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Science and policy integration issues for stream and wetland jurisdictional determinations in a semi-arid region of the western U.S.

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Abstract In the semi-arid western U.S., rivers and streams are becoming increasingly stressed and degraded, and wetlands lost, due to human development and associated management policies and actions that are generally ineffective for aquatic resources protection and restoration. There is often a significant disconnect between policy and management with science that leads to continued degradation of surface waters. Recent Supreme Court decisions and subsequent U.S. Army Corps of Engineers and Environmental Protection Agency guidance regarding determination of jurisdiction as 'waters of the US' that can be protected under Clean Water Act Section 404 (permitting discharge of dredged and fill materials into wetlands and other waters) is an example of this gap. This study identifies and evaluates key science and policy integration issues for stream and wetland jurisdictional determinations (JDs) in a semi-arid region of the western U.S., including much of the Rocky Mountains, Great Plains and Colorado Plateau. Issues discussed include identification and evaluation of navigable waters, hydrologic permanence/flow duration of perennial and intermittent/ephemeral streams, stream order, significant nexus, aggregation of waters and effects, human impacts and changes, resource inventories and tools, and JD outcomes. Recommendations are also presented to help address the identified issues for more effective management.

Keywords Streams · Wetlands · Jurisdiction · Intermittent · Ephemeral · Perennial · Headwaters

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Introduction

It is widely recognized that many rivers and streams throughout the world are severely stressed and becoming increasingly degraded due to human activities. Wetlands have also been lost at an accelerated rate in the past few decades. Many policy and management efforts to protect and restore surface water resources are generally ineffective at halting the decline (Poff et al. 1997; Baron et al. 2002; Millenium Ecosystem Assessment 2005; Poff 2009). In the U.S., nonpoint source pollution management and river and aquatic ecosystem restoration efforts are two examples of initiatives where millions of dollars have been spent over the years that have not achieved desired or needed results due to policies that are not well integrated with science, and inadequate monitoring of the effectiveness of measures and application of knowledge gained (ELI 2000; EPA 2001a; Palmer and Allan 2006; Bernhardt et al. 2005; Wohl et al. 2005). In the arid and semi-arid western

U.S., the scarcity of water can make impacts from human development and ineffective policies and management more severe. Activities associated with significant population and urban growth, agriculture, energy development, and water diversion and use have profound impacts on aquatic resources in this region (Stoddard et al. 2005; EPA 2006; Johnson et al. 2008; Caruso and Haynes 2010). Confounding development pressure, there is often a significant disconnect between policy and management with science that leads to continued degradation of water resources.

Recent U.S. Supreme Court decisions and subsequent U.S. Army Corps of Engineers (COE), and Environmental Protection Agency (EPA) guidance regarding determination of jurisdiction as 'waters of the US' that can be protected under Clean Water Act (CWA) Section 404 is an example of this gap between science and policy (Nadeau and Rains 2007; Leibowitz et al. 2008; Caruso and Haynes 2010). COE and EPA have joint responsibility for implementing Section 404, which involves the permitting of the discharge of dredged and fill material into wetlands and other waters. A Supreme Court decision in 2001 for the case of *Solid Waste Agency of Northern Cook County v. U.S. Army Corps of Engineers*, 531 U.S. 159 (2001) (*SWANCC*) led to non-jurisdictional status for geographically isolated wetlands regulated solely on the basis of migratory bird use (Ducks Unlimited 2001). However, some isolated wetlands are still jurisdictional under CWA Section 404 if they exhibit substantial interstate commerce or are designated as a traditional navigable water (TNW). A decision in 2006 for the case of *Rapanos v United States* and *Carabell v United States* (consolidated into one decision, *Rapanos v United States* 2006) resulted in many non-navigable streams and adjacent wetlands (NNSAWs) that are tributary to TNWs not being jurisdictional (Leibowitz et al. 2008). These two cases have significantly reduced the protection of intermittent and ephemeral streams and geographically isolated wetlands.

COE and EPA issued joint field Guidance in December 2008 based on the Rapanos decision, which includes methods for jurisdictional determinations (JDs) and coordination between the two agencies (EPA/COE 2008; http://www.epa.gov/owow/wetlands/pdf/CWA_Jurisdiction_Following_Rapanos120208.pdf). EPA and COE have joint responsibility and coordinate on JDs to evaluate geographic isolation of wetlands, NNSAWs, hydrologic permanence, and the 'significant nexus' of intermittent and ephemeral streams with downstream TNWs. COE District offices develop draft JDs associated with individual 404 permit applications, and submit them to EPA regional offices for review. COE developed a standard JD form and associated Instruction Guidebook that provides important, supplemental guidance to COE staff in filling out the form and making JD calls (http://www.usace.army.mil/CECW/Pages/cwa_guide.aspx). However, there is still considerable discretion used and inconsistency in making JD calls within the various COE Districts. The 404 permit applicant provides site and preliminary jurisdictional information to COE as part of their application. Generally the burden of proof with regard to jurisdiction is on the applicant or their agents, and COE staff can request additional information for supporting preliminary JDs from them. The COE draft JD form is then submitted to the EPA regional office, which has 15 calendar days to review and decide whether to take the draft JD as a special case. They can discuss the JDs with COE field staff, concur with them, or request changes. EPA ultimately has Section 404(c) or special case authority to overturn COE permit approvals or JDs, but this is rarely done. Section 404(c) authorizes EPA to prohibit, restrict, or deny the discharge of dredged or fill material at defined sites in waters of the U.S. (including wetlands) whenever it determines, after notice and opportunity for public hearing, that use of such sites for disposal would have an unacceptable adverse impact on one or more of various resources, including fisheries, wildlife, municipal water supplies, or recreational areas.

TNWs and their adjacent wetlands are jurisdictional waters of the U.S. and automatically regulated under Section 404. NNSAWs can be considered jurisdictional based on their hydrologic permanence or flow duration and/or a case-by-case analysis of their significant nexus based on physical, chemical and biological connectivity with the nearest downstream TNW. They are jurisdictional if they are relatively permanent standing or flowing bodies of water, including seasonal rivers (generally flowing >3 months out of the year). These relatively permanent waters (RPWs) include natural, man-altered, or man-made tributaries and adjacent wetlands that carry flow directly or indirectly into a TNW. Some general procedures for assessing wetland adjacency, flow permanence, and significant nexus are presented in the Guidance. According to the Guidance, a tributary is the entire stream reach 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)." This tributary is the 'relevant reach' for classification as an RPW or non-RPW, and for significant nexus evaluation for those classified as non-RPWs. The concept of relevant reach based on stream order is also used for TNW classification. Therefore, waters are classified based on their physical and regulatory characteristics into three primary groups based on the Guidance and these interpretations (Caruso and Haynes 2010): (1) TNWs (jurisdictional), (2) NNSAWs, further subdivided into RPWs (jurisdictional) and intermittent or ephemeral waters (non-RPWs, jurisdictional or non-jurisdictional, depending on whether they have a significant nexus with the nearest downstream TNW), and (3) isolated waters (not jurisdictional) as per *SWANCC* (not discussed in detail in this paper) (Table 1). The position of intermittent or ephemeral non-RPWs and adjacent wetlands in a watershed in relation to the closest downstream TNW is key in determining jurisdiction (Fig. 1).

The Guidance states that the "flow regime that best characterizes the entire tributary should be used where data indicates the flow regime at the downstream limit is not representative of the entire tributary (e.g., where data indicates the tributary is relatively permanent at its downstream limit but not for the majority of its length, or vice versa)" to determine if the tributary is relatively permanent. Based on the Guidance, TNWs and RPWs are typically identified and significant nexus evaluations performed only by COE on a case-by-case basis for each JD or 404 permit application. For cases involving isolated waters or significant nexus, COE evaluates isolation or the physical, chemical, and biological nexus between the relevant reach with downstream TNWs, prepares a draft JD, and coordinates with EPA for review of the draft JD. Known TNWs, RPWs, and non-RPWs listed as part of JDs form only a very small subset of all waters in much of the semi-arid west since comprehensive regional analysis of these classes of waters has not been performed (Caruso and Haynes 2010). The waters that remain are the vast majority of waters that have not been identified or classified in these three categories through the individual JD process because JDs have not been required for them yet. A high percentage of the total stream length in EPA Region 8 (Colorado, Montana, North Dakota, South Dakota, Utah, and Wyoming) are classified as intermittent or ephemeral in the USGS National Hydrographic Dataset (NHD) based on USGS mapping at the 1:100,000 and 1:24,000 scale, but it is not currently known if there is a proportional correlation between stream length and contribution to the biological, chemical, and physical integrity of regulated waters (Caruso and Haynes 2011).

It is apparent that the *SWANCC* and more recent *Rapanos* decisions have resulted in a loss of federal protection under the CWA Section 404 program to many waters in arid and semi-arid regions of the U.S., including much of the Rocky Mountains, Great Plains and Colorado Plateau in EPA Region 8 (Caruso and Haynes 2010). The extent of the loss of protection in other more humid parts of the country is not known. An act of Congress is required to restore the reach of the CWA, including intermittent and ephemeral streams and isolated wetlands, in order to protect the biological, physical, and chemical integrity of our nation's waters as Congress clearly intended. However, if and when this will happen is currently unknown. Erosion of the CWA and associated regulatory decision making, not management or policy per se, has resulted in the loss of protection. But it is also recognized that until the reach of the CWA is restored, the policy (joint agency Guidance) could be more transparent, clearer, consistent, and better integrated with science for improved JDs. Consistent application of joint Guidance between COE District offices is an issue raised in a 2004 General Accounting Office review of earlier JD practices after the *SWANCC* decision (GAO-04-297; GAO 2004) which recommended that COE in consultation with EPA: (1) Survey District office practices in making JDs to determine if significant differences exist, (2) Evaluate whether and how these differences need to be resolved, and (3) Require Districts to document their practices and make information publicly available. At least some of these practices, such as making JDs available for public review, have occurred in many districts.

Table 1 Definitions of types of JDs and aquatic resources, resulting determinations, and required analysis and coordination with EPA

JD type	Resource type	Comments	Determinations	Analysis and coordination required
TNW	Stream or waterbody	"All waters wich are currently used, or were used in the past, or may be susceptible to use in interstate or foreign commerce, including all waters which are subject to the ebb and flow of the tide." Includes RHA Section 10 navigable waters and navigable-in-fact waters	Jurisdictional	No significant nexus analysis or coordination with EPA required
RPW	Stream	Non-navigable tributaries of TNWs. Waters that typically (e.g., except due to drought) flow year-round or waters that have a continuous flow at least seasonally (e.g., typically 3 months).	Jurisdictional	No significant nexus analysis or coordination with EPA required
Wetlands adjacent to a TNW	Wetland	Adjacent is "bordering, contiguous, or neighboring"; a surface connection is not required.	Jurisdictional	No significant nexus analysis or coordination with EPA required
Waterbody within an RPW	Waterbody		Jurisdictional	No significant nexus analysis or coordination with EPA required
Wetlands directly abutting an RPW	Wetland	Must have a continuous surface connection with an RPW	Jurisdictional	No significant nexus analysis or coordination with EPA required
Wetlands adjacent to but not directly abutting an RPW	Wetland	Separated from an RPW by uplands, a berm, dike or similar feature.	Significant Nexus positive or negative	Significant nexus analysis and coordination with EPA required
Non-RPW	Stream	Intermittent or ephemeral tributary of an RPW or TNW	Significant Nexus positive or negative	Significant nexus analysis and coordination with EPA required
Waterbody within a non-RPW	Waterbody		Significant Nexus positive or negative	Significant nexus analysis and coordination with EPA required
Wetlands or waterbody adjacent to a non-RPW	Wetland or waterbody		Significant Nexus positive or negative	Significant nexus analysis and coordination with EPA required
Isolated waters or wetlands	Stream, waterbody or wetland	Isolated waters are intrastate, non-navigable waters that have no significant nexus with TNWs	Isolated positive or negative	Isolated analysis and coordination with EPA required

TNW traditional navigable water, *RPW* relatively permanent water, *RHA* Rivers and Harbors Act

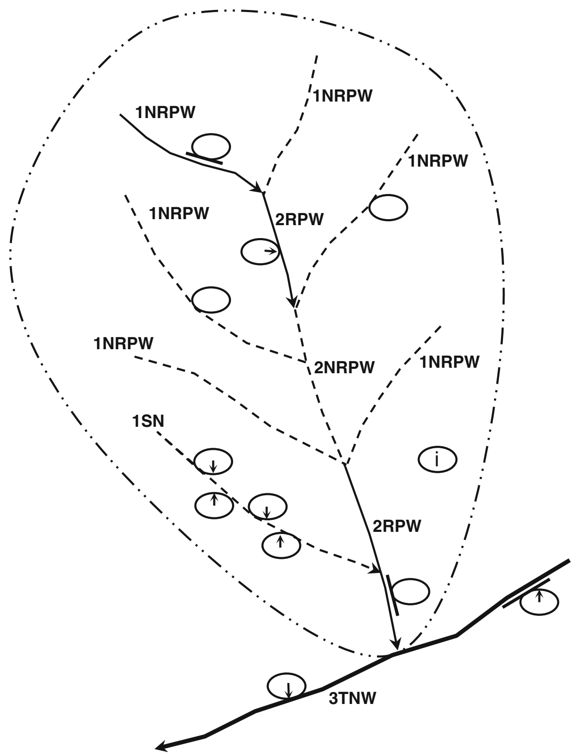

Fig. 1 Schematic representation of a watershed with different types of waters and their jurisdiction as "waters of the U.S." based on stream order, hydrologic permanence, significant nexus and position in the watershed. Streams: Perennial rivers and streams are shown by *solid lines*, and intermittent or ephemeral streams are *dashed lines*. The first number is stream order, TNW is a traditional navigable water that is always jurisdictional, RPW is relatively permanent water that is always jurisdictional, NRPW is non-relatively permanent water that is nonjurisdictional, and SN is a non-relatively permanent water that has a significant nexus with the TNW so is jurisdictional. *Arrows* indicate jurisdictional streams. Wetlands: Wetlands are shown by ellipses. Wetlands without *arrows* are non-jurisdictional because they are isolated (with an i) as per *SWANCC*, adjacent to a non-jurisdictional stream or adjacent to a RPW but separated by a berm shown by a *straight line*. Wetlands with *arrows* are jurisdictional because they are adjacent to the TNW (even when one is separated from the TNW by a berm), or are adjacent to a jurisdictional stream or similarly situated

Several studies have more recently discussed numerous problems with the *Rapanos* decision and Guidance, (Murphy 2007; EarthJustice et al. 2009), and their scientific and technical challenges (Downing et al. 2007; Nadeau and Rains 2007; Leibowitz et al. 2008) that can lead to further degradation of surface waters. Uncertainties in the Guidance and variations in interpretation and implementation among COE districts, EPA regions, and Section 404 permit applicants exist that create problems for effective CWA compliance. Many waters have been determined to be non-jurisdictional, are not regulated, and may be subject to degradation, and many more may also be vulnerable. In EPA Region 8 in the semi-arid western U.S., these include many of the prairie pothole wetlands in the northern Great Plains, as well as numerous intermittent, ephemeral, and low-order headwater streams, and their adjacent wetlands (Caruso and Haynes 2010). Most of the prairie potholes are non-jurisdictional based on *SWANCC* isolation, while streams and adjacent wetlands can be non-jurisdictional because they are not relatively permanent and have no significant nexus based on *Rapanos*. Although the extent of these vulnerable aquatic resources has been largely unknown, some tools are now available to attempt to quantify them and analyze their connectivity and vulnerability across large spatial scales instead of on a case-by-case basis. In this region, interpretation and implementation of the Guidance is even more difficult due to the large proportion of intermittent and ephemeral waters; RPWs that become non-RPWs downstream due to natural dry conditions and loss to groundwater, damming, and diversions; and other widespread human alterations to water resources (Graf 1988; Levick et al. 2008; Johnson et al. 2008; Caruso and Haynes 2010). Classification of these waters according to the Guidance leads to regulation or nonregulation, depending on the JD outcomes, which may then lead to degradation. There is a scientific and technical challenge in classifying waters correctly so that they can be adequately regulated to minimize degradation (Caruso and Haynes 2011).

The objective of this paper was to identify and evaluate key science and policy integration issues for stream and wetland JDs in a semi-arid region of the western U.S. that can lead to ineffective management and protection of surface water resources, and to make recommendations to help address the identified issues. This includes much of the Rocky Mountains, Great Plains and Colorado Plateau in EPA Region 8, which comprises six states (Colorado, Montana, South Dakota, North Dakota, Utah and Wyoming) and portions of three COE districts (Albuquerque in southeastern Colorado, Sacramento in Utah and western Colorado, and Omaha throughout the rest of EPA Region 8). Issues evaluated and discussed

Table 2 Summary of key JD science/policy integration issues and recommendations for improvement

JD Issue	Science/Policy Integration Issues	Recommendations for Improvement
TNWs	Consistent methods for TNW identification and mapping extent are lacking; extent and important biophysical and flow characteristics not identified or evaluated for significant nexus analysis of upstream waters	Perform regional analyses to identify and map TNWs using consistent methodologies and make available to stakeholders; identify and evaluate key biophysical and flow characteristics for significant nexus analysis of upstream tributaries
Hydrologic permanence and RPWs	Hydrologic permanence/flow duration information is critical for identification of RPWs, but usually lacking; data often sparse for intermittent and headwater streams; field methods and models becoming available but are constrained by resources; hydrologic permanence can change over space and time	Develop high resolution data for NHDPlus to better identify and evaluate intermittent streams, especially in headwaters; develop and refine other regional and spatial modelling tools, such as StreamStats, to help characterize and estimate flows for perennial and intermittent streams and the flow start and stop locations
Stream order	Headwaters often not well defined due to field and mapping limitations, but are most numerous and most susceptible to being non-jurisdictional; flow and other data often lacking	Develop high resolution data for NHDPlus to better identify and evaluate headwaters and other stream orders; develop and refine other regional modeling tools to help characterize and estimate flows for headwaters
Significant nexus	Definition and consistent methodologies for evaluation are lacking; can be physical, biological, or chemical but is often difficult to determine; proportion of contributions to TNWs is key but difficult to estimate; timing, losses and gains, attenuation, and interactions with groundwater may be important	Refine Guidance on how to determine and what is significant; develop stream connectivity indices using key stream and catchment/network characteristics available as GIS data over watershed or regional scales; apply other types of models, such as flow or pollutant transport models, to evaluate significant nexus if needed
Aggregate waters and effects	Difficult to determine individual waters nexus with TNW, can be even more complex to determine aggregate or cumulative effects of multiple waters or a class of waters; evaluation and use of aggregate or cumulative effects of tributary streams on significant nexus with TNWs are not explicitly allowed in JDs	Revise Guidance to explicitly allow evaluation and use of tributary streams aggregate or cumulative effects on TNWs information, at least within specific watersheds; develop and apply GIS and other tools to evaluate broad-scale contributions to TNWs and effects
Human impacts and changes	Intermittency and disconnection of waters can be natural or human induced, but these are usually difficult to distinguish; they are increasing in the semi-arid west due to increasing human impacts and changes/trends such as drought and climate change	Guidance should clarify evaluation of existing or "naturalized" flows and stream connectivity; attempt to evaluate and estimate natural flows and intermittency to enable distinguishing human impacts and changes
Resource inventories and tools	Large-scale, regional or watershed information on aquatic resources, types, and characteristics relevant to JDs are lacking; especially true for headwater and intermittent streams; some tools, such as NHDPlus and StreamStats, are available to help with inventories but have limitations	Use existing field and digital information, along with refining GIS tools such as NHDPlus and StreamStats, to better characterize and evaluate key aquatic resources and classes across regions and watersheds; refine information on headwater and intermittent streams using higher resolution data in NHDPlus, and develop methods for estimating intermittency
JD outcomes	It is not known how and if completed JDs are being tracked and evaluated by agencies or others on a consistent or ad hoc basis; JD outcomes and resource impacts are largely unknown; tracking is needed to evaluate outcomes of the new JD process and resource impacts	Track and evaluate completed JDs using GIS and other tools to evaluate patterns and outcomes in important watersheds and across regions and the nation; disseminate results to stakeholders and use results to refine the Guidance and for adaptive management

include TNWs; hydrologic permanence/flow duration and RPWs (perennial and intermittent/ephemeral streams) stream order; significant nexus; aggregation of waters and effects; human impacts and changes; resource inventories and tools; and outcomes of JDs (Table 2). Similar issues are likely important for other areas of the semi-arid western U.S., but may be different for more humid regions of the country. The focus is on the recent *Rapanos* Guidance and JDs involving significant nexus, but similar issues exist for geographically isolated wetland JDs based on the earlier *SWANCC* decision.

Most of the recommendations are based on results from previous studies and experience with implementation and management of the JD process in EPA Region 8 (Caruso and Haynes 2010, 2011). However, to provide some additional quantitative information and analysis of the key JD science and policy integration issues to support the discussion of gaps and recommendations, evaluation of a sample of completed JDs in EPA Region 8 was performed. A stratified random sample of 30 JDs for Rapanos significant nexus calls (including TNWs, RPWs and non-RPWs) in the region was collected from publicly available information on the three COE district internet sites and reviewed to quantify and analyze the science data and information used for JDs. JD information was not publicly available for the Sacramento District (Utah and western Colorado) at the time of this study, so only information from the other two districts was used. The Albuquerque District only includes the southeastern portion of Colorado, while the Omaha District covers the rest of the region. Therefore, the review included five JDs from Albuquerque in Colorado and 25 JDs from Omaha (5 from each of the following: Wyoming, Montana, South Dakota, North Dakota, and the remainder of eastern Colorado). Data and information from the JD forms were categorized into six of the key science/policy integration issues, and into multiple sub-issues (information/source/method type) for each key issue (Table 3). The total number of JDs and percentage of the total that included each information type was calculated. The gaps and recommendations discussed here are based on this analysis as well as results from previous studies and JD implementation and management experience in EPA Region 8.

Science and policy issues

Scientific information from sample of JDs

Of the sample of 30 JDs in the region, 13 disclaimed jurisdiction, 11 required a significant nexus for adjacent wetlands and 14 evaluated stream reaches. Of the stream reaches, five of the JDs included a significant nexus for intermittent streams and nine were limited to a review of ephemeral streams. Lastly, six of the JDs disclaimed jurisdiction citing the feature as an upland swale only.

One third of sample JDs used both office and field methods and 63% used only office analysis (Table 3). The other 4% used only field information. Although most JDs (73%) listed the nearest downstream TNW (or the TNW itself if it was a JD for a TNW), much fewer included either the data source or method (10%) or extent (7%) for the TNW identification.

While all JDs listed the hydrologic permanence/flow duration in one way or another, only 20% listed a data source or used actual flow data (typically from a USGS gauge) or some type of simple model, such as a USGS regression model, to determine hydrologic permanence. Visual observation based on the field visit or anecdotal information from others was used for 1/3 of cases, but this was typically only for a limited observation period. The approximate number of flow events was listed for 30% of JDs for intermittent or ephemeral RPWs or non-RPWs, but data sources or methods were never included. The ordinary high water mark (OHWM) was used for 2/3 of JDs to help determine hydrologic permanence and extent, and information on the bed and banks was used for 40% of cases. For 43% of JDs the presence of a riparian or wetland margin/fringe, or adequate aquatic habitat or presence of aquatic biota was used to determine hydrologic permanence, but this was never quantified. Only 17% of JDs listed the stream order, and none included the data source or method used to determine the order.

The distance to a TNW and number of tributaries downstream to the TNW were each listed or considered for 1/3 of JDs for both positive and negative significant nexus JDs associated with non-RPWs. The OHWM and riparian/wetland margin were used for some JDs (20 and 23% respectively), while the tributary watershed area proportion to TNW

Table 3 Summary of JD science issue and scientific information/methods used for random sample of 30 JDs in EPA Region 8

JD science issue	Information/source/method	Total	Percent
General method	Office	19	63
	Field	1	3
	Office and field	10	33
TNWs	TNW listed	22	73
	Data source or method included	3	10
	Extent included	2	7
Hydrologic permanence and RPWs	Hydrologic permanence listed		
	Data source included or gauge/model used	6	20
	Visual observation used	10	33
	# of flow events listed	9	30
	# of flow events data source or method included	0	0
	OHWM used	20	67
	Bed and banks data used	12	40
	Riparian/wetland margin or aquatic habitat/biota used	13	43
Stream order	Stream order listed	5	17
	Data source or method included	0	0
Significant nexus	Distance to TNW used	10	33
	# of tributaries downstream to TNW used	10	33
	OHWM used	6	20
	Riparian margin used	7	23
	Watershed area proportion to TNW watershed area used	5	17
	Data used for chemical nexus	0	0
	Visual or related land use information used for chemical nexus	8	27
	Data used for biological nexus	0	0
	Visual biological/habitat information used for biological nexus	7	23
	Aerial or other photos used	2	7
Aggregate waters and effects	Streams included	0	0
	Wetlands included	4	13
Human impacts and changes	Natural tributary listed	5	17
	Manipulated tributary listed	6	20
	Both listed	9	30
	Explanation of manipulation included	15	50
	Manipulation includes flows	2	7
Resource inventories and tools	USGS maps used	25	83
	Aerial or other photos used	24	80
	NWI used	9	30
	NHD/NHDPlus used	1	3

watershed area was also used in some cases (17%). Visual or related land use information was used for chemical nexus evaluation for 27% of JDs, and visual biological or habitat information was used for biological nexus for 23%. In no cases was actual data listed as being used for chemical or biological nexus. Aerial or other photos were used for two JDs to help with significant nexus evaluation.

None of the JDs listed consideration of the aggregate or cumulative effects of multiple streams, and only 13% listed consideration of aggregate effects of multiple wetlands. In terms of human impacts and changes, natural tributaries were listed for 17% of JDs, manipulated tributaries were listed for 20%, while both were listed for 30%. The other 30% did not list whether the tributary was natural or manipulated. In addition, half of the JDs included some kind of explanation of the type of manipulation, but only 7% included information on whether there was any manipulation of flows. With regard to resource inventories and tools, most used USGS topographic maps (83%) and/or aerial or other photos (80%), but much fewer used information from the National Wetlands Inventory (NWI) (30%) and only one JD listed NHD or NHDPlus as being used. In no cases was any type of broader, regional or previous resource inventory or analysis discussed in the JD.

It is apparent from this sample analysis that many JD forms contain some key scientific information for decisions on a case-by-case basis, but most don't contain or apply a range of important information that could be useful or needed. There are significant data gaps and inconsistencies in the types and quantification of information and methods used. The gaps and recommendations discussed here are based on this analysis as well as results of previous studies and experience with JD implementation and management in EPA Region 8.

TNWs

The term "navigable waters of the United States", as it is used to define authorities of COE, is defined in 33 CFR part 329 as "those waters that are subject to the ebb and flow of the tide and/or are presently used, or have been used in the past, or may be susceptible for use to transport interstate or foreign commerce." However, the details of how TNWs are determined for JDs are not well-defined in the joint agency *Rapanos* Guidance. Criteria for designation generally include "waters which are currently used, or were used in the past, or may be susceptible to use in interstate or foreign commerce, including all waters which are subject to the ebb and flow of the tide." This includes use of rivers for commercial navigation, such as transport or commercial floating/recreation. Consistent methods for identification and mapping the location and extent of TNWs are lacking. The extent of identified TNWs across the nation or in specific regions is not currently known. Preliminary information from EPA Region 8 during the first year of Guidance implementation (June 2007–June 2008) indicates that only a very small percentage of streams were classified as TNWs (<3% or approximately 27,500 km) as part of the case-by case JD process (Caruso and Haynes 2010). Most TNWs are perennial rivers, but some may not be or may not be designated as such in national databases such as NHD or the more recent NHDPlus (www.horizon-systems.com/nhdplus/). It is currently unknown if all designated TNWs are actually perennial, or classified as perennial in NHD. The initial data from EPA Region 8 during the first year of the Guidance indicates that a small percentage of the TNWs (3%) were classified as intermittent in NHDPlus (Caruso and Haynes 2011).

The important biophysical and flow characteristics of designated TNWs that may be needed for the analysis of significant nexus of upstream tributaries have generally not been identified or evaluated. For example, information on the flow characteristics of TNWs is needed to evaluate the flow contribution of tributaries and their adjacent wetlands to the TNWs that is a critical part of their physical connectivity and nexus and plays a significant role in their chemical and biological connectivity as well. The median annual flow for the identified TNWs in EPA Region 8 during the first year of Guidance implementation was 525 cfs, but these waters had very large flow ranges.

It is recommended that consistent methodologies be developed and applied across COE districts and that regional analyses are performed to identify and map TNWs. This information should be made available to other agencies and stakeholders for use in 404 permit applications and planning. Key biophysical and flow characteristics of TNWs should be identified and evaluated that are needed for significant nexus JDs of upstream waters. For example, the proportion of flow from a tributary relative to TNW flow represents its flow contribution and is a strong indicator of the physical nexus between these waters. As part of their flow characteristics, the hydrologic permanence of TNWs should be evaluated in more detail since preliminary information from EPA Region 8 indicates that some of these are classified as intermittent in NHD. The study in Region 8 showed that this approach provided useful information for regional JD planning and analysis on the number of TNWs, locations, extent/stream length, and flow characteristics, as well as data on the proportion of these attributes in relation to other classes and all rivers and streams in the region (Caruso and Haynes 2011).

Hydrologic permanence—RPWs, perennial, intermittent and ephemeral streams

Hydrologic permanence or flow duration is the most critical parameter determining whether a tributary stream is an RPW and, therefore, jurisdictional and protected under Section 404. In the semi-arid western U.S., interpretation and implementation of the Guidance is complex due to a large proportion intermittent and ephemeral waters and RPWs that become non-RPWs downstream due to natural dry conditions and loss to groundwater, damming, and diversions; and other widespread human alterations to water resources (Graf 1988; Levick et al. 2008; Johnson et al. 2008; Caruso and Haynes 2010). Preliminary data in EPA Region 8 during the first year of Guidance implementation suggests that only a very small percentage of streams were classified as RPWs (<1% or approximately 5,000 km) as part of the case-by case JD process (Caruso and Haynes 2010). Out of these streams, almost 1/4 are classified as intermittent in NHDPlus. The median annual flow for the identified RPWs was 12.5 cfs, but these streams also had very large flow ranges.

The Guidance only presents general methods for determining hydrologic permanence without adequate, specific recommended methods. It uses the terminology "continuous flow at least seasonally (e.g., typically 3 months)" for classification as an RPW. COE has the primary responsibility for determining hydrologic permanence as part of JDs, but EPA may need to confirm the hydrologic permanence designation of some JDs as part of their review. According to the Guidance EPA only has 15 days to review each JD, and must request, receive, and evaluate more information from COE within that time frame. In some cases, upon special request, the 15 days may be extended. Requesting additional data from the 404 permit applicant or reviewing a QA/QC plan or methods used to collect flow data should also be performed when this information is needed. Where actual historic flow records are available from USGS gauges or others or from nearby flow stations, these should be checked or analyzed to the extent possible for some streams. However, for many perennial streams and most intermittent and ephemeral streams, especially smaller tributaries and headwaters, there are no flow gauging stations providing needed historical data on flow duration and other characteristics. The perennial status of some streams may also need to be confirmed through additional analysis of aerial photos and satellite imagery.

For some important or controversial JDs and when staff resources and time are available, field checking or observation of flows should be performed. Some JDs do appear to be more "important" or controversial than others. For example, a JD on a larger stream that goes dry part of the year due to either natural or human causes, but that is a recreational water or water supply for agriculture, may appear to be more important and need more detailed analysis than a small 1st order tributary far removed from any beneficial uses. Therefore, in some cases EPA will perform field visits to confirm COE JDs and observe flows and other characteristics. To address the need for information on hydrologic permanence, detailed field methods for indicators of hydrologic permanence have recently been proposed (Fritz et al. 2006; Fritz et al. 2008), including the Oregon Streamflow Duration Assessment Method (OSDAM; Topping et al. 2009, http://www.oregon.gov/DSL/PERMITS/streamflow.shtml). This is a useful, detailed method for evaluating up to 21 different geomorphic, hydrologic, and biological indicators of streamflow duration that assigns a score to each. The method requires the user to undergo training to assure accuracy and consistency in results. OSDAM was primarily developed for Oregon and the Pacific Northwest and may have some limitations if used in other regions, but is being tested in a number of areas and may have wider application in the future. However, the hydrologic permanence of most NNASWs reviewed by EPA regional offices cannot be evaluated based on detailed field visits due to the very short time frame for JD review and inadequate human and financial resources.

NHD and NHDPlus classify streams as perennial and intermittent based on the "blue line" mapping and classification on U.S. Geological Survey 1:24,000 and 1:100,000 scale contour maps, respectively. However, studies have shown that the mapping and classification of these streams are not necessarily accurate depending on a number of factors (Leopold 1994; Nadeau and Rains 2007; Caruso and Haynes 2011). NHDPlus also has the capability of estimating mean annual flows based on regional regression approaches that can potentially help with the evaluation of hydrologic permanence, but doesn't estimate flow duration or low flows. New methods are being developed using spatial data and modeling to predict the proper classification of perennial and intermittent streams (Simley 2003). Some tools, such as StreamStats, will provide more detailed estimates of flow characteristics, including low flows, for rivers and streams across the U.S. in the future. StreamStats is a water resources web-based GIS created by USGS and the Environmental Systems Research Institute, Inc. (ESRI) that allows users to easily obtain streamflow statistics, basin characteristics, and descriptive information for USGS gauging stations and user selected ungauged sites (Ries et al. 2008). Limitations and capabilities of these types of tools are discussed in more detail below under "Resource Inventories and Tools." Hydrologic permanence and flow intermittency can also change considerably over space and time (Schmidt et al. 2009a, b; Larned et al. 2010). Intermittency is likely increasing in the semi-arid western U.S. primarily due to human impacts such as increasing water abstractions, construction of dams and reservoirs, increasing drought, and climate change impacts (IPCC 2007; Field et al. 2007; EPA 2008a, b).

The estimation of hydrologic permanence/flow duration (not just mean annual flow) and locations of intermittent and ephemeral reaches over space and time are critical areas for future work. It is recommended that the high resolution data for perennial and intermittent reaches available in NHD be further developed, refined and incorporated into NHDPlus to better identify and classify the hydrologic permanence of streams, especially in headwaters, as shown by Caruso and Haynes (2011). Other regional and spatial modelling tools, such as StreamStats, should be further developed to help characterize and estimate flows, including low flows and flow duration, for perennial and intermittent streams and flow start and stop locations. Other studies have demonstrated that new methods using regional regression equations can predict hydrologic permanence more accurately than previous methods and can be incorporated into programs like StreamStats in the future (Simley 2003; Bent and Steeves 2006; Rea and Skinner 2009).

Stream order

The Guidance requires that significant nexus JDs be performed on a case-by-case basis for an individual tributary, which is the entire reach of the stream that is of the same order. Analysis of TNWs and RPWs are also based on stream order. However, specific methods for determining stream order are not provided in the *Rapanos* Guidance. The Strahler Method (1952, 1957) is widely used and accepted, but other methods are also available. Stream order can also vary somewhat depending on if it is determined in the field, from aerial photos/satellite imagery, or from different scale USGS maps. Headwaters (1st and 2nd order streams) are the most numerous in the majority of watersheds in the arid and semi-arid western U.S. and most susceptible to being considered non-jurisdictional because they are farthest from TNWs (Nadeau and Rains 2007; Levick et al. 2008; Caruso and Haynes 2010).

These streams are often not well defined on maps or in NHDPlus due to field and mapping limitations. Some studies have found that the medium resolution data may be inaccurate and underestimate the extent of these streams by up to 200% (Leopold 1994; Meyer and Wallace 2001; EPA 2006; Nadeau and Rains 2007; Meyer et al. 2007; Caruso and Haynes 2011). Flow and other data are also often lacking for these streams because of their location near the watershed interfluve, and gauging stations are typically located on larger, higher order streams and rivers.

A consistent methodology, such as the Strahler Method, could be identified and beneficial for designating and using stream order to determine TNWs, RPWs, and making significant nexus JDs. Like for hydrologic permanence, the high resolution stream data available in NHD should be used and incorporated into NHDPlus to better identify and estimate the extent of 1st and 2nd order reaches. Caruso and Haynes (2011) evaluated stream order using these tools and discussed the utility of their application to JDs in EPA Region 8. Other regional modeling tools, such as StreamStats, can also be refined and used in the future to help estimate and characterize flows for streams of specific orders, such as headwaters.

Significant nexus

Significant nexus, and how to evaluate or determine it, is a key issue that goes back to the *SWANCC* and earlier Supreme Court (*United States v Riverside Bayview* 1985) decisions in their discussions of the significant nexus between wetlands and navigable waters (Kusler 2004; Murphy 2007; Kalen 2007). In determining significant nexus, the *Rapanos* Guidance discusses consideration of a tributary's contribution to restoring and maintaining the chemical, physical and biological integrity of the Nation's TNWs. Hydrological nexus is a primary component of physical nexus, and is usually also a key driver of chemical and biological nexus. Significant nexus includes consideration of hydrologic factors such as the volume, duration, and frequency of flow, and of certain physical characteristics of the tributary such as proximity to the TNW, size of the watershed, average annual rainfall, and average annual winter snow pack. It also includes consideration of ecologic factors such as the potential of tributaries to carry pollutants and flood waters to TNWs, provision of aquatic habitat that supports a TNW, potential of wetlands to trap and filter pollutants or store flood waters, and maintenance of water quality in TNWs. However, details on how to evaluate these connections are not discussed in the Guidance. In addition, maintenance of characteristic beneficial uses in a downstream regulated water of the U.S., and whether these would be significantly modified by not making a significant nexus call for a wetland adjacent to a non-RPW or non-RPW tributary to a RPW, should be considered. In general, significant nexus based on these multiple connections can be difficult to determine and inconsistent, especially because the term 'significant' is not well defined. The Guidance only describes significant as "neither speculative nor insubstantial."

In addition to problems with use of consistent methods for determining what and what is not significant, there are several key scientific issues complicating evaluation of significant nexus. One issue not explicitly discussed in the Guidance is information on the characteristics of downstream TNWs needed or useful for significant nexus evaluation and JDs. In particular, information on flow characteristics of TNWs is needed. For example, the proportion of flow from the tributary of interest relative to the TNW is an important consideration. However, the flow proportion is also affected by the timing of flows as well as the overall flow gains and losses between the tributary and the catchment outlet at the TNW. This can require considerable detailed analysis. Infrequent but critical flood flows of short duration from a tributary can also create a significant nexus, and is discussed in the Guidance, but information on methods for analysis are not presented and consideration of this nexus varies considerably among JDs and COE Districts and staff. Most of these intermittent and ephemeral streams have no daily gage data or gages to evaluate shorter duration high flows. Another important issue is attenuation of physical/hydrological, chemical, or biological/ecological contributions from the tributary to the TNW, which can be related to the distance and/or factors that impede these contributions between the two water bodies. For example, water diversion, existence of dams or impoundments, and occurrence of intermittent reaches can alter connectivity and the significance of nexus considerably. Some of these attenuation factors are often difficult to identify or estimate their effect, and are often not explicitly accounted for in JDs. An additional example is the connectivity between tributaries and TNWs through groundwater or shallow subsurface flow paths that may be critical in maintaining the physical, chemical and biological integrity of jurisdictional waters. This is a vital issue in the semi-arid western U.S. where numerous (in some regions most) streams are intermittent, lose surface flows to alluvial channels, or transport water and constituents through the hyporheic zone (Graf 1988; Levick et al. 2008). However, they still may contribute significantly to larger downstream rivers and may be their primary or only water source (Graf 1988; Winter 2007). Evaluation of the aggregate effects of wetlands adjacent to tributaries and "similarly situated lands" (wetlands) on TNWs, but not the aggregate effects of the tributaries themselves, is another key science issue for significant nexus discussed further below.

Several hydrogeomorphic functional assessment methods have been adopted for evaluating the relative importance or functional attributes of individual wetlands and cumulative effects or functions of wetlands adjacent to a non-RPW stream on maintenance of characteristic uses (Brinson 1993; Hauer and Smith 1998). By extension this includes the relative importance of these wetlands on the biological, chemical and physical integrity of downstream regulated waters. Watershed and receiving water quality models, such as EPA's Better Assessment Science Integrating Point and Nonpoint Sources (BASINS; EPA 2001b, http://www.epa.gov/waterscience/basins/bsnsdocs.html), Hydrologic Simulation Program Fortran (HSPF), and the Water Quality Analysis Simulation Program (WASP; Wool et al. 2001; http://www.epa.gov/athens/wwqtsc/html/wasp.html), could be used to help evaluate contributions from tributaries and significant nexus with TNWs.

Although it is difficult to define exactly what is and is not significant among physical, chemical, and biological contributions to TNWs over time and space, the Guidance should discuss this in more detail with more specific recommendations on how to determine significant nexus and what may be considered significant. The flow characteristics of TNWs should explicitly be evaluated, either on a case-by-case or broad-scale basis, including analyzing the proportion of flows from tributaries in question relative to those of the TNW. This analysis should also include consideration of the timing of flows, overall flow gains or losses between the tributary and the catchment outlet at the TNW, flood flows, and attenuation including human-induced attenuation from diversion, dams or impoundments, and intermittent reaches and losses to or flow through groundwater. The proportions of chemical and biological contributions should also be evaluated considering these factors. Stream classes can be developed based on biophysical characteristics, such as hydrologic permanence and stream order, to help evaluate significant nexus and extrapolate results across streams within a particular class. A study in the Upper Colorado River Basin using some of these approaches showed that intermittent 1st order streams had somewhat higher average flows than intermittent higher order streams, indicating that these 1st order streams could have a more significant nexus with TNWs in terms of hydrologic contribution (Caruso and Haynes 2011). It may also be feasible and useful to develop a 'connectivity index' for all tributaries in a watershed using key stream and watershed/network characteristics available as GIS data over watershed or regional scales. Watershed hydrologic, chemical loading, and receiving water quality or pollutant fate and transport models should also be used in specific cases where detailed analysis of significant nexus is required. To date, however, this type of site-specific modeling approach for significant nexus JDs has not been presented in the literature.

Aggregation of waters and effects

According to the Guidance, JDs and significant nexus must be evaluated on a case-by-case basis for an individual tributary stream of the same order, and the aggregate effects of multiple tributaries on downstream TNWs should not be considered. However, it specifically allows all wetlands "adjacent" to a jurisdictional water and "similarly situated lands" to also be considered jurisdictional. Adjacent is defined as "bordering, contiguous, or neighboring." Wetlands are adjacent to a TNW if one of three criteria is satisfied: (1) there is an unbroken surface or shallow sub-surface connection to jurisdictional waters (this hydrologic connection may be intermittent, but finding a continuous surface connection is not required if one of the other two criteria are met), (2) they are physically separated from jurisdictional waters by man-made dikes or barriers, natural river berms, or beach dunes, or (3) their proximity to a jurisdictional water is reasonably close. For jurisdictional RPWs or non-RPWs with a significant nexus to a TNW, on the other hand, wetlands adjacent to the jurisdictional water must have a "continuous surface connection" with the water where the wetland directly abuts the tributary (is not separated by uplands, a berm, dike, or similar feature) to be considered jurisdictional (EPA/COE 2008). Although an adjacent wetland, in combination with all other adjacent wetlands within the relative reach, can still be jurisdictional if a significant nexus to a downstream TNW is established, the criteria used to determine jurisdictional adjacent wetlands is inconsistent between classes of waters.

The primary issue is that the Guidance doesn't allow evaluation of the significant nexus of similarly situated non-RPW tributary streams with a TNW (Murphy 2007; Nadeau and Rains 2007). This appears to be a contradictory approach between some wetlands and streams, and is used despite EPA and COE emphasizing 'watershed' and 'ecosystem' approaches in many CWA, civil works, and restoration programs in recent years (EPA 1991, 2008c; NRC 1999; Federal Register 2000; Hanson and Fischenich 2002; Murphy 2007).

Although the connectivity or nexus of a single intermittent/ephemeral or headwater stream with downstream TNWs may be important, it may be determined to be insignificant as part of a JD and the stream may therefore be deemed non-jurisdictional. Cumulatively across a watershed or larger spatial scales, however, numerous studies have shown that these streams provide a very significant contribution to the physical, chemical and biological integrity of downstream waters (Freeman et al. 2007; Wipfli et al. 2007; Nadeau and Rains 2007; Vance 2009).

The determination of an individual tributary's nexus with a TNW can be difficult, and it can be even more complex to estimate the aggregate effects of multiple waters or a class of waters (Brinson 1988; Johnston et al. 1990). Land use management and effects also contribute to aggregate or cumulative effects and must be considered (Sidle and Sharpley 1991; Swank and Bolstad 1994). Distinguishing between the contributions of one tributary and all tributaries can also be complex. Field investigations and monitoring data may be needed to evaluate individual tributary contributions or aggregate effects from multiple streams. Statistical and deterministic models, as well as GIS and spatial modelling tools such as NHDPlus, can also be used help to evaluate aggregate effects.

The Guidance should be revised to explicitly allow the aggregation of tributaries and use of information on their associated aggregate effects for JDs. This is particularly needed for tributaries within an individual watershed network contributing to a specific TNW. It would also be useful for classes of streams with similar biophysical characteristics, where the contribution or nexus of one stream with a TNW that is evaluated in some detail is similar to that of another stream with the same characteristics. GIS using NHDPlus and other spatial modelling tools can be used and refined to help evaluate broad-scale contributions to TNWs and effects. Using these tools, for example, Caruso and Haynes (2011) found that tributary 1st order streams comprise more than 3/4 of the total stream length and watershed area in the Upper Colorado River Basin, and could contribute an even greater proportion of water and other constituents important for ecosystem services to TNWs. Evaluation and understanding of aggregate (or similar cumulative) effects has been beneficial in protecting adjacent wetlands that have significant nexus with TNWs and reducing cumulative wetland loss and degradation across the nation in recent years (Bedford and Preston 1988). It has also helped reduce impacts in other related environmental management arenas including under the National Environmental Policy Act (McDonald 2000) and for more holistic, watershed or ecosystem approaches to environmental and watershed management in general (Murphy 2007; EPA 2008a). This indicates that allowance of aggregation of tributaries and consideration of their effects on TNWs would be beneficial to the JD process as well.

Human impacts and changes

Intermittency and the disconnection of streams with TNWs or wetlands with jurisdictional streams can be natural or human induced. However, these causes are usually difficult to distinguish. In the semi-arid western U.S., in particular, human impacts and changes over time are significant due to the scarcity of water and the damming of rivers, water diversion and use, and filling of channels or conduits that disconnect small streams with downstream waters. Intermittency is also likely increasing in this region due to increasing human impacts and changes/trends such as drought and climate change. Drier conditions and earlier snowmelt are anticipated in many areas of the semi-arid west, which will result in decreased runoff and river flows in late summer and autumn when water consumption is highest (IPCC 2007; Field et al. 2007; EPA 2008b, c). In addition to historic impacts from agriculture and mining, this region has some of the highest population and urban growth in the nation, and energy and water resources development projects will continue to impact stream connectivity and hydrologic permanence in the future. Alternatively, there are also some cases where surface flow increases due to urban development, resulting in natural ephemeral or intermittent streams being converted to a perennial flow regime. This can result in a stream being designated as an RPW under the *Rapanos* Guidance based on the altered condition.

The Guidance doesn't explicitly discuss what role human impacts on streams or future changes on hydrologic permanence or connectivity should play in JDs. If a dam is present that has disconnected an upstream tributary reach from a downstream TNW causing a downstream reach to go dry, does that mean that both should be considered non-jurisdictional, or should the pre-impact natural conditions be used for the JD? In general, the assumptions and approaches between COE Districts and staff are not consistent. The fact that this distinction is not clearly stated in the Guidance is a significant issue for interpretation of waters of the US and JDs. It is often difficult to know or estimate what the human impacts are and to distinguish between existing or impacted flows and historic or natural flows. In addition, the natural flows are often not known in impacted systems and methods to 'naturalize' flows are not well defined or consistent. When flows change and intermittency and disconnectivity increase due to a range of human impacts and changes, what once was or should be a jurisdictional water historically and under more natural conditions may be non-jurisdictional after these changes. However, the Guidance does not explicitly acknowledge or discuss this or present methods for addressing these issues. Therefore, these human impacts and lack of guidance to address them complicate JDs, and this may only get worse in some parts of the semi-arid west.

Although revision to the Guidance cannot directly address the problem of human impacts and changes, it is recommended that the Guidance acknowledge, discuss, and address this issue to the extent possible to improve JDs. Revision should clearly state and discuss what role human impacts on surface waters and changes on hydrologic permanence or connectivity should play in JDs. It is recommended that the Guidance state that JDs should be based on the best estimate of natural, pre-impact conditions. Those performing JDs should attempt to evaluate and estimate natural flows and intermittency to enable distinguishing human impacts and changes. Scientifically robust and consistent methods should be used for this analysis to the extent possible. The agencies should consider a joint study to evaluate, discuss, and recommend methods for evaluating existing impacts to streams and naturalizing flows that may be most useful for JDs. For example, flow naturalization methods that have been discussed and useful in other studies for environmental flow evaluation and setting include both statistical and deterministic modeling methods (Sanborn and Bledsoe 2006; Carlisle et al. 2010).

Resource inventories and tools

Large-scale, regional or watershed information on aquatic resources and types relevant to JDs are generally lacking. A number of geospatial methods and tools have been developed in recent years that can be used for resource inventories and management. Digital tools that can be used to assist with evaluation of key biophysical characteristics of aquatic resources are discussed by Caruso and Haynes (2011). In addition to NHD and NHDPlus, NWI can be used to map and help evaluate wetlands in many areas. However, in the semi-arid western US digital NWI data are very limited. In EPA Region 8, for example, data cover all of North and South Dakota, most of Wyoming, about a third of Montana, but only small portions of Colorado and Utah. Therefore, NWI has not generally been used for review of most COE draft JDs in this region. Other spatial classification and analysis tools, such as Hydrological Landscape Regions (Winter 2001; Wolcock et al. 2004) and classification and profiling based on key JD attributes such as stream order and hydrologic permanence (Caruso and Haynes 2011), have been developed and could be useful for regional resource inventories and evaluation.

NHDPlus is a key tool developed by EPA and USGS and integrates NHD with the National Elevation Dataset (NED) and the Watershed Boundary Dataset (WBD) to enable determination of stream segment catchments and their associated drainage areas, and also has the ability to estimate flow volume and velocity (www.horizon-systems.com/nhdplus/). NHD data are available at a 1:24,000 scale (high resolution) and include perennial and intermittent stream classifications based on digitizing the 'blue line mapping' and stream symbolization on USGS 7.5 min quadrangle topographic maps. NHDPlus data are available at 1:100,000 scale (medium resolution) and include perennial and intermittent status as well as Strahler stream order. USGS defines 'perennial' as "contains water throughout the year, except for infrequent periods of severe drought", and defines 'intermittent' as "contains water for only part of the year, but more than just after rainstorms and snowmelt." There are differences between these definition and interpreted regulatory definitions for RPWs and non-RPWs (Caruso and Haynes 2011). However, the NHDPlus classifications can serve as initial indicators of hydrologic permanence over large regions. They can provide preliminary information for individual JDs for more effective evaluation of jurisdictional waters. For example, TNWs would generally be expected to be classified as 'perennial.' Intermittent and ephemeral streams may be expected to be 'intermittent' in NHDPlus. Ephemeral streams may not appear in the dataset at all. RPWs, on the other hand, could fall in between and be classified as either perennial or intermittent.

Aerial photo interpretation was primarily used for the blue-line mapping and perennial and intermittent classifications on topographic maps used in NHD. USGS performed extensive field reconnaissance when the maps were compiled or revised to verify these (Simley 2003). Channels were classified as perennial and intermittent streams large enough to be represented on the 1:24,000-scale maps, and relative to the surrounding landscape. What might be considered significant in an arid or sparse landscape might be insignificant in a wet or highly developed location. High density stream networks in wet regions may be under-represented, and thin networks in dry areas may be over-represented for a specific streamflow (Simley 2007). However, studies indicate that NHD data, especially medium resolution NHDPlus data, can be inaccurate based on field evaluation and generally underestimate headwater and intermittent, and ephemeral stream length (Leopold 1994; Meyer and Wallace 2001; Svec et al. 2005; Berner 2009; EPA 2006; Nadeau and Rains 2007; Meyer et al. 2007). Caruso and Haynes (2011) showed that the high resolution data can increase the total stream length in mountainous area of the Upper Colorado River Basin more than 100%, and in some arid areas may increase it by 200%. The increase primarily occurs for intermittent streams. The high resolution NHD data include hydrologic permanence classifications, but not stream order. However, the vast majority of streams in this dataset that are not included in the 1:100,000 data are 1st order streams. Due to the work of USGS, EPA and other local data producers such as the U.S. Forest Service, the NHDPlus data have improved significantly in recent years.

NHDPlus also has the capability of estimating mean annual flow for each stream reach based on regional regression analysis and historical flow data from USGS gauges. However, it doesn't have the capability of estimating low flows or flow duration. New logistic regression equations for estimating the probability of streams flowing perennially based on key watershed parameters, and an automated procedure for mapping this probability, have been developed in Massachusetts (Bent and Archfield 2002; Bent and Steeves 2006). The closer to the originating point of the stream, the more inaccurate the estimates. Perennial streams and low-flow statistics, including 7-day, 2-year low flows, were also estimated in Idaho using regional regression equations (Rea and Skinner 2009). These types of equations may be incorporated into NHDPlus or StreamStats in the future. Even with the limitation discussed above, NHDPlus may be a very useful tool for general resource inventory, mapping, classification and profiling of aquatic resources across broad spatial scales, such as EPA regions, for regulatory purposes and assistance with JDs (Caruso and Haynes 2011). The use of NHD and NHDPlus data to provide critical, regional resource information, and as an indicator of general patterns across regions and watersheds, fills an important need. These tools can be used to identify and map intermittent and perennial streams, and reaches of the same order as part of the new regulatory requirements for JDs. The utility of these types of spatial tools for the new regulatory requirements, aquatic resources classification, and analysis should be studied in more detail. The accuracy of NHDPlus hydrologic permanence and stream order data, as well as other data types, is an important area of future research. This tool will continue to be refined with more accurate data, including use of the high resolution data. The regional regression equations and models to better estimate flow, including low flows and flow duration, should be incorporated into both StreamStats and NHDPlus as they are refined. In addition, the NWI digital data will be finalized for the entire U.S. and will be a useful spatial analysis tool for JDs, including evaluation of wetlands. Application and evaluation of tools such as NHD and NHDPlus in EPA Region 8 showed that they could be very useful for resource inventories, mapping, classification and profiling of aquatic resources across broad management units and ecoregions based on different types of waters relevant to JDs (Caruso and Haynes 2011). In the previous study, they were used for preliminary identification and analysis of hydrologic permanence and stream order, two critical resource characteristics for JDs.

JD outcomes

To date there is almost no quantitative information available or presented in the literature documenting or evaluating the outcomes of JDs in the semi-arid western U.S., and this may also be the case in other regions of the country or across the US. Caruso and Haynes (2010) discussed jurisdictional issues and tracked and quantified JD outcomes for wetlands, streams, and other water bodies in the semi-arid western US in the Rocky Mountains and Great Plains of EPA Region 8 for the first year of Guidance implementation (June 2007–June 2008). The regional office reviewed draft JDs from three COE districts for 1,265 individual waters. The JDs resulted in 793 wetlands, 12 streams, and 18 water bodies considered non-jurisdictional due to isolation. This included approximately 2,000 ha of prairie pothole wetlands in North and South Dakota, most of which were non-jurisdictional due to geographic isolation under *SWANCC*. However, significant nexus evaluation was required for 441 waters, of which 49 wetlands, 66 streams and 14 other water bodies were considered non-jurisdictional. A few other studies by environmental groups have also documented outcomes for some specific case study JDs (EarthJustice et al. 2009; Buechler 2010; Vance 2010). Most of these analyses have shown outcomes resulting in adverse impacts to streams and wetlands and subsequent aquatic ecosystem functions and services. In Region 8, two COE District offices are routinely tracking JDs and this information is readily available to the public on their regulatory websites, but the third office did not appear to have this information online. In general, however, information on individual JDs has not been analyzed or synthesized and presented in a summary form to the public or Congress. Therefore, overall outcomes across larger-scale management units (such as EPA regions, COE districts, or states) or ecoregions, are unknown. Tracking, quantitative documentation and analysis of results, and dissemination to stakeholders is needed to evaluate the outcomes of this relatively new JD process and associated resource impacts. Spatial analysis and mapping, including use of GIS, NHDPlus, and NWI, are key tools to help with this need.

It is highly recommended that the agencies, researchers, and other stakeholders develop a robust but simple system to track JDs and their outcomes, such as that developed in EPA Region 8. The completed JDs and outcomes should also be evaluated using GIS and spatial analysis tools to understand patterns and results in key watersheds and across regions and the nation. It is also recommended that the implications for aquatic resources and impacts of these outcomes be monitored and evaluated, and that results be documented and disseminated to stakeholders. Adaptive management of the JD process and revisions to the Guidance should be implemented where needed based on these results, especially if the proposed Clean Water Restoration Act attempting to refine the definition of jurisdictional waters of the U.S. is not passed or implemented. Evaluation of JD outcomes in EPA Region 8 has demonstrated the utility of these approaches and recommendations (Caruso and Haynes 2010).

Conclusions

Out of the issues discussed, the development and use of resource inventories and tools is considered the highest priority because it can help address most of the other issues more effectively (Table 4). Tracking and reporting on JD outcomes is also a high priority that should be done in parallel to document outcomes for stakeholders and Congress and adaptive management of the JD process until the reach of the CWA is restored. A number of tools, such as NHDPlus, can be used by 404 permit applicants and agencies to help document hydrologic support functions of streams and wetlands. While NHDPlus is a useful tool, it has inherent limitations and the higher resolution data on intermittent and perennial streams are not always accurate. Numerous other tools and models also are available, including hydrologic and pollutant transport models, OSDA, and various indices of biologic integrity reported in the literature. The burden should be on the JD applicant to use these tools as appropriate to clearly document whether or not a water may be considered jurisdictional. Although useful tools are available, it is recognized by both COE and EPA that site-specific data are best for JDs. For most of the scientific and policy issues discussed

Table 4 Priority ranking of key JD science/policy integration issues and rationale

JD issue	Priority rank	Priority rationale
Resource inventories and tools	1	Needed to a certain extent for most other issues, including identification, mapping and defining characteristics for stream order, TNWs, RPWs, and JD outcomes, and assisting with evaluation of significant nexus, aggregation, and human impacts
JD outcomes	1a	Should be tracked, documented and analyzed in parallel to use of resource inventories and tools and addressing other issues. Needed for reporting to stakeholders and Congress and adaptive management of the JD process
Stream order	2	Required for evaluation of TNWs, RPWs, and significant nexus, and can assist with analysis of aggregation and human impacts
TNWs	3	Needed to identify key jurisdictional waters and endpoints for significant nexus JDs
Hydrologic permanence and RPWs	4	Also required as part of identification of jurisdictional waters and non-jurisdictional waters requiring significant nexus JDs
Significant nexus	5	Needed for all non-RPW intermittent and ephemeral streams
Aggregate waters and effects	6	Will aid in significant nexus JDs
Human impacts and changes	7	Will aid in significant nexus JDs

here, however, the shorter term focus of the agencies should be to assess and communicate whether whatever methods are used for JDs are reasonable.

The recent Supreme Court decisions and agency Guidance on determination of jurisdictional waters of the U.S. has had a profound impact on management and protection of streams and wetlands under Section 404 of the CWA, and has significant implications for other CWA programs as well. A high percentage of the intermittent and ephemeral streams and wetlands in parts of the semi-arid western U.S. and EPA Region 8 have been determined to have no significant nexus or are isolated with regard to jurisdictional navigable waters (Caruso and Haynes 2010) and are not protected by the CWA. The scientific literature is clear that these unprotected waters cumulatively contribute significantly to the biological, chemical, and physical integrity of waters of the U.S. Consequently, there could be a substantial loss of these aquatic resources contributing to a cumulative impact on the integrity of the nation's waters in the absence of protection by state and local government laws and regulations or restoration of the reach of the CWA to protect all waters. The gaps in integration between science and policy for JDs discussed in this paper are significant and can lead to additional confusion among stakeholders, inconsistent and inadequate implementation of the Guidance and JDs, and increased degradation of the nation's waters. Aquatic resources in many parts of the semi-arid western U.S., where water and aquatic habitat are scarce but provide irreplaceable ecosystem services, are especially at risk. This issue is symptomatic of the larger problem of the disconnect between science and policy for effective water resources management in the U.S. and many other areas of the world.

In addition to revision of the Guidance to improve JDs in the short term, it is strongly recommended that Congress restore the reach of the CWA to protect all of the nation's waters, including intermittent and ephemeral streams and isolated wetlands, in order to protect the biological, physical, and chemical integrity of our waters as Congress clearly intended. This is even more important given the climate change predictions for increased drought in portions of the semi-arid western U.S. and EPA Region 8 that will likely increase the number of intermittent and isolated waters unprotected under the current CWA Section 404 Program.

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