

**Science Advisory Board (SAB) Draft Report (3/25/14) to Assist Meeting Deliberations - Do not Cite or Quote**

This draft is a work in progress, does not reflect consensus advice or recommendations, has not been reviewed or approved by the chartered SAB, and does not represent EPA policy.

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EPA-SAB-14-xxx

The Honorable Gina McCarthy  
Administrator  
U.S. Environmental Protection Agency  
1200 Pennsylvania Avenue, N.W.  
Washington, D.C. 20460

Subject: SAB Review of the Draft EPA Report *Connectivity of Streams and Wetlands to Downstream Waters: A Review and Synthesis of the Scientific Evidence*

Dear Administrator McCarthy:

The EPA’s Office of Research and Development (ORD) requested that the Science Advisory Board (SAB) review the draft report titled *Connectivity of Streams and Wetlands to Downstream Waters: A Review and Synthesis of the Scientific Evidence (September 2013 External Review Draft)* (“Report”). The Report is a review and synthesis of the peer-reviewed literature on the connectivity or isolation of streams and wetlands relative to large water bodies such as rivers, lakes, estuaries, and oceans. The Report was developed by ORD to inform an EPA and U.S. Army Corps of Engineers rulemaking to clarify the jurisdiction of the Clean Water Act.

In response to the EPA’s request, the SAB convened an expert panel to review the Report. The Panel was asked to comment on: the clarity and technical accuracy of the Report; whether it includes the most relevant peer reviewed literature; whether the literature has been correctly summarized; and whether the findings and conclusions are supported by the available science. The enclosed report provides the consensus advice and recommendations of the Panel.

The Report is a thorough and technically accurate review of the literature on the connectivity of streams and wetlands to downstream waters. However, the SAB recommends some revisions to improve the clarity of the document, better reflect the scientific evidence, and make it more useful to decision-makers. The SAB disagrees with one of the Report’s key conclusions concerning the connectivity of non-floodplain wetlands. Our major comments and recommendations are provided below.

- The Report often treats connectivity as a binary property, either present or absent, rather than as a gradient. In order to make the Report more technically accurate and useful to decision makers, the SAB recommends that the interpretation of connectivity be revised from a dichotomous, categorical distinction (connected versus not connected) to a gradient approach that recognizes variation in the strength, duration and magnitude, and consequences of those connections.

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- The Report presents a conceptual framework that describes the hydrologic elements of a watershed and the types of connections that link them. The literature review supporting the framework is technically accurate and clearly presented. However, to strengthen and improve its usefulness, the SAB recommends that the framework be expressed as continuous hydrological (surface and subsurface), chemical, and biological flowpaths that connect watersheds. The water body classification system used in the Report should be mapped onto the flowpath framework to show that continuous phenomena interact across landscape settings. In addition, the SAB recommends that each section of the Report be clearly linked to the framework.
  - The SAB recommends that the Report more explicitly address the cumulative and aggregative effects of streams and wetlands on downstream waters. In particular, the Report should contain a discussion of the spatial and temporal scales at which streams and wetlands are functionally aggregated. We also recommend that, throughout the Report, the EPA expand coverage of several important issues including the role of biological connectivity, biogeochemical transformation processes, and the effects of human alteration of connectivity.
  - In the Report, the EPA has classified waters and wetlands as either having the potential for “bidirectional” or “unidirectional” hydrologic flows with rivers and lakes. The SAB finds that these terms do not adequately describe the four-dimensional nature of connectivity and recommends that they be replaced with more commonly understood terms that are grounded in the peer-reviewed literature.
  - The SAB commends the EPA for the comprehensive literature review in the Report. To make review process more transparent, we recommend that the EPA more clearly describe the approach used to screen, compile, and synthesize the information. The EPA should verify and explicitly state that the Report summarizes those studies that failed to show connectivity along with those that demonstrate connectivity.
  - The SAB finds that the review of the literature describing connectivity of headwater streams reflects the pertinent literature and is strongly grounded in current science. The literature review provides strong scientific support for the conclusion that streams exert a strong influence on the character and functioning of downstream waters and that all tributary streams are connected to downstream waters. We recommend that the literature review more thoroughly address hydrologic exchange flows between main channels and off channel areas, the influence of stream temperature on downstream waters, and the movement of biota throughout stream systems to use critical habitats.
  - The SAB finds that the literature on the connectivity of waters and wetlands in riparian/floodplain settings has been correctly summarized in the Report. There is strong scientific support for the overall conclusion that riparian and floodplain water bodies and wetlands are highly connected to receiving waters through multiple pathways. However, the SAB recommends that the Report be reorganized to clarify the functional role of floodplains and riparian areas in maintaining the ecological integrity of streams and rivers. We also recommend that the Report more fully reflect the literature on lateral exchange between

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1 floodplains and rivers, and more explicitly discuss how floodplain environments are linked to  
2 river systems by means of the flood pulse.

- 3
- 4 • The SAB finds that the review and synthesis of the literature on the connectivity of non-  
5 floodplain (“unidirectional”) waters and wetlands is generally thorough, technically accurate,  
6 and clearly presented. We recommend including additional information on material flows  
7 generated by avian fauna.  
8
  - 9 • The SAB disagrees with the EPA’s conclusion that the literature reviewed did not provide  
10 sufficient information to evaluate or generalize about the degree of connectivity (absolute or  
11 relative) or the downstream effects of wetlands in unidirectional landscape settings. The SAB  
12 finds that the scientific literature does provide information to support a more definitive  
13 statement and recommends that the EPA revise the conclusion to better articulate those  
14 aspects that are clearly supported by the literature and the issues that still need to be resolved.  
15 The SAB also recommends that the Report indicate that over sufficiently long time scales all  
16 aquatic habitats are connected to downstream waters through the transfer of water, chemicals  
17 or biota, though the magnitude and effects of these connections vary widely across wetlands.  
18
  - 19 • Finally, the SAB finds that the EPA’s Report could be strengthened by careful editing to  
20 ensure that it is more clearly organized and written in a consistent style and voice.  
21

22 The SAB appreciates the opportunity to provide the EPA with advice on this important subject.  
23 We look forward to receiving the agency’s response.  
24

25  
26 Sincerely,  
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This report has been written as part of the activities of the EPA Science Advisory Board (SAB), a public advisory group providing extramural scientific information and advice to the Administrator and other officials of the Environmental Protection Agency. The SAB is structured to provide balanced, expert assessment of scientific matters related to problems facing the Agency. This report has not been reviewed for approval by the Agency and, hence, the contents of this report do not necessarily represent the views and policies of the Environmental Protection Agency, nor of other agencies in the Executive Branch of the Federal government, nor does mention of trade names of commercial products constitute a recommendation for use. Reports of the SAB are posted on the EPA Web site at <http://www.epa.gov/sab>.

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**U.S. Environmental Protection Agency  
Science Advisory Board  
Panel for the Review of the EPA Water Body Connectivity Report**

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\* Resigned from the Panel in March, 2014

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## 1. EXECUTIVE SUMMARY

The National Center for Environmental Assessment in the EPA Office of Research and Development (ORD) has developed a draft report titled *Connectivity of Streams and Wetlands to Downstream Waters: A Review and Synthesis of the Scientific Evidence (September 2013 External Review Draft)*. The draft report (hereafter referred to as the “Report”) is a review and synthesis of 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 Report is to summarize the current understanding of these connections, the factors that influence them, and the mechanisms by which connected waters affect the function or condition of downstream waters. The Report was developed to inform an EPA and U.S. Army Corps of Engineers rulemaking to clarify the jurisdiction of the Clean Water Act. The Report is a scientific review and, as such, it does not set forth legal standards for Clean Water Act jurisdiction.

The literature review and synthesis in the Report focuses on describing: (1) a conceptual framework that represents the hydrologic elements of a watershed, the types of physical, chemical, and biological connections that link them, and the watershed climatic factors that influence connectivity at various spatial and temporal scales; (2) the downstream connectivity and effects of ephemeral, intermittent, and perennial streams; (3) the downstream connectivity and effects of waters and wetlands in riparian/floodplain settings; and (4) the downstream connectivity and effects of waters and wetlands in non-riparian/non-floodplain settings. Four case studies from the literature are included in the report to illustrate the connectivity of water bodies in different landscape settings and geographic regions.

The EPA asked the SAB to review the Report and comment on: the clarity and technical accuracy of the document; whether it includes the most relevant peer reviewed literature; whether the literature has been correctly summarized; and whether the findings and conclusions in the Report are supported by the available science. This Executive Summary highlights the findings and recommendations of the SAB in response to the charge questions provided in Appendix A.

### **Overall Clarity and Technical Accuracy of the Report**

The SAB was asked to provide its overall impressions of the clarity and accuracy of the Report. The SAB generally finds that the Report is an extensive review of the literature on the connectivity of streams and wetlands to downstream waters that is both thorough and technically accurate. However, the Report could be strengthened by careful editing to ensure that it is more clearly organized and written in a consistent style and voice. Some terms and definitions are not used consistently in all parts of the document. The SAB recommends that the conceptual framework describing the hydrologic elements of a watershed and the connections that link them be used to integrate the entire Report. Each section of the document should be clearly linked to this framework. In addition, the key points in each chapter of the Report should be clearly stated at end of the chapter, and a succinct table summarizing all of the key findings of the Report should be included in the executive summary.

The Report is a science, not policy document, but it was written to support the EPA’s efforts to clarify the jurisdiction of the Clean Water Act. The SAB finds that the report could be more useful to decision-makers if it brought more clarity to the interpretation of connectivity, especially with respect to: (1) quantification of the degree, magnitude, or consequences of connectivity, and (2) the cumulative or aggregate effects of streams and wetlands on downstream waters. The Report often treats connectivity as



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1 a binary property, either present or absent, rather than as a gradient. The SAB recommends that the  
2 interpretation of connectivity be revised from a dichotomous, categorical distinction (connected versus  
3 not connected) to a gradient approach that recognizes variation in the strength, duration and magnitude  
4 and effect of those connections. The SAB also recommends that the Report more explicitly address the  
5 cumulative effects of streams and wetlands on downstream waters, particularly the spatial and temporal  
6 scales at which streams and wetlands are functionally aggregated.

7  
8 The literature review in the Report could be strengthened by more clearly describing the approach used  
9 to screen, compile, and synthesize the information and by including additional references provided by  
10 the SAB. The EPA should confirm and state that studies failing to show connectivity were cited in the  
11 Report along with those that demonstrate connectivity. The SAB finds that the case studies in the Report  
12 provide helpful illustrations of the connectivity of streams and wetlands in certain geographic areas to  
13 downstream waters, but the relevance of the case studies would be more apparent if the Report  
14 explained how they were selected and also presented them more succinctly in text boxes throughout the  
15 document.

16  
17 **Clarity and Technical Accuracy of the Conceptual Framework in the Report**

18  
19 The SAB was asked to comment on the clarity and technical accuracy of the conceptual framework of  
20 watershed structure and function presented in the Report. The literature review supporting the  
21 conceptual framework is thorough and technically accurate but the SAB recommends some revisions to  
22 improve the clarity, accuracy, and usefulness of the framework. Connectivity should be defined at the  
23 beginning of the Report and the SAB recommends that this definition include connections within and  
24 among entire watersheds and underlying aquifers. The EPA should clearly state in the Report what are  
25 considered “waters” and “wetlands” and how they are distinct from the federal regulatory definition.

26  
27 The SAB recommends that the conceptual framework in the Report be expressed as continuous  
28 hydrological (surface and subsurface), chemical, and biological flowpaths connecting watersheds. The  
29 framework should also illustrate the importance of climate, geology, and relief on flow and transport and  
30 highlight the four-dimensional nature of connectivity. In the Report, the EPA discusses connectivity  
31 within a classification system based on discrete landscape settings (i.e., rivers and streams; waters and  
32 wetlands in riparian/floodplain settings; and waters and wetlands in non-riparian/non-floodplain  
33 settings). The SAB recommends that this classification system be mapped onto the flowpath framework  
34 to show that continuous phenomena interact across these discrete landscape settings. There should be  
35 more emphasis in the conceptual framework on the importance of groundwater connectivity and  
36 biological connectivity. Additional layers of complexity also should be included in the conceptual  
37 framework to reflect important issues such as spatial and temporal scales and human alteration of the  
38 hydrological landscape.

39  
40 In the conceptual framework, the EPA has classified waters and wetlands based on their potential to  
41 have bidirectional or unidirectional hydrologic flows with rivers and lakes. Some unidirectional  
42 wetlands are also called “geographically isolated wetlands.” However, the terms “bidirectional” and  
43 “unidirectional” do not adequately describe the four-dimensional nature of connectivity and therefore  
44 should be replaced with more commonly understood terms that are grounded in the peer-reviewed  
45 literature. The term “geographically isolated wetlands” is misleading because all waters and wetlands  
46 are connected at sufficiently long time scales. The Report should explain that the term “geographically

1 isolated” does not imply functional isolation. In addition, the SAB recommends that a summary and  
2 synthesis of the conceptual framework be added to the end of Chapter 3 of the Report.

### 3 4 **Literature on Connectivity and Effects of Ephemeral, Intermittent, and Perennial Streams**

5  
6 The Report contains an excellent review of the scientific literature describing the connectivity of  
7 headwater streams to downstream waters. Nevertheless, further discussion of the literature on several  
8 specific topics is warranted. The review should be expanded to include more complete discussion of  
9 temporal dynamics of connectivity as well as the processes involved in hydrologic exchange flows  
10 between main channels and off channel areas. The discussion of naturally occurring chemical  
11 constituents, contaminants, contaminant transformation processes, and the influence of stream  
12 temperature on downstream connectivity also should be expanded. In addition, the Report should more  
13 thoroughly document the evidence that the biological integrity of headwater streams and downstream  
14 waters is affected by the movement of biota throughout the lotic system. Other important topics that  
15 should be further discussed include: the consequences of human alteration of headwater streams;  
16 aggregate and cumulative effects of headwater streams on downstream waters; the effects of streamside  
17 vegetation on stream ecosystems; the importance of food-webs from riparian areas to stream  
18 ecosystems; and the degree or strength of downstream connections.

### 19 20 **Findings and Conclusions Concerning Ephemeral, Intermittent, and Perennial Streams**

21  
22 The Report concludes that streams exert a strong influence on the character and functioning of  
23 downstream waters and that all tributary streams are physically, chemically, and biologically connected  
24 to downstream waters. While strong scientific support has been provided for these conclusions and  
25 related findings, the conclusions and findings should be quantified whenever possible, related to the four  
26 dimensions of connectivity, and give more attention to biogeochemical transformations and biological  
27 connections. In addition, some hydrologic aspects of connectivity require additional detail. These  
28 include descriptions of key linkages and exchanges in tributary streams, such as groundwater-surface  
29 water interactions, as well as the role of transition areas between uplands and headwaters. Likewise, the  
30 Report should explain how hydrologic connectivity sustains aquifers, particularly in alluvial systems in  
31 the southwest and in karst systems in the eastern U.S. The EPA should also consider summarizing and  
32 displaying the conclusions in the Report in matrix form with brief characterizations of the temporal and  
33 spatial scales over which given functions or phenomena occur. Articulating the rationale for choosing  
34 the specific the case studies would help ensure that the keys points are well illustrated.

### 35 36 **Literature on Waters and Wetlands in Riparian/Floodplain Settings**

37  
38 The literature on the connectivity and downstream effects of waters and wetlands in riparian/floodplain  
39 settings has been correctly summarized and characterized in the Report. The literature review  
40 substantiates the conclusion that floodplains, riparian areas, and waters and wetlands in  
41 riparian/floodplain settings support the hydrological, chemical, and biological integrity of downstream  
42 waters. However, additional emphasis of certain topics, and in some cases review of more recent and  
43 diverse literature, is needed in the Report. The review of the literature on riparian and floodplain  
44 wetlands should be reorganized to clarify the functional role of floodplains and riparian areas in  
45 maintaining the ecological integrity of streams and rivers. The SAB recommends that the Report discuss  
46 the functional role of floodplains and wetlands in the entire landscape setting. The term “bidirectional  
47 wetlands” should therefore be replaced with the term “waters and wetlands in riparian/floodplain

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1 settings” to reflect landscape position. The review should more fully reflect the literature on lateral  
2 exchange between floodplains and rivers followed by downstream transport. In addition, an integrated  
3 discussion of the functional attributes of floodplains as habitats should be included in the review.  
4

5 Other topics should also be emphasized. The Report should more explicitly discuss how floodplain  
6 environments are intimately linked to river systems by means of the flood pulse. In this regard, the  
7 importance of the short duration high intensity and long duration low intensity events should be  
8 compared and contrasted. The Report should also review additional literature on: channel migration  
9 zones (which demonstrate the variable nature of connectivity of floodplains); the importance of  
10 sediment movement, erosion and deposition; lateral connections that create a diversity of habitats  
11 supporting a wide array of species; and human impacts on connectivity. In addition, the Report requires  
12 a more recent and diverse review of the biogeochemical implications of exchange flow, including the  
13 literature on the role of wetlands and floodplains as sources, sinks, and transformers of nutrients and  
14 other chemical contaminants. The SAB also recommends that the examples used in the Report be  
15 broadened to make it more representative of the U.S. In particular, studies on peatlands in floodplain  
16 settings and forested wetlands, including bottomland hardwoods, should be incorporated.  
17

18 **Findings and Conclusions Concerning Waters and Wetlands in Riparian/Floodplain Settings**  
19

20 The findings and conclusions concerning waters and wetlands in riparian/floodplain settings are  
21 discussed in Section 1.4.2 of the Report. There is strong scientific support for the overall conclusion that  
22 riparian and floodplain water bodies and wetlands are highly connected to downstream waters through  
23 physical, chemical, and biological pathways. However, additional literature would bolster the findings  
24 and conclusions in Section 1.4.2 of the Report. A broad discussion of floodplain systems is warranted,  
25 including an explanation of the floodplain areas that can and cannot be classified as wetlands. The  
26 discussion of the findings and conclusions should further address a number of other issues including: the  
27 temporal dimension of connectivity of waters and wetlands in riparian/floodplain settings; the role of  
28 these waters and wetlands in storing and transforming chemical constituents; the role of biological  
29 connectivity, the effects of human alteration of connectivity; and the importance of considering  
30 aggregate/cumulative downstream effects of these waters and wetlands. In addition, the SAB  
31 recommends that the conclusions be more empirically and/or specifically described (e.g., indicating the  
32 percentage of studies that supported a conclusion) and that consistent terminology be used throughout  
33 the report to describe riparian and floodplain wetlands.  
34

35 **Literature on Waters and Wetlands with the Potential for Unidirectional Hydrologic Flows to**  
36 **Rivers and Lakes**  
37

38 In general, the EPA’s review and synthesis of the literature on the downstream connectivity and effects  
39 of wetlands and open waters with the potential for unidirectional connectivity is thorough, technically  
40 accurate, and clearly presented. The SAB recommends that the EPA consider adding some additional  
41 publications on biological connections and “geographically isolated” wetlands. Inclusion of publications  
42 that analyze material flows generated by birds is important. The term “unidirectional wetlands” as used  
43 in the report is misleading because it implies one-way hydrologic flows when, in fact, connectivity can  
44 have many spatial and temporal dimensions. The SAB recommends that the terms “unidirectional” and  
45 “geographically isolated” waters and wetlands be replaced in the report with the term “non-floodplain  
46 waters and wetlands.” The SAB also recommends that the EPA frame the discussion about the temporal  
47 and spatial scales, types, and gradients of various connections between and among floodplain wetlands

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1 and non-floodplain wetlands and downstream waters by considering the magnitude, duration and  
2 frequency of surface and subsurface connections. The magnitude, frequency, and durations of the  
3 connections should be specified to the degree possible from the literature, with acknowledgment that all  
4 aquatic habitats are connected to downstream waters over sufficiently long time scales. In addition, the  
5 Report should discuss the importance of assessing wetland connectivity and connectivity pathways in  
6 terms of aggregated wetland complexes and the legacy effects of human disturbances.  
7

8 **Findings and Conclusions Concerning Waters and Wetlands with the Potential for Unidirectional**  
9 **Hydrologic Flows to Rivers and Lakes**

10  
11 The SAB disagrees with the EPA’s overall conclusion in Section 1.4.3 of the Report indicating that “The  
12 literature we reviewed does not provide sufficient information to evaluate or generalize about the degree  
13 of connectivity (absolute or relative) or the downstream effects of wetlands in unidirectional landscape  
14 settings.” To the contrary, the SAB finds that the scientific literature does provide information to support  
15 a more definitive statement (i.e., numerous functions of unidirectional wetlands have been shown to  
16 benefit downstream water quality) and recommends that the EPA revise the conclusion to focus on  
17 aspects that are clearly supported by the literature and the issues that still need to be resolved. The SAB  
18 also recommends that the EPA’s conclusions concerning “unidirectional” wetlands explicitly recognize  
19 connectivity as a gradient rather than a dichotomous categorical variable and highlight the fact that there  
20 are multiple mechanisms resulting in connectivity that occur over gradients of space and time. The  
21 following text should be included in these conclusions: *Over sufficiently long time scales all aquatic*  
22 *habitats are connected to downstream waters through the transfer of water, chemicals or biota, though*  
23 *the magnitude and effects of these connections vary widely among wetlands.*  
24

25 The SAB recommends several revisions to improve the findings concerning “unidirectional” waters and  
26 wetlands. Reference to specific studies should be removed as the findings are intended to summarize  
27 general themes arising from a broad synthesis of the diverse literature. The key findings should be more  
28 explicitly presented and clearly explained in the text of the Report. In addition, the key findings should  
29 include: the biological functions and biological connectivity of unidirectional wetlands, differences  
30 between natural and manmade wetlands, the importance of spatial proximity as a determinant of  
31 connectivity, and the importance of cumulative or aggregate impacts of unidirectional wetlands.  
32

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**2. INTRODUCTION**

The National Center for Environmental Assessment in the EPA Office of Research and Development (ORD) has developed a draft report titled *Connectivity of Streams and Wetlands to Downstream Waters: A Review and Synthesis of the Scientific Evidence (September 2013 External Review Draft)*. The draft report (hereafter referred to as the “Report”) is a review and synthesis of 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 Report is to summarize the current understanding of these connections, the factors that influence them and the mechanisms by which connected waters affect the function or condition of downstream waters. The Report was developed to inform an EPA and U.S. Army Corps of Engineers rulemaking on waters that are under the jurisdiction of the Clean Water Act. The Report is a scientific review and, as such, it does not set forth legal standards for Clean Water Act jurisdiction.

The literature review and synthesis in the Report focus on describing: (1) a conceptual framework that represents the hydrologic elements of a watershed, the types of physical, chemical, and biological connections that link them, and the watershed climatic factors that influence connectivity at various spatial and temporal scales; (2) the downstream connectivity and effects of ephemeral, intermittent, and perennial streams; (3) the downstream connectivity and effects of waters and wetlands in riparian/floodplain settings; and (4) the downstream connectivity and effects of waters and wetlands in non-riparian/non-floodplain settings. Four case studies from the literature are included in the report to illustrate the connectivity of water bodies in different landscape settings and geographic regions.

The EPA asked the SAB to review the Report and comment on: the clarity and technical accuracy of the document, whether it includes the most relevant peer-reviewed literature, whether the literature has been correctly summarized, and whether the findings and conclusions in the Report are supported by the available science. In response to the EPA’s request, the SAB convened an expert panel to conduct the review. The Panel held a public meeting on December 16-18, 2013 to deliberate on the charge questions. This report provides the findings and recommendations of the SAB in response to the charge questions in Appendix A. The SAB recommendations are highlighted at the end of each section of this report. The order in which the recommendations are presented does not connote their relative importance.

### 3. RESPONSES TO EPA’S CHARGE QUESTIONS

#### 3.1. Overall Clarity and Technical Accuracy of the Draft Report

*Charge Question 1. Please provide your overall impressions of the clarity and technical accuracy of the draft EPA Report, “Connectivity of Streams and Wetlands to Downstream Waters: A Review and Synthesis of the Scientific Evidence.”*

The SAB was asked to provide its overall impression of the clarity and technical accuracy of EPA’s draft report on the connectivity of streams and wetlands to downstream waters. The Report is an extensive review of the literature that is both thorough and technically accurate. However, the SAB finds that the Report could be strengthened by careful editing to: (1) ensure consistency and continuity in style and organization throughout the document; (2) improve the usefulness of the document to decision-makers; (3) strengthen the literature review; (4) provide additional detail and clarification of text in some parts of the document; and (5) restructure the case studies.

#### **3.1.1. Style and Organization of the Draft Report**

There are stylistic differences among the chapters of the EPA’s Report, and the writing needs to be reworked for consistency and continuity so that it is written in a single voice. There also is a strong need to check for consistent use of terms and definitions among the chapters, subchapter sections, and the glossary. The authors also should exercise caution when using words that may denote particular legal or regulatory meanings (e.g., significant, adjacent). The Report is quite long and can be repetitive in places, and the main points are easily lost in the volume of material presented. Superfluous or redundant information should be removed, being careful that only concise text supporting the key findings is included. The EPA should consider hiring a technical editor to address these issues.

Several organizational changes will improve the readability of the Report. First, the conceptual framework should integrate the entire Report. Each section of the Report should be clearly linked to the conceptual framework. As written, the chapters of the Report are not always consistent with the conceptual framework. Second, each paragraph and/or subsection of the Report should have parallel structure where main points are clearly articulated at the end – perhaps even in bold or underlined text. Third, the key points should be stated simply and directly at the end of each chapter, not buried in detail. Fourth, the authors should consider including in the executive summary a succinct table that summarizes the key findings of the Report. The report of the Intergovernmental Panel on Climate Change (IPCC 2007) is an excellent model.

#### *Recommendations*

- The Report should be edited to ensure that it is written in a consistent style and single voice.
- Terms and definitions should be used consistently throughout the Report and caution should be exercised when using words that may have legal or regulatory meanings.

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- 1 • Superfluous or redundant information should be removed from the Report. Each section of the  
2 Report should be clearly linked to the conceptual framework.  
3
- 4 • Each paragraph and/or subsection of the Report should have a parallel structure where main points  
5 are clearly articulated at the end.  
6
- 7 • Key points should be clearly stated at the end of each chapter.  
8
- 9 • A succinct table summarizing the key findings of the report should be included in the executive  
10 summary.  
11

12 **3.1.2. Improving the Usefulness of the Report to Decision-Makers**

13  
14 Although the Report is a science, not policy, document, the SAB is aware that it was written to support  
15 the EPA’s efforts to clarify the jurisdiction of the Clean Water Act. As such, the Report could be written  
16 in a more strategic manner that focuses less heavily on reviewing the basic dynamics of systems and  
17 more on dealing with complex or nuanced issues about which the synthesis can provide important  
18 insights. For example, the degree, magnitude, or consequences of connectivity could be better quantified  
19 throughout the Report. The authors might consider an approach similar to that used in the report of the  
20 Intergovernmental Panel on Climate Change (IPCC 2007) which would provide an estimate of the  
21 relative certainty of connectivity or an effect. As written, the EPA Report often treats connectivity as a  
22 binary property - either present or absent, rather than as a gradient. The SAB is mindful of comments  
23 received from many members of the public who indicated that the binary perspective in the Report  
24 implies that any connectivity must significantly affect the biological, physical, or chemical integrity of  
25 downstream waters. As further discussed in Section 3.8.1 of this report, the SAB recommends that the  
26 interpretation of connectivity be revised from a dichotomous, categorical distinction (connected versus  
27 not connected) to a gradient approach that recognizes variation in the strength, duration and magnitude,  
28 and consequences of those connections. The Report also would be strengthened if it were to more  
29 explicitly address the cumulative effects of streams and wetlands on downstream waters (i.e., streams  
30 and wetlands considered in “aggregate”). In particular, a discussion of the spatial and temporal scales at  
31 which streams and wetlands are functionally aggregated would be useful.  
32

33 *Recommendations*

- 34  
35 • There should be greater focus in the Report on complex issues about which synthesis can provide  
36 important insights (e.g., better quantification of the degree, magnitude or consequences of  
37 connectivity).  
38
- 39 • As further discussed in Section 3.8.1 of this report, the SAB recommends that the interpretation of  
40 connectivity be revised from a dichotomous, categorical distinction (connected versus not  
41 connected) to a gradient approach that recognizes variation in the strength, duration and magnitude,  
42 and consequences of those connections.  
43
- 44 • The Report should more explicitly address the cumulative and aggregate effects of streams and  
45 wetlands on downstream waters. In particular, the Report should contain a discussion of the spatial  
46 and temporal scales at which streams and wetlands are functionally aggregated.

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1  
2 **3.1.3. Strengthening the Literature Review**  
3

4 The literature review in the Report can be strengthened by clarifying what was considered as peer-  
5 reviewed literature, the kinds of evidence used to support the findings and conclusions in the Report, and  
6 the number and types of studies selected for review. The approach used for screening, compiling, and  
7 synthesizing information needs to be made explicit. In particular, the “weight of evidence” approach  
8 used to evaluate multiple references should be described in more detail. The SAB finds that the absence  
9 of references to studies that failed to show connectivity gives an appearance of bias towards certain  
10 studies or even perhaps an effort to “prove” that systems are connected. The literature review should  
11 include studies both showing and failing to show connectivity. If an exhaustive literature review of these  
12 studies has been performed, this should be explicitly stated in the Report. The SAB has provided  
13 numerous additional references in this SAB report and other references have been suggested in written  
14 comments from the public.  
15

16 *Recommendations*  
17

- 18 • The literature review in the Report should be clarified to indicate: (1) what was considered to be peer  
19 reviewed literature; (2) the kinds of evidence used to support the findings and conclusions; and (3)  
20 the number and types of studies selected for review.
- 21
- 22 • The Report should clearly describe the approach used to screen, compile, and synthesize  
23 information.
- 24
- 25 • Studies that failed to show connectivity should be cited in the Report along with those that  
26 demonstrate connectivity.
- 27
- 28 • EPA should consider including in the Report additional information from references provided by the  
29 SAB and members of the public.  
30

31 **3.1.4. Additional Detail and Clarification of Text Needed in the Report**  
32

33 As further discussed in other sections of this SAB report, the following topics in the EPA Report require  
34 clarification and/or additional detailed information:  
35

- 36 – The importance and relevance of different spatial and temporal scales.
- 37 – Biological connections, especially for birds, mammals, and salamanders, across the full life  
38 cycle. As part of this, connectivity via food webs should be included.
- 39 – Case studies of a greater range of geographic regions (e.g., arctic) and systems, including human  
40 modified systems, forested wetlands, and bottomland forests.
- 41 – Why a watershed perspective is needed to understand connectivity.
- 42 – The importance of considering water bodies in aggregate for evaluations of connectivity.
- 43 – Human modifications and their impacts on connectivity. Modifications can include directly  
44 removing/diminishing or restoring/enhancing connectivity, roads, agricultural tiles, dams,  
45 pumping groundwater, irrigation, channelization, and other manmade infrastructure (piped  
46 streams, stormwater pipes).



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- 1     – Definitions of river, unidirectional and bidirectional wetlands, geographically isolated wetlands,  
2     and consistent use of these terms in text.
- 3     – Future research, technological, and methodological needs that will improve our ability to  
4     understand and estimate connectivity.

5  
6     *Recommendation*

- 7
- 8     • The topics listed above should be clarified or discussed in more detail in the Report.
- 9

10    **3.1.5. Restructuring the Case Studies in the Report**

11  
12    The SAB finds that the case studies in the Report provide helpful illustrations of connectivity between  
13    downstream waters and geographically-specific types of systems. That said, case studies could be even  
14    more helpful if they were selected and organized to allow comparisons among geographic regions, such  
15    as Southwest arid and Midwest mesic systems. As discussed in Section 3.4.1 of this report, comparisons  
16    among geographic regions could be accomplished by using hydrology (which varies regionally) as a  
17    framework for the case studies. The case studies are currently long and densely-written accounts, and  
18    this can make it difficult to identify which concept is being illustrated. The rationale for selecting  
19    different case studies and the key points being illustrated by each should be explicitly stated early in the  
20    text. An alternative structure that the authors might consider is to present the case studies as brief, easily  
21    read, textboxes that clearly and simply articulate key points. Within these textboxes the expanded  
22    versions could be referenced and included in appendices. As further discussed in Sections 3.3.10 and  
23    3.5.6 of this report, it would be useful to include case studies of a human dominated system and a  
24    bottom land hardwood system in the Report.

25  
26    *Recommendations*

- 27
- 28     • The case studies in the Report should be carefully selected and organized to allow comparison of the  
29     connectivity of water bodies in different geographic regions.
- 30
- 31     • The rationale for selecting different case studies and the key points illustrated in each should be  
32     clearly stated early in the text.
- 33
- 34     • EPA should consider presenting the case studies in text boxes throughout the Report. The text boxes  
35     could reference more detailed information in Report appendices.
- 36

37    **3.2. Conceptual Framework: An Integrated, Systems Perspective of Watershed Structure**  
38    **and Function**

39  
40    *Charge Question 2. Chapter 3 of the draft Report presents the conceptual basis for describing*  
41    *the hydrologic elements of a watershed; the types of physical, chemical, and biological*  
42    *connections that link these elements, and watershed climatic factors that influence connectivity*  
43    *at various temporal and spatial scales (e.g., see Figure 3-1 and Table 3-1). Please comment on*  
44    *the clarity and technical accuracy of this Chapter and its usefulness in providing context for*  
45    *interpreting the evidence about individual watershed components presented in the Report.*  
46

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1 The SAB was asked to comment on the clarity and technical accuracy of the conceptual framework of  
2 watershed structure and function presented in Chapter 3 of the EPA’s Report and the usefulness of the  
3 framework in providing context for interpreting information in the Report. The SAB finds that the  
4 literature review in Chapter 3 of the Report is thorough, technically accurate, and readable. The  
5 literature review generally does not need to be changed, although it could be strengthened with technical  
6 editing. However, the conceptual framework needs to be revised and clearly articulated at the beginning  
7 of the Chapter to better enable the reader to access and understand the material. As further discussed  
8 below, the SAB finds that the following revisions are needed to improve the clarity, accuracy, and  
9 usefulness of the conceptual framework in the Report: (1) connectivity should be clearly defined at the  
10 beginning of Chapter 3; (2) the scope of the Report (i.e., the breadth of the literature review) should be  
11 clearly defined at the beginning of Chapter 3; (3) the conceptual framework should be expressed as  
12 continuous hydrological, chemical, and biological flowpaths; (4) certain terms (e.g., unidirectional and  
13 bidirectional) used in the Report should be replaced with more commonly understood terminology that  
14 is grounded in the peer-reviewed literature; (5) additional layers of complexity, such as the influence of  
15 human activities, should be represented in the conceptual model in the Report; and (6) a summary and  
16 synthesis of the conceptual model should be added at the end of Chapter 3.

17  
18 **3.2.1. Defining Connectivity**

19  
20 Because connectivity can be defined in many ways, the Report needs to define and concisely discuss  
21 what is meant by “connectivity” at the beginning of Chapter 3. Currently, connectivity is not defined  
22 until page 3-28, long after much of the conceptual framework, as currently described, has been presented  
23 and discussed. The definition of connectivity also should be extended to the entire landscape (i.e., not  
24 just to waters and wetlands but to entire watersheds and underlying aquifers) through a broader vision of  
25 local- to landscape-scale physical, chemical, and biological exchanges. The definition and discussion of  
26 connectivity at the beginning of Chapter 3 could be brief, with the many details and nuances to be  
27 addressed later in the following sections of the Chapter.

28  
29 *Recommendations*

- 30
- 31 • Connectivity should be defined and discussed at the beginning of Chapter 3 of the Report.
  - 32
  - 33 • The definition of connectivity in the Report should be extended to the entire landscape through a  
34 broad vision of local- to landscape-scale physical, chemical, and biological exchanges.
  - 35

36 **3.2.2. Defining the Scope of the Report**

37  
38 The SAB finds that the scope of the Report needs to be clearly defined and discussed at the beginning of  
39 Chapter 3. As a synthesis of the scientific literature, the Report appropriately includes discussion of the  
40 relevant literature on hydrologic, climatic, and other processes that occur across landscapes to connect  
41 various water bodies and wetlands. The breadth of the literature discussed in the Report need not be  
42 constrained by regulatory definitions of waters and wetlands. However, the SAB notes that a primary  
43 use of the Report is to assess connectivity among waters and wetlands and downgradient waters. As  
44 currently written, the Report is not clear about the degree to which its definitions of water bodies and  
45 wetlands include broader portions of the landscape (e.g., whether wetlands or rivers include their  
46 floodplains). The Report uses the wetland definition of Cowardin et al. (1979) to describe wetlands, and  
47 many public commenters have expressed concern about the potential expansion of the scope of

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1 jurisdiction of the underlying Clean Water Act – from “three-parameter<sup>1</sup>” to “one-parameter” waters and  
2 wetlands. These confusions and concerns could be explicitly addressed in a separate section outlining  
3 the scope of the Report immediately after the section defining connectivity. Waters and wetlands should  
4 be clearly identified as being the large set of waters and wetlands as defined by Cowardin et al. (1979), a  
5 subset of which is covered by the Clean Water Act as set forth under 33 CFR 328.3. As part of that  
6 discussion, the Report should explain why the Cowardin et al. definition of a wetland was used<sup>2</sup>. The  
7 SAB recognizes that the Report is a scientific and not a policy document, but finds that ignoring this  
8 distinction only serves to create unnecessary confusion and concern among the readership.

9  
10 *Recommendations*

- 11
- 12 • The scope of the Report should be clearly delineated, with special attention paid to clearly defining  
13 what are considered waters and wetlands.
- 14
- 15 • The Report should consider the functional role of floodplains and riparian areas irrespective of their  
16 classification as wetlands or other water bodies (see discussion in Section 3.5.2 of this report). The  
17 Report should clearly indicate that waters and wetlands covered in the Report are considered to be  
18 the large set of waters and wetlands as defined by Cowardin et al. (1979), a subset of which is  
19 covered by the Clean Water Act as set forth under 33 CFR 328.3. As part of that discussion, the  
20 Report should explain why the Cowardin et al. definition of a wetland was used.
- 21

22 **3.2.3. Use of a Flowpath Framework**

23  
24 As currently written, Chapter 3 of the Report contains detailed information about river system  
25 characteristics, the effects of streams and wetlands on downstream waters, and factors influencing  
26 connectivity. However, the Chapter lacks an explicit conceptual framework, which makes it difficult to  
27 categorize and organize this detailed information. Thus, the SAB recommends that a conceptual  
28 framework be established and discussed at the beginning of Chapter 3. This conceptual framework could  
29 be expressed as continuous hydrological (surface and subsurface), chemical, and biological flowpaths  
30 connecting watersheds from “ridge to reef,” and therefore connecting waters and wetlands to  
31 downgradient waters. The flowpath framework should highlight the four-dimensional nature of  
32 connectivity, because four-dimensional connectivity scaled in a habitat to catchment context is a  
33 foundational aspect of freshwater ecology (e.g., Ward 1989). The flux and transformation of water,  
34 materials, and organisms – which fundamentally control the integrity of downgradient freshwater  
35 ecosystems – occur at varying rates primarily determined by climate, geology, and relief and primarily  
36 expressed in terms of surface-water and groundwater storage and flow through the landscape (e.g.,  
37 uplands, wetlands, lakes, rivers, and floodplains). Therefore, these flowpaths are inherently multi-  
38 directional (i.e., longitudinal, lateral, vertical, and through time).

---

<sup>1</sup> The “one parameter” wetland classification system (Cowardin et al., 1979) classifies an area as a wetland if it has one or more of the following three attributes: (1) the area supports predominantly hydrophytes at least periodically; (2) the land has substrate that is predominantly undrained hydric soil; or (3) the land has nonsoil substrate that is saturated with water or covered by shallow water at some time during the growing season of each year. The “three parameter” classification system (33CFR 328.3(b); USACE 1987) requires that an area have all three of these attributes to be classified as a wetland.

<sup>2</sup> In response to questions from the SAB about the use of the “one parameter” wetland classification, EPA scientists explained that much of the scientific literature does not specify the method used to delineate the wetlands under study. Thus, EPA scientists used the broader ‘one parameter’ definition of wetlands to more fully assess the entirety of the available scientific literature.

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1 The flowpath framework could be briefly presented and discussed in the context of a revised Figure 1-1  
2 (currently on page 1-2 of the Report), which could be moved to the beginning of Chapter 3 and  
3 expanded to include at least some representation of hydrological, chemical, and biological flowpaths. In  
4 the revised figure, each representative type of flowpath could be color coded (e.g., hydrological=blue,  
5 chemical=red, and biological=green). The revised Figure 1-1 would thus become Figure 3-1. In the  
6 conceptual framework, hydrological flowpaths should be expressed in terms of both surface-water and  
7 groundwater flowpaths, with the latter including the potential for groundwater connections to cross  
8 watershed boundaries. For example, the Ogallala aquifer underlies parts of South Dakota, Nebraska,  
9 Wyoming, Colorado, Kansas, Oklahoma, New Mexico, and Texas, and the Floridan aquifer, underlies  
10 all of Florida as well as portions of Mississippi, Alabama, Georgia, and South Carolina. Chemical  
11 flowpaths should be expressed as largely following hydrological flowpaths, with subtle differences such  
12 as the typically tight nutrient spiraling that transitions to increasingly open spiraling from the headwaters  
13 to the outlet. However, chemical flowpaths could also be expressed as sometimes following biological  
14 flowpaths, with examples including marine-derived nutrients being transported to headwater streams by  
15 anadromous fish and nutrients being transported between waters and wetlands by birds that eat in one  
16 location and defecate in another. Biological flowpaths should be expressed as aquatic, terrestrial, and  
17 aerial flowpaths connecting watersheds internally, “ridge to reef,” and “reef to ridge,” and including the  
18 potential for biological connections to cross watershed boundaries. Taken to the extreme, the revised  
19 Figure 1-1 could become almost infinitely complex and equally incomprehensible, so it is important to  
20 clearly state that this is a conceptual framework with representative rather than complete flowpaths.

21  
22 Groundwater connectivity, in particular, could be better represented in the Report. The U.S. Geological  
23 Survey (USGS) has published numerous reports and learning tools on groundwater connectivity,  
24 including examples of flowpath frameworks expressed in block diagrams (Heath 1983; 1984; Winter et  
25 al. 1998). Care should be taken not to imply that bedrock is impermeable, given that groundwater flows  
26 through bedrock are important flowpaths that connect hydrologic landscapes over long distances and  
27 often across watershed boundaries (e.g., Roses et al. 1996).

28  
29 An important next step is to state how the revised conceptual framework is used in the Report. The SAB  
30 recommends that connectivity be discussed as a continuous phenomenon. However, we recognize that  
31 the EPA has chosen to discuss landscape settings discretely in the Report, with separate sections for  
32 rivers and streams, waters and wetlands in riparian/floodplain settings, and waters and wetlands in non-  
33 riparian/non-floodplain settings. This approach is not problematic, as long as the discrete classification  
34 is mapped onto the continuous conceptual framework. The integration of the discrete classification and  
35 continuous framework could be achieved by adding two panels to the revised Figure 1-1 described  
36 above, using the same base block diagram. In the second block diagram, all flowpaths could be removed  
37 and the classification system showing the three landscape settings (i.e., rivers and streams, waters and  
38 wetlands in riparian/floodplain settings, and waters and wetlands in non-riparian/non-floodplain  
39 settings) could be added. Then, in the third block diagram, the first and second block diagrams could be  
40 merged, clearly showing that the continuous phenomena (i.e., the hydrological, chemical, and biological  
41 flowpaths) interact across the discrete landscape settings (i.e., connect rivers and streams, waters and  
42 wetlands in riparian/floodplain settings, and waters and wetlands in non-riparian/non-floodplain settings  
43 to one another at the landscape scale).

44  
45 Some editorial or technical corrections are needed in the Report to address various omissions,  
46 inconsistencies, and errors in the hydrology section, as well as other sections, of the Report. These have  
47 been identified in the line-by-line preliminary written comments provided by SAB Panel members.

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Hillslope hydrology is discussed independently here because it is so central to the flowpath framework connecting all parts of the watershed, with water flowing from the “ridge to the reef” and potentially passing through or otherwise interacting with waters and wetlands along the way. The EPA Report should clearly describe the following four pathways through which water flows across the landscape:

1. Infiltration-Excess Overland Flow: This is the overland flow that occurs when the rainfall rate exceeds the infiltration rate, resulting in excess rainfall running overland despite a below-surface water table. This flow is also known as Hortonian overland flow because it was first described in the literature by Horton (1945).
2. Saturation-Excess Overland Flow: This is the overland flow that occurs when the water table rises to the surface, so that all additional rainfall runs overland. This is also known as Dunne’s mechanism because it was first described by Dunne and Black (1970).
3. Interflow: This is rapid lateral flow in the unsaturated zone of soil and rock. Interflow commonly occurs because above a low-permeability layer there are interconnected macropores that intercept and channel rainfall as would a subsurface pipe (e.g., Beven and Germann 1982).
4. Saturated Groundwater Flow: This is the normal saturated groundwater flow, where infiltrating rainfall reaches the water table and then flows laterally along with the general flow in the aquifer.

The Report should further discuss variable source areas and how they expand and contract, and therefore change the way that landscapes connect through storms and seasons (Dunne and Black 1970). Variable source areas have particularly important implications in regards to both infiltration-excess and saturation-excess overland flow, both of which are highly variable in space and time. The incomplete discussion of variable source areas is a critical shortcoming of the current version of the Report because it is through variable source area expansion that waters and wetlands in non-riparian/non-floodplain settings can intermittently or ephemerally become the headward extent of headwater streams (e.g., Rains et al. 2006; 2008). In other words, these waters and wetlands can functionally change landscape position, from functionally being waters and wetlands in non-riparian/non-floodplain settings under some conditions to functionally being rivers and streams under other conditions. This type of switching behavior is one of the reasons for the SAB recommendation that connectivity be discussed as a continuous phenomenon. As previously noted, the EPA has chosen to discuss landscape settings discretely and has organized the Report in sections focusing on rivers and streams, waters and wetlands in riparian/floodplain settings, and waters and wetlands in non-riparian/non-floodplain settings. If landscapes are considered to be discrete, it is important to clearly state that the lines delineating these landscape categories are conceptual and/or fluid, i.e., that there are no fixed bright lines between the categories.

To provide a better understanding of groundwater connectivity, and the way that groundwater connectivity might vary spatially, the SAB recommends that the EPA also consider using the ASTM D5979-96 Standard Guide for Conceptualization and Characterization of Groundwater Systems (ASTM 1996). This document was developed with funding from the EPA and it provides an effective way to characterize groundwater systems in diverse hydrogeological settings (e.g., Kolm et al. 1996). To better characterize regional-scale groundwater connectivity, the SAB recommends that the EPA also consider using findings from the U.S. Geological Survey Regional Aquifer Systems Analysis (RASA) Program.

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1 An understanding of regional groundwater flow systems is critical to the understanding of four-  
2 dimensional hydrologic connectivity on both the local and regional scales. Understanding groundwater  
3 flow in unique hydrogeologic settings, including the Floridan aquifer system (karst systems), the High  
4 Plains aquifer system (semi-arid systems), and the Snake River Plain aquifer system (volcanic bedrock  
5 systems), is especially important. These and other unique hydrogeological settings are covered by the  
6 RASA Program. More information, including a complete list of aquifer systems covered by the RASA  
7 Program, can be found in Sun et al. (1991).

8  
9 The SAB also recommends that the EPA include in the Report additional evidence of biological  
10 connectivity. Organisms use habitats that are critical to their life-history requirements (i.e., their life  
11 cycles cannot be completed without these habitats). These habitats are dispersed throughout watersheds  
12 and organisms move among the habitats often throughout their life cycles (e.g., Schlosser and  
13 Angermeier 1995; Falke et al. 2010). Some species maintain populations in downgradient waters but  
14 move upstream or laterally to use habitats that are dry seasonally and in some cases are dry several years  
15 in a row. Thus, these sometimes-dry habitats can be critical to the biological integrity of downgradient  
16 waters. Species using these habitats range across many different taxa, even within fish. The examples  
17 used in the Report tend to focus on only a few taxa, primarily salmon and other anadromous fish species.  
18 Many fish restricted to freshwater and many other taxa including invertebrates, amphibians, reptiles,  
19 birds, and mammals require these critical habitats and move to access them. When these upstream,  
20 lateral, and disconnected habitats are degraded or destroyed, populations decline and species can  
21 become threatened or endangered (or otherwise imperiled), or are extirpated entirely, thus connectivity  
22 is a key to the biological integrity of downgradient waters. Ignoring these connections can create new  
23 threatened and endangered species, especially for highly imperiled vertebrate groups like amphibians,  
24 but also invertebrates like mussels that are transported by fish (as glochidia, their larval stage)  
25 throughout watersheds.

26  
27 *Recommendations*

- 28
- 29 • The conceptual framework in the Report should be fully described at the beginning of Chapter 3.  
30 The framework should have a flowpath focus showing that watersheds are connected from “ridge to  
31 reef,” and that waters and wetlands in the landscape are therefore connected to downgradient waters  
32 by hydrological (surface and subsurface), chemical, and biological flowpaths.  
33
  - 34 • The conceptual framework in the Report should generally express the importance of climate,  
35 geology (surface and subsurface), and relief on flow and transport (e.g., hydrological and chemical  
36 connectivity). The resulting three-dimensional structure should show potential surface, near surface,  
37 and subsurface pathways, which then can be analyzed in terms of hydrological, chemical, and  
38 biological connectivity in four dimensions (i.e., with the temporal dimension included).  
39
  - 40 • The discrete-landscape classification system should be mapped onto the revised conceptual  
41 framework in the Report, with explicit acknowledgment that the classification system serves only as  
42 a communication tool. For example, rivers and streams, waters and wetlands in riparian/floodplain  
43 settings, and waters and wetlands in non-riparian/non-floodplain settings could be mapped onto the  
44 flowpath framework, explicitly showing that connections span these boundaries and that the  
45 boundaries are simply convenient ways to bound the landscape for discussion purposes.  
46

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- 1 • Groundwater connectivity, including regional groundwater connectivity across watershed divides,  
2 should be better defined in the Report and described in the context of connectivity between waters  
3 and wetlands and downgradient waters.  
4
- 5 • Biological connectivity should be better defined in the Report and described in the context of  
6 connectivity between waters and wetlands and downgradient waters.  
7

#### 8 **3.2.4. Revising and Defining the Terminology Used in the Report**

9  
10 With regard to the discrete categories of systems discussed in the Report (i.e., rivers and streams, waters  
11 and wetlands in riparian/floodplain settings, and waters and wetlands in non-riparian/non-floodplain  
12 settings), the SAB finds that “bidirectional” and “unidirectional” are misleading terms. The Report uses  
13 these terms to describe wetlands and open waters with: (1) the potential for non-tidal, bidirectional  
14 hydrologic flows with rivers and lakes; or (2) the potential for unidirectional hydrologic flows to rivers  
15 and lakes. As previously noted, the four-dimensional nature of connectivity is a foundational aspect of  
16 freshwater ecology (e.g., Ward 1989). Bidirectional and unidirectional hydrologic flow certainly  
17 describe a key difference among wetland and open water systems. Indeed, in some landscape settings,  
18 there are two-way fluxes of water and water-borne materials between the landscape and the rivers and  
19 streams, while in other landscape settings, there are only one-way fluxes of water and water-borne  
20 materials from the landscape to the rivers and streams. Although this is an important difference, it does  
21 not adequately characterize the four-dimensional fluxes in both landscapes, most particularly in regards  
22 to the movement of biota. The key difference in the respective settings is landscape position, with some  
23 waters and wetlands having flood-pulse exchanges with rivers and streams and other waters and  
24 wetlands not having flood-pulse exchanges with rivers and streams. Therefore, the SAB recommends  
25 that bidirectional wetlands be called “waters and wetlands in riparian/floodplain settings” and  
26 unidirectional wetlands be called “waters and wetlands in non-riparian/non-floodplain settings.” These  
27 terms would employ a commonly understood classification system that is grounded in the literature.  
28 This is important not only for communication purposes but also because it is consistent with the peer-  
29 reviewed, literature-based focus of the entire Report.  
30

31 The SAB also finds that use of the term “geographically isolated wetlands” by itself in the Report is  
32 problematic. The words “geographically isolated wetlands” technically mean “wetlands isolated in  
33 space.” However, “geographically isolated wetlands” are defined in the Report to mean “wetlands  
34 surrounded by uplands.” These are very different definitions. The SAB acknowledges that the term  
35 “geographically isolated wetlands” has been established in the literature, and is commonly used (e.g.,  
36 Tiner 2003b; 2003c). However, in the flowpath framework recommended by the SAB, there are no truly  
37 isolated waters or wetlands. Furthermore, as discussed in other sections of this SAB report, all waters  
38 and wetlands are connected over sufficiently long time scales. This conclusion is supported by the  
39 review and synthesis of the literature in the EPA Report. In other words, there are no isolated wetlands;  
40 rather, all waters and wetlands are connected, differing only in the degree of connection and the degree  
41 to which those connections matter to the chemical, physical, and biological integrity of downgradient  
42 waters. Therefore, the term “geographically isolated wetlands” runs counter to the continuous flowpath  
43 conceptual framework recommended by the SAB. A final point is that the term “geographically isolated  
44 wetlands” does not even fit into the current conceptual framework in the Report because the Report  
45 explicitly states that geographically isolated wetlands can occur in both riparian/floodplain settings and  
46 non-riparian/non-floodplain settings. The SAB therefore recommends that the EPA carefully define  
47 “geographically isolated wetlands” in terms of the literature, explain that the term “geographically

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1 isolated wetlands” was never meant to imply functional isolation, and then further explain that  
2 “geographically isolated wetlands” will not be used as an organizational term in Report. The SAB  
3 further recommends that the EPA then remove the term from later sections of the Report or, at the very  
4 least, ensure that the term is used consistently and not interchangeably with other terms, as it has been  
5 on occasion in the section of the Report on unidirectional wetlands.

6  
7 *Recommendations*

- 8
- 9 • The terms “bidirectional” and “unidirectional” do not adequately describe the four-dimensional  
10 nature of connectivity. These terms should be replaced in the Report with more commonly  
11 understood terms that are grounded in the peer-reviewed literature. The SAB recommends that  
12 bidirectional wetlands be called “waters and wetlands in riparian/floodplain settings” and  
13 unidirectional wetlands be called “waters and wetlands in non-riparian/non-floodplain settings.”  
14
  - 15 • The term “geographically isolated wetlands” is misleading because it implies isolation in spite of the  
16 fact that the flowpath framework implies that all parts of the watershed are connected, and that a  
17 fundamental finding of the SAB is that all waters and wetlands are connected at sufficiently long  
18 time scales. Therefore, the term “geographically isolated wetlands” should be defined in the Report  
19 in terms of the literature. The EPA should explain that use of the term “geographically isolated  
20 wetlands” does not imply functional isolation. The SAB recommends that, to the extent possible, the  
21 EPA avoid using the term in the Report.

22  
23 **3.2.5. Layers of Complexity in the Conceptual Framework**

24  
25 Once the EPA has described the flowpath framework and explained how the framework is used in the  
26 Report, additional layers of complexity (focusing on the issues discussed below) should be represented  
27 in the conceptual model. The SAB recognizes that some of these issues are already addressed in various  
28 parts of the Report. In those cases, the SAB recommends expanding upon or moving the discussion to  
29 the section of the Report that outlines the major concepts underlying the conceptual framework.

30  
31 *Functions*

32  
33 The SAB recommends layering water and wetland function on the flowpath framework. The Report  
34 should indicate that each water and wetland performs functions broadly categorized as source, sink, lag,  
35 transformation, and refuge, and that the degree to which each function is performed is dependent upon  
36 landscape position and related connectivity. The importance of including this in the discussion of the  
37 conceptual framework is to explain up front that some functions are enhanced by connectivity and others  
38 by relative isolation. This is an important point, one that is implicitly made throughout the report and  
39 explicitly made in the section on unidirectional wetlands. Including a functions layer in the conceptual  
40 framework will help clarify the later discussion of functions that are enhanced by connectivity or  
41 relative isolation.

42  
43 *Spatial and Temporal Scales*

44  
45 Spatial and temporal scales are critical aspects of connectivity and the role it plays in the chemical,  
46 physical, and biological integrity of downgradient waters. Low-frequency events that affect the  
47 chemical, physical, and biological integrity of downgradient waters can be particularly important if the



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1 effects are long lived or cumulative. Long lived effects might be best exemplified by debris flows, which  
2 are low-frequency events that nevertheless can be an important source of sediment, large clasts, and  
3 large woody debris to rivers. Though such debris flows occur infrequently, the consequences can be  
4 long lived, and can play important roles in controlling the structure and function of downgradient waters  
5 over the scale of decades. Important cumulative effects might be best exemplified by ephemeral flows in  
6 arid landscapes, low-frequency events that may nevertheless provide most of the subsidies to  
7 downgradient waters (e.g., Izbicki 2007). The SAB recommends that the Report compare and contrast  
8 the humid east and the arid southwest and indicate that downgradient waters in the humid east may get  
9 the bulk of their materials through moderate-frequency, moderate-magnitude events while downgradient  
10 waters in the arid southwest might get the bulk of their materials through low-frequency, high-  
11 magnitude events. The latter are no less important to the integrity of the downgradient waters, even  
12 though their duration may be negligible in comparison. Therefore, the importance of the connectivity is  
13 not just a function of the frequency or duration of the connection. One way to conceptualize this in the  
14 Report is by developing a matrix of probability  $\times$  consequence, which would facilitate a discussion of  
15 spaces occupied by given waters and wetlands. This would go a long way toward helping readers better  
16 understand the regional context of the spatial and temporal scale of connectivity.

17  
18 *Human Altered Systems*

19  
20 There are few, if any, ecosystems unaltered by humans. The role that these alterations play in the  
21 conceptual framework should be addressed explicitly in the Report. Waters and wetlands are  
22 "connected" in the sense that they are integrated into the broader hydrological landscape and therefore  
23 can play important roles in maintaining the chemical, physical, and biological integrity of downgradient  
24 waters. They perform a variety of functions (which are broadly classified in the Report as source, sink,  
25 lag, transformation, and refuge functions) at rates that are characteristic to where they are located on the  
26 gradient of connectivity. Therefore, downgradient waters might suffer consequences if the degree of  
27 connectivity is altered by human activities. Alterations can be of three types—some can directly  
28 decrease connectivity (e.g., dams), some can directly increase connectivity (e.g., ditches), and some can  
29 indirectly change the magnitude, timing, and/or duration of connectivity (e.g., impervious surfaces in the  
30 contributing watershed). Each of these three types of alterations constitute alterations to connectivity and  
31 therefore to the chemical, physical, and biological integrity of the downgradient waters.

32  
33 *Flow and Transport Forcings and Regionalization*

34  
35 The SAB finds that the Report fails to provide an adequate framework for considering connectivity in a  
36 regional context, especially for states such as Hawaii and Alaska. This problem has been identified by a  
37 number of public commenters. The EPA therefore should consider expressing flow and transport  
38 forcings in terms of Hydrologic-Landscape Regions, or HLRs (Wolock et al. 2004). This would not  
39 represent a large departure from the approach used in the Report because HLRs are fundamentally a  
40 function of climate, geology, and relief, which are already recognized as central controls on watershed  
41 hydrology. Using HLRs to consider flow and transport functions would ground the discussion to  
42 consistent terminology. The terminology in the Report is currently inconsistent, sometimes referring to  
43 climate, geology, and relief, sometimes to climate and watershed characteristics, and other times  
44 focusing only on climate. Using the HLRs also would ground the discussion in the Report to peer-  
45 reviewed literature on this matter. This could then serve as a means to discuss regionalization, because  
46 generalizations are context dependent, i.e., the expressions of chemical, physical, and biological  
47 phenomena depend on environmental setting (e.g., climatic, geologic, topographic). Associated with this

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1 issue is the fact that much more is known about connectivity in some settings than others. The Report  
2 could be improved by explicitly recommending that readers use the HLRs to better understand the  
3 relevance of the findings in the document to their respective regions.

4  
5 *Aggregate or Cumulative Effects*

6  
7 The aggregate or cumulative effect of many waters and wetlands on the chemical, physical, and  
8 biological integrity of downgradient waters is sufficiently important to merit its own subsection in the  
9 Report. Mainstem rivers integrate and accumulate the mass, materials, and organisms of numerous  
10 waters and wetlands, including tributaries. This is an important concept because the individual effect of  
11 any single water or wetland on downgradient waters might be negligible at sufficient spatial scale, but  
12 the cumulative effects of many similarly situated waters and wetlands on downgradient waters might  
13 nevertheless still be important. For example, at the scale of a single 200 km<sup>2</sup> watershed, the flow and  
14 sediment originating from a single headwater stream with a drainage area of < 1 km<sup>2</sup> may make a  
15 minimal contribution to the sediment budget of the mainstem river, but the space-time integration of all  
16 headwater streams with drainage areas of < 1 km<sup>2</sup> in the watershed governs the total sediment budget of  
17 the mainstem larger river and the resulting in-channel sediment storage, channel morphology, and  
18 aquatic habitat.

19  
20 Cumulative effects could be defined as an emergent property of all headwater streams in the watershed  
21 (i.e., a river network statistical attribute). A measurable effect on downgradient waters may not be  
22 detected if only a small number of headwater streams within a watershed were impacted, whereas there  
23 could be substantial and possibly cascading effects on downgradient waters were a larger number of  
24 headwater streams impacted. Moreover, the extent of downgradient effects reflects a convolution—both  
25 in space and time—of each headwater stream’s time-varying flux of mass, materials, and organisms. For  
26 example, in a watershed with a 200-year recurrence interval of debris flows on headwater streams, the  
27 probability of a debris flow on any given headwater stream in a given year is 0.5% - likely a negligible  
28 effect on fish habitat in downgradient waters. However, at the watershed scale, there are hundreds of  
29 headwater streams, which means that the annual probability of a debris flow in the “population” of  
30 headwater streams is much higher and more likely to substantially affect downgradient fish habitats.  
31 Many studies have been published on these kinds of cumulative effects (e.g., Johnston et al. 1990).  
32 Therefore, any evaluation of changes to individual waters and wetlands must consider the context of past  
33 and planned alterations of other waters and wetlands in the watershed.

34  
35 *Map Scale*

36  
37 The important issue of map resolution is mentioned in several parts of the Report but it needs to be more  
38 clearly and thoroughly presented in a separate section, or perhaps in a figure comparing the results of  
39 using different technologies. A related topic that could be addressed in the Report is the increasing  
40 availability of light detection and ranging (LiDAR) digital elevation models (DEMs) and thus the  
41 increasing ability to create more accurate and denser stream networks; this illustrates how new  
42 technologies may influence the scientific understanding of connectivity.

43  
44 It is critical that readers of the Report understand that many databases fail to include small streams and  
45 thus do not represent the full extent and magnitude of the river and stream network. For example, Meyer  
46 and Wallace (2001) have indicated that in a North Carolina watershed 0.8 km of stream channel are  
47 shown on a 1:500,000 scale map whereas 56 km of stream channel are shown on a 1:7200 scale map;

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1 only 21% of stream channel length is shown on a 1:24000 scale map in another watershed. The  
2 increasing availability of high resolution DEM, including the National Elevation Dataset (NED) 10 m  
3 DEM. (USGS 2014) and more robust flow routing algorithms means that more accurate stream maps are  
4 becoming increasingly available. Thus the ability to predict (and discern) physical, chemical, and  
5 biological connections between small and large streams is increasing rapidly. Hence, the degree of  
6 connectivity will be determined in some part by advances in technology.

7  
8 *Recommendations*

- 9
- 10 • Once the EPA has described the flowpath framework and explained how the framework is used in  
11 the Report, additional layers of complexity should be represented in the conceptual model. In  
12 developing additional layers of complexity, the EPA should focus on the following issues.  
13
    - 14 – A water and wetland function framework should be layered on the flowpath framework. EPA  
15 should indicate that each water and wetland performs functions broadly categorized as source,  
16 sink, lag, transformation, and refuge, with the degree to which each function is performed being  
17 dependent upon landscape position and related connectivity.
    - 18 – Spatial and temporal scales should be addressed in the discussion of connectivity and the role it  
19 plays in the chemical, physical, and biological integrity of downgradient waters. Of particular  
20 importance is the potential importance of low-frequency events.
    - 21 – The role that human alterations play in the conceptual framework should be addressed explicitly.
    - 22 – The EPA should consider expressing forcings in terms of Hydrologic-Landscape Regions, or  
23 HLRs (Wolock et al. 2004). This would better enable readers to understand the regional  
24 relevance of findings in the Report.
    - 25 – The aggregate or cumulative effect of many waters and wetlands on the chemical, physical, and  
26 biological integrity of downgradient waters is sufficiently important to merit its own subsection  
27 in the Report.
    - 28 – The important issue of map resolution is mentioned in several parts of the report, but it should be  
29 more clearly and thoroughly presented in a separate section.
- 30

31 **3.2.6. Summary and Synthesis of the Conceptual Framework**

32  
33 The SAB finds that Chapter 3 of the Report ends abruptly, with no summary or synthesis of the  
34 conceptual framework. The SAB recommends that the EPA consider moving Figure 6.1 (The role of  
35 connectivity in maintaining the physical, chemical, and biological integrity of water) to the end of  
36 Chapter 3. The figure could then be used as a means of summarizing and synthesizing the conceptual  
37 model and explaining how the model guides the way that the agency is thinking about and presenting  
38 evidence of connectivity between waters and wetlands and downgradient waters. This figure succinctly  
39 shows the role played by connectivity in maintaining the chemical, physical, and biological integrity of  
40 downgradient waters and hence would serve this purpose well in Chapter 3.

41  
42 *Recommendation*

- 43
- 44 • A summary and synthesis of the conceptual framework should be added to the end of Chapter 3 of  
45 the Report using what is currently Figure 6.1 to frame the discussion.
- 46  
47

### 3.3. Review of the Literature on Ephemeral, Intermittent, and Perennial Streams

*Charge Question 3(a). Chapter 4 of the draft Report reviews the literature on the directional (downstream) connectivity and effects of ephemeral, intermittent, and perennial streams (including flow-through wetlands). Please comment on whether the Report includes the most relevant published literature with respect to these types of streams. Please also comment on whether the literature has been correctly summarized. Please identify any published peer reviewed studies that should be added to the Report, any cited literature that is not relevant to the review objectives of the Report, and any corrections that may be needed in the characterization of the literature.*

The SAB finds that Chapter 4 of the Report is an excellent review of the peer reviewed literature that describes the connectivity of headwater streams to downstream waters. The Report documents the current scientific understanding that there are numerous ways that headwater streams are connected to downstream ecosystems and that these connections are essential in promoting the physical, chemical, and biological integrity of downstream ecosystems. The connections between headwaters and downstream ecosystems are well established as a foundational concept in stream ecology.

The review is based on pertinent literature and is strongly grounded in current science. However, the SAB provides a number of recommendations to improve the literature review in Chapter 4 of the Report. The SAB has also identified additional references to relevant peer reviewed literature that the EPA should consider citing in the Report.

#### 3.3.1. Expanding the Review of Hydrologic Exchange Flows between Main Channels and Off Channel Areas

The SAB recommends that the literature review in Chapter 4 of the Report be expanded to include the description of exchanges between main channels and relatively slow moving subsurface waters and surface waters located at channel margins (in pools and in recirculating eddies). The review should include a more complete discussion of the processes involved and give more attention to spatial and temporal variability. The revised text should also include broader discussion of associated biogeochemical transformations that change the form and mobility of dissolved chemicals that affect downstream water quality. The discussion should go beyond solely discussing nitrate removal to include phosphorus removal and examples of fate and transport of contaminants such as toxic metals and organic contaminants. The review should also describe how surface-subsurface water interactions affect stream temperature and habitat for fish and other organisms, particularly when surface water flows diminish but subsurface flow is present.

The following references (and others that are similar) should be considered for inclusion in a broader discussion of hyporheic processes: Buffington and Tonina (2009); Karwan and Saiers (2012); Poole et al. (2006); Sawyer, et al. (2011); and Stonedahl et al. (2010).

#### *Recommendations*

- The review of hydrologic exchange flows between main channels and off channel areas should be expanded in the Report to include the topics summarized above.

- 1 • The additional references identified above (and others that are similar) should be considered for  
2 inclusion in the Report for a broader discussion of hyporheic processes.  
3

4 **3.3.2. Expanding the Discussion of Naturally Occurring Chemical Constituents, Contaminants,  
5 and Contaminant Transformations**  
6

7 The EPA should expand the discussion in the Report of naturally occurring chemical constituents other  
8 than nutrients (i.e., nitrogen and phosphorus), contaminants, and contaminant transformations. The SAB  
9 finds that the Report needs a more thorough characterization of upslope (surface and subsurface) effects  
10 of geology, soils, and hydrology on overall water chemistry (e.g., conductivity, alkalinity, pH, major  
11 cations) and the consequences of altering these upslope processes on downstream water chemistry and  
12 associated ecological responses. The role of nutrient spiraling as a demonstration of connections between  
13 headwaters and downstream ecosystems is covered in the Report, but the Report could be strengthened if  
14 more attention were given to the important transformations that affect mobility, toxicity, and time lags of  
15 storage or degree of removal that occurs and how it affects downstream loading of nutrients and  
16 contaminants. The Report should also further discuss sediment bound contaminants and their downstream  
17 movement and effects on downstream waters.  
18

19 The following references (and others that are similar) should be considered for inclusion in the  
20 discussion of naturally occurring chemical constituents, contaminants and contaminant transformation  
21 processes: Baker et al. (2000); Bourg and Bertin (1993); Conant et al. (2004); Doyle et al. (2003);  
22 Ensign et al. (2008); Fuller and Harvey (2000); Harvey and Fuller (1998); Harvey et al. (2013); Hedin et  
23 al. (1998); Kim et al. (1992); Kim et al. (1995); Kimball et al. (1994); Lautz and Fanelli (2008);  
24 Malcolm et al. (2005); and O'Connor and Harvey (2008).  
25

26 *Recommendations*  
27

- 28 • The Report should be revised to include discussion of naturally occurring chemical constituents  
29 other than nutrients (i.e., nitrogen, phosphorus), contaminants, and to consider nutrients,  
30 contaminants, and contaminant transformation processes.  
31
- 32 • The additional references identified above, and others that are similar, should be considered for  
33 inclusion in the discussion of naturally occurring chemical constituents, contaminants and  
34 contaminant transformation processes.  
35

36 **3.3.3. Expanding the Discussion of Factors that Influence Stream Temperature**  
37

38 The SAB finds that the discussion of the role of upslope factors affecting the relative contributions of  
39 surface and shallow and deeper subsurface waters to channel flow and stream temperature should be  
40 expanded. The Report should more explicitly describe the effects of hyporheic flow and storage and  
41 resulting lag and attenuation effects that buffer temperature extremes within streams. The discussion of  
42 these latter subsurface hyporheic effects should include a comparison to direct groundwater discharge in  
43 terms of their comparative effects on stream temperature dynamics. In addition, the treatment of the  
44 direct and indirect effects of upstream/upslope riparian shading, channel morphology, and channel  
45 network topology on stream temperature should be expanded. The SAB recommends that the Report be  
46 revised to expand the discussion of how environmental alterations in channels and upslope areas

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1 influence stream temperature dynamics. The SAB further recommends that the Report directly address  
2 the influence of stream temperature on downstream connectivity.

3  
4 The following references (and others that are similar) should be considered for inclusion in the  
5 discussion of factors that influence stream temperature: Arrigoni et al. (2008); Hester et al. (2009); and  
6 Sawyer et al. (2012).

7  
8 *Recommendations*

- 9
- 10 • The discussion of upslope factors that influence stream temperature should be expanded to include:  
11 hyporheic flow and storage, a comparison to groundwater effects on stream temperature;  
12 upstream/upslope riparian shading; channel morphology; channel network topology; and  
13 environmental/human alterations in upslope areas and channels.
  - 14
  - 15 • The Report should explicitly discuss the influence of stream temperature on downstream  
16 connectivity.
  - 17
  - 18 • The additional references identified above, and others that are similar, should be considered for  
19 inclusion in the discussion of factors that influence stream temperature.
  - 20

21 **3.3.4. Clarifying the Temporal Dynamics of Flow-Related Aspects of Connectivity**

22  
23 The Report does not contain a succinct yet comprehensive paragraph that covers the temporal dynamics  
24 of connectivity for headwater streams (e.g., headwaters that connect perennial, intermittent, and  
25 ephemeral channels with their variable source areas) and effects on the transport of materials and  
26 sediment and on downstream water quality. The SAB finds that Chapter 4 would benefit from a separate  
27 section on this topic. Such a section should more fully characterize the temporal dynamics of streamflow  
28 (i.e., magnitude, frequency, duration, and timing) and its effects on downstream connectivity. In  
29 particular, the section should note that it is the *effect* of flows that determines their importance to  
30 downstream connectivity. For example, the Report correctly describes how headwater streams can  
31 contribute a large fraction of the water in downstream ecosystems over an annual cycle, even though  
32 they are periodically dry. The SAB recommends that the discussion of ecological consequences of flow  
33 connections provided by headwater streams be expanded. The SAB also finds that short-term flow  
34 connections can be important. That is, connectivity can be highly episodic, but this does not reduce its  
35 inherent importance to downstream ecosystems.

36  
37 More discussion and additional literature citations should be included in the Report to highlight the  
38 importance of short duration floods and longer duration droughts and their effects on downstream  
39 ecosystems. The SAB recommends that the Report be revised to explicitly recognize the important role  
40 of variable hydraulic residence times in river networks and their effects on the storage and  
41 transformation of organic matter and nutrients in downstream waters. In addition, the Report should  
42 discuss how human alterations affect the temporal dimensions of connectivity (e.g., via water  
43 withdrawal or augmentation). Overall, the SAB recommends tightening the entire report to make it clear  
44 how intermittent and ephemeral streams are connected in space and time to downstream ecosystems.

45  
46 The following references (and others that are similar) should be considered for inclusion in the Report to  
47 illustrate the ways in which intermittent and ephemeral streams are connected in space and time to

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1 downstream ecosystems and the effects of these connections: Boano et al. (2013); Constantz (2008);  
2 Harvey et al. (2012); and O'Connor et al. (2012).

3  
4 *Recommendations*

- 5
- 6 • The Report should include a new section that explicitly examines the temporal dynamics of  
7 connectivity for headwater streams (e.g., headwaters that connect perennial, intermittent, and  
8 ephemeral channels with their variable source areas) and effects on the transport of materials and  
9 sediment and on downstream water quality. The new section should note that it is the *effect* of flows  
10 that determines their importance to downstream connectivity.
  - 11
  - 12 • The Report should be revised to explicitly recognize the important role of variable hydraulic  
13 residence time in river networks and its effects on the storage and transformation of organic matter  
14 and nutrients in downstream waters.
  - 15
  - 16 • The Report should include discussion of how human alterations affect the temporal dimensions of  
17 connectivity, e.g. via water withdrawal or augmentation.
  - 18
  - 19 • The additional references identified above (and others that are similar) should be considered for  
20 inclusion in the Report to illustrate the ways in which intermittent and ephemeral streams are  
21 connected in space and time to downstream ecosystems and the effects of these connections.
  - 22

23 **3.3.5. Strengthening the Review of Biological Connectivity**

24  
25 As previously discussed, the report should be revised to more thoroughly document evidence that biota  
26 move throughout the lotic system (e.g., in upstream, lateral, and downstream waters) to use critical  
27 habitats and that these movements have strong and important effects on biological integrity. A more  
28 thorough treatment of biological connectivity would strengthen Chapter 4 of the report. The following  
29 key points should be included in the Chapter:

- 30
- 31 – Organisms require habitats that are dispersed throughout watersheds (i.e., their populations  
32 cannot persist without these habitats), and many species move among these habitats during  
33 their life cycles.
  - 34 – Some species maintain populations in downstream receiving waters, but move upstream or  
35 laterally to use habitats that are dry seasonally and in some cases are dry several years in a row.  
36 Thus, these intermittent or ephemeral habitats often can be critical to the biological integrity of  
37 downstream waters.
  - 38 – These mobile species range across many different taxa, even within fish, and include many  
39 more than those identified in the Report, which focuses largely on salmon and other  
40 anadromous fish. Many fish living solely in freshwater, and many other taxa including  
41 amphibians, reptiles, birds, mammals, and important invertebrates, require these habitats and  
42 move to access them.
  - 43 – Data from comparative studies and experiments show that these animal populations decline or  
44 are extirpated entirely when upstream, lateral, and disconnected habitats are degraded or  
45 destroyed. Thus, connectivity to these habitats is a key to the biological integrity of  
46 downstream waters.

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- Ignoring these critical habitat connections can create new threatened and endangered species, especially for highly imperiled vertebrate groups like amphibians, but also highly imperiled groups of invertebrates like mussels whose larvae are transported throughout watersheds by their fish hosts.

*Recommendation*

- The Report should more thoroughly document evidence that biota move throughout the lotic system (e.g., in upstream, lateral, and downstream waters) in order to use critical habitats and that these movements have strong and important effects on biological integrity of downstream waters, as detailed in the points above.

**3.3.6. Review of the Human-Modified Headwater Stream Literature**

As previously mentioned, the SAB finds that the Report lacks references to the literature on human-modified headwater streams. This literature should be included in the Report in order to provide information about the consequences of alterations of headwater systems to water quality and biota of downstream ecosystems. Many headwater stream ecosystems are altered by human activity that often disrupts connectivity; the effects of such disruptions illustrate the importance of headwaters to downstream areas in various landscapes. The SAB recommends that connectivity be discussed within the context of the following human alterations: agricultural ditches and tile drains, urban lined channels and buried streams, removal of riparian trees, cattle grazing, gravel mining, channel diversions, low dams, grade control structures, stream restoration, and effluent dominated streams. Some of these alterations reduce connections to downstream waters, but some alterations increase the frequency and magnitude of connections. In addition, human-altered or even human-created streams may provide significant ecological functions that can affect downstream waters. A succinct discussion of the downstream consequences of stream restoration would also strengthen the Report.

The following references (and others that are similar) should be considered for inclusion in the Report to illustrate the effects of human alterations to headwater streams: Lautz et al. (2008); and O'Connor et al. (2010).

*Recommendations*

- The draft Report should be revised to include information about the consequences of alteration of headwater systems to water quality and biota of downstream ecosystems. These revisions should include discussion of the positive and negative effect of: agricultural ditches and tile drains, urban lined channels and buried streams, removal of riparian trees, cattle grazing, gravel mining, channel diversions, low dams, grade control structures, stream restoration, and effluent dominated streams.
- The additional references identified above, and others that are similar, should be considered for inclusion in the Report in order to illustrate the effects of human alterations to headwater streams.



1 **3.3.7. Highlighting the Role of Headwater Streams in Aggregate and Cumulative Effects**  
2 **On Downstream Ecosystems**  
3

4 The SAB recommends that a new section on the role of headwater streams in aggregate and cumulative  
5 effects on downstream ecosystems be added to Chapter 4 of the Report. This new section should draw  
6 upon the large body of literature on cumulative watershed effects of land use, based on both modeling  
7 and empirical studies. In addition, the existing section on watershed modeling should be improved by  
8 expanding the discussion to include results from models beyond the SPARROW model (SPATIally  
9 Referenced Regressions On Watershed attributes).

10  
11 The following references (and others that are similar) should be considered for inclusion in the Report to  
12 document the role of headwater streams in aggregate and cumulative effects on downstream ecosystems:  
13 Alexander et al. (2009); Böhlke et al. (2009); and Helton et al. (2011).

14  
15 *Recommendations*  
16

- 17 • A new section on aggregate and cumulative effects of headwater streams on downstream ecosystems  
18 should be added to Chapter 4 of the Report.
- 19
- 20 • The findings of the modeling and empirical studies on the cumulative effects of land use on water  
21 quality should be summarized in the Report.
- 22
- 23 • The modeling section of the Report should be expanded to include results from additional models.
- 24
- 25 • The additional references identified above, and others that are similar, should be considered for  
26 inclusion in the Report to document the aggregate and cumulative effects to downstream  
27 connectivity.
- 28

29 **3.3.8. Expanding the Discussion of the Effects of Streamside Vegetation on Stream Ecosystems**  
30

31 The SAB notes that many of the beneficial ecological effects of streamside vegetation are not  
32 exclusively associated with riparian wetland function (e.g., effects of leaf litter inputs to downstream  
33 food resources, effects of woody debris on channel morphology, sediment and organic matter storage,  
34 hydrologic retention, and modulation of stream temperature, among others). These beneficial effects  
35 occur along the entire longitudinal profile, but are especially important to headwater streams. The SAB  
36 recommends that the draft Report be revised to expand the discussion of the effects of streamside  
37 vegetation on stream ecosystems.

38  
39 *Recommendation*  
40

- 41 • The Report should be revised and additional references should be added to expand the discussion of  
42 the effects of streamside vegetation on stream ecosystems.
- 43
- 44
- 45
- 46
- 47

### 3.3.9 Food-web Connections from Riparian Zones to Streams that Support Aquatic Organisms

The SAB recommends adding a new section to the Report to thoroughly address the importance of food-web connections from riparian zones to streams that support aquatic organisms. The Report focuses on strictly aquatic connections, however, organisms that define the biological integrity of downstream waters are embedded in food webs and these food webs transcend aquatic-terrestrial boundaries. The following key points should be included in the new text:

- Streams receive leaves, wood, and other plant litter from riparian vegetation, and these supply carbon and nutrients to biota ranging from microbes to invertebrates, which in turn feed larger invertebrates, fish, amphibians, reptiles, birds, and mammals.
- Streams also receive terrestrial invertebrates, which are used directly as prey by fish and amphibians, either in the same reach, or after flowing downstream from headwaters into reaches that support these predators.
- Linkages between riparian zones and streams are critical to maintaining the biological integrity of the Nation’s waters, and data from comparative studies and experiments support the generalization that cutting off these connections can cause emigration or extirpation of organisms that rely on food web connections from streams to riparian zones.
- Finally, food webs integrate aquatic and terrestrial landscapes and therefore provide a useful lens through which to view connectivity in aquatic ecosystems.

#### *Recommendations*

- The SAB recommends adding a new section (with additional references) to the Report to thoroughly document the importance of food-web connections from riparian zones to streams; the new section should discuss the points itemized above.

### 3.3.10. Clarifying How Case Studies Were Selected

As previously discussed, the SAB recommends that text be added to the Report to clarify how the case studies were selected. In addition, a case study that focuses on human-dominated systems should be added to the Report in order to include information about the effect of human-dominated systems on downstream waters. For example, the Rio Grande case study on arid rivers provides excellent examples of human-modified systems and its description of human effects could be expanded.

#### *Recommendations*

- The Report text should explain the rationale for selecting case studies.
- The Report should contain a case study that illustrates the downstream effects of human-modified systems, perhaps through revising the Rio Grande case study.

1 **3.3.11. Clarifying the Report Findings Concerning the Strength or Degree of Downstream**  
2 **Connectivity**  
3

4 The SAB recommends that the Report text be revised to address the strength or degree of downstream  
5 connectivity. At a minimum, this clarification should be addressed in the Chapter 4 section on headwater  
6 streams, but the topic should also be clarified throughout the Report. In particular, the SAB finds that the  
7 Report needs a more focused discussion of the relative strength/degree of connectivity of intermittent  
8 and ephemeral streams and their variable source areas. This could be achieved through a discussion of  
9 the frequency, duration, and magnitude of surface and subsurface connections. It is important to note  
10 that subsurface flows often persist after surface flows wane; further, these subsurface flows may provide  
11 important connectivity functions from ephemeral streams to downstream waters. In addition, as  
12 previously discussed, even ephemeral streams and short duration surface water connections in source  
13 water areas may have substantial effects on the chemistry and biology of downstream waters.

14  
15 The SAB recommends that the following reference (and others that are similar) be considered for  
16 inclusion in the Report to document the strength or degree of downstream connectivity: Larsen et al.  
17 (2012).

18  
19 *Recommendations*  
20

- 21 • The SAB recommends that the degree/strength of downstream connections be highlighted or  
22 discussed in each major subsection of Chapter 4 and in other sections of the Report (e.g. for  
23 subsections on temperature, chemical, and biological connections).
- 24  
25 • The additional reference identified above (and others that are similar) should be considered for  
26 inclusion in the Report to document the strength or degree of downstream connectivity.
- 27

28 **3.4. Review of the Findings and Conclusions Concerning Ephemeral, Intermittent, and**  
29 **Perennial Streams**  
30

31 *Charge Question 3(b). Conclusion (1) in section 1.4.1 of the draft Report Executive*  
32 *Summary discusses major findings and conclusions from the literature referenced in*  
33 *Charge Question 3 (a) above. Please comment on whether the conclusions and findings*  
34 *in section 1.4.1 are supported by the available science. Please note alternative wordings*  
35 *for any conclusions and findings that are not fully supported.*  
36

37 Conclusion 1 in Section 1.4.1 of the Report states that: *The scientific literature demonstrates that*  
38 *streams, individually or cumulatively, exert a strong influence on the character and functioning of*  
39 *downstream waters. The Report further states that: All tributary streams, including perennial,*  
40 *intermittent, and ephemeral streams, are physically, chemically, and biologically connected to*  
41 *downstream rivers via channels and associated alluvial deposits where water and other materials are*  
42 *concentrated, mixed, transformed, and transported. The SAB finds that the Report provides strong*  
43 *scientific support for these conclusions and related findings. The SAB strongly supports the current*  
44 *emphasis in this Section on the importance of considering cumulative impacts and recommends minor*  
45 *but nevertheless important changes in the conclusions and findings in Section 1.4.1.*  
46

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1 The Report should be revised so that the conclusions and findings in Section 1.4.1 are clearly linked to  
2 the foundational concept that connectivity is expressed in four dimensions (i.e., three dimensional space,  
3 plus time) within the context of a catchment. The SAB recommends that the conclusions emphasize not  
4 only hydrologic linkages, but also include biogeochemical transformations and diverse biological  
5 connections. The text in Section 4.6 of the Report, “Synthesis and Implications,” (p. 4-35) could be  
6 improved through the use of bullets that would highlight the main findings. This would underscore the  
7 key functions summarized in Table 4.1 which outline the five key stream functions and their effect on  
8 downstream waters: sources, sinks, refuges, transformations, and lags. The SAB recommends adding  
9 connectivity itself to Table 4.1, perhaps using biological connections as an example. In addition, the  
10 Report’s five key functions and linkages (six if connectivity is included) should be reiterated succinctly<sup>1</sup>  
11 and consistently across the relevant Report chapters. These are Sections 4.6, “Streams: Synthesis and  
12 Implications” (p. 4-35); Section 1.4.1, “Key Findings” (p.1-7); and Section 6.1, “Major Conclusions” (p.  
13 6-1). At present, these summaries vary in content, length, presentation style, and number of literature  
14 citations and, most importantly, these inconsistencies obscure the Report’s conclusions.

15  
16 *Recommendations*

- 17
- 18 • The conclusions in Section 1.4.1 of the Report should be clearly linked to the foundational  
19 concept that connectivity is expressed in four dimensions (i.e., three dimensional space plus  
20 time) within the context of a catchment.
- 21
- 22 • The conclusions in Section 1.4.1 should emphasize not only hydrologic linkages, but also include  
23 biogeochemical transformations and diverse biological connections.
- 24
- 25 • Bullet points should be used to highlight main findings in the text on “Synthesis and  
26 Implications.”
- 27
- 28 • “Connectivity” should be added to Table 4.1 using biological connections as an example.
- 29
- 30 • The Report’s key functions and linkages should be succinctly and consistently summarized  
31 across all the relevant Report chapters.
- 32

33 **3.4.1. Recommendations to Strengthen the Findings and Conclusions Concerning Ephemeral,  
34 Intermittent, and Perennial Streams**

35  
36 The SAB recommends that the Report be revised to strengthen the findings and conclusions concerning  
37 ephemeral, intermittent, and perennial streams by addressing the specific issues discussed below.

38  
39 *Connectivity, Boundaries and Linkages*

40  
41 The SAB recommends that the statements in the Report that support conclusions about the connectivity  
42 of streams should be stated in quantitative terms wherever possible (For example: “of X studies, X%  
43 support the conclusion of connectivity.”)  
44

---

<sup>1</sup> The summary should not include reference to literature already cited in the Report.

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1 The SAB also recommends that the text of the Report be revised to provide better definition of  
2 boundaries (e.g., transitions between uplands and headwaters) and acknowledge where boundaries are  
3 difficult to define. The report should also better define and emphasize key linkages and exchanges that  
4 influence connectivity (e.g., groundwater-surface water interactions, flooding or other episodic events,  
5 and the influence of riparian zones) and how these linkages influence biota and food webs and vice  
6 versa. For example, the first sentence in Section 4.6, “Streams: Synthesis and Implications,” should be  
7 revised to state that “A substantial body of evidence unequivocally demonstrates connectivity *above and*  
8 *below ground.*” The conclusions should also reiterate how these linkages and exchanges influence  
9 physical, chemical, and biological connectivity with downstream systems.

10  
11 The SAB finds that connectivity linkages that occur during flooding are not well-represented in the  
12 conclusions. In addition, the SAB recommends that text be added to the Report to explain how  
13 hydrologic connectivity sustains aquifers. Alluvial systems in the southwest and karst systems in the  
14 eastern U.S. should be used as examples.

15  
16 *Ephemeral Streams*

17  
18 The Report concludes that existing evidence supports a sufficient link between ephemeral streams and  
19 downstream systems. The SAB finds that this conclusion could be strengthened in three ways: (1) by  
20 adding text that describes spatial and temporal variation in linkages of ephemeral streams with  
21 downstream waters; (2) by summarizing existing evidence of the frequency of these connections; and (3)  
22 by identifying where further research needed. For example, the Report currently emphasizes the  
23 important role of variable source areas (e.g., swales) in downstream connectivity; this role should be  
24 reiterated in the conclusions. In addition, the conclusions in the Report should emphasize that dynamic  
25 groundwater-surface water connections not only maintain the ecological integrity of ephemeral streams,  
26 but also connect them structurally and functionally to downstream waters, whether or not the upstream  
27 channels are perennial. Finally, the SAB recommends that the conclusions concerning ephemeral  
28 streams be strengthened by clarifying how and when ephemeral headwaters provide critical habitat and  
29 corridors for biota to move among their habitats.

30  
31 *Chemical Connectivity and Nutrients*

32  
33 The SAB finds that the summary of chemical functions that has been included in the Report could be  
34 strengthened by adding details about how headwater streams influence sediment-bound nutrients,  
35 dissolved organic matter (DOM), and contaminants; the text now focuses primarily on nitrogen, with  
36 detailed examples provided only for nitrate as it related to denitrification.

37  
38 The SAB also finds that the Chapter 4 of the Report is currently too focused on headwaters as hotspots  
39 for uptake and transformation of nitrogen; more breadth across solutes should be added. The text should  
40 also be revised to include nutrient removal processes in the discussion on the importance of nutrient  
41 spiraling because both assimilatory and dissimilatory processes are important. Currently, the text focuses  
42 on the role of denitrification processes in removing nitrate-N from streams.

43  
44 *Treatment of Uncertainty*

45  
46 The SAB recommends that the authors consider summarizing and displaying the Report’s conclusions in  
47 matrix form. A well designed matrix could have several advantages as it would better communicate: the

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1 evidence underlying each conclusion, the uncertainty for a given conclusion across different functions  
2 (i.e., source, sink, refuge, lag, and transformation), and the confidence in conclusions across different  
3 system types (e.g., streams versus adjacent wetlands). The SAB also recommends including in the  
4 Report brief characterizations of the temporal or spatial scales over which given functions or phenomena  
5 occur and their sizes, intensities, and effects. Use of graphical methods to convey the level of confidence  
6 in the Report's conclusions, e.g., similar to Intergovernmental Program on Climate Change report (IPCC  
7 2007) would also help to better communicate findings. For example, conclusions drawn at broad  
8 regional scales could have a high level of certainty and conclusions drawn for an individual site at a  
9 local scale could have lower certainty.

10  
11 *Case Studies and Context*

12  
13 The SAB finds that it is difficult to discern the intended illustrative points of the Report's case studies  
14 within the broader discussion of streams in Chapter 4. The SAB recommends that the Report be revised  
15 to clarify the intended use of the case studies, whether as examples of common situations or examples of  
16 unusual extremes. For example, in the case study on prairie streams, the key point was how human  
17 alterations influence connectivity. The SAB also finds that some case study conclusions appear to be  
18 overreaching (e.g., the arid streams example) and are not presented within the context of geographic  
19 differences (e.g., flow in arid streams in urban environments can be dominated by waste treatment  
20 effluent, such as for Rio Grande River at Albuquerque, New Mexico). Thus, for this case, real-world  
21 management scenarios can contrast greatly with the situations described in the case study for arid  
22 streams.

23  
24 The SAB also recommends that the EPA develop an alternative case study framework that uses  
25 hydrology as a unifying theme. For example, stream flow is a function of runoff, which is in turn a  
26 function of weather and underlying geology, all of which vary regionally. For the summary conclusions,  
27 the SAB recommends that the authors consider distinguishing flow-, geology- and weather-dependent  
28 conclusions from the broader more general conclusions. The SAB finds that conclusions for the case  
29 studies could be improved by being explicit about how human activities alter (both increase and  
30 decrease) above and below ground connectivity of streams with downstream waters, ideally through the  
31 use of specific examples (e.g., perhaps using the Report's existing case studies). The SAB notes that  
32 each case study has its own unique bulleted list of conclusions, which makes it difficult to draw  
33 conclusions across the case studies or to relate individual case studies to the Report's general  
34 conclusions.

35  
36 *Consistent Statement of Conclusions throughout the Text*

37  
38 The SAB also notes that it is essential that descriptions of functions and linkages in the Report be  
39 consistently and succinctly stated in Section 4.6 "Streams: Synthesis and Implications," (pages 4-35 and  
40 4-36) and Section 1.4.

41  
42 *Recommendations*

- 43  
44 • Statements in the Report that support conclusions about the connectivity of streams should be stated  
45 in quantitative terms wherever possible.

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- 1 • The text of the Report should be revised to describe system boundaries, e.g., transitions between  
2 uplands and headwaters, and to provide better definition of the boundaries of a stream.  
3
- 4 • The report should better define and emphasize key linkages and exchanges that affect connectivity  
5 (such as groundwater-surface water interactions, flooding or other episodic events, and the influence  
6 of riparian zones) and how these linkages influence biota and food webs and vice versa. The  
7 conclusions in the Report should also reiterate how these linkages and exchanges influence physical,  
8 chemical, and biological connectivity with downstream systems.  
9
- 10 • Text should be added to the Report to explain how hydrologic connectivity sustains aquifers.  
11 Alluvial systems in the southwest and karst systems in the eastern U.S. should be used as examples.  
12
- 13 • The conclusions concerning ephemeral streams should be strengthened by: (1) adding text that  
14 describes spatial and temporal variations in linkages of ephemeral streams with downstream waters;  
15 (2) summarizing existing evidence of the frequency of these connections; (3) identifying where  
16 further research needed; and (4) clarifying how and when ephemeral headwaters provide critical  
17 habitat and corridors for biota to move among their habitats.  
18
- 19 • The summary of chemical functions that has been included in the Report should include details  
20 about the ways that headwater streams influence sediment-bound nutrients, dissolved organic matter  
21 (DOM), and contaminants.  
22
- 23 • The EPA should consider summarizing and displaying the Report’s conclusions in matrix form and  
24 including brief characterizations of the temporal or spatial scales over which given functions or  
25 phenomena occur, and their sizes, intensities, and effects.  
26
- 27 • The intended use of the case studies should be clarified in the Report. An alternative framework for  
28 the case studies could be used in which hydrology is a unifying theme. In the case studies, the EPA  
29 could also consider distinguishing flow, geology- and weather-dependent conclusions from broader  
30 general conclusions.  
31
- 32 • Descriptions of functions and linkages should be consistently and succinctly stated in Section 4.6  
33 (pages 4-35 and 4-36) of the Report “Streams: Synthesis and Implications” and Section 1.4.  
34

35 **3.5. Review of the Literature on Waters and Wetlands in Riparian/Floodplain Settings**

36  
37 *Charge Question 4(a). Section 5.3 of the Report reviews the literature on the directional*  
38 *(downstream) connectivity and effects of wetlands and certain open waters subject to non-tidal,*  
39 *bidirectional hydrologic flows with rivers and lakes. Please comment on whether the Report*  
40 *includes the most relevant published peer reviewed literature with respect to these types of*  
41 *wetlands and open waters. Please also comment on whether the literature has been correctly*  
42 *summarized. Please identify any published peer reviewed studies that should be added to the*  
43 *Report, any cited literature that is not relevant to the review objectives of the Report, and any*  
44 *corrections that may be needed in the characterization of the literature.*  
45  
46

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1 The SAB was asked to comment on whether the Report includes the most recent peer reviewed literature  
2 with respect to wetlands and open waters subject to non-tidal bidirectional hydrologic flows with rivers  
3 and lakes, and whether the literature has been correctly summarized and characterized. The SAB  
4 generally finds that the literature on waters and wetlands in riparian/floodplain settings has been  
5 correctly summarized and characterized in the Report. The literature review substantiates the conclusion  
6 that floodplains, riparian areas, and waters and wetlands in riparian/floodplain settings support the  
7 hydrological, chemical, and biological integrity of downstream waters. However, as further discussed,  
8 additional emphasis, discussion, and reorganization of the information presented (and in some cases  
9 review of more recent and diverse literature) are needed in the Report to address the significance of  
10 bidirectional connectivity.

11  
12 **3.5.1. Structure of Section 5.3 of the Report**

13  
14 Chapter 5 of the Report addresses the subject of physical, chemical, and biological connections of  
15 wetlands to rivers. Section 5.3 focuses on riparian and floodplain wetlands and covers a wealth of topics.  
16 The Section could be strengthened by reorganizing the information presented, incorporating key  
17 literature that is now missing, and by technical editing of both the text and glossary.

18  
19 Section 5.3 of the Report should be reorganized to clarify the functional role of floodplains and riparian  
20 areas in maintaining the ecological integrity of streams and rivers. Much of the text in Section 5.3 is  
21 focused on riparian areas and the importance of headwater, streamside areas to in-stream structure and  
22 function. The SAB recommends that this material be moved from Section 5.3 to Chapter 4, which  
23 discusses physical, chemical, and biological connections of streams and riparian areas. In particular, the  
24 material in Sections 5.3.1 and 5.3.2, which focus on the physical and chemical influence of riparian  
25 areas on streams, is more appropriately located in Chapter 4. Chapter 4 already includes discussions of  
26 the role of riparian forests in regulating water temperature and providing inputs of large woody debris,  
27 but leaves the discussion of other functions, such as ability of these areas to act as nutrient sinks and  
28 transformers, to Chapter 5. Consolidating all of the literature review on riparian areas into Chapter 4  
29 would help organize and clarify the text for the reader. This change would free Section 5.3 to give more  
30 emphasis to higher order structure and function related to the lateral dimensions of river systems and  
31 less emphasis to lower order riparian interactions.

32  
33 As written, Section 5.3 of the Report is 16 pages in length, with only about 6 pages that focus  
34 specifically on floodplain dynamics. As described below, this section should be strengthened  
35 considerably to more fully reflect the literature on the physical, chemical and biological linkages  
36 between floodplains and receiving waters (i.e., lateral exchange between floodplains and rivers followed  
37 by downstream transport). Some references are provided in Section 3.5.8 of this report.

38  
39 The EPA should consider reorganizing the information on the different taxonomic groups (plants and  
40 phytoplankton, vertebrates, and invertebrates) that are described in Sections 5.3.3.1-5.3.3.3 of the Report  
41 to integrate the functional attributes of floodplains as habitats, rather than addressing each group one  
42 after the other, textbook style.

43  
44 *Recommendations*

- 45  
46 • Section 5.3 of the Report should be reorganized to clarify the functional role of floodplains and  
47 riparian areas on the ecological integrity of streams and rivers. Text in Section 5.3 that focuses on



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1 riparian areas and the role of headwater, streamside areas on in-stream structure and function should  
2 be moved to Chapter 4 of the Report.

- 3
- 4 • Section 5.3 of the Report should be strengthened considerably to more fully reflect the literature on  
5 the physical, chemical and biological linkages between floodplains and receiving waters (i.e., lateral  
6 exchange between floodplains and rivers followed by downstream transport).
- 7
- 8 • EPA should consider reorganizing the information on the different taxonomic groups (plants and  
9 phytoplankton, vertebrates, invertebrates) that are described in Sections 5.3.3.1-5.3.3.3 of the Report  
10 to integrate the functional attributes of floodplains as habitats, rather than addressing each group one  
11 after the other.

12

13 **3.5.2. Terminology in Section 5.3 of the Report**

14

15 As previously discussed, the terms “unidirectional” and “bidirectional” wetlands should be revised to  
16 reflect the landscape position of the water body and/or wetland in question. Thus, it is recommended that  
17 bidirectional wetlands be called “waters and wetlands in riparian/floodplain settings.” This change in  
18 terminology is needed to acknowledge the two-way flux of water and materials between floodplains and  
19 riparian areas and adjacent rivers and streams. Consistent use of this term is important for clarity, as the  
20 inconsistent uses of “riparian/floodplain wetlands,” “riparian areas,” or “floodplains” in some sections of  
21 Chapter 5 is confusing to readers. Likewise, the definitions of “Riparian Area,” “Riparian Wetland,”  
22 “Floodplain,” “Floodwater,” and “Floodplain Wetland” in the glossary of the Report should align with  
23 the ways the terms are used in the text.

24

25 The treatment of floodplains in the Report presents challenges because (1) much of the literature on  
26 floodplains and riparian areas does not specify whether or not areas studied were wetlands, and (2) even  
27 when a floodplain is identified as a wetland, the literature seldom indicates if it was a jurisdictional  
28 wetland. Given this, the SAB agrees with the approach of the authors of the Report, which was to take a  
29 broad view of floodplains that allowed a much more representative cross section of the literature to be  
30 used. Moreover, the critical ecological and functional roles of floodplains and riparian areas must be  
31 acknowledged in the Report regardless of their status as wetlands as defined by Cowardin et al. (1979).  
32 This approach is consistent with the rest of the Report, as wetlands discussed in the Report were not  
33 limited to those meeting the federal regulatory definition of wetland (33CFR 328.3(b); USACE 1987).  
34 Including a statement that the text refers to “riparian areas, floodplains and waters and wetlands in  
35 riparian/floodplain settings” would clarify that the Report is referring to the landscape setting in its  
36 entirety, with its characteristic four-dimensions of connectivity (Ward 1989). However, the SAB also  
37 recommends that the authors clearly indicate these areas are covered in the report because of functional  
38 linkages, and not in an attempt to expand the definition of waters and wetlands under the jurisdiction of  
39 the Clean Water Act. Making this distinction will clarify the scope of the report and reinforce the goal of  
40 the report as a scientific, and not a policy, document.

41

42 *Recommendations*

- 43
- 44 • The terms “unidirectional” and “bidirectional” wetlands should be revised to reflect the landscape  
45 position of the water body and/or wetland in question. Thus, it is recommended that bidirectional  
46 wetlands be called “waters and wetlands in riparian/floodplain settings.”

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- 1 • The definitions of “Riparian Area,” “Riparian Wetland,” “Floodplain,” “Floodwater” and  
2 “Floodplain Wetland” in the glossary of the Report should align with the ways the terms are used in  
3 the text.  
4
- 5 • The Report should discuss the functional role of floodplains and riparian areas regardless of their  
6 status as wetlands as defined by Cowardin et al. (1979). However, it should be made clear that this  
7 discussion does not imply an expansion of the definition of waters and wetlands under the  
8 jurisdiction of the Clean Water Act.  
9

### 10 **3.5.3. Spatial and Temporal Connectivity of Floodplain Environments to River** 11 **Systems**

12  
13 Section 5.3 of the Report should include a new subsection that explicitly discusses how floodplain  
14 environments (including the terrestrial components thereof) are intimately linked to river systems, both  
15 spatially and temporally, by means of the “flood pulse.” The authors of the Report recognize the  
16 importance of spatial and temporal scales of connectivity between rivers streams and floodplains in the  
17 abstract, writing:

18  
19 *Connections between riparian/floodplain wetlands and other water bodies and streams or rivers can*  
20 *be permanent, can occur frequently (e.g., if the wetland is located within the mean high-water mark),*  
21 *or can occur infrequently (e.g., if the wetland occurs near the edge of the floodplain). Even*  
22 *riparian/floodplain wetlands that rarely flood can have important, long-lasting effects on streams and*  
23 *rivers. (p. 5-1, lines 12-16)*  
24

25 However, Chapter 5 does not discuss this point. This is an important omission given that gradients in  
26 spatial and temporal connectivity between the stream and floodplain are primary determinants of  
27 physical and biological processes occurring within both the stream and the floodplain (Junk et al. 1989).  
28 The SAB recommends that a new spatial and temporal scale subsection in Chapter 5 emphasize that  
29 floodplain environments (including the terrestrial components thereof) are intimately linked to river  
30 systems through the “flood pulse.” The “flood pulse concept” should be employed as the conceptual  
31 backbone of the subsection, stressing higher order structure and function (as noted above, this is in  
32 comparison to lower-order, headwater stream systems where the riparian area is an interface with the  
33 terrestrial environment). While the Report recognizes that the flood pulse concept is a fundamental  
34 paradigm in river ecology (p. 5–6, line 5; page 6–4, lines 1-2), its hydrologic character in either spatial  
35 or temporal dimensions remains undeveloped and separate from the conceptualization of how  
36 “riparian/floodplain wetlands” operate. The Report does recognize the extension of the flood pulse  
37 concept to include “flow pulses” (Tockner et al. 2000) but does little to emphasize how floodplains (and  
38 the wetlands within them) are differentially connected to river systems through storm-related changes in  
39 flow, seasonal variation in water abundance and river discharge, and longer-term changes related to  
40 climate shifts and precipitation regimes. The term “flood pulse” is used only 9 times in the body of the  
41 entire Report. Most of the references to “flood pulse” in the Report relate to attenuation of flooding in  
42 main channel (p. 5–6, lines 5, 29; Table 5–3, page 5–38), or the influence of the flood pulse on  
43 biological entities (e.g., page 5–20, lines 16, 22, 29).  
44

45 There should also be increased emphasis in the Report on the temporal aspects of floodplain systems as  
46 guided by the short duration high intensity “flood pulse concept” for surface waters and long duration  
47 low intensity lateral discharge for groundwater. The temporal progression of the flood pulse should be

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1 discussed, including descriptions of the influence of the flood pulse on residence time of surface water,  
2 seasonal exchanges with groundwater, chemical and biological linkages, and ecosystem processes. For  
3 example, the effects of a high-intensity flood event of low frequency and duration on downstream waters  
4 will be mostly physical, including water storage, peak flow attenuation, and sediment and wood  
5 transport and/or deposition. This is a low-frequency, high-intensity flood that occurs on a decadal or  
6 centennial return interval. The spatial scale of this type of flood event tends to be extensive, dictated  
7 largely by topography, and covering all available habitats. At the other end of the spectrum, the effects  
8 of high-frequency low-intensity forms of connectivity (such as hyporheic groundwater flow) may be  
9 more biological or biogeochemical, including nutrient and contaminant transformation and organic  
10 matter accumulation. The spatial scale of this type of connectivity depends on whether groundwater  
11 discharge in the floodplain is discrete (e.g., a spring) or diffuse, and whether it travels through the  
12 floodplain as channelized flow or in the hyporheic zone.

13  
14 One very practical reason for including an explicit discussion of the scales of connectivity in the Report  
15 is that some floodplains that are inundated at a low frequency may not exhibit wetland soils, vegetation,  
16 or hydrology required to meet the federal regulatory (33 CFR 328.3) or the Cowardin et al. (1979)  
17 definition of wetland. However, even this occasional connectivity to rivers and streams plays an  
18 important role in river hydrology and water quality. Where streams are disconnected from their  
19 floodplains, low-frequency, high-intensity floods can have major negative impacts on downstream  
20 ecosystems and human communities.

21  
22 Placing the wetlands of “riparian/floodplain” environments into the context of the “river corridor”  
23 requires developing a perspective of linkage and expansion. The authors of the Report need to clearly  
24 articulate the bidirectional nature of fluxes and connections back to the river channel, focusing on the  
25 fluxes of water, materials, and biota and emphasizing how exchange flows respond to the temporal  
26 progression of the flood pulse and move back to the channel. As such, Section 5.3 of the Report needs to  
27 stress the effects of floodplains not only on river flows, but also on chemistry, sediments, and biota of  
28 downstream waters. The SAB provides a number of specific recommendations in this regard. Flood-  
29 forecasting methods should be used as a means to quantify the strength of connectivity (spatial and  
30 temporal) between floodplains and rivers. Hydrological methods in flood frequency – floodplain  
31 inundation provide estimates of water residence time (or hydroperiod) on floodplains, with implications  
32 for fluxes of biota and biogeochemical processing, for example, of nitrogen (N) and phosphorus (P). The  
33 results are measures of vertical and lateral connectivity. Analyses of this kind require that recurrence  
34 intervals be explicitly defined, for example making estimates over a reasonable range of overbank flows  
35 (2 years out of 3, to 10-yr and 100-yr events), to establish variability in the time scales of connectivity.  
36 Such analyses would focus much needed attention on magnitude-frequency relationships.

37  
38 The EPA should consider incorporating into the Report examples of floodplain classification systems  
39 that would address floodplain geomorphological and functional diversity and place emphasis on the  
40 continuum of floodplains along stream networks. This would lead to a better understanding of factors  
41 that shape the degree of connectivity between floodplains and receiving waters by describing  
42 floodplain/channel geomorphology and the duration of flooding or saturation. The SAB also  
43 recommends addressing channel migration zones, which describe the movement of channels within  
44 floodplains over time as a result of large floods, and explaining the variable nature of connectivity (in  
45 space and time) of floodplains and the waters/wetlands that they contain.

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1 The Report should emphasize the importance of hydrological connections and processes such as  
2 sediment movement, erosion and deposition that operate through downstream, lateral, vertical and  
3 temporal dimensions. Additional literature should be reviewed and cited in the Report to demonstrate  
4 that lateral connections create a diversity of lotic, semi-lotic and lentic habitats, supporting a wide array  
5 of species (fish, amphibians, birds, mammals) and high levels of diversity. More emphasis is needed in  
6 Section 5.3 of the Report on these biological exchanges. The SAB has provided some references (cited  
7 below) that address the role of wetlands and off-channel waters on floodplains as fish nurseries that act  
8 to populate downstream fisheries. These references include studies describing fish species that spawn  
9 and rear in backwaters and floodplain wetlands, which flood in the winter and early spring wet season,  
10 then dry down in the summer. As previously mentioned, these habitats are particularly important for fish  
11 larvae. Similarly, some endangered fishes have been shown to use backwaters extensively for spawning  
12 and rearing (e.g., Modde et al. 2001; 2005; Bestgen et al. 2007). The report would be further  
13 strengthened by discussing the importance of these habitats for species that are economically important  
14 and/or listed as threatened or endangered by federal and state agencies.

15  
16 The SAB also finds that it would be instructive to broaden the range of examples used in the Report and  
17 make it more representative of the U.S. as a whole. For instance, the EPA could incorporate studies on  
18 peatlands in floodplain settings that have bidirectional flows, as in northern tier states and Alaska.

19  
20 *Recommendations*

- 21
- 22 • Section 5.3 of the Report should contain a new subsection that explicitly discusses how floodplain  
23 environments (including the terrestrial components thereof) are intimately linked to river systems,  
24 both spatially and temporally, by means of the “flood pulse.” The “flood pulse concept” should be  
25 employed as the conceptual backbone of the new subsection, stressing higher order structure and  
26 function (in comparison to lower–order, headwater stream systems where the riparian area is an  
27 interface with the terrestrial environment).
  - 28
  - 29 • Section 5.3 of the Report should emphasize the importance of the temporal dimension of floodplain  
30 systems as guided by the short duration high intensity “flood pulse concept” for surface waters and  
31 long duration low intensity lateral discharge for groundwater.
  - 32
  - 33 • Section 5.3 of the Report should emphasize the effects of floodplains not only on river flows, but  
34 also on chemistry, sediments, and biota of downstream waters.
  - 35
  - 36 • Flood-forecasting methods should be used as a means to quantify the strength of connectivity  
37 (spatial and temporal) between floodplains and rivers.
  - 38
  - 39 • The EPA should consider incorporating into the Report examples of floodplain classification  
40 systems to address the geomorphological and functional diversity of floodplains, and to place  
41 emphasis on the continuum of floodplains along stream networks.
  - 42
  - 43 • The Report should include a discussion of channel migration zones, which describe the movement of  
44 channels within floodplains over time as a result of large floods, and demonstrate the variable nature  
45 of connectivity (in space and time) of floodplains and the waters/wetlands that they contain.
  - 46

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- 1 • The Report should stress the importance of hydrological connections and processes such as sediment  
2 movement, erosion and deposition that operate through downstream as well as lateral, vertical and  
3 temporal dimensions.  
4
- 5 • Additional literature should be reviewed and cited in the Report to demonstrate that lateral  
6 connections create a diversity of lotic, semi-lotic and lentic habitats, supporting a wide array of  
7 species (fish, amphibians, birds, mammals) and high levels of diversity. More emphasis is needed in  
8 Section 5.3 of the Report on these biological exchanges.  
9
- 10 • The range of examples used in the Report should be broadened to make it more representative of the  
11 U.S. as a whole. For instance, the EPA could incorporate studies on peatlands in floodplain settings  
12 that have bidirectional flows, as in northern tier states and Alaska.  
13

#### 14 **3.5.4. Export versus Exchange**

15  
16 Floodplains and waters and wetlands in floodplain settings are shaped by repeated inundation,  
17 saturation, erosion and deposition of sediment, and movement of biota. Water and materials flow  
18 laterally between floodplains and rivers (i.e., receiving waters), moving onto the floodplain in periods of  
19 high flows and back to the channel as floods recede. As mentioned above, the Report text as written  
20 does not clearly articulate the bidirectional nature of fluxes/connections between the floodplain and  
21 channel. The SAB recommends strengthening the focus of the Report on the fluxes of water, materials  
22 and biota to emphasize how exchange flows respond to the temporal progression of the flood pulse.  
23

#### 24 *Recommendation*

- 25  
26 • There should be a stronger focus in the Report on the fluxes of water, materials and biota to  
27 emphasize how exchange flows respond to the temporal progression of the flood pulse.  
28

#### 29 **3.5.5. Biogeochemical Linkages**

30  
31 Wetlands and floodplains serve as sinks, sources and transformers of nutrients and other chemical  
32 contaminants, and have a significant impact on downstream water quality and ecosystem productivity.  
33 The primary driver of wetland processes is ecosystem biogeochemistry, which involves the exchange or  
34 flux of materials between living and non-living components. These fluxes involve interaction of  
35 complex physical, chemical, and biological processes in various components of the wetland ecosystem.  
36 Biota (plants, microbes, and fauna) can be considered as exchange pools, which are small in size and  
37 undergo rapid turnover and cycling. Abiotic components of wetlands (e.g., soil), which are large in size,  
38 undergo slow turnover and provide long-term storage similar to a reservoir. The amount of a given  
39 constituent in these pools depends on its residence time. These issues are important to acknowledge in  
40 the Report. The SAB recommends that the authors of the Report provide a more recent and diverse  
41 assessment of the biogeochemical implications of exchange flows. This can be accomplished by  
42 enhancing the review of the literature on the role of wetlands and floodplains as sources, sinks, and  
43 transformers of materials including: nutrients, metals, organic contaminants, and sediments. The Report  
44 sections on nitrogen processing (denitrification), phosphorus cycling, and sediments (including legacy  
45 sediments and associated chemicals) could be strengthened with an expansion of the literature reviewed.  
46 The review on nitrogen processes in Section 5.3.2.2 of the Report is of particular concern due to its very  
47 heavy reliance on a single paper by Vidon et al. (2010), cited fully 20 times in that section, on the fate

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1 and fluxes of nitrogen in riparian areas. There is an extensive literature on this subject and while the  
2 Report correctly characterizes nitrogen transformations in a general sense, there are many key references  
3 that are not included. For example, Section 5.3.2.2 of the Report should be updated to provide a more  
4 recent and diverse assessment of biogeochemical implications of “hot-spots and hot-moments” in  
5 nitrogen fluxes that are associated with hydrologic exchanges between surface and subsurface waters  
6 (McClain et al. 2003); see also extensive work by Groffman et al. (2003). The SAB also recommends  
7 that, in general, the literature findings in the Report be reported more quantitatively and not by simple  
8 qualitative statements indicating, for example, that nitrogen levels increased or decreased. In this  
9 specific example the Report should indicate the percent concentration change. The SAB notes that,  
10 depending on hydrologic connectivity, riparian/floodplain soils exhibit a range of redox conditions,  
11 which then regulate biogeochemical cycling of key nutrients, metals, and organic compounds.

12  
13 The Report should indicate that changing climatic conditions may stimulate or alter rates, fluxes and  
14 storage pools of key elements (carbon, nitrogen phosphorus, and sulfur) involved in biogeochemical  
15 processes and services provided by wetlands. For example, accelerated decomposition of organic matter  
16 can potentially increase nutrient generation, which may lead to increased nutrient/contaminant loading  
17 to adjacent water bodies. Important inorganic elements in wetlands are mobile and thus their  
18 concentrations may increase upon flooding and drainage cycles, water withdrawals, sea level rise, and  
19 increases in temperature. The bioavailability of many inorganic elements required for key biological  
20 processes (e.g., plant growth and decomposition) will respond to these changing conditions. Drainage  
21 also increases enzyme and microbial activities, which facilitates oxidation of organic matter, leading to  
22 subsidence and loss of organic soils. Many studies have shown that oxidation of organic matter in  
23 wetlands is dependent on water-table depth, temperature, nutrient loading, vegetation communities and  
24 release of nutrients. Bidirectional exchange of particulate organic matter (POM) and dissolved organic  
25 matter (DOM) in riparian areas and floodplains can be an important source of POM and DOM to  
26 streams and rivers. Further treatment of the residence time of water should also be considered. Water  
27 residence time is a critical concept that can have significant biological impacts, which can be  
28 particularly relevant to downstream waters. Powers et al. (2012) point out that aquatic ecosystem  
29 components that have relatively high nutrient processing rates may not contribute substantially to total  
30 ecosystem retention unless enabled by hydrological connections.

31  
32 *Recommendations*

- 33
- 34 • The Report should provide a more recent and diverse assessment of the biogeochemical implications  
35 of exchange flows. This can be accomplished by enhancing the review of the literature on the role of  
36 wetlands and floodplains as sources, sinks, and transformers of materials including: nutrients,  
37 metals, organic contaminants, and sediments (additional references are provided in section 3.5.8 of  
38 this SAB report).
  - 39  
40 • The Report sections on nitrogen processing (denitrification), phosphorus cycling, and sediments  
41 (including legacy sediments and associated chemicals) should be strengthened by expanding the  
42 literature reviewed. In particular, Section 5.3.2.2 of the Report should be updated to provide a more  
43 recent and diverse assessment of biogeochemical implications of “hot-spots and hot-moments” in  
44 nitrogen fluxes that are associated with hydrologic exchanges between surface and subsurface waters  
45 (Groffman et al. 2003; McClain et al. 2003).
- 46

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- 1 • Literature findings in the Report be reported more quantitatively and not by simple qualitative  
2 statements, for example, that nitrogen levels increased or decreased.  
3
- 4 • The Report should further discuss how changing climatic conditions may stimulate or alter rates,  
5 fluxes and storage pools of key elements (carbon, nitrogen phosphorus, and sulfur) involved in  
6 biogeochemical processes and services provided by wetlands (additional references are provided in  
7 section 3.5.8 of this SAB report).  
8
- 9 • The EPA should consider including in the Report further discussion of the residence time of water.  
10 Water residence time is a critical concept that can have significant biological impacts, which can be  
11 particularly relevant to downstream waters (additional references are provided in section 3.5.8 of this  
12 SAB report).  
13

14 **3.5.6. Case Study on Forested Wetlands**  
15

16 The SAB finds that the report would benefit from more discussion of forested wetlands, including  
17 bottomland hardwoods, given their ecological importance, rate of loss, and unique attributes. These  
18 wetlands represent a significant portion of remaining U.S. wetlands. A box case study could address  
19 this gap, and include the role of bottomland forests on river biogeochemistry and flood storage.  
20

21 *Recommendation*  
22

- 23 • A case study of the role of forested wetlands (including bottomland hardwoods) in river  
24 biogeochemistry and flood storage should be included in the Report.  
25

26 **3.5.7. Human Impacts to Floodplains and Aggregate Effects**  
27

28 The effect of human impacts to waters and wetlands in riparian/floodplain settings on connectivity is an  
29 important issue that should be addressed in the Report. An example of such an impact is channel  
30 incision or levee construction that breaks the link between riparian wetlands/floodplains with  
31 downstream waters. Alterations that decrease the connectivity of floodplains and waters and wetlands in  
32 riparian/floodplain environments provide some of the clearest demonstrations of the functional role of  
33 these areas with respect to downstream waters (for example, through degraded water quality). A key  
34 approach to this analysis is to provide examples of the aggregate effects of floodplain impacts on  
35 downstream waters in terms of flooding, biodiversity, and materials flux. The water quality benefits of  
36 riparian areas and floodplains should also be highlighted in the Report by explicitly pointing out that  
37 their destruction exacerbates nutrient runoff from agricultural lands by reducing or eliminating  
38 nutrient uptake, denitrification, and sedimentation of adsorbed phosphorus.  
39

40 *Recommendations*  
41

- 42 • The Report should address the effects of human impacts to waters and wetlands in  
43 riparian/floodplain settings on connectivity.  
44
- 45 • The water quality benefits of riparian areas and floodplains should be highlighted in the Report by  
46 explicitly pointing out that their destruction exacerbates nutrient runoff from agricultural lands by

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1 reducing or eliminating nutrient uptake, denitrification, and sedimentation of adsorbed  
2 phosphorus.

3  
4 **3.5.8. Recommended References**

5  
6 The SAB recommends that the EPA consider adding the following selected references to the Report.

- 7  
8 • References to studies emphasizing how the hydrologic phenomenon of the flood pulse links rivers to  
9 the floodplain (and consequently to wetlands within them): Alford and Walker (2013); Anderson  
10 and Lockaby (2012); Benke et al. (2000); Bunn et al. (2006); Ellis et al. (2001); Galat et al. (1998);  
11 Granado and Henry (2014); Heiler et al. (1995); Henson et al. (2007); Hudson et al. (2012); Hudson  
12 et al. (2013); Magana (2013); Nanson and Croke (1992); Opperman et al. (2010); Power et al.  
13 (1995a,b); Powers et al. (2012); Rooney et al. (2013); Schramm and Eggleton (2006); Sullivan and  
14 Rodewald 2012; Sullivan and Watzin (2009); Thorp et al. (2006); Tockner et al. (2000); Toth and  
15 van der Valk (2012); and Valett et al. (2005).  
16  
17 • References on Biogeochemistry: Aitkenhead-Peterson, et al. (2003); Fowler (2004); Bridgham et al.  
18 (2001); Bridgham et al. (2006); Buresh et al. (2008); Fennessy and Cronk (1997); Freeman et al.  
19 (2004a); Freeman et al. (2004b); Hefting et al. (2004); McClean et al. (2003); Osborne (2005);  
20 Qualls and Richardson. (2003); Reddy et al. (1999); Reddy et al. (2005); Reddy et al. (2011); Strack  
21 et al. (2008); Wetzel (1990); and Wetzel (2002).  
22  
23 • References on human impacts: Dudley and Platania (2007); and Verhoeven et al. (2006).  
24  
25 • References on fauna: Brooks and Brinson (2013); Baxter et al. (2005); Bestgen et al. (2006);  
26 Bestgen et al. (2007); Bottom et al. (2005); Fausch (2010); Flecker et al. (2010); Gresswell (2011);  
27 Koel et al. (2005); McIntyre et al. (2007); Mion et al. (1998); Modde et al. (2001); Modde et al.  
28 (2005); Schick and Lindley (2007); Spinola et al. (2008); and Zelasko et al. (2010).  
29

30 **3.6. Review of the Findings and Conclusions Concerning Waters and Wetlands in**  
31 **Riparian/Floodplain Settings**

32  
33 *Charge Question 4(b). Conclusion (2) in section 1.4.2 of the Report Executive Summary*  
34 *discusses major findings and conclusions from the literature referenced in Charge Question 4(a)*  
35 *above. Please comment on whether the conclusions and findings in section 1.4.2 are supported*  
36 *by the available science. Please suggest alternative wording for any conclusions and findings*  
37 *that are not fully supported.*  
38

39 **3.6.1. Scientific Support for the Findings and Conclusions Concerning Waters and Wetlands in**  
40 **Riparian/Floodplain Settings**

41  
42 The SAB is in agreement that there is strong scientific support for the conclusion that riparian and  
43 floodplain water bodies and wetlands are highly connected to downstream waters through multiple  
44 pathways, including hydrological, chemical, and biological connectivity. However, as further discussed  
45 below, the SAB recommends that additional literature be included in the Report to bolster these  
46 findings, particularly as related to chemical connectivity. In addition, the SAB notes that the key  
47 findings and conclusions presented in Section 1.4.2 of the executive summary of the Report should be



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1 directly related to the information presented in Section 5.3 on Riparian and Floodplain Wetlands. The  
2 discussion of findings and conclusions in these two sections should be parallel. Any conclusions  
3 presented in Section 1.4.2 of the executive summary should also align with conclusions presented in  
4 Sections 5.5, the wetlands synthesis and implications discussion, and 6.1, the discussion of major  
5 conclusions.

6  
7 Currently, many of the conclusions in the Report are drawn from literature related to riparian zones that  
8 are adjacent to water bodies other than floodplains that are periodically inundated (i.e., non-floodplain  
9 riparian zones). This weakens the potential opportunity to present direct evidence of connectivity (or  
10 lack thereof) between waters and wetlands in riparian/floodplain settings and receiving systems. The  
11 SAB views this discrepancy as highly problematic. In addition, there appears to be a lack of clarity in  
12 distinguishing the science (and cited literature) related to floodplain areas that are not wetlands from the  
13 science related to floodplains that either contain wetlands (floodplain wetlands) or are inundated with  
14 sufficient frequency to be classified as wetlands. The SAB recommends presenting a broad discussion of  
15 floodplain systems in Section 5.3 (to replace the current riparian focus), but the distinction between  
16 floodplain areas that are not wetlands and floodplain areas that contain or are wetlands needs to be clear  
17 relative to the implications for connectivity, and should be highlighted and carried through the text and  
18 conclusions. The discussion of floodplains that are neither wetlands nor inundated frequently enough to  
19 be wetlands may risk criticism because it appears to either expand the definition of a river or  
20 downstream waters (not now included in the definition of rivers in the glossary) or to bring into the  
21 Report another landform unrelated to rivers per se (active channel) and wetlands or other water bodies.

22  
23 *Recommendations*

- 24
- 25 • There is strong scientific support for the conclusion that riparian and floodplain water bodies and  
26 wetlands are highly connected to receiving waters through multiple pathways, including  
27 hydrological, chemical, and biological connectivity. However, additional literature should be  
28 included in the Report to bolster these findings, particularly as related to chemical connectivity.  
29
  - 30 • Key findings and conclusions presented in Section 1.4.2 of the executive summary of the Report  
31 should be directly related to the information presented in Section 5.3 on Riparian and Floodplain  
32 Wetlands.  
33
  - 34 • Conclusions presented in Section 1.4.2 of the executive summary should align with conclusions  
35 presented in Sections 5.5, the wetlands synthesis and implications discussion, and 6.1, the discussion  
36 of major conclusions.  
37
  - 38 • A broad discussion of floodplain systems should replace the current riparian focus and be included  
39 in Section 5.3 of the Report, but the distinction between floodplain areas that are not wetlands and  
40 floodplains that contain or can be classified as wetlands needs to be clear relative to the implications  
41 for connectivity, and should be highlighted and carried through the text and conclusions.  
42

43 **3.6.2. Additional Recommendations Concerning the Findings and Conclusions Regarding**  
44 **Waters Wetlands in Riparian/Floodplain Settings**

45  
46 The SAB recommends that the EPA address the following issues in the discussion of waters and  
47 wetlands in riparian /floodplain settings.

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*Inconsistent Terminology*

As previously mentioned, the Report language referring to riparian and floodplain wetlands should remain consistent both within the key findings and conclusions sections as well as throughout Section 5.3. The terms “riparian areas,” “riparian and floodplain areas,” and “riparian/floodplain waters” are used inconsistently in Tables 5.1 and 5.3. The SAB finds the use of the terms “riparian” and “floodplain” areas to be particularly problematic, as these terms extend beyond water bodies. The terms “riparian” or “riparian areas” should used sparingly unless they refer directly to riparian wetlands or floodplains that are classified as wetlands by frequency of inundation because it leaves the appearance of relying on non-wetland riparian areas to support the report, thereby extending the report beyond its key objectives. The SAB notes that the glossary definitions in the Report distinguish between “riparian areas” and “riparian wetlands” as well as among “floodplain,” “floodwater,” and “floodplain wetland.” “Upland” is also defined in the glossary as: (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) three-attribute wetland definition.* As previously discussed, the SAB recommends that “bidirectional” wetlands be called “waters and wetlands in riparian/floodplain settings.” The terminology used in the key findings and conclusions of the Report must align with the glossary definitions and the conceptual framework.

*Temporal Component*

As previously mentioned, the key findings and conclusions in the Report should recognize the temporal dimension of waters and wetlands in riparian/floodplain settings relative to downstream connectivity, consistent with the four-dimensional nature of the conceptual framework set forth in Chapter 2; water residence times and the transient nature of floodplains should be key points. This temporal perspective, combined with an emphasis on developing (and illustrating) a strength of connectivity, could be done using the well-developed science of flood forecasting (probability) as a function of vertical and lateral connectivity. Incorporating discussion of flood frequency-floodplain inundation science into the Report might prove to be the best way to highlight how hydrologists estimate the degree of connectivity. As previously mentioned, discussion of “channel migration zones” would further address the lateral connectivity of rivers to their valley floors (not necessarily floodplains but including non-floodplain valley floors). In one year a floodplain can exist on one side of the channel and the next year, following a large flood, the active channel may have migrated 100 meters to the opposite size, stranding the former floodplain and creating new floodplains on that side. Thus floodplains, including wetlands, are temporally variable and transient, and connectivity could include what has been referred to as the “channel migration zone.” Some states have promulgated regulations about how to define and protect (regulate development) channel migration zones that are non-floodplain portions of the valley floor. Overall, the EPA’s conclusions concerning connectivity of waters and wetlands in riparian/floodplain settings should reflect the main message of a new spatial and temporal subsection in Section 5.3, as recommended in the SAB response to Charge Question 4(a).

*Further Quantification of Key Conclusions*

The key conclusions in the Report should be more empirically and/or more specifically described. Whenever possible, the degree of and/or strength of evidence for connectivity should be quantified (e.g., of X studies, X% support conclusion of connectivity).

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*Chemical Linkages*

The role of waters and wetlands in riparian/floodplain settings in storing and transforming chemical constituents should be expanded under Key Finding (d) in Section 1.4.2 of the Report. This may require additional literature review (in Section 5.3) in order to refer to literature on riparian and floodplain wetlands and water bodies rather than rely on riparian and upland examples. Changes to nitrate and dissolved organic carbon (DOC), as well as sediment storage, should be easily documented. There is ample literature on the water purification function of wetlands, and this is the rationale for constructed wetlands.

*Biological Linkages Including Food Webs*

The role of biological connectivity between waters and wetlands in riparian/floodplain settings and receiving systems should be further highlighted in the key findings and conclusions. In particular, the SAB encourages the EPA to highlight the point that waters and wetlands in riparian/floodplain settings and receiving systems are intimately linked through biological connections (including integrated wetland-river food webs) across a range of spatial and temporal scales. In this regard, the report should explicitly discuss linkages to downstream waters. For example: “Riparian wetlands can provide critical nursery habitat for fish, *which then disperse into downstream waters, becoming part of river food webs and serving as a biological vector of nutrients.*” There also may be an opportunity to mention the importance of waters and wetlands in riparian/floodplain settings to species that are economically important as well as those species that are state and/or federally listed as endangered, but this would have to be first developed in the body of the Report.

*Export versus Exchange*

As previously discussed, an “exchange” versus “export” framework (i.e., reciprocal exchanges between waters and wetlands in riparian/floodplain settings and receiving waters) should be used in the Report. In this way, the EPA can clearly indicate that bidirectional biological, chemical, and hydrological transfers characterize the connections between the two systems.

*Case Studies*

The SAB finds that the case studies in the Report are useful. However, the findings from the case studies should be more explicitly linked to the overall conclusions in Section 1.4 of the Report.

*Human Impacts*

In some cases, human alteration of connectivity provides the clearest demonstration of how the function of waters and wetlands in riparian/floodplain settings is linked to adjacent waters. Thus, the conclusions in the Report could be strengthened by explicitly mentioning how human activities (impairment as well as restoration) alter connectivity of waters and wetlands in riparian/floodplain settings with downstream waters. Mention should be made of alterations that both increase connectivity, such as ditches, and decrease connectivity, such as levees. Again, using the flood frequency-lateral connectivity argument, this might represent a strong opportunity to illustrate how diking has clearly diminished connectivity

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1 both in individual river segments and in aggregate. Many floodplains along long stretches of rivers, if  
2 not entire rivers, may be affected by diking.

3  
4 *Aggregate/Cumulative Effects*

5  
6 The importance of considering waters and wetlands in riparian/floodplain settings in the aggregate  
7 should be underscored in the key findings and conclusions of the Report. For example, these sections  
8 could briefly illustrate how floodplain storage in the aggregate (e.g., floodplains in dozens to hundreds  
9 of individual channel reaches) yields many ecological services, including flood attenuation.

10  
11 *Recommendations*

- 12
- 13 • Report language referring to riparian and floodplain wetlands should remain consistent both within  
14 the key findings and conclusions sections as well as throughout Section 5.3.
  - 15
  - 16 • The terms “riparian” or “riparian areas” should used sparingly unless they refer directly to riparian  
17 wetlands or floodplains that are classified as wetlands by frequency of inundation because it leaves  
18 the appearance of relying on non-wetland riparian areas to support the report, thereby extending the  
19 report beyond its key objectives.
  - 20
  - 21 • The terminology used in the key findings and conclusions of the Report must align with the glossary  
22 definitions and the conceptual framework.
  - 23
  - 24 • The key findings and conclusions in the Report should recognize the temporal dimension of waters  
25 and wetlands in riparian/floodplain settings relative to downstream connectivity, consistent with the  
26 four-dimensional nature of the conceptual framework set forth in Chapter 2; water residence times  
27 and the transient nature of floodplains should be key points. The well-developed science of flood  
28 forecasting (probability) as a function of vertical and lateral connectivity may be particularly useful  
29 in developing this temporal perspective
  - 30
  - 31 • The key conclusions in the Report should be more empirically and/or more specifically described.  
32 Wherever possible, the degree of and evidence for connectivity should be quantified (e.g., of X  
33 studies, X% support conclusion of connectivity).
  - 34
  - 35 • The findings from the case studies in the Report should be explicitly linked to the overall  
36 conclusions.
  - 37
  - 38 • The role of waters and wetlands in riparian/floodplain settings in storing and transforming chemical  
39 constituents should be expanded under Key Finding d in Section 1.4.2 of the Report.
  - 40
  - 41 • The role of biological connectivity between waters and wetlands in riparian/floodplain settings and  
42 downstream waters should be further highlighted in the key findings and conclusions.
  - 43
  - 44 • The conclusions in the Report should explicitly discuss how human activities (impairment as well as  
45 restoration) alter connectivity of waters and wetlands in riparian/floodplain settings with  
46 downstream waters.

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- The importance of considering waters and wetlands in riparian/floodplain settings in the aggregate should be underscored in the key findings and conclusions of the Report.

**3.6.3. Alternative Wording for Findings and Conclusions**

The SAB recommends the technical and editorial corrections provided in Appendix B to clarify the findings and conclusions in Section 1.4.2 of the Report.

**3.7. Review of the Literature on Non-floodplain (“Unidirectional”) Waters and Wetlands**

*Charge Question 5(a). Section 5.4 of the draft Report reviews the literature on the directional (downstream) connectivity and effects of wetlands and certain open waters, including “geographically isolated wetlands,” with potential for unidirectional hydrologic flows to rivers and lakes. Please comment on whether the Report includes the most relevant published peer reviewed literature with respect to these types of wetlands and open waters. Please also comment on whether the literature has been correctly summarized. Please identify any published peer reviewed studies that should be added to the Report, any cited literature that is not relevant to the review objectives of the Report, and any corrections that may be needed in the characterization of the literature.*

The SAB finds that the review and synthesis of the literature on the downstream connectivity and effects of wetlands and open waters with the potential for unidirectional connectivity is generally thorough, technically accurate, and readable. As previously mentioned, the SAB recommends the authors reconsider use of the terms “unidirectional” and “geographically isolated wetlands”. The SAB finds that the focus on hydrologic connections in Section 5.4 and elsewhere does not account for important biological exchanges that can strongly influence the integrity of downstream waters. The SAB recommends that the Report be reorganized to reflect the types of connections between wetlands and downstream waters, including surface water, ground water, and biological connections, with specific attention paid to the magnitude, duration, and frequency of these connections. The SAB recommends that spatial landscape position and scale be considered in the evaluation of the degree of connectivity, given that regional context (e.g., geology, climate, landforms, and surficial sediments) is a major driver of the temporal and spatial scales of hydrologic linkages. Consideration of landscape position and scale will likely provide further justification for treating wetland complexes as aggregates rather than as individual units based on geographic distribution. As previously discussed, the SAB also finds that human disturbance may change the type of connections as well as the magnitude, frequency, and duration of the connections. The SAB recommends that the draft Report be revised to acknowledge the role of humans in these changes. In addition the draft Report should discuss the differences between manmade wetlands and those found in natural settings.

**3.7.1. Summary of the Literature on Non-floodplain (“Unidirectional”) Wetlands**

The SAB finds that the Report captures the most relevant peer-reviewed literature on “unidirectional wetlands” and “geographically isolated wetlands”. While the Report already includes several major review papers, the SAB recommends adding the 2013 review paper, “Concepts of hydrological connectivity: research approaches, pathways and future agendas,” by L.J. Bracken, et al. The SAB also recommends that additional citations on biological connections (e.g., Naiman et al 1994), especially

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1 those that address material flows generated by avian fauna, be added to the Report. Findings from  
2 additional literature on the biological exchanges between unidirectional wetlands and downstream  
3 waters created by major species assemblages (e.g., amphibians, birds, reptiles, and invertebrates) are  
4 particularly important to include. These biological exchanges potentially influence the biological  
5 integrity of downstream waters through bulk exchange of materials (e.g., energy, nutrients, and  
6 contaminants), introduction of disease vectors or other living matter, or provision of habitat essential for  
7 biological integrity and completion of life cycles of downstream species.

8  
9 *Recommendations*

- 10
- 11 • The literature review in Section 5.4 of the Report is generally thorough, technically accurate and  
12 readable; however, the SAB recommends that the 2013 review article by L.J. Bracken et al. be added  
13 to the Report.
  - 14
  - 15 • The EPA should consider including additional publications on the subject of biological connections,  
16 some of which are referenced throughout this SAB report. Publications that analyze material flows  
17 generated by avian fauna will be especially important to review.
  - 18
  - 19 • The SAB recommends that the EPA also consider adding to the Report the following selected  
20 references that are particularly pertinent to the discussion of isolated wetlands: Brunet and  
21 Westbrook (2012); Croke et al. (2005); Conly et al. (2001); Fang and (2008); Gray et al. (1984);  
22 Hayashi and Van der Kamp (2000); Hayashi et al. (2003); Montgomery (1994); Shaw et al. (2012);  
23 Spence (2007); Spence and Woo (2003); Stichling and Blackwell (1957); Thompson et al. (2008);  
24 Van der Kamp et al. (2003); Van der Kamp et al. (2008); Wemple et al. (1996); Wemple et al.  
25 (2001); Wigmosta and Perkins (2001); Woo and Rowsell (1993); and Yang, et al. (2010).

26 **3.7.2. Clarification of Terms in Section 5.4 of the Report**

27  
28 The SAB finds that the new term “unidirectional wetlands “ as used in the Report implies on the  
29 presence of only one-way hydrologic flows, when in fact, connectivity can have many physical,  
30 chemical, and biological dimensions far beyond surface and shallow subsurface water flows. The SAB  
31 suggests that the draft Report’s uni- and bi-directional terminology be replaced by terms that better  
32 describe landscape position. In this case, “bidirectional wetlands” would be redefined as those within  
33 floodplains, and “unidirectional wetlands” as those not within a floodplain (i.e., non-floodplain  
34 wetlands). The influence of floodplain and non-floodplain wetlands on downstream connectivity can  
35 then be explained in the context of their landscape setting and with respect to the conceptual framework,  
36 as described below.

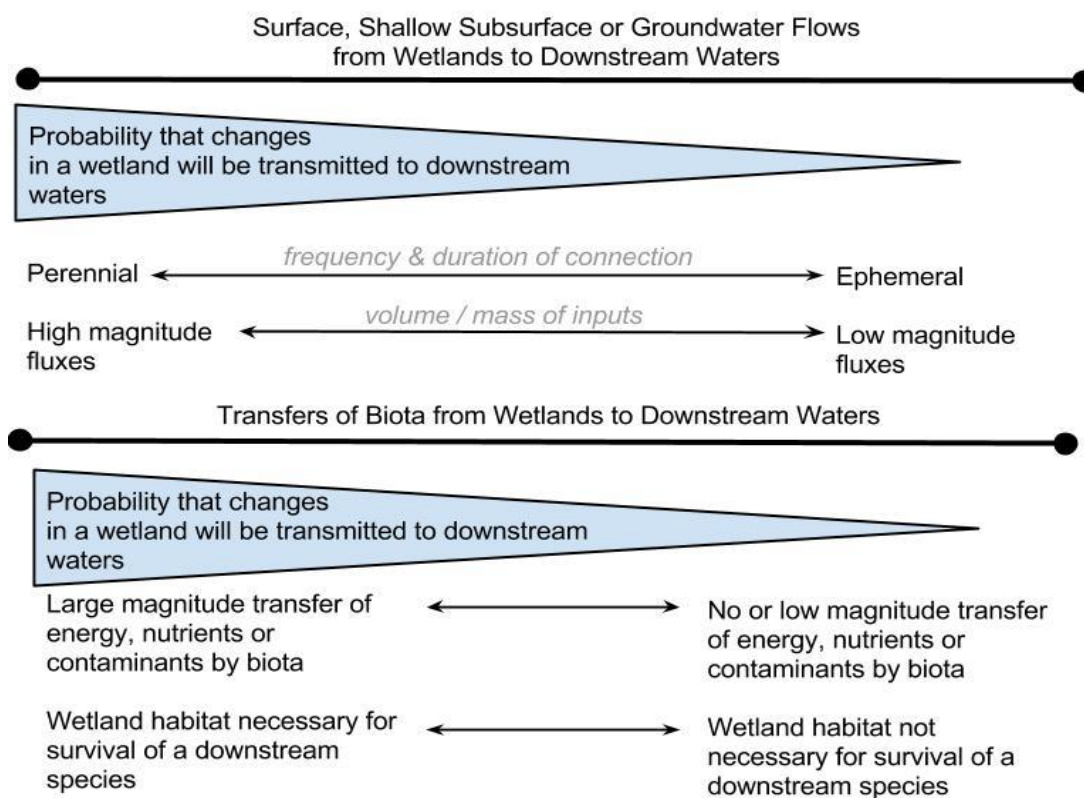
37  
38 *Recommendation*

- 39
- 40 • The terms “unidirectional” and “geographically isolated” wetlands should be replaced in the Report  
41 with the term “non-floodplain wetlands.”
- 42  
43  
44  
45

1 **3.7.3. Recommended Conceptual Framework for Synthesizing Types and Gradients of**  
 2 **Connectivity**  
 3

4 As discussed in the response to charge question 2, the SAB recommends the Report be revised to use a  
 5 conceptual framework with multiple flowpaths that correspond to the multiple dimensions of  
 6 connectivity. The five functional flowpaths used to describe connectivity in the draft Report (i.e., source,  
 7 sink, refuge, lag, transformation) are differentially affected by the type and characteristics of  
 8 connections. The framework recommended by the SAB is envisioned as a potential way to map the five  
 9 functional flowpaths across different regional settings in order to assess the consequences and relative  
 10 extent of hydrologic, biological, and beneficial chemical functions provided by non-floodplain  
 11 (“unidirectional”) wetlands to downstream waters.

12  
 13 Similarly the SAB recommends that Figure 1, shown below, be used to frame the discussion about the  
 14 type and gradient of various connections between and among floodplain wetlands and non-floodplain  
 15 wetlands and downstream waters (or “bidirectional” and “unidirectional wetlands,” respectively, using  
 16 the Report’s original nomenclature).  
 17



18  
 19  
 20 Figure 1: Framework representing the potential consequences of changes to downstream waters with increases in the  
 21 magnitude, duration, and frequency of surface and subsurface connections.  
 22

23 The multiple dimensions of connectivity to downstream waters include connections provided by surface  
 24 waters, ground water, chemical transformation, and biological functions. Each dimension of  
 25 connectivity should be arrayed as a gradient, as illustrated in Figure 1. This approach could be used to  
 26 synthesize findings from the literature in terms of the degree of connectivity pathways (e.g., magnitude,

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1 duration, frequency<sup>1</sup>) rather than just the presence of any connection. Endpoints for each gradient should  
2 be identified where possible. For example, terminal salt lakes and playas are examples of wetlands and  
3 open water bodies that have weak hydrologic connections. The SAB finds that such an analysis is  
4 possible and would be useful for summarizing the effects of such connections in semi-quantitative  
5 terms.

6  
7 *Recommendations*

- 8
- 9 • When describing connectivity for floodplain and non-floodplain wetlands and certain open waters,  
10 the EPA should refer to the conceptual framework the SAB has recommended for the Report (see  
11 Section 3.2.3 of this report).
  - 12
  - 13 • The EPA should use Figure 1 in this SAB report to frame the discussion of connectivity gradients  
14 and magnitude, duration, and frequency of connectivity pathways among floodplain wetlands and  
15 non-floodplain wetlands and downstream waters.
  - 16
  - 17 • The EPA should identify endpoints for each connectivity gradient, and quantify each connection to  
18 the degree possible.
  - 19

20 **3.7.4. Temporal and Spatial Scales of Connections among Non-Floodplain Wetlands and**  
21 **Open Waters**

22

23 Temporal and spatial scales of connections among non-floodplain wetlands and open waters should be  
24 addressed explicitly with the magnitude, frequency, and duration of connections quantified whenever  
25 possible. In particular, the SAB recommends that the authors examine the degree of connectivity  
26 through a range of time scales (e.g., days versus thousands of years) to establish the magnitude,  
27 duration, and frequency of connections. For example, groundwater dynamics occur at a much longer  
28 time scales than those of surface and shallow subsurface flows. Consequently, groundwater connections,  
29 where they exist, may not have an immediate influence on downstream water. On the other hand,  
30 groundwater flows may be important in sustaining flows in rivers and streams during drought periods.  
31 High magnitude floods may infrequently connect non-floodplain wetlands with downstream waters and  
32 the subsequent effect on downstream waters may be short lived and inconsequential unless floods  
33 transfer a toxic pollutants, an invasive species, or pathogen with subsequent long-lived damaging  
34 effects. Such instances are likely to be unusual circumstances and case specific. Geographic differences  
35 across spatial scales are also important determinants of rainfall patterns and streamflow frequency; such  
36 effects should be evaluated using the scientific literature.

37

38 The SAB recommends that the authors consider including in the Report the following statement that  
39 reflects the temporal dynamics of connections of minimally connected wetlands: *Over sufficiently long*  
40 *time scales all aquatic habitats are connected to downstream waters through the transfer of water,*  
41 *chemicals or biota, yet the effects of these connections vary widely in magnitude across wetlands.* The  
42 SAB also recommends that the report discuss the various types of connectivity in terms of their *effect* on  
43 downstream water quality and biological integrity, not just in terms of frequency or magnitude. That is,  
44 low frequency or high magnitude events can “re-set” biological and ecological functions in important

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<sup>1</sup> Note that, in this context, frequency, magnitude, and duration, apply to all five functional flowpaths, and not to just hydrologic connectivity.



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1 ways. A summary of such effects could be gleaned from the literature or from examples provided in the  
2 Report's case studies.

3  
4 *Recommendations*

- 5
- 6 • The EPA should recognize in the Report that all aquatic habitats are connected to downstream water  
7 (in various magnitudes) over sufficiently long time scales.
  - 8
  - 9 • The EPA should assess connectivity in terms of downstream effects, not just in terms of frequency,  
10 magnitude, or duration of connections.
- 11

12 **3.7.5. Assessing Wetland Connectivity Based on Aggregate Analysis of Wetland Complexes**

13  
14 Assessment of the degree of wetland connectivity is best conducted on aggregated wetland complexes  
15 rather than on individual wetlands because over a range of precipitation regimes the boundaries of any  
16 single wetland may vary through space and time. The regional context (e.g., geology, climate,  
17 landforms, and surficial sediments) is a major driver of the temporal and spatial scales of hydrologic  
18 linkages. Thus, regional context and spatial landscape position and scale should also be considered when  
19 evaluating the degree of connectivity, e.g., distance from and size of wetlands (or similar wetland types).  
20 The SAB notes that various frameworks for regionalization exist and include characterizations of  
21 landscapes at nested scales, such as regional, sub-regional, and local. These nested scales can be used to  
22 summarize variability in connectivity identified in the peer-reviewed literature.

23

24 *Recommendations*

- 25
- 26 • The Report should be clearly explain why, and recommend that, wetland connectivity must be  
27 assessed in terms of aggregated wetland complexes, rather than individual wetlands.
  - 28
  - 29 • The Report should discuss the usefulness of regionalization methods to summarize information  
30 about wetland connectivity at nested scales.
- 31

32 **3.7.6. Discussion of Human Alteration of Landscapes in Section 5.4 of the Report**

33  
34 The Report tends to focus on natural wetland systems or those with minimal disturbance. As previously  
35 discussed, human disturbances (and related legacy effects) alter the type, strength and magnitude of  
36 connectivity pathways. Some types of disturbances promote connections where none previously existed,  
37 others alter existing types of connections or trigger the transport of novel chemical or biological species.  
38 In addition, there are many instances where man-made isolated wetlands occur within the landscape.  
39 These features are often found behind levees or within isolated parcels within urban landscapes and do  
40 not provide the same ecosystem functions as natural wetlands. The SAB recommends that Section 5.4,  
41 as well as other sections of the Report acknowledge these types of alterations or man-made habitats and  
42 include a discussion of current and past (legacy) human disturbances and how they alter the type,  
43 strength, and magnitude of connectivity pathways.

44  
45  
46  
47

1 *Recommendation*

- 2
- 3 • Section 5.4, and other sections of the Report, should be revised to discuss the legacy effects of  
4 human disturbances and their effect on the type, strength, and magnitude of connectivity  
5 pathways.

6 **3.8. Review of the Findings and Conclusions Concerning Non-floodplain (“Unidirectional”)**  
7 **Waters and Wetlands**

8

9 *Charge Question 5(b). Conclusion (3) in section 1.4.3 of the Report Executive Summary*  
10 *discusses major findings and conclusions from the literature referenced in Charge Question 5(a)*  
11 *above. Please comment on whether the conclusions and findings in section 1.4.3 are supported*  
12 *by the available science. Please suggest alternative wording for any conclusions and findings*  
13 *that are not fully supported.*

14

15 In responding to EPA’s findings and conclusions regarding connectivity among open waters and  
16 unidirectional (non-floodplain) wetlands and downstream waters (Section 1.4.3 of the Report), the SAB  
17 focused on knowledge drawn from the peer-reviewed literature, especially that: (1) connectivity extends  
18 beyond hydrologic connectivity, (2) each connectivity flowpath can be described as a gradient that  
19 varies over space and time, and (3) that each connectivity flowpath contributes to the downstream  
20 effects of multiple connectivity flowpaths.

21

22 **3.8.1. Scientific Support for the Conclusions Concerning Waters and Wetlands with Potential**  
23 **For Unidirectional Hydrologic Flows to Rivers and Lakes**

24

25 The SAB disagrees with the overall conclusion in Section 1.4.3 of the Report (Conclusion 3) indicating  
26 that, “The literature we reviewed does not provide sufficient information to evaluate or generalize about  
27 the degree of connectivity (absolute or relative) or the downstream effects of wetlands in unidirectional  
28 landscape settings.” This statement is inconsistent with the text immediately preceding it, which  
29 describes numerous scientifically-established functions of non-floodplain wetlands that can benefit  
30 downstream water quality and integrity. Furthermore, the conclusion largely overlooks the effect of  
31 biological connections on downstream waters. The SAB finds that the scientific literature provides  
32 ample information to support a more definitive statement, and strongly recommends that the authors  
33 revise this conclusion to focus on what is supported by the scientific literature and articulate the specific  
34 gaps in our knowledge that must be resolved (e.g., degree of connectivity, analyses of temporal or  
35 spatial variability).

36

37 The SAB recommends that Conclusion 3 in the Report explicitly recognize connectivity as a gradient  
38 rather than a dichotomous, categorical variable. The SAB recommends that the following text be  
39 included in Conclusion 3 in order to highlight the fact that there are multiple mechanisms resulting in  
40 connectivity, and these occur over gradients of both space and time.

41

42 *“Over sufficiently long time scales all aquatic habitats are connected to downstream waters*  
43 *through the transfer of water, chemicals or biota, yet the magnitude and effects of these*  
44 *connections vary widely across wetlands.”*

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1 The SAB recommends that all of the Report’s conclusions encompass connections beyond hydrologic  
2 ones, and that the frequency, magnitude, and duration of these connections be considered.  
3 The SAB recommends that within the text of Conclusion 3 in the Report, the authors explicitly state the  
4 four pathways by which unidirectional wetlands can be connected to downstream waters: via surface  
5 water, shallow subsurface or groundwater flowpaths, or through the movement of biota. It is the  
6 magnitude and effect of material, water or biotic fluxes rather than the simple presence or absence of a  
7 flux that determines the strength of the connection between a wetland and downstream waters.  
8 The SAB disagrees with the notion that even minimal hydrologic connections are more important than  
9 biological connections, no matter how large the flux. The SAB recommends that this emphasis must  
10 shift in order to account for strong connections along any one of the four pathways of connection. If the  
11 goal of defining and estimating connectivity is to protect downstream waters, the interpretation must  
12 move from a dichotomous, categorical distinction (connected vs. not connected) towards a gradient  
13 approach that recognizes variation in the strength, duration and magnitude and effect of those  
14 connections.

15  
16 *Recommendations*

- 17  
18 • The overall conclusion for floodplain and non-floodplain wetlands (Conclusion 3 in Section 1.4.3)  
19 should be revised to focus on what is supported by the scientific literature and to provide more  
20 specifics on what still needs to be resolved (e.g. degree of connectivity, analyses of temporal or  
21 spatial variability).
- 22  
23 • The following text should be included in Conclusion 3 of the Report: *“Over sufficiently long time  
24 scales all aquatic habitats are connected to downstream waters through the transfer of water,  
25 chemicals or biota, yet the magnitude and effects of these connections vary widely across wetlands.”*
- 26  
27 • All of the Report’s conclusions should encompass connections beyond hydrologic connectivity (i.e.,  
28 to include biotic connections), and the frequency, magnitude, and duration of these connections  
29 should be considered.
- 30  
31 • Conclusion 3 of the Report should explicitly state the four pathways by which non-floodplain  
32 wetlands can be connected to downstream waters: i.e., via surface water, shallow subsurface  
33 flowpaths or groundwater flowpaths, or through the movement of biota.
- 34  
35 • The conclusions in the Report should state that connectivity is based on the magnitude and effect of  
36 water, material, and biotic fluxes to downstream waters.
- 37  
38 • The SAB recommends that assessment of connectivity be revised from a dichotomous, categorical  
39 distinction (connected vs. not connected) to a gradient approach that recognizes variation in the  
40 strength, duration and magnitude, and effect of those connections.

41  
42 **3.8.2. Recommendations Concerning Findings for Waters and Wetlands with Potential**  
43 **For Unidirectional Hydrologic Flows to Rivers and Lakes**

44  
45 The SAB provides a number of recommendations to improve the presentation of findings in Section  
46 1.4.3 of the Report.

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The SAB recommends that, as has been done for prior conclusions, the authors remove references to specific studies within the text of the key findings. The Report’s conclusions are intended to summarize general themes arising from a broad synthesis of diverse literature. The SAB finds that it is not necessary to attribute these overarching findings to one or a few specific studies. Further, the SAB recommends that the key findings be short and concisely stated.

The SAB also recommends that the key findings be more explicitly presented in the text of the Report. Conclusions about non-floodplain wetlands are summarized in Table 5-4, but these same summary points are not clearly explained in the text itself. In addition, Table 5-4 discusses functions of wetlands but does not present conclusions on how those functions translate to an effect on downstream water quality based on the magnitude or duration of any of the modes of connection discussed in the literature. For example, the statement that “unidirectional wetlands can remove, retain, and transform many nutrient inputs” refers to such functions, but there is no conclusion about how these would affect downstream waters.

The SAB recommends that the EPA revise several of the key findings in Section 1.4.3 of the Report. These revisions are consistent with the literature synthesis performed and the SAB’s knowledge of the subject.

*Key Finding a*

The SAB agrees with this general statement about the hydrosphere and general interconnectivity of wetlands and has no recommendations for changes in the existing text.

*Key Finding b*

The SAB recommends including the following statement in the Report as an additional key finding on the *biological functions* of unidirectional wetlands:

*“Wetlands provide unique and important habitats for many organisms, both common and rare. Some of these organisms require multiple types of waters to complete their full life cycle, including downstream waters. Other organisms, especially abundant species, play important roles in transferring energy and materials between wetlands and downstream waters.”*

The SAB also notes that the Report’s conclusion on the similarity between wetlands and water bodies needs further substantiation from the literature as the functions within each are quite different, especially in nutrient and organic matter production. In addition, this conclusion should recognize the differences between natural wetland systems and those which are man-made or are found in urban environments. The functions and values of these wetlands may be severely compromised or absent and therefore may not similarly influence downstream waters as natural wetlands may have.

*Key Finding c*

The SAB recommends including the following statement in the Report as an additional key finding about unidirectional wetlands and downstream waters to parallel the preceding finding on “hydrologic connectivity”:

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1  
2        “Biological connectivity can occur between [non-floodplain] wetlands and downstream waters  
3 through two major mechanisms: 1) activities of biological organisms within wetlands, and 2)  
4 movements of animals and plants. Activities of biological organisms within wetlands (e.g.,  
5 foraging, breeding, roosting) can change the amount, concentration, and spatial density of  
6 organic and/or inorganic components within the water column or soils, which can be transmitted  
7 down-gradient by fluxes of surface water or groundwater. Movements of animals (i.e.,  
8 macroinvertebrates, fish, amphibians, reptiles, birds, mammals) and plants (i.e., seeds,  
9 propagules, including colonization by invasive species or pathogens) can also occur among  
10 waters with varying magnitude, frequency, duration, and distance. Many species in these groups  
11 that use both stream and wetland habitats are capable of dispersal distances equal to or greater  
12 than distances between many [non-floodplain] wetlands and river networks. Migratory  
13 waterbirds (e.g., waterfowl, shorebirds, waders, and colonial species) can be an important  
14 vector of long-distance dispersal of plants, invertebrates, parasites, and pathogens between these  
15 waters and the river network. In addition, the magnitude of translocated biomass and nutrients  
16 can be substantial, when large numbers of individuals move temporarily, periodically, or  
17 permanently between waters.”

18  
19 *Key Finding d*

20  
21 The SAB has no recommendations for changes in the existing text.

22  
23 *Key Finding e*

24  
25 The SAB has no recommendations for changes in the existing text.

26  
27 *Key Finding f*

28  
29 The SAB recommends including the following two additional key findings that summarize important  
30 information from the main body of the document that was not emphasized in the original wording of the  
31 key findings f.

32  
33        Suggested additional key finding on *spatial proximity* of non-floodplain wetlands: “*Spatial*  
34 *proximity is an important determinant of the magnitude, frequency and duration of connections*  
35 *between wetlands and streams that will ultimately influence the fluxes of water, materials and*  
36 *biota between wetlands and downstream waters.*”

37  
38        Suggested additional key finding on the *cumulative or aggregate impacts* of non-floodplain  
39 wetlands: “*The cumulative influence of many individual wetlands within watersheds can*  
40 *strongly affect the spatial scale, magnitude, frequency, and duration of hydrologic, biologic and*  
41 *chemical fluxes or transfers to downstream waters. Because of their aggregated influence, any*  
42 *evaluation of changes to individual wetlands should be considered in the context of past and*  
43 *predicted changes to other wetlands within the same watershed.*”

44  
45 The SAB recommends that the Report authors cite the following references in support of this last  
46 statement: Preston and Bedford (1988); Lee and Gosselink (1988).

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1 *Recommendations*

2

3 • The authors should remove references to specific studies within the text of the key findings in the  
4 Report. The Report's conclusions are intended to summarize general themes arising from a broad  
5 synthesis of diverse literature.

6

7 • The key findings should be more explicitly presented in the text of the Report. Conclusions about  
8 unidirectional wetlands are summarized in Table 5-4, but these same summary points are not clearly  
9 explained in the text itself.

10

11 • The SAB recommends revising several of the key findings in Section 1.4.3 of the Report (see  
12 recommended text above).

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1  
2 **APPENDIX A: THE EPA’S CHARGE QUESTIONS**  
3  
4  
5

6 **Connectivity of Streams and Wetlands to Downstream Waters:**  
7 **A Review and Synthesis of the Scientific Evidence**  
8

9 **Technical Charge to External Peer Reviewers**  
10  
11

12 Understanding the physical, chemical, and biological connections by which streams, wetlands,  
13 and open-waters affect downstream waters such as rivers, lakes, and oceans is central to  
14 successful watershed management and to meeting water quality goals. It is also central to  
15 informing policy decisions that guide our efforts to meet these goals. The purpose of this Report,  
16 titled *Connectivity of Streams and Wetlands to Downstream Waters: A Review and Synthesis of*  
17 *the Scientific Evidence* is to summarize the current scientific understanding of broadly applicable  
18 ecological relationships that affect the condition or function of downstream aquatic ecosystems.  
19 The focus of the Report is on small or temporary non-tidal streams, wetlands, and open-waters.  
20 Examples of relevant connections include transport of physical materials such as water or wood,  
21 chemical compounds such as nutrients or pesticides, movement of biological organisms such as  
22 fish or insects, and processes or interactions that alter material transport, such as nutrient  
23 spiraling. Materials reviewed in this Report are limited to peer reviewed scientific literature.  
24 Findings from this Report will help inform EPA and the U.S. Army Corps of Engineers in their  
25 continuing policy work and efforts to clarify what waters are covered by the Clean Water Act. As  
26 a scientific review, the Report does not consider or make judgments regarding legal standards for  
27 Clean Water Act jurisdiction.  
28

29 The Report is presented in six chapters. Key findings and major conclusions are summarized in  
30 Chapters 1 (Executive Summary) and 6 (Conclusions and Discussion). Chapter 2 (Introduction)  
31 describes the purpose and scope of the document and the literature review approach. Chapter 3  
32 presents a conceptual framework that describes the hydrologic elements of a watershed, the types  
33 of physical, chemical, and biological connections that link them, and watershed climatic factors  
34 that influence connectivity at various temporal and spatial scales. Chapter 4 surveys the literature  
35 on stream networks with respect to physical, chemical, and biological connections between  
36 upstream and downstream habitats. Chapter 5 reviews the literature on connectivity and effects  
37 of non-tidal wetlands and certain open waters on downstream waters. All terms are used in  
38 accordance with standard scientific meanings, and definitions which are in the Report glossary.  
39  
40

## TECHNICAL CHARGE QUESTIONS

### Overall Clarity and Technical Accuracy of the Draft Report

1. Please provide your overall impressions of the clarity and technical accuracy of the draft EPA Report, *Connectivity of Streams and Wetlands to Downstream Waters: A Review and Synthesis of the Scientific Evidence*.

### Conceptual Framework: An Integrated, Systems Perspective of Watershed Structure and Function

2. Chapter 3 of the draft Report presents the conceptual basis for describing the hydrologic elements of a watershed; the types of physical, chemical, and biological connections that link these elements, and watershed climatic factors that influence connectivity at various temporal and spatial scales (e.g., see Figure 3-1 and Table 3-1). Please comment on the clarity and technical accuracy of this chapter and its usefulness in providing context for interpreting the evidence about individual watershed components presented in the Report.

### Lotic Systems: Ephemeral, Intermittent, and Perennial Streams

- 3(a) Chapter 4 of the Report reviews the literature on the *directional (downstream) connectivity and effects* of ephemeral, intermittent, and perennial streams (including flow-through wetlands). Please comment on whether the Report includes the most relevant published peer reviewed literature with respect to these types of streams. Please also comment on whether the literature has been correctly summarized. Please identify any published peer reviewed studies that should be added to the Report, any cited literature that is not relevant to the review objectives of the Report, and any corrections that may be needed in the characterization of the literature.

- 3(b) Conclusion (1) in section 1.4.1 of the Report Executive Summary discusses major findings and conclusions from the literature referenced in Charge Question 3(a) above. Please comment on whether the conclusions and findings in section 1.4.1 are supported by the available science. Please suggest alternative wording for any conclusions and findings that are not fully supported.

### Lentic Systems: Wetlands and Open Waters with the Potential for Non-tidal, Bidirectional Hydrologic Flows with Rivers and Lakes

- 4(a) Section 5.3 of the Report reviews the literature on the *directional (downstream) connectivity and effects* of wetlands and certain open waters subject to non-tidal, bidirectional hydrologic flows with rivers and lakes. Please comment on whether the Report includes the most relevant published peer reviewed literature with respect to these types of wetlands and open waters. Please also comment on whether the literature has been correctly summarized. Please identify any published peer reviewed studies that should be added to the Report, any cited literature that is not relevant to the review

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1 objectives of the Report, and any corrections that may be needed in the characterization  
2 of the literature.

3  
4 4(b) Conclusion (2) in section 1.4.2 of the Report Executive Summary discusses major  
5 findings and conclusions from the literature referenced in Charge Question 4(a) above.  
6 Please comment on whether the conclusions and findings in section 1.4.2 are supported  
7 by the available science. Please suggest alternative wording for any conclusions and  
8 findings that are not fully supported.

9  
10 **Lentic systems: Wetlands and Open Waters with Potential for Unidirectional Hydrologic**  
11 **Flows to Rivers and Lakes, Including “Geographically Isolated Wetlands”**

12  
13 5(a) Section 5.4 of the draft Report reviews the literature on the *directional (downstream)*  
14 *connectivity and effects* of wetlands and certain open waters, including “geographically  
15 isolated wetlands,” with potential for unidirectional hydrologic flows to rivers and lakes.  
16 Please comment on whether the Report includes the most relevant published peer  
17 reviewed literature with respect to these types of wetlands and open waters. Please also  
18 comment on whether the literature has been correctly summarized. Please identify any  
19 published peer reviewed studies that should be added to the Report, any cited literature  
20 that is not relevant to the review objectives of the Report, and any corrections that may be  
21 needed in the characterization of the literature.

22  
23 5(b) Conclusion (3) in section 1.4.3 of the Report Executive Summary discusses major  
24 findings and conclusions from the literature referenced in Charge Question 5(a) above.  
25 Please comment on whether the conclusions and findings in section 1.4.3 are supported  
26 by the available science. Please suggest alternative wording for any conclusions and  
27 findings that are not fully supported.

28

## APPENDIX B: TECHNICAL AND EDITORIAL CORRECTIONS FOR THE FINDINGS AND CONCLUSIONS

### *Recommended Wording for Section 1.4.2*

- Use “waters and wetlands in riparian/floodplain settings” throughout
- Page 1-9 line 9. After “and maturation habitat for stream insects” add, “and thus form integral components of river food webs” or other language that underscores food-web connectivity.
- Page 1-9 line 15, bullet a. Delete first sentence. Strive for consistency in terminology; i.e., suggest using “waters and wetlands in riparian/floodplain settings”.
- Page 1-9 line 21, bullet a. Delete “some”.
- Page 1-9 line 25, bullet b. Is “densely” needed? Suggest “variably”.
- Page 1-9 line 35, bullet c. Specify waters and wetlands in riparian/floodplain settings in lead sentence.
- Page 1-9 line 35, bullet c. Suggest “storing and subsequently releasing” rather than “desynchronizing”.
- Page 1-10 line 3, bullet d. Lead with “Waters and wetlands in riparian/floodplain settings”.
- Page 1-10 lines 5-6, bullet d. This example looks like an agricultural BMP and may not be appropriate. Suggest revisiting p 5-7 lines 24-35 for a more relevant example.
- Page 1-10 line 7, bullet e. Lead sentence emphasizes ecosystem function but body of paragraph describes biological connectivity. This might require a different lead sentence or an additional bullet on functional components/processes.
- Page 1-10 line 23, bullet e. Suggest including the importance of waters and wetlands in riparian/floodplain settings to birds, and how birds can spatially integrate the watershed landscape.

### *Recommended Wording for Other Sections*

- Use “waters and wetlands in riparian/floodplain settings” throughout.
- Page 5-37 top paragraph lines 6-17. This is a strong paragraph and may be preferable to the opening paragraph of 1.4.2. At least try to get some of these points into the opening of 1.4.2.
- Table 5.3. Bullets use “riparian areas” and it would be preferable to call out “waters and wetlands in riparian/floodplain settings.” The second bullet appears to be bit over generalized, as there can be high variability in lateral flow and exchange along the drainage network (e.g., beads on a string). Also, if the text in this chapter on riparian areas is moved to the streams chapter and replaced with other material, further changes may be needed.
- Page 6-1 lines 23-34. This additional conclusion section is fine, but again check for consistency of terms. Also, sediments are identified as both a source and sink in the same paragraph. Most commonly they are a sink. It might be preferable to refer to sediment exchange influencing channel dynamics.
- Page 6-1 line 30. Suggest connecting nursery habitat to healthy downstream populations. Also suggest reinforcing that waters and wetlands in riparian/floodplain settings are tightly coupled through food-web linkages. Role and importance of birds should also be mentioned.