literature on these systems. Research published in or after 2014 has seen an increase in studies on connectivity and effects across multiple spatial scales, from individual systems to landscape- and watershed-scale findings reviewed here support the findings of the Science Report as well as fill data gaps. For example, 133 papers reviewed were marked as specifically focusing on a known non-floodplain wetland and/or open water and sufficiently descriptive to address the major conclusions. Of those, 99% (n=131) were reported to support the conclusions of the Science Report, noting the nutrient removal, flood-peak attenuation, base-flow maintenance, and habitat functions of non-floodplain wetlands and open waters affecting downgradient aquatic systems. These scientific advancements now provide a solid scientific foundation that builds upon the Scientific Report's conclusions on wetlands and open waters in non-floodplain wetland settings. Based on the abstracts reviewed here, and on a recent review by Lane *et al.* (2018) which also updated the Science Report, the literature demonstrates that non-floodplain wetlands and open waters, particularly when evaluated in the aggregate, have substantive effects on downstream waters through hydrological, biogeochemical, and biological connectivity pathways and gradients, performing functions affecting downstream water integrity.

The Science Report concludes that all tributaries, including ephemeral and intermittent systems, are demonstrably and conclusively connected downgradient through physical, chemical, and biological pathways. Nearly 100 scientific papers published in or after 2014 specifically addressing the connectivity and effects of ephemeral and intermittent stream systems were identified through the screening process (98 papers; 28 ephemeral stream studies plus 70 ephemeral and intermittent stream studies). When sufficient information in the abstracts from which to draw conclusions was available (57 papers), 100% of the papers were noted by abstracts reviewed here to support the finding that these stream systems, individually and cumulatively, exert a demonstrative effect on downstream waters. These additional papers further underpin while continuing to advance the scientific findings specific to ephemeral and intermittent systems.

Likewise, riparian and floodplain wetlands and open waters were found in the Science Report to be integrated with and connected to downgradient waters through processes that improve water quality, recharge groundwater, and attenuate storm flows. In this analysis, 98% of 298 scientific papers published in or after 2014 that explicitly focused on floodplain wetlands and open waters were found to support the Science Report, underlining the connections between and multiple functions performed by floodplain wetlands and open waters directly affecting downgradient rivers, streams, lakes, and other larger waters.

The abstracts reviewed for this analysis included studies conducted outside of the United States. This research was reviewed to investigate the validity of scientific principles developed from studies inside the United States by comparing them to principles developed from research on similar systems in other locations. For example, studies on the Canadian Prairie Pothole Region encompass wetlands north of the Prairie Pothole Region in the United States that are part of the same ecoregion, and provide insights into the intrinsic functions of similar wetlands in the United States that are generally more drained or filled for agriculture and other purposes. In addition, research on ephemeral streams in arid regions of Australia can be informative of the functions of similar ephemeral streams in arid portions of the United States.

The sections below provide a scientific narrative on the connectivity, functions, and effects of the three aquatic systems on downgradient rivers, streams, and other larger waters that draws on findings from the screening, as well as the available scientific literature. The screeners identified papers within each of the three focal systems analyzed wherein connectivity and/or effects were illustrative; these papers were noted and a plain-text assessment of their content provided in Appendix C2. Incorporation of additional peer-reviewed scientific literature places the summary review in the context of the existing scientific knowledge on the connectivity and effects of ephemeral, intermittent, and perennial streams, floodplains and open waters, and non-floodplain wetlands and open waters on downstream waters. After contextualizing the findings, the few papers found in the screening of the titles and abstracts marked as disagreeing with the findings of the Science Report are discussed. This section concludes with a note on the benefits and limitations of this analysis.

1. *Ephemeral, Intermittent, and Perennial Streams*

The Science Report, as well as the peer-reviewed updated synthesis of the scientific literature by Fritz *et al.* (2018), Schofield *et al.* (2018), and Goodrich *et al.* (2018), conclude that the scientific evidence unequivocally demonstrates that streams, including ephemeral, intermittent, and perennial streams and rivers are physically, chemically, and biologically connected to downstream rivers via channels and associated alluvial deposits. The scientific evidence in the Science Report (and Fritz *et al.* 2018, Schofield *et al.* 2018, Goodrich *et al.* 2018) notes that streams, individually or cumulatively, exert a strong influence on the integrity of downstream waters, and that all tributaries, regardless of size or flow duration, are connected to and strongly influence the functioning of downstream waters. ORD's analyses of 4,194 relevant abstracts published in or after 2014 supports these findings.

The past seven years of published, peer-reviewed scientific literature have seen an increased research focus on the extent, abundance, connectivity, and effects of these flowing water systems. For instance, though Horton (1945) established that headwater streams are the most abundant components of the fluvial network, recent estimates suggest that nearly 89% of global stream longitudinal extent is comprised of headwater stream systems. Allen *et al*. 2018. In the United States, headwater stream systems represent ~50-80% of the total currently mapped conterminous United States stream length (Nadeau and Rains 2007; Hill *et al.* 2014; Colvin *et al.* 2019), certainly an underestimation of headwater stream abundance (Fesenmyer *et al*. 2021). For instance, Fritz *et al*. (2013) analyzed nine forest watersheds and determined that the high-resolution (1:24,000-scale or better) National Hydrography Dataset (NHD) depicted only 21-33% of the actual linear stream network length in seven of the nine watersheds. Fesenmyer *et al.* (2021) recently coupled the high-resolution NHD with a contributing area threshold model, concluding that 48% of stream length in the conterminous United States is likely ephemeral (43-56%, depending on flow-area characteristics).

Ephemeral, intermittent, and perennial stream networks are hydrologically connected to downstream systems, from the source area of headwaters to the flowing waters connected downgradient, to their terminus at endorheic lakes or estuarine systems. For instance, headwater streams supply the majority of flow in most river systems. Alexander *et al.* 2007; Fritz *et al.* 2018. By providing flows to higher-order systems that comprise the full watershed network, headwaters directly connect to and affect downstream waters.

Flow response in headwater streams from precipitation varies regionally, affected by transmission, evaporation, transpiration, and groundwater recharge. The headwater streamflow response to precipitation and downgradient volume contributions can be nonlinear, with substantial increases (and decreases) in flow volumes as headwater-drained contributing areas become active on the rising limb and inactive on the falling limb of the hydrograph. McGuire and McDonnell 2010; Bergstrom *et al.* 2016. For instance, van Meerveld *et al.* (2019) noted that travel times (*e.g.*, of water, material in the stream network, etc.) changed based on stream-network extension (during periods of higher precipitation) and retraction (during periods of lower precipitation). Travel times were skewed towards shorter, faster transit of dissolved and entrained materials during wetter periods as the stream network fully reconnected and longer, more uniform travel times during drier periods as the network retracted.

The spatial and temporal distribution of river network connectivity is a primary nonlinear control on the network's precipitation-runoff response. Bachmair and Weiler 2014. When water begins to flow in headwater tributaries and longitudinally connect with other parts of the network, their confluence with larger-order streams can have profound effects on the receiving system due to the abrupt increase in water, sediment, wood, and other entrained materials. Benda *et al.* 2004a; Xu 2016. For instance, sediments from ephemeral tributaries provided important salmonid habitat in downgradient waters in a study in the United Kingdom. Marteau *et al*. 2020. Reconnecting a tributary to downgradient receiving waters increased sediment yield to the receiving water by 65%. Marteau *et al.* 2017.

As the network contracts and disconnects during hydrograph recession, streams that were temporarily higher-order systems (*e.g.*, stream order 2+, depending on flow characteristics) revert to performing headwater stream functions. Phillips *et al*. 2011. Godsey and Kirchner (2014) demonstrated the dynamism of headwater networks, mapping a 2.6 to 7.5-fold increase in both flowing network lengths and drainage densities in four drainages between fall (dry conditions) and spring (wet conditions). Surface-flow disconnected, low-order stream reaches may also function similarly to ponded or perched wetland systems (*e.g.*, Rains *et al.* 2006) until network re-wetting and subsequent expansion. For instance, Gallo *et al.* (2020) found Arizona streams in their study area – which were noted to be important groundwater recharge systems – were highly variable in their expansion and retraction. Streams supported flowing waters for 0.6-82.4% of the time, but water was present for 4-33x longer than the stream flow (from 10-301 days) likely providing habitat, a water source, aquatic refugia, and a biogeochemically active area.

The dynamic nature of headwater streams and downgradient connectivity is well-supported in the literature – headwater streams are neither spatially nor temporally invariant but rather dynamic systems that expand, contract, fragment, and reconnect across predictable spatial and temporal scales. Hewlett and Nutter 1970. The heterogeneity of dynamic flow paths creates storage and (subsequent) flow asynchronies by ephemeral, intermittent, and perennial stream systems, by delaying and attenuating downgradient storm flows and maintaining baseflows. Saco and Kumar 2002. Similarly, the variability in vulnerable water source area expansion and contraction (*i.e.*, parts of watersheds that generate overland flow) produces subsequent variability in the timing of headwater stream connectivity at the reach-scale. The connectivity response by ephemeral, intermittent, and perennial streams thereby affects the timing and magnitude of watershed-scale hydrological fluxes in non-linear ways. The convolution of these diverse vulnerable water storages and flows across watersheds imparts hydrological stability, deepening the aquatic network's resistance to drought and deluge perturbations *See*, *e.g.*, Chezik *et al.* 2017; Li 2019; Rupp *et al.* 2021.

Headwater streams without apparent surface flow often have complex and abundant hyporheic flow that maintains a downgradient hydrological connection, supports characteristic surface flows (Covino 2017; Magliozzi *et al.* 2018), and maintains habitats. In fact, Stanley *et al.* (1997) noted that in arid environments, streams and rivers unconstrained by valley topography may have zero surface flow for weeks to months yet flow in the hyporheic zone for thousands of meters before reconnecting with (and hence directly affecting) the surface-flowing network. Ebersole *et al.* (2015) found that even where they do not provide direct habit for salmon themselves, ephemeral streams can contribute to the habitat needs of salmon by supplying sources of cold water that these species need to survive (*i.e.*, by providing appropriate physical conditions for cold water upwelling to occur at river confluences), transporting sediment that supports fish habitat downstream, and providing and transporting food for juveniles and adults downstream. Similarly, Kelson and Carlson (2019) determined that groundwater discharge to tributaries in California were important in supporting steelhead trout habitat, especially during dry years.

Many organisms use and connect the entirety of the stream network, including ephemeral, intermittent, and perennial reaches. Schofield *et al.* 2018. Koizumi *et al.* (2017) found that a small tributary dried during the summer, yet four months after resuming flow, >10,000 immature fish of three species (including rainbow trout) were found using the stream. Samia and Lutscher (2017) showed that upstream habitats are important refugia maintaining organisms (*i.e.*, fish), especially those with high dispersal abilities, during hydrologic disturbances (*e.g.*, droughts, floods). Upstream systems, such as headwater streams, contribute to downstream protist and rotifer community persistence and stability in the face of disturbances. Seymour *et al.* 2015. Teachey *et al.* (2019) reported that a microbial study in Georgia showed that upgradient systems repeatedly enriched (or repopulated) down-stream systems, contributing to the stability of the aquatic network. Similarly, variation in stream networks and habitat mosaics across a large, free-flowing watershed in Alaska was shown to support Pacific salmon populations by maintaining resilient natal and juvenile rearing habitat in face of climatic and other perturbations. Brennan *et al.* 2019. In some cases, headwater stream networks and dispersal dynamics increase or decrease genetic diversity, which was found by Chiu *et al.* (2020) to also depend on metapopulation (*i.e.*, a group of spatially distributed populations) characteristics of macroinvertebrates.

Headwater streams are biogeochemical reactors within hydrologic networks, transforming and sequestering materials affecting downgradient physical and chemical characteristics and concentrations along the full aquatic network. Sanford *et al.* 2007; Creed *et al.* 2015; Fritz *et al.* 2018. The full extent of the draining river network routes significant material fluxes from the terrestrial landscape into the watershed's aquatic ecosystems via overland flow and other dispersed flow paths. Sabo and Hagen 2012; Li 2019. Headwater streams affect the variability of downgradient network exports, such as carbon (*e.g.*, Creed *et al*. 2015, Senar *et al.* 2018), with effects increasing with flow magnitude, drainage density expansion, and hydrogeochemical interactions.

Concomitant with the longitudinal expansion and contraction as well as varying lateral and hillslope connectivity (*e.g.*, Jencso *et al.* 2009), headwater streams function as both sinks and sources of carbon, nitrogen, dissolved organic matter, and sediment in flowing hydrologic networks. Minshall *et al.* 1983, Benda *et al.* 2004b, Creed and Beall 2009, Phillips *et al.* 2011. These biogeochemical functions can markedly affect downgradient metabolism, trophic states, and integrity. Creed *et al*. 2015; Ali and English 2019; Fovet *et al*. 2020. For instance, dissolved organic material varies in its carbon lability and forms a basis for energy inputs supporting stream and river metabolism. The conveyance and sequestration of heterogenous dissolved organic material by headwater streams affects the state of downgradient systems. Lynch *et al*. 2019. For example, Creed *et al*. (2015) demonstrated high spatial heterogeneity and temporal variability in dissolved organic material in headwater streams across the United States, noting that storm events affected organic-material inputs into headwater streams. These ephemeral, intermittent, and perennial streams were sources of dissolved organic material during storm events, with mineral-soil flow paths rapidly transitioning to rich organic-soil flow paths. Mooney *et al*. (2020) noted that smaller tributaries connected to the Great Lakes and provided disproportionately high nutrient loads (biased towards dissolved inorganic forms) than expected for their relative area. Marcarelli *et al*. (2019) similarly analyzed over 2,800 tributaries to Lake Superior, finding these ephemerally, intermittently, or perennially flowing waters were detectable nutrient and organic-matter sources, contributing the bulk of these constituents to the lake during snow-melt driven flows in the winter and spring and rain-driven flows during the other times of the year. Iowa tributaries contributed excessive nitrate to the Gulf of Mexico (Jones *et al.* 2018c). Volumetric mixing and dilution suggest the biogeochemical influence of headwater streams on downgradient systems and disturbance-mitigation capacity may wane with increasing tributary contributions and stream order in the flowing network. *See, e.g.*, Vannote *et al*. 1980; Benda *et al*. 2004a; Kellman 2004; Covino 2017.

Research has shown that headwater stream systems can readily remove nitrogen (*e.g.*, up to 50% of dissolved inorganic nitrogen; *see, e.g.,* Cooper 1990; Ranalli and Macalady 2010), and headwater biogeochemical processing rates are most efficient at low flows. *See, e.g.*, Alexander *et al.* 2007; Preston *et al.* 2011. Scanlon *et al.* (2010) noted that low-order streams "dominate the overall removal of nitrogen, primarily due to the large portion of the network that is composed of these headwater reaches." Christensen *et al*. (2013) reported down-stream nitrogen concentrations were primarily a function of inputs at headwater stream reaches, with stream-buffer removal effectiveness decreasing markedly with increasing stream size. Schmadel *et al*. (2019) reported highest nitrogen removal in headwater stream systems, though the removal efficiency varied across river networks of the Mid-Atlantic and New England. In-channel denitrification was more efficient within first-to-third order streams as they removed ~8% of the nitrogen versus 16% in first-to-fifth order streams. Alexander *et al*. 2007; Wollheim *et al*. 2008. French *et al*. (2020) found that smaller headwater stream systems in Alaska played a disproportionately important role in predicting stream chemistry through the river network. Similar findings were reported in a European study by Abbott *et al*. (2018). Shogren *et al*. (2019) reported the dominant spatial scale for controlling organic carbon and inorganic nutrient stream concentrations were (headwater) watersheds of 3-30 km^2 in area.

Biogeochemical dynamics in headwater stream systems that are longitudinally, laterally, and vertically expanding, contracting, and mixing with groundwater or hyporheic flow for thousands of meters affects downgradient systems. Covino 2017. Nutrient inputs to headwater streams are removed through multiple pathways, including abiotic and biotic processes that either sequester or transform nutrients as they move to downgradient systems. Hedin *et al*. 1998; Bernhardt *et al*. 2005. Stanley *et al*. (1997) noted that the occurrence of nitrification in headwater streams and arid river hyporheic zones stimulated microbial and algal productivity for hundreds of meters downgradient of stream (re)emergence. Hyporheic exchange flows are predominantly a function of headwater stream systems and "play a significant role in biogeochemical cycling (*e.g.*, [carbon]) and nutrient availability and transformation, ecological food webs, and habitat for diverse organisms." Magliozzi *et al.* 2018 at 6163.

It is evident that flow variability emerging from ephemeral, intermittent, and perennial stream network storage and their source areas is asynchronously connected over time and space and maintains an adaptive downgradient system, resilient to watershed-scale perturbations. *See, e.g.*, Moore *et al.* 2015; Chezik *et al*. 2017; Rupp *et al*. 2021. Watershed properties (*e.g.*, Klaus *et al.* 2015) coupled with precipitation patterning (*e.g.*, Jencso *et al*. 2009) affect headwater stream storage and flows (Ward *et al.* 2018), with downgradient implications. Ephemeral, intermittent, and perennially flowing waters create a varied mosaic of aquatic habitats that are connected over space and time, through surface, near-surface (*e.g.*, hyporheic), and groundwaters to affect downgradient stream communities. *See, e.g.*, Ebersole *et al.* 2015; Schofield *et al.* 2018; Kelson and Carlson 2019; Chiu *et al*. 2020. Alterations affecting the synchrony of timed storage and fluxes from headwater streams at the reach-scale similarly decrease network-scale resilience to hydrologic disturbance. Headwater streams also incontrovertibly affect downgradient systems through export of food resources (Schofield *et al.* 2018) and biogeochemical processing and functioning. Headwater streams affect the delivery, timing, and concentrations (*see, e.g.*, Enanga *et al.* 2017, Senar *et al*. 2018) of entrained materials into downgradient waterways, with changes in timing and concentration amplified by the interaction between climate, drainage areas, and the receiving headwater stream systems. Mengistu *et al*. 2013a; Mengistu *et al.* 2013b.

2. Floodplain Wetlands and Open Waters

The Science Report concludes that floodplain wetlands and open waters are physically, chemically, and biologically integrated with rivers via functions that improve downstream water quality. Among other functions, the Science Report notes that these systems buffer downstream waters from pollution through biogeochemical processing and sedimentation, desynchronize floodwaters and thereby decrease flood magnitudes, and are essential components of river food webs. Our analysis of the titles and abstracts of 4,183 papers published in or after 2014 supports the findings of the Science Report.

Floodplain wetlands and open waters are integrated with streams and rivers through surface and groundwater interactions and exchanges. Surface water interactions occur when riverbanks are overtopped and the floodplain, including wetlands and open waters, is inundated. Groundwater connectivity occurs through discharge from the floodplain system to the flowing water network, as well as recharge from the flood-induced inundation events. Covino 2017. For instance, Webb *et al*. (2017) reported floodplain inundation occurred during only 12% of their study period yet contributed to 72-76% of the groundwater discharge (to the river network). Inundation events often provide nutrient-laden floodwaters to floodplain wetlands and open waters wherein both physical settling and biogeochemical processing occurs. Gordon *et al*. (2020) reviewed the literature and found that floodplains remove an average of 200 kg-N ha^{-1} yr^{-1} of nitrate and 21 kg-P ha^{-1} yr^{-1} of total or particulate phosphorus; their synthesis reported that floodplain wetlands are most effective when located within river systems with higher nutrient loads. Dwivedi *et al*. (2018), who analyzed Colorado River riparian areas, demonstrated that reduced zones (*i.e.*, areas low in sediment oxygen, such as wetlands) in the floodplain had 70% greater nitrate removal capacity than non-reduced zones. Scott *et al.* (2014) analyzed nitrate removal in the Atchafalaya River floodplain during a 2011 major flood event, noting that ~75% nitrate reduction occurred within the floodplain, reducing total nitrate delivered downgradient by 17%. A similar result was found by Macdonald *et al.* (2018), who noted nitrate reduction from floodplain systems as important for protecting local drinking water supplies. Gillespie *et al.* (2018) analyzed sedimentation, nutrient loading, and mineralization in floodplain systems of the Valley and Ridge physiographic province in the United States and found that nutrient and sediment removal in floodplain systems improved downgradient water quality. Jensen and Ford (2019) coupled high-resolution water quality data and simulation modeling to assess the physical (*e.g.*, hydrologic, hydraulic) and biogeochemical processes affecting nitrate cycling in a confluence floodplain wetland along the Ohio River (June 2017-June 2018). Despite the wetland comprising only 0.42% of the overall watershed drainage area, 2.6% to 58.5% of the annual nitrate loads entering the wetland were removed by the wetland. Longer water residence times in the wetland and less frequent connectivity with the river (and its oxygenated waters, which decrease denitrification rates) allowed nitrate removal to occur at higher rates. The findings by Jensen and Ford (2019, p.1545) “demonstrate the significance of [wetland] connectivity [and disconnectivity] on watershed nitrate loadings to floodplain wetland soils.”

Floodplain wetlands and open waters are intimately connected to riverine food webs. Rees *et al.* (2020) studied riverine food webs through isotopic analyses, noting that floodplain-derived carbon following floodplain inundation was incorporated into the riverine food webs and was measurably found for up to four months following the flood peak. Battauz *et al*. (2017) noted that floodplain open waters were often highly vegetated with floating and emergent plants serving as zooplankton sources for downgradient waters when reconnected by flood events. Zooplankton are important food web components, and over 70 different zooplankton species were found on roots and submerged parts awaiting the proper environmental cues to emerge.

Floodplain wetlands and open waters are important habitats. Pyron *et al*. (2014, p.14) sampled and examined fish assemblages in 41 floodplain open waters and wetlands in the Ohio River Basin. Their results demonstrated "that floodplain lakes in the Ohio River basin contain high species richness and are important habitats to conserve because they have the potential to act as source pools for river fish populations." Carlson *et al*. (2016) noted that backwater habitats in the Missouri River flowing through South Dakota and Nebraska provided floodwater refugia, important for maintaining fish assemblages. Martens and Connolly (2014) found seasonally disconnected side channels (*i.e.*, floodplain open waters) resulted in improved survival for juvenile salmon during periods of disconnection. Upon reconnection with the main channel, the previous cohort would rejoin the main population while new young of year salmon would move into the side channels.

Floodplain wetlands and open waters also exert significant controls on downgradient stream temperature, impacting in-stream refugia. Dick *et al*. (2018) analyzed riparian wetlands and found that in periods of high river and riparian wetland connectivity (*i.e.*, inundation), the coupled saturation and connectivity decreased the relative importance of the riparian wetland for temperature regulation. Conversely, dry periods with less river and riparian floodplain hydrologic connectivity were found to be important periods of distinctions between river water and riparian wetland temperatures (*e.g.*, lower-temperature waters were coming from the riparian wetland to the riverine system).

High river flows can create downgradient flood hazards. Flow through floodplain wetlands and open waters slows river flows, desynchronizing floodwaters and mitigating flood magnitude effects. Quin and Destouni (2018) found that watersheds comprised of approximately 15% lakes and 0.5% floodplain wetlands decreased the streamflow variability to around 10-15%, compared to areas without lakes or floodplain wetlands, which had approximately 20-25% higher streamflow variabilities due to low landscape water storages. Similarly, Fossey *et al.* (2016) incorporated floodplain wetlands into a hydrological model, reporting that floodplain moderation of high flows (and support of base flows) occurred in proportion to the frequency of floodplain connectivity. Floodwaters significantly expand the connectivity of the stream, riparian, and non-riparian wetlands. Vanderhoof *et al.* (2016) analyzed remotely sensed data, finding that surface waters connected stream networks and wetlands from 90 m to 1,400 m, depending on the (Upper Midwestern) ecoregion. Most of the stream and wetland connectivity occurred through riparian (*i.e.*, floodplain) wetlands.

Physical, chemical, and biological connectivity and effects by floodplain wetlands and open waters were found abundantly in the screened scientific literature that was reviewed. The peer-reviewed, scientific literature strongly supports the findings that floodplain wetlands and open waters are intimately connected to and affect downstream waters.

3. *Non-Floodplain Wetlands and Open Waters*

The Science Report concludes that wetlands and open waters located outside of riparian areas and floodplains (*i.e.*, non-floodplain wetlands and open waters), even when lacking surface water connections, provide numerous functions that can affect the integrity of downstream waters. The report further noted that the literature at that time (circa 2014) was insufficient to provide a definitive conclusion regarding the connectivity and effects of specific classes or groups of non-floodplain wetlands, with notable exceptions (for example, the Report concludes that non-floodplain wetlands situated between a pollution source and a downstream water, intercepting the [surface or near-surface] flowpath, do affect downstream waters through sink functions). However, substantive scientific advances since the publication of the Science Report have focused on the connectivity and effects of non-floodplain wetlands (*e.g.*, Creed *et al.* 2017), which recent studies conclude comprise approximately 16% of existing total freshwater-wetland areal extent in the conterminous United States. Lane and D'Amico 2016.

Based on this analysis of 4,282 scientific peer-reviewed papers published in or after 2014, it is evident that non-floodplain wetlands – individually and in the aggregate – are connected to and can affect the physical, chemical, and biological conditions and characteristics of downgradient waters (*e.g.*, streams, rivers, and lakes). As noted in an updated 2018 analysis and synthesis on the connectivity and effects of non-floodplain wetlands, Lane *et al.* (2018) stated that peer-reviewed scientific research in hydrological modeling, remote sensing analyses, field-based observations, and coupled field and remote-sensing studies were sufficiently advanced to conclude that all non-floodplain wetlands were unequivocally interconnected with stream and river networks. *See, e.g.*, Marton *et al.* 2015, Cohen *et al.* 2016, Rains *et al.* 2016, Calhoun *et al.* 2017, Creed *et al.* 2017. They further noted that connectivity of non-floodplain wetlands and open waters occurs along a gradient (*see also* Science Report at 1-4) and:

> "varies in frequency, duration, magnitude, and timing [and that this] complex landscape-scale connectivity, in turn, affects water and material fluxes — the resultants of substantial hydrological, physical, and chemical functioning in NFWs [non-floodplain wetlands] — that modify the characteristics and function of downstream waters…"

Lane *et al.* 2018 at 363.

The findings noted in the cited literature above plus the literature we reviewed for this evidentiary summary (published in or after 2014) demonstrate that non-floodplain wetlands, particularly when analyzed in the aggregate, are connected to and can exert a substantive and important influence on the integrity of downstream waters through notable functions affecting downgradient systems including hydrological lag and storage functions (*i.e.*, affecting baseflow and stormflows/flood-hazards in stream systems) and biogeochemical functions (*i.e.*, microbial, physical, or chemical functions transforming compounds, such as denitrification, carbon mineralization, and phosphorus sequestration).

Similarly, in a 2018 peer-reviewed review paper, Schofield *et al.* (2018) provided an updated analysis of the biological connectivity and effects of non-floodplain wetlands (*e.g.*, serving as refugia, migratory "stepping-stones," resting and feeding habitats, and breeding habitats). They concluded that biota connected streams and non-floodplain wetlands, part of the landscape-scale "freshwater ecosystem mosaic," through the lateral active or passive movements of organisms and propagules. Our analysis of the current literature supports these findings. For instance, Michelson *et al.* (2018) noted that tree swallows (*Tachycineta bicolor*), an avian insectivore, specialized in feeding on emergent aquatic insects in non-floodplain wetland dominated landscapes. Kappas *et al.* (2017) hypothesized that avian species providing passive transportation between relatively isolated non-floodplain wetland and open waters were one potential reason fairy shrimp (*Streptocephalus torvicornis*) were genetically panmictic, or expressed high genetic diversity suggesting abundant genetic transmission across landscapes in a European study. Likewise, Mushet *et al.* (2013) noted that northern leopard frogs (*Lithobates pipiens*) were found to use the streams, non-floodplain wetlands, and other available habitat throughout the breadth of their 68-kilometer North Dakota study area, with high genetic diversity suggesting abundant population connectivity. However, distance between available wetland (and stream) habitats is important for many species (*e.g.*, Uden *et al.* 2014), such as the reticulated flatwoods salamander (*Ambystoma bishopi*) of the Southeastern United States. Wendt *et al.* (2021) reported that migration between wetland habitats >400 meters was low, limiting population interactions. However, distances from streams (*i.e.*, increased aquatic "isolation") can often limit fish presence in non-floodplain open waters and wetlands. The lack of amphibian predators can positively affect certain species. For instance, Davis *et al.* (2017) reported that the ornate chorus frog (*Pseudacris ornata*), an "ephemeral wetland specialist" responded positively to drought conditions as fish were excluded. Coupling the hydrological and biogeochemical functions noted above (and further discussed below), it is evident that across all three connectivity and effect types (*i.e.*, physical, chemical, and biological), some benefits of non-floodplain wetlands are due to their relative isolation rather than their connections. Creed *et al.* 2017.

Non-floodplain wetlands are the flow-generating origins of many downgradient systems. By providing water to downgradient systems, non-floodplain wetlands maintain and affect the physical, chemical, and biological integrity of those systems. In a chloride-tracer study across 260 North American catchments, Thorslund *et al.* (2018) determined that non-floodplain wetlands generated surface runoff contributing to downstream systems at ~1.2 times the catchment averages (*i.e.*, they were watershed-scale sources of water). Nearly 90% of Florida's headwaters are sourced by non-floodplain wetlands. White and Crisman 2016; Lane *et al.* 2018. Brooks *et al.* (2018) conducted an isotopic analysis of a North Dakota watershed dominated by non-floodplain wetlands and found that surface water originating in wetlands contributed significant amounts of water to the perennial stream across high- to low-flow conditions. Vanderhoof *et al.* (2016) reported that surface-water expansion (*e.g.*, increased stream flows coupled with wetland filling, merging, and spilling) resulted in increased wetland and stream connections, in some cases connecting over 90-1,400 meters. Ameli and Creed (2017) modeled non-floodplain wetland interactions with draining networks in Alberta and found quantifiable contributions from non-floodplain wetlands occurred up to 30-kilometers from the stream, further indicating non-floodplain wetlands have the potential to impart substantial flow affecting downstream systems and flow-synchrony. Similarly, at the maximum expansion of the spatially variable contributing source area, non-floodplain wetlands (*i.e.*, vernal pools and swales) in the Central Valley of California were fully surface-water connected into – and hence contributing to – an integrated and hydrologically dynamic headwater drainage network, often for months (Rains *et al.* 2006). Likewise, Vanderhoof *et al.* (2017) found that spring expansion of the hydrologic network in Maryland and Delaware connected streams and depressional wetlands, increasing hydrologic interactions (and likely material exchanges) by 12-93% by area and 12-60% by count.

In contrast to their flow-generating properties, non-floodplain wetlands can also act as flow-dampening systems, attenuating surface flow through storage functions and providing watershed-scale resilience to hydrologic disturbances. Rains *et al.* 2016; Cohen *et al.* 2016. The watershed-scale effects provided by surface-water and groundwater "disconnected" non-floodplain wetlands is demonstrated throughout the literature. Shaw *et al.* (2012) noted 61% of a studied watershed's wetlands were disconnected from overland flow paths, hence serving as so-called flow gate-keepers (*i.e.*, holding back and thereby dampening stream flow and modifying the aquatic network until a flow-threshold is crossed and flow-connections occur; Leibowitz *et al.* 2016). Shook *et al.* (2021) reported that depressional (wetland) water storage was found to control the fraction of the watershed that contributes flow to downgradient stream systems. The effects of depressions varied – when there were few extant depressions, their size and location on the landscape was most important. In systems with greater depression abundance, depressions still controlled the relationship between water storage and the fraction of the watershed contributing surface flow downgradient, but the spatial location within the watershed decreased in importance. Nasab and Chu (2020) analyzed flows in the Red River (North Dakota, South Dakota, Minnesota), finding that non-floodplain wetlands controlled flow, most dramatically in the early spring months (*e.g.*, preventing rain-on-snow events from creating down-stream deluges). Similarly, Shook *et al.* (2015) reported depressions in the Canadian Prairie Pothole Region controlled precipitation and runoff (*e.g.*, through storage and lag functions), directly altering stream flows. Nasab *et al.* (2017) reported gate-keeper effects of non-floodplain wetlands predominated at low flows, whereas non-floodplain wetlands increased streamflow during high precipitation events (*e.g.*, as the network wetted up and the watershed became increasingly connected). Yeo *et al.* (2019) found that non-floodplain wetlands of coastal Maryland and Delaware functioned in the aggregate to control (attenuate) streamflow and reduce flood magnitudes. Golden *et al.* (2016) analyzed non-floodplain wetlands in North Carolina, concluding that increased water storage associated with non-floodplain wetlands decreased streamflows. Rajib *et al.* (2020) modeled the effects of 455,000 non-floodplain wetlands in the Upper Mississippi River Basin, reporting that streamflow simulations showed statistically significant changes in 70% of the basins when non-floodplain wetland storages were incorporated into the model—meaning wetland storage was an important control on downstream flows. Similar findings were reported by Mekonnen *et al.* (2016) in the Prairie Pothole Region. Green *et al.* (2019) found that drained non-floodplain wetlands and open waters in Iowa could (still) store over 900 million m^3 of runoff, enough to contain a one-year, 24-hour rainfall event. Evenson *et al.* (2018) modeled a 1.3 to 2.8-fold increase in runoff-contributing areas affecting stream flow when non-floodplain wetlands and their cumulative water-retention capacities were lost from the landscape. This increase produced higher flood peaks and greater flow velocities in modeled downgradient systems. Similarly, modeled hydrological retention in non-floodplain wetlands was found to decrease peak stream flows by 7 to 16% (Fossey and Rousseau 2016). Wang *et al.* (2019) analyzed the influence of small, spatially distributed surface depressions (*i.e.*, non-floodplain systems inferred to be Prairie Pothole wetlands and open waters) in North Dakota, with model results demonstrating that depressions in the aggregate retained precipitation, demonstrably preventing excessive downgradient storm flows. Ameli and Creed (2019) reported wetlands closer to streams performed greater peak-flow attenuation than distal non-floodplain wetlands, while both types regulated baseflow (*i.e.*, dampened baseflow variance).

Non-floodplain wetlands and open waters are frequently connected to their local and regional aquifers, and hence to the stream networks, through groundwater flows (Nitzsche *et al.* 2017, Neff and Rosenberry 2018). For instance, Park *et al.* (2020) found groundwater discharge (in)to studied non-floodplain wetlands in the Southeastern United States, and that the groundwater contributing area increased during drier periods (which may in effect retard stream baseflow). Like Brooks *et al.* (2018) in the Prairie Pothole Region, Bugna *et al.* (2020) used isotopic analyses in Florida and demonstrated groundwater connectivity between non-floodplain wetlands and a nearby sinkhole. Lewis and Feit (2015) reported surface-water and groundwater connectivity in a regional aquifer in Florida, noting that increased groundwater withdrawals changed biogeochemical dynamics in groundwater-connected non-floodplain wetlands. Bam *et al.* (2020) demonstrated that not only do non-floodplain wetlands connect to and recharge local and regional groundwaters (providing water to farm and rural communities), but that ephemerally inundated non-floodplain wetlands were the dominant recharge source. Sampath *et al.* (2015) demonstrated that an "isolated" Michigan fen was connected to local and regional groundwater, other regional fens, as well as a nearby pond through a groundwater "pipeline." Ameli and Creed (2017) noted that non-floodplain wetlands have "fast" surface-water and slow groundwater connections and that groundwater connected non-floodplain wetlands from throughout the watershed (while storm events connected the system via surface waters). Neff and Rosenberry (2018) noted that geologic heterogeneity can either promote or prevent groundwater connectivity and synchrony between wetlands and downstream waters because of variations in bedrock properties (*e.g.*, composition and associated permeability). McLaughlin *et al.* 2014 simulated the regional hydraulic effects of non-floodplain wetlands, which were likened to a capacitor – dampening the effects of hydrologic disturbances to the aquatic network by modulating surficial aquifer dynamics and buffering stream baseflow. In their study, non-floodplain wetlands functioned as groundwater sinks during wet periods and water sources during drier periods. McLaughlin *et al.* (2014) further emphasized "that the role these [non-floodplain wetlands] play in buffering surficial dynamics and downstream base flow is realized even where water in these systems may never physically reach downstream systems."

Non-floodplain wetlands are bioreactors (*sensu* Marton *et al.* 2015) performing important sink and transformation functions affecting downgradient waters, which is well-supported in the literature. Bernal and Mitsch 2013; Biggs *et al.* 2017; Cheng and Basu 2017; Creed *et al.* 2017; Lane *et al.* 2018; Leibowitz *et al.* 2018; Golden *et al.* 2019. Non-floodplain wetland biogeochemical functions emerge from the convolution of aerobic and anaerobic microbial processes (*e.g.*, denitrification), plant uptake, physical processes (*e.g.*, settling, photo-degradation), and residence time in the wetland. These processes are controlled, in part, by hydrologic connectivity and isolation (*i.e.*, degrees of "disconnectivity") characteristics (Cohen *et al.* 2016), which affect transformation, sequestration, and transport rates. Reddy and DeLaune 2008; Baron *et al.* 2013; Evenson *et al.* 2018. For instance, Senar *et al.* (2018) noted watershed-scale carbon dynamics were controlled by microbial biogeochemical processing within non-floodplain wetlands and via precipitation-mediated transport to nearby headwater streams and on to downgradient systems. Excessive carbon export from non-floodplain wetlands with increasing drought and deluge cycling (allowing for carbon build up during drought followed by rapid flushing events) and temperature-mediated microbial activity could result in "brownification" (Monteith *et al.* 2007) of downstream waterbodies and concomitantly change aquatic metabolism (and hence affect aquatic integrity) by blocking light affecting primary productivity. Senar *et al.* 2018. Enanga *et al.* (2016; 2017) similarly noted watershed-scale nitrogen dynamics were controlled by microbial biogeochemical processing within non-floodplain wetlands and via precipitation-mediated transport to headwater streams and on to downgradient systems.

Storage, sequestration, and processing within non-floodplain wetlands and open waters are substantive. For example, Marton *et al.* (2015) reviewed the scientific literature, estimating that non-floodplain wetlands sequestered or processed 21-317 g carbon m^{-2} yr^{-1}, 0.01-5.0 g phosphorus m^{-2} yr^{-1}, and 0.8-2.0 g nitrogen m^{-2} yr^{-1}. In a synthesis of over 600 articles, Cheng and Basu (2017) determined that the first-order reaction rate constants for nitrogen and phosphorus were inversely proportional to wetland water residence times, a result that implies that >50% of the nitrogen removal across all water bodies occurs in small wetlands (<325 m^2). Cohen *et al.* (2016) found that most non-floodplain wetlands were "unambiguously small," suggesting an out-sized role in landscape nutrient dynamics. Evenson *et al.* (2018) modeled wetland water residence times at the watershed scale, noting a 75% decrease in residence time (and hence opportunities lost for biogeochemical processing) when smaller non-floodplain wetlands were removed from the landscape. Incorporating non-floodplain wetlands into a watershed model by Golden *et al.* (2019) resulted in a 7% average annual decrease in the nitrate yield to downgradient systems. A recent model analyses of the nearly 500,000 km^2 Upper Mississippi River Basin determined cumulative restoration of ~2% of the area to non-floodplain wetlands would result in ~12% nitrate reduction (Evenson *et al.* 2021). Martin *et al.* (2019) analyzed farmed non-floodplain wetlands, reporting that their study wetlands reduced nitrate levels in 85% of the multi-day inundation events while serving as downstream phosphorus sources from phosphorus absorbed onto agricultural soils. Denver *et al.* (2014) found that farmed non-floodplain wetlands in Delaware and Maryland improved water quality through nutrient processing (*i.e.*, transformation and sink functions). Similarly, Flint and McDowell (2015) reported headwater non-floodplain wetlands decreased nitrate and increased dissolved organic carbon, while seasonally affecting downstream total dissolved nitrogen concentrations.

The abstracts that were reviewed provide additional evidence that non-floodplain wetlands and open waters substantively affect downgradient streams, rivers, lakes, and other aquatic systems through variable connections which support diverse functions that improve downstream waters. Non-floodplain wetlands and open waters exist along physical, biogeochemical, and biological connectivity continuums that affect downstream waters at all points along those continuums. Many of the functions of non-floodplain wetlands and open waters are most readily discerned and quantified in the aggregate (*e.g.*, flood-magnitude attenuation, excessive nutrient mitigation, groundwater recharge, support for metapopulation dynamics). Importantly, many of the functions performed by non-floodplain wetlands and open waters that affect downstream waters result from the disconnections (often hydrological, *e.g.*, surface water storage) that create and maintain conditions conducive to the performance of beneficial functions (frequently hydrological and biogeochemical, *e.g.*, mitigation of flood peak flows, sequestration of contaminants).

iv. Abstracts Noted in the Screening Process to Disagree with the Major Conclusions of the Science Report

The Science Report concluded that the scientific evidence unequivocally demonstrates that streams, including ephemeral, intermittent, and perennial streams and rivers are physically, chemically, and biologically connected to downstream rivers via channels and associated alluvial deposits. The Science Report similarly concluded that floodplain wetlands and open waters are physically, chemically, and biologically integrated with rivers via functions that improve downstream water quality. Further, the Science Report noted non-floodplain wetlands and open waters affect the integrity of downstream waters through numerous functions, including storage of floodwater; recharge of ground water that sustains river baseflow; retention and transformation of nutrients, metals, and pesticides; export of organisms or reproductive propagules to downstream waters; and habitats needed for stream species. Despite ample evidence that non-floodplain wetlands provide hydrologic, chemical, and biological functions that affect material fluxes to downstream waters, few scientific studies explicitly addressing connections between non-floodplain wetlands and river networks had been published in the peer-reviewed literature – with notable exceptions. For example, the Science Report concluded that non-floodplain wetlands affect downstream waters when they intercept flowpaths and runoff emanating from pollution sources.

The evidence presented in the overwhelming majority of the scientific papers addressing the connectivity and effects of the three systems analyzed led ORD subject-matter experts to confirm that recent research reinforces the findings from the Science Report, and that substantive scientific advances in or after 2014 have expanded scientific knowledge regarding the mechanisms of connectivity and quantitative effects of these systems. For instance, when sufficient information was provided in the abstract to make a determination, 100% of the scientific publications specific to ephemerally and intermittently flowing stream systems screened (n=57) were found to support the Science Report that ephemeral and intermittent streams are connected to and significantly affect downgradient systems. Non-floodplain wetlands and open waters were found to connect to and/or perform functions substantively affecting downgradient systems in 99% of the sufficiently descriptive papers screened (131 of 133). The Science Report concluded that floodplain wetlands and open waters were integrated to river networks, performing important functions affecting downgradient waters. The literature screened similarly incontrovertibly supports that finding, with 99% (n=292 of 298) papers with floodplain wetlands and open waters types discerned marked in support of the 2015 Science Report conclusions.

Papers noted as both supporting and refuting, or outright refuting the findings were rarely found. Screeners noted six stream papers of 515 with a refuting conclusion determination (1%); of those two were noted as both supporting and refuting (Milner *et al.* 2019; Richardson 2019) and four stream papers were noted as refuting the findings (Fryirs and Gore 2014; Laughlin *et al.* 2016; Schmidt *et al.* 2018; Anderson *et al.* 2020). However, of those papers, only Richardson (2019) and Anderson *et al.* (2020) were noted as addressing a focal stream type (headwater stream and perennial stream, respectively); the other four stream papers were marked by screeners as “stream type not discernible.”

Ten screened and included floodplain wetland and open water papers of 449 (2%) were noted as both supports and refutes (Azinheira *et al.* 2014; Puttock *et al.* 2017; Kasak *et al.* 2018; Wegener *et al.* 2018; Gulbin *et al.* 2019; Redder *et al.* 2021; Leuthold *et al.* 2021; n=7) refuting and cannot be discerned (Quin *et al.* 2015, Beesley *et al.* 2020), and refuting (Painter *et al.* 2015). Riverine (within-channel) systems were noted as the focal ecosystem type for Painter *et al.* (2015), Puttock *et al.* (2017); and Kasak *et al.* (2018). Quin *et al.* (2015) was noted as wetland type not discernible, whereas Gulbin *et al.* (2019) was noted as addressing multiple wetland types and/or spatial locations (*e.g.*, floodplain, riverine, non-floodplain wetland, etc.). Azinheira *et al.* (2014), Wegener *et al.* (2018), and Beesley *et al.* (2020) were noted as conducting research on both floodplain (or riparian system) and riverine (*i.e.*, within-channel) systems, while Redder *et al.* (2021) and Leuthold *et al.* (2021) addressed floodplain wetlands and open waters.

Five non-floodplain wetland and open water papers of 230 (2%) were noted as both supporting and refuting (Sullivan *et al.* 2019a, Acreman *et al.* 2021) or refuting (Quin *et al.* 2015; Arheimer and Pers 2017; Johnston and McIntyre 2019). The focal system under study was not discernible for Arheimer and Pers (2017). Both Quin *et al.* (2015) and Acreman *et al.* (2021) were marked as addressing multiple wetland types and/or spatial locations noted (*e.g.*, non-floodplain wetlands, floodplain wetlands, streams, etc.). Only Johnston and McIntyre (2019) and Sullivan *et al.* (2019a) were noted by the screener to be papers explicitly about a known non-floodplain wetland type (*e.g.*, geographically isolated wetland, non-floodplain wetland, etc.).

1. Ephemeral, Intermittent, and Perennial Stream Systems

Examining stream abstracts, a screener reported that Schmidt *et al.* (2018, p.320) found subtle population genetic structure in a common fish (*Leiopotherapon unicolor*) that disperses widely in arid Australian river systems. However, the same species in a tropical river system was found to have small but detectable genetic differences between upstream and downstream populations. This suggests that for this species, dispersal between tributaries and the mainstem of the river itself is more limited in the tropical system, possibly due to differences in migratory patterns. Laughlin *et al.* (2016, p.1808) analyzed stable isotopes from the otoliths of channel catfish (*Ictalurus punctatus*) and blue catfish (*Ictalurus furcatus*) between the middle Mississippi River and tributaries. Though differences in river water constituents were found between the main channel and tributaries, otolith characteristics suggested that channel and blue catfish were “primarily recruited from the large rivers (Missouri and Mississippi)…with minimal contributions from smaller tributaries.” Fryirs and Gore (2014) analyzed sediment movement between a tributary and a mainstem river. This paper was noted as refuting the Science Report findings as the tributary in this study was found to not provide any sediment because the main stem river had created a sediment block that prevented sediments from reaching the main river. Anderson *et al.* (2020) assessed the effects of a high-head dam along the perennially flowing Upper Mississippi River, finding similarity in upgradient and downgradient assemblages (a “supporting” statement) while also noting certain migratory species, such as skipjack herring (*Alosa chrysochloris*) were not present above the dam (a “refuting” statement regarding upstream/downstream connectivity).

Two stream paper abstracts were noted as both supporting and refuting the Science Report. Richardson (2019) wrote a scientific review that was marked in the screening process as both supporting and refuting the Report’s findings. The abstract notes that headwaters are the (hydrologic) source of all stream networks, a supporting statement. Conversely, the screener noted that the abstract also stated that a characteristic of some headwaters was “isolation,” implying a limited of lack of connectivity to downgradient systems (*i.e.*, two ends of a connectivity gradient). Lastly, Milner *et al.* (2019) analyzed macroinvertebrate assemblages of dammed and free-flowing stream tributaries in the Sierra Nevada Mountains in California, finding that macroinvertebrate diversity was higher in the tributaries on the free-flowing river (a supporting claim) but that there were no differences in macroinvertebrate diversity downgradient of tributary junctions nor differences in diversity within the dammed river (a refuting claim).

An examination of these abstracts points to these papers, which focused on very specific kinds of connections and effects (*e.g.*, of species responses to their environments), as exceptions to the general rules summarized in Major Conclusions 1, 2, and 3 of the Science Report. Their findings are consistent with the Science Report’s Major Conclusion 4, that variations in the type, degree and downstream effects of connections are determined by characteristics of the physical, chemical, and biological environments and by human activities, and that these variations support different ecosystem functions. As discussed in section I.A.i above, connectivity of streams to downstream waters occurs along a continuum that can be described in terms of the frequency, duration, magnitude, timing, and rate of change of water, material, and biotic fluxes to downstream waters. These connectivity descriptors characterize the range over which streams and wetlands vary and shift along the connectivity gradient in response to changes in natural and anthropogenic factors and, when considered in a watershed context, can be used to predict probable effects of different degrees of connectivity over time.

2. *Floodplain Wetland and Open Water Systems*

A screener marked that Painter *et al.* (2015) refuted the floodplain wetland and open water findings of the Science Report. The refutation in this case hinged on the data in the abstract demonstrating that mercury from sediments in the systems studied (beaver ponds within a riparian zone) was transformed (methylated) in the floodplain open waters and subsequently incorporated into the aquatic food web, demonstrating both chemical and biological connection. But, in this case, the connection resulted in degrading water quality (though through transformation functions affecting downgradient waters). However, this paper also supports the Report's conclusion that floodplain wetlands and waters serve as an important part of the food web for species that also utilize downstream waters. Beesley *et al.* (2020) and Quin *et al.* (2015) were papers marked as both refute and "cannot be discerned." Beesley *et al.* (2020) reported that local biofilms within floodplain habitats supported fish during inundation periods (*i.e.*, fish fed in connected floodplain habitats when inundated) but articulated that large-bodied fish (specifically) of a northern Australian river were not found to transport carbon from the floodplain and return it to the river. Quin *et al.* (2015) conducted a statistical modeling approach analyzing the effects of wetlands and other features on downstream pollutant retention. They found that the main effects were distance the pollutant traveled before reaching the coastal waters and the presence of major lakes; wetland contributions to pollution abatement were not detected. The screener marked this paper as both refuting and "cannot be discerned" and noted that the specific wetland type (*e.g.*, floodplain wetland and open water) was not detailed in the abstract.

Seven papers were noted during the screening process as both supporting and refuting the Science Report's major conclusions for floodplain wetlands and open waters. Azinheira *et al.* (2014, p.6168) modeled floodplain solute retention, finding that modeled "inset" floodplains were inundated ~1% of the year (a supporting statement regarding connectivity), yet the flow amount residence times were too short and hence this paper was also marked as refuting the major conclusions, as there was no "substantial impact on dissolved contaminants flowing downstream." Puttock *et al.* (2017, p.430) found riparian beaver activity substantively increased floodplain wetland and open water storage, sedimentation, nitrogen and phosphorus retention, and flow attenuation, resulting "in lower diffuse pollutant loads in water downstream." A screener noted that these riparian open waters also increased dissolved organic carbon contributions, which was perceived by the screener as deleterious to downstream water quality. Kasak *et al.* (2018, p.1) reported a two-year old constructed "in-stream free surface flow" wetland removed annually 14% of phosphate (improving water quality, a supporting claim) but was a source of total nitrogen (a pollutant in excess, a refuting claim). Wegener *et al.* (2018) analyzed nitrate dynamics in riparian areas of mountainous stream reaches in Colorado, finding that studied riparian zones were sources of nitrate (noted as a refuting claim) while one wider zone was also a nitrate sink at high flows (marked as a supporting statement). Gulbin *et al.* (2019) developed a hydrologic model of the endorheic Devils Lake in North Dakota, finding that given the climate drivers affecting the region wetland restoration does not change the current flood risk (perceived as a refuting statement) but restoration would provide complimentary flood-mitigation benefits under modified climate scenarios. Both Redder *et al.*

(2021) and Leuthold *et al.* (2021) addressed the movement of nitrogen from riparian systems to streams, indicating connectivity between floodplain wetlands and open waters. Redder *et al.* (2021) noted that groundwater seeps in riparian areas were connecting to downgradient waters (supporting phrase), providing nutrients that may end up degrading water quality (the refuting clause). Similarly, Leuthold *et al.* (2021) found riparian wetlands connected with downgradient systems through a late-winter flush of mineralized nitrogen (a supporting point regarding connectivity), a potential pollutant (refuting point).

An examination of these abstracts suggests that the results of the studies are consistent with the Science Report's finding that the floodplain wetlands and open waters function as a source, sink, and transformer of materials, including nutrients. Regardless of the perceived benefit (*e.g.*, nutrient sink) or detriment (*e.g.*, nutrient source), the connection between the floodplain and the downstream water effect remains. The Report noted that these functions are not mutually exclusive; for example, the same wetland can be both a source of one nutrient and a sink for another nutrient. The presence or absence of these functions, which depend on the biota, hydrology, and environmental conditions in a watershed and can change over time. Some of the "refuting" papers also likely support the conclusion that connectivity occurs on a continuum, as discussed in section I.C.iv.1.

3. Non-Floodplain Wetland and Open Water Systems

Three papers screened for non-floodplain wetland and open water systems were noted as refuting the major conclusions of the Science Report. Quin *et al.* (2015; also noted immediately above in the floodplain wetlands and open water section (section I.C.iv.2)), determined that wetland contributions to pollution retention were not detected in their study (though specific wetland type, such as a non-floodplain wetland or open water, was not described or noted by the screeners). Arheimer and Pers (2017) conducted a study in Sweden of over 1,574 constructed wetlands, demonstrating that their effects on nutrient reductions were minor (*i.e.*, 0.2% for nitrogen and 0.5% for phosphorus); this was marked as a refuting paper, though it should be noted that wetland type was not discernable and that the reductions though minor were nonetheless found to reduce the pollutant loads to the seas. Johnston and McIntyre (2019) conducted a study on the effects of grassland-to-cropland conversion on various geospatial metrics of non-floodplain wetland (prairie pothole) connectivity in North and South Dakota. They found that wetland area across the study system decreased by 25%, wetland size decreased by ~0.4 ha, and wetland density decreased by 16%, largely due to splitting of large wetlands into smaller wetlands and reduction in the area of smaller wetlands. Their analysis of landscape connectivity metrics, however, found that the geospatial connectivity of remaining wetlands remained intact, and could still support metapopulation dynamics for some species (*e.g.*, waterfowl).

Acreman *et al.* (2021) explored the effectiveness of nature-based solutions to water issues in Africa; this paper was screened and noted as both supporting and refuting the Science Report's major conclusions for non-floodplain wetlands and open waters. This review paper addressed multiple wetland types and determined that floodplain wetlands can improve water quality and reduce flood risk, whereas headwater (non-floodplain) wetlands were only found to positively affect water quality (and not affect flood risk). Sullivan *et al.* (2019a) analyzed non-floodplain wetlands that had been ditched, drained, and converted to agricultural production until they were restored; this paper was noted as both refuting and supporting the major conclusions of the Science Report. The legacy agricultural nutrients ("agrochemicals") in the wetlands were noted to be threats to downgradient waters (a refuting statement), with wetlands closer to streams and conveyances having a greater threat potential. Wetlands further from the stream network would be expected to better retain the agrochemicals (a supporting statement).

The abstracts described in this section focus on research pertaining to two findings in the Science Report: (1) connectivity and associated effects occur along discernable gradients and (2) non-floodplain wetland functions are not mutually exclusive (*e.g.*, a wetland can improve water quality, attenuate floods, or both (*see, e.g.*, Evenson *et al.* 2018), as further discussed in sections I.C.iv.1 and 2. The Science Report found that gradients of non-floodplain connectivity can be described in terms of the frequency, duration, magnitude, timing, and rate of change of water, material, and biotic fluxes to downstream waters. As discussed in section I.A.i, these descriptors are influenced by factors such as climate, geology, and terrain, which interact with other factors such as the magnitudes of the various functions within wetlands (*e.g.*, amount of water storage or carbon export) and their proximity to downstream waters to determine where wetlands occur along the connectivity gradient. Recognizing these complexities, the Science Report noted that evaluations of individual wetlands or groups of wetlands, however, could be possible through case-specific analysis.

v. Screening Benefits and Limitations

There are two main approaches to screening scientific literature for review, that of a “brute-force” approach wherein hundreds to thousands of papers are read and summarized, and an active-screening approach used here, with machine-learning models prioritizing papers to be screened. The brute-force approach is laborious and time-consuming. However, by reading the full paper, its context as well as specifics necessary to answer important questions on the findings can often be discerned. Conversely, the active-screening approach allows for thousands of papers to be screened expeditiously, but the screening consists only of an abstract, and important contextual details are often missing.

Furthermore, while screeners were all presented with the same instructions as to include or exclude a paper and to complete the additional information section, experiential and perceptual differences between screeners exist, nonetheless. Thus, these differences may result in different characterizations of some abstracts. The screening was also conducted such that each abstract was only screened by one person rather than two or more persons screening (and then requiring unanimity to “accept” an abstract for inclusion). There was a necessary trade-off between the number of papers to be screened and measured concordance between screeners.

Due to the available time for this review and the number (>17,000) of abstracts to review, only abstracts were read. The active-screening approach calculated that screeners reviewed between 81-90% of the relevant scientific literature. But, like any review, some relevant papers were likely missed during the screening process. The screening population is established early, and papers that end up being missed by the forward-citation mapping (*e.g.*, papers that are published subsequent to the mapping process) are not presented to the screeners as those papers are simply not part of the population of papers to be screened (*e.g.*, Crabot *et al*. 2021; Evenson *et al.* 2021; Golden *et al.* 2021a). Further limitations include some assumptions that may have been made. For instance, abstracts exploring the effects of “depressions” (*e.g.*, Wang *et al.* 2019) were typically assumed to be depressional wetlands (*e.g.*, Lewis and Feit 2015). Floodplain ecosystems include wetlands and open waters, as well as non-wetland systems.

Biogeoochemical processing, such as denitrification, often requires anoxic or reduced soil conditions typically found in wetlands and open waters. Hence, in references where biogeochemical processing was noted to occur within floodplains, it was assumed to be occurring within floodplain wetlands and open waters (unless material in the abstract characterized the study differently). A complete read of each paper would likely obviate many uncertainties but was beyond the scope of this review. However, given that the scientific papers published in or after 2014 and reviewed by the team provided overwhelming support substantiating the findings and conclusions of the Science Report, the limitations of the approach are unlikely to affect the main findings reported here.

In late October 2021, ORD reviewers additionally identified another 37 scientific papers the initial effort had not captured since their review began in mid-June 2021 (*e.g.*, scientific manuscripts accepted or published since the screening process began or missed by the original screening; *see* Appendix C3 for the 37 papers). Some of these papers were identified because the ORD reviewers were co-authors of the papers, while others were found in part by reviewing scientific journal tables of contents or by Google Scholar queries.

vi. Review of Additional Literature

As part of the notice and comment process, the agencies solicited comment on the scientific literature contained in Appendix C of the Technical Support Document for the Proposed Rule and requested from the public additional scientific literature and references relevant to the Science Report's conclusions on the connectivity and effects of streams, floodplain wetlands and open waters, and non-floodplain wetlands and open waters on the chemical, physical, and biological integrity of larger downstream waters. Several commenters provided additional literature to the agencies.

The agencies reviewed those citations submitted as part of the notice and comment process along with the 37 scientific papers noted above for relevance to the report. Some of the references provided by public commenters were already included in Appendix C of the Technical Support Document for the Proposed Rule and were not reviewed because they had already been screened by the agencies, as described further in section I.C.i. Other submitted references were determined to not meet the agencies' criteria (*i.e.*, they were not published in or after 2014, they were not peer-reviewed, or the agencies could not ascertain if the references had undergone peer review). Other references were determined to not be relevant to the conclusions of the Science Report (*i.e.*, the findings of the paper were outside the context described in section I.C). The agencies have considered such references for relevance to other aspects of this Technical Support Document and have included such relevant references where appropriate (*e.g.*, where they were relevant to implementation of the final rule).

In total, the agencies reviewed and read 80 additional peer-reviewed scientific papers published in or after 2014 to determine if their findings are relevant to the conclusions of the Science Report. This included the 37 scientific papers that the agencies had identified in October 2021 (*see* Appendix C2ii) as well as 43 peer-reviewed citations published in or after 2014 that were submitted to and assessed by the agencies as part of the public comment process. Thirty papers were found to have sufficient information to draw conclusions regarding the most up-to-date and submitted literature on the findings of the Science Report. In all cases, the conclusions of the Science Report were substantiated by these scientific references. *See* Appendix C3 for additional information.

vii. Summary and Conclusions

After analyzing the available abstracts of 12,659 scientific peer-reviewed papers published in or after 2014 and additional literature published during that period (*see* section I.C.vi), the evidence reviewed is conclusive: ephemerally, intermittently, and perennially flowing streams, floodplain wetlands and open waters, and non-floodplain wetland and open waters are hydrologically, biologically, chemically, and functionally connected to downstream systems and substantively and definitively affect down-gradient aquatic systems. This conclusion echoes the findings relative to streams and floodplain systems, while updating the non-floodplain wetland and open water findings of the Science Report. ORD's review across all three systems found overwhelming evidence from the abstracts that were screened conclusively supporting the connectivity and down-gradient effects of stream, floodplain, and non-floodplain wetland and open water systems.

Furthermore, science has substantively advanced since 2014 regarding, in particular, the downstream connectivity and effects of non-floodplain wetlands and open waters, with many examples of consequential effects in the Discussion section (section I.C.iii) above. Those advances include evidence from a study by Rains *et al.* (2016) titled "Geographically isolated wetlands are part of the hydrological landscape" that analyzed how non-floodplain wetlands (geographically isolated wetlands, or GIWs, in their parlance) were nodes in hydrologic networks that had aquatic network-scale effects (*e.g.*, through lag, sink, and source functions). Non-floodplain wetlands were the dominant source of groundwater recharge, replenishing groundwaters for farm and rural communities in an isotopic study by Bam *et al.* (2020). Isotopic analyses, a relatively recently applied tool for hydrologic studies, have conclusively demonstrated surface-water connectivity between non-floodplain wetlands and stream systems. *See, e.g.*, Brooks *et al.* 2018. An additional large spatial-scale hydrological analysis of 260 non-floodplain wetland catchments across 10 study regions throughout North America by Thorslund *et al.* (2018) found that non-floodplain wetlands were watershed sources to downgradient systems. Importantly, Thorslund *et al.* (2018) noted there was no specific relationship between landscape position (*e.g.*, linear distance vis-à-vis a stream network) and the hydrologic connectivity of the non-floodplain wetland catchments. They reported the following:

> Significant positive correlations between GIW [geographically isolated wetland] subcatchment runoff generation and distance measures…were observed in only 2 of 53 investigated cases. We therefore conclude with regard to Research Question 3 [how well can runoff generation of GIW subcatchments be predicted from simple geographic characteristics (*e.g.*, distance and elevation relative to the stream network)?] that runoff generation is poorly predicted by simple geography. This contradicts the contention that GIWs are less hydrologically connected when further away from the stream network. The absence of distance, or indeed any consistent linear predictive associations, provides support for the explanation that runoff generation controls are specific to local topography (*e.g.*, spill elevations), vegetation (impacting ET [evapotranspiration] and infiltration), and geology (impacting groundwater conveyance).

Thorslund *et al.* 2018 at 5. Golden *et al*. (2016, p. 21) found that more distal geographically isolated wetlands may be less frequently connected to downstream waters than wetlands that are closer to the stream network, but that can still have hydrologic impacts downstream ("The further GIWs are from a stream, the greater their capacity to increase streamflow due to the physiographic setting, hypothesized transit times, and sequencing of watershed hydrologic connectivity in the study area.")

The presence of hydrologic heterogeneity in wetland connectivity – which includes varying degrees of disconnection – across the landscape is important for biological, biogeochemical, and hydrological functions cumulatively affecting downgradient systems. According to Cohen *et al.* (2016, p.1978), the heterogenous hydrologic connectivity of non-floodplain wetland systems (*i.e.*, the presence of a connectivity continuum) is "precisely what enhances some GIW [geographically isolated wetland] functions and enables others." Marton *et al.* (2015) conducted a review of the biogeochemical functions of non-floodplain wetlands, determining that non-floodplain wetlands were "biogeochemical reactors" on the landscape due to their chemical processing rates and sequestration functions that influence and effect water quality (*i.e.*, sink and transformation functions). Marton *et al.* (2015, p.408) note that non-floodplain wetlands are "integral to biogeochemical processing on the landscape and therefore [to] maintaining the integrity of US waters." Cohen *et al.* (2016, p.1978) conclude that "sustaining landscape functions requires conserving the entire continuum of wetland connectivity, including GIWs." This is echoed by Creed *et al.* (2017), who also note that "vulnerable waters" such as headwater streams and non-floodplain wetlands provide $15.7 trillion and $673 billion, respectively, in ecosystem services in the conterminous United States annually. These findings and others were summarized by Lane *et al.* (2018) in an updated and peer-reviewed state-of-the-science on the connectivity and effects of non-floodplain wetlands and open waters. They concluded (p. 363) all non-floodplain wetlands "are interconnected with streams and river networks" and that the emergent heterogeneity of those convoluted connections and disconnections affect the hydrological, biogeochemical, and physical functions of non-floodplain wetlands, "modify[ing] the characteristics and function[s] of downstream waters."

It is evident that the conclusions of the Science Report have been bolstered by scientific advances published since 2014. The science demonstrates that the aquatic systems analyzed in the Science Report and in subsequent publications are dynamically connected laterally, longitudinally, vertically, and over time with other surface waters, with groundwater, and with the landscapes in which they function. These connections exist on gradients that vary across space and time from highly connected to highly disconnected streams, wetlands, and open waters. Similarly, the functions that affect downgradient waters also occur along connectivity gradients, from functions that predominate during highly connected periods to those that occur more so at periods of lower or no connectivity. Disconnections (*i.e.*, less connected or "isolated" conditions) such as stream-network surface-flow fragmentation (*e.g.*, as can occur with ephemeral or intermittent reaches), wetland perched on clay substrates within a floodplain, or non-floodplain wetlands embedded in uplands, often provide the optimal conditions for biogeochemical, hydrological, and biological functions of streams, wetlands, and open waters that substantively affect down-gradient waters.

D. Closing Comments on the Science Report and Updated Literature

This section updates the Closing Comments from the Executive Summary of the Science Report with information from the scientific literature published since the Report's release, including the literature reviewed and discussed in section I.C.

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 illustrated in the introduction to this report. Thus, the effects of streams, wetlands, and open waters on rivers are determined by the presence of (1) physical, chemical, or biological pathways that enable or inhibit the transport of materials and organisms to downstream waters; and (2) functions within the streams, wetlands, and open waters that alter the quantity and quality of materials and organisms transported along those pathways to downstream waters.

The strong hydrologic connectivity of river networks is apparent in the existence of stream channels that form the physical structure of the network itself. Given the evidence reviewed in the Science Report and in more recent literature, it is clear that streams and rivers are much more than a system of physical channels for efficiently conveying water and other materials downstream. The presence of physical channels, however, is a compelling line of evidence for surface-water connections from tributaries, or water bodies of other types, to downstream waters. Physical channels are defined by continuous bed-and-banks structures, which can include apparent disruptions (such as by bedrock outcrops, braided channels, flow-through wetlands) associated with changes in the material and gradient over and through which water flows. The continuation of bed and banks downgradient from such disruptions is evidence of the surface connection with the channel that is upgradient of the perceived disruption.

Although the peer-reviewed literature available at the time of the Science Report's publication (January 2015) did not provide information to categorically identify types of non-floodplain wetlands that have the types of connections or disconnections that confer important functional effects to downstream waters, the evidence did support the conclusion that non-floodplain wetlands provide these functions and that additional information (*e.g.*, from field assessments, analysis of existing or new data, reports from local resource agencies) could be used in combination with evidence from literature in case-specific analysis. The Science Report also concluded that information from emerging research on functions occurring along the gradients of connectivity observed in non-floodplain wetlands, including studies of the types identified in Section 4.5.2 of the Science Report, could close some of the existing data gaps in the near future:

> Recent scientific advances in the fields of mapping, assessment, modeling, and landscape classification indicate that increasing availability of high-resolution data sets, promising new technologies for watershed-scale analyses, and methods for classifying landscape units by hydrologic behavior can facilitate and improve the accuracy of connectivity assessments. Emerging research that expands our ability to detect and monitor ecologically relevant connections at appropriate scales, metrics to accurately measure effects on downstream integrity, and management practices that apply what we already know about ecosystem function will contribute to our ability to identify waters of national importance and maintain the long-term sustainability and resiliency of valued water resources.

Science Report at ES-15.

ORD's update of relevant literature published since 2014-2015 shows that scientific understanding of the watershed functions of non-floodplain wetlands has substantively advanced in recent years. The results of recent research confirm that functions provided by these systems support water quality and availability in streams, rivers, lakes, reservoirs, coastal waters, and aquifers and increase the resilience of communities and ecosystems to a changing climate by mitigating for effects of floods and droughts. The research described in section I.C of this document provides new insights into the factors governing the types and degrees of connectivity that confer functional effects downstream, including evidence supporting the Science Report's finding that spatial distance must be considered in context with other factors such as topography, vegetation, soils, geology and climate, to determine the magnitude of downstream effects of non-floodplain wetland systems.

E. Other Scientific Support

In preparation for this final rule, the agencies considered scientific and technical information other than the Science Report and the literature updating the Report discussed in section I.C. This includes peer-reviewed published literature, other publications, and other information that was outside the scope of the Science Report. The agencies also reviewed and considered other data and information including jurisdictional determinations, relevant agency guidance and implementation manuals, federal and state reports, letters and commentary from the SAB on past rulemaking efforts, comment letters received on previous rulemaking efforts, consultation comment letters for this rule, letters received to the pre-proposal recommendations docket, and timely comments and associated scientific literature provided as part of the public comment period. This additional technical and scientific support is cited throughout this technical support document.

F. Emerging Science

As the agencies work to finalize and then implement the rule, they will be guided by the transparent review and application of the best available science that further informs and underpins regulatory decisions and fills data gaps on connectivity and effects across stream systems, floodplain wetlands and open waters, and non-floodplain wetlands and open waters. Examples of recent advances include quantifying the probability of perennial stream flow (*e.g.*, Jaeger *et al.* 2019), quantifying streamflow responses to shifts in future climates (*e.g.*, Jaeger *et al*. 2014), mapping stream systems (*e.g.*, Allen *et al*. 2018; Hafen *et al*. 2020), isotopically analyzing material exchange between floodplain wetlands and adjoining stream networks (*e.g.*, Tetzlaff *et al*. 2014; Sánchez-Carrillo and Álvarez-Cobelas 2018), and incorporating high temporal and high spatial resolution data into coupled floodplain and stream models (*e.g.*, Hansen *et al*. 2018; Jensen and Ford 2019).

Emerging scientific advances since 2015 have continued to inform the connectivity and effects of non-floodplain wetlands and open waters, in particular when assessed at the watershed-scale. As stated in Conclusion 3 of the Science Report, the connectivity and effects of wetlands and open waters that are not hydrologically linked to other water resources by surface water or by stream channels and their lateral surface extensions into riparian areas and floodplains are more difficult to address solely from evidence available in peer-reviewed studies at the time of the report's publication. However, as discussed in section I.C, advances have been made since then that can help inform case-specific significant nexus determinations. The currently available scientific literature on non-floodplain wetlands and open waters shows that these systems have important hydrologic, water-quality, and habitat functions that can affect the integrity of downstream waters. The Science Report noted these effects were particularly evident where (a) connections from the non-floodplain wetlands and open waters to the downstream waters exist, (b) when non-floodplain wetlands and open waters intersect flow paths from known point or non-point sources, or (c) when considered cumulatively with other non-floodplain wetlands and open waters. The current scientific literature supports these findings, and also provides additional examples of the direct effects of non-floodplain wetland and open water "isolation" on downstream water integrity, *e.g.*, through attenuating flood peaks and mitigating excessive nutrient levels. Currently available peer-reviewed literature and scientific wetland classification systems clearly document the importance of natural variation in the types and degrees of connectivity in non-floodplain wetlands and open waters, and the effects of that natural variation on the types of ecosystem functions and services such wetlands provide.

The body of peer-reviewed scientific literature regarding the watershed functions of non-floodplain wetlands and open waters and their cumulative effects on downstream waters continues to grow since the publication of the Science Report (*e.g.*, Marton *et al*. 2015; Rains *et al*. 2016; Cohen *et al*. 2016; Creed *et al*. 2017; Alexander *et al*. 2018; Mushet *et al*. 2019; Mengistu *et al*. 2020; Evenson *et al*. 2021; Golden *et al*. 2021a). Importantly, data from ongoing and emerging research not yet published in the peer-reviewed literature could close perceived data gaps in the near future. Scientific advances in the fields of mapping (*e.g.*, Heine *et al*. 2004; Tiner 2011; Lang *et al*. 2012; Wu *et al*. 2014b; Wu *et al*. 2015; Wu and Lane 2016; Lane and D'Amico 2016; Wu and Lane 2017; Allen *et al*. 2018, Colvin *et al*. 2019; Vanderhoof and Lane 2019; Borja *et al*. 2020; Fesenmyer *et al*. 2021), assessment (*e.g.*, McGlynn and McDonnell 2003; Gergel 2005; McGuire *et al*. 2005; Ver Hoef *et al*. 2006; Leibowitz *et al*. 2008; Moreno-Mateos *et al*. 2008; Lane and D'Amico 2010; Ver Hoef and Peterson 2010; Shook and Pomeroy 2011; Powers *et al*. 2012; McDonough *et al*. 2015; Harvey *et al*. 2019; Schmadel *et al*. 2019; Ali and English 2019; Harvey *et al*. 2021), modeling (*e.g.*, Golden *et al*. 2013; McLaughlin *et al*. 2014; Fossey and Rousseau 2016; Jones *et al*. 2018a; Rajib *et al*. 2020; Evenson *et al*. 2021; Golden *et al*. 2021a), and landscape classification (*e.g.*, Wigington *et al*. 2013; White and Crisman 2016; Klammler *et al*. 2020) indicate that increasing availability of high-resolution data sets, promising new technologies for watershed-scale analyses, and methods for classifying landscape units by hydrologic behavior can facilitate such individual and cumulative functional characterizations by broadening their scope and improving their accuracy. *Id.* at 6-13. Emerging research that expands the ability to detect and monitor chemically, physically, and biologically relevant connections at appropriate scales, metrics to accurately measure effects on downstream integrity, and management practices that apply what is already known about non-floodplain wetlands and open water functioning, will contribute to advance the ability to maintain the long-term sustainability and resiliency of valued water resources. Scientific inventories of wetlands and wetland functions or ecosystem systems are likely to continue to expand the understanding of the benefits non-floodplain wetland and open water ecosystem functions and services provide to humans and the environment.

G. SAB Review of the Proposed Rule

The agencies also engaged with the SAB on several occasions during the development of this rule. As discussed in section I.B., the SAB was established in 1978 to provide independent scientific and technical advice to the EPA Administrator on the technical basis for agency positions and regulations.

On January 28, 2022, during the public comment period, the agencies met with the SAB Work Group for Review of Science Supporting EPA Decisions to explain the proposed rule, including its basis, and to address the SAB Work Group's initial questions. On February 7, 2022, the SAB Work Group signed a memorandum recommending that the Chartered SAB should review the adequacy of the science supporting the proposed rule. SAB 2022a. On March 7, 2022, during the public meeting of the Chartered SAB, the Chartered SAB unanimously voted to review the scientific and technical basis of the proposed rule. The SAB has similarly reviewed the technical and scientific basis of other past rulemakings revising the definition of "waters of the United States." *See* SAB 2014b; SAB 2020. The SAB formed a Work Group of its chartered members which issued a draft review on May 9, 2022, and the Chartered SAB held a public meeting on the matter on May 31 and June 2, 2022. The SAB issued their final review on July 5, 2022. SAB 2022b (hereafter 2022 SAB Review). All materials related to the 2022 SAB Review are available in the docket for this rule and on the SAB's website.

The SAB's review of the proposed rule was overall supportive of the science underpinning the proposed rule, including the Technical Support Document, and the discussion of shallow subsurface flow. The SAB made some recommendations on the discussion of climate change. The SAB's recommendations relevant to the final rule were also raised during the public comment period and have been considered by the agencies during their drafting of this Technical Support Document. A memorandum summarizing the agencies' interactions with the SAB and the SAB's review of the proposed rule and its supporting documents is available in the docket for this rule.

H. Other Scientific Information

i. Ecosystem Services

Streams, wetlands, lakes, ponds, and other types of aquatic resources are well-known to provide a variety of functions that translate into ecosystem services. *See*, *e.g.*, Creed *et al*. 2017. Ecosystem services are benefits that humans obtain from ecosystems, including provisioning, regulating, cultural, and supporting ecosystem services. Millennium Ecosystem Assessment 2005. Provisioning services relate to the food, water, timber, fiber, and other resources provided by wetlands and other aquatic resources that are consumed. *Id.* Regulating services affect climate, floods, disease, wastes, and water quality. *Id.* Cultural services include all non-material benefits obtained from ecosystems and can include recreational, aesthetic, educational, and spiritual benefits. *Id*. Supporting services are necessary for the production of other ecosystem services and include nutrient cycling, photosynthesis, and soil formation. *Id.*

Wetlands are recognized as one of the most valuable ecosystems in the planet. Costanza *et al*. 1997; Mitsch *et al.* 2015. For example, wetlands provide a wide range of ecosystem services that are directly used or appreciated by humans. *See, e.g*., Brander *et al.* 2012a; Brander *et al*. 2012b; Chaikumbung *et al*. 2016; De Groot *et al*. 2018; Ghermandi *et al*. 2010; McLaughlin and Cohen 2013; Mitsch and Gosselink 2007; Mitsch *et al*. 2015. Provisioning services provided by wetlands include the maintenance of fisheries and wildlife for consumption, the production of rice for food, fuel sources (such as peat), medicines and pharmaceuticals derived from wetland plants and animals, ornamental resources (*e.g.*, animal and plant products used as ornaments or for landscaping), and surface and groundwater supply. *See, e.g.,* Millennium Ecosystem Assessment 2005. Regulating services include flood protection (Ameli and Creed 2019; Evenson *et al*. 2018; Lawrence *et al*. 2019; Martinez-Martinez *et al*. 2014; Tang *et al*. 2020; Taylor *et al*. 2022; Watson 2016; Wu *et al*. 2008), water purification (Ewel 1997; Ghermandi *et al*. 2010), erosion control/sediment retention (Hopkins *et al*. 2018; Richardson *et al*. 2011), groundwater recharge (Cowdery *et al*. 2019; Harvey *et al*. 2004; Williams *et al*. 2015), carbon sequestration (Nag *et al*. 2017; Nahlik *et al*. 2016; Mitsch *et al*. 2013; Tangen *et al*. 2020), and natural hazard regulation (*e.g.*, the role coastal wetlands play in reducing the damage of hurricanes) (Millennium Ecosystem Assessment 2005). Some of these services have been monetarily valued, as discussed further in the Economic Analysis. For example, Lawrence *et al*. (2019) and Watson (2016) both provide examples of monetized flood protection benefits via avoided property damages. Additionally, Hopkins *et al*. (2018) provides an example of monetized sediment-bound nitrogen retention benefits. Cultural services provided by wetlands include cultural diversity; spiritual and religious values; educational values; inspiration for art, folklore, national symbols, architecture, and advertising; aesthetic values (*e.g.*, parks, scenic viewpoints); social relations; sense of place; cultural heritage values (including culturally significant species); and recreation and ecotourism. Millennium Ecosystem Assessment 2005. Supporting services provided by wetlands include soil formation, photosynthesis in wetland plants, primary production, nutrient cycling, and water cycling. *Id*. Some ecosystem services like erosion control can be categorized as both a supporting and a regulating service, depending on the time scale and how immediately humans benefit from the ecosystem service. *Id*.

Similarly, streams, including headwater streams, provide many ecosystem services to society. This includes water supply, water quality benefits (for example, via nitrogen transformation and phosphorus sequestration), and climate regulation (for example, via carbon sequestration). Creed *et al.* 2017. Streams provide of the same provisioning, regulating, cultural, and supporting services that wetlands provide to society.

Ephemeral streams and their associated wetlands, wetlands that did not meet the 2020 NWPR's revised adjacency criteria, and other aquatic resources not protected by the 2020 NWPR provide numerous and critical ecosystem services, as discussed in the Science Report. *See also* Sullivan *et al.* 2020 ("Removal of federal protection [of ephemeral streams and non-floodplain wetlands] is likely to diminish numerous ecosystem services, such as safeguarding water quality and quantity, reducing or mitigating flood risk, conserving biodiversity, and maintaining recreationally and commercially valuable fisheries"). This is echoed by Creed *et al.* (2017), who also note that "vulnerable waters" such as headwater streams and non-floodplain wetlands provide $15.7 trillion and $673 billion, respectively, in ecosystem services in the conterminous United States annually. These findings and others were summarized by Lane *et al.* (2018) in an updated and peer-reviewed state-of-the-science on the connectivity and effects of non-floodplain wetlands and open waters.

As discussed further in section III.E.iv, a significant nexus analysis is limited to an assessment of only those functions that have a nexus to the chemical, physical, or biological integrity of traditional navigable waters, the territorial seas, or interstate waters. Therefore, there are some important functions provided by wetlands, tributaries, and waters evaluated under paragraph (a)(5) that translate into ecosystem services that benefit society that will not assessed in a significant nexus analysis under the final rule because they do not relate to the chemical, physical, or biological integrity of traditional navigable waters, the territorial seas, and interstate waters. There are also a wide variety of functions that streams, wetlands, and open waters provide that translate into ecosystem services that benefit society that would not be assessed in a significant nexus analysis under this rule. These include provision of areas for personal enjoyment (*e.g.*, fishing, hunting, boating, and birdwatching areas), ceremonial or religious uses, production of fuel, forage, and fibers, extraction of materials (*e.g.*, biofuels, food, such as shellfish, vegetables, seeds, nuts, rice), plants for clothes and other materials, and medical compounds from wetland and aquatic plants or animals. While these types of ecosystem services can contribute to the economy, they are not relevant to the chemical, physical, or biological integrity of paragraph (a)(1) waters and would not be considered in a significant nexus analysis under this rule. *See also* section III.E.iv for a discussion of functions that can be considered as part of the significant nexus analysis.

The Economic Analysis for the Final Rule also discusses ecosystem services, with a focus on the monetized benefits of ecosystem services provided by wetland areas protected due to Clean Water Action section 404 mitigation requirements.

II. Executive Order 13990 and Review of the Navigable Waters Protection Rule

A. Executive Order 13990

On January 20, 2021, President Joseph R. Biden, Jr. signed Executive Order 13990, entitled "Executive Order on Protecting Public Health and the Environment and Restoring Science to Tackle the Climate Crisis," which provides that "[i]t is, therefore, the policy of my Administration to listen to the science; to improve public health and protect our environment; to ensure access to clean air and water; to limit exposure to dangerous chemicals and pesticides; to hold polluters accountable, including those who disproportionately harm communities of color and low-income communities; to reduce greenhouse gas emissions; to bolster resilience to the impacts of climate change; to restore and expand our national treasures and monuments; and to prioritize both environmental justice and the creation of the well-paying union jobs necessary to deliver on these goals." 86 FR 7037 (published January 25, 2021, signed January 20, 2021). The order "directs all executive departments and agencies (agencies) to immediately review and, as appropriate and consistent with applicable law, take action to address the promulgation of Federal regulations and other actions during the last 4 years that conflict with these important national objectives, and to immediately commence work to confront the climate crisis." *Id.* at section 2(a). "For any such actions identified by the agencies, the heads of agencies shall, as appropriate and consistent with applicable law, consider suspending, revising, or rescinding the agency actions." *Id.* The order also specifically revoked Executive Order 13778 of February 28, 2017 (Restoring the Rule of Law, Federalism, and Economic Growth by Reviewing the "Waters of the United States" Rule), which had initiated development of the Navigable Waters Protection Rule (2020 NWPR).

After completing the review mandated by the Executive Order and reconsidering the record for the 2020 NWPR, on June 9, 2021, the agencies announced their intention to revise or replace the rule. The agencies' decision was based on consideration of the text of the Clean Water Act; Congressional intent and the objective of the Clean Water Act; Supreme Court precedent; the current and future harms to the chemical, physical, and biological integrity of the nation's waters due to the 2020 NWPR; concerns raised by stakeholders about the 2020 NWPR, including implementation-related issues; the principles outlined in the Executive Order; and issues raised in ongoing litigation challenging the 2020 NWPR. EPA and the Army concluded that the 2020 NWPR did not appropriately consider the effect of the revised definition of "waters of the United States" on the integrity of the nation's waters, and that the rule threatened the loss or degradation of waters critical to the protection of traditional navigable waters, among other concerns.

The agencies' review of the 2020 NWPR consistent with Executive Order 13990, as well as consideration some of the other directives of the Order are discussed in the sections below. The agencies also believe that they have fulfilled the Order's directive to "listen to the science," as is appropriate, and their consideration of the science is discussed in more detail in sections I and III.

B. Review of the 2020 NWPR

Pursuant to the direction in Executive Order 13990, the agencies reassessed the administrative record and basis for the 2020 NWPR and have a number of serious concerns about the 2020 NWPR. The agencies are concerned about the rule's failure to consider the statutory objective in determining the scope of "waters of the United States," including through its elimination of the significant nexus standard and the absence of any alternative standard that would protect the chemical, physical, and biological integrity of the nation's waters. The 2020 NWPR is also inconsistent with scientific information about protecting water quality, and indeed, it drastically reduced the numbers of waters protected by the Clean Water Act, including waters that significantly affect the integrity of downstream traditional navigable waters, the territorial seas, and interstate waters. Finally, implementing the 2020 NWPR posed significant technical challenges for federal, state, and tribal agency staff as well as stakeholders because foundational concepts of the rule are confusing and not reasonably implementable, resulting in arbitrary outcomes.

i. Impacts of the 2020 NWPR

The failure of the 2020 NWPR to advance the objective of the Clean Water Act, as well as its inconsistency with science and the challenges it presents in implementation, have had real-world consequences. The agencies have found that substantially fewer waters are protected by the Clean Water Act under the 2020 NWPR compared to previous rules and practices. It is important to note that the definition of "waters of the United States" affects most Clean Water Act programs designed to restore and maintain water quality—including not only the section 402 NPDES and section 404 dredged and fill permitting programs, but water quality standards under section 303, identification of impaired waters and total maximum daily loads under section 303, section 311 oil spill prevention, preparedness, and response programs, and the section 401 Tribal and State water quality certification programs—because the Clean Water Act provisions establishing such programs use the term "navigable waters" or "waters of the United States." While the 2020 NWPR was promulgated with the expressed intent to decrease the scope of federal jurisdiction, the agencies now are concerned that the actual decrease in water resource protections was more pronounced than the qualitative predictions in the 2020 NWPR preamble and supporting documents anticipated and acknowledged to the public. These data support the agencies' conclusion that the 2020 NWPR is not a suitable alternative to the final rule.

Through an evaluation of jurisdictional determinations completed by the Corps between 2016 and 2021,[7] EPA and the Army have identified consistent indicators of a substantial reduction in waters protected under the Clean Water Act by the 2020 NWPR. *See* section II.B.i for discussion on methods and results of the agencies' analyses. These indicators include an increase in the number and proportion of jurisdictional determinations completed where aquatic resources were found to be non-jurisdictional, an increase in determinations made by the Corps that no Clean Water Act section 404 permit is required for specific projects, and an increase in requests for the Corps to complete approved jurisdictional determinations (AJDs), rather than preliminary jurisdictional determinations (PJDs) which treat a feature as jurisdictional. These trends all reflect the narrow scope of jurisdiction in the 2020 NWPR's definitions. Additionally, the agencies find that these indicators likely account for only a fraction of the 2020 NWPR's impacts, because many project proponents did not seek any form of jurisdictional determination for waters that the 2020 NWPR categorically excluded, such as ephemeral streams, and the Corps would not have knowledge of or ability to track such projects. A closer look at each of these indicators will help demonstrate some of the more pronounced impacts of the 2020 NWPR on traditional navigable waters, the territorial seas, and interstate waters than were identified for the public in the 2020 NWPR and its supporting documents. As explained in detail above and in the final rule's preamble, when a water falls outside the scope of the Clean Water Act, that means, among other things, that no federal water quality standards will be established, and no federal permit will be required to control the discharge of pollutants, including dredged or fill material, into such waters unless the pollutants reach jurisdictional waters. And since many entities did not believe that they would need to seek a jurisdictional determination under the 2020 NWPR, it is impossible to fully understand the scope of degradation the 2020 NWPR's definition caused to traditional navigable waters, the territorial seas, and interstate waters.

1. Review of Jurisdictional Determinations and Permit Data

Consistent with Executive Order 13390, EPA and Army staff conducted four assessments on the effects of the 2020 NWPR on jurisdictional determinations and related individual aquatic resources using data sourced from the Corps' internal regulatory management database, Operation and Maintenance Business Information Link, Regulatory Module (referred to as the ORM2 database). *See supra* note 7. The aim of these assessments is to identify any noticeable trends relating to jurisdictional findings under

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[7] A jurisdictional determination is a written Corps determination that a water is subject to regulatory jurisdiction under section 404 of the Clean Water Act (33 U.S.C. 1344) or a written determination that a waterbody is subject to regulatory jurisdiction under section 9 or 10 of the Rivers and Harbors Act of 1899 (33 U.S.C. 401 *et seq*.). Jurisdictional determinations are identified as either preliminary or approved, and both types are recorded in determinations through an internal regulatory management database, called Operation and Maintenance Business Information Link, Regulatory Module (ORM2). This database documents Department of the Army authorizations under Clean Water Act section 404 and Rivers and Harbors Act section 10, including permit application processing and jurisdictional determinations. This database does not include aquatic resources that are not associated with a jurisdictional determination or that are not associated with alternatives to jurisdictional determinations (such as delineation concurrences or "No jurisdictional determination required" findings, where the Corps finds that a jurisdictional determination is not needed for a project), or permit request or resource impacts that are not associated with a Corps permit or enforcement action. An approved jurisdictional determination (AJD) is an official Corps document stating the presence or absence of "waters of the United States" on a parcel or a written statement and map identifying the limits of "waters of the United States" on a parcel. A preliminary jurisdictional determination (PJD) is a non-binding written indication that there may be "waters of the United States" on a parcel; an applicant can elect to use a PJD to voluntarily waive or set aside questions regarding Clean Water Act jurisdiction over a particular site and thus move forward assuming all waters will be treated as jurisdictional without making a formal determination.

the 2020 NWPR compared to prior regulatory practice—in particular, the implementation of 1986 definitions[8] of "waters of the United States" consistent with relevant caselaw and associated guidance documents.[9] This implementation will be referred to as pre-2015 practice for brevity, even though the regulatory regime was in place after 2015 (both in light of litigation surrounding the 2015 Clean Water Rule and due to finalization of the 2019 Repeal Rule, which intended to restore pre-2015 practice).

Trends in jurisdictional findings are assessed nationally and in two states within the arid West – Arizona and New Mexico. The arid West is assessed in order to determine if the 2020 NWPR is having geographically unequal impacts across the nation. A further analysis of trends in number of actions that did not require Clean Water Act section 404 permits due to definitions of "waters of the United States" is carried out at the national scale.

The four assessments use the following metrics:

- Total number of approved jurisdictional determinations (AJDs) and preliminary jurisdictional determinations (PJDs) by given time period (*see* Methods).
    - The above metric was further broken down by total number of AJDs that included jurisdictional and non-jurisdictional determinations.[10]
- Total number of individual aquatic resources found to be jurisdictional and non-jurisdictional within AJDs by given time period.
    - The above metric was further broken down for individual aquatic resource types found to be jurisdictional and non-jurisdictional under the 2020 NWPR – in particular, wetlands and streams are enumerated.[11]
- Total number of individual aquatic resources tied to AJDs, PJDs, delineation concurrences and findings of no JD required in two states in the arid West, Arizona and New Mexico, that were found to be jurisdictional and non-jurisdictional. This was further broken down by stream resources.[12]

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[8] EPA and the Corps have separate regulations defining the statutory term "waters of the United States," but their interpretations were substantially similar and remained largely unchanged between 1977 and 2015. *See, e.g.*, 42 FR 37122, 37144 (July 19, 1977); 44 FR 32854, 32901 (June 7, 1979). For convenience, in this document and in the preamble the agencies will generally cite the Corps' longstanding regulations and will refer to them as "the 1986 regulations," "the pre-2015 regulations," or "the regulations in place until 2015." These references are inclusive of EPA's comparable regulations that were recodified in 1988 and of the exclusion for prior converted cropland, which both agencies added in 1993.

[9] As implemented in the time period under these assessments, the 1986 regulations were bolstered by multiple memorandums and guidance documents, including guidance related to Supreme Court decisions. This included the *Rapanos* Guidance. *See* U.S. EPA and U.S. Army Corps of Engineers. Clean Water Act Jurisdiction Following the U.S. Supreme Court's Decision in *Rapanos v. United States* and *Carabell v. United States* (Dec. 2, 2008) ("*Rapanos* Guidance"), available at https://www.epa.gov/sites/default/files/2016-02/documents/cwa_jurisdiction_following_rapanos120208.pdf.

[10] The 2020 NWPR AJD data entry in ORM2 allows for and is often used to compile determinations about both jurisdictional and non-jurisdictional aquatic resources together for a single project site; under prior regulatory regimes, data entry in ORM2 restricted project managers to entering AJDs in separate entries for jurisdictional and non-jurisdictional resources on the same project site.

[11] Individual aquatic resources were only assessed under the 2020 NWPR because jurisdictional determinations carried out under prior regimes had less clear differentiation between types of aquatic resources. For example, a lake under prior regimes could have been classified as a tributary, an impoundment, a traditional navigable water, an interstate water, and sometimes even an adjacent water or adjacent wetland.

[12] Arizona and New Mexico were assessed because the ecosystems in these states are predominantly desert.

- Total number of projects that resulted in ‘No Permit Required’ closure methods.

The ORM2 database was deployed to all of the Corps’ 38 districts in 2008 and has been continuously improving since that time. Because of changes to regulatory practice and tracking priorities, the data are most reliable from the year 2016 to present.[13]

a. Background

The Operation and Maintenance Business Information Link, Regulatory Module (ORM2) is the Corps’ internal database that documents Clean Water Act section 404 application and permit data, including information on jurisdictional determinations (JDs).[14] JDs are identified as either preliminary or approved, and both types are recorded in ORM2. An AJD is an official Corps document stating the presence or absence of “waters of the United States” on a parcel or a written statement and map identifying the limits of “waters of the United States” on a parcel. A PJD is a non-binding written indication that there may be “waters of the United States” on a parcel; an applicant can elect to use a PJD to voluntarily waive or set aside questions regarding Clean Water Act jurisdiction over a particular site and thus move forward assuming all waters will be treated as jurisdictional without making a formal determination.[15]

b. Methods

In the ORM2 database, an AJD can contain one or multiple aquatic resources. For this reason, the agencies assessed data on the AJD-level and at the individual aquatic resource level (*i.e.*, total number of individual aquatic resources). Similarly, PJD data was assessed at both the PJD-level and at the aquatic resource level, although information on the type of aquatic resource is not defined for PJDs. For arid west (Arizona and New Mexico) data, delineation concurrences and findings of “no JD required” were also included to give scale to the total number of resources considered in those states. Delineation concurrences and findings of “no JD required” are excluded from the national assessments due to differences in application by Corps staff at the district level and potential error in how resources were denoted when these methods were used. Additionally, a separate permitting dataset was provided by the Corps, which provided information on when AJDs and PJDs had permits associated with them and details on projects that are deemed to not require permits.

(i) Data Quality Assurance and Control

2020 NWPR AJD Data from ORM2 was refined to account for foundational differences in how AJD information is reported under the 2020 NWPR compared to prior regulatory regimes. Because a

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[13] ORM2 was not created for the purposes of assessing trends in jurisdiction; rather, it exists as a project management tool for the Corps. As such, the tool has updated over time, with changes to how data is entered into the system. Database rules associated with required field entries changed in 2016 which made data more consistent.

[14] The public interface for the Corps’ ORM2 Database is available at: https://permits.ops.usace.army.mil/orm-public.

[15] When the Corps provides a PJD, or authorizes an activity through a general or individual permit relying on a PJD, the Corps is not making a legally binding determination of any type regarding whether jurisdiction exists over the particular aquatic resource in question even though the applicant or project proponent proceeds as though the resource were jurisdictional. A PJD is “preliminary” in the sense that a recipient of a PJD can later request and obtain an AJD if that becomes necessary or appropriate during the permit process or during the administrative appeal process. *See* 33 CFR 331.2.

single AJD in ORM under the 2020 NWPR can contain both jurisdictional and non-jurisdictional determinations, the instances of these "mixed" AJD forms had to be split in two.[16] To explain, when totaling whether an AJD was for a jurisdictional or non-jurisdictional resource, if an AJD under the 2020 NWPR contained both jurisdictional and non-jurisdictional resources, it was counted in both categories (*i.e.*, a tally would be added under the jurisdictional category and the non-jurisdictional category). This refinement was made on 1,631 AJDs and thus normalized the 2020 NWPR AJDs so that it could be compared to AJDs conducted under the prior regulatory regimes. Additionally, any AJDs that were conducted on drylands/uplands or Rivers and Harbors Act section 10 waters only were excluded from this analysis, as they are either excluded from the definition of "waters of the United States" or do not fall under the joint jurisdiction of the EPA and Corps under the Clean Water Act. This led to 1,354 AJDs from ORM2 being excluded from this analysis under the 2020 NWPR timeframe and a range of 1,163 to 2,479 AJDs being excluded from these analyses under the pre-2015 practice timeframes analyzed.[17] If and when PJD, delineation concurrence and "no JD required" data were used, data that was found to be erroneous were removed.[18]

The agencies also assessed actions from 2016 to 2021 associated with the Corps' "No Permit Required" closure method within ORM2, looking specifically at closure methods for "Activities that occur in waters that are no longer WOTUS under the 2020 NWPR" and "Activities that do not occur in WOTUS." "Activity does NOT occur in WOTUS" relates to a finding of "no permit required" that is based on that activity occurring entirely outside of any "water of the United States." While there may be aquatic resources on the site, the activity will not touch those resources. "Activities that occur in waters that are no longer WOTUS under the 2020 NWPR" is a new closure method created by the Corps for the ORM2 database following implementation of the 2020 NWPR that helps track actions that were pending or in progress when the 2020 NWPR came into effect and would have required a permit prior to the 2020 NWPR, but that no longer required a permit due to the 2020 NWPR's revised definition of "waters of the United States and therefore needed to be denoted as not requiring a permit in ORM2. However, as implementation methods and training were still in development through much of the 2020 NWPR implementation period, this closure method was not uniformly used across the Districts and by Corps project managers and thus likely undercounts the number of projects that would have required a permit prior to the 2020 NWPR but that no longer did while the 2020 NWPR was implemented.[19]

Time frames considered

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[16] Under the pre-2015 regulatory regime and the 2015 Clean Water Rule, AJDs in ORM could contain only jurisdictional features or only non-jurisdictional features.

[17] June 22, 2016 – June 21, 2017: 2,479 AJDs removed; June 22, 2017 – June 21, 2018: 2,112 AJDs removed; December 23, 2019- June 21, 2020: 1,163 AJDs removed.

[18] Features associated with PJDs and these delineation alternatives are presumed jurisdictional; however, there were certain aquatic resources that were denoted as being non-jurisdictional in this data; thus, they were removed. This was an insubstantial amount of data removed.

[19] This closure method did not exist until July 20, 2020, a month after the 2020 NWPR was implemented. This closure method also can only be used when all resources in a given AJD are found to be non-jurisdictional. Under the 2020 NWPR, in ORM2, AJD entries can have both non-jurisdictional and jurisdictional individual aquatic resources; in those cases, the permit(s) associated with the jurisdictional resources would prevent the 'no permit required' closure method from being selected. Finally, the use of this new closure method could simply have been overlooked by staff if they had not gone through training on its use.

In comparing overall AJD and PJD trends at the national scale, the following timeframes were used:

- June 22, 2020 to June 21, 2021 for the 2020 NWPR: one year of data associated with implementation of the 2020 NWPR;
- The three most recent periods (broken into years with the same calendar dates as feasible) in which the definition of "waters of the United States" under the 1986 regulations, implemented consistent with relevant caselaw and associated guidance documents, were in use nationwide.
    - June 22, 2016 to June 21, 2017
    - June 22, 2017 to June 21, 2018
    - December 23, 2019 to June 21, 2020[20]

In order to assess significance of changes under the 2020 NWPR, a further assessment was carried out on data separated by years using the calendar dates of June 22 to June 21 for the years of 2016 to 2021. These significance tests were carried out using pre-2015 practice data compared to the 2020 NWPR, and using both pre-2015 practice and 2015 Clean Water Rule data compared to the 2020 NWPR (Section II.B.i.b.ii: Statistics).

In looking at trends in Arizona and New Mexico and looking at the "No Permit Required" analysis, year by year comparisons were carried out during the calendar dates of June 22 to June 21 for the years of 2016 to 2021. In Arizona and New Mexico, all determinations data were derived from either pre-2015 practice or the 2020 NWPR (no determinations were carried out under the Clean Water Rule in these states). The "No Permit Required" analysis uses data from all regulatory regimes (including pre-2015 practice and the 2015 Clean Water Rule regime) in order to capture the volume of these findings over time.

(ii) Statistics

Because data within ORM2 are imperfect in nature—due to varying regulatory regimes, spatial distribution of determinations, and economic and development trends, and general human error related to data entry—the assessment carried out is summary in nature. Cursory statistics on significance have been run through comparing the 2020 NWPR data to the 95% confidence interval calculated via annual data from 2016-2020. This was done for the following comparisons:

- Proportion of AJDs and PJDs carried out under the 2020 NWPR compared to pre-2015 practice;
- Proportion of non-jurisdictional findings for total number of individual resources via AJDs under the 2020 NWPR compared to AJDs under pre-2015 practice from 2016 to 2020 (using only pre-2015 practice data limits the assessment to the proportion of resources being found to be jurisdictional or non-jurisdictional);
- Proportion and total number of non-jurisdictional findings for total number of individual resources via AJDs under the 2020 NWPR compared to all AJDs from 2016 to 2020 (using both pre-2015 practice and 2015 Clean Water Rule data allows for assessing the 95% confidence interval based on overall volume (*i.e.*, total number by year) as well as proportion of resources being found to be jurisdictional or non-jurisdictional);

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[20] December 23, 2019, was the day in which the 2019 Rule went into effect, which recodified the 1986 regulations.

- Total number of AJD individual aquatic resources and PJD and delineation alternative[21] individual aquatic resources (with a further non-jurisdictional breakdown by both proportion and total number) in New Mexico and Arizona under the 2020 NWPR compared to pre-2015 practice from 2016 to 2020; and
- Total number of No Permit Required findings under the 2020 NWPR compared to pre-2015 practice.

At the national scale, rather than comparing total numbers between different time periods, it is more telling to compare percentages. This allows for a comparison between the 2020 NWPR and pre-2015 practice, even when time frames considered are not equal in length.

One test of significance based on total numbers of individual aquatic resources was carried out at the national scale which included the 2015 Clean Water Rule data in order to compare volume of resources assessed over time. For the Arizona and New Mexico analysis and the "No Permit Required" analysis, total numbers of findings are compared on a year-by-year basis. While there are external trends that can impact the overall quantity of AJDs and individual aquatic resources reviewed under AJDs, year by year comparisons of total numbers in these specific data show a substantial shift under the 2020 NWPR that the agencies believe are tied directly to definitions of "waters of the United States."

For all analyses, while exact numbers are not obtainable from the data there is more than sufficient volume and accuracy of the data to demonstrate clear trends.

c. Results and Discussion

(i) AJDs and PJDs over time

Rather than comparing jurisdictional determinations under the 2020 NWPR to all prior jurisdictional determinations, the analyses here looked specifically at the pre-2020 NWPR determinations defined by the 1986 regulations and associated guidance documents that were issued following Supreme Court decisions (*i.e.*, under pre-2015 practice).

Of the 14,143 jurisdictional determinations carried out as either AJDs or PJDs under the 2020 NWPR from June 22, 2020, to June 21, 2021, 66.5% were carried out as AJDs (Table 1, Figure 1).[22] Under the various timeframes considered for pre-2015 practice, the percentage of determinations carried out as AJDs ranged from 15.6% to 23.4%. In comparing the two regimes, there has been a 183% to 326% increase in the percent of determinations carried out as AJDs under the 2020 NWPR. Proportionally fewer PJDs indicate that fewer project proponents are requesting that aquatic resources on their project site be treated as if they are jurisdictional. This has two implications: under the 2020 NWPR, project proponents were requesting AJDs rather than PJDs and/or they were simply not notifying the Corps of their activities that might result in the discharge of dredged or fill material into aquatic resources because they believed those resources were not jurisdictional under the 2020 NWPR. The lower rates of PJD requests under the

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[21] "Delineation alternatives" refers to delineation concurrences and "No JD required" findings. These are similar to PJDs in that projects on sites with such findings would move forward with permitting as if the associated resources on these sites are jurisdictional.

[22] PJDs are not formal determinations and aquatic resources addressed through a PJD are treated as jurisdictional for the purposes of any associated permit action.

2020 NWPR may be the most striking metric for how trends in jurisdiction have changed. When looking at individual resources associated with jurisdictional determinations, this comparison between overall numbers considered as part of AJDs versus as part of PJDs is even more dramatic, with a 4-fold to 5-fold increase in the percent of aquatic resources assessed through AJDs under the 2020 NWPR (Table 1, Figure 2). In order to test for the significance of this shift, a further analysis was carried out, splitting pre-2015 practice data from June 22, 2016, to June 21, 2020, by calendar year, calculating the percent of AJDs and PJDs carried out for each year, and comparing the 95% confidence interval for those years to the percent found for the 2020 NWPR. The test of significance on the proportion of AJDs and PJDs carried out under the 2020 NWPR compared to pre-2015 practice shows that this shift towards more AJDs and fewer PJDs is in fact significant and outside the bounds of the 95% confidence interval for pre-2015 practice data (Table 2).

The agencies found within the AJDs completed under the 2020 NWPR, the probability of finding resources to be non-jurisdictional increased precipitously. Of the 9,399 AJDs completed by the Corps under the 2020 NWPR during the first 12 months in which that rule was in effect,[23] the agencies found approximately 75% of AJDs completed had identified non-jurisdictional aquatic resources and approximately 25% of AJDs completed identified jurisdictional waters (Table 1, Figure 3).[24] Conversely, during similar one-year intervals when the 1986 regulations and applicable guidance were in effect (including following the 2019 recodification of those regulations), substantially more jurisdictional waters were identified in AJDs on average per year than compared to the first twelve months of the 2020 NWPR. During similar one-year calendar intervals when the 1986 regulations and applicable guidance were in effect, approximately 28% to 45% of AJDs completed identified non-jurisdictional aquatic resources, and 56% to 72% of AJDs completed identified jurisdictional resources.[25] Although the percentages varied during these periods, the change from a range of 28% to 45% non-jurisdictional AJD findings prior to the 2020 NWPR to 75% non-jurisdictional findings after issuance of the 2020 NWPR indicates that substantially fewer waters were protected by the Clean Water Act under the 2020 NWPR. This constitutes a 69% to 171% increase in the percent of AJDs resulting in non-jurisdictional findings (Table 1). Similarly, when individual aquatic resources associated with AJDs are reviewed by jurisdictional findings, there was an increase of 28% to 94% in the percent of resources being found to be non-jurisdictional under the 2020 NWPR (Table 1). Again, as commenters on the proposed rule noted, these

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[23] These AJDs were completed by the Corps between the 2020 NWPR's effective date of June 22, 2020, and June 21, 2021. Data were extracted from ORM2 in September 2021.

[24] This excludes dry land AJDs and waters identified as jurisdictional only under section 10 of the Rivers and Harbors Act. In addition, under the 2020 NWPR, a single AJD in the Corps' database can include both affirmative and negative jurisdictional determinations. Under prior regulatory regimes, the Corps' database was structured such that a single AJD could be either affirmative, or negative, but not both. To account for this change in the structure of the database, a 2020 NWPR jurisdictional determination that includes both affirmative and negative jurisdictional resources was normalized and counted as two separate AJDs, one affirmative and one negative. The total number of AJDs considered after this process was carried out was 9,399. Prior to this normalization, the total number of AJDs considered was 7,769.

[25] The time periods evaluated were June 22, 2016, to June 21, 2017; June 22, 2017, to June 21, 2018; and December 23, 2019, to June 21, 2020. The date ranges here constitute periods of time when the 1986 regulations (including the 2019 Repeal Rule's recodification of those regulations) and applicable guidance were in effect nationally. Thus, 2015 Clean Water Rule determinations were not part of this analysis. Data were extracted from ORM2 in September 2021.

numbers do not account for the many entities that did not seek AJDs because they knew their features were excluded under the 2020 NWPR.

In evaluating how the 2020 NWPR's non-jurisdictional values compare to the distribution of non-jurisdictional findings from prior years, the percent of non-jurisdictional findings at the individual aquatic resource level under pre-2015 practice from 2016 to 2020 were used (separated by the June 22 – June 21 calendar year) (Table 3). The percent of non-jurisdictional findings for individual aquatic resources under the 2020 NWPR were outside the bounds of the 95% confidence intervals calculated for the 2016 to 2020 data, indicating that the Corps was significantly more likely to find projects did not require section 404 permits with these closure methods under the 2020 NWPR compared to pre-2015 practice. Within the time frame of 2016 to 2020, pre-2015 practice and the 2015 Clean Water Rule were both in effect; as such, the annual distribution of total number of non-jurisdictional resources could not be compared. A separate comparison was carried out using the total number of non-jurisdictional findings at the individual aquatic resource level as associated with all AJDs from 2016-2020 (pre-2015 practice and 2015 Clean Water Rule AJDs) (Table 4). In this case, both the percent of non-jurisdictional findings and the total number of individual resources found to be non-jurisdictional under the 2020 NWPR were outside of the bounds of the 95% confidence intervals calculated from those datasets. The proportion and scale of non-jurisdictional findings at the individual aquatic resource level under the 2020 NWPR is significantly higher than the proportion and scale of non-jurisdictional findings from prior years.

Together, there were proportionally fewer PJDs and more AJDs being carried out under the 2020 NWPR, there were fewer resources being found to be jurisdictional when AJDs were being carried out, and there were elevated findings of no section 404 permits being needed for projects based on the definition of "waters of the United States" under the 2020 NWPR.

Table 1: Jurisdictional determinations over time

JDs: PJDs vs AJDs

Regulatory Regime	Pre-2015 Practice			2020 NWPR
Time period	June 22, 2016-June 21, 2017	June 22, 2017 - June 21, 2018	Dec. 23, 2019 - June 21, 2020	June 22, 2020 - June 21, 2021
PJD	21,383	13,459	4,539	4,744
PJD Resources	92,010	81,998	60,578	26,712
AJD	3,957	3,505	1,390	9,399
AJD Resources	11,978	14,267	6,603	48,313
Total JDs	25,340	16,964	5,929	14,143
% AJD	15.6%	20.7%	23.4%	66.5%
% Change in % AJD	**326%**	**222%**	**183%**	
Total JD Resources	103,988	96,265	67,181	75,025
% AJD Resources	11.5%	14.8%	9.8%	64.4%
% Change in % AJD Resources	**459%**	**335%**	**555%**	

AJDs: Jurisdictional vs. Non-jurisdictional

Regulatory Regime	Pre-2015 Practice			2020 NWPR
Time period	June 22, 2016-June 21, 2017	June 22, 2017 - June 21, 2018	Dec. 23, 2019 - June 21, 2020	June 22, 2020 - June 21, 2021
Jurisdictional AJDs	2,858	2,120	771	2,335
Non-jurisdictional AJDs	1,099	1,385	619	7,064
Jurisdictional AJD Resources	7,343	5,903	3,781	11,929
Non-jurisdictional AJD Resources	4,635	8,364	2,822	36,384
Total AJDs	3,957	3,505	1,390	9,399
% Jurisdictional AJDs	72.2%	60.5%	55.5%	24.8%
% Non-jurisdictional AJDs	27.8%	39.5%	44.5%	75.2%

% Change in % Non-jurisdictional AJDs	**171%**	**90%**	**69%**	
Total AJD Resources	11,978	14,267	6,603	48,313
% Jurisdictional AJD Resources	61.3%	41.4%	57.3%	24.7%
% Non-jurisdictional AJD Resources	38.7%	58.6%	42.7%	75.1%
% Change in % non-jurisdictional AJD Resources	**94%**	**28%**	**76%**	

Table 2: The 2020 NWPR compared to prior years of implementation under pre-2015 practice (AJD/PJD)

	Pre-2015 Practice				2020 NWPR
	2016-2017	2017-2018	2018-2019	2019-2020	2020-2021
AJD	3,957	3,505	1,971	2,172	9,399
PJD	21,383	13,459	7,024	7,478	4,744
Percent AJD	16%	21%	22%	23%	**66%**
Percent PJD	84%	79%	78%	77%	**34%**
	Pre-2015 Practice Summary Stats				
	Mean	Standard Deviation	95% Confidence Interval		
Percent AJD	20%	3%	**14%**	**26%**	
Percent PJD	80%	3%	**74%**	**86%**	

Table 3: The 2020 NWPR compared to prior years of implementation under pre-2015 practice (jurisdictional/non-jurisdictional)

	Pre-2015 Practice				2020 NWPR
	2016-2017	2017-2018	2018-2019	2019-2020	2020-2021
Jurisdictional Resources	7,343	5,903	5,010	5,736	12,537
Non-jurisdictional Resources	4,635	8,364	3,486	4,161	37,799
Percent non-jurisdictional	39%	59%	41%	42%	**75%**
	Pre-2015 Practice Summary Stats				
	Mean	Standard Deviation	95% Confidence Interval		
Percent non-jurisdictional	45%	9%	**27%**	**63%**	

Table 4: The 2020 NWPR compared to prior years of pre-2015 practice and 2015 Clean Water Rule implementation (jurisdictional/non-jurisdictional)

	Pre-2020 NWPR				2020 NWPR
	2016-2017	2017-2018	2018-2019	2019-2020	2020-2021
Jurisdictional Resources	7,343	5,903	6,532	6,819	**12,537**
Non-jurisdictional Resources	4,635	8,364	5,277	5,754	**37,799**
Percent non-jurisdictional	39%	59%	45%	46%	**75%**
Pre-2020 NWPR Summary Statistics					
	Mean	Standard Deviation	95% Confidence Interval		
Jurisdictional Resources	6,649	600	**5,473**	**7,826**	
Non-jurisdictional Resources	6,008	1,637	**2,800**	**9,215**	
Percent non-jurisdictional	47%	8%	**31%**	**63%**	

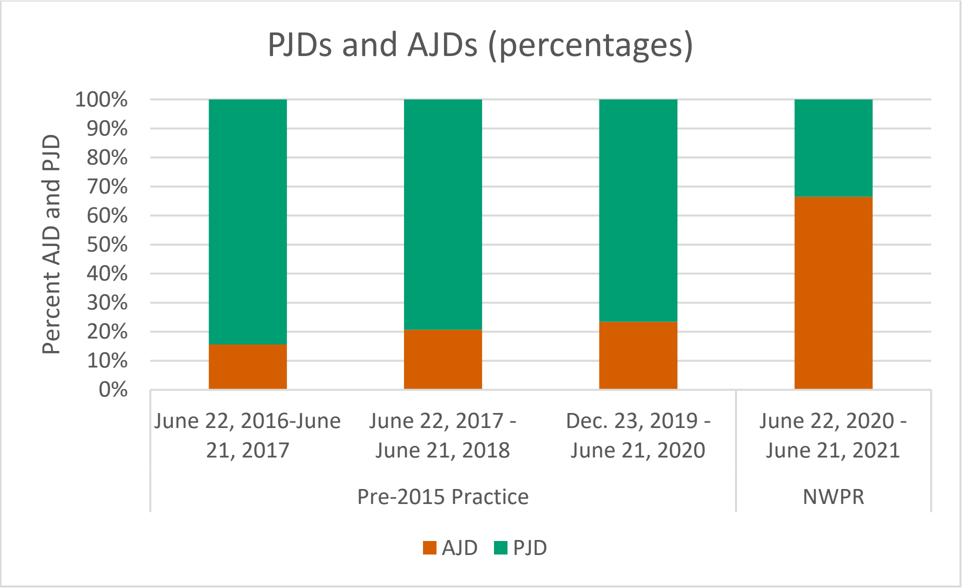

Figure 1: AJD and PJD (percentages). The number of determinations being carried out under the 2020 NWPR as PJDS has decreased compared to pre-2015 practice, while the number of AJDs has increased. These data exclude both “RHA-only” AJDs and “Dry Land” AJDs as well as data from implementation of the 2015 Clean Water Rule. Data have been normalized.

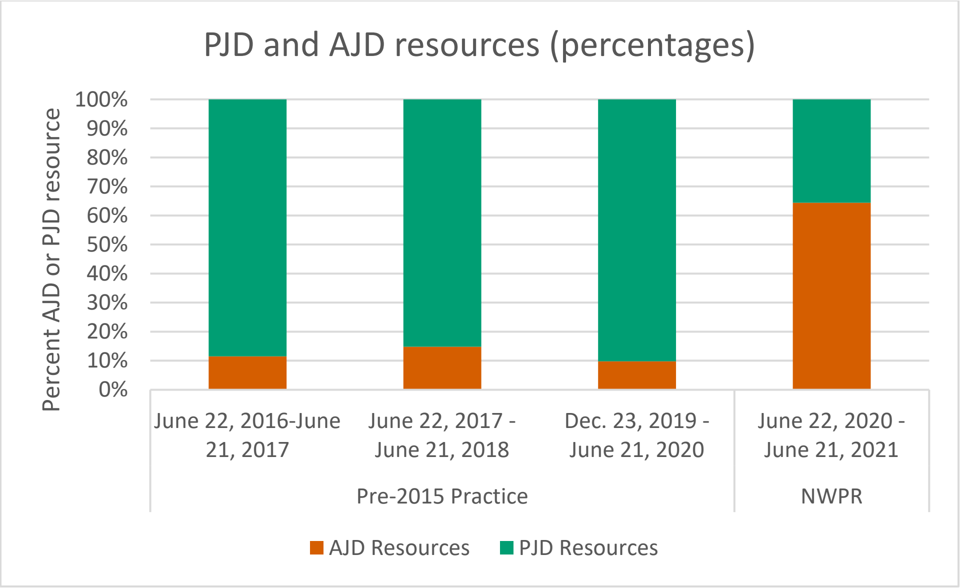

Figure 2: AJD and PJD resources (percentages). The number of resources tied to determinations being carried out under the 2020 NWPR as PJDs has decreased compared to pre-2015 practice, while the number of resources tied to AJDs has increased. This data excludes both Rivers and Harbors Act only (“RHA-only”) AJDs and “Dry Land” AJDs as well as data from implementation of the 2015 Clean Water Rule.

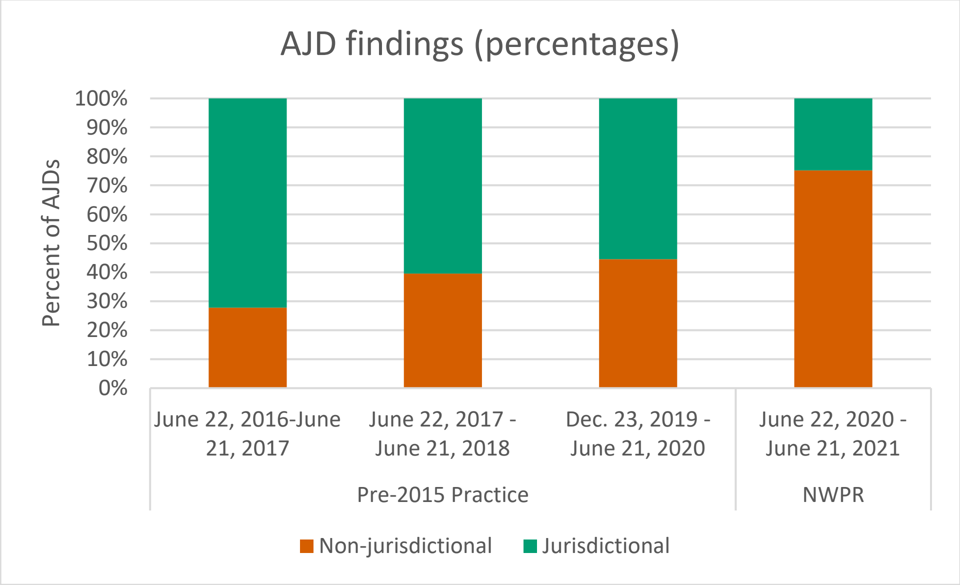

Figure 3: AJD findings (percentages). Breakdown of AJDs (by percentages) that found jurisdictional and non-jurisdictional waters for each of the four periods of record. These data exclude both "RHA-only" AJDs and "Dry Land" AJDs as well as data from implementation of the 2015 Clean Water Rule. Data have been normalized.

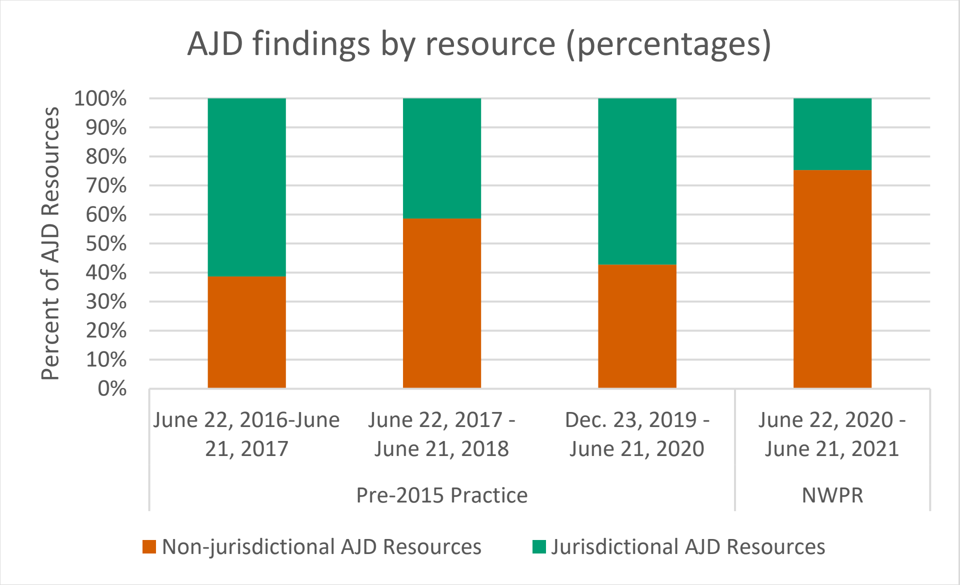

Figure 4: AJD Findings by Resource (Percentages). Percentage of AJD resources that were found to be jurisdictional and non-jurisdictional for each of the four periods of record. This data excludes both "RHA-only" AJDs and "Dry Land" AJDs as well as data from implementation of the Clean Water Rule. Data have been normalized.

(ii) Individual Aquatic Resources Associated with 2020 NWPR AJDs

When evaluating the effect of the 2020 NWPR on the number of jurisdictional individual aquatic resources (as opposed to the number of AJDs completed), the agencies found a similar significant reduction in protections. The Corps' ORM2 database contains AJDs that evaluated 48,313 individual aquatic resources under the 2020 NWPR between June 22, 2020, and June 21, 2021; of these individual aquatic resources, approximately 75% were found to be non-jurisdictional by the Corps (Table 1). Specifically, 70% of streams and wetlands were found to be non-jurisdictional, including 11,044 ephemeral features (mostly streams) and 15,675 wetlands that did not meet the 2020 NWPR's revised adjacency criteria (and thus are non-jurisdictional under the 2020 NWPR). Ditches were also frequently excluded (4,706 individual exclusions). When looking at the total number of aquatic resources considered under the 2020 NWPR versus under the pre-2015 regulatory regime (assessed by data split by calendar year from June 22 to June 21 for the years of 2016 to 2020), the percent of non-jurisdictional findings under the 2020 NWPR (75%) was significantly higher than the percent of non-jurisdictional findings under pre-2015 practice (average annual non-jurisdictional finding: 45%) (Table 3).

Table 5: Specific Resources found Non-Jurisdictional under the 2020 NWPR

Resource Type	Wetlands and streams	Wetland	Stream
All resources considered	38,611	21,824	16,787
Jurisdictional	11,364	6,062	5,302
Non-Jurisdictional	27,247	15,762	11,485
Percent Non-jurisdictional	71%	72%	68%

(iii) Arid West AJDs

2020 NWPR AJDs in Arizona and New Mexico were found to be dominated by non-jurisdictional ephemeral channelized features (Table 6). The number of stream features that were found non-jurisdictional in Arizona and New Mexico under the first year of 2020 NWPR implementation totaled 1,784.[26] Comparatively, nationally, there were 11,485 stream reaches found to be non-jurisdictional under the first year of the 2020 NWPR implementation. 15.5% of all non-jurisdictional streams across the nation in the first year of 2020 NWPR implementation were in Arizona and New Mexico.[27] This represents a geographic inequality in the implications of implementation of the 2020 NWPR.

The number of individual aquatic resources - in particular, streams - being considered under AJDs in the past year of data under the 2020 NWPR in Arizona and New Mexico is significantly higher than has occurred in recent years, with the total number of non-jurisdictional individual streams under the 2020 NWPR exceeding the 95% confidence interval for annual non-jurisdictional findings on individual streams from 2016-2020 data for both Arizona and New Mexico (Table 7, Figures 5 and 6). The total number of individual streams being assessed via AJDs in these states is significantly higher than the total number of individual streams that were assessed in the pre-2015 practice time frame considered here.

Looking at all types of aquatic resources and comparing non-jurisdictional AJD findings under the 2020 NWPR to prior years of implementation under pre-2015 practice (averaged over four years), there has been more than a 10-fold increase in non-jurisdictional findings on individual aquatic resources in both Arizona and New Mexico (Table 6). When individual streams considered under AJDs are inspected in this manner, there was more than a 10-fold increase in non-jurisdictional findings for individual streams in Arizona and more than a 30-fold increase in non-jurisdictional findings for individual streams in New Mexico under the 2020 NWPR (Table 5). Additionally, the number of stream resources considered under PJDs and other alternatives to AJDs (*i.e.*, Delineation Concurrences and No

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[26] The 2020 NWPR water types included within this calculation included (a)(2) tributaries, (b)(1) surface water channel that does not contribute surface water flow directly or indirectly to an (a)(1) water in a typical year, and (b)(3) ephemeral streams. There are other water types associated with 2020 NWPR AJDs, such as (a)(1) Traditional Navigable Waters and Territorial Seas, which can contain streams but were not included in the total. Note that the numbering of the water types in this footnote are associated with the numbering in the 2020 NWPR and not with this rule.

[27] The next highest rate of non-jurisdictional findings (11%) for AJDs conducted under the 2020 NWPR is in the state of Utah, which similarly contains vast areas of arid West ecosystems.

JD required closure methods) decreased by a range of 75% to 100% under the 2020 NWPR (Table 6, Figures 7, and 8). In all years, the majority of resources considered were ephemeral streams. Under the 2020 NWPR, wetlands adjacent to ephemeral streams are also not jurisdictional, whereas under pre-2015 practice could have been considered for jurisdiction under a case-specific significant nexus analysis; thus, this decrease in jurisdiction and assumed jurisdiction could have cascading effects on multiple types of resources if the 2020 NWPR were reinstated.

The arid West, as exemplified by Arizona and New Mexico, experienced a comparatively higher share of non-jurisdictional findings on stream reaches than the nation as a whole did under the 2020 NWPR. The number of non-jurisdictional stream reaches is significantly elevated compared to prior years, and simultaneously, the number of PJDs and other AJD alternatives has decreased compared to prior years. The agencies thus believe that the 2020 NWPR caused disproportionate and more severe impact on aquatic resources in the arid West.

Table 6: Arizona and New Mexico Impacts to Scope of "Waters of the United States" under the 2020 NWPR (2020-2021) Compared to Pre-2015 Practice (2016-2017, 2017-2018, 2018-2019, 2019-2020)

ALL Resources

	Arizona				New Mexico			
	AJD		PJD	NoJD and DC*	AJD		PJD	NoJD and DC*
Delineation type	Juris	Non-Juris			Juris	Non-Juris		
2016-2017	0	17	562	5	0	17	203	71
2017-2018	5	233	386	22	4	17	309	96
2018-2019	16	261	669	25	2	18	25	99
2019-2020	17	42	2,145	32	0	4	0	49
2016-2020 avg	10	138	941	21	2	14	134	79
2020-2021	4	1,538	52	0	2	280	35	0
% change from avg to 2020 NWPR	-58%	1,012%	-94%	-100%	33%	1,900%	-74%	-100%

Stream resources

	Arizona				New Mexico			
	AJD		PJD	NoJD and DC*	AJD		PJD	NoJD and DC*
Delineation type	Juris	Non-Juris			Juris	Non-Juris		
2016-2017	0	17	547	5	0	7	193	69
2017-2018	5	231	378	16	4	15	301	83
2018-2019	16	261	658	17	2	2	24	91
2019-2020	17	42	2,113	29	0	4	0	46
2016-2020 avg	10	138	924	17	2	7	130	72
2020-2021	4	1,521	45	0	0	263	33	0

% change from avg to 2020 NWPR	-58%	1,004 %	-95%	-100%	-100%	3,657%	-75%	-100%

Ephemeral resources

	Arizona				New Mexico			
	AJD		PJD	NoJD and DC*	AJD		PJD	NoJD and DC*
Delineation type	Juris	Non-Juris			Juris	Non-Juris		
2016-2017	0	17	547	0	0	7	193	43
2017-2018	4	231	378	15	4	15	301	32
2018-2019	16	261	658	11	1	2	24	26
2019-2020	17	42	2,113	26	0	3	0	11
2016-2020 avg	9	138	924	13	1	7	130	28
2020-2021	4	1,518	45	0	0	263	33	0
% change from avg to 2020 NWPR	-57%	1,002 %	-95%	-100%	-100%	3,796%	-75%	-100%

**NoJD and DC refer to No JD Required and Delineation Concurrence closure methods within ORM. These are equivalent to delineation substitutes. They are included here because the data associated with these categories in these specific states were not erroneous, and they show a more complete picture of how resources have been reviewed by the Corps.*

Table 7: Test of statistical significance for 2020 NWPR compared to prior years of implementation under pre-2015 practice for stream resources in Arizona and New Mexico.

ARIZONA					
	Pre-2015 Practice				**2020 NWPR**
	2016-2017	2017-2018	2018-2019	2019-2020	2020-2021
All AJD resources	17	236	277	59	**1,525**
Jurisdictional AJD resources	0	5	16	17	4
Non-jurisdictional AJD resources	17	231	261	42	**1,521**
PJD and Alternatives to AJDs resources	552	394	675	2,142	45
Percent non-jurisdictional resources	100.0%	97.9%	94.2%	71.2%	99.7%
Pre-2015 Practice Summary Statistics					
	Mean	SD	95% CI		
All AJD resources	147	128	**-104**	**399**	
Jurisdictional AJD resources	10	8	-7	26	
Non-jurisdictional AJD resources	138	126	**-109**	**385**	
PJD and Alternatives to AJDs resources	941	809	-645	2,526	
Percent non-jurisdictional resources	91%	13%	65%	117%	

NEW MEXICO					
	Pre-2015 Practice				**2020 NWPR**
	2016-2017	2017-2018	2018-2019	2019-2020	2020-2021
All AJD resources	7	19	4	4	**263**
Jurisdictional AJD resources	0	4	2	0	0
Non-jurisdictional AJD resources	7	15	2	4	**263**
PJD and alternatives to AJDs resources	262	384	115	46	33

Percent non-jurisdictional resources	100.0%	78.9%	50.0%	100.0%	100.0%
Pre-2015 Practice Summary Statistics					
	Mean	SD	95% CI		
All AJD resources	9	7	**(5)**	**22**	
Jurisdictional AJD resources	2	2	(2)	5	
Non-jurisdictional AJD resources	7	6	**(4)**	**18**	
PJD and alternatives to AJDs resources	202	151	(95)	498	
Percent non-jurisdictional resources	82.2%	23.7%	35.8%	128.6%	

Note: No 2015 Clean Water Rule determinations were carried out during these years in these states.

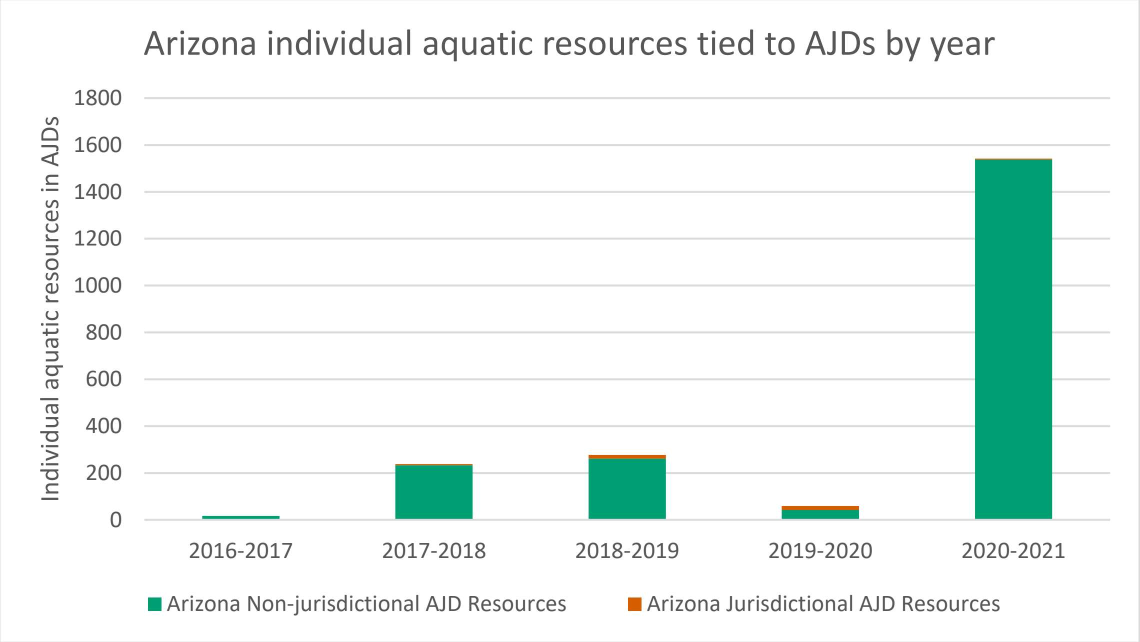

Figure 5: Individual aquatic resources found to be non-jurisdictional in Arizona over the past five years. Under the 2020 NWPR (2020-2021), there has been over a 10-fold increase in non-jurisdictional findings for individual aquatic resources in both Arizona and New Mexico.

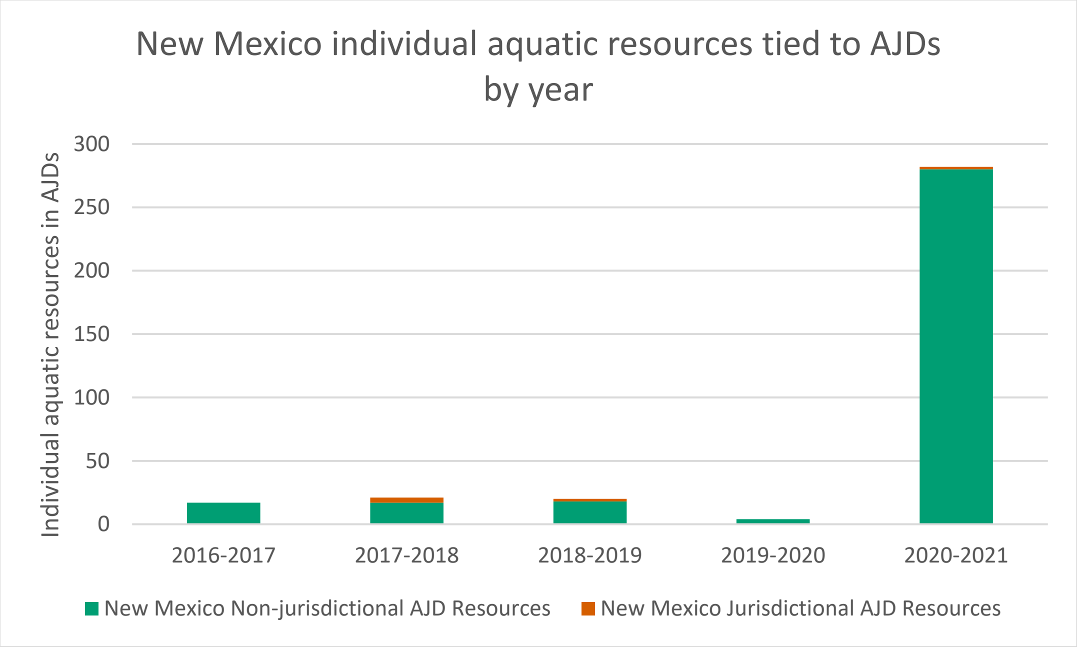

Figure 6: Individual aquatic resources found to be non-jurisdictional in New Mexico over the past five years. Under the 2020 NWPR (2020-2021), there has been over a 10-fold increase in non-jurisdictional findings for individual aquatic resources in both Arizona and New Mexico.

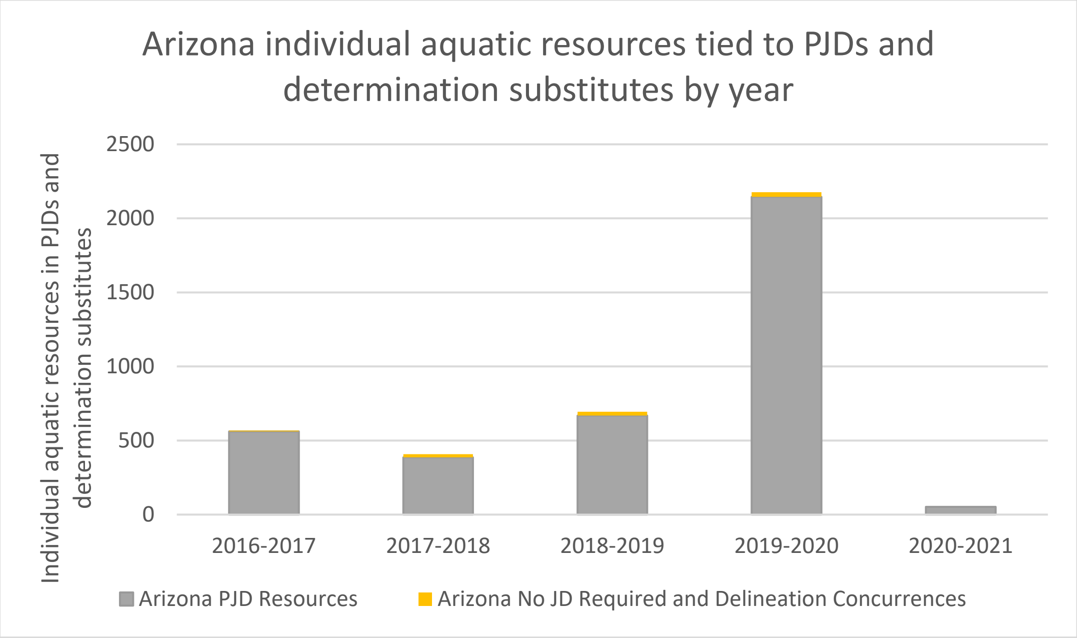

Figure 7: **Arizona Individual Aquatic Resources Tied to PJDs and Determination Substitutes by Year.** Under the 2020 NWPR (2020-2021), there has been more than a nine-fold decrease in individual aquatic resources reviewed through PJDs and determination substitutes in Arizona. Note that in 2020, there was a single transmission line project that was related to the majority of the individual resources tied to PJDs in that year.

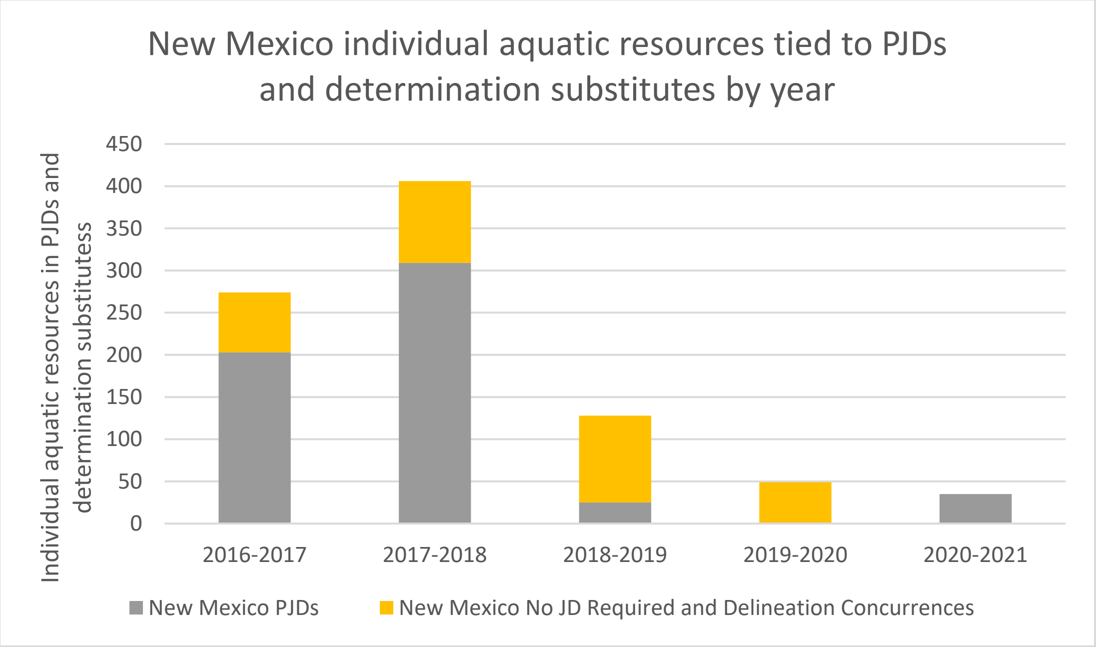

Figure 8: New Mexico Individual Aquatic Resources Tied to PJDs and Determination Substitutes by Year. Under the 2020 NWPR (2020-2021), there has been more than a seven-fold decrease in individual aquatic resources reviewed through PJDs and determination substitutes in New Mexico. Note that in 2017, there was a single transmission line project that was related to the majority of the individual resources tied to PJDs in that year.

(iv) No Permit Required based on AJDs only

Based on an assessment of the two specific “No Permit Required” closure methods in ORM2 related to projects associated with AJDs, under the 2020 NWPR there has been more than a 150% increase in projects that do not require Clean Water Act section 404 permits as compared to what was reported under the previous regulatory regimes (Table 8, Figure 9).[28] Even when the new reporting field of “Activity occurs in waters that are no longer WOTUS under the 2020 NWPR” is excluded, the total number of projects that do not require Clean Water Act section 404 permits under the 2020 NWPR exceeds the 95% confidence interval for values from the 2016 to 2020 timeframe. Given that this closure method, “Activities that occur in waters that are no longer WOTUS under the 2020 NWPR,” has not been used uniformly by all Corps project managers across the United States, it is likely that the overall number of projects that fit into this category are under-represented.

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[28] This is a revised calculation that updates the prior assessment of No Permit Required data presented within the Declarations of Radhika Fox and Jaime A. Pinkham, filed in *Conservation Law Found. et al. v, EPA et al.*, 20-cv-10820-DPW (D. Mass. Jun. 9, 2021) as well as in every other district court challenge to the NWPR. The revised calculation is based on additional data spanning a longer time period and corrected underlying calculations of the percent change between the number of projects that do not require Clean Water Act section 404 permits under the NWPR compared to prior time periods.

Table 8: No Permit Required test of significance for 2020 NWPR compared to prior years of implementation under pre-2015 practice

	Pre-2015 Practice				**2020 NWPR**
	2016-2017	2017-2018	2018-2019	2019-2020	2020-2021
Activity does NOT occur in WOTUS	414	452	294	355	**769**
Activity occurs in waters that are NO longer WOTUS under the 2020 NWPR	-	-	-	-	368
Total	414	452	294	355	**1,137**
Percent change between given year and 2020 NWPR for Activity does NOT occur in WOTUS	86%	70%	162%	117%	
Percent change between given year and 2020 NWPR for Total	175%	152%	287%	220%	
Pre-2015 Practice Summary Statistics					
	Mean	SD	95% CI		
Activity does NOT occur in WOTUS	379	69	**243**	**514**	

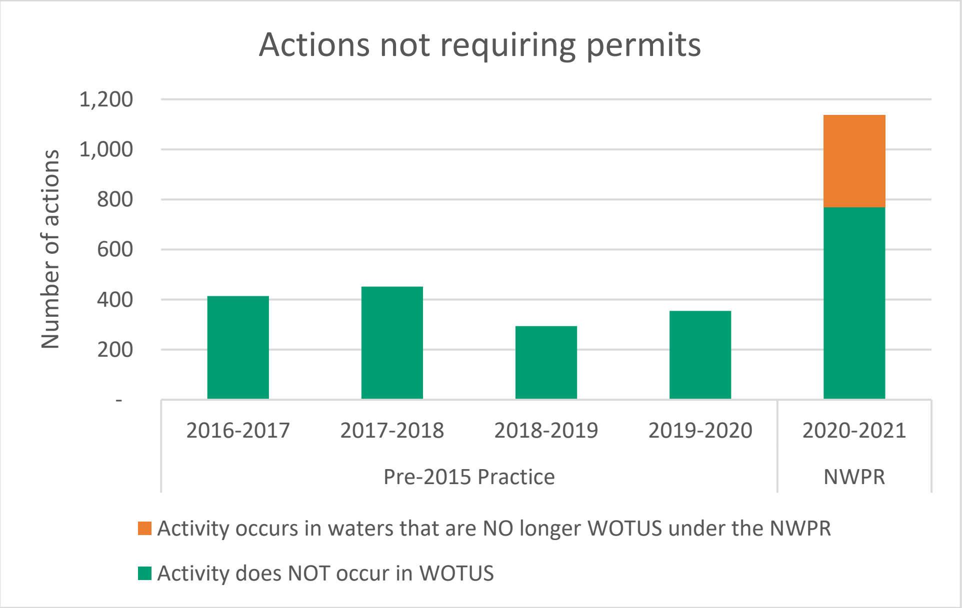

Figure 9: Actions Not Requiring Permits Under Pre-2015 Practice and 2020 NWPR. This figure presents the number of actions (*i.e.*, projects) with "No permit required" closure methods of '"Activities that do not occur in WOTUS" and "Activities that occur in waters that are no longer WOTUS under the 2020 NWPR."

d. Data Limitations

While ORM2 contains data on individual aquatic resources that the Corps has determined are or are not jurisdictional on a site-specific basis, JDs are typically conducted at the request of the landowner or project proponent. In other words, they usually represent where landowners or project proponents want to know if jurisdictional waters are located within their properties or project sites, including but not limited to for purposes of conducting dredged or fill activities. Thus, some aquatic resource types may be over- or underrepresented in the population of PJDs and AJDs.

The agencies recognize that these PJDs and AJDs may not be uniformly distributed across the country. There may be selection bias in terms of where the Corps has available information on JDs. A landowner or applicant can decide whether they would like an AJD – meaning the Corps makes an official determination of whether an aquatic resource is jurisdictional – or whether they would prefer to voluntarily waive or set aside questions regarding jurisdiction with the use of a PJD). In addition, Corps Districts across the country vary in their receipt of requests for AJDs versus PJDs, with some Districts primarily being requested to complete PJDs, particularly prior to the 2020 NWPR. Because PJDs do not make an official determination of the jurisdictional status of an aquatic resource (*e.g.*, it cannot conclude that an aquatic resource is not a "water of the United States"), and in light of the reduction in jurisdiction under the 2020 NWPR, the use of PJDs has appeared to decrease.

The states of New Jersey and Michigan have assumed administration of the Clean Water Act section 404 permit program for certain waters within their state boundaries. On December 17, 2020, Florida became the third state to receive approval to assume administration of the program. The Corps, however, retains administration of the section 404 permitting program for specific waters listed under the parenthetical of Clean Water Act section 404(g)(1) within states which have assumed the section 404 permitting program. Thus, the Corps conducts JDs for only a subset of waters within New Jersey, Michigan, and Florida, which have been included in the analysis of ORM2 data where available. In Florida, the number of 2020 NWPR JDs conducted by the Corps will be limited compared to the number of JDs in that state conducted under the prior regulatory regimes, as EPA's approval for the state to assume administration of the section 404 program occurred a few months after the effective date of the 2020 NWPR.

The new ORM closure method "Activities that occur in waters that are no longer WOTUS under the 2020 NWPR" was not uniformly used across the Districts and by Corps project managers and was added one month after implementation of the 2020 NWPR, and thus likely undercounts the number of projects that would have required a Clean Water Act section 404 permit prior to the 2020 NWPR but that no longer do. However, it serves as the best available indicator of projects that were tracked and no longer required a section 404 permit in light of the 2020 NWPR's reduction in Clean Water Act jurisdiction.

Despite these limitations, the agencies have concluded that assessing the ORM2 data associated with the 2020 NWPR is a reasonable way to evaluate the effects of that rule. The data represent the best national-level information on the resources that were called non-jurisdictional under the 2020 NWPR prior to its vacatur, and the agencies have concluded that it is reasonable to compare the 2020 NWPR data from 2020-2021 with data from the same time period in prior years that are associated with determinations made under the 2015 Clean Water Rule and the pre-2015 regulatory regime, which was reestablished with the 2019 Rule.

ii. Stakeholder Concerns

The agencies have heard concerns from a broad array of stakeholders, including states, tribes, scientists, and non-governmental organizations, that corroborated the agencies' data and indicated that the 2020 NWPR's reduction in the jurisdictional scope of the Clean Water Act resulted in significant environmental harms. As discussed in the Economic Analysis for the Final Rule, many Tribes and States do not regulate waters more broadly than the Clean Water Act. *See* Economic Analysis for the Final Rule, Chapter II; 2020 NWPR EA at 30-31. While some Tribes and States have authority to regulate "waters of the Tribe" or "waters of the State" more broadly than the federal government under their own laws, projects also proceeded in newly non-jurisdictional waters on Tribal lands and in States that do not and sometimes cannot regulate waters beyond those covered by the federal Clean Water Act.[29] Based on

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[29] Even if a tribe has the legal authority to regulate "waters of the tribe" more broadly than the federal government, the agencies have heard from many tribes that they lack the resources and expertise to do so as a practical matter, and therefore rely on Clean Water Act protections. *See, e.g.,* 85 FR 22336-22337 ("many Tribes may lack the capacity to create a tribal water program under tribal law, to administer a program, or to expand programs that currently exist. Other tribes may rely on the Federal government for enforcement of water quality violations"). In their Tribal consultation comment letter for this rulemaking the Southern Ute Indian Tribe noted, "Unlike some states where waters that are not classified as WOTUS can be protected by state-only water quality laws, the checkerboard nature of the Reservation and the division of jurisdiction means the Tribe's water quality laws alone

available information, the agencies therefore expect that these projects could have resulted in discharges without any regulation or mitigation from federal, Tribal, or State agencies. Contrary to the predictions made in the 2020 NWPR Economic Analysis, during the year in which the 2020 NWPR was in effect, the net change made by States was deregulatory in nature. Two States which had previously protected state waters beyond the scope of "waters of the United States" removed these expansive protections, and no States that lacked these broader protections established them. *See* 2020 NWPR EA at 39-41 (estimating that some States are likely to continue their current permitting practices for dredged and fill material) and the Economic Analysis for the Final Rule Chapter II (indicating that two of those States reduced the scope of State clean water protections after the 2020 NWPR was finalized, and none of them formerly expanded protections as a direct result of the 2020 NWPR); *see also* preamble section IV.B.3.

Given the limited authority of many Tribes and States to regulate waters more broadly than the federal government, a narrowing of federal jurisdiction would mean that discharges into the newly non-jurisdictional waters would no longer be subject to regulation, including permitting processes and mitigation requirements designed to protect the chemical, physical, and biological integrity of the nation's waters. Ephemeral streams and their associated wetlands, wetlands that do not meet the 2020 NWPR's revised adjacency criteria, and other aquatic resources not protected by the 2020 NWPR provide numerous ecosystem services, as discussed in the Science Report and this document. *See also* Sullivan *et al.* 2020. The absence of protections for such resources and any subsequent unregulated and unmitigated impacts to such resources would have caused cascading, cumulative, and substantial downstream harm, including damage connected to water supplies, water quality, flooding, drought, erosion, and habitat integrity. The removal of protections from the nation's waters, and resulting detriment to the services they provide, undermines the objective of the Clean Water Act, as discussed in section IV.A.2 of the preamble to this final rule. Such effects on the chemical, physical, and biological integrity of the nation's waters were inadequately considered during the 2020 NWPR rulemaking process. *See Pascua Yaqui v. EPA*, no. 4:20-cv-00266-TUC-RM, slip op. at 9-10 (citing evidence that the agencies and plaintiffs provided of a "substantial reduction in waters covered under the 2020 NWPR" as demonstrating "the possibility of serious environmental harm" that weighed in favor of vacating the rule.); *see also Navajo Nation v. Regan*, no. 2:20-cv-00602, slip op. at 6-7 (citing the same reduction particularly "'an increase in determinations by the Corps that waters are non-jurisdictional,' including excluded ephemeral resources, 'and an increase in projects for which CWA Section 404 permits are no longer required,'" as weighing in favor of vacatur.).

iii. Scientific and Technical Review

1. 2020 NWPR

Science plays a critical role in understanding how to protect the integrity of the nation's waters. The agencies have carefully reviewed the 2020 NWPR and its administrative record and found that the 2020 NWPR did not properly consider the extensive scientific evidence demonstrating the

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might not be effective at protecting water quality within the entire Reservation. In other words, unlike states, the Tribe cannot easily enforce a definition of "tribal waters" that is broader than the EPA and Corps' definition of WOTUS and any attempt to do so could trigger lengthy and expensive jurisdictional litigation. Therefore, given the jurisdictional uncertainties of the scope of the Tribe and the State of Colorado's independent authority to protect all waters of the Reservation, the EPA and Corps current, more narrow definition of WOTUS [the 2020 NWPR] disadvantages the Reservation and leaves certain Reservation waters unprotected." Baker 2021.

interconnectedness of waters and their downstream effects, thereby undermining Congress's objective to restore and maintain the chemical, physical, and biological integrity of the nation's waters. The 2020 NWPR's definition of "waters of the United States" does not adequately consider the way pollution moves through waters or the way filling in a wetland affects downstream water resources.

The 2020 NWPR's exclusion of major categories of waters from the protections of the Act, specifically in the definitions of "tributary" and "adjacent wetlands," runs counter to the scientific record demonstrating how such waters can affect the integrity of downstream waters. Specifically, its categorical exclusion of ephemeral features and large categories of wetlands is inconsistent with the scientific record before the agencies. In addition, the 2020 NWPR's limits on the scope of protected wetlands to those that touch or demonstrate evidence of a regular surface water connection to other jurisdictional waters were counter to the ample scientific information demonstrating the effects of wetlands on downstream waters when they have other types of connections.

This section will first describe how the 2020 NWPR's treatment of tributaries and adjacent wetlands is inconsistent with the scientific understanding of these ecosystems, and then provide detailed explanations of those inconsistencies using specific examples from the 2020 NWPR preamble where the agencies indicated that they "considered scientific principles" in the definition of "waters of the United States."

The 2020 NWPR's definition of "waters of the United States" runs counter to long-standing scientific understanding of tributaries, lakes, reservoirs, coastal waters, wetlands, and other types of waters. This is most evident by the 2020 NWPR's (1) failure to recognize ecosystem functions, *i.e.*, the processes by which aquatic ecosystems support fundamental needs, including good water quality and safe, reliable supplies of fresh water for communities, industry, and agriculture; (2) failure to accommodate the cumulative effects of headwaters, non-perennial flows, and wetlands on downstream water integrity, and (3) exclusion of ephemeral streams, many floodplain wetlands, and most non-floodplain wetlands in its definition of "waters of the United States."

Variations represented as hydrological, biogeochemical, and biological connectivity gradients operate in all aquatic ecosystems, and at all spatial and temporal scales. These variations are necessary to maintain the full range of functions by which upstream waters affect (*i.e.*, have consequences for) downstream water integrity. Such functions include short- and long-term storage of water, nutrients, and sediment in wetlands (*e.g.*, Jacques and Lorenz 1988; Vining 2002; Gleason *et al.* 2003; McEachern *et al*. 2006; Gleason *et al*. 2007; Fossey and Rousseau 2016; Golden *et al*. 2016; Mekonnen *et al.* 2016; Evenson *et al.* 2018; Green *et al.* 2019; Wang *et al.* 2019; Yeo *et al.* 2019; Nasab and Chu 2020; Rajib *et al.* 2020; Shook *et al.* 2021), transformation or sequestration of contaminants, removal or transformation of excess nutrients in temporary wetlands and non-perennial headwaters (*e.g.*, Reddy *et al.* 1999; Kao *et al*. 2002; Boon 2006; Jordan *et al*. 2007; Mitsch and Gosselink 2007; Reddy and DeLaune 2008; Kadlec and Wallace 2009; Cheesman *et al.* 2010; Marton *et al.* 2015; Cheng and Basu 2017; Golden *et al.* 2019; Martin *et al*. 2019), provision of habitat for aquatic and semiaquatic species in wetlands and headwater streams (*e.g.*, Scrivener *et al.* 1994; Curry 1997; Pires *et al.* 1999; Bradford *et al.* 2001; Meyer and Wallace 2001; Meyer *et al*. 2004; Cairns *et al.* 2005; Huryn *et al*. 2005; Wigington *et al.* 2006; Woodford and McIntosh 2010), recharge of river baseflow (*e.g.*, Goodrich *et al*. 1997; Baillie *et al.* 2007; Callegary *et al*. 2007; Izbicki 2007; Brooks *et al.* 2018; Min *et al.* 2020), and provision of drinking water for humans and wildlife from variably connected surface waters of all types (*e.g.*, Levick *et al*. 2008; Lohse *et al*. 2020). Connections with low values for some descriptors of hydrologic connectivity (*e.g.*, low-frequency, short-duration flooding) can have important downstream effects when values for other descriptors are high (*e.g.*, large-magnitude downstream transfer of floodwaters, sediment, large woody debris, and organisms). At the other end of the frequency gradient, high-frequency, low-magnitude vertical and lateral flows contribute to aquatic biogeochemical processes, including nutrient and contaminant transformation and organic matter accumulation. *See, e.g.*, Brunke and Gonser 1997; Karwan and Saiers 2012; Lawrence *et al.* 2013; Dwivedi *et al.* 2018; Evenson *et al.* 2018. These and other functions discussed in depth above and in the Science Report are absent from the 2020 NWPR's definition of "waters of the United States."

As the discussion of the agencies' scientific record also makes clear, the cumulative effects of upstream aquatic ecosystems on downstream water integrity should be considered in three ways:

- First, when evaluating the effect of an individual stream or wetland, all the contributions and functions that the stream or wetland provides must be considered. For example, the same stream can transport water, remove excess nutrients, mitigate flooding, and provide refuge for fish when conditions downstream are unfavorable; ignoring any of these functions would underestimate the overall effect of that stream. Note that these different functions may not all occur simultaneously, but all contribute over time. *See* Science Report.

- Second, effects of multiple streams and wetlands and the watersheds they drain are fundamentally cumulative in how those watersheds are formed and maintained. Excess precipitation that is not evaporated, taken up by organisms, or stored in soils and geologic layers moves downgradient as overland or subsurface flow or through channels, which concentrates flows and carries sediment, chemical constituents, and organisms. Flows from headwater tributaries longitudinally connect with other parts of the network, and their confluence with larger-order streams can have profound effects on the receiving system due to the abrupt increase in water, sediment, wood, and other entrained materials. As flows from numerous headwater channels combine in larger channels, the volume and effects of those flows accumulate as they move downstream through the river network. As a result, the incremental contributions of individual streams and wetlands accumulate in the downstream waters. Important cumulative effects are exemplified by ephemeral flows, which are key sources of baseflow for downgradient waters in arid and semi-arid regions (Schlesinger and Jones 1984; Baillie *et al.* 2007; Izbicki 2007), and by the high rates of denitrification in headwater streams (Fritz *et al.* 2018; Science Report). The amount of nutrients removed by any one stream over multiple years or by all headwater streams in a watershed in a given year can have substantial consequences for hypoxia and eutrophication in downstream waters (Alexander *et al.* 2007; Alexander *et al.* 2009; Böhlke *et al.* 2009; Helton *et al.* 2011). Similarly, a single pollutant discharge could be negligible, but the cumulative effect of multiple unregulated discharges can and has degraded the integrity of jurisdictional waters. Thus, the overall probability of a large-magnitude transfer of materials is higher when considered for all headwater streams in a watershed—that is, there is a *high-frequency connection* when considered cumulatively at the watershed scale, compared with probabilities of transport for streams individually. *See* Science Report.

- Third, evaluating cumulative contributions over time is critical in streams and wetlands with variable degrees of connectivity. For example, denitrification in a single headwater stream in any given year might not affect downstream waters; over multiple years, however, this effect accumulates. Western vernal pools provide another example of cumulative effects over time. These pools typically occur as complexes in which the hydrology and ecology are tightly coupled with the local and regional geological processes that formed them. When seasonal precipitation exceeds wetland storage capacity and wetlands overflow into the river network through swales and shallow subsurface flows that generate streamflow, the vernal pool basins, swales, and seasonal streams function as a single surface-water and shallow ground-water system connected through the river network. *See* Science Report.

The definition of the term "tributary" in the 2020 NWPR categorically excluded ephemeral streams from the regulatory protections of the Act, contrary to scientific information emphasizing the vital role these streams can play in protecting the integrity of downstream waters. The 2020 NWPR's definition of the term "tributary" states that the agencies "relied on the available science to help inform where to draw the line of federal jurisdiction over tributaries," and that the "agencies' decisions in support of this final rule have been informed by science." 85 FR 22288 (April 21, 2021). The science, however, is clear that aggregate effects of ephemeral streams "can have substantial consequences on the integrity of the downstream waters" and that the evidence of such downstream effects is "strong and compelling," as discussed above. Science Report at 6-10, 6-13. The SAB in their review of the draft Science Report explains that ephemeral streams "are no less important to the integrity of the downgradient waters" than perennial or intermittent streams. SAB 2014a at 22-23, 54 fig. 3. While in the arid Southwest, features flow into downstream waters less frequently than they do in the wetter East, the Science Report emphasizes that short duration flows through ephemeral streams can transport large volumes of water to downstream rivers. Science Report at 6-10. For instance, the report notes that ephemeral streams supplied 76% of flow to the Rio Grande following a large rainstorm. Science Report at 3-8. The SAB emphasizes that the "cumulative effects" of ephemeral flows in arid landscapes can be "critical to the maintenance of the chemical, physical, and biological integrity" of downstream waters. SAB 2014a at 22.

Similarly, the 2020 NWPR's definition of "adjacent wetlands" excluded many categories of wetlands that can play a vital role in protecting the integrity of waters to which they are connected, including traditional navigable waters. In defining "adjacent wetlands," the 2020 NWPR limited the scope of wetlands protected by the Clean Water Act's regulatory programs to those that either abut or have evidence of certain surface water connections to other protected waters in a typical year. 85 FR at 22340. Specifically, the rule encompassed wetlands that (i) abut, meaning to touch, another jurisdictional water; (ii) are flooded by a jurisdictional water in a typical year; (iii) are separated from a jurisdictional water only by a natural feature, such as a berm, which provides evidence of a direct surface hydrological connection with that water; or (iv) are separated from a jurisdictional water only by an artificial structure so long as that structure allows for a direct hydrologic surface connection between the wetlands and the water in a typical year. *Id*. As with the tributary definition, the 2020 NWPR stated that the definition of "adjacent wetlands" is "informed by science." *Id.* at 22314. Yet the 2020 NWPR's limits on the scope of protected wetlands to those that touch or demonstrate evidence of a regular surface water connection to other jurisdictional waters were counter to the ample scientific information before the agencies demonstrating the effects of wetlands on downstream waters when they have other types of surface connections, such as wetlands that overflow and flood jurisdictional waters or wetlands with less frequent surface water connections due to long-term drought; wetlands with shallow subsurface connections to other protected waters; or other wetlands proximate to jurisdictional waters. *See Rapanos*, 547 U.S. at 786 (Kennedy, J., concurring in the judgment) ("[g]iven the role wetlands play in pollutant filtering, flood control, and runoff storage, it may well be the absence of a hydrologic connection (in the sense of interchange of waters) that shows the wetlands' significance for the aquatic system.").

Indeed, the overwhelming scientific information before the agencies weighs decisively against repromulgating the definition of "adjacent wetlands" in the 2020 NWPR. Available scientific information demonstrates the significant effects of categories of newly excluded wetlands on the chemical, physical, and biological integrity of downstream traditional navigable waters. For example, whereas the 2020 NWPR provided that wetlands flooded by jurisdictional waters are only protected if the flooding occurs in a "typical year," the Science Report stated that wetlands that are "rarely" or "infrequently" flooded by streams and rivers can be "highly connected" to those waters and have "long-lasting effects" on them. Science Report at 4-39. The Science Report noted that effects "critical to maintaining the health of the river" result from large floods that provide "infrequent connections" with more distant wetlands. *Id*. Reflecting these concerns, the October 16, 2019 SAB Draft Commentary on the proposed 2020 NWPR stated that the narrow definition of "adjacent wetlands" in the 2020 NWPR as it was proposed "departs from established science." The agencies have weighed these statements and in light of the information about the importance of "infrequently" flooded wetlands to downstream waters, the agencies believe that the 2020 NWPR's exclusion of wetlands that lack the limited, specific types of surface water connections to other jurisdictional waters in a typical year lacked scientific support.

The SAB's assessment of the 2020 NWPR proposal recognized that the proposed rule was not consistent with the scientific information in the record, including the Draft Science Report that the SAB had previously reviewed. SAB 2020. The 2020 SAB Commentary emphasized that the proposal does not "fully incorporate the body of science on connectivity" that the SAB had reviewed in the Draft Science Report and offers "no scientific justification for disregarding the connectivity of waters accepted by current hydrological science." *Id*. at 2.

The 2020 NWPR stated that the "agencies' decisions in support of this final rule have been informed by science." 85 FR at 22288. However, the only scientific information the agencies provided in support of excluding ephemeral features and large categories of wetlands in the 2020 NWPR mischaracterized the scientific record before the agencies. For example, the scientific information that the 2020 NWPR cited as a basis for excluding ephemeral tributaries is the concept of a "connectivity gradient." *Id*., *citing* SAB 2014a at 3. The 2020 NWPR referred to the SAB's recommendation in their review of the draft Science Report that the agencies recognize that connectivity occurs along a gradient allowing for variation in chemical, physical, and biological connections. *Id*. at 22288, citing SAB 2014a at 3. The 2020 NWPR asserted that there is a "decreased" likelihood that waters with "less than perennial or intermittent" flow, *i.e.*, ephemeral streams, will affect the chemical, physical, and biological integrity of downstream waters. *Id.*

Upon careful review, however, the agencies have concluded the 2020 NWPR's conclusion takes the SAB's recommendation out of context and is inconsistent with the information in SAB 2014a as a whole and in the scientific record that was before the agencies. The agencies recognize that the SAB explained that the connectivity gradient the 2020 NWPR cited was just a hypothetical example[30] meant to illustrate just one aspect of connectivity— duration of surface hydrological, or physical connectivity— and sheds no light on the many other ways that features connect to and affect downstream waters. *See, e.g.*, Sullivan *et al*. 2019a at 11559 ("The near-exclusive emphasis of the proposed rule on hydrologic connectivity contradicts the CWA's mandate to protect chemical and biological connectivity as well"). According to the SAB itself, the only scientific information the agencies provided in support of categorically excluding ephemeral features does not fully represent the discussion in the cited SAB review of the draft Science Report and runs counter to key elements of the scientific record before the agencies. SAB 2020. The SAB in their review of the draft Science Report noted that "low levels of connectivity" can have "meaningful" effects on the integrity of downstream waters. SAB 2014a at 2. In addition, members of the SAB Panel that reviewed the Draft Science Report ("SAB Panel members") noted, "The agencies improperly used the [] figure from the SAB review to support removing federal protection for ephemeral streams and non-floodplain wetlands. The conceptual figure is meant to convey that connectivity between streams and wetlands and downstream waters is more appropriately represented by a connectivity gradient (A and B); this is not a binary property. Aggregate effects and low levels of connectivity can be important." Sullivan *et al*. 2019a at 11560. Further, the SAB Panel members stated, "Although the connectivity gradient does suggest that certain ephemeral streams and non-floodplain wetlands may be comparably less connected to downstream waters than perennial streams and floodplain wetlands, the SAB affirmed that even low levels of connectivity can be important relative to impacts on the chemical, physical, and biological integrity of downstream waters." *Id*. Similarly, Sullivan *et al.* 2020 (at 766) noted, "such exclusions [of ephemeral streams and non-floodplain wetlands under the 2020 NWPR] are inconsistent with evidence demonstrating that these waters are functionally connected to and support the integrity of downstream waters. Removal of federal protection is likely to diminish numerous ecosystem services, such as safeguarding water quality and quantity, reducing or mitigating flood risk, conserving biodiversity, and maintaining recreationally and commercially valuable fisheries."

In addition, several SAB Panel members have expressed that the 2020 NWPR as proposed "largely ignores or misrepresents several conclusions of the [Science] Report and SAB review." Sullivan *et al*. 2019a at 11559. *See also* Sullivan *et al*. 2019b at 7 ("As members of the previous SAB panel that reviewed the Connectivity Report and the 2015 [Clean Water Rule (CWR)], we are intimately familiar with the science supporting the 2015 CWR and the critical role played by the CWA in protecting our Nation's waters. We strongly oppose the proposed Rule, which we find to be inconsistent with science, based upon flawed logic, and too ambiguous for decision-making.") Some SAB Panel members stated that the proposal was "inconsistent with the best-available science regarding scale, structural and functional connectivity, and consideration of the multiple dimensions of connectivity" and that "its exclusions are justified with information from the SAB review that has been misinterpreted or taken out of context." Sullivan *et al.* 2019a at 11559, 11560. These SAB Panel members, along with other scientists, have similarly reviewed the 2020 NWPR as finalized and have concluded that the rule disregards or misinterprets the science. Sullivan *et al*. 2020; CASS 2021. Scientists have noted that "the 2020 NWPR promotes regulations contrary to what science shows about effective water protection" (*id.*

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[30] The figure cited is captioned in part as "*Hypothetical illustration* of connectivity gradient and potential consequences to downstream waters." SAB Review at 54 (emphasis added). Nowhere in its review does the SAB review indicate that this is the actual or only connectivity gradient.

at 767) and "conflicts with the object of the CWA: to restore and maintain the 'chemical, physical, and biological integrity of (the) Nation's waters'" (Fesenmyer *et al*. 2021 at 252).

The SAB (2014, at 22) emphasized that the "cumulative effects" of ephemeral flows in arid landscapes can be "critical to the maintenance of the chemical, physical, and biological integrity" of downstream waters. Contrary to the statements in the 2020 NWPR, the Science Report made clear that the aggregate effects of ephemeral streams "can have substantial consequences on the integrity of the downstream waters" and that the evidence of such downstream effects is "strong and compelling." Science Report at 6-13; *id.* at ES-7.

The record thereby contains robust scientific information demonstrating the importance of ephemeral streams to the integrity of the Nation's waters. The SAB's assessment of the 2020 NWPR proposal recognized that the proposed rule was not consistent with the scientific information in the record, including the Draft Science Report that the SAB had previously reviewed. SAB 2020. The SAB emphasized that the proposal does not "fully incorporate the body of science on connectivity" that the SAB had reviewed in the Draft Science Report and offers "no scientific justification for disregarding the connectivity of waters accepted by current hydrological science." *Id.* at 2. According to the SAB itself, the only scientific information the agencies provided in support of categorically excluding ephemeral features does not fully represent the discussion in the cited SAB Review and runs counter to key elements of the scientific record before the agencies. *Id*. The 2020 NWPR did not explain how the agencies reconciled that information with their decision to categorically exclude ephemeral streams from the definition of "tributaries," and thus failed to articulate "a rational connection between the facts found and the choice made." *State Farm*, 463 U.S. at 43; *see also District Hosp. Partners, L.P. v. Burwell*, 786 F.3d at 59.

The 2020 NWPR also stated that the line it draws between regulated and non-regulated wetlands, which excludes large categories of wetlands previously covered by the Act, is "informed by science." 85 FR at 22314. The 2020 NWPR cited statements from the SAB's review of the Draft Science Report to the effect that wetlands situated alongside other types of waters are likely to be connected to those waters, whereas "those connections become less obvious" as the distance "increases." *Id*. *citing* SAB 2014a at 55; *see also id.* at 22314, *citing* SAB 2014a at 60 ("[s]patial proximity is one important determinant" influencing the connections between wetlands and downstream waters"). In addition, the 2020 NWPR cited a statement in the Science Report that explained, "areas that are closer to rivers and streams have a higher probability of being connected than areas farther away." *Id*. at 22314, *citing* the Science Report at ES-4.[31]

Despite these citations, the 2020 NWPR's definition of adjacent is not based on proximity, but instead on factors that are distinct from proximity – *i.e.*, a "direct hydrologic connection," a "continuous surface [water] connection." *See id*. at 22340. Thus, the 2020 NWPR's definition of "adjacent wetlands" may exclude wetlands a dozen feet away from jurisdictional waters (therefore proximate under any interpretation of the term) if they are separated by a levee that does not convey flow in a typical year, but include wetlands much further away so long as they are inundated by flooding from the jurisdictional

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[31] This excerpt in the NWPR omits the end of the sentence in the Science Report, which qualifies the cited phrase: "...when conditions governing the type and quantity of flows—including soil infiltration rate, wetland storage capacity, hydraulic gradient, etc.—are similar". Science Report at ES-4.

water in a typical year. In addition, the statements the 2020 NWPR cites, addressing the importance of proximity, are taken out of context.

The 2020 NWPR preamble cites four examples where the agencies "considered scientific principles" in the definition of "waters of the United States:"

1. Use of streamflow duration classification in the definition of "tributary"
2. Definition of "adjacent" wetlands
3. Discussion of a hypothetical gradient of streamflow
4. A standard for assessing "normal" precipitation conditions ("typical year")

The first three examples use scientific terminology in their discussion rebutting public comments that the 2020 NWPR definitions and exclusions are not supported or informed by science but fail to apply the underlying scientific principles. *Id.* at 22271, 22288. The fourth example ("typical year") is informed by the traditional international standard for estimating "climate normals" but has significant flaws in its approach to evaluating "normal" precipitation conditions for assessing streamflow. The 2020 NWPR's inconsistent treatment or misapplication of long-standing scientific understanding in each of these four examples is described below.

a. Use of streamflow duration classification in the 2020 NWPR's regulatory definition of "tributary"

The 2020 NWPR includes many streams and reaches characterized by intermittent or perennial flows, but excludes all streams and reaches characterized by ephemeral flows as defined in that rule, stating that "this definition effectively furthers both the objective of the [Clean Water] Act to "restore and maintain the chemical, physical, and biological integrity of the nation's waters" and the "policy of Congress to recognize, preserve, and protect the primary responsibilities and rights of States to prevent, reduce, and eliminate pollution [and] to plan for the development and use (including restoration, preservation, and enhancement) of land and water resources . . . ." 33 U.S.C. 1251(b); *see also Rapanos*, 547 U.S. at 737 (Scalia, J., plurality)." *Id*. at 22287-22288. The 2020 NWPR's assertion that limiting jurisdiction over tributaries to those that have at least intermittent flow in a "typical year" furthers the objective to "restore and maintain the chemical, physical, and biological integrity of the nation's waters" is not supported by science and represents a misuse of long-standing scientific principles.

The scientific principle of hydrologic connectivity, or the water-mediated transfer of matter, energy, and/or organisms within or between elements of the hydrologic cycle (Pringle 2003) applies to all streams. Streamflow duration is a fundamental component of hydrologic connectivity, and has been classified by the terms ephemeral, intermittent, and perennial. Hedman and Osterkamp 1982; Hewlett 1982. However, the importance of flows *(i.e.*, the functions and effects associated with flow) and the significance of their contributions to downstream waters, cannot be inferred from flow duration alone. Science Report.

Stream classification in the 2020 NWPR merely identifies three classes of flow duration – perennial, intermittent, and ephemeral. It says nothing about the functions or downstream effects of a given streamflow duration class. In applying this approach, the 2020 NWPR excludes relevant scientific information to the question of how those three classes of streamflow affect the integrity of downstream waters that would be considered jurisdictional, and the mechanisms by which different degrees of hydrologic connectivity influence aquatic ecosystem function (further discussed above in this section).

Ward (1989) summarized the hydrologic connectivity of river ecosystems along four dimensions: longitudinal, lateral, vertical (surface-subsurface), and temporal connections. Degrees of hydrologic connectivity (*i.e.*, a hydrologic gradient) in a river network are established in each dimension by variations in the frequency, duration, magnitude, timing, and rate of change of flow. Poff *et al.* 2007. For example, functional methods for classifying streamflow consider the timing and magnitude of short-duration surface flows that transport large volumes of water and organic materials (*e.g.*, sediment) downstream (Nolan *et al.* 1987; Reid *et al.* 1995); changes in the frequency and duration of flow in response to regional climate, landscape, land use, and water use (Fritz *et al.* 2020); or the influence of water withdrawals, impoundments, and other human activities on shifting patterns of flow (*e.g.*, from perennial to intermittent or ephemeral) (Datry *et al.* 2014). For example, Gallo *et al.* (2020) quantified hydrologic discontinuities in streamflow and stream water presence in Arizona and found that, on a regional scale, stream channel density is a better predictor of streamflow and water presence than rainfall alone. In addition, their results showed that water presence as soil moisture and/or surface ponding can be 4–33 times greater than the duration of streamflow at the driest sites, which has important implications for biogeochemical processes in arid river systems. Gallo *et al.* 2020.

Hydrological connections along longitudinal (upstream-downstream), lateral (channel-to-floodplain or non-floodplain wetlands) and vertical (exchanges between surface and hyporheic flow) gradients are the physical backbone of healthy river networks. Direct evidence of hydrologic connectivity throughout river networks is apparent in the existence of stream channels that form the physical structure of the network itself. Science Report. Transitions in flow duration shape and re-form channels, distribute materials throughout the stream network, provide habitat for a wide diversity of plants and animals, and establish functional linkages between stream, wetland, and terrestrial ecosystems across space and through time. Datry *et al.* 2014. In addition to efficient transport of water and materials, infiltration from ephemeral flows recharges local aquifers that support riparian vegetation and animals (Science Report; Zimmer and McGlynn 2017) and regional aquifers that support baseflow in intermittent and perennial rivers (Min *et al.* 2020). Ephemeral flows also are important for survival and dispersal of aquatic organisms, including native fish species, during dry periods. De Jong *et al.* 2015. In the western U.S., 89% of streams are ephemeral or intermittent (Gallo *et al.* 2020) but even in forested watersheds, field-based surveys have shown that ephemeral channels can comprise the majority (up to 71%) of headwater stream miles (Hansen 2001; Fritz *et al.* 2013) based on physical channel extent. By categorically excluding an entire class of stream flows (ephemeral) from jurisdiction, the 2020 NWPR disaggregates flow-integrated stream networks, imposing arbitrary breaks in longitudinal, lateral, and vertical connections that support water quality, biodiversity, and ecosystem functioning in larger downstream waters.

Another line of evidence in the arbitrariness of the 2020 NWPR's definition of "tributary" is the inclusion of intermittent and perennial reaches upstream of ephemeral reaches when the connecting ephemeral reach flows at least once per year in a "typical year." Here the argument is that ephemeral reaches that flow at least once per year do provide a meaningful stream connection to downstream waters if the water and material could pass through a perennial or intermittent reach first, though the ephemeral reaches themselves continue to be excluded under the rule. The preamble attempts to "re-assemble" portions of the stream network via the hydrologic connectivity established by ephemeral flows, while the rule text excludes all ephemeral streams that are instrumental in shaping and defining the river network from headwater sources.

Scientific methods for classifying flow duration (*e.g.*, as ephemeral, intermittent, perennial) assign conceptual transitions along the temporal gradient of channelized surface flows through a river network. Fritz *et al.* 2020. They support a variety of research and management objectives in river systems, which are characterized by time-varying flows that support different but equally important functions. Bracken *et al.* 2013; Science Report. The scientific principles used to develop flow classification methods do not support the notion that flows of one flow duration class are more ecologically important to downstream water integrity than flows in other classes.

There are many slight variations in the definitions of intermittent flow developed and used by scientists (*see, e.g.*, Busch *et al.* 2020), including those that specify ranges of flow duration (Fritz *et al.* 2020). None of the scientific definitions of flow duration class are based on effects on downstream water integrity. Rather, they reflect differences in application and characteristics of the location (*e.g.*, regional climate, geology, topography). Having defined durations of surface flow enables the use of USGS streamflow gage and other continuously monitored datasets for informing classifications. Because there are only three classes, most reaches will fall within specified ranges, but because flow duration itself is a gradient and the factors driving flow duration and its temporal variation are complex, there will be some reaches that fall near the interface between two flow duration classes and will be above a specified threshold one year but below it for another year, even when both years are considered “typical years.” This interannual variation in streamflow permanence means that a given stream can appear to have ephemeral flow in one “typical year” and intermittent flow in a different “typical year.” The 2020 NWPR does not address how to account for such interannual variation for assessing jurisdiction.

The 2020 NWPR’s definition of “tributary” disproportionately excludes headwater streams, which are the major sources of water to river networks. Science Report. Intermittent and ephemeral streams conservatively account for 59% of the total length of streams in the contiguous United States, most of which are comprised of headwater networks. Nadeau and Rains 2007; *see also* Science Report at 2-29 (citing *id*.). A recent global model by Messager *et al.* (2021) estimated that 44-53% of stream reach length dries for at least 1 month per year, and that the wettest climate zone still had up to 30% of stream length being non-perennial whereas the driest climate zone had 99% of stream length being non-perennial. Non-perennial flows activated during rainfall or snowmelt events are efficient at transporting water and materials (including permitted discharges) that accumulate in dry stream channels to downstream waters.

Changes in the spatial extent of stream networks due to expansion in response to precipitation and snowmelt and contraction during dry periods are most pronounced in the arid and semiarid Southwest, where more than 80% of all streams are intermittent or ephemeral. Levick *et al*. 2008. Godsey and Kirchner (2014) demonstrated the dynamism of headwater networks, mapping a 2.6 to 7.5-fold increase in both flowing network lengths and drainage densities in four drainages between fall (dry conditions) and spring (wet conditions). The dominant sources of water to a stream can shift during river network expansion and contraction in response to precipitation or snowmelt. Malard *et al.* 1999; McGlynn and McDonnell, 2003; McGlynn *et al.* 2004; Malard *et al.* 2006. The larger the rainfall or snowmelt event, the more ephemeral streams flow, increasing the total length of channels contributing water and materials throughout the river network. Ephemeral flows cease within days after rainfall or snowmelt, and the flowing portion of the river network seasonally shrinks as the spatial extent of aquifers in contact with streams contract, precipitation-evapotranspiration balance shifts, and intermittent streams dry. In many river systems across the United States, stormflow comprises a major portion of annual streamflow. Hewlett *et al.* 1977; Miller *et al.* 1988; Turton *et al.* 1992; Goodrich *et al.* 1997; Vivoni *et al.* 2006. In these systems, intermittent and ephemeral streams are major sources of river water. Science Report at 2-18.

The propagation of stormflow through river networks also provides clear evidence of hydrologic connectivity between ephemeral, intermittent, and perennial headwater streams to rivers, particularly when an intense storm occurs over only the headwater portions of a river network. The contribution of tributaries to rivers during widespread floods manifests as stepped increases in discharge immediately below confluences, as water flows accumulate through a river network. Science Report at 3-7. Such propagation was recorded following a monsoonal storm event through an arid network of ephemeral channels in the watershed of the Rio Puerco River, a semiarid tributary to the Río Grande River, in the early 2000s. Vivoni *et al.* 2006. A storm dropped approximately 18−25% of annual rainfall on the Rio Puerco's approximately 16,000 square kilometer (approximately 6,200 square miles) drainage area over a two-day period. Discharge recorded at two USGS gages on the Rio Puerco and three USGS gages on the Río Grande downstream of the confluence illustrated sequential time lags in peak flows from the upstream gage to the downstream gage, demonstrating the downstream transfer of flows from headwaters, and increases during peak flows at least 127 km (approximately 79 miles) downstream. *Id.* Stormflow contributions from the ephemeral Rio Puerco accounted for 76% of flow at the Río Grande during this event, although just 3.6% of rainfall resulted in tributary runoff. A total of 49% of the flood volume recharged shallow aquifers in the mainstem of the river and the remainder entered the reservoir at the outlet. *Id.*; Science Report at 3-7, 3-8. However, this river, if it meets the 2020 NWPR's definition of ephemeral, would have been excluded under the 2020 NWPR despite the large quantity of flow that is provided downstream to the Río Grande during a storm event that is likely to occur annually.

The 2020 NWPR is inconsistent in its consideration of physical indicators of flow. 85 FR 22292. As noted above, physical indicators can be evidence of flows that provide important functions to larger downstream waters, including traditional navigable waters, the territorial seas, and interstate waters. The channel form and other fluvial geomorphic features are physical indicators of the recurrent, concentrated surface flow of water through the stream network to downstream waters. Without the recurrent transport of water and materials, terrestrialization (soil development, terrestrial vegetation colonization/growth) transforms channels to uplands, making them indistinguishable from the surrounding landscape. The 2020 NWPR preamble notes the value of physical indicators as a line of evidence but excludes them on the basis that they cannot be used to evaluate flow duration under "typical year" conditions (*see* section II.B.iv.1 for discussion of the 2020 NWPR's use of "typical year"). As noted above, flow magnitude (*e.g.*, flooding, transfer of stored materials in high-magnitude, short-duration events) can have large effects on downstream waters. Physical indicators often reflect transport magnitude to a stronger degree than transport duration because indicators of intermediate and lower magnitude flows are often effaced by higher flows. In addition to representing responses, physical indicators can be hydrologic drivers and be represented at not only the local, reach scale, but larger scales (*e.g.*, watershed, regional). Costigan *et al.* 2016.

If the scientific justification for limiting jurisdiction to intermittent and perennial reaches is that they are fed primarily by groundwater or snowpack meltwater – as the 2020 NWPR's definition of "tributary" indicates – the 2020 NWPR fails to address two essential points: (a) all three of the 2020 NWPR's streamflow duration classes convey stormflow and materials downstream, and (b) individual streams often transition longitudinally between flow duration classes, from ephemeral to intermittent to perennial, creating patchworks of ephemeral, intermittent, and perennial reaches within a single segment or tributary of a stream network. Science Report. The 2020 NWPR preamble states that the "regular and predictable" hydrologic behavior—*i.e.*, intermittent and perennial flows within a "typical year," however they are distributed within and across tributaries—qualifies them for Clean Water Act jurisdiction. 85 FR 22278. By its regulatory definition of jurisdictional streams (*i.e.*, "tributaries") based on flow classes, the 2020 NWPR attests that the scope of the Clean Water Act is therefore determined largely by conditions that reflect snowpack and groundwater inputs to streamflow. In effect, the 2020 NWPR preferentially regulates streams in those locations having climate and landscape conditions that support persistent or seasonal flow or inundation—conditions that do not exist nationally and that are subject to predictable changes in climate patterns over the next 30+ years. It also favors protection for streams in human-dominated watersheds that receive a significant proportion of their baseflow from municipal and industrial wastewater effluent discharges, stormwater detention basins, and irrigation return flow, all of which are more likely to be impaired than streams without such augmented source water and would otherwise be non-perennial (and many of which, particularly in the arid West, would otherwise by ephemeral and excluded under the 2020 NWPR). Streams whose instream flows are entirely dependent on effluent discharges are called effluent-dependent streams, whereas those that receive most, but not all, of their flow from effluent are called effluent-dominated streams. Brooks *et al.* 2006. About 25% of permitted effluent discharges in the United States enter streams with mean annual flows incapable of diluting effluents by more than 10-fold. This percentage of permitted effluent discharges entering streams incapable of diluting effluents by more than 10-fold increases to 60% when low-flow discharge is considered. Brooks *et al.* 2006; Science Report at 3-12, 3-13. While effluent-dependent or effluent-dominated streams can have unique water quality characteristics (Brooks *et al*. 2006), there is also no scientific justification to regulate them and to not also regulate ephemeral streams, as the 2020 NWPR does.

b. Definition of "adjacent wetlands"

The 2020 NWPR preamble incorrectly cites the Science Report by quoting partial sentences out of context. For example, the 2020 NWPR preamble notes that "areas that are closer to rivers and streams have a higher probability of being connected than areas farther away" *Id*. at 22314 (citing the Science Report at ES-4). However, the complete sentence text in the Report is: "In addition, although areas that are closer to rivers and streams have a higher probability of being connected than areas farther away when conditions governing the type and quantity of flows—including soil infiltration rate, wetland storage capacity, hydraulic gradient, etc.—are similar, information to determine if this similarity holds is generally not provided in the studies we reviewed." Science Report at ES-4. The Science Report states elsewhere that, "*All factors being equal*, wetlands closer to the stream network will have greater hydrologic and biological connectivity than wetlands located farther from the same network." *Id*. at 2-40 (emphasis added). However, proximity is not a factor in the 2020 NWPR's definition of "adjacent wetlands." Wetlands that are very close to the stream network are not considered "adjacent wetlands" under that rule unless they have the very specific hydrologic connections that the 2020 NWPR prescribes for "adjacent wetlands."

In the same section, the 2020 NWPR preamble also cites the SAB Review as saying that "[w]etlands that are situated *alongside* rivers and their tributaries are likely to be connected to those waters through the exchange of water, biota and chemicals. As the distance between a wetland and a flowing water system increases, these connections become less obvious." 85 FR 22314 (citing SAB 2014a at 55) (emphasis added in 2020 NWPR preamble). In the SAB Review, this sentence opened the section in which the SAB discusses the importance of "less obvious" connections from less-proximal (*i.e.*, non-floodplain) wetlands that influence downstream waters.

The 2020 NWPR preamble also quotes fragments of text from the Science Report and the SAB Review incorrectly and out of context in its discussion of limiting Clean Water Act jurisdiction to wetlands having a "near-permanent" hydrologic connection to a jurisdictional water in a "typical year." The 2020 NWPR defines "adjacent wetlands" as wetlands that:

> (i) Abut, meaning to *touch at least at one point or side of*, a water identified in paragraph [traditional navigable water or territorial sea, tributary, or lake, pond, or impoundment of a jurisdictional water];
> (ii) Are *inundated by flooding* from a [traditional navigable water or territorial sea, tributary, or lake, pond, or impoundment of a jurisdictional water] in a typical year;
> (iii) Are physically separated from a [traditional navigable water or territorial sea, tributary, or lake, pond, or impoundment of a jurisdictional water] only by a natural berm, bank, dune, or similar natural feature; or
> (iv) Are physically separated from a [traditional navigable water or territorial sea, tributary, or lake, pond, or impoundment of a jurisdictional water] only by an artificial dike, barrier, or similar artificial structure so long as that structure allows for a *direct hydrologic surface connection* between the wetlands and the [traditional navigable water or territorial sea, tributary, or lake, pond, or impoundment of a jurisdictional water] in a typical year, such as through a culvert, flood or tide gate, pump, or similar artificial feature. An adjacent wetland is jurisdictional in its entirety when a road or similar artificial structure divides the wetland, as long as the structure allows for a direct hydrologic surface connection through or over that structure in a typical year.

Id. at 22338 (emphasis added). There is no scientific or conventional context in which proximity can be interpreted as having a direct or continuous surface water connection. When taken properly in context with scientific evidence, spatial proximity is one of multiple important physical factors influencing ecological exchanges of water, materials and biota between streams, wetlands, open waters, and downstream waters. Other factors cited in the Science Report and related publications are the individual size, number, climate, geology, terrain/slope, land use/land cover, distinctiveness, and intervening units. Fritz *et al.* 2018 at Table 2 (Key factors affecting connectivity from streams and riparian wetlands to downstream waters and its resulting effects). In addition, although the 2020 NWPR preamble cites the SAB Review as support for limiting jurisdiction to wetlands at close spatial proximity to "waters of the United States," the rule makes no reference to spatial distance - the ordinary interpretation of spatial proximity - in its definition of "adjacent wetlands." Under the 2020 NWPR, wetlands located at considerable distance from lakes or rivers could be jurisdictional, whereas more spatially proximate wetlands might not. For example, under the 2020 NWPR, normal expansion of lakes in the Prairie Pothole Region that merge with previously disconnected wetlands via continuous surface water at distances up to 38 km (Vanderhoof and Alexander 2016) could be jurisdictional whereas coastal, riparian, and floodplain wetlands that are in fact directly spatially proximal to "waters of the United States" have been found to be non-jurisdictional.

Further, wetlands running alongside a tributary have been found to be non-jurisdictional on the basis of factors such as channel incision, build-up of bank materials from past floods that do not meet subjective criteria for a natural berm, or absence of evidence showing a single-point of "near continuous" surface connection to the tributary. This also contradicts the emphasis added in the 2020 NWPR preamble to the SAB Review's comment about wetlands that run "*alongside* of rivers and their tributaries" cited above.

The 2020 NWPR preamble states:

> The final rule also provides that wetlands separated from jurisdictional waters only by a natural berm, bank, dune, or other similar natural feature are adjacent wetlands. These natural features are indicators of a sufficient hydrologic surface connection between the jurisdictional water and the wetland, and the agencies conclude that wetlands that are separated from jurisdictional waters only by such features are inseparably bound up with the adjacent jurisdictional waters and are therefore "part of those waters."

Id. at 22280 (citing *Rapanos,* 547 U.S. at 740 (Scalia, J., plurality). The preamble goes on to say that "Physically remote isolated wetlands (*i.e.*, wetlands that do not abut, are separated by more than a natural berm from, are not inundated by flooding in a typical year from, and do not have a direct hydrologic surface connection in a typical year to a jurisdictional non-wetland water) are not adjacent wetlands under the final rule." *Id.* The 2020 NWPR consequently misapplies the term "physically remote" to wetlands that are not remote in any ordinary sense of the word, and/or not "isolated" in any scientific sense from a jurisdictional water. Marton *et al.* 2015; Fossey and Rousseau 2016; Rains *et al.* 2016; Cohen et al 2016; Creed *et al.* 2017, Evenson *et al.* 2018; Lane *et al.* 2018; Golden *et al.* 2019.

Similar to streams, the occurrence and persistence of riparian/floodplain wetland and non-floodplain wetland hydrologic connections with river networks, via surface water (both channelized and non-channelized) or shallow or deep groundwater, can be continuous, seasonal, or ephemeral, depending on the overall hydrologic conditions in the watershed. For example, a wetland might have a direct shallow subsurface connection with a river network during wet conditions but an indirect regional groundwater connection (via groundwater recharge) under dry conditions. Non-floodplain wetlands can be hydrologically connected to the river network via non-channelized surface flow (*e.g.*, swales or overland flow) (*see, e.g.*, Rains *et al.* 2006; Wilcox *et al.* 2011) or subsurface flows that support river baseflow (Science Report at 2-14, 4-2. Therefore, the assertion that they do not have a "direct hydrologic surface connection in a typical year to a jurisdictional non-wetland water" is erroneous. In fact, wetlands that outflow to streams seasonally through swales that likely would have met the definition of "waters of the United States" prior to the 2020 NWPR were no longer jurisdictional under the 2020 NWPR. However, in some cases the swales themselves – which formerly were not "waters of the United States"—were found to be jurisdictional under the 2020 NWPR. This example illustrates how jurisdiction based entirely on flow duration and flow direction and the application of 2020 NWPR categories of "adjacent wetlands" run counter to scientific understanding of stream-wetland connectivity and function in ways that subvert the objective of the Clean Water Act.

The 2020 NWPR's preamble incorrectly claimed that the rule's limits on wetlands that are jurisdictional were consistent with "longstanding practice." 85 FR at 22280. The preamble claimed consistent with longstanding practice "wetlands can be jurisdictional only if they are adjacent to territorial seas or a traditional navigable water, tributary, lake, pound, or impoundment of a jurisdictional water but the rule's definition of "waters of the United States" was not consistent with which categories of wetlands are regulated under the agencies' pre-2015 regulatory regime. For example, the 2020 NWPR did not include interstate waters as a separate category of jurisdiction even though such waters had been regulated for decades prior to the 2020 NWPR. As a result, interstate wetlands were not included as "waters of the United States" unless they met one of the rule's categories of jurisdictional waters. Similarly, wetlands adjacent to interstate waters were not be regulated under the 2020 NWPR unless they met one of the four paragraph (a) waters under that rule, which is also counter to longstanding practice. In addition, the definition of "adjacent wetlands" under the 2020 NWPR was modified to such an extent that even wetlands "running alongside" perennial streams and rivers were found to be non-jurisdictional under that rule. For example, in one approved jurisdictional determination, an area of pine flatwoods in the Mississippi Coastal Plain, the area of adjacent wetlands was reduced from 144 acres under the 2015 Clean Water Act to 9.5 acres under the 2020 NWPR. In another example, a heavy mineral sands mining project in Georgia withdrew its permit for development under the 2015 Clean Water Rule, which found 400 acres on the site near the Okefenokee NWR to be jurisdictional, and re-applied under the 2020 NWPR, which reduced the number jurisdictional wetlands acres to zero acres. At least one Corps district saw an eight-fold increase in the number applications for Approved Jurisdictional Determinations (~50/year to ~400/year) in the first year of 2020 NWPR implementation, and 3,300 acres of coastal plain wetlands were determined to be non-jurisdictional over that period. Although the agencies generally have not used paragraph (a)(3) of the pre-2015 regulations to assert jurisdiction over "other waters" since the decision in *Solid Waste Agency of Northern Cook County v. U.S. Army Corps of Engineers*, 531 U.S. 159 (2001) (*SWANCC*), the Supreme Court did not invalidate that regulation. To advance the objective of the Act, and in accordance with Supreme Court precedent and the agencies' experience and expertise, the final rule provides that intrastate waters that do not meet the criteria set forth in paragraphs (a)(1) through (a)(4), (now listed under paragraph (a)(5) of the final rule) must meet either the relatively permanent standard or the significant nexus standard in order to be jurisdictional.

c. The 2020 NWPR's standard for assessing normal climate conditions ("typical year")

The 2020 NWPR's concept of "typical year" is fundamental to jurisdiction in that some regulatory definitions (*e.g.*, of a tributary, certain adjacent wetlands, and certain lakes, ponds, and impoundments of jurisdictional waters) apply only if flows are observed "when precipitation and other climatic variables are within the normal periodic range (*e.g.*, seasonally, annually) for the geographic area of the applicable aquatic resource based on a rolling thirty-year period." 85 FR 22274. Therefore, the 2020 NWPR's definition of "typical year" is a linchpin of jurisdictional decisions under the rule.

(i) Applicable Period of Record

The 2020 NWPR definition of "typical year" draws from an international standard for calculating and reporting "climate normals" – *i.e.*, a suite of statistics for temperature, precipitation, and other climatological variables from U.S. weather stations – established in the mid-1940s by the International Meteorological Organization (IMO; predecessor of the World Meteorological Organization (WMO)). A 30-year averaging period was selected by IMO because at the time, only 30 years of global climate data were available. WMO 2017. In addition, 30 observations were considered sufficient for estimating average values under relatively stable climate conditions (stationarity, *i.e.*, when temperature, precipitation, and other climate variables fluctuate seasonally or annually above or below a constant but do not show positive or negative trends) or when changes in climate patterns are small or slow-moving. WMO 2007; Wilks 2013.

One drawback of relying only on a 30-year averaging period to estimate "typical" conditions is that climate conditions in the United States are not stable. Consistent regional and national trends in temperature, precipitation, and other climatological variables are rapidly shifting climate averages (NOAA a; data available at https://www.ncei.noaa.gov/access/monitoring/us-trends/), and climate extremes are becoming more intense, frequent, and/or persistent (data available at https://www.climate.gov/maps-data/dataset/severe-storms-and-extreme-events-data-table and https://www.ncei.noaa.gov/products/severe-weather). These trends have been apparent in records dating back to the start of the 20th century and have become more pronounced over the past 30 years. Steinacker 2021. Both types of change – trends in temperature/precipitation and more frequent/intense climate extremes – invalidate assumptions of climate stationarity and increase error in estimation of "normals" based on 30-year averaging intervals. Arguez *et al.* 2019. While important as long-term benchmarks of climate change, in the early 2000s WMO 30-year climate normals were found to be "no longer generally useful for the design, planning, and decision-making purposes for which they were intended." Livezey *et al.* 2007 at 1759.

In response, the National Oceanic and Atmospheric Administration (NOAA) has developed several alternatives (optimal climate normals; OCN; Huang *et al.* 1996) to account for monotonic climate change. OCN include seasonal averages computed using 10-year annually-updated averaging periods for temperature and 15-year annually-updated averaging periods total precipitation. Arguez *et al.* 2019. In addition, NOAA OCN are adjusted for systematic interannual variability (*e.g.*, El Niño–Southern Oscillation; ENSO) by conditioning climate normals on the phase and intensity of ENSO events in five sets of climate normals, thereby accounting for climate anomalies, as well as background climate trends, in estimates of temperature and precipitation "normals." *Id*.

In general, shorter periods and annual updating improve the performance of climate normals in the presence of rapid trends, although determining the "best" period of record over which trends are evaluated for any given location remains challenging because optimal intervals vary by effect (*e.g.*, temperature, total precipitation) and time of year. Huang *et al.* 1996. In recent decades, NOAA has recommended that users of conventional benchmarks also consider alternative benchmarks estimated using annual updates over shorter fixed (5, 10, 15, 20-year) intervals or variable optimized intervals that are automatically adjusted to provide more accurate information for a particular time and location. NOAA 2019. Starting in May 2021, NOAA began publishing 15-year NOAA climate normals in tandem with 30-

year WMO climate normals, now updated each decade, as a standard practice. NOAA 2021; NOAA 2022b.

The 2020 NWPR improves upon the historical WMO approach by using a rolling 30-year interval updated annually. The preamble states that the agencies "considered other alternative [averaging] time periods" for assessing "normalcy" but maintained the 30-year record because it was established "[n]early a century ago." 85 FR 22274. The only justification given for retaining a 1940s-era standard is a reference to the NOAA webpage linking users to information about alternatives, including OCN, estimated over shorter averaging time periods to account for rapid changes in average climate conditions. *Id*. at 22274-22275, citing NOAA 2019. While the 2020 NWPR's approach is slightly preferable to the historical WMO approach, a more flexible approach that allows for the use of 10-year or 15-year climate normals, such as those published by NOAA, would generally be better in light of rapidly changing climatic conditions in certain parts of the country

(ii) Accuracy of Prediction Based on Historical Precipitation Quantiles

While agreeing that precipitation is just one of many important drivers of streamflow and wetland inundation, the 2020 NWPR preamble uses precipitation total as the sole basis for quantifying a "typical year" by relying on "the normal range of precipitation," estimated for given location as follows: "The agencies evaluate normal precipitation conditions based on the three 30-day periods preceding the observation date. For each period, a weighted condition value is assigned by determining whether the 30-day precipitation total falls within, above, or below the 70th and 30th percentiles for totals from the same date range over the preceding 30 years. The agencies make a determination of 'normal,' 'wetter than normal,' or 'drier than normal' based on the condition value sum." *Id.* at 22274. The preamble provides no justification for using this method to assess normalcy, except that it draws from methods developed by the National Resource Conservation Service (NRCS) and the Corps for assessments of *wetland* hydrology.

To the agencies' knowledge, the "typical year" concept had not been validated for accuracy (reliability) of predicted assessments of precipitation, or the effects of precipitation on stream hydrology for that location prior to finalization of the 2020 NWPR. Other key factors driving variations in streamflow include evapotranspiration, temperature, available water capacity in soils, snowpack conditions, groundwater conditions, and water withdrawals, all of which vary interannually but are unaccounted for in the 2020 NWPR definition of "typical year." A recent study by the Corps found that precipitation normalcy (as calculated based on the methodology described in the preamble to the 2020 NWPR) was neither a reliable predictor of streamflow normalcy, nor was it a precise predictor of streamflow percentiles, in an analysis of watersheds across the United States. Sparrow *et al*. 2022.

Further, the 2020 NWPR provides no evidence to support its assumption that "normal precipitation" across the country is accurately captured by the middle 40% of the precipitation totals recorded over the 90-day date range of interest over the 30-year period of record. Nor does it provide evidence to justify the exclusion of 60% of precipitation events because they are assumed to be "too wet" or "too dry" for jurisdiction. *Id*. The uncertainty associated with the 2020 NWPR "typical year" guidelines is particularly high for areas currently facing rapid changes in climate variables (*e.g.*, including in the Midwest, where 100-year floods occur with more frequency in a "typical year") or climate anomalies caused by cyclic events (*e.g.*, ENOS) create conditions in which emphasis on the middle range of precipitation totals is particularly prone to over- or under-estimation of normal conditions. Given the 2020 NWPR's heavy reliance on "typical year" for Clean Water Act jurisdiction, the 2020 NWPR could have required that estimates of uncertainty associated with weighting the middle 40% of precipitation observations across the United States be provided as part of a jurisdictional determination, along with probabilities that recent events fall above, within, or below the 30th and 70th percentiles. Considering only 40% of prior events also can eliminate channel-forming events, including ephemeral stormflows that transport large volumes of water and materials to downstream waters (*e.g.*, the Rio Puerco and Río Grande example cited in section II.B.iii.1.a).

The 2020 NWPR's preamble alludes to the inadequacy of that rule's primary method for assessing "typical" climate by stating that the agencies "recognize there may be other accurate and reliable measurements of normal precipitation conditions" and places a burden of proof on those seeking more scientifically-defensible methods to assess "normal" conditions by stating that "alternative methods" must be "developed and appropriately validated, including different statistical percentiles, evaluation periods, or weighting approaches for condition values." 85 FR 22274. No such comparable support for the rolling 30-year average is provided in the preamble or elsewhere in the public record. In practice, the difficulty of finding, assembling, integrating, validating, and analyzing datasets that could provide a more accurate estimate of climate "normals" presents a high bar for implementing robust and reliable methods. As a result, most assessments of "typical year" resorted to the use of 30-year precipitation records as recommended in the 2020 NWPR preamble.

Lastly, while precipitation is an important predictor of streamflow (Eng *et al.* 2016; Jaeger *et al.* 2019; Konrad 2019), there is no support for relating the "typical year" precipitation "condition value sum" to flow behavior at the basin, tributary, or reach scale. Thus, while claiming to provide a "predictable, implementable regulatory framework" for regulating tributaries, the 2020 NWPR methods add uncertainty to assessments of flow duration class (perennial, intermittent, or ephemeral), use standards for assessing climate normals ("typical year") that have limited ability to assess current or near-future conditions, and in practice, depend on historical records of streamflow or wetland inundation that frequently do not exist.

d. Jurisdiction of lakes, ponds, impoundments, wetlands by one-way inundation

The 2020 NWPR preamble states that inundation by flooding of lakes (including oxbow lakes), ponds, impoundments of jurisdictional waters, and "adjacent wetlands" from jurisdictional waters in a "typical year" is "sufficient to establish jurisdiction [when it] occurs only in one direction, from the [traditional navigable water or territorial sea, tributary, or lake, pond, or impoundment of a jurisdictional water] to the lake, pond or impoundment of jurisdictional waters, rendering the feature 'itself a part of those waters' 'that are 'waters of the United States' in their own right.'" 85 FR 22303 (citing *Rapanos*, 547 U.S. at 740, 742 (Scalia, J., plurality). This requirement is inconsistent with the science on the importance of flows that occur in the other direction—from a wetland or open water to the tributary network—and from other types of hydrologic connections.

Wetlands and open waters in riparian areas and floodplains are physically, chemically, and biologically integrated with rivers and other jurisdictional water via functions that can benefit from, but are not dependent upon, near-permanent, continuous surface water connections established by outflows from jurisdictional waters. Wetlands improve water quality of nearby jurisdictional waters by transformation and/or sequestration of pollutants that can degrade water integrity, intercept sediment, and store local ground water for late-season baseflow in rivers. They also provide breeding and nursery habitat for fish, amphibians, and aquatic insects that are integral components of riverine, lacustrine, and estuarine food webs. These facts are all supported by the science synthesized in the Science Report.

Long established aquatic science considers streams and rivers to have four dimensions – longitudinal connections between upstream and downstream reaches, vertical connections between the surface and subsurface, lateral connections between the river and its floodplain, and temporal connections that occur over time. Ward 1989. Lateral connections between lakes or river channels to floodplains, including wetlands and open waters, can occur through seasonal or episodic expansion and contraction of river networks or through outflows from wetlands and other surface waters to lakes and streams. These lateral connections—and the seasonal or longer-term absence of surface connections—provide numerous functions that contribute to the chemical, physical, and biological integrity of downstream waters. For example, these wetlands can attenuate stormflow, increase baseflow, be a source of carbon and organic matter, and a sink for sediment, nitrate, and other constituents that degrade water quality. Science Report.

As discussed in the Science Report:

> Riparian/floodplain wetlands can be hydrologically connected to streams and rivers through unidirectional flows (*i.e.*, from wetlands to rivers and streams, but not vice versa) of surface water and ground water from upgradient areas (*e.g.*, hillslopes and nearby uplands). In addition, riparian/floodplain wetlands have bidirectional connections to streams and rivers (*i.e.*, from wetlands to streams and rivers and vice versa) through lateral movement of surface and ground water between the channel and riparian/floodplain areas. Connections between riparian/floodplain wetlands and streams or rivers occur over a gradient of connectivity, for example, they can be permanent, can occur frequently (*e.g.*, if the wetland is located within the mean high-water mark), or can occur infrequently (*e.g.*, if the wetland occurs near the edge of the floodplain; Sections 1.2.2 and 2.4.2). Even riparian/floodplain wetlands that rarely flood can have important, long-lasting effects on streams and rivers. Riparian/floodplain wetlands can reduce flood peaks by storing floodwaters, store large amounts of sediment and nutrients from upland areas, influence stream geomorphology by providing woody debris and sediment, and regulate stream temperature. Riparian/floodplain wetlands also are sources of food for stream and river invertebrates and serve as rearing habitat for fish."

Science Report at 4-1. Further, the Report states:

> Wetlands in non-floodplain landscape settings lack bidirectional hydrologic connections with channels (*i.e.*, water flows from the wetland to the channel but not from the channel to the wetland). These settings, however, have the potential for unidirectional hydrologic flows from wetlands to the river network through surface water or ground water. Non-floodplain wetlands can attenuate floods through depressional storage and can recharge ground water and thereby contribute to baseflow. These wetlands can affect nutrient delivery and improve water quality by

> functioning as sources (*e.g.*, of dissolved organic carbon) and as sinks for nutrients (*e.g.*, nitrogen), metals, and pesticides. Non-floodplain wetlands also can provide habitat or serve as sources of colonists for biological communities in downstream waters, through movement of amphibians, reptiles, birds, and mammals. The extent to which non-floodplain wetlands perform these functions depends on their hydrologic and biological connectivity with downstream waters. Non-floodplain wetlands also occur on a hydrologic gradient, from wetlands having permanent connections with perennial channels, to geographically isolated wetlands having groundwater or occasional surface-water connections, to highly isolated wetlands having minimal hydrologic connection to the river network (but which could include surface and subsurface connections to other wetlands; Section 4.4.2 [of the Science Report]). Non-floodplain wetlands that are connected to the river network through a channel (*i.e.*, wetlands that serve as stream origins) will have an effect on downstream waters, regardless of whether the outflow is permanent, intermittent, or ephemeral. For non-floodplain wetlands that do not connect to the river network through a stream channel (*i.e.*, geographically isolated wetlands and wetlands that spill into losing streams that are completely disconnected from the river network), the type and degree of connectivity with downstream waters will vary with position in the watershed and over time.

Id. at 4-1 to 4-2. The limitation in the 2020 NWPR results in wetlands and open waters that affect that chemical, physical, and biology integrity of traditional navigable waters, the territorial seas, and interstate waters being categorically excluded from jurisdiction.

Restricting jurisdiction to those wetlands with only one-way flow from jurisdictional waters to other types of waters is inconsistent with long-standing practice. For example, the *Rapanos* Guidance (p. 5) clearly states that wetlands can be adjacent if "there is an unbroken surface or shallow subsurface connection to jurisdictional waters." This criterion for a surface connection in the guidance accounts for other types of hydrologic connections than does the 2020 NWPR. In addition, the Guidance also states that wetlands are adjacent if "their proximity to a jurisdictional water is reasonably close, supporting the science-based inference that such wetlands have an ecological interconnection with jurisdictional waters." *Rapanos Guidance* at 5-6. Such proximity does not require inundation by flooding or other types of surface connections from the wetland to the jurisdictional water. Under the 2020 NWPR, seasonal swales (or "vernal swales") as opposed to vernal wetland pools were found to be jurisdictional as "adjacent wetlands." Vernal wetland pools that outflow to stream networks that would be jurisdictional under the pre-2015 practice as adjacent wetlands were found to not meet the definition of "adjacent wetlands" under the 2020 NWPR and thus were found to be non-jurisdictional. Swales are important features of vernal pool wetland complexes, and were found to be jurisdictional as adjacent wetlands under pre-2015 practice, as well as the vernal wetland pools. They are hydrologically connected to the pools and often support similar plant communities as vernal pools, but typically do not pond water long enough to support large ESA-listed branchiopod or amphibian species. For the same reason, they are also very dynamic systems and may not reliably delineate as three-parameter wetlands in any given year. Mitigation bankers are required to include interconnecting swales in vernal pool restoration plans, but the swales are often utilitarian (*e.g.*, constructed to help maintain hydrology at the stie) and bankers do not request credit for them since they are inherently risky and not a highly-desired credit type. So, while vernal swales are important, it is ironic and arbitrary that they are now considered the most important wetlands in vernal pool complexes under 2020 NWPR, whereas the vernal wetland pools, which provide even more functions affecting traditional navigable waters, the territorial seas, or interstate waters, are considered non-jurisdictional under that rule.

2. *White Paper*

As part of the administrative record for the 2020 NWPR, the agencies added to the docket a white paper entitled "Limitations of the National Hydrography Dataset at High Resolution and the National Wetlands Inventory and their use for Determining the Scope of Waters Subject to Clean Water Act Jurisdiction." EPA and Army 2020b, hereafter "White Paper." The agencies used the White Paper in part to support their arguments at the time that the USGS National Hydrography Dataset (NHD) and the U.S. FWS National Wetlands Inventory (NWI) were inappropriate to use on a national level to estimate the 2020 NWPR's potential effect on the extent of waters that would no longer be jurisdictional under the rule, particularly as standalone datasets. While the White Paper was factual in stating that the datasets were not designed as regulatory datasets and do not explicitly depict the full geospatial scope of Clean Water Act jurisdiction, based on further analysis and interagency review the agencies have determined that the datasets can be used in national assessments of the potential effects of a revised definition of "waters of the United States," as appropriately caveated. The agencies also find that the White Paper presented flawed arguments, including a disproportionate focus on limitations of the datasets, but failed to adequately consider the positive value of the datasets and the breadth of the available literature surrounding both datasets.

a. Background

The NHD and the NWI are the most comprehensive and detailed hydrography and wetlands datasets for the nation and are the most accurate national datasets at the spatial scale that is relevant to Clean Water Act decision-making. Despite being the most comprehensive available datasets of their kind, however, neither the NHD or NWI were designed to be regulatory datasets, both have certain known limitations, and neither can be used as a standalone tool to determine the full scope of Clean Water Act jurisdiction. Additionally, the definitions that the datasets use may differ from regulatory definitions under the Clean Water Act (*e.g.*, the NWI's Cowardin definition of "wetlands" is broader than the regulatory definition). As Federal Geographic Data Committee (FGDC) National Geospatial Data Assets (NGDAs) that support a broad range of users and applications, it is important that these datasets maintain this non-regulatory focus. However, EPA, the Army, and other interagency partners view these datasets as able to form the foundation of a decision support system that overlays regulatory-related information (*e.g.*, location of traditional navigable waters, modeled flow permanence and hydrologic connectivity, and approved jurisdictional determinations).

As for any rulemaking, accurately estimating the potential effects of a proposed or final action can be challenging, and a rule defining the scope of Clean Water Act jurisdiction is no exception. In a rulemaking, in the absence of precise data for all cases, the agencies typically use the best available data to estimate the direction and magnitude of potential effects of a rule. For purposes of assessing the effects of revising the definition of "waters of the United States," the agencies in their economic analysis have often relied on data from the Corps' ORM database regarding where jurisdictional determinations and Clean Water Act section 404 permits have been issued. *See* 2015 Clean Water Rule EA; 2020 NWPR EA; Economic Analysis for the Final Rule. Because the 2020 NWPR as proposed was assumed to reduce the scope of jurisdictional waters compared to the legal status quo, the agencies initially attempted to also utilize NHD and NWI to estimate the potential effects of that proposed rule. Proposed 2020 NWPR RPA;

2020 NWPR RPA. However, at that time the agencies determined that technical limitations of the datasets presented significant challenges for the purpose of determining potential effects of the proposed and final 2020 NWPR. *Id.*

b. The White Paper Presented Flawed Arguments

The limitations of the NHD and NWI noted in the White Paper can be placed into two basic categories. The first category would include limitations due to the spatial resolution. For example, streams of small length (*e.g.*, many headwater streams) are absent from high-resolution NHD maps drawn at 1:24,000 scale. Positional accuracy is also a function of the spatial resolution of the data. The White Paper, however, contains a general lack of conceptual understanding of spatial resolution and map scale and incorrectly lists numerous examples of errors or "inaccuracies" that are in fact differences due to spatial resolution and appropriate use of spatial data sources. A map is not inaccurate if it does not include information that is more detailed than the map scale is meant to depict. The exclusion of features is purposeful. The reason for excluding features is to prevent overcrowding of the map so features at the map's scale can be clearly depicted. Again, based on this fact the number and length of streams, for example, are not underrepresented for the given map scale. In addition, it is impractical to delineate in fine detail the bends in a river for a 1:24,000 scale map. These limitations should not be characterized as inaccuracies but instead are a function of the scale at which they are drawn. The way this is written in the White Paper implies that the issue is with the dataset, when the real issue is with using the dataset for a more detailed purpose than supported by the map scale. Thus, the section on limitations is incorrectly framed and should instead have been a discussion on appropriate spatial resolutions for estimating stream and wetland location and extent in jurisdictional determinations.

The second category of limitations identified in the White Paper includes data accuracy, including data entry errors. Data entry errors include incorrect or missing attribute information such as a waterbody name, feature type, flow direction, or flow classification. The USGS manages a robust data stewardship program that empowers state and federal agencies to correct mistakes within the NHD. Similarly, the NWI data are regularly updated and maintained.

Because the White Paper fails to describe application requirements and state key definitions clearly or quantitatively, it is impossible to thoroughly assess the validity of position statements contained therein. For example, the definition of "reliable" data is not properly defined, and this presents challenges when addressing the validity of the positions taken in the paper. The expression and use of "error" and "accuracy" are used widely and improperly throughout the White Paper. A definition of these terms would be necessary to determine whether a dataset meets the degree of accuracy required for a specific application of that dataset. The comparisons made in the White Paper between the NHD and NWI and validated field data do not follow established scientific protocols for determining level of "error" or "accuracy" of remotely sensed datasets. *See*, *e.g.*, Congalton and Green 1990. A fundamental principle of accuracy assessment is that the reference (field) dataset must measure the same thing as the dataset being assessed (validated) and do so with a higher degree of certainty. *Id.* In the studies cited in the White Paper, a different classification system is being applied to the reference dataset and the dataset being assessed (*i.e.*, NHD or NWI). For example, the White Paper cites to Colson *et al*. (2008) as supporting that there are horizontal positional inaccuracies in the NHD dataset, but the authors used a different metric (three meters) than the metric used by the USGS (12.2 meters) and thus it is not appropriate to cite this study in reporting inaccuracies. In addition, another analysis the White Paper cites compared NWI data from the early 1980s to field data from 2003-2010 (Wu *et al*. 2014a); the study did not assess NWI accuracy and thus the White Paper erred in including it in the section titled "NWI Has Certain Errors." Wu *et al*. (2014a, p. 27) specifically states, "Due to differences in definitions and techniques, there will be discrepancies in the determination of the wetland status of sampling sites when using the NWI and [Corps] methods. This study *did not attempt to assess the accuracy of either method* but to conduct a differential assessment of the results obtained when using these two methods" (emphasize added). Wu *et al.* (2014a, p. 28) also provides a more balanced perspective than the White Paper, acknowledging, "In addition, human errors from both map producers and users might also affect accuracy of the NWI map data. However, at least some of the factors above can also affect the accuracy of [Corps] field interpretations." Similarly, Matthews *et al*. (2016) compared areas using two different wetland definitions and therefore should not be used to determine NWI "error" or "accuracy." In addition, while errors are highlighted throughout the White Paper, there is no mention of what level of error (either of omission/commission or longitudinal accuracy) is acceptable to the agencies for estimating potential effects of rulemaking. Some degree of measurement error will occur with any dataset, independent of type (*e.g.*, aerial photography, satellite imagery, field observations) and resolution, but that does not make such data not valuable for informing regulatory decisions. Importantly, the White Paper also fails to account for natural variability in wetland extent and stream hydrologic flow over time when describing sources of error. Hafen *et al*. 2020.

The White Paper also argued that since wetland definitions differ between the agencies and the NWI, NWI data should not be considered. However, those differences can largely be addressed by excluding NWI classification codes that by definition would not meet the regulatory definition of wetlands, such as codes for unvegetated NWI wetland types. This capability is not addressed in the White Paper, even though the agencies used it to exclude non-vegetated wetland types in the case study analyses for the 2020 NWPR EA.

Comparison studies between the NWI wetlands and wetlands that meet the regulatory definition often fail to exclude such NWI wetland types in their assessments, including most of those cited as supporting literature in the White Paper. Some of the references cited in the White Paper as supporting its conclusions for both the NHD and NWI were between 12 and 20 years old at the time of the White Paper's release. The NHD and NWI are continuously updated datasets, so the currency of the references cited is important. The references did not appear to be reviewed to ensure they are still pertinent to the points being made, or that current datasets were used. For example, one of the references cited information from an archived version of a webpage from the NHD website (USGS 2014) that is out of date and should not have been included in the White Paper.

c. The White Paper Contained Technical Errors

The White Paper also contains technical errors in the description of the NHD and NWI products. For example, it misrepresents characterization of NWI mapping standards (*e.g.*, the minimum threshold for wetland inclusion in the NWI is cited as being 0.05 acres, but that is not a national standard). The resolution information presented in the White Paper are only accurate for modern NWI data and not contextually relevant to legacy data, as legacy data are evaluated in the paper. Furthermore, the NWI section of the White Paper contains citations that do not address the NWI dataset (*e.g.*, Downing *et al*.

2007); were "updated" data that were not included in the NWI database (*e.g.*, Matthews *et al.* 2016[32]); may be taken out of context; or are no longer current (*e.g.*, NWI disclaimer and biological wetlands definition within NWI classification standard). For example, the White Paper cites a "Special Note" found on NWI paper maps (Tiner 1997a), but the NWI no longer produces paper maps. The current relevant disclaimer on the NWI's Wetlands Mapper is: "The wetland information displayed at this site show wetland type and extent using a biological definition of wetlands. There is no attempt to define the limits of proprietary jurisdiction of any Federal, state, or local government, or to establish the geographical scope of the regulatory programs of government agencies." U.S FWS 2021.

d. The White Paper Contained Broad Generalizations and Selectively Used Citations

The White Paper also contains broad generalizations that are drawn from a singular or small number of examples that do not represent an issue fully and therefore cannot be used to prove a larger point. This type of overgeneralization is repeated throughout the paper. For example, the White Paper has a strong focus on the smallest waters that are often at or below the level of detection for the various methods of remote sensing or imagery used to construct the national maps. While it is often such features where questions of jurisdiction arise, this focus is not clearly stated, and the White Paper improperly implies that the same issues for mapping small waters are pervasive for all waters, including large rivers and wetlands. The NHD and NWI, for example, are more accurate in mapping and classifying hydrologic permanence of larger streams and wetlands but this fact is not discussed in the paper. Yamazaki *et al*. (2015), for example, looked at the relationship between water body size and the relative error (difference) in delineation by the NHD and G3WBM (an independent map derived from Landsat imagery). The density of points around high levels of disagreement is clearly greater for smaller waterbodies (streams and others) than for larger waterbodies. *Id.* at 348 (Figure 10(c)). Wu *et al.* (2019) compared the NHD to a digital elevation model (DEM) derived network for an entire watershed (not just headwater streams). They report high agreement (~99%) at this scale between the NHD at high resolution and DEM-derived networks for the Rogue River basin in Oregon. The White Paper does not provide information on to what degree the NHD or NWI under- or overrepresents the extent of larger-order streams and rivers, reservoirs, lakes, and coastal waters. As presented, the White Paper gives the impression that the datasets poorly represent water bodies regardless of their size and geographic location but does not provide support for such a conclusion regarding all waterbodies. For example, the White Paper cites one paper in one lowland watershed that has been heavily ditched for agriculture, making it difficult to map headwater stream networks in that geographic area (Lang *et al*. 2012), but the NHD contains over nine million stream segments nationwide, and more evidence from studies in a large number of geographically and hydrologically diverse watersheds would be needed to support the White Paper's broad generalizations. Furthermore, the agencies are unaware of any studies that have evaluated the accuracy of the entirety of the NHD in terms of flow permanence class.

The White Paper does not consider the breadth of literature available and only touches on a few relevant literature sources. The agencies have ascertained that the White Paper did not accurately represent the literature cited to support presumed errors or inaccuracies in the datasets, as discussed

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[32] The data in the study that were considered to be "updated NWI" were deemed by the NWI Program to not meet NWI standards and were therefore never included in the NWI database.

above. For example, results of the literature described in the section "NWI Has Certain Errors" actually validate the accuracy of that dataset by exhibiting good correlation between NWI data and field observations. *See* Stolt and Baker 1995; Kudray and Gale 2000; Dvorett *et al.* 2012; Sharpe *et al.* 2016. The White Paper points out perceived "errors" of the NWI from one study (Sharpe *et al.* 2016) while seemingly ignoring the study's relatively high correlations between NWI and the reference dataset. Sharpe *et al.* (2016, p. 547) in fact states, "This research *highlights the relative strength of NWI mapping* for landscape level wetland analysis, and the need to support remote sensing data by allocating field resources for accuracy assessment in specific areas based on management goals" (emphasis added).

The White Paper also selectively uses portions of cited works to support its conclusions, while ignoring other portions of the same studies that conflict with those conclusions. For example, in citing Simley (2011), the White Paper notes that in the South Platte River, some mapped stream segments in the high resolution NHD (1:24,000-scale) do not match up well with contemporary orthophotographs (1:4,000-scale), but leaves out quotations from the same citation noting good correlation at finer scale, including, "However, at 1:18,000-scale the NHD lines up quite well to the imagery," "At 1:18,000-scale the mismatch is not particularly evident," "at 1:18,000-scale the river lines up very well," etc. In addition, this study was for sections of the river with many meanders and may not be reflective of the accuracies of the NHD for the South Platte network as a whole. It is also possible that the original maps met the mapping standard, but the meanders have naturally migrated since the original map was compiled that the NHD data would not currently pass the criterion for current location. When not artificially constrained, most streams and rivers shift their position in the landscape over time. Leopold *et al.* 1964.

Some of the critiques of the NWI in the White Paper regarding use of the data for regulatory purposes (Tiner 1997a; Tiner 1997b; Kusler 2006) are statements about using the NWI data alone to determine the jurisdictional status of individual wetlands as required by law. Subsequently at the time of the rule's proposal and then finalization, the agencies were criticized by a wide variety of stakeholders for not utilizing the NHD and the NWI for estimating the extent of waters that would be no longer jurisdictional under the proposed and final rule. *See* Association of State Wetland Managers 2019; Fesenmyer *et al.* 2021. The citations in the White Paper are not directed at the broader use of NWI data along with other datasets to support the jurisdictional decision-making process. For example, the citations do not address the use of NWI data to assess policy change impacts on the overall direction and magnitude of jurisdiction under the Clean Water Act.

The review in the White Paper would have been made more complete and useful by recognizing that quantifying the uncertainty, error, and limitations of any dataset are part of the research process, and by citing appropriate applications of NHD and NWI datasets, including a discussion of cases where they have been or can be used successfully to inform questions about Clean Water Act jurisdiction (*e.g.*, as supporting data for state and federal agencies or the regulated community). For example, one of the studies cited in the White Paper noted that 90% of the sampling locations within wetland boundaries identified on NWI maps were categorized as wetlands that also met the agencies' wetland delineation criteria (Wu *et al.* 2014a), which demonstrates very high correlation between NWI mapped wetlands and wetlands that meet the agencies' regulatory definition. The White Paper could have also been more balanced by a discussion of the attributes of the databases that could be used in moving toward a more accurate dataset to inform regulatory decisions. For example, the White Paper could have included studies that apply recent technology and approaches to improve the NHD and reduce some of its past or current limitations. *See*, *e.g.*, Poppenga *et al*. 2013; Stanislawski *et al*. 2015; Stanislawski *et al*. 2016; Stanislawski *et al*. 2017; Stanislawski *et al*. 2018; McManamay and DeRolph 2019. The White Paper mentions that LIDAR-derived stream networks can have errors of commission but does not similarly note that numerous studies have made a concerted effort to improve methods for deriving fine-scale hydrologic features from LIDAR-derived digital elevation models. *See* Goulden *et al*. 2014 and references therein; Shavers and Stanislawski 2020 and references therein. Mapping of ephemeral streams, and small streams generally, for example, is a clear research need, including from a regulatory perspective. More recent studies, like Fesenmyer *et al*. (2021), have taken approaches to better map ephemeral streams.

e. Conclusions

Decision-making is based on weighing advantages and disadvantages of the underlying datasets used in analyses. The White Paper heavily weighted some disadvantages of the NHD and NWI and therefore created an imbalanced perspective of their value to Clean Water Act decision-making as the best available national datasets for stream and wetland systems. As OMB-A-16 National Geospatial Data Assets and the hydrography and wetlands layers of the Federal Geographic Data Committee National Spatial Data Infrastructure, the NHD and NWI are the authoritative, most up-to-date, and comprehensive mapping of hydrography and wetlands for the nation. Additionally, the USGS has agreements with 41 states plus Washington DC to co-manage the NHD, enabling investment in the dataset form the local to national level. Citations and quotes are also available in the literature to support the advantages of the datasets, including high levels of dataset accuracy, but these citations (*see, e.g.*, Nichols 1994) and quotations are not included in the White Paper (*see, e.g.*, Stolt and Baker 1995; Kudray and Gale 2000; Simley 2011; Dvorett *et al*. 2012; Sharpe *et al*. 2016). In addition, information presented in the White Paper was generally limited geographic examples from older data rather than of the current versions of the national datasets evaluated as a whole. Because hydrologic conditions vary significantly across the country, it may not be accurate to take an analysis of the datasets in one area and assume that the results apply to the entire dataset and nation. Also, several references are out of date. The NHD framework was intended to improve accuracy over time while maintaining hydrologic connectivity and relationships within the network. For that reason, the NHD and NWI are continually updated by numerous partners engaged in their maintenance and improvement. Therefore, references that evaluate older versions of NHD (including topographic maps) and NWI are not based on the current datasets and thus should be interpreted with caution.

While the agencies agree with the White Paper's conclusion that the NHD are NWI are generally not sufficient as a sole basis for making jurisdiction determinations under the Clean Water Act and do not depict the full scope of waters that are or are not jurisdictional under the Act, the agencies now believe that it is scientifically defensible to use the datasets in national analyses to quantify the potential impact of their rulemaking efforts, so long as uncertainty and other appropriate caveats are also assessed and conveyed. In fact, the agencies used both the NHD and the NWI, in combination with programmatic data, in the 2020 NWPR EA's case study analyses. 2020 NWPR EA. In fact, one of the references that the White Paper cites, supports the use of the datasets for national analyses, stating, "hydrographical datasets, such as the NHD, are highly valuable at national, regional, and even local scales." Lang *et al*. 2012 at 462. Furthermore, as the White Paper notes, the agencies continue to agree that "NHD and NWI may be used in accordance with applicable law along with other information as part of the agencies' Clean Water Act jurisdictional determination process." White Paper at 1. In addition, the NHD serves as the underlying framework for most water data applications throughout the country, including several Clean Water Act applications within EPA. For example, EPA uses the NHD for other EPA regulatory requirements such as tracking impaired waters under Clean Water Act section 303(d), reporting Total Maximum Daily Loads (TMDLs), tracking state-submitted drinking water quality data (SDWIS), and calculating programmatic measures, among others. The NHD and NWI were not designed to be stand-alone decision-making tools, but rather were designed to work in concert with other available data to support nationwide analyses for informing decisions. For example, both NHD and NWI are often used in conjunction with additional sources of information to support jurisdictional determinations. In addition, under section 303(d) of the Clean Water Act, states do not exclusively use the NHD to determine whether a water is impaired. Rather, they use multiple lines of evidence to make that determination. However, once the determination is made, states do use the NHD to document the spatial extent and location of those impairments. All datasets have limitations, including the NHD and NWI, but there is tremendous value in these datasets—including their use to help assess the potential impacts of a rule defining "waters of the United States."

EPA and the Army have been working with other federal agencies on improving aquatic resource mapping and modeling, including through the Advanced Water Mapping and Analytics interagency initiative with the Department of Interior (DOI) to better align EPA and the Army's regulatory needs with DOI's existing processes and national mapping capabilities. EPA, USGS, and FWS have a long history of working together to map the nation's aquatic resources. The agencies will continue to collaborate with DOI and other federal agencies to enhance the NHD, NWI, and other products to better map the nation's water resources while enhancing the utility of such geospatial products for implementation of Clean Water Act programs.

iv. Implementation Challenges

The agencies experience implementing the 2020 NWPR for over a year prior to its vacatur made clear that foundational concepts underlying much of the 2020 NWPR are confusing and difficult to implement in the way the 2020 NWPR requires. A key example is that no available tools, and certainly not the tools the 2020 NWPR preamble recommends, reliably demonstrate whether a surface water connection exists in a "typical year" in many important contexts. Surface water connection in a typical year is a necessary element of most categories of jurisdictional waters under the 2020 NWPR and demonstrating it in the way required by the rule was often difficult. While any rule that draws lines between jurisdictional waters and non-jurisdictional waters will involve some implementation challenges, the agencies have found the challenges imposed by the 2020 NWPR to be impracticable in important respects. Based on the agencies' experience, the 2020 NWPR did not achieve its stated purpose to "provide[] clarity and predictability for Federal agencies, States, Tribes, the regulated community, and the public." *See* 85 FR 22252 (April 21, 2020). The challenges that the 2020 NWPR imposed to establish jurisdiction for features that it appears to define as jurisdictional, and that significantly affect the integrity of traditional navigable waters, the territorial seas, and interstate waters, further undermine the 2020 NWPR's viability as an alternative to the final rule.

1. *Typical Year Metric*

The “typical year” is a concept fundamental to many of the 2020 NWPR’s definitions. 85 FR 22273. Under that rule, tributaries and lakes, ponds, and impoundments of jurisdictional waters are only jurisdictional if they have certain surface water connections with a traditional navigable water or the territorial seas at least once in a typical year. 33 CFR 328.3(c)(6), (12). Two categories of wetlands only meet the adjacency test for jurisdiction if they have a surface water connection with other jurisdictional waters at least once in a typical year. 33 CFR 328.3(c)(1). As a scientific matter, the concept of “typical year conditions,” including precipitation normalcy, may be relevant to ensuring that certain surface water connections in natural streams are not being observed under conditions that are unusually wet or dry. In terms of implementation, the concept of precipitation normalcy as valid in certain contexts, such as to inform determinations as to the presence of a wetland. However, in many important contexts, available tools, including the tools the 2020 NWPR preamble recommended, cannot reliably demonstrate the presence of surface water connections in a typical year, which are a necessary element of most categories of jurisdictional waters under the 2020 NWPR. For example, a recent study by the Corps found that precipitation normalcy (as calculated based on the methodology described in the preamble to the 2020 NWPR) was neither a reliable predictor of streamflow normalcy, nor was it a precise predictor of streamflow percentiles, in an analysis of watersheds across the United States. Sparrow *et al*. 2022. These challenges undermine the 2020 NWPR’s claim that it enhances the “predictability and consistency of Clean Water Act programs.” *See* 85 FR 22250 (April 21, 2020).

One of the significant implementation challenges of the typical year metric is that it can be difficult and sometimes impossible to identify the presence of a surface water connection in a typical year. Such connections are often not apparent from visual field observation alone. For example, on the day of a visit to an intermittent stream that flows only several months or several weeks a year, it is very unlikely that an observer would see surface water flows connecting to a downstream jurisdictional water, particularly based on the time of year during which that site visit takes place. Similarly, though many ponds or wetlands may be frequently inundated by flooding from another water, those in arid areas may be inundated only a few times every year, and sometimes the inundation occurs on a single day or within a matter of hours. While these waters satisfy the 2020 NWPR’s jurisdictional test, agency staff would probably not be able to determine that they do, given how unlikely they would be to observe these infrequent connections. The difficulty of finding the direct hydrologic connections required by the typical year concept during a field visit is exacerbated by the fact that the 2020 NWPR discouraged reliance on field indicators. *See, e.g.*, *id*. at 22292 (“The agencies . . . conclude that physical indicators of flow, absent verification of the actual occurrence of flow, may not accurately represent the flow classifications required for tributaries under this rule.”).

Given the insufficiency of visual field observation to assess the presence of a surface water connection as specified in the 2020 NWPR, under that rule agency staff often needed to expend substantial time and resources to try to obtain ancillary data to determine flow conditions at a particular site in a typical year. Hydrologic modeling tools and advanced statistical analyses could be employed where sufficient flow data are available, but often data needed to conduct such an analysis is limited or lacking altogether, especially for smaller streams. Few streams across the country have hydrologic gages that continuously measure flow, as most such gages are located larger rivers with perennial flow. Flow and discharge data are rarely available for the small and/or non-perennial tributaries that collectively constitute the largest number of stream miles in the United States; in addition, the number of long-term stream gages have declined over time and are geographically biased. Poff *et al.* 2006; Ruhi *et al.* 2018; Krabbenhoft *et al.* 2022. Moreover, "typical year conditions" are often irrelevant to the extent of flow in human-altered streams, including effluent-dependent streams. The 2020 NWPR did not explain why human-altered hydrology should be subject to the same typical year requirement as natural streams.

For the same reasons that agency staff are unlikely to witness the specific surface water connections required under the 2020 NWPR during a site visit in dry regions or during the dry season, they are also unlikely to capture evidence of a surface water connection between a stream and a downstream traditional navigable water or the territorial seas using available aerial photographs taken during typical year conditions. Available aerial photographs are often taken just once per year or once every other year, and staff have no way of ensuring that they were taken during a typical year. High-resolution satellite imagery can serve as a reliable source to demonstrate specific hydrologic connections and potentially provide additional coverage. But the availability and usability of such imagery vary across the country, depending on access, update intervals, cloud cover, and land cover (*i.e.*, vegetation or trees that obscure aerial views of stream channels), so that such tools may be unlikely to demonstrate that specific surface water connections are occuring in a typical year. High resolution satellite imagery also is not an "off the shelf" product and requires pre-processing and classification (*i.e.*, advanced tools) to identify features of interest or the presence of water. *See, e.g.*, Mueller *et al*. 2016. Moreover, as the 2020 NWPR acknowledged, "characteristics of tributaries may not be visible in aerial photographs" taken during periods of "high shrub or tree cover" (85 FR 22299 (April 21, 2020)), further reducing the chances that a photograph could capture surface water connections.[33] Commenters on the proposed rule stated that Tribes and States lacked sufficient data, aerial photography, and access to other tools required to support the use of the typical year test in many locations. *See, e.g.*, National Association of Wetland Managers 2022. They expressed concern that under-resourced communities suffer a particular lack of data necessary to support this test. *Id.* New satellites that are launching soon are expected to surmount some of these issues in the future (*see, e.g.*, NASA; NASA 2019), but as this information is not yet available, regulators could not use it to inform jurisdictional decisions based on the requirements in the 2020 NWPR. Remote tools, such as aerial or satellite imagery, are often useful in implementing any definition of "waters of the United States," but the 2020 NWPR's typical year criteria made use of these resources particularly challenging.

The same difficulties created challenges in detecting surface hydrologic connections that occurred in a typical year to meet the 2020 NWPR's definition of "adjacent wetlands" or "lakes and ponds, and impoundments of jurisdictional waters." The 2020 NWPR's standard of inundation by flooding in a typical year was not tied to any commonly calculated flood interval, such as flood recurrence intervals[34]

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[33] Tree canopy cover varies across the country. The USDA Forest Service (USFS) produces percent tree canopy cover data layers for the National Land Cover Database (NLCD). USFS 2020. The most recent Tree Cover Canopy product shows the variation in tree canopy cover across the United States, with New Hampshire, West Virginia, and Maine having the highest percentage of cover in the conterminous United States, and North Dakota, Nebraska, and South Dakota have the lowest percentage. *Id.* About 24% of the land cover in the conterminous United States is forested as mapped in the 2019 NLCD (MRLC), while the USFS has estimated that about one third of the country is forested (USFS 2017).

[34] For example, the Federal Emergency Management Agency (FEMA) develops flood insurance rate maps based on the probability of a flood event occurring (*e.g.*, 100-year floods have a 1% probability of occurring in a given year or

(*see* USGS c; FEMA 1995), and the agencies are not aware of a tool capable of collecting the type of inundation data the 2020 NWPR required. Demonstrating that a wetland, lake, pond, or impoundment is inundated by flooding once in a typical year would require a field visit or high-resolution aerial photograph or satellite image coinciding with the exact time that the flooding occurs from a tributary to a wetland, lake, pond, or impoundment, as well as being able to demonstrate that this flooding occurred in a typical year. Determining that inundation by flooding occurs in a typical year was therefore extremely difficult, and sometimes impossible. Demonstrating that an artificial feature allows for a direct hydrologic surface connection between a wetland and a tributary in a typical year poses similar obstacles, requiring either auspiciously timed field visits, aerial photography, high-resolution satellite imagery, or data that the agencies may not be able to access, such as construction plans or operational records for an artificial levee.

The 2020 NWPR suggested the agencies "will generally use" precipitation data from NOAA to help determine the presence of a surface water connection in a typical year (*see* 85 FR 22274 (April 21, 2020), but the methodology described in the 2020 NWPR preamble for determining precipitation in a typical year made it difficult to use these data to inform jurisdiction. NOAA precipitation totals over the three months prior to a site observation are compared to precipitation totals observed over the preceding 30 years to determine if conditions were wetter than normal, drier than normal, or normal ("typical"). Using the methodology in the 2020 NWPR preamble, only 40% of observations over a rolling 30-year period of record are considered "normal," while 30% of observations are considered to be "wetter than normal" and 30% of observations are considered to be "drier than normal." If surface water flow was observed during normal or dry conditions, the agencies could have higher confidence that the surface water observations represented flow in a "typical year." However, if flow was observed during the 30% of conditions that are "wetter than normal," the surface water observations did not reveal whether flow would occur during a typical year. And if flow was *not* observed, precipitation data from the previous three months did not indicate whether flow might occur in that particular water feature under typical year conditions at a different point in the year. Therefore, if a site visit is conducted when surface water flow is not present, the agencies' suggested approach for evaluating whether a feature meets the typical year test often did not provide meaningful and relevant information for the agencies to make accurate determinations of jurisdiction. Indeed, a commenter on the proposed rule emphasized that Tribes and States have found the "typical year" requirement to require extensive hydrologic modeling and advanced statistical analyses in complex conditions. National Association of Wetland Managers 2022. Under any regulatory regime, the agencies use a weight of evidence approach to determine jurisdiction, but the 2020 NWPR typical year requirement placed onerous and, in many instances, arbitrary constraints on the data that can be used as evidence.

Use of NOAA precipitation data to assess whether surface water flow occurs in a typical year for purposes of the 2020 NWPR presents other implementation challenges. The data rely on reports from weather stations that are sometimes at a different elevation from the site in question, or far away from the site, so that their indications as to whether precipitation at a given site is normal, wetter than normal, or drier than normal can be inaccurate. Furthermore, the typical year concept as applied to the 2020 NWPR

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500 year-floods have a 0.2% probability of occurring in a particular year). FEMA 2020. Flood insurance rate maps are developed by applying models and other information to identify areas that would be inundated by a flood event of a particular probability of recurring. *See, e.g.*, FEMA 1995.

does not account for the increasing number of recurrent heat waves, droughts, storms, and other extreme weather events in many parts of the country. These events can have profound impacts on local and regional hydrology, including streamflow. *See* section II.B.iv.1.c. Although the concept of "typical year" in the 2020 NWPR sought to factor in long-term climatic changes over time to some degree by considering a thirty-year rolling period of data (*see* 33 CFR 328.3(c)(13)), the 2020 NWPR did not allow the agencies flexibility to consider other time intervals when appropriate to reflect effects of a rapidly changing climate, including positive trends in temperature, increasing storm events, and extended droughts. In response to more rapid recent changes in climate, NOAA has developed alternative approaches for estimating climate normals, including seasonal averages computed using shorter, annually updated averaging periods for temperature (10-year seasonal average) and total precipitation (15-year seasonal average). The rigid rolling thirty-year approach to determining typical year in the 2020 NWPR did not allow the agencies to use these updated methods.

The 2020 NWPR noted that the agencies can look to sources of information other than site visits, aerial photographs, and precipitation data to assess whether a feature has surface water flow in a typical year. It identified the Web-based Water-Budget Interactive Modeling Program, Climate Analysis for Wetlands Tables, and the Palmer Drought Severity Index. 85 FR 22275 (April 21, 2020). These methods, which provide information useful in many other contexts, often only look at climate-related conditions generally, have well documented limitations, and often did not specifically answer the jurisdictional questions required by the 2020 NWPR. For example, the Palmer Drought Severity Index is difficult to correlate with specific water resource variables such as runoff and reservoir storage and does not account for delayed runoff from snow and ice. Further, none of these sources of information address whether surface water flow might connect a particular stream to a downstream traditional navigable water or the territorial seas, whether a particular wetland was inundated by or connected to a jurisdictional water as required under the 2020 NWPR, or how uncertainties at different locations and in different months affected the accuracy of condition estimates. While precipitation is an important factor, other information is also relevant to streamflow and surface water connections in a typical year, including the abundance of and contributions of flow from wetlands, upgradient streams, and open waters in the watershed; evapotranspiration rates; water withdrawals including groundwater pumping; and other climatic conditions. *See* section II.B.iii.1.c. Yet collecting this information from a variety of sources and interpreting it can be extremely time- and resource-intensive and may require special expertise, such as in climate science, remote sensing, statistical analysis, geospatial analysis, or other disciplines, that in many cases may not be feasible given available agency staff and resources. While the agencies have substantial experience using a weight of evidence approach to determine jurisdiction, for example as part of the significant nexus analysis, the "typical year" requirement of the 2020 NWPR makes it significantly more difficult to interpret available data and narrows the scope of data that can be used to determine jurisdiction.

Finally, the challenges presented by determining the presence of surface water flow in a typical year are even greater when evaluating a tributary at a distance from the downstream traditional navigable water or the territorial seas. Even streams that flow perennially or intermittently often travel many miles prior to reaching the closest traditional navigable water or the territorial seas, meaning many downstream reaches may need to be assessed. Under the 2020 NWPR, any ephemeral reaches along that pathway that did not carry surface water flow once in a typical year would render all upstream waters non-jurisdictional. 85 FR 22277 (April 21, 2020). The need to assess lengthy tributary systems imposed an extraordinarily high burden of proof on the agencies to evaluate surface water flow in a typical year along the entire flow path from a stream of interest to a downstream traditional navigable water or the territorial seas. The longer the pathway, the more challenging the analysis. As a commenter on the 2020 NWPR's proposal noted, in adopting the test, the 2020 NWPR inserted case-specific analyses for every jurisdictional determination despite the rule's claim that it "provide[s] a predictable framework in which to establish federal jurisdiction." *Id.* at 22273–22274. The uncertainty and implementation challenges generated by the 2020 NWPR's foundational typical year test are yet another basis to replace that rule.

2. Determining Adjacency

The 2020 NWPR provided that wetlands are "adjacent" when they: (1) abut a traditional navigable water or the territorial seas; a tributary; or a lake, pond, or impoundment of a jurisdictional water; (2) are inundated by flooding from one of these waters in a typical year; (3) are physically separated from one of these waters only by a natural berm, bank, dune, or similar natural feature; or (4) are physically separated from one of these waters only by an artificial dike, barrier, or similar artificial structure so long as that structure allows for a direct hydrologic surface connection between the wetlands and the water in a typical year, such as through a culvert, flood or tide gate, pump, or similar artificial feature. *Id.* at 22338; 33 CFR 328.3(c)(1). In practice, agency staff have found several of these criteria for adjacency extremely difficult to implement in certain circumstances, in addition to the difficulties discussed above of assessing whether certain surface hydrologic connections exist in a typical year.

The artificial barrier provision led to arbitrary results. For example, under the fourth way to meet the adjacency definition, a wetland may be jurisdictional if it is separated from a jurisdictional water by an artificial structure, such as a levee, that allows for a direct hydrologic surface connection in a typical year through a culvert. However, the same wetland would not be jurisdictional if there was no levee present, even if there was a direct hydrological surface connection in a typical year through a culvert (assuming the wetland did not meet another criterion for adjacency). The 2020 NWPR therefore established that certain wetlands with a direct hydrologic surface connection to a jurisdictional water are *only* jurisdictional due to the presence of an artificial barrier. This discrepancy bears no relationship to the actual connections between the features at issue and is not supported by science or the agencies' experience.

Moreover, the provision establishing that a wetland is "adjacent" if a jurisdictional water inundates it by flooding in a typical year was extremely difficult to implement. *See* 33 CFR 328.3(c)(1)(ii). Inundation by flooding in a typical year is not a metric that is normally recorded either by implementing agencies or the regulated community. Available models generally focus on flood recurrence intervals, which do not necessarily correspond to the likelihood of inundation by flooding in a given or typical year, and the agencies would typically be unable to demonstrate that these indicators reflect typical year conditions. Indeed, the 2020 NWPR acknowledged that inundation by flooding in a typical year could correspond to a variety of flood recurrence intervals depending on location, climate, season, and other factors. 85 FR 22311. Given the absence of existing records of inundation by flooding, determining whether inundation by flooding has occurred in a typical year is challenging in many circumstances.

Compounding the challenge, the 2020 NWPR provided that wetlands can be jurisdictional if they are inundated by flooding from a jurisdictional water in a typical year—but inundation in the other direction, *from* the wetlands *to* the jurisdictional water, is not grounds for jurisdiction. Not only is there no scientific evidence (*see* section II.B.iv.b) or legal basis (*see United States v. Riverside Bayview Homes Inc.*, 474 U.S. 121, 134 (1985), upholding the Corps' assertion of jurisdiction over "wetlands that are not flooded by adjacent waters [but] may still tend to drain into those waters") for distinguishing between inundation *of* the wetland as opposed to inundation *from* the wetland, but determining whether the limited available photographs, satellite images, or other evidence of inundation reflects flooding in one direction as opposed to another adds to the difficulty in evaluating whether this standard is met. The same challenges apply to determining whether lakes, ponds, or impoundments of jurisdictional waters are inundated by flooding in a typical year, one basis for demonstrating Clean Water Act jurisdiction over these features. 85 FR 22338-39 (April 21, 2020); 33 CFR 328.3(c)(vi). While any rule that draws lines between jurisdictional waters and non-jurisdictional waters will involve some implementation challenges, the agencies have found the challenges imposed by the 2020 NWPR to be exceptionally burdensome and impracticable.

3. Ditches

Among other requirements, the 2020 NWPR provided that a ditch[35] is jurisdictional as a tributary if it was originally built in a tributary or adjacent wetland, as those terms are defined in the 2020 NWPR, and emphasized that the agencies bear the burden of proof to determine that a ditch was originally constructed in a tributary or adjacent wetland. 85 FR 22299 (April 21, 2020); 33 CFR 328.3(a)(2) and (c)(12). In other words, in order to find a ditch jurisdictional, the agencies had to demonstrate that a ditch was (1) originally constructed in a stream (2) that, at the time of construction, had perennial or intermittent flow and (3) a surface water connection to a downstream traditional navigable water or the territorial seas (4) in a "typical year." Alternatively, the agencies had to show that a ditch was (1) originally constructed in a wetland (2) that either abutted or had certain surface hydrologic connections to a jurisdictional water at the time the ditch was constructed (3) in a "typical year," in order to demonstrate that the ditch is jurisdictional. Americans have been building ditches, straightening streams, and draining wetlands for hundreds of years. By contrast, to determine whether a ditch was jurisdictional under the 2020 NWPR, the agencies had to determine if it was originally built in a tributary or adjacent wetland that would have been jurisdictional under the 2020 NWPR, and therefore had to address all of the implementation challenges discussed in the preceding sections involved in determining surface water connections and wetland adjacency in a typical year—but often for ditches built twenty, fifty, one hundred, or even several hundred years ago. To the extent that sparse evidence is available to demonstrate a surface water connection in a typical year for tributaries using tools available today, evidence is even more difficult to find when looking so far back in time. States have approached the agencies seeking assistance in assessing the jurisdictional status of ditches, but the agencies were often unable to provide meaningful help given the burdens imposed by the 2020 NWPR's ditch definition.

The 2020 NWPR also provided that ditches are jurisdictional if they relocate a tributary, as that term was defined in the rule (85 FR 22341; 33 CFR 328.3(a)(2) and (c)(12)), but this standard, too, is often extremely difficult to meet. The 2020 NWPR explains that a relocated tributary is "one in which an *entire portion* of the tributary may be moved to a different location." 85 FR at 22290. In other words, the

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[35] Ditches perform many of the same functions as natural tributaries. For example, like natural tributaries, ditches that are part of the stream network convey water that carries nutrients, pollutants, and other constituents, both good and bad, to downstream traditional navigable waters, the territorial seas, and interstate waters. *See* section III.A.iv.

2020 NWPR appears to require a ditch to divert 100% of the tributary’s flow to meet the “relocate a tributary” test. While prior rules have defined relocated tributaries as jurisdictional, the requirement that the entire portion be relocated is new and has created significant implementation challenges. As a practical matter, when a tributary is relocated it often reroutes just a portion of its flow to the ditch. Assessing whether a ditch relocated 100% of a tributary’s flow, as opposed to 80% or 50% of its flow, is extremely difficult and may not be possible in some circumstances. The scientific literature indicates that features like ditches that convey water continue to connect to and affect downstream waters. *See* section III.A.iv of this Technical Support Document. By establishing a jurisdictional standard that is extremely difficult to meet, the 2020 NWPR effectively removed from the protections of the Clean Water Act large numbers of ditches that function as tributaries and that significantly affect the integrity of downstream traditional navigable waters, the territorial seas, and interstate waters. As is the case with tributaries, lakes and ponds, impoundments, and wetlands, the 2020 NWPR’s impracticable approach to ditches made it extremely difficult to implement. In the agencies’ judgment, any efficiencies the 2020 NWPR may have achieved through categorical exclusions are outweighed by the challenges the agencies encountered in implementing the rule, coupled with its failure to implement the objective of the Clean Water Act by removing protections for waters that are properly within the statute’s scope. These deficiencies of the 2020 NWPR further undermine the viability of the 2020 NWPR as an alternative to the final rule.

4. Results of Regional Survey

EPA’s Office of Wetlands, Oceans, and Watersheds sought information from Regional staff about potential challenges they may have encountered implementing the 2020 NWPR. A seven-question survey that included both multiple choice and open-ended questions was provided to EPA staff in all ten Regional offices. Twenty-six staff persons provided responses to the survey, including representatives from all ten EPA Regions. While the number of respondents per region varied considerably, over 60% of respondents came from EPA Regions lying mostly west of the Mississippi River (*i.e.*, Regions 6-10) (Figure 10). Although an imperfect demarcation boundary between generally more humid/temperate climatic conditions to the East and drier ones to the West, the responses provided by EPA staff west of the Mississippi River differed in some notable ways from those of staff in the eastern parts of the country.

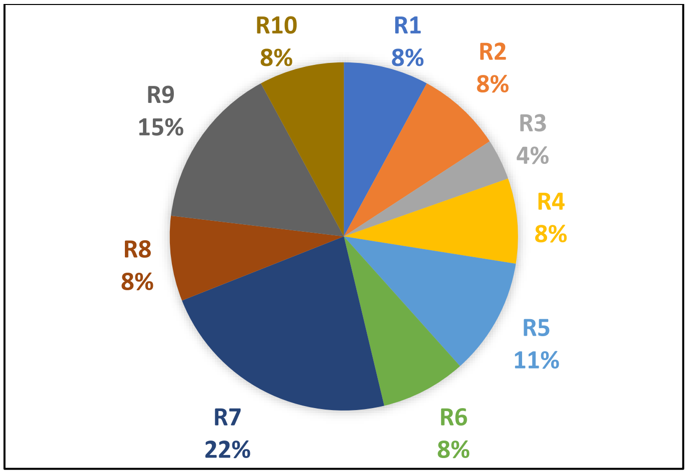

Figure 10: Proportion of questionnaire respondents from each EPA Region.

EPA Regional field staff reported different implementation challenges with the 2020 NWPR, but some challenges were significantly more often cited than others. Respondents were asked to identify the single biggest implementation challenge with the 2020 NWPR, and then they were also asked to identify their next Top 3 biggest challenges. The same four primary issues were cited most often in response to these questions, and each of the four gathered nearly the same number of cumulative responses:

- "Documenting or determining historic conditions," (18% of responses)
- "Documenting flow regime in the dry season/dry season evaluations," (18% of responses)
- "Disproportionate burden of proof for asserting jurisdiction," (18% of responses)
- "Typical year," (17% of responses)

Despite the similarity of major implementation challenges cited cumulatively in response to the aforementioned pair of survey questions, there was greater differentiation among concerns considered by respondents as the single "biggest challenge." Almost one-quarter of respondents (23%) reported that "documenting or determining historic conditions" was the biggest implementation challenge (Figure 11). Interestingly, over two-thirds of the respondents who cited documenting historic conditions as the biggest challenge came from EPA Regions east of the Mississippi River. "Documenting flow regime during the dry season (~ dry season evaluations)" and "Typical year" were each cited as the biggest implementation challenge by 19% of respondents. In contrast to the geographic distribution of responses for historic conditions, 100% of respondents who cited dry season evaluations as the single biggest challenge of the 2020 NWPR came from EPA Regions west of the Mississippi River. "Typical year" was evenly split among EPA Regions lying in the East and West.

The only other implementation challenge cited by at least ten percent of respondents as the biggest challenge was "disproportionate burden of proof to assert jurisdiction" (15%), and three-quarters of respondents citing burden of proof as the biggest 2020 NWPR implementation challenge came from Western EPA Regions. Other aspects of 2020 NWPR for which at least one respondent reported to be the most significant implementation challenge included "ditches and water diversions," distinguishing between bridges and culverts, and "inability to evaluate flows on properties for which agency staff have no authorization to enter."

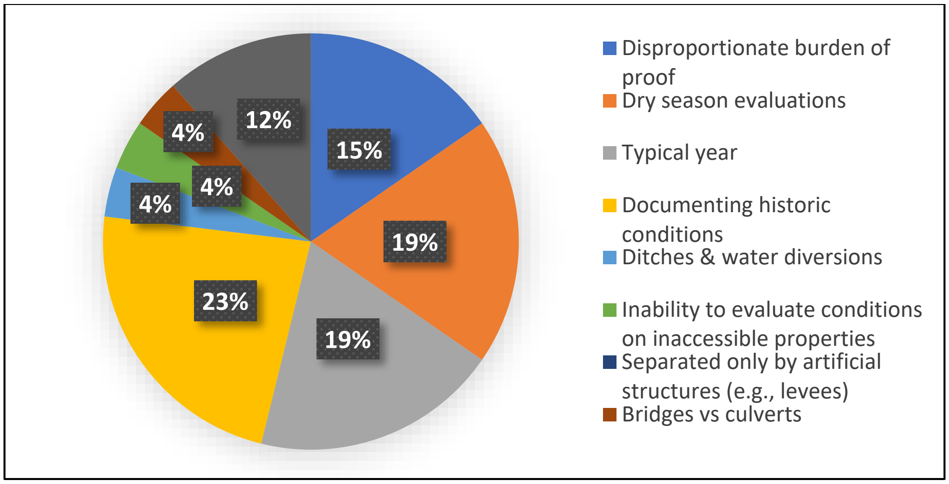

Figure 11: Issues cited by EPA Regional staff as the "biggest implementation challenge" with the 2020 NWPR (n=26 responses)

Specific reasons cited by the survey respondents explaining implementation challenges with the 2020 NPWR included many of the same issues previously described in this section. Respondents reported that a lack of historic aerial photographs or other sources of historic information rendered it difficult or impossible to document or determine historic conditions consistent with the 2020 NWPR's requirements. This affected staff's ability to assess the flow regime of ditches excavated decades ago or whether those ditches drained wetlands that would have been considered "adjacent wetlands" under the 2020 NWPR. Staff observed that even if historic imagery were available, land use, land cover, and climatic conditions prevalent at the time often bore no resemblance to more contemporary conditions.

Challenges under the 2020 NWPR associated with documenting flow regime in the dry season and other dry season evaluations centered on the timing of site visits, as one would expect. Staff noted that site visits often only occur on a single date. When this takes place during a time of year for which intermittent stream flow would not normally even be expected to occur, for example, there is little information available upon which an assessment of flow regime as defined in the 2020 NWPR can be based. Other staff noted that it is nearly impossible to differentiate intermittent flow from ephemeral flow in small streams from aerial photographs; a challenge made even more acute under a dense canopy of vegetation cover.

EPA Regional staff observed that assessing stream flow in a "typical year" had a very high likelihood for errors of omission, whereby a stream might be determined not to flow (and thereby be non-jurisdictional), when in fact it may flow on a different date during even the same typical year. For example, field conditions at the low end of the precipitation range represented by a typical year analysis provide no indication at all of what field conditions would be like at the upper end of the typical year range. Staff noted that the probability of observing a qualifying flow event (*e.g.*, stream flow, surface connection, inundation by flooding, etc.) that occurs only rarely in a "typical year" is very low.

Challenges and demands associated with proving a given feature is a jurisdictional water included a disproportionate burden of time, effort, and resources necessary for locating and researching applicable information. Regional staff noted, for example, that in some cases, on-scene coordinators have to assess the jurisdictional status of waters quickly, often at the request of other agencies on-site of an oil spill incident. Some staff felt that the 2020 NWPR was written with no consideration of Clean Water Act section 311(c) response authorities or time frames. In addition, the regulatory agencies often do not have the time or manpower to devote to collection and assessment of historic information, so they are often compelled to accept whatever information the permit applicant provides them.

Implementation challenges of the 2020 NWPR associated with ditches encompass most other 2020 NWPR implementation challenges (*i.e.*, historic conditions, flow regime, adjacency criteria, typical year, burden of proof, etc.). Ditches excavated decades ago through wetlands have since drained those wetlands, often leaving little record that they were once wetlands and so are now impossible to prove (or disprove) that they would have been jurisdictional "adjacent wetlands" at the time of ditch excavation, as the 2020 NWPR requires. Other staff noted that ditches excavated in uplands still transport pollutants directly to jurisdictional waters, and that there was no scientific justification for 100% of flow to be redirected into a ditch before the diversion ditch itself becomes a jurisdictional water, as the 2020 NWPR stipulated in the 2020 NWPR preamble.

Other challenges cited by at least one EPA Regional staff person in response to the survey included the need to periodically access multiple properties to document wetland adjacency to the nearest tributary, which is often not feasible; and the disparate treatment of culverts and bridges under the 2020 NWPR, given that in the field there is often no clear distinction between them (*e.g.*, what is an open-bottomed culvert?).

C. Climate Change

Consistent with Executive Order 13990, the agencies, where consistent with the objective of the Clean Water Act, considered the impact of climate change on water resources to the extent those impacts would affect the chemical, physical, or biological integrity of traditional navigable waters, the territorial seas, or interstate waters.

The Intergovernmental Panel on Climate Change (IPCC) notes that, "Recent climate changes have had widespread impacts on human and natural systems." IPCC 2014 at 2. The IPCC explains that "Surface temperature is projected to rise over the 21st century under all assessed emission scenarios. It is very likely that heat waves will occur more often and last longer, and that extreme precipitation events will become more intense and frequent in many regions. The ocean will continue to warm and acidify, and global mean sea level to rise." *Id.* at 10. Furthermore, climate change has important implications for communities with environmental justice concerns. "Climate change will amplify existing risks and create new risks for natural and human systems. Risks are unevenly distributed and are generally greater for disadvantaged people and communities in countries at all levels of development." *Id.* at 13.

As a result of well documented climate trends, the traditional locations of rain belts and deserts are shifting. UCAR 2022. Current climate models indicate that rising temperatures will intensify the water cycle, leading to an increase in the rate of evaporation worldwide. NASA 2021; UCAR 2022. On average, this increase in evaporation is leading to more precipitation, and the impacts are likely to increase over the century as the climate continues to warm. UCAR 2022. However, changes in evaporation and precipitation rates are not distributed evenly. *Id*. In some regions, increased evaporation rates are leading to higher levels of water vapor in the air, which in turn increases the intensity and frequency of precipitation events, including storms. NASA 2021; U.S. EPA 2022e; USGCRP 2018. As a result, storm-affected areas, such as the Northeast and the Midwest, are likely to experience increases in precipitation and increased risk of flooding. NASA 2021; UCAR 2022; U.S. EPA 2022i; USGCRP 2018. In other regions, less precipitation and increased risk of drought is associated with more frequent and intense heatwaves. Across much of the country, surface soil moisture is also anticipated to decrease as the climate warms, driven largely by increased evaporation rates. USGCRP 2018. All else being equal, this will result in increased intensity, frequency, and duration of heatwaves and droughts in these regions. *Id*. These trends are likely to be strongest in the Southwest and Southern Great Plains, where precipitation is projected to decrease in most seasons and droughts may become more frequent, prolonged, and intense. *Id*.

Climate change is expected to have a variety of impacts on water resources. Runoff from more intense and frequent storms can impair water quality as pollutants deposited on land wash into water bodies. Changes in the size and frequency of heavy precipitation events, streamflow, snowmelt timing, and snowpack accumulation may also cause river floods to become larger or more frequent than they used to be in some places. U.S. EPA 2022f. Climate change is already affecting streamflow characteristics such as the magnitude, duration, and timing of flows (U.S. EPA 2022h), in part due to changes in snowpack magnitude and seasonality. U.S. EPA 2022g. Heatwaves and associated drought can cause streams and wetlands to become drier, negatively affecting both water supplies and water quality. Heatwaves and associated drought reduce surface and soil moisture thereby increasing the extent and duration of wildfires, which can alter water quality and impact wetlands and their functions. U.S. EPA 2022b. Wetland loss and changes to stream habitat can also lead to reduced habitat for fish and other aquatic and semi-aquatic species and worsen existing shifts in species ranges. *Id*. A warming climate can also result in increased and more variable temperatures in streams, leading to fish kills and negatively affecting other aquatic species that can live only in colder water. *See, e.g.*, Mantua *et al*. 2010; Ebersole *et al.* 2020.

Climate change has been well established to contribute to sea level rise. Rising sea levels are affecting human activities in coastal areas and making coastal infrastructure more vulnerable to storm damage. Furthermore, rising sea level inundates low-lying wetlands and dry land, and further contributes to coastal flooding and erosion. U.S. EPA 2022b; U.S. EPA 2022c.; USGCRP 2018. Repeated inundation of low-lying wetlands results in the loss or migration landward of coastal wetlands. However, inland migration of wetlands can be impeded by coastal development, thereby placing these wetlands at risk of being lost. Kirwan and Megonigal 2013; Borchert *et al*. 2018; USGCRP 2018. Both tidal and non-tidal wetlands may be at risk from sea-level rise: wetland types that are vulnerable to climate change include salt marshes, bottomland hardwood swamps, freshwater marshes, mangrove swamps, and pocosins. U.S. EPA 2022b. Sea level rise can introduce saltwater into non-tidal wetlands which can lead to substantial impacts on the wetland health and distribution. Herbert *et al*. 2015. These impacts can be further exacerbated by climate-related reductions of inflows from rivers that deliver freshwater to non-tidal wetlands, illustrating that many wetlands face cumulative climate impacts from multiple sources. *Id*. Climate change can also inhibit the ability of sediment accretion in tidal wetlands leading to vegetation "drowning." This occurs when the rate of sea level rise surpasses the ability of coastal wetlands to keep pace via sediment accretion and can lead to certain wetlands becoming submerged. Borchert *et al*. 2018.

Although water resources are vulnerable to the effects of climate change, when their interconnectedness and extent are maintained, streams and wetlands perform a variety of functions that can help restore ecologic function of other water resources in light of climate change (*i.e.,* contribute to climate resiliency) and mitigate the negative effects of climate change on other water resources, including larger downstream waters. For instance, despite their vulnerability to the effects of sea level rise, many coastal wetlands are resilient ecosystems that have the capacity to adjust to sea level rise through vertical adjustments due to feedbacks between plant growth, inundation, and sediment deposition and through the landward migration of wetlands. *Id*. In addition, wetlands inside and outside of floodplains store large volumes of floodwaters, thereby reducing flood peaks and protecting downstream watersheds. Science Report; U.S. EPA 2006; U.S. EPA 2022b. For example, during Hurricane Sandy in 2012, wetlands are estimated to have helped prevent $625 million in damage by protecting properties from flooding. Narayan 2017. Coastal wetlands also help buffer storm surges and slow winds from tropical storms and hurricanes (U.S. EPA 2022b), which are increasing in intensity due to climate change (USGCRP 2017). As natural filters, wetlands also help purify and protect the quality of other waters, including drinking water sources—a function which is more important than ever as intense precipitation events spurred by a changing climate mobilize excess sediment, nutrients, and other pollutants. Additionally, small streams are particularly effective at retaining and attenuating floodwaters, a function that is increasing important in light of continued climate change. *See, e.g.,* Science Report at ES-8. Biological communities and geomorphic processes in small streams, including ephemeral streams, and wetlands break down leaves and other organic matter, burying and sequestering a portion of that carbon that could otherwise be released into the atmosphere as either carbon dioxide or methane. Guinessey *et al.* 2019; Kirwan and Megonigal 2013. Carbon sequestered in soils, sediments, and vegetation is released to the atmosphere when these streams or wetlands are drained, dredged, or otherwise disturbed, contributing to greenhouse gas emissions which have negative effects on water resources. More streams are expected to become ephemeral under a changing climate. Lohse *et al*. 2020.

The 2020 NWPR did not appropriately acknowledge or take account of the effects of a changing climate on the chemical, physical, and biological integrity of the nation's waters. For example, its rolling thirty-year approach to determining a "typical year" did not allow the agencies flexibility to account for the effects of a rapidly changing climate, including positive trends in temperature, increasing storm events, and extended droughts (*see* section II.B). The 2020 NWPR also categorically excluded ephemeral streams and their adjacent wetlands from the definition of "waters of the United States." These exclusions, if in effect, would disproportionately impact the arid West. Aquatic systems comprised largely of ephemeral streams are increasingly critical to protecting and maintaining downstream integrity, for example by contributing streamflow and organic matter to larger downstream waters. This is especially true in the Southwestern United States, where the climate continues to get hotter and drier and the spatial extent of arid conditions is expanding, with increased risks of more extreme drought. Some portions of the arid West are experiencing altered monsoon seasons that have fewer but more intense storms that contribute to so-called "flashy" stream hydrology (*i.e.*, higher runoff volume, leading to more rapidly rising and falling streamflow over shorter periods of time). The agencies' use of the significant nexus standard in the final rule (*see* section III.E.iv.1) allows the agencies to consider the effects that water resources like ephemeral streams and wetlands have on the chemical, physical, or biological integrity of downstream traditional navigable waters, the territorial seas, and interstate waters, including important functions that may intersect with climate change.

D. Environmental Justice

While impacts on communities with environmental justice concerns are not a basis for determining the scope of the definition of “waters of the United States,” the agencies recognize that the burdens of environmental pollution and climate change often fall disproportionately on communities with environmental justice concerns (*e.g.*, minority (Indigenous peoples and/or people of color) and low-income populations, as specified in Executive Order 12898). Compared to the average populations, these communities are more likely to experience environmental and social stressors like contaminated drinking water, limited access to clean water, and inadequate water infrastructure, that increase their likelihood of being exposed to pollutants. In addition to external stressors, behavioral and cultural characteristics of these communities, like engaging in subsistence fishing and consuming higher rates of fish from polluted waters, increases their vulnerability to pollution. Taken together, these environmental, social, and behavioral factors often increase the risk of these communities experiencing negative health outcomes because of their exposure.

As the IPCC Synthesis Report notes, in addition to the existing risks that communities with environmental justice concerns face, the impacts of climate change have important additional implications for these communities. “Climate change will amplify existing risks and create new risks for natural and human systems. Risks are unevenly distributed and are generally greater for disadvantaged people and communities in countries at all levels of development.” IPCC 2014 at 13. Risks to human systems like sea level rise, flooding, and drought can all have disproportionate effects on these communities. For example, prolonged droughts pose a particular threat to Indigenous populations because of their economic and cultural dependence on land and water supplies. U.S. EPA 2022d. Similarly, decreased summer streamflow, habitat loss due to increasing storm intensity and flooding, warmer stream and ocean temperatures, and seasons of reduced snowpack are impacting Pacific salmon populations in the Northwest, threatening Indigenous communities that rely culturally and economically on salmon. USGCRP 2018. Because of existing environmental and social stressors and their reliance on natural resources (*e.g.*, fish and other aquatic life for income or food) that may be negatively impacted by climate change, these communities may be less able to mitigate and adapt to the effects of climate change.

Numerous groups have raised concerns that the 2020 NWPR had disproportionate impacts on Tribes and Indigenous communities.[36] The 2020 NWPR decreased the scope of Clean Water Act

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[36] *See, e.g.*, Tribal Consultation Comment Letter from President Jonathan Nez and Vice President Myron Lizer, Navajo Nation, October 4, 2021 (“The Navajo Nation relies greatly on all its surface waters, including ephemeral, intermittent, and perennial surface waters. The Navajo Nation currently lacks the resources to implement CWA permitting and other programs necessary to maintain and protect water quality and relies on the Agencies to fill that need. Therefore, any new WOTUS rule must not reduce the scope of the waters that the Agencies can protect, or it will have ‘disproportionately high and adverse human health or environmental effects’ on the Navajo Nation.”), and Tribal Consultation Comment Letter from Clarice Madalena, Interim Director, Natural Resources Department, Pueblo of Jemez, October 4, 2021 (“The combination of these factors—[desert] hydrology and the geographic location of Native communities—means that the Navigable Waters Rule had the effect of disparately stripping Clean Water Act protections from areas with higher Native populations. This means that the Rule disproportionately harmed Native American communities. This discriminatory impact violates the principles of environmental justice” (citations omitted). *See also* section IV.B.3.d of the preamble for the final rule.

jurisdiction across the country, including in geographic regions where regulation of waters beyond those covered by the Act is not authorized under current Tribal or State law (*see* section IV.B.3.d of the preamble for the final rule). If the 2020 NWPR were in effect, without regulations governing discharges of pollutants into previously jurisdictional waters, population groups of concern where these waters are located could experience increased water pollution and impacts from associated increases in health risk.

Further, the 2020 NWPR's categorical exclusion of ephemeral streams disproportionately impacted Tribes and communities with environmental justice concerns in the arid West. Many tribes lack the authority and resources to regulate waters within their boundaries, and they may also be affected by pollution from adjacent jurisdictions. *See supra* note 36. Therefore, if in effect, the 2020 NWPR could disproportionately expose Tribes to increased pollution and health risks.

In this final rule the agencies affirm their commitment to assessing impacts of a revised definition of "waters of the United States" on population groups of concern (*see* Chapter IV of the Economic Analysis for the Final Rule).

III. Scientific Support for the Final Rule

The objective of the Clean Water Act to protect water quality must be considered when defining "waters of the United States." The latest science supports the conclusion that the categories of waters identified in the final rule, such as impoundments (paragraph (a)(2) waters in the final rule), tributaries (paragraph (a)(3) waters in the final rule), adjacent wetlands (paragraph (a)(4) waters in the final rule), and intrastate waters that do not meet the criteria to be jurisdictional under other categories of the final rule (paragraph (a)(5) waters in the final rule), provide functions that restore and maintain the chemical, physical, and biological integrity of traditional navigable waters, the territorial seas, and interstate waters (paragraph (a)(1) waters in the final rule). The best available science thus confirms that the final rule provides a definition of "waters of the United States" that furthers the water quality objective of the Clean Water Act. As explained in the preamble, the final rule also establishes limitations reflecting consideration of the statute as a whole and relevant Supreme Court decisions. The agencies thus believe that the latest science informs the conclusion that the categories of waters identified in the final rule provide functions that restore and maintain the chemical, physical, and biological integrity of traditional navigable waters, the territorial seas, and interstate waters.

In the preamble to the final rule, the agencies' reference to a "connection" to traditional navigable waters, the territorial seas, or interstate waters (when used without qualification such as "continuous surface connection" or an "unbroken surface or shallow subsurface connection") includes all the types of connections relevant to either the relatively permanent standard or the significant nexus standard that are discussed in the Science Report and in this Technical Support Document: physical (including hydrological), chemical, biological, or functional relationships (including where the water retains floodwaters or pollutants that would otherwise flow to the traditional navigable water, the territorial seas, or an interstate water). A "requisite" connection is one that satisfies either the relatively permanent or significant nexus standard.

Although the scientific conclusions of the Science Report, the research published since its release, and other literature that the agencies reviewed to support this rulemaking play a critical role in informing the agencies' interpretation of the Clean Water Act's scope, the agencies' interpretive task in this final rule – determining which waters are "waters of the United States"– requires scientific and policy judgment, as well as legal interpretation. The agencies also acknowledge that science can support other approaches to implementation, particularly regarding which waters to consider in combination with similar waters and the region in which to consider similarly situated waters but have made policy choices regarding implementation of this final rule. The agencies reiterate their previous conclusion that significant nexus is not a purely scientific determination. 80 FR 37054, 37060 (June 29, 2015). As the agencies charged with interpreting the statute, EPA and the Corps must develop the outer bounds of the scope of the Clean Water Act and science does not provide bright line boundaries for purposes of the Clean Water Act. *Riverside Bayview*, 474 U.S. at 132-33. This section summarizes the best available science in support of the final rule and the agencies' conclusion that the rule advances the objective of the Clean Water Act. This section reflects the scientific consensus on the strength of the effects that upstream tributaries, adjacent wetlands, and intrastate waters considered under paragraph (a)(5) of the final rule can and do have on downstream traditional navigable waters, the territorial seas, and interstate waters. However, a significant nexus determination requires legal, technical, and policy judgment, as well as scientific considerations, to assess the significance of any effects. Section IV.C of the preamble and section IV of this document discuss the agencies' approaches to making case-specific relatively permanent and significant nexus determinations under the final rule. The science demonstrates that waters fall along gradients of chemical, physical, and biological connection to traditional navigable waters, the territorial seas, and interstate waters, and it is the agencies' task to determine where along that gradient to draw lines of jurisdiction under the Clean Water Act. In making this determination, the agencies must rely, not only on the science, but also on their technical expertise and practical experience in implementing the Clean Water Act during a 50-year period.

To be clear, under the final rule no waters considered under paragraph (a)(5) are categorically jurisdictional. Rather, the agencies will assess tributaries, adjacent wetlands, and intrastate waters that do not fall with paragraphs (a)(1) through (a)(4) utilizing the relatively permanent or significant nexus jurisdictional standards. This approach advances the objective of the Clean Water Act and is consistent with the best available science because waters in these categories can have significant effects on traditional navigable waters, the territorial seas, and interstate waters. The agencies are also adding the relatively permanent and significant nexus standards to certain categories of waters based on their conclusion that together those standards are consistent with the statutory text, advance the objective and policies of the Act, and are supported by the scientific record. Indeed, the agencies are not reaching any conclusions, categorical or otherwise, about which tributaries, wetlands (other than those wetlands adjacent to traditional navigable waters, the territorial seas, or interstate waters), lakes, ponds, or other types of waters meet either the relatively permanent or the significant nexus standard. Instead, the final rule enables the agencies to make science-informed determinations of whether or not a water that falls within these categories meets either jurisdictional standard and is therefore a "water of the United States," on a case-specific basis.

A. Tributaries

Under the final rule, tributaries of traditional navigable waters, the territorial seas, interstate waters, or jurisdictional impoundments are "waters of the United States" where they meet either the relatively permanent or significant nexus standard. Asserting Clean Water Act jurisdiction over tributaries where they meet either the relatively permanent or significant nexus standards as outlined in paragraph (a)(3) of the final rule aligns with the scientific literature, as well as the agencies' scientific and technical expertise and experience, which confirm that tributaries, regardless of flow regime, have chemical, physical, or biological effects on downstream waters.

The scientific literature documents that tributary streams, including perennial, intermittent, and ephemeral streams, certain lakes and ponds, and certain categories of ditches are integral parts of river networks because they are directly connected to rivers via permanent surface features (channels and associated alluvial deposits) that concentrate, mix, transform, and transport water and other materials, including food resources, downstream. Alluvial deposits, or alluvium, are deposits of clay, silt, sand, gravel, or other particulate materials that have been deposited by a stream or other body of running water in a streambed, on a flood plain, on a delta, or at the base of a mountain. Science Report at A-1. Tributaries transport, and often transform, chemical elements and compounds, such as nutrients, ions, dissolved and particulate organic matter and contaminants, influencing water quality, sediment deposition, nutrient availability, and biotic functions in rivers. Streams also are biologically connected to downstream waters by dispersal and migration, processes which have critical implications for aquatic populations of organisms that use both headwater and river or open water habitats to complete their life cycles or maintain viable populations. The scientific literature clearly demonstrates that cumulatively, streams exert strong influence on the character and functioning of rivers. *See id.* at ES-2 and Chapter 3. In light of these well documented connections and functions, the agencies conclude that tributaries, either alone or in combination with similarly situated waters, can significantly affect the chemical, physical, or biological integrity of a traditional navigable water, the territorial seas, or an interstate water. The scientific literature supports this conclusion for ephemeral tributaries, as well as for intermittent and perennial tributaries; for tributaries both near to and far from the downstream traditional navigable water, the territorial seas, or interstate water; and for natural tributaries, human-altered, or human-made tributaries, which may include certain ditches and canals. For tributaries that meet the relatively permanent standard, such tributaries, either alone or in combination with similarly situated waters in the region, will virtually always significantly affect the chemical, physical, or biological integrity of traditional navigable waters, the territorial seas, or interstate waters. For tributaries that do not meet the relatively permanent standard, under the final rule they will be evaluated, either alone or in combination with similarly situated waters in the region, on a case-specific basis to determine whether they significantly affect the chemical, physical, or biological integrity of traditional navigable waters, the territorial seas, or interstate waters.

The connections that tributaries have to downstream waters and functions they provide that impact those downstream waters continue even where the tributary has a natural or human-made break in its channel or ordinary high water mark (OHWM). The presence of a channel, bed and banks, or other indicators of OHWM upstream or downstream of the break is an indication that hydrological connections still exist. *See, e.g., id.* at 2-2. The connections between a tributary and a downstream water and associated functions remain intact even where the tributary flows underground for a portion of its length, such as in regions with karst geology or topography or lava tubes. Artificial breaks can occur, for example, when a stream has been buried (*e.g.*, diverted into pipes or other conveyances), which is common in urban watersheds. *See, e.g.*, *id.* at 3-3. Where the hydrologic connection still exists, chemical and biological connections mediated by the hydrologic connection can also still exist. Similarly, flow through boulder fields does not sever the hydrologic connection. When a tributary flows through a wetland enroute to another or the same tributary, connectivity and effects still exist even though the channel or ordinary high water mark is broken for the length of the wetland. Adjacent wetlands located within a tributary can provide numerous benefits downstream (*see* section III.B), and the location of the wetland in-stream can provide additional water quality benefits to the receiving waters. Flow in flat areas with very low gradients may temporarily break a tributary's channel or OHWM, but these systems continue to be connected downstream and can provide functions that benefit downstream waters. These are just illustrative examples of break in the stream channel or ordinary high water mark.

The discussion below summarizes the key points in the literature regarding the chemical, physical, and biological connections and functions of tributaries that affect downstream waters. The scientific literature does not use legal terms like "relatively permanent" to describe streamflow permanence classes. Rather, the literature uses terms like "perennial," "intermittent," or "ephemeral" to describe and classify streamflow permanence. Tributaries that meet the relatively permanent standard under the final rule are those that have flowing or standing water year-round or continuously during certain times of the year. The agencies have decided against defining the relatively permanent standard by specific stream flow classifications in the final rule (*e.g.*, perennial, intermittent, or ephemeral). However, flow characteristics like duration and timing of flow will be considered in determining whether tributaries meet the relatively permanent or significant nexus standard. Tributaries that do not meet the relatively permanent standard include tributaries with flowing or standing water for only a short duration in direct response to precipitation. The approach to the relatively permanent standard for tributaries in the final rule would encompass tributaries considered relatively permanent under the 2020 NWPR, as well as those considered relatively permanent under the *Rapanos* Guidance, providing continuity in approach for the regulated community and other stakeholders. Tributaries that do not meet the relatively permanent standard must be assessed under the significant nexus standard. The relatively permanent standard is discussed in section III.F below and the significant nexus standard is discussed in section III.E below.

In addition, the evidence regarding human-altered and human-made tributaries and headwater streams and non-perennial streams, types of tributaries whose important functional relationships to downstream traditional navigable waters, the territorial seas, and interstate waters might not be obvious, is summarized. The evidence regarding headwater or in-stream lakes and ponds is also summarized. The scientific literature does not use legal terms like "traditional navigable water," "the territorial seas," or "interstate water." Rather, the literature assesses tributaries in terms of their connections to and effects on larger downstream waters in a watershed. Traditional navigable waters, the territorial seas, and interstate waters are simply a subset of downstream waters, and their distinction is a legal, not scientific, one; the strength of the connections and effects does not change because a river does not meet the legal standards for being traditionally navigable. While the final rule, consistent with Supreme Court case law and the Clean Water Act, addresses only those tributaries that drain (contribute flow directly or indirectly) to a traditional navigable water, the territorial seas, interstate water, or jurisdictional impoundments, the conclusions of the scientific literature with respect to the effects of tributaries on downstream waters are applicable to the subset of downstream waters that are traditional navigable waters, the territorial seas, or interstate waters.

Based on the importance of the functions that are provided by tributaries to traditional navigable waters, the territorial seas, and interstate waters, the agencies' final rule to interpret the Clean Water Act to protect those tributaries that meet either the relatively permanent standard or the significant nexus standard reflects proper consideration of the objective of the Act and the best available science.

i. Tributaries Can Provide Functions that Restore and Maintain the Physical Integrity of Downstream Traditional Navigable Waters, the Territorial Seas, and Interstate Waters

The scientific literature unequivocally demonstrates that tributaries exert a strong influence on the physical integrity of larger downstream waters. Tributaries, even when seasonal, are the dominant source of water in most rivers, rather than direct precipitation or groundwater input to main stem river segments. *See, e.g.,* Science Report at 3-5 (citing Winter 2007; Bukaveckas 2009). Distant headwaters with stronger connections to groundwater or consistently higher precipitation levels than downstream reaches contribute more water to downstream rivers. *Id.* In the northeastern United States headwater streams contribute greater than 60% of the water volume in larger tributaries, including navigable rivers. *See, e.g., id.* (citing Alexander *et. al.* 2007). The contributions of tributaries to river flows are often readily measured or observed, especially immediately below confluences, where tributary flows increase the flow volume and alter physical conditions, such as water temperature, in the main stream. The physical effects of tributaries are particularly clear after intense rainfall occurs over only the upper tributary reaches of a river network. For example, a study of ephemeral tributaries to the Río Grande in New Mexico found that after a storm event contributions of the stormflow from ephemeral tributaries accounted for 76% of the flow of the Río Grande. *Id.* at 3-7 to 3-8 (citing Vivoni *et. al.* 2006). A key effect of tributaries on the hydrologic response of river networks to storm events is dispersion, or the spreading of water output from a drainage basin over time. Geomorphic dispersion of connected tributaries influences the timing and volume of water reaching a river network outlet. *See, e.g., id.* at 3-10 (citing Saco and Kumar 2002). Tributaries also can reduce the amount of water that reaches downstream rivers and minimize downstream flooding, often through infiltration or seepage through channel beds and banks or through evapotranspiration. *See, e.g., id.* at 3-11 (citing Hamilton *et al*. 2005; Costelloe *et.al.* 2007).

One of the primary functions of tributaries is transporting sediment to downstream waters. Tributaries, particularly headwaters, shape and maintain river channels by accumulating and gradually or episodically releasing sediment and large woody debris into river channels. Sediment transport is also clearly provided by ephemeral streams. Effects of the releases of sediment and large woody debris are especially evident at tributary-river confluences, where discontinuities in flow regime and temperature clearly demonstrate physical alteration of river structure and function by headwater streams. Science Report at 3-14, 3-16, 3-18, 3-20 to 3-21. Sediment movement is critical for maintaining the river network, including rivers that are considered to be traditional navigable waters, as fluvial (produced by the action of a river or stream) sediments are eroded from some channel segments, and deposited in others downstream to form channel features, stream and riparian habitat which supports the biological communities resident downstream, and influence the river hydrodynamics. *See, e.g.,* Florsheim *et al.* 2008; Science Report at 3-13 (citing Church 2006). While essential to river systems, too much sediment can impair ecological integrity by filling interstitial spaces, blocking sunlight transmission through the water column, and increasing contaminant and nutrient concentrations. *Id.* (citing Wood and Armitage 1997). Over-sedimentation thus can reduce photosynthesis and primary productivity within the stream network and otherwise have harmful effects on downstream biota, including on the health and abundance of fish, aquatic macrophytes (plants), and aquatic macroinvertebrates (insects) that inhabit downstream waters. *See, e.g.*, Wood and Armitage 1997. Headwater streams tend to trap and store sediments behind large structures, such as boulders and trees, that are transported downstream only during infrequent large storm events and that are the dominant means for downstream sediment transport. Science Report at 3-15 (citing Gomi and Sidle 2003; Gooderham *et al.* 2007). Similarly, large, infrequent disturbance events are the primary drivers for wood movement from headwater streams to downstream waters. *Id.* at 3-17 (citing Benda and Cundy 1990; Benda *et al.* 2005; Bigelow *et al*. 2007).

Tributaries can greatly influence water temperatures in tributary networks. This is important because water temperature is a critical factor governing the distribution and growth of aquatic life, both directly (through its effects on organisms) and indirectly (through its effects on other physiochemical properties, such as dissolved oxygen and suspended solids). *Id.* at 3-19 (citing Allan 1995). For instance, water temperature controls metabolism and level of activity in cold-blooded species like fish, amphibians, and aquatic invertebrates. *See, e.g.*, Ice 2008. Temperature can also control the amount of dissolved oxygen in streams, as colder water holds more dissolved oxygen, which fish and other fauna need to breathe. Connections between tributaries and downstream rivers can affect water temperature in river networks. *See, e.g.*, Science Report at 3-19 (citing Knispel and Castella 2003; Rice *et al*.2008). In particular, tributaries provide both cold and warm water refuge habitats that are critical for protecting aquatic life in downstream traditional navigable waters, the territorial seas, and interstate waters. *Id.* at 3-42. Because headwater tributaries often depend on groundwater inputs, temperatures in these systems tend to be warmer in the winter (when groundwater is warmer than ambient temperatures) and colder in the summer (when groundwater is colder than ambient temperatures) relative to downstream waters. *Id*. (citing Power *et al*. 1999). Thus, tributaries provide organisms with both warm water and coldwater refuges at different times of the year. *Id*. (citing Curry *et al*. 1997; Baxter and Hauer 2000; Labbe and Fausch 2000; Bradford *et al*. 2001). For example, when temperature conditions in downstream waters are adverse, fish can travel upstream and use tributaries as refuge habitat, such as cold-water fish like Pacific salmon that seek important thermal refuge from warm downstream waters in small, cold tributaries. *Id.* (citing Curry *et al*. 1997; Cairns *et al*. 2005); Ebersole *et al*. 2015. Tributaries also help buffer temperatures in downstream waters. Science Report at 3-19 (citing Caissie 2006). Temperatures in tributaries affect downstream water temperature many kilometers away. *Id*. at 3-20 (citing Gardner and Sullivan 2004; Johnson *et al*. 2010).

ii. Tributaries Can Provide Functions that Restore and Maintain the Chemical Integrity of Downstream Traditional Navigable Waters, the Territorial Seas, and Interstate Waters

The scientific literature unequivocally demonstrates that tributaries exert a strong influence on the chemical integrity of downstream waters. Tributaries transform and export significant amounts of nutrients and carbon to downstream waters, serving important source functions that greatly influence the chemical integrity of downstream waters. Organic carbon, in both dissolved and particulate forms, exported from tributaries is consumed by downstream organisms. The organic carbon that is exported downstream thus supports biological activity (including metabolism) throughout the river network. *See, e.g.,* Science Report at 3-30 (citing Fisher and Likens 1973; Meyer 1994; Wallace *et al.* 1997; Hall and Meyer 1998; Hall *et al*. 2000; Augspurger *et al*. 2008). Much or most of the organic carbon that is exported from tributaries has been altered either physically or chemically by ecosystem processes within the tributary streams, particularly by headwater streams. In addition to transformations associated with microbial and invertebrate activity, organic matter in streams can be transformed through other processes such as immersion and abrasion; photodegradation also can be important in ephemeral and intermittent streams where leaves accumulate in dry channels exposed to sunlight. *Id.* (citing Paul *et al.* 2006; Corti *et al.* 2011; Dieter *et al.* 2011; Fellman *et al.* 2013).

Nutrient export from tributaries has a large effect on downstream water quality, as excess nutrients from surface runoff from lawns and agricultural fields can cause algal blooms that reduce dissolved oxygen levels and increase turbidity in rivers, lakes, estuaries, and territorial seas. Water low in dissolved oxygen cannot support aquatic life; this widely-recognized phenomenon, known as hypoxia or "dead zones," occurs along coasts throughout the country, including the northern Gulf of Mexico and the Chesapeake Bay. Committee on Environment and Natural Resources 2000; Díaz and Rosenberg 2011; Murphy *et al.* 2011. Hypoxia threatens valuable commercial and recreational fisheries, including in the northern Gulf of Mexico, and reduces aquatic habitat quality and quantity. Committee on Environment and Natural Resources 2000; Freeman *et al.* 2007; Díaz and Rosenberg 2011; O'Connor and Whitall 2007; He and Xu 2015. The amount of nitrogen that is exported downstream varies depending on stream size, and how much nitrogen is present in the system. Nitrogen loss is greater in smaller, shallow streams, most likely because denitrification and settling of nitrogen particles occur at slower rates in deeper channels. Science Report at 3-23 (citing Alexander *et al.* 2000). At low loading rates, the biotic removal of dissolved nitrogen from water is high and occurs primarily in small tributaries, reducing the loading to larger tributaries and rivers downstream. At high nitrogen loading rates, tributaries become nitrogen saturated and are not effectively able to remove nitrogen, resulting in high nitrogen export to rivers. *Id.* at 3-25 to 3-26 (citing Mulholland *et al*. 2008). The transport of nitrogen and phosphorus downstream has also been well-documented, particularly in the cases of the Gulf of Mexico and the Chesapeake Bay. Tributary streams in the uppermost portions of the Gulf and Bay watersheds transport the majority of nutrients to the downstream waters; an estimated 85% of nitrogen arriving at the hypoxic zone in the Gulf originates in the upper Mississippi (north of Cairo, Illinois) and the Ohio River Basins. Goolsby *et al.* 1999. The export of nutrients from streams in the Mississippi River Basin has an effect on anoxia, or low oxygen levels, in the Gulf. Science Report at 3-24 (citing Rabalais *et al*. 2002). Similarly, nutrient loads from virtually the entire 64,000 square mile watershed affect water quality in the Chesapeake Bay. Simulation tools have been used to determine the nutrient and sediment load reductions that must be made at many different points throughout the entire watershed in order to achieve acceptable water quality in the mainstem of the Bay. These reductions included specific annual nitrogen caps on the upper reaches of the Susquehanna River in New York State, more than 400 miles from the mouth of the Chesapeake Bay. *See e.g.*, Rabalais *et al*. 2002; U.S. Environmental Protection Agency 2003; New York Department of Environmental Conservation 2021.

Although tributaries export nutrients, carbon, and contaminants downstream, they also transform these substances. Phosphorous and nitrogen arrive at downstream waters having already been cycled, or taken up and transformed by living organisms, many times in headwater and smaller tributaries. Science Report at 1-3, 3-26 to 3-27 (citing Webster and Patten 1979; Newbold *et al.* 1981; Elwood *et al.* 1983;

Ensign and Doyle 2006). In addition, some of the nutrients taken up as readily available inorganic forms are released back to the water as organic forms that are less available for biotic uptake. *Id*. at 3-27 (citing Mulholland *et al*. 1988; Seitzinger *et al*. 2002). Similarly, nutrients incorporated into particulates are not entirely regenerated, but accumulate in longitudinally increasing particulate loads (*i.e.*, increases moving downstream). *Id*. (citing Merriam *et al.* 2002; Whiles and Dodds 2002; Hall *et al*. 2009). Headwater streams have seasonal cycles in the concentrations of phosphorous and nitrogen that are delivered downstream by accumulating nutrient derived from temporarily growing streambed biomass. *Id.* (citing Mulholland and Hill 1997; Mulholland 2004). Such variations have been demonstrated to affect downstream productivity. *Id*. (citing Mulholland *et al*. 1995). Nitrification, the microbial transformation of ammonium to nitrate, affects the form of downstream nutrient delivery. Nitrification occurs naturally in undisturbed headwater streams, but increases sharply in response to ammonium inputs, thereby reducing potential ammonium toxicity from pollutant inputs. *Id*. at 3-28 (citing Newbold *et al*. 1983; Chapra 1996; Bernhardt *et al*. 2002). Denitrification, the removal of nitrate from streamwater through transformation to atmospheric nitrogen, is widespread among headwater streams; research indicates that small, tributaries free from agricultural or urban impacts can reduce up to 40% of downstream nitrogen delivery through denitrification. *Id.* at 3-28 (citing Mulholland *et al*. 2008). Small tributaries also affect the downstream delivery of nutrients through abiotic processes. Streams can reduce phosphorus concentrations through sorption (*i.e*., "sticking") to stream sediments. *Id.* (citing Meyer and Likens 1979). This is particularly beneficial to downstream chemical integrity where phosphorus sorbs to contaminants such as metal hydroxide precipitates. *Id.* (citing Simmons 2010).

Tributaries also store significant amounts of nutrients and carbon, functioning as important sinks for river networks so that they do not reach downstream traditional navigable waters, the territorial seas, or interstate waters. Small tributary streams in particular often have the greatest effect on downstream water quality, in terms of storage and reducing inputs to downstream waters. For instance, uptake and transformation of inorganic nitrogen often occurs most rapidly in the smallest tributaries. *See, e.g., id.* at 3-25 (citing Peterson *et al.* 2001). Small tributaries affect the downstream delivery of nutrients such as phosphorus through abiotic processes; such streams can reduce phosphorus concentrations by sorption to stream sediments.

Tributaries can also serve as a temporary or permanent source or sink for contaminants that adversely affect organisms when occurring at excessive or elevated concentrations, reducing the amounts of such pollutants that reach downstream traditional navigable waters, the territorial seas, or interstate waters. The transport of contaminants to downstream waters can impact water quality downstream if they are not stored in tributaries. *See, e.g.*, *id.* at 3-34 (citing Wang *et al*. 2007). Tributaries can also serve as at least a temporary sink for contaminants that would otherwise impair downstream water quality. *See, e.g., id.* at 3-36 to 3-37 (citing Graf 1994).

The distances and extent of metal contaminant transport was shown in separate studies in the upper Arkansas River in Colorado, and Clark Fork River in Montana, where past mining activities impacted the headwater tributaries. River bed sediments showed that metals originating from the mining and smelting areas in the headwaters were reaching water bodies up to 550 km downstream. *Id.* at 3-34 (citing Axtmann and Luoma 1991; Kimball *et al*. 1995).

Military studies of the distribution, transport, and storage of radionuclides (*e.g.*, plutonium, thorium, uranium) have provided convincing evidence for distant chemical connectivity in river networks because the natural occurrence of radionuclides is extremely rare. From 1942 to 1952, prior to the full understanding of the risks of radionuclides to human health and the environment, plutonium dissolved in acid was discharged untreated into several intermittent headwater streams that flow into the Rio Grande at the Los Alamos National Laboratory, New Mexico. *Id.* at 3-36 (citing Graf 1994; Reneau *et al.* 2004). Also during this time, nuclear weapons testing occurred west of the upper Rio Grande near Socorro, New Mexico (Trinity blast site) and in Nevada, where fallout occurred on mountainous areas with thin soils that are readily transported to headwater streams in the upper Rio Grande basin. The distribution of plutonium within the Rio Grande illustrates how headwater streams transport and store contaminated sediment that has entered the basin through fallout and from direct discharge. Los Alamos Canyon, while only representing 0.4% of the drainage area at its confluence with the Rio Grande, had a mean annual bedload contribution of plutonium almost seven times that of the mainstem. *Id.* (citing Graf 1994). Much of the bedload contribution occurred sporadically during intense storms that were out of phase with flooding on the upper Rio Grande. Total estimated contributions of plutonium between the two sources to the Rio Grande were approximately 90% from fallout to the landscape and 10% from direct effluent discharge at Los Alamos National Laboratory. *Id.* at 3-36 to 3-37 (citing Graf 1994).

iii. Tributaries Can Provide Functions that Restore and Maintain the Biological Integrity of Downstream Traditional Navigable Waters, the Territorial Seas, and Interstate Waters

Tributaries are biologically linked to downstream waters through the movement of living organisms or their reproductive propagules, such as eggs or seeds. For organisms that drift with water flow, biological connections depend on hydrological connections. However, many aquatic organisms are capable of active movement with or against water flow, and others disperse actively or passively over land by walking, flying, drifting, or “hitchhiking.” All of these different types of movement form the basis of biological connectivity between headwater tributaries and downstream waters.

Headwater tributaries increase the amount and quality of habitat available to aquatic organisms. Under adverse conditions, small tributaries provide safe refuge, allowing organisms to persist and recolonize downstream areas once adverse conditions have abated. *See, e.g.*, Science Report at 3-38 (citing Meyer and Wallace 2001; Meyer *et al*. 2004; Huryn *et al*. 2005). Use of tributaries by salmon and other anadromous fish for spawning and by American eels and other catadromous fish for other life cycle needs is well-documented, but even non-migratory species can travel great distances within the river and tributary networks. *See, e.g.*, *id.* at 3-40 (citing Gorman 1986; Sheldon 1998; Hitt and Angermeier 2008). Anadromous and catadromous fish are both types of diadromous fauna, which as explained in sections I.A.iv, require both freshwater and marine habitats over their life cycles. Anadromous fish are born in freshwater, spend most of their lives in saltwater, and return to freshwater to lay eggs. Catadromous fish breed in the ocean and spend most of their lives in freshwater. Tributaries also serve as an important source of food for biota in downstream rivers. Tributaries export plankton, vegetation, fish eggs, insects, invertebrates like worms or crayfish, smaller fish that originate in upstream tributaries and other food sources that drift downstream to be consumed by other animals. *See, e.g.*, *id.* at 3-38 (citing Progar and Modenke 2002). For example, many fish feed on drifting insects, and numerous studies document the downstream drift of stream invertebrates that then are eaten by fish in larger rivers. *See, e.g.*, *id.* at 4-29 to 4-30 (citing Nakano and Murakami 2001; Wipfli and Gregovich 2002).

Biological connectivity also allows gene flow, or genetic connectivity, among tributary and river populations. Gene flow is needed to maintain genetic diversity in a species, a basic requirement for that species to be able to adapt to environmental change. Populations connected by gene flow have a larger breeding population size, making them less prone to the deleterious effects of inbreeding and more likely to retain genetic diversity or variation. *Id*. at 3-43 (citing Lande and Shannon 1996). Genetic connectivity exists at multiple scales and can extend beyond one a single river watershed, and for species capable of long distance movement (such as salmon), reveals complex interactions among spatially distant populations of aquatic organisms *Id.* (citing Hughes *et al.* 2009; Anderson 2010; Bohonak and Jenkins 2003).

Headwater streams provide unique habitat and protection for amphibians, fish, and other aquatic or semi-aquatic species living in and near the stream that may use the downstream waters for other portions of their life stages. *See, e.g.*, Report at ES-8; Meyer *et al*. 2007. They also serve as migratory corridors for fish. Tributaries can improve or maintain biological integrity and can control water temperatures in the downstream waters. *See, e.g.*, Report at 3-20 (citing Ebersole *et. al.* 2003; Gardner and Sullivan 2004; Johnson *et al.* 2010). Headwater streams also provide refuge habitat for riverine organisms seeking protection from temperature extremes, flow extremes, low dissolved oxygen, high sediment levels, or the presence of predators, parasites, and competitors. *See, e.g.*, *id.* at 3-42 (citing Scrivener *et al.* 1994; Fraser *et al.* 1995; Curry 1997; Pires *et al.* 1999; Bradford *et al.* 2001; Cairns *et al.* 2005; Wigington *et al.* 2006; Woodford and McIntosh 2010). Headwater streams serve as a source of food materials such as insects, larvae, and organic matter to nourish the fish, mammals, amphibians, and other organisms in downstream streams, rivers, and lakes. *See, e.g.*, *id.* at 4-22, 3-30, 3-31 (citing Fisher and Likens 1973; Meyer 1994; Wallace *et al.* 1997; Hall and Meyer 1998; Hall *et al.* 2000; Gomi *et al.* 2002; Augspurger *et al.* 2008). Disruptions in these biological processes affect the ecological functions of the entire downstream system. *See, e.g.*, Kaplan *et al.* 1980; Vannote *et. al.* 1980. Headwater streams can help to maintain base flow in the larger rivers downstream, which is particularly important in times of drought. *See, e.g.*, Science Report at 3-6, B-42, B-48 (citing Brooks and Lemon 2007; Tetzlaff and Soulsby 2008). At the same time, the network of headwater streams can regulate the flow of water into downstream waters, mitigating low flow and high flow extremes, reducing local and downstream flooding, and preventing excess erosion caused by flooding. *See, e.g.*, Levick *et al.* 2008.

iv. Human-made or Human-altered Tributaries Can Provide Functions that Restore and Maintain the Chemical, Physical, and Biological Integrity of Downstream Traditional Navigable Waters, the Territorial Seas, and Interstate Waters

Under the final rule, human-made and human-altered tributaries are jurisdictional where they meet either the relatively permanent or significant nexus standard under paragraph (a)(3), except where they are excluded under paragraph (b). As discussed in the preamble, the agencies are adding an exclusion to the final rule for ditches (including roadside ditches) excavated wholly in and draining only dry land and that do not carry a relatively permanent flow of water. Under the pre-2015 regulatory regime, such ditches were considered generally non-jurisdictional. The scientific literature indicates that structures that convey water continue to connect to and effect downstream waters, though the connectivity and effects can be different than that of natural streams. Indeed, because structures like ditches and canals can reduce water losses from evapotranspiration and seepage, such structures could enhance the extent of connectivity by more effectively conveying the water downstream. For example, ditches typically are constructed to move water off the landscape and to downstream waters more quickly, and moving that water more quickly can influence the functions that ditches perform.

Human-made and human-altered tributaries under the final rule include impoundments (which are also considered under paragraph (a)(2) of the final rule and discussed further in section III.C), ditches, canals, channelized streams, piped streams, and the like. Ditches and canals are wide-spread across the United States. Where ditches are streams that have been channelized, they would be tributaries under the final rule if they otherwise meet the provisions to be a "tributary" under paragraph (a)(3). *See* section IV.C.4 of the final rule preamble. Where ditches are constructed in natural streams, they are typically are purposely constructed to allow the hydrologic flow of the tributary to continue downstream and often straighten natural channels. Ditches can also intersect the water table, which can change the hydrological flow permanence as compared to the formerly natural stream. Human-made and human-altered tributaries, despite human manipulation, can continue to have chemical, physical, or biological connections to downstream waters supported by flow, though many of the natural functions may be lost or altered. Often-times human-made tributaries create channelized connections where they did not previously exist, such as canals that connect two rivers in different watersheds. Science Report at 1-11.

Tributary ditches and other human-made or human-altered waters can impact downstream waters individually or cumulatively with other tributaries and their adjacent wetlands. Tributary ditches and the like, as with other tributaries, can have chemical, physical, and biological connections with downstream waters that could impact those waters. Tributary ditches and canals can have perennial, intermittent, or ephemeral flow. Due to the often straightened and channelized nature of ditches, these tributaries quickly move water downstream to traditional navigable waters, the territorial seas, or interstate waters. Ditches reduce water storage on the landscape and increase conveyance, generally altering the timing of peak flows and shortening the response times to storms. Blann *et al*. 2009. Ditches, canals, and human-altered streams, like other tributaries, export sediment, nutrients, and other materials downstream and are effective at transporting water and these materials, including nitrogen, downstream. *See, e.g.*, Morris *et al*. 2014; Schmidt *et al.* 2007; Sharpley *et al.* 2007; Strock *et al*. 2007. The more effective transport reduces residence time within sediments and limits nutrient cycling. Bukaveckas 2007; Needelman *et al*. 2007; Dollinger *et al*. 2015; Morris *et al*. 2014. The greater connection to the landscape often leads to higher nutrient loads down gradient, adding to downstream eutrophication. Alexander *et al*. 2008; David *et al*. 2010. Ditches provide habitat for fish and other aquatic organisms and can seasonally serve as a refuge for native fish species and as sheltered breeding grounds. *See, e.g.*, Smiley Jr. *et al*. 2008; Colvin *et al*. 2009; Leslie *et al*. 2012. Fish and other aquatic organisms utilize canals and ditches to move to different habitats, sometimes over long distances. Rahel 2007. While ditches can have lower biodiversity than other aquatic ecosystems, they can provide habitat for species not found in larger waters. Leslie *et al*. 2012.

Human-made or human-altered tributaries can continue to have chemical, physical, and biological connections that affect the integrity of traditional navigable waters, the territorial seas, or interstate waters. Though the human-made or human-altered nature of such tributaries can change the nature of the connections, it does not eliminate them. Thus, human-made and human-altered tributaries can continue to serve some of the same functions as natural tributaries, which in turn can greatly impact downstream traditional navigable waters, the territorial seas, or interstate waters, particularly when their functional contributions to the chemical, physical, and biological conditions of such downstream waters are evaluated in the aggregate.

v. Ephemeral and Intermittent Tributaries Can Provide Functions that Restore and Maintain the Chemical, Physical, or Biological Integrity of Downstream Traditional Navigable Waters, the Territorial Seas, and Interstate Waters

Tributaries do not need to flow perennially to have a material influence on downstream traditional navigable waters, the territorial seas, or interstate waters. As described above in section I.A.iv., approximately 59% of streams across the United States (excluding Alaska) flow intermittently or ephemerally based on an analysis of National Hydrography Dataset (NHD). Science Report at 2-29 (citing Nadeau and Rains 2007). A more recent study found that ephemeral streams are undermapped or unmapped in the NHD, particularly in non-Western states, and estimated that ephemeral streams comprise 48% (range 43-56%) of stream channels by length in the conterminous United States. Fesenmyer *et al.* 2021. Compared with the humid regions of the country, stream and river networks in arid regions have a higher proportion of channels that flow ephemerally or intermittently. For example, ephemeral and intermittent streams are particularly prevalent in the arid and semi-arid Southwest, where they account for over 81% of streams. Levick *et al.* 2008; Fesenmyer *et al*. 2021. In Arizona, most of the stream channels—96% by length—are classified as ephemeral or intermittent. Despite their intermittent or ephemeral flow, these streams nonetheless perform many of the same ecological and hydrological functions documented in the scientific literature on perennial streams, through their movement of water, nutrients, and sediment to downstream waters. Levick *et al.* 2008; Science Report; Sullivan *et al*. 2019a, 2020; Fesenmyer *et al*. 2021. The importance of intermittent and ephemeral streams is documented in a 2008 peer-reviewed report by EPA's Office of Research and Development and the U.S. Department of Agriculture's Agricultural Research Service (Levick *et al*. 2008), which addresses the hydrological and ecological significance of ephemeral and intermittent streams in the arid and semi-arid Southwestern United States and their connections to downstream waters; the report is a state-of-the-art synthesis of current knowledge of the ecology and hydrology in these systems. *Id*.

Intermittent and ephemeral streams are chemically, physically, and biologically connected to downstream waters, and these connections have effects downstream. *See, e.g., id*. In some areas, stormflows channeled into alluvial floodplain aquifers by intermittent and ephemeral streams are the major source of annual streamflow in rivers. Perennial flows are not necessary for chemical connections. Periodic flows in ephemeral or intermittent tributaries can have a strong influence on biogeochemistry by connecting the channel and other landscape elements. *See, e.g.,* Report at 3-22 (citing Valett *et. al.* 2005). This episodic connection can be very important for transmitting a substantial amount of material into downstream rivers. *See, e.g., id.* (citing Nadeau and Rains 2007). Intermittent and ephemeral streams contribute to water quality in downstream traditional navigable waters, the territorial seas, and interstate waters by processing and uptaking nutrients like nitrogen. *Id.* at ES-8; Addy *et al.* 2019. Ephemeral desert streams have been shown to export particularly high sediment loadings. *See*, Science Report at 3-15 (citing Hassan 1990). Ephemeral streams can also temporarily and effectively store large amounts of sediment that would otherwise wash downstream, contributing to the maintenance of downstream water quality and productive fish habitat. *See, e.g., id.* at 3-15 to 3-16 (citing Duncan *et al.* 1987; Trimble 1999; May and Gresswell 2003). This temporary storage of sediment thus helps maintain the chemical and biologic integrity of downstream waters.

Tributaries also need not be large rivers to have a material influence on downstream waters. As discussed above, the scientific literature supports the conclusion that tributaries, including headwater streams, provide important contributions to the chemical, physical, or biological integrity of traditional navigable waters, the territorial seas, and interstate waters. Headwater tributaries, the small streams at the uppermost reaches of the tributary network, are the most abundant streams in the United States. *See, e.g., id.* at 3-4 (citing Nadeau and Rains 2007). Collectively, they help shape the chemical, physical, and biological integrity of downstream waters, and provide many of the same functions as non-headwater streams. *See, e.g., id.* at ES-2, ES-7 to ES-9, 3-1. For example, headwater streams reduce the amount of sediment delivered to downstream waters by trapping sediment from water and runoff. *See, e.g.,* Dieterich and Anderson 1998. Headwater streams shape river channels by accumulating and gradually or episodically releasing sediment and large woody debris into river channels. They are also responsible for most nutrient cycling and removal, and thus transforming and changing the amount of nutrients delivered to downstream waters. *See, e.g.,* Science Report at 3-25 (citing Peterson *et al.* 2001). A close connection exists between the water quality of these streams and the water quality of traditional navigable waters, the territorial seas, and interstate waters. *See, e.g., id.*; Ohio Environmental Protection Agency 2015. Activities such as discharging a pollutant into one part of the tributary system are well-documented to affect other parts of the system, even when the point of discharge is far upstream from the water that experiences the effect of the discharge. *See, e.g.,* National Research Council 1997; Dunnivant and Anders 2006.

The Science Report provides case studies of prairie streams and Southwest intermittent and ephemeral streams, two stream types whose jurisdictional status has been called into question post-*Rapanos*. These case studies highlight the importance of these streams to downstream waters, despite their small size and ephemeral or intermittent flow regime.

For example, the Science Report assessed the connectivity of prairie streams that drain temperate grasslands in the Great Plains physiographic region of the central United States and Canada. *Id.* at B-22 to B-37. Eventually, these streams drain into the Mississippi River or flow directly into the Gulf of Mexico or the Hudson Bay. *Id.* at 5-6, B-23. Climate in the Great Plains region ranges from semiarid to moist subhumid and intra- and interannual variation in precipitation and evapotranspiration is high. *Id.* at 5-6, B-23 to B-24 (Borchert 1950; Lauenroth *et al.* 1999; Boughton *et al.* 2010). This variation is reflected in the hydrology of prairie streams, which include ephemeral, intermittent, and perennial streamflows. *Id.* at 5-6, B-24 (citing Matthews *et al.* 1985; Matthews 1988; Brown and Matthews 1995; Sawin *et al.* 1999; Dodds *et al.* 2004; Bergey *et al.* 2008). Prairie streams are frequently subjected to the extremes of drying and flooding, and intermittent or flashy hydrology is prevalent in river networks throughout most of the Great Plains. *Id.* at B-24 (citing Matthews 1988; Zale *et al*. 1989; Poff 1996; Dodds *et al*. 2004). Prairie streams typically represent a collection of spring-fed, perennial pools and reaches, embedded within larger, intermittently flowing segments. *Id.* at B-36 (citing Labbe and Fausch 2000). Row cropping and livestock agriculture are the dominant land uses in the region, resulting in the withdrawal of water from stream channels and regional aquifers and its storage in reservoirs to support agriculture. *Id.* at 5-6, B-27 to B-28 (citing Cross and Moss 1987; Ferrington 1993; Galat *et al.* 2005; Matthews *et al.* 2005; Sophocleous 2010; Falke *et al.* 2011).

Prairie streams typically are connected to downstream waters. Like other types of streams, prairie streams present strong fluvial geomorphic evidence for connectivity to downstream waters, in that they have continuous channels (bed and banks) that make them physically contiguous with downstream waters. *Id.* at 5-6. Prairie river networks are dendritic and generally have a high drainage density, so they are particularly efficient at transferring water and materials to downstream waters. *Id.* Their pool-riffle morphology, high sinuosity, and seasonal drying, however, also enhance material storage and transformation. *Id.* The timing of connections between prairie streams and downstream waters is seasonal and therefore relatively predictable. *Id.* For example, high-magnitude floods tend to occur in late fall into later spring, although they also occur at other times during the year; this observation indicates that the magnitude of connections to downstream also varies seasonally. *Id.* at 5-6 and B-28 (citing Fausch and Bramblett 1991; Hill *et al.* 1992; Fritz and Dodds 2005).

The frequent and predictable connections between prairie streams and downstream waters have multiple physical, chemical, and biological consequences for downstream waters. Dissolved solids, sediment, and nutrients are exported from the prairie river network to downstream waters. *Id.* at 5-6. Ultimately, the expansion of the hypoxic zone in the Gulf of Mexico is a downstream consequence of cumulative nutrient loading to the Mississippi River network. *Id.* Relative to small streams and large rivers draining the moist eastern parts of the Mississippi River basin, small to midsized prairie streams deliver less than 25–50% of their nutrient load to the Gulf of Mexico. *Id.* at 5-6, B-32 (citing Alexander *et al.* 2008). Nonetheless, given the large number and spatial extent of headwater prairie streams connected to the Mississippi River, their cumulative effect contributes to downstream nutrient loading. *Id.* at 5-6, B-32.

Organisms inhabiting prairie streams have adapted to their variable hydrologic regimes and harsh physicochemical conditions via evolutionary strategies that include rapid growth, high dispersal ability, resistant life stages, fractional reproduction (*i.e.*, spawn multiple times during a reproductive season), and life cycles timed to avoid predictably harsh periods. *Id.* at 5-6, B-26 (citing Matthews 1988; Dodds *et al.* 1996b; Fausch and Bestgen 1997). Alterations in the frequency, duration, magnitude, and timing of flows —and thus hydrologic connectivity—are associated with the extinction or extirpation of species in downstream systems. *Id.* at 5-6, 3-41 (citing Morita and Yamamoto 2002; Letcher *et al.* 2007). Moreover, many fish species (*e.g.*, Arkansas River shiner, speckled chub, flathead chub) in prairie river networks require sufficient unfragmented (*i.e.*, connected) channel length with adequate discharge to keep their nonadhesive, semibuoyant eggs in suspension for incubation and early development. *Id.* at 5-6 to 5-7, B-35 (citing Cross and Moss 1987; Fausch and Bestgen 1997; Platania and Altenbach 1998; Durham and Wilde 2006; Perkin and Gido 2011). When these conditions are not met, the biological integrity of downstream waters is impaired. *Id.* at 5-7.

Human alteration of prairie river networks has affected the physical, chemical, and biological connectivity to and their consequences for downstream waters. Impoundments and water removal, through both surface flow diversions and pumping of ground-water aquifers, are common in this region. *Id.* at 5-7, B-27 to B-28 (citing Smith *et al.* 2002; Galat *et al.* 2005; Matthews *et al.* 2005; Sophocleous 2010). These activities have reduced flood magnitude and variability, altered timing, and increased predictability of flows to downstream waters. *Id.* As a result, physical, chemical, and biological connections to downstream waters have been altered. *Id.* at B-28 (citing Cross and Moss 1987; Hadley *et al.* 1987; Galat and Lipkin 2000). In addition to the altered land uses and application of nutrients and pesticides for agriculture, human alteration of the river network itself, through channelization, levee construction, desnagging, dredging, and ditching, has enhanced longitudinal connectivity while reducing lateral and vertical connectivity with the floodplain and hyporheic zone, respectively. *Id.* at 5-7. Pumping from streams and ground water has caused historically perennial river segments to regularly dry during summer months. *Id.* at 5-7, B-27 to B-28 (citing Cross and Moss 1987; Ferrington 1993; Falke *et al.* 2011). Changes to the prairie's grazing (from bison to cattle) and burning regimes increase nutrient and suspended sediment loading to downstream waters. *Id.* at 5-7. Introduced species have extirpated endemic species and altered food web structure and processes in prairie streams, thereby affecting the biological integrity of downstream waters. *Id.*

Prairie streams have significant chemical, physical, and biological connections to downstream waters, despite extensive alteration of historical prairie regions by agriculture, water impoundment, water withdrawals, and other human activities, and the challenges these alterations create for assessing connectivity. *Id.* at B-36 to B-37 (citing Matthews and Robinson 1998; Dodds *et al*. 2004). The most notable connections are via flood propagation, contaminated sediment transport, nutrient retention and transformation, the extensive transport and movement of fish species (including eggs and larvae) throughout these networks, and refuges for prairie fishes. *Id.* at B-37 (citing Matthai 1969; Horowitz *et al*. 1988; Marron 1989; Dodds *et al*. 1996a; Fausch and Bestgen 1997; Platania and Altenbach 1998; Fritz and Dodds 2004; Fritz and Dodds 2005; Franssen *et al*. 2006; Alexander *et al*. 2008; Perkin and Gido 2011).

Similarly, southwestern intermittent and ephemeral streams exert strong influences on the structure and function of downstream waters, and the case study (included in the Science Report) echoes many of the findings of the functions of intermittent and ephemeral tributaries generally, which are described above. *See also* Goodrich *et al.* 2018. The case study focuses on the heavily studied San Pedro River, located in southeast Arizona, in particular, as a representative example of the hydrological behavior and the connectivity of rivers in the Southwest, but also examines evidence relevant to other Southwestern streams. *See* Science Report at B-37 to B-60.

Southwestern streams are predominantly ephemeral and intermittent (nonperennial) systems located in the southwestern United States. *Id.* at 5-7, B-37. Based on the NHD, 94%, 89%, 88%, and 79% of the streams in Arizona, Nevada, New Mexico, and Utah, respectively, are nonperennial. *Id.* (citing NHD 2008). Most of these streams connect to downstream waters, although 66% and 20% of the drainage basins in Nevada and New Mexico, respectively, are closed and drain into playas (dry lakes). *Id.* at 5-7. Southwestern streams generally are steep and can be divided into two main types: (1) mountainous streams that drain higher portions of basins and receive higher rates of precipitation, often as snow, compared to lower elevations; and (2) streams located in valley or plateau regions that generally flow in response to high-intensity thunderstorms. *Id.* at 5-7, B-39 (citing Blinn and Poff 2005). Headwater streams are common in both types of southwestern streams.

Nonperennial southwestern streams, excluding those that drain into playas, are periodically connected to downstream waters by low-duration, high-magnitude flows. *Id.* at 5-7. In contrast to streams in humid regions where discharge is typically supplemented by ground water as drainage area increases, many southwestern streams lose streamflow to channel transmission losses as runoff travels downstream. *Id.* Connection of runoff and associated materials in ephemeral and intermittent streams to downstream waters is therefore a function of distance, the relative magnitude of the runoff event, and transmission losses. *Id.*

Spatial and temporal variation in frequency, duration, and timing of southwestern stream runoff is largely explained by elevation, climate, channel substrate, geology, and the presence of shallow groundwater. *Id.* at 5-8. In nonconstraining substrate, southwestern rivers are dendritic and their watersheds tend to have a high drainage density. *Id.* When high flows are present, southwestern streams are efficient at transferring water, sediment, and nutrients to downstream reaches. *Id.*; Goodrich *et al.* 2018. Ephemeral headwater streams shape larger downstream river channels by accumulating and gradually or episodically releasing stored materials such as sediment and large woody debris.[37] These materials help structure downstream river channels by slowing the flow of water through channels and providing substrate and habitat for aquatic organisms. Due to the episodic nature of flow in ephemeral and intermittent channels, sediment and organic matter can be deposited some distance downstream, and then moved farther downstream by subsequent precipitation events. *Id.* Over time, sediment and organic matter continue to move downstream and affect downstream waters. *Id.*

The southwestern streams case study describes the substantial connection and important consequences of runoff, nutrients, and particulate matter originating from ephemeral tributaries on the integrity and sustainability of downstream perennial streams. Channel transmission losses can be an important source of ground-water recharge that sustains downstream perennial stream and riparian systems. Science Report. For example, isotopic studies indicate that runoff from ephemeral tributaries like Walnut Gulch, Arizona supplies roughly half the San Pedro River's baseflow through shallow alluvial aquifer recharge. *Id.* Important cumulative effects of tributaries—that is the incremental contributions of individual streams in combination with similarly situated tributaries—are exemplified by ephemeral stream flows in arid landscapes, which are key sources of baseflow for downgradient waters. *Id* at 1-10 (citing Schlesinger and Jones 1984; Baillie *et al*. 2007; Izbicki 2007); Goodrich *et al.* 2018.

Human alterations to southwestern river networks affect the physical, chemical, and biological connectivity to downstream waters. Impoundments trap water, sediment, and particulate nutrients and result in downstream impacts on channel morphology and aquatic function. Science Report at 5-8. Diversion of water for consumptive can decrease downstream baseflows but typically does not affect the magnitude of peak flows. *Id.* Excessive ground-water pumping can lower ground-water tables, thereby diminishing or eliminating baseflows. *Id.* Urbanization increases runoff volume and flow velocity,

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[37] Videos of ephemeral streams flowing after rain events in the Southwest highlight how effective ephemeral streams can be in transporting woody debris (*e.g.*, tree branches) and sediment downstream during the rainy season. *See, e.g.*, U.S. Department of Agriculture, Agricultural Research Service, *Multiflume Runoff Event August 1, 1990*, https://www.tucson.ars.ag.gov/unit/WGWebcam/WalnutGulchWebcam.htm; U.S. Geological Survey, *Post-fire Flash Flood in Coronado National Memorial, Arizona* (August 25, 2011), https://www.youtube.com/watch?v=qJ8JxBZt6Ws; Santa Clara Pueblo Fire/Rescue/EMS Volunteer Department, Greg Lonewolf, *#4 Santa Clara Pueblo Flash Flood Event 01 Sept 2013* (April 14, 2017), https://www.youtube.com/watch?v=nKOQzkRi4BQ; Rankin Studio, *Amazing Flash Flood / Debris Flow Southern Utah HD* (July 19, 2019), https://www.youtube.com/watch?v=_yCnQuILmsM.

resulting in more erosive energy that can cause bank erosion, streambed down-cutting, and reduced infiltration to ground water. *Id.*

Flows from ephemeral streams are one of the major drivers of the dynamic hydrology of Southwest rivers (particularly of floods during monsoon seasons). *Id.* at B-42, B-49 (citing Goodrich *et al*. 1997; Yuan and Miyamoto 2008); Goodrich *et al*. Downstream river fishes and invertebrates are adapted to the variable flow regimes that are influenced strongly by ephemeral tributary systems, which provide isolated pools as refuges for fish during dry periods. Science Report at B-57 to B-58 (citing John 1964; Meffe 1984; Labbe and Fausch 2000; Rinne and Miller 2006; Lytle *et al*. 2008). Ephemeral tributaries in the Southwest also supply water to mainstem river alluvial aquifers, which aids in the sustaining river baseflows downstream. *Id*. at B-46 (citing Goodrich *et al*. 1997; Callegary *et al*. 2007); Goodrich *et al.* 2018. Ephemeral tributaries export sediment downstream during major hydrologic events; the sediment, in turn, influences the character of river floodplains and alluvial aquifers of downstream waters. Science Report at B-47 (citing Nanson and Croke 1992; Shaw and Cooper 2008); Goodrich *et al*. 2018. The nutrient and biogeochemical integrity of downstream Southwestern rivers, such as the San Pedro River, is heavily influenced by nutrient export from ephemeral tributaries after storm flow events. Science Report at 3-25, B-48 (citing Brooks and Lemon 2007; Fisher *et al*. 2001); Goodrich *et al*. 2018. Extensive downstream river riparian communities are supported by water, sediment and nutrients exported to the river from ephemeral tributaries; these riparian communities have a profound influence on the river attributes through shading, allochthonous (originating from outside of the channel) inputs of organic matter, detritus, wood, and invertebrates to the river. Science Report at B-47 to B-48 (citing Gregory *et al*. 1991; National Research Council 2002; Naiman *et al*. 2005; Stromberg *et al*. 2005; Baillie *et al*. 2007); Goodrich *et al*. 2018.

Ephemeral streams often have physical indicators of flow, such as an ordinary high water mark. *See, e.g.*, Lichvar and McColley 2008; Mersel and Lichvar 2014. Even discontinuous ephemeral streams, or streams characterized by alternating erosional and depositional reaches (*e.g.*, channelized flow interspersed with channel fans or other depositional areas) can exhibit OHWMs, and the Corps has developed field indicators to help field staff identify OHWM in these and other common stream types in the arid West. Lichvar and McColley 2008. In addition to discontinuous ephemeral streams, the Arid West OHWM manual also looks at alluvial fans, compound channels (streams characterized by a mosaic of terraces within a wide, active floodplain and frequently shifting low-flow channel(s)), and single-thread channels with adjacent floodplains. Lichvar and McColley 2008. These arid West stream types can exhibit an OHWM. *Id.*; Lefebvre *et al.* 2013. In arid non-perennial streams, the active floodplain represents a zone that most closely fits the concept of "ordinary" stream flow for use in delineating the OHWM. Lichvar and McColley 2008; Lichvar *et al*. 2009.

Intermittent and ephemeral tributaries are distinct from erosional features like rills and gullies that typically lack a defined channel or an ordinary high water mark. Gullies are small, relatively deep channels that are ordinarily formed on valley sides and floors where no channel previously existed. They are commonly found in areas with low-density vegetative cover or with soils that are highly erodible. *See, e.g.*, Brady and Weil 2002. Rills are very small incisions formed by overland water flows eroding the soil surface during rain storms. *See, e.g.*, Leopold 1994; Osterkamp 2008. Rills are less permanent on the landscape than streams and typically lack an ordinary high water mark, whereas gullies are younger than streams in geologic age, smaller than streams in size, and also typically lack an ordinary high water mark;

time has shaped streams into geographic features distinct from gullies and rills. *See, e.g.*, American Society of Civil Engineers 1996; Osterkamp 2008. A rill is it is one of the first and smallest incisions to be formed as a result of concentrated flow eroding the land surface. *Id*. The two main processes that result in the formation of gullies are downcutting and headcutting, which are forms of longitudinal (incising) erosion. These actions ordinarily result in erosional cuts that are often deeper than they are wide, with very steep banks, often small beds, and typically only carry water during precipitation events. The principal erosional processes that modify streams are also downcutting and headcutting. In streams, however, lateral erosion is also very important. The result is that streams, except on steep slopes or where soils are highly erodible, are typically characterized by the presence of channel and an ordinary high water mark as compared to typical erosional features that are more deeply incised. It should be noted that some ephemeral streams are called “gullies” or the like in local parlance, even though they are not “gullies” in the technical sense. Such streams that meet the requirements to be jurisdictional as tributaries under paragraph (a)(3) of the final rule will be considered “waters of the United States,” regardless of the name they are given locally. Similarly, a swale is a shallow trough-like depression that carries water mainly during rainstorms or snowmelt. Science Report at A-12. A swale might or might not be considered a wetland depending on whether it meets the three-factor wetland criteria, and only wetlands that meet the definition of “waters of the United States” are considered jurisdictional. A swale does not have the defined channel, including an ordinary high water mark, that a stream exhibits.

Through evidence provided throughout the report, including case studies on intermittent and ephemeral prairie streams and arid Southwestern streams, the Science Report is clear that intermittent and ephemeral streams can have important connections and impacts on downstream waters, regardless of where they are located geographically. The functions and effects of intermittent and ephemeral streams are discussed throughout the Science Report and this document.

vi. Tributary Lakes and Ponds Can Provide Functions that Restore and Maintain the Chemical, Physical, or Biological Integrity of Downstream Traditional Navigable Waters, the Territorial Seas, or Interstate Waters

Lakes and ponds can be considered tributaries under the final rule where they are directly part of the tributary system—that is, where they are in-stream or “run of the stream” (sometimes called “in-line” lakes and ponds), including lakes and ponds that are at the headwaters of the stream network. Lakes and ponds are also considered tributaries when they are connected to the tributary system via a pipe, culvert, dam, or similar structure. This is consistent with pre-2015 practice. The agencies recognize that the SAB has previously recommended that such lakes and ponds (which are considered lentic or “still water” systems) should not be combined into the same category as streams and rivers (which are considered lotic or “moving water” systems). SAB 2014b. Lakes and ponds that are considered tributaries outlet to the tributary network and contribute flow downstream at the outlet point. Thus, the agencies believe that considering such lakes and ponds to be tributaries under the final rule is consistent with information on the contributions of flow downstream of such lakes and ponds. In addition, one of the goals of this rulemaking effort is to retain the protections of the longstanding regulatory framework, and continuing to consider in-stream lakes and ponds as tributaries is consistent with that framework. Such lakes and ponds that are tributaries to traditional navigable waters, the territorial seas, interstate waters, or jurisdictional impoundments would be considered jurisdictional where they meet either the plurality or significant nexus standard under paragraph (a)(3) of the rule.

An in-stream lake or pond can be part of the headwaters (*e.g.*, a headwater lake or pond that is directly connected to the headwater stream) or can be further downstream where, for example, a tributary flows into a lake that then flows into another tributary. Headwater and run-of-the-stream lakes and ponds serve many functions that affect the chemical, physical, and biological integrity of downstream waters. Such open waters can act as sinks, storing floodwaters, sediment, and nutrients, as these materials have the opportunity to settle out, at least temporarily, as water moves through the lake to downstream waters. *See, e.g.*, Phillips *et al.* 2011; Kalinin *et al.* 2016. The attenuation of floodwaters can also maintain stream flows downstream. Phillips *et al.* 2011. Harvey and Schmadel (2021) found that present-day in-stream lakes and ponds lengthen the water transit times through watersheds by months or even years. In addition to lengthening transit times, Harvey and Schmadel (2021) also found that the in-stream lakes and ponds moderate downstream flow variability by lowering the flow peaks exacerbated by impervious surfaces and piped and tiled drainage (citing Graf 2006; Poff *et al*. 2006; Poff *et al*. 2007; Eng *et al.* 2013). Tributary lakes and ponds often elevate and shorten the frequency of low flows. *Id.* Tributary lakes and ponds can also act as sources, contributing flow, nutrients, sediment, and other materials downstream. Total Maximum Daily Loads (TMDLs) for nutrients have been established for many in-stream lakes across the country in recognition of the ability of lakes to transport nutrients downstream, contributing to downstream impairments. *See, e.g.*, Maine Department of Environmental Protection 2006; U.S. Environmental Protection Agency 2012. Tributary lakes and ponds can also serve as habitat for species that then move downstream. For instance, brook trout that are stocked in headwater lakes in Idaho and Montana are capable of invading most downstream habitat, including through very steep channel slopes and waterfalls. Adams *et al*. 2001. These non-native species can then affect the biological integrity of downstream waters by impacting populations of native fish species, such as cutthroat trout, downstream. *See, e.g.*, Dunham *et al.* 2002. For example, non-native trout were introduced in headwater lakes to the Little Kern River in the southern Sierra Nevada and dispersed downstream, causing the near-extinction of the native Little Kern golden trout. Knapp and Matthews 2000. These studies demonstrate the ability of organisms to travel from tributary lakes and ponds to downstream waters, which is not limited to just non-native species; many other species can also move downstream and back again.

B. Adjacent Wetlands

Under the final rule, not all adjacent wetlands are jurisdictional. Adjacent wetlands are jurisdictional where they are wetlands adjacent to traditional navigable waters, the territorial seas, or interstate waters or where they are adjacent to jurisdictional impoundments or tributaries and meet either the relatively permanent or significant nexus standard. Adjacent wetlands meet the relatively permanent standard under the final rule where they have a continuous surface connection with tributaries that also meet the relatively permanent standard or with relatively permanent impoundments. Asserting Clean Water Act jurisdiction adjacent wetlands where they meet the standards in paragraph (a)(4) of the final rule aligns with the scientific literature, as well as the agencies' scientific and technical expertise and experience, which confirm that adjacent wetlands have chemical, physical, and biological effects on traditional navigable waters, the territorial seas, and interstate waters.

Adjacent wetlands serve many functions that directly influence the integrity of downstream waters including traditional navigable waters, the territorial seas, and interstate waters. Adjacent wetlands store water, which can reduce flooding of downstream waters, and the loss of adjacent wetlands has been shown, in some circumstances, to increase downstream flooding. Adjacent wetlands maintain water quality and quantity, trap sediments, store and modify potential pollutants, and provide habitat for plants and animals, thereby sustaining the biological productivity of rivers, lakes, reservoirs, and estuaries, which may be traditional navigable waters, the territorial seas, or interstate waters. The scientific literature and Science Report support these conclusions, as discussed in greater detail below.

Based on the importance of the functions that are provided by adjacent wetlands to traditional navigable waters, the territorial seas, or interstate waters, the final rule's interpretation that the Clean Water Act protects adjacent wetlands where those adjacent wetlands are adjacent to traditional navigable waters, the territorial seas, or interstate waters or where those adjacent wetlands meet either the relatively permanent standard or the significant nexus standard reflects proper consideration of the objective of the Act and the best available science.

i. Adjacent Wetlands under the Final Rule

As discussed further in section III.B.ii below, in this final rule, the agencies are retaining the definition of "adjacent" unchanged from the 1986 regulations: "*Adjacent* means bordering, contiguous, or neighboring. Wetlands separated from other waters of the United States by man-made dikes or barriers, natural river berms, beach dunes, and the like are 'adjacent wetlands.'" In addition to retaining the definition of "adjacent" from the 1986 regulations, the final rule retains the adjacent wetlands provision of the 1986 regulations, with amendments to reflect the agencies' interpretation of the statutory limits on the scope of the "waters of the United States" informed by the law, the science, and agency expertise. Aquatic resources that meet this rule's definitions of "wetlands" and "adjacent" are assessed under this provision, where such wetlands are adjacent to traditional navigable waters, the territorial seas, interstate waters, jurisdictional impoundments, and tributaries. Adjacent wetlands that would be jurisdictional under the final rule include (1) wetlands adjacent to traditional navigable waters, the territorial seas, or interstate waters; (2) wetlands adjacent to and with a continuous surface connection to relatively permanent paragraph (a)(2) impoundments or jurisdictional tributaries when the jurisdictional tributaries meet the relatively permanent standard; and (3) wetlands adjacent to paragraph (a)(2) impoundments or jurisdictional tributaries when the wetlands meet the significant nexus standard. Under this rule, the relatively permanent standard (*see* section III.B.i.2) and the significant nexus standard (*see* section III.B.i.3) are independent jurisdictional standards for wetlands adjacent to impoundments of jurisdictional waters and for wetlands adjacent to tributaries. This is consistent with the pre-2015 regulatory regime.

As discussed further in sections I.A.iv and IV.A.iii, in the final rule the agencies are retaining their longstanding definition of "wetlands" from the 1986 regulations: "Wetlands means those areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs, and similar areas." Asserting Clean Water Act jurisdiction over adjacent wetlands as outlined in paragraph (a)(4) of the final rule is supported by the scientific literature, as well as the agencies' scientific and technical expertise and experience, which confirm that such adjacent wetlands have chemical, physical, or biological effects on traditional navigable waters, the territorial seas, and interstate waters.

1. Wetlands Adjacent to Traditional Navigable Waters, the Territorial Seas, or Interstate Waters

Under the final, wetlands adjacent to traditional navigable waters, the territorial seas, or interstate waters are jurisdictional without need for further assessment. Wetlands must meet the definition of “adjacent’ in paragraph (c)(2) of the final rule, which is described in more detail in section III.B.ii below. This is consistent with the pre-2015 regulatory regime. Asserting Clean Water Act jurisdiction over wetlands adjacent to traditional navigable waters, the territorial seas, interstate waters, or aligns with the scientific literature, as well as the agencies’ scientific and technical expertise and experience, which confirm that such wetlands have chemical, physical, and biological effects on the waters to which they are adjacent, as discussed in sections III.B.iii, III.B.iv, III.B.v. For example, the scientific literature supports that wetlands within close proximity to traditional navigable waters, the territorial seas, or interstate waters improve water quality through assimilation, transformation, or sequestration of nutrients, sediment, and other pollutants that can affect water quality in such paragraph (a)(1) waters. These waters also provide important habitat for aquatic-associated species that utilize paragraph (a)(1) waters to forage, breed, and rest in.

2. Adjacent Wetlands under the Relatively Permanent Standard

Under the relatively permanent standard, wetlands that have a continuous surface connection with a tributary that meets that relatively permanent standard or with a relatively permanent impoundment are jurisdictional without the need for a significant nexus finding. The determination of whether a wetland is “adjacent” is distinct from whether an “adjacent” wetland meets the relatively permanent standard; however, wetlands that have a continuous surface connection to a relatively permanent water meet the definition of “adjacent” and thus are a subset of adjacent wetlands. Under the relatively permanent standard for adjacent wetlands, wetlands meet the continuous surface connection requirement if they physically abut, or touch, a relatively permanent paragraph (a)(2) impoundment or a jurisdictional tributary when the jurisdictional tributary meets the relatively permanent standard, or if the wetlands are connected to these waters by a discrete feature like a non-jurisdictional ditch, swale, pipe, or culvert. A natural berm, bank, dune, or similar natural landform between an adjacent wetland and a relatively permanent water does not sever a continuous surface connection to the extent it provides evidence of a continuous surface connection.

A continuous surface connection does not mean a continuous *surface water* connection and does not require surface water to be continuously present between the wetland and water to which it is adjacent. The plurality opinion indicates that “continuous surface connection” is a “physical connection requirement.” 547 U.S. at 751 n.13 (referring to “our physical-connect requirement” and later stating that *Riverside Bayview* does not reject “the physical-connection requirement”). The agencies’ approach is consistent with science, as well as the regulatory definition of “wetlands,” which does not require such aquatic resources to have water on the surface. As noted in paragraph (c)(1) of the final rule, wetlands are “those areas that are inundated or saturated by surface or groundwater at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions.” Under this longstanding definition, wetlands are not required to express water at the surface—rather, wetland hydrology may be at the subsurface, for instance where soils are saturated by groundwater during the growing season. *See also* the Corps 1987 Wetlands

Delineation manual (noting that one of the key provisions of the agencies' regulatory definition is "[i]inundated or *saturated* soil conditions resulting from permanent or periodic inundation by *groundwater* or surface" (emphasis added)). Corps 1987 at p. 6. While some wetlands are permanently or semipermanently inundated, many aquatic resources that meet the regulatory definition of "wetlands" may never have surface water (*i.e.*, have saturated soils), may only have surface water during or immediately after precipitation events (*i.e.*, are irregularly inundated), or may only have water at the surface seasonally (*i.e.*, are seasonally inundated). Since wetlands frequently do not contain surface water, a requirement for continuous surface water between a relatively permanent water and adjacent wetlands would be illogical as a scientific and practical matter.

As discussed in section III.B.ii.1, scientific literature and the agencies technical expertise supporting regulating such wetlands with a continuous surface connection to tributaries that meet the relatively permanent standard and to jurisdictional relatively permanent impoundments as "waters of the United State" under the final rule.

3. *Adjacent Wetlands under the Significant Nexus Standard*

Under the significant standard for adjacent wetlands under paragraph (a)(4)(iii), wetlands adjacent to jurisdictional impoundments or to tributaries meet the significant nexus standard when the wetlands, either alone or in combination with similarly situated waters in the region, significantly affect the chemical, physical, or biological integrity of traditional navigable waters, the territorial seas, or interstate waters. Under the significant nexus standard in the final rule, the unit of analysis for assessing adjacent wetlands is the adjacent wetland, the tributary or impoundment to which it is adjacent, and all other adjacent wetlands that are in the tributary's catchment. The tributary includes the tributary reach of the same order, as well as any tributaries that are upstream. That portion of the tributary system, plus any adjacent wetlands, would be assessed to determine whether the adjacent wetland, in combination with similarly situated waters in the region, significantly affects the chemical, physical, or biological integrity of traditional navigable waters, the territorial seas, or interstate waters. Wetlands adjacent to tributaries that meet the relatively permanent standard but that lack a continuous surface connect to such tributaries will also be assessed under the significant nexus standard, consistent with the pre-2015 regulatory regime. *See Rapanos* Guidance at 8. A determination of *adjacency* is based on an evaluation of the relationship between a wetland and the nearby jurisdictional water, which includes consideration of distance (proximity) and both physical and ecological connections between those waterbodies. In contrast, a determination of *significantly affects* is a different inquiry, which is based on evaluating whether there is a significant nexus between that adjacent wetland (in combination with similarly situated waters in the region) and a traditional navigable water, the territorial seas, or an interstate water.

As discussed in section III.B.ii, scientific literature and the agencies technical expertise supporting protecting adjacent wetlands that meet the significant nexus standard, as such wetlands, individually or in combination with similarly situated waters in the region, significantly affect the chemical, physical, or biological integrity of traditional navigable waters, the territorial seas, or interstate waters.

ii. Definition of "Adjacent" Wetlands

Under the final rule, "adjacent" means bordering, contiguous, or neighboring, including wetlands separated from other "waters of the United States" by constructed dikes or barriers, natural river berms, beach dunes and the like. Further, waters that connect segments of, or are at the head of, a stream or river are "adjacent" to that stream or river. The term "adjacent" is a policy term and is not one that is used in the scientific literature. The terms "bordering," "contiguous," and "neighboring" are discussed further below. Under this definition, adjacency is focused on the distance between the wetland and the jurisdictional water. Whether the distance between the wetland and the jurisdictional water qualifies the wetland as bordering, contiguous, or neighboring (and therefore "adjacent") depends on the factual circumstances.

For purposes of adjacency, the entire wetland is adjacent if any part of the water is bordering, contiguous, or neighboring. Thus, under the relatively permanent standard, if any portion of a wetland has a continuous surface connection with a tributary that meets the relatively permanent standard or with a jurisdictional relatively permanent impoundment, the entire wetland meets the standard and thus is considered jurisdictional under paragraph (a)(4)(ii) of the final rule. The agencies' determination that an entire wetland is adjacent if any part of the water meets the definition of "adjacent" is informed by science and the agencies technical expertise and experience and is consistent with longstanding practice. It would be artificial to separate a single wetland into an adjacent and non-adjacent portion, as the entire wetland is a single functional unit, and the agencies' longstanding practice is to treat an entire adjacent wetland as one entity.

The agencies are continuing the practice outlined in the preamble to the proposed rule, consistent with the *Rapanos* Guidance, for the three well-established factors to determine adjacency. The agencies consider wetlands to be bordering, contiguous, or neighboring, and therefore "adjacent" if at least one of following three criteria is satisfied:

(1) There is an unbroken surface or shallow sub-surface hydrologic connection to jurisdictional waters (discussed in section III.B.ii.2.a); or
(2) They are physically separated from jurisdictional waters by "man-made dikes or barriers, natural river berms, beach dunes, and the like" (discussed in section III.B.ii.2.b); or
(3) Where their proximity to a jurisdictional water is reasonably close such that "adjacent wetlands have significant effects on water quality and the aquatic ecosystem." *Riverside Bayview*, 474 U.S. at 135 n.9 (discussed in section III.B.ii.2.c).

If any one of the criteria is met, the wetland is "adjacent," but may require further analysis to determine if it meets the definition of "waters of the United States." *See Rapanos* Guidance at 5-8.

The agencies have determined that the longstanding regulation properly defines the term "adjacent" for purposes of the Clean Water Act because it is based on the concept of both reasonable proximity and scientific connections. Based on the scientific literature and the agencies' technical expertise and experience, as discussed further in the sections below, the agencies' longstanding definition of "adjacent" is supported by the science. This includes the terms to define "adjacent," "bordering, contiguous, or neighboring," including wetlands separated from other jurisdictional waters by man-made dikes or barriers, natural river berms, beach dunes, and the like. Wetlands that meet the definition of "adjacent' are physically proximate to and integrated with the water to which they are adjacent and, in turn, can individually or cumulatively affect the chemical, physical, or biological integrity of traditional navigable waters, the territorial seas, or interstate waters. The agencies have also determined that the longstanding implementation criteria for adjacency are supported by the science and the agencies' technical expertise and experience. The three criteria are well-established, are based on scientific principles about the relationship of wetland to the water to which it is adjacent, and complement the regulatory definition of "adjacent." Such wetlands that meet one of the three criteria can provide functions that significantly affect the chemical, physical, and biological integrity of traditional navigable waters, the territorial seas, and interstate waters.

1. Bordering, Contiguous, or Neighboring Wetlands

The final rule continues to include wetlands that are bordering, contiguous, or neighboring within the definition of "adjacent," consistent with the current regulatory regime and the agencies' longstanding definition that existed prior to the 2020 NWPR. Within the definition of "adjacent," the terms bordering and contiguous are well understood. For continuity and clarity, the agencies will continue to interpret and implement the terms "bordering, contiguous, or neighboring" consistent with the current policy and practice. The science demonstrates that bordering, contiguous, or neighboring wetlands are integrated with the water to which they are adjacent and can affect the chemical, physical, or biological integrity of traditional navigable waters, the territorial seas, or interstate waters.

Wetlands that are bordering, contiguous, or neighboring wetlands include wetlands with an unbroken surface or shallow subsurface connection to jurisdictional waters; wetlands separated by constructed dikes or barriers, natural river berms, beach dunes, and the like; and wetlands within reasonably close proximity to other jurisdictional waters. This can include wetlands in the floodplain or the riparian area, wetlands that are outside of the floodplain or riparian area, run-of-the-stream wetlands, headwater wetlands, wetlands with a continuous surface connection to jurisdictional waters, wetlands behind a natural berm or similar natural landform, and wetlands behind artificial levees and similar artificial features, amongst others. Wetlands that are bordering or contiguous often directly abut the water which they are adjacent. (*e.g.*, they are not separated by uplands, an artificial dike, or similar artificial feature). *See, e.g.*, U.S. Army Corps of Engineers 2007a. Neighboring wetlands may or may not have a continuous surface connection to the waters to which they are adjacent, but science still demonstrates that they individually or cumulatively provide important functions that can impact on the chemical, physical, and biological integrity of traditional navigable waters, the territorial seas, and interstate waters.

As discussed further below, wetlands that are bordering, contiguous, or neighboring perform a myriad of critical chemical, physical, and biological functions that affect the integrity of traditional navigable waters, the territorial seas, or interstate waters. Such wetlands are integrally linked with the jurisdictional waters to which they are adjacent. Because of their close physical proximity to nearby jurisdictional waters, bordering, contiguous, or neighboring wetlands readily exchange their waters through the saturated soils surrounding the jurisdictional water or through surface exchange. This commingling of waters allows bordering, contiguous, or neighboring wetlands to both provide chemically transformed waters to streams and to absorb excess stream flow, which in turn can significantly affect traditional navigable waters, the territorial seas, or interstate waters. The close proximity also allows for the direct exchange of biological materials, including organic matter that serves as part of the food web of traditional navigable waters, the territorial seas, or interstate waters.

As previously discussed, “adjacent” is a policy term and not one found in the scientific literature. Similarly, “bordering, contiguous, or neighboring” are not terms found readily in the scientific literature regarding the relationship of a wetland to the tributary system. However, the agencies’ technical expertise and experience support that bordering or contiguous wetlands are generally but not always found with the riparian area or floodplain. In addition, neighboring waters can also be located within the floodplain or a riparian area. Though this section addresses how bordering, contiguous, or neighboring wetlands can affect the chemical, physical, and biological integrity of traditional navigable waters, the territorial seas, and interstate waters, largely drawing from the scientific literature regarding waters in the floodplain or riparian area, the discussion of wetlands located outside the floodplain or riparian area used throughout this document, where appropriate and applicable, can also be used to support the agencies’ determination that “bordering, contiguous, or neighboring” wetlands that meet the criteria to be jurisdictional under paragraph (a)(4) of the final rule should be considered “waters of the United States.”

The scientific literature supports that “bordering, contiguous, or neighboring” wetlands located in riparian areas and floodplains are chemically, physically, and biologically connected to downstream traditional navigable waters, the territorial seas, or interstate waters and affect the integrity of such waters. The Science Report concludes that wetlands located in “riparian areas and floodplains are physically, chemically, and biologically integrated with rivers via functions that improve downstream water quality, including the temporary storage and deposition of channeling-forming sediment and woody debris, temporary storage of local ground water that supports baseflow in rivers, and transformation and transport of stored organic matter.” Science Report at ES-2 to ES-3. Such waters act as the most effective buffer to protect downstream waters from nonpoint source pollution (such as nitrogen and phosphorus), provide habitat for breeding fish and aquatic insects that also live in streams, and retain floodwaters, sediment, nutrients, and contaminants that could otherwise negatively impact the condition or function of downstream waters.

Bordering, contiguous, or neighboring wetlands that are in the riparian area or floodplain lie within landscape settings that have bidirectional hydrological exchange with the waters to which they are adjacent. *Id.* at 2-7. Such wetlands play an integral role in the chemical, physical, and biological integrity of the waters to which they are adjacent and to traditional navigable waters, the territorial seas, or interstate waters. Riparian areas and floodplains often describe the same geographic region. *Id.* at 2-5. Therefore, the discussion of the functions of wetlands in riparian areas will typically apply to floodplains unless otherwise noted. Where connections arise specifically from the act of inundation of adjoining land during times of higher-than-normal water, the term “floodplain” is solely used to describe the area.

Riparian areas are transition zones between terrestrial and aquatic ecosystems that are distinguished by gradients in biophysical conditions, ecological processes, and biota. *Id.* at 2-4. Like riparian areas, wetlands are also transitional areas between terrestrial and aquatic ecosystems. Wetlands are often but not always found in riparian areas, but not all of the riparian area is a wetland. As noted in paragraph (c)(1) of the final rule, from a Clean Water Act regulatory perspective, wetlands are those areas that are inundated or saturated by surface or groundwater at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Only those wetlands that meet the provisions of paragraphs (a)(1) through (a)(5) of this final rule will be considered “waters of the United States.” Wetlands in riparian areas significantly influence exchanges of energy and matter with aquatic ecosystems. *See, e.g., id.* (citing National Research Council 2002).

As discussed in section I.A.iv, floodplains are low areas bordering streams, rivers, lakes, and impoundments and are inundated during moderate to high water events. *Id.* (citing Leopold 1994; Osterkamp 2008). Floodplains are also considered riparian areas, but not all riparian areas have floodplains. *Id.* at 2-5. Similar to riparian areas, wetlands are often but not always found in floodplains, but not all of the floodplain is a wetland. All rivers and streams within river networks have riparian areas, but small streams in constrained valleys are less likely to have floodplains than larger streams and rivers in unconstrained valleys. *Id.*

Wetlands, like open waters, are considered in-stream or "run-of-the-stream" where they are directly part of the tributary system. For example, an in-stream wetland can be part of the headwaters (*e.g.*, a headwater wetland) or can be further downstream where, for example, a tributary flows into a wetland that then flows into another tributary. For bordering, contiguous, or neighboring wetlands that are run-of-the-stream wetlands, the fact that such wetlands are in-stream often enhances their ability to filter pollutants and contaminants that would otherwise make it downstream; in-stream wetlands also attenuate floodwaters during wet periods and provide important sources of baseflow downstream during dry periods. *See, e.g.*, *id.* at 4-21 (citing Morley *et al.* 2011).

One type of wetland often located in-stream are wetlands that are connected to the river network through a channel (*e.g.*, wetlands that serve as stream origins). These are wetlands from which a stream channel originates. Science Report at 4-2. Where these wetlands directly flow into jurisdictional waters, they are bordering, contiguous, or neighboring, and they meet the implementation criteria for a continuous surface connection. Because these adjacent wetlands are often located at the headwaters, the stream to which they are adjacent may not be large enough to have a floodplain (*e.g.*, they may lie at the hillslope or in high gradient areas), and thus in such circumstances they are generally non-floodplain wetlands (however, some stream-origin wetlands can be located within the floodplain or riparian area). They are part of the stream network itself, and along with first- and second-order streams, form the headwaters of the river network. Such bordering, contiguous, or neighboring wetlands have a direct hydrologic connection to the tributary network via unidirectional flow from the wetland to the headwater stream.

Wetlands that serve as stream origins connect via perennial, intermittent, or ephemeral drainages to river networks. *Id.* at 4-21 (citing Rains *et al*. 2006; Rains *et al*. 2008; Morley *et al*. 2011; McDonough *et al.* 2015). Regardless of the permanence of flow, such wetlands have an impact on downstream waters. *Id.* at 4-2, 4-40. Wetland seeps, for example, can form where groundwater discharges from breaks in slope. *Id.* at 4-20 (citing Hall *et al*. 2001; O'Driscoll and DeWalle 2010). They often have perennial connections to the stream, providing important sources of water downstream, particularly during summer baseflow. *Id.* at 4-21 (citing Morley *et al*. 2011). In Maine, for example, seeps were found to provide 40 to 80% of stream water during baseflow periods. *Id*. In other cases, surface connections between channel origin wetlands and streams are intermittent or ephemeral. In addition to surface water connections, groundwater flow can hydrologically connect wetlands that serve as stream origins with the stream network. *Id.* at 4-22.

Wetlands at the channel origin generally have chemical, physical, and biological effects on traditional navigable waters, the territorial seas, or interstate waters, including hydrologic, water quality, and habitat functions, regardless if the outflow from the wetland to the stream is perennial, intermittent, or ephemeral. *Id.* Like other wetlands, wetlands that serve as stream origins can transport channel-forming sediment and woody debris, transport stored organic matter, remove and transform pollutants and excess nutrients such as nitrogen and phosphorus, attenuate and store floodwaters, contribute to stream baseflow through groundwater recharge, and provide habitat for breeding fish, amphibians, reptiles, birds, and other aquatic and semi-aquatic species that move from the wetlands to the river network. *Id*. at 4-40, 4-42. In some cases, however, where wetlands that serve as stream origins are already saturated prior to rainfall, they can convey stormwater quickly downstream and thus actually increase flood peaks. *Id.* (citing Bullock and Acreman 2003). This is because the wetland soil, if completely saturated, cannot store any additional water, making the wetland unable to store floodwater. *Id.*

Bordering, contiguous, or neighboring wetlands, including wetlands that serve as stream origins, have important chemical, physical, and biological connections downstream that affect traditional navigable waters, the territorial seas, and interstate waters. Where they have a direct hydrologic connection to the stream network, that connection facilitates the impact they have downstream. This impact on downstream waters occurs regardless of whether their connection to the tributary network is perennial, intermittent, or ephemeral. Thus, bordering, contiguous, or neighboring wetlands serve important functions, which in turn can impact traditional navigable waters, the territorial seas, and interstate waters, particularly when their functional contributions to the chemical, physical, or biological conditions of downstream waters are combined at a catchment or watershed scale.

Bordering, contiguous, or neighboring wetlands can include those wetlands located outside the riparian area or floodplain. Such wetlands include wetlands with an unbroken surface or shallow subsurface connection to jurisdictional waters (particularly when the connection is via a discrete feature like a non-jurisdictional ditch, swale, pipe, or culvert or via an unbroken shallow subsurface connection), wetlands separated from a jurisdictional water by a natural berm or the like or by a constructed levee or the like, and wetlands within reasonably close proximity of a jurisdictional water. The science and the agencies' technical expertise and experience support implementing the definition of "adjacent" to include such wetlands, and such wetlands are integrated with the water to which they are adjacent and can provide functions that significantly affect the chemical, physical, and biological integrity of traditional navigable waters, the territorial seas, and interstate waters.

Wetlands with an unbroken surface or shallow subsurface connection to other jurisdictional waters are "bordering, contiguous, or neighboring." As discussed further in section III.B.ii.2.a below, the science and the agencies' technical expertise and experience support implementing the definition of "adjacent" to include such wetlands, and such wetlands are integrated with the water to which they are adjacent and can provide functions that significantly affect the chemical, physical, and biological integrity of traditional navigable waters, the territorial seas, and interstate waters.

Wetlands separated from other "waters of the United States" by man-made dikes or barriers, natural river berms, beach dunes, and the like are "bordering, contiguous, or neighboring" and thus "adjacent" under the final rule, consistent with the agencies' longstanding definition of "adjacent." As discussed further in section III.B.ii.2.b. below, the science and the agencies' technical expertise and experience support including such wetlands in the definition of "adjacent," and such wetlands can provide functions that significantly affect the chemical, physical, and biological integrity of traditional navigable waters, the territorial seas, and interstate waters.

Wetlands within reasonably close proximity of jurisdictional waters are "bordering, contiguous, or neighboring." The agencies have always recognized that adjacency is bounded by proximity. In addition, the science is clear that a wetland's proximity to downstream waters influences its impact on those waters. The Science Report states, "[s]patial proximity is one important determinant of the magnitude, frequency and duration of connections between wetlands and streams that will ultimately influence the fluxes of water, materials and biota between wetlands and downstream waters." *Id.* at ES-11. Generally, wetlands that are closer to a jurisdictional water are more likely to be connected to that water than wetlands that are farther away. As discussed further in section III.B.ii.2.c below, the science and the agencies' technical expertise and experience support implementing the definition of "adjacent" to include such wetlands. "Bordering, contiguous, or neighboring" wetlands that are within close proximity of the jurisdictional water are integrated with the water to which they are adjacent and can have significant chemical, physical, and biological connections with and effects on traditional navigable waters, the territorial seas, or interstate waters.

Based on a review of the scientific literature and the agencies' technical expertise and experience, the final rule continues the longstanding interpretation in regulations predating the 2020 NWPR that wetlands that are "bordering, contiguous, or neighboring" to other jurisdictional waters are "adjacent," including wetlands separated from other jurisdictional waters by man-made dikes or barriers, natural river berms, beach dunes, and the like. Under the final rule, adjacent wetlands are jurisdictional when they are adjacent to a traditional navigable water, the territorial seas, or an interstate water, and where they are adjacent to jurisdictional tributaries and jurisdictional impoundments and meet either the relatively permanent standard or the significant nexus standard as described in paragraph (a)(4).

2. Determination of Adjacent Wetlands

As with the proposed rule, the final rule will continue the well-established practice outlined in the *Rapanos* Guidance for the three criteria to determine adjacency. First, there is an unbroken surface or shallow subsurface connection to jurisdictional waters; this hydrologic connection maybe intermittent. Second, the wetlands are physically separated from jurisdictional waters by human-made dikes or barriers, natural river berms, beach dunes, and the like (discussed in section III.B.ii.2.b). Or third, their proximity to a jurisdictional water is reasonably close such that "adjacent wetlands have significant effects on water quality and the aquatic ecosystem." *Riverside Bayview*, 474 U.S. at 135 n.9. *See also Rapanos* Guidance at 5-6. Wetlands that adjacent will need to meet one of these under the factors under the final rule and are "bordering, contiguous, or neighboring." Such wetlands would then be assessed under paragraph (a)(4) to determine if they are "waters of the United States" under the final rule. These longstanding criteria are derived from the regulatory definition of "adjacent," and the science, along with the agencies' technical and expertise, supports including such wetlands in the definition of "adjacent." As discussed further below in this section, such wetlands can provide functions that significantly affect the chemical, physical, and biological integrity of traditional navigable waters, the territorial seas, and interstate waters.

a. Wetlands with an Unbroken Surface or Shallow Subsurface Connection

Adjacent wetlands under the final rule include wetlands with an unbroken surface or shallow subsurface connection. Wetlands that meet the relatively permanent standard will always meet this criterion, as they have a continuous surface connection to the jurisdictional water to which they are adjacent. An unbroken surface or shallow subsurface connection can be established, for example, where the wetland directly abuts the jurisdictional water or by a non-jurisdictional physical feature that provides the direct connection between the wetland and a jurisdictional water, such as a pipe, culvert, non-jurisdictional ditch, or flood gate, that has at least periodic flow. Under the final rule, an unbroken surface connection includes but is not limited to surface hydrologic connections, including confined surface hydrologic connections.

An unbroken surface or shallow subsurface hydrologic connection to jurisdictional waters may be established by a physical feature or discrete conveyance that supports periodic flow between the wetland and a jurisdictional water, such as a pipe, culvert, non-jurisdictional ditch, or flood gate. Water does not have to be continuously present in this hydrologic connection and the flow between the wetland and the jurisdictional water may move in either or both directions. The hydrologic connection need not itself be a jurisdictional water.

Both confined surface and shallow subsurface connections are forms of direct hydrologic connections between adjacent wetlands and the waters to which they are adjacent. Confined surface connections consist of permanent, intermittent, or ephemeral surface connections through directional flowpaths, such as (but not limited to) swales, gullies, rills, and ditches. In some cases, these connections will be a result of "fill and spill" hydrology, but only where such a surface connection is unbroken. A directional flowpath is a path where water flows repeatedly from the wetland to the nearby jurisdictional water that at times contains water originating in the adjacent wetland as opposed to just directly from precipitation.

A shallow subsurface hydrologic connection is lateral water flow through a shallow subsurface layer, such as may be found in steeply sloping forested areas with shallow soils, soils with a restrictive horizon, or in karst systems. Devito *et al.* 1996; O'Driscoll and Parizek 2003; Cook and Hauer 2007. A shallow subsurface connection also exists, for example, when the adjacent wetland and the water to which it is adjacent are in contact with the same shallow aquifer (*e.g.*, an alluvial aquifer) or with the same shallow water table which fluctuates within the soil profile, sometimes rising to or near the ground surface. In addition, water can move within confined human-made subsurface conveyance systems such as drain tiles and storm sewers (Science Report at 3-3 and 4-24 (citing Schiller *et al*. 2012)), and within natural subsurface conveyance systems such as karst topography or lava tubes (s*ee, e.g.*, Miller *et al*. 2013; O'Driscoll and Parizek 2003; U.S. EPA 2002). Shallow subsurface connections may be found below the ordinary root zone (below 12 inches), where other wetland delineation factors may not be present. A combination of physical factors may reflect the presence of a shallow subsurface connection, including, position in the landscape (for example, on a slope directing flow from wetland to jurisdictional waters), stream hydrograph, and soil surveys (for example, exhibiting indicators of high transmissivity over an impermeable layer), and information indication that the water table in the stream is lower than in the shallow subsurface.

Shallow subsurface connections are distinct from deeper groundwater connections, which do not satisfy the requirement for adjacency, in that the former exhibit a direct connection to the water found on the surface in wetlands. While they may provide the connection establishing jurisdiction, these shallow subsurface flows are not "waters of the United States."

The Science Report supports that the functions of non-floodplain wetlands clearly affect the condition of downstream waters if a visible (*e.g.*, channelized) surface-water or a regular shallow subsurface-water connection to the river network is present. Science Report at ES-3. The SAB also noted the importance of shallow subsurface connections and stated, "[t]he available science…shows that groundwater connections, particularly via shallow flow paths in unconfined aquifers, can be critical in support the hydrology and biogeochemical functions of wetlands and other waters." SAB 2014b. For non-floodplain wetlands connected through ground-water flows, less distant areas are generally connected through shallower flowpaths, assuming similar soil and geologic properties. *Id.* at 2-39. These shallow subsurface flows have the greatest interchange with surface waters and travel between points in the shortest amount of time. *Id.* Water can move within confined man-made subsurface conveyance systems such as drain tiles and storm sewers, and in karst topography. *See, e.g.*, Miller *et al*. 2013; O'Driscoll and Parizek 2003; U.S. EPA 2002. Confined subsurface systems can move water, and potential contaminants, directly to surface waters rapidly without the opportunity for nutrient or sediment reduction along the pathway. Science Report at 3-28; 4-24 (citing Royer *et al.* 2004). Shallow subsurface connections move quickly through the soil and impact surface water directly within hours or days rather than the years it may take long pathways to reach surface waters. The Science Report refers to local groundwater flow or shallow groundwater flow, which is a type of shallow subsurface connections. *Id.* at 2-11. Such shallow subsurface connections flow from the highest elevations of the water tables to nearby lowlands or surface waters. *Id.* (citing Winter and LaBaugh 2003). These are dynamic hydrologic connections that have the greatest interchange with surface waters. *Id.* The presence of a confining layer near the surface also leads to shallow subsurface flows through the soil. *Id.* at 2-34.

Asserting Clean Water Act jurisdiction over adjacent wetlands with an unbroken surface or shallow subsurface connection to jurisdictional waters where they are adjacent to traditional navigable waters, the territorial seas, or interstate waters, or where they meet either the relatively permanent or significant standard, aligns with the scientific literature, as well as the agencies' scientific and technical expertise and experience, which confirm that such wetlands have chemical, physical, and biological effects on downstream traditional navigable waters, the territorial seas, and interstate waters.

b. Wetlands Separated by Constructed Dikes or Barriers, Natural River Berms, Beach Dunes, and the Like

Wetlands separated from other "waters of the United States" by constructed dikes or barriers, natural river berms, beach dunes and the like are adjacent under the final rule, which is consistent with the pre-2015 regulatory regime and continued from the regulatory definition of "adjacent" that existed prior to the 2020 NWPR. This has been a longstanding part of the concept of adjacency under the agencies' regulations defining "waters of the United States" (except in the 2020 NWPR), and the agencies are restoring their longstanding definition of "adjacent." Including wetlands behind certain natural features or artificial barriers as adjacent wetlands is also consistent with Justice Kennedy's opinion, which noted the important functions that such wetlands can play: "In many cases, moreover, filling in wetlands separated from another water by a berm can mean that floodwater, impurities, or runoff that would have been stored or contained in the wetlands will instead flow out to major waterways. With these concerns in mind, the Corps' definition of adjacency is a reasonable one, for it may be the absence of an interchange of waters prior to the dredge and fill activity that makes protection of the wetlands critical to the statutory scheme." *Rapanos*, 547 U.S. at 775.

If a wetland is separated from a jurisdictional water by man-made dikes or barriers, natural river berms, beach dunes, and the like, then the wetlands adjacent under this rule, consistent with the 1986 regulations. Waters separated by constructed dikes or barriers, natural river berms, beach dunes, and the like are considered bordering, contiguous, or neighboring, and the presence of the artificial barrier or natural landform does not affect their adjacency. No additional identification of a hydrologic connection between the wetland and the jurisdictional water is required for such wetlands to be considered adjacent. For example, a wetland that is separated from a jurisdictional tributary simply by a 40-foot road meets the longstanding definition of adjacent. With respect to beach dunes and similar natural landforms like river berms, more than one dune may exist between an adjacent wetland and jurisdictional water (including primary and secondary dunes), because beach dunes typically function as an interdunal system (particularly on barrier islands). For example, interdunal wetlands which are located between dune ridges would be adjacent. Similarly, more than one natural river berm may exist between an adjacent wetland and a jurisdictional water because such natural river berms were formed as a system in the floodplain due to overbank flooding of the river and typically function as a system. Thus, more than one natural river berm may exist between an adjacent wetland and the jurisdictional water.

In some cases, a wetland may be separated from a jurisdictional water by more than one human-made dike or barrier or multiple types of barriers and landforms (*e.g.*, a wetland separated by a human-made barrier and a natural river berm). The agencies will assess such wetlands consistent with the other adjacency criteria previously described (*i.e.*, by identifying the presence of an unbroken surface or shallow subsurface connection or determining that their proximity to a jurisdictional water is reasonably close).

Under the final rule, such wetlands adjacent to traditional navigable waters, the territorial seas, or interstate waters are jurisdictional under paragraph (a)(4)(i). Such wetlands that are adjacent to tributaries or impoundments would likely require a significant nexus analysis under paragraph (a)(4)(iii) of the final rule, with the exception of wetlands behind natural landforms where the river berm, beach dune, or the like serves as an indication of a continuous surface connection and wetlands behind artificial barriers or natural landforms that maintain a continuous surface connection to relatively permanent impoundments or tributaries, such as through a culvert, flood gate, or break in the dam, beach dune, or levee. Such wetlands with a continuous surface connection to relatively permanent waters would be evaluated under paragraph (a)(4)(ii) of the final rule. Asserting Clean Water Act jurisdiction over adjacent wetlands separated from other jurisdictional waters by constructed dikes or barriers, natural river berms, beach dunes and the like, where the wetlands meet the standards in paragraph (a)(4) of the final rule, aligns with the scientific literature, as well as the agencies' scientific and technical expertise and experience, which confirm that such wetlands have chemical, physical, and biological effects on traditional navigable waters, the territorial seas, and interstate waters.

If uplands separating a wetland from jurisdictional water can reasonably be characterized as "man-made dikes or barriers, natural river berms, beach dunes, and the like," then, under the final rule, the wetlands are adjacent even if no apparent hydrologic connection exists. The terms earthen dam, dike, berm, and levee are used to describe similar structures whose primary purpose is to help control flood waters. Such structures vary in scale and size. A levee is an embankment whose primary purpose is to furnish flood protection from seasonal high water and which is therefore subject to water loading for periods of only a few days or weeks a year. Earthen embankments that are subject to water loading for prolonged periods (longer than normal flood protection requirements) are called earth dams. There are a wide variety of types of structures and an even wider set of construction methods. These range from a poorly constructed, low earthen berm pushed up by a backhoe to a well-constructed, impervious core, riprap lined levee that protects houses and cropland. Generally, levees are built to detach the floodplain from the channel, decreasing overbank flood events. Franklin *et al*. 2009. The investigation methods to determine the presence or absence of the hydrologic connection depend on the type of structure, the underlying soils, the presence of groundwater, and the depth of the water table. U.S. Army Corps of Engineers 2000 at 1-1.

Barriers between wetlands and jurisdictional waters have been constructed for centuries (*see, e.g.*, National Geographic Society 2022 ("As early as 2500 BCE, the Indus Valley Civilization, with urban centers in what is today Mohenjo Daro and Harappa, Pakistan, used levees to protect land near the Indus River" and "Since the 18th century, levees have protected Louisiana and other nearby states from flooding by the Mississippi River")). Human-made berms and the like are fairly common along streams and rivers across the United States and often accompany stream channelization. Franklin *et al*. 2009; Morrison *et al*. 2018. One study conducted in Portland, Oregon found that 42% of surveyed wetlands had dams, dikes, or berms. Kentula *et al*. 2004. Likewise, over 90% of the tidal freshwater wetlands of the Sacramento-San Joaquin Delta have been diked or leveed. Simenstad *et al*. 1999. At least 40,000 kilometers of levees, floodwalls, embankments, and dikes are estimated across the United States, with approximately 17,000 kilometers (more than 10,000 miles) of levees in the Upper Mississippi Valley alone. Gergel *et al*. 2002.

Adjacent wetlands separated from the tributary network by dikes, levees, berms, and the like typically continue to have a hydrologic connection to the jurisdictional waters to which they are adjacent. This is because berms and similar features typically do not block all water flow. Indeed, even dams, which are specifically designed and constructed to impound large amounts of water effectively and safely, do not prevent all water flow, but rather allow seepage under the foundation of the dam and through the dam itself. *See, e.g.,* International Atomic Energy Agency 2003; U.S. Bureau of Reclamation; Federal Energy Regulatory Commission 2005.

Seepage is the flow of a fluid through the soil pores. Seepage through a dam, through the embankments, foundations or abutments, or through a berm is a normal condition. Kovacic *et al*. 2000; Federal Energy Regulatory Commission 2005. This is because water seeks paths of least resistance through the berm or dam and its foundation. Association of State Dam Safety Officials 2021. All earth and rock-fill dams are subject to seepage through the embankment, foundation, and abutments. U.S. Army Corps of Engineers 1993; U.S. Army Corps of Engineers 2004. Concrete gravity and arch dams similarly are subject to seepage through the foundation and abutments. U.S. Army Corps of Engineers 1993. Levees and the like are subject to breaches and breaks during times of floods. Nilsson *et al*. 2005.

Levees are similarly subject to failure in the case of extreme events, such as the extensive levee failures caused by Hurricanes Katrina and Rita. Day *et al*. 2007. In designing levees and similar structures, seepage control is necessary to prevent possible failure caused by excessive uplift pressures, instability of the downstream slope, piping through the embankment and/or foundation, and erosion of material by migration into open joints in the foundation and abutments. *Id.*; Kovacic *et al*. 2000; U.S. Bureau of Reclamation; International Atomic Energy Agency 2003; California Division of Safety of Dams 1993.

The rate at which water moves through the embankment depends on the type of soil in the embankment, how well it is compacted, the foundation and abutment preparation, and the number and size of cracks and voids within the embankment. All but the smallest earthen dams are commonly built with internal subsurface drains to intercept water seeping from the reservoir (*i.e.*, upstream side) to the downstream side. U.S. Army Corps of Engineers 1995. Where it is not intercepted by a subsurface drain, the seepage will emerge downstream from or at the toe of the embankment. Association of State Dam Safety Officials 2021. Seepage may vary in appearance from a “soft,” wet area to a flowing “spring.” It may show up first as an area where the vegetation is lush and darker green. Cattails, reeds, mosses, and other marsh vegetation may grow in a seepage area. *Id*.

Engineered berms are typically designed to interfere with the seasonal pattern of water level (hydroperiod) of the area behind the berm, reducing the frequency and severity of inundation. Berms are not designed to eliminate all hydrologic connection between the channel on one side and the area behind the berm on the other. It is almost always impracticable to build a berm that will not be overtopped by a flood of maximum severity, and most berms are not designed to withstand severe floods. *See, e.g.,* U.S. Army Corps of Engineers 1993. Levees are designed to allow seepage and are frequently situated on foundations having natural covers of relatively fine-grain impervious to semipervious soils overlying pervious sands and gravels. U.S. Army Corps of Engineers 2005a. These surface strata constitute impervious or semipervious blankets when considered in connection with seepage. Principal seepage control measures for foundation underseepage are (a) cutoff trenches, (b) riverside impervious blankets, (c) landslide berms, (d) pervious toe trenches, and (e) pressure relief wells. U.S. Army Corps of Engineers 2000. Overtopping of an embankment dam is very undesirable because the embankment materials may be eroded away. Additionally, only a small number of concrete dams have been designed to be overtopped. Water normally passes through the main spillway or outlet works; it should pass over an auxiliary spillway only during periods of high reservoir levels and high water inflow. All embankment and most concrete dams have some seepage. *See, e.g.,* Texas Commission on Environmental Quality 2006. However, it is important to control the seepage to prevent internal erosion and instability. Proper dam construction, and maintenance and monitoring of seepage provide control.

It is important to note that natural river berms are formed by sediment deposits accumulating at or near the stream bank during flood events. Such berms vary in height from inches to feet, and also can be quite wide. Wharton *et al.* 1982. Berm-like landforms known as natural levees occur naturally and do not isolate adjacent wetlands from the streams that form them. Hydrologic connections can be bidirectional across berms or other similar features when integrated over time during and after floods when the hydraulic or hydrostatic gradient changes direction. Natural levees and the wetlands and waters behind them are part of the floodplain, including along some small streams and streams in the arid West. Johnston *et al*. 2001. Every flowing watercourse transports not only water, but sediment—eroding and rebuilding its banks and floodplains continually. Federal Interagency Stream Restoration Working Group

1998. Different deposition patterns occur under varying levels of streamflow, with higher flows having the most influence on the resulting shape of streambanks and floodplains. *Id*. In relatively flat landscapes drained by low-gradient streams, this natural process deposits the most sediment on the bank immediately next to the stream channel while floodplains farther from the channel are usually lower-lying wetlands ("backswamps" or "backwater wetlands") that receive less sediment. *See, e.g.,* Johnston *et al*. 1997. The somewhat elevated land thus built up at streamside is called a natural levee, and this entirely natural landform is physically and hydrologically similar to narrow, human-made berms. *See, e.g.,* Leopold *et al*. 1964. Natural levees are discontinuous, which allows for a hydrologic connection to the stream or river via openings in the levees and thus the periodic mixing of river water and backwater. Johnston *et al*. 2001. Such discontinuities in natural levees can contribute to a continuous surface connection that is sufficient to satisfy the requirements for jurisdiction of wetlands adjacent to relatively permanent impoundments or tributaries under paragraph (a)(4)(ii) of the final rule. In addition, streams with natural levees, in settings with no human interference whatsoever, retain hydrologic connection with their wetlands behind the levees by periodic flooding during high water and via seepage through and under the levee. Similarly, human-made berms are typically periodically overtopped with water from the near-by stream, and as previously mentioned, are connected via seepage.

Wetlands separated from a stream by a natural or human-made berm serve many of the same functions as those discussed above on other adjacent wetlands. Furthermore, even in cases where a hydrologic connection may not exist, there are other important considerations, such as chemical and biological factors, that result in important connections between the adjacent wetlands and the nearby "waters of the United States," that affect downstream waters.

The movement of surface and subsurface water both over berms and through soils and berms adjacent to rivers and streams is a hydrologic connection between wetlands and flowing watercourses. The intermittent connection of surface waters over the top of, or around, natural and human-made berms further strengthens the evidence of hydrologic connection between wetlands and flowing watercourses. Both natural and human-made barriers can be topped by occasional floods or storm events. *See, e.g.,* Turner *et al.* 2006; Keddy *et al*. 2007. When berms are periodically overtopped by water, wetlands and waters behind the barriers are directly connected to and interacting with the nearby stream and its downstream waters. In addition, surface waters move to and from adjacent soils (including adjacent wetland soils) continually. Along their entire length, streams alternate between effluent (water-gaining) and influent (water-losing) zones as the direction of water exchange with the streambed and banks varies. Federal Interagency Stream Restoration Working Group 1998. The adjacent areas involved in this surface water exchange with a stream or river are known as the hyporheic zone. Hyporheic zone waters are part of total surface waters temporarily moving through soil or sediment. Like within-channel waters, these waters are oxygenated and support living communities of organisms in the hyporheic zone.

Because a hydrologic connection between adjacent wetlands and downstream waters still exists despite the presence of a berm or the like, the chemical and biological connections that rely on a hydrologic connection also exist. For instance, adjacent wetlands behind berms can still serve important water quality functions, serving to filter pollutants and sediment before they reach downstream waters. Wetlands behind berms can function to filter pollutants before they enter the nearby tributary, with the water slowly released to the stream through seepage or other hydrological connections. *See, e.g.,* Osborne and Kovacic 1993; Kovacic 2000. Their ability to retain sediment and floodwaters may be enhanced by the presence of the berm. For instance, some backwater wetlands in floodplain/riparian areas exhibit higher sedimentation rates than streamside locations. Kuenzler *et al*. 1980; Johnston *et al*. 2001. The presence of manmade levees can actually increase denitrification rates, meaning that the adjacent wetlands can more quickly transform nitrogen. Gergel *et al*. 2005. However, the presence of manmade berms does limit the ability of the river to connect with its adjacent wetlands through overbank flooding and thus limits sediment, water and nutrients transported from the river to the adjacent wetlands. *Id.*; Florsheim and Mount 2003. However, the presence of a berm does not completely eliminate the transport of sediments and water from the river to the nearby adjacent wetland, as suspended sediments and water can overflow both natural and human-made levees, though the transport is usually more pronounced in settings with natural levees. *See, e.g.*, Turner *et al*. 2006; Keddy *et al*. 2007. Sediment deposition over levees is particularly enhanced by extreme events like hurricanes. *Id.*; Reed *et al*. 2006. Wetlands behind berms, where the system is extensive, can help reduce the impacts of storm surges caused by hurricanes. Day *et al*. 2007.

Adjacent wetlands separated from water bodies by berms and the like maintain ecological connection with those water bodies. Though a berm may reduce habitat functional value and may prevent some species from moving back and forth from the wetland to the river, many major species that prefer habitats at the interface of wetland and stream ecosystems remain able to utilize both habitats despite the presence of such a berm. Additional species that are physically isolated in either stream or wetlands habitat still interact ecologically with species from the other component. Thus, adjacent wetlands with or without small berms can retain numerous similarities in ecological function. For example: wetland bird species such as wading birds are able to utilize both wetland and adjacent stream/ditch habitats; wetland amphibians would be able to bypass the berm in their adult stage; aquatic invertebrates and fish would still interact with terrestrial/wetland predators and prey in common food web relationships despite the presence of a berm. *See, e.g.*, Butcher and Zimpel 1991; Willson and Halupka 1995; Cederholm *et al*. 1999; Schwartz and Jenkins 2000; Bilton *et al*. 2001.

Beach dunes are another form of a natural barrier that does not sever adjacency. Beach dunes are formed by tidal or wave action. Multiple beach dunes may exist between a wetland and jurisdictional water (including primary and secondary dunes), because beach dunes typically function as an interdunal system (particularly on barrier islands). Adjacent wetlands behind beach dunes include intradunal and interdunal wetlands located in coastal areas, including some areas of the Great Lakes and along barrier islands. Interdunal wetlands form in swales or depressions within open dunes or between beach ridges along the coast and experience a fluctuating water table seasonally and yearly in synchrony with sea or lake level changes. Odum 1988; Albert 2000; Albert 2003; Albert 2007. For those along the ocean coast, they are typically formed as a result of oceanic processes where the wetlands establish behind relict dune ridges (dunes that were formed along a previously existing coast line). These wetlands occur in depressional areas between sand dunes or beach ridges. The waters, including wetlands, generally form when water levels of the territorial seas fall or the Great Lakes drop, creating swales that support a diverse mix of wetland vegetation and many endangered and threatened species. Odum 1988; Albert 2000; Albert 2003; Tiner 2003c; Albert 2007. Wetlands in the interdunal system are in close proximity to each other and to the surrounding traditional navigable waters or territorial seas. Their proximity to one another and to the traditional navigable waters or territorial seas indicates a close physical relationship between interdunal wetland systems and the traditional navigable waters, the territorial seas, or interstate waters. Despite the presence of the beach dunes, interdunal wetlands have chemical, physical, or biological connections that greatly influence the integrity of the nearby traditional navigable waters or territorial seas. The wetlands are hydrologically connected to these traditional navigable waters or territorial seas through unconfined, directional flow and shallow subsurface flow during normal precipitation events and extreme events. As previously noted, they are linked to the rise and fall of the surrounding tides or water levels in the case of the Great Lakes—the water-level fluctuations of the nearby traditional navigable waters or territorial seas are important for the dynamics of the wetlands. Albert 2003. The wetlands provide floodwater storage and attenuation, retaining and slowly releasing floodwaters before they reach the nearby traditional navigable waters or territorial seas. Like other adjacent wetlands, interdunal wetlands also have important chemical connections to the nearby traditional navigable waters or territorial seas as they serve important water quality benefits. The wetlands store sediment and pollutants that would otherwise reach the surrounding traditional navigable waters or territorial seas. The wetlands are biologically connected to the surrounding traditional navigable waters or territorial seas. For instance, they provide critical habitats for species that utilize both the wetlands and the nearby traditional navigable waters or territorial seas, supporting high diversity and structure. Habitat uses include basic food, shelter, and reproductive requirements. Aquatic insects, amphibians, and resident and migratory birds all use interdunal wetlands as critical habitat, and the wetlands provide better shelter than the nearby exposed beach. Albert 2000; Smith *et al*. 2008. In marine coastal areas, the wetlands are often the only freshwater system in the immediate landscape, thus providing critical drinking water for the species that utilize both the wetlands and the nearby traditional navigable waters or territorial seas, although some interdunal wetlands are brackish in nature. *See, e.g.*, Heckscher and Bartlett 2004.

Wetlands behind the extensive levee system in the Yazoo Basin are an example of adjacent wetlands behind human-made barriers. A regional hydrogeomorphic approach guidebook for the Yazoo Basin of the Lower Mississippi River Alluvial Valley assesses the functions of these wetlands. Smith and Klimas 2002. An extensive levee system was built along the river system to prevent flooding of the Mississippi River, resulting in drastic effects to the hydrology of the basin. *Id.* Despite the alteration of hydrology in the basin, extensive wetlands systems still exist behind the human-made and natural levees and maintain a hydrologic connection to the river system. These wetlands detain floodwater, detain precipitation, cycle nutrients, export organic carbon, remove elements and compounds, maintain plant communities, and provide fish and wildlife habitat. *Id*. The functions in turn provide numerous benefits to the nearby river.

c. Reasonably Close Wetlands

Adjacent wetlands under the final rule include wetlands that are within reasonably close proximity to jurisdictional waters such that “adjacent wetlands have significant effects on water quality and the aquatic ecosystem.” *Riverside Bayview*, 474 U.S. at 135 n.9. The Supreme Court in *Riverside Bayview* deferred to the Corps’ judgment that adjacent wetlands “that form the border of or are in reasonable proximity to” other “waters of the United States” “may be defined as waters under the Act.” *Riverside Bayview*, 474 U.S. at 134. The agencies have long considered adjacent wetlands to include those within reasonably close proximity of other jurisdictional waters. *See* 42 FR 37128 (July 19, 1977) (Corps’ preamble to the 1977 definition of “navigable waters,” noting that “Federal jurisdiction under Section 404 must include any adjacent wetlands that form the border of or are in *reasonable proximity to other waters of the United States*, as these wetlands are part of this aquatic system”) (emphasis added). The ecological relationship between jurisdictional waters and their adjacent wetlands is well documented in the scientific literature and reflects their physical proximity as well as shared hydrological and biological characteristics. *Rapanos* Guidance at 9. The agencies conclude that close proximity between an adjacent wetland and a jurisdictional water means the wetland can modulate water quantity or water quality in the jurisdictional water, and the jurisdictional water can modulate water quantity or quality in the wetland. For example, wetlands typically help to store floodwaters, pollutants, and sediments that could otherwise reach the jurisdictional water to which they are adjacent. They can also provide flow contributions to the jurisdictional waters to which they are adjacent during high hydroperiods, where water spills from the wetland to the nearby jurisdictional water, and such contributions of flow are facilitated by the wetland's close proximity to the jurisdictional water. The proximate jurisdictional waters can serve as important sources of water for adjacent wetlands, for example, through overtopping events where flow from the jurisdictional waters is stored in the wetlands.

While under this rule the agencies are not establishing distance limits for adjacency, the agencies recognize that as the distance between the wetland and jurisdictional water increases, the reasonableness of the connection between the waters will generally decrease, particularly in the absence of the type of surface or shallow subsurface connections described above, and a finding of adjacency is less likely. The distance between a jurisdictional water and its adjacent wetlands may vary by region, as well as based on site-specific factors within regions. The distance between a jurisdictional water and an adjacent wetland can vary from site to site and region to region due to differences in climate, geomorphology, landscape setting, hydrology, soils, vegetation, elevation, size of the jurisdictional water, and other site-specific variables. Because of regional variability and its effects on proximity for purposes of adjacency, wetlands in the arid West—where rainfall is generally lower, evaporation rates are higher, and riparian areas and floodplains often do not extend far from the tributary network—may often be closer to the jurisdictional water than in more humid parts of the country. On the other hand, where the jurisdictional water is wide (*e.g.*, a wide river), topography is flat lending to larger floodplains and riparian areas, and rainfall is higher, wetlands are more likely to be determined to be reasonably close at a distance that is further from the jurisdictional water than in other circumstances because the site-specific conditions contribute to the close relationship between the wetland and the jurisdictional water, including any unbroken surface or shallow subsurface hydrologic connections between the waters.

While bright-line rules (for example, rules that state that wetlands that are more than a specific number of feet from a jurisdictional water are not "adjacent") are generally easiest to understand and implement, convenience is not the only goal the agencies must consider in administering the Clean Water Act. Because the relationship between a jurisdictional water and a proximate wetland can depend upon a number of site-specific factors, like climate, geomorphology, landscapes, hydrology, and size of the jurisdictional water (*e.g.*, the ocean compared to a headwater stream), and because the central purpose of the Act is to protect the integrity of the nation's waters, a more nuanced analysis is required. While science says that all things being equal, distance, location in a riparian area or floodplain, or discrete hydrologic connections are more likely to strengthen the relationship between a wetland and a nearby water, science does not provide bright lines on appropriate distances to determine adjacency. In implementing this provision over the years, the agencies have worked hard to balance the desire for clarity and predictability with the agencies' scientific understanding of the resources Congress has charged the agencies with protecting. The agencies have carefully considered options for nationally applicable bright lines with respect to adjacency, such as establishing that any wetland within a certain number of feet from a jurisdictional tributary is *per se* jurisdictional, in order to facilitate implementation of the Clean Water Act and to minimize the burden on both landowners and the agencies to evaluate the scope of "waters of the United States." However, the United States is a vast country with many different types of waters, watersheds, landscapes, and hydrology. In fact, in the 2015 Clean Water Rule the agencies sought to establish a distance-based bright line for determining adjacency. As discussed in section IV.B.1 of the preamble, that rule was immediately challenged, and the distance-based limitations were a substantial factor in many of the challenges. As the Supreme Court itself has recognized, the scope of Clean Water Act jurisdiction does not easily lend itself to bright lines: "In sum, we recognize that a more absolute position . . . may be easier to administer. But, as we have said, those positions have consequences that are inconsistent with major congressional objectives, as revealed by the statute's language, structure, and purposes." *Maui*, 140 S. Ct. at 1477. Ultimately, for purposes of the final rule, the agencies concluded that there was not a reasoned basis, consistent with the text of the statute, to establish such a regulatory bright line.

Under the pre-2015 regulatory regime, the agencies have stated that a wetland's reasonably close proximity supports the science-based inference that such wetlands have an ecological interconnection with jurisdictional waters.[38] Because of the scientific basis for this inference, determining whether a wetland is reasonably close to a jurisdictional water does not generally require a case-specific demonstration of an ecological interconnection. In the case of a jurisdictional water and a reasonably close wetland, such implied ecological interconnectivity is neither speculative nor insubstantial. For example, species, such as amphibians or anadromous and catadromous fish, move between such waters for spawning and their life stage requirements. In assessing whether a wetland is reasonably close to a jurisdictional water, the proximity of the wetland (including all parts of a single wetland that has been divided by road crossings, ditches, berms, etc.) in question is evaluated. This is consistent with pre-2015 practice. *See Rapanos* Guidance at 6.

Based on a review of the scientific literature and the agencies' expertise and experience, the agencies determined that adjacent wetlands that are within reasonably close proximity to a jurisdictional water are integrally linked to the chemical, physical, or biological functions of waters to which they are adjacent and to the integrity of traditional navigable waters, the territorial seas, or interstate waters, where such wetlands meet the requirements to be jurisdictional under paragraph (a)(4) of the final rule.

Although determining whether a wetland is reasonably close to a jurisdictional water does not generally require a case-specific demonstration of an ecologic interconnection, there may be instances where the presence of such an ecological interconnection between the wetland and the jurisdictional waterbody demonstrates that the wetlands is reasonably close and therefore adjacent. For example, if resident aquatic species (*e.g.*, amphibians, aquatic turtles, fish, or ducks) rely on both the wetland and the jurisdictional waterbody for all or part of their life cycles (*e.g.*, nesting, rearing, or feeding), that may demonstrate that the wetland is within reasonably close proximity and thus adjacent. The agencies recognize that as the distance between the wetland and jurisdictional water increases, the potential ecological interconnection between the waters is likely to decrease. The distance between a jurisdictional

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[38] *See, e.g.*, *Riverside Bayview Homes*, 474 U.S. at 134 (". . .the Corps' ecological judgment about the relationship between waters and their adjacent wetlands provides an adequate basis for a legal judgment that adjacent wetlands may be defined as waters under the Act.")

water and its adjacent wetlands may vary by region, as well as based on site-specific factors within regions.

Wetlands that are reasonably close to a jurisdictional water perform a myriad of critical chemical, physical, and biological functions associated with a traditional navigable water, the territorial seas, or an interstate water. Such wetlands are often located within the riparian area or floodplain and are often connected via surface and shallow subsurface hydrology to the water to which they are adjacent. While the SAB in its review of the Science Report was clear that distance is not the only factor that influences connections and their effects downstream, due to their close proximity to jurisdictional waters, reasonably close wetlands are often located within a landscape position that allows for them to receive and process surface and shallow subsurface flows before they reach nearby streams and rivers. These waters can individually and collectively affect the integrity of traditional navigable waters, the territorial seas, and interstate waters by acting primarily as sinks that retain floodwaters, sediments, nutrients, and contaminants that could otherwise negatively impact the condition or function of such paragraph (a)(1) waters. Wetlands within close proximity of jurisdictional waters improve water quality through assimilation, transformation, or sequestration of nutrients, sediment, and other pollutants that can affect the integrity of traditional navigable waters, the territorial seas, or interstate waters. These waters, including wetlands, also provide important habitat for aquatic-associated species to forage, breed, and rest. Such species can travel between the wetlands and the nearby jurisdictional water, as well as to the traditional navigable waters, the territorial seas, and interstate waters.

As noted above, reasonably close wetlands may be within the riparian area even if the floodplain is limited. Riparian wetlands within floodplains and riparian wetlands that occur in systems that do not have floodplains are an important part of the overall riverine landscape. Science Report at 4-7 (citing Ward 1998). Wetlands within riparian areas are also connected to streams and rivers by a diverse set of hydrologic inputs and outputs. *Id.* (citing Junk *et al.* 1989; Winter and Rosenberry 1998; Benke *et al.* 2000; Tockner *et al.* 2000; Bunn *et al.* 2006). Waters in stream and river channels can readily reach wetlands in riparian areas via overbank flow, which occurs when floodwaters flow over stream and river channels. *Id.* at 2-12 (citing Mertes 1997).

Riparian areas can have a diverse array of hydrologic inputs and outputs, which, in turn influence riparian wetlands. *Id.* at 2-14. Riparian areas receive water from precipitation; overland flow from upland areas; local, intermediate, regional ground water; and hyporheic flows. *Id.* (citing National Research Council 2002; Richardson *et al*. 2005; Vidon *et al*. 2010). Water flowing over the land surface in many situations can infiltrate soils in riparian areas. If low permeability subsoils or impervious clay layers are present, water contact with the plant root zone is increased and the water is subject to ecological functions such as denitrification before it reaches the stream channel. *Id.* (citing National Research Council 2002; Naiman *et al*. 2005; Vidon *et al.* 2010). Riparian wetlands can have bidirectional, lateral hydrologic connections to the river network, either through overbank flooding (*i.e.*, lateral expansion of the network) or hyporheic flow, in addition to unidirectional flows from upland and ground-water sources. *Id.* at 2-20.

Floodplain wetlands that are reasonably close to jurisdictional waters perform important functions that improve downstream water quality, including the temporary storage and deposition of channeling-forming sediment and woody debris, temporary storage of local ground water that supports baseflow in rivers, and transformation and transport of stored organic matter. *Id.* at ES-2 to ES-3. Floodplain wetlands improve water quality through the assimilation, transformation, or sequestration of pollutants, including excess nutrients and chemical contaminants such as pesticides and metals, that can degrade downstream water integrity. *Id.* at ES-3. In addition to providing effective buffers to protect downstream waters from point source and nonpoint source pollution, these systems form integral components of river food webs, providing nursery habitat for breeding fish and amphibians, colonization opportunities for stream invertebrates, and maturation habitat for stream insects. *Id.* Lateral expansion and contraction of the river in its floodplain result in an exchange of organic matter and organisms, including fish populations that are adapted to use floodplain habitats for feeding and spawning during high water, that are critical to river ecosystem function. *Id.* Floodplain wetlands also affect the integrity of downstream waters by subsequently releasing (desynchronizing) floodwaters and retaining large volumes of stormwater, sediment, and contaminants in runoff that could otherwise negatively affect the condition or function of downstream waters. *Id.*

As discussed in section I, riparian and floodplain wetlands lie within landscape settings that have bidirectional hydrological exchange with the jurisdictional waters. This can occur through overbank flooding (*i.e.*, lateral expansion of the network) or hyporheic flow or from unidirectional overflow from the wetland to the channel. *Id*. at 2-20. Although elevation is the primary factor determining areas that are inundated through overbank flooding, connectivity with the river generally will be higher for riparian/floodplain wetlands located near the river's edge compared with riparian/floodplain wetlands occurring near the floodplain edge. *Id.* at 2-39.

Science demonstrates that distance is a factor in the connectivity and the strength of connectivity of wetlands to downstream waters. Science Report at ES-4, ES-11, 4-2, 5-6-5. The Science Report states, "[s]patial proximity is one important determinant of the magnitude, frequency and duration of connections between wetlands and streams that will ultimately influence the fluxes of water, materials and biota between wetlands and downstream waters." Science Report at ES-11. Thus, waters that are more distant generally have less opportunity to be connected to and to effect downstream waters. Wetlands closer to the stream network or coastline generally will have greater hydrologic and biological connectivity than waters located farther from the same network. *See, e.g., id.* at 2-38. For instance, wetlands that are more closely proximate have a greater opportunity to contribute flow, as water is likely to be lost from the channel through evaporation or transpiration. *Id.* Via their hydrologic connectivity, proximate wetlands also have chemical connectivity to and effects on traditional navigable waters, the territorial seas, or interstate waters and are more likely to impact water quality due to their close distance. Waters more closely located to other water resources are also more likely to be biologically connected to such waters more frequently and by more species, including amphibians and other aquatic animals.

All factors being equal, wetlands closer to the tributary network will have greater hydrologic and biological connectivity than wetlands located farther from the same network. *Id.* at 2-40. Distance is a factor that is well known to have various effects on physical and biological processes within and between system components. *Id.* at 4-44. Sometimes this is due to the direct effect of distance. In some cases, there is an indirect effect due to distance controlling how long transport of a material will take. This fact is embedded in the time of concentration concept in hydrology, whereby under similar slope and velocities, water traveling from more distant points and with a longer flowpath will—because of the length of time in transit—have greater potential for evapotranspiration and soil infiltration losses before reaching a stream. *Id.* at 2-39; Blanco-Canqui and Lal 2008. There are many examples in the scientific literature of distance effects from various factors with respect to chemical, physical, and biological processes. Graf 1984; Marron 1989; Leigh 1997; King *et al*. 2005; Alexander *et al.* 2007; Attum *et al.* 2007; Subalusky 2007; Van Sickle and Johnson 2008; Colvin *et al.* 2009; Flitcroft *et al.* 2012; Greathouse *et al.* 2014.

With respect to provision of water quality benefits downstream, non-floodplain wetlands within close proximity of the stream network often are able to have more water quality benefits than those located at a distance from the stream. Many studies indicate that the primary water quality and habitat benefits will generally occur within a several hundred foot zone of a water. *See, e.g.,* Peterjohn and Correll 1984; Hawes and Smith 2005. In addition, the scientific literature indicates that to be effective, contaminant removal needs to occur at a proximate distance prior to entry into stream network and subsequently into the downstream traditional navigable waters, the territorial seas, or interstate waters. Some studies also indicate that fish, amphibians (*e.g.*, frogs, toads), reptiles (*e.g.*, turtles), and small mammals (*e.g.*, otters, beavers, etc.) will use a reasonably close zone for foraging, breeding, nesting, and other life cycle needs. Dole 1965; Smith and Green 2005; Semlitsch 2008; Steen *et al*. 2012.

Based on a review of the scientific literature and the agencies' expertise and experience, there is clear evidence that the reasonably close wetlands adjacent to traditional navigable waters, the territorial seas, or interstate waters or reasonably close wetlands adjacent to jurisdictional impoundments or tributaries and that meet either the relatively permanent or significant standard under paragraph (a)(4) of the final rule perform critical processes and functions discussed in the sections below.

iii. Adjacent Wetlands Can Provide Functions that Restore and Maintain the Physical Integrity of Traditional Navigable Waters, the Territorial Seas, and Interstate Waters

Scientific research shows that adjacent wetlands are important in protecting the physical integrity of downstream traditional navigable waters, the territorial seas, and interstate waters. This includes adjacent wetlands in riparian areas and floodplains, which exhibit bidirectional exchange of water with the waters to which they are adjacent and that play an important role in determining the volume and duration of stream flow. Such adjacent wetlands also have an essential role in regulating and stabilizing sediment transport to downstream traditional navigable waters, the territorial seas, and interstate waters. These characteristics are fundamental to the physical integrity of streams as well as downstream traditional navigable waters, the territorial seas, and interstate waters.

Adjacent wetlands located in riparian areas and floodplains are important for the reduction or delay of floods. *Id.*at 2-21, 4-7 (citing Mertes *et al.* 1995; Walton *et al.* 1996; Bullock and Acreman 2003; Poole *et al*. 2006; Rassam *et al*. 2006). Such adjacent wetlands control flooding during times of high precipitation or snowmelt by capturing water from overbank flow and storing excess stream water. *Id.* at 4-7. One study found that peak flows in the Cache River in Arkansas decreased by 10-20% mainly because of floodplain water storage. *Id.* (citing Walton *et al*. 1996). Research has shown that floodplain wetlands in Ohio store about 40% of the flow of small streams. *Id.* (citing Gamble *et al.* 2007). These and similar findings point to the close hydrological influence that adjacent wetlands in riparian and floodplain areas have on streams and downstream traditional navigable waters, the territorial seas, and interstate waters.

Adjacent wetlands are bordering, contiguous, or neighboring jurisdictional waters. Because of their close physical proximity to nearby jurisdictional waters, they can readily exchange their waters through the saturated soils surrounding the stream or through surface exchange. This commingling of waters allows bordering, contiguous, or neighboring wetlands to both provide chemically transformed waters to streams and to absorb excess stream flow.

Flow between neighboring wetlands and streams tends to be more longitudinal (downslope) at headwaters and more lateral further downstream. *Id.* at 4-40, Table 4-3. These connections in part determine stream flow volume and duration. Adjacent wetlands in riparian areas connect to nearby water bodies through various surface and subsurface connections. *See, e.g., id.* at 2-4 (citing National Research Council 2002). Floodplains, similarly, are closely associated with the groundwater found beneath and beside river channels (which are considered shallow aquifers), and adjacent wetlands in floodplains readily exchange water with such aquifers. *Id.* at 2-12 (citing Stanford and Ward 1993; Amoros and Bornette 2002; Poole *et al.* 2006). Riparian and floodplain wetlands are frequently contiguous with streams and other water bodies and can significantly influence the physical form, hydrology, chemistry, and biology of such water bodies. *Id.* at 4-6 (citing Junk *et al*. 1989; Abbott *et al*. 2000; Tockner *et al*. 2000; Woessner 2000; Amoros and Bornette 2002; Ward *et al*. 2002; King *et al*. 2003; Naiman *et al*. 2005; Church 2006; Kondolf *et al*. 2006; Poole *et al*. 2006; Poole 2010; Tockner *et al*. 2010; Vidon *et al*. 2010; Helton *et al*. 2011; McLaughlin *et al*. 2011; Humphries *et al*. 2014). Adjacent wetlands located in floodplains are important for the reduction or delay of floods by capturing water from overbank flow and by storing excess water from the streams to which they are adjacent. *Id.* at 4-7 (citing Bullock and Acreman 2003).

Adjacent wetlands in riparian areas and floodplains filter sediment washed down from uplands and collect sediment from overbank flow as the river or stream floods. *Id.* at 4-8 (citing Boto and Patrick 1979; Whigham *et al*. 1988). For example, riparian areas were observed to collect 80-90% of the sediment from farmlands in a study in North Carolina. *Id.* (citing Cooper *et al*. 1987; Daniels and Gilliam 1996; Naiman and Decamps 1997). Maintaining the equilibrium between sediment deposition and sediment transport is important to maintain the physical shape and structure of stream channels, including of downstream traditional navigable waters, the territorial seas, and interstate waters. Significant changes to upstream channels can affect the chemical, physical, and biological condition of downstream traditional navigable waters, the territorial seas, and interstate waters.

The physical effects of excess sediment can impair chemical and ecological integrity in a variety of ways. *Id.* at 5-9 (citing Wood and Armitage 1997). Excess sediment is linked to increasing contaminant and nutrient concentrations, all of which tributaries can transmit downstream, affecting the water quality of traditional navigable waters, the territorial seas, and interstate waters. Excess sediment may block and absorb sunlight transmission through the water column, inhibiting plant photosynthesis and warming the water in the stream. Sediment may fill the interstitial spaces between rocks in a streambed, which many fish and aquatic species use for mating, reproduction, and shelter from predators. This kind of physical degradation of tributary streambeds results in less suitable habitat available for animals and fish that move between upstream and downstream waters. Adjacent wetlands located in riparian areas retain sediments and thus protect downstream traditional navigable waters, the territorial seas, and interstate waters from the effects of excess sediment.

Because adjacent wetlands support riparian vegetation, they affect the capacity of riparian vegetation to influence stream flow, morphology, temperature, and habitat provided in the nearby water body. Vegetation in adjacent wetlands located in riparian areas influences the amount of water in the stream by capturing and transpiring stream flow and intercepting groundwater and overland flow. *Id.* at 2-21, 4-8 (citing Meyboom 1964). Riparian vegetation in adjacent wetlands also reduces stream bank erosion, serving to maintain the physical integrity of the channel. *See*, *e.g.*, *id.* at 4-8 to 4-9 (citing Beeson and Doyle 1995; Naiman and Decamps 1997; Burt *et al*. 2002; Zaimes *et al*. 2004). In addition, inputs of woody debris from aquatic vegetation or logs into waters make important contributions to the channel's geomorphology and the stream's aquatic habitat value. *Id.* at 4-9 (citing Anderson and Sedell 1979; Harmon *et al.* 1986; Nakamura and Swanson 1993; Abbe and Montgomery 1996; Naiman and Decamps 1997; Gurnell *et al.* 2002; Brummer *et al*. 2006; Sear *et al*. 2010; Collins *et al*. 2012). Also, the riparian vegetation in adjacent wetlands that overhangs streams provides shade, providing a critically important function of reducing fluctuations in water temperature helping to reduce excessive algal production and to maintain life-supporting oxygen levels in streams and other types of waters. *Id.* at 4-9 to 4-10 (citing Gregory *et al*. 1991; Volkmar and Dahlgren 2006). Even small changes in water temperature can have significant impacts on the type and number of species present in waters, with higher temperatures generally associated with degraded habitat which supports only those species that can tolerate higher temperatures and reduced levels of dissolved oxygen. Higher water temperatures are associated with streams and rivers with less valuable recreational and commercial fisheries. As discussed below, these physical characteristics of headwater streams influence what types of organisms live in the region.

Headwaters and nearby adjacent wetlands supply downstream traditional navigable waters, the territorial seas, and interstate waters with dissolved organic carbon as a result of decomposition processes from dead organic matter such as plants. Both production and consumption of organic and inorganic carbon occur in adjacent wetlands. *Id.* at 4-13. Adjacent wetlands are an important source of dissolved organic carbon (DOC) to downstream waters. Allochthonous inputs from adjacent wetlands to streams are important to aquatic food webs, particular in headwaters. *Id.* (citing Tank *et al.* 2010). Allochthonous inputs are terrestrial organic materials that enter the stream through vegetation litter (*i.e.*, woody debris, leaves, and partially decomposed plant parts), erosion, and hydrologic flows. *Id.* (citing Wetzel 1992). These inputs of organic matter are the primary source of energy flow into the food webs of streams. *Id.* Organic matter inputs are important because they affect food availability to aquatic organisms by releasing organic carbon and nitrogen into streams. *Id.* (citing Wetzel and Manny 1972; Mulholland and Hill 1997). This organic carbon contributes to the downstream foodweb and ultimately supports downstream fisheries, including in traditional navigable waters, the territorial seas, and interstate waters. *See, e.g., id.* at 4-16. Export of DOC to downstream waters supports primary productivity, effects pH and buffering capacity, and can protect aquatic organisms from the harmful effects of UV-B radiation. *Id.* at 4-28 (citing Eshelman and Hemond 1985; Hobbie and Wetzel 1992; Hedin *et al*. 1995; Schindler and Curtis 1997; Nuff and Asner 2001; Reddy and DeLaune 2008). However, too much organic matter downstream can have negative effects because contaminants, such as methylmercury and other trace metals, can be adsorbed to it. *Id.* (citing Thurman 1985; Driscoll *et al.* 1995).

iv. Adjacent Wetlands Can Provide Functions that Restore and Maintain the Chemical Integrity of Traditional Navigable Waters, the Territorial Seas, and Interstate Waters

As stated above in section III.A on tributaries, pollutants such as petroleum waste products and other harmful pollutants dumped into any part of the tributary system are likely to flow downstream, or to be washed downstream, and thereby pollute traditional navigable waters, the territorial seas, and interstate waters from which American citizens take their drinking water, shellfish, fin fish, water-based recreation, and many other uses. Some wetlands perform the valuable function of trapping or filtering out pollutants (such as fertilizers, silt, and some pesticides), thereby reducing the likelihood that those pollutants will reach and pollute the tributaries of traditional navigable waters, the territorial seas, and interstate waters (and eventually pollute those larger waters themselves). However, many other pollutants (such as petroleum wastes and toxic chemical wastes), if dumped into wetlands that are adjacent to tributary streams or to jurisdictional impoundments, may reach those tributaries or impoundments themselves, and thereafter flow downstream to pollute traditional navigable waters, the territorial seas, and interstate waters, posing risks to the nation's drinking water supply, fisheries, and recreation areas.

Adjacent wetlands in riparian areas and floodplains play a critical role in controlling the chemicals that enter streams and other "waters of the United States" and as a result are vital in protecting the chemical, physical, and biological integrity of traditional navigable waters, the territorial seas, and interstate waters. Runoff (the water that has not evaporated or infiltrated into the groundwater) from uplands is a large source of pollution, but research has shown that adjacent wetlands in riparian areas trap and chemically transform a substantial amount of the nutrients, pesticides, and other pollutants before they enter streams, river, lakes, and other downstream waters.

Chemicals and other pollutants enter waters from point sources such as outfalls and pipes, non-point sources (*e.g.*, runoff from agricultural and urban fields and lawns), dry and wet (*e.g.*, rain, snow) atmospheric deposition, upstream reaches, and through the hyporheic zone, a region beneath and alongside a stream bed where surface water and shallow groundwater mix. *Id.* at 4-10 (citing Nixon and Lee 1986; Tiner 2003c; Whigham and Jordan 2003; Comer *et al.* 2005; Whitmire and Hamilton 2008). Throughout the stream network, but especially in headwater streams and their adjacent wetlands, chemicals are sequestered via sorption (adsorption and absorption) or sedimentation processes, assimilated into the flora and fauna, transformed into other compounds, or lost to the atmosphere through transformational processes performed by microbes, fungi, algae, and macrophytes present in riparian waters and soils. *Id.* (citing Nixon and Lee 1986; Johnston 1991; Boon 2006; Mitsch and Gosselink 2007; Reddy and DeLaune 2008). These chemical processes reduce or eliminate pollution that would otherwise enter streams, rivers, lakes, and other types of waters and subsequently downstream traditional navigable waters, the territorial seas, or interstate waters.

The removal of the nutrients nitrogen and phosphorus is a particularly important role for adjacent wetlands. As described previously, nutrients are necessary to support aquatic life, but the presence of excess nutrients can lead to eutrophication and the depletion of oxygen (hypoxia) in nearby waters and in waters far downstream. *See*, *e.g.*, *id.* at ES-8. Eutrophication is a large problem in waters across the United States including such important ecosystems as the Chesapeake Bay and Lake Spokane in Washington. Kemp *et al* 2005; Moore and Ross 2010; Murphy *et al.* 2011. Eutrophication is the natural or artificial enrichment of a water body by nutrients, typically phosphates and nitrates. Science Report at A-4. It can occur when plants and algae grow in waters to such an extent that the abundance of vegetation monopolizes the available oxygen, detrimentally affecting other aquatic organisms. Protection of these waters therefore helps maintain the chemical integrity of the nation's waters, including downstream traditional navigable waters, the territorial seas, and interstate waters.

The removal of nitrogen is an important function of adjacent wetlands. Adjacent wetlands located in riparian areas regularly remove more than half of dissolved nitrogen found in surface and subsurface water by plant uptake and microbial transformation. *Id.* at 4-11 (citing Vidon *et al*. 2010). Denitrification potential in surface and subsurface flows is highest where there is high organic matter and/or anoxic conditions. *Id.* at 4-12 (citing McClain *et al.* 2003; Orr *et al.* 2014). The highest denitrification potentials occur in adjacent wetlands located in floodplain and riparian areas where high organic matter, denitrifying microbes, and saturated soil conditions are present, and rates increase with proximity to streams. *Id.* (citing Gregory *et al*. 1991; Vidon *et al*. 2010). Adjacent wetlands are therefore important in maintaining the conditions important for denitrification, which in turn protects streams, rivers, lakes, and downstream traditional navigable waters, the territorial seas, and interstate waters from nitrogen pollution.

Plant uptake of dissolved nitrogen in subsurface flows through wetlands located in riparian areas also accounts for large quantities of nitrogen removal. *Id.* (citing Vidon *et al.* 2010). Riparian forests have been found to remove 75% of dissolved nitrate transported from agricultural fields to a Maryland river. *Id.* (citing Vidon *et al.* 2010). Likewise, riparian forests in Georgia remove 65% of nitrogen and 30% of phosphorus from agricultural sources. *Id.* (citing Vidon *et al.* 2010). A Pennsylvania forested riparian area removed 26% of the total nitrate input from the subsurface. *Id.* (citing Newbold *et al*. 2010). The vegetation associated with adjacent wetlands in riparian waters also removes nitrogen from subsurface flows. Therefore, the conservation of adjacent wetlands helps protect downstream traditional navigable waters, the territorial seas, and interstate waters from influxes of dissolved nitrogen.

Phosphorus is another potentially harmful nutrient that is captured and processed in adjacent wetlands, including those located in riparian areas. *Id.* at 4-12 to 4-13 (citing Dillaha and Inamdar 1997; Sharpley and Rekolainen 1997; Carlyle and Hill 2001). Biogeochemical processes, sedimentation, and plant uptake account for high rates of removal of particulate phosphorus in riparian areas. *Id.* at 4-12 (citing Hoffmann *et al*. 2009). The amount of contact the water has with nearby soils and the characteristics of that soil determine the ability of the riparian area to remove phosphorus. *Id.* Adjacent wetlands in riparian areas are phosphorus sinks in oxic soils (containing oxygen), while riparian soils generally can serve as sources of phosphorus when soils are anoxic (lacking oxygen) or when mineral dissolution releases phosphorus. *Id.* at 4-12 (citing Baldwin and Mitchell 2000; Carlyle and Hill 2001; Chacon *et al*. 2008). Adjacent wetlands in riparian areas where agricultural sediments are deposited are phosphorus sources to streams if the phosphorus is desorbed and leached but can be sinks by adsorbing dissolved phosphorus if sediment phosphorus concentrations are low. *Id.* at 4-12 to 4-13 (citing Dillaha and Inamdar 1997; Sharpley and Rekolainen 1997). Adjacent wetlands in riparian areas also serve as phosphorus sinks when upland surface runoff travels through the riparian area or when fine-grained sediment containing phosphorus is deposited overbank onto the riparian area. *Id* at 4-13 (citing Dillaha and Inamdar 1997). These sediments, however, can become sources of phosphorus if they are later saturated with water and iron and manganese are reductively dissolved during anoxic conditions, thus causing them to desorb phosphorus. *Id.* (citing Reddy and DeLaune 2008). The function of adjacent wetlands to move and uptake phosphorus is crucial for maintaining the chemical and biological integrity of the waters to which they are adjacent, and for preventing eutrophication in downstream traditional navigable waters, the territorial seas, and interstate waters, thereby helping to restore and maintain the integrity of those larger fundamental waters. In the case where adjacent wetlands are acting as a source of phosphorus for traditional navigable waters, the territorial seas, and interstate waters, this also can significantly affect the chemical and biological integrity of these downstream waters.

v. Adjacent Wetlands Can Provide Functions that Restore and Maintain the Biological Integrity of Traditional Navigable Waters, the Territorial Seas, and Interstate Waters

Adjacent wetlands support the biological integrity of downstream traditional navigable waters, the territorial seas, and interstate waters in a variety of ways. They provide habitat for aquatic and water-tolerant plants, invertebrates (aquatic insects), and vertebrates, and provide feeding, refuge, and breeding areas for invertebrates and fish. Seeds, plants, and animals move between adjacent wetlands and the nearby streams, and from there colonize or utilize downstream waters, including traditional navigable waters, the territorial seas, and interstate waters.

Organic matter from adjacent wetlands is critical to aquatic food webs, particularly in headwaters, where it is the primary source of energy flow due to low light conditions that inhibit photosynthesis. *See, e.g.*, *id.* at 4-13 (citing Tank *et al*. 2010). Headwater streams tend to be located in heavily vegetated areas compared to larger waters, so they are more likely to contain leaf litter, dead and decaying plants, and other organic matter that forms the basis of headwater food webs. The organic matter is processed by microbes and insects that make the energy available to higher levels of stream life such as amphibians and fish. Studies have shown that aquatic insects rely on leaf inputs in headwater streams and that excluding organic litter from a stream resulted in significant changes to the food web at multiple levels. *Id.* (citing Minshall 1967; Wallace and Webster 1996; Wallace *et al*. 1997; Meyer *et al*. 1998). Fish and amphibian species found in headwaters travel downstream and in turn become part of the food web for larger aquatic organisms in traditional navigable waters, the territorial seas, and interstate waters. Organic material provided by adjacent wetlands to small, headwater streams is therefore important not only to the small streams that directly utilize this source of energy to support their biological populations but also to the overall biological integrity of downstream traditional navigable waters, the territorial seas, and interstate waters that benefit from the movement of fish and other species that contribute to the food web of larger streams, rivers, estuaries, and the ocean.

Adjacent wetlands accumulate organic carbon and nitrogen, an important function influenced by the size and frequency of floods from rivers to which they are adjacent. *See, e.g., id.* at B-11 (citing Cabezas *et al*. 2009). These stored chemicals are available for exchange with river water when hydrological connections are present. Organic materials are the basis for the food web in stream reaches where photosynthetic production of energy is absent or limited, particularly in headwater systems where vegetative litter alone makes up the base of the aquatic food web. The maintenance of floodplain wetlands is therefore an important component of protecting the biological integrity of traditional navigable waters, the territorial seas, and interstate waters into which the headwaters flow.

Adjacent wetlands play an important role in the removal of pesticides. *Id.* at 4-14 (citing Vidon *et al*. 2010). Microbes near plant roots break down these pesticides. *See, e.g., id.* (citing Voos and Groffman 1996). Uptake by aquatic plants has also been shown to be an important mechanism of removal of the pesticides alachlor and atrazine. *Id.* (citing Paterson and Schnoor 1992). Adjacent wetlands also trap and hold pesticide contaminated runoff preventing it from harming neighboring waters.

Adjacent wetlands located in riparian areas and floodplains are dynamic places that support a diversity of aquatic, amphibious, and terrestrial species adapted to the unique habitat created by periodic or episodic flooding or inundation events. *Id.* at 4-15 (citing Power *et al*. 1995a; Power *et al*. 1995b; Galat *et al*. 1998; Robinson *et al*. 2002; Toth and van der Valk 2012; Rooney *et al*. 2013; Granado and Henry 2014). Plants, aquatic insects, and vertebrates use adjacent wetlands for habitat, nutrients, and breeding. As a result, adjacent wetlands act as sources of organisms, particularly during inundation events, replenishing the waters to which they are adjacent with organisms, seeds, and organic matter. Inundation and hydrological connectivity of adjacent wetlands to the tributary network greatly increase the area of aquatic habitats and species diversity. *Id.* at 4-15, 4-16 (citing Junk *et al*. 1989; Tockner *et al*. 2000; Jansson *et al*. 2005; Brooks and Serfass 2013). Aquatic animals, including amphibians and fish, take advantage of the adjacent wetlands, either inhabiting them or moving between the wetlands and the waters to which the wetlands are adjacent. *Id.* at 4-15, 4-17 through 4-19 (citing Copp 1989; Smock *et al.* 1992; Smock 1994; Robinson *et al.* 2002; Richardson *et al.* 2005; Ilg *et al.* 2008; Shoup and Wahl 2009). Likewise, seeds, plant fragments, and whole plants move between adjacent wetlands and the river network. *Id.* at 4-15 (citing Schneider and Sharitz 1988; Middleton 2000; Nilsson *et al*. 2010).

Hydrological connections are often drivers of biological connections, and flooding events enhance the existing connections between adjacent wetlands and the river network. As a result, adjacent wetlands have important functions for aquatic health. Many species have cycles timed to flooding events, particularly in circumstances where flooding is associated with annual spring snowmelt or high precipitation. *Id.* at 4-15 to 4-16, 4-19 (citing Thomas *et al.* 2006; Tronstad *et al*. 2007; Gurnell *et al.* 2008). Adjacent wetlands act as sinks of seeds, plant fragments, and invertebrate eggs and as sources of such biological material during times of periodic flooding, allowing for cross-breeding and resulting gene flow across time. *Id.* at 4-16, 4-19 to 4-20 (citing Middleton 2000; Jenkins and Boulton 2003; Frisch and Threlkeld 2005; Gurnell *et al*. 2008; Vanschoenwinkel *et al*. 2009). Stream macroinvertebrates (*e.g.*, insects, crayfish, and mollusks) and microinvertebrates (*e.g.*, zooplankton such as cladocerans, copepods, rotifers, and gastropods) colonize nutrient rich waters within riparian areas and floodplains in large numbers during periods of seasonal or episodic inundation, facilitating an increase in population and sustaining them though times of limited resources and population decline. *Id.* at 4-19 to 4-20 (citing Fisher and Willis 2000; Frisch and Threlkeld 2005; Junk *et al*. 1989; Malmqvist 2002; Ilg *et al.* 2008). Such animals are adapted to high floods, desiccation (drying out), or other stresses that come with these regular, systemic fluctuations. *Id.* at 4-19. Adjacent wetlands, including those in riparian areas and floodplains therefore maintain various biological populations, which periodically replenish jurisdictional waters to which they adjacent and to traditional navigable waters, the territorial seas, and interstate waters, serving to maintain their biological integrity.

Plants and animals use adjacent wetlands for habitat, food, and breeding. Adjacent wetlands also provide food sources for stream invertebrates, which colonize during inundation events. *Id.* at 4-19 (citing Junk *et al*. 1989; Ilg *et al*. 2008). Adjacent wetlands also form an integral part of the river food web, linking primary producers and plants to higher animals. *Id.* (citing Malmqvist 2002; Woodward and Hildrew 2002; Stead *et al*. 2005; Woodford and McIntosh 2010). Likewise, adjacent wetlands located in floodplains are important foraging, hunting, and breeding sites for fish, amphibians, and aquatic macroinvertebrates. *Id.* at 4-15 (citing Copp 1989; Smock *et al*. 1992; Smock 1994; Bestgen *et al*. 2000; Richardson *et al*. 2005; Schramm and Eggleton 2006; Sullivan and Watzin 2009; Alford and Walker 2013; Magana 2013).

Plants and animals move back and forth between adjacent wetlands and the river network. This movement is assisted in some cases when flooding events create hydrological connections. For instance, these floodplain and riparian wetlands provide refuge, feeding, and rearing habitat for many fish species. *Id.* at 4-17 (citing Wharton *et al*. 1982; Boltz and Stauffer 1989; Matheney and Rabeni 1995; Pease *et al*. 2006; Henning *et al.* 2007; Jeffres *et al*. 2008). Seeds of aquatic and riparian plants ingested by animals such as carp are dispersed in stream channels and associated waters. *See, e.g.*, *id.* at 4-16 (citing King *et al.* 2003; Pollux *et al*. 2007). Also, phytoplankton move between adjacent wetlands located in the floodplain and the river network. *Id.* at 4-16 (citing Angeler *et al*. 2010). In turn, the primary productivity conditions in such adjacent wetlands results in large populations of phytoplankton that enrich river networks when hydrological connections form. *Id.* at 4-16 to 4-17 (citing Lehman *et al*. 2008). This influx of carbon into the river system nourishes the aquatic food webs of downstream foundation waters, for example, by supporting fisheries.

However, even when hydrological connections are absent, some aquatic organisms can move between adjacent wetlands and their nearby tributaries by overland movement in order to complete their life cycle. River-dwelling mammals, such as river otters, move from the river to riparian/floodplain wetlands. *Id.* at 4-17 (citing Newman and Griffin 1994). In addition, both river otters and beavers have a strong preference for riparian areas that are pond- and lake-dominated (Swimley *et al*. 1999). Several species of amphibians and reptiles including frogs, snakes and turtles use both streams and neighboring wetlands. *Id.* at ES-10, 3-47 (Table 3-1), 4-15 (citing Richardson *et al*. 2005). Movement between adjacent wetlands and the river network also occurs by the dispersal of seed and plant fragments and the wind dispersal of invertebrates. *Id.* at 4-15 to 4-16, 4-20 (citing Schneider and Sharitz 1988; Middleton 2000; Gurnell 2007; Gurnell *et al*. 2008; Nilsson *et al*. 2010; Tronstad *et al*. 2007; Vanschoenwinkel *et al*. 2009). Animals, particularly migratory fish, can thus move between adjacent wetlands and traditional navigable waters, the territorial seas, and interstate waters. And even when some species do not traverse the entire distance from adjacent wetlands to traditional navigable waters, the territorial seas, and interstate waters, the larger downstream waters still benefit from the ecological integrity that persists because of the close relationship that adjacent wetlands have with the waters to which they are adjacent. This is because the chemical and biological properties that arise from interactions between adjacent wetlands and tributaries or impoundments move downstream and support the integrity of traditional navigable waters, the territorial seas, and interstate waters.

C. Impoundments

The final rule retains the provision in the 1986 regulations that defines “waters of the United States” to include impoundments of “waters of the United States.” Under paragraph (a)(2) of the final rule, impoundments of traditional navigable waters, the territorial seas, interstate waters, jurisdictional tributaries, and jurisdictional adjacent wetlands are "waters of the United States." As discussed in section IV.C.3 of the preamble of the final rule, the caselaw supports that damming or impounding a jurisdictional water does not make a water non-jurisdictional. Impoundments can be natural (like beaver ponds) or artificial (like reservoirs). Impoundments under this rule can be located off-channel or in-line with the channel. They vary in size and volume, from small ponds on headwater streams to large reservoirs, based in part on the water that is being impounded and type of structure that creates the impoundment.

Asserting Clean Water Act jurisdiction over impoundments also aligns with the scientific literature, as well as the agencies' scientific and technical expertise and experience, which confirm that impoundments have chemical, physical, and biological effects on downstream waters through surface or subsurface hydrologic connections. Impoundments do not sever the effects the impounded "waters of the United States" have on the chemical, physical, or biological integrity of traditional navigable waters, the territorial seas, and interstate waters, though the impounding of the jurisdictional water may change the nature of the effects that the impoundment has on downstream waters. For example, dams often remove much of the sediment from transport, whereas most streams naturally are sediment sources. Science Report at 3-16. Impoundments trap water, sediment, and particulate nutrients and result in downstream impacts on channel morphology and aquatic function in traditional navigable waters, the territorial seas, and interstate waters. *See, e.g.*, *id*. at 5-8.

Berms, dikes, and similar features used to create impoundments typically do not block all water flow. Even dams, which are specifically designed and constructed to impound large amounts of water effectively and safely, generally do not prevent all water flow, but rather allow seepage under the foundation of the dam and through the dam itself. *See, e.g.*, International Atomic Energy Agency 2003 ("All dams are designed to lose some water through seepage"); U.S. Bureau of Reclamation ("All dams seep, but the key is to control the seepage through properly designed and constructed filters and drains"); Federal Energy Regulatory Commission 2005 ("Seepage through a dam or through the foundations or abutments of dams is a normal condition"). As discussed in section III.B.ii.2, seepage occurs not only for earthen dams but for concrete structures as well. *See, e.g.*, Texas Commission on Environmental Quality 2006.

Further, as an agency with expertise and responsibilities in engineering and public works, the Corps extensively studies water retention structures like berms, levees, and earth and rock-fill dams. The agency has found that all water retention structures are subject to seepage through their foundations and abutments. *See, e.g.*, U.S. Army Corps of Engineers 1992; U.S. Army Corps of Engineers 1993; U.S. Army Corps of Engineers 2004. The Supreme Court has recognized that a canal and an impoundment area separated by levees were hydrologically connected (and might even be considered a single water body) because, inter alia, the "levees continually leak." *South Florida Water Mgmt. District v. Miccosukee Tribe of Indians*, 541 U.S. 95, 110 (2004).

The inevitability of seepage is a consequence not of poor design, but of physics: water will flow downward where it can and thus will seep through small spaces in the structure and in the ground beneath it. *See, e.g.,* U.S. Army Corps of Engineers 1993; U.S. Army Corps of Engineers 2000. Thus, good engineering practices do not entail the prevention of all seepage; rather, they assume seepage and entail steps to manage it so that it will not compromise the integrity of berms, levees, and dams. *See, e.g.,* U.S.

Army Corps of Engineers 1993; U.S. Army Corps of Engineers 2004; U.S. Army Corps of Engineers 2000; U.S. Army Corps of Engineers 1992; U.S. Army Corps of Engineers 2005a; Federal Energy Regulatory Commission 2005.

Many tributary systems in the United States have impoundments located along their reach. There are more than 91,000 dams in the United States as documented in the National Inventory of Dams, with over 6,800 exceeding 50 feet (approximately 15 meters) in height. U.S. Army Corps of Engineers 2020a. Although, the National Inventory of Dams is comprehensive, it only includes approximately 1-2% of the impoundments in the country and likely excludes millions of small impoundments. Renwick *et al*. 2005. Nearly all river networks in prairie regions have been altered by impoundments for irrigation storage and flood control, from small farm ponds in headwaters to large reservoirs on river mainstems. Science Report at B-28 (Smith *et al*. 2002; Galat *et al*. 2005; Matthews *et al*. 2005). The purpose of a dam is to impound (store) water for any of several reasons (*e.g.*, flood control, human water supply, irrigation, livestock water supply, energy generation, containment of mine tailings, recreation, erosion control, or pollution control such as sediment trapping). *See* Association of State Dam Safety Officials 2021; Field and Lichvar 2007; Renwick *et al.* 2005. Many dams fulfill a combination of the above functions. Because the purpose of a dam is to retain water effectively and safely, the water retention ability of a dam is of prime importance. Water may pass from the reservoir to the downstream side of a dam by: passing through the main spillway or outlet works; passing over an auxiliary spillway; overtopping the dam; seepage through the abutments; and seepage under the dam. *Id.* All water retention structures are subject to seepage through their foundations and abutments. U.S. Army Corps of Engineers 1992. Thus, waters behind a dam still maintain a hydrologic connection to downstream waters, though the presence of the dam can reduce the hydrological connectivity to downstream traditional navigable waters, the territorial seas, or interstate waters.

Impoundments store water and can have impacts on hydrology downstream. Dams alter the natural flow regime of the river, affecting movement of water and sediment. Science Report at 5-4. For example, impoundments for irrigation storage and flood control have altered flood magnitude, altered flow timing, and reduced flow variability and turbidity across the prairie regions. *Id*. at B-37 (citing Cross and Moss 1987; Hadley *et al*. 1987; Galat and Lipkin 2000). Under the Federal Flood Control Act of 1944, detention impoundments were extensively constructed on headwater streams in the Great Plains to retard flooding in downstream rivers. Science Report at B-29 (citing Schoof *et al*. 1978; Van Haveren 1986). Headwater impoundments reduced runoff to the Washita River in Oklahoma by 36%, but channel dredging of streams offset these reductions by increasing flow from ground water and reducing transmission loss. *Id.* (citing Schoof *et al*. 1978). Downstream, dams decrease peak stream volumes during the normal high-runoff seasons, while increasing minimum flows during normal low-flow seasons—an overall dampening of stream-flow variability *Id.* at 2-45 (citing Poff *et al*. 2007).

Numerous studies have shown that dams impede biotic movements, reducing biological connectivity between upstream and downstream locations. Science Report at 2-45 (citing Greathouse *et al.* 2006; Hall *et al*. 2011). They also form a discontinuity in the normal stream-order-related progression in stream ecosystem structure and function. *Id.* (citing Stanford and Ward 1984). Dams, however, can have the opposite effect with respect to natural lakes: increasing their biological connectivity with respect to invasive species by adding impoundments that decrease average distances between lakes and serving as stepping stone habitat. *Id.* (citing Johnson *et al.* 2008). Dams alter but typically do not sever the hydrologic connection between upstream and downstream waters. Riparian areas are permanently inundated upstream of large dams, increasing hydrological connectivity. Downstream, peak flows decrease during normal high-runoff seasons, while minimum flows increase during normal low-flow seasons—an overall reduction of stream-flow variability. *Id.* (citing Poff *et al.* 2007). Many species that live in or near rivers are adapted (via life history, behavioral, and morphological characteristics) to the seasonality of natural flow regimes, so a reduction in flow variability can have harmful effects on the persistence of such species where dams have been built. *Id.* (citing Lytle and Poff 2004). This reduction in high flows also decreases the connectivity of riparian wetlands with the stream by reducing the potential for overbank lateral flow. Reducing overbank lateral flow can affect downstream water quality, because overbank flow deposits sediment and nutrients that otherwise remain entrained in the river. *Id.* (citing Hupp *et al*. 2009).

Dams also modify sediment dynamics within river networks. Science Report at 3-14. The reservoirs behind dams are very effective at retaining sediment (*see, e.g.*, O'Melia 1998), which can reduce the amount of sediment delivered downstream and affect downstream waters. Kondolf *et al*. 2014. In the early 20th century, government agencies encouraged and funded various soil conservation practices and the construction of small impoundments on headwater streams to trap sediment and provide stable water supplies for livestock, irrigation, and recreation. Science Report at 3-15 (Person *et al*. 1936; Renwick *et al*. 2005). Although most such ponds are small (≤1 hectare or 2.5 acre) and represent only approximately 20% of the total impounded area (or 0.4% of the total watershed area), they can cumulatively have a significant effect on downstream waters. *Id.* For example, Smith and Kraft (2005) estimated that the approximately 2.3 million ponds distributed primarily on headwater streams of the Mississippi River network cumulatively captured 25–50% of the eroded soil from the landscape. *Id*. Similarly, Blum and Roberts (2009) estimated that the Mississippi River's natural sediment load has been reduced by an estimated 50% through dam construction in the Mississippi Basin. Sediment concentrations and suspended loads can be reduced for hundreds of kilometers downstream of dams, as is especially apparent in river networks in the semiarid and arid West. Science Report at 3-14 (citing Williams and Wolman 1984). The disruption of downstream sediment supply by dams alters the balance between sediment supply and transport capacity. *Id.* (citing Williams and Wolman 1984; Kondolf 1997). As described above in section III.A.i, sediment is a necessary material needed in river networks in certain quantities. *Id.* at 3-13. Too much sediment can impact downstream water integrity, but too little sediment can also impact downstream waters. Sediment helps structure stream and river channels by slowing the flow of water through channels and providing substrate and habitat for aquatic organisms. *Id.* at ES-8. At some point in the lower portions of river networks, sediment deposition becomes the dominant process and floodplains form. *Id*. at 2-4. Sediment also helps to build wetlands in coastal areas. Mitsch and Gosselink 2007. In coastal Louisiana, an estimated 25-38 square miles of wetlands are being lost each year to open water areas on the coastline due in part to the loss of sediment upstream behind the levee systems. Mitsch and Gosselink 2007. The river is no longer able to naturally replenish the sediment that rebuilds the marsh system. The disruption of downstream sediment supply by dams alters the balance between sediment supply and transport capacity. Science Report at 3-14 (citing Williams and Wolman 1984; Kondolf 1997). In addition, water released from dams lacks sediment load and thus has excess energy. This energy often downcuts channels downstream of dams, causing channel incision and streambed coarsening as finer gravels and sands are transported downstream over time. *Id.* (citing Williams and Wolman 1984; Kondolf 1997). The elimination of floods enables the encroachment of terrestrial vegetation, resulting in channel narrowing and the conversion of complex, multithreaded channels into simple, single-thread channels.

Impoundments can also be created by natural processes, such as the construction of beaver dams. Factors such as hydrology, channel characteristics, topography, and building materials can influence the size and structure of beaver dams, as can ecological factors. Brazier *et al*. 2021. For example, primary beaver dams that maintained a lodge pond can be much larger than secondary dams, which are often used to improve mobility and the transport of woody material. *Id*. The size of individual beaver dams can be large, especially across wetland habitats. Larsen *et al*. 2021. The area impounded by beaver dams can be large: In the Kabetogama Peninsula of Minnesota, impounded area accounted for up to 13% of the landscape, with an average pond area of about four hectares. Science Report at 2-44 (citing Johnston and Naiman 1990a; Johnston and Naiman 1990b). Beaver dams do not completely restrict transport of water, sediment, and biology downstream. *Id*. at 3-18. Beaver dams typically reduce hydrologic connectivity downstream by impounding streams, increasing the extent of open water, and generally modifying conditions above the dam from lotic (flowing) to lentic (still). *Id.* at 2-44; Brazier *et al*. 2021; Larsen *et al*. 2021. Beaver dams, however, can increase connectivity laterally and vertically (*e.g.*, hyporheic connectivity) by forcing water into nearby riparian areas, inundating floodplains, creating wetland and diverse habitats, and contributing to soil and groundwater recharge. Brazier *et al*. 2021; Larsen *et al*. 2021. These changes in hydrological connectivity are the bases for all subsequent impacts. Larsen *et al*. 2021. Beaver dams can hold large volumes of water in the impoundments they create and also expand riparian wetlands and water tables. Wegener *et al.* 2017. In a review of the effects of beaver dams on stream ecosystems, Collen and Gibson (2001) noted that, although the hydrologic effects of a single beaver dam can be small, the impact of a series of dams on streams can be significant; for example, up to 30% of the water in an Oregon catchment was impounded by beaver dams. Science Report at 2-44. Beaver dams can slow the flow of water, moderating peak flows downstream, and storing and slowly releasing waters during times of low flow or drought. Brazier *et al*. 2021. Westbrook *et al*. (2006) found that beaver dams in the Colorado River affected depth, extent, and duration of inundation resulting from a 10-year flood event. Science Report at 4-18. In addition, beaver dams attenuated declines in water tables during drier summer periods in 25% of their 58-hectare study area. *Id.* They concluded that the main hydrologic effects occurred downstream, however, rather than near the dam. *Id.* (citing Westbrook *et al*. 2006). The hydraulic head generated by the dam raised the water level above the banks, resulting in lateral and downstream spreading of flows during high- and low-flow periods; these effects extended over hundreds of meters. *Id.* For example, mottled soils occurred throughout the study area, suggesting that the beaver dams caused waterlogged soils for extended periods. *Id.* Increased overbank flooding increases hydrologic connectivity between riparian areas and streams. *Id.* In contrast, when no dams were present, flooding was limited to the area immediately near the stream channel. *Id.* Similar to human constructed dams, beaver dams can directly affect material transport (*e.g.*, the ability of the stream to carry sediment is reduced) and alter biogeochemical characteristics. Science Report at 2-44 (citing Naiman *et al*. 1994; Collen and Gibson 2001) and 4-18. For example, beaver dams modify nutrient cycling and decomposition dynamics and can affect downstream transport of materials. *Id.* at 4-18 (citing Naiman *et al*. 1988; Naiman *et al*. 1994). Wegener *et al.* (2017) found that a segment of river network with beaver dams served as a sink for water, carbon, and nutrients during high flows, while subsequently becoming a source of these materials as flows decreased. Beaver dams slow the downstream transport of organic matter, enabling instream organisms to process the carbon and slowly leak material downstream Science Report at 3-32 (citing Wohl and Beckman 2014). By slowing the flow of water, beaver dams and the ponds they create can result in the storage of sediment and nutrients that might otherwise be transported downstream. Brazier *et al.* 2021; Larsen *et al*. 2021. Beaver-dam wetlands can serve as a source of methylmercury Science Report at 4-18 (citing Roy *et al*. 2009). Beaver dams also can affect biological connectivity, for example, by obstructing upstream migration, and cause changes in fish distributions. Science Report at 2-44 (citing Collen and Gibson 2001); Brazier *et al*. 2021; Larsen *et al*. 2021. However, beaver dams can also increase habitat diversity due to the creation of beaver ponds and wetlands, which provide habitat for different life cycle needs for fish and other aquatic species that also utilize the water being impounded, including breeding, rearing, and feeding habitat. Brazier *et al*. 2021; Larsen *et al*. 2021. Beaver dams can also potentially stabilize downstream water temperatures. Larsen *et al*. 2021. Thus, impoundments of jurisdictional waters created by beaver dams can have chemical, physical, and biological effects on downstream traditional navigable waters, the territorial seas, and interstate waters.

Many adjacent wetlands are impounded for a variety of purposes, including for waterfowl habitat creation, aquaculture, agriculture, flood control, hurricane protection, mosquito control, and control of marsh subsidence and erosion. Day *et al.* 1990; U.S. Army Corps of Engineers b. For example, impoundments of wetlands in Louisiana were historically constructed to help control seasonal flooding of the Mississippi River or for agricultural purposes, later were constructed for wildlife management, and more recently have been constructed in coastal Louisiana to enclose wetlands in an attempt to reduce wetland loss. Day *et al.* 1990. Wetlands can be naturally impounded by beaver dams. Larsen *et al*. 2021. In addition, levees with gated culverts or pumps for controlling water levels can be used to impounded wetlands. Bryant *et al.* 1998. Dikes and constructed dams can also impound adjacent wetlands. One study that conducted an inventory of impounded wetlands on the Louisiana coast found that an area equal to approximately 30% of the total wetland area in the Louisiana coastal zone was currently or historically impounded. Day *et al*. 1990. Impoundments created in adjacent wetlands are similar to impoundments created on flowing bodies of water, like rivers that are traditional navigable waters or streams that are tributaries, and the impoundments can serve different functions than that of the wetlands that they are created from. Sometimes impoundments created from adjacent wetlands create open water, well other times wetland characteristics are maintained, depending on the structure that creates the impoundment. *See, e.g., id*. Levees that are constructed to impound adjacent wetlands restrict water movement between the impounded area and the wetland that is impounded and restrict sediment input to the impounded wetlands. Bryant *et al.* 1998. This may be a result of the prevention of delivery of floodwaters and associated sediments to the impounded areas, with the exception of overtopping of the levees during storm events. *Id.* Seepage can still occur through or under the levee. When adjacent wetlands are impounded by beaver dams, hydrologic connectivity is reduced, impacting the associated movement of materials like sediment. *See*, *e.g.*, Larsen *et al*. 2021. Thus, the impoundment of adjacent wetlands could result in increased sediment deposition in downstream traditional navigable waters, the territorial seas, and interstate waters, due to the reduced ability of in-stream sediment to be deposited in the impounded portions of the adjacent wetlands. The scientific literature and the agencies' technical expertise and experience support that impoundments of adjacent wetlands can continue to have chemical, physical, and biological effects on traditional navigable waters, the territorial seas, and interstate waters.

Though the impoundment of traditional navigable waters, the territorial seas, interstate waters, jurisdictional tributaries, and jurisdictional adjacent wetlands can change the nature of the chemical, physical, and biological connections that such waters have downstream, it does not eliminate them. Thus, impoundments continue to serve many important functions as an integral part of the tributary system, which in turn impact traditional navigable waters, the territorial seas, and interstate waters. *See, e.g.*, Science Report; Kondolf *et al*. 2014; Schmadel *et al*. 2019.

D. Intrastate Lakes and Ponds, Streams, or Wetlands Evaluated Under Paragraph (a)(5)

Paragraph (a)(5) of the final rule defines "waters of the United States" to include "intrastate lakes and ponds, streams, or wetlands not identified in paragraphs (a)(1) through (4)" that meet either the relatively permanent standard or the significant nexus standard. Thus, under paragraph (a)(5) of the final rule, jurisdiction over such waters would be based on the relatively permanent or significant nexus standards, not based on the interstate commerce test of the 1986 regulations.[39] The agencies have made important changes to the 1986 regulations to reflect the agencies' construction of the statutory limits on the scope of "waters of the United States" informed by the relevant provisions of the Clean Water Act and the statute as a whole, the scientific record, relevant Supreme Court precedent, and the agencies' experience and technical expertise after more than 45 years of implementing the longstanding pre-2015 regulations defining "waters of the United States." *See* section IV.C.6 of the final rule preamble. The final rule would provide for case-specific analysis of waters not addressed by any other provision of the definition to determine whether they are "waters of the United States" under the relatively permanent or significant nexus standards. As described in section III.D.i below, waters assessed under paragraph (a)(5) can provide functions that restore and maintain the chemical, physical, and biological integrity of traditional navigable waters, the territorial seas, and interstate waters. Therefore, the agencies have determined that including the category for paragraph (a)(5) waters in this rule best advances the objective of the Clean Water Act.

Under the final rule, such intrastate waters meet the relatively permanent standard when they are relatively permanent, standing or continuously flowing bodies of water with a continuous surface connection to traditional navigable waters, the territorial seas, interstate waters, and tributaries that meet the relatively permanent standard. For example, an intrastate lake with relatively permanent standing water that is not a traditional navigable water, is not a tributary, is not a jurisdictional impoundment, and is not an adjacent wetland may have a continuous surface connection to a traditional navigable water. Under paragraph (a)(5)(i) of the final rule such a water is evaluated for jurisdiction under the relatively permanent standard. Intrastate lakes and ponds, streams, or wetlands not identified in paragraphs (a)(1) through (4) of this rule that do not meet the relatively permanent standard are considered for jurisdiction under the significant nexus standard, where they are not excluded under paragraph (c) of the final rule. Waters assessed under paragraph (a)(5)(i) of the final rule can meet the continuous surface connection requirement if they are connected to a traditional navigable water, the territorial seas, or an interstate water or a tributary that is relatively permanent by a discrete feature like a non-jurisdictional ditch, swale, pipe, or culvert. Similarly, a natural berm, bank, dune, or similar natural landform between a water assessed under paragraph (a)(5) and a traditional navigable water, the territorial seas, or an interstate water or a tributary that is relatively permanent does not sever a continuous surface connection to the

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[39] Under the 1986 regulations, such intrastate waters were evaluated under paragraph (a)(3) of that rule and were sometimes referred to as "(a)(3) waters" or "other waters."

extent it provides evidence of a continuous surface connection. *See* section IV.A of this document and section IV.C.5.c of the final rule preamble for a description of implementation tools that can be used to assess a continuous surface connection for a water assessed under paragraph (a)(5).

Under the significant nexus standard, waters assessed under paragraph (a)(5)(ii) are jurisdictional if they, either alone or in combination with similarly situated waters in the region, significantly affect the chemical, physical, or biological integrity of traditional navigable waters, the territorial seas, or interstate waters.

The final rule contains an exclusive list of water types that could be jurisdictional under this provision if they are not jurisdictional under the other provisions of the definition: "[i]ntrastate lakes and ponds, streams, or wetlands." The list of water types does not reflect a conclusion that these waters are necessarily jurisdictional; rather the list is simply meant to inform the public of types of waters that can be jurisdictional if they meet the requisite test (either the relatively permanent standard or the significant nexus standard), even though they do not fall within the other provisions of the final rule. Though this list differs from the list in the 1986 regulations, this revision to the regulatory text is not meant to reflect a change in the types of waters that will be considered for jurisdiction under this provision; rather, based on public comment, the agencies believe that a streamlined list provides more clarity to the public. The agencies have identified the water types listed in the rule so that the more specific water types that were previously listed in paragraph (a)(3) of the 1986 regulations fall within one of the four water types in the final rule. For example, prairie potholes were in the list of water types in the 1986 regulations and, depending upon the characteristics of a particular prairie pothole, they may fall within the wetlands water type on the list (where they meet the regulatory definition of wetlands) or they may be lakes or ponds. Other examples include sloughs, as they typically fall within the wetlands water type or the streams water type, and playa lakes, which may fall within the lakes or ponds water type depending upon their size.

Intrastate waters that are not tributaries, jurisdictional paragraph (a)(2) impoundments, or adjacent wetlands under the final rule are sometimes referred to in scientific literature as "geographically isolated waters" and in policy as "isolated waters." Some geographically isolated wetlands also meet the definition of adjacent, such as wetlands behind berms and the like and wetlands within reasonably close proximity of other jurisdictional waters. The term "geographically isolated" should be used with caution, and cannot be used to infer a lack of connectivity to downstream waters, as these wetlands are often connected to downstream waters through deeper groundwater connections, biological connections, or spillage. The degree of connectivity of such wetlands will vary depending on landscape features such as distance from downstream waters and proximity to other wetlands of similar nature that as a group connect to jurisdictional downstream waters. Science Report at 3-43, 5-2.

The Science Report shows that intrastate waters evaluated under paragraph (a)(5) of the final rule—examples of which include, but are not limited to, depressional non-adjacent wetlands, non-tributary streams, open waters like lakes and ponds, and non-adjacent peatland wetlands—can provide important hydrologic (*e.g.*, flood control), water quality, and habitat functions which vary as a result of the diverse settings in which they exist across the country. *Id.* at 6-1. These functions are particularly valuable when considered cumulatively across the landscape or at the watershed scale and are often similar to the functions that adjacent wetlands provide, including water storage to control streamflow and mitigate or lessen downstream flooding; interruption and delay of the transport of water-borne pollutants (such as excess nutrients and contaminants) over long distances; and retention of sediment. When there is a significant nexus, these functions restore and maintain the chemical, physical, or biological integrity of downstream traditional navigable waters, the territorial seas, and interstate waters. For non-floodplain wetlands and open waters lacking a channelized surface or regular shallow subsurface connection, generalizations from the literature available at the time of the Science Report's publication about their specific effects on downstream waters are difficult because information on both function and connectivity is needed (Science Report at ES-3) with notable exceptions (for example, the Report concluded that non-floodplain wetlands situated between a pollution source and a downstream water, intercepting the surface or shallow subsurface flowpath, will affect downstream waters through sink functions (Science Report at 60)), and thus case-specific analysis of significant nexus is appropriate from policy perspective to determine the specific effects that intrastate waters that do not meet the relatively permanent standard have on traditional navigable waters, the territorial seas, or interstate waters.

Intrastate waters evaluated under paragraph (a)(5) of the final rule individually span the gradient of hydrologic connectivity identified in the Science Report; they can be open waters located in the riparian area or floodplain of traditional navigable waters, the territorial seas, or interstate waters (*e.g.*, oxbow lakes) and otherwise be physically proximate to the stream network (similar to adjacent wetlands) or they can be open waters or wetlands that are fairly distant from the network. *See, e.g.*, Science Report at ES-12. They can be connected to traditional navigable waters, the territorial seas, or interstate waters via confined surface or subsurface connections (including channels, culverts, pipes, and tile drains), unconfined surface connections, shallow subsurface connections, deeper groundwater connections, biological connections, or spillage. They can also provide additional functions such as storage and mitigation of peak flows, natural filtration by biochemical uptake and/or breakdown of contaminants, and in some locations, high volume aquifer recharge that contributes to the baseflow in larger downstream waters. *Id.* at ES-10 to ES-11; McLaughlin *et al*. 2014; Lane *et al.* 2018; Neff and Rosenberry 2018. The strength of functions provided by such intrastate waters on traditional navigable waters, the territorial seas, and interstate waters will vary depending on the type (*e.g.*, chemical, physical or hydrologic, or biological) and degree of connection (*i.e.*, from highly connected to highly isolated) to downstream waters and landscape features such as proximity to stream networks and similarly situated waters that function as a group to influence downstream traditional navigable waters, the territorial seas, or interstate waters. *See, e.g.*, Science Report at ES-11.

Since the publication of the Science Report in 2015, the published literature has expanded scientific understanding and quantification of functions that such intrastate waters perform that affect the integrity of traditional navigable waters, the territorial seas, and interstate waters, particularly in the aggregate. As discussed in section I.C, the more recent literature (*i.e.*, 2014-present) has determined that non-floodplain wetlands can have demonstrable hydrologic and biogeochemical downstream effects, such as decreasing peak flows (Fossey and Rousseau 2016; Golden *et al.* 2016; Wang *et al*. 2019; Yeo *et al.* 2019; Rajib *et al.* 2020), maintaining baseflows (McLaughlin *et al*. 2014; Golden *et al.* 2019), and performing nitrate removal (Golden *et al.* 2019; Evenson *et al.* 2021), particularly when considered cumulatively.

Some intrastate waters considered under paragraph (a)(5) would meet the final rule's definition of "adjacent" if it applied to non-wetland waters like lakes and ponds. This would include, for example, lakes and ponds located behind berms but that are not impoundments of jurisdictional waters, non-tributary lakes and ponds with an unbroken surface or shallow subsurface connection to jurisdictional waters, and lakes and ponds that are in close physical proximity to jurisdictional waters (*e.g.*, oxbow lakes). As discussed in section III.B.ii.3.b, the science is clear that a water's proximity to downstream waters influences its impact on those waters. Open waters within close proximity of jurisdictional waters improve water quality through assimilation, transformation, or sequestration of nutrients, sediment, and other pollutants that can affect the integrity of traditional navigable waters, the territorial seas, or interstate waters. These waters also provide important habitat for aquatic-associated species to forage, breed, and rest. Some intrastate waters considered under paragraph (a)(5) have a shallow subsurface connection to jurisdictional waters. As discussed in section III.B.ii.3.a, the science demonstrates that waters with a shallow subsurface connection to jurisdictional waters can have important effects on traditional navigable waters, the territorial seas, and interstate waters. Some open waters are located within the riparian area or floodplain of the water to which they are proximate. Waters in stream and river channels can readily reach open waters in riparian areas via overbank flow, which occurs when floodwaters flow over stream and river channels. Science Report at 2-12 (citing Mertes 1997). The scientific literature, including the Science Report, supports that open waters in riparian areas and floodplains are chemically, physically, and biologically connected to traditional navigable waters, the territorial seas, or interstate waters and provide important functions that affect the integrity of such waters. *See, e.g.*, ES-2 to ES-3.

Riparian and floodplain waters take many different forms. Some may be wetlands, while others may be ponds, oxbow lakes, or other types of open waters. Intrastate waters considered under paragraph (a)(5) of the final rule that are located in riparian areas or floodplains "are physically, chemically and biologically integrated with rivers via functions that improve downstream water quality, including the temporary storage and deposition of channel-forming sediment and woody debris, temporary storage of local ground water that supports baseflow in rivers, and transformation and transport of stored organic matter." Science Report at ES-2 to ES-3. Such wetlands and open waters act as an effective buffer to protect larger downstream waters from nonpoint source pollution (such as nitrogen and phosphorus), provide habitat for breeding fish and aquatic insects that also live in streams, and retain floodwaters, sediment, nutrients, and contaminants that could otherwise negatively impact the condition or function of traditional navigable waters, the territorial seas, and interstate waters. This inclusion of a case-specific significant analysis for such waters evaluated under paragraph (a)(5) that are located in the floodplain is supported by the SAB's review of a previous proposed rule. The SAB concluded that "distance should not be the sole indicator used to evaluate the connection of 'other waters' to jurisdictional waters." SAB 2014b at 3. In allowing the case-specific evaluation of waters that do not otherwise meet the definition of "waters of the United States" under the final rule's other categories, the agencies are allowing for the functional relationship of those floodplain waters to be considered regardless of proximity to the jurisdictional water. The SAB also supported the Science Report's conclusion that "the scientific literature strongly supports the conclusions that streams and 'bidirectional' floodplain wetlands are physically, chemically, and/or biologically connected to downstream navigable waters; however, these connections should be considered in terms of a connectivity gradient." SAB 2014b at 1. In addition, the SAB noted, "the literature review does substantiate the conclusion that floodplains and waters and wetlands in floodplain settings support the physical, chemical, and biological integrity of downstream waters." *Id*. at 3. By allowing for intrastate waters, including wetlands, that are located within the floodplain of a jurisdictional water to be considered for a case-specific analysis under the significant nexus standard where the water does not meet the jurisdictional criteria under the rule's other categories of waters, the agencies are recognizing the science supporting the important effects that floodplain waters have on the chemical, physical, and biological integrity of traditional navigable waters, the territorial seas, and interstate waters.

Oxbow lakes and ponds (hereafter referred to as oxbow lakes), commonly found in floodplains of large rivers, are formed when river meanders (curves) are cutoff from the rest of the river. These waters, could be evaluated under paragraph (a)(5) of the final rule. *Id.* at 5-3. The Science Report presents a case study of these floodplain waters and concludes that the scientific evidence supports that oxbow lakes periodically connect to the active river channel and the connection between oxbow lakes and the active river channel provides for several ecological effects on the river ecosystem. *Id.* at B-8. Oxbow lakes and other lakes and ponds that are in close proximity to jurisdictional waters, that are located within floodplain or riparian areas, or that are connected via surface and shallow subsurface hydrology to the stream network or to other "waters of the United States" also perform critical chemical, physical, and biological functions that affect downstream traditional navigable waters, the territorial seas, and interstate waters. Like adjacent wetlands, these waters individually and collectively can affect the integrity of downstream waters by acting as sinks that retain floodwaters, sediments, nutrients, and contaminants that could otherwise negatively impact the condition or function of downstream waters. *Id*. at B-10, B-11. They also provide important habitat for aquatic species to forage, breed, and rest. Oxbow lakes play similar roles as floodplain wetlands as they are an integral part of alluvial floodplains of meandering rivers. *Id.* at B-8 (citing Winemiller *et al*. 2000; Glinska-Lewczuk 2009). They connect to rivers by periodic overland flow, typically from the river during flooding events, and bidirectional shallow subsurface flow through fine river soils (bidirectional means flow occurs both from the river to oxbow lake when the river has a high water stage and from the oxbow lake to the river at low water stage). *Id.* at B-9 to B-10. Oxbow lakes generally have an important influence on the chemical, physical, and biological condition and function of rivers. *Id.* at B-13 to B-14. That influence can vary with the distance from the river and the age of the oxbow, reflecting the frequency and nature of the exchange of materials that takes place between the two water bodies. Oxbow lakes also have high mineralization rates, suggesting that similar to adjacent wetlands they process and trap nutrients in runoff before the runoff reaches the river channel. Science Report at B-11 (citing Winemiller *et al*. 2000). Oxbow lakes in the floodplain provide critical fish habitat needed for feeding and rearing, leading researchers to conclude that the entire floodplain should be considered a single functional unit, essential to the river's biological integrity. *Id.* at 4-17 (citing Shoup and Wahl 2009). Since ponds that are near the tributary network are structurally and biologically similar to oxbow lakes, they serve similar functions relative to the nearby river or stream.

Waters evaluated under paragraph (a)(5) can be connected downstream through unidirectional flow from the wetland or open water to a nearby tributary. Such connections can occur through a surface or a shallow subsurface hydrologic connection. *Id*. at 2-7, 4-1 to 4-2, 4-22. Outside of the riparian zone and floodplain, surface hydrologic connections between waters assessed under paragraph (a)(5) of the final rule and jurisdictional waters can occur via confined flows (*e.g.*, a swale, gully, ditch, or other discrete feature). In some cases, these connections will be a result of "fill and spill" hydrology. A directional flowpath is a path where water flows repeatedly from the wetland or open water to the nearby jurisdictional water that at times contains water originating in the wetland or open water as opposed to just directly from precipitation. *Id.* at B-12 (citing Winter and Rosenberry 1998; Leibowitz and Vining 2003). Water connected through such flows originate from the "other water," travel to the downstream jurisdictional water, and are connected to those downstream waters by swales or other directional flowpaths on the surface. Surface connections can also be unconfined (non-channelized flow), such as overland flow. *Id.* at 2-14.

A confined surface hydrologic connection, which may be perennial, intermittent, or ephemeral, supports periodic flows between the water assessed under paragraph (a)(5) and the jurisdictional water. For example, wetland seeps are likely to have perennial connections to streams that provide important sources of baseflow, particularly during summer. *Id.* at 4-21 (citing Morley *et al.* 2011). Some waters assessed under paragraph (a)(5) of the final rule are connected to streams via intermittent or ephemeral conveyances and can contribute flow to downstream waters via their surface hydrologic connection. *Id.* (citing Rains *et al.* 2006; Rains *et al.* 2008; McDonough *et al.* 2015). The surface hydrologic connection of the waters evaluated under paragraph (a)(5) to the jurisdictional water can contribute to the effects these waters have on traditional navigable waters, the territorial seas, or interstate waters. Waters evaluated under paragraph (a)(5) that are connected to jurisdictional waters through a confined surface hydrologic connection can have an impact on traditional navigable waters, the territorial seas, or interstate waters, regardless of whether the outflow is permanent, intermittent, or ephemeral. *See, e.g., id.* at 4-40.

Waters evaluated under paragraph (a)(5) with confined surface connections can affect the physical integrity of waters to which they connect. Such waters can provide an important source of baseflow to nearby streams, helping to sustain the water levels in those streams, and ultimately in traditional navigable waters, the territorial seas, and interstate waters. *Id.* at 4-21 to 4-22 (citing Morley *et al.* 2011; Rains *et al.* 2006; Rains *et al.* 2008; Wilcox *et al.* 2011; McDonough *et al.* 2015); Lee *et al.* 2010. Waters evaluated under paragraph (a)(5) with a confined surface connection to downstream jurisdictional waters can affect streamflow by altering baseflow or stormflow through several mechanisms, including surface storage and groundwater recharge. Science Report at 4-24. Waters evaluated under paragraph (a)(5) with confined surface connections can affect water quality of jurisdictional waters through source and sink functions, often mediated by transformation of chemical constituents. The surface hydrologic connections to nearby jurisdictional waters provide pathways for materials transformed in the waters evaluated under paragraph (a)(5) (such as methylmercury or degraded organic matter) to reach and affect the nearby waters and the traditional navigable waters, the territorial seas, and interstate waters. *Id.* at 4-26 to 4-27. Waters evaluated under paragraph (a)(5) with confined surface connections also can affect the biological integrity of waters to which they connect. Movement of organisms between these waters and the nearby jurisdictional water is governed by many of the same factors that affect movement of organisms between adjacent wetlands and the river network. *See, e.g., id.* at 4-30. Because such waters evaluated under paragraph (a)(5) are at least periodically hydrologically connected to the nearby jurisdictional tributary network on the surface, dispersal of organisms can occur actively through the surface connection or via wind dispersal, hitchhiking, walking, crawling, or flying. *See, e.g., id.* at 4-30 to 4-31.

Biological connections between waters evaluated under paragraph (a)(5) and river systems do not always increase with hydrologic connections. In some cases, the lack of connection improves the biological contribution provided by such waters to nearby streams, rivers, and lakes and downstream traditional navigable waters, the territorial seas, and interstate waters. For instance, the periodic hydrologic disconnectedness of oxbow lakes is *necessary* for the accumulation of plankton, an important source of carbon more easily assimilated by the aquatic food chain than terrestrial forms of carbon. *Id.* at

B-11 to B-12 (citing Baranyi *et al*. 2002; Keckeis *et al*. 2003). Similarly, some degree of hydrological disconnectedness is important in increasing the number of mollusk species and macroinvertebrate diversity in oxbow lakes, which in turn support the diversity of mollusks throughout the aquatic system. *Id.* at B-12 (citing Reckendorfer *et al*. 2006; Obolewski *et al.* 2009).

Some waters assessed under paragraph (a)(5) are wetlands that are located too far from jurisdictional waters to be considered "adjacent" or are lakes and ponds that are not proximate to jurisdictional waters. The agencies have always recognized that adjacency is bounded by proximity. The science is clear that a water's proximity to downstream waters influences its impact on those waters. The Science Report states, "[s]patial proximity is one important determinant of the magnitude, frequency and duration of connections between wetlands and streams that will ultimately influence the fluxes of water, materials and biota between wetlands and downstream waters." Science Report at ES-11. Generally, waters that are closer to a jurisdictional water are more likely to be connected to that water than waters that are farther away.

The specific distance from jurisdictional waters may vary based on the characteristics of the aquatic resources being evaluated, but they are often located outside of the riparian area or floodplain, lack a confined surface or shallow subsurface hydrologic connection to jurisdictional waters, or exceed the minimum distances necessary for aquatic to utilize both the subject waters and the waters in the broader tributary network. Some intrastate waters considered under paragraph (a)(5) of the rule may be too removed from the stream network or from jurisdictional waters to have significant effects on traditional navigable waters, the territorial seas, or interstate waters. However, particularly when considered in the aggregate, some intrastate waters considered under paragraph (a)(5) can, in certain circumstances, have strong chemical, physical, and biological connections to and effects on traditional navigable waters, the territorial seas, or interstate waters. Sometimes it is their relative isolation from the stream network (*e.g.*, lack of a hydrologic surface connection) that contributes to the important effect that they have downstream; for example, depressional non-floodplain wetlands lacking a confined surface outlet can function individually and cumulatively to retain and transform nutrients, retain sediment, provide habitat, and reduce or attenuate downstream flooding, depending on site-specific conditions such as landscape characteristics (*e.g.*, slope of the terrain, soil permeability). *Id.* at 4-38; Lane *et al.* 2018; Golden *et al.* 2019; *see* section I.C.vii.

Some waters assessed under paragraph (a)(5) are located outside of the floodplain. Non-floodplain waters perform many of the same functions as floodplain waters, but as discussed above, their connectivity to downstream waters varies. Generalizations about their effects on downstream waters can be difficult to ascertain from the available scientific literature. The functions of non-floodplain waters are discussed below.

Waters assessed under paragraph (a)(5) that are located outside the floodplain can affect streamflow by altering baseflow or storm flow through several mechanisms, including surface storage and groundwater recharge. Science Report at 4-24. Studies at the larger scale have shown that by storing water, wetlands, reduce peak flows and thus, downstream flooding. *Id.* at 4-25 (citing Jacques and Lorenz 1988; Vining 2002; McEachern *et al*. 2006; Gleason *et al*. 2007).

Non-floodplain waters evaluated under paragraph (a)(5), including wetlands, contain diverse microbial populations that perform various chemical transformations, acting as source of compounds and potentially influencing the water quality downstream. *Id.* at 4-27 (citing Reddy and DeLaune 2008). Sulfate-reducing bacteria found in some non-floodplain wetlands produce methylated mercury, which is then transported downstream by surface flows. *Id.* (citing Linqvist *et al.* 1991; Mierle and Ingram 1991; Driscoll *et al.* 1995; Branfireun *et al*. 1999). Wetlands, including those that are waters assessed under paragraph (a)(5), are the principal sources of dissolved organic carbon (DOC) in forests to downstream waters. *Id.* at 4-28 (citing Mulholland and Kuenzler 1979; Urban *et al.* 1989; Eckhardt and Moore 1990; Koprivnjak and Moore 1992; Kortelainen 1993; Clair *et al*. 1994; Hope *et al*. 1994; Dillon and Molot 1997; Gergel *et al*. 1999). Export of DOC to traditional navigable waters, the territorial seas, and interstate waters from waters evaluated under paragraph (a)(5) can support primary productivity, affect pH and buffering capacity, and regulate exposure to UV-B radiation. *Id.* (citing Eshelman and Hemond 1985; Hedin *et al*. 1995; Schindler and Curtis 1997; Nuff and Asner 2001).

Non-floodplain waters assessed under paragraph (a)(5) also act as sinks and transformers for pollutants, including excess nutrients, through such processes as denitrification, ammonia volatilization, microbial and plant biomass assimilation, sedimentation, sorption and precipitation, biological uptake, and long-term storage of plant detritus. *Id.* at 4-29 (citing Ewel and Odum 1984; Nixon and Lee 1986; Johnston 1991; Detenbeck *et al*. 1993; Reddy *et al*. 1999; Mitsch and Gosselink 2007; Reddy and DeLaune 2008; Kadlec and Wallace 2009). Specifically, non-floodplain waters evaluated under paragraph (a)(5) can reduce phosphorus, nitrate, and ammonium by large percentages. *Id.* (citing Dierberg and Brezonik 1984; Dunne *et al*. 2006; Jordan *et al*. 2007; Cheesman *et al.* 2010). Wetland microbial processes reduce other pollutants, such as pesticides, hydrocarbons, heavy metals, and chlorinated solvents. *Id.* at 4-30 (citing Brooks *et al*. 1977; Kao *et al*. 2002; Boon 2006).

Non-floodplain waters considered under paragraph (a)(5) can have biological connections downstream that have the potential to impact the integrity of traditional navigable waters, the territorial seas, or interstate waters. Emergent and aquatic vegetation found in such non-floodplain waters disperse downstream by water, wind, and hitchhiking on (*i.e.*, adhering to) migratory animals. *Id.* at 4-31 (citing Soons and Heil 2002; Soons 2006; Nilsson *et al*. 2010). Similarly, fish move between the river network and non-floodplain waters evaluated under paragraph (a)(5) during times of surface water connections. *Id.* at 4-34 (citing Snodgrass *et al*. 1996; Zimmer *et al*. 2001; Baber *et al*. 2002; Hanson *et al*. 2005; Herwig *et al*. 2010). Mammals that can disperse overland can also contribute to connectivity. *Id.* (citing Shanks and Arthur 1952; Roscher 1967; Serfass *et al.* 1999; Clark 2000; Spinola *et al.* 2008). Insects also hitchhike on birds and mammals from non-floodplain wetlands to the stream network, which can then serve as a food source for downstream waters. *Id*. at 4-31 (citing Figuerola and Green 2002; Figuerola *et al*. 2005). Insects that are flight-capable also use both the stream and non-floodplain waters moving from the stream to the wetland to find suitable habitat for overwintering, refuge from adverse conditions, hunting, foraging, or breeding. *Id.* at 4-34 (citing Williams 1996; Bohonak and Jenkins 2003). Amphibians and reptiles, including frogs, toads, and newts, also move between streams or rivers and non-floodplain waters to satisfy part of their life history requirements, feed on aquatic insects, and avoid predators. *Id*. at 4-34 to 4-35 (citing Lamoureux and Madison 1999; Babbitt *et al*. 2003; Adams *et al.* 2005; Green 2005; Hunsinger and Lannoo 2005; Petranka and Holbrook 2006; Attum *et al*. 2007; Subalusky *et al*. 2009a; Subalusky *et al*. 2009).

The science itself does not establish bright lines for establishing where waters do not have a significant nexus to traditional navigable waters, the territorial seas, and interstate waters. For instance, as noted above, the SAB concluded that distance should not be a sole factor used to evaluate the connection of waters to jurisdictional waters. SAB 2014b at 3. A case-specific analysis for waters assessed under paragraph (a)(5) of the final rule allows such waters to be considered jurisdictional only where they meet the relatively permanent or significant nexus standard.

The agencies emphasize that they fully support efforts by Tribes and States to protect under their own laws any additional waters, including locally important waters that may not be within the federal interests of the Clean Water Act as the agencies have interpreted its scope in this final rule. Indeed, the final rule and the definition of “waters of the United States” do not foreclose Tribes and States from acting consistent with their Tribal and State authorities to establish protection for waters that fall outside of the protection of the Clean Water Act.

Based on the functions that can be provided by intrastate lakes and ponds, streams, and wetlands that are not paragraph (a)(1) through (4) waters to traditional navigable waters, the territorial seas, and interstate waters, the final rule provides that such waters will be assessed to determine whether they meet either the relatively permanent standard or the significant nexus standard reflects proper consideration of the objective of the Act, relevant Supreme Court discussions, and the best available science.

i. Intrastate Waters Evaluated Under Paragraph (a)(5) Can Provide Functions that Restore and Maintain the Chemical, Physical, and Biological Integrity of Traditional Navigable Waters, the Territorial Seas, and Interstate Waters

Intrastate lakes and ponds, streams, and wetlands that do not meet the relatively permanent standard can provide functions that restore and maintain the chemical, physical, and biological integrity of downstream traditional navigable waters, the territorial seas, and interstate waters, and such waters will be evaluated on a case-specific basis under the final rule. This section will focus on intrastate waters evaluated under paragraph (a)(5) of the final rule and the functions they provide that benefit traditional navigable waters, the territorial seas, and interstate waters.

Though much of the literature cited in the Science Report relates to waters evaluated under paragraph (a)(5) that are streams or wetlands, the Science Report indicates that open waters also can have chemical, physical, or biological connections that significantly impact downstream waters. For instance, ponds or lakes that are not part of the tributary network can still be connected to downstream waters through chemical, physical, and biological connections. Lake storage has been found to attenuate peak streamflows in Minnesota. *Id.* at 4-25 (citing Jacques and Lorenz 1988; Lorenz *et al*. 2010). Similar to wetlands, ponds are often used by invertebrate, reptile, and amphibian species that also utilize downstream waters for various life history requirements, particularly because many ponds, particularly temporary ponds, are free of predators, such as fish, that prey on larvae. The American toad and Eastern newt, for example, are widespread habitat generalists that can move among streams, wetlands, and ponds to take advantage of each aquatic habitat, feeding on aquatic invertebrates, and avoiding larger predators. *See, e.g., Id.* at 4-35 (citing Babbitt *et al*. 2003; Green 2005; Hunsinger and Lannoo 2005; Petranka and Holbrook 2006).

The physical effect that intrastate waters evaluated under paragraph (a)(5) of the final rule have downstream can be less obvious than the physical connections of adjacent wetlands and of tributaries that do not meet the relatively permanent standard when such waters are physical distant from the stream network or from jurisdictional waters. Despite this physical distance, they are frequently connected in some degree through either surface water or groundwater systems; over time, impacts in one part of the hydrologic system will be felt in other parts. Winter and LaBaugh 2003. For example, waters assessed under paragraph (a)(5) that overspill into downstream water bodies during times of abundant precipitation are connected over the long term. *Id*. Wetlands that lack surface connectivity in a particular season or year can, nonetheless, be highly connected in wetter seasons or years. Science Report at 4-24. Floodplain waters and non-adjacent wetlands are connected to traditional navigable waters, the territorial seas, or interstate waters via both surface and subsurface hydrologic flowpaths and can reduce flood peaks by storing floodwaters. *Id.* at ES-9. Many waters assessed under paragraph (a)(5) interact with groundwater, either by receiving groundwater discharge (flow of groundwater to the case-specific water), contributing to groundwater recharge (flow of water from the case-specific water to groundwater), or both. *Id.* at 4-22 (citing Lide *et al.* 1995; Devito *et al*. 1996; Matheney and Gerla 1996; Rosenberry and Winter 1997; Pyzoha *et al.* 2008). Factors that determine whether a water recharges groundwater or is a site of groundwater discharge include topography, geology, soil features, and seasonal position of the water table relative to the water. *Id*. at 4-23 (citing Phillips and Shedlock 1993; Shedlock *et al*. 1993; Lide *et al*. 1995; Sun *et al.* 1995; Rosenberry and Winter 1997; Pyzoha *et al.* 2008; McLaughlin *et al*. 2014). Similarly, the magnitude and transit time of groundwater flow from a water assessed under paragraph (a)(5) to downstream traditional navigable waters, the territorial seas, or interstate waters depend on several factors, including the intervening distance and the properties of the rock or unconsolidated sediments between the water bodies (*i.e.*, the hydraulic conductivity of the material). *Id.* at 4-23. Surface and groundwater hydrological connections are those generating the capacity for waters assessed under paragraph (a)(5) to affect downstream waters, as water from the aquatic resource being assessed may contribute to baseflow or stormflow through groundwater recharge. *Id*. at 4-24. Contributions to baseflow are important for maintaining conditions that support aquatic life in downstream traditional navigable waters, the territorial seas, and interstate waters. As discussed further below, even in cases where waters assessed under paragraph (a)(5) lack a connection to downstream waters, they can influence downstream waters through water storage and mitigation of peak flows. *Id*. at 4-2, 4-42, 4-43.

The chemical effects that waters assessed under paragraph (a)(5) have on downstream waters are linked to their hydrologic connection downstream, though a surface connection is not needed for a water to influence the chemical integrity of the downstream traditional navigable water, the territorial seas, or interstate water. When waters assessed under paragraph (a)(5) are hydrologically connected to downstream waters via surface or groundwater connections, such waters can affect water quality downstream (although these connections do not meet the definition of adjacency for wetlands). Whigham and Jordan 2003. Waters assessed under paragraph (a)(5) can act as sinks and transformers for nitrogen and phosphorus, metals, pesticides, and other contaminants that could otherwise negatively impact downstream traditional navigable waters, the territorial seas, and interstate waters. Science Report at 4-29 to 4-30 (citing Brooks *et al.* 1977; Hemond 1980; Davis *et al*. 1981; Hemond 1983; Ewel and Odum 1984; Moraghan 1993; Craft and Chiang 2002; Kao *et al*. 2002; Boon 2006; Dunne *et al*. 2006; Cohen *et al*. 2007; Jordan *et al*. 2007; Whitmire and Hamilton 2008; Bhadha *et al*. 2011; Marton *et al*. 2014). *See also*, *e.g.*, Isenhart 1992. Schmadel *et al.* (2019) found that small ponds nearby the stream network are the dominant nitrogen sinks in headwater catchments, while small ponds not near the stream network are the dominant phosphorus sinks. The body of published scientific literature and the Science Report indicate that sink removal of nutrients and other pollutants by waters assessed under paragraph (a)(5) is significant and geographically widespread. Science Report at 4-30. Such waters located on floodplains provide water quality benefits for the downstream traditional navigable waters, the territorial seas, and interstate waters, including retention of sediment and organic matter and retention, cycling, and transformation of pollutants like nutrients. *Id.* at ES-9. Water quality characteristics of waters assessed under paragraph (a)(5) are highly variable, depending primarily on the sources of water, characteristics of the substrate, and land uses within the watershed. Whigham and Jordan 2003. These variables inform whether a water assessed under paragraph (a)(5) has a significant nexus to a traditional navigable water, the territorial seas, or an interstate water. *See also* section III.E.ii. For instance, some prairie potholes may improve water quality and may efficiently retain nutrients that might otherwise cause water quality problems in larger downstream waters; in such systems it may be their lack of a direct hydrologic connection that enables the prairie potholes to retain nutrients more effectively. Whigham and Jordan 2003; Science Report at 2-28 to 2-29.

Waters assessed under paragraph (a)(5) can be biologically connected to each other and to downstream traditional navigable waters, the territorial seas, and interstate waters through the movement of seeds, macroinvertebrates, amphibians, reptiles, birds, and mammals. Science Report at 4-30 to 4-35; Leibowitz 2003. The movement of organisms between such waters and downstream waters is governed by many of the same factors that affect movement of organisms between adjacent wetlands and downstream waters. *See* section III.B; Science Report at 4-30. For example, “waters assessed under paragraph (a)(5) that are located in the floodplain of a jurisdictional water are hydrologically connected to traditional navigable waters, the territorial seas, or interstate waters by lateral expansion and contraction of the jurisdictional water in its floodplain, resulting in an exchange of matter and organisms with the jurisdictional water and further downstream to traditional navigable waters, the territorial seas, or interstate waters. One example of such a connection is fish populations that are adapted to use wetlands and open waters in the floodplain for feeding and spawning during high water. *Id.* at ES-9 to ES-10. Many waters assessed under paragraph (a)(5) are further away from stream channels than adjacent wetlands, making hydrologic connectivity less frequent, and increasing the number and variety of landscape barriers over which organisms must disperse. *Id*. Plants, though non-mobile, have evolved many adaptations to achieve dispersal over a variety of distances, including water-borne dispersal during periodic hydrologic connections, “hitchhiking” on or inside highly mobile animals, and more typically via wind dispersal of seeds and/or pollen. *Id*. at 4-31 (citing Galatowitsch and van der Valk 1996; Murkin and Caldwell 2000; Amezaga 2002; Figuerola and Green 2002; Soons and Heil 2002; Soons 2006; Haukos *et al.* 2006 and references therein; Nilsson *et al.* 2010). Mammals that disperse overland can also contribute to connectivity and can act as transport vectors for hitchhikers such as algae. *Id.* at 4-34 (citing Shanks and Arthur 1952; Roscher 1967; Serfass *et al.* 1999; Clark 2000; Spinola *et al.* 2008). Invertebrates also utilize birds and mammals to hitchhike, and these hitchhikers can be an important factor structuring invertebrate metapopulations in case-specific waters and in aquatic habitats separated by hundreds of kilometers. *Id.* at 4-31 through 4-32 (Figuerola and Green 2002; Figuerola *et al*. 2005; Allen 2007; Frisch 2007). Numerous flight-capable insects use both waters assessed under paragraph (a)(5) and downstream traditional navigable waters, the territorial seas, or interstate waters; these insects move outside the tributary network to find suitable habitat for overwintering, refuge from adverse conditions, hunting, foraging, or breeding, and then can return back to the tributary network for other life cycle needs. *Id.* at 4-34 (citing Williams 1996; Bohonak and Jenkins 2003). Amphibians and reptiles also move between waters assessed under paragraph (a)(5) and downstream waters to satisfy part of their life history requirements. *Id*. at 4-34. Alligators in the Southeast, for instance, can move from tributaries to shallow, seasonal limesink wetlands for nesting, and also use these wetlands as nurseries for juveniles; sub-adults then shift back to the tributary network through overland movements. *Id*. (citing Subalusky *et al*. 2009a; Subalusky *et al*. 2009b). Similarly, amphibians and small reptile species, such as frogs, toads, and newts, commonly use both tributaries and waters assessed under paragraph (a)(5), during one or more stages of their life cycle, and can at times disperse over long distances. *Id.* at 4-34 to 4-35 (citing Knutson *et al*. 1999; Lamoureux and Madison 1999; Babbitt *et al*. 2003; Adams *et al*. 2005; Green 2005; Hunsinger and Lannoo 2005; Petranka and Holbrook 2006; Attum *et al*. 2007).

Even when a surface or groundwater hydrologic connection between a water assessed under paragraph (a)(5) of the final rule and a downstream traditional navigable water, the territorial sea, or interstate water is visibly absent, many waters still have the ability to have a material influence on the integrity of those downstream fundamental waters. Such circumstances would be uncommon, but can occur, for instance, where a wetland recharges a deep groundwater aquifer that does not feed surface waters, or it is located in a basin where evapotranspiration is the dominant form of water loss. *Id.* at 4-21 to 4-24. Aquatic systems that may seem disconnected hydrologically are often connected but at irregular timeframes or through subsurface flow, and perform important functions that can be vital to the chemical, physical, or biological integrity of downstream traditional navigable waters, the territorial seas, and interstate waters. Some wetlands that may be hydrologically disconnected most of the time but connected to the stream network during rare high-flow events or during wetter seasons or years. Although the Science Report focuses primarily on the benefits that connectivity can have on downstream systems, isolation also can have important positive effects on the condition and function of downstream traditional navigable waters, the territorial seas, and interstate waters. *Id.* at 2-28. For instance, the lack of a hydrologic connection allows for water storage in such waters, attenuating peak streamflows, and, thus, downstream flooding, and also reducing nutrient and soil pollution in downstream waters. *Id.* at 2-28 to 2-29, 4-2, 4-38. Prairie potholes a great distance from any tributary, for example, are thought to store significant amounts of runoff. *Id.* at 4-38 (citing Novitzki 1979; Hubbard and Linder 1986; Vining 2002; Bullock and Acreman 2003; McEachern *et al.* 2006; Gleason *et al*. 2007). Filling wetlands reduces water storage capacity in the landscape and causes runoff from rainstorms to overwhelm the remaining available water conveyance system. *See, e.g.,* Johnston *et al*. 1990; Moscrip and Montgomery 1997; Detenbeck *et al*. 1999; Detenbeck *et al.* 2005. Wetlands, even when lacking a hydrologic connection downstream, improve downstream water quality by accumulating nutrients, trapping sediments, and transforming a variety of substances. *See, e.g.,* National Research Council 1995.

The structure and function of a river are highly dependent on the constituent materials that are stored in, or transported through, the river. Most of the materials found in rivers originate outside of them. Thus, the fundamental way that waters evaluated under (a)(5) are able to affect river structure and function is by providing or altering the materials delivered to the river. Science Report at 1-13. Since the alteration of material fluxes depends on the functions within these waters evaluated under paragraph (a)(5) and the degree of connectivity, it is appropriate to consider both these factors for purposes of the significant nexus standard under the final rule.

Based on the functions that can be provided by waters evaluated under paragraph (a)(5) to traditional navigable waters, the territorial seas, and interstate waters, the agencies' assessment of such intrastate waters on a case-specific basis to determine whether they meet either the relatively permanent standard or the significant nexus standard in the final rule reflects proper consideration of the objective of the Clean Water Act and the best available science.

E. Significant Nexus Standard

i. Waters Subject to the Significant Nexus Standard

Under the final rule, several categories of waters require a case-specific analysis to determine if they meet the significant nexus standard. This includes tributaries not meeting the relatively permanent standard, wetlands adjacent to tributaries and impoundments and that do not meet the relatively permanent standard, and intrastate waters assessed under paragraph (a)(5) that do not meet the relatively permanent standard.

The agencies have concluded that the significant nexus standard is consistent with the statutory text, advances the objective of the Clean Water Act, is informed by the scientific record and Supreme Court case law, and appropriately considers the policies of the Act. The agencies have also concluded that the relatively permanent standard on its own identifies only a subset of the "waters of the United States," although it is being retained because it provides important administrative efficiencies. The terms in this rule are generally familiar and implementable as they reflect consideration of the agencies' experience and expertise, as well as updates in implementation tools and resources.

The scientific literature documents the functions of waters that do meet the final rule's relatively permanent standard, including the chemical, physical, and biological impact they can have downstream. Available literature indicates that such waters can have important hydrologic, water quality, and habitat functions that have the ability to affect downstream traditional navigable waters, the territorial seas, and interstate waters, if and when a connection exists between the water and those larger downstream waters. Science Report at 6-5. Connectivity of waters evaluated under the significant nexus standard to traditional navigable waters, the territorial seas, and interstate waters, and for waters evaluated under paragraph (a)(5) in particular, will vary within a watershed and over time. The agencies have determined that where such waters do not meet the relatively permanent standard, as a matter of policy that a case-specific significant nexus evaluation is appropriate. *See*, *e.g.*, *id*. The types of chemical, physical, and biological connections between such waters and traditional navigable waters, the territorial seas, and interstate waters are described below for illustrative purposes. As described in the rule's preamble, when the agencies are conducting a case-specific evaluation for significant nexus, they examine the connections between the water (including any similarly situated waters in the region) and downstream traditional navigable waters, the territorial seas, or interstate waters, assess the relevant factors that affect connectivity and functions, and determine if those waters have a material influence on the chemical, physical, or biological integrity of the traditional navigable water, the territorial seas, or the interstate water, using any available site-information and field observations, relevant scientific studies or data, or other information.

The hydrologic connectivity of waters evaluated under the significant nexus standard to traditional navigable waters, the territorial seas, or interstate waters occurs on a gradient and can include waters in the floodplain, waters that have groundwater or occasional surface water connections (through overland flow) to the tributary network, and waters that have no hydrologic connection to the tributary network or to jurisdictional waters. *Id.* at 4-2. The connectivity of waters analyzed under the significant nexus standard to downstream traditional navigable waters, the territorial seas, or interstate waters will vary within a watershed as a function of local factors (*e.g.*, position, topography, and soil characteristics). *Id.* at 4-41. Connectivity also varies over time, as the tributary network and water table expand and contract in response to local climate. *Id*. Lack of connection does not necessarily translate to lack of impact; even when lacking connectivity, waters can still impact chemical, physical, and biological conditions downstream. *Id.* at 4-42 to 4-43.

Under the final rule, on a case-specific basis, waters that meet the significant nexus standard are "waters of the United States" under paragraphs (a)(3)(ii), (a)(4)(iii), and (a)(5)(ii). The scientific literature and data cited in the Science Report and this Technical Support Document demonstrate that these waters, along with any similarly situated waters in the region, significantly affect the chemical, physical, or biological integrity of traditional navigable waters, the territorial seas, and interstate waters.

The agencies also rely on the extensive experience the Corps has gained in making significant nexus determinations since the *Rapanos* decision. Since the *Rapanos* decision, the agencies have developed extensive experience making significant nexus determinations. The agencies have made determinations in every state in the country, for a wide range of waters in a wide range of conditions.

The rule's requirements for these waters, coupled with those for waters meeting the relatively permanent standard, create an integrated approach that tailors the regulatory regime based on the Supreme Court decisions and the agencies' policy objectives and informed by science. Providing for case-specific significant nexus analysis for waters that do not meet the relatively permanent standard is consistent with science, agency experience, and longstanding pre-2015 practice and will ensure protection of the important waters whose protection will advance the goals of the Clean Water Act.

For these reasons, the agencies decided to allow case-specific determinations of significant nexus for tributaries not meeting the relatively permanent standard, wetlands adjacent to tributaries and impoundments and that do not meet the relatively permanent standard, and intrastate waters assessed under paragraph (a)(5) that do not meet the relatively permanent standard. Under the rule, these waters are jurisdictional only where they individually or cumulatively (if it is determined that there are other similarly situated waters in the region) have a significant nexus to traditional navigable waters, the territorial seas, or interstate waters.

ii. "Similarly Situated"

Science supports analyzing the contributions of similarly situated waters in combination with each other for their effect on downstream traditional navigable waters, the territorial seas, and interstate waters. The agencies are establishing an approach to "similarly situated" for adjacent wetlands and tributaries and a different approach to "similarly situated" for intrastate waters assessed under paragraph (a)(5)(ii).

In implementing the final rule, the agencies consider tributaries and their adjacent wetlands to be "similarly situated" waters for purposes of the significant nexus standard. This is consistent with longstanding practice, and the agencies believe that this integrated approach to considering tributaries and their adjacent wetlands together when assessing the effects of these waters on the chemical, physical, or biological integrity of traditional navigable waters, the territorial seas, or interstate waters reflects that these waters act together to influence downstream waters, as discussed further in this section. In considering how to apply the significant nexus standard, the agencies have long focused on the integral relationship between the ecological characteristics of tributaries and those of their adjacent wetlands, which determines in part their contribution to restoring and maintaining the chemical, physical, or biological integrity of traditional navigable waters, the territorial seas, and interstate waters.

In implementing the significant nexus standard for waters assessed under paragraph (a)(5) of the final rule, the agencies generally intend to analyze such waters individually to determine if they significantly affect the chemical, physical, or biological integrity of a paragraph (a)(1) water. This approach reflects the agencies' consideration of public comments, as well as implementation considerations for waters assessed under paragraph (a)(5). While the agencies' regulations have long authorized the assertion of jurisdiction on a case-specific basis over waters that do not fall within the jurisdictional provisions by water type, since *SWANCC* and the issuance of the *SWANCC* guidance with its requirement of headquarters approval over determinations under that provision, the agencies have not in practice asserted jurisdiction over paragraph (a)(3) "other waters" under the pre-2015 regulatory regime.[40] The agencies addressed such waters individually on a case-specific basis under pre-2015 practice and have concluded at this time that individual assessments are practical and implementable for significant nexus determinations for waters assessed under paragraph (a)(5). The agencies note that generally assessing waters evaluated under paragraph (a)(5) on an individual basis represents a policy decision. One conclusion of Science Report was that the incremental effects of individual streams and wetlands are cumulative across entire watersheds and therefore should be evaluated in context with other streams and wetlands.

Streams, wetlands, and other surface waters interact with ground water and terrestrial environments throughout the landscape, "from the mountains to the oceans." *Id.* at 1-2 (citing Winter *et al*. 1998). Thus, an integrated perspective of the landscape, provides the appropriate scientific context for evaluating and interpreting evidence about the chemical, physical, and biological connectivity of streams, wetlands, and open waters to downstream traditional navigable waters, the territorial seas, and interstate waters.

Connectivity has long been a central tenet for the study of aquatic ecosystems. The River Continuum Concept viewed the entire length of rivers, from source to mouth, as a complex hydrologic

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[40] Note that when the 2015 Clean Water Rule was in effect, the agencies did assert categorical jurisdiction over waters if they were adjacent waters as defined by that rule and asserted jurisdiction on a case-specific basis over waters that fell within the provisions requiring case-specific significant nexus determinations where such waters were determined to have a significant nexus. Under the pre-2015 regulatory regime, such waters would have been assessed under paragraph (a)(3) of the agencies' 1986 regulations. The 2020 NWPR also asserted jurisdiction over certain lakes and ponds that would have been considered under the paragraph (a)(3) "other waters" category under the pre-2015 regulatory regime.

gradient with predictable longitudinal patterns of ecological structure and function. *Id.* (citing Vannote *et al.* 1980). The key pattern is that downstream communities are organized, in large part, by upstream communities and processes. *Id.* (citing Vannote *et al.* 1980; Battin *et al*. 2009). The Serial Discontinuity Concept built on the River Continuum Concept to improve our understanding of how dams and impoundments disrupt the longitudinal patterns of flowing waters with predictable downstream effects. *Id.* (citing Ward and Stanford 1983). The Spiraling Concept described how river network connectivity can be evaluated and quantified as materials cycle from dissolved forms to transiently stored forms taken up by living organisms, then back to dissolved forms, as they are transported downstream. *Id.* at 1-3 (citing Webster and Patten 1979; Newbold *et al*. 1981; Elwood *et al*. 1983). These three conceptual frameworks focused on the longitudinal connections of river ecosystems, whereas the subsequent flood pulse concept examined the importance of lateral connectivity of river channels to floodplains, including wetlands and open waters, through seasonal expansion and contraction of river networks. *Id.* (citing Junk *et al*. 1989). Ward (1989) summarized the importance of connectivity to lotic ecosystems along four dimensions: longitudinal, lateral, vertical (surface-subsurface), and temporal connections; he concluded that running water ecosystems are open systems that are highly interactive with both contiguous habitats and other ecosystems in the surrounding landscape. *Id.* As these conceptual frameworks illustrate, scientists have long recognized the hydrologic connectivity the physical structure of river networks represents.

More recently, scientists have incorporated this connected network structure into conceptual frameworks describing ecological patterns in river ecosystems and the processes linking them to other watershed components, including wetlands and open waters. *Id.* (citing Power and Dietrich 2002; Benda *et al*. 2004b; Nadeau and Rains 2007; Rodriguez-Iturbe *et al*. 2009). Sheaves (2009) emphasized the key ecological connections—which include process-based connections that maintain habitat function (*e.g.*, nutrient dynamics, trophic function) and movements of individual organisms—throughout a complex of interlinked freshwater, tidal wetlands, and estuarine habitats as critical for the persistence of aquatic species, populations, and communities over the full range of time scales. *Id.*

Scientists routinely aggregate the effects of groups of waters, multiplying the known effect of one water by the number of similar waters in a specific geographic area, or to a certain scale. This kind of functional aggregation of non-adjacent (and other types of waters) is well-supported in the scientific literature. *See, e.g.*, Stevenson and Hauer 2002; Leibowitz 2003; Gamble *et al*. 2007; Lane and D’Amico 2010; Wilcox *et al.* 2011. Similarly, streams and rivers are routinely aggregated by scientists to estimate their combined effect on downstream waters in the same watershed. This is because chemical, physical, or biological integrity of downstream waters is directly related to the aggregate contribution of upstream waters that flow into them, including any tributaries and connected wetlands. As a result, the scientific literature and the Science Report consistently document that the health of larger downstream waters is directly related to the aggregate health of waters located upstream, including waters such as wetlands that may not be hydrologically connected but function together to prevent floodwaters and contaminants from reaching downstream traditional navigable waters, the territorial seas, and interstate waters.

Stream and wetland connectivity to downstream waters, and the resulting effects on the integrity of downstream traditional navigable waters, the territorial seas, and interstate waters, is best understood and assessed when considered cumulatively. Science Report at 1-10. First, when considering the effect of an individual stream or wetland, including the cumulative effect of all the contributions and functions that a stream or wetland provides is essential. For example, the same stream transports water, removes excess nutrients, mitigates flooding, and provides refuge for fish when conditions downstream are unfavorable; ignoring any of these functions would underestimate the overall effect of that stream.

Secondly, and perhaps more importantly, stream channel networks and the watersheds they drain are fundamentally cumulative in how they are formed and maintained. Excess precipitation that is not evaporated, taken up by organisms, or stored in soils and geologic layers moves downgradient as overland flow or through channels, which concentrate flows and carry sediment, chemical constituents, and organisms. As flows from numerous headwater channels combine in larger channels, the volume and effects of those flows accumulate as they move through the river network. As a result, the incremental contributions of individual streams and wetlands accumulate in the downstream waters. Important cumulative effects are exemplified by ephemeral flows in arid landscapes, which are key sources of baseflow for downgradient waters, and by the high rates of denitrification in headwater streams. *Id.* (citing Schlesinger and Jones 1984; Baillie *et al*. 2007; Izbicki 2007). The amount of nutrients removed by any one stream over multiple years or by all headwater streams in a watershed in a given year can have substantial consequences for downstream waters. *Id.* (citing Alexander *et al*. 2007; Alexander *et al.* 2009; Böhlke *et al*. 2009; Helton *et al*. 2011). Similar cumulative effects on downstream waters have been documented for other material contributions from headwater streams in the Science Report. For example, although the probability of a large-magnitude transfer of organisms from any given headwater stream in a given year might be low (*i.e*., a low-frequency connection when each stream is considered individually), headwater streams are the most abundant type of stream in most watersheds. Thus, the overall probability of a large-magnitude transfer of organisms is higher when considered for all headwater streams in a watershed—that is, there is a high-frequency connection when considered cumulatively at the watershed scale, compared with probabilities of transport for streams individually. Similarly, a single pollutant discharge might be negligible but the cumulative effect of multiple discharges could degrade the integrity of downstream traditional navigable waters, the territorial seas, or interstate waters.

Evaluating cumulative contributions over time is critical in streams and wetlands with variable degrees of connectivity. *Id.* at 1-11. For example, denitrification in a single headwater stream in any given year might affect downstream waters; over multiple years, however, this effect could accumulate. Western vernal pools provide another example of cumulative effects over time. These pools typically occur as complexes in which the hydrology and ecology are tightly coupled with the local and regional geological processes that formed them. When seasonal precipitation exceeds wetland storage capacity and wetlands overflow into the river network and generate stream discharge, the vernal pool basins, swales, and seasonal streams function as a single surface-water and shallow ground-water system connected to the river network.

In the aggregate, similarly situated waters may have significant effects on the quality of water many miles away, particularly in circumstances where numerous similarly situated waters are located in the region and are performing like functions that combine to influence downstream waters. *See, e.g.*, Jansson *et al*. 1998; Mitsch *et al*. 2001; Forbes *et al.* 2012. Cumulatively, many small wetlands can hold a large amount of snowmelt and precipitation, reducing the likelihood of flooding downstream. Science Report at 4-24 (citing Hubbard and Linder 1986).

Scientists can and do routinely classify similar waters and wetlands into groups for a number of different reasons; because of their inherent physical characteristics, because they provide similar functions, because they were formed by similar geomorphic processes, and by their level of biological diversity, for example. Classifying wetlands based on their functions is also the basis for the U.S. Army Corps of Engineers hydrogeomorphic (HGM) classification of wetlands. Brinson 1993. The HGM method is a wetlands assessment approach pioneered by the Corps in the 1990s, and extensively applied via regional handbooks since then. The Corps HGM method uses a conceptual framework for identifying broad wetland classes based on common structural and functional features, which includes a method for using local attributes to further subdivide the broad classes into regional subclasses. Assessment methods like the HGM provide a basis for determining if waters provide similar functions based on their structural attributes and indicator species. Scientists also directly measure attributes and processes taking place in particular types of waters during in-depth field studies that provide reference information that informs the understanding of the functions performed by many types of aquatic systems nationwide.

Consideration of the aggregate effects of wetlands and other types of waters often gives the most complete information about how such waters influence the chemical, physical, or biological integrity of downstream traditional navigable waters, the territorial seas, and interstate waters. In many watersheds, wetlands have a disproportionate effect on water quality relative to their surface area because wetland plants slow down water flow, allowing suspended sediments, nutrients, and pollutants to settle out. They filter these materials out of the water received from large areas, absorbing or processing them, and then releasing higher quality water. National Research Council 1995. For an individual wetland, this is most pronounced where it lies immediately upstream of a drinking water intake, for example. *See, e.g.,* Johnston *et al.* 1990. The cumulative influence of many individual wetlands within watersheds can strongly affect the spatial scale, magnitude, frequency, and duration of hydrologic, biological, and chemical fluxes or transfers of water and materials to downstream waters. Science Report at ES-11.

For example, as discussed in section III.A.ii, excess nutrients discharged into small tributary streams in the aggregate can cause algal blooms downstream that reduce dissolved oxygen levels and increase turbidity in traditional navigable waters, traditional navigable waters, the territorial seas, and interstate waters. This oxygen depletion in waters, known as hypoxia, has impacted commercial and recreational fisheries in the northern Gulf of Mexico, as water low in dissolved oxygen cannot support living aquatic organisms. Committee on Environment and Natural Resources 2000; Rabalais *et al.* 2002; Freeman *et al.* 2007; Colvin 2019. In this instance, the cumulative effects of nutrient export from the many small headwater streams of the Mississippi River have resulted in large-scale ecological and economically harmful impacts hundreds of miles downstream. *See, e.g.,* Goolsby *et al.* 1999; Rabotyagov *et al.* 2014; Colvin 2019.

In their review of the scientific and technical adequacy of a previous rulemaking effort, the SAB panel members “generally agreed that aggregating ‘similarly situated’ waters is scientifically justified, given that the combined effects of these waters on downstream waters are often only measurable in aggregate. Panelists also were generally comfortable with the idea of using “similarly situated” waters to guide aggregation.” SAB 2014a at 4 to 5. One of the main conclusions of the Science Report is that the incremental contributions of individual streams and wetlands are cumulative across entire watersheds, and their effects on downstream waters should be evaluated within the context of other streams and wetlands in that watershed. For example, the Science Report finds, “[t]he amount of nutrients removed by any one stream over multiple years or by all headwater streams in a watershed in a given year can have substantial consequences for downstream waters.” Science Report at 1-10. Cumulative effects of streams, wetlands, and open waters across a watershed must be considered because "[t]he downstream consequences (*e.g.*, the amount and quality of materials that eventually reach a river) are determined by the aggregate effect of contributions and sequential alterations that begin at the source waters and function along continuous flowpaths to the watershed outlet." *Id*. at 1-19.

iii. "In the Region"

For the reasons discussed in section III.E.ii, the agencies believe that science supports analyzing the contributions of similarly situated waters "in the region" for their effect on traditional navigable waters, the territorial seas, or interstate waters because the incremental contributions of individual streams and wetlands are cumulative, and their effect on downstream waters should be evaluated within the context of other streams and wetlands in the appropriate region.

For tributaries and their adjacent wetlands, the agencies consider similarly situated waters to be "in the region" when they lie within the catchment area of the tributary of interest. Identifying the catchment area for purposes of this significant nexus analysis is described below. The agencies developed this updated evaluation method from the current pre-2015 implementation approach informed by their experience, the best available science, Supreme Court decisions, and public comments. Accordingly, in implementing the significant nexus standard under this rule, all tributaries and adjacent wetlands within the catchment area of the tributary of interest will be analyzed as part of the significant nexus analysis.[41] This approach to significant nexus analysis recognizes the ecological relationship between the tributaries and their adjacent wetlands, and the role those similarly situated waters have in influencing the chemical, physical, or biological integrity of downstream traditional navigable waters, the territorial seas, and instated waters.

In the case of wetlands adjacent to tributaries, science supports the consideration of the effects of not just a singular adjacent wetland, but any wetland adjacent to the tributary for assessing if there is significant effect on the integrity of downstream waters. Additionally, science supports that similarly situated waters are "in the region" when they lie within the catchment area of the tributary of interest because all the upstream tributaries and their adjacent wetlands in that catchment cumulatively have an impact on larger downstream waters. Because the adjacent wetlands are integrated with the tributary, science also supports the consideration of all wetlands adjacent to that tributary in combination with the tributary itself when conducting a significant nexus analysis.

Using a catchment (*i.e.*, the watershed of the tributary of interest) as the framework for conducting significant nexus evaluations for tributaries and their adjacent wetlands is also scientifically supportable. Watersheds are generally regarded as the most appropriate spatial unit for water resource management. *See, e.g.*, Omernik and Bailey 1997; Montgomery 1999; Winter 2001; Baron *et al*. 2002; Allan 2004; U.S. Environmental Protection Agency 2008; Wigington *et al.* 2013. The watershed framework is consistent with over two decades of practice by EPA and many other governmental, academic, and other entities which recognize that a watershed approach is generally the most effective

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[41] This implementation approach to the region for purposes of the significant nexus standard is a change from the *Rapanos* Guidance. *See* section IV.C.9.c of the preamble and section IV.B of this document for additional discussion on implementing the significant nexus analysis.

framework to address water resource challenges. *See, e.g.,* U.S. Environmental Protection Agency 1996; U.S. Environmental Protection Agency 2010. In addition, the Science Report also supports evaluating waters on a watershed scale, concluding, "[c]umulative effects *across a watershed* must be considered when quantifying the frequency, duration, and magnitude of connectivity, to evaluate the downstream effects of streams and wetlands." Science Report at ES-14 (emphasis added). In addition, the Science Report notes, "[a] river is the time-integrated result of all waters contributing to it, and connectivity is the property that spatially integrates the individual components of the watershed. In discussions of connectivity, the watershed scale is the appropriate context for interpreting technical evidence about individual watershed components." *Id.* at 2-1 (citing Newbold *et al*. 1982b; Stanford and Ward 1993; Bunn and Arthington 2002; Power and Dietrich 2002; Benda *et al.* 2004b; Naiman *et al.* 2005; Nadeau and Rains 2007; Rodriguez-Iturbe *et al*. 2009). The Science Report also states that watersheds are integrated at multiple spatial and temporal scales by flows of surface water and ground water, transport and transformation of physical and chemical materials, and movements of organisms. *Id*. at 6-8. The movement of water from watershed drainage basins to river networks and lakes shapes the development and function of these systems in a way that is critical to their long-term health. *See, e.g.*, Montgomery 1999. Anthropogenic actions and natural events can have widespread effects within the watershed that collectively impact the quality of the traditional navigable water, the territorial seas, or interstate water. Levick *et al.* 2008. From a water quality management perspective, science supports the evaluation of the effects of tributaries and their adjacent wetlands on a catchment scale as the integrity of downstream traditional navigable waters, the territorial seas, and interstate waters is dependent on the condition of the contributing upstream waters, including streams, lakes, and ponds connected to the tributary network and wetlands adjacent to such waters. The functions of the contributing waters are inextricably linked and have a cumulative effect on the integrity of the downstream traditional navigable water, the territorial sea, or interstate water. Thus, the watershed reflects specific water management objectives and can be scaled up or down as is appropriate to meet that objective or to meet specific policy needs. For purposes of implementing this final rule, the agencies have scaled the watershed to the "catchment level"—meaning, as described above, the catchment of the tributary of interest.

Because waters assessed under paragraph (a)(5) of the final rule will generally be evaluated individually for their effects on traditional navigable waters, the territorial seas, or interstate waters, the agencies have not established what would be considered "in the region" for this such waters, as it is not needed to implement the final rule, as such waters will generally be considered on an individually basis.

Other potential approaches were considered in the Technical Support Document for the Proposed Rule, including ecoregions (Omernik 1987; Omernik 1995; Omernik and Griffith 2014; U.S. EPA 2022j; U.S. EPA 2022k), hydrologic landscape units (Winter 2001; Wolock 2003), and physiographic divisions (Fenneman 1917; Fenneman and Johnson 1946), or a combination of hydrologic landscape regions and physiographic divisions for further refinement of regions (*e.g.*, Blackburn-Lynch *et al*. 2017). These methods could present implementation challenges, whereby the region is too large and obscures the measurable effects of single aquatic resources or is difficult to implement in the field. The agencies solicited comment on what constitutes an appropriate "region" for purposes of analyzing if waters significantly affect the chemical, physical, or biological integrity of downstream traditional navigable waters, the territorial seas, or interstate waters. Based on a review of the public comments, the best available science, and the agencies' technical expertise and experience, the agencies have determined that the final rule's approach to implementing "in the region" under the significant nexus standard for tributaries and their adjacent wetlands is clear and implementable. The agencies have determined that the catchment of the tributary is a reasonable and technically appropriate scale. The catchment is an easily identified and scientifically defensible unit for identifying the scope of waters that together may have an effect on the chemical, physical, or biological integrity of a particular traditional navigable water, the territorial seas, or an interstate water.

iv. “Significantly Affect”

Paragraph (c)(6) of the final rule defines the term “significantly affect” for purposes of determining whether a water meets the significant nexus standard to mean “a material influence on the chemical, physical, or biological integrity of” traditional navigable waters, the territorial seas, or interstate waters. Under this rule, waters, including wetlands, are evaluated either alone, or in combination with other similarly situated waters in the region,[42] based on the functions the evaluated waters perform. The final rule identifies specific functions that will be assessed and identifies specific factors that will be considered when assessing whether the functions provided by the water, alone or in combination, have a material influence on the chemical, physical, or biological integrity of a traditional navigable water, the territorial seas, or an interstate water. The agencies are not requiring the use of “functional assessments” for significant nexus analyses under this rule; *see* section IV.C.9.c of the preamble for further discussion.

The functions in this rule are indicators that are tied to the chemical, physical, and biological integrity of traditional navigable waters, the territorial seas, and interstate waters. The functions include contribution of flow; trapping, transformation, filtering, and transport of materials (including nutrients, sediment, and other pollutants); retention and attenuation of floodwaters and runoff; modulation of temperature in traditional navigable waters, the territorial seas, or interstate waters; or provision of habitat and food resources for aquatic species located in traditional navigable waters, the territorial seas, or interstate waters.

The factors in this rule are readily understood criteria that influence the types and strength of chemical, physical, or biological connections and associated effects on those downstream traditional navigable waters, the territorial seas, or interstate waters. These factors include the distance from a paragraph (a)(1) water; hydrologic factors, such as the frequency, duration, magnitude, timing, and rate of hydrologic connections, including shallow subsurface flow; the size, density, or number of waters that have been determined to be similarly situated; landscape position and geomorphology; and climatological variables such as temperature, rainfall, and snowpack.

The definition of “significantly affect” is derived from the objective of the Clean Water Act and is informed by and consistent with Supreme Court case law. It is also informed by the agencies’ technical and scientific judgment and supported by the best available science regarding the functions performed by upstream waters relevant to achieving the Clean Water Act’s objective. The significant nexus standard established by the final rule is carefully constructed to fall within the bounds of the Clean Water Act. Not all waters subject to evaluation under the significant nexus standard will have a material influence on

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[42] *See* sections III.E.ii and IV.B.i for discussion of how the agencies’ intend to implement “similarly situated” and sections III.E.iii and IV.B.ii for discussion of how the agencies’ intend to implement “in the region” as discussed in the final rule’s preamble.

traditional navigable waters, the territorial seas, or interstate waters sufficient to be determined jurisdictional. First, the standard is limited to consideration of effects on traditional navigable waters, the territorial seas, and interstate waters. Second, the standard is limited to effects only on the three statutorily identified aspects of those fundamental waters: chemical, physical, or biological integrity. Third, the standard cannot be met by merely speculative or insubstantial effects on those aspects of those traditional navigable waters, the territorial seas, and interstate waters, but rather requires the demonstration of a "material influence." In the final rule, the phrase "material influence" establishes that the agencies will be assessing the influence of the waters either alone or in combination have on the chemical, physical, or biological integrity of a traditional navigable water, the territorial seas, or an interstate water and will provide qualitative and/or quantitative information (based on the factual record, relevant scientific data and information, and available tools) and articulate a reasoned basis for determining that the waters being assessed significantly affect that fundamental downstream water.

Under the significant nexus standard, to be jurisdictional, waters, alone or in combination with other similarly situated waters in the region, must have a material influence on the chemical, physical, or biological integrity of a traditional navigable water, the territorial seas, or an interstate water. The final definition is generally consistent with the pre-2015 regulatory regime. Under the *Rapanos* Guidance, the agencies evaluate whether waters "are likely to have an effect that is more than speculative or insubstantial on the chemical, physical, and biological integrity of a traditional navigable water." *Rapanos* Guidance at 11. Under the final rule, a water may be determined to meet the definition of "waters of the United States" when it "significantly affects" any one form of chemical, physical, or biological integrity of a traditional navigable water, the territorial seas, or an interstate water, consistent with the pre-2015 regulatory regime.

Significant nexus is not purely a scientific determination. Further, the opinions of the Supreme Court have noted that as the agencies charged with interpreting the statute, EPA and the Corps, must develop the outer bounds of the scope of the Clean Water Act, while science does not provide bright lines with respect to where "water ends" for purposes of the Clean Water Act. Therefore, the agencies' interpretation of the Clean Water Act is informed by science, but not dictated by it.

With this context, this section of the Technical Support Document addresses the factors that will be considered in a significant nexus evaluation as well as the relevant scientific functions that streams, wetlands, and open waters perform that will be evaluated to determine whether such waters, either alone or with similarly situated waters in the region, significantly affect the chemical, physical, or biological integrity of traditional navigable waters, the territorial seas, or interstate waters.

The agencies are adding to the final rule's definition of "significantly affect" a specific list of functions to be assessed when making a significant nexus determination after soliciting comment on whether it would be useful to add such a list to the definition. The *Rapanos* Guidance identified some of the relevant functions upstream waters can provide for downstream traditional navigable waters, the territorial seas, or interstate waters including temperature regulation; sediment trapping and transport; nutrient recycling, retention, and export; pollutant trapping, transformation, filtering, and transport; retention and attenuation of floodwaters and runoff; contribution of flow; provision of habitat for aquatic species that also live in traditional navigable waters, the territorial seas, or interstate waters (*e.g.*, for refuge, feeding, nesting, spawning, or rearing young); and provision and export of food resources for aquatic species located in traditional navigable waters, the territorial seas, or interstate waters. Evaluation of such functions is consistent with the agencies' implementation of the pre-2015 regulatory regime. *See Rapanos* Guidance at 8, 9.

Under the final rule, a water does not need to perform all of the listed functions. This is consistent with the pre-2015 regulatory regime. *See* U.S. Army Corps of Engineers 2007a. If a water, either alone or in combination with similarly situated waters, performs just one function, and that function has a more than speculative or insubstantial impact on the integrity of a traditional navigable water, the territorial seas, or an interstate water, that water has a significant nexus under the final rule, consistent with the pre-2015 regulatory regime.[43] The functions listed in the final rule's definition of "significantly affect" and how they can affect the chemical, physical, or biological integrity of traditional navigable waters, the territorial seas, or interstate waters are discussed below and throughout sections I and III of this document.

Contribution of flow. The contribution of flow downstream is an important role, as upstream waters can be a cumulative source of the majority of the total mean annual flow to larger downstream rivers and waters, including via the recharge of baseflow. Streams, wetlands, and open waters contribute surface and subsurface water downstream, and are the dominant sources of water in most rivers. Contribution of flow can significantly affect the physical integrity of traditional navigable waters, the territorial seas, and interstate waters, helping to sustain the volume of water in these larger waters.

Trapping, transformation, filtering, and transport of materials (including nutrients, sediment, and other pollutants). States identify sediment and nutrients as the primary contaminants in the nation's waters. Sediment storage and export via streams to downstream waters is critical for maintaining the river network, including the formation of channel features. Although sediment is essential to river systems, excess sediment can impair ecological integrity by filling interstitial spaces, reducing channel capacity, blocking sunlight transmission through the water column, and increasing contaminant and nutrient concentrations. Streams and wetlands can prevent excess deposits of sediment downstream and reduce pollutant concentrations in downstream waters. Thus, the function of trapping of excess sediment, along with export of sediment, can have a significant effect on the chemical, physical, and biological integrity of downstream waters.

Nutrient recycling results in the uptake and transformation of large quantities of nitrogen and other nutrients that otherwise would be transported directly downstream, thereby decreasing nutrient loads and associated impairments due to excess nutrients in downstream waters. Streams, wetlands and open waters improve water quality through the assimilation, transformation, or sequestration of pollutants, including excess nutrients and chemical contaminants such as pesticides and metals that can degrade downstream water integrity. Nutrient transport exports nutrients downstream and can degrade water quality and lead to stream impairments. Nutrients are necessary to support aquatic life, but excess nutrients lead to excessive plant growth and hypoxia, in which over-enrichment causes dissolved oxygen concentrations to fall below the level necessary to sustain most aquatic animal life in the downstream

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[43] *See, e.g.*, Memorandum to Assert Jurisdiction for SPL-2007-261-FBV (December 6, 2007), *available at* https://usace.contentdm.oclc.org/utils/getfile/collection/p16021coll5/id/1433.

waters. Nutrient recycling, retention, and export can significantly affect downstream chemical integrity by impacting downstream water quality.

Streams, wetlands, and open waters improve water quality through the assimilation and sequestration of pollutants, including excess nutrients and chemical contaminants such as pesticides and metals that can degrade downstream water integrity. In addition to nutrient recycling, removal of nutrients by streambed algal and microbial populations, subsequent feeding by fish and insects, and release by excretion or decomposition, delays the export of nutrients downstream. Riparian, floodplain and non-floodplain wetlands and open waters are active sites for aerobic and anaerobic microbial processes (*e.g.*, denitrification) and physical processes (*e.g.*, settling, photo-degradation) that enhance the assimilation and sequestration of pollutants, thereby limiting their transport to downstream waters. When pollutants reach a wetland, they can be trapped in sediments, assimilated into wetland plants and animals, biogeochemically transformed into less harmful or mobile forms or compounds, or lost to the atmosphere. Importantly, many of the functions performed by non-floodplain wetlands and open waters that affect downstream waters (*e.g.*, surface water storage) result from the disconnections (often hydrological) that create and maintain conditions conducive to the performance of beneficial functions (frequently hydrological and biogeochemical, *e.g.*, mitigation of flood peak flows, sequestration of contaminants).

Retention and attenuation of floodwaters and runoff. Small streams and wetlands are particularly effective at retaining and attenuating floodwaters. By subsequently releasing floodwaters and retaining large volumes of stormwater and runoff (*i.e.*, overland flow) that could otherwise negatively affect the condition or function of downstream waters, streams, wetlands, and open waters can affect the physical integrity of traditional navigable waters, the territorial seas, or interstate waters. This function can reduce flood peaks downstream and can also maintain downstream river baseflows by recharging alluvial aquifers. Runoff occurs when rain, snowmelt, or stormflow exceeds the infiltration rate of soils or storage capacity of soils, streams, wetlands, and open waters. Runoff is an important source of stream and river baseflow. Runoff also carries deposits of sediment and human-made contaminants such as petroleum, pesticides, and fertilizers and is therefore a major source of non-point pollution. Annual runoff generally reflects water surplus and varies widely across the United States. The flowing portions of river networks tend to have their maximum extent during seasons with the highest water surplus, when conditions for flooding are most likely. The Southwest experiences summer monsoonal rains, while the West Coast and Pacific Northwest receive most precipitation during the winter season. Throughout the West, winter precipitation in the mountains occurs as snowfall, where it is stored as seasonal snowpack and is released during the spring and summer melt seasons to sustain streamflow during late spring and summer months. Typically, the occurrence of ephemeral and intermittent streams is greatest in watersheds with low annual runoff and high water-surplus seasonality. Ephemeral tributaries in arid and semi-arid areas convey large volumes of stormflow into alluvial aquifer storage; runoff through ephemeral tributaries that is not stored as groundwater provides baseflow for rivers like the Rio Grande. Precipitation and water surplus in the Eastern United States is less seasonal than in Western states. In temperate climates, headwater tributaries store water and sediment from runoff, reducing the volume and velocity of flows that cause bank erosion, streambed down-cutting, and reduced infiltration to ground water. Riparian, floodplain, and non-floodplain wetlands and open waters store and subsequently release stormflows, desynchronizing floodwaters and retaining large volumes of runoff (*i.e.*, stormwater, sediment, and contaminants) that could otherwise negatively affect the condition or function of downstream waters.

Modulation of temperature in traditional navigable waters, the territorial seas, or interstate waters. Tributaries can greatly influence water temperatures in tributary networks. *See* section III.A.i. This is important because water temperature is a critical factor governing the distribution and growth of aquatic life, both directly (through its effects on organisms) and indirectly (through its effects on other physiochemical properties, such as dissolved oxygen and suspended solids). For example, water temperature controls metabolism and level of activity in cold-blooded species like fish, amphibians, and aquatic invertebrates. Temperature can also control the amount of dissolved oxygen in streams, as colder water holds more dissolved oxygen, which fish and other fauna need to breathe. Tributaries provide both cold and warm water refuge habitats that are critical for protecting aquatic life. Because headwater tributaries often depend on groundwater inputs, temperatures in these systems tend to be warmer in the winter (when groundwater is warmer than ambient temperatures) and colder in the summer (when groundwater is colder than ambient temperatures) relative to downstream waters. Thus, tributaries provide organisms with both warm water and coldwater refuges at different times of the year. *Id.* at 3-42. For example, when temperature conditions in downstream waters are adverse, fish can travel upstream and use tributaries as refuge habitat. Tributaries also help buffer temperatures in downstream waters that are many kilometers away. Adjacent wetlands and open waters located in floodplains also exert substantial controls on water temperature in the downgradient tributary network and ultimately in the traditional navigable water, the territorial seas, or the interstate water.

Provision of habitat and food resources for aquatic species located in traditional navigable waters, the territorial seas, or interstate waters. Streams, wetlands, and open waters provide life-cycle dependent aquatic habitat (such as foraging, feeding, nesting, breeding, spawning, and use as a nursery area) for species located in traditional navigable waters, the territorial seas, or interstate waters. Many species require different habitats for different resources (*e.g.*, food, spawning habitat, overwintering habitat), and thus move throughout the river network over their life cycles. For example, headwater streams can provide refuge habitat under adverse conditions, enabling fish to persist and recolonize downstream areas once conditions have improved. These upstream systems form integral components of downstream food webs, providing nursery habitat for breeding fish and amphibians, colonization opportunities for stream invertebrates, and maturation habitat for stream insects, including for species that are critical to downstream ecosystem function. Streams, wetlands, and open waters can also serve as a refuge for aquatic species also located in traditional navigable waters, the territorial seas, and interstate waters. The provision of life-cycle dependent aquatic habitat for species located in such larger downstream waters significantly affects the biological integrity of those downstream waters.

Streams, wetlands, and open waters supply habitat and food resources for downstream waters, such as dissolved and particulate organic matter (*e.g.*, leaves, wood), which support biological activity throughout the river network. In addition to organic matter, streams, wetlands, and open waters can also export other food resources downstream, such as aquatic insects that are the food source for fish in downstream waters. The export of organic matter and food resources downstream is important to maintaining the food webs and thus the biological integrity of traditional navigable waters, the territorial seas, and interstate waters.

It is also important to note that the agencies’ significant nexus standard in the final rule is carefully tailored so that only particular types of functions provided by upstream waters can be considered for their effects on traditional navigable waters, the territorial seas, and interstate waters. Wetlands, streams, and open waters are well-known to provide a wide variety of functions that translate into ecosystem services. *See* section I.H.i. A significant nexus analysis, however, is limited to an assessment of only those functions identified in the final rule that have a nexus to the chemical, physical, or biological integrity of traditional navigable waters, the territorial seas, or interstate waters. Thus, there are some important functions provided by wetlands, tributaries, and waters evaluated under paragraph (a)(5) that will not be considered by the agencies when making jurisdictional decisions under the final rule.

For example, for purposes of a jurisdictional analysis under the significant nexus standard, the agencies will not be taking into account the carbon sequestration benefits that aquatic resources like wetlands provide. Provision of habitat for non-aquatic species, such as migratory birds, and endemic aquatic species would not be considered as part of a significant analysis under the final rule.[44] Furthermore, the agencies would not assess soil fertility in terrestrial systems, which is enhanced by processes in stream and wetland soils and non-floodplain wetlands that accumulate sediments, prevent or reduce soil erosion, and retain water on the landscape, benefiting soil quality and productivity in uplands. There are also a wide variety of functions that streams, wetlands, and open waters provide that translate into ecosystem services that benefit society that would not be assessed in a significant nexus analysis under the final rule. These include provision of areas for recreation and personal enjoyment (*e.g.*, fishing, hunting, boating, and birdwatching areas); ceremonial or religious uses; production of fuel, forage, and fibers; extraction of materials (*e.g.*, biofuels, food, such as shellfish, vegetables, seeds, nuts, rice); plants for clothes and other materials; and medical compounds from wetland and aquatic plants or animals. While these types of ecosystem services can contribute to the economy, they are not relevant to the chemical, physical, or biologic integrity of paragraph traditional navigable waters, the territorial seas, and interstate waters and would not be considered in a significant nexus analysis under the final rule.

In evaluating a water individually or in combination with other similarly situated waters for the presence of a significant nexus to a traditional navigable water, the territorial seas, or an interstate water, the agencies will consider factors that influence the types and strength of the chemical, physical, or biological connections and associated effects on those downstream waters. The agencies include in the definition of “significantly affect” the factors to be considered in assessing the strength of the effects: (1) the distance from the traditional navigable water, the territorial seas, or interstate water; (2) hydrologic factors, such as the frequency, duration, magnitude, timing, and rate of hydrologic connections, including shallow subsurface flow; (3) the size, density, or number of waters that have been determined to be similarly situated (and thus can be evaluated in combination); (4) landscape position and geomorphology; and (5) climatological variables such as temperature, rainfall, and snowpack.

These factors influence the strength of the connections and associated effects that streams, wetlands, and open waters have on the chemical, physical, and biological integrity of traditional navigable waters, the territorial seas, and interstate waters and are not the functions themselves that the agencies will

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[44] As the agencies have discussed, consideration of biological functions such as provision of habitat is relevant for purposes of significant nexus determinations under the final rule only to the extent that the functions provided by tributaries, adjacent wetlands, and waters assessed under paragraph (a)(5) significantly affect the biological integrity of a traditional navigable water, the territorial seas, or an interstate water. For example, to protect Pacific and Atlantic salmon in traditional navigable waters (and their associated commercial and recreational fishing industries), protections must be provided from the headwater streams where the fish are born and spawn to the marine waters where they spend most of their lives. *See, e.g.,* Science Report at 2-40.

consider as part of the significant nexus standard. These factors also cannot be considered in isolation, but rather must be considered together and in the context of the case-specific analysis. For example, the likelihood of a connection with associated significant effects is generally greater with increasing number and size of the aquatic resource or resources being considered and decreasing distance from the identified traditional navigable water, the territorial seas, or interstate water as well as with increased density of the waters for such waters that can be considered in combination as similarly situated waters. However, the agencies also recognize that in watersheds with fewer aquatic resources, even a small number or low density of similarly situated waters can have disproportionate effects on traditional navigable waters, the territorial seas, or interstate waters. Hydrologic factors include volume (or magnitude), duration, timing, rate, and frequency of flow, size of the watershed or subwatershed, and surface and shallow subsurface hydrologic connections. The presence of a surface or shallow subsurface hydrologic connection, as well as increased frequency, volume, or duration of such connections, can increase the chemical, physical (*i.e.*, hydrologic), or biological impact that a water has on traditional navigable waters, the territorial seas, or interstate waters. In other situations, streams with low duration but a high volume of flow can significantly affect downstream traditional navigable waters, the territorial seas, or interstate waters by transporting large volumes of water, sediment, and woody debris that help maintain the integrity of those larger downstream waters. Science Report at ES-5, ES-8, 6-9. The lack of hydrologic connections can also contribute to the strength of effects for certain functions such as floodwater attenuation or the retention and transformation of pollutants. *Id.* at 4-26. Climatological factors like temperature, rainfall, and snowpack in a given region can influence the agencies' consideration of the effects of subject waters on downstream traditional navigable waters, the territorial seas, or interstate waters by providing information about expected hydrology and the expected seasonality of connections and associated effects.

The agencies have more than a decade of experience implementing the significant nexus standard by making determinations of whether a water alone or in combination with similarly situated waters in the region significantly affects the chemical, physical, and biological integrity of downstream traditional navigable waters, the territorial seas, or interstate waters. The agencies under the pre-2015 regulatory regime routinely concluded that there was no significant nexus. Based on the agencies' experience, many waters under the final rule will not have a significant nexus to downstream traditional navigable waters, the territorial seas, or interstate waters, and thus will not be jurisdictional under the Act. The agencies also note that the vast majority of resources assessed in approved jurisdictional determinations under the *Rapanos* Guidance were not assessed under the significant nexus standard. Historically, roughly 11% of resources assessed in approved jurisdictional determinations under the *Rapanos* Guidance required a significant nexus analysis. It is the agencies' expectation that the number of significant nexus analyses will increase under this rule due to the assessment of paragraph (a)(5) waters, but it is correspondingly expected that the percent of resources found to be jurisdictional under significant nexus analyses will decrease. *See* section IV below for more information on significant nexus determinations.

The scientific record demonstrates that the aquatic functions provided by smaller streams, ponds, wetlands, and other types of waters are important for protecting the chemical, physical, and biological integrity of larger downstream traditional navigable waters, the territorial seas, and interstate waters. For example, states have identified sediment and nutrients as the primary contaminants in the nation's waters. *See, e.g.,* U.S. Environmental Protection Agency 2003; U.S. Environmental Protection Agency 2008; U.S. Environmental Protection Agency 2017. Sediment storage and export via streams to downstream waters is critical for maintaining the river network, including the formation of channel features. Science

Report at 3-13. Although sediment is essential to river systems, excess sediment can impair ecological integrity by filling interstitial spaces (*e.g.*, burying gravel or cobble habitats in streambeds that are essential for the sustainability of aquatic insects and fish spawning sites), reducing channel capacity which can lead to increased flood risk downstream;, blocking sunlight transmission through the water column which impacts fish feeding and schooling practices and can deprive aquatic plants of light needed for photosynthesis, increasing water temperatures which can negatively impact fish and other aquatic species, clogging and irritating the gills of fish, and increasing contaminant and nutrient concentrations. *Id*. (citing Wood and Armitage 1997). Thus, too much sediment in streams can reduce water clarity, harm aquatic species, interfere with the recreational use of streams, and affect drinking water supplies (*see, e.g.*, Mukundan *et al*. 2013). Streams and wetlands can prevent excess deposits of sediment downstream and reduce pollutant concentrations in downstream waters. *Id.* at ES-2 to ES-3; ES-8. Degraded streams can be a source of excess sediment to downstream waters. The function of trapping excess sediment, along with export of sediment, has an effect on the chemical, physical, and biological integrity of downstream waters.

Streams, wetlands, and open waters improve water quality through the assimilation, transformation, or sequestration of pollutants, including excess nutrients and chemical contaminants such as pesticides and metals that can degrade downstream water integrity. *Id.* at ES-2 to ES-3, ES-13. Nutrients, for example, are necessary to support aquatic life, but excess nutrients lead to excessive plant growth and hypoxia or “dead zones,” in which over-enrichment causes dissolved oxygen concentrations to fall below the level necessary to sustain most aquatic animal life in the downstream waters. *Id.* at ES-8. Nutrient recycling that occurs in streams, wetlands, and open waters results in the uptake and transformation of large quantities of nitrogen and other nutrients that otherwise would be transported directly downstream, thereby decreasing nutrient loads and associated impairments due to excess nutrients in downstream waters. *Id.* at ES-8. Streams can transport excess nutrients downstream, which can degrade water quality and lead to stream impairments. *Id.* at ES-2. Nutrient recycling, retention, and export thus can affect downstream chemical integrity by impacting downstream water quality.

The contribution of flow downstream is also an important function of streams, wetlands, and open waters, as upstream waters can be a cumulative source of the majority of the total mean annual flow to bigger downstream rivers and waters, including via the recharge of baseflow. *Id.* at ES-8. Streams, wetlands, and open waters contribute surface and subsurface water downstream, and are the dominant sources of water in most rivers. *Id.* at ES-2, ES-7, ES-9, ES-11. Contribution of flow can affect the physical integrity of downstream waters, helping to sustain the volume of water in larger waters.

Small streams and wetlands are particularly effective at retaining and attenuating floodwaters, thereby contributing to maintaining the integrity of downstream waters. *Id.* at ES-2, ES-8, ES-9, ES-10. By subsequently and slowly releasing (desynchronizing) floodwaters and retaining large volumes of stormwater that could otherwise negatively affect the condition or function of downstream waters, streams, wetlands, and open waters affect the physical integrity of downstream traditional navigable waters, the territorial seas, or interstate waters. *Id.* at ES-3. This function can reduce flood peaks downstream and can also maintain downstream river baseflows by recharging alluvial aquifers (shallow aquifers near stream channels).

Streams, wetlands, and open waters supply downstream waters with dissolved and particulate organic matter (*e.g.*, leaves, wood), which support biological activity throughout the river network. *Id.* at ES-2, ES-3. In addition to organic matter, streams, wetlands, and open waters can also export other food resources downstream, such as aquatic insects that are the food source for fish in downstream waters. *Id*. The export of organic matter and food resources downstream is important to maintaining the food webs and thus the biological integrity of traditional navigable waters, the territorial seas, or interstate waters.

Streams, wetlands, and open waters provide life-cycle dependent aquatic habitat (such as foraging, feeding, nesting, breeding, spawning, and use as a nursery area) for species that travel to and from traditional navigable waters, the territorial seas, or interstate waters. *Id.* at ES-2, ES-3, ES-8, ES-9, ES-11. Many species require different habitats for different resource needs (*e.g.*, food, spawning habitat, overwintering habitat), and thus move throughout the river network to over their life-cycles. *Id.* at ES-11, 3-38 (citing Schlosser 1991; Fausch *et al*. 2002). For example, headwater streams can provide refuge habitat when adverse conditions exist in the larger waterbodies downstream, enabling fish to persist and recolonize downstream areas once conditions have improved. *Id.* at 3-38 (citing Meyer and Wallace 2001; Meyer *et al*. 2004; Huryn *et al*. 2005). These upstream systems form integral components of downstream food webs, providing nursery habitat for breeding fish and amphibians, transport of aquatic insects and other food resources to downstream communities, colonization opportunities for stream invertebrates, and maturation habitat for stream insects, including for species that are critical to downstream ecosystem function. *Id.* at ES-3. The provision of life-cycle dependent aquatic habitat for species located in traditional navigable waters, the territorial seas, and interstate waters has important affects the biological integrity of those downstream waters.

To be clear, the agencies would consider biological functions for purposes of significant nexus determinations under the final rule only to the extent that the functions provided by tributaries, adjacent wetlands, and waters assessed under paragraph (a)(5) significantly affect the integrity of the downstream traditional navigable waters, the territorial seas, or interstate waters. For example, to protect Pacific and Atlantic salmon in traditional navigable waters (and their associated commercial and recreational fishing industries), headwater streams must be protected because Pacific and Atlantic salmon require both freshwater and marine habitats over their life cycles and therefore migrate along river networks, providing one of the clearest illustrations of biological connectivity. *See, e.g.*, *id.* at 2-40. Many Pacific salmon species spawn in headwater streams, where their young grow for a year or more before migrating downstream, living their adult life stages in the ocean, and then migrating back upstream to spawn. *Id.* Even where they do not provide direct habitat for salmon themselves, ephemeral streams can contribute to the habitat needs of salmon by supplying sources of cold water that these species need to survive (*i.e.*, by providing appropriate physical conditions for cold water upwelling to occur at downstream confluences, *see, e.g.,* Ebersole *et al*. 2015), by transporting sediment that supports fish habitat downstream (Marteau *et al*. 2020), and by providing and transporting food for juveniles and adults downstream. *See, e.g.*, Science Report. These species thereby create a biological connection along the entire length of the river network and functionally help to maintain the biological integrity of the downstream traditional navigable water. *Id*. at 2-40. Many other species of anadromous fish like certain species of lamprey; American eels and other species of catadromous fish; and species of freshwater fish like rainbow trout and brook trout also require small headwater streams to carry out life cycle functions.

Streams, wetlands, and open waters can perform multiple functions, including functions that change depending upon the season. *Id.* at 2-24. For example, the same stream can contribute flow when evapotranspiration is low and can retain water when evapotranspiration is high. *Id*. These functions, particularly when considered in aggregate with the functions of similarly situated waters in the region, can significantly affect the chemical, physical, or biological integrity of a traditional navigable water, the territorial seas, or an interstate water. When considering the effect of an individual stream, wetland, or open water, the science supports that all contributions and functions that the water provides should be evaluated cumulatively. *Id.* at 6-10. For example, the same wetland retains sediment, removes excess nutrients, mitigates flooding, and provides habitat for amphibians that also live downstream; if any of these functions is ignored, the overall effect of that wetland would be underestimated. *See, e.g.*, *id.* at ES-7, 6-10. It is important to note, however, that a water or wetland can provide just one function that may significantly affect the chemical, physical or biological integrity of the downstream water.

1. The significant nexus standard allows for consideration of the effects of climate change on water resources consistent with the best available science

There are ways the agencies can consider a changing climate under the significant nexus standard, but only to the extent it is relevant to the evaluation of whether upstream waters significantly affect the chemical, physical, or biological integrity of traditional navigable waters, the territorial seas, or interstate waters. For example, a lake that dries up from warming temperatures due to climate change and no longer has a surface hydrologic connection to downstream waters might become non-jurisdictional, whereas another lake that previously had limited surface hydrologic connectivity might have increased hydrologic connectivity with higher precipitation conditions under a changing climate.

In addition, under the significant nexus standard the agencies can consider the functions of streams, wetlands, and open waters that support the resilience of the chemical, physical, or biological integrity of traditional navigable waters, the territorial seas, or interstate waters to climate change. For example, as more intense and frequent storms and other shifts in precipitation cause floods to increase in frequency and volume in some areas of the United States, a significant nexus determination can evaluate the strength of the effect of runoff storage in wetlands, open waters, and headwater tributaries in mitigating increased flood risk associated with climate change in downstream traditional navigable waters, the territorial seas, and interstate waters. In addition, as drought leads to decreased baseflows in traditional navigable waters or interstate waters in other areas of the country, the transmission of flows into alluvial or regional aquifer storage through tributaries and wetlands can mitigate for these climate change-related conditions, and those benefits to downstream traditional navigable waters or interstate waters can be assessed as part of a significant nexus analysis. Changes in flow in tributaries caused by climate change will also be relevant to the relatively permanent standard, but that standard may not allow the agencies to take into account the contribution of upstream waters to the resilience of the integrity of downstream waters.

As discussed in section III.E.iv, the agencies believe that there are climate benefits that streams, wetlands, and open waters provide that are not related to restoring or maintaining the integrity of downstream traditional navigable waters, the territorial seas, or interstate waters, such as carbon sequestration. Those functions would not be considered under this rule because they are not directly related to the chemical, physical, and biological integrity of downstream waters. However, considering a changing climate when conducting jurisdictional decisions by considering on a case-specific basis the functions of aquatic resources that contribute to the resilience of the integrity of downstream traditional navigable waters, the territorial seas, and interstate waters to climate change is consistent with the policy and goals of the Clean Water Act, case law, and the policy goals of this administration as articulated in Executive Order 13990.

F. The Relatively Permanent Standard

The agencies also conclude that federal protection is appropriate where a water meets the relatively permanent standard. Waters that are evaluated under the standard include tributaries, adjacent wetlands, and intrastate lakes and ponds, streams, and wetlands that do not meet the jurisdictional criteria under one of the final rule's other categories. Waters that meet the relatively permanent standard are an example of a subset of waters that will virtually always significantly affect traditional navigable waters, the territorial seas, or interstate waters, and therefore properly fall within the Clean Water Act's scope. As discussed in section IV.A.3.a.ii of the preamble to the final rule, the relatively permanent standard is administratively useful but is insufficient as the sole standard for geographic jurisdiction under the Clean Water Act because by itself it is inconsistent with the Act's text and objective. Protecting only waters that meet the relatively permanent standard also runs counter to the scientific principles underlying protection of water quality. The agencies are thus promulgating an approach to tributaries, adjacent wetlands, and waters evaluated under paragraph (a)(5) of the final rule that includes, but that is not limited, to the relatively permanent standard.

Under the final rule, tributaries meet the relatively permanent standard when they are relatively permanent, standing or continuously flowing bodies of water. This category includes surface waters that have flowing or standing water year-round or continuously during certain times of the year and more than in direct response to precipitation. The agencies have decided to implement this approach for tributaries under the relatively permanent standard because it is consistent with the *Rapanos* plurality opinion, it reflects and accommodates regional differences in hydrology and water management, and it can be implemented using available, easily accessible tools, as discussed further in section IV.A.ii.1.

The agencies decided not to establish a minimum flow duration for the relatively permanent standard for tributaries because flow duration varies extensively by region. Establishing a uniform number equally applicable to the deserts in the arid West, the Great Lakes region, and New England forests would not be scientifically sound. The agencies instead have chosen to establish a more flexible approach to implementing this rule that accounts for specific conditions in each region. Moreover, it would often be infeasible for the regulated community or agency staff to determine whether a stream ordinarily flows or whether a lake contains standing water, for example, 12 weeks as opposed to 11 weeks per year. Even if this determination was possible, such a bright line cutoff would not reflect hydrological diversity among different regions and alterations in flow regimes. The agencies' conclusion that a minimum duration is not feasible is consistent with the pre-2015 regulatory regime, which did not establish a bright line cutoff (though provided three months as an example of seasonal flow)[45] and with

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[45] *See, e.g.*, Memorandum to Assert Jurisdiction for NWP-2007-945 (January 23, 2008), *available at* https://usace.contentdm.oclc.org/utils/getfile/collection/p16021coll5/id/1437 (joint EPA-Corps memorandum in

the approach of the 2020 NWPR. *See* 85 FR 22292.

Implementation of relatively permanent tributaries in this rule does not require that relatively permanent flow come from particular sources. This rule's approach is consistent with the plurality opinion in *Rapanos*, which lays out the relatively permanent standard and does not require that relatively permanent waters originate from any particular source. *See*, *e.g.*, 547 U.S. at 739. This rule's approach is also science-based, as the source of a tributary's flow does not influence its effect on downstream waters, including traditional navigable waters, the territorial seas, or interstate waters. This rule's approach is similar to the familiar approach taken in the *Rapanos* Guidance and the 2020 NWPR, which also did not specify that relatively permanent flow come from particular sources.

Sources of flow in relatively permanent tributaries may include an elevated groundwater table that provides baseflow to a channel bed. Relatively permanent flow could also result from upstream contributions of flow, effluent flow, or snowpack that melts slowly over time in certain geographic regions or at high elevations. In addition, in certain regions relatively permanent flow could result from a concentrated period of back-to-back precipitation events that leads to sustained flow through a combination of runoff and upstream contributions of flow or an elevated groundwater table that provides baseflow to the channel bed. In contrast, non-relatively permanent tributaries may flow only during or shortly after individual precipitation events (including rainfall or snowfall events). Non-relatively permanent flow may occur simply because it is raining or has very recently rained, or because a recent snow has melted.

Streamflow that occurs during the monsoon season in certain parts of the country (typically June through September in the arid West) may be relatively permanent or non-relatively permanent, depending on the conditions at the location. Many tributaries in the arid West are dominated by coarse, alluvial sediments and exhibit high transmission losses, resulting in streams that often dry rapidly following a storm event (*e.g.*, within minutes, hours, or days). These streams are not relatively permanent under this rule. However, relatively permanent flow may occur as a result of multiple back-to-back storm events throughout a watershed, during which the combination of runoff and upstream contributions of flow is high enough to exceed rates of transmission loss for an extended period of time. Relatively permanent flow may also follow one or more larger storm events, when floodwaters locally recharge the riparian aquifer through bank infiltration, which supplies sustained baseflow throughout the monsoon season.

As discussed in section III.A.vi, tributaries encompass lakes, ponds, and impoundments that are part of the tributary network, as such waters outlet to the tributary network and contribute flow downstream at the outlet point. In addition, "flowing water" under the final rule is meant to encompass those tributaries that are frozen for parts of the year. Such tributaries typically have flowing water underneath the frozen surface. Although some streams may appear to have standing water without a current, particularly at certain times of the year, such waters do contribute flow downstream, either slowly or episodically. The phrase "standing water" is intended to describe waters assessed under paragraph (a)(5) that are lentic or "still" systems, such as lakes, ponds, and impoundments, which are characterized

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which the agencies found that two months of continuous flow, for example, is considered "seasonal" flow in certain regions of the country and could be sufficient to support a relatively permanent designation under the pre-2015 regulatory regime).

by standing water.

The phrase “certain times of the year” is intended to include extended periods of standing or continuously flowing water occurring in the same geographic feature year after year, except in times of drought. The defining characteristic of relatively permanent waters with flowing or standing water continuously during only certain times of the year is a temporary lack of surface flow, which may lead to isolated pools or dry channels during certain periods of the year. The phrase “direct response to precipitation” is intended to distinguish between episodic periods of flow associated with discrete precipitation events versus continuous flow for extended periods of time.

Tributaries under the final rule that are “relatively permanent” include those that are “relatively permanent” under the *Rapanos* Guidance, though the standard under the rule encompasses additional tributaries. Thus, tributaries that meet the relatively permanent standard under the final rule include those that flow year-round or at least seasonally (*e.g.*, typically three months). *See Rapanos* Guidance at 6-7. While relatively permanent flow may occur seasonally, the phrase is also intended to encompass tributaries in which extended periods of standing or continuously flowing water are not linked to naturally recurring annual or seasonal cycles. Specifically, relatively permanent waters may include tributaries in which flow is driven more by various water management regimes and practices, such as tributaries with extensive flow alteration (*e.g.*, diversions, bypass channels, water transfers) and effluent-dependent streams. For example, in areas of the West where water withdrawals or groundwater pumping can substantially modify flow characteristics, onset and cessation of streamflow in some tributaries may be more closely tied to changes in water use associated with irrigation than with seasons of the year. *See, e.g.*, Kustu *et al*. 2010; Science Report at B-39; Vogl and Lopes 2009. In such flow-altered tributaries, streamflow may change abruptly throughout the year due to adjustments in facility operations or may vary from year to year due to changes in water rights or water management regimes. In addition, tributaries that typically flow throughout the spring may run dry in years following a drought while storage reservoirs are being refilled. When evaluating these types of artificially manipulated regimes, the agencies may consider information about the regular manipulation schedule and may potentially consider other remote resources or on-site information to assess flow frequency.

Under the relatively permanent standard for adjacent wetlands, wetlands meet the continuous surface connection requirement if they physically abut, or touch, a relatively permanent paragraph (a)(2) impoundment or a jurisdictional tributary when the jurisdictional tributary meets the relatively permanent standard, or if the wetlands are connected to these waters by a discrete feature like a non-jurisdictional ditch, swale, pipe, or culvert. A natural berm, bank, dune, or similar natural landform between an adjacent wetland and a relatively permanent water does not sever a continuous surface connection to the extent it provides evidence of a continuous surface connection. Wetlands that have a continuous surface connection to a relatively permanent paragraph (a)(2) impoundment or a jurisdictional tributary when the jurisdictional tributary meets the relatively permanent standard are a subset of adjacent wetlands. Wetlands that do not have a continuous surface connection but are adjacent to paragraph (a)(2) impoundments or jurisdictional tributaries will be evaluated for jurisdiction under the significant nexus standard.

Under the relatively permanent standard for adjacent wetlands and waters evaluated under paragraph (a)(5), the continuous surface connection is a physical connection that does not have to be hydrologic—for example, a pond with relatively permanent standing water that touches a tributary of a traditional navigable water that meets the relatively permanent standard but that does not contribute flow downstream and thus is not a tributary could be considered under the standard. The continuous surface connection could include a confined surface connection like a swale or non-jurisdictional ditch that connects a pond with relatively permanent standing water to tributary that meets the relatively permanent standard. As discussed in section III.B.ii.3.a, waters with a visible (*e.g.,* channelized) surface-water connection to the river network clearly have effects on downstream waters. Science Report at ES-3. In addition, a natural berm, bank, dune, or similar natural landform between an adjacent wetland and a relatively permanent water does not sever a continuous surface connection to the extent it provides evidence of a continuous surface connection.

Waters that meet the relatively permanent standard are within the scope of the Clean Water Act because scientific evidence supports the conclusion that tributaries of traditional navigable waters, the territorial seas, and interstate waters with relatively permanent, standing, or continuously flowing water perform important functions that either individually, or cumulatively with similarly situated waters in the region, have a material influence on the chemical, physical, or biological integrity of downstream traditional navigable waters, the territorial seas, or interstate waters. *See* section III.A. For example, tributaries that meet the relatively permanent standard contribute consistent flow to downstream traditional navigable waters, the territorial seas, or interstate waters, and with that flow export nutrients, sediment, and food resources, contaminants, and other materials that can both positively (*e.g.*, by contributing to downstream baseflow, providing food for aquatic species, contributing to downstream aquatic habitat) and negatively (*e.g.,* if exporting too much sediment, runoff, or nutrients or if exporting pollutants) affect the integrity, including the water quality, of those larger downstream waters. In addition, wetlands with a continuous surface connection to such relatively permanent waters can attenuate floodwaters, trap sediment, and process and transform nutrients that might otherwise reach downstream traditional navigable waters, the territorial seas, or interstate waters. The relatively permanent standard is useful because it generally requires less information gathering and assessment and because it focuses on flow and includes wetlands with a continuous surface connection. As such, while both the significant nexus and relatively permanent standards require case-specific, fact-specific inquiries before determining whether a water is meets the definition of “waters of the United States,” the relatively permanent standard will generally require less assessment.

Standing alone as the sole test for Clean Water Act jurisdiction, the relatively permanent standard is insufficient. The standard’s apparent exclusion of major categories of waters from the protections of the Clean Water Act, specifically with respect to tributaries that are not relatively permanent (such as ephemeral streams) and adjacent wetlands that do not have a continuous surface water connection to other jurisdictional waters, is inconsistent with the Act’s text and objective and runs counter to the science demonstrating how such waters can affect the integrity of downstream waters, including traditional navigable waters, the territorial seas, and interstate waters. The 2020 NWPR, for example, excluded federal jurisdiction over the many ephemeral tributaries that regularly and directly provide sources of freshwater to the sparse traditional navigable waters in the arid Southwest, such as portions of the Gila River.

As discussed in sections III.A.v and III.B, there is overwhelming scientific information demonstrating the effects ephemeral streams can have on downstream waters and the effects wetlands can have on downstream waters when they do not have a continuous surface connection. The science is clear that aggregate effects of ephemeral streams “can have substantial consequences on the integrity of the downstream waters” and that the evidence of such downstream effects is “strong and compelling.” Science Report at 6-10, 6-13. The SAB explained that ephemeral streams “are no less important to the integrity of the downgradient waters” than perennial or intermittent streams. SAB 2014c at 22-23, 54 fig. 3.

The science is also clear that wetlands may significantly affect downstream waters when they have other types of surface connections, such as wetlands that overflow and flood jurisdictional waters or wetlands with less frequent surface water connections due to long-term drought; wetlands with shallow subsurface connections to other protected waters; or other wetlands proximate to jurisdictional waters. Such wetlands provide a number of functions, including water storage that can help reduce downstream flooding, recharging groundwater that contributes to baseflow of downstream rivers, improving water quality through processes that remove, store, or transform pollutants such as nitrogen, phosphorus, and metals, and serving as unique and important habitats including for aquatic species that also utilize larger downstream waters. *See, e.g.,* Science Report at 4-20 to 4-38. For example, adjacent, interdunal wetlands separated from the Atlantic Ocean only by beach dunes would not meet the relatively permanent standard, but provide numerous functions, including floodwater storage and attenuation, storage and transformation of sediments and pollutants, and important habitat for species that utilize both the wetlands and the ocean, that significantly affect the Atlantic Ocean (both a traditional navigable water and territorial sea).

The relatively permanent standard includes waters that will virtually always significantly affect traditional navigable waters, the territorial seas, or interstate waters, and thus waters that meet the standard properly fall within the Act’s protections. As a result, the final rule’s incorporation of jurisdictional limitations based upon the relatively permanent standard and the significant nexus standard reflect the agencies’ careful consideration of the science and their technical expertise and experience. Waters that meet the relatively permanent standard under the final rule include certain tributaries, certain adjacent wetlands, and certain intrastate lakes and ponds assessed under paragraph (a)(5).[46] The many functions that such waters provide that can significantly affect the chemical, physical, and biological integrity of traditional navigable waters, the territorial seas, and interstate waters are discussed in more detail in sections III.A, III.B, and III.D above. For waters that meet the relatively permanent standard, their impacts on traditional navigable waters, the territorial seas, or interstate waters are facilitated by the surface connections that have to such paragraph (a)(1) waters. For example, tributaries that meet the relatively permanent standard have flowing or standing water year-round or continuously during certain times of the year and that flow directly or indirectly through another water or waters to a paragraph (a)(1) water or to a paragraph (a)(2) impoundment. Scientific evidence supports the conclusion that such tributaries perform important functions that either individually, or cumulatively with similarly situated waters in the region, have significant effects on the chemical, physical, or biological integrity of paragraph (a)(1) waters. *See* section III.A above. The same is true of adjacent wetlands and relatively permanent open waters with continuous surface connections to tributaries that meet the relatively permanent standard. *See* sections III.B and III.D. Tributaries that meet the relatively permanent standard contribute consistent flow to paragraph (a)(1)

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[46] Streams that meet the relatively permanent standard under the final rule would be considered tributaries. Similarly, wetlands that meet the relatively permanent standard under the final rule would be considered adjacent wetlands. Thus, under paragraph (a)(5), waters that meet the relatively standard under the final rule will typically be lakes and ponds.

waters and, with that flow, export nutrients, sediment, food resources, contaminants, and other materials that can both positively (*e.g.*, by contributing to downstream baseflow, providing food for aquatic species, and contributing to downstream aquatic habitat) and negatively (*e.g.*, by exporting too much sediment, runoff, or nutrients or exporting pollutants) affect the integrity of those paragraph (a)(1) waters. In such cases, the frequency and duration of hydrologic connections help contribute to the influence that such tributaries have on paragraph (a)(1) waters, either alone or in combination with similarly situated waters in the region. In addition, wetlands with a continuous surface connection to tributaries that meet the relatively permanent standard can and do attenuate floodwaters, trap sediment, and process and transform nutrients that might otherwise reach traditional navigable waters, the territorial seas, or interstate waters. Similarly, lakes and ponds that meet the relatively permanent standard and that are assessed under paragraph (a)(5), such as oxbow lakes and ponds, are often physically proximate to a traditional navigable water, the territorial seas, an interstate water, or a relatively permanent tributary and have a continuous surface connection to such waters. The proximity and the continuous surface connection impact the frequency and nature of the exchange of materials that takes place between the lake or pond and the jurisdictional water. Intrastate lakes and ponds that meet the relatively permanent standard process and trap nutrients in runoff that might otherwise reach a paragraph (a)(1) water, provide critical habitat needed for feeding and rearing for semi-aquatic and aquatic species, contribute flow downstream, and serve other functions that are similar to adjacent wetlands. If the agencies assessed waters that meet the relatively permanent standard (*e.g.*, tributaries that meet the relatively permanent standard or adjacent wetlands with a continuous surface connection to such tributaries) they would virtually always find evidence of strong factors, particularly hydrologic factors like flow frequency and duration, that lead to strong connections and associated effects on paragraph (a)(1) waters. Therefore, the agencies have concluded that waters that meet the relatively permanent standard will virtually always meet the significant nexus standard.

IV. Implementation of the Final Rule

The preamble to the final rule contains information on implementing the final rule. This Technical Support Document provides additional citations.

A. Resources for Making Jurisdictional Determinations

The final rule preamble provides implementation guidance informed by sound science, implementation tools, and other resources, drawing on more than a decade of post-*Rapanos* implementation experience. The following discussion is provided to clarify how available data, tools, and methods inform the agencies' determinations and to confirm that interested parties may use these same resources to inform their own siting decisions, if so desired.

Many field-based and remote tools and sources of data are available to determine Clean Water Act jurisdiction under the final rule. In some cases, a property owner may be able to determine whether a property includes a jurisdictional water based on observation or experience. In other cases, a property owner may seek assistance from a consultant to assess the jurisdictional status of features on their property. Property owners may also seek a jurisdictional determination from the Corps, which provides jurisdictional determinations as a public service. When conducting a jurisdictional determination, the Corps will review any documentation that a property owner, or consultant, provides to assist in making a jurisdictional determination. EPA staff also regularly assess the jurisdictional status of waters in implementing Clean Water Act programs. The agencies expect that EPA and Corps staff, as well as private consultants, would be the primary users of the tools and sources of remote data described below, and they have ample experience in using them from prior regulatory regimes.

The agencies utilize many tools and many sources of information to help support decisions on jurisdiction, including USGS and State and local topographic maps, geospatial datasets, aerial photography, satellite imagery, gage data, soil surveys, NWI maps, floodplain maps, watershed studies, modeling tools, scientific literature and references, and field work. As discussed further in section IV.G of the preamble for the final rule and section IV.A.i.3 of this document, these tools have undergone important technological advances, and have become increasingly available, since the *Rapanos* decision. For example, USGS, Tribal, State, and local stream maps and datasets, aerial photography, gage data, watershed assessments, monitoring data, and field observations are often used to help assess the flow contributions of tributaries, including intermittent and ephemeral streams, to downstream traditional navigable waters, the territorial seas, or interstate waters. Similarly, floodplain and topographic maps from federal, State, and local agencies, modeling tools, and field observations can be used to assess how wetlands are storing floodwaters that might otherwise affect the integrity of traditional navigable waters, the territorial seas, or interstate waters. Further, the agencies utilize the large body of scientific literature regarding the functions of tributaries, including tributaries with ephemeral, intermittent, and perennial flow, and of wetlands and open waters to inform their significant nexus analyses. In addition, the agencies have experience and expertise from decades of making decisions on jurisdiction that considered hydrology, ordinary high water mark and its associated indicators (*see* section IV.C.8.d of the preamble), biota, and other technical factors in implementing Clean Water Act programs. The agencies' immersion in the science, along with the practical expertise developed over more than decade of case-specific determinations across the country, have helped the agencies determine which waters have a significant nexus and where to draw boundaries demarking the "waters of the United States."

The resources covered in this section include tools for identifying tributaries, including tributaries that meet the relatively permanent standard; tools for identifying wetlands, including wetlands adjacent to traditional navigable waters, the territorial seas, interstate waters, impoundments, or tributaries; tools for identifying impoundments; and tools for applying a significant nexus standard. This section presents a non-exclusive list of tools that the agencies have used in the past and will continue to use to assist in making jurisdictional decisions, but other tools could also be used to determine jurisdiction. The agencies have also identified a number of recent advancements in the data, tools, and methods that can be used to make jurisdictional decisions (section IV.A.i.3).

i. Available Tools

In this section, tools and resources that can be used to support jurisdictional decisions are discussed more generally, with more detail on they can be used in implementation for different categories of the final rule in the sections that follow. Additional tools are also discussed in those sections.

1. Mapping and Remote Sensing

Multiple federal agencies provide data, maps, web-based viewers and tools that can help implement this rule. These include, but are not limited to, USGS, U.S. FWS, NRCS, NOAA, Federal Emergency Management Agency (FEMA), EPA, and the Corps.

The USGS provides publicly and freely available historic and recent topographic maps, aerial photography, the National Hydrography Dataset (NHD), and other data and applications which depict and classify many features relevant to identifying "waters of the United States." One of the most commonly used geospatial datasets from the USGS is the NHD, which was created to assist scientists in modeling hydrologic features and for cartographic mapping purposes. Simley 2018. The NHD depicts aquatic resources such as lakes, ponds, streams, rivers, wetlands, and oceans throughout the United States (including many canals and ditches). *Id*. NHD High Resolution is at the 1:24,000 scale[47] or higher. In Alaska, the NHD is available at the 1:63,360 scale. Stream and river "flowlines" in NHD are characterized as "ephemeral," "intermittent," or "perennial." This hydrographic categorization was initially based on the original pre-digital mapping effort of USGS topographic maps, with periodic updates from the USGS and data stewards. In NHD, perennial reaches are presumed to carry water throughout the year except during drought, whereas intermittent reaches are assumed to lack flow for some duration.[48] The NHD defines ephemeral as having water only during or after, a local rainstorm or heavy snowmelt, although the NHD did not start classifying some streams in the digital dataset as "ephemeral" until the 2000s. Simley 2006; Simley 2015; Dewald 2017. Although many ephemeral streams are not mapped, those that are mapped are primarily mapped in NHD at high resolution. That said, even in the high-resolution dataset, many ephemeral streams are included in the "intermittent" category, particularly those outside of the arid West. Many, but not all, canals and ditches, lakes and ponds, wetlands, and reservoirs are also mapped in the NHD. The high-resolution dataset is currently the most up-to-date and detailed hydrography dataset for the nation, mapping more streams and other aquatic resources than the medium resolution dataset.

In 2006, USGS and EPA developed the first medium-resolution version of the NHDPlus to support modeling the occurrence of water and to provide the ability to connect detailed information from the surrounding landscape to the stream network. Buto and Anderson 2020. The NHDPlus is a suite of geospatial products that that build upon and extend the capabilities of the NHD, the National Elevation Dataset, and the Watershed Boundary Dataset. The NHDPlus includes a stream network, catchments, and streamflow estimates, as well as other attributes that enable stream "navigation" (*e.g.*, allow users to "navigate" up- and downstream from a given point in the stream network).[49] An NHDPlus catchment is

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[47] Scale is the relationship between distance on the map and distance on the ground. If the scale were 1:24,000, for instance, then one inch on the map would represent 24,000 inches or 2,000 feet on the ground. If the scale were 1:63,360, then one inch on the map would represent 63,360 inches or one mile on the ground. *See* USGS 1992.

[48] Definitions of terms used in the NHD and additional information on NHD features are available in the National Hydrography Dataset Feature Catalog, available at https://nhd.usgs.gov/userGuide/Robohelpfiles/NHD_User_Guide/Feature_Catalog/NHD_Feature_Catalog.htm.

[49] "Navigate" and "navigation" in this context refer to the ability to trace a stream network upstream and downstream using GIS. The terms do not refer to actual navigability of a water and do not imply that a feature is or is not navigable.

the land surface area that flows directly to an NHDPlus feature (*e.g.*, a single stream (reach)) in the NHD stream network. Moore *et al.* 2019. For most features, the catchment represents the incremental area that drains directly to each feature or stream segment. The medium resolution NHDPlus is currently available for the conterminous United States, Hawaii, and the U.S. territories at https://www.epa.gov/waterdata/nhdplus-national-hydrography-dataset-plus. USGS has also developed the NHDPlus High Resolution (NHDPlus HR) in an iterative fashion throughout the country using updated, high-resolution datasets (high-resolution NHD, Watershed Boundary Dataset (WBD) data, and 3D Elevation Program (3DEP) 10-meter digital elevation model (DEM)) to create a modern, scalable, and openly accessible hydrography framework for the inland waters of the nation. *Id.* Data are available for download and as web-based map services at https://www.usgs.gov/national-hydrography/access-national-hydrography-products. An initial production of NHDPlus HR has been created for the conterminous United States, Hawaii, and several U.S. territories including Puerto Rico, Guam, and American Samoa. USGS 2021. USGS is in the process of creating a second or updated production in those areas. As part of a longer-term project to update the NHD and WBD in Alaska, NHDPlus HR is currently in production in that state, with some areas in Alaska are currently available. *Id.* NHDPlus HR contains a set of value-added attributes, in addition to the standard NHD attributes, that enhance stream network navigation, analysis and display, including (a) catchment characteristics, including mean annual precipitation, mean annual temperature, and mean annual runoff, and mean latitude; (b) cumulative drainage area characteristics; and (c) mean annual flow (1971-2000) and velocity estimates for each flowline in the stream network. *Id.*; USGS d. NHDPlus HR will provide a consistent modeling framework to enable a better understanding of the water quality and contaminant transport in the nation's streams by models such as SPARROW (SPAtially Referenced Regression On Watershed attributes). Buto and Anderson 2020. NHDPlus HR will also provide the hydrography base for the National Water Model, which simulates streamflow volume and velocity over the entire continental United States to help forecasters predict when and where flooding can be expected. *Id.*; *see also* section IV.D.iii.2 for a discussion of models. The USGS is also starting to implement the new 3D Hydrography Program (3DHP), which will greatly improve the level of detail, currency, and content of hydrography data by deriving updated stream networks and watersheds from high-quality 3DEP data. USGS a. The USGS believes that 3DHP will better support hydrologic modeling and improve attribution of important hydrologic characteristics like streamflow permanence. *Id.*

Historic and recent USGS topographic maps can be found at https://www.usgs.gov/the-national-map-data-delivery/topographic-maps. In addition to the traditional topographic maps the USGS also provides map viewers, data download capability, and application tools relevant to implementing this rule. In addition to NHD data, USGS watershed and elevation data can viewed and downloaded via the National Map at https://apps.nationalmap.gov/downloader/#/.

The Watershed Boundary Dataset (WBD) is a seamless, national dataset depicting hydrologic units or watersheds—that is, the area of the landscape that drains to a portion of the stream network. USGS e. In the WBD, a hydrologic unit may represent all or only part of the total drainage area to an outlet point so that multiple hydrologic units may be required to define the entire drainage area at a given outlet. *Id.* Topographic, hydrologic, and other relevant landscape characteristics are used to delineate the hydrologic unit boundaries in the WBD. *Id*. The WBD's hydrologic units (HU) are arranged in a nested, hierarchical system with each HU in the system identified using a unique code called the hydrologic unit code (HUC). *Id.* WBD contains eight levels of progressive hydrologic units identified by unique 2- to 16-

digit codes. *Id.* The dataset is complete for the United States at the HUC-12 level, while the 14- and 16-digit hydrologic units are optional and are not complete for the nation. *Id*.

The USGS has several elevation products and programs, including managing the interagency 3D Elevation Program (3DEP). The goal of the 3DEP is to complete nationwide three-dimensional (3D) elevation data acquisition by 2023 in the form of light detection and ranging (LIDAR) data to provide the first-ever national baseline of consistent high-resolution 3D data, including bare earth elevations and 3D point clouds, collected in a timeframe of less than a decade. Lukas and Baez 2021. The 3DEP products and services available through the National Map consist of standard digital elevation models (DEMs) at various horizontal resolutions (*e.g.*, 10 meter, 30 meter), and elevation source (*e.g.*, LIDAR) and associated datasets.

The USGS has several different portals for accessing remote sensing data and geospatioal information. The National Map (https://apps.nationalmap.gov/downloader/#/) includes high resolution aerial images from USDA's National Agriculture Imagery Program (NAIP), high-resolution elevation data from 3DEP, hydrography data from the NHD, wetland data from NWI, topographic maps, and landcover data from the NLCD. In addition to the online mapper, the National Map supports data download and geospatial data services. The EarthExplorer data portal (https://earthexplorer.usgs.gov/) allows the public to obtain earth imagery across available geospatial data types. USGS b. This includes Landsat satellite imagery, Radar data, unmanned aircraft systems (UAS) data, digital line graphs, digital elevation model data, aerial photography, Sentinel satellite data, some commercial satellite imagery including IKONOS and OrbView3, land cover data, digital map data from the National Map, and many other datasets. *Id.* Users can search by exact location via the interactive map or input specific coordinates to view what data types are available. *Id.* Date searches can also be made for specific date ranges. USGS 2012. The Global Visualization Viewer (GloVis) is another tool for accessing remote sensing data (https://glovis.usgs.gov/app).

The U.S. FWS established the National Wetlands Inventory (NWI) to conduct a nationwide inventory of wetlands to provide biologists and others with information on the distribution and type of wetlands to aid in conservation efforts. U.S. FWS a; U.S. FWS 2020. Today, the NWI Wetlands Data Layer is used for general mapping of wetlands[50] and deepwater habitats and for purposes of data analyses and modeling. *Id.* The NWI Wetlands Data Layer is a mapping dataset that provides detailed information on the extent, characteristics, functions, and distribution of wetlands and deepwater habitats across the United States. *Id.* These data are primarily derived from manual aerial image interpretation. The NWI is available as digital data at the 1:24,000 scale or higher throughout the country, except for portions of Alaska (data in Alaska are at the 1:63,360 scale). The NWI data are available for download (available at https://www.fws.gov/program/national-wetlands-inventory/data-download), as an interactive web mapping application (available at https://www.fws.gov/program/national-wetlands-inventory/wetlands-mapper), and as web mapping services (https://www.fws.gov/program/national-wetlands-inventory/web-mapping-services).

USDA, mainly through the NRCS, produces several products and online mappers relevant to evaluating aquatic resources. NAIP (https://naip-usdaonline.hub.arcgis.com/) is administered through the USDA's Farm Production and Conservation Business Center, and the imagery program acquires aerial

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[50] The NWI uses the Cowardin (1979) definition of "wetlands."

imagery during the agricultural growing seasons in the United States (*i.e.*, “leaf-on” imagery). The imagery is available to the public through the NAIP website and through the National Map. The NRCS produces data and maps which contain information relative to implementing the final rule including, but not limited to, the potential presence of wetlands, the locations of tributaries and details on the properties of soils, including flood frequency and duration, ponding frequency and duration, hydric soils, and drainage class. These NRCS resources can be obtained through https://websoilsurvey.sc.egov.usda.gov/App/WebSoilSurvey.aspx or via the NRCS Soil Survey Geographic Database (SSURGO) available at https://catalog.data.gov/dataset/soil-survey-geographic-database-ssurgo). The NRCS National Water and Climate Center is responsible for producing and disseminating accurate and reliable water supply forecasts and other climatic data. NRCS b. The Center administers the Snow Telemetry (SNOTEL) program which consists of over 900 automated and semi-automated data collection sites across the western United States and tracks snowpack depths, precipitation, and other climate information (available at https://www.wcc.nrcs.usda.gov/snow/). NRCS a. All the data collected at the National Water and Climate Center are placed in a comprehensive database known as the Water and Climate Information System (WCIS), available at https://www.nrcs.usda.gov/wps/portal/wcc/home/aboutUs/monitoringPrograms/wcis/ (*see* https://www.nrcs.usda.gov/wps/portal/wcc/home/quicklinks/imap for an interactive map of WCIS data). NRCS b. In addition to the data collected through SNOTEL and manual snow data collection processes, the Center also incorporates precipitation, streamflow, and reservoir data from the Corps, the U.S. Bureau of Reclamation (BOR), the Applied Climate Information System (ACIS), the USGS, various water districts, and other entities into the WCIS database. *Id*. Information in the WCIS database which may be useful in estimating tributary runoff in the areas of the country where data are collected and available.

NOAA publishes a variety of climate information that may be relevant to accessing jurisdiction. The National Centers for Environmental Information, for example, publishes precipitation records (available at https://www.ncdc.noaa.gov/cdo-web/) and the National Weather Service publishes snow analysis maps (available at https://www.nohrsc.noaa.gov/nsa/). This information may be useful for understating tributary runoff frequency and duration.

FEMA produces flood zone or other floodplain maps which can give an estimate of frequency of flooding and other physical floodplain factors (FEMA 2021) that may have relevance in implementing this rule. These maps are publicly available and provide a readily accessible and transparent tool for locating the 100-year floodplain, where FEMA has mapped such information. The FEMA Map Service Center allows the public to search for flood maps by address or location (available at https://msc.fema.gov/portal/home), and the National Flood Hazard Layer Viewer is an interactive web mapping application that displays the current effective flood hazard data (available at https://msc.fema.gov/nfhl).

EPA also has several resources useful for the implementation of this rule. EPA’s How’s My Waterway (available at https://www.epa.gov/waterdata/hows-my-waterway) maps streams and identifies Clean Water Act section 303(d) listed waters, water quality impairments, and Total Maximum Daily Loads (TMDLs). EPA’s NEPAssist (available at https://www.epa.gov/nepa/nepassist), provides locations and information on wastewater discharge facilities and hazardous-waste sites. EPA also publishes ecoregion maps (https://www.epa.gov/eco-research/ecoregions-north-america). The EPA Watershed Assessment, Tracking, and Environmental Results System (WATERS) GeoViewer is an example of a webmapping application that provides accessibility to many spatial dataset layers like NHDPlus and watershed reports for analysis and interpretation (https://www.epa.gov/waterdata/waters-geoviewer). This includes EPA's Stream-Catchment (StreamCat) Dataset, which provides metrics for approximately 2.65 million stream segments and their associated catchments (https://www.epa.gov/national-aquatic-resource-surveys/streamcat-dataset-0). *See* Hill *et al.* 2016. The GeoViewer also allows users to conduct upstream/downstream searches and to delineate watersheds. Although not available in WATERS, the EPA's Lake-Catchment (LakeCat) Dataset is similar to StreamCat, and currently contains over 300 metrics for over 375,000 lakes and their associated catchments. *See* Hill *et al.* 2018. Data are available at https://www.epa.gov/national-aquatic-resource-surveys/lakecat-dataset.

The Corps' Geospatial Platform provides Corps geospatial data, services, and applications for use by partner agencies and the public (https://geospatial-usace.opendata.arcgis.com/). For example, the Corps manages geospatial data related to navigation (*e.g.*, the Navigation Data Center) and reservoirs and lakes owned and operated by the Corps. In addition, the Corps manages the National Inventory of Dams (https://nid.usace.army.mil/#/), which contains information from states and federal agencies on the location of over 91,000 dams across the country. U.S. Army Corps of Engineers 2020a.

In addition to these federal agencies most states have geo-spatial data gateways for viewing and downloading both USGS and potentially other federal agency data but also sometimes state specific aerial photography and geo-spatial data. A web search of a specific state plus "geo-spatial" should provide information on available resources. Some Tribal, Territorial, and local governments may also have geospatial information.

2. Hydrologic Models

Golden *et al.* (2014) provided a review and critique of modeling approaches to quantify the connectivity and (cumulative) effects of geographically isolated wetlands on other types of waters. They include (listed in Table 1 of the paper) Soil and Water Assessment Tool (SWAT), Hydrologic Simulation Program - FORTRAN (HSPF), DRAINMOD for Watershed (DRAINWAT), TOPMODEL, Grid Based Mercury Model (GBMM), and Visualizing Ecosystems for Land Management Assessment (VELMA)). The authors also explored different groundwater (*e.g.*, MODFLOW Wetlands Package; Table 2 of the paper) and coupled surface-subsurface flow models (*e.g.*, GS-FlOW; Table 3 of the paper) for modeling geographically isolated wetland hydrologic connectivity. Jones *et al.* (2019) provided an update to modeling connectivity and effects between non-floodplain wetlands and other systems using process-based models (such as SWAT), providing case studies to inform best modeling to guide the model application. Additional models noted by Jones *et al.* (2019) as applicable include (but are not limited to) MODFLOW (Harbaugh *et al.* 2005; available at https://www.usgs.gov/mission-areas/water-resources/science/modflow-and-related-programs), the Wetland Hydrologic Capacitance model (Mclaughlin *et al.* 2014), the USGS model VS2DI (Hsieh *et al.* 2000; Rossi and Nimmo 1994), and fully distributed coupled surface and subsurface models (Ameli and Creed 2017). Model application examples in Jones *et al.* (2019) include Wetland Hydrologic Capacitance (*e.g.*, Watts *et al.* 2015; Jones *et al.* 2018b), modifications to the SWAT model by Evenson *et al.* (2016; 2018), and Lee *et al.* (2018), and application of VS2DI by Neff and Rosenberry (2018) (available at https://www.usgs.gov/software/vs2di-version-13). From the case studies presented, Jones *et al.* (2019) provided a table summarizing the models, including their fidelity and resource requirements (Table 2 of the paper).

Additional application of hydrologic models and/or advancements to models (*e.g.*, SWAT) include the hydrologic equivalent wetland approach (Golden *et al.* 2014, citing Wang *et al.* 2008; Yang *et al.* 2010; Neitsch *et al.* 2011), P2P (puddle-to-puddle) modeling (Chu *et al.* 2013), and a hybrid SWAT/empirical (Spatial Stream Network) modeling approach (Golden *et al*. 2016). EPA has developed a web-based interactive water quality and quantity modeling system (Hydrologic and Water Quality System, HAWQS, *see* U.S. EPA 2022l) that is being used to assess the cumulative effects of wetlands on downgradient waters (G. Evenson, personal communication). HAWQS employs SWAT as its core modeling engine and is available at https://www.epa.gov/waterdata/hawqs-hydrologic-and-water-quality-system. U.S. EPA 2022l. Recently, Driscoll *et al*. (2020) used the USGS's National Hydrologic Model to analyze the surface-depression storage. Rajib *et al.* (2020) applied a modified SWAT model to assess surface water storage and stream-effects of non-floodplain wetlands across the ~500,000 km^2 Upper Mississippi River basin, finding that including non-floodplain wetlands into the modeling domain improved the modeling accuracy of stream flows (*e.g.*, the non-floodplain wetland storage effect, once quantified, increased model performance hence demonstrating the substantive effect of non-floodplain wetlands on downgradient systems). Further, Golden *et al.* (2021a) recently noted that the effects of non-floodplain wetlands on water storage were substantive and important such that ignoring the systems would lead to erroneous model responses.

Additional approaches to quantifying hydrologic storage include statical models, such as including LIDAR-based topography with precipitation totals. *See*, *e.g.*, Green *et al.* 2019. Both statistical and process-based models have been used to quantify downgradient nutrient assimilation and mitigation effects of non-floodplain wetlands. Golden *et al.* 2019. These include applying SWAT residence times to assess potential (*e.g.*, Evenson *et al.* 2018), to incorporating non-floodplain wetlands into large basin-scale nutrient analyses (*e.g.*, Evenson *et al.* 2021). Golden *et al.* (2019) found incorporating non-floodplain wetlands into a SWAT watershed model for Iowa resulted in a 7% reduction in nitrate concentrations. Mengistu *et al.* (2020), which looked at how wetlands mediate the amount of nitrogen and phosphorus reaching streams and rivers, is an additional statistical model.

3. *Advancements in Implementation Data, Tools, and Methods*

Since the *Rapanos* decision, there have been dramatic advancements in the data, tools, and methods used to make jurisdictional determinations, including in the digital availability of information and data. In 2006, when the agencies began to implement the *Rapanos* and *Carabell* decisions, there were fewer implementation tools and support resources to guide staff in jurisdictional decision-making under the relatively permanent and significant nexus standards. Agency staff were forced to rely heavily on information provided in applicant submittals and available aerial imagery to make jurisdictional decisions or to schedule an in-person site visit to review the property themselves. The 2007 U.S. Army Corps of Engineers Jurisdictional Determination Form Instructional Guidebook encouraged practitioners to utilize maps, aerial photography, soil surveys, watershed studies, scientific literature, previous jurisdictional determinations for the review area, and local development plans to complete accurate jurisdictional decisions or analysis. U.S. Army Corps of Engineers 2007a. For more complicated situations or decisions involving significant nexus evaluations, the Guidebook encouraged practitioners to identify and evaluate the functions relevant to the significant nexus by incorporating literature citations and/or references from studies pertinent to the parameters being reviewed. *Id.* For significant nexus decisions specifically, the Guidebook instructed practitioners to consider all available hydrologic information (*e.g.*, gage data, precipitation records, flood predictions, historic records of water flow, statistical data, personal observations/records, etc.) and physical indicators of flow including the presence and characteristics of a reliable OHWM. *Id.*

The Corps also issued Regulatory Guidance Letter (RGL) No. 07-01[51] in 2007. U.S. Army Corps of Engineers 2007b. RGL No. 07-01 laid out principal considerations for evaluating the significant nexus of a tributary and its adjacent wetlands which included the volume, duration, and frequency of flow of water in the tributary, proximity of the tributary to a traditional navigable water, and functions performed by the tributary and its adjacent wetlands. *Id*. This RGL highlighted wetland delineation data sheets, delineation maps, and aerial photographs as important for adequate information to support all jurisdictional decision-making. *Id.* Gathering the data necessary to support preliminary or approved jurisdictional decisions was often time consuming for staff and the regulated public. There were not many nationally available repositories for much of the information that the agency staff utilized in decision-making, particularly during the first years of implementing of the guidance. Despite these challenges, the agencies and others in the practitioner community gained substantial collective experience implementing the relatively permanent and significant nexus standards from 2006 to 2015.

Since 2015, there have been dramatic improvements to the quantity and quality of water resource information available on the internet. The agencies and other practitioners can use online mapping tools to determine whether waters are connected or sufficiently close to "waters of the United States," and new user interfaces have been developed that make it easier and quicker to access information from a wide variety of sources. Furthermore, some information used to only be available in hard-copy paper files, including water resource inventories and habitat assessments, and many of these resources have been made available online or updated with new information.

The following overview of several tools and data that have been developed or improved since 2015 is intended to demonstrate how case-specific evaluations can be made more quickly and consistently than ever before. Advancements in geographic information systems (GIS) technology and cloud-hosting services have led to an evolution in user interfaces for publicly available datasets frequently used in jurisdictional decision-making such as the NWI, USGS NHD, soil surveys, aerial imagery, and other geospatial analysis tools like USGS StreamStats (https://streamstats.usgs.gov/ss/). Not only are the individual datasets more easily accessible to users, but it has also become much easier for users to quickly integrate these various datasets using desktop or online tools like map viewers to consolidate and evaluate the relevant data in one visual platform. Such map viewers can assist, for example, with considering the factors and assessing the functions in paragraph (c)(6) of the final rule that are relevant to the significant nexus analysis. The EPA WATERS GeoViewer (https://www.epa.gov/waterdata/waters-geoviewer) is an example of a web mapping application that provides accessibility to many spatial dataset layers like NHDPlus and watershed reports for analysis and interpretation. Another web mapping application is the EPA's EnviroAtlas (https://www.epa.gov/enviroatlas/enviroatlas-interactive-map), which provides information and interpretative tools to help facilitate surface water assessments using multiple data layers such as land cover, stream hydrography, soils, and topography. Several States also have state specific interactive online mapping tools called Water Resource Registries (WRRs). Watershed Resources

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[51] It should be noted that RGL No. 07-01 was later superseded by RGL 08-02 and RGL 16-01, neither of which addressed significant nexus evaluations.

Registry 2022. WRRs host publicly available GIS data layers providing various information such as the presence of wetlands, land use/cover, impaired waters, and waters of special concern. Other websites like the Corps' Jurisdictional Determinations and Permits Decision site (https://permits.ops.usace.army.mil/orm-public) and webservices like EPA's Enforcement and Compliance History Online (ECHO) Map Services (https://echo.epa.gov/tools/map-service) allow users to find geospatial and technical information about Clean Water Act section 404 and NPDES permitted discharges. Information on approved jurisdictional determinations finalized by the Corps is also available on the Corps' Jurisdictional Determinations and Permit Decisions site (https://permits.ops.usace.army.mil/orm-public) and EPA's Clean Water Act Approved Jurisdictional Determinations website (https://watersgeo.epa.gov/cwa/CWA-JDs/).

The data that are available online have increased in quality as well as quantity. The NHD has undergone extensive improvements in data availability, reliability, and resolution since 2015, including the release of NHDPlus High Resolution datasets for the conterminous U.S. and Hawaii, with Alaska under development. Buto and Anderson 2020; USGS 2021. One notable improvement in NHD data quality is that the flow-direction network data are much more accurate than in the past. Improvements have also been made to the NWI website and geospatial database, which has served as the primary source of wetland information in the United States for many years. In 2016, NWI developed a more comprehensive dataset (NWI Version 2) that is inclusive of all surface water features in addition to wetlands. U.S. FWS a. This NWI Version 2 dataset provides more complete geospatial data on surface waters and wetlands than has been available in the past and provides a more efficient means to make determinations of flow and water movement in surface water basins and channels, as well as in wetlands. The agencies and other practitioners can use this dataset to help assess potential hydrologic connectivity between waterways and wetlands. For example, it can be used in part to help the agencies identify wetlands that do not meet the definition of "adjacent" (waters assessed under paragraph (a)(5) of the final rule).

The availability of aerial and satellite imagery has improved dramatically since 2015. This imagery is used to observe the presence or absence of flow and identify relatively permanent flow in tributary streams and hydrologic connections to waters. The agencies often use a series of aerial and satellite images, spanning multiple years and taken under normal climatic conditions, to determine the flow characteristics for a tributary, as a first step to determine if additional field-based information is needed to determine the flow characteristics, such as timing and duration of flow. Other practitioners may also use aerial and satellite images to identify aquatic resources and inform assessments of those aquatic resources. The growth of the satellite imagery industry through services such as DigitalGlobe (available at https://discover.maxar.com/) in addition to resources for aerial photography and imagery, such as USGS EarthExplorer (available at https://earthexplorer.usgs.gov/) and National Aeronautics and Space Administration (NASA) Earth Data (available at https://earthdata.nasa.gov/) have reduced the need to perform as many field investigations to verify Clean Water Act jurisdiction. Some of these services charge a fee for use, but others are freely available. The USGS Landsat Level-3 Dynamic Surface Water Extent (DSWE) product (available at https://www.usgs.gov/landsat-missions/landsat-dynamic-surface-water-extent-science-products?qt-science_support_page_related_con=0#qt-science_support_page_related_con) is a specific example of a tool that may be useful for identifying surface water inundation on the landscape in certain geographic areas (*e.g.*, large rivers in the arid

Southwest).[52]

Similarly, LIDAR data have increased in availability and utility for informing decisions on Clean Water Act jurisdiction. LIDAR produces high-resolution elevation data (<1-3 meter) which can be used to create maps of local topography. The high-resolution maps can highlight the potential hydrologic connections and flowpaths at a site. *See, e.g.*, Lang *et al*. 2012. Where LIDAR data have been processed to create a bare earth model, detailed depictions of the land surface reveal subtle elevation changes and characteristics of the land surface, including the identification of tributaries. *See, e.g.*, *id.*; Grau *et al.* 2021. Hydrologists, for example, have long used digital elevation models of the earth's surface to model watershed dynamics (*see, e.g.*, Tarboton 1997), and the agencies have used such information where available to help inform jurisdictional decisions. LIDAR-derived digital elevation models tend to be high resolution (<1-3 meter), so they are particularly helpful for identifying fine-scale surface features. For example, LIDAR-indicated tributaries can be correlated with aerial photography or other tools to help identify channels and to help determine flow permanence (*e.g.*, relatively permanent flow) in the absence of a field visit. The agencies have been using such remote sensing and desktop tools to assist with identifying jurisdictional tributaries for many years, and such tools are particularly critical where data from the field are unavailable or a field visit is not possible. High-resolution LIDAR data are becoming more widespread for engineering and land use planning purposes. The USGS is in the process of collecting LIDAR data for the entire United States. USGS f. LIDAR data are available for download via the National Map Download Client (*available at* https://apps.nationalmap.gov/downloader/#/) and LIDAR-derived digital elevation models are available via the 3DEP LidarExplorer (available at https://apps.nationalmap.gov/lidar-explorer/#/). However, LIDAR-derived elevation maps are not always available, so the agencies use other elevation data, including digital elevation models derived from other sources (*e.g.*, 10-meter digital elevation models) and topographic maps to help determine the elevation on a site and to assess the potential location of tributaries.

Since 2015, tools have been developed that automate some of the standard practices the agencies rely on to assist in jurisdictional determinations. One example of this automation is the Antecedent Precipitation Tool (APT), which was released to the public in 2020 and had been used internally by the agencies prior to its public release. The APT is a desktop tool developed by the Corps and is commonly used by the agencies to help determine whether field data collection and other site-specific observations occurred under normal climatic conditions. Gutenson and Deters 2022; Sparrow *et al.* 2022. In addition to providing a standardized methodology to evaluate normal precipitation conditions ("precipitation normalcy"), the APT can also be used to assess the presence of drought conditions, as well as the approximate dates of the wet and dry seasons for a given location. Gutenson and Deters 2022. As discussed in section IV.B.3 of the final rule preamble and section II.B above, precipitation data are often not useful in providing evidence as to whether a surface water connection exists in a typical year, as required by the 2020 NWPR. *See also* Sparrow *et al.* 2022. However, the agencies have long used the methods employed in the APT to provide evidence that wetland delineations are made under normal circumstances or to account for abnormalities during interpretation of data. *See, e.g.*, Gutenson and Deters 2022; Sprecher and Warne 2000. The development and public release of the APT has accelerated the

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[52] Though DSWE is a useful product for many water-related applications (Jones 2019), due to its resolution (30 meters) and potential issues with canopy cover (*see, e.g.*, Taylor *et al*. 2022), it may be useful only in certain geographic areas for purposes of supporting jurisdictional decisions.

speed at which these analyses are completed; has standardized methods, which reduces errors; and has enabled more people to perform these analyses themselves, including members of the public. Automated tools like the APT will continue to be important for supporting jurisdictional decision-making.

Site visits are still sometimes needed to perform on-site observations of surface hydrology or collect regionally-specific field-based indicators of relatively permanent flow (*e.g.*, the presence of riparian vegetation or certain aquatic macroinvertebrates). The methods and instruments used to collect field data have also improved since 2015, such as the development of rapid, field-based stream duration assessment methods (SDAMs) that use physical and biological indicators to determine the flow duration class of a stream reach. The agencies have previously used existing SDAMs developed by federal and State agencies to identify perennial, intermittent, or ephemeral streams. *See* Nadeau 2015; Fritz *et al*. 2020; Mazor *et al.* 2021. The agencies will continue to use these tools whenever they are determined to be a reliable source of information for the specific water feature of interest. *See* Nadeau 2015; Fritz *et al*. 2020; Mazor *et al.* 2021. The agencies are currently working to develop region-specific SDAMs for nationwide coverage (U.S. EPA 2022m), which will promote consistent implementation across the United States in a manner that accounts for differences between each ecoregion (*see, e.g.*, Fritz *et al.* 2020). The region-specific SDAMs will be publicly available, with user manuals that will guide not only the agencies, but also other practitioners, in applying the methods to assess aquatic resources. Additional information on the agencies' efforts to develop SDAMs is available on the Regional Streamflow Duration Assessment Methods webpage, available at https://www.epa.gov/streamflow-duration-assessment. Consistent with longstanding practice, the agencies will make decisions based on the best available information.

ii. Identifying Tributaries

Tributaries, including those that are relatively permanent, under the final rule include rivers, streams, lakes, ponds, and impoundments that flow directly or indirectly through another water or waters to a traditional navigable water, the territorial seas, an interstate water, or a paragraph (a)(2) impoundment. A tributary may flow through a number of downstream waters, including non-jurisdictional features. The lateral limits of tributaries, in the absence of adjacent wetlands, is typically delineated by the ordinary high water mark. The final rule at paragraph (c)(4) defines ordinary high water mark, retaining the pre-2015 definition, as "that line on the shore established by the fluctuations of water and indicated by physical characteristics such as clear, natural line impressed on the bank, shelving, changes in the character of soil, destruction of terrestrial vegetation, the presence of litter and debris, or other appropriate means that consider the characteristics of the surrounding areas."

While EPA and Corps field staff must exercise judgment to identify the OHWM on a case-specific basis, the regulations at 33 CFR 328.3(e) and 329.11(a)(1) list the factors to be applied. Regulatory Guidance Letter (RGL) 05-05 further explains these regulations. U.S. Army Corps of Engineers 2005b. Delineation of an OHWM in tributaries relies on identification and interpretation of physical features, including topographic breaks in slope, changes in vegetation characteristics (*e.g.*, destruction of terrestrial vegetation and change in plant community), and changes in sediment characteristics (*e.g.*, sediment sorting and deposition). Gartner *et al*. 2016a (citing U.S. Army Corps of Engineers 2005b; Lichvar and McColley 2008; Mersel and Lichvar 2014). Field indicators, remote sensing, and mapping information can also help identify an OHWM. The Corps continues to improve regulatory practices across the country through ongoing research (*see, e.g.*, Lichvar *et al.* 2009; Gartner *et al*. 2016b; Wohl *et al*. 2016; Hamill and David 2021) and the development of regional and national ordinary high water mark delineation procedures (*see* Lichvar and McColley 2008; Mersel and Lichvar 2014). For example, the Corps has developed field indicators to help field staff identify the OHWM in common stream types in the arid West. Lichvar and McColley 2008. A series of Corps manuals and technical reports aims to clarify procedures and to reduce some of the difficulties in delineating the OHWM in rivers and streams (*e.g.*, Lichvar *et al*. 2006; Lichvar and McColley 2008; Curtis *et al*. 2011; Mersel and Lichvar 2014). These resources focus on the use of field evidence for delineating the OHWM, especially three primary indicators—lateral topographic breaks in slope, changes in vegetation characteristics, and changes in sediment characteristics.

While OHWM delineation is principally a field-based exercise, delineating the OHWM based on visual observations alone can be challenging in some circumstances. In such circumstances, hydraulic modeling, hydrologic modeling and flow frequency analysis, or a combination of the two can be used as an additional line of evidence to help support potential OHWM locations observed in the field. Gartner *et al.* 2016a; Gartner *et al*. 2016b; Gartner *et al*. 2016c. Hydraulic and hydrologic modeling each have advantages and disadvantages. Hydraulic modeling can be used to simulate the water surface elevation and lateral extent of water and other hydraulic parameters at a given location for a given discharge. Gartner *et al.* 2016a. Hydrologic modeling can be used to determine the amount of flow discharge at a given location for a given recurrence interval, and in this use, it is one of several methods used in flow frequency analysis. Gartner *et al*. 2016a; Gartner *et al*. 2016b. The scale of the two different types of modeling also differs. Hydraulic modeling focuses on the reach scale (*i.e.*, a given length of a river or stream), often taking the amount of water delivered to a reach as a given input and then simulating the hydraulic properties of the water as it flows through a reach. Gartner *et al*. 2016a. Hydrologic modeling often is conducted on a basin-wide view because the conditions throughout a contributing area can affect the amount of water delivered to the location of interest. *Id*.

Computational hydraulic modeling can be helpful in OHWM delineations but can be misleading if performed or applied improperly. *Id*. Hydraulic models use a set of algebraic and differential equations based on fundamental physical processes, such as Newton's laws of motion, or well-established empirical relations, such as the Manning equation. Gartner *et al*. 2016c. The models convert a measured or estimated input (*e.g.*, geometry, discharge rate, and channel roughness) into an output (*e.g.*, water elevation and flow velocity). *Id.* These models usually make certain assumptions to simplify the calculations, such as assuming that the water flows only directly downstream and that the water surface elevation varies in only the downstream direction, not from one side of a channel to the other. *Id.* (citing Novak *et al*. 2010). With a hydraulic model, a user can test if a physical feature or potential OHWM location corresponds with flow levels that are reasonably associated with the OHWM. Gartner *et al.* 2016a. Gartner *et al*. (2016a) demonstrated that one-dimensional models, such as the Manning equation (it is well established and relatively simple), the Hydraulic Engineering Center River Analysis System (HEC-RAS) (it is a free and widely used hydraulic modeling program), and HEC-GeoRAS (it enhances visualization of the OHWM in concert with digital elevation models (DEMs) and remotely sensed imagery and allows interpolation of model results between surveyed cross sections), are the most suitable choices if one were to model the OHWM because one-dimensional models have reasonable data requirements and long-standing records of use in simulating water elevations.

The goal of flow frequency analysis is to determine how often flows of various magnitudes occur, for example, the peak flow that occurs once every 5 years on average. Gartner *et al*. 2016b. Each of the three primary ways to determine flood flow frequencies has benefits and limitations: (1) stream-gage analysis, (2) regression equations, and (3) rainfall-runoff modeling. *Id.* Broadly, these are all hydrologic models in that they use a set of inputs (such as stream- or rain-gage records or watershed characteristics) to mathematically compute a desired hydrologic result (in this case, recurrence-interval estimates of high flows). *Id*. Gartner *et al*. (2016b) found that in most cases, regional regression equations are the first choice for estimating flood recurrence intervals for OHWM purposes, unless there is a gage at the site, in which case Log-Pearson Type III analysis may be preferred because of the narrower confidence intervals.

In some circumstances, field observations of OHWM indicators may not be possible due to potential illegal activity (*e.g.*, filling in a stream). In some cases, knowledge of the flow characteristics at a site can assist in OHWM delineation beyond the information provided by field evidence. Gartner *et al*. 2016b. The OHWM is not associated with a specific streamflow recurrence interval (or flow frequency); however, it is generally associated with streamflow levels well above mean discharge but less than extreme and infrequent flood events. Gartner *et al.* 2016a. (citing Lichvar and McColley 2008; Mersel and Lichvar 2014). In non-perennial arid streams, for instance, the OHWM signature has been associated with flows generally ranging from about the 1- to 15-year flood event. *Id.* (citing Curtis *et al*. 2011). Some streams may have conflicting field indicators or multiple potential OHWM locations based on the available field evidence, particularly in arid and semi-arid stream systems with one or more low-flow channels within a broader active channel. Gartner *et al.* 2016b. In challenging OHWM delineation situations, knowledge of the streamflow recurrence intervals associated with various field indicators can sometimes be used to rule out or support potential OHWM locations. *Id.* (citing Gartner *et al*. 2016a). For example, in a situation in the arid West, conflicting field indicators can be evaluated in the context of modeled recurrence-interval flows; the larger channel corresponds with approximately a 5- to 10- year flood event, which is consistent with the range of recurrence intervals associated with the OHWM in semi-arid systems. *Id.* (citing Lichvar *et al*. 2006; Curtis *et al*. 2011). Thus, in this example, quantitative analysis can effectively be used to rule out the field indicators associated with the smaller channel and to provide supporting evidence for the field indicators associated with the larger channel. *Id.*

In addition, the agencies will assess any discontinuity in the OHWM and, consistent with pre-2015 practice, a natural or human-made discontinuity in the OHWM does not necessarily sever jurisdiction upstream. A discontinuity may exist where the stream temporarily flows underground. Tributaries may temporarily flow underground in regions with karst geology or topography or lava tubes, for example, often maintaining similar flow characteristics underground and at the downstream point where they return to the surface. *See* section III.A. The agencies will also continue their familiar practice that a discontinuity in the OHWM also does not typically sever jurisdiction upstream where the OHWM has been removed by development, agriculture, or other land uses. For example, tributaries can be relocated below ground to allow reasonable development to occur. In urban areas, surface waters are often rerouted through an artificial tunnel system to facilitate development. *See, e.g.*, Science Report at 3–3, and section III.A of this Technical Support Document. Underground streams are distinct from groundwater due to their very direct hydrologic connection to the portions of the tributaries that are or re-surface above ground. Typically, groundwater connections would be much slower than connections via underground streams. Tributaries that have been rerouted underground are contained within a tunnel system or other similar channelized subsurface feature, while naturally occurring subterranean streams flow within natural conduits like karst formations or lava tubes. *See, e.g.*, Science Report at 3-3; U.S. EPA 2002; Weary and Doctor 2014. The agencies will look for indicators of flow both above and below the discontinuity. For example, a discontinuity in the OHWM may exist due to constructed breaks (*e.g.*, culverts, pipes, or dams)[53] or natural breaks (*e.g.*, debris piles or boulder fields). Site specific conditions will continue to determine the distance up the tributary network that is evaluated to see if the feature creates a temporary break or if it severs the upstream connection and constitutes the start of the tributary system.

The agencies will apply the regulations, RGL 05-05, and applicable OHWM delineation manuals and tools and take other steps as needed to ensure that the OHWM identification factors are applied consistently nationwide. *See Rapanos* Guidance at 10-11 n.36.

A variety of field and remote tools can be used to determine whether a water is a tributary. Due to limitations associated with some remote tools, field verification for accuracy may be necessary (*e.g.*, due to scale or vegetation cover, not all tributaries may be visible in aerial photographs, satellite imagery, or mapped in the NHD). Examples of field indicators will be discussed in more detail below.

Tributaries can be identified on the landscape using direct observation or various remote sensing resources such as USGS stream gage data (available at https://waterdata.usgs.gov/nwis/rt), USGS topographic maps (available at https://www.usgs.gov/the-national-map-data-delivery/topographic-maps), high-resolution elevation data (including digital terrain depictions created from LIDAR) and associated derivatives (*e.g.*, slope or curvature metrics), FEMA flood zone maps (available at https://msc.fema.gov/portal/home), NRCS soil maps (available at https://websoilsurvey.sc.egov.usda.gov/App/WebSoilSurvey.aspx), NHD data, NWI data, maps and geospatial datasets from Tribal, State, Territorial, or local governments, and/or aerial or satellite imagery. For example, tributaries are often observable in aerial imagery and high-resolution satellite imagery by their topographic expression, characteristic linear and curvilinear patterns, dark photographic tones, or the presence of riparian vegetation. USGS topographic maps often include different symbols to indicate mapped hydrographic features such as perennial, intermittent, and ephemeral streams and rivers. *See* USGS 2005. Due to limitations associated with some remote tools, field verification for accuracy may be necessary (*e.g.*, due to scale or vegetation cover, not all tributaries may be visible in satellite imagery and aerial photographs or mapped in the NHD).

Determining whether a waterbody is a tributary under the final rule includes identifying whether the waterbody is part of the tributary system of a traditional navigable water, the territorial seas, or an interstate water. The tributary must flow directly or indirectly through another water or waters to a traditional navigable water, the territorial seas, or interstate water, as discussed further in section IV.C.4.c.i of the preamble. Waters through which a tributary may flow indirectly include, for example, impoundments, wetlands, lakes, ponds, and streams. A tributary may flow through a number of downstream waters, including non-jurisdictional features and jurisdictional waters that are not tributaries,

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[53] Under past practice, the agencies have sometimes characterized bridges as artificial breaks, such as under the 2015 Clean Water Rule. *See* 80 FR 37106. However, bridges do not necessarily create discontinuity in the OHWM, and the agencies recognize that tributaries flowing under bridges may still show evidence of an OHWM and in such circumstances would continue to be jurisdictional where they meet either the relatively permanent or significant nexus standard.

such as an adjacent wetland. But, the tributary must be part of a tributary system that eventually flows to a traditional navigable water, the territorial seas, or an interstate water to be jurisdictional. A tributary may flow through another stream that flows infrequently, and only in direct response to precipitation, and the presence of that stream is sufficient to demonstrate that the tributary flows to a traditional navigable water, the territorial seas, or an interstate water. Tributaries are not required to have a surface flowpath all the way down to the traditional navigable water, the territorial seas, or the interstate water. For example, tributaries can contribute flow through certain natural and artificial breaks (including certain non-jurisdictional features), some of which may involve subsurface flow.

In evaluating the flowpath from a water feature, the agencies can use USGS maps and hydrography data; NWI data; Tribal, State, Territorial, and local knowledge or maps; dye tests, tracers, or other on the ground tests; field observations; aerial photography; or other remote sensing information. The agencies can also use available models, including models developed by federal, Tribal, State, Territorial, and local governments, academia, and the regulated community. One such available GIS tool is the USGS StreamStats "Flow (Raindrop) Path," which allows the user to click a point on a map, after which a flow path is drawn to estimate where water may flow from that point to the stream network, eventually making its way to the ocean if the tributary network allows for it. The StreamStats "Flow (Raindrop) Path" tool may potentially be used to identify the flow path from the subject waters to the downstream traditional navigable water, the territorial seas, or interstate water. The tool is available on USGS's website at https://streamstats.usgs.gov/ss/. Similarly, via WATERS, EPA provides both its web-based mapping application (WATERS GeoViewer, available at https://www.epa.gov/waterdata/waters-geoviewer) and application programming interface (API) services (available at https://watersgeo.epa.gov/openapi/waters/#/Navigation) that can perform downstream network "navigation" to trace the flowpath downstream. *See supra* note 49. These tools could be used in conjunction with field observations, data, and other desktop tools to evaluate whether a tributary flows directly or indirectly to a traditional navigable water, the territorial seas, or an interstate water. For tributaries to impoundments of "waters of the United States," a flowpath to the impoundment and to a traditional navigable water, the territorial sea, or an interstate water can be identified using these same tools.

The following section discusses tools for identifying tributaries that meet the relatively permanent standard. Many of the tools discussed below can also be used for identifying tributaries more generally.

1. Identifying Tributaries That Meet the Relatively Permanent Standard

Under the final rule, tributaries meet the relatively permanent standard when they are relatively permanent, standing or continuously flowing bodies of water. Under the final rule, this category includes surface waters that have flowing or standing water year-round or continuously during certain times of the year and more than in direct response to precipitation. In contrast, tributaries not meeting the relatively permanent standard may flow only during or shortly after individual precipitation events (including rainfall or snowfall events). In implementing the relatively permanent standard, the agencies draw key concepts from the 2020 NWPR's interpretation, but modify that rule's approach to ensure the term can be practically implemented. The approach in the final rule would encompass tributaries considered relatively permanent under the 2020 NWPR, as well as those considered relatively permanent under the *Rapanos* Guidance, providing continuity in approach for the regulated community and other stakeholders. Under the final rule, tributaries that do not meet the relatively permanent standard will be evaluated according to the significant nexus standard, as discussed in section IV.A.v of this document and section IV.C.4.c.iii of the final rule preamble.

A key factor that the agencies typically consider when assessing relatively permanent flows[54] is the geographic region. Many factors, including climate, hydrology, topography, soils, and other conditions, may affect the period in which relatively permanent flow may occur for those relatively permanent waters that do not have continuously flowing or standing water year-round. The factors which affect streamflow and flow cessation are climatically and geographically specific and therefore the periods during which a tributary might have relatively permanent flow vary by region. Non-relatively permanent tributaries are similarly diverse, and the mechanisms which differentiate relatively permanent flow from non-relatively permanent flow also vary by region.

For example, in parts of the Southeastern United States (Southeast), precipitation is distributed somewhat uniformly throughout the year, but increased evapotranspiration during the growing season can reduce surficial ground water levels and reduce or remove surface flows late in the growing season (*e.g.*, late summer or early autumn). *See*, *e.g.*, Anandhi *et al* 2018; Mulholland *et al*. 1997. Consequently, certain streams in the Southeast may flow primarily in the winter or early spring. Non-relatively permanent tributaries in the Southeast may often be characterized by the repeated sequence of streamflow, flow cessation, and channel drying throughout the year, where the onset of streamflow coincides with distinct rainfall events and is driven primarily by storm runoff. Streamflow in these systems may persist anywhere from a few hours to days at a time, where the cessation of flow is most often associated with termination of overland flow, hillslope runoff recession, and the depletion of water in saturated soils. Although streamflow in these tributaries may occur regularly, off and on, over the duration of a season or longer, they do not exhibit continuously flowing water for an extended period at any point during the year. In other areas, snowpack melt drives streamflow more than rainfall, and relatively permanent flow may therefore coincide with warming temperatures typically in the spring or early summer.

Many headwater streams in mountainous regions flow through channels incised in bedrock with no groundwater interface with the bed of the stream. Instead, these streams are often fed primarily by high elevation snowpack melt. The same scenario may also exist in Northern regions, where flows could be fed almost exclusively through melting snowpack absent elevated groundwater tables. In these regions, relatively permanent flows coincide with warming temperatures in the spring or early summer and may persist well into the summer until there are no longer enough inputs to sustain surface water, or later into autumn when more permanent sources of meltwater (*e.g.*, glaciers or snowfields) begin to freeze. Non-relatively permanent flows in these regions may occur in basins with thin layers of snow, where snow melts rapidly at the onset of spring thaw, and the snowmelt produced is not sufficient to sustain flows for an extended period and into the summer.

Sources of flow in tributaries that meet the relatively permanent standard may include an elevated groundwater table that provides baseflow to a channel bed. Relatively permanent flow could also result

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[54] While "flow" is used throughout this section, it is meant to include circumstances where tributaries such as lakes, ponds, or impoundments have standing water during certain parts of the year, as such waters outlet to the tributary network and contribute flow downstream at the outlet point.

from upstream contributions of flow, effluent flow, or snowpack that melts slowly over time in certain geographic regions or at high elevations. In addition, relatively permanent flow could result from a concentrated period of back-to-back precipitation events in certain regions that leads to sustained flow through a combination of runoff and upstream contributions of flow or an elevated groundwater table that provides baseflow to the channel bed. In contrast, non-relatively permanent tributaries may flow only during or shortly after individual precipitation events (including rainfall or snowfall events). Non-relatively permanent flow may occur simply because it is raining or has very recently rained, or because a recent snow has melted.

Streamflow that occurs during the monsoon season in certain parts of the country (typically June through September in the arid West) may be relatively permanent or non-relatively permanent, depending on the conditions at the location. Many tributaries in the arid West are dominated by coarse, alluvial sediments and exhibit high transmission losses, resulting in streams that often dry rapidly following a storm event (*e.g.*, within minutes, hours, or days). Such streams are not relatively permanent under this rule. However, relatively permanent flow may occur as a result of multiple back-to-back storm events throughout a watershed, during which the combination of runoff and upstream contributions of flow is high enough to exceed rates of transmission loss for an extended period of time. Relatively permanent flow may also follow one or more larger storm events, when floodwaters locally recharge the riparian aquifer through bank infiltration, which supplies sustained baseflow throughout the monsoon season.

Similar to the 2020 NWPR’s approach, the agencies will consider tributaries that flow in direct response to “snowfall” for only a short duration during or shortly after that snowfall event to be non-relatively permanent waters under this rule. Streams that flow as a result of “snowpack melt” will be considered relatively permanent waters under this rule, where snowpack is defined as “layers of snow that accumulate over extended periods of time in certain geographic regions or at high elevation (*e.g.*, in northern climes or mountainous regions).” *See* 85 FR at 22275.

As a general matter, the agencies will assess tributaries as they find them, based on current conditions. For example, if a tributary were not a relatively permanent water because of routine water withdrawals, the agencies would assess the tributary under the significant nexus standard. Conversely, if a tributary routinely receives effluent flow that makes it a relatively permanent water, the agencies will assess it under the relatively permanent standard, even if the tributary would otherwise be a non-relatively permanent water without the inputs of effluent.

To determine the flow characteristics of a tributary for purposes of implementing this rule, the agencies will evaluate the entire reach of the tributary that is of the same Strahler stream order (*i.e.*, from the point of confluence, where two lower order streams meet to form the tributary, downstream to the point such tributary enters a higher order stream). Science Report at 2-2; Strahler 1957; *see* Figure 12. The flow characteristics of lakes, ponds, and impoundments that are part of the tributary network will be assessed in conjunction with the stream they connect to. Consistent with the pre-2015 regulatory regime, the agencies will assess the flow characteristics of a particular tributary at the farthest downstream limit of such tributary (*i.e.*, the point the tributary enters a higher order stream). *Rapanos* Guidance at 6, n. 24. Where data indicate the flow characteristics at the downstream limit are not representative of the entire reach of the tributary, the flow characteristics that best characterize the entire tributary reach will be used.

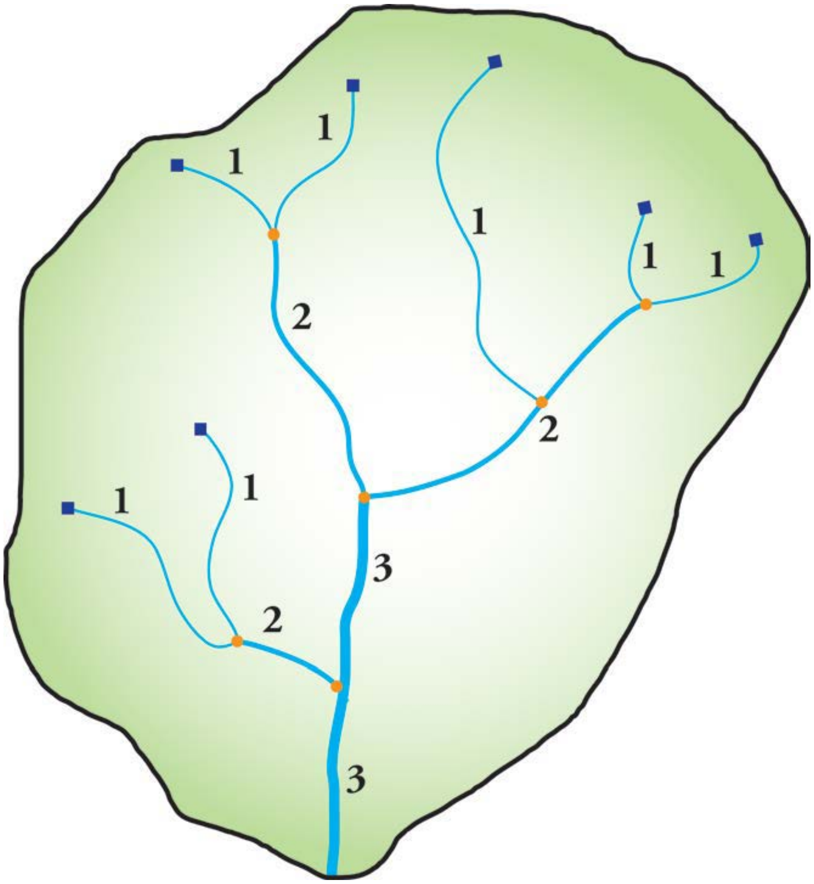

Figure 12: A generalized example of a stream network to illustrate stream order. Blue lines illustrate the river network, within the light green area of its watershed. Numbers represent Strahler stream order, with streams increasing in order when two streams of equal order join. Blue squares indicate channel heads, and orange dots depict confluences. Source: Science Report (Figure 2-1).

Direct observations and various remote tools and resources can be used to identify tributary reaches based on stream order, and topographic characteristics can assist in determining stream order. USGS topographic map blue line symbology and contour line patterns can be used to interpret the connectivity and contribution of flow within a river network, as well as topography within an evaluation area. LIDAR-based elevation models may also illustrate tributary connectivity and flow patterns, as well as topography. In addition, aerial and satellite imagery along with maps or geospatial mapping products (*e.g.*, NHD, NWI, soil maps, and state, tribal, or local maps) can be used to help identify tributary reaches based on stream order. In addition to remote tools and resources, factors identified through field observations can also be used to help determine the extent of a tributary reach. For example, tributary systems can be traversed to identify and characterize the branches of the network that contribute flow to a particular evaluation area. Certain geographic features (*e.g.*, ditches, swales) may also be found to contribute to a tributary's surface hydrology. The agencies also have experience evaluating relatively permanent flow and will continue to use multiple tools, including direct observations and remote and field-based indicators to inform decisions.

Direct observation and various remote or desktop tools can help the agencies and the public better understand streamflow and inform determinations of relatively permanent flow. These tools include local maps, StreamStats by the USGS (available at https://streamstats.usgs.gov/ss/; *see* Ries *et al*. 2017), Probability of Streamflow Permanence (PROSPER) by the USGS, which provides streamflow permanence probabilities during the summer for stream reaches in the Pacific Northwest (available at https://www.usgs.gov/centers/wy-mt-water/science/probability-streamflow-permanence-prosper?qt-science_center_objects=0#qt-science_center_objects), and NRCS hydrologic tools and soil maps.

Other tools include regional desktop tools or models that provide for the hydrologic estimation of a discharge sufficient to generate intermittent or perennial flow (*e.g.*, a regional regression analysis or hydrologic modeling), or modeling tools using drainage area, precipitation data, climate, topography, land use, vegetation cover, geology, and/or other publicly available information. Some models that are developed for use at the reach scale may be localized in their geographic scope. The USGS has developed models for some states for estimating the probability of perennial or non-perennial (*e.g.*, intermittent) flow, including Arizona (Anning and Parker 2009), Idaho (Rea and Skinner 2009), Massachusetts (Bent and Steeves 2006), and Vermont (Olson and Brouillette 2006). Other similar models have been developed for different regions of the United States for classifying different flow classes, including for arid regions of the United States (Merritt *et al*. 2021), California (Lane *et al.* 2017), North Carolina (Russell *et al.* 2015), the northern Rocky Mountains (Sando and Blasch 2015), the upper Colorado River Basin (Reynolds *et al.* 2015). In addition, several models have been developed to classify ephemeral, intermittent, and perennial stream reaches in the Appalachian coal basin of eastern Kentucky. Villines *et al.* 2015; Williamson *et al.* 2015.

Remote or desktop tools can also help the agencies and the public better understand stream flow and whether tributaries have continuously flowing or standing water year-round or during certain times of the year for more than for a short duration and more than in direct response to precipitation. Aerial photographs showing visible water on multiple dates can provide evidence about the presence and duration of continuously flowing or standing water. Aerial photographs may also show other indicators commonly used to identify the presence of an OHWM (*see* definition of OHWM in section IV.A.ii and U.S. Army Corps of Engineers 2020b for additional information on OHWM). Lichvar and McColley 2008; Mershal and Lichvar 2014. These indicators may include the destruction of terrestrial vegetation, the absence of vegetation in a channel, and stream channel morphology with evidence of scour, material sorting, and deposition. These indicators from aerial photographs can be correlated to the presence of USGS stream data (*e.g.*, NHD or topographic maps) to support an assessment of the duration and timing of flow for a tributary.

In addition to aerial photographs, desktop tools, such as a regional regression analysis and the Hydrologic Modeling System (HEC-HMS), provide for the hydrologic estimation of stream discharge in tributaries under regional conditions. The increasing availability of LIDAR derived data can also be used to help implement this final rule. Where LIDAR data have been processed to create elevation data such as a bare earth model, detailed depictions of the land surface are available and subtle elevation changes can indicate a tributary’s bed and banks and channel morphology. Visible linear and curvilinear incisions on a bare earth model can help inform the potential duration and timing of flow of a water in greater detail than aerial photography interpretation alone. Several tools (*e.g.*, TauDEM, Whitebox, GeoNet) can assist in developing potential stream networks based on contributing areas, curvature and flowpaths using GIS.

Potential LIDAR-indicated tributaries can be correlated with aerial photography or high-resolution satellite imagery interpretation and USGS stream gage data, to reasonably conclude the presence of an OHWM and shed light on the potential flow characteristics.

Sources of information that can facilitate the evaluation of relatively permanent flow from snowmelt are NOAA national snow analyses maps (available at https://www.wcc.nrcs.usda.gov/snow/), NRCS sources (available at https://www.wcc.nrcs.usda.gov/snow/), or use of hydrographs to indicate a large increase in stream discharge due to the late spring/early summer thaws of melting snow.

Regional field observations can be used to verify desktop assessments of whether a tributary meets the relatively permanent standard, when necessary. Geomorphic indicators could include active/relict floodplain, substrate sorting, clearly defined and continuous bed and banks, depositional bars and benches, and recent alluvial deposits. Hydrologic indicators might include wrack/drift deposits, hydric soils, or water-stained leaves. Biologic indicators could include aquatic mollusks, crayfish, benthic macroinvertebrates, algae, and wetland or submerged aquatic plants. The agencies have been working to develop regionalized streamflow duration assessment methods (SDAMs, *see* https://www.epa.gov/streamflow-duration-assessment) which are rapid field-based assessment methods that can be used to classify streamflow duration. Nadeau *et al.* 2015; Fritz *et al*. 2020; Mazor *et al.* 2021. These SDAMS can be used to assist in determining whether tributaries at the reach scale meet the relatively permanent standard. These methods rely on physical and/or biological field indicators, such as the presence of hydrophytic vegetation and benthic macroinvertebrates, that can be collected or observed in a single site visit to determine the flow duration of a tributary in a reliable and rapid way. EPA, the Corps, and the State of Oregon developed a regionalized SDAM that has been validated for use throughout the Pacific Northwest. Nadeau 2015. EPA and the Corps have also developed a beta SDAM for the arid West (Mazor *et al*. 2021a) and the Western Mountains (Mazor *et al.* 2021b). EPA and the Corps are working to develop additional regionalized SDAMs in other parts of the country (U.S. Environmental Protection Agency 2021l). The agencies, co-regulators, and stakeholders can use the regionalized field indicators from SDAMs to quickly and easily identify “relatively permanent” tributaries as interpreted by the agencies under this rule. In addition, several states have developed their own methods for evaluating streamflow classifications, including Ohio (Ohio Environmental Protection Agency 2020), New Mexico (New Mexico 2020), North Carolina (North Carolina Division of Water Quality 2010), Tennessee (Tennessee DEC 2020), and Virginia (Virginia Department of Conservation and Recreation 2010). Some local governments have similarly developed their own methods. *See, e.g.*, Fairfax County 2003; James City County 2009. Such state and local flow duration classifications may also be useful tools. Ultimately, multiple indicators, data points, and sources of information may be used to determine whether a water, including a tributary, is relatively permanent.

iii. Identifying Wetlands

Before determining if a wetland is jurisdictional, the agencies first determine if the wetland in question meets the definition of “wetlands.” Wetlands have long been defined by the agencies as “those areas that are inundated or saturated by surface or groundwater at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs, and similar areas.”

33 CFR 328.3(b) (1987); 33 CFR 328.3(c)(16) (2021); 40 CFR 230.3(t) (1988); 40 CFR 120.2(3)(xvi) (2021). The final rule does not change the longstanding regulatory definition of "wetlands."

As under prior regimes, wetlands are identified in the field in accordance with Corps' 1987 Wetland Delineation Manual (Corps 1987) and applicable regional delineation manuals. The 1987 Wetland Delineation Manual was regionalized following recommendations from the National Research Council (1995) to improve sensitivity to regional differences in climate, hydrologic and geologic conditions, and other wetland characteristics. Wakeley *et al*. 2002. Between 2002 and 2012, the Corps developed ten regional supplements covering every region of the conterminous United States, as well as Alaska, the Caribbean Islands, and Hawaii and the Pacific Islands. U.S. Army Corps of Engineers c. Each of the regional supplements possesses uniform format and field methods, while accounting for regional variability through application of field indicators of hydrophytic vegetation, hydric soils, and wetland hydrology. Berkowitz 2011.

Field work is often necessary to confirm the presence of a wetland and to accurately delineate its boundaries. However, in addition to field observations on hydrology, vegetation, and soils, remote tools and resources can be used to support the identification of a wetland, including USGS topographic maps, NRCS soil maps and properties of soils including flood frequency and duration, ponding frequency and duration, hydric soils, and drainage class, aerial or high-resolution satellite imagery, high-resolution elevation data, and NWI maps.

Wetland mosaics are landscapes where wetland and non-wetland components are too closely associated to be easily delineated or mapped separately. These areas often have complex microtopography, with repeated small changes in elevation occurring over short distances. U.S. Army Corps of Engineers 2010. In certain regions where wetland mosaics are common, Corps regional wetland delineation manuals address how to delineate such wetlands. *Id.;* U.S. Army Corps of Engineers 2007c; U.S. Army Corps of Engineers 2011; U.S. Army Corps of Engineers 2012. Longstanding practice is that wetlands in the mosaic are not individually delineated, but that the Corps considers the entire mosaic and estimates percent wetland in the mosaic.

Under longstanding agency practice, a wetland is also delineated as a single wetland if a human-made levee or similar artificial structure divides it, but a hydrologic connection is maintained between the divided wetlands. *See, e.g.,* U.S. EPA and U.S. Army Corps of Engineers 2008. One example of this concept is a wetland that is divided by a road or railway bed. In this example, evidence of a potential hydrologic connection via a shallow subsurface connection could be observed if the wetland continued to function similarly and retain similar species on either side of the human-made structure. The wetland should thus be delineated as a single wetland for the purposes of assessing wetland adjacency and, if required under the final rule, for assessing if the wetland has a significant nexus.

1. Identifying Wetlands Adjacent to Traditional Navigable Waters, the Territorial Seas, Interstate Waters, Impoundments, or Tributaries

Once a feature is identified as a wetland per the agencies' longstanding definition of that term, if the wetland itself is not a traditional navigable water (*i.e.*, it is not a tidal wetland) or an interstate water, the agencies assess whether it is adjacent to a traditional navigable water, the territorial seas, an interstate water, a jurisdictional impoundment, or a tributary. Wetlands that are not a traditional navigable water or an interstate water or that are not adjacent to a traditional navigable water, the territorial seas, an interstate water, a jurisdictional impoundment, or a tributary are assessed under paragraph (a)(5) of the final rule. A variety of remote tools can help to assess adjacency, including maps, high-resolution elevation data, aerial photographs, and high-resolution satellite imagery. For example, USGS topographic maps, elevation data, and NHD data (including NHDPlus) may identify a physical barrier or illustrate the location of the traditional navigable water, the territorial seas, the interstate water, the jurisdictional impoundment, or the jurisdictional tributary; the wetland's proximity to the jurisdictional water; and the nature of topographic relief between the two aquatic resources. Aerial photographs or high-resolution satellite imagery may illustrate hydrophytic vegetation from the boundary (*e.g.*, ordinary high water mark for non-tidal waters or high tide line for tidal waters) of the traditional navigable water, the territorial seas, the interstate water, the jurisdictional impoundment, or the jurisdictional tributary to the wetland boundary, or the presence of water or soil saturation. NRCS soil maps may identify the presence of hydric soil types, hydrologic soil groups based on the soil's runoff potential, soil saturation, and the occurrence of a high or seasonal water table, which can be used to help assess potential surface or shallow subsurface hydrologic connections. The soils information from the Natural Resources Conservation Service Soil Survey is available for nearly every county in the United States. *See* NRCS 2017. Additionally, methods that overlay depressions on the landscape with hydric soils and hydrophytic vegetation can be used to identify likely wetlands and hydrologic connections. Other indicators of a shallow subsurface connection include slope soil permeability, saturated hydraulic conductivity, the presence of an aquitard (confining layer), and permafrost. *See, e.g.,* Science Report at 2-34. Direct visual observations on the ground, such as noting a change in vegetation or evidence of hillslope springs or seeps can be indicators, as can direct measurements of the water table. Location with a floodplain or riparian area is also an indicator of shallow subsurface connection, as wetlands located within a floodplain or riparian area of a water often have shallow subsurface flows to that water that contribute to connectivity and function. Science Report at ES-9.

NWI maps may identify that the wetlands are near the traditional navigable water, the territorial seas, the interstate water, the jurisdictional impoundment, or the jurisdictional tributary. Field work can help confirm the presence and location of the OHWM or high tide line of the traditional navigable water, the territorial seas, the interstate water, the jurisdictional impoundment, or the jurisdictional tributary and can provide additional information about the wetland's potential adjacency to that water (*e.g.*, by traversing the landscape from the traditional navigable water, the territorial seas, the interstate water, the jurisdictional impoundment, or the jurisdictional tributary to the wetland and examining topographic and geomorphic features, as well as hydrologic and biologic indicators). Wetlands adjacent to the traditional navigable waters, the territorial seas, or the interstate waters do not need further analysis to determine if they are "waters of the United States."

For a wetland adjacent to relatively permanent, non-navigable tributaries and relatively permanent impoundments of jurisdictional waters, similar remote tools and resources as those described above may be used to identify if the wetlands has a continuous surface connection to such waters. The tools and resources most useful for addressing this standard are those that reveal breaks in the surface connection between the wetland and the relatively permanent water, such as separations by uplands, or a berm, dike, or similar feature. For example, USGS topographic maps may show topographic highs between the two features, or simple indices can be calculated based on topography to indicate where these connectivity breaks occur. FEMA flood zone or other floodplain maps may indicate constricted floodplains along the length of the tributary channel with physical separation of flood waters that could indicate a break. High-resolution elevation data can illustrate topographic highs between the two features that extend along the tributary channel. Aerial photographs or high-resolution satellite imagery may illustrate upland vegetation along the tributary channel between the two features, or bright soil signatures indicative of higher ground. NRCS soil maps may identify mapped linear, upland soil types along the tributary channel. Field work may help to confirm the presence and location of the relatively permanent, non-navigable tributary's OHWM. In addition, field work may confirm whether there is a continuous physical connection between the wetland and the relatively permanent, non-navigable tributary, or identify breaks that may sever the continuous surface connection (*e.g.*, by traversing the landscape from the tributary to the wetland and examining topographic and geomorphic features, as well as hydrologic and biologic indicators).

For wetlands adjacent to jurisdictional tributaries or jurisdictional impoundments but that do not meet the relatively permanent standard, the agencies will conduct a significant nexus analysis to assess if the wetlands are jurisdictional. Tools to assess if the adjacent wetlands significant affect traditional navigable waters, the territorial seas, or interstate waters are discussed in section IV.A.v below.

All wetlands within a wetland mosaic are ordinarily considered collectively when determining adjacency. The agencies have long considered wetland mosaics to be delineated as one wetland, and this is consistent with pre-2015 practice. Wetlands present in such systems act generally as a single ecological unit. A "wetland mosaic" refers to a landscape where wetland and non-wetland components are too numerous and closely associated to be appropriately delineated or mapped separately. These areas often have complex microtopography, with repeated small changes in elevation occurring over short distances. Barrett 1979; U.S. Army Corps of Engineers 2007c; Michigan Natural Features Inventory 2010; Liljedahl *et al*. 2012; Lara *et al*. 2015. Tops of ridges and hummocks are often non-wetland but are interspersed with wetlands having hydrophytic vegetation, hydric soils, and wetland hydrology. Low-centered polygonal tundra and patterned ground bogs (also called strangmoor, string bogs, or patterned ground fens) are an example of wetland mosaics and are considered a single water for purposes of the final rule because their small, intermingled wetland and non-wetland components are physically and functionally integrated. *See, e.g.,* U.S. Army Corps of Engineers 2007c. Science demonstrates that these wetlands function as a single wetland matrix and ecological unit having clearly hydrophytic vegetation, hydric soils, and wetland hydrology. Corps regional wetland delineation manuals address how to address wetland/non-wetland mosaics, that is a landscape where wetland and non-wetland components are too closely associated to be easily delineated or mapped separately. U.S. Army Corps of Engineers 2007c; U.S. Army Corps of Engineers 2012. For example, at Klatt Bog, one of the prominent patterned ground bogs in Anchorage, Alaska, the plant communities (and thus the wetland and non-wetland areas) intersperse more than can be mapped. Hogan and Tande 1983. Ridges and hummocks are often non-wetland but are interspersed throughout a wetland matrix having clearly hydrophytic vegetation, hydric soils, and wetland hydrology. *Id.* The agencies are continuing the longstanding practice that wetlands in the mosaic are not individually delineated, and that the agencies will consider the entire mosaic and estimate percent wetland in the mosaic. *See, e.g.,* U.S. Army Corps of Engineers 2007c; U.S. Army Corps of Engineers 2012. As a result, the agencies will continue to evaluate these wetlands as a single water under the final rule. This applies for all aquatic resources that meet the regulatory definition of wetland, including tidal wetlands that are traditional navigable waters, interstate wetlands, adjacent wetlands,and wetlands assessed under paragraph (a)(5) of the final rule.

iv. Impoundments

Impoundments of jurisdictional waters were not addressed in the *Rapanos* decision and thus were not directly addressed by the agencies in the *Rapanos* Guidance. In this rule, the paragraph (a)(2) impoundments[55] category provides that a jurisdictional water does not lose its jurisdictional status simply because it is impounded. However, in a change from the 1986 regulation, waters that are determined to be jurisdictional under paragraph (a)(5) and that are subsequently impounded do not retain their jurisdictional status as "waters of the United States" by rule under this provision. Such subsequently impounded jurisdictional paragraph (a)(5) waters may still be determined to be jurisdictional under one of the other categories of "waters of the United States" under this rule (*i.e.*, as a traditional navigable water, the territorial seas, an interstate water, a jurisdictional tributary, a jurisdictional adjacent wetland, or a paragraph (a)(5) water).

In implementing this rule, the agencies consider paragraph (a)(2) impoundments to include impoundments created in "waters of United States" that were jurisdictional at the time the impoundment was created, as well as impoundments of waters that are currently "waters of the United States" under paragraph (a)(1), (a)(3), or (a)(4) of this rule. The agencies also note that an impoundment of a water that does not initially meet the definition of "waters of the United States" can become jurisdictional under another provision of the regulation; for example, an impounded water could become navigable-in-fact and covered under paragraph (a)(1)(i) of the final rule. In addition, under the final rule impounding a water can create a relatively permanent water, even if the water that is being impounded is a non-relatively permanent water. For purposes of implementation, relatively permanent waters include waters where water is standing or ponded at least seasonally.

Consistent with the 1986 regulations, tributaries under this rule may be tributaries to traditional navigable waters, the territorial seas, or interstate waters or to jurisdictional impoundments. Therefore, tributaries to impoundments that are jurisdictional under paragraph (a)(2), wetlands adjacent to such tributaries, and wetlands adjacent to paragraph (a)(2) impoundments are jurisdictional if they meet either the relatively permanent standard or the significant nexus standard. For tributaries to paragraph (a)(2) impoundments to meet the relatively permanent standard, the agencies must be able to trace evidence of a flowpath (*e.g.*, physical features on the landscape, such as a channel, ditch, pipe, or swale) directly or indirectly through another water or waters downstream from the structure that creates the paragraph (a)(2) impoundment to a paragraph (a)(1) water. For wetlands adjacent to paragraph (a)(2) impoundments or to tributaries to paragraph (a)(2) impoundments that meet the relatively permanent standard, to determine if the wetlands meet the relatively permanent standard field staff would assess whether the impounded water

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[55] Impounded waters may be jurisdictional under provisions other than the (a)(2) impoundments provision. For example, they may be impoundments that are traditional navigable waters and would be jurisdictional under paragraph (a)(1), or they may be impounded adjacent wetlands and meet the requirements to be jurisdictional under the paragraph (a)(4) adjacent wetlands provision. To provide clarity in the preamble of the final rule, when the agencies are discussing the subsection of impoundments that are jurisdictional under paragraph (a)(2) because they are impoundments of "waters of the United States," they will refer to "paragraph (a)(2) impoundments."

is relatively permanent, standing or continuously flowing and then determine whether the wetlands have a continuous surface connection to the impoundment or the tributary. *See* section IV.A.ii.1 and section IV.A.iii.1 of this document for additional information on evaluations under the relatively permanent standard for tributaries and adjacent wetlands. For tributaries to paragraph (a)(2) impoundments and for wetlands adjacent to either a paragraph (a)(2) impoundment or a tributary to a paragraph (a)(2) impoundment that are assessed under the significant nexus standard, the significant nexus must be to a paragraph (a)(1) water. *See* section IV.A.v for additional information on significant nexus evaluations for tributaries and adjacent wetlands.

Impoundments are distinguishable from natural lakes and ponds because they are created by discrete structures (often human-built) like dams or levees that typically have the effect of raising the water surface elevation, creating or expanding the area of open water, or both. Impoundments can vary in size, with some being very small, like many beaver ponds, and others being very large, like Lake Mead, a reservoir on the Colorado River that is created by the Hoover Dam. Paragraph (a)(2) impoundments under this rule can include both natural impoundments (like beaver ponds) and artificial impoundments (like reservoirs). Paragraph (a)(2) impoundments under this rule can be located off-channel or in-line with the channel.

An impoundment is jurisdictional under paragraph (a)(2) of the final rule if (1) the impounded water met the definition of "waters of the United States" based on the final rule's definition when the impoundment was created[56] (other than an impoundment of a paragraph (a)(5) water) or (2) the water that is being impounded is currently meets the definition of "water of the United States" under paragraph (a)(1), (a)(3), or (a)(4) of the final rule, regardless of the water's jurisdictional status at the time the impoundment was created. This approach to implementation of impoundments is generally consistent with pre-2015 practice.

The agencies can utilize a variety of tools to help identify impoundments, including many of the tools discussed in section IV.A.ii on identifying tributaries. In addition, as discussed in section IV.A.i, the Corps manages geospatial data related to reservoirs owned and operated by the Corps (*see* https://geospatial-usace.opendata.arcgis.com/) and also manages the National Inventory of Dams (https://nid.usace.army.mil/#/), which contains information from States and federal agencies on the location of over 91,000 dams across the country (U.S. Army Corps of Engineers 2020a.). In the field, agency staff can look for evidence that a water is being impounded (*e.g.*, evidence of a dam or similar structure that would create an impoundment) and then can assess if the water meets the criteria under paragraph (a)(2) of the rule to be considered jurisdictional as an impoundment. Additional information about implementation of paragraph (a)(2) impoundments is in section IV.C.3 of the final rule preamble.

v. Applying a Significant Nexus Standard

Categories of waters under the final rule that require an analysis of significant effects are tributaries that do not meet the relatively permanent standard, wetlands adjacent to tributaries and

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[56] Note, however, if an impoundment is a waste treatment system constructed prior to the 1972 Clean Water Act amendments, it is eligible for the exclusion under paragraph (b) of this rule so long as the system is in compliance with currently applicable Clean Water Act requirements, such as treating water such that discharges, if any, from the system meet the Act's requirements. *See* section IV.C.7.b of the preamble.

impoundments and that do not meet the relatively permanent standard (*i.e.*, wetlands adjacent to tributaries that do not meet the relatively permanent standard or to non-relatively permanent impoundments of jurisdictional waters and wetlands adjacent to but not directly abutting tributaries that meet the relatively permanent standard or to non-relatively permanent impoundments of jurisdictional waters), or for waters assessed under paragraph (a)(5) that do not meet the relatively permanent standard.

For purposes of this rule for significant nexus analyses involving tributaries and their adjacent wetlands, the agencies will assess the tributaries and their adjacent wetlands in a catchment, as described in section III.E.iii. If the tributaries in the region, including the tributary under assessment, have no adjacent wetlands, the agencies consider only the factors and functions of the tributaries in determining whether there is a significant effect on the chemical, physical, or biological integrity of downstream traditional navigable waters, the territorial seas, or interstate waters. If any of the tributaries in the region, including the tributary under assessment, have adjacent wetlands, the agencies will consider the factors and functions of the tributaries, including the tributary under assessment, together with the functions performed by the wetlands adjacent to the tributaries in the catchment, in evaluating whether a significant nexus is present. Tools relevant to implementing “similarly situated” and “in the region” relevant to tributaries and their adjacent wetlands is discussed in section IV.B. As discussed in the preamble and in section III.E.i, the agencies generally intend to analyze such waters individually to determine if they significantly affect the chemical, physical, or biological integrity of traditional navigable waters, the territorial seas, or interstate waters.

In conducting a significant nexus analysis under the final rule, the agencies will evaluate available hydrologic information (*e.g.*, gage data, precipitation records, flood predictions, historic records of water flow, statistical data, personal observations/records, etc.) and physical indicators of flow including the presence and characteristics of a reliable OHWM. To understand the chemical, physical, and biological functions provided by tributaries and their adjacent wetlands or by waters evaluated under paragraph (a)(5), and the effects those functions have on traditional navigable waters, the territorial seas, or interstate waters, it is important to use relevant geographic water quality data in conjunction with site-specific data from field sampling and hydrologic modeling.

The agencies have used many tools and sources of information to assess significant effects on the chemical, physical, and biological integrity of downstream traditional navigable waters, the territorial seas, or interstate waters. Some tools and resources that the agencies have used to provide and evaluate evidence of a significant effect on the physical integrity of traditional navigable waters, the territorial seas, or interstate waters include USGS stream gage data, floodplain maps, statistical analyses, hydrologic models and modeling tools such as USGS’s StreamStats (*see* USGS 2019) or the Corps’ Hydrologic Engineering Centers River System Analysis System (HEC-RAS) (*see* U.S. Army Corps of Engineers a), physical indicators of flow such as the presence and characteristics of a reliable OHWM with a channel defined by bed and banks, or other physical indicators of flow including such characteristics as shelving, wracking, water staining, sediment sorting, and scour, information from NRCS soil surveys, precipitation and rainfall data, and NRCS SNOTEL data or NOAA national snow analyses maps.

To evaluate the evidence of a significant effect on the biological integrity of traditional navigable waters, the territorial seas, or interstate waters, the agencies and practitioners have used tools and resources such as: population survey data and reports from federal, Tribal, State, Territorial, and local resource agencies, natural history museum collections databases, bioassessment program databases, fish passage inventories, U.S. FWS and NOAA Critical Habitat layers (U.S. FWS b; NOAA 2022a), species distribution models, and scientific literature and references from studies pertinent to the distribution and natural history of the species under consideration.

Tools and resources that provide and evaluate evidence of a significant effect on the chemical integrity of traditional navigable waters, the territorial seas, or interstate waters include data from USGS water quality monitoring stations; state, tribal, and local water quality reports; water quality monitoring and assessment databases; EPA's How's My Waterway, which identifies Clean Water Act section 303(d) listed waters, water quality impairments, and TMDLs (available at https://www.epa.gov/waterdata/hows-my-waterway); watershed studies; stormwater runoff data or models; EPA's NEPAssist, which provides locations and information on wastewater discharge facilities and hazardous-waste sites (available at https://www.epa.gov/nepa/nepassist); the National Land Cover Database (NLCD), which provides nationally consistent information on land cover classifications (available at https://www.usgs.gov/centers/eros/science/national-land-cover-database); and scientific literature and references from studies pertinent to the parameters being reviewed. As discussed in section IV.A.i.2, EPA's HAWQS model can be used to assess the cumulative effects of wetlands on the larger downstream waters into which they drain. Additional approaches to quantifying the hydrologic storage capacity of wetlands include statistical models, such as pairing LIDAR-based topography with precipitation totals (*e.g.*, Lane and D'Amico 2010; Shook *et al.* 2013; Wu and Lane 2016). Both statistical and process-based models have been used to quantify the nutrient removal capacities of non-floodplain wetlands (*e.g.*, Cheng *et al.* 2020), and in some cases to assess the effects of non-floodplain wetland nutrient removal, retention, or transformation on downstream water quality (*e.g.*, Evenson *et al.* 2021). Evaluations of a significant effect on the chemical integrity of a traditional navigable water, the territorial seas, or an interstate water may include qualitative reviews of available information or incorporate quantitative analysis components including predictive transport modeling.

A variety of modeling approaches can be used to quantify the connectivity and cumulative effects of wetlands, including non-floodplain wetlands, on downstream waters, as discussed in section IV.A.i.2. Some examples include SWAT (available at https://swat.tamu.edu/), the Hydrologic Simulation Program in Fortran (available at https://www.epa.gov/ceam/hydrological-simulation-program-fortran-hspf), and DRAINWAT available at (https://www.bae.ncsu.edu/agricultural-water-management/drainmod/). Other examples of models applicable to identifying effects of wetlands on downstream waters include MODFLOW (available at https://www.usgs.gov/mission-areas/water-resources/science/modflow-and-related-programs?qt-science_center_objects=0#qt-science_center_objects) and VS2DI (available at https://www.usgs.gov/software/vs2di-version-13), as well as the hydrologic models discussed in section IV.A.i.2.

When assessing whether a water significantly affects traditional navigable waters, the territorial seas, or interstate waters, the significant nexus analysis can consider whether surface or shallow subsurface connections contribute to the type and strength of functions provided by a water either alone or with similarly situated waters. The SAB (2014b) has noted the importance of shallow subsurface connections and stated, "[t]he available science…shows that groundwater connections, particularly via shallow flow paths in unconfined aquifers, can be critical in support the hydrology and biogeochemical functions of wetlands and other waters." However, neither shallow subsurface connections nor any type of groundwater, shallow or deep, are themselves “waters of the United States.”

B. Case Specific Significant Nexus Analysis

i. Similarly Situated

As discussed in the preamble for the final rule and in section III.E.ii of this document, the agencies are taking an approach to which waters are “similarly situated” that is comparable to the *Rapanos* Guidance for tributaries and their adjacent wetlands. Like pre-2015 practice, the agencies consider tributaries and their adjacent wetlands to be “similarly situated” waters. The *Rapanos* Guidance also interpreted “similarly situated” to mean a tributary and its adjacent wetlands.

The agencies note that the best available science supports evaluating the connectivity and effects of streams, wetlands, and open waters to downstream waters in a cumulative manner in context with other streams, wetlands, and open waters. Science Report at ES-5 to ES-6, ES-13 to ES-14, 6-10 to 6-12.

Many of the tools described in section IV.B.ii below for delineating the catchment (*i.e.*, “the region”) can also be used for helping to determine which tributaries should be considered as similarly situated. Such tools, when coupled with aerial photography, NWI maps, NHD, and other sources or methods for identifying adjacent wetlands (as discussed in section IV.A.iii.1), can also be used for identifying which adjacent wetlands should be considered as similarly situated.

In implementing the significant nexus standard for waters assessed under paragraph (a)(5) of the final rule, the agencies generally intend to analyze such waters individually to determine if they significantly affect the chemical, physical, or biological integrity of traditional navigable waters, the territorial seas, or interstate waters. This approach reflects the agencies’ consideration of public comments, as well as implementation considerations for waters assessed under paragraph (a)(5). While the agencies’ regulations have long authorized the assertion of jurisdiction on a case-specific basis over waters that do not fall within the jurisdictional provisions by water type, since *SWANCC* and the issuance of the *SWANCC* guidance with its requirement of headquarters approval over determinations under that provision, the agencies have not in practice asserted jurisdiction over paragraph (a)(3) “other waters” under the pre-2015 regulatory regime. The agencies addressed such waters individually on a case-specific basis under pre-2015 practice and have concluded at this time that individual assessments are practical and implementable for significant nexus determinations for waters assess under paragraph (a)(5). *See* also section III.E.ii.

ii. In the Region

In the final rule for tributaries and their adjacent wetlands, the agencies consider similarly situated waters to be “in the region” when they lie within the catchment area of the tributary of interest. Accordingly, in implementing the significant nexus standard under this rule, all tributaries and adjacent wetlands within the catchment area of the tributary of interest will be analyzed as part of the significant nexus analysis. For purposes of a significant nexus analysis for tributaries and adjacent wetlands, the agencies will identify the “region” as the catchment that drains to and includes the tributary of interest. Catchments will be delineated from the downstream-most point of the tributary reach of interest and include the land uphill that drains to that point. For example, if the tributary of interest is a second order stream, the catchment would be delineated from the point that the second order stream enters a third order stream (including at the point where the second order stream confluences with another second order stream). This is a change from implementation under the *Rapanos* Guidance, which relied on a concept of a relevant “reach” of a tributary—defined as the entire reach of the stream that is of the same order (*i.e.*, from the point of confluence, where two lower order streams meet to form the tributary, downstream to the point such tributary enters a higher order stream). *Rapanos* Guidance at 10.

Because waters assessed under paragraph (a)(5) of the final rule will generally be evaluated individually for their effects on traditional navigable waters, the territorial seas, or interstate waters, the agencies have not established what would be considered “in the region” for this such waters, as it is not needed to implement the final rule, as such waters will generally be considered on an individually basis. *See also* section III.E.iii.

The agencies sought comment on a range of approaches for determining the “region” in which similarly situated waters lie. One such option was for a watershed to be delineated from the downstream-most point of the “relevant reach”—that is, the region would be the watershed that drains to and includes the relevant reach in question. This is the option that the agencies have chosen to implement in this final rule as discussed above, informed by their experience, the best available science, Supreme Court decisions, and public comments. Note that “catchment” as used in the final rule is the watershed that drains to the downstream-most point of the tributary of interest.

Many existing spatial analysis tools based on watershed frameworks and elevation models can be used to delineate catchments quickly and reliably in most parts of the country. USGS topographic maps can be manually interpreted to delineate catchments based on the location of the outlet point (the downstream-most point of the tributary of interest where the tributary enters a higher order stream), using calculations informed by topographic contours, the alignment of topographic high spots, and grouping of lower, valley bottoms. Various GIS tools, web applications, and automated modeling systems can also delineate catchments based on one of the more of the many factors that can influence drainage, including surface topography, climate, land use, the presence of hydrologic sinks, topology of sewer systems, and design of wastewater treatment plant (WWTP) service areas. For example, NHDPlus provides delineated catchments for individual stream segments, by linking the mapped stream network to the landscape. U.S. EPA 2022a. The WATERS GeoViewer, available at https://www.epa.gov/waterdata/waters-geoviewer, utilizes NHDPlus to provide interactive watershed delineation. U.S. EPA 2022n. This is also available through WATERS as an API service (available at https://watersgeo.epa.gov/openapi/waters/#/Delineation). StreamStats by the USGS (available at https://streamstats.usgs.gov/ss/) is a map-based web tool that can delineate drainage areas for streams and estimate flow characteristics for selected sites, based on stream gage data, basin characteristics, climate, and other factors. USGS has also developed the NHD Watershed Tool (available at https://www.usgs.gov/national-hydrography/nhd-watershed-tool) that allows users to delineate a watershed from any point on any NHD reach in a fast, accurate, and reliable manner. EPA’s EnviroAtlas Interactive Map (available at https://www.epa.gov/enviroatlas/enviroatlas-interactive-map) has a wide variety of tools that can help delineate catchments, including a tool that illustrates how precipitation will flow over the land surface, mapped elevation profiles for selected tributaries, and designations of upstream and downstream watersheds within a stream network.

Appendices to the Technical Support Document for the “Revised Definition of ‘Waters of the United States’” Rule

U.S. Environmental Protection Agency

and

Department of the Army

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Appendices Table of Contents

Appendices List of Tables

Appendix A: Glossary

Most of the terms in this glossary are derived directly from EPA's 2015 report *Connectivity of Streams and Wetlands to Downstream Waters: A Review and Synthesis of the Scientific Evidence* (hereafter the Science Report). Some terms are denoted by Clean Water Act, Final Rule, 2020 NWPR, or Science Report to indicate if they are being defined in the context of the Clean Water Act (including under the agencies' longstanding regulations and the final rule defining "waters of the United States"), the final rule, the 2020 Navigable Waters Protection Rule (2020 NWPR), or the Science Report, respectively.

Allochthonous: Describing organic material that originates from outside of streams, rivers, wetlands, or lakes (*e.g.*, terrestrial plant litter, soil).

Alluvial Aquifer: An aquifer with geologic materials deposited by a stream or river (alluvium) that retains a hydraulic connection with the depositing stream.

Alluvial Deposits: *See* Alluvium.

Alluvium: Deposits of clay, silt, sand, gravel, or other particulate materials that have been deposited by a stream or other body of running water in a streambed, on a flood plain, on a delta, or at the base of a mountain. *See* Colluvium.

Aquatic Ecosystem: Any aquatic environment, including all of the environment's living and nonliving constituents and the interactions among them.

Aquifer: A geologic formation (*e.g.*, soil, rock, alluvium) with permeable materials partially or fully saturated with ground water that yields ground water to a well, spring, or stream.

Autochthonous: Describing organic matter that originates from production within streams, rivers, wetlands, or lakes (*e.g.*, periphyton, macrophytes, phytoplankton).

Bank Storage: Storage of water that flows from a stream to an alluvial aquifer during a flood or period of high streamflow. The volume of water is stored and released after the high-water event over days to months. The volume of water stored and the timing of release depends on the hydraulic properties of the alluvial aquifer.

Baseflow: Sustained flow of a stream (or river) in the absence of stormflow (direct runoff). Natural baseflow is sustained by ground-water discharge in the stream network. Baseflow also can be sustained by human sources (e.g., irrigation recharges to ground water).

Carolina Bays: Elliptical, ponded, depressional wetlands that range along the Atlantic Coastal Plain from northern Florida to New Jersey. *See* Delmarva Bays.

Catadromous: Species that breed in the ocean and spend most of their lives in freshwater.

Catchment: The area drained by a stream, river, or other water body; typically defined by the topographic divides between one water body and another. *Synonymous with* Watershed *and* Drainage Basin.

Channel: A natural or constructed passageway or depression of perceptible linear extent that conveys water and associated material downgradient.

Channelization: A type of artificial drainage in which complex channels are straightened to increase the rate of water flow from an area.

Channelized Flow: Flow that occurs in a natural or artificial channel.

Colluvium: A layer of unconsolidated soils, sediment and rock fragments deposited by surface runoff and gravitational processes; colluvium generally occurs as a blanket of poorly sorted sediment and rock fragments on the lower parts of hillslopes underlain by bedrock. *See* Alluvium.

Condition: General health or quality of an ecosystem, typically assessed using one or more indicators.

Confined Aquifer: An aquifer bounded above and below by confining units of distinctly lower permeability than that of the aquifer itself.

Confluence: The point at which two stream channels intersect to form a single channel.

Connectivity: The degree to which components of a river system are joined, or connected, by various transport mechanisms; connectivity is determined by the characteristics of both the physical landscape and the biota of the specific system.

Connectivity Descriptors (for streams and wetlands): The frequency, duration, magnitude, timing, and rate of change of fluxes to and biological exchanges with downstream waters.

Contributing Area: Location within a watershed/river network that serves as a source of stream flow or material flux.

Contaminants: Any material that might be harmful to humans or other organisms when released to the environment.

Deep Ground Water: Ground-water flow systems having the deepest and longest flowpaths; also referred to as regional ground-water flow systems, they can occur beneath local and intermediate ground-water flow systems. *See* Local Ground Water, Regional Ground Water.

Delmarva Bays: Carolina bays that are geographically specific to the Delmarva Peninsula. These wetlands frequently have the same elliptical shape and orientation as Carolina bays. *See* Carolina Bays.

Dendritic Stream Network: A stream network pattern of branching tributaries (see Figure 2-19B).

Depressional Wetland: A wetland occupying a topographic low point that allows the accumulation of surface water. Depressional wetlands can have any combination of inlets and outlets or lack them completely. Examples include kettles, prairie potholes, and Carolina bays. This category also includes slope wetlands (wetlands associated with surface discharge of ground water or saturated overflow with no channel formation).

Diadromous: Migratory between fresh and salt waters.

Direct Runoff: Runoff that occurs in direct response to precipitation. *See* Stormflow.

Discharge (Science Report): The volume of water (surface water or ground water) that passes a given location over a given period of time; the rate of runoff. Often expressed as cubic feet per second ($ft^3\ s^{-1}$) or cubic meters per second ($m^3\ s^{-1}$).

Discharge (Clean Water Act): The term "discharge" when used without qualification includes a discharge of a pollutant, and a discharge of pollutants. Clean Water Act section 502(16).

Discharge of a pollutant (Clean Water Act): The term "discharge of a pollutant" and the term "discharge of pollutants" each means (A) any addition of any pollutant to navigable waters from any point source, (B) any addition of any pollutant to the waters of the contiguous zone or the ocean from any point source other than a vessel or other floating craft. Clean Water Act section 502(12).

Discontinuous Flow: Refers to stream and river reaches that have flow in one part of the reach but not another part of the reach. *See* Reach.

Dispersal: Movement from natal breeding sites to new breeding sites.

Drainage Area: The spatial extent of a drainage basin. Typically expressed in square miles (mi^2) or square kilometers (km^2).

Drainage Basin: The area drained by a stream, river, or other water body; typically defined by the topographic divides between one water body and another. *Synonymous with* Catchment *and* Watershed.

Drainage Density: The total length of stream channels per unit drainage area (e.g., per mi2 or km2).

Drainage Network: *See* River Network.

Egg Bank: Viable dormant eggs that accumulate in soil or in sediments under water. *See* Seed bank.

Endorheic Basins: A closed drainage basin with no outflows to other water bodies.

Endorheic Stream: A stream or river reach that experiences a net loss of water to a ground-water system. *See* Losing Stream or Wetland.

Ephemeral (NWPR): The term *ephemeral* means surface water flowing or pooling only in direct response to precipitation (*e.g.*, rain or snow fall). 85 FR 22338; 33 CFR 328.3(c)(3) (2021).

Ephemeral Stream (Science Report): A stream or river that flows briefly in direct response to precipitation; these channels are always above the water table.

Eutrophication: Natural or artificial enrichment of a water body by nutrients, typically phosphates and nitrates. If enrichment leads to impairment (*e.g.*, toxic algal blooms), eutrophication is a form of pollution.

Evapotranspiration: The combined loss of water to the atmosphere due to evaporation and transpiration losses. Transpiration is the loss of water vapor to air by plants.

Fen: A peat-accumulating wetland characterized by mineral-rich water inputs.

Flood: The occurrence of stream or river flow of such magnitude that it overtops the natural or artificial banks in a reach of the stream or river; where a floodplain exists, a flood is any flow that spreads over or inundates the floodplain. Floods also can result from rising stages in lakes and other water bodies.

Flood (100-year): Flood level (stage or discharge) with a 1% probability of being equaled or exceeded in a given year.

Flood Flows: Discharge or flow of sufficient (or greater) magnitude to cause a flood.

Flood Recurrence Interval: The average number of years between floods of a certain size is the recurrence interval or return period. The actual number of years between floods of any given size varies a lot because of the naturally changing climate. USGS.

Flood Stage: The stage at which streams or rivers overtop their natural or artificial banks.

Floodwater: Water associated with a flood event.

Floodplain: A level area bordering a stream or river channel that was built by sediment deposition from the stream or river under present climatic conditions and is inundated during moderate to high flow events. Floodplains formed under historic or prehistoric climatic conditions can be abandoned by rivers and form terraces.

Floodplain Wetland: Portions of floodplains that meet the Cowardin *et al.* (1979) three-attribute definition of a wetland (*i.e.*, having wetland hydrology, hydrophytic vegetation, or hydric soils). *See* Wetland.

Flow: Water movement above ground or below ground.

Flow Duration Class: A classification that assigns streamflow duration to ephemeral, intermittent, or perennial classes.

Flow Regime: Descriptor of flow types in a temporal or magnitude sense (i.e., slow-flow regime, low-flow regime)

Flowpath: *See* Hydrologic Flowpath.

Fluvial: Refers to or pertains to streams; *e.g.*, stream processes (fluvial processes), fluvial landforms, such as fluvial islands and bars, and biota living in and near stream channels.

Flux: Flow of materials between system components per unit time.

Gaining Stream or Wetland: A wetland or a stream or river reach that experiences a net gain of water from ground water (see Figure 2-5). In this situation, the water table elevation near the stream or wetland is higher than the stream or wetland water surface. Conditions conducive to losing or gaining streams and wetlands can change over short distances within river networks and river basins. *See* Losing Stream or Wetland.

Geographically Isolated Wetland: A wetland that is completely surrounded by uplands; for example, hydrophytic plant communities surrounded by terrestrial plant communities or undrained hydric soils surrounded by nonhydric soils. This term often is mistakenly understood to mean hydrologically isolated. Geographically isolated wetlands vary in their degree of hydrologic and biotic connectivity.

Ground Water: Any water that occurs and flows in the saturated zone. *See* Saturated Zone.

Ground-water Discharge: The flow of ground water to surface waters; discharge areas occur where the water tables intersect land surfaces. *See* Seep, Spring.

Ground-water Discharge Wetland: A wetland that receives ground-water discharge.

Ground-water Flow: Flow of water in the subsurface saturated zone.

Ground-water Recharge: The process by which ground water is replenished; a recharge area occurs where precipitation or surface water infiltrates and is transmitted downward to the saturated zone (aquifer). *See* Infiltration, Percolation, Transmission.

Ground-water Recharge Wetland: A wetland that recharges ground water.

Ground-water System: Reference to the ground water and geologic materials comprising the saturated zone; the ground-water system, as a whole, is a three-dimensional flow field.

Ground water–Surface water Interactions: Movement of water between surface-water bodies and ground-water systems. Flows can occur in either direction.

Ground-water Withdrawal: Pumping of water from aquifers for human uses.

Habitat: Environment (place and conditions) in which organisms reside.

Headwater: Areas from which water originates within a river or stream network. This term typically refers to stream channels but can also describe wetlands or open waters, such as ponds.

Headwater Stream: Headwater streams are first- to third-order streams. Headwater streams can be ephemeral, intermittent, or perennial. *See* Stream Order, Flow Duration Class.

Hillslope: A sloping segment of land surface.

Hydraulic Conductivity: A measure of the permeability of a porous medium. For a given hydraulic gradient, water moves more rapidly through media with high hydraulic conductivity than low hydraulic conductivity.

Hydraulic Gradient: Slope of the water table. *See* Water Table.

Hydraulic Head: The height above a standard datum of the surface of a column of water that can be supported by the static pressure at a given point; for a well, the hydraulic head is the height of the water level in the well compared to a datum elevation.

Hydraulics: The physics of water in its liquid state.

Hydric: An area, environment, or habitat that is generally very wet with plenty of moisture.

Hydrograph: A graph of stream or river discharge over time. Stage or water table elevation also can be plotted.

Hydrologic Event: An increase in streamflow resulting from precipitation or snowmelt.

Hydrologic Flowpath: The pathway that water follows as it moves over the watershed surface or through the subsurface environment.

Hydrology: The study of the properties, distribution, and effects of water as a liquid, solid, and gas on Earth's surface, in the soils and underlying rocks, and in the atmosphere.

Hydrologic Landscape: A landscape with a combination of geology, soils, topography, and climate that has characteristic influences on surface water and ground water.

Hydrologic Permanence: The frequency and duration of streamflow in channels or the frequency and duration of standing water in wetlands.

Hyporheic Flow: Water from a stream or river channel that enters subsurface materials of the streambed and bank and then returns to the stream or river.

Hyporheic Exchange: Water and solutes exchanged between a surface channel and the shallow subsurface. *See* Hyporheic Flow.

Hyporheic Zone: The area adjacent to and beneath a stream or river in which hyporheic flow occurs. The dimensions of the hyporheic zone are controlled by the distribution and characteristics of alluvium and hydraulic gradients between streams and local ground water.

Hypoxia: The condition in which dissolved oxygen is below the level necessary to sustain most animal life. *See* Anoxic Conditions.

Infiltration: The downward entry of water from the land surface into the subsurface.

Intermittent (2020 NWPR): The term *intermittent* means surface water flowing continuously during certain times of the year and more than in direct response to precipitation (*e.g.*, seasonally when the groundwater table is elevated or when snowpack melts).

Intermittent (Science Report): This term also can be applied to other surface-water bodies and ground-water flow or level. *See* Intermittent Stream.

Intermittent Stream: A stream or portion of a stream that flows continuously only at certain times of year; for example, when it receives water from a spring, ground-water source, or a surface source such as melting snow. At low flow, dry segments alternating with flowing segments can be present.

Inundation: To cover dry land with floodwaters.

Isolation: Condition defined by reduced or nonexistent transport mechanisms between system components.

Lag Function: Any function within a stream or wetland that provides temporary storage and subsequent release of materials without affecting cumulative flux (exports = imports); delivery is delayed and can be prolonged.

Lateral Source Stream: A first-order stream that flows into a higher order stream.

Lentic: Of, relating to, or living in still water. *See* Lotic.

Levee (Artificial): An engineered structure built next to a stream or river from various materials to prevent flooding of surrounding areas. The levee raises the elevation of the channel height to convey greater discharge of water without flooding.

Levee (Natural): A broad, low ridge or embankment of coarse silt and sand that is deposited by a stream on its floodplain and along either bank of its channel. Natural levees are formed by reduced velocity of flood flows as they spill onto floodplain surfaces and can no longer transport the coarse fraction of the suspended sediment load.

Local Ground Water: Ground water with a local flow system. Water that recharges at a high point in the water table that discharges to a nearby lowland. Local ground-water flow is the most dynamic and shallowest of ground-water flow systems. Therefore, it has the greatest interchange with surface water. Local flow systems can be underlain by intermediate and regional flow systems. Water in these deeper flow systems have longer flowpaths and longer contact time with subsurface materials. Deeper flow systems also eventually discharge to surface waters and influence their condition.

Losing Stream or Wetland: A stream, wetland, or river reach that experiences a net loss of water to a ground-water system (*see* Figure 2-5 of the Science Report). In this situation, the water table elevation near the stream or wetland is lower than the stream or wetland water surface. Conditions conducive to losing or gaining streams and wetlands can change over short distances within river networks and river basins. *See* Gaining Stream or Wetland.

Lotic: Of, relating to, or living in moving water. *See* Lentic.

Mainstem: Term used to distinguish the larger (in terms of discharge) of two intersecting channels in a river network.

Materials: Any physical, chemical, or biological entity, including but not limited to water, heat energy, sediment, wood, organic matter, nutrients, chemical contaminants, and organisms.

Meltwater: Liquid water that results from the melting of snow, snowpacks, ice, or glaciers.

Migration: Long-distance movements undertaken by organisms on a seasonal basis.

Non-floodplain Wetland: An area outside of the floodplain that meets the Cowardin *et al*. (1979) three-attribute definition of a wetland (i.e., having wetland hydrology, hydrophytic vegetation, or hydric soils). For the purposes of this report, riparian wetlands that occur outside of the floodplain are not included as non-floodplain wetlands, since these wetlands are subject to bidirectional, lateral hydrologic flows. *See* Floodplain, Wetland.

Nutrients (In Aquatic Systems): Elemental forms of nitrogen, phosphorus, and trace elements, including sulfur, potassium, calcium, and magnesium, that are essential for the growth of organisms but can be contaminants when present in high concentrations.

Nutrient Spiraling: Longitudinal cycles ("spirals") of nutrient uptake and release along the stream or river continuum. The spirals are created as aquatic organisms consume, transform, and regenerate nutrients, altering the rates of nutrient transport to downstream waters.

Open-channel Flow: Water flowing within natural or artificial channels.

Open Waters: Nontidal lentic water bodies such as lakes and oxbow lakes that are frequently small or shallow.

Overbank Flow: Streamflow that overtops a stream or river channel.

Overland Flow: The portion of streamflow derived from net precipitation that fails to infiltrate the land surface at any point and runs over the surface to the nearest stream channel.

Oxbow Lakes: Water bodies that originate from the cutoff meanders of rivers; such lakes are common in floodplains of large rivers.

Peatland: A wetland that accumulates partially decayed organic matter. Fens and bogs are common examples.

Perched Ground Water: Unconfined ground water separated from an underlying body of ground water by an unsaturated zone; perched ground water is supported by a perching layer (bed) for which the permeability is so low that water percolating downward to the underlying unsaturated zone is restricted.

Percolation: The downward movement of water through soil or rock formations.

Perennial (2020 NWPR): The term *perennial* means surface water flowing continuously year-round.

Perennial (Science Report): *See* Perennial Stream. This term can be applied to other surface-water bodies and to ground-water flow or level.

Perennial Stream: A stream or portion of a stream that flows year-round and is maintained by local, intermediate, or regional ground-water discharge or flow from higher in the river network.

Permanent Waters: Water bodies that contain water year-round; perennial waters.

Permeability: Property of a porous medium that enables it to transmit fluids under a hydraulic gradient. For a given hydraulic gradient, water will move more rapidly through high permeability materials than low permeability materials.

Potential Evapotranspiration: The amount of water that would be lost to the atmosphere over a given area through evaporation and transpiration, assuming no limits on the water supply. *See* Evapotranspiration.

Prairie Potholes: Complex of glacially formed wetlands, usually lacking natural outlets, found in the central United States and Canada.

Precipitation: Water that condenses in the atmosphere and falls to a land surface. Common types include rain, snow, hail, and sleet.

Precipitation Intensity: The rate at which precipitation occurs; generally refers to rainfall intensity.

Primary Production: The fixation of inorganic carbon into organic carbon (*e.g.*, plant and algae biomass) through the process of photosynthesis. Primary production is the first level of the food web, and provides most of the autochthonous carbon produced in ecosystems. The rate of fixation is referred to as gross primary productivity (GPP) or net primary productivity (NPP), where NPP is equal to GPP minus respiration. *See* Respiration, Secondary Production.

Propagule: Any part of an organism that can give rise to a new individual organism. Seeds, eggs, and spores are propagules.

Reach (Science Report): A length of stream channel with relatively uniform discharge, depth, area, and slope.

Recession [of Flow]: Decrease in flow following a hydrologic event.

Recharge Area: An area in which water infiltrates the surface and reaches the zone of saturation.

Refuge Function: The protective function of a stream or wetland that allows an organism (or material) to avoid mortality (or loss) in a nearby sink area, thereby preventing the net decrease in material flux that otherwise would have occurred (exports = imports). This term typically refers to organisms but can be used for nonliving materials. *See* Sink Function.

Regional Ground Water: Ground water with a deep, regional-scale flow system; also referred to as deep ground water. These flow systems can occur beneath local and intermediate ground-water flow systems. *See* Local Ground Water, Deep Ground Water.

Respiration: The chemical process by which organisms break down organic matter and produce energy for growth, movement, and other biological processes. Aerobic respiration uses oxygen and produces carbon dioxide.

Return Flow: Water that infiltrates into a land surface and moves to the saturated zone and then returns to the land surface (or displaces water that returns to the soil surface).

Riparian Areas: Transition areas or zones between terrestrial and aquatic ecosystems that are distinguished by gradients in biophysical conditions, ecological processes, and organisms. They are areas through which surface hydrology and subsurface hydrology connect water bodies with their uplands. They include those portions of terrestrial ecosystems that significantly influence exchanges of energy and matter with aquatic ecosystems. Riparian areas are adjacent to perennial, intermittent, and ephemeral streams, lakes, and estuarine-marine shorelines. *See* Upland.

Riparian Wetland: Portions of riparian areas that meet the Cowardin *et al*. (1979) three-attribute definition of a wetland (i.e., having wetland hydrology, hydrophytic vegetation, hydric soils). *See* Wetland.

River: A relatively large volume of flowing water within a visible channel, including subsurface water moving in the same direction as the surface water, and lateral flows exchanged with associated floodplain and riparian areas. *See* Stream.

River Network: A hierarchical, interconnected population of channels or swales that drain water to a river. Flow through these channels can be perennial, intermittent, or ephemeral.

River Network Expansion/Contraction: The extent of flowing water in a river network increases during wet seasons and large precipitation events and decreases during dry periods. *See* Variable Source Area.

River System: A river and its entire drainage basin, including its river network, associated riparian areas, floodplains, alluvial aquifers, regional aquifers, connected water bodies, geographically isolated water, and terrestrial ecosystems.

Runoff: The part of precipitation, snowmelt, or other flow contributions (e.g., irrigation water) that appears in surface streams at the outlet of a drainage basin; it can originate from both above land surface (e.g., overland flow) and below land surface sources (e.g., ground water). Units of runoff are depth of water (similar to precipitation units, e.g., mm). This measurement is the depth of water if it were spread across the entire drainage basin. Can also be expressed as a volume of water (i.e., m3, feet3, acre-ft).

Saturated Zone: The zone below the land surface where the voids in soil and geologic material are completely filled with water. Water in the saturated zone is referred to as ground water. The upper surface of the saturated zone is referred to as the water table. *See* Ground Water, Unsaturated Zone, Water Table.

Saturation Overland Flow: Water that falls onto a saturated land surface and moves overland to the nearest stream or river.

Seasonality: Refers to the seasonal distribution of water surplus of a river system. *See* Water Surplus.

Secondary Production: The generation of biomass of consumer organisms that feed on organic material from primary producers (algae, microbes, aquatic and terrestrial plants), and biomass of predators that feed on consumer organisms. *See* Primary Production.

Seed Bank: Viable dormant seeds that accumulate in soil or in sediments under water. *See* Egg bank.

Seep: A small area where water slowly flows from the subsurface to the surface. A seep can also refer to a wetland formed by a seep; such a wetland is referred to as a ground-water slope wetland.

Seepage: Water that flows from a seep.

Shallow Ground Water: Ground water with shallow hydrologic flowpaths. *See* Local Ground Water.

Significantly Affect (Final Rule Paragraph (c)(6)): *Significantly affect* means a material influence on the chemical, physical, or biological integrity of waters identified in paragraph (a)(1) of this section. To determine whether waters, either alone or in combination with similarly situated waters in the region, have a material influence on the chemical, physical, or biological integrity of waters identified in paragraph (a)(1) of this section, the functions identified in paragraph (c)(6)(i) below will be assessed and the factors identified in paragraph (c)(6)(ii) below will be considered:

- (i) Functions to be assessed:
  - (A) Contribution of flow;
  - (B) Trapping, transformation, filtering, and transport of materials (including nutrients, sediment, and other pollutants);
  - (C) Retention and attenuation of floodwaters and runoff;
  - (D) Modulation of temperature in waters identified in paragraph (a)(1) of this section; or
  - (E) Provision of habitat and food resources for aquatic species located in waters identified in paragraph (a)(1) of this section;
- (ii) Factors to be considered:
  - (A) The distance from a water identified in paragraph (a)(1) of this section;
  - (B) Hydrologic factors, such as the frequency, duration, magnitude, timing, and rate of hydrologic connections, including shallow subsurface flow;
  - (C) The size, density, or number of waters that have been determined to be similarly situated;
  - (D) Landscape position and geomorphology; and
  - (E) Climatological variables such as temperature, rainfall, and snowpack.

Sink Function: Any function within a stream or wetland that causes a net decrease in material flux (imports exceed exports).

Snowpack (Science Report): Accumulation of snow during the winter season; an important source of water for streams and rivers in the western United States.

Snowmelt: The complete or partial melting and release of liquid water from seasonal snowpacks.

Solute: A substance that is dissolved in water.

Source Area: The originating location of water or other materials that move through a river system.

Source Function: Any function within a stream or wetland that causes a net increase in material flux (exports exceed imports).

Spillage: Overflow of water from a depressional wetland to a swale or channel.

Spring: A surface-water body formed when the side of a hill, a valley bottom, or other excavation intersects a flowing body of ground water at or below the local water table.

Stable Isotope Tracer: Certain elements such as oxygen, hydrogen, carbon, and nitrogen have multiple isotopes that occur in nature that do not undergo radioactive decay. These isotopes can be used to track the source and movement of water and other substances.

Stage: The elevation of the top of a water surface.

Stream: A relatively small volume of flowing water within a visible channel, including subsurface water moving in the same direction as the surface water, and lateral flows exchanged with associated floodplain and riparian areas. *See* River.

Stream Burial: The process of incorporating streams—particularly headwaters—into storm sewer systems, usually by routing through underground pipes.

Stream Power: A measure of the erosive capacity of flowing water in stream channels or the rate of energy dissipation against the stream bed or banks per unit of channel length that has the mathematical form: $\omega a = \rho gQS$ where ωa is the stream power, ρ is the density of water (1000 kg/m3), g is acceleration due to gravity (9.8 m/s2), Q is discharge (m3/s), and S is the channel slope.

Stream Network—*See* River Network. A stream network is the same as river network, but typically refers to a smaller spatial scale.

Stream Reach: *See* Reach.

Storm: A precipitation event that produces an increase in streamflow.

Stormflow: The part of flow through a channel that occurs in direct response to precipitation; it includes surface and subsurface sources of flow. *See* Direct Runoff.

Stream Order (Strahler): A method for stream classification based on relative position within a river network, when streams lacking upstream tributaries (*i.e.*, headwater streams) are first-order streams and the junction of two streams of the same order results in an increase in stream order (*i.e.*, two first-order streams join to form a second-order stream, two second-order streams join to form a third-order stream, and so on). When streams of different order join, the order of the larger stream is retained. Stream-order classifications can differ, depending on the map scale used to determine order.

Streamflow: Flow of water through a stream or river channel. *See* Discharge.

Subsurface Water: All water that occurs below the land surface.

Surface Runoff: *See* Overland Flow.

Surface Water: Water that occurs on Earth’s surface (e.g., springs, streams, rivers, lakes, wetlands, estuaries, oceans).

Surface-water Bodies: Types of water bodies that comprise surface water. *See* Surface Water.

Swale (Science Report): A nonchannelized, shallow trough-like depression that carries water mainly during rainstorms or snowmelt. A swale might or might not be considered a wetland depending on whether it meets the Cowardin *et al.* (1979) three-attribute wetland criteria. *See* Wetland.

Symmetry Ratio: The size ratio of a minor tributary ($T2$) to a major tributary ($T1$) at a confluence. Discharge ($Q2/Q1$), drainage area ($A2/A1$), or channel width ($W2/W1$) can be used to characterize the ratio of tributary size.

Terminal Source Stream: A first-order stream that intersects another first-order stream.

Terrace: An historic or prehistoric floodplain that has been abandoned by its river and is not currently in the active floodplain. *See* Floodplain.

Tracer: A substance that can be used to track the source and movement of water and other substances.

Transformation Function: Any function within a stream or wetland that converts a material into a different form; the amount of the base material is unchanged (base exports equal base imports), but the mass of the different forms can vary.

Transmission Loss: The loss of runoff water by infiltration into stream and river channel beds as water moves downstream; this process is common in arid and semiarid environments.

Transport Mechanism: Any physical mechanism, such as moving water, wind, or movement of organisms, which can transport materials or energy. As used in this report, the term specifically refers to physical mechanisms that move material or energy between streams or wetlands and downstream waters.

Tributary (Science Report): A stream or river that flows into a higher order stream or river.

Unconfined Aquifer: An aquifer that has a water table; the aquifer is not bounded by lower permeability layers. *See* Confined Aquifer.

Unsaturated Zone: Also referred to as the vadose zone. The zone between land surface and the water table within which the moisture content is less than saturation and pressure is less than atmospheric. Soil pore spaces also typically contain air or other gases. *See* Saturated Zone.

Uplands: (1) Higher elevation lands surrounding streams and their floodplains. (2) Within the wetland literature, specifically refers to any area that is not a water body and does not meet the Cowardin *et al.* (1979)-attribute wetland definition. *See* Wetland.

Uptake Length (for dissolved nitrogen in streams): The distance traveled in the water column before algal and microbial assimilation occurs.

Valley: A depression of the earth's surface that drains water between two upland areas.

Variable Source Area: Neither stormflow nor baseflow is uniformly produced from the entire surface or subsurface area of a basin. Instead, the flow of water in a stream at any given moment is influenced by dynamic, expanding or shrinking source areas, normally representing only a few percent of the total basin areas. The source area is highly variable during stormflow. During large rainfall or snowmelt events, the flowing portions of the river network, and associated source areas, expand. As the event ends, the network and source areas contract.

Vernal Pool: Shallow seasonal wetlands that generally accumulate water during colder, wetter months and gradually dry down during warmer, dryer months.

Water Balance: The accounting of the volume of water that enters, leaves, and is stored in a hydrologic unit, area, or arbitrarily defined control volume, typically a drainage basin or aquifer, during a specified period of time.

Water Body: Any sizable accumulation of water on the land surface, including streams, rivers, lakes, and wetlands.

Water Surplus: Water that is available for streamflow or recharge of ground water; precipitation minus evapotranspiration.

Water Table: The top of the zone of saturation of an unconfined aquifer.

Watershed: The area drained by a stream, river, or other water body; typically defined by the topographic divides between one water body and another. *Synonymous with* Catchment *and* Drainage Basin.

Wet Channel: Channel with flowing or standing water.

Wetland (Science Report): An area that generally exhibits at least one of the following three attributes (Cowardin *et al*., 1979): (1) is inundated or saturated at a frequency sufficient to support, at least periodically, plants adapted to a wet environment; (2) contains undrained hydric soil; or (3) contains nonsoil saturated by shallow water for part of the growing season.

Wetlands (Clean Water Act): The term *wetlands* means areas that are nundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs, and similar areas.

Wetland Storage: The capacity of a wetland to detain or retain water from various sources.

Appendix B: References

Note that the below references are only those that were cited in this technical support document. The references for the Science Report are available in that Report, which is available in the Docket for the proposed rule and on EPA's website at http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=296414. In addition, EPA's Office of Research and Development considered additional peer-reviewed literature for the completion of the Science Report and in the review of literature published since the Science Report's publication. The references considered for the literature update are available in Appendix C. The agencies also solicited comment on whether additional citations published since the Science Report's publication (*i.e.*, since 2014) should be considered by the agencies. The agencies' review of those references is available in Appendix C3.

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Appendix C: References from the Literature Update Screening and Public Comments on Literature Published Since 2014

As discussed in section I.C of the Technical Support Document, subject-matter experts from the U.S. Environmental Protection Agency's Office of Research and Development conducted a screening analysis to identify papers that were relevant to the major conclusions of the Science Report. Appendix C1 contains those references that the screeners believed were relevant to the conclusions of aquatic systems: (1) ephemeral, intermittent, and perennial streams; (2) floodplain wetlands and open waters; and (3) non-floodplain wetlands and open waters and is broken out by aquatic system. Appendix C2 contains plain-text summaries of the abstracts for a sample of the relevant literature (note that Appendix C2 was numbered Appendix C3 in the Technical Support Document for the Proposed Rule, but no other changes have been made to this Appendix). Appendix C3 contains 37 additional references identified by the screeners as being relevant to the Science Report's major conclusions and the agencies' review of those 37 references (note that Appendix C3 was numbered Appendix C2 in the Technical Support Document for the Proposed Rule). The agencies solicited comment on the scientific literature contained in Appendix C of the Proposed Rule and on whether additional scientific literature and references published since 2014 are relevant to the Science Report's conclusions on the connectivity and effects of streams, wetlands, and open waters on the chemical, physical, and biological integrity of downstream water. Several commenters provided additional literature published since 2014, and the agencies' review of those citations is contained in Appendix C3.

Appendix C1: References Relevant to the Conclusions of the Science Report Published Since 2014

The agencies believe the below references are relevant to conclusions of the Science Report and have been published since 2014. The agencies are seeking comment on this list of references and if additional references are relevant to the report's conclusions but are not listed below. This list of references is derived mainly from the agencies' screening process, which is discussed in section I.C of this document. That screening process yielded 2,022 unique citations that were found to be relevant to the conclusions of the Report. The results of that screening process have been supplemented with additional literature published since 2014 that the agencies believe is relevant to the findings of the Report but that was not captured through the screening process. For purposes of the screening, the agencies conducted screenings for references that were relevant to the Science Reports conclusions on (1) streams; (2) riparian and floodplain wetlands and open waters, and (3) riparian and non-floodplain wetlands and open waters. Note that some references are relevant to more than one system but may not be denoted as such in the below appendix.

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Zhao, Q., T.W. Arnold, J.H. Devries, D.W. Howerter, R.G. Clark, and M.D. Weegman. 2019. “Land-use change increases climatic vulnerability of migratory birds: Insights from integrated population modelling.” *Journal of Animal Ecology* 88(10): 1625-1637.

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Zhu, X., Y. Yuan, D.M. Mushet, and M.L. Otte. 2019. “Can Multi-Element Fingerprinting of Soils Inform Assessments of Chemical Connectivity Between Depressional Wetlands?” *Wetlands* 39(5): 1015-1027.

Appendix C2: Plain-Text Language from the Abstracts of Illustrative Scientific Papers

The screening process identified illustrative peer-reviewed papers for each of the three aquatic systems (as discussed in section I.C of the Technical Support Document). Screeners further provided a “Plain Text” summary of the content based on the abstract. The papers are not ordered or prioritized and represent a sample of the references screened. This Appendix has been renumbered and was Appendix C3 in the Technical Support Document for the Proposed Rule. No other changes have been made to this Appendix.

Ephemeral, Intermittent, and Perennial Streams

Reference	**Plain Text Summary**
Ebersole, J. L., P. J. Wigington, S. G. Leibowitz, R. L. Comeleo and J. Van Sickle (2015). “Predicting the occurrence of cold-water patches at intermittent and ephemeral tributary confluences with warm rivers.” *Freshwater Science* 34(1): 111-124	Small tributary streams, including ephemeral channels when they do not contain surface flow, serve as sources of cold water to warmer downstream waters. Tributary basins with higher water surpluses at the end of the preceding wet season were more likely to serve as summer cold water sources; basin area and the presence of surface flow at the time of sampling were not strong predictors. Continued release of groundwater from tributary basins creates refuges for cold-water taxa.
Chara-Serna, A. N. and J. S. Richardson (2021). “Multiple-Stressor Interactions in Tributaries Alter Downstream Ecosystems in Stream Mesocosm Networks.” *Water* 13(9)	Using a mesocosm study, researchers examined how stressor interactions in tributaries affected downstream second-order channels. Results showed that (1) Ephemeroptera, Plecoptera, and Trichoptera (EPT) density and richness were higher in downstream channels when stressors were applied separately in tributaries, rather than in combination, and (2) combined stressors within a tributary reduced macroinvertebrate drift into downstream channel. These results support the hypothesis that cumulative upstream disturbance can influence downstream systems.
Shogren, A. J., J. P. Zarnetske, B. W. Abbott, F. Iannucci, R. J. Frei, N. A. Griffin and W. B. Bowden (2019). “Revealing biogeochemical signatures of Arctic landscapes with river chemistry.” *Scientific Reports* 9(1): 12894.	The dominant spatial scale controlling organic carbon and inorganic nutrient concentrations within three Alaska watersheds was 3-30 km2, indicating that fine scale landscape patches and a continuum of diffuse and discrete sourcing and processing dynamics are driving solute generation and transport.
Chiu, M. C., B. i. Li, K. e. Nukazawa, V. H. Resh, T. Carvajal and K. Watanabe (2020). “Branching networks can have opposing influences on genetic variation in riverine metapopulations.” *Diversity and Distributions* 26(12): 1813-1824	This study was designed to examine how branching complexity within stream networks can simultaneously increase and decrease genetic divergence of macroinvertebrate metapopulations. Simulation experiments showed that more branched stream networks had both greater landscape connectivity (resulting from shorter watercourse distance) and greater isolation of headwater streams. These two spatial features have negative and positive influences on genetic divergence, with their relative importance varying among species and dispersal characteristics.

Reference	**Plain Text Summary**
Seymour, M., E. A. Fronhofer and F. Altermatt (2015). “Dendritic network structure and dispersal affect temporal dynamics of diversity and species persistence.” *Oikos* 124(7): 908-916	This study examined the effect of dendritic versus linear network structures on local (alpha), regional (beta) and total (gamma) diversity, using protist and rotifer assemblages as a test community. Local diversity remained higher in dendritic networks over time, especially at highly connected sites. Regional diversity was initially greater in linear networks due to dispersal limitation, but over time became more similar to regional diversity in dendritic networks. Results indicate that dispersal and network connectivity alone may, to a large extent, explain diversity dynamics.
Brennan, S. R., D. E. Schindler, T. J. Cline, T. E. Walsworth, G. Buck and D. P. Fernandez (2019). “Shifting habitat mosaics and fish production across river basins.” *Science* 364(6442): 783-786	Researchers quantified how habitat mosaics (including headwaters) are expressed across a range of spatial scales within a large, free-flowing river in Alaska. The relative productivity of locations across the river network varies widely among years and across a broad range of spatial scales, and these shifts in natal and juvenile rearing habitat help stabilize interannual Pacific salmon production at the scale of the entire basin.
Sarker, S., A. Veremyev, V. Boginski and A. Singh (2019). “Critical Nodes in River Networks.” *Scientific Reports* 9(1): 11178	In this study, researchers used an algorithm to determine the set of critical nodes (channel intersections) along river networks whose removal results in maximum network fragmentation. Results based on both simulated and natural basins in the US indicated a power-law relationship between the number of connected node pairs in the remaining river network and the number of removed critical nodes (i.e., one varies as a power of the other).
Teachey, M. E., J. M. McDonald and E. A. Ottesen (2019). “Rapid and Stable Microbial Community Assembly in the Headwaters of a Third-Order Stream.” *Applied and Environmental Microbiology* 85(11)	This study examined the development and stability of microbial communities along a first- through third order stream in Georgia. Results show that the bacterioplankton community develops rapidly and predictably from the headwater population with increasing total stream length. Along the length of the stream, the microbial community exhibits substantial diversity loss and enriches repeatedly for select taxa across days and years, although the relative abundances of individual taxa vary over time and space. This repeated enrichment of a stable stream community likely contributes to the stability and flexibility of downstream communities.
Samia, Y. and F. Lutscher (2017). “Downstream flow and upstream movement determine the value of a stream reach for potadromous fish populations.” *Theoretical Ecology* 10(1): 21-34	Because water flow transports certain local conditions downstream and individuals move upstream and downstream through river networks, the overall effects of disturbances should be examined at the scale of the entire network. Results from a fish population model show that upper stream reaches can be highly significant for population persistence if downstream transport of abiotic conditions or upstream movement of individuals is strong.

Reference	Plain Text Summary
Chezik, K. A., S. C. Anderson and J. W. Moore (2017). "River networks dampen long-term hydrological signals of climate change." *Geophysical Research Letters* 44(14): 7256-7264	Trends over 37 years between climate and daily flow data from 55 river gauging stations within the Fraser River network in British Columbia, Canada were examined to see if flow trends diminish with increasing river size or aggregation of tributary contributions. Long-term changes in discharge variability was dampened by >91% in larger rivers than in smaller tributaries and was >3.1 times the dampening when accounting for differences in sample size (more small tributaries than large rivers in a river network). The authors suggest their findings show that integration of the contributions in a river network (i.e., river network portfolio) has a stabilizing influence on long-term hydrologic trends of downstream rivers.
Rupp, D. E., O. S. Chegwidden, B. Nijssen and M. P. Clark (2021). "Changing River Network Synchrony Modulates Projected Increases in High Flows." *Water Resources Research* 57(4): e2020WR028713	Daily streamflow along the Columbia River and its tributaries were simulated (without dams and irrigation) to understand how climate change scenarios could influence downstream flood magnitude. One mechanism that affects flood magnitude is timing or synchrony of flooding between on a river and its branches or tributaries. Under moderate warming scenarios, synchrony and flooding was predicted to be lower for coldwater tributaries. However, under sufficient warming the main flow source is expected to transition from mixture of snowmelt and rain to rain-dominated which leads to higher synchrony and downstream flood magnitudes.
Jaeger, K. L., J. D. Olden and N. A. Pelland (2014). "Climate change poised to threaten hydrologic connectivity and endemic fishes in dryland streams." *Proceedings of the National Academy of Sciences* 111(38): 13894	The authors used a surface water model to forecast future streamflows within Verde River Basin and characterized the change in temporal and spatial dimensions of streamflow or hydrologic connectivity or fragmentation throughout the river network. The model predicted that the number of days which the river stops flowing to increase by 27% in 2050 and the frequency of river drying events to increase by 17%. The overall length of flowing stretches within the Verde River network was predicted to drop between 8% and 20% in spring and early summer with greater declines during the drier portions of the year. This will result in less spawning habitat and refuge from seasonal drying. Using dispersal models to contextualize the impact from climate change projections, the authors estimated the Verde River network will have 6-9% and 12-18% lower hydrologic connectivity during the year and spring spawning months, respectively. This finding has strong implications on the persistence of endemic fish fauna under climate change.

Reference	Plain Text Summary
Marcarelli, A. M., A. A. Coble, K. M. Meingast, E. S. Kane, C. N. Brooks, I. Buffam, S. A. Green, C. J. Huckins, D. Toczydlowski and R. Stottlemyer (2019). “Of Small Streams and Great Lakes: Integrating Tributaries to Understand the Ecology and Biogeochemistry of Lake Superior.” *Journal of the American Water Resources Association* 55(2): 442-458	Approximately 2,800 tributaries flow into and contribute nutrients and dissolved organic matter to the nearshore areas of Lake Superior. Tributaries contribute bulk of these materials to Lake Superior during snowmelt-driven flows in the spring and rain-driven flows following rain during other times of the year. Temporary storage and transformations of these material occur during transport in the tributaries prior to entering Lake Superior. Despite being such a large water body, distinct physical and chemistry signals are detected where tributaries enter Lake Superior during periods of high runoff but are quickly transported and mixed with the bulk of the lake volume. The use of different technologies (e.g., automated sampling, remote imagery, drones) will enhance the monitoring and understanding of tributary-lake connections.
Kelson, S. J. and S. M. Carlson (2019). “Do precipitation extremes drive growth and migration timing of a Pacific salmonid fish in Mediterranean-climate streams?” *Ecosphere* 10(3)	Climate change is expected to cause more frequent weather extremes leading to more severe droughts and floods. Steelhead are migratory trout that live in the South Fork Eel River and its tributaries in California. This study examined extremely wet and dry years over the period of 2015-2018 to see how stream flow affected the steelhead growth, health, and migration timing. Despite strong differences in the timing and magnitude of winter-spring floods and summer low-flows between years, the growth, health, migration timing was not affected. The authors attributed the lack of impact on steelhead detected between extremes was due to the high quality of habitat provided by groundwater-fed tributaries that provided cool and stable base flows even in the driest years.
Marteau, B., R. J. Batalla, D. Vericat and C. Gibbins (2017). “The importance of a small ephemeral tributary for fine sediment dynamics in a main-stem river.” *River Research and Applications* 33(10): 1564-1574	An ephemeral tributary in the United Kingdom had key moments of influence on a downstream river (River Ehen) through the temporal mismatch between sediment transport from an ephemeral tributary and flooding in a mainstem river. Despite draining only 1.2% of the river catchment and flowing only ephemerally, the recently reconnected ephemeral tributary increased annual sediment yield in the downstream river by 65%.
Xu, J. (2016). “Sediment jamming of a trunk stream by hyperconcentrated floods from small tributaries: case of the Upper Yellow River, China.” *Hydrological Sciences Journal* 61(10): 1926-1940	The study describes floods in ten small desert tributaries that transport large amounts of sediment which exacerbates downstream flooding in the Yellow River in China. The authors investigated in detail one such flooding event and developed a tool to understand the downstream influence of flood-driven sediment from tributaries over immediate (days to weeks) and longer time periods (decades).

Reference	Plain Text Summary
Swanson, B. J. and G. Meyer (2014). “Tributary confluences and discontinuities in channel form and sediment texture: Rio Chama, NM.” *Earth Surface Processes and Landforms* 39(14): 1927-1943	Tributaries (arroyos) periodically deliver sediment downstream to the Rio Chama in northern New Mexico. The sediment is delivered by floods induced by summer thunderstorms. Channel measurements were collected from 203 cross-sections located upstream and downstream from 26 tributary confluences over a 17-km reach of the Rio Chama. The slope, bed sediment size, and cross-sectional area of the river channel was affected by tributaries and influence the transport and storage of sediment along the river. On a larger scale, tributaries have a stronger influence on the Rio Charma in the upper two-thirds of the 17-km reach than the lower third which had fewer tributaries and was dominated by canyon narrows. Tributaries and their associated watershed characteristics (e.g., geology) contribute the morphology of downstream rivers.
Marteau, B., C. Gibbins, D. Vericat and R. J. Batalla (2020). “Geomorphological response to system-scale river rehabilitation I: Sediment supply from a reconnected tributary.” *River Research and Applications* 36(8): 1488-1503	An ephemeral tributary (Ben Gill) in the United Kingdom was reconnected to its sediment-limited downstream river (River Ehen) and the subsequent 2 years sediment transport from the tributary to the river was measured. Sufficient coarse sediment is critical to maintaining economically and culturally important salmonid habitat. An estimated minimum of 384 m3 of coarse sediment was exported to the downstream river and contributed to the habitat formation. The small, ephemeral stream (0.55 km2 or 1.2% of the river’s drainage area) which flows only ~20% of the year approximately doubled the volume of coarse sediment estimated to occur in the confluence area prior to reconnection and so is providing needed critical material for salmonid habitat in the downstream river.
French, D. W., D. E. Schindler, S. R. Brennan and D. Whited (2020). “Headwater Catchments Govern Biogeochemistry in America’s Largest Free-Flowing River Network.” *Journal of Geophysical Research: Biogeosciences* 125(12)	Water chemistry samples collected from the Kuskokwim River (largest U.S. river without dams), Alaska was studied to understand the influence of the surrounding watershed and instream conditions from different parts of the river network. The conditions in small, headwater streams play a disproportionately important role in predicting the streamwater chemistry throughout the river network. Nutrients that are rapidly used by algae and microbes are spatially more variable in the river network when compared to chemicals that have lower biological demand.
Koizumi, I., Y. Tanaka and Y. Kanazawa (2017). “Mass immigration of juvenile fishes into a small, once-dried tributary demonstrates the importance of remnant tributaries as wintering habitats.” *Ichthyological Research* 64(3): 353-356	A small tributary of the Otofuke River in northern Japan went dry during the summer. Four months after resuming flow more than 10,000 immature fish of three species, including rainbow trout used the tributary for wintering habitat.

Reference	Plain Text Summary
Fovet, O., D. M. Cooper, D. L. Jones, T. G. Jones and C. D. Evans (2020). “Dynamics of dissolved organic matter in headwaters: comparison of headwater streams with contrasting DOM and nutrient composition.” *Aquatic Sciences* 82(2)	The processes by which headwater streams functionally alter terrestrial dissolved organic matter (carbon and nutrients) are influenced by local factors, including soils, land-use, and human pressures. This study compared the effects of sunlight, presence/absence of aquatic biota, and nutrient supplementation on DOM processing in two contrasting stream types – one, a headwater with low inorganic nutrient loadings (peatland stream) and the other a headwater with high nutrient loadings (an agricultural grassland stream). Exposure to sunlight resulted in net abiotic organic matter loss (removal) in the peatland stream but net biological production (increase) of organic matter in the agricultural stream. Nutrient addition accelerated DOM production in both streams. These results show that the quantity and quality of net DOM exported from headwaters are influenced by the composition of terrestrial DOM inputs, landscape setting, and exposure to sunlight. The author suggest that these results indicate that headwaters may be more active processors of carbon and nutrients than previously thought.
Gallo, E. L., T. Meixner, K. A. Lohse and H. Nicholas (2020). “Estimating Surface Water Presence and Infiltration in Ephemeral to Intermittent Streams in the Southwestern US.” *Frontiers in Water* 2(47)	Streamflow in arid and semi-arid regions is predominantly temporary, and of significant importance for groundwater recharge and biogeochemical processes. However, temporary streamflow, especially ephemeral flows, remain poorly quantified. The authors used in-stream streamflow data loggers and USGS stream gauge data in 15 southern Arizona streams spanning a climate gradient (mean annual precipitation from 160 to 750 mm) to quantify temporary streamflow as (a) streamflow presence and (b) water presence, which included streamflow, ponding and soil moisture. In addition, stream channel sediment data were used to estimate saturated hydraulic conductivity and potential annual infiltration. Annual streamflow ranged 0.6–82.4% or 2–301 days; while water presence ranged from 2.6 to 82.4% or 10 to over 301 days, or 4–33 times longer than streamflow. These data were used to develop 5 statistically distinct flow regimes based on the annual percent streamflow and water presence: (1) dry-ephemeral, (2) wet-ephemeral, (3) dry-intermittent, (4) wet-intermittent, and (5) seasonally-intermittent. Stream channel density was a better predictor of annual streamflow and water presence than annual rainfall alone. The dry-ephemeral and wet-ephemeral flow regimes varied with seasonal precipitation, while the dry-intermittent, wet intermittent and seasonally-intermittent flow regimes did not. These results coupled with the potential infiltration estimates indicate that streamflow at the driest sites occurs in response to rainfall and overland flow while groundwater discharge and vadose zone contributions enhance streamflow at the wetter sites. Flow regime classifications that include both stream flow and water presence, rather than on stream flow alone, may be important for predicting thresholds in ecological functions and refugia in these dryland systems.

Reference	Plain Text Summary
Hill, B. H., R. K. Kolka, F. H. McCormick and M. A. Starry (2014). “A synoptic survey of ecosystem services from headwater catchments in the United States.” *Ecosystem Services* 7: 106-115	“Ecosystem production functions for water supply, climate regulation, and water purification were estimated for 568 headwater streams and their catchments. Results are reported for nine USA ecoregions. Headwater streams represented 74-80% of total catchment stream length. Water supply per unit catchment area was highest in the Northern Appalachian Mountains ecoregion and lowest in the Northern Plains. C, N, and P sequestered in trees were highest in Northern and Southern Appalachian and Western Mountain catchments, but C, N, and P sequestered in soils were highest in the Upper Midwest ecoregion. Catchment denitrification was highest in the Western Mountains. In-stream denitrification was highest in the Temperate Plains. Ecological production functions paired with published economic values for these services revealed the importance of mountain catchments for water supply, climate regulation, and water purification per unit catchment area. The larger catchment sizes of the plains ecoregions resulted in their higher economic value compared to the other ecoregions. The combined potential economic value across headwater catchments was INT \$14,000 ha(-1) yr(-1), or INT \$30 million yr(-1) per catchment. The economic importance of headwater catchments is even greater considering that our study catchments statistically represent more than 2 million headwater catchments in the continental United States.”
Jones, C. S., J. K. Nielsen, K. E. Schilling and L. J. Weber (2018). “Iowa stream nitrate and the Gulf of Mexico.” *PLoS ONE* 13(4): e0195930	The objective of this study was to quantify and update Iowa’s contribution of nitrate-nitrogen to the Mississippi River stream network against the backdrop of Gulf of Mexico hypoxia. Stream nitrate and discharge data collected from 1999 until 2016 at 23 Iowa stream sites near watershed outlets, along with publicly available data for sites downstream of Iowa on the Missouri and Mississippi Rivers shows that Iowa contributes between 11 and 52% of the long-term nitrate load to the Mississippi-Atchafalaya Basin, 20 to 63% to the Upper Mississippi River Basin, and 20 to 89% to the Missouri River Basin, with averages of 29, 45 and 55% respectively. Since 1999, nitrate loads in the Iowa inclusive basins have increased and these increases do not appear to be driven by changes in discharge and cropping intensity unique to Iowa. The 5-year running annual average of Iowa nitrate loading has been above the 2003 level for ten consecutive years.

Reference	Plain Text Summary
Jones, E. F., N. Griffin, J. E. Kelso, G. T. Carling, M. A. Baker and Z. T. Aanderud (2020). "Stream Microbial Community Structured by Trace Elements, Headwater Dispersal, and Large Reservoirs in Sub-Alpine and Urban Ecosystems." *Frontiers in Microbiology* 11: 491425	Functional stream bacterioplankton communities are needed to maintain surface water quality and other aquatic ecosystem services. The diversity and composition of stream bacterioplankton communities influence their function. This study quantified the role of environmental conditions, bacterioplankton dispersal, and human infrastructure (dams) on community composition in rivers from sub-alpine to urban environments in three watersheds (Utah, United States) across three seasons. Bacterioplankton community diversity decreased downstream along parts of the stream continuum but was disrupted where large reservoirs increased water residence time by orders of magnitude, potentially indicating a shift in the relative importance of environmental selection and dispersal at these sites. Reservoirs also had substantial effects on community composition, similarity, and species interactions. Communities downstream of reservoirs were enriched with anaerobic Sporichthyaceae, methanotrophic Methylococcaceae, and iron-transforming Acidimicrobiales, suggesting alternative metabolic pathways became active in the hypolimnion of large reservoirs. The results identify that human activity affects river microbial communities, with potential impacts on water quality through modified biogeochemical cycling.
Larson, J. H., J. M. Vallazza and B. C. Knights (2019). "Estimating the degree to which distance and temperature differences drive changes in fish community composition over time in the upper Mississippi River." *PLoS ONE* 14(12): e0225630	Similarity in aquatic communities often declines with increasing distance between habitat locations. In addition to spatial separation, distance-dissimilarity relationships are driven by the presence of environmental gradients that alter habitat suitability for particular species. The Mississippi River is aligned mostly north-to-south so greater distances along the river roughly correspond to differences in latitude, which in turn correspond to different thermal regimes, which are important determinants of fish community structure. The authors of this study used a 21-year dataset of fish communities in the upper Mississippi River to examine the effect of distance on variation in community composition and to assess whether the effect of distance is primarily due to its effect on thermal regime. The results showed a moderate distance-similarity relationship, suggesting greater distance leads to less similarity, which appeared to increase slightly over time. Using a subset of data for which air temperature was available, models that incorporated both difference among sites in degree days (a surrogate for thermal regime) and physical distance (river km) found that temperature alone appears to be more strongly associated with differences in the Mississippi River fish community than spatial distance alone.

Reference	Plain Text Summary
Mooney, R. J., E. H. Stanley, W. C. Rosenthal, P. C. Esselman, A. D. Kendall and P. B. McIntyre (2020). “Outsized nutrient contributions from small tributaries to a Great Lake.” *Proceedings of the National Academy of Sciences of the United States of America* 117(45): 28175-28182	For lakes across the United States, eutrophication is driven largely by nonpoint nutrient sources from tributaries that drain surrounding watersheds, which are relatively understudied in lake systems despite their ubiquity and potential importance to lake water quality. The authors of this study quantified a ‘snapshot’ of nutrient inputs from nearly all tributaries of Lake Michigan – the world’s fifth largest freshwater lake by volume – to determine how land cover and dams alter nutrient inputs across different watershed sizes. Loads, concentrations, stoichiometry, and bioavailability (percentage dissolved inorganic nutrients) varied by orders of magnitude among tributaries, creating a mosaic of coastal nutrient inputs. The six largest of 235 tributaries accounted for approximately 70% of the daily nitrogen and phosphorus delivered to Lake Michigan. However, small tributaries exhibited nutrient loads that were high for their size and biased toward dissolved inorganic forms. Higher bioavailability of nutrients from small watersheds suggests greater potential to fuel algal blooms in coastal areas, especially given the likelihood that their plumes become trapped and then overlap in the nearshore zone. The findings reveal an underappreciated role that small streams may play in driving coastal eutrophication in large water bodies.
Schilling, K. E. and C. S. Jones (2019). “Hydrograph separation of subsurface tile discharge.” *Environmental Monitoring and Assessment* 191(4): 231	Baseflow is an important component of streamflow and watershed hydrologic budgets. The fraction of baseflow contributed by tile drainage has rarely been reported. The authors of this study quantified baseflow discharge from three central Iowa drainage district tile mains using two different hydrograph separation methods and found that baseflow comprised approximately 60% of the annual flow for a 5-year period (2009–2013). The results of this study provide methods to better quantify hydrologic pathways throughout tiled landscapes.

Reference	Plain Text Summary
van Meerveld, H. J. I., J. W. Kirchner, M. J. P. Vis, R. S. Assendelft and J. Seibert (2019). "Expansion and contraction of the flowing stream network alter hillslope flowpath lengths and the shape of the travel time distribution." *Hydrology and Earth System Sciences* 23(11): 4825-4834	"Flowing stream networks dynamically extend and retract, both seasonally and in response to precipitation events. These network dynamics can dramatically alter the drainage density and thus the length of subsurface flow pathways to flowing streams. We mapped flowing stream networks in a small Swiss headwater catchment during different wetness conditions and estimated their effects on the distribution of travel times to the catchment outlet. For each point in the catchment, we determined the subsurface transport distance to the flowing stream based on the surface topography and determined the surface transport distance along the flowing stream to the outlet. We combined the distributions of these travel distances with assumed surface and subsurface flow velocities to estimate the distribution of travel times to the outlet. These calculations show that the extension and retraction of the stream network can substantially change the mean travel time and the shape of the travel time distribution. During wet conditions with a fully extended flowing stream network, the travel time distribution was strongly skewed to short travel times, but as the network retracted during dry conditions, the distribution of the travel times became more uniform. Stream network dynamics are widely ignored in catchment models, but our results show that they need to be taken into account when modeling solute transport and interpreting travel time distributions."
Wilkinson, M. E. and J. C. Bathurst (2018). "A multi-scale nested experiment for understanding flood wave generation across four orders of magnitude of catchment area." *Nordic Hydrology* 49(3): 597-615	Current understanding of flood response is deficient concerning the variation of flood generation as a function at different spatial scales as a result of spatial and temporal variations in storm rainfall. This study investigates flood response to spatially variable rainfall through a multi-scale nested experiment. Hydrological data from an extensive network in the Eden catchment, UK, were collected for a range of flood events over varying scales from 1.1 km^2 to 2,286 km^2. Peak specific discharge for winter events appears to remain constant for areas up to 20-30 km^2, corresponding to upland headwater catchments. The flood response to the convective storms depends on the location of the rainfall, and the downstream rates of change of runoff and peak discharge can vary significantly from the winter storm relationships. Particularly for large synoptic storms, average scaling laws for peak discharge have been quantified (exponents ranging between 0.75 and 0.86), illustrating the non-linear nature of the cross-scale variations.

Floodplain Wetlands and Open Waters

Reference	Plain Text Summary
Thom, R. M., S. A. Breithaupt, H. L. Diefenderfer, A. B. Borde, G. C. Roegner, G. E. Johnson and D. L. Woodruff (2018). "Storm-driven particulate organic matter flux connects a tidal tributary floodplain wetland, mainstem river, and estuary." *Ecological Applications* 28(6): 1420-1434	The authors used a multi-model approach to simulate organic matter transport from a recently connected and restored tidal emergent marsh in the Grays River tributary to the Columbia River estuary. They found that "restored floodplain wetlands can contribute significant amounts of organic matter to the estuarine ecosystem and thereby contribute to the restoration of historical trophic structure."
Yang, W., Y. Liu, C. Ou and S. Gabor (2016). "Examining water quality effects of riparian wetland loss and restoration scenarios in a southern ontario watershed." *Journal of Environmental Management* 174: 26	"The purpose of the study [was] to develop [watershed-scale] wetland modelling to examine water quality effects of riparian wetland loss and restoration scenarios in the 323-km Black River watershed in southern Ontario, Canada." The model was applied to examine various riparian wetland loss scenarios on sediment and nutrient loads to the river network. The model outputs suggest that as riparian wetland loss increases, environmental functional losses increase at an accelerated rate. For example, sediment, total nitrogen, and total phosphorous loads to the river increased between by 2-, 3-, and 9-fold, respectively, with 100% riparian wetland loss, compared to current conditions. "The results further demonstrate the importance of targeting priority areas for stopping riparian wetland loss and initiating riparian wetland restoration based on scientific understanding of watershed wetland effects."
Pyron, M., L. Etchison and J. Backus (2014). "Fish Assemblages of Floodplain Lakes in the Ohio River Basin." *Northeastern Naturalist* 21(3): 419-430	The authors sampled and examined fish assemblages in 41 floodplain lakes [wetlands] in the Ohio River Basin (summer 2012). Their results demonstrated "that floodplain lakes in the Ohio River basin contain high species richness and are important habitats to conserve because they have the potential to act as source pools for river fish populations."
Mengistu, S. G., H. E. Golden, C. R. Lane, J. R. Christensen, M. L. Wine, E. D'Amico, A. Prues, S. G. Leibowitz, J. E. Compton, M. H. Weber and R. A. Hill (2020). "Wetland Flowpaths Mediate Nitrogen and Phosphorus Concentrations across the Upper Mississippi River Basin." *Journal of the American Water Resources Association:* 1-18	The authors developed a large, novel set of spatial variables characterizing hydrological connectivity from wetlands (floodplain and non-floodplain) to streams across the ~0.5 million km^2 Upper Mississippi River Basin. They found that wetland connectivity variables provided insights into "processes governing how wetlands influence watershed-scale TN and TP concentrations". For example, they demonstrated that wetland connectivity variables describing how water transport slows along the flowpath from the wetland to the stream (e.g., in flowpaths with high soil porosity, which slows water via infiltration into the soils) were statistically related to lower total nitrogen and total phosphorus concentrations. This means that it is not just the wetlands, but the flowpaths/connectivity between wetlands and streams, that control their water quality effects on downstream surface waters.

Reference	Plain Text Summary
Jensen, A. K. and W. I. Ford (2019). "Quantifying nitrate dynamics of a confluence floodplain wetland in a disturbed Appalachia watershed: High-resolution sensing and modeling." *Transactions of the ASABE* 62(6): 1545-1565	The authors coupled high-resolution water quality data and simulation modeling to assess what physical (hydrologic, hydraulic) or biogeochemical processes affect nitrate cycling in a confluence floodplain wetland along the Ohio River (June 2017-June 2018). Despite the wetland comprising only 0.42% of the overall watershed drainage area, 2.6% to 58.5% of the annual nitrate loads entering the wetland were removed by it. Longer water storage times in the wetlands and less frequent connectivity with the river allowed nitrate removal to occur at higher rates. The findings therefore "demonstrate the significance of [wetland] connectivity [and disconnectivity] on watershed nitrate loadings to floodplain wetland soils".
Hansen, A., C. L. Dolph, E. f. Foufoula-Georgiou and J. C. Finlay (2018). "Contribution of wetlands to nitrate removal at the watershed scale." *Nature Geoscience* 11(2): 127	The authors evaluate how existing wetlands (floodplain and non-floodplain) across the landscape of the Minnesota River Basin affect in-stream nitrate concentrations. They found that "under moderate-high streamflow, wetlands are five times more efficient per unit area at reducing riverine nitrate concentration than the most effective land-based nitrogen mitigation strategies, which include cover crops and land retirement". Their results suggest that "wetland restorations that account for the effects of spatial position in stream networks could provide a much greater benefit to water quality then previously assumed."
Fossey, M., A. N. Rousseau and S. Savary (2016). "Assessment of the impact of spatio-temporal attributes of wetlands on stream flows using a hydrological modelling framework: a theoretical case study of a watershed under temperate climatic conditions." *Hydrological Processes* 30: 1768-1781	The authors applied a hydrological model to assess how floodplain and non-floodplain wetlands affect streamflow in the Becancour River watershed of the St Lawrence Lowlands, Quebec, Canada. Their model simulations suggested that the more often floodplain wetlands are connected to the main stem channel, the greater their effects on moderating high flows and providing baseflow support. They suggest that wetland effects on streamflow depends on the "combined effect of wetland and landscape attributes".
Daneshvar, F., A. P. Nejadhashemi, U. Adhikari, B. Elahi, M. Abouali, M. R. Herman, E. Martinez-Martinez, T. J. Calappi and B. G. Rohn (2017). "Evaluating the significance of wetland restoration scenarios on phosphorus removal." *Journal of Environmental Management* 192: 184-196	The authors used a calibrated Soil and Water Assessment Tool (SWAT) model to assess what areas of the Saginaw River Watershed, Michigan, had the highest potential for successful (floodplain and non-floodplain) wetland restoration related to decreasing downstream phosphorous loads. They found that "wetlands located in headwaters and downstream had significantly higher phosphorus reduction than the ones located in the middle of the watershed. More specifically, wetlands implemented at distances ranging from 200 to 250 km and 50-100 km from the outlet had the highest impact on phosphorus reduction at the subwatershed and watershed levels, respectively".
Blanchette, M., A. N. Rousseau, É. Foulon, S. Savary and M. Poulin (2019). "What would have been the impacts of wetlands on low flow support and high flow attenuation under steady state land cover conditions?" *Journal of Environmental Management* 234: 448-457	The authors use a physically based hydrological model to quantify how land cover change, particularly for wetlands both inside and outside floodplains, affect streamflow in the St. Charles River, Quebec, Canada. They found that with 15% loss of wetlands in the watershed area, baseflow decreased and peak (or flood) flows increased. Their results suggested that "the loss of wetland areas generally leads to a loss of hydrological services and highlighted the need for wetland conservation programs and restoration actions."

Reference	Plain Text Summary
Bellmore, R. A., J. E. Compton, J. R. Brooks, E. W. Fox, R. A. Hill, D. J. Sobota, D. J. Thornbrugh and M. H. Weber (2018). "Nitrogen inputs drive nitrogen concentrations in U.S. streams and rivers during summer low flow conditions." *Science of the Total Environment* 639: 1349-1359	The authors examined how in-stream nitrogen (N) concentrations are related to N inputs to watersheds (e.g., atmospheric deposition, synthetic fertilizer), land cover characteristics (e.g., wetland presence), and stream network characteristics across the United States. They found that (floodplain and non-floodplain) wetlands mediated. i.e., lowered, N concentrations in streams with watersheds draining areas of high agricultural N inputs across the US.
Carlson, A. K., M. J. Fincel, C. M. Longhenry and B. D. S. Graeb (2016). "Effects of historic flooding on fishes and aquatic habitats in a Missouri River delta." *Journal of Freshwater Ecology* 31(2): 271-288	Fish assemblages were studied pre and post flood in the Missouri River, Lewis and Clark delta in SD and NE. Findings suggest that backwater habitats in the delta provided refuge from floodwaters during the disturbance. Maintaining habitat connectivity in deltas during and after floods is particularly important for fisheries conservation.
Tetzlaff, D., C. Birkel, J. Dick, J. Geris and C. Soulsby (2014). "Storage dynamics in hydropedological units control hillslope connectivity, runoff generation, and the evolution of catchment transit time distributions." *Water Resources Research* 50(2): 969-985	In a montane catchment in NE Scotland, storage dynamics and isotopic analysis of riparian peatlands showed that water stored in the peats were typically >80% of flow, including base flow and storm flow. The riparian areas were a key zone, acting as a regulator of stream water composition and transit time.
Rudolph, J. C., C. A. Arendt, A. G. Hounshell, H. W. Paerl and C. L. Osburn (2020). "Use of Geospatial, Hydrologic, and Geochemical Modeling to Determine the Influence of Wetland-Derived Organic Matter in Coastal Waters in Response to Extreme Weather Events." *Frontiers in Marine Science* 7	Using a flood model, the contribution of Organic Matter (OM) from wetlands from a recent hurricane was quantified in Neuse River Estuary-Pamlico Sound (NRE-PS), in eastern North Carolina. The hurricane created a pulse of OM, with wetland contributing 48% and 18% of annual DOC loads to the NRE and PS respectively. The study highlights the importance of rare large events on the transport of materials within the connected riverine-estuarine system.
Bourgault, M. A., M. Larocque and M. Roy (2014). "Simulation of aquifer-peatland-river interactions under climate change." *Nordic Hydrology* 45(3): 425-440	In a peatland complex within Quebec Canada, a ground water (GW) model was used to investigate the role of the peatlands in supporting river baseflows. The model estimated that on average 77% of the annual river base flow originates from the peatland. Future climate scenarios both indicated reductions to the peat from the surrounding GW and then from the peat to the river.
Vanderhoof, M. K., H. E. Distler, M. W. Lang and L. C. Alexander (2018). "The influence of data characteristics on detecting wetland/stream surface-water connections in the Delmarva Peninsula, Maryland and Delaware." *Wetlands Ecology and Management* 26: 63-86	Remote sensing techniques indicated springtime connections of wetlands and streams in a Delmarva Peninsula river. Using Lidar, Landsat and Worldview imagery, between 12-60% of wetlands connected to streams, indicating that 50-94% of the watershed contributed direct surface water runoff to stream flows.

Reference	Plain Text Summary
Manfrin, A., M. Bunzel-Drüke, A. W. Lorenz, A. Maire, M. Scharf, O. Zimball and S. Stoll (2020). “The effect of lateral connectedness on the taxonomic and functional structure of fish communities in a lowland river floodplain.” *Science of the Total Environment* 719: 137169	Using an 18-year data set of fish abundance, researchers in Germany compared fish communities in main channels and floodplain habitats. While the overall diversity and relative abundance of species decreased from the main channel to more isolated floodplain wetlands, the floodplain waterbodies showed distinct assemblages with different life histories and feeding strategies. This highlights the importance of including the complete spectrum of connected floodplains in conservation.
Gordon, B. A., O. Dorothy and C. F. Lenhart (2020). “Nutrient Retention in Ecologically Functional Floodplains: A Review.” *Water* 12(10)	In a review of North American and European literature, the authors quantify the removal of nitrogen (N) and phosphorus (P) within floodplains. The review found that floodplains remove an average of 200 kg-N/ha/yr of nitrate and 21 kg-P/ha/yr of total or particulate P and floodplain wetlands are most effective when located within river systems with higher nutrient loads.
Atkinson, C. L., B. C. van Ee, Y. Lu and W. Zhong (2019). “Wetland floodplain flux: temporal and spatial availability of organic matter and dissolved nutrients in an unmodified river.” *Biogeochemistry* 142(3): 395-411	Within an unregulated, low gradient river in Alabama, extensive floodplains including the Sipsey Swamp were found to exert strong controls of organic materials and nutrients. Over two years at 10 sites, nutrients declined through the floodplains while the same floodplains supplied large amounts of organic material downstream. This research highlights the importance of floodplain complexes on the transport of organics and nutrients.
Abrial, E., L. A. Espinola, A. n. Rabuffetti, M. F. Eurich, A. R. Paira, M. C. M. Blettler and M. L. Amsler (2019). “Variability of hydrological connectivity and fish dynamics in a wide subtropical-temperate floodplain.” *River Research and Applications* 35(9): 1520-1529	Researchers analyzed fish abundance and richness within a large floodplain system in the Parana River of Brazil over seven years. Fish dispersal, abundance and migration patterns during the different wet and dry seasons could largely be explained by the variation in connectivity of the floodplain habitats. The study demonstrates the importance of dynamic connection and isolation of floodplains on the makeup of the fish community.
Martens, K. D. and P. J. Connolly (2014). “Juvenile Anadromous Salmonid Production in Upper Columbia River Side Channels with Different Levels of Hydrological Connection.” *Transactions of the American Fisheries Society* 143(3): 757-767	Young salmon use side or off channel habitat that can connect and disconnect from the main river channel. This study looked at seasonally and continually connected side channels on the Upper Columbia river and measured salmon survival. Seasonally disconnected side channels resulted in improved survival for juvenile salmon during periods of disconnection. Upon reconnection with the main channel, the previous cohort would rejoin the main population while new young of year salmon would move into the side channels.
De Giudici, G., D. Medas, R. Cidu, P. Lattanzi, F. Podda, F. Frau, J. C. l. Dick, D. Tetzlaff and C. Soulsby (2018). “Role of riparian wetlands and hydrological connectivity in the dynamics of stream thermal regimes.” *Nordic Hydrology* 49(3): 634-647	Riparian wetlands were analyzed for their important in determining stream temperatures. The authors found that in periods of high river and riparian wetland connectivity, the coupled saturation and connectivity decreased the relative importance of the riparian wetland for temperature regulation. Conversely, dry periods with less river and riparian floodplain hydrologic connectivity were found to be important periods of distinctions between river water and riparian wetland temperatures (e.g., lower temperature waters were coming from the riparian wetland to the riverine system).

Reference	Plain Text Summary
Battauz, Y. S., S. B. Jose de Paggi and J. C. Paggi (2017). "Macrophytes as dispersal vectors of zooplankton resting stages in a subtropical riverine floodplain." *Aquatic Ecology* 51(2): 191-201	Aquatic plants located in floodplain open waters were analyzed as potential sources for zooplankton dispersal into the riverine food web. Six plant species from Brazilian floodplain lakes (at least three of which occur in North American open waters) were analyzed as sources of passive zooplankton dispersal. The roots and submerged parts of the plants were found to host 70 different zooplankton taxa in resting stage (i.e., awaiting the proper environmental cues to emerge). The authors concluded that aquatic plants in floodplain open waters are important downstream dispersers of zooplankton, which are important base components of riverine food webs.
Vanderhoof, M. K., J. R. Christensen and L. C. Alexander (2016). "Patterns and drivers for wetland connections in the Prairie Pothole Region, United States." *Wetlands Ecology and Management* 25(3): 1-23	A remote sensing study in the Prairie Pothole Region of the US noted that precipitation-based expansion of surface waters connected wetlands and stream networks across a wide range, averaging from 90-1400 m, depending on the ecoregion studied. Most of the wetland to stream connections occurred first through consolidation, where clusters of wetlands connected to each other, followed by the stream connection which occurred most frequently through a riparian wetland.
Rees, G. N., R. A. Cook, N. S. P. Ning, P. J. McInerney, R. T. Petrie and D. L. Nielsen (2020). "Managed floodplain inundation maintains ecological function in lowland rivers." *Science of the Total Environment* 727: 138469	An inundated floodplain riparian zone was shown to be highly connected to the river food web, with substantively higher dissolved organic carbon, seston carbon, nutrients (nitrogen), and chlorophyll levels downstream of where the flood waters reentered the river. Isotopic analyses demonstrated that floodplain-derived carbon was incorporated into the riverine food webs and was measurably found for up to four months following the flood peak.
Macdonald, D. M. J., A. J. Dixon and D. C. Gooddy (2018). "Water and nitrate exchange between a managed river and peri-urban floodplain aquifer: Quantification and management implications." *Ecological Engineering* 123: 226-237	A study in the United Kingdom measured river water with high nitrate levels, which was noted to move into the riparian floodplain and recharge the local aquifer during overbank floods. The authors reported substantial microbially mediated denitrification occurred in the shallow riparian groundwater table due to carbon availability, oxygen-free conditions, and high nitrate concentrations. The lowland floodplain studied was able to annual remove substantial amounts of nitrate, though this was estimated to be three orders of magnitude less than the annual flux within the river. The floodplain nitrate reduction was noted to be locally important (e.g., for local drinking water supplies sourced from the river's alluvial aquifer).
Gillespie, J. L., G. B. Noe, C. R. Hupp, A. C. Gellis and E. R. Schenk (2018). "Floodplain Trapping and Cycling Compared to Streambank Erosion of Sediment and Nutrients in an Agricultural Watershed." *Water Resources Bulletin* 54(2 (Apr 2018)): 565	The authors analyzed sedimentation, nutrient loads, and mineralization of a floodplain in an agricultural watershed in the Valley and Ridge physiographic province of the US. All study reaches were areas of net sediment deposition (e.g., river-borne sediments were deposited), had high nitrogen (N) and phosphorus (P) deposited by the river, high mineralization of N and P, and high concentrations of N and P in the floodplain soils. They conclude that the net sediment and nutrient trapping functions of their study watershed floodplains (Smith Creek) benefit downgradient water quality.

Reference	Plain Text Summary
Webb, J. R., I. R. Santos, B. Robson, B. e. Macdonald, L. Jeffrey and D. T. Maher (2017). "Constraining the annual groundwater contribution to the water balance of an agricultural floodplain using radon: The importance of floods." *Water Resources Research* 53(1): 544-562	Groundwater dynamics of an extensively drained agricultural floodplain was analyzed using radon to create a water budget. Flooding in the riparian zone occurred only 12% of the study period but contributed 72-76% of the groundwater discharge (to the river network). Annually, groundwater discharge contributed 30-80% of the total surface water discharged to the river system, which the authors propose is related to the high density of constructed drainage features (12.4 km per km^2) altering the hydrology of the floodplain.
Scott, D. T., R. F. Keim, B. L. Edwards, C. N. Jones and D. E. Kroes (2014). "Floodplain biogeochemical processing of floodwaters in the Atchafalaya River Basin during the Mississippi River flood of 2011." *Journal of Geophysical Research: Biogeosciences* 119(4): 537-546	The Atchafalaya River and floodplain was extensively flooded during the 2011 Lower Mississippi River flood event, with up to half of the water in the channel moving into the floodplain. The authors analyzed river water over the flood event and found that significant nitrate reduction (around 75%) occurred within the floodplain. The floodplain system was found to reduce total nitrate by 16.6% over the course of the flood event.
Quin, A. and G. Destouni (2018). "Large-scale comparison of flow-variability dampening by lakes and wetlands in the landscape." *Land Degradation & Development* 29(10): 3617-3627	A modeling study in Sweden used data from 82 catchments from 1984-2013 to investigate the floodwater attenuation capacity of floodplain wetlands and lakes. The storage function of lakes and floodplain wetlands lakes was responsible for decreasing the variability (e.g., "flashiness") of streamflow. Watersheds comprised of approximately 15% lakes and 0.5% floodplain wetlands decreased the streamflow variability to around 10-15%, compared to areas without lakes or floodplain wetlands, which had approximately 20-25% higher streamflow variabilities due to low landscape water storages.
Dwivedi, D., B. Arora, C. I. Steefel, B. Dafflon and R. Versteeg (2018). "Hot Spots and Hot Moments of Nitrogen in a Riparian Corridor." *Water Resources Research* 54(1): 205-222	Groundwater within the Colorado River riparian zone was modeled to typically flow towards the river, except during flood stages when oxygenated and nitrate-laden river water overtops the banks and then infiltrates downwards in the riparian area. Riparian area sediments differ in their nitrate removal capacity, and reduced zones along the river (or areas of low oxygen, as found in most wetland soils) were found to have approximately 70% greater nitrate removal capacity than non-reduced zones. However, the nitrate removal capacity of the reduced zones varied based on the oxygen content of the infiltrating water from 70% greater than non-reduced zones to ~5% greater than non-reduced zones.

Non-Floodplain Wetlands and Open Waters

Reference	Plain Text Summary
Vanderhoof, M. K., H. E. Distler, M. W. Lang and L. C. Alexander (2017). "The influence of data characteristics on detecting wetland/stream surface-water connections in the Delmarva Peninsula, Maryland and Delaware." *Wetlands Ecology and Management* 26: 63-86	A remote-sensing study in Maryland and Delaware found that streams and depressional wetlands were surface-water connected in spring 2015. The range reported in the large studied watershed, 12-60% of wetlands by count and 21-93% of wetlands by area, varied due to the spatial and temporal wetland and stream characteristics and the accuracy and resolution of the input remote-sensing datasets.

Reference	Plain Text Summary
Park, J., D. Wang and M. Kumar (2020). "Spatial and temporal variations in the groundwater contributing areas of inland wetlands." *Hydrological Processes* 34(5)	Hydrologic connections between groundwater and wetlands were measured in a study in the southern US. The study noted that a) groundwater contributing areas to wetlands often have a different extent and shape than topographic contributing areas, and b) groundwater-fed wetlands in the study area were found to expand their groundwater contributing area (and received greater groundwater) during dry periods which could influence baseflow in downstream waters (depending on hydraulic gradients).
Wang, N., X. Zhang and X. Chu (2019). "New Model for Simulating Hydrologic Processes under Influence of Surface Depressions." *Journal of Hydrologic Engineering* 24(5): https://doi.org/10.1061/(ASCE)HE.1943-5584.0001772	In a North Dakota study, a model was developed to assess the effects of depressions on rainfall-runoff processes and mechanisms of dynamic water release from depressions affecting down-gradient systems. The hydrologic model demonstrated that depressions captured and held back precipitation from down-gradient systems such that the majority of the study area did not contribute water directly to the stream system. This finding supports the hydrologic lag and sink functions of depressions (wetlands) in attenuating storm flows and maintaining baseflows.
Bugna, G. C., J. M. Grace and Y. P. Hsieh (2020). "Sensitivity of using stable water isotopic tracers to study the hydrology of isolated wetlands in North Florida." *Journal of Hydrology* 580: 124321	In a North Florida water isotopic study of "isolated wetlands," the authors found that so-called isolated wetlands stored and evaporated rainwater (thereby retaining water and performing hydrological lag and sink functions). A sinkhole (pond) was found to connect to both groundwater and precipitation. Wetlands and sinkholes were measurably important to quantifying and determining hydrological budgets for forested watersheds.
Lewis, D. B. and S. J. Feit (2015). "Connecting carbon and nitrogen storage in rural wetland soil to groundwater abstraction for urban water supply." *Global Change Biology* 21(4): 1704-1714	Depressional wetlands were hydrologically affected by groundwater withdrawals for urban use (e.g., drinking water). Groundwater withdrawals diminished wetland hydroperiods, which in turn negatively affected carbon, nitrogen, and soil organic matter stocks in the wetlands (e.g., carbon sink functions of wetlands were diminished).
Shook, K., S. Papalexiou and J. W. Pomeroy (2021). "Quantifying the effects of Prairie depressional storage complexes on drainage basin connectivity." *Journal of Hydrology* 593: 125846	In a Canadian hydrologic modeling study, Prairie Pothole depression water storage was found to control the fraction of the watershed that contributes flow to down-gradient stream systems. The effects of depressions varied: when there were few extant depressions, their size and location on the landscape was most important. In systems with greater depression abundance, depressions still controlled the relationship between water storage and the fraction of the watershed contributing surface flow down-gradient but the spatial location within the watershed decreased in importance.
Vasic, F., C. Paul, V. Strauss and K. Helming (2020). "Ecosystem Services of Kettle Holes in Agricultural Landscapes." 10(9)	Kettle holes are glacially formed wetlands in Europe similar to the North American prairie potholes. A European literature review determined kettle hole wetlands provided important ecosystem services, including flood control and hydrological cycling, biogeochemical functions, and habitat. Agricultural activities around kettle hole wetlands were noted to potentially affect the provisioning of wetland ecosystem services.

Reference	Plain Text Summary
Nasab, M. T. and X. Chu (2020). “Macro-HyProS: A new macro-scale hydrologic processes simulator for depression-dominated cold climate regions.” *Journal of Hydrology* 580: 124366	A hydrological modeling study of the Red River of the North (northern Great Plains) found that (wetland) depression-dominated areas controlled (or regulated) the connectivity of large areas of the basin via storage affecting surface-driven runoff. This was particularly important in the early spring months (i.e., during periods of rain-on-snow events, snowmelt, etc.).
Michelson, C., R. G. Clark and C. A. Morrissey (2018). “Agricultural land cover does not affect the diet of Tree Swallows in wetland-dominated habitats.” *The Condor* 120(4): 751-764	Feeding habits of tree swallows, an insectivorous bird, were analyzed in a Canadian prairie landscape. Tree swallows were found to specialize in feeding on aquatic insects in wetland-dominated habitats (i.e., those insects emerging from wetlands). Agricultural land cover (e.g., grasslands, crops) within the study area did not affect tree swallow foraging success, though tree swallows were larger and in better condition in grasslands than cropped landscapes.
Martin, A. R., M. L. Soupir and A. L. Kaleita (2019). “Seasonal and intra-event nutrient levels in farmed Prairie Potholes of the Des Moines Lobe.” *Transactions of the ASABE* 62(6): 1607-1617	Farmed wetlands (drained and under corn-soybean rotation) in the Des Moines Lobe of Iowa were found to reduce nitrate that entered into the wetland in 85% of the multi-day inundation events. Phosphorous was found to increase in the wetland water column over the inundation period (e.g., possibly through release from phosphorus sorbed onto soil particles), meaning that in addition to serving as nitrate removal areas, farmed wetlands were sources of total and soluble reactive phosphorus.
Shook, K., J. Pomeroy and G. van Der Kamp (2015). “The transformation of frequency distributions of winter precipitation to spring streamflow probabilities in cold regions; case studies from the Canadian Prairies.” *Journal of Hydrology* 521: 395-409	Large-scale analyses of climate and basin processes contributing to streamflow in the Canadian Prairies were investigated. The authors found three major controls on streamflow, including a) the creation and distribution of the spring snowpack, b) the spring melt of the snowpack over frozen ground, and c) the subsequent filling and spilling of depressional (wetland) storage that connected fields, ponds, wetlands, and down-gradient lake systems.
Al Sayah, M. J., R. Nedjai, K. Kaffas, C. Abdallah and M. Khouri (2019). “Assessing the Impact of Man-Made Ponds on Soil Erosion and Sediment Transport in Limnological Basins.” *Water* 11(12): 2526	Ponds, open-water systems in a French study, were analyzed in a modeling study to determine their effects on erosion and sediment transport at the watershed scale. The presence of ponds controlled sediment transport and erosion risk, with ~78% of the basin corresponding to no- or low-erosion risk zones and 22% noted as moderate to high-erosion risk. Without ponds, <2% of the basin was determined to be no- or low-erosion risk, while 98% was modeled as moderate to high erosion risk. Without ponded systems, the sediment pattern completely shifted to zones of higher sediment yields.
Kappas, I., G. Mura, D. Synefiaridou, F. Marrone, G. Alfonso, M. Alonso and T. J. Abatzopoulos (2017). “Molecular and morphological data suggest weak phylogeographic structure in the fairy shrimp *Streptocephalus torvicornis* (Branchiopoda, Anostraca).” *Hydrobiologia* 801(1): 21-32	A pan-European study analyzed the genetic structure of a fairy shrimp found in temporary ponds. Their results demonstrated there was unhindered gene flow and widespread connectivity between populations across the study area. One of five hypothesized reasons includes frequent dispersal by avian species throughout the range.

Reference	Plain Text Summary
Wendt, A., C. A. Haas, T. Gorman and J. H. Roberts (2021). “Metapopulation genetics of endangered reticulated flatwoods salamanders (*Ambystoma bishopi*) in a dynamic and fragmented landscape.” *Conservation Genetics*	Population dynamics of the reticulated flatwoods salamander, found in forested ponds and riparian zones in the southeastern U.S., were analyzed. Distance between ponds was found to be an important factor controlling metapopulation dynamics, with very low migration among ponds further than 400 m.
Yeo, I. Y., M. W. Lang, S. Lee, G. W. McCarty, A. M. Sadeghi, O. Yetemen and C. Huang (2019). “Mapping landscape-level hydrological connectivity of headwater wetlands to downstream waters: A geospatial modeling approach - Part 1.” *Science of the Total Environment* 653: 1546-1556	A modeling study analyzed the hydrologic connectivity of so-called geographically isolated wetlands of the Mid-Atlantic region of the US. Wetland inundation and stream flows were well correlated, demonstrating a similar relationship. Wetlands with longer flooding duration were more strongly correlated with stream discharge than shorter-duration inundated wetlands. The authors conclude that the wetlands function in aggregate and that both the streams and the wetlands of their 300 km2 study area were connected via groundwater pathways.
Vanderhoof, M. K., J. R. Christensen and L. C. Alexander (2016). “Patterns and drivers for wetland connections in the Prairie Pothole Region, United States.” *Wetlands Ecology and Management* 25(3): 1-23	A remote-sensing study (1990-2011) quantified surface-water connections between streams and wetlands across the US Prairie Pothole Region. They reported surface-water connections varied across ecoregions of the Prairie Pothole Region, averaging 90-1400 m. Connections were controlled by the arrangement and abundance of wetlands and surface-water expansion.
Neff, B. P. and D. O. Rosenberry (2017). “Groundwater Connectivity of Upland-Embedded Wetlands in the Prairie Pothole Region.” *Wetlands* 38(1): 51-63	Local to regional groundwater connectivity between wetlands and other waters in the Prairie Pothole Region of North Dakota was modeled. Sand layers were found to facilitate wetland connectivity through groundwater, whereas water-table mounds were found to retard connectivity if completely surrounding the wetland or wetland complex. In the absence of restricting water-table mounds, connectivity was modeled to occur.
Golden, H. E., H. A. Sander, C. R. Lane, C. Zhao, K. Price, E. D’Amico and J. R. Christensen (2015). “Relative effects of geographically isolated wetlands on streamflow: a watershed-scale analysis.” *Ecohydrology* 9(1): 21-38	A modeling study in North Carolina found that geographically isolated wetlands influenced streamflow. Increased water storage associated with increased geographically isolated wetland extent decreased streamflow. The distance of geographically isolated wetlands was positively associated with streamflow, affecting (or reflecting) the movement of water across the landscape.
Brooks, R. J., D. M. Mushet, M. Vanderhoof, S. G. Leibowitz, J. R. Christensen, B. P. Neff, D. Rosenberry, W. D. Rugh and L. C. Alexander (2018). “Estimating Wetland Connectivity to Streams in the Prairie Pothole Region: An Isotopic and Remote Sensing Approach.” *Water Resources Research* 54(2): 955-977.	A water isotope study in a North Dakota watershed found that Prairie Pothole wetlands had high evaporation rates, and that groundwater typified winter precipitation-based recharge. However, the evaporative isotopic signal in the steam indicated that surficial flow from wetlands contributed to and connected to the stream network throughout the summer.

Reference	Plain Text Summary
Ameli, A. A. and I. F. Creed (2019). "Does Wetland Location Matter When Managing Wetlands for Watershed-Scale Flood and Drought Resilience?" *Journal of the American Water Resources Association* 55(3): 529-542	A Canadian modeling study in the Prairie Pothole Region found that wetland loss affected streamflow, increasing peak flows from storm events that led to major down-gradient flooding in cities. Concurrently, wetland losses decreased base flow. Wetlands closer to the stream network were found to be disproportionately important to peak flow attenuation, while wetlands were found to be important controllers of baseflow regardless of their location vis-à-vis the stream network.
McKenna, O. P., S. R. Kucia, D. M. Mushet, M. J. Anteau and M. T. Wiltermuth (2019). "Synergistic Interaction of Climate and Land-Use Drivers Alter the Function of North American, Prairie-Pothole Wetlands." *Sustainability* 11(23): 6581	Twenty-five wetland basins were modeled over a 70-year period to ascertain the influence of both climate and land-use drivers on floods. During an extremely wet period (1993-2000), Prairie Pothole wetland drainage decreased watershed-scale water storage, resulting in 10 times the volume of water transiting towards local stream networks.
Bam, E., A. M. Ireson, G. Kamp and J. Hendry (2020). "Ephemeral Ponds: Are They the Dominant Source of Depression-Focused Groundwater Recharge?" *Water Resources Research* 56(3): e2019WR026640	Prairie wetland ponds within a Canadian study area are sources of recharge to confined groundwater aquifers providing water to farm and rural communities. An isotopic analysis found that permanently inundated wetland ponds were not the dominant groundwater recharge source. Ephemerally inundated wetlands were found to have identical isotopic signatures as the groundwater in aquifers. Ephemeral wetlands were the dominant source of groundwater recharge.
Ameli, A. and I. F. Creed (2019). "Groundwaters at Risk: Wetland Loss Changes Sources, Lengthens Pathways, and Decelerates Rejuvenation of Groundwater Resources." *Journal of the American Water Resources Association* 55(2): 294-306	A modeling analysis of a Canadian study area explored the connections and effects of wetlands, and wetland losses, on local and regional waters. Wetland losses decreased contributing areas affecting baseflows of local surface waters. Modeled wetland losses increased the contributions to regional surface waters through subsurface hydrologic connections, which increased regional baseflows.
Sampath, P. V., H. Liao, Z. K. Curtis, P. J. Doran, M. E. Herbert, C. A. May and S. Li (2015). "Understanding the Groundwater Hydrology of a Geographically-Isolated Prairie Fen: Implications for Conservation." *PLoS ONE* 10(10): e0140430	An analysis of a geographically isolated Michigan fen wetland determined the wetland was groundwater-fed by four sources: local recharge, regional recharge, a regional groundwater mound, and a nearby pond. The authors conclude a 3-dimensional groundwater 'pipeline' connects this fen to other fen cluster throughout southern Michigan, an interconnected and larger network of fens.
Marton, J. M., I. F. Creed, D. B. Lewis, C. R. Lane, N. B. Basu, M. J. Cohen and C. B. Craft (2015). "Geographically Isolated Wetlands are Important Biogeochemical Reactors on the Landscape." *BioScience* 65(4): 408-418	The authors conducted a literature review of biogeochemical functions performed by geographically isolated wetlands. They found these wetlands provided biogeochemically mediated ecosystem services such as sediment and carbon retention, nutrient transformations, and water quality improvement that maintain the integrity of US waters.

Reference	Plain Text Summary
Cohen, M. J., I. F. Creed, L. Alexander, N. B. Basu, A. J. K. Calhoun, C. Craft, E. D'Amico, E. Dekeyser, L. Fowler, H. E. Golden, J. W. Jawitz, P. Kalla, L. K. Kirkman, C. R. Lane, M. Lang, S. G. Leibowitz, D. B. Lewis, J. Marton, D. L. McLaughlin, D. M. Mushet, H. Raanan-Kiperwas, M. C. Rains, L. Smith and S. C. Walls (2016). "Do geographically isolated wetlands influence landscape functions?" *Proceedings of the National Academy of Sciences of the United States of America* 113(8): 1978-1986	Geographically isolated wetlands across the conterminous US were described as existing along a connectivity continuum. They were found to provide a disproportionately large fraction of wetland edges where many biogeochemical functions were enhanced. They also found that the slow (e.g., through groundwater) or episodic (e.g., through surface water) nature of wetland hydrologic connectivity to other waters provided the conditions for biogeochemical processing, sediment retention, and both biological and hydrological functioning.
Flint, S. A. and W. H. McDowell (2015). "Effects of headwater wetlands on dissolved nitrogen and dissolved organic carbon concentrations in a suburban New Hampshire watershed." *Freshwater Science* 34(2): 456-471	Ten headwater wetlands, a possible type of non-floodplain wetland system, were analyzed in New Hampshire. The headwater wetlands were found to decrease nitrate and increase dissolved organic carbon and nitrogen concentrations, and to vary the seasonal values of total dissolved nitrogen. These functions would affect the downgradient system.
Denver, J. M., S. W. Ator, M. W. Lang, T. R. Fisher, A. B. Gustafson, R. Fox, J. W. Clune and G. W. McCarty (2014). "Nitrate fate and transport through current and former depressional wetlands in an agricultural landscape, Choptank Watershed, Maryland, United States." *Journal of Soil and Water Conservation* 69(1): 1-16	Depressional wetlands in the Choptank River, a tributary to the Chesapeake Bay, were analyzed for biogeochemical processing. Natural wetlands had conditions conducive to nitrogen pollution removal for longer than farmed wetlands or restored wetlands but were generally groundwater-connected and were not exposed to nitrogen-laden waters; they were found to provide water to streams that diluted pollution concentrations. Farmed wetlands and restored wetlands that were exposed to nitrate pollution through groundwater removed substantial amounts of nitrate, but contributions to water quality improvement hinged on exposure to polluted waters.
Rajib, A., H. E. Golden, C. R. Lane and Q. Wu (2020). "Surface depression and wetland water storage improves major river basin hydrologic predictions." *Water Resources Research* 56(7): e2019WR026561	In an Upper Mississippi River Basin study, 455,000 depressional wetlands and open waters were incorporated into a hydrologic model and significantly affected and improved streamflow measures; these waters further improved the remotely sensed water yield across 70% of the study area. These results demonstrate the significant influence of wetlands and open waters on stream flow, and that wetlands and open waters affect landscape-scale hydrological conditions (e.g., rootzone wetness).
Schmadel, N. M., J. W. Harvey, G. E. Schwarz, R. B. Alexander, J. D. Gomez-Velez, D. Scott and S. W. Ator (2019). "Small Ponds in Headwater Catchments Are a Dominant Influence on Regional Nutrient and Sediment Budgets." *Geophysical Research Letters* 46(16): 9669-9677	Small ponds and impoundments across the Northeastern US were found to be important biogeochemical and physical sinks, retaining 34% of nitrogen, 69% of all phosphorus, and 12% of sediments in the study area. Their influence was dominant in headwater catchments, where they contained 54% of nitrogen, 85% of phosphorus, and 50% of sediments decreasing loads and thereby affecting downstream waters.

Reference	Plain Text Summary
Nasab, M. T., V. Singh and X. Chu (2017). “SWAT Modeling for Depression-Dominated Areas: How Do Depressions Manipulate Hydrologic Modeling?” *Water* 9(1): w9010058	Hydrologic modeling in a large watershed in North Dakota found that depression (e.g., Prairie Potholes) storage exerted a gate-keeper effect on downstream flows, decreasing surface runoff contributing to stream flow during low-flow scenarios. Conversely, during high precipitation scenarios, depressions (hydrologic gatekeepers) increased surface runoff peak flows.
Green, D. I. S., S. M. McDeid and W. G. Crumpton (2019). “Runoff Storage Potential of Drained Upland Depressions on the Des Moines Lobe of Iowa.” *JAWRA Journal of the American Water Resources Association* 55(3): 543-558	Drained depressions (possibly Prairie Pothole wetlands in farmed landscapes) in Iowa were found to store up to 903.5 million m3 of runoff. Runoff from a 1-yr, 24-hr event would likely exhaust this storage, while rainfall runoff from a 5-yr, 24-hr event would exceed the capacity of the drained depressional storage.
Thorslund, J., M. J. Cohen, J. W. Jawitz, G. Destouni, I. F. Creed, M. C. Rains, P. Badiou and J. Jarsjö (2018). “Solute evidence for hydrological connectivity of geographically isolated wetlands.” *Land Degradation & Development* 29(11): 3954-3962	In an analysis across North America, geographically isolated wetlands were found to generate runoff at 1.2x the mean catchment rate which implies they are well-connected watershed-scale sources of water to down-gradient systems.
McKenna, O. P., D. M. Mushet, D. O. Rosenberry and J. W. LaBaugh (2017). “Evidence for a climate-induced ecohydrological state shift in wetland ecosystems of the southern Prairie Pothole Region.” *Climatic Change* 145(3): 273-287	Changing precipitation patterning in the Prairie Pothole Region has resulted in an increased number of ponded wetlands and open waters, increases in runoff to wetlands altering wetland solute concentrations, tile drainage connecting wetlands to down-stream systems, and increases in stream flows.
Evenson, G. R., H. E. Golden, C. R. Lane, D. L. McLaughlin and E. D’Amico (2018). “Depressional Wetlands Affect Watershed Hydrological, Biogeochemical, and Ecological Functions.” *Ecological Applications* 28(4): 953-966	In a North Dakota hydrologic modeling study, the influence of non-floodplain wetlands on down-gradient stream characteristics was analyzed. Small depressional wetlands (<3.0 ha) significantly affected inundation characteristics (inundated area, hydrologic residence time, and inundation heterogeneity). Larger non-floodplain wetlands were gatekeepers, controlling flows to the stream network. Scenarios of wetland loss based on distance (30-m and 450-m from streams) decreased inundated areas and inundation residence time (for biogeochemical processing). Depression wetlands also attenuated peak flows, decreasing the probability of downstream flooding.
Schofield, K. A., L. C. Alexander, C. E. Ridley, M. K. Vanderhoof, K. M. Fritz, B. C. Autrey, J. E. DeMeester, W. G. Kepner, C. R. Lane, S. G. Leibowitz and A. I. Pollard (2018). “Biota Connect Aquatic Habitats throughout Freshwater Ecosystem Mosaics.” *Journal of the American Water Resources Association* 54(2): 372-399	A review paper wherein freshwater streams, rivers, and wetlands were noted to form a ‘freshwater ecosystem mosaic’ that sustained aquatic life through connectivity and biotic linkages of organisms within and among these components. The biotic connectivity of these aquatic systems was considered to be critical to the ecological integrity of freshwaters.

Reference	**Plain Text Summary**
Ameli, A. A. and I. F. Creed (2017). “Quantifying hydrologic connectivity of wetlands to surface water systems.” *Hydrol. Earth Syst. Sci.* 21: 1791-1808	In a modeled analysis in the North American Prairie Pothole Region, geographically isolated wetlands were found to have both “fast” surface-water connections and “slow” subsurface water connections to downgradient systems. Subsurface connections linked geographically isolated wetlands from throughout the watershed to the flowing water network, while surface water connections mainly emanated from large precipitation events and originated from wetlands closer to the stream network.
Mekonnen, B. A., K. A. Mazurek and G. Putz (2016). “Incorporating landscape depression heterogeneity into the Soil and Water Assessment Tool (SWAT) using a probability distribution.” *Hydrological Processes* 30(13): 2373-2389	A hydrologic modeling study in the Canadian Prairie Pothole Region contrasted the effects of models with multiple small landscape (wetland) depressions versus a more typical and coarser modeling approach. Incorporating landscape depressions into the model improved streamflow estimates, suggesting that the hydrologic effects of depressions have an effect on down-gradient stream system characteristics.
Nitzsche, K. N., T. Kalettka, K. Premke, G. Lischeid, A. Gessler and Z. E. Kayler (2017). “Land-use and hydroperiod affect kettle hole sediment carbon and nitrogen biogeochemistry.” *Science of The Total Environment* 574: 46-56	European kettle holes, like Prairie Potholes in North America, are wetland systems formed by past glaciation. An isotopic analysis of 51 kettle holes in Germany determined that in addition to processing organic matter from the surrounding area, kettle holes were coupled with shallow groundwater and were not closed hydrological systems but systems that connected with groundwater.
Golden, H. E., A. Rajib, C. R. Lane, J. R. Christensen, Q. Wu and S. Mengistu (2019). “Non-floodplain Wetlands Affect Watershed Nutrient Dynamics: A Critical Review.” *Environmental Science & Technology* 53(13): 7203-7214	A review paper on the influence of non-floodplain wetlands on water quality at watershed scales. Includes analysis of how including non-floodplain wetlands in a Midwestern-US watershed-scale nutrient model markedly changes the predicted nutrient levels in down-gradient systems.
Evenson, G. R., H. E. Golden, C. R. Lane and E. D’Amico (2015). “Geographically isolated wetlands and watershed hydrology: A modified model analysis.” *Journal of Hydrology* 529, Part 1: 240-256	In a hydrologic modeling study in a ~202 km2 North Carolina watershed, the authors directly analyzed the watershed-scale hydrologic effects of geographically isolated wetlands on stream characteristics. They found that geographically isolated wetlands: 1) seasonally affected stream baseflow, 2) decreased or attenuated storm peak flows, and 3) quantifiably affected the water balance (or the movement of water through various parts of the water cycle) at the watershed scale.

Appendix C3: Additional References

Appendix C3i: Reference Review Process and Findings

As discussed in section I.C.v of this Technical Support Document, reviewers from the U.S. Environmental Protection Agency's Office of Research and Development (ORD) identified an additional 37 papers in October 2021 that were not captured during the initial screening process. Additionally, the agencies solicited for and received additional scientific literature and references published since 2014 from the public during the notice and comment process. The agencies reviewed the 37 papers noted in section I.C.v (and cited in Appendix C3ii of the Technical Support Document for the Proposed Rule) as well as the literature submitted by the public, assessing first whether the literature was peer-reviewed and published in or after 2014, then (for the submitted literature) if it had already been included in Section I.C. (Updates to the Literature since Publication of the Science Report). Then, the agencies read each of the additional submitted papers that had been peer-reviewed and published in or after 2014 to discern if the paper provided updates on the "…scientific understanding about the connectivity and mechanisms by which streams and wetlands, singly or in aggregate, affect the physical, chemical, and biological integrity of downstream waters." Science Report at ES-1. To wit, the agencies assessed each paper for the charge questions listed in section I.C.i. (Update Process):

> A. What are the physical, chemical, and biological connections to and effects of ephemeral, intermittent, and perennial streams on downstream waters (*e.g.*, rivers, lakes, reservoirs, estuaries)?
>
> B. What are the physical, chemical, and biological connections to and effects of riparian or floodplain wetlands and open waters (*e.g.*, riverine wetlands, oxbow lakes) on downstream waters?
>
> C. What are the physical, chemical, and biological connections to and effects of wetlands and open waters in non-floodplain settings (*e.g.*, most prairie potholes, vernal pools) on downstream waters?

Subsequently, the agencies assessed whether each paper provided findings relevant to the major conclusions of the Science Report (see sections I.A.i and I.A.ii), and determined this by aquatic system type as reported in the paper.

> Streams: *The scientific literature unequivocally demonstrates that streams, individually or cumulatively, exert a strong influence on the integrity of downstream waters. All tributaries, regardless of size or flow duration, are physically, chemically, and biologically connected to downstream waters and strongly influence their function*.
>
> Floodplain Wetlands and Open Waters: *Wetlands and open waters in riparian areas and floodplains are physically, chemically, and biologically integrated with rivers via functions that improve downstream water quality. These systems buffer downstream waters from pollution and are essential components of river food webs*.
>
> Non-Floodplain Wetlands and Open Waters: *Wetlands and open waters located outside of riparian areas and floodplains, even when lacking surface water connections, provide numerous*

> *functions that could affect the integrity of downstream waters. Some benefits of these wetlands are due to their relative isolation rather than their connections.*

The agencies chose from the following review responses: “supports findings,” “refutes findings,” or “cannot be discerned.”

The agencies reviewed and assessed the citations they received during the public comment period. After assessing the publicly submitted citations as well as those 37 citations described in section I.C.v (*i.e.*, those added to the Technical Support Document in October 2021), the agencies determined that 80 new peer-reviewed references from the scientific literature had been published in or after 2014 needed to be assessed for their findings relevant to the Science Report’s conclusions. The agencies did not include those papers which had not been peer-reviewed (or for which peer-review could not be ascertained) or those papers that were published prior to 2014 in this review, as they did not meet the criteria established for inclusion as part of the initial screening process. However, such papers were generally considered for relevance for other aspects of the Technical Support Document for the final rule. Some citations provided to the agencies were already part of the agencies’ initial screening process (as described in section I.C of this Technical Support Document) and thus were not included in this review of additional references.

Specific to the 37 citations in Appendix C3ii (and noted below), the agencies were able to discern the relevant typology addressed in the paper in 31 cases (19 stream systems, five floodplain wetlands and open waters, seven non-floodplain wetlands and open waters). Seventeen of the papers with a determined typology from Appendix C3ii had sufficient information in the citation for the agencies to characterize a conclusion regarding the findings of the Science Report. In each case where a conclusion was reached (*i.e.*, all 17 citations), the agencies determined that the Science Report findings were supported by the literature (11 stream systems, three floodplain wetlands and open waters, and three non-floodplain wetlands and open waters papers; see Table 1).

Table C-8: References Relevant to the Conclusions of the Science Report (of the 37 Identified by the Agencies in October 2021 as Not Captured During the Screening Process). Seventeen of the 37 citations noted by ORD scientists as potentially relevant but that were not captured during the initial screening process (*see* section I.C.iv) were found to have sufficient information to discern system typology (*e.g.*, stream; non-floodplain wetlands and open waters; or floodplain wetlands and open waters) as well as a determination of whether the paper supports, refutes, or neither supports nor refutes the findings of the Science Report. In all 17 cases, the papers were found by ORD reviewers to support the findings of the Science Report.

Citation	Aquatic System Type	Science Report Findings
Acworth, R.I., G.C. Rau, M.O. Cuthbert, K. Leggett, and M.S. Andersen. 2021. “Runoff and focused groundwater-recharge response to flooding rains in the arid zone of Australia.” *Hydrogeology Journal* 29 (2): 737-764. https://doi.org/10.1007/s10040-020-02284-x.	Streams	Supports

Citation	**Aquatic System Type**	**Science Report Findings**
Arce, M.I., M.d.M. Sánchez-Montoya, and R. Gómez. 2015. “Nitrogen processing following experimental sediment rewetting in isolated pools in an agricultural stream of a semiarid region.” *Ecological Engineering* 77: 233-241. https://doi.org/10.1016/j.ecoleng.2015.01.035.	Streams	Supports
Arora, B., M. Burrus, M. Newcomer, C.I. Steefel, R.W.H. Carroll, D. Dwivedi, W. Dong, K.H. Williams, and S.S. Hubbard. 2020. “Differential C-Q Analysis: A New Approach to Inferring Lateral Transport and Hydrologic Transients Within Multiple Reaches of a Mountainous Headwater Catchment.” *Frontiers in Water* 2 (24). https://www.frontiersin.org/article/10.3389/frwa.2020.00024.	Streams	Supports
Baulch, H., C. Whitfield, J. Wolfe, N. Basu, A. Bedard-Haughn, K. Belcher, R. Clark, G. Ferguson, M. Hayashi, A. Ireson, P. Lloyd-Smith, P. Loring, J.W. Pomeroy, K. Shook, and C. Spence. 2021. “Synthesis of science: findings on Canadian Prairie wetland drainage.” *Canadian Water Resources Journal / Revue canadienne des ressources hydriques*: 1-13. https://doi.org/10.1080/07011784.2021.1973911.	Streams	Supports
Carroll, R.W.H., D. Gochis, and K.H. Williams. 2020. “Efficiency of the Summer Monsoon in Generating Streamflow Within a Snow-Dominated Headwater Basin of the Colorado River.” Geophysical Research Letters 47 (23): e2020GL090856. https://doi.org/10.1029/2020GL090856.	Streams	Supports
Crabot, J., C.P. Mondy, P. Usseglio-Polatera, K.M. Fritz, P.J. Wood, M.J. Greenwood, M.T. Bogan, E.I. Meyer, and T. Datry. 2021. “A global perspective on the functional responses of stream communities to flow intermittence.” *Ecography* 44 (10): 1511-1523. https://onlinelibrary.wiley.com/doi/abs/10.1111/ecog.05697.	Streams	Supports
Evenson, G.R., H.E. Golden, J.R. Christensen, C.R. Lane, A. Rajib, E. D’Amico, D.T. Mahoney, E. White, and Q. Wu. 2021. “Wetland restoration yields dynamic nitrate responses across the Upper Mississippi river basin.” *Environmental Research Communications* 3 (9): 095002. http://dx.doi.org/10.1088/2515-7620/ac2125.	Non-floodplain Wetlands and Open Waters	Supports

Citation	Aquatic System Type	Science Report Findings
Gall, H.E., S.A. Sassman, B. Jenkinson, L.S. Lee, and C.T. Jafvert. 2015. "Comparison of export dynamics of nutrients and animal-borne estrogens from a tile-drained Midwestern agroecosystem." *Water Research* 72: 162-173. https://www.sciencedirect.com/science/article/pii/S0043135414006083.	Streams	Supports
Gallo, E.L., K.A. Lohse, C.M. Ferlin, T. Meixner, and P.D. Brooks. 2014. "Physical and biological controls on trace gas fluxes in semi-arid urban ephemeral waterways." *Biogeochemistry* 121 (1): 189-207. https://doi.org/10.1007/s10533-013-9927-0.	Streams	Supports
Golden, H.E., C.R. Lane, A. Rajib, and Q. Wu. 2021. "Improving global flood and drought predictions: integrating non-floodplain wetlands into watershed hydrologic models." *Environmental Research Letters 16* (9): 091002. http://dx.doi.org/10.1088/1748-9326/ac1fbc.	Non-floodplain Wetlands and Open Waters	Supports
Gómez-Gener, L., A.R. Siebers, M.I. Arce, S. Arnon, S. Bernal, R. Bolpagni, T. Datry, G. Gionchetta, H.-P. Grossart, C. Mendoza-Lera, V. Pohl, U. Risse-Buhl, O. Shumilova, O. Tzoraki, D. von Schiller, A. Weigand, G. Weigelhofer, D. Zak, and A. Zoppini. 2021. "Towards an improved understanding of biogeochemical processes across surface-groundwater interactions in intermittent rivers and ephemeral streams." *Earth-Science Reviews* 220: 103724. https://www.sciencedirect.com/science/article/pii/S0012825221002257.	Streams	Supports
Hansen, A.T., T. Campbell, S.J. Cho, J.A. Czuba, B.J. Dalzell, C.L. Dolph, P.L. Hawthorne, S. Rabotyagov, Z. Lang, K. Kumarasamy, P. Belmont, J.C. Finlay, E. Foufoula-Georgiou, K.B. Gran, C.L. Kling, and P. Wilcock. 2021. "Integrated assessment modeling reveals near-channel management as cost-effective to improve water quality in agricultural watersheds." *Proceedings of the National Academy of Sciences* 118 (28): e2024912118. http://www.pnas.org/content/118/28/e2024912118.abstract.	Floodplain Wetlands and Open Waters	Supports
Jakubínský, J., M. Prokopová, P. Raška, L. Salvati, N. Bezak, O. Cudlín, P. Cudlín, J. Purkyt, P. Vezza, C. Camporeale, J. Daněk, M. Pástor, and T. Lepeška. 2021. "Managing floodplains using nature-based solutions to support multiple ecosystem functions and services." *WIREs Water* 8 (5): e1545. https://doi.org/10.1002/wat2.1545.	Floodplain Wetlands and Open Waters	Supports

Citation	Aquatic System Type	Science Report Findings
Kavehei, A., D.B. Gore, A.A. Chariton, and G.C. Hose. 2021. "Impact assessment of ephemeral discharge of contamination downstream of two legacy base metal mines using environmental DNA." *Journal of Hazardous Materials* 419: 126483. https://www.sciencedirect.com/science/article/pii/S0304389421014485.	Streams	Supports
Klammler, H., C.J. Quintero, J.W. Jawitz, D.L. McLaughlin, and M.J. Cohen. 2020. "Local Storage Dynamics of Individual Wetlands Predict Wetlandscape Discharge." *Water Resources Research* 56 (11): e2020WR027581. https://agupubs.onlinelibrary.wiley.com/doi/abs/10.1029/2020WR027581.	Non-floodplain Wetlands and Open Waters	Supports
Rau, G.C., L.J.S. Halloran, M.O. Cuthbert, M.S. Andersen, R.I. Acworth, and J.H. Tellam. 2017. "Characterising the dynamics of surface water-groundwater interactions in intermittent and ephemeral streams using streambed thermal signatures." *Advances in Water Resources* 107: 354-369. https://www.sciencedirect.com/science/article/pii/S0309170817300891.	Streams	Supports
Schulz-Zunkel, C., M. Baborowski, T. Ehlert, H.D. Kasperidus, F. Krüger, P. Horchler, B. Neukirchen, H. Rupp, M. Scholz, L. Symmank, and S. Natho. 2021. "Simple modelling for a large-scale assessment of total phosphorus retention in the floodplains of large rivers." *Wetlands* 41 (6): 68. https://doi.org/10.1007/s13157-021-01458-x.	Floodplain Wetlands and Open Waters	Supports

Of the 43 citations received by the agencies during the public comment period that were found to be peer-reviewed and published during or after 2014, the agencies were able to discern the appropriate and relevant aquatic system typology in 22 cases (15 stream systems, one floodplain wetlands and open water, three non-floodplain wetlands and open waters, and three papers that addressed both headwater streams and non-floodplain wetlands and open waters). The agencies were able to assess a conclusion on findings relevant to the Science Report in 13 of the 22 papers (seven stream-system focused papers, two papers that focused on both streams and non-floodplain wetlands and open waters, and one paper that focused solely on non-floodplain wetlands and open waters; see Table 2). All 13 papers were found to support the conclusions of the Science Report.

Table C-9: Peer-Reviewed References Published Since 2014 Provided During the Public Comment Period Relevant to the Conclusions of the Science Report. Thirteen of the 43 peer-reviewed citations (published in or after 2014) provided to the agencies during the public comment period were found to have sufficient information to discern system typology (*e.g.*, stream, non-floodplain wetlands and open waters, or floodplain wetlands and open waters) as well as a determination of whether the paper supports, refutes, or neither supports nor refutes the findings of the Science Report. In all 13 cases, the papers were found by ORD reviewers to support the findings of the Science Report.

Citation	Aquatic System Type	Science Report Findings
Callahan, M. K., Rains, M. C., Bellino, J. C., Walker, C. M., Baird, S. J., Whigham, D. F., & King, R. S. 2015. "Controls on temperature in salmonid-bearing headwater streams in two common hydrogeologic settings, Kenai Peninsula, Alaska." *Journal of the American Water Resources Association* 51(1): 84-98.	Streams	Supports
Epting, S. M., Hosen, J. D., Alexander, L. C., Lang, M. W., Armstrong, A. W., & Palmer, M. A. 2018. "Landscape metrics as predictors of hydrologic connectivity between Coastal Plain forested wetlands and streams." *Hydrological Processes* 32(4): 516-532.	Non-floodplain wetlands and Open Waters; Streams	Supports
Fesenmyer, K., *et al*. 2021. "Large portion of USA streams lose protection with new interpretation of Clean Water Act." *Freshwater Science* 40: 252-258.	Streams	Supports
Jackson, C. R., Sytsma, C., Sutter, L. A., & Batzer, D. P. 2021. "Redefining Waters of the US: a Case Study from the Edge of the Okefenokee Swamp." *Wetlands* 41(8): 1-10.	Non-floodplain Wetlands and Open Waters	Supports
Lane, C. R., I. F. Creed, H. E. Golden, S. G. Leibowitz, D. M. Mushet, M. C. Rains, Q. Wu, E. D'Amico, L. C. Alexander, G. A. Ali, N. B. Basu, M. G. Bennett, J. R. Christensen, M. J. Cohen, T. P. Covino, B. DeVries, R. A. Hill, K. Jencso, M. W. Lang, D. L. McLaughlin, D. O. Rosenberry, J. Rover and M. K. Vanderhoof. 2022. "Vulnerable Waters are Essential to Watershed Resilience." *Ecosystems*. https://doi.org.10.1007/s10021-021-00737-2.	Non-floodplain wetlands and Open Waters; Streams	Supports
Merritt, A. M., Lane, B., & Hawkins, C. P. 2021. "Classification and Prediction of Natural Streamflow Regimes in Arid Regions of the USA." *Water* 13(3): 380.	Streams	Supports

Citation	**Aquatic System Type**	**Science Report Findings**
Miller, O. L., Putman, A. L., Alder, J., Miller, M., Jones, D. K., & Wise, D. R. 2021. "Changing climate drives future streamflow declines and challenges in meeting water demand across the southwestern United States." *Journal of Hydrology* 11: 100074.	Streams	Supports
New Mexico Bureau of Geology and Mineral Resources. 2022. *Climate change in New Mexico over the next 50 years: Impacts on water resources*. New Mexico Bureau of Geology and Mineral Resources, Bulletin 164. https://geoinfo.nmt.edu/ClimatePanel/report/.	Streams	Supports
Paller, M. H., Prusha, B. A., Fletcher, D. E., Kosnicki, E., Sefick, S. A., Jarrell, M. S., Sterrett, S. C., Grosse, A. M., Tuberville, T. D., & Feminella, J. W. 2016. "Factors influencing stream fish species composition and functional properties at multiple spatial scales in the Sand Hills of the southeastern United States." *Transactions of the American Fisheries Society* 145(3): 545-562.	Streams	Supports
Price, S. J., Muncy, B. L., Bonner, S. J., Drayer, A. N., & Barton, C. D. 2016. "Effects of mountaintop removal mining and valley filling on the occupancy and abundance of stream salamanders." *Journal of Applied Ecology* 53(2): 459-468.	Streams	Supports
Speir, S. L., Tank, J. L., Bieroza, M., Mahl, U. H., & Royer, T. V. 2021. "Storm size and hydrologic modification influence nitrate mobilization and transport in agricultural watersheds." *Biogeochemistry* 156(3): 319-334.	Streams	Supports
Sullivan, S.M.P., *et al*. 2020. "Distorting science, putting water at risk." *Science* 369(6505): 766-768.	Stream and Wetlands	Supports
Zimmer, M. A., & McGlynn, B. L. (2017). "Bidirectional stream–groundwater flow in response to ephemeral and intermittent streamflow and groundwater seasonality." *Hydrological Processes* 31(22): 3871-3880.	Streams	Supports

Appendix C3ii: Additional References Not Captured During Screening Process (October 2021)

The below references were identified by ORD reviewers in late October 2021 as potentially relevant to the effort but not captured in the original screening began in mid-June 2021 (*e.g.*, they were scientific manuscripts accepted or published since the screening process began or were missed in the original screening). These references were included as Appendix C2 in the Technical Support Document for the

Proposed Rule. As described above, these, in addition to the literature received during the public comment period, were reviewed for their relevance to the Science Report conclusions.

Acworth, R.I., G.C. Rau, M.O. Cuthbert, K. Leggett, and M.S. Andersen. 2021. “Runoff and focused groundwater-recharge response to flooding rains in the arid zone of Australia.” *Hydrogeology Journal* 29(2): 737-764. https://doi.org/10.1007/s10040-020-02284-x.

Arce, M.I., C. Mendoza-Lera, M. Almagro, N. Catalán, A.M. Romaní, E. Martí, R. Gómez, S. Bernal, A. Foulquier, M. Mutz, R. Marcé, A. Zoppini, G. Gionchetta, G. Weigelhofer, R. del Campo, C.T. Robinson, A. Gilmer, M. Rulik, B. Obrador, O. Shumilova, S. Zlatanović, S. Arnon, P. Baldrian, G. Singer, T. Datry, N. Skoulikidis, B. Tietjen, and D. von Schiller. 2019. “A conceptual framework for understanding the biogeochemistry of dry riverbeds through the lens of soil science.” *Earth-Science Reviews* 188: 441-453. https://www.sciencedirect.com/science/article/pii/S001282521830059X.

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Arora, B., M. Burrus, M. Newcomer, C.I. Steefel, R.W.H. Carroll, D. Dwivedi, W. Dong, K.H. Williams, and S.S. Hubbard. 2020. “Differential C-Q Analysis: A New Approach to Inferring Lateral Transport and Hydrologic Transients Within Multiple Reaches of a Mountainous Headwater Catchment.” *Frontiers in Water* 2 (24). https://www.frontiersin.org/article/10.3389/frwa.2020.00024.

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Crabot, J., C.P. Mondy, P. Usseglio-Polatera, K.M. Fritz, P.J. Wood, M.J. Greenwood, M.T. Bogan, E.I. Meyer, and T. Datry. 2021. “A global perspective on the functional responses of stream communities to flow intermittence.” *Ecography* 44 (10): 1511-1523. https://onlinelibrary.wiley.com/doi/abs/10.1111/ecog.05697.

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Dollinger, J., C. Dagès, S. Negro, J.-S. Bailly, and M. Voltz. 2016. "Variability of glyphosate and diuron sorption capacities of ditch beds determined using new indicator-based methods." *Science of The Total Environment* 573: 716-726. https://www.sciencedirect.com/science/article/pii/S0048969716318708.

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Evenson, G.R., H.E. Golden, J.R. Christensen, C.R. Lane, A. Rajib, E. D'Amico, D.T. Mahoney, E. White, and Q. Wu. 2021. "Wetland restoration yields dynamic nitrate responses across the Upper Mississippi river basin." *Environmental Research Communications* 3 (9): 095002. http://dx.doi.org/10.1088/2515-7620/ac2125.

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Gala, T.S., and D. Young. 2021. "Geographically Isolated Depressional Wetlands – Hydrodynamics, Ecosystem Functions and Conditions." *Applied Ecology and Environmental Sciences* 3 (4): 108-116. http://pubs.sciepub.com/.

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