Compilation of Preliminary Individual Comments from Panel Members

(as of December 11, 2013)

Dr. Allison Aldous

EPA Science Advisory Board Draft Report: Connectivity of Streams and Wetlands to Downstream Waters: A Review and Synthesis of the Scientific evidence

Responses to Charge Questions

Dr. Allison Aldous
December 9, 2013

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.

This technical document is a well-researched, well-organized, clearly-written, and thorough summary of the peer-reviewed literature documenting the biological and physical connections among certain types of streams and wetlands, and their associated downstream water bodies. Overall, the synthesis of this body of information is technically accurate, and the majority of my comments are minor corrections, additions, or clarifications. Major comments are found at the beginning of each section.

For each type of water body under consideration, first the relevant literature quantifying connectivity is reviewed and then an assessment is made whether the amount of scientific evidence is adequate to conclude those water bodies are significantly connected to one another. There is some lack of clarity on how that decision was made.

Following the well-established concepts of watershed science described in Section 3, all aspects of a watershed are connected to one another via multiple pathways, to varying degrees. The question being answered appears to be how many studies have been done to quantify those pathways of connectivity. The amount of research is related to how easy it is to study a certain ecosystem or process, in terms of available methods and geographic scope and access. For example, direct river-floodplain connections are easier to study with available methods than the cumulative water budget effects of hydrologic changes to small dispersed wetlands across an ecoregion. Therefore this part of the assessment is troublesome because the decision of significant connection (or not) is somewhat arbitrary.

Additional clarification is needed on how the decision was made that some types of wetlands were found to have significant connections to downstream waters, and others were not. For example, the wetlands for which the authors expressed the greatest uncertainty were unidirectional wetlands with no surface water connection to downstream water bodies (Section 5.4). In case studies, they concluded that there was adequate evidence for the relatively well- studied prairie potholes but not enough evidence for the less well-studied Delmarva & Carolina Bays, despite many hydrologic similarities between them. The same conclusion could have been drawn for vernal pools had it not been for the detailed studies by Rains et al. (2006; 2008). Moreover, no research is described that concludes no connectivity between wetlands and downstream waters.

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.

<u>MajorComments</u>.

The conceptual model presented in this chapter uses the watershed as the unit for analysis of connectivity among water bodies. This is an appropriate and useful scale of analysis, and one under which flow systems of different scales can be nested. Within the watershed unit, the types and relationships of water bodies are accurately and clearly described, with some exceptions described below, as are the ways in which water bodies are connected to one another and to downstream waters.

An important exception to the watershed concept is that groundwater catchments don't necessarily coincide with surface water catchments, particularly in areas with low relief. This is because surface waters move along topographic gradients, whereas groundwater flows along head gradients due to differences in aquifer characteristics. This exception is more important for regional confined aquifers than the surficial unconfined aquifers considered in this report, but it should be noted regardless in the section on groundwater (p.3-9 to 3-12).

Figure 3-5 (p. 3-11), illustrating the relationships between shallow groundwater flowpaths and rivers and wetlands, is not accurate and a number of corrections need to be made.

1. The water table should be sloped, not flat
    a. A water table is rarely flat in a landscape with as much topography as is pictured here. The main intermediate or regional flowlines shown between the confining layers show deeper groundwater flow from left to right, which could not be driven by a flat water table.
    b. Unless there are unusual geologic features, the water table of the unconfined aquifer should be a subdued replica of topography. For example, the water table should be slightly higher under the hills.
    c. The water table should slope towards the gaining stream on the right, or else there is no hydraulic head gradient to drive groundwater flow to that stream. The alternative would be a geologic structure providing artesian conditions in proximity to the channel.

2. The flowline that is shown moving as an arc up and over the local confining layer in the upper left is not correct. Instead, a flowline showing precipitation should move through the unsaturated zone above the confining layer. That water will either flow around the confining layer to the left, and continue to move through the unsaturated zone until it hits the water table, or it will discharge to the surface along the slope in the area indicated as a spring.

3. The flowline showing a spring discharging directly from the confining layer should be drawn above the confining layer.
4. Groundwater flowpaths should not turn at nearly right angles as shown for the flowpaths on the left side of the diagram.
5. This diagram could have been drawn to include a wetland that has developed at a point of shallow groundwater discharge (e.g. a sloping fen). This kind of wetland would develop where the water table is close to and intersects the ground surface, such as at a break in slope along one of the hillsides. This hydrogeologic cross-section is a good opportunity to illustrate the ways that shallow groundwater connects unidirectional wetlands to streams, as discussed in section 5.4.2.

Figure 3-15 on p. 3-34 and accompanying text on p. 3-40 do not adequately describe the role of groundwater in streamflow.

1. The figure caption defines runoff as "…*the difference between precipitation and evapotranspiration at the watershed scale*". This definition ignores the role of groundwater recharge, which accounts for some of the deposited precipitation, as well as groundwater discharge to streams, which accounts for baseflow. Baseflow accounts for major differences in the 5 hydrographs depicted, from the Metolius which has very high baseflow, to the San Pedro which has no baseflow.
2. Text describing the hydrograph of the Noyo River (p. 3-40, lines 14-21) is confusing. The statement "…*impermeable bedrock prevents precipitation water from moving to deep groundwater"* implies that baseflow in this drainage is low. Thus the statement *"...baseflow levels are high during the winter and low during the dry summer season*" is not accurate as baseflow should be low year-round. In this system, baseflow is easily seen as the area under the curve in Sep-Oct.
3. The hydrograph for the San Pedro shows no flow for most of the year, and this is used as an example of a type of hydrograph common to desert SW streams. Depending on where this gage is in the basin, this lack of baseflow could be due to groundwater pumping from the shallow alluvial and deeper aquifers or land use changes that have altered floodplain connectivity to the water table (Stromberg et al. 1996; Leenhouts et al. 2005; Marshall et al. 2010). The figure caption should indicate whether or not this hydrograph is highly altered from its recent historic condition, which will determine the extent to which it can be used as a hydrograph illustrating this type of system.

<u>MinorComments</u>.
Page 3-5, line 12. Confusing sentence. *"Like riparian areas, wetlands are transitional areas…*". This makes it sound like riparian areas are not wetlands. Suggested edit: "Wetlands are transitional areas…as was described previously for riparian wetlands"

Figure 3-4 legend (p. 3-9) state that the water table is indicated by an inverted triangle

Definition of aquiclude (p. 3-10, line 5-6) should indicate that in addition to not transmitting water, it often prevents water from moving between geologic strata.

p. 3-12 lines 34-36. Return flow is a term not generally used for springs supported by shallow groundwater discharge. Return flow is most commonly used to refer to irrigation water that is not consumed, and is returned to a stream, lake, or wetland. Unless there is a citation for this statement (there isn't one at the moment), I suggest this sentence be deleted. The term is not used elsewhere in the report.

Lotic Systems: Ephemeral, Intermittent, and Perennial Streams

3(a) Chapter4 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.

MajorComments

Chapter 4 contains a comprehensive summary of the large body of literature on upstream- downstream connectivity. This section is technically accurate with some minor exceptions listed below.

Section 4.5 "*Biological Connections*" should include a section on plants. For example, streams provide important means of dispersal for many floodplain species, such as cottonwood and willow.

p. 4-41, lines 13-23. This section needs more information about how the Ogallala aquifer is connected to streams in the prairies. The current text states, "*Regional movement of water through the aquifer is from west to east, but locally the water moves toward major tributaries*". However, there is no information about the spatial and temporal distribution of discharge to the stream, how groundwater-surface water interactions affect streamflow, and how this has changed with water table declines in the aquifer.

MinorComments.

p. 4-3, lines 30-32. The term baseflow is not used correctly. Baseflow is only the groundwater discharge component of the hydrograph. It does not include direct precipitation or overland flow resulting from precipitation. The sentence should read, "*For example, headwater streams which have stronger connections to groundwater ~~orwhichconsistentlyreceivemoreprecipitation~~, relative to downstream reaches, will have a larger effect on river baseflows*".

p. 4-3 and 4-4, lines 34-35 and 1-3. Explanation of Shaman et al. 2004 study is unclear. "*Baseflow discharge in smaller streams (i.e., with watersheds <8 km2) was more weakly correlated with mainstem discharge than discharge in larger streams; the authors concluded that this pattern reflected greater contributions by deep groundwater as drainage area increased (Shaman et al., 2004).*"

Is this a clearer explanation of these results? "*Discharge in tributary and mainstem streams was more strongly correlated in larger (>8 km^2) compared to smaller watersheds (Shaman et al.,* *2004). The authors concluded that this pattern reflected greater contributions by deep groundwater as drainage area increased.*"

p. 4-6, figure 4-1. Typo. Y-axis top number should be 550.

p. 4-7, figure 4-2. Figure caption is missing information. What are (a) and (b)? Where are stream gages in relation to one another?

p. 4-10, line 28. Sentence is missing the word *tributary*? "A long-term sediment budget for the Coon Creek watershed (360 km^2), a tributary stream to the Mississippi River in Wisconsin…"

p. 4-13, lines 29-33. A good citation for the sentence, "*Groundwater temperature is largely buffered from seasonal and short-term changes that affect air temperature, so that in temperate climates, groundwater tends to be cooler than air temperature in summer but warmer in winter*." is Manga (2001).

> 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.

The conclusions discussed in this section are supported by the science described in Section 3.

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

This section is technically accurate, with the following proposed changes.

p. 5-3, line 26. The report states that papers on riparian and floodplain wetlands do not state if the area is a wetland. The authors do not list the papers, so it is not possible to confirm this statement, however it should be possible from the intent of the paper to determine if the study ecosystem is a wetland or not.

p. 5-14, lines 10-14. Confusing sentence with proposed edits underlined. "*In addition, microbial biomass has been shown to be positively correlated with the loss of the herbicides 2,4-D (2,4-dichlorophenoxyacetic acid) and dicamba, suggesting* <u>*thegreater*</u> ~~*arelationshipbetween*~~ *the amount of microbial biomass in the soil,* <u>*thegreater*</u> *the capacity of an ecosystem to degrade pesticides (Voos and Groffman, 1996)*".

p. 5-17, lines 7-9. Missing information indicated in parentheses. "*From January to June 2003, 14 and 31% of total diatom and total green algae biomass [of a certain reach of the Sacramento River?], respectively, was produced in the floodplain (Lehman et al., 2008).*"

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

The conclusions discussed in this section are supported by the science described in Section 4.

Lentic systems: Wetlands and Open Waters with Potential for Unidirectional Hydrologic Flows to Rivers and Lakes, Including "Geographically Isolated Wetlands"

> 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.

This section is technically accurate, with the following proposed edits.

Section 5.4.2.2, Groundwater Connections: additional literature

1. Shallow groundwater can support the peatland water table, thus connecting wetlands across larger areas to each other and to streams, as demonstrated in northern Minnesota (Glaser et al. 1997; Siegel et al. 1995). These studies show that the peatland water table is a balance between precipitation and the local groundwater flow system. Groundwater discharge at the base of the peat is low during wet years, because the hydraulic head of precipitation maintains a high water table. During dry years, the groundwater rises higher in the peat column, thus preventing the water table from dropping as much as it might with no groundwater discharge. Thus the groundwater partly decouples the peatland water table mound from climatic variation and connects the peatland to the local or regional groundwater flow system.

2. Data from over 70 fens in the Midwest are summarized by Amon and co-authors (2002).

The fens discussed are all supported by discharging groundwater; however, they differ in the amount and form of water flowing out of the fens, ranging from significant sheet flow, to no outflow.

3. Additional studies describing how groundwater flows through headwater wetlands and towards mainstem rivers, often in shallow sub-surface pathways: Hill and Devito (1997); Almendinger and Leete (1998).

Section 5.4.3.2, Unidirectional Wetlands as Sinks and Transformers for Downstream Waters: additional literature

1. A number of studies have demonstrated the importance of peatlands in removing nitrogen deposited from atmospheric sources. Peatland mosses have been shown to remove 50-100% of N applied aerially (Aldous 2002; Bayley et al. 1987; Li and Vitt 1997; Jauhiainen et al. 1999) and 100% of N from natural precipitation (Woodin and Lee 1987).

2. Several studies document how headwater peatlands help to maintain stream water quality by intercepting excess nutrients and sediments coming from uplands (Drexler et al. 1999; Boomer and Bedford 2008a; 2008b) and export organic matter, which often forms the base of food webs in streams and lakes (Schiff et al. 1998).

<u>MinorComments</u>

p. 5-21, lines 18-19. Slope wetlands such as fens often have diffuse inflow via groundwater but channelized outflow – see notes and literature above related to section 5.4.2.2

p. 5-24, lines 31-32. Please provide an example for this unusual case, I cannot think of any examples: *"A wetland can also be hydrologically isolated from streams and rivers if it recharges a groundwater aquifer that does not feed surface waters*."

Table 5-2, p. 5-34, Oregon spotted frog (*Rana pretiosa*) should be included in this list. Habitat requirements of the Oregon spotted frog differ depending on the stage of its life cycle; it lays its eggs in shallow temporary pools, often in unidirectional wetlands, and moves to deeper perennial streams as an adult (Pearl et al. 2005; 2009).

Table 5-3, p. 5-38. Final bullet point under "Physical Connectivity and Function" should include flow, as in "*Groundwater that flows through riparian areas and into the stream helps moderate stream temperatures <u>andflow</u>*"

Table 5-4, p. 5-39. Second bullet point should include surficial geology, which in many cases plays a more important role than soils. "*The degree to which outputs (or connections) are dominated by surface water vs. groundwater is controlled in part by <u>surficialgeologyand</u> soil permeability: Permeable <u>geologicdepositsand</u> soils favor groundwater outputs, while impermeable <u>geologicdeposits and</u> soils result in surface water outputs. Other factors, such as topographic setting, can also play a role.*"

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

Major Comments

The conclusions drawn here are thorough and technically accurate. However, see comment above (listed under the first question related to overall clarity and technical accuracy), which applies directly to this section.

Minor Comments

p. 1-10, lines 29-30. The term *baseflow* is not used correctly. Baseflow is only the groundwater component of the river hydrograph. Better phrasing is "*These functions include storage of floodwater; retention, and transformation of nutrients, metals, and pesticides; and recharge of groundwater thatwillsupport ~~sourcesof~~ river baseflow.*"

Literaturecited:

Aldous, A. R. 2002. "Nitrogen retention by *Sphagnum* mosses: responses to atmospheric nitrogen deposition and drought." CanadianJournalofBotany 80: 721-731.

Almendinger, J. E. and J. H. Leete, 1998. "Regional and local hydrogeology of calcareous fens in the Minnesota River basin, USA." Wetlands 18:184-202.

Amon, J. P., C. A. Thompson, Q. J. Carpenter and J. Miner. 2002. "Temperate zone fens of the glaciated midwestern USA." Wetlands 22(2): 301-317.

Bayley, S. E., D. H. Vitt, R. W. Newbury, K. G. Beaty, R. Behr and C. Miller. 1987. "Experimental acidification of a *Sphagnum*-dominated peatland: first year results." Canadian JournalofFisheriesand AquaticScience 44(Suppl. 1): 194-205.

Boomer, K. and B. Bedford, 2008a. "Groundwater-induced redox-gradients control soil properties and phosphorus availability across four headwater wetlands, New York, USA." Biogeochemistry 90:259-274.

Boomer, K. B. and B. L. Bedford, 2008b. "Influence of nested groundwater systems on reduction-oxidation and alkalinity gradients with implications for plant nutrient availability in four New York fens". JournalofHydrology 351:107-125

Drexler, J. Z., B. L. Bedford, A. DeGaetano and D. I. Siegel, 1999. "Quantification of the water budget and nutrient loading in a small peatland." JournaloftheAmericanWaterResources Association 35:753-769

Glaser, P. H., D. I. Siegel, E. A. Romanowicz and Y. P. Shen. 1997. "Regional linkages between raised bogs and the climate, groundwater, and landscape of north-western Minnesota." Journal of Ecology 85: 3-16.

Hill, A. R. and K. J. Devito, 1997. Hydrological-chemical interactions in headwater forest wetlands. *In: Northern Forested Wetlands Ecology and Management*, C. C. Trettin, M. F. Jergensen, D. F. Grigal, M. R. Gale and J. K. Jeglum (C. C. Trettin, M. F. Jergensen, D. F. Grigal, M. R. Gale and J. K. Jeglum(C. C. Trettin, M. F. Jergensen, D. F. Grigal, M. R. Gale and J. K. Jeglums). CRC Lewis Publishers, Boca Raton, FL, pp. 213-229.

Jauhiainen, J., J. Silvola and H. Vasander. 1999. "The effects of increased nitrogen deposition and CO2 on *Sphagnum angustifolium* and *S. warnstorfii*." AnnalsBotanicaFennici 35: 247-256.

Leenhouts, J. M., J. C. Stromberg and R. L. Scott. 2005. Hydrologic Requirements of and Consumptive Ground-Water Use by Riparian Vegetation along the San Pedro River, Arizona. U.S. Geological Survey Scientific Investigations Report 2005-5163, 154 p.

Li, Y. and D. H. Vitt. 1997. "Patterns of retention and utilization of aerially deposited nitrogen in boreal peatlands." Ecoscience 4: 106-116.

Manga, M. 2001. "Using springs to study groundwater flow and active geologic processes." Annual ReviewofEarthPlanetSciences 29: 201-228.

Marshall, R. M., M. D. Robles, D. R. Majka and J. A. Haney. 2010. "Sustainable Water Management in the Southwestern United States: Reality or Rhetoric?" PLoSOne 5(7). Published online July 2010.

Pearl, C.A., J. Bowerman, and D. Knight. 2005. Feeding behavior and aquatic habitat use by Oregon spotted frogs (*Rana pretiosa*) in central Oregon. NorthwesternNaturalist 86:36-38.

Pearl, C.A., M.J. Adams, and N. Leuthold. 2009. Breeding habitat and local population size of the Oregon spotted frog (*Rana pretiosa*) in Oregon, USA. NorthwesternNaturalist 90:136-147.

Schiff, S., R. Aravena, E. Mewhinney, R. Elgood, B. Warner, P. Dillon and S. Trumbore, 1998. Precambrian Shield Wetlands: Hydrologic Control of the Sources and Export of Dissolved Organic Matter. ClimaticChange 40:167-188

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Stromberg, J. C., R. Tiller and B. Richter. 1996. "Effects of groundwater decline on riparian vegetation of semiarid regions: the San Pedro, Arizona." EcologicalApplications 6(1): 113-131.

Woodin, S. J. and J. A. Lee. 1987. "The fate of some components of acidic deposition in ombrotrophic mires." EnvironmentalPollution 45: 61-72.

Dr. Genevieve Ali

Last modified: December 1st, 2013

I would like to acknowledge a thoroughly documented report on downstream connectivity-related research with countless impeccable figures, tables, paragraphs and sections. The elements currently included in the draft report generally require no correction or further explanation but I would be interested in knowing why some areas of research were not covered (or not detailed) in the draft report. I tried to separate my general, overall comments (see part A) from my answers to the technical charge questions (part B).

A) GENERAL COMMENTS

- Would it be possible to relax the constraint that was set by the authors about using only peer-reviewed material as the basis for this draft report? I understand that a line had to be drawn when establishing a methodology but government publications, in particular, might have provided interesting case studies to report on.

- The effects of altering (i.e., enhancing or preventing) or restoring connectivity through human modifications of the landscape are mentioned in passing in multiple places in Chapters 3, 4 and 5 but not covered extensively. I find it to be the main weakness of the draft report, especially in light of the technical charge document which states that:

  > "*understanding the physical, chemical, and biological connections by which streams, wetlands, and open-waters affect downstream waters such as rivers, lakes, and oceans is central to successful watershed management and to meeting water quality goals. It is also central to informing policy decisions that guide our efforts to meet these goals"*

  and also that:

  > *"findings from this Report will help inform EPA and the U.S. Army Corps of Engineers in their continuing policy work and efforts to clarify what waters are covered by the Clean Water Act."*

  In relation to streams, for example, it is unclear to me why man-made drainage features such as surface drains, roadside ditches or tile drains were not discussed in more detail. Also, in relation to wetlands, it might have been interesting to include case studies on the altered connectivity of wetlands that have been fully drained, consolidated, cropped, etc. I think that the issue of connectivity in highly anthropized environments would gain in being detailed in a separate chapter or emphasized in Chapter 6, especially when it comes to stream restoration (what stream properties should be restored?), surface drainage (artificial versus natural drainage density), wetland drainage and wetland restoration (what wetland functions should be restored?). Another suggestion could be, for Chapters 4 and 5, to include an additional case study that specifically addresses the impact of human landscape features on connectivity.

- The draft report does not include any significant discussion of potential competing watershed management goals, e.g., enhancing biological connectivity while preventing hydrologic and chemical connectivity. While watershed management is a vital end-use of research around connectivity (and that is the motivation for the draft report), the real issue "in practice" is often to determine the appropriate level of connectivity or disconnectivity to be achieved for each niche: hydrological, chemical, biological, etc. (Bracken et al., 2013). Those issues could be emphasized in Chapter 6.

- Concepts of temporal thresholds and tipping points are not at all discussed in the report, but they should as they would clarify the definition of (and assumptions behind the concept of) isolated wetlands. Please refer to my answer to technical charge question 5a).

- Research studies on the connectivity of roads to streams are not described in the draft report and should, at least, be mentioned if not detailed in a "case study" format. Roads are human landscape features that are critical to consider not only because of their connectivity with channels at stream crossings but also because road-associated gullying leads to an extension of the channel network (e.g., Montgomery, 1994; Wemple *et al*., 1996, 2003; Croke and Mockler, 2001; Wigmosta and Perkins, 2001; Croke et al., 2005; Thompson *et al*., 2008).

- Chapter 6 opens a small window on the issue of detecting impairments to connectivity but does not expand on it, especially when it comes to techniques that might be available to isolate effects or impairments that are cumulative.

- While the use of multiple case studies is great to support the elements presented in Chapters 4 and 5, the draft report fails to do a synthesis of techniques or assessment methods to characterize (measure) connectivity in practice. It is true that there is no consensus about the variables, metrics or indicators to use to measure the magnitude, duration or timing of connectivity (especially hydrologic connectivity) but it would be worth stating lack of consensus. In its current state, the report seems to imply that the science around hydrologic connectivity is well established and relies on a universal (or largely agreed upon) methodological framework, while it is not at all the case.

- Figure 6.1 should probably be expanded to include some of the "*metrics and indicators used in EPA's national assessments of streams, rivers, lakes, wetlands, and coastal waters*" (page 6-5). Also, the literature on connectivity indicators or metrics cited in Chapter 6 is mostly of ecological nature and mostly concerns longitudinal connectivity. It would be worth specifying why we need connectivity indicators or metrics for management purposes: some indicators or metrics available in the literature can be used to characterize the degree of connectivity from data collected in the field, while some others can only help us answer the question: what leads a potential stream or wetland function to become an actual one? In association with Figure 6.1, it would be beneficial to make a list of such indicators or metrics and classify them according to whether they are stress indicators, exposure indicators or response indicators.

B) ANSWERS TO 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.

As stated in my general comments above, I find the draft report to be very thorough in its treatment of the topics that are indeed included in the report. Most of my comments above and below concern elements that were not treated in the drafted report.

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.

Chapter 3 is very easy to read and very pedagogical in its description of the conceptual framework. My only comment is about the definition of connectivity adopted throughout the report, namely "*the degree to which components of a system are joined, or connected, by various transport mechanisms*". This definition raises two questions that are not explicitly addressed in the remainder of the draft report. First, the phrase "the degree to which" clearly implies that connectivity is not a binary property but rather a continuum of system states, which I agree with; however the draft report does not explicitly describe how those successive states should be measured or monitored. Also, in the definition of connectivity, the phrase "*transport mechanisms*" does not specify the timescale of interest, i.e. it is unclear whether system components linked via regional groundwater over decadal scales are considered in the same way as system components linked via surface flow at the scale of precipitation events. That issue of timescale or cutoff time for the definition of connectivity is especially important when defining the isolation of wetlands (see my answer to question 5a) below).

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.

I was expecting to find explicit references to environmental flow requirements, especially in relation to biological connectivity. As for the concept of nutrient spiraling or spiraling length: can it be used to define levels of (scientifically and socially) acceptable and unacceptable chemical connectivity?

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.

I did not find any major discrepancy between the material in Chapter 4 and the executive summary of the draft report.

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

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

The draft report states that "*riparian and floodplain areas can reduce flood peaks by storing and desynchronizing floodwaters*" (page 1-9 and elsewhere) and although that statement is generally true, it should be nuanced in light of the impact of seasonally frozen ground, especially in northern Prairie States (where frozen soil inhibits the runoff and nutrient trapping capacity of riparian areas).

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

I did not find any major discrepancy between the material in section 5.3 and the executive summary of the draft report.

<u>Lentic systems: Wetlands and Open Waters with Potential for Unidirectional Hydrologic Flows to Rivers and Lakes, Including "Geographically Isolated Wetlands"</u>

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.

One clarification question: the phrase "geographic isolation" does not mean a lack of hydrologic connectivity but does it mean a lack of other types of connectivity (e.g., genetic)?

The draft report mentions issues related to the delineation of geographically isolated wetlands from coarse-resolution maps and also suggests that wetlands should not be considered individually but rather as part of larger complexes (i.e., consider wetland complexes as functional units). However no guidance is given as to how to delineate complexes rigorously from maps (while avoiding the coarse resolution issue, that is).

The draft report rightfully states that geographic isolation (concept used for wetlands completely surrounded by uplands, with uplands being areas that do not meet any of the three Cowardin criteria) should not be confused with functional isolation. The draft report also states that spatial scale is important when evaluating geographic isolation but the importance of temporal scale with respect to functional isolation is largely omitted. When comparing Chapters 4 and 5, it was interesting for me to realize that the adopted definitions of perennial, intermittent and ephemeral streams were very precise and tied to specific time scales (i.e. streams flowing all year long, seasonally or in response to precipitation events only) while the terminology used for wetlands was much more vague with references to permanent, frequent or infrequent surface water connection or inundation. For wetlands that are groundwater-dominated, the way (functional) isolation is (or should be) defined is strongly dependent on the relative presence of local, intermediate or regional flow systems (described in Chapter 3) and groundwater travel time. For example, assuming a typical Prairie Pothole setting with intermediate groundwater flow systems and groundwater travel times to the stream ranging from 90 to 400 days, if a cutoff time of one month were chosen to define functional isolation, then all unidirectional, geographically isolated wetlands (potholes) would also be functionally isolated. Using a cutoff time of one year, however, would only lead the most geographically (and hydraulically) remote potholes to be considered functionally isolated. I find the idea of a cutoff time critical for process understanding and management purposes because:

- It helps define a gradient of functional connectivity (or isolation) that the draft report currently refers to but deems difficult to establish (page 5-33).

- It is aligned with the definition of connectivity adopted in the draft report and that refers to "the degree to which system components are connected"; the "degree to which" is not only timescale-dependent (in its definition) but also time-variable (in its climate-driven evolution).

- It can be applied differentially for different niches, i.e. the cutoff time for chemical connectivity should probably be much longer than for hydrologic connectivity to prevent contaminants "trapped" in geographically (but not functionally) isolated wetlands from reaching the stream network in a short period of time. It might even be worth discussing what a socially acceptable definition of isolation (for water versus contaminants) should be and establish standard cutoff times for the definition of functional connectivity accordingly.

One valuable paper about the importance of the temporal scale or cutoff time to define (functional) isolation is Winter and Labaugh (2003): it is currently cited in the draft report but only in reference to the definition of groundwater systems and not in relation to the characterization of wetland isolation. If possible, I think that more emphasis should be put on functional isolation and a little less on geographic isolation because the former provides more information about system behaviours and its understanding can lead to better targeted management decisions.

Lastly, the draft report mentions the beneficial effects of isolation versus the beneficial effects of connectivity (depending on the material fluxes considered): would it be possible, in the report, to summarize the beneficial effects of connectivity versus isolation in a table and suggest a continuum of desirable and undesirable conditions and hence go beyond the simple literature review?

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

I did not find any major discrepancy between the material summarized in section 5.4 and the executive summary of the draft report.

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Dr. David Allan

RESPONSE TO TECHNICAL CHARGE QUESTIONS

J. David Allan, December 7, 2013

Charge Question 1: The overall clarity and technical accuracy of the draft EPA Report, "*Connectivity of Streams and Wetlands to Downstream Waters: A Review and Synthesis of Scientific Evidence*" is excellent. The Report is extremely thorough, comprehensive, and, where appropriate, cautious about the state of knowledge.

Charge Question 2: Chapter 3 of the Report sets forth the conceptual framework for connectivity in detail. It is essential to understand river systems from a network perspective, to appreciate the very important role of headwaters, and to recognize the extent of downstream influences as well as upstream influences as, for example, by movement of fish and other organisms. Connectivity as a fundamental property of streams and wetlands, and the factors that influence connectivity (or isolation), are explained clearly and accurately. This conceptual framework is very helpful for interpreting evidence about individual watersheds and appreciating the complexity of interacting factors.

Charge Question 3a: Chapter 4, Lotic Systems, provides a comprehensive, clear and compelling explanation of the physical, chemical and biological connections that link ephemeral, intermittent and perennial streams into a stream or river network. The reviewed literature is the most relevant, and it is correctly summarized and woven together to fully explain how river systems "work". While additional papers could no doubt be identified to further elaborate some details, the authors have included the appropriate literature.

Charge Question 3b: Conclusion (1) in section 1.4.1 and the major findings and conclusions to Charge Question 3(a) are fully supported by the available science.

Charge Question 4a: Section 5.3 of the Report summarizes existing knowledge with regard to (directional) downstream connectivity and the interactions of riparian and floodplain wetlands with rivers. Physical, chemical and biological connectivity are amply documented and clearly explained. Table 5-1 of the Report provides an excellent summary of the five functions (source, sink, refuge, transformation and lag) that make up the mechanisms of linkage. Table 5.3 provides a well-supported list of key conclusions regarding the effects of riparian and floodplain wetlands on physical, chemical and biological connectivity with rivers. The evidence in support of connectivity is significant and without question. While additional papers could no doubt be identified to further elaborate some details, the authors have included the appropriate literature.

Charge Question 4b: Conclusion (2) in section 1.4.2 and the major findings and conclusions to Charge Question 4(a) are fully supported by the available science.

Charge Question 5a: Section 5.4 of the Report summarizes existing knowledge with regard to (directional) downstream connectivity and effects of diverse types of wetlands with rivers. The Report refers to these wetlands as unidirectional wetlands, occurring along a gradient of hydrologic connectivity. The Report suitably notes that the state of scientific knowledge for this class of wetlands makes it difficult to generalize about the degree of connectivity, such that case by case studies may be necessary for specific situations. Nonetheless, Table 5.4 provides a well-supported list of key conclusions regarding the effects of unidirectional wetlands on physical, chemical and biological connectivity with rivers. The Report further makes it clear that use of the term "geographically isolated wetlands" should be used with extreme caution, if at all, because distance alone, especially in the absence of detailed hydrologic analyses, could result in incorrect conclusions about actual connectivity. While additional papers could no doubt be identified to further elaborate some details, the authors have included the appropriate literature.

Charge Question 5b: Conclusion (3) in section 1.4.3 and the major findings and conclusions to Charge Question 5(a) are fully supported by the available science. As new methods of analysis become available, future research may increase the ability to make scientific generalizations about unidirectional wetlands.

Dr. Lee Benda

Dr. Lee Benda (Earth Systems Institute)
Answers to Charge Questions 1 – 5b.

Question 1: Overall impression of the clarity and technical accuracy of EPA's draft report.

I have a good overall impression of EPA's draft report. It appears to be very thorough in many (most) respects without building an entire text book on the topic, which of course the topic could merit. I thought the figures were helpful and appropriate, with many of them designed to introduce physical and biological concepts to a lay audience.

I agree with the general structure as outlined in the table of contents, although I might suggest adding another subheading under the "Conceptual Framework" that discusses the issue of connectivity significance but at the population level of headwater streams (see Question 2 below).

I found some of the information covered in Section 5.0 difficult to sort out since it is complicated by the issue raised about the literature on floodplains and riparian areas vs. riparian/floodplain wetlands (pg. 5-3). I understand the author's dilemma and their solution to use all literature. However, all riparian areas are not wetlands; all floodplains are not wetlands. In the various subsections in 5.0, some of them continually refer to "riparian/floodplain wetlands" while other sections only mention "riparian areas" or "floodplains" (as if they were written by different authors which they might have been). I would like to see a bit more discussion about how wetlands and riparian area research is used interchangeably. I do not doubt the logic process but the approach needs to stand up to scrutiny by a skeptical audience.

I liked the case studies at the end of the Report. If the Report included an highlighted section on connectivity significance in terms of integration of the entire population of tributary and wetland source areas (see Question #2), it would be effective to include a case study illustrating that, but it might need to rest on simulation results, given the expanded space and time elements of that concept.

Question 2: Overall impression of the clarity, technical accuracy, and usefulness of the conceptual framework describing the hydrological elements of a watershed and the physical, chemical and biological connections linking these elements.

The Conceptual Framework section of the EPA Stream and Wetland Connectivity Report is quite comprehensive and highlights the general state of the watershed sciences as it pertains to river networks and wetlands within a watershed context. The level of detail it contains is approximately equivalent to an undergraduate course in geomorphology but with a heavy focus on connectivity that is more likely found in graduate level classes in lotic ecology and fluvial geomorphology.

The Conceptual Framework could use a bit of reinforcing in a couple of key areas.
(1) Although mentioned in several areas of the Framework (and also within the body of the Report), the concept of the "aggregate effect" or the integration of the many smaller, headwater streams on the functioning of larger rivers in a watershed need to be additionally highlighted and discussed. I think it is sufficiently relevant and important to merit its own subsection (e.g., Assessing Connectivity Significance: Single versus the Integrated Effects of Numerous Smaller Tributaries and Wetlands). This is an important concept because any individual small stream (or wetland) may be ecologically *insignificant* to any single larger (navigable) river (or other water body). As highlighted in the House of Representative's letter to Drs. Rodewald and Allen (Nov. 6, 2013), the question of "significant nexus" (Justice Kennedy in Rapanos v. United States, 2006) is raised. Contained in the House's additional charge questions is: "The real question…is the scientific significance of…connections on downstream traditional navigable waters…does the science provide a method to establish whether connections are significant?"

In the context of mainstem rivers integrating and accumulating the flow, sediment, nutrient, and biological materials of numerous smaller headwater tributaries (and connected and disconnected wetlands), the *significance* of connectivity must be heavily facilitated by the *integration* of all of the smaller (and perhaps individually *insignificant*) sources. For example, at the scale of a single 200 km^2 watershed, the flow and sediment originating from a single first-order stream with a drainage area of < 1 km^2 would be considered insignificant (to the mainstem river) but the space-time integration of all 200 first- and second-order streams in the watershed governs the total sediment mass balance of the larger river and the resulting in-channel sediment storage, channel morphology and aquatic habitat.

In this vein, the "significance nexus", although it could rest on location to location connectivity of a single small tributary or wetland to a larger river, could also be defined more appropriately as a population attribute of all small headwater streams and wetlands in a watershed (a river network statistical attribute). This infers that a number of headwater streams and wetlands could be ecologically compromised without serious ramifications to mainstream rivers; there is also a dilution effect. However, ecological impairment of mainstem rivers could occur if a sufficient number of the intersecting smaller streams and wetlands was impacted. Thus, the test of "significance" rests on a convolution (both in space and time) of each headwater tributaries' time series of water, sediment, organic debris, nutrients, and biological material production, export and storage downstream through larger river channels. This concept could be highlighted, discussed and illustrated in its own subsection of the Report, or it could be highlighted here and there in a sentence or two in several sections of the Report as it now occurs.

There are a number of other charge questions from the House (which I understand from Tom Armitage that we are not to address at this time) that could also motivate a few upgrades in the Conceptual Framework. For example, "What is the difference between a stream (using the Report's definition) and a road side or agricultural ditch? Do a majority of ditches perform the entire suite of functions performed by streams?" (e.g., the Conceptual Framework could include a subsection on "Artificial Channels, Diversions and Ditches", considering the proliferation of such drainage structures across the U.S.).

(2) The Conceptual Framework section could also use a bit more heft when it discusses Factors Influencing Connectivity, specifically Human Activities and Alterations (3.4.4). About ½ page is devoted to the issue of dams, which could be expanded to cover many impacts not discussed such as fish migration barriers and sediment starvation downstream, thereby altering channel and floodplain habitats. In addition, the question of negative cumulative watershed effects could be discussed in detail. It has ramifications for the concept of the aggregate (positive) influences of many small tributaries on mainstem rivers (as outlined above), but from the flip side of integrating numerous negative impacts originating from many small tributaries including increased sediment, thermal and nutrient pollution. The concurrence between negative cumulative watershed effects framed within the structure of network integration of many point sources (of everything) would add a nice theoretical touch to the Framework.

Question 3 (a): Comments on EPA's review and characterization of the literature on directional (downstream) connectivity and effects of ephemeral, intermittent, and perennial streams.

This section is relatively thorough and touches on the majority of relevant topics concerning physical, chemical, and biological connections to rivers. However, it could use additions in a couple of key areas.

The issue of map resolution on headwater stream delineation (such as the NHD 100,000 scale coverage missing many first and second order streams), although mentioned in several areas in the Report, could be effectively illustrated in a figure. A related topic is the increasing availability of LiDAR digital elevation models (DEMs) and thus the increasing ability to create more accurate and densified synthetic stream networks (e.g., the NHD is a cartographic product created from maps such as the blue line topographic maps [NHD+]). A comparison between the different technologies in a figure would be informative, including for the lay person, further illustrating how new technologies may influence the findings of connectivity significance.

Perhaps part of the reason why headwater streams (and perhaps small wetlands) are off the radar screen (at least in some state and federal jurisdictions) is because they remain poorly mapped. However, the increasing availability of high resolution DEMs (including the National Elevation Dataset [NED] 10 m DEM) and more robust flow routing algorithms means that more accurate stream maps (or GIS layers) are becoming increasingly available. Thus the ability to predict (and discern) hydrologic, geomorphic and ecological connections between small and large streams is increasing rapidly. For example, using better DEMs, many organizations are rapidly building higher resolution stream networks, fish habitat maps, more accurate floodplain maps, and predicting headwater streams prone to debris flows during storms and following wildfires. Thus, information about headwater streams will greatly increase in the near future and that information will be broadly disseminated across agencies, NGOs, and the public, oftentimes freely from websites. Hence, "connectivity" and "significant nexus" are not only issues related to the best available science (e.g., House charge questions, Smith and Stewart 2013) but are also issues pertaining to (and will be determined in some part by) technology (e.g., better digital data and more web dissemination).

For example, only in the last decade has the science and technology arrived to the point where it can predict the risk posed by mudflows or debris flows originating from small headwater streams (< 1 km^2) either following wildfires and logging (even if this risk has a low probability of occurrence of once every 200 years). Prior to this technology, small headwater streams were commonly off the policy radar screen, even if professional qualitative judgment indicated otherwise. Thus, has the significance of the nexus changed over a period of a decade based primarily on new technology? In addition, the significance question relates to the aggregation or population of tributaries outlined in #2 above. For instance, perhaps the risk of debris flows every 200 years on downstream fish habitat (not to mention homes and highways, not addressed here) would be considered not a significant nexus. However, at the scale of entire watersheds containing hundreds of individual headwater streams, the annual probability of debris flows increases to 100%. At the population level, the nexus is significant.

Question 3 (b): Comments on EPA's findings and conclusions concerning the directional (downstream) connectivity and effects of ephemeral, intermittent, and perennial streams (including flow through wetlands) are supported by the available science.

I agree overall with the findings and conclusions concerning the issue of connectivity and its relationship to ephemeral, intermittent, and perennial streams in the Report (e.g., they are supported by the available science). A few comments follow. In a couple of places in the Report, it states that salmon utilize "headwater streams" (pgs 3-41, 4-30). By definition in the Report, headwater streams are primarily first- through third (Strahler) order. In general in the Pacific Northwest, scientists consider "headwater" streams to be off limits to anadromous salmonids, too steep and too small; headwaters are usually defined as first and second order streams. I might suggest reviewing the distinction between headwater and non-headwater streams. In the Pacific Northwest, for example, the distinction is usually made at the second order–third order break, because first and second order channels are filled with a combination of alluvium and colluvium and thus are distinct from larger, higher order streams that are dominated by alluvium.

The "geomorphologic dispersion" (Rodriguez-Iturbe and Valdes 1979) (pg. 4-8/4-8) is often referred to as the "geomorphic unit hydrograph" concept.

If the Conceptual Framework of the Report included greater discussion (or its own subsection) on mainstem integration of tributary sources (see Question 2 above), then parts of Section 4.0, specifically the ones dealing with sediment and wood, could be expanded to account for this integrative characteristic of watersheds (again highlighting that connectivity significance is a function of the population behavior of tributaries that varies in both space and time, rather than the behavior of any single tributary).

Human modifications to physical (chemical) connectivity are mentioned briefly on pg. 4-16. Would Section 4.0 benefit from an expanded treatment of human alternations? The literature on this topic is rather extensive. Or is that covered sufficiently in the Conceptual Framework (but see comment in Question 2 above)? For example, Section 4 could include a subsection (4.x) that reviews how land use can alter the natural patterns (and thus connectivity) of the fluxes and storage of water, sediment, wood, nutrients and thermal, including at the population of channels level (e.g., cumulative watershed effects).

Question 4 (a): Comments on EPA's review and characterization of the literature on directional (downstream) connectivity and effects of wetlands and certain open waters.

I am not an expert in wetland science by education or experience and thus I am not qualified to weigh in on the wetland section in detail, other than those aspects that deal indirectly with hydrology, floodplains and channels. Overall, I thought the wetland section, as it relates to fluvial geomorphology and hydrology, is sound.

However, I had some difficulty with mixing floodplains and riparian area science (and literature) with floodplain wetlands and riparian wetlands science and literature (see my comment in Question #1).

Question 4 (b): Comments on EPA's findings and conclusions concerning the directional (downstream) connectivity and effects of wetlands and certain open waters (including flow through wetlands) are supported by the available science.

As indicated above, I lack the background in wetland science to determine if the material on wetlands in the Report reflects the available science. My quick reading over this material suggests that it does use the available science and draws sound conclusions. I can see from the House's charge questions, specifically addressing wetlands and their connections to other bodies of water (larger rivers), that there are issues that might need clarifying in the wetland section of the Report. For example and as it relates to my comment on mixing the large body of floodplain/riparian science/literature with wetland science/literature, House charge questions include "did the peer-review studies examined with respect to wetlands evaluate features which met the Cowardin definition of wetland or the federal regulatory definition of wetland."

Question 5 (a): Comments on EPA's review and characterization of the literature on directional (downstream) connectivity and effects of wetlands and certain open waters, including geographically isolated wetlands, with potential for unidirectional flows to rivers and lakes.

As indicated above, I lack the knowledge to comment on the science review of geographically isolated wetlands. Nevertheless, the section seems solid, particularly in reference to subsurface hydrology and the number of supporting citations. However, as stated in the Report, it is not a trivial exercise to determine specific subsurface and groundwater conditions of geographically isolated wetlands. The Report highlights the challenges in determining whether and how these types of wetlands are connected to other wetlands and to stream networks, on a case by case basis. Typically some form of subsurface drilling and or tracer work would be required to determine source of incoming flow and groundwater field conditions.

Given that earlier in the Report it states that approximately 50% of wetlands (presumably mostly geographically isolated) in the U.S. have been drained (and developed), it might be useful to elaborate (possibly in a new subsection) how historical and present day land uses have impacted and continue to impact wetland functions. In addition, if many of the geographically isolated wetlands had some type of connectivity (hydrologic, biotic, other), then a reduction of some 50% of wetlands should have had some profound ecological impacts, either on the remaining wetlands or on the stream network they were connected to (if not, were they significantly connected?). The Report could highlight what these impacts are so that one could infer what ecological impacts the continuing loss of geographically isolated wetlands would have.

Question 5 (b): Comments on EPA's review and characterization of the literature on directional (downstream) connectivity and effects of wetlands and certain open waters, including geographically isolated wetlands, with potential for unidirectional flows to rivers and lakes are supported by the available science.

Because I lack academic experience with the wetland literature, I am not in a position to comment on the available science. As indicated above, the review of the science (based on the number of citations and geographic variation of them), appears valid.

Dr. Emily Bernhardt

Comments of Emily S. Bernhardt

EPA Connectivity Report

In response to the Technical Charge

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*.

This EPA report represents a heroic effort to synthesize the vast literature describing how rivers work as hydrologic, chemical and biological systems. I particularly liked the opening sentence of Chapter 3 which recognizes that "A river is the time-integrated result of all waters contributing to it, and connectivity is the property that spatially integrates individual components."

That said, this well researched document seems less strategic than it could be, if it is indeed designed to help inform regulatory decisions about the scope and jurisdiction of the federal government in enforcing the Clean Water Act. Much of the energy and length of this document is aimed at explaining dynamics in systems that are unquestionably connected to waters of the United States. Far too little text is devoted to the truly thorny issues of establishing **where streams begin**, **how many features a channel must have to qualify as a stream** (e.g. duration of flow, presence of aquatic biota), and **how isolated a wetland must be to be "unconnected"**. No text is devoted at all to the manmade infrastructure (agricultural ditches, stormwater pipes, piped streams) that is directly linked into the stream network, effectively expanding drainage network density in many agricultural and urban settings.

The present document is a catalogue of well organized information that would be a useful primer for students of Aquatic Ecology or water resources courses, yet I wish that a more focused and strategic document could have been created that dealt with the hard issue of defining the edge of connectivity. In the actual world, all components of the land surface are to some degree connected to draining streams, the issue is where along this continuum a line could usefully be drawn to protect the structure and function of our nation's waters.

Because there is so much information and detail, it is quite difficult to find the main points of the document. This is less a document about connectivity than one about aquatic ecosystem structure and function.

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.

This chapter does a nice job laying out the many key terms and concepts that are necessary to interpret connectivity.

Line 28 on p. 3-27 – The statements that the more frequently a material is delivered to the river, the greater its effect or that The effect of an infrequently supplied material, however, can be large if the material has a long residence time in the river are poorly supported. Episodic pulses of toxins, salts or sediments can have devastating effects even if they happen only once. The focus here on woody debris and salmon as the only examples is problematic. I would recommend either removing this paragraph completely or more thoroughly examining the literature on this topic of material additions to streams.

Line 29 on p. 3-30 – "…cations in stream water convert dissolved organic matter to fine particulate organic matter (FPOM, particle size <1 mm) that is taken up directly by benthic bacteria, delaying its export downstream.", - this sentence should include a description of the mechanism of cation bridging that I assume the line refers to and a citation.
I think Figure 3-20 is very instructive and useful.

Line 22 p. 3-50, this paragraph appears to mix empirical data, conceptual ideas and mathematical models indiscriminately. More focus on real data on these issues would improve this section. I especially take issue with this last sentence that says restoration improves floodplain connectivity based on a model… how about some data on this one.

At the beginning of section 3.4.5, please provide some justification for investing this much text in describing a single place. Is this particularly data rich, particularly illustrative of some particular point. Please justify the decision to spend so much time on this paper. Rather than repeating this comment for each chapter, I will say here that these case studies require some more justification for their inclusion. They add tremendous bulk to the document to no clear purpose.

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.

This chapter is technically sound, but left me wondering why it was necessary to invest 70 pages of text in drawing the extremely basic conclusion that headwaters are connected to downstream rivers. I wish this section were more targeted to focus on the most questionable portions of the network, addressing the connectivity of ephemeral streams and dry washes, or manmade conveyances that are directly hooked into river networks (stormwater pipes, agricultural ditches and tile drains). The long discussion of the processing of materials and the movement of organisms through stream networks does not seem particularly useful to the difficult issue of deciding what is and is not connected to downstream waters.

Given the exhaustive nature of the review of literature, I was surprised and disappointed that this article was not included in this chapter, as it directly addresses the issue of connectivity of headwaters. This paper reflects my more comprehensive thoughts on how to assess connectivity between streams and rivers.

Doyle, M.W. and **E.S. Bernhardt** 2011. What is a stream? Environmental Science and Technology 45:354-359.

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.

1.4.1a – yes, well put
1.4.1b – example not necessary for this high level conclusion
1.4.1.c – remove example
1.4.1.d - far too long for an overarching conclusion, the first two sentences are all that are required
1.4.1.e – is this conclusion about nitrogen or about nutrients? Is it a conclusion (really) if it says streams are sources and sinks? I would suggest that this one be subsumed in point d. I certainly would not refer to a single study (not cited) in a report conclusion.
1.4.1.f – okay, but more specifically to the issue of connectivity, do all headwaters provide critical habitats… I would state this differently than all preceding conclusions, because this is not universally true. Desert washes are headwaters, but they are so ephemeral that this is not a function one would expect them to serve.

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 objectives of the Report, and any corrections that may be needed in the characterization of the literature. Page 3

This section provides a good summary of the relevant literature on the hydrologic connectivity of wetlands to downstream waters and on the exchange of materials and biota. I do not find the case study examples at the end of the chapter to be particularly useful.

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

1.4.2.a – with the caveat that those buffers actually have to be in contact with inflows – many riparian zones are short-circuited by pipes or tile drains. So position and residence time make some riparian wetlands more effective than others.

1.4.2.b The conclusions seem to oscillate between talking about riparian/floodplain areas vs. talking more specifically about wetlands in floodplains or riparian zones. I would prefer to see a separate conclusion specific to riparian/floodplain wetlands.

1.4.2.c – remove example and reference to an unnamed study and simply state the conclusion.

1.4.2.d – remove reference and summary from an unnamed study.

1.4.2.e – this could be simpler, many aquatic organisms rely upon access to riparian and floodplain habitats during some portion of their life cycle, thus damage to these habitats can damage aquatic communtities.

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

This section provides a good summary of the relevant literature on the hydrologic connectivity of wetlands to downstream waters and on the exchange of materials and biota. I do not find the case study examples at the end of the chapter to be particularly useful.

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

1.4.3.a. First sentence is all that is needed here.

1.4.3.b same comment
1.4.3.c middle sentence adds very little

1.4.3.d good.

1.4.3.e I would place this as the first conclusion

1.4.3.f – It is not clear to me that this is of broad enough significance to qualify as a major conclusion.

Dr. Robert Brooks

EPA's Connectivity of Streams and Wetlands…
(Written comments on draft report from Robert P. Brooks, 9 Dec 2013)

Executive Summary

The summary conclusions satisfactorily characterize the findings of the report. Major points are sufficiently separated for clarity. My only substantive comment pertains to Sec. 1.4.3.e Unidirectional Wetlands. Although it is difficult to generalize about the (hydrologic) connectivity between these types of wetlands (prairie potholes, vernal pools, etc.), the statement "…can make it difficult to determine or generalize…", I believe we can be more specific when speaking about single types, and therefore, we should attempt to do that even if generalization is difficult.

Introduction

Sec. 3 – Could add a couple of citations that focus on holistic views of headwaters (Brooks et al. 2006, Brooks et al. 2013).

pdf p.39 – "Headwater streams are first to third order…" Although this is a suitable definition for the report, a quick mention that the literature varies in what orders are used to designate headwater streams (perhaps second to fourth – and add a few citations), but many use first through third order, as revealed on 1:24,000 scale USGS topographic maps. Map scale can greatly influence where to begin with a first order designation.

[p. 91 - OKAY, THIS IS DISCUSSED FURTHER ON P.91 W/R SCALE ISSUES, BUT WITH NHD ONLY ESTIMATED JUST ABOVE 50% OF THE TOTAL, THIS SEEMS GROSSLY INADEQUATE AND MISLEADING TO THE READER. ALSO, COMING LATER IN THE REPORT MAY LEAVE THE READER WITH CONFUSING PERSPECTIVES.]

p.43 – Do we want to include examples of regional wetland (water) classification systems? (e.g., Stewart and Kantrud 1971 report (prairie potholes), Golet and Larson 1974(?) report (NE wetlands), Brooks et al. 2011 Wetlands (HGM for Mid-Atlantic). Some may provide more explicit descriptions and distinctions among difficult types, like prairie potholes.

p.55 Fig. 3-9 – Because these figures were constructed from NHD 1:100,000 data, it is likely that the report's definition of a first order (and maybe second order) stream will not be included here. This scale of data often misses the lowest order streams. Okay to use the figures, but should be qualified in the text and figure caption regarding this scale issue – otherwise, the legend %s are misleading.

p.59 – Inclusion of Bullock and Acremann 2003 % of studies showing flood storage is a good way to show predominance in the literature (23 of 28 studies).

Sec. 3.4 (e.g., p.59 lines 13-23) – Here, I do not see adequate mention of (or diagramming of) wetlands that have intimate contact with stream channels over long distances – where connectivity would be maximized. Examples would include saturated valley bottoms that remain permanently saturated at or near the surface yearround due to significant groundwater outputs with highly meandering streams, and/or broad landscapes with high water tables where the shallow stream channels highly meander through the terrain, with bog or marsh habitats lining the streambanks (e.g., muskeg, coastal plain freshwater emergent wetlands). These types of systems are NOT affected significantly by flood pulses or floodwaters, but rather they tend to have fairly constant water levels over time due to landscape position and high groundwater flows. Perhaps these are considered bidirectional systems in the report's terminology?

Also, Hychka et al. 2013 (or her dissertation, Hychka 2010) provides analysis of wetland well data, and how they respond to both drought and disturbance.

p.62 – Too much reliance on Leibowitz et al. 2008 (although an important reference!). Would like to see the four dimensions detailed by Thorp et al. 2006 also described and discussed (longitudinal, lateral, vertical, and temporal). This would bring in concepts from Ward & Poff, for example (which are mentioned in the next section 3.3.2.1)

Sec. 3.4.3 - p.84 – Should add more on aquatic invertebrates, e.g., obligates to stream or floodplain, vs. facultative species that move back and forth with fluctuating waters. Suzy Yetter (Yetter 2013, in Brooks and Wardrop 2013) has a good book chapter that proposes a model for this, including effects of degradation on the system. I can provide a copy.

Sec 4. Streams to Rivers – generally, the flux of materials is handled well, and has adequate citations to back up statements.

4.5 Biological Conditions - p.118 Invertebrates and fishes are covered, but not another vertebrate group that often replaces fish as the top headwater predator – salamanders (Stream Plethodontid Assemblage, see Rocco et al. 2004 (research report to EPA), especially for the vulnerable Appalachians. These should be added, as they are important in eastern streams (vs. salmonids in western streams).

4.7 Prairie Streams Case Study – seems well states, but outside my area of expertise.

4.8 Southwestern Streams Case Study - seems well states, but outside my area of expertise.

5 Wetlands …

5.3 – Riparian Wetlands and Floodplains – if these are bidirectional wetlands w/r to hydrologic flows, the same comments listed for 3.4 above, apply (repeated here) – Sec. 3.4 (e.g., p.59 lines 13-23) – Here, I do not see adequate mention of (or diagramming of) wetlands that have intimate contact with stream channels over long distances – where connectivity would be maximized. Examples would include saturated valley bottoms that remain permanently saturated at or near the surface yearround due to significant groundwater outputs with highly meandering streams, and/or broad landscapes with high water tables where the shallow stream channels highly meander through the terrain, with bog or marsh habitats lining the streambanks (e.g., muskeg, coastal plain freshwater emergent wetlands). These types of systems are NOT affected significantly by flood pulses or floodwaters, but rather they tend to have fairly constant water levels over time due to landscape position and high groundwater flows. Perhaps these are considered bidirectional systems in the report's terminology? – NO, THEY ARE NOT.

5.3.2 – Inputs into and through riparian zones: Extensive work by Peter Groffman and others (NY, late 1990s, early 2000s) and CC Hoffman and others (Denmark, 1990s through late 2000s) should be considered for citations – multiple papers each. See also, Mahaney et al. 2004.

5.3.3.3 – Wetland invertebrates (repeated comment from 3.4.3) - Should add more on aquatic invertebrates, e.g., obligates to stream or floodplain, vs. facultative species that move back and forth with fluctuating waters. Suzy Yetter (Yetter 2013, in Brooks and Wardrop 2013) has a good book chapter that proposes a model for this, including effects of degradation on the system. I can provide a copy.

5.4.4. - p.191 – The statement "Mammals that can disperse overland can also contribute to connectivity." does not properly address the inherent importance of wetland- and riparian-dependent mammals to move long distances longitudinally and laterally through these systems, which in fact, is a measure of connectivity (i.e., requisite habitat, removal of prey, deposition of urine and feces, etc.). Also, the importance of these areas for habitat by resident and migratory bird species, sometimes numbering the 100,000s to millions of individuals, is not addressed. In addition to potential dispersal of algae, vascular plant seed, invertebrates, and disease organisms, massive amount of carbon and nitrogen can be displaced through foraging activities. For example, see: Brooks 2013 (summarizing biological connectivity in streams and wetlands), and Spinola et al. 2008 (connectivity for otters).

The role of amphibians and reptiles is given minor consideration, but is insufficient. There is additional information provided in the vernal pool case study. (see Rocco et al. 2008 on importance of connectivity for bog turtles).

5.4.4 p.192 – Geographic isolation of unidirectional wetlands – Given the potential controversies surrounding connectivity of these types, this section should be more fully developed and researched from published literature. As written, it leaves the reader with a vague notion of what we do and do not know.

5.4.5 – p.193 – Table 5-2 should be more comprehensive, or at least represent a sample of species from varied habitats (e.g., vernal pools, forested wetlands, arid specialists).

5.5 Wetlands Synthesis – This summary seems to have received unequal treatment compared to other summary sections. In particular, there is a lack of information on "fringing" wetlands, that border lake-like rivers with slow, meandering, but with unidirectional flows. Some of these systems are dammed, either by human-built dams, beaver dams, or other natural obstructions that impound waters, and some exist as deltaic types where river flows slow upon entering a lake or reservoir. Perhaps collectively, the review panel can expand upon the literature cited. In particular, there is strong evidence of many different types of biological connections that can be described.

5.6 Oxbow lakes – For the most part, this brief synopsis does establish strong connectivity. The importance of fisheries (and corresponding biomass) is covered, but less so the dependency upon this resource by avian (herons, egrets, cormorants, etc.), mammalian (giant river otters, mink), and reptilian (caimans, other crocs, turtles) predators.

5.7 Carolina Bays - Coverage and documentation is thorough.

5.8 – Prairie Potholes – Coverage and documentation is quite thorough, but the tremendous importance and impact of the pothole landscape on migratory waterfowl and waterbirds should receive more emphasis. This region represents about 70+% of the breeding habitat for dabbling ducks, and when they move to other potholes, or migrate from the area, this represents a very large shift in biomass; food consumed, and the birds themselves. There are substantial studies in the wildlife literature documenting movements through radio- and satellite-telemetry among ponds, and along migratory flyways. The USFWS's bird banding and recovery records are substantial, both in regard to local and continental movements. Many of these movements take birds from these "isolated" depressions to small and large rivers, oxbows, bottomland hardwood swamps of the SE, and estuarine wetlands and waters. These should be cited, as they confirm connectivity – albeit a different type than hydrologically-driven connectivity.

5.9 – Vernal Pools – More details are needed and available. The book on vernal pools edited by Calhoun and DeMaynadier (2007) is cited, but not fully mined for relevant information. Julian (2009) provides examples of vernal pool hydrologic connectivity with significant information, summaries, and cited literature.

6 – Discussion and Conclusions – This section summarizes much of what is discussed and cited, but any identified gaps need to be added. Also, it would be more valuable to the reader if more bulleted lists and tables were used to list, compare, and contrast the findings.

Graphics and Tables throughout are simple and understandable, with descriptive captions.

Citations for possible addition to the references:

Brooks, RP, C. Snyder, and MM Brinson. 2006. Structure and functioning of tributary watershed ecosystems in the Eastern Rivers and Mountains Network: Conceptual models and vital signs monitoring. Natural Resources Report NPS/NER/NRR-2006/009. National Park Service, Philadelphia, PA. 88pp.

Brooks, RP, MM Brinson, KJ Havens, CS Hershner, RD Rheinhardt, DH Wardrop, DF Whigham, AD Jacobs, and JM Rubbo. 2011. Proposed hydrogeomorphic classification for wetlands of the Mid-Atlantic Region, USA. Wetlands 31(2):207-219.

Brooks, RP, and DH Wardrop, editors. 2013. Mid-Atlantic Freshwater Wetlands: Advances in science, management, policy, and practice. Springer Science+Business Media, 491+xiv pp.
(Book published after report written, offers 5 (of 14) chapters as syntheses for relevant topics.)

Brooks, RP. 2013. Conservation and management of wetlands and aquatic landscapes: the vital role of connectivity. Pages 463-477, Chapter 14 in RP Brooks and DH Wardrop (eds.) Mid-Atlantic Freshwater Wetlands: Advances in science, management, policy, and practice. Springer Science+Business Media, 491+xiv pp.

Brooks, RP, C Snyder, MM Brinson. 2013. Aquatic Landscapes: the importance of integrating waters. Pages 1-37, Chapter 1 in RP Brooks and DH Wardrop (eds.) Mid-Atlantic Freshwater Wetlands: Advances in science, management, policy, and practice. Springer Science+Business Media, 491+xiv pp.

Hychka, KC. 2010. Characterizing hydrologic settings and hydrologic regimes of headwater riparian wetlands in the Ridge and Valley Pennsylvania. Dissertation, Geography. Pennsylvania State University, University Park, PA 195pp.

Hychka, KC, RP Brooks, and CA Cole. 2013. Hydrology of Mid-Atlantic freshwater wetlands. Pages 109-127, Chapter 4 in RP Brooks and DH Wardrop (eds.) Mid-Atlantic Freshwater Wetlands: Advances in science, management, policy, and practice. Springer Science+Business Media, 491+xiv pp.

Julian, James T. 2009. Evaluating amphibian occurrence models and the importance of small, isolated wetlands in the Delaware Water Gap National Recreational Area. Dissertation, Ecology. Pennsylvania State University, University Park, PA 119pp.

Julian, JT, GL Rocco, MM Turner, and RP Brooks. 2013. Assessing wetland-riparian amphibian and reptile communities. Pages 313-337, Chapter 9 in RP Brooks and DH Wardrop (eds.) Mid-Atlantic Freshwater Wetlands: Advances in science, management, policy, and practice. Springer Science+Business Media, 491+xiv pp.

Mahaney, WM, DH Wardrop, and RP Brooks. 2004. Impacts of sedimentation and nitrogen enrichment on wetland plant community development. Plant Ecology 175:227-243.

O'Connell, TJ, RP Brooks, SE Laubscher, RS Mulvihill, and TL Master. 2003. Using bioindicators to develop a calibrated index of regional ecological integrity for forested headwater ecosystems. Report No. 2003-01, Penn State Cooperative Wetlands Center, Final Report to U.S. Environ. Prot. Agency, STAR Grants Program, Washington, DC. 87pp.+app.

Rocco, G. L., R. P. Brooks, and J. T. Hite. 2004. Stream plethodontid assemblage response (SPAR) index: development, application, and verification in the MAHA. Final Report. U.S. Environmental Protection Agency, STAR Grants Program, Washington, DC. Rep. No. 2004-01. Penn State Cooperative Wetlands Center, University Park, PA. 33pp+figs& app.

Rocco, GL, RP Brooks, RB McKinstry, and JF Thorne. 2008. Habitat Conservation Plan to establish conservation banks for the threatened bog turtle (*Glyptemys muhlenbergii*) in portions of Chester County, Pennsylvania and New Castle County, Delaware, Corresponding to the Delaware West Recovery Unit. Final Report to the Pennsylvania Fish and Boat Commission and U.S. Fish and Wildlife Service, Habitat Conservation Planning Grant (4100016440). Penn State Cooperative Wetlands Center, Pennsylvania State University, University Park, PA. 166pp.

Spinola, RM, TL Serfass, and RP Brooks. 2008. Survival and post-release movements of river otters translocated to western NY. Northeastern Naturalist 15(1):13-24.

Yetter, SL. 2013. Freshwater invertebrates of the Mid-Atlantic Region. Pages 339-380-477, Chapter 14 in RP Brooks and DH Wardrop (eds.) Mid-Atlantic Freshwater Wetlands: Advances in science, management, policy, and practice. Springer Science+Business Media, 491+xiv pp.

Charge Question 5(b). Comments on whether EPA's findings and conclusions concerning 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 are supported by the available science. Lead discussants are: *Drs. Robert **Brooks**, Emily Bernhardt, Michael Gooseff, Mark Murphy*

(Brooks) The primary topic in need of further elaboration, from my perspective, is the role of biological communities in providing scientifically-defensible connectivity among wetlands and streams/rivers. More can be included from Karr and Chu (1998) on the significance of biological integrity of these systems. [I will draw from comments above, and from O'Connell et al. 2003.]

Writing assignment:
Lentic systems: wetlands and open waters with potential for unidirectional hydrologic flows to rivers and lakes, including geographically isolated wetlands (**charge questions 5a and 5b**): *Drs. Ali, Josselyn, Johnson (5a), **Brooks**, Bernhardt (5b), Gooseff, Murphy*

Dr. Kurt Fausch

TECHNICAL CHARGE QUESTIONS – Responses from Kurt D. Fausch, Colorado State University – 7 December 2013

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*.

Overall, I found the report structured logically, well written, and rather thorough. Therefore, I spent most time considering what might be useful to clarify, or add to the report, and present comments on this by section, page, and line number below. The sentence of concern is first shown in quotes, followed by my comments in bold.

Executive Summary

P 1-3 line 20: Streams are biologically connected to downstream waters by the dispersal and migration of aquatic and semiaquatic organisms, including fish, amphibians, plants, microorganisms, and invertebrates, that use both up- and downstream habitats during one or more stages of their life cycles, or provide food resources to downstream communities. – **Semi-aquatic mammals and birds may also contribute substantial nutrient and carbon flux to downstream waters, although this has not been measured. For example, tens of thousands of birds of several species used Yellowstone Lake, which is directly connected to the Yellowstone River, the longest undammed river in the conterminous US (see Gresswell 2011).**

Gresswell, R. E. 2011. Biology, status, and management of the Yellowstone cutthroat trout. North American Journal of Fisheries Management 31:782-812.

P 1-5, line 34 : We have identified five functions by which streams, wetlands, and open-waters influence material transport into downstream waters:

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

What seems missing in this list is the function of connectivity itself, or transport pathways. Without the connections, many organisms would be extirpated (and often are).

P 1-6, line 33: Streams are biologically connected to downstream waters by the dispersal and migration of aquatic and semiaquatic organisms, including fish, amphibians, plants, microorganisms, and invertebrates, that use both up- and downstream habitats during one or more stages of their life cycles, or provide food resources to downstream communities.

P 1-8, line 29; Headwaters provide critical habitat during one or more life cycle stages of many organisms capable of moving throughout river networks. This review found strong evidence that headwaters provide habitat for complex life-cycle completion, refuge from predators or adverse physical conditions in rivers, and reservoirs of genetic- and species-level diversity. Use of headwater streams as habitat is especially obvious for the many species that migrate between small streams and marine environments during their life cycles (e.g., Pacific and Atlantic salmon, American eels, certain lamprey species), and the presence of these species within river networks provides robust evidence of biological connections between headwaters and larger rivers. In prairie streams, many fishes swim upstream into tributaries to release eggs, which develop as they are transported downstream. Small streams also provide refuge habitat for riverine organisms seeking protection from temperature extremes, flow extremes, low dissolved oxygen, high sediment levels, or the presence of predators, parasites, and competitors.
I think it will be important to emphasize that a wide variety of organisms (especially fishes) in downstream waters move upstream into headwater habitats (even those that are intermittent or seasonally dry) to use them for key life history stages such as spawning, rearing, or refuging. Examples include not only anadromous salmon, eels, and lampreys, but many wholly freshwater fishes that have fluvial (living as adults in rivers and spawning in tributaries), adfluvial (living as adults in lakes and spawning in rivers or streams), and even "resident" life histories (living wholly in a river or stream). As a result, connectivity is not simply a one-way street of materials and organisms moving downstream from headwaters to larger rivers, but a complex interaction among organisms throughout the network, which can move organic carbon and critical nutrients upstream into headwaters as well. I present a variety of examples below with references to support this point.

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.

P 3-8, line 19 - "Note that our usage of unidirectional and bidirectional is limited to the direction of hydrologic flow, and should not be construed as suggesting directionality of geochemical or biological flows. For example, mobile organisms can move from a stream to a unidirectional wetland (e.g., Subalusky et al., 2009a; Subalusky et al., 2009b). In Alaska, transport of live salmon or their carcasses from stream to riparian area by brown bears (*Ursus arctos*) may account for over 20% of riparian nitrogen budgets (Helfield and Naiman, 2006). While this occurs within a bidirectional setting, it serves as an example of how geochemical fluxes can be decoupled from hydrologic flows." **I agree that this is a very important distinction. Biological organisms can swim, crawl, walk, run, or fly upstream or laterally to place key life history stages in perennial, intermittent, or ephemeral stream channels, or in wetlands connected in various ways, and populations can be lost or put at risk of extirpation if these connections are lost.**

Page 3-9, line 18 - "**Groundwater** refers to any water that occurs and flows in the saturated zone beneath a watershed surface (Winter et al., 1998)." **This is a detail, but given that the unsaturated zone also contains some water, what is this water called? Is it not also groundwater?**

Page 3-14, line 31 – "The relative importance of these different hydrologic flowpaths among river systems varies, creating streams and rivers with different flow duration (or hydrologic permanence) classes (see Figure 3-7). **Perennial streams** or stream reaches (see Figure 3-7a) typically flow year-round, and are maintained by local or regional groundwater discharge or streamflow from higher in the stream or river network. **Intermittent streams** or stream reaches (see Figure 3-7b) flow continuously, but only at certain times of the year (e.g., during certain seasons such as spring snowmelt); drying occurs when the water table drops lower than the channel bed elevation. **Ephemeral streams** or stream reaches (see Figure 3-7c) flow briefly (typically hours to days) during and immediately following precipitation; these channels are above the water table at all times." **I'm not sure whether here, or elsewhere, it is clear that changes from intermittent to perennial can occur not only seasonally, but also between years, because channels may change from intermittent to perennial over long segments and flow during wet years, whereas they may be intermittent or dry (ephemeral) over these long segments during dry years (see maps and figures in Scheurer et al. 2003, Falke et al.**

2011, cited in the report).

P 3-25, line 16, Section 3.3.1 - "Leibowitz et al. (2008) identified three functions, or general mechanisms of action, by which streams and wetlands influence material fluxes into downstream waters: **source**, **sink**, and **refuge**. We have expanded on this framework to include two additional functions: **lag** and **transformation**. These five functions (summarized in Table 3-1) provide a framework for understanding how physical, chemical, and biological connections between streams and wetlands and downstream waters influence river systems." **Here again, what is missing, and critical to biological organisms, is the concept of connectivity itself. Aquatic organisms need connections among critical habitats for each life stage, or risk mortality because these connections are lacking. "Materials" in the footnote to Table 3-1 include organisms and reproductive propagules.**

P 3-28, line 1 – "3.3.2.1. *Connectivity and Isolation* The functions discussed above represent general mechanisms by which streams and wetlands influence downstream waters. For these altered material fluxes to affect a river, however, transport mechanisms that deliver (or could deliver) these materials to the river are necessary. **Connectivity** describes the degree to which components of a system are connected and interact through various transport mechanisms; connectivity is determined by the characteristics of both the physical landscape and the biota of the specific system. This definition is related to, but is distinct from, definitions of connectivity based on the actual flow of materials between system components (e.g., Pringle, 2001)." **This section seems confusing, because after much information above about how physical and chemical materials are transported, then reference to biota and the importance of connectivity appears suddenly here. This key function is what was missing just above in Table 3-1 and the description on p 3-25. In addition, the last sentence here sets up two different meanings of connectivity, but the difference between them is not explained. Likewise, given the new focus on biota in this section, the references by Fausch et al. (2002) and Fausch (2010) which focus on the importance of connectivity for fish might be added to the references on theory at the end of this paragraph (although the first paper is also referenced in the next paragraph).**

Fausch, K. D. 2010. A renaissance in stream fish ecology. American Fisheries Society Symposium 73:199-206.

P 3-28, line 30 – "Movements include dispersal, or movement away from an existing population or parent organism; migration, or long-distance movements undertaken on a seasonal basis; localized movement over an organism's home range to find food, mates, or refuge from predators or adverse conditions; and movement to different habitats to complete life-cycle requirements. At the population and species levels, dispersal and migration contribute to persistence at local and regional scales via colonization of new habitats (e.g., Hecnar and McLoskey, 1996; Tronstad et al., 2007), location of mates and breeding habitats (Semlitsch, 2008), rescue of small populations threatened with local extinction (Brown and Kodric-Brown, 1977), and maintenance of genetic diversity (e.g., Waples, 2010). These movements can result from passive transport by water, wind, or other organisms (e.g., birds, terrestrial mammals), from active movement with or against water flow (e.g., upstream fish migration), or from active movement over land (for biota capable of terrestrial dispersal) or through the air (for birds or insects capable of flight). Thus, biological connectivity can occur within aquatic ecosystems or across ecosystem or watershed boundaries, and it can be multidirectional. For example, biota can move downstream from perennial, intermittent, and ephemeral headwaters to rivers, upstream from estuaries to rivers to headwaters, or laterally between floodplain wetlands, geographically isolated wetlands, rivers, lakes, or other water bodies. Significant biological connectivity can also exist between aquatic and terrestrial habitats (Nakano et al., 1999; Gibbons, 2003; Baxter et al., 2004), but here we focus on connections among components of aquatic systems." **A few details might be important here: 1) migration is usually referred to not only as seasonal but also cyclical ("….long distance cyclical movements….") because organisms eventually return to the same place at the same life stage; 2) localized movements (often called ranging behavior) can also contribute to persistence via colonization of newly created habitats (e.g., Gowan and Fausch 1996a, 1996b); 3) in the last sentence, a review by Baxter et al. (2005) could be a useful reference, in addition or to replace another.**

Baxter, C. V., K. D. Fausch, and W. C. Saunders. 2005. Tangled webs: reciprocal flows of invertebrate prey link streams and riparian zones. Freshwater Biology 50:201-220.

Gowan, C., and K. D. Fausch. 1996a. Long-term demographic responses of trout populations to habitat manipulation in six Colorado streams. Ecological Applications 6:931-946.

Gowan, C., and K. D. Fausch. 1996b. Mobile brook trout in two high-elevation Colorado streams: re-evaluating the concept of restricted movement. Canadian Journal of Fisheries and Aquatic Sciences 53:1370-1381.

P 3-29, line 21 – "The form of the exported material can change as it moves down the river network (see Figure 3-14), however, making quantitative assessments of the importance of individual stream and wetland resources within the entire river system difficult. For example, organic matter can be exported from headwater streams and consumed by downstream macroinvertebrates (see Figure 3-14). Those invertebrates can drift farther downstream and be eaten by juvenile fish that eventually move into the mainstem of the river, where they feed further and grow." **Would it be useful to continue this example and report that adult fish could then migrate upstream to spawn, and some of them then die, thus transporting nutrients and materials back to the headwaters? Examples might include not only salmon but *Prochilodus* migrations in Venezuelan rivers studied by Alex Flecker and Pete McIntyre of Cornell University (McIntyre et al. 2007; Flecker et al. 2010; McIntyre is now at UW Madison). Even populations of small minnows may move upstream some to many kilometers throughout their life cycle to spawn (see Schlosser 1987, and review in Fausch and Bestgen 1997, both cited in the report). Figure 3-14 also lacks any arrows showing that biota may move upstream and transport materials and nutrients into the headwaters.**

Flecker, A.S., P.B. McIntyre, J.W. Moore, J.T. Anderson, B.W. Taylor, and R.O. Hall. 2010. Migratory fishes as material and process subsidies in riverine ecosystems. *American Fisheries Society Symposium* 73:559-592.

McIntyre, P.B., L.E. Jones, A.S. Flecker, and M.J. Vanni. 2007. Fish extinctions alter nutrient recycling in tropical freshwaters. ***Proceedings of the National Academy of Sciences*** **104: 4461-4466.**

P 3-29, line 33 "The opposite of connectivity is **isolation**, or the degree to which transport mechanisms (i.e., pathways between system components) are lacking; isolation acts to reduce material fluxes between system components." **Lacking here also is any mention of the effects of isolation on preventing biota from moving downstream, and upstream, and hence also preventing the nutrients and materials they carry from being transported. See McIntyre et al. (2007) above, and Helfield and Naiman (2006) cited in the report for the significance of these biological transport mechanisms.**

P 3-30, line 3 "Increased isolation can decrease the spread of pathogens (Hess, 1996) and invasive species (e.g., Bodamer and Bossenbroek, 2008), and increase the rate of local adaptation (e.g., Fraser et al., 2011). Thus, both connectivity and isolation should be considered when examining material fluxes from streams and wetlands, and biological interactions should be viewed in light of the natural balance between these two factors." **The tradeoff between invasion and isolation for salmonids has been reviewed in Fausch et al. (2009; cited elsewhere), which might be a useful reference here. The second sentence seems awkward, and might be better cast as "Thus, both connectivity and isolation should be considered when examining material fluxes from streams and wetlands via physical factors as well as movements of biota.", or something similar.**

P 3-30, line 13 "This can introduce a lag between the time when the function occurs and the time when the material arrives at the river. In addition, the distribution of streams and wetlands can be a function of their distance from the mainstem channel. For example, in a classic dendritic network there is an inverse geometric relationship between number of streams and stream order. In such a case, the aggregate level of function could potentially be greater for terminal source streams, compared to higher order or lateral source streams." **The meaning here is rather opaque, and I wonder if it could be simplified? The point appears to be that because there are many more first order streams than any other size, any functions they provide can be very important, so although first-order streams are small (and hence easily modified) they should be protected.**

P 3-32, line 10 – "Perennial streams have year-round connectivity with a downstream river, while intermittent streams have seasonal connectivity. The temporal characteristics of connectivity for ephemeral streams depend on the duration and timing of storm events." **I'm not sure whether it is relevant, but connectivity can also change markedly owing to human effects, such as pumping groundwater. See Falke etal. (2011, cited in the report), for an example from the western Great Plains, where a river system that originally had many ephemeral and intermittent reaches in the headwaters has now become disconnected at its downstream end and made largely intermittent throughout, and is projected to dry up within about 35 years.**

P 3-32, line 21 – "When dispersal, migration, and other forms of biotic movement are mediated by the flow of water, biological and hydrologic connectivity can be tightly coupled. For example, seasonal flooding of riparian/floodplain wetlands creates temporary habitat that fish, aquatic insects, and other organisms use (Smock, 1994; Robinson et al., 2002; Tronstad et al., 2007)." **Although there are many references to the coupling of hydrological and biological connectivity in this paragraph, several about dispersal of small fish into riparian wetlands adjacent to an intermittent Great Plains river to spawn might be useful here (Falke et al. 2010a, 2010b, Falke and Fausch 2010, 2012; the first listed is already cited in the report), given the focus of the report on intermittent systems.**

Falke, J. A., and K. D. Fausch. 2010. From metapopulations to metacommunities: linking theory with empirical observations of the spatial population dynamics of stream fishes. American Fisheries Society Symposium 73:207-233.

Falke, J. A., K. D. Fausch, K. R. Bestgen, and L. L. Bailey. 2010b. Spawning phenology and habitat use in a Great Plains, USA, stream fish assemblage: an occupancy estimation approach. Canadian Journal of Fisheries and Aquatic Sciences 67:1942-1956.

Falke, J. A., L. L. Bailey, K. D. Fausch, and K. R. Bestgen. 2012. Colonization and extinction in dynamic habitats: an occupancy approach for a Great Plains stream fish assemblage. Ecology 93:858-867.

P 3-33, line 1 – "Riverbeds or streambeds that temporarily go dry are utilized by aquatic biota having special adaptations to wet and dry conditions, and can serve as egg and seed banks for a number of organisms, including aquatic invertebrates and plants (Steward et al., 2012)." **Examples of fish that can quickly recolonize long segments of dry channels when they become wet again, in western Great Plains streams, can be found in the following publications, several of which are cited later in the report, as well as those by Falke et al. cited just above.**

Fausch, K. D., and R. G. Bramblett. 1991. Disturbance and fish communities in intermittent tributaries of a western Great Plains river. Copeia 1991:659-674.

Lohr, S. C., and K. D. Fausch. 1997. Multiscale analysis of natural variability in stream fish assemblages of a western Great Plains watershed. Copeia 1997: 706-724.

Labbe, T. R., and K. D. Fausch. 2000. Dynamics of intermittent stream habitat regulate persistence of a threatened fish at multiple scales. Ecological Applications 10:1774-1791.

Scheurer, J. A., K. D. Fausch, and K. R. Bestgen. 2003. Multi-scale processes regulate brassy minnow persistence in a Great Plains river. Transactions of the American Fisheries Society 132:840-855.

P 3-33, line 26 "Annual runoff generally reflects water surplus and varies widely across the United States (see Figure 3-15). Seasonality of water surplus during the year determines when and for how long runoff and groundwater recharge occur. Precipitation and water surplus in the eastern United States is less seasonal than in the West (Finkelstein and Truppi, 1991). The Southwest experiences summer monsoonal rains (see Section 4.8), while the West Coast and Pacific Northwest receive most precipitation during the winter season (Wigington et al., 2012). Throughout the West, winter precipitation in the mountains occurs as snowfall, where it accumulates in seasonal snowpack and is released during the spring and summer-melt seasons to sustain streamflow during late spring and summer months (Brooks et al., 2012)." **In this section, it would seem very useful to cite Poff (1996, already cited in the report) as well as the original Poff and Ward (1990), given LeRoy Poff's focus on developing a typology of flow patterns for use in explaining ecological characteristics of biota in streams and rivers.**

Poff NL, Ward JV. 1989. Implications of streamflow variability and predictability for lotic community structure: a regional analysis of streamflow patterns. Canadian Journal of Fisheries and Aquatic Sciences 46:1805-1818.

P3-34, Figure 3-15 – I wonder if it would be better to expand the Y-axes on these figures (perhaps by converting this from landscape to portrait), because this would facilitate comparison of these flow regimes. At present, they look "flat" and are not that easy to compare. Likewise, the 3-dimensional plots in papers by Poff (cited above) make the point more clearly about the timing and predictability of flows in different regions and types.

P 3-36, Figure 3-16 – Although I realize that this figure is modified from another publication, I was surprised to see the extensive groundwater table beneath the mountains in Panel A. Mountain Valley. Although I suppose some mountains are made of porous bedrock, many others are not, and so the water table would be limited to the colluvium near the stream channel, wouldn't it? (I am not a hydrologist, so others would be better to comment here). However, perhaps all of this is covered in Figure 3-17, which I saw next. Likewise, I found more discussion of how impermeable vs. porous bedrock in mountainous terrain can alter flow regimes, on P 3-40, in reference to Figure 3-15.

P 3-38, line 1 - "Rivers and wetlands can shift from losing reaches (or recharge wetlands) during dry conditions to gaining reaches (or discharge wetlands) during wet conditions. Wet, high water-table conditions influence both groundwater and surface water connectivity. When water tables are near the watershed surface, they create conditions in which swales and small stream channels fill with water and flow to nearby water bodies (Wigington et al., 2003; Wigington et al., 2005)." **As an added complexity, irrigation can raise water tables and cause ephemeral channels to flow, sometimes creating perennial streams. See Groce et al. (2012) for a case where an imperiled fish species was translocated to these "new" streams, which are sustained by flood irrigation via canals that divert water from a major river nearby, in the western Great Plains.**

Groce, M. C., K. D. Fausch, and L. L. Bailey. 2012. Evaluating the success of Arkansas

darter translocations in Colorado: an occupancy sampling approach. Transactions of the American Fisheries Society 141:825-840.

P 3-43, line 3 – "Biological connectivity among streams and wetlands is also influenced by distance from the river network. For example, mortality of a given organism due to predators and natural hazards generally increases with the distance it has to travel. The likelihood that organisms or propagules traveling randomly or by diffusive mechanisms such as wind will arrive at the river network decreases as distance increases." **Overall, this short paragraph about the role of distance in branching networks on connectivity for biological organisms seems inadequately brief. Bill Fagan and his colleagues (e.g., Evan Campbell-Grant) and Winsor Lowe and his have written extensively on this topic in various publications (Fagan 2002, Grant et al. 2007, Lowe et al. 2006, all but the last cited in the report), and some of the newer literature for fish (e.g., Schick and Lindley 2007) is reviewed in Fausch (2010, see above).**

Lowe, W. H., G. E. Likens, and M. E. Power. 2006. Linking scales in stream ecology. BioScience 56:591–597.

Schick, R. S., and S. T. Lindley. 2007. Directed connectivity among fish populations in a riverine network. Journal of Applied Ecology 44:1116–1126.

P 3-47, line 1: "Biological connectivity results from the interaction of physical characteristics of the environment**—**especially those promoting or restricting dispersal**—**and species' traits or behaviors, such as life-cycle requirements, dispersal ability, or responses to environmental cues. Thus, the biota within a river system are integral in determining its connectivity, and species traits that necessitate or facilitate movement of organisms or their reproductive elements tend to increase biological connectivity among water bodies." **As above, the first phrase in the second sentence here introduces confusion about the ideas of connectivity as they relate to biota. Movements of biota are blocked when connectivity is severed, but the biota do not determine the physical connectivity. Perhaps the point could be made by using the useful distinction between "structural" vs. "functional" connectivity for organisms (Crooks and Sanjayan 2006; see also this entire book titled *Connectivity Conservation*). Structural connectivity refers to physical connections, as when water flows between two reaches, whereas functional connectivity refers to actual use by organisms of these pathways.**

Crooks, K. R., and M. A. Sanjayan. 2006. Connectivity conservation: maintaining connections for nature. Pages 1-19 *in* K. R. Crooks and M. Sanjayan, editors. Connectivity conservation. Cambridge University Press.

P 3-47, line 14 – "For example, many Pacific salmon species spawn in headwater streams, where their young grow for a year or more before migrating downstream, living their adult life stages in the ocean, and then migrating back upstream to spawn. Many taxa can also exploit temporary hydrologic connections between rivers and floodplain wetland habitats, moving into these wetlands to feed, reproduce, or avoid harsh environmental conditions and then returning to the river network (Copp, 1989; Junk et al., 1989; Smock, 1994; Richardson et al., 2005**; Falke et al.**

2010a *Trans Amer Fish Soc*, cited elsewhere in the report). Biological connectivity does not solely depend on diadromy, however, as many nondiadromous organisms are capable of significant movement within river networks. For example, organisms such as pelagic-spawning fish and mussels release eggs or larvae that disperse downstream with water flow (e.g., Platania and Altenbach, 1998; **Dudley and Platania 2007;** Schwalb et al., 2010); many fish swim significant distances both upstream and downstream (e.g., Gorman, 1986; **Schlosser 1987, cited elsewhere;** Hitt and Angermeier, 2008); and many aquatic macroinvertebrates actively or passively drift downstream (e.g., Elliott, 1971; Müller, 1982; Brittain and Eikeland, 1988; Elliott, 2003). Taxa capable of movement over land, via either passive transport (e.g., wind dispersal or attachment to animals capable of terrestrial dispersal**; Grant et al. 2010, cited elsewhere**) or active movement (e.g., terrestrial dispersal or aerial dispersal of winged adult stages), can establish biotic linkages between river networks and wetlands, as well as linkages across neighboring river systems (Hughes et al., 2009)." **I suggest adding the references in bold here.**

Dudley, R. K., and S. P. Platania. 2007. Flow regulation and fragmentation imperil pelagic-spawning riverine fishes. Ecological Applications 17:2074-2086.

Section 3.4.3 on Biota, at less than a page, also seems too brief to adequately address the importance of connectivity for biota, and of these mobile biota for the functioning of lotic ecosystems and their watersheds. For this report, an understanding of the structural connectivity for, and functional connectivity of, biota is important for at least two key reasons:

1. These organisms can transport large amounts of nutrients (e.g., N and P) and carbon in a direction against the flow of water and gravity (Flecker et al. 2010). The nutrients transported by salmon are well known, but in the original condition similar fish migrations were common in many wholly freshwater ecosystems, such as by fishes like walleye and lake trout emigrating from the Great Lakes into tributary streams (e.g., Mion et la. 1998), and even small minnows from larger streams into the headwaters (Schlosser 1987). Pete McIntyre has studied migrations of suckers from Lake Michigan into tributaries (although apparently as yet unpublished), and Gresswell (2011) reported migrations of tens of thousands of Yellowstone cutthroat trout from Yellowstone Lake into each of several tributaries to spawn (sadly, now lost owing to lake trout invasion). Much of this biomass, and the nutrients incorporated in it, was eaten by mammals and birds and the nutrients transferred into riparian areas to fuel the growth of plants (Helfield and Naiman 2006; Koel et al. 2005; Gresswell 2011). Overall, we are just beginning to appreciate the nutrient fluxes that have been lost when functional connectivity of biota is lost, and how these drove ecosystems.

2. Many species of fish and other organisms have several to many life history types, which use different habitats dispersed throughout river ecosystems, and hence are differently affected when connectivity is blocked (see Fausch et al. 2002 for general discussion, cited elsewhere). Importantly, many of these taxa are also imperiled, and those that move the longest distances are often listed as threatened or endangered under the Endangered

Species Act. Therefore, the issue of connectivity intersects other important Federal legislation via these fish and other organisms. Moreover, these listings are now altering many water resource management decisions (e.g., stopping or requiring alterations of reservoir construction plans, and changing flow releases from established reservoirs) with major economic impacts, especially in the West. A few examples of these diverse life history types and imperiled species include:

a. Salmon, of course, and these species often have several to many different life history types in river basins. For example, a short 30-mile-long coastal river in Oregon was found to have five different life history types of Chinook salmon, and five more of coho salmon. Oregon coastal coho are a threatened Evolutionarily Significant Unit under the ESA. Each of the 10 life history types of these salmon reared for different periods in different parts of the basin, from headwaters to estuaries (e.g., Bottom et al. 2005). Reconnecting tributaries that traverse salt marshes in the river's estuary (blocked and leveed to create dairy pastures) restored several key life history types that had declined.

b. Federally endangered razorback sucker and Colorado pikeminnow use seasonally flooded backwaters (bidirectional wetlands, in the parlance of this report) for rearing of the larval through juvenile life stages (Bestgen et al. 2006, 2007; Zelasko et al. 2010), and restoration of backwaters that were lost is a major issue for recovery of these species.

c. Federally endangered Rio Grande silvery minnow are one of the guild of southern Great Plains fish species described in the report that spawn semi-buoyant eggs, which develop and hatch while drifting downstream. The adults then make their way upstream long distances over the course of the lives. Dudley and Platania (2007) showed that the entire guild of these small minnows in the Rio Grande and Pecos rivers, described as "pelagophils", have been lost in segments that were shorter than 100 km owing to fragmentation by dams and diversions. Thus, 3-inch minnows like these can require 100 km of river habitat to persist.

Bestgen, K. R., D. W. Beyers, J. A Rice, and G. B. Haines. 2006. Factors affecting recruitment of young Colorado pikeminnow: synthesis of predation experiments, field studies, and individual-based modeling. Transactions of the American Fisheries Society 135:1722–1742.

Bestgen, K. R. and 12 coauthors. 2007. Population Status of Colorado Pikeminnow in the Green River Basin, Utah and Colorado. Transactions of the American Fisheries Society 136:1356-1380.

Bottom, D. L., K. K. Jones, R. J. Cornwell, A. Gray, and C. A. Simenstad. 2005. Patterns of Chinook salmon migration and residency in the Salmon River estuary (Oregon). Estuarine, Coastal, and Shelf Science 64:79-93.

Flecker, A.S., P.B. McIntyre, J.W. Moore, J.T. Anderson, B.W. Taylor, and R.O. Hall. 2010. Migratory fishes as material and process subsidies in riverine ecosystems. *American Fisheries Society Symposium* 73:559-592.

Gresswell, R. E. 2011. Biology, status, and management of the Yellowstone cutthroat trout. North American Journal of Fisheries Management 31:782-812.

Koel, T. M., P. E. Bigelow, P. D. Doepke, B. D. Ertel, and D. L. Mahony. 2005. Nonnative lake trout result in Yellowstone cutthroat trout decline and impacts to bears and anglers. Fisheries 30(11):10–19.

Mion, J. B., R. A. Stein, and E. A. Marschall. 1998. River discharge drives survival of larval walleye. Ecological Applications 8:88–103.

Zelasko, K. A., K. R. Bestgen, and G. C. White. 2010. Survival rates and movement of hatchery-reared razorback suckers in the upper Colorado River Basin, Utah and Colorado. Transactions of the American Fisheries Society 139:1478–1499.

Page 3-47, Section 3.4.4. Human Activities and Alterations – Depending on the purpose of the report, this section also appears brief, and could be expanded greatly. Some references to these human-caused alterations are given above, such as groundwater pumping for agriculture and its effects on streamflow and connections required by fish for persistence of their populations (e.g., see Falke et al. 2011).

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.

P 4-1, line 5 - "Substantial evidence supports physical, chemical, and biological connections from headwater streams**—**including those with ephemeral, intermittent, and perennial flows**—**to waters immediately downstream through transport of water and associated materials, as well as movement of organisms and reproductive propagules, and bidirectional geomorphic adjustments." **Movement of organisms is also bidirectional, not just in the downstream direction. For example, many fish move upstream into headwater reaches to spawn, transporting carbon and nutrients and potentially colonizing or invading new habitats.**

P 4-1, line 15 – "Infrequent, high-magnitude events are especially important for transmitting materials from headwater streams in most river networks." **Although this may be true for some materials like large wood, I suspect that geomorphologists would argue that an intermediate discharge (the effective discharge, in their parlance, as I recall) would transport the most sediment. Likewise, I assume that biogeochemists might have a different view, for solutes, for example. As a result, I wonder about this statement.**

General comment: Parts of Chapter 4 appear to repeat information already presented in Chapter 3, such as that low-order headwater channels make up most of the miles of channels in any basin. Might this redundancy be reduced?

P 4-2, line 24 "For example, over 80% of mapped (1:25,000 scale topographic maps) stream terminuses in a Massachusetts watershed that were surveyed underestimated the upstream extent of the channels (Brooks and Colburn, 2011). On average these unmapped upstream segments were nearly 0.5 km in length and 40% had one or more upstream tributaries (Brooks and Colburn, 2011)." **At what flow were these channels examined?**

P 4-13, line 12 "Wood entering headwater streams can affect the downstream transport of water and materials in headwater streams, but also can be transported downstream from headwater streams where it is important habitat for aquatic life, a source of dissolved and particulate organic matter (POM), and influential in controlling hydrodynamics and channel morphology of rivers." **I'm not sure if references to support the importance of wood in creating habitat for aquatic biota (in this case, fish) would be helpful, but below are several that might be useful.**

Fausch, K. D., and T. G. Northcote. 1992. Large woody debris and salmonid habitat in a small coastal British Columbia stream. Canadian Journal of Fisheries and Aquatic Sciences 49:682-693.

Gowan, C., and K. D. Fausch. 1996. Long-term demographic responses of trout populations to habitat manipulation in six Colorado streams. Ecological Applications 6:931-946.

Fausch, K. D., and M. K. Young. 2004. Interactions between forests and fish in the Rocky Mountains of the USA. Pages 463-484 *in* T. G. Northcote and G. F. Hartman, editors. Fishes and Forestry: Worldwide Watershed Interactions and Management. Blackwell Science, Oxford, U.K.

P4-15, line 17 "Despite having a relatively minor effect on temperature over the length of entire rivers, however, streams provide constant cold-water habitats that are important for aquatic life (see Section 4.5.2)." **The real power and significance in the work by Torgersen et al. is in linking longitudinal "snapshots" of river temperatures along 30-60 km of rivers like the John Day River in OR to fish habitat and fish distribution, to explain how fish like imperiled Chinook salmon in this Columbia River tributary actually access and use the habitats that are critical to their survival. A summary of this linkage, using this example of infrared thermal**

imagery, is provided in Fausch et al. (2002, cited in the report). Chinook salmon ascend the river in mid-summer, and must find the unique combination of large-volume pools with cool temperatures in which to find refuge until they spawn in the fall. The importance of longitudinal river connectivity and these thermal characteristics to the habitat requirements of salmon was not entirely clear before this "riverscape" scale analysis.

P4-22, line 10 "Leaf litter contributes an average of 50% of the organic matter inputs to forested headwater streams (Benfield, 1997), but leaves and leaf fragments (>1 mm) only account for 2% or less of organic matter exports (Naiman and Sedell, 1979; Wallace et al., 1982; Minshall et al., 1983)." **I wonder how this compares or relates to the finding of Finlay (2001) based on analysis of studies using stable isotopes, that only in quite small headwater streams (watershed area < 10 km^2) does allochthonous material (leaves and wood) make up the majority of organic carbon that fuels the food web (i.e., only these small streams are heterotrophic). Even in shaded headwater streams many of the invertebrates are built from algal carbon, which has a low standing biomass but a high turnover rate owing to higher palatability and rapid grazing by invertebrates. Thus, although leaves and wood appear to provide a large pool of carbon, they are much less palatable and are processed and used at a much slower rate. See also Finlay et al. (2002) for very interesting results based on a particular study river, the Eel River in northern California.**

Finlay, J. C. 2001. Stable carbon isotope ratios of river biota: implications for energy flow in lotic food webs. Ecology 84:1052-1064.

Finlay, J. C., S. Khandwala, and M. E. Power. 2002. Spatial scales of carbon flow in a river food web. Ecology 83:1845-1859.

P 4-29, line 9 – "Biological connections are linkages between headwater streams, including those with intermittent and ephemeral flow, and their downstream waters that are mediated by living organisms or organism parts. In this section, we examine biological connections in terms of the materials (invertebrates, fishes, and genes) that move along river networks, and their effects on downstream waters (for discussion of particulate organic matter dynamics, see Section 4.4.2)." **As in Chapter 3, the connections of biota between headwaters and other reaches are assumed to occur in a downstream direction, yet fish and some invertebrates make substantial upstream movements (or among tributaries in some cases, for invertebrates) during parts of their life cycles, and this should be acknowledged.**

A key conceptual paper missing from the report is by Wipfli and Baxter (2010), which links processes at scales from fishless tributaries to oceans, including organic matter, nutrients, invertebrates, and fish. Many of the examples used to support the model are from their extensive work on these connections, such as in Alaska watersheds.

Wipfli, M. S., and C. V. Baxter. 2010. Linking ecosystems, food webs, and fish production: subsidies in salmonid watersheds. Fisheries (Bethesda) 35:373-387.

However, I see that the next paragraph acknowledges the upstream and lateral movement of organisms, although no references are cited to support this, which is an omission.

P4-29, line 24 "For downstream organisms capable of significant upstream movement, headwater tributaries can increase both the amount and quality of habitat available to those organisms. Under adverse conditions, small streams provide refuge habitat, allowing organisms to persist and recolonize downstream areas once adverse conditions have abated (Meyer and Wallace, 2001; Meyer et al., 2004; Huryn et al., 2005)." **A more complete model of habitat use, at least for stream fishes, is provided by Schlosser and Angermeier (1995), and developed further in Falke and Fausch (2010). This theoretical model rests on two key points: 1) Critical habitats on which fish depend for spawning, rearing/growing, and refuging are dispersed throughout watersheds, often at some distance, even for small fishes like minnows; and 2) These habitats are linked together by fish movement, again often over substantial distances, even for small fishes. Thus, headwaters may indeed provide refuge habitat, but may also be used for spawning, or rearing, depending on the species and life stage. These fish movements link even intermittent headwaters with downstream reaches through these biological connections. Loss of critical habitats can mean loss of species.**

Falke, J. A., and K. D. Fausch. 2010. From metapopulations to metacommunities: linking theory with empirical observations of the spatial population dynamics of stream fishes. American Fisheries Society Symposium 73:207-233.

Schlosser, I. J., and P. L. Angermeier. 1995. Spatial variation in demographic processes in lotic fishes: conceptual models, empirical evidence, and implications for conservation. American Fisheries Socity Symposium 17:360-370.

P 4-29, line 33 – "These aquatic and terrestrial invertebrates can be transported downstream with water flow and ultimately serve as food resources for downstream biota." **This is another place which could profit from citing the Wipfli and Baxter (2010) synthesis.**

P4-30, line 16 – "As with organic matter, assessing the effect of headwater invertebrate production and export on downstream waters is difficult. Wipfli and Gregovich (2002) estimated that drifting insects and detritus (i.e., particulate organic matter; see Section 4.4.2) from fishless headwater tributaries in Alaska supported between 100 and 2,000 young-of-year salmonids per km in a large, salmon-bearing stream. This estimate of headwater importance in systems where juvenile salmonids move into headwater tributaries to feed and grow is likely conservative (see Section 4.5.2). Other studies have shown increased fish growth with increased invertebrate drift (Wilzbach et al., 1986; Nielsen, 1992; Rosenfeld and Raeburn, 2009), indicating that drift does provide a valuable food resource, especially when food is limiting (Boss and Richardson, 2002)." **One issue about invertebrates that becomes muddled by this point is the distinction between secondary production of aquatic insects that subsequently drift (i.e., drifting aquatic invertebrates) versus transport of terrestrial invertebrates that fall into streams and are carried downstream. These sentences imply that the "invertebrate drift" discussed is primarily drifting aquatic invertebrates, and yet a substantial number of studies show**

that about half the diet of fish in small streams (e.g., Nakano et al. 1999, cited in the report; see Baxter et al. 2005 for a review, cited above), and half the total annual energy budget where it has been measured (Nakano and Murakami 2001, cited in the report), comes from terrestrial invertebrates that fall into streams. Thus, it would be wise to keep this distinction when these results are presented, because the insects transported from fishless headwater tributaries are a mixture of both. In addition, the terrestrial invertebrates typically average about 10 times the mass of aquatic ones, and drift on the surface and during times of day when they are more available to fish, and so are often preferred prey (see Saunders and Fausch 2007, 2012 for examples of these important terrestrial prey resources).

Saunders, W. C., and K. D. Fausch. 2007. Improved grazing management increases terrestrial invertebrate inputs that feed trout in Wyoming rangeland streams. Transactions American Fisheries Society 136:1216-1230.

Saunders, W. C., and K. D. Fausch. 2012. Grazing management influences the subsidy of terrestrial prey to trout in central Rocky Mountain streams (USA). Freshwater Biology 57: 1512-1529.

P4-31, line 18 – "Even nonmigratory taxa, however, can travel substantial distances within the river networks (Gorman, 1986; Sheldon, 1988; Hitt and Angermeier, 2008)." **Yes, this is a key point, and I suggest adding references to a few more diverse taxa, such as nonmigratory salmonids (Dunham and Rieman 1999; Meka et al. 2003), small plains fishes (Falke et al. 2010. Trans. Amer. Fish. Soc, cited above) and a review paper on the general ubiquity of movement among "resident" stream fishes (Gowan et al. 1994).**

Dunham, J. B., and B. E. Rieman. 1999. Metapopulation structure of bull trout: influences of physical, biotic, and geometrical landscape characteristics. Ecological Applications 9:642-655.

Gowan, C., M. K. Young, K. D. Fausch, and S. C. Riley. 1994. Restricted movement in resident stream salmonids: a paradigm lost? Canadian Journal of Fisheries and Aquatic Sciences 51:2626-2637.

Meka, J. M., E. E. Knudsen, D. C. Douglas, and R. B. Benter. 2003. Variable migratory patterns of different adult rainbow trout life history types in a southwest Alaska watershed. Transactions of the American Fisheries Society 132:717-732.

P 4-32, line 7 "In prairie streams (see Section 4.7), the importance of hydrologic connectivity is especially evident, as many fishes broadcast spawn, or release eggs into the water column, which then develop as they are transported downstream (Cross and Moss, 1987; Fausch and Bestgen, 1997); adult fish then migrate upstream prior to egg release (Fausch and Bestgen, 1997). Thus, these fishes require hydrologic connectivity for egg development and upstream migration of adult fish, to maintain populations (Fausch and Bestgen, 1997)." **All of this is true, but it would be wise to cite more recent work on these pelagophils, such as Dudley and Platania (2007) cited above, and perhaps some references therein. This is especially important for**

the endangered Rio Grande silvery minnow. Likewise, it is important to make the point that, owing to these biological connections, a simple low diversion dam can extirpate small minnows in this pelagophilic guild from entire tributaries (see Fausch and Bestgen 1997).

P4-32, line 28 – "Headwater tributaries also can provide refuge from flow extremes. Fish can move into headwaters (including intermittent streams) to avoid high flows downstream (Wigington et al., 2006); fish also can move downstream during peak flows (Sedell et al., 1990), demonstrating the bidirectionality of biological connections within these systems. Low flows can cause adverse conditions for biota, as well, and residual pools, often fed by hyporheic flow, can enable organisms to survive dry periods within intermittent streams (Pires et al., 1999; May and Lee, 2004; Wigington et al., 2006)." **In addition, when intermittent tributaries flow again, fish find these new habitats with amazing speed, as indicated in Larimore et al. (1959) for an Illinois stream, and Scheurer et al. (2003) and Falke et al. (2010, Trans Amer Fish Soc) for a Great Plains stream (both the latter are cited above).**

LARIMORE, R. W., W. F. CHILDERS, AND C. HECKROTTE. 1959. Destruction and re-establishment of stream fish and invertebrates affected by drought. Trans. Amer. Fish. Soc. 88:261–285.

P4-33, line 9 – "similarly, most genetically pure cutthroat trout populations are confined to small, high-elevation streams that are naturally or anthropogenically isolated (Cook et al., 2010)." **This "invasion-isolation" paradox has been reviewed by Fausch et al. (2009, cited above).**

P4-35, line 25 – "A substantial body of evidence unequivocally demonstrates connectivity between streams and downstream rivers via both structural and functional connectivity (as defined in Wainwright et al., 2011)." **As suggested above, it would appropriate here to cite the Crooks and Sanjayan (2006) book and book chapter, which also define these terms for use in discussing biological connectivity.**

P 4-36, line 22 – "In fact, the importance of headwater streams (including intermittent and ephemeral streams) in the life cycles of many organisms capable of moving throughout river networks provides strong evidence for connectivity among these systems." **I would emphasize this point, again, owing to our data from intermittent Great Plains streams showing that fish larvae colonize rewetted stream channels and backwaters immediately (Scheurer et al. 2003; Falke et al. 2010, TAFS, see above). Likewise, these fish spawn in simple flooded riparian backwaters that subsequently dry and look similar to the rest of the short-grass prairie by mid-summer.**

P 4-37, Table 4-1 – The functions in this table appear incomplete for biota, because connected streams and headwaters can provide 1) spawning habitats, 2) feeding/rearing habitats, and 3) corridors to access critical habitats dispersed throughout the riverscape (*sensu* Fausch et al. 2002). Moreover, even fishless

headwater streams can provide large amounts of terrestrial and aquatic invertebrates on which fish growth and abundance depends (see earlier discussion in the report, and Wipfli and Baxter 2010).

Case Study – Prairie Streams

P 4-41, line 24 – "Most headwater streams originating in the prairie have riffle-pool morphology with alluvial gravel;" **Great Plains streams are known for being predominately sand and silt substrate (often, relatively little gravel or large substrates), so this should be highlighted.**

P 4-41, line 29 – "In contrast to headwater streams in forested regions, the riparian areas of prairie headwater streams typically lack overhanging trees. Because of intense flooding, prairie streams tend to form wide, deep channels relative to their drainage areas, regardless of flow permanence (Hedman and Osterkamp, 1982; Brown and Matthews, 1995)." **There are cottonwood gallery forests, but these are patchily distributed because they are produced by infrequent and patchily distributed floods in most cases. Papers by Jonathan Friedman and his associates at USGS could be cited. Second, in my experience from the central western Great Plains in CO and WY, river channels are wide, shallow, and braided, not wide and deep. The description of the Platte River in western NE is classic…. "a mile wide and a foot deep….too thick to drink, too thin to plow…." (see Fausch and Bestgen 1997 for references). In their original conditions, prevalence of quicksand in river beds was also a characteristic.**

P 4-42, line 12 – "For example, water surfaces can be covered with ice in winter, whereas summer water temperatures can reach 35−40°C with 9−10°C diel (i.e., daily) fluctuations (Matthews, 1988; Matthews and Zimmerman, 1990). Concomitant fluctuations in dissolved oxygen occur, which when combined with stream respiration, contribute to dissolved oxygen values approaching anoxic conditions." **Actually, these fluctuations in DO are not really "concomitant", but opposite. DO is high when temperature is high in late afternoon, but sags to very low levels (e.g., 0.03 mg/L; Scheurer et al. 2003) at dawn when community respiration has drawn it down the most. This is important because these are the alternating harsh physicochemical conditions to which fish are exposed (i.e., high temp and high DO alternating with moderate temps but very low DO). If the changes were concomitant (i.e., high temp and low DO at the same time), the fish would be even more stressed and probably not persist. Indeed, many must use aquatic surface respiration at night, because if the enter minnow traps and cannot reach the surface, even the most tolerant species die overnight.**

P 4-43, line 23 – "Gallery forests farther downstream provide shade and contribute organic matter." **In my experience in Colorado (western Great Plains) streams, even small tributaries can have cottonwood gallery forests, and they were prevalent where mountains meet plains on the South Platte and Arkansas river systems. These forests are indeed patchy (see above), but I wonder about the accuracy of this statement.**

P 4-44, line 13 – "Fish are a well-studied component of river networks in the Great Plains, and are among the most threatened (Rabeni, 1996; Fausch and Bestgen, 1997; Hubert and Gordon, 2007; Hoagstrom et al., 2010)." **I'm not sure I agree with either of these assertions. Compared to other fishes farther east in the Mississippi River basin, we know little about the ecology of many fishes in Great Plains/prairie streams, such as what they eat, or where and when they spawn. Second, many are indeed threatened in a general sense, but most are very widely distributed in the entire Mississippi River basin, so there are few on the federal ESA list. This contrasts sharply with the Colorado River basin, where many are endemic and many are on the ESA list.**

P 4-44, line 26 "Periodic floods are important for creating perennial refugia and providing connectivity between habitats for the dispersal of fish and their eggs **and larvae** in prairie stream networks (see Section 4.7.3.3; Labbe and Fausch, 2000; **Scheurer et al. 2003;** Franssen et al., 2006; **Falke et al. 2010 [in TAFS], 2012**)." **I suggest the changes in bold.**

P 4-48, line 7 - 4.7.3.1.2. ***Temperature (heat energy)*** **– The discussion here focuses on high temperatures owing to solar heating. However, groundwater can have large effects on water temperature by cooling it, and groundwater-fed pools can be strongly stratified during hot summer days (e.g., temperature differences of >10 C from surface to bed). Pools with groundwater can remain ice-free during winter, whereas those without can freeze to the bed (see figure in Labbe and Fausch 2000). Backwaters fed by groundwater are more benign habitats for fish than those that are not (see Scheurer et al. 2003; Falke et al. 2010 in TAFS). These papers could also be used as references for P 4-54, line 27, on this point.**

P 4-53, line 35 – "Prairie stream fishes generally are highly vagile, with adults capable of long-distance migrations." **To be clear, these peregrinations made by adults are movements, not migrations, which are defined as cyclical. One might describe the entire movement cycle made by the species as a migration, but not by the adults alone. In addition, all of this is based on indirect evidence. That is, I know of no one who has actually marked (e.g., with PIT tags) adults of these pelagophilic minnows, and positively detected these long-distance movements (other than Kevin Bestgen following some plains minnow upstream, which you describe in the next sentences). Perhaps the movement back upstream occurs over several generations, for example, in phases, but I don't think we know.**

P 4-54, line 16 – "Because many small prairie streams have intermittent flow, maintenance of fish populations often depends on dispersal out of intermittent reaches before drying occurs and recolonization of these habitats once water flow resumes—both of which require hydrologic connectivity along the stream network." **We have no direct evidence that fish can sense when pools are drying and leave them before they are disconnected (Labbe and Fausch 2000; Scheurer et al. 2003). We always find fish concentrated in drying pools, and find evidence of their dying or being eaten. However, we do have direct evidence of rapid recolonization, by both larvae and adults, or habitats wetted again, often nearly immediately (e.g., Falke et al. 2010, TAFS). See also P 4-55, line 35 about this same point (that fish probably do not leave drying reaches as much as we might think, because many die there, although of**

course some probably do leave).

P 4-54, line 22 – "For dispersal and recolonization to occur, fishes must be able to access refuge habitats under adverse conditions, and then expand into newly habitable areas once adverse conditions abate." **Here again, the general metapopulation-habitat model proposed by Falke and Fausch (2010, see above) could be a very useful reference. See also P 4-55, line 38.**

P 4-54, line 32- "During and after floods, juvenile and adult fishes can move upstream or downstream (or get displaced downstream) into newly available habitat (Fritz et al., 2002; Franssen et al., 2006; **Falke et al. 2010, 2012**). Once channels are rewetted, prairie stream fishes can move quickly into these previously unoccupied habitats (Harrell et al., 1967; **Labbe and Fausch 2000;** Fritz et al., 2002; **Scheurer et al. 2003;** Franssen et al., 2006)." **These are all great references, and I would suggest adding those in bold, to expand the range of systems and species examined.**

P 4-68, line 21 - "Native fish species of southwestern streams and rivers are adapted to these dynamic environments (John, 1964; Meffe, 1984). Rinne and Miller (2006) compared fish assemblage data in river networks for two southwestern rivers, the Gila River (New Mexico and Arizona) and the Verde River (Arizona) over 7 to 12 years. They included river hydrology and geomorphology data in their analysis and found that variable streamflows and higher flow volumes favor native fish species over nonnatives. They also noted that the presence of unconstrained alluvial valley river reaches with shallow pools favored native fish. Furthermore, when humans alter the hydrologic dynamics of ephemeral and intermittent tributaries such that flows connecting them to the river network are more frequent or more consistent, nonnative fish can invade (Turner and List, 2007). Recent nonnative invasion and a corresponding decline in native fish species diversity was observed in the lower reaches of the Aravaipa Creek, a tributary of the San Pedro River, which historically was rarely connected to the mainstem (Eby et al., 2003)." **Missing from this discussion is a great paper analyzing similar ecological differences between native and nonnative invasive fish in the Colorado River system, by Olden et al. (2006).**

Olden, J.D., Poff, N.L., and K.R. Bestgen. 2006. Life-history strategies predict fish invasions and extirpations in the Colorado River Basin. Ecological Monographs 76:25-40.

P 4-69, line 21 – "Mainstem river native fishes and invertebrates are adapted to the variable flow regimes that ephemeral tributary streams strongly influence. Ephemeral flows prevent or mitigate invasion by introduced species." **Although this is true, and an important point to understand about fish ecology in these systems, it doesn't seem to serve the goal of showing how ephemeral streams are connected to downstream waters. Would it be better to focus on the goal, and reduce or delete material that doesn't contribute to that goal? There were no other bullets in this summary that relate to fish or invertebrates, so it might be wise to state the obvious, that these dynamic habitats are critical habitats for those species that evolved in them, and provide not only places to spawn, rear, and refuge, but also corridors to move among these critical habitats. I suspect there is literature on at least fish movements in**

these rivers, to support this statement, and this might be included in the appropriate section above.

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

P 5-13, line 10 – "In small forested watersheds, overhanging trees provide organic matter inputs, while simultaneously reducing photosynthesis by autotrophic organisms (Vannote et al., 1980). This dual effect makes allochthonous inputs the primary source of energy flow into the food web of these streams." **See above for discussion of meta-analysis by Findlay (2001) showing that this assertion is apparently true in general only for very small streams, with watershed areas <10 km^2.**

P 5-15, Section 5.3.3.1 Vascular Plants and Phytoplankton – Missing from this section is mention of the work by David M. Merritt and colleagues on the importance of hydrologic connections to plants that disperse their seeds in flowing water, like cottonwood trees (*Populus*). Dams that disrupt connectivity also disrupt this seed dispersal, with drastic effects on riparian vegetation. One example publication is:

Merritt, D. M., M. L. Scott, N. L. Poff, G. T. Auble, and D. A. Lytle. 2009. Theory, methods and tools for determining environmental flows for riparian vegetation: riparian vegetation-flow response guilds. Freshwater Biology 55:206-225.

P 5-17, line 21 – "Such wetlands provide refuge, feeding, and rearing habitat for many fish species and function as sources by augmenting recruitment to the river network; examples include fish taxa in forested floodplain wetlands of the southeastern and southwestern United States and salmonids of the northwestern United States such as Coho salmon (*Oncorhynchus kisutch*) and Chinook salmon (*Oncorhynchus tshawytscha*; e.g., Wharton et al., 1982; Matheney and Rabeni, 1995; Pease et al., 2006; Henning et al., 2007; Jeffres et al., 2008)." **The paper cited elsewhere by Brown and Hartman (1988) is important to support this point. Wetlands that were dry during summer and could be degraded by forestry activities were very important winter rearing habitats for juvenile coho salmon along Vancouver Island streams. Likewise, Scheurer et al. (2003) and Falke et al. (2010, TAFS) found that a set of Great Plains fish species spawned and reared in riparian wetlands (backwaters) that subsequently went dry during summer. Falke et al. (2010, CJFAS, cited above) reported on the importance of these habitats for larvae of these fishes, similar to the King et al. (2003) paper from Australia cited at the end of this paragraph. Likewise, as mentioned above, endangered fishes in the Colorado River basin, such as Colorado pikeminnow and razorback sucker, use floodplain wetlands (backwaters) extensively for spawning and/or**

rearing (Modde et al. 2001, 2005; Bestgen et al. 2007).

Bestgen, K. R. and 12 coauthors. 2007. Population Status of Colorado Pikeminnow in the Green River Basin, Utah and Colorado. Transactions of the American Fisheries Society 136:1356-1380.

Modde, T., Z. H. Bowen, and D. C. Kitcheyan. 2005. Spatial and temporal use of a spawning site in the middle Green River by wild and hatchery-reared razorback suckers. Transactions of the American Fisheries Society 134:937–944.

Modde, T., R. T. Muth, and G. B. Haines. 2001. floodplain wetland suitability, access, and potential use by juvenile razorback suckers in the Middle Green River, Utah. Transactions of the American Fisheries Society 130:1095-1105.

Lentic systems: Wetlands and Open Waters with Potential for Unidirectional Hydrologic Flows to Rivers and Lakes, Including "Geographically Isolated Wetlands"

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.

P 5-38, Table 5-3 – "Riparian/floodplain wetlands and oxbow lakes can be sources or sinks of organisms; one of the most important source functions is to provide **spawning and** rearing habitat for fish." **I suggest the addition in bold. See Falke et al. (2010a, 2010b) for examples from a western Great Plains river.**

Summary and Conclusions

P 6-1, line 29, "They provide **spawning and** nursery habitat for breeding fish, colonization opportunities for stream invertebrates, and maturation habitat for stream insects." **I suggest adding the words in bold. Fish also spawn in riparian wetlands.**

P 6-3, line 5 – "Thus, *connectivity* (or *isolation*) of streams, wetlands, and open-waters enables (or prevents) the movement of materials and organisms downstream;" **As in sections early in the report, this suggests that the only connections important are from upstream to downstream, whereas for many fish and other organisms, connections that allow organisms to move upstream and use habitats for spawning, feeding, and refuging are equally important. Connectivity is often a two-way street where biological organisms are concerned. This issue is a general one, throughout this section and parts of the entire report.**

P 6-4, line 8 – "While scientists long focused on the hydrologic connectivity represented by the physical structure of river networks, more recently they have incorporated the network structure explicitly in conceptual frameworks to describe ecological patterns in river ecosystems, and the processes linking them to other watershed components, including wetlands and open-waters (Power and Dietrich, 2002; Benda et al., 2004; Nadeau and Rains, 2007a; Rodriguez-Iturbe et al., 2009)." **Here or in the next sentence I suggest including reference to the riverscape concept in Fausch et al. (2002), which highlighted the importance of understanding how fish use habitats dispersed throughout stream and river networks.**

Dr. Siobhan Fennessy

Preliminary Comments on EPA Connectivity Report
Siobhan Fennessy, Biology Department, Kenyon College

The charge questions set to the SAB on the report, *Connectivity of Streams and Wetlands to Downstream Waters: a review and synthesis of the scientific evidence* are addressed below.

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*.**

Overall this report is a thorough and comprehensive synthesis of the physical, chemical, biological factors that connect waters. It is clearly written and organized, technically accurate, well documented and accessible. The EPAs approach to compiling the best available science has provided a framework to understand the connectivity of streams and wetlands to downstream waters, and evaluate the transport of physical materials, chemicals and biota in the surface and groundwater flows within a watershed. This is an essential analysis needed to inform decisions on policy that will guide efforts to fully implement the goals of the clean water act. Of particular note is that the report clearly establishes the importance of wetlands and headwater streams (permanent, intermittent, and ephemeral) to the integrity of downstream stream networks.

There are several areas where the report can be strengthened. For instance, the conclusion that there is insufficient evidence to determine or generalize about the degree of connectivity of unidirectional wetlands in order to evaluate their ecological effects on downstream systems is at odds with evidence provided in the report. The evidence clearly indicates that wetlands in unidirectional landscape settings are important to the structure and function of downstream waters, both by transporting materials, or by reducing the movement of water and materials (for instance, by storing water or acting as sinks for nutrients, sediments and contaminants). To suggest that it is not possible to determine the role of unidirectional wetlands is not supported by the literature, which shows clear connections between unidirectional wetlands and streams and rivers in the watershed.

The report could also be strengthened by more explicitly addressing the cumulative effects of wetlands and headwater streams on downstream waters within a watershed (referred to as ‘aggregation’ in the report). There connection between wetlands and downstream water quality has been extensively documented, both the beneficial effects of the presence of wetlands, and the cumulative effects of wetland alterations that degrade water quality. Assessing the net contribution of wetlands requires a landscape view that recognizes their geomorphological setting and the functions that landscape position confers. The watershed is the appropriate geographic unit at which to evaluate the ecologically relevant connections between water bodies. Using this approach to assess the contribution of wetlands and streams to watershed function in the aggregate is paramount.

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.

Chapter 3 describes the conceptual basis for the connectivity of a watershed's hydrologic elements. The report makes a clear and technically accurate assessment of the connectivity between streams, wetlands and rivers, and uses the flows of water and materials (physical, chemical and biological) to organize the connections fostered in watersheds. The role of connectivity on maintaining the ecological integrity of those hydrologic elements is discussed. I applaud the use of an integrated systems perspective to address the questions raised in the report. Figure 3-2 shows the range of aquatic ecosystems that are discussed, and the potential for flows of physical, chemical and biological materials between them in the watershed network. The functions by which streams and wetlands affect downstream material flux are clearly articulated. The conceptual framework also clearly recognizes the watershed (drainage basin) as the geographic area that contains the river network and wetlands. The watershed as an organizing tool could be used more prominently throughout the report to discuss the integrated flow of water, energy and materials through the landscape.

As a point of clarification, page 3-5, line 12 states that wetlands are transitional between terrestrial and aquatic systems. They can be thought of as transitional between terrestrial and aquatic systems in terms of their characteristics, but clarifying that they are not always transitional due to their landscape position is warranted.

I applaud the distinction made between the actual functions and potential functions of streams and wetlands (page 3-27, line 15). However, it is not clear how, as the text states, that ignoring potential function can lead to situations where degraded streams and wetlands receive more protection than less impacted systems.

Figure 3-16 shows generalized hydrologic landscape forms. These hydrologic landscape units have also been used by Bedford (1996) to describe what are termed the hydrologic 'templates for wetland development'. Broadening the discussion here to more fully incorporate how wetlands fit into the these models of landscape forms would be valuable and would make clear the links between groundwater flows, land form, wetlands and channel flows. An earlier source for this figure is:

Winter, T. C. 1992. A physiographic and climatic framework for hydrologic studies of wetlands. Pages 127-148 in R. D. Robarts and M. L. Bothwell, editors. Aquatic ecosystems in semi-arid regions: implications for resource management. N.H.R.I. Symposium Series 7. Environment Canada, Saskatoon, Saskatchewan, Canada.

Bedford, B. 1996. The need to define hydrologic equivalence at the landscape scale for freshwater wetland mitigation. Ecological Applications 6: 57-68.

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.

This report comprehensively addresses how the transport of water, materials (sediment, nutrients, contaminants, organisms) from upstream locations drives the structure and function of downstream ecosystems. The findings are well documented, and key conceptual models of river and stream function are discussed (including the river continuum concept and biogeochemical nutrient spiraling). The critical role that headwater streams have on nutrient processing and habitat provision are well documented, and provide compelling evidence of the connection between those streams and downstream rivers. The cumulative effects of the network of small streams and wetlands on larger rivers within a watershed are discussed. To further stress the value of these systems, it would be beneficial to document the degree to which the length of headwater streams and the area wetland have been reduced by human actions (perhaps on a regional basis). The loss of such habitats leads to the degradation of downstream rivers, whose structure and function can be highly altered by such losses. For instance, the recent National Aquatic Resource Survey to quantify the ecological condition of streams and rivers in the U.S. found that 55% of the nation's river and stream miles do not support healthy aquatic life (i.e., they were rated in poor condition. See: USEPA. 2013. National Rivers and Streams Assessment 2008-2009: A collaborative Survey. EPA/841/D-13/001. Washington, DC).

As the report discusses, one of the key stressors to streams and rivers is nutrient enrichment. The following papers by Seitzinger may be useful when reporting on the key process of denitrification (as a means to remove nitrate from waters) in rivers.

Laursen, A., S. Seitzinger, 2004. Diurnal patterns of denitrification, oxygen consumption and nitrous oxide production in rivers measured at the whole-reach scale. Freshwater Biology 49:1448-1458.

Seitzinger, S.P., R. V. Styles, E. Boyer, R. B. Alexander, G. Billen, R. W. Howarth, B. Mayer, N.Van Breemen. 2002. Nitrogen retention in rivers: model development and application to watersheds in the northeastern USA. Biogeochemistry 57:199-237.

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.

Section 1.4.1 of the Executive Summary provides a sound summary of the findings and conclusions presented in Chapter 4. The wording on page 1-8, line 22 reads as a bit of faint praise by referring to one "one study" on nitrogen when, in fact, there are many studies documented in the report. For those that might only read the Executive Summary, inserting "For example, one study…" might be helpful.

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

Section 5.3 of the report focuses on riparian and floodplain wetlands located in bidirectional settings. Taking a broad approach to the literature ensures that studies relevant to riparian and floodplain wetlands could be included. Given the inconsistency of the peer-reviewed literature in identifying whether study wetlands are jurisdictional, this approach allowed for a much more representative cross section of the literature to be used.

Throughout the discussion of riparian and floodplain wetlands, much of the literature reviewed is on forested wetlands, although this is rarely specified in the report. Because forested riparian/floodplain wetlands are particularly effective at performing the functions described here (for example, organic matter export, denitrification), and because they are such a widespread wetland type, this should be made more clear in section 5.3.

As discussed in section 5.3.2.2, riparian wetlands are effective sinks for nitrogen, particularly the highly mobile form, nitrate. The efficiency with which riparian zones transform N has become a rationale for their conservation and restoration (Fennessy and Craft 2012). In Section 5.3.2.2

there is a very heavy reliance on a single paper by Vidon et al. (2010) on the fate and fluxes of N in riparian zones. There is an extensive literature on this subject, and while the report correctly characterizes N transformations, there are many references that are not included, or not used as effectively as they might be. For example, there are studies that have shown riparian zones can remove nearly 100% of the nitrate that enters them in surface or shallow ground water which are not included in the report. The following are examples:

Groffman, P. M., E. Axelrod, J. Lemunyou, and W. Sullivan. 1990. Denitrification in grass and forest vegetated filter strips. Journal of Environmental Quality 20:671-674.

Haycock, N. E., G. Pinay, and C. Walker. 1993. Nitrogen retention in river corridors – European perspective. Ambio 22:340-346.

Haycock, N. E., and G. Pinay. 1993. Groundwater nitrate dynamics in grass and poplar vegetated buffer strips during the winter. Journal of Environmental Quality 22:273-278.

Jacobs, T. C., and J. Gilliam. 1985. Riparian losses of nitrate from agricultural drainage water. Journal of Environmental Quality 14:472-478.

Johnston, C.A., S.D. Bridgham, and J.P. Schubauer-Berigan. 2001. Nutrient dynamics in relation to geomorphology of riverine wetlands. Soil Science Society of America Journal 65:557- 577.

McClain, M.E., E.W. Boyer, C.L. Dent, S.E. Gergel, N.B. Grimm, P.M. Groffman, S.C. Hart, J.W. Harvey, C.A. Johnston, E. Mayorga, W.H. McDowell, and G. Pinay. 2003. Biogeochemical hot spots and hot moments at the interface of terrestrial and aquatic ecosystems. Ecosystems 6:301-312.

Fennessy, M. S., and J. K. Cronk. 1997. The effectiveness and restoration potential of riparian ecotones for the management of nonpoint source pollution, particularly nitrate. *Critical Reviews in Environmental Science and Technology* 27:285-317.

Fennessy, M. S. and C. Craft. 2011. Effects of agricultural conservation practices on wetland ecosystem services in the Glaciated Interior Plains. Ecological Applications 21: s49-64.

Section 5.3.3.2 mentions the positive relationship between riparian and floodplain wetlands and the in-stream values of the index of biotic integrity for fish communities. This is compelling evidence on the importance of connectivity in maintaining the ecological integrity of aquatic systems. Given the emphasis in water programs I the U.S. on biological monitoring, and the resulting literature that documents the effects of riparian/floodplain communities on the ecological integrity of streams and rivers (for example by mitigating nonpoint source pollution, providing nursery areas and critical habitat for aquatic biota and dsynchronizing flood peaks), this line of reasoning could be expanded in the report.

4(b) Conclusion (2) in section 1.4.2 of the Report Executive Summary discusses major findings and conclusions from the literature referenced in Charge Question 4(a) above. Please comment on whether the conclusions and findings in section 1.4.2 are supported by the

available science. Please suggest alternative wording for any conclusions and findings that are not fully supported.

Section 1.4.2 of the Executive Summary provides a sound summary of the findings and conclusions presented in Chapter 5.3.

Lentic systems: Wetlands and Open Waters with Potential for Unidirectional Hydrologic Flows to Rivers and Lakes, Including "Geographically Isolated Wetlands"

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.

In section 5.4, the authors conclude that there is insufficient evidence to determine or generalize about the degree of connectivity of unidirectional wetlands, or evaluate their effects on downstream systems. This is at odds with evidence provided in the report that clearly indicates that wetlands in unidirectional landscape settings are important to the structure and function of downstream waters; they are sinks for nutrients (N and P), sediments, and other contaminants (pesticides, metals), provide habitat for amphibians, birds, invertebrates and mammals, and are often hydrologically connected (perennially or periodically) by surface or subsurface flows. They store water and so their presence in a watershed can reduce flood peaks downstream. The discussion of prairie pothole wetlands in section 5.8 clearly makes the case for the connectivity of unidirectional wetlands. To suggest that the role of these wetlands cannot be determined is also not supported by the wider literature (much of it reviewed here), which shows clear connections between unidirectional wetlands, streams, and rivers in watersheds. It is vital to point out the strengths of the relationship between these watershed elements.

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

Section 1.4.3 of the Executive Summary provides a clear summary of the findings and conclusions presented in Chapter 5.4. However it should also be modified to reflect the comments above.

Dr. Michael Gooseff

Michael Gooseff responses to technical charge questions. All question text copied from provided .pdf and pasted below. Responses are provided in red italics below.

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*.

In general, the overall clarity of the draft report has been achieved. I noted a few locations in the very long report that need some minor clarification, but it otherwise is a very clearly written report. I have the bias of being a scientist, so it is a bit difficult for me to determine how well it would/will be understood by non-specialists. However, the extensive effort to include definitions and examples from the scientific literature should go a long way toward properly orienting a non-technical person to the concepts covered. My overall opinion is that the technical accuracy is good, given the scope of the topic and the literature considered.

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.

Chapter 3 communicates a good conceptual framework for describing the channel vs. the river, wetlands, etc. The definitions are useful and the further discussion of their properties is complete enough to discuss the issues of connectivity among the different parts of the watershed. The suite of connections that were discussed was clear and, for the most part, complete. One point of emphasis that I would have like to have seen is that the general shape of water tables does not always follow the land surface. Part of the issues with this is the strong reliance of the report on the work of Winter, who often promoted this. Furthermore, that these flow directions and quantities are generally invisible to us at the surface, would also be an important point to make. It is often difficult to visualize linkages among water bodies across space and time in the subsurface.

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.

Chapter 4 is clear and well-written with some excellent examples of particular cases observed around the US. The literature cited is correctly represented and summarized within. The two highlighted situations of desert southwest streams (largely ephemeral) and prairie streams provide two distinct situations in which streams appear to be disconnected from landscapes (at the surface). The space-time dynamics of the actual connections is highlighted very well within and provides a good basis for evaluating the challenges to understanding connectivity in the context of functioning watersheds and their ecosystems. Some opportunity is missed, however, to emphasize the changing connections (in space and time) of even perennial streams to watersheds.

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.

The conclusions appear to be well supported by the literature review provided in section 4. I am particularly glad to see some emphasis of cumulative downstream impacts of streams or other wetlands as this is a concept that is often ignored.

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

The focus on 'downstream' connectivity is a bit challenging when discussing lateral influences of landscapes or groundwater on open channel flows of the stream network. Technically, groundwater that is lateral to a stream channel and, for example, contributes water to the channel, is providing water 'down-gradient' (i.e., down the gradient of the water table adjacent to the channel). As soon as that water is in the channel, contributing to discharge, then of course it 'downstream' is a more applicable term to be used. My review of this section concluded that the literature that was summarized was done so properly.

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

The phrasing of section 1.4.2 with respect to riparian groundwater serving as a source to rivers is a bit misleading, in my opinion. I follow (and like) the notion of bidirectional exchanges noted in the summary prior to the itemized points. It is my opinion that this statement should be more clear about the bidirectional exchanges of water in the subsurface. The hyporheic zone is referred to several times throughout this report, yet I get the sense that the authors consider it to be more of a vertical feature than a lateral feature. That conceptual model is incomplete. There are numerous studies that have identified 'water from the open channel' of a river in bank-side wells and more distal wells (Stanford and Ward or Stanford and Gauphin note that hyporheos were found in alluvial gravels 2 km away from the river!!! – I do not have ready access to that citation at this moment, but will find it prior to our panel discussion).

Lentic systems: Wetlands and Open Waters with Potential for Unidirectional Hydrologic Flows to Rivers and Lakes, Including "Geographically Isolated Wetlands"

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.

My knowledge of wetland and other lentic ecosystem literature is fairly limited. Hence, I can only really conclude that I found this section to be organized well and informative, but I cannot provide a reasonable evaluation of the scope of the literature here. The potential for connection among water bodies is very high when you view the world through the lens of a groundwater hydrologist. However, the realities of the heterogeneities of the subsurface are the invisible controls that are often difficult to fully characterize at scales that matter to flow directions and rates.

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

My sense is that this will be a significant topic of conversation and discussion at our panel meeting in person. However, at the moment, my evaluation of the content of section 5 and the conclusions and findings in section 1.4.3 of the executive summary are congruent. I am particularly struck by the conclusion about the comparison of geographic isolation vs. functional isolation. That is a very strong point and one that is important to make, in my opinion, because proximity is not the only qualifier of connectivity.

Dr. Judson Harvey

Comments on Charge Question 1: Clarity and Technical Accuracy:

I reviewed the EPA draft report report "Connectivity of Streams and Wetlands to Downstream Waters: A Review and Synthesis of the Scientific Evidence" and found it to be scholarly and exceptionally well- written. My overall assessment is that that the authors have done a truly outstanding job in synthesizing a difficult topic, and that minor to moderate revisions will improve and strengthen what is already a thorough and carefully prepared synthesis and literature review of hydrologic transport processes and ecological consequences in watersheds. Given that the upcoming scientific review panel will review many details this review, I focused my written comments on what I felt were major overriding issues that potentially have implications throughout the report. Below I outline three major comments and several minor ones. I very much look forward to participating in the panel and discussing these and many more comments.

Comments on Charge Question 2: Conceptual Framework:

Major Comment 1: Connectivity is formally defined on page 1-4 and in the Glossary (page A-3) as "the degree to which components of a river system are joined, or connected, by various transport mechanisms". The problem with such a broad definition is that it does not distinguish between two differing concepts of connectivity. For example, the term connectivity is frequently used to refer the degree of connectivity between upstream and downstream waters (e.g., page 1-6, line 29 and 34; 1-7, line 2). Figure 1-1 (page 1-2), for example, strongly suggests that connectivity is the degree of connection between watershed elements and downstream waters. Also, at various locations in the text connectivity is described as the "degree of transport connection to downstream waters", e.g., page 1-1, line 25 "longitudinal connectivity"; 1-3, line 14. However, the term connectivity is also used to refer to the degree of connectivity between main channel waters and off-channel storage areas such as ponds and subsurface flow (e.g., page 1-7, line 26 and 27).

I would suggest that the definition elaborate on the two complementary concepts for connectivity as *longitudinal* and *lateral* connectivity. Longitudinal connectivity is the degree of connection between upstream waters with waters located downstream. Lateral connectivity is the degree of lateral (e.g. horizontal and vertical) connections between relatively fast flowing waters, such as main channel waters, with slowly moving waters stored off the channel in ponds and/or in the subsurface. The problem with such a broad definition is that longitudinal and lateral connectivity are often inversely related, that is, high longitudinal connectivity of waters is thought to be associated with low lateral connectivity of waters and vice versa. Therefore when the term connectivity is used in the report the specific meaning may be unclear, and so it seems imperative to distinguish between them.

Major Comment 2: Connectivity as discussed by the report is a qualitative metric rather than a quantitative metric which becomes confusing when combined with the broad definition that does not distinguish longitudinal from lateral connectivity. For example, rather than being described by a value the connectivity of a water body is qualitatively assessed as varying along a scale between "highly connected" and "isolated" (page 1-4, line 40 to page 1-5, line 3). There are two problems that arise: 1) first is the issue described above that if connectivity is said to qualitatively "high" it will be uncertain whether longitudinal or lateral connectivity is meant and 2) an even more important issue is that the report acknowledges that there is no simple positive or negative relation between the degree of connectivity and associated watershed functional values. The relation between connectivity and functional values is made on a case by case basis with a higher or lower connectivity said to be either impart beneficial or harmful effects depending on the specific functional value in question. I should note that in the body of the report a good job is done tabulating many functional values and there relation to connectivity. However, this reviewer feels it will be an improvement if longitudinal and lateral connectivity are distinguished, and if the report is more forthright in Section 1 in acknowledging that connectivity has no simple positive or negative relation with watershed functional values, rather that certain functional values are best supported by connectivity falling within a specified sub-range between highly connected and isolated.

Comments on Charge Question 3: Ephemeral, Intermittent, and Perennial Streams:

Major Comment 3: Two types of connectivity (bi-directional and unidirectional) are first mentioned on page 1-1, line 30. The caption for Figure 1-1 states that bi-directional exchanges are omitted for clarity. This leaves the reader confused about whether bi-directional and unidirectional types are and why the concepts are important, why the terms only refer only to wetlands rather than including ponds and subsurface waters located away from the channel, and why the terms are not discussed as part of the formal definition of connectivity (p 1-4) since they are not discussed in more detail until section 3 (page 3-7). The glossary says that bi-directional connections involve two-way hydrologic exchanges between wetlands and rivers and those unidirectional connections involve one way connections from wetlands toward rivers. It is not clear why only wetlands are involved, i.e, ponds or subsurface waters could have the same relationship with rivers and if it is important for wetlands it should also be important for ponds and subsurface waters. This reviewer wondered whether the report is using *unidirectional connectivity* as a concept that is synonymous with *longitudinal connectivity* discussed in this reviewer's comment 1 and bi-directional connectivity as a term synonymous with the term lateral connectivity as discussed in comment 1? Unidirectional connectivity seems like reasonable term to distinguish longitudinal connections flowing from upstream to downstream. Bi-directional connectivity seems like a reasonable term to distinguish lateral, back-and-forth connections between main channels and more slowly moving surface and subsurface waters located off the channel. My suggestion is to consider how these concepts for unidirectional and bi-directional connections can be discussed in relation to longitudinal and lateral connections and, after selecting final terminology, how to integrate the terms into the formal definition on page 1-4 and in the glossary, as well as verifying consistent usage throughout.

Minor Comments Pertaining to Charge Questions 3:

- Page 3-1, line 7, consider citing Winter et al., 1998 here with the references already present since none of the references currently used cover groundwater- surface water connectivity

- Page 3-14, line 23, consider citing Harvey and Wagner, 2000 as a standard hydrological reference for hyporheic zones to add to the ecological references already given.
- Page 3-27, line 20. Suggest adding two sentences before the sentence beginning "In many cases". The sentences could read "Biogeochemical hot spots often are associated with hydrologic exchanges between surface and subsurface waters (McClain et al., 2003). For example, hyporheic flow enhances delivery of materials being transported in surface waters to microbially and geochemically active sites in the subsurface where chemical reactions may be stimulated to remove contaminants such as toxic metals, organic compounds, and excess nutrients from flowing waters (Harvey and Wagner, 2000)."

Comments on Charge Question 4: Lentic Systems and Bi-directional Flows:

No preliminary comments beyond the potentially important comment for Charge question 3 that apply here as well.

Comments on Charge Question 5: Lentic Systems and Unidirectional Flows

No preliminary comments beyond the potentially important comment for Charge question 3 that apply here as well.

References suggested that are not already cited in the report:

Harvey, J.W., and Wagner, B.J., 2000, Quantifying hydrologic interactions between streams and their subsurface hyporheic zones, p. 3 – 44 in Jones, J.A., and Mulholland, P.J. (eds.), *Streams and Ground Waters*, Academic Press, San Diego. p. 3 – 44.

McClain, M.E., Boyer, E.W., Dent, C.L., Gergel, S.E., Grimm, N.B., Groffman, P.M., Hart, S.C., Harvey, J.W., Johnston, C.A., Mayorga, E., McDowell, W.H., Pinay, G., 2003, Biogeochemical hot spots and hot moments at the interface of terrestrial and aquatic ecosystems, *Ecosystems* 6(4):301-312. doi: 10.1007/s10021-003-0161-9.

Dr. Charles Hawkins

Charles Hawkins comments to SAB charge questions.

1.

In general I thought the report was well written and reasonably well organized. I appreciate that a review of this type must be primarily synthetic rather than encyclopediac in reviewing the relevant literature. However, the report sometimes relies on citing previous overviews rather than the most pertinent primary literature when characterizing the connectivity between upstream and downstream features and processes.

2.

The conceptual framework succeeded in describing the structural elements and functional processes required to understand connectivity of streams and wetlands to downstream waters. The distinction between bi-directional and uni-directional flows were useful, although I found the definitions of the two processes a bit confusing. For example, if I interpreted the definitions correctly, the situation where X flows into Y and Y then flows into Z in which X and Z can be different stream segments is defined as bi-directional. To me a more intuitive definition of bi-directional would occur when X flows to Y and then Y can flow back to X, i.e., the direction of flow between X and Y is reversible.

3(a) and 3(b).

The report provided a generally comprehensive characterization of our knowledge of the connectivity of ephemeral, intermittent, and perennial streams with downstream waters. Most of my concerns were minor. There were sections that were either unnecessarily long and others that could have benefitted from additional synthesis of existing (sometimes more recent) information. For example, water chemistry is largely discussed in the context of nutrients (N, P) and contaminants, but other naturally occurring chemical constituents are also ecologically important. I would have liked to have seen a more thorough characterization of upstream effects of geology and hydrology on overall water chemistry (e.g., conductivity, alkalinity, pH, major cations, etc). The treatment of ions in section 4.4.3 is overly brief. The stream temperature section could also use some clarification. Some specific comments include:

I could not find Rice et al. 2008 that discusses thermal effects of tributaries, only his work on geomorphic effects at tributaries. The Knispel & Castella paper does cover this issue though. There is inadequate treatment of the role that channel structure (e.g., % pools) can have on stream temperature. Hawkins et al (1997) showed that % pool and channel slope was the best predictor of daytime stream temperature across 45 streams spanning the length of California. These factors overwhelmed effects of latitude, elevation, and riparian shading (Channel morphology, water temperature, and assemblage structure of stream insects. Journal of the North American Benthological Society 16:728-749.).

Use Allan & Castillo (2007) instead of Allan (1995). (Allan, J. D., and M. M. Castillo. 2007. Stream ecology: structure and function of running waters. 2nd edition. Springer, Dordrecht, The Netherlands).

Add precipitation and dew point temperature to climate factors that affect stream temperatures.

See Schmidt et al (2006) for effects of groundwater on stream temperature (Characterization of spatial heterogeneity of groundwater-stream water interactions using multiple depth streambed temperature measurements at the reach scale. Hydrology and Earth System Sciences, 10, 849-859). The review by Webb et al. (2008) is also a good source on groundwater influences as well as timber harvesting effects on stream temperatures (Webb, B. W., D. M. Hannah, R. D. Moore, L. E. Brown, and F. Nobilis. 2008. Recent advances in stream and river temperature research. Hydrological Processes 22:902-918).

Isaak et al. (2010) is a good example of how the spatial structure of networks may affect stream temperature (Isaak, D. J., C. H. Luce, B. E. Rieman, D. E. Nagel, E. E. Peterson, D. L. Horan, S. Parkes, and G. L. Chandler. 2010. Effects of climate change and wildfire on stream temperatures and salmonid thermal habitat in a mountain river network. Ecological Applications 20:1350-1371).

Holloway's results may not be very generalizable (watershed rock N was not a predictor in a model of dissolved total nitrogen that one of my PhD students developed for western USA streams)(see Olson, J. R., and C. P. Hawkins. 2012. Predicting natural base-flow stream water chemistry in the western United States. Water Resources Research 48:W02504.).

The role of upstream stream ecosystem metabolism could be better characterized. For example, Hall and Tank 2003 (Ecosystem metabolism controls nitrogen uptake in streams in Grand Teton National Park, Wyoming, L&O) noted that production and respiration explained 82% of the variation in NH4 uptake, and production alone explained 75% of variation in NO3 uptake. Upstream removal of N depends in large part on the amount of production in these systems.

The role of river systems as a source of CO2 to the atmosphere needs to be highlighted. The report notes that "58% of the carbon inputs were respired within the river networks", but this needs to be connect this to the eventual outgassing of CO2. Battin et al. 2008 (Biophysical controls on organic carbon fluxes in fluvial networks, Nature Geoscience) provides a nice review. Butman and Raymond (2011, Significant efflux of carbon dioxide from streams and rivers in the United States, Nature Geoscience) note that riverine DOC could generate ~3:56 Tg of C/yr. Inorganic C is not mentioned at all, but Butman and Raymond (2011) show that as a source of atmospheric CO2, inorganic C dominates.

4(a) and 4(b).

The report provided a generally accurate description of the state of knowledge regarding the connectivity of bi-directional wetlands with downstream rivers and lakes. However, there was an over-reliance on general reviews regarding the structure and function of riparian ecosystems, and an independent synthesis of the relevant primary literature would have been more useful. Alternatively, new knowledge could have been better (and more explicitly) incorporated into a summary of what existing reviews show with a view toward pointing out where generality has emerged and where generality has not yet been established. The report sometimes, but not always, addressed issues of context dependency and in some cases tended to overly generalize from geographically limited studies.

The effects of riparian wetlands on stream temperature was perhaps the weakest part of this section. The report relies heavily on 2 main sources (Gregory et al. 1991 & Beschta et al. 1987). These are excellent summaries of our knowledge up to 1990, but other more targeted reviews exist. For example, information from the Caissie, Webb, and Poole & Berman papers cited in earlier sections should have been incorporated where appropriate. As indicated in the report, riparian vegetation has been observed to limit maximum stream temperatures in certain types of streams under certain climatic conditions (e.g., small streams, mesic climates). However, the report does not indicate that this might not happen under other conditions (larger streams, more xeric climates). An additional way that riparian vegetation can influence stream temperatures is by reducing heat lost from the stream as long-wave radiation (http://pubs.acs.org/doi/pdf/10.1021/es902654f). Also, although the report describes how beaver dams can affect hydrologic connections, it does not summarize how beaver dams can affect downstream stream temperatures.

The Nitrogen section relied on the review by Vidon et al. (2010). Weller et al. (2011, Effects of riparian buffers on nitrate concentrations in watershed discharges: new models and management implications, Ecological Applications) provide additional detail and perhaps insight.

5(a) and 5(b)

The report provided a generally comprehensive and accurate summary of the connectivity between wetlands with unidirectional flows and downstream rivers and lakes. Lack of ability to generalize across all types of unidirectional wetlands was acknowledged in several instances indicating the importance of context dependency. Incorporation of additional, recent literature would help better understand some of the processes unidirectional wetlands affect. For example, Olson and Hawkins found that lake and wetland size to be more important in predicting base flow P concentrations in streams than wetland location (Developing site-specific nutrient criteria from empirical models. 2013. Freshwater Science 32:719-740). However, the authors are correct in inferring that the same basic processes operate across wetland types and that connectedness between wetlands and downstream rivers and lakes is the rule rather than the exception.

Dr. Lucinda Johnson

Connectivity of Streams and Wetlands to Downstream Waters
Technical Charge Questions
Lucinda Johnson

1. Overall Clarity.
   The report is extremely well written and carefully documented. It is clear that this report has already been through several rounds of review. Writing was generally very clear, references cited appear to accurately reflect the citations in the text; tables and text were well formatted; few typos were encountered. For a report this size, this is quite an accomplishment.

   I feel the report, as a whole, would benefit from development of additional summary tables / information for each section that summarizes the evidence and includes: the types of applicable connections (direct surface water connection; intermittent surface water via overland; anthropogenic connection (tiles / drainage); direct groundwater; etc.) and whether the function is directly or indirectly affected, and the level of certainty for each type of conclusion. An IPCC type approach that identifies the relative certainty of an effect would give this report greater credibility.

   Be certain to use the words “direct” and “indirect” to mean the same thing with respect to connectivity throughout the document. (What is “direct evidence” of connectivity, versus “indirect”; what is an direct connection versus an indirect connection, etc.)

   This may be outside the scope of this report, but the conclusion section would benefit from a discussion about risks associated with the lack of protection / management. There have been some published papers addressing this (AWRA special issue and elsewhere) so it would not have to be conjecture o the author’s part. A discussion of risk could also include a discussion of the relative magnitude of connections (including the temporal frame). At some point the question will be asked- what is the size or the frequency of a connection that raises it to the point of having a “significant” effect.

   Also needed is a list of research questions that the agency should identify to increase the certainty of the effects noted, especially with respect to the unidirectional wetlands.

2. Chapter 3: Clarity and technical accuracy; relevance of citations, corrections:

   This section could be strengthened with the inclusion of a short section on the types of disturbances (natural and anthropogenic) that reduce or enhance connectivity. Those are partially addressed at the end of Chapter 3, but could be strengthened. (and… what about the effects of climate change on connectivity?) Also- not all types of connectivity are positive- dam removal can increase / enhance the spread of invasive species, for example.

Since the report deals with the issue of connectivity the definition of connectivity should occur MUCH sooner than section 3.3.2.1. This definition should be front and center at the very beginning of the document.

Figure 1-1 does not show a "wetland complex"; since the concept of a wetland complex is very critical to the discussion of connectivity in unidirectional wetlands, a complex should be represented in this figure. See also, comment below regarding wetland complexes.

Since geochemical cycles are repeatedly mentioned in the various chapters (esp nitrogen and mercury); it would be helpful to include a diagram depicting these cycles.

I was surprised that the concept of source and sink populations was not better explained (in the first section before Section 4.5.3. Genes), much less the lack of mention of metapopulations. At the very least it should be stated that this is a very active area of research and many assemblages have species or species groups that exhibit metapopulation tendencies. Examples of charismatic species that require such connections to persist would be powerful.

Pg 5-24, last paragraph about hydrologic connectivity between unidirectional wetlands and other waters. This begs the question… how many overland flow events constitute a connection in order to support the functions that are identified for unidirectional wetlands? Which functions would be supported if the only connection is through a 500 year overland flow event?

- clarify what "non-soil substrate" means (pg 3-5, L 16)
- define "infrequent flooding", L 30, pg 3-7
- A figure that captures the difference between unidirectional and bidirectional wetlands would be helpful. (or move fig. 3-18 to the location in the text where unidirectional wetlands are defined? And then create a different figure that makes that single unidirectional wetland into a complex.)
- Figure 3-5 is useful for describing hydrologic flowpaths in stream – watershed systems. Lay persons have a difficult time understanding how flow systems operate in a wetland environment (especially in a complex where one wetland may be connected via downstream flow but the other wetlands may "appear isolated"). A figure that captures the possible flowpaths within and among wetlands and downstream waters would greatly contribute to the discussion in chapter 5. (Fig 3-16 is helpful, but should be cited much earlier in the section).
- Pg 3-47, L 30. s/b within and between river networks and wetlands.

5(a): Chapter 5:

Overall comments: There will be a lot of criticism directed at the issue of connectivity for unidirectional wetlands in geographically isolated landscapes. Thus, it will be very important to be very clear about the types of possible connections, the magnitude and duration of possible connections, and whether they are direct versus indirect. As stated previously for Chapter 3, these issues could be communicated more clearly using better figures, and tables could be developed to succinctly state the relevant functions and the connection types.

Relevant publications: There are a number of relevant publications missing from the report. I will compile this list and will send it under separate cover.

Accuracy of summary: Pg 5-4. Table 5.1. Since riparian wetlands and unidirectional wetlands do have somewhat different functions, I suggest grouping functions associated with each wetland type within each section. Since the text distinguishes the different wetland types, follow a similar organization for the table. This will reduce possible confusion about functions associated with unidirectional versus riparian wetlands.

Amphibian habitat support is listed as an important function for the geographically isolated wetlands, but birds are not mentioned as prominently (mentioned once or twice only in this chapter). I think the evidence that connectivity is required for birds is much weaker, therefore suggest deleting reference to birds. Alternatively, provide further explanation of mechanisms and explanations about facultative versus obligate traits.

Although lakes and ponds are not a part of this review, there is some pertinent literature dealing with landscape position and lake water chemistry that directly informs the discussion about connectivity of isolated wetlands (Kratz et al. from the UW Limnology group).

- Table 5.1: 3rd cell: Unidirectional wetlands lacking a channel outlet. Can be sources of water via overland flow … They also can provide water via subsurface drains or surface ditches (ALSO, GROUNDWATER CONNECTIONS)

- 6TH CELL: (Nitrogen cycling) Nitrification also requires organic matter…
- Sink Functions: Cells 2 and 3 are very similar and contain overlapping information.

- Pg 5-16, L 19: clarify this or provide an example.

- Pg 5-23, L 14. Hunt et al. (2006) … remove second reference to (Hunt et al. 2006)

- Table 5-4. This table seems clearly written by multiple authors and needs to be edited so that the information content and style is consistent across sections. The amt of detail different across sections of the table. Some thought could be given to presenting the most compelling (best evidence) data first in each section.

- Cell #2. Increasing the amt of impervious surface will also increase the amt of overland flow. By and large, the role of human disturbances (esp. urbanization) is not well addressed in terms of increasing or decreasing connectivity.

- Table 5-4, cell # 4. The mention of "various time frames" is among the few in the document. How does the temporal scale of connectivity affect the delivery or support of functions discussed?

- Table 5-4, cell 6: probably need to qualify this as MAY BE or IS COMMONLY the first line of defense. There is not always a riparian buffer between a wetland and a stream.

- Cell 7: would be more powerful to state how (in general) water quality and nutrient delivery is affected.

- Pg 5-43: oxbow lakes commonly connect with active river channels (only in certain landform types- clarify those)

- Pg 5-54. A single study that demonstrates A groundwater connection in A Carolina bay is awfully weak evidence, and is not a strong way to start out this section. Suggest stressing the data that are derived from multiple bays.

- It seems the words "directly " and "indirectly" are used in slightly different ways throughout the document. If there are fish in Carolina bays that are not planted by humans, how else would the fish arrive unless there was a direct connection to some other water body?

- Pg 5-57. L 14 – 20. The waffling language in this paragraph is contradicted by some of the statements above in the synthesis. If fish are found in bays that dry out, and there is certainty that the fish were not planted by humans, then the bay MUST be connected to another water body via overland flow at some interval. That is direct evidence of a connection. Ditching is direct evidence of a connection. Certain types of flightless invertebrates (fairy shrimp) require overland connections and are common residents of bays (and vernal pools).

- Pg 5-73- 5-74. To be consistent, group the 3 bullets for western pools (i.e., move bullet 5 to #3 position.)

5(b): Conclusions from Chapter 1 (and Chapter 6)

"Biological connectivity can also occur between unidirectional wetlands and downstream waters, through movement of amphibians, aquatic insects, aquatic reptiles, migratory birds, and riverine mammals that require or opportunistically use both river and wetland or open-water habitats." (L 2-5, pg 1-14. Since birds and reptiles are relatively mobile species, the report must be careful to discuss the circumstances under which specific species within these groups require connectivity among their habitats. One of the comments specifically addressed this issue (if two cities are connected by airplanes are they considered "connected" to the extent they should be managed similarly (or something like this)).

A matrix that summarizes the Ecosystem Type; Type of Connection; Environmental Conditions that Regulate Connection; Functions Affected; [Duration of Connection?]; [Relative Magnitude of Connection?]; Level of Certainty.

A list of research questions that could be formulated to address the lingering questions would also be a good idea.

The conclusions suggest that there are tools and data needed to support the evidence that a unidirectional, geographically isolated wetland is truly isolated or not. It would be a good idea to provide further explanation of the types of tools and databases (and current state of availability or development) that would provide these answers. The suggestion is that decisions about excluding geographically isolated wetlands should be made on a case by case basis; it is very likely (and has been proposed by comments) that the opposite be the case- that these be excluded and included as evidence is presented. Are there any data or studies that address the potential risks associated with the opt in, versus the opt out approach with respect to management / regulation of these isolated systems?

Dr. Michael Josselyn

Comments by Michael Josselyn, PhD

I am prefacing my remarks by stating that I am honored to be appointed to this Board and to serve with so many distinguished and highly qualified panel members. I look forward to reading their comments, participating in informative and critical discussions on the science, listening and reviewing the information that has been and will be submitted by the public and interested groups, and preparing our formal review.

My approach to my review of the Draft Report is through the critical eye of a scientist with the practical experience of a professional consultant. I believe strongly in clearly stating the outcomes of scientific findings balanced with the uncertainties and limitations associated with that science. It is true that the scientific community has produced a highly diverse and significant amount of work in the field of stream and wetland science over the past 50 years; however, it is equally true to many of the practical problems that we must face when regulating specific areas are not often the focus of those studies. As a result, there is a great deal of uncertainty associated with making decisions that apply to the range of conditions that exist in the natural world and more so within the human altered world.

My preliminary comments to the Charge Questions are:

Overall Impression of the Clarity and Technical Accuracy

The Draft Report covers a broad range of literature with over 1000 citations including many that represent the synthesis of other studies. It is the result of numerous hours of compilation, internal review, and peer review. As a result, it is likely that the question is not whether all the science has been discovered during this process as it relates to rivers, streams, and wetlands; but has it been presented such that the conclusions reached are valid and the analysis useful to the issue at hand, e.g. the regulation of the Nations' waters, including wetlands. I am not convinced that the Draft Report meets those two expectations.

The Draft Report does present literature and findings on hydrologic connections between various types of streams and wetlands. It also discusses chemical and biological processes that are performed in those streams and wetlands. These connections and processes are based on well known physical and biochemical factors occurring in streams and wetlands. I believe that the authors and previous peer reviewers have done an excellent job in explaining complex processes with text and figures that are clear and accurate.

However, the Draft Report presumes that the presence of any linkage, whether by surface or groundwater, or the occurrence of a biological or chemical conversion process within those features are significant in terms of downstream water quality. However, while these processes in of themselves are important, few of the articles cited dealt with the level of significance to downstream water quality. Fewer still discuss the role that frequency and duration of flow have to play in affecting downstream water quality[1]**.** These issues are critical to understanding how the scientific literature supports or refutes conclusions in this Draft Report that will eventually be used to promulgate regulatory policy.

The Draft Report states that "this report does not consider or make judgments regarding legal standards for CWA jurisdiction". On the other hand, the EPA and the Corps intend to use the Final Report for that very reason and therefore, the clarity of the report as it relates to the regulatory issues at hand needs substantial improvement. In particular, understanding how frequency and duration of flow through surface connections affect downstream water quality is extremely important, yet there is no quantitative (and little qualitative) discussion on these two factors. The question related to how similar wetlands within a specific setting or region affect water quality is also an issue that needs to be analyzed by the science. As a result, fundamental questions that need to be addressed by the EPA and Corps in formulating regulatory guidance have not been discussed in the Draft Report.

Of particular concern is the need for a set of definitions that are consistent with current regulatory policy and to common scientific understanding. The definitions of river, stream, wetland, and tributary need to be consistent with how they will be used in a regulatory setting (Leibowitz and Nadeau 2003). Otherwise, the Draft Report will be assuming one definition in its analysis of the science when, in fact, the regulatory documents will be using a separate definition[2]**.** For example, the Draft Report relies on the Cowardin wetland classification system for its definition of "wetland" rather than the regulatory definition used by the EPA and Corps. While the Cowardin classification system is certainly a well supported and documented system, it is much broader in its inclusion of areas that would not be considered as "wetlands" or "other water" under any regulatory rule. It will be difficult to support a regulatory decision based on the science, if there is inconsistency in the basic understanding of what was being considered as a wetland. While I understand that the science rarely classifies the wetlands in a regulatory sense (or even in the Cowardin sense), this must be acknowledged as an uncertainty, and where possible, a means to select appropriately referenced literature.

A key consideration in reviewing the literature also relates to the interpretation of significance. In my experience, Corps regulatory staff, consultants advising clients, and the public do not have a clear understanding of how to interpret "significant nexus" in terms of understanding how wetlands and streams are regulated. The Draft Report uses the word "significant" in various ways without defining how it is used, either as a statistical parameter or simply as a general statement. Because a key element of the regulation that will be proposed by the EPA with support from this Draft Report must deal with a determination of the level of significance of any physical, biological, or chemical process; the Draft Report should carefully define how the term is used in this document and how the science reported therein provides support for determining a "significant nexus".

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[1] The Draft Report does state that "readers should refer to the cited publications for quantitative information" which, of course, should in fact be the basis of a thorough analysis in the Draft Report and not just left for the reader to do on their own.

[2] A recently circulated version of a draft rule by the EPA and Corps, for example, uses a different definition "tributary" than the one in the Draft Report.

While the word "significant" appears many times in the document with different meanings, the word "uncertainty" or "uncertain" does not appear at all within the document. However, this must be a key concern to scientists who are publishing in this field and to understanding the issues that must continue to be investigated. Many of EPA's Science Advisory Boards have devoted specific attention to data validation and uncertainty analysis in their review of the science in a variety of topics ranging from air quality to public health. I believe that the Draft Report should devote a specific section to the topics that have not been well documented by scientific research, to be clear as to the uncertainties affecting the findings, and recommend research that could be undertaken in those areas.

Usefulness of the Conceptual Framework

The conceptual framework is based on fundamental processes affecting the hydrologic cycle and includes both surface and groundwater influences on rivers, streams, and wetlands. This conceptual framework provides the basis for the subsequent chapters that focus on riverine systems (e.g. rivers and streams) and on two types of wetlands, those which are found in floodplains and labeled as "bidirectional" and those outside of floodplains which are labeled as "unidirectional"[3]. Both of these terms have been developed, to my knowledge, within the framework of this document. I recommend that a more commonly used classification system be used such as the hydrogeomorphic (HGM) classification system developed by Brinson (1993) as this has been adopted uniformly by wetland scientists and the literature is often based on such classifications.

Definitions of commonly used terms such as "river" and "stream" need to be better distinguished as currently the only distinguishing characteristic is the relative volume of water. It will be particularly confusing in the arid west where the flows are non-existent for long periods, but then flows following rain events can be substantial and short lived. Furthermore, the terms perennial, intermittent, and ephemeral may be applied to both "rivers" and "streams" in the arid west as defined under the Draft Report; though the commonly accepted assumption is that rivers are perennial and streams may be any of those categories. I suggest that the SAB consider expanding on the use of the Strahler system using stream order using sizes that range from a first order stream all the way to the largest, a 12th order stream. First through third order streams are also called headwater streams[4] and constitute any waterways in the upper reaches of the watershed. Going up in size and strength, streams that are classified as fourth through sixth order are medium streams while anything larger (up to 12th order) is considered a river. This may reduce the ambiguity and allow the SAB to focus on the science related to these various stream order groupings.

I also believe that this section of the Draft Report would benefit from a more thorough discussion of flood flow frequency and flood zones. At present, the Draft Report only deals with the floodplain in general; but does not distinguish between those areas that are subject to flooding

3 I suggest that the terms applied to wetlands within and outside of floodplains be more neutral as the pre-analysis implication associated with the current word selection is an assumption of connectivity; perhaps just floodplain wetlands and non-floodplain wetlands would be a better choice.

4 The glossary states that headwater streams are first to third order; however, the conceptual framework is not consistent with this definition and instead relies on the less precise terminology of river and stream.

every year or those subject to flooding in a 100 or 500 year event. This discussion would allow for a greater understanding of the frequency and duration that wetlands within a floodplain may experience at differing distances and elevations within the floodplain.

One concept that is introduced in this chapter is that of "connectivity" which is defined as the "degree to which components of the system are connected and interact through various transport mechanisms". In addition, the concept of "isolation" is discussed as the "degree to which transport mechanisms are lacking"[5]. The Draft Report argues that both play a role in affecting downstream water quality. However, in the context of the regulatory environment, the focus should be on the term "degree" as defined by frequency and duration and relative to the position of the wetland in the landscape. There is very little analysis in the Draft Report on this important term in the definition of connectivity.

The Conceptual Framework also discusses the science the role of groundwater in affecting rivers, streams, and wetlands. The scientific basis for these concepts is well founded and accurate. However, there should be some discussion on the differences in timing as it relates to groundwater flows which may range from days to tens of years in terms of the movement of water. In addition, there should be some mention that some wetland types may be isolated from groundwater connections by aquitards.

One missing concept that is assumed, but not specifically discussed is that of watersheds. While the Draft Report states that "In a discussion of connectivity, the watershed scale is the appropriate context for interpreting technical evidence about individual watershed components", there is very little discussion about watershed scales within the context of the conceptual model. The terms "catchment" and "drainage basin" are introduced in the glossary, but with no discussion as to their scale and significance. This is particularly important to understand as it relates to the definition of "similarly situated wetlands in the landscape" that is discussed later in the document.

Comments on Characterization of Review and Literature on Downstream Connectivity and Support by Available Science

I believe that this section is well supported by the literature as cited and conveys the many potential connections, both physical and biological that can occur along the stream gradient. As suggested above, I believe that this section should reorganized such that it is clearer when references are made to headwater streams, streams within the middle of the Strahler system, and those which are considered as rivers. Given that the proposed rule making to be supported by this Draft Report is on headwater streams and particularly those that are either intermittent or ephemeral in their flows, this reorganization would allow the reader to better understand the status of the science in these systems. It would also allow the SAB to better understand how to assess the level of study, degree of uncertainty, and need for further research in the headwater systems. At present, it is difficult to separate out those studies that focused on rivers vs those in headwater systems.

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5 See comments related to isolation on page 9

In an analysis of the literature, further refinement may be needed as often the database used will affect the conclusions reached. For example, the Draft Report cites Alexander et al (2007) that modeled flow in first order streams; however, when reading their report, they focused on only streams that were considered perennial and therefore may not be reflective of first order headwater streams in general, and particularly in the western US. Conclusions reached from their excellent analysis on nutrient dynamics; therefore, would only be applicable to perennial streams in a specific region of the US. I recommend that the Draft Report organize the literature based on geographic location as it would then be easier to understand significant differences between various regions of the US.

An important distinction that also should be evaluated is the duration of flow within the headwater streams and their role in affecting downstream processes. The Draft Report contains references that are focused on more perennial and intermittent flowing streams, but presents very little information on the processes occurring within ephemeral streams. Because these systems are often the focus of jurisdictional disputes, the specific case history discussion contained in the Draft Report on southwestern streams is very useful. A conclusion reached is that such systems are important to recharging local groundwater systems following surface flow events; however, it is not clear how this would relate to downstream water quality. The findings by Hassan (1990) were cited in which it was found that sediment transport in these ephemeral desert streams did not provide a “sufficient link” to perennial rivers. This was supported by other evidence from Lane et al (1997) for the San Pedro River. Yet, the conclusion reached in this section was that “ephemeral streams export sediment to rivers in major hydrologic events” without discussion on the uncertainly and frequency at which this might happen. I recommend that the Draft Report should acknowledge when the scientific knowledge is weak related to certain systems and to recommend the type of research that will be needed to address these areas.

Comments on Characterization of Review and Literature on Floodplain Connectivity and Support by the Available Science

The Draft Report states that:

> Most of the literature that we evaluate in this chapter does not specify the type or size of the stream or river (or other water body) that the wetland(s) are connected to or influence. If available, we note this information, but in many cases we can only discuss generic connections to streams, rivers, or downstream waters. However, given that rivers are connected to all upstream components of the river network, including streams (see Chapter 3), and the functional relationships between streams and rivers (see Chapter 4), we consider any evidence of connectivity with a stream (other than losing streams that are completely disconnected from the river network) to be evidence of connectivity with the river and other downstream waters.

In my opinion, this statement appears to discount a key element of the purpose of the Draft Report: to provide scientific evidence that could support a regulatory finding related to the *degree of connectivity* between wetlands and downstream waterbodies. If the science does not contain sufficient evidence, it should be so stated and those studies may be given less relevance than those which do contain sufficient information to make valid conclusions on the degree of connectivity.

In this chapter, the Draft Report states that since "most papers on riparian areas and floodplains do not specific whether the area is a wetland", the Draft Report will then combine all papers dealing with floodplains into one category. Clearly, this does not assist in formulating specific policy for wetlands as questions will be raised as to the validity of the conclusions reached; especially since wetlands may be widely distributed by distance and elevation over floodplains[6]**.** It is better to recognize this as an uncertainty and then focus only on that research which provides the level of distinction needed to evaluate the degree of connectivity between wetlands in floodplains. Because many riparian areas are closely related to the edges of streams and rivers, it must be assumed that close proximity is a factor in evaluating connectiveness; however, it is not clear what the degree of connectivity is between wetlands found a greater distance and at higher elevations (e.g. within 25, 50, 100 and 500 year floodplains). Because these areas are usually of most concern to regulatory policy, the Draft Report should provide greater scrutiny of such studies.

Comments on Characterization of Review and Literature on "Unidirectional Wetlands" Connectivity and Support by the Available Science

I am pleased with the discussion of hydrogeomorphic classification in this section as it helps the reader understand the overly broad and conclusive adjective ("unidirectional") used in the Draft Report for this wetland category. I recommend that this discussion on hydrogeomorphic classification be broaden so that the multitude of wetland types being covered within this section is understood. I also believe that such an approach is more in tune with the scientific literature (Tiner 2003). It is also important to note the type of wetland system being studied, e.g. permanent, seasonal, or temporarily flooded or inundated as the duration and frequency that the wetlands are wet will affect the processes being described. For example, most of the studies cited under the section dealing with unidirectional wetlands as sinks or sources are perennially wet systems which are more likely to support the type of nutrient transformations described based on the long duration of anaerobic conditions. The Draft Report would be of greater benefit to understanding the degree of connectivity if the classification system used were more precise and the duration of flooding or wetness was described for the findings reached.

The Draft Report also argues that even those wetlands that are truly isolated are still important to nearby or even distant tributaries. The Draft Report suggests that if these wetlands were not present, downstream water quality would be diminished. In my opinion, such an argument presents a classic example of a false premise. The fact is, if the wetland was not present, some other habitat similar to that which surrounds the wetland would occupy that area such as woodland, prairie grassland, desert scrub, chaparral, or non-wetland riparian woodland. To suggest that these habitats have no function or role in ecological functions and/or downstream water quality is simply not true. Grasslands can hold soil and are an important source of primary productivity, woodlands also provide important nutrient transformation from organic matter to nutrients within the complex biota of the soil, and chaparral and desert scrub provide important habitat and biodiversity to the system. I do not believe it is a correct argument to suggest that if these upland areas were instead replaced by isolated wetlands, that the ecology of downstream

[6] The glossary definition of a floodplain is also vague and needs better definition as it simply states it is the area inundated under moderate or high flows. This definition has little meaning in understanding the difference between wetlands located in an active floodplain that may be inundated on a 2 to 10 year basis from an inactive floodplain or terrace that is inundated every 25 to 100 years.

tributaries would be improved. I recommend that the Draft Report remove this discussion as a basis for asserting that the absence of connectivity is equivalent to or somehow beneficial to downstream water quality.

As one of the members assigned to this section of the Draft Report, I look forward to further participation with fellow Panel members to review this section of the Draft Report and to provide joint recommendations to the SAB for inclusion in its final report.

This concludes my preliminary remarks for the Panel's consideration. I understand that the Panel will be receiving public comment and letters and that Panel members will distribute their Preliminary Comments prior to our meeting. I am sure that this input will be valuable to our deliberations and I look forward to these discussions and to hearing from my colleagues on the Panel for suggestions that can improve the quality of the Draft Report and to assist the EPA and the Corps in providing a critical assessment of the state of wetland science related to this important national issue.

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Dr. Latif Kalin

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*.

Overall, the report is written well and it is very clear. There is some redundancy and overemphasis of certain things, but that does not affect the flow of the report. Technically, the report is generally sound, although there appears to be a bias toward certain literature. Very few papers are listed (in some chapters none) that do not support the major conclusions. This, indeed, might be the case, but authors should/could have shown that every effort was made to exhaust all the relevant literature. The major conclusions listed in the report are generally supported by the literature cited in the report. In several occasions the conclusions are overstretched. For instance, based on the literature cited, the report states that unidirectional wetlands are hard to evaluate for connectedness. The report then goes on and says the conclusions still apply to such systems because of their potential. Further, connectedness is addressed in a simple way. Strength of connectedness or significance of connectedness, in general, is not addressed. In several occasions loose linkages are used to show connectedness (e.g. bug moving from one system to another, fish eating the bug, etc.). With the same logic everything and everyone is connected (see the ***six degrees of separation*** theory, for instance).

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.*

This chapter is written in a very plain language with a lot of educational material in it. It presents a very nice introduction to the river systems, flow generating mechanisms, and how different water bodies can be connected through various hydrologic pathways. This background, therefore, is very useful to the general audience for interpreting many the evidences presented throughout the report on the connectivity of various water bodies.

A key point laid out in this chapter is the definition of “wetland”. This report uses Cowardin et al.’s (1979) definition, not the federal regulatory definition. Cowardin et al. (1979) defines three attributes. If an area meets any one of those three conditions then it is considered to be a wetland. The federal regulations, on the other hand, require all three conditions, and therefore are more restrictive. Consequently, swamps, bogs, fens, marshes, ponds, and pools are all considered to be wetlands.

The report lists 5 functions by which streams and wetlands affect material fluxes to downstream, waters: source, sink, refuge, lag and transformation. This list is actually extension of Leibowitz et al.’s (2008) list. The latter two in the list are added by the authors. In my opinion lag and transformation are redundant, i.e. Leibowitz et al.’s (2008) original list should suffice. Refuge and lag are very similar terms and can explain the same phenomena. Also, transformation can be considered under sink.

On page 3-28, connectivity is described as "the degree to which components of a system are connected and interact through various transport mechanisms; connectivity is determined by the characteristics of both the physical landscape and the biota of the specific system." I don't think connectivity is assessed in terms of "degree of connectivity" in this report. The focus was whether there is a direct or indirect connectivity, but not so much on the degree.

On page 3-35, lines 5-10: Overland flow does not only occur when rainfall intensities exceed infiltration rate (Hortonian type). It also occur when rainfall falls on saturated areas (saturation excess overall flow), which is the common type of overland flow generating mechanism in forested settings.

Page 3-17: I don't disagree that biota should be considered in establishing connectivity. However, I do believe that this is the weakest link. Biotic linkages happen at a much larger spatial extent. If we use biotic linkages as a base, we can end up concluding that most terrestrial lands are connected to downstream waters. I think biotic linkages should be assessed with care and be given lower weights.

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.

This section provides good amount of literature, which are summarized nicely. Some corrections are needed though. In my view this section provides the strongest case for connectivity as it is easier to show connections of lotic systems. "nutrient spiraling" is a very important concept in showing connectivity of upstream headwater streams to downstream waters.

One topic that slightly bothers me is the use of floods as means for connectivity. First, I don't think there is a need to convince anybody that when flooded, there is a strong connectivity. In that sense the example given on page 4-46 (top of page) is redundant. During a flood many other things can be connected to downstream waters. Rare events should not be a base for connectivity.

The section on temperature (4.7.3.1.2) on page 4-48 can be deleted. It does not provide much relevant info on connectivity or isolation.

Section 4.7.3.2.1 Nutrient and other Chemicals: The second paragraph is a little deceiving and I believe the Dodds et al. (1996a) study is not interpreted correctly. The report claims that "nitrogen transport through four second- and third-order streams in the Kings Creek watershed ranged from 0.01 to 6.0% of the total nitrogen supplied by precipitation, the balance being retained by the stream system." Nitrogen was not retrained in these streams; rather it was mostly retained in the terrestrial system. Similarly, the report refers to Alexander et al. (2008) study and list "instream nutrient uptake" as the likely reason for large streams delivering more of their N and P loads. I did not see any reference to nutrient uptake in that study.

Table 4-1 is not cited in text. Figure 4-8 needs better quality; streams are not visible.

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

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

The literature presented in this chapter is relevant. Some care is needed in interpreting literature. Improvement in text is needed in several places.

In several occasions in this chapter (including Table 5-1) wetlands are listed as the sources of downstream water. This statement is hydrologically not correct. Wetlands are not the sources of water; rather they are/can be located at the sources of water, such as springs. The conditions might favor the presence of a wetland.

The evidence on the first of paragraph of page 7 on the riparian vegetation influencing water levels needs some attention. Such effects are usually diurnal. Also, the statement “Phreatophytes (plants that obtain their water from the saturated zone) can intercept groundwater and overland flow before it enters a stream and decrease stream flow by directly taking up stream water through their roots” is very weak. The reference given for this is a 50 year old reference of Meyboom (1964). No other citation is given and I am personally not aware of such a citation supporting this.

The paragraph from line 11-23 on page 5-8 is contradicting. The first sentence states that “riparian areas can be a source of sediment to the stream, particularly through stream bank erosion.” All the citations given in that paragraph show the importance of riparian vegetation in controlling sediment. There is no evidence of riparian areas being sediment source.

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

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.

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

In my view this is the most critical part of the report. Isolated wetlands are likely the most sensitive issue. The authors did a good job in summarizing the literature. However, as I mentioned at the beginning, very few papers are listed arguing their major conclusions. Again, indeed there might be very few or no such studies. Eventually, showing existence of something is easier than showing its nonexistence.

The last paragraph of page 5-16 forces the limits of connectivity. One does not need to go that far to show connection. The question is "what is the significance of such indirect connections". This whole paragraph needs to be removed.

Section 5.4.2.1 "Surface Water Connections" of Unidirectional Wetlands refer to some really neat studies showing the connectivity of such systems. Yet, one asks the question, how long and how often water should flow from unidirectional wetlands to downstream waters to have a significant connection? This is not an easy question to answer. At the end of page 5-22 under the same section, an example is given. In 1996 during heavy spring days 28% of the wetlands in a study area had surface water connection. This is an example to extreme weather conditions and should not be used to reach general conclusions.

In section 4.2.2.2 case is made about groundwater connection (either as recharge or discharge). I would like to add that any recharge area is connected to Groundwater, and therefore warrants protection.

Section 5.4.4. Biological Connection: I maintain my stance again on biological connectivity. This is often a weak link and the report overstretches this issue. For instance, on line 23-24 connection is established through wind dispersing seeds and pollen. Later in the same paragraph migratory birds are listed for dispersing seeds. This is simply too much. On line 13-16 of page 5-32 biological connectivity between proximal lakes and wetlands are established based on similarities of plant communities. Same can be said for terrestrial land. Plant communities will get more similar as they get closer. Again, overforcing the issue.

Page 5-36, line 11-13: Again, wetlands are not the source of the water. They are often located at the source.

Last two paragraphs of section 5.7.2.5 are not much related to the topic of connectivity. I suggest their deletion.

Dr. Kenneth Kolm

Preliminary Comments in Response to the Connectivity Panel's Charge Questions:
Connectivity of Streams and Wetlands to Downstream Waters:
A Review and Synthesis of the Scientific Evidence

Kenneth E. Kolm, Ph.D.
Submitted on December 9, 2013

Overall Clarity and Technical Accuracy of the Draft Report

Charge Question 1. Overall impressions of the clarity and technical accuracy of EPA.s draft Report: *Connectivity of Streams and Wetlands to Downstream Waters: A Review and Synthesis of the Scientific Evidence.*

EPA's Report *Connectivity of Streams and Wetlands to Downstream Waters: A Review and Synthesis of the Scientific Evidence* attempts to summarize the current scientific understanding of broadly applicable ecological relationships that affect the condition or function of downstream aquatic ecosystems. The Report focuses on three primary aspects of Connectivity: hydrology, chemistry, and biology; and selects three types of natural systems as the upstream or upgradient origins for connectivity: Lotic headwater stream systems that are directional, including ephemeral, intermittent, and perennial; Lentic wetland systems that are bidirectional; and Lentic wetland systems that are unidirectional, including "geographically isolated wetlands". The downstream aquatic ecosystems are presumably the mainstems of river systems, lakes, and oceanic water bodies (lagoons, etc). The goal of the report, which is to understand connectivity based upon peer reviewed literature and larger scale studies or case histories, is timely and welcomed as a holistic approach or integrated systems analysis is long overdue for understanding natural systems and the cascading effects of anthropogenic activities.

To accomplish the goals of the Report, and to accomplish successful watershed and wetlands management for water supply and water quality, it is important to understand the physical, chemical, and biological connections by which streams, wetlands, and open-waters affect downstream waters such as rivers, lakes, and oceans. Therefore, the Report correctly begins by presenting a conceptual framework (Chapter 3) that describes the hydrologic elements of a watershed, the types of physical, chemical, and biological connections that link them, and watershed factors that influence connectivity at various temporal and spatial scales. The Report then builds on the conceptual framework to discuss the Lotic (Chapter 4) and Lentic (Chapter 5) Systems in context. In summary, the overall report structure is excellent.

The major technical accuracy issue regards the development of conceptual models for wetlands and watersheds to determine connectivity focused on in Chapter 3, and built upon in Chapters 4 and 5. The conceptual models as presented in Chapters 2 and 3 are simplistic, inaccurate, and/or incomplete; the resulting analysis based on the conceptual models presented will, in many case histories, miss the connectivity relationships, or be quantitatively inaccurate for spatial and temporal analysis. Chapters 4 and 5 have good organization and information, and the case histories rely on the geologic, geomorphologic, hydrogeologic, and groundwater system knowledge that needs to be presented in Chapters 2 and 3 for completeness. Chapter 2 needs to be expanded to discuss the approach and development of Conceptual Models for wetlands and watersheds to determine connectivity that includes geology, geochemistry, geomorphology, hydrogeology, hydrochemistry, and groundwater systems with surface water and biological systems. Based on the approach and development of Conceptual Models, the peer-reviewed literature should then be organized to support each of the Conceptual Model systems, which would include surface water, groundwater, wetlands, and watershed scale studies. Chapter 3 needs to be greatly expanded to include the geologic, geochemical, geomorphologic, hydrogeologic, hydrochemical, and the groundwater systems to compliment the surface water systems that are presented. Chapters 2 and 3 need to discuss the multivariate time-space relationships that are critical for understanding connectivity amongst the system variables that are discussed in some of the case histories of Chapters 4 and 5.

A discussion on the development of conceptual models for wetlands and watersheds to determine connectivity is presented for clarification and technical guidance. This is followed by general comments and specified edits on clarity and technical accuracy of the Report particularly focused on Chapters 1,2, and 6.

Development of Conceptual Models for Wetlands and Watersheds to Determine Connectivity:

Wetlands and Wetland Downstream/Down gradient Connectivity can be viewed conceptually like the human body. The critical parts of the wetlands and watershed/groundwater basin system are the "skeleton", or geologic framework of the system; the "skin", or geomorphologic "cover" of the system; the circulatory system, or the surface water hydrology of the system; the lymph system, or the groundwater hydrology of the system; and ultimately the living organism itself, or the biogeohydrochemical nature of the organism as a whole – the wetland and the watershed upstream and downstream. Wetlands and watershed/groundwater basins are multi-scale and multi-temporal entities, and should be approached dynamically as such. The EPA Report falls short by not discussing all of the key components, including scale and temporal aspects, of the wetlands and watershed systems.

The "skeleton" of the wetland/watershed system is the geologic framework. The geology provides the framework or subsurface structure, and is the foundation upon which wetlands/watershed-groundwater basin derives its surface and subsurface water quantity and water quality, and controls the landscape setting with such variables as topography, gradient, and climate interaction and resolution. The geology and corresponding hydrogeology is critical in connectivity for providing long term sustainability of groundwater and surface water systems, particularly in arid, semi-arid, and subhumid environments, and including the alpine and arctic environments. Examples of these bedrock-controlled wetlands and watersheds are found throughout the western United States and Alaska. Fractured Karst and Volcanic (for example, basalt) bedrock control the surface and subsurface hydrologic systems in ALL climates, and are critical to understanding the downstream connectivity of wetlands systems. Examples of these bedrock controlled wetlands and watersheds are found throughout the karst regions of the United States, including Florida, Illinois, Indiana, Pennsylvania through Virginia, West Texas and New Mexico, and the volcanic regions of the United States, including Washington, Idaho, Oregon, Colorado, and New Mexico. All conceptual models for wetland and watershed systems should be developed with a firm understanding of the geologic/hydrogeologic materials and structure as the "skeleton" or framework for the physical, hydrological, chemical, and biological analysis of wetlands and watershed, including connectivity. The EPA Report falls short by not discussing the geologic/hydrogeologic framework as a key component of the connectivity of aquatic systems as there is a large quantity of literature available on these topics.

The "skin" of the wetland/watershed system is the geomorphologic "blanket" that covers most of the earth surfaces, and is the culmination of the geomorphologic processes and responses (unconsolidated materials) over time that covers the "skeleton" or geology. All geomorphologic materials will affect the surface and subsurface movement, chemistry, and biology of water, and are critical to the understanding of stream and wetland connectivity. Typical hydrogeomorphic materials can include pedogenic (soils), fluvial (floodplain, terrace -- abandoned floodplain, fans and bajada), eolian (sand dunes, loess), mass wasting (all sorts of gravity induced materials such as landslides), glacial (moraines, till and drift, outwash plain), oceanic (dunes, marine deposits), and human debris (such as builder's "colluvium"). These materials are responsible for the response time for surface water hydrographs, which is the process of through flow or interflow or temporary "saturated flow" during an event. Overland flow only exists on such surfaces as parking lots, roof tops, roads, and sidewalks; plowed fields or other agricultural alterations to the land surface; and also on the Navajo Sandstone in Arches and Canyonlands National Park, OR if the precipitation event is so rapid and so intense or so long that the saturated materials can't absorb any more rain making water flow on the surface feasible. In most cases, through flow and interflow are the main processes, and the hydrogeomorphic materials are the "skin" framework for stream and wetland connectivity with downstream waters. This "skin" is responsible for the short-term sustainability of most wetland and watershed systems, and is usually working in conjunction with the bedrock hydrogeologic framework for the long-term sustainability of these systems. A hydrobiological "skin" of special interest is peat, which is formed usually as the result of long-term groundwater and biological processes working together. All conceptual models for wetland and watershed systems should be developed with a firm understanding of the geomorphological processes (past and current) and the resulting hydrogeologic unconsolidated materials (composition, continuity, and geometry) as the "skin" or unconsolidated framework for the physical, hydrological, chemical, and biological analysis of wetlands and watersheds, including connectivity. The EPA Report falls short by not discussing the geomorphologic processes and resulting framework or materials, particularly the hydrogeomorphic relations, as a key component of the connectivity of aquatic systems as there is a large quantity of literature available on these topics.

The circulatory system of the wetland/watershed system is the surface water hydrology and its components, like dissolved constituents and particulate sediments, and biological material, and is the culmination of the geological/hydrogeological "skeleton", and the surface and near surface geomorphologic processes (including climate) and responses (unconsolidated materials or "skin") over time. The physical aspects of the surface water system are usually conceptualized as a water balance or water budget, and includes natural and anthropogenic inputs (climate, groundwater into gaining streams, reservoirs and diversions, wetlands, for example), outputs (flow downstream, evapotranspiration, human diversions, for example), and storage/change in storage (for example, wetlands and floodplain processes) if transient, and most systems are transient. The physical attributes are the foundation (yet again) for the chemical and biological (human) materials, and frequently the mass balance approach can be used for measurement. All conceptual models for wetland and watershed systems and their connectivity should be developed with a firm understanding of the surface water processes (past and current) as the circulatory system for the physical, hydrological, chemical, and biological analysis of wetlands and watersheds, including connectivity. The EPA Report falls short by not discussing surface water systems in the context of the geology/hydrogeology, and the geomorphologic processes and resulting framework or materials, particularly the hydrogeomorphic relations and the processes of through flow and interflow, as key components of the connectivity of aquatic systems as there is a large quantity of literature available on these topics.

The lymph system of the wetland/watershed system is the groundwater hydrology and its components, like dissolved constituents and particulate sediments and biological material, and is the culmination of the geological/hydrogeological "skeleton", the surface and near surface geomorphologic processes (including climate) and responses (unconsolidated materials or "skin"), and the surface water system (circulatory system) over time. The physical aspects of the groundwater system are usually conceptualized as a water balance or water budget, and includes natural and anthropogenic inputs (climate – precipitation and infiltration, surface water such as losing streams and reservoirs, irrigation such as lawn watering and cropland, for example), outputs (flow down gradient into a regional groundwater system, evapotranspiration by phreatophytes and other wetland species, human intrusions such as wells, for example) , and storage/change in storage (for example, wetlands and stream interaction processes) if transient, and most systems are transient. The physical attributes are the foundation (yet again) for the chemical and biological (human) processes, and frequently the mass balance approach can be used for measurement. All conceptual models for wetland and watershed systems and their connectivity should be developed with a firm understanding of the groundwater processes (past and current) as the lymph system for the physical, hydrological, chemical, and biological analysis of wetlands and watersheds, including connectivity. The EPA Report falls short by not discussing groundwater systems in the context of the geology/hydrogeology, the geomorphologic processes and resulting hydrogeomorphic framework or materials, and the interactions with the surface water systems as key components of the connectivity of aquatic systems as there is a large quantity of literature available on these topics.

Finally, the "living organism" itself, or the biogeohydrochemical nature (including connectivity) of the organism as a whole – the wetland and the watershed, is the culmination of the geological/hydrogeological "skeleton", the surface and near surface geomorphologic processes and responses (unconsolidated materials or "skin"), the surface water system (circulatory system), and the groundwater system (lymph system) over time. The chemical system, including inputs, outputs, movement, transformation of substances, and storage; and the biological system (microbial through human forms, the concept of landscape ecology at multiple scales) should be analyzed hierarchically in the context of the other four subsystems. The chemical systems can have origins from without and within the wetlands or upstream waters. The upstream waters and wetlands can transport, store, and transform the chemical species. The chemical species can then move (connectivity) to the downstream waters in physical (such as sediment), hydrological (sediment, dissolved, biological), and biological pathways. The biological systems (all scales) can have origins from without and within the wetlands and upstream waters. The upstream waters and wetlands can transport, store, and transform the biological species. The biological species can then move (connectivity) to the downstream waters in physical (such as airborne and terrestrial mechanisms), hydrological (hitchhiking on sediment, swimming, floating, etc.), and biological pathways (airborne and terrestrial). All conceptual models for wetland and watershed systems and their connectivity should be developed with a firm understanding of the "skeleton", "skin", circulatory system, lymph system, and the biogeohydrochemical nature. The EPA Report does begin to address the relations of these "foundation" systems in Chapters 4 and 5, particularly in the Case Histories presented in Sections 5-6 thru 5-9, but falls short by not discussing the geology/hydrogeology, the geomorphologic processes and resulting hydrogeomorphic framework or materials, and the groundwater systems as key components of the chemical and biological connectivity of aquatic systems in Chapters 2 and 3.

Wetlands and watershed/groundwater basins and their connectivity are multi-scale and multi-temporal entities, and should be approached dynamically as such. The tendency for most investigators is to focus more closely to the microbial or site scale, and not pay attention to the subregional and regional aspects of the area, or is to focus on the immediate process/response systems (annual thru decadal engineering time) and not the dynamic changes occurring over longer time periods (millennial thru geomorphological time) to properly evaluate the temporal aspects of the connectivity being studied. These short-time period, site-scale studies frequently result in large amounts of non-cost effective data being incorrectly collected at less optimal locations and analyzed out of context. The EPA Report falls short by not discussing in Chapters 2 and 3 the multi-scale and multi-temporal aspects of wetlands and watershed/groundwater basins and their connectivity as there is a large quantity of literature available on these topics.

Finally, connectivity is a multivariate phenomenon and most studies are not holistic and tend to focus on single-variable cause and effect relations. Most of the peer-reviewed literature studied is of this venue, and to generalize the results, as many chapters in this Report have presented, can result in inaccurate conclusions. Each system is unique, and the analog or case history approach may not have the answer to the connectivity question as applied to a different area. Hence, an integrated, hierarchical multidisciplinary approach that satisfies the rigor of each discipline is needed for application to each stream/wetland connectivity situation (see Kolm and others, 1996; also Kolm and Langer, 2001).

In order to guide the conceptualization of the study area for wetlands connectivity to downstream waters, a logic diagram is provided (Attachment #1 modified from Kolm and others, 1996; Kolm and Langer, 2001), an ASTM STP reference is provided specifically related to groundwater (Attachment #2: Kolm and others, 1996); and the ASTM D 5979-96 Standard Guide for

Conceptualization and Characterization of Groundwater Systems is provided (Attachment #3). The ASTM D 5979-96 Standard Guide was sponsored by US EPA in the 1990s for the development of Groundwater Standards and Standard Guides.

Clarity and Technical Accuracy of Document

In summary, the major technical accuracy issue regards the development of conceptual models for wetlands and watersheds to determine connectivity focused on in Chapter 3, and built upon in Chapters 4 and 5. To restate for emphasis, the conceptual models as presented in Chapters 2 and 3 are simplistic, inaccurate, and/or incomplete; the resulting analysis based on the conceptual models presented will, in many case histories, miss the connectivity relationships, or be quantitatively inaccurate for spatial and temporal analysis. Chapters 4 and 5 have good organization and information, and the case histories rely on the geologic, geomorphologic, hydrogeologic, and groundwater system knowledge that needs to be presented in Chapters 2 and 3 for completeness. To restate for emphasis, Chapter 2 needs to be expanded to discuss the approach and development of Conceptual Models for wetlands and watersheds to determine connectivity that includes geology, geochemistry, geomorphology, hydrogeology, hydrochemistry, and groundwater systems with surface water and biological systems. Based on the approach and development of Conceptual Models, the peer-reviewed literature should then be organized to support each of the Conceptual Model systems, which would include surface water, groundwater, wetlands, and watershed scale studies. To restate for emphasis, Chapter 3 needs to be greatly expanded to include the geologic, geochemical, geomorphologic, hydrogeologic, hydrochemical, and the groundwater systems to compliment the surface water systems that are presented. Chapters 2 and 3 need to discuss the multivariate time-space relationships that are critical for understanding connectivity amongst the system variables that are discussed in some of the case histories of Chapters 4 and 5.

The following are specific comments referring to Chapters 1, 2, and 6, and contain the main problems with clarity and technical accuracy of the document. Additional comments are provided with each Charge Question. In addition, the document should be edited to remove the informal “we” and “our” as this is a technical document, and there are many edits, such as the ubiquitous usage of ambiguous pronouns that need to be removed. Finally, the document should be edited for one style as the current document reads like a conglomeration of vastly different styles.

I.0 Executive Summary Comments:

Comment #1:

P 1-1 Lines 3 – 13: Paragraph 1: Initial concern that bedrock systems, such as karst and fracture rock (granite, for example), and sandstone hydrogeologic systems, will not be considered and, particularly in the western US, these are the main sustainability and fluid suppliers to local and regional downstream events. There is a tendency to focus on the surface and near surface geomorphic systems, including peat and alluvium, whereas the long term contaminant and fluid flow is frequently hidden beneath in the bedrock systems whose structure and function is to sustain the shallow systems. This is actually true for most climates.

Comment #2:

P 1-2: Figure 1.1 : This diagram confirms Comment #1 that the bedrock systems are ignored, and, in wetlands and streams, bedrock systems simply cannot be ignored. It appears that the materials surrounding the stream shown on Figure 1.1 are weathering (soils) or mass wasting (Qls on many geologic maps) or maybe even eolian (Qs on many geologic maps) in origin and character. In most of the arid, semi-arid, and sub-humid hydrologic systems, these materials are, at best, in the infiltration/recharge zones of groundwater systems, or interflow/through flow zones (temporary saturation at best) during precipitation events. These materials can be important to wetlands and downstream activities, but not necessarily as shown in Figure 1.1. Figure 1.1 needs to show a more robust, integrated surface water and ground water system that includes the possibility of bedrock systems, and connects all the features to wetlands and streams. Most wetlands are not disconnected from the big system in some way. Figure 1.1 can be easily made to show at least two scales: 1) wetlands and stream scale, and 2) watershed scale; whereas the current figure shows something in between 1) and 2) that can be misleading. Since the document has two approaches in later chapters to analyzing the hydrologic systems, these should be included on Figure 1.1. In the western US lands, two different categories of wetlands define these approaches: 1) Slope wetlands, which are unidirectional usually groundwater controlled wetlands and downstream events; and 2) Riverine wetlands and streams, which are bidirectional due to seasonal watershed events verses long-term sustainable groundwater system processes.

Comment #3:

P 1-2 and 1-3: The case histories used in the document do not represent the arid, semi-arid, sub-humid, and high elevation areas of the western third of the United States. The section of California chosen as an example is not representative of the vast major of wetlands located west of the 100 meridian. If this document is to be used as guidance for downstream connections, this region of the country must be represented as the other case histories fail to give guidance to these kinds of wetlands and watershed landscapes.

1.2 Summary of Major Conclusions

Comment #4:

P 1-3 Lines 11-27: Tributary streams and main stem rivers all function in the same way: transportation of sediment (natural and human-natural), water (on occasion in some locations), chemical compounds (in solution, suspension, and bedload), and biological materials (micro to macro, fish, etc), so it is relatively indisputable as to the main function of a stream. The devil is in the details: how much, when and how often, and by what process, for starters – not all tributaries and main stems are created equal. This concept is not really emphasized in conclusion 1) and should be. The importance of a correct conceptual model of how the system works is critical to this analysis.

P 1-3 Lines 28 – 39: Bidirectional wetlands and river segments, referred to as seasonally gaining and losing streams that show interaction between the surface water and groundwater systems OR referred to sometimes as "riverine" wetlands in the literature, have tremendous function in downstream waters due to BOTH surface and groundwater systems. The devil is in the details: what structure and function: how much, when and how often, and by what process; and this should be emphasized in the conclusions. The importance of a correct conceptual model of how the system works is critical to this analysis.

P 1-3 Line 40-43; P 1-4 Lines 1-20: Unidirectional wetlands and river segments, which are usually closed-basin/climate controlled or groundwater controlled (referred to as "slope" wetlands in the Rocky Mountains, Colorado Plateau, and Great Basin among other areas), have a variety of diverse functions based on landscape position, and other environmental variables. Again, the devil is in the details: structure and function: amount, when and how often, and by what process; and this should be emphasized in the conclusions. The importance of determining a correct conceptual model of how the hydrologic system (surface and groundwater, physical, chemical, and biological) works is critical to this analysis.

Comment #5:

P 1-4 Lines 22-24: The role of the groundwater system is not emphasized in the 3 conclusions. The groundwater system is the lymph system of the landscape whereas the surface water system is the circulatory system. The role of the geology/hydrogeology and the geomorphology is not emphasized in the 3 conclusions. The geology/hydrogeology and geomorphology provide the basic structure and materials to the system, and enable many of the functions to occur, so these physical features act as the skeleton and the skin of the system. A holistic systematic approach needs to be part of the summary of major conclusions and needs to include the skeleton, skin, circulatory, and lymph system or the actual structure and function of the wetlands and upstream waters for downstream surface water system connectivity will be missed. This is the elephant having the foot, trunk, and ear being studied, but the whole body of the elephant is not taken into account.

1.3 CONCEPTUAL FRAMEWORK OVERVIEW

Comment #6: Line 10 p. 1-5

The statement should be water movement through the surface water and groundwater systems provides connectivity of the upstream and downstream processes (circulatory and lymph system). A paragraph about how to formulate a correct conceptual model to determine the connectivity of wetland/upstream waters and downstream waters should be provided.

Comment #7:

Line 17 Page 1-5: Other factors are equally important. Need to summarize geology/hydrogeology and geomorphology/hydrogeomorphology (skeleton and skin) before discussing aquifers. For a holistic, multidisciplinary systems analysis, all the hydrologic system factors should be mentioned: Topography, soils, vegetation and ecosystem components of interest, surface water (amount, type, and distribution), climate (precipitation type and distribution, etc), geomorphology, geology (structure, geochemistry, etc), hydrogeology (potential aquifers), and include anthropogenic activities that influence all of these other aspects (humans are part of the natural system). The study of non-anthropogenic ("natural") vrs anthropogenic ("human") changes could be mentioned (before and after). In addition, the term used in hydrology for downstream or down gradient (groundwater) effects is "cascading effects".

1.4 DISCUSSION OF MAJOR CONCLUSIONS

1.4.1 Conclusion (1) : Streams

Comment #8:

P 1-6 Line 29, 30: Downstream connectivity through groundwater functions not considered. This is very important in arid, semi-arid, sub-humid hydrologic systems.
Line 32 Groundwater discharge to streams in the middle and lower part of watersheds also important for transport of physical, biological, chemical constituents.

Why the huge emphasis on nutrient spiraling?

Comment #9:

P 1-7 Line 15-24: Regional bedrock systems sustain the majority of the southwest aquifers along with geomorphic deposits like alluvium. Many of the groundwater systems would be dried up if totally reliant on alluvial systems. Regional aquifers are important though out the US and the world. In the eastern US, the karst systems are critical to many areas. In the western US, the Pre-Cambrian bedrock systems sustain the Rocky Mountain streams equally to the snowpack scenarios that are advertized.

Why the emphasis on woody material? The major material moved is sediment of various sizes and chemistry.

Comment #10:

P 1-8 Line 5: Beneficial transformation – why not just transformation? "Beneficial" is a judgment or economic call. The emphasis seems to be nutrient cycling – other examples?

Comment #11:

P 1-8 Lines 19-28: There is an overwhelming emphasis on nutrient cycling. This is a specific application for a general document. Why emphasize this in the introduction, summary, and conclusions?

1.4.2 Conclusion (2): Riparian/Floodplain Waters

1.4.3 Conclusion (3); Unidirectional Wetlands

Comment #12: P 1-10 Line 29: Retention of sediments should be mentioned. Many of these wetlands are groundwater driven, particularly in the arid, semi-arid, subhumid systems of the western US. Many of these wetlands have a downstream exit to the surface hydrologic system, and are an important water source (flow) with specific water chemistry and water biology at the wetland source, and wetland exit. Most of the sediment is derived from non-channel sources (mass wasting processes or overland flow, for example).

Comment #13: P 1-11 Line 30: Unidirectional wetlands can also serve as a source for pollutants as well. The groundwater quality of the groundwater discharge determines the chemistry in many cases. The bedrock system, including both natural and altered hydrogeochemistry is an important variable.

Comment #14: P 1-12 Lines 12 – 33: Conclusions d, e. Conclusion d is close to the truth. Conclusion e needs to state clearly the importance of hydrologic systems analysis and a conceptual model for determining connectivity. Most of these unidirectional wetlands are connected in some way to the larger system. There are some exceptions, such as the Nebraska potholes, that these depression wetlands once were the termination of the hydrologic system. Some of the Nevada playa lakes similarly function in this manner.

1.5 CLOSING COMMENTS

Comment #15. P. 1-13 Line 18: Is heat energy a "material"? The discussion is mostly about mass, not energy.

P. 1-13 Lines 29, 30: connected by…… shallow or bedrock groundwater systems, perennial or intermittent flow of streams.

Comment #16. Line 35: Most unidirectional wetlands in the arid lands are groundwater to surface water or slope wetlands, so they don't attenuate floods as a general statement. Instead, these unidirectional wetlands provide sustainability for surface water flow downgradient, interesting water chemistry (natural or human induced), and frequently biota from the subsurface along with sustaining wetland species on the surface.

Comment #17 P 1-14 Lines 8 – 19: Agree strongly with the paragraph on "geographically isolated" wetlands! If the proper conceptual model is completed, most of these wetlands are not "geographically isolated". Lines 20 – 36: This is what a systems approach is all about, but not just for small ponds or swales. This is a multiscale approach connecting these small features with the landscape perspective.

2.0 INTRODUCTION

2.1 PURPOSE AND SCOPE

Comment #18 P 2-1 Line 24, 25: Statement is totally incorrect if not misleading. Bedrock systems sustain the vast majority of arid, semi-arid, sub-humid, and many of the remaining climatic regime wetlands and downstream rivers. In the humid regions, karst and fracture flow systems are very prevalent. This is a major flaw for the entire report.

General Comment #66: Section 5.5 WETLANDS: SYNTHESIS AND APPLICATION: This section needs a complete rewrite and reorganization. This is an important section, and it is apparent that the section as written does not recognize the systematic approach to determine the structure and function of unidirectional wetlands, or how to conceptualize the wetland hydrology in these cases. This is not new science for hydrogeologists, surface water and groundwater hydrologists, who have the tools and conceptual models to determine the connectivity of both surface and subsurface hydrological systems to unidirectional wetlands. Most of these types of wetlands exist spatially and temporally because of the geology, geomorphology, hydrogeology, and hydrologic (groundwater and surface water) systems caused by these three aspects of the landscape. This section should be written with these systems as the foundation.

6.0 CONCLUSIONS AND DISCUSSION

6.1 MAJOR CONCLUSIONS

General edits
:
Conclusion #1: P 6-1 Lines 6,7. Change “exert a strong influence” to “are connected to downstream waters; therefore, these streams affect the character, structure, and function of downstream waters”. Line 13: “Wood” is organic matter; just state “organic matter”. Line 19 – 22: Rewrite as: ‘Streams and downstream waters are connected physically, hydrologically, chemically, and biologically. The physical characteristics of connectivity include WWW and are measured and evaluated by WWW methods. The hydrological characteristics of connectivity include XXX and are measured and evaluated by XXX methods. The chemical characteristics of connectivity are YYY and are measured and evaluated by YYY methods, and the biological characteristics of connectivity are ZZZ, and are measured and evaluated by ZZZ methods.

Conclusion #2: P 6-1.Line 28. Replace “they” with “Bidirectional wetlands”… Replace “they” with “phosphorus, and provide…” Line 30 Omit “Moreover”, line 32 omit “they”.

Conclusion #3: P 6-1 Line 40 Omit “we refer to as” replace with “are classified as “. P 6-2 Lines 3-5 Omit “Because such wetlands occur….available literature”. In fact, rewrite lines 1 – 15. Most of this is hedge babble. Just state the facts from the literature. Omit the “we”s like “we reviewed”, etc.

6.2 DISCUSSION
General edits: P 6-2 Line 18 Omit “Our review of the literature”. This is not a progress report. The opening sentence should be declarative: “There is abundant evidence……”

General comment # 69: Connectivity is not a function. The streams and surface water systems have structure and function. The wetlands have structure and function. The hydrogeology, hydrogeomorphology, and groundwater systems have structure and function. The steams, wetlands, and hydrogeology work together resulting in connectivity. The physical nature of these systems can be characterized and documented for connectivity. The chemical nature of these systems can be characterized and documented in the context of the physical systems for connectivity. The biological nature of these systems can be characterized and documented in the context of the physical and chemical systems for connectivity. This is how the Discussion should be organized.

P 6-2 Lines 21, 22: Heat energy is not a material or mass and should be omitted here. Wood is a subset of organic matter, and should not be singled out here. Omit "heat energy" and "wood". Line 24: "river system is" should be replaced by "surface water and groundwater systems are" ; omit "but certainly not the only".

Comment #70: This entire discussion will need to be rewritten based on responses to comments and changes recommended by the Panel and other contributors to the document.

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

Charge Question 2. Comments on the clarity, technical accuracy, and usefulness of the conceptual framework describing the hydrologic elements of a watershed and the physical, chemical, and biological connections linking these elements.

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, the watershed climate factors that influence connectivity at various temporal and spatial scales (e.g. see Figure 3-1 and Table 3-1). In concept, Chapter 3 is not only useful, but along with Chapter 2, necessary for Chapters 4 and 5 to have context and meaning with regards to connectivity.

The conceptual models as presented in Chapter 3 are simplistic, inaccurate, and/or incomplete, and need to be revised/expanded to include bedrock and geomorphologic hydrogeology and groundwater systems and connections along with surface water and climatic systems. The case histories presented in Chapters 4 and 5 have good organization and information, and rely on the geologic, geomorphologic, hydrogeologic, and groundwater system knowledge that needs to be presented in Chapter 3 for completeness. As stated earlier, Chapter 2 needs to be expanded to discuss the approach and development of Conceptual Models for wetlands and watersheds to determine connectivity that includes geology, geochemistry, geomorphology, hydrogeology, hydrochemistry, and groundwater systems with surface water and biological systems. Chapter 3 needs to be restructured and greatly expanded to include the geologic, geochemical, geomorphologic, hydrogeologic, hydrochemical, and the groundwater systems to compliment the surface water systems that are presented. Chapter 3, like Chapter 2, needs to discuss the multivariate time-space relationships that are critical for understanding connectivity amongst the system variables that are discussed in some of the case histories of Chapters 4 and 5.

The following are specific comments referring to Chapter 3, and contain/reiterate the main problems with clarity and technical accuracy. In addition, Chapter 3 should be edited to remove the informal “we” and “our” as this is a technical document, and there are many edits, such as the ubiquitous usage of ambiguous pronouns that need to be removed. Finally, Chapter 3 should be edited for one style as the current draft reads like a conglomeration of vastly different styles.

3.0 EFFECTS OF STREAMS AND WETLANDS ON DOWNSTREAM WATERS: A CONCEPTUAL FRAMEWORK

3.1 INTRODUCTION

Comment #19: P 3-1 Lines 4-20: Opening paragraph: Need more references on integrated systems approach (see general comments). The introduction shows that the document starts at the circulatory system (river system) without building the skeleton or skin (geologic and geomorphologic, hydrogeologic and hydrgeomorphologic framework). References on HGM are needed.

3.2 AN INTRODUCTION TO RIVER SYSTEMS

3.2.1 River System Components

Comment #20: P 3-1 Line 25, and again in P 3-2 Line 7 Subsurface water is tied to the definition of stream. This is not how hydrologists or engineers define streams as this definition ties together the circulatory system (streams and rivers) to the lymph system (groundwater), which have two totally separate functions physically, chemically, and biologically, and are measured and quantified as separate, but related systems.

Comment #21: P 3-2 Stream Order. The entire concept of stream order is flawed for the characterization of connectivity since each tributary has a unique set of environmental variables at the headwaters, midstream, and main trunk. A hierarchical hydrologic and environmental systems analysis will show this. Stream Order was an attempt to quantify regional features in similar geologic, geomorphic, and climatic areas to gain some statistical knowledge of the distribution of flow and contaminants to a river system. Whereas this may give some regional insight, the methods fall apart under actual field scrutiny. The literature cited is old and would not stand up in legal proceedings in today’s environmental issues. Strahler’s work is a great attempt to find some regional correlations between geographic and geomorphologic stream variables, but stream connectivity analysis would be better defined using the sediment type, water and sediment chemistry, and biology, for example. We can also quantify the circulatory system (stream flows (Qs)) and lymph system (groundwater flows (Qgw)) with great sophistication.

Comment #22 P 3-4 line 28: Terraces by definition are abandoned floodplains. These can be abandoned due to climate, tectonics (locally an uplift, for example), or anthropogenic activities such as cattle grazing – not just climate.

Comment #23 P 3-6: Figure 3-3 a. This figure is confusing; draw phreatophytes next to the stream and river on figures, or use the term potential riparian or floodplain area.

Comment #24 P 3-7 Line 31 and 32: Tiner (2011) has a valid point, and most of the bedrock Rocky Mountain Wetlands are not bidirectional, and, in fact, show where groundwater is controlling the input into streams and rivers. These wetlands should not be considered bidirectional as rarely do bank overflows influence the riparian system in these situations. Again, a hydrologic and environmental systems analysis will show these relationships. The real problem is that many landscape settings for bidirectional wetlands are gradational, which make evaluation and classification problematic.

3.2.2 River System Hydrology

Comment #25: P 3-9: General discussion of saturated vrs unsaturated zone: A sentence regarding the transient nature of this boundary called the water table is needed as the temporary "saturated zone", frequently referred to as through flow or interflow in surface water analysis and modeling, is a real process that moves chemical and biological materials. In the Rocky Mountain systems, this through flow or interflow process is responsible for the hydrograph responses in rivers and streams frequently and incorrectly called "overland flow", when in reality the process of interflow is occurring through geomorphic materials.

P 3-9: Figure 3.4 is OK for gaining streams, but does not address the issue of losing streams seen in the arid and semi-arid lands of the western US, or the losing streams in karst regions located in all climates.

Comment #26: P 3-11 Line 1 and 2: The document is flawed by not considering bedrock groundwater systems and related connectivity to streams – particularly in karst and fracture flow regions, such as Missouri, S Illinois, Arkansas and Oklahoma, the Appalachian Mtns, and Florida, and in areas of regional discharge, such as the coastal plains of the east coast US under the Carolina Bays or the Ogallala aquifer discharge zones of the high plains in the central US. These bedrock systems are critical to most of the wetlands and downstream environment and processes in the corresponding regions. The diagram should be expanded to include these types of aquifer systems as well.

P 3-11 – 3-13: The document is finally providing a brief description of the lymph system (groundwater) within the circulatory system (stream and river flow) in this section. There is still minimal discussion of framework (geology and hydrogeology) or hydrogeomorphology, which is needed.

Comment # 27: 3-12 and 3-13 and 3-14 Line 2: General discussion and diagrams: Need a definition of through flow or interflow for surface water systems. Return flow means subsurface water comes back out to the river, stream, spring, or seep. Overland flow works for sidewalks, streets, Pierre shale surfaces in the badlands of South Dakota, plowed agricultural fields and denuded lands, and slick rock surfaces in the canyon lands of Utah. Through flow /interflow, not overland flow, is one of the dominant mechanisms for moving near surface water through geomorphic materials resulting in the hydrograph peak of a precipitation event in the Rocky Mountains and western US. The Rocky Mountains have a very porous hydrogeomorphology (glacial debris and deposits, mass wasting, alluvial, and even eolian deposits) to transmit this subsurface water to the wetlands and streams, for example.

Comment #28: Figure 3-7: Suggest showing at least two seasons for each cycle. Good figure.

Comment #29: Figure 3-8 needs to be labeled time or days/hours instead of October 1973. Figure 3-9 is not useful for this discussion and can be eliminated.

General comment – the discussion of water movement between floodplains and rivers/streams is generally good.

Comment # 30: Figure 3-13 on P 3-24: Draw the water table as flat to the flooded surfaces. The "dip" in the water table shown is very temporary, and the WT responds to the river level and flood level almost instantaneously in most cases. In the bottom part of the figure, the new water table should be drawn like the top part.

3.3 INFLUENCE OF STREAMS AND WETLANDS ON DOWNSTREAM WATERS

Comment #31: P3-25 Line 3 Is heat energy a "material" or a property? Line 8 fluxes to changed to "to and in the river." Line 27 minor edit For should be for.

3.3.1. Effects of Streams and Wetlands on Material Fluxes

Comment #32 P. 3-27 Line18, 19 such as the river itself???? River flow maybe?

3.3.2. Connectivity and Transport of materials to and from Streams and Wetlands

3.3.2.1. Connectivity and Isolation

Comment #33 P 3-28 Lines 10-20 Still downplaying the groundwater component. Groundwater is also the "hydraulic waterway" in connectivity.

P 3-30 Figure 3-14 is a good diagram for illustration purposes.

3.3.2.2. Spatial and Temporal Variability of Connectivity

Comment #34: P 3-32 Line 11 Rewrite as "have seasonal or event, such as short-term flash flooding, connectivity". Flooding after an event has large instantaneous, but short-duration connectivity.

3.4 FACTORS INFLUENCING CONNECTIVITY

Comment group #35: P 3-33 Line 12-14:

Probably the single biggest factor of connectivity, besides a channel, is groundwater. This should be the key factor for connectivity – whether by interflow, through flow, or saturated groundwater flow. A good hydrologic systems analysis yielding a conceptual site model will reveal the connectivity. Needs to be stated.

General comment: would not recommend the usage of the word "we" is this technical writing domain.

Line 16 and 17 Prairie potholes are not representative of most connected vrs disconnected wetlands in the western third of the United States. To generalize the factors from this case history will be subject to regionalisms that will not accurately fit other wetlands in other climatic, topographic, geologic/hydrogeologic, and geomorphologic settings.

Line 22 at all spatial scales, climate……. Should be all instead of largest. Also, amount, type and distribution of precipitation also includes snow or snowpack, annual precipitation is one measure, but events are also important for connectivity. In addition, the term "surplus" is not a hydrologic term. Suggest the water budget approach for terminology: Inputs = outputs +/- change in storage. Assume "surplus" may be an output, but specific names may be overland flow, through flow, channel flow. It is important to note each process as pathway becomes important for connectivity and transport.

Comment #36: P 3-34 Figure 3-15: Caption: Runoff can be conceived as the difference between precipitation and evapotranspiration at the watershed scale. Disagree – for a holistic approach, this does not address many significant factors, most notably the groundwater system. Simplicity is not what this document is calling for when determining connectivity. Annual runoff does not necessarily reflect the "water surplus", a term used by dam builders and water developers, but does reflect the combination of various subsystems allowing water and materials to leave that part of the hydrologic system for that time period to another subsystem (downriver, lake, ocean, etc). Note: Water input equals water "surplus"? plus or minus change in water (and materials) storage. Surface water "surplus" (surface water out) does not tell explicitly of groundwater out (water lost to the groundwater system from the surface water system), water released from or taken into storage (for example from peat), human water use (wells and diversions), etc.

Recommend that the concept of "water surplus" be eliminated from the document. The term is "surface water flow" with discharge into and out of various locations in a watershed being measured. The concept of "water surplus" is for water developers, not hydrologists or wetland specialists.

Comment #37: P 3-35. Line 8-10: This statement is inaccurate. Most of the southwest US have geomorphic materials that are highly permeable and underdeveloped with respect to clay materials, and overland flow in the natural sense is not a major factor. The occurrence of high intensity events, due to the climatic nature of the region, is prevalent, and the underdeveloped nature of stream system has difficulty in responding to these events. Through flow and interflow are quite prevalent, but difficult to measure. Debris flows and flash floods are quite common since the development of many arid, semi-arid, and sub-humid stream systems are in “fits and starts” as compared to humid systems, which are formed continuously over similar periods of time.

Comment #38: P3-36 Figure 3-16. B. Playas can be either recharge or discharge playas. This suggests one way flow only, which is misleading.

Comment #39: P 3-38: Floodplain paragraph. There is some truth to the concepts in this first paragraph. However, even the Class 3 floodplain may have higher hydraulic conductivities than underlying bedrock units (frequently shale in these environments) and the water exchange between the stream and the groundwater system is significant, although less rapid than many Class 1 and Class 2 floodplains. There may be significant differences in lateral flowpaths vrs vertical flowpaths in Class 3 floodplains, due to the alluvial structure, which affects biological and chemical processes and transformations (function). This is discussed in the 2nd paragraph.

Comment #40: 3-40 Line 4 Water “surplus” concept needs to be changed. East is not a hydrologic region that is unique. Line 7 Delete the word “East”. Climate seems to dominate the discussion, but it is only ONE variable in the equation. Line 15 Change “surplus” to surface water discharge out of the system. Line 22 Crystal River – has actually 2 flow regimes: snowpack runoff in May and June, and monsoon season in late July and August. Other years chosen will show this. Line 34 This is exactly why the geologic/hydrogeologic variables (skeleton and skin) must be addressed in this document as a separate section.

3.4.2 Spatial Distribution Patterns

Comment #41: P3-42

Drainage density and drainage pattern tell a lot about the geology, watershed hydrology and groundwater system, and ultimately is important for pathway prediction (surface water and groundwater systems). This should be included in the discussion, which is focused on water delivery distance and time (velocity, residence time) in the drainage basin. Drainage density tells of the bedrock geology (ability to erode, ability to take in groundwater from the surface water system, geologic features such as faults and fracture zones, which indicate groundwater systems features) given the climate variables and time. Drainage pattern also tells a lot about geology and various hydrostructures, and a brief discussion would be useful in this section. The connectivity story, besides residence time and pathway, needs to involve surface water and groundwater.

Comment #42 : P3-43 Lines 8-16. Why does this generalization matter? Each system will be different and should be analyzed as such. Statistical relationships for generalizations, such as distribution of distances, do not matter in a holistic evaluation of a wetland or watershed.

Comment #43: P3-43 Lines 17-31 and related figures.

This section isn't relevant to the holistic systems analysis regarding connectivity between wetlands and river network. The examples given fail to discuss that groundwater flowpath direction and distance between wetland and stream is the dominant connection of fluids, biology, and chemistry to the river network. Each system has to be evaluated separately using a hydrologic system analysis, and flow pathways determined. There are examples of close wetlands that have NO connection to the nearby stream network (eolian blowouts in the northern High and Great Plains, for example), and distant wetlands that have ABSOLUTE connection to the distant stream network (karst regions are notorious for this type of wetland hydrology). There are "climatic" wetlands (closed basin systems) in some regions (SE Nebraska historically had some of this type) that are near drainages, but had no connection (until sod busting, when the hydrologic regime changed).

3.4.3 Biota

Comment #44: Entire page.

This section seems incomplete. Biological connectivity is broader than fish, although that is an obvious example. On the physics of the system, fluids, and materials carried by the fluids, are the habitat and transport mechanisms of interest. Connectivity through the fluids (chemical, biological, physical) involves surface water and ground water origins, flow paths, and sinks. Input/output includes climate (atmospheric introductions, fluid and eolian processes) and zoological/human activities and alterations (see next section). Plants are more "passive players", seed dispersal can be eolian- or fluid-based. Using From the fluid side of the house, biological and chemical connectivity can be directly evaluated from surface water (and sediment) or groundwater processes and pathways. Summary: if the skeleton (hydrogeology), skin (geomorphological materials), circulatory and lymph systems (surface and groundwater) are understood, connectivity can be evaluated with greater certainty.

3.4.4 Human Activities and Alterations

3.4.5. Interactions Among Factors

In general, this section needs editing with regards to jargon and generalizations. Comments are in the manuscript.

Comment #45: P3-51 Line 7,8

Disagree – groundwater conditions can be predicted between wetlands if the proper analysis is completed. Hence, groundwater is probably one of the primary factors for wetland function.

General comment: A Hydrologic Systems Analysis should be conducted on this Case History region (Prairie Potholes) to rethink the Conceptual Site Model of the region. I think the case history is a good one for showing connectivity dominated by groundwater, which is a theme that is not emphasized in many areas of Section 3.

Lotic Systems: Ephemeral, Intermittent, and Perennial Streams
Charge Question 3(a). Comments on EPA 's review and characterization of the literature on the directional (downstream) connectivity and effects of ephemeral, intermittent, and perennial streams (including flow-through wetlands).

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). In concept, Chapter 4's discussion on Lotic systems is not only useful, but along with Chapters 2 and 3, necessary for the headwater streams to have context and meaning with regards to connectivity. It is recommended that three case histories be presented that represent long range studies in humid climates: Hubbard Brook (NH), Coweeta (GA) and Fraser (CO). Again, the effects and quantification of groundwater flow, particularly as related to surface water connectivity, tend to be omitted from the discussions, and need to be included (referenced) and supported by an expanded Chapter 2 and Chapter 3. Discussions on sediment need to be coordinated with the geology and sedimentology literature, which has been established long before most of the literature cited in this chapter of the Report. There are 3 types of sediment described and characterized in the geologic and hydrologic engineering literature: dissolved, suspended, and bedload (based on type of movement and size). Combining the sedimentology literature with the current literature, including contaminant transport, is recommended.

The following are specific comments referring to Chapter 4 Lotic Systems, and contain/reiterate the main problems with clarity and technical accuracy. In addition, Chapter 4 of the Report should be edited to remove the informal "we" and "our" as this is a technical document, and there are many edits, such as the ubiquitous usage of ambiguous pronouns that need to be removed. Finally, Chapter 4 should be edited for one style as the current draft reads like a conglomeration of vastly different styles.

4.1 ABSTRACT

Minor edits.

4.2 INTRODUCTION

Comment #46: P4-2: Since there is no limit on pages in this document, a true case history of the eastern US where humid conditions exist, and very dynamic stream connectivity is documented should be added. Why not Hubbard Brook (NH) or the Coweeta (GA) watershed? Or in the western US, why not the Fraser Experimental Forest (CO)? There are vast studies of these watersheds back to the 70s which must document connectivity of both wetlands and tributaries to downstream rivers.

Recommend adding these three case histories: Hubbard Brook, Coweeta, and Fraser; to the document as examples of connectivity.

4.3 PHYSICAL CONNECTIONS

4.3.1 Water

Comment #47: P 4-3 Line 14-15. Temperature (heat energy) is not a material but a property.

Comment #48: P 4-3 Line 21-23. Statements like this discourage the holistic search for truth in connectivity. Rivers receive water from multiple sources, and that should be the message of this entire document! Streams are but one source of river water, and in many cases, the tributaries rule, but why make a statement like this. Note the case history example is the northeast US where tributaries are the main variable in most cases.

General comment: As Section 4.3.1 progresses, quantification of surface water processes is introduced. A parallel discussion in groundwater flow and transport quantification needs to be included in the document.

Comment #49: P 4-6 Hydrodynamic dispersion.

Whereas the move to discuss quantification is positive in this document, dispersion is not a real watershed or even transport property, but a mathematical representation that tries to predict the behavior of fluids, chemistry, and even biology in the system. Dispersion is empirical and should be introduced as such. Kdiss in groundwater applications is entirely empirical, and not a true groundwater property. The real concept introduced in this section is that not all water molecules move down the stream system at the same time and in the same space. This is actually an advanced property of connectivity beyond the fact that streams and rivers are connected.

P 4-8 Line 15 The term transmission would be better replaced by infiltration from stream to stream beds to groundwater system. The terms “gaining and losing streams” are the surface water processes (Qin and Qout). Groundwater recharge, discharge, and change in storage are the groundwater processes. The term losses and gains need to be specifically directed to surface water or groundwater systems.

General comment on Section 4: This section could be organized around a water balance with discussion on the gains, storage changes, and losses related to connectivity of rivers and streams in various parts of the water balance equation. Or, a mass transport balance equation could be used for the chemical and biological aspects. This would orient Section 4 into a Systems way of thinking.

4.3.2. Sediment

Comment #50: P4-9 Line18 -19 Sedimentologists list three modes of transport: dissolved, suspended, and bedload; as cited in the literature and textbooks for the past 60 plus years. Important to include “dissolved” since this is a primary connectivity factor. There is quite a bit of transport modeling literature around this topic. The main variable for determining sediment in the form of stream competency and stream capacity is Qsw and sediment source availability (geology and geomorphology). Sediment (dissolved, suspended, and bedload) in some form is

always moving down the river and connectivity can be measured in the changing of these various loads. Dissolved sediment is omnipresent.
Comment #51 P 4-1 Line 1, 2 Symmetry ratio is another empirical relationship that does not address the real causes of connectivity. Recommend leaving this concept out of the discussion.

4.3.3 Wood

Good section.

4.3.4 Temperature (Heat Energy)

Good section, although this is energy, not mass.

4.4 CHEMICAL CONNECTIONS

4.4.1. Nutrients

Comment #52: P 4-19 Line 6 “under-predicted” No such term if the conceptual model is correct. This means that other processes need to be documented or investigated.
Line 14 -r 28: Nutrient Spiraling, Spiral or Helix; spiral length:

Definition of spiral: winding in a continuous and gradually widening (or tightening) curve, either around a central point on a flat plane or about an axis so as to form a cone.
This is not what the nutrients are doing spatially and the concept is misleading. The nutrients may be increasing or decreasing downstream based on a variety of other variables, but not in a spiral or helix fashion in the spatial or temporal sense. The debate as to what constitutes a “cycle” in space and time is more confusing in the holistic sense. Most of the geomorphic cycles that are written about do not exist, because rarely does a “cycle” come to completion – the process is too multivariate, multi-temporal, and multi-spatial. Thornbury’s geomorphological cycles have long been dismissed as too simplistic. Nutrient spiraling has the same problems. The real issue is how does this concept DIRECTLY relate to connectivity.

4.4.2. Dissolved and Particulate Organic Matter

Comment #53: P 4-23 Line 29 and 30. “Carbon turnover length”: This is the bottom line in that carbon turnover length is not the direct measure of connectivity, similar to hydrodynamic dispersion is not a true measure of the process of chemical movement in groundwater or surface water. These are empirical representations only, not actual measurements. Transport and mass balances are the direct measure of connectivity, besides “tagging” individual molecules.

Comment #54: P 4-24 Lines 1-15 Purpose of this section? Why are we calculating anything from the literature in this document? Much editing particularly the words “we” and “they”. Remove the calculations as this is just a literature search.

4.4.3. Ions

4.4.4. Contaminants

Given the tracer nature of these chemical species, this section is directly related to connectivity.

4.5 BIOLOGICAL CONNECTIONS

4.5.1 Invertebrates

4.5.2 Fishes

4.5.3 Genes

4.6 STREAMS SYNTHESIS AND IMPLICATIONS

Comment #55: P4-37 Table 4.1

Great Table! Add bedrock groundwater systems to alluvium on sink function. Spiraling is a description or concept, not a process. Spiraling is not applicable as a function similar to “dispersion”. P 4-38 Lag is not a function. “Storage”, which includes lag in a time sense, is the function. In hydrology literature, pertaining to water and mass balance studies, the term “change in storage” for the storage and release of water, sediments, etc. is used. Lag is a temporal term.

4.7 CASE STUDY: PRAIRIE STREAMS

4.7.1 Abstract

P 4-38 Lines 8-10. These systems have great connectivity via groundwater, which needs to be mentioned in the abstract.

4.7.2 Introduction

4.7.2.1 *Geography and Climate*

4.7.2.2 *Hydrology and Geomorphology*

4.7.2.3. *Physicochemistry*

4.7.2.4. *Ecology*

4.7.2.5 *Human Alterations* P4-44 Line 31-32 See edits. P 4-45 Line 6 “dry out completely” to “become intermittent”

4.7.3 P 4-45 Line 21 “Evidence” should be “Evidence of Connectivity”

4.7.3.1. *Physical Connections*

4.7.3.1.1. *Water*

General edits in section. P 4-46 Line 4 Storms do not fall, but have precipitation.

4.7.3.1.2. *Temperatures (Heat Energy)*

General edits P 4-48

4.7.3.1.3 *Sediment*

4.7.3.2. *Chemical Connections*

4.7.3.2.1. *Nutrients and other Chemicals*

Comment #56: P 4-49 – 4-50. Much of this nutrient discussion should be focused on farmland and reduction of the natural environment for nutrient source, transport, and storage. Line 3 P 4-50 finally gets to this point. Line 14 Nonpoint should be "nonpoint source".

4.7.3.2.2. *Dissolved and Particulate Organic Matter*

4.7.3.3. *Biological Connections*

4.7.3.3.1 *Invertebrates*

General edits in manuscript.

4.7.3.3.2. *Fish (not Fishes)*

Fish is singular and plural. Edit all "fishes" in this section P 4-54.

4.7.4. Prairie Streams: synthesis and Implications

4.8 CASE STUDY: SOUTHWESTERN INTERMITTENT AND EPHEMERAL STREAMS

Comment #57: P 4-59 – 4-60 This case history and particularly this section advocate the need for a groundwater section in Section 3.0. This Section would be critical to supporting the Synthesis and Implications Section on P 4-69 and P 4-70

4.8.1 Abstract

4.8.2 Introduction

4.8.3 Southwestern Rivers

4.8.4 San Pedro River

4.8.4.1 *Basin Characteristics*

4.8.4.2. *Ephemeral Stream Connections to and Influence on the San Pedro River*

4.8.5. Other Southwestern Rivers

4.8.5.1. *Physical Connections*

4.8.5.2. *Fish and aquatic Insects*

4.8.6. Southwester Intermittent and Ephemeral Streams: Synthesis and Implications

Lotic Systems: Ephemeral, Intermittent, and Perennial Streams

Charge Question 3(b). Comments on whether EPA 's findings and conclusions concerning the directional (downstream) connectivity and effects of ephemeral, intermittent, and perennial streams (including flow-through wetlands) are supported by the available science.

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). The following are specific comments referring to Conclusion (1) in section 1.4.1. of the Report, and contain/reiterate the main problems with clarity and technical accuracy stated in Charge Question 3(a). In addition, Conclusion (1) in section 1.4.1. of the Report should be edited to remove the informal "we" and "our" as this is a technical document, and the ubiquitous usage of ambiguous pronouns need to be removed. Finally, Conclusion (1) in section 1.4.1. of the Report should be edited for one style as the current draft reads like a conglomeration of vastly different styles.

1.4.1 Conclusion (1) : Streams

Comment #8:

P 1-6 Line 29, 30: Downstream connectivity through groundwater functions not considered. This is very important in arid, semi-arid, sub-humid hydrologic systems and needs to be stated. Line 32 Groundwater discharge to streams in the middle and lower part of watersheds also important for transport of physical, biological, chemical constituents and needs to be stated. Why the huge emphasis on nutrient spiraling? Needs to be direct connectivity, not inferred.

Comment #9:

P 1-7 Line 15-24: Regional bedrock systems sustain the majority of the southwest aquifers along with geomorphic deposits like alluvium. Many of the groundwater systems would be dried up if totally reliant on alluvial systems. Regional aquifers are important though out the US and the world. In the eastern US, the karst systems are critical to many areas. In the western US, the Pre-Cambrian bedrock systems sustain the Rocky Mountain streams equally to the snowpack scenarios that are advertized. This concept needs to be stated in the conclusions.
Why the emphasis on woody material? The major material moved is sediment of various sizes and chemistry.

Comment #10:

P 1-8 Line 5: Beneficial transformation – why not just transformation? "Beneficial" is a judgment or economic call, and should be omitted. The emphasis seems to be nutrient cycling – other examples?

Comment #11:

P 1-8 Lines 19-28: There is an overwhelming emphasis on nutrient cycling. This is a specific application for a general document. Why emphasize this in the introduction, summary, and conclusions? This is also not a direct connection, but an inferred process.

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

Charge Question 4(a). Comments on EPA 's review and characterization of 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.

Chapter 5 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. In concept, Chapter 5 Section 5.3's discussion on bidirectional Lentic systems is not only useful, but along with Chapters 2 and 3, necessary for these wetlands and open waters to have context and meaning with regards to connectivity.

Section 5.3 containes a lot of useful information, and Table 5.1 is excellent!. The following are specific comments referring to Chapter 5 Section 5.3 Bidirectional Lentic Systems, and contain/reiterate the main problems with clarity and technical accuracy. In addition, Section 5.3 of the Report should be edited to remove the informal "we" and "our" as this is a technical document, and there are many edits, such as the ubiquitous usage of ambiguous pronouns that need to be removed. Finally, Chapter 5 Section 5.3 should be edited for one style as the current draft reads like a conglomeration of vastly different styles.

5.1 Abstract

Comment #58: P 5-1 Line 4 Recommend a straight forward definition of wetland, or a series of definitions to be agreed on by everyone. References?

Comment #59: P 5-2 Line 17-18. Recommend adding " or by groundwater connections".

5.2 INTRODUCTION

Comment #60: General edit document wide as illustrated on P 5-2 Lines 27 and 31 the word "we" provide, address, etc. isn't appropriate for this document. Two questions are addressed, or definitions are discussed…etc. Line 34, 35 we limit… we provide… How benevolent. Most of this entire introduction should be edited. It reads more like a casual conversation. P 5-3 Line 9, 10, 12 We note, we can only discuss, we consider… we, we, we….Needs to be edited out of the paragraph
.
"Endpoints of interest" should be "goals" or "purpose".

5.3 RIPARIAN AND FLOODPLAIN WETLANDS

Comment #61: General edit document wide as illustrated on P 5=3 Lines 29 thru 34, P 5-5 Lines 3 thru 12, the word "we" and "our" followed by include, incorporate, judged, discussion, response, etc. isn't appropriate for this document. Eliminate the word "ample" on Line 24. P 5-6 Line 2 for example eliminate the word "indeed". Most of this entire introduction for Section 5.3

should be edited. This Section reads more like a casual conversation. Comment #62. Table 5.1 is EXCELLENT and is what this whole document should be about. References to authors and refereed papers should be part of this table. Table 5.1 should be edited to have a direct statement for each bullet on connectivity and effect on downstream waters.

5.3.1 The Physical Influence of Riparian Areas on Streams

5.3.1.1. *Hydrology*

P 5-6 and 5-7 General edits noted in the document. For example, P 5-7 Line 11 "directly taking up" would be "direct uptake".

5.3.1.2. *Geomorphology (Sediment-Vegetation Interaction)*

P 5-7 Line 18 "Infiltrate" should be "infiltration of water and deposition of sediments into". Line 21 and 26 "it" is ambiguous. P 5-8 Line 2 "against" should be "from" and Line 6 "which" should be "that" with no comma. Line 8 "take longer" is actually "require greater energy reduction". All "it" s should be removed due to ambiguity. Line 14 "are devoid of" should be "lack". The word "reported" should be "showed". Ambiguous usage of the word "they" should be replaced by specific noun.

5.3.1.3. *Temperature and Sunlight"*

P 5-8 Line 36 "highly" is an elevation term. Use the word "greatly".

P 5-9 Line 5 The expression "play a role in" is for Macbeth. The expression should be "riparian areas modify stream temperatures". Line 11 The ambiguous word "it" needs editing. Line 15 the word "their" needs editing. "Higher" should be "greater".

P 5-9 Line 25 How does shading of the stream relate to our ultimate goal of connectivity of wetlands? This paragraph is interesting, but does not relate to the goal of the document. Comment #63: Granted, shading is important to various biological functions of a stream including temperature, productivity, etc. However, this is not related to the connectivity function which is the focus of the document. Why is this discussed? Are we establishing Riparian areas that are separate from the stream, but near enough to be able to shade the stream, as our discussion point? If so, we need to make this clear. Most of the Riparian areas discussed in these papers seem to be directly connected physically with stream function.

5.3.2 The Chemical-Nutrient Influence of Riparian Areas on Streams.

5.3.2.1. Hyporheic/Soil Processing of Nutrients

Comment #64. P 5-10 Line 26-28. Statement not true. Riparian areas can affect both shallow and bedrock aquifer systems, and riparian areas are frequently the result of the bedrock ("deep") systems. "tools" should be replaced by processes on line 24.

5.3.2.2. Nitrogen

Numerous edits: 5-11. Line 9 “flow” should be travel or be transported. Removal should be Removal of nitrogen…. Additional edits on lines 10 – 12. Eliminate “indeed” in line 12. “intact”? Meaning functional or continuous? “finds its way” should be “travels”. Line 24 remove “some”. Line 31 “three-quarters” should be “75%”.

5.3.2.3. Phosphorus

Numerous edits: 5-12. Line 5 “coincidence” should be “interaction” or “combination”. Lines 10 and 11 “dictates” should be “causes”, and “drive” should be “result in”. Line 18 “generally act as” should be “are”. Line 20 “act as” should be “can be”. “Portions” should be “parts”. Line 24 “act as” should be “be”. Line 27 “if they are later” should be “when”. Line 28 Remove “them”, “desorb” should be “desorption”.

5.3.2.4. Carbon and Allochthonous Inputs

Numerous edits including: P 5-13 Line 2, 3 “low-lying flatlands” may be “low-elevation valley bottoms or plains” Lines 4, 5 “This is why” should be “As a result,”. Line 16 “For instance” should be “For example”. Instance is a time term. Line 20 Edit out “its”. Line 25, edit out “concomitantly”.

5.3.2.5. Pesticides

P 5-13 Line 34 Is “subsurface flow” referring to surface water or groundwater? Assume surface water. “Subsurface flow” is usually a term of groundwater description.
P 5-14 Line 9 “can become better at degrading” should be “function to degrade”.

5.3.2.6. Mercury

Numerous edits: Line 18 “it” replaced by “, and can” connecting the previous sentence. Line 25 “driver” replaced by “mechanism”. Line 31 Edit out “they”. Line 33, 34 “ends up” replaced by “terminates”.

5.3.3. Biological Connections Between Riparian Areas and Streams

General edits: Line 6 Eliminate “it”. Line 14 “Here, we review” eliminated. Add “are reviewed” in line 16.

5.3.3.1 Vascular Plants and Phytoplankton

General edits: P 5-15 Line 30 -32 Restructure sentence starting with “in another example,……” to “ In another example in two United Kingdom rivers, 41%......”. P 5-16 Line 21,22 Rewrite as follows: “actively consumed and dispersed by animals. For example, seeds…” Line 24 Second half of sentence confusing starting with “, which elsewhere have been observed…” what exactly has been observed? Line 32 Remove “itself”.

General comment #65: The use of pronouns like "it" and "these" should be eliminated throughout the document, and specific reference to a subject is proper. Finally, "portion" is a meal, "part" is more formal and correct (see P 5-17 Line 5).

5.3.3.2. Vertebrates

General edits: P 5-17 Line 19 "River network" should be "river". "Strong and abundant" should be removed. Does the evidence lift weights in great numbers? Line 27 "section" could be "reach". Line 33 "intrinsic" replaced by "characteristic".

P 5-18 Lines 10 – 14. Interesting information. Relevant to connectivity?

P 5-18 Line 18, 19. Eliminate ""although it would seem that" and "their", and restructure the sentence. Line 23 "their" referring to beavers or investigators? This is the problem with using pronouns. See comment #65. "They" hints at investigators. P 5-19 Line 1 and line 8: western US National Parks? Line 5: "This" is vague. Why not state the US National Parks specifically to compare climates, geology, etc….?? Please read this sentence aloud and try not to chortle and shake your head: "the removal of apex predators due to extirpation increased ungulate herbivory which altered riparian plant communities…." I think it means the killing of grizzly bears and wolves resulted in other animals eating more wetland and stream bank plants reducing plant cover resulting in stream bank erosion. Why can't we say that this way? I last sung the word "extirpation" in Mendelssohn's *Elijah,* which is probably where the word belongs.

5.3.3.3. Invertebrates

General edits: P 5-19 Line 25 "Remove "they become". Line 35, 36 "came from" replaced by "originated"

Good section!

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

Charge Question 4(b). Comments on whether EPA 's findings and conclusions concerning the directional (downstream) connectivity and effects of wetlands and certain open waters subject to non-tidal, bidirectional hydrologic flows with rivers and lakes are supported by the available science.

Conclusion (2) in section 1.4.2. of the Report Executive Summary discusses major findings and conclusions from the literature referenced in Charge Question 4(a). Conclusion (2) in section 1.4.2. is well written and contains useful information supported by the available science. The following are specific comments referring to Conclusion (2) in section 1.4.2. of the Report, and contain/reiterate a few of the main problems with clarity and technical accuracy stated in Charge Question 4(a). In addition, Conclusion (2) in section 1.4.2. of the Report should be edited to remove the informal "we" and "our" as this is a technical document, and the ubiquitous usage of ambiguous pronouns need to be removed. Finally, Conclusion (2) in section 1.4.2. of the Report should be edited for one style as the current draft reads like a conglomeration of vastly different styles.

1.4.2 Conclusion (2): Riparian/Floodplain Waters

Minor comments. See 5.5 WETLAND, SYNTHESIS AND IMPLICATIONS.

5.5 WETLANDS: SYNTHESIS AND IMPLICATIONS

5.5.1. Riparian and Floodplain Wetlands

General edits: P 5-37 Line 6 Replace "our" with "literature review". Replace "highly", which is an elevation term, with "greatly". Line 9 Add " ; and the connectivity due to groundwater systems." Line10 Does connectivity has frequency? Replace "frequency" with "amount". Line 12 Replace "—" with "," in both places.

P 5-38 Table 5-3:

General edits and comments: "highly" replaced with "greatly". Omit "so much so that". Add "Riparian areas also re-accumulate sediments at the end of a flooding event influencing stream geomorphology". What does "shade" have to do with connectivity, and why it is listed in this table as an effect of connectivity. Remove the "shade" statement from Table 5-3. Replace "through" with "from". Omit "influences its ability". Near stream vrs near field not a connectivity statement – omit.

Lentic Systems: Wetlands and Open Waters with Potential for Unidirectional Hydrologic Flows to Rivers and Lakes, Including "Geographically Isolated Wetlands"

Charge Question 5(a). Comments on EPA 's review and characterization of the literature on the directional (downstream) connectivity and effects of wetlands and certain open waters, including "geographically isolated wetlands," with potential for unidirectional hydrological flows with rivers and lakes.

Chapter 5 Section 5.4 of the 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 hydrological flows with rivers and lakes. In concept, Chapter 5 Section 5.4's discussion on unidirectional Lentic systems, which are primarily groundwater driven, is not only useful, but along with Chapters 2 and 3, necessary for these wetlands and open waters to have context and meaning with regards to connectivity.

Section 5.4 and the companion Case Histories Sections 5.6 – Section 5-9 contain a lot of useful information. However, there are some inaccuracies such as the locations of seeps, and the relations of unidirectional wetlands to groundwater systems are frequently omitted or inadequately discussed, and need to be included for connectivity. The following are specific comments referring to Chapter 5 Section 5.4 Unidirectional Lentic Systems and Sections 5-6 thru 5.9, and contain/reiterate the main problems with clarity and technical accuracy. In addition, Section 5.4 and Sections 5-6 thru 5-9 of the Report should be edited to remove the informal "we" and "our" as this is a technical document, and there are many edits, such as the ubiquitous usage of ambiguous pronouns that need to be removed. Finally, Chapter 5 Section 5.4 should be edited for one style as the current draft reads like a conglomeration of vastly different styles.

5.4 UNIDIRECTIONAL WETLANDS

5.4.1. Introduction

P 5-21 Line 16 "(also known as seeps) are located in breaks of slopes" is incorrect/inaccurate. Seeps are a small subset of slope wetlands. These are not necessarily located at the "breaks of slopes", and in fact are frequently located along stream beds where groundwater functions from bedrock systems override most stream functions. Line 22 "this type" is vague. Lines 24,25: "water inputs to bogs are generally dominated by precipitation," not necessarily true. Many bogs are dominated by groundwater flow input along the sides and underneath/beneath the bog, hence why the bog is there. Lines 29-32 "we examine" should be replaced by "downstream waters are examined". "We then briefly consider" should be replaced by "wetlands are considered".

5.4.2. The Physical Influence of Unidirectional Wetlands on Streams

P 5-22 Lines 3,4: "we give" should say "we gave at the office….." OK, should be "streamflow are given in the following sections."

5.4.2.1. Surface Water Connections

P 5-22 Line 18 "Even" should be omitted. Line 19 "them" should be omitted. Line 27 "intermontane West" should be "intermontane region of the western United States". Line 32 "latter" studies – omit "latter".

5.4.2.2. Groundwater Connections

General edits: P 5-23 Line 12 Omit "clearly". Line 20,21 Omit "of these". P 5-34 Line 30 Omit "it" and "if lacking". Line 32 Omit "it". Pesky pronouns are so vague.

5.4.2.3. Effects of Unidirectional Wetlands on Streamflow

P 5-25 Line 7 add "groundwater recharge, discharge, and change in groundwater storage". "aboveground" replace using "land surface".

Lines 7-10. This sentence starting with "Wetlands effectively store water because…" not exactly true for reasons given and the sentence should be eliminated. In the Rocky Mountains, upland areas have large talus slopes which can store vast amounts of water – more than the wetlands themselves. So the soil particles and rock do not reduce water storage volume, and their potential Specific Yield could be great. However, given other variables such as topography and hydraulic conductivity, water just passes through as through flow/interflow and is not stored. This is not a Specific Yield cause. It is the other landscape variables that allow the wetlands to store and release water including specific yield.

P 5-26 Line 14-16. Omit the sentence: "This might mean that wetlands……..saturated conditions" There are lots of other explanations for these observations. Lines 25, 26: Omit "actually", rewrite entire sentence and omit "this was the case" and "studies they surveyed". Line 34 Omit "mechanism", replace with "process". Lines 25 – 36 and P 5-27 Lines 1 – 6: This entire section is awkward and needs rewriting. P 5-27 Line 4 Replace "finding" with "observation". Line 5 "they" is vague.

5.4.3. Effects of Unidirectional Wetlands on Water Quality

General edits: P 5-27 Line 9 "can affect downstream water quality…." Connectivity is the theme. Line 13 Omit "their" as being vague. Line 22 Omit "Below we show that" Line 23 Omit "we describe how" Line 29 Omit "it" – vague. Line 30 Omit "we discuss how", add is discussed at the end of the sentence.

5.4.3.1. Unidirectional wetlands as Sources for Downstream Waters

General edits: P 5-28 Line 2 Omit "Like all wetlands". Line 29 "it" is vague. P 5-29 Line 5 "their" is vague. Line 20, 21 Restructure sentence "Further linking….".

5.4.3.2. Unidirectional wetlands as Sinks and Transformers for Downstream Waters

General edits: P 5-29 Lines 30,31. Replace “act on the large pool” with “affect”. P 5-30 Line 9 “comprised unidirectional marsh” should be “was comprised of marshes that were unidirectional wetlands”. Line 10: Here is another line for chortles: “microbially mediated denitrification enzyme activity”. Any better way to say this? Line 11: add because “these flats”. Line 15 write out “greater than”. Line 31 Omit “extensively”.

5.4.4. Biological Connections Between Unidirectional Wetlands and Streams

General edits: P 5-31 Lines 5-7 “Unidirectional wetlands, however…….” Statement is not true particularly for mountain unidirectional wetlands, which are located directly next to the streams. The second part of the sentence is also not true – connectivity is immediate and complete. Recommend modifying sentence to first half, Omit “hydrologic connectivity much less frequent, if present at all”. Lines 7, 8: “Distance.. of landscape barriers” does not make sense. “Distance overcome between water bodies, due to landscape barriers” might make more sense. Line 17 Omit “we review”, add “are reviewed” to end of sentence. Line 20 Omit “Despite being nonmobile”. P5-32 Line 26 Omit “Recent evidence suggests”.

5.4.5. Geographic Isolation of Unidirectional Wetlands

General edits: P 5-33 Lines 24, 25: Omit “we noted”. Line 32 Omit “which”. P 5-36 Line 1-13: I wonder if the investigators looked at groundwater linkages among the wetlands, particularly on coastal plain sediments, where the depressions are generally connected by groundwater systems. Line 20, 21: Add “(4) wetlands of this category may be connected by groundwater systems”. Line 22: Add “geographically “and hydrologically” isolated.”OK, I found “groundwater connectivity” in the next sentence! Line 27: Omit “it is noted that it is precisely……that” Start sentence with “This isolation is responsible…” Line 29: Is a function “supplied” Omit “that are supplied by”, add “of” Line 31 Vague “them” (omit).

5.6 CASE STUDY: OXBOW LAKES

5.6.1 Abstract

P 5-42 Line 8 rewritten as “originate as cutoff meanders of streams or rivers”. Omit “they” as ambiguous. This abstract misses the main point, so add: “and, (3) Oxbow meanders are in direct connectivity with the stream through input and output of groundwater, which sustains the levels of water in the oxbow lake. “

5.6.2 Introduction

5.6.2.1 Origin and Description

P 5-42 Lines 17 – 21. Recommend a good published definition of “oxbow lakes” from the geomorphological literature. Replace this paragraph with published definition and published process definition.

5.6.3. Evidence (of what??)

5.6.3.1 Physical Connections

General edits: P 5-43 Line 17 Omit "we focus on". P 5-44 Line 1 Omit "demonstrates this" as vague. Next sentence "when river was introduced to the lakes" is awkward. Lines 2-5. This is not necessarily a valid conclusion. If there are underground channels connecting oxbow lakes farther away from the stream, their groundwater functions will be more rapid and greater than "nearness to stream". Line 25. Omit "on one hand"; Line 26 "their" is ambiguous Omit "on the other hand". Jargon.

5.6.3.2. Chemical Connections

General edits: P 5-45 Line 15 Omit "play a more important role" Line 30 Omit "importantly". Line 31 "them" is ambiguous. Line 35 Replace "high" with "large".

5.6.3.3. Biological Connections

General edits: This section is actually quite interesting and needs to be clear to nonbiologists. P 5-46 Line 14, 15. Sentence is awkward as written. Concept is interesting. Line 18 Omit "likewise". Line 20 "Recently inundated floodplain water bodies" is exactly what? Puddles? The nearby river? Rewrite as: "Water bodies that are the result of floodplains that were recently inundated". Lines 26, 27: "within-oxbow productivity" rewrite as "oxbow lake productivity" is there a without? P 5-47 Line 25 Omit "relatively". Line 30 Omit "clearly". P 5-48 Line 8, 9: Delete "giving" "added significance". Use "illustrating". Delete "owing to " (not a bank…), replace with "due to" or "because of". Line 12 Delete "likewise".

5.6.4. Oxbow Lakes: Synthesis and Implication.

Comment # 67: One of the most major connections between the oxbow lake and the river is the groundwater system. Add:

- Evidence indicates the presence of physical, chemical, and biological connections between oxbow lakes and the river channel site by the groundwater system.

5.7 CASE STUDY: CAROLINA AND DELMARVA BAYS

General comment: This case study is very well written and informative!

5.7.1. Abstract

5.7.2 Introduction

5.7.2.1 Definition and Geographic Extent

General edits: P 5-49 Line 29 “They” is vague.

5.7.2.2. Geology

So, what is the geology of these areas? This was a soil description. Is it karst? Is it eolian sand dunes? This is critical to understanding the connectivity of the study area!

5.7.2.3. Hydrology

5.7.2.4. Water Chemistry

5.7.2.5. Biological Communities

5.7.3 Evidence of Connectivity

5.7.3.1. Physical Connections

General edits: P 5-53 Line 32 Replace “active “ with “ongoing” Recommend eliminating Lines 32 -34. Paragraph not needed. P 5-54 Line 1: Replace “found” with “revealed”. Line 11: Replace “ran from” (transects do not have running shoes….) with “were located”. Replace “local groundwater strongly influenced” with “ bays region was indicated by the bay water levels”. Line 16 omit “more than”. “Line 18: Change ”surface-groundwater connections” to “surface water-groundwater connections”. Line 24: Change “inferred” to “specified” since this is a model. P 5-55 Line 9: Omit “perhaps”.

5.7.3.2. Chemical Connections

P 5-55 Line 16: Omit “one”.

5.7.3.3. Biological Connections

General edits: P 5-55. Line 33 “hotspots” a legitimate term? P 5-56 Line 1, 2: Eliminate sentence. Line 28: Replace “extremely high” with “substantial”.

5.7.4. Carolina and Delmarva Bays: Synthesis and Implications

P 5-57 Line 1: Conclusion number 1: “groundwater inputs and outputs that foster connectivity to surrounding surface water and groundwater systems”. Lines 14 – 20: Eliminate paragraph “Although generally……at this time”.

5.8 CASE STUDY: PRAIRIE POTHOLES

5.8.1. Abstract

General edits: P 5-57 Line 26 “they” is ambiguous. Line 27: Omit “in terms of”. Line 28: Omit “themselves”. Line 31 Omit “entire”. Line 33: Omit “their”. P 5-58 Line 3. Omit “they”.
5.8.2 Introduction

General edits: P 5-58 Line 9: Write out PPR since it is the first time used in the document. Replace “by” with “during”. Line 11: Omit “widely”.

5.8.2.1. Hydrologic Dynamics

General Comment #68: Each of these case histories could use a cross-sectional diagram illustrating the hydrology and connectivity of the features and region. It is difficult for most readers to visualize these descriptions of structure and function.

General edits: P 5-59 Lines 15 – 16: Replace “>” with “greater than” and “<” with “less than”. Line 6: Replace “today” with “currently”.

5.8.2.2 Chemical Functions

P 5-60 Line 16 Replace “takes place” with “occurs”.

5.8.2.3. Ecological Characteristics

P 5-60 Line 20 Replace “high” with “large”. Line 28 Replace “disrupting” with “altering”. Line 30: “their role” with “function”. Omit “Perhaps”.

5.8.3. Evidence

5.8.3.1. Physical Connections

General edits: P 5-61 Line 11: Replace “via” with “by”. Line 14: Rewrite sentence and remove “puts”, use “estimates”. Line 18 Replace “hold” with “stores”. Line 34 Replace “weaker with “small”. P 5-62 Line 6: Omit “discussed previously”. Line 9: Omit “yet”. Line 19, 20 Replace “high” with “large”, “via” with “by”. Line 23, 24 Omit “all else being equal”. Lines 33, 35 Replace “via” with “by”. In general, replace all “via”s with “by”s like P 5-63 Lines 5, 8.

5.8.3.2. Chemical Connections

P 5-63 Line 27 Omit “their”. Line 30 Omit “they”. Line 33 Omit “itself”. P 5-64 Omit “they” as ambiguous. Line 4: Omit “On the other hand” as jargon. Change “periodically hydrologically connected” to “connected periodically by hydrology”. Line 11 Change “found” to “observed”. Line 19: Replace “The most fruitful” with “A”.

5.8.3.3 Biological Connections

General edits: P 5-64 Line 25 Omit “they must”. Line 35: Change “found” to “observed”. P 5-65 Line 2. Replace “;” with “.” Start new sentence with “Because….” Line 13: Change “manmade” to “anthropogenic”. Line 22: “<” written out as “Less than”, “they” is ambiguous. P 5-66 Line 2: Omit “severely”. It is either limited, or it is not!

5.8.4. Prairie Potholes: Synthesis and Implications

P 5-66 Line 24: Add the following conclusion:

- Potholes exhibit connectivity by groundwater systems.

Isn’t this the purpose of this document???

Line 31: Omit “highly”.

5.9 CASE STUDY: VERNAL POOLS

General comment: This is a very interesting case history!

5.9.1. Abstract

P 5-66 Line36: Change “dry down” to “become dry”. Line 37: Change “findings” to “observations”. P 5-67 Line 4, 5: Move “opportunistically” from line 4 to line 5 after “vernal pools”. Line 6: Is “stepping-stone” a formal term?

5.9.2. Introduction

5.9.2.1. Geography and Geology

5.9.2.1.1. Western vernal pools

P 5-67 Line 27: Replace “go by” with “have”.

5.9.2.1.2. Northern vernal pools

P 5-68 Line 12: Omit “profoundly”.

5.9.2.2.. Temporal Dynamics

P 5-69 Line18: Replace “dry down” with “become dry”.

5.9.2.3. Ecology

P 5-69 Line 26: Replace “plays an important role” with “functions as”. Line 29: Replace “Despite” with “Given”. Line 30: Ambiguous “they”.

5.9.3. Evidence

5.9.3.1. Physical Connections

P 5-70 Line 6: Replace "precipitation fed" with "Vernal pools receive water primarily by precipitation, and …..". Line 7: Omit "they" as ambiguous.

5.9.3.1.1. Western vernal pools

P 5-70 Lines 18, 19: Replace "–"with ",". Line 24: "connected by swale to a seasonal stream" what does that mean? Not clear as written. Line 25: Replace "via" with "by". Line 30: "Horizontal subsurface flows" Is this "through flow" or "interflow", if so replaces original statement. Line 32: What does "discharging from the swale to the seasonal stream" mean? This is not clear. P 5-71 Line 12: What does "stepping-stone spillage" mean? This is not clear.

5.9.3.1.2. Northern vernal pools

P 5-71 Line 23: I would wager that consultants have worked with these ponds. P 5-72 Line 2 Omit "he". Line 5: If "classic", which model? So state. Line 10: Omit "Individually".

5.9.3.2. Biological Connections

P 5-72 Line 19: "it" is ambiguous. Line 26: Omit or change "highly". Line 28: Omit "tightly". P 5-73 Line 9: "vectors" proper for "transport agents"?

5.9.4. Vernal pools: Synthesis and Implications

P 5-74 Line 2: Change "via" to "by". Line 6: Move "opportunistically" to "vernal pools opportunistically". Line 11: Ambiguous "they".

Lentic Systems: Wetlands and Open Waters with Potential for Unidirectional Hydrologic Flows to Rivers and Lakes, Including "Geographically Isolated Wetlands"

Charge Question 5(b). Comments on whether EPA 's findings and conclusions concerning directional (downstream) connectivity and effects of wetlands and certain open waters, including "geographically isolated wetlands," with potential for unidirectional hydrological flows with rivers and lakes are supported by the available science.

Conclusion (3) in section 1.4.3. of the Report Executive Summary and Section 5.5 WETLANDS: SYNTHESIS AND IMPLICATIONS discusses major findings and conclusions from the literature referenced in Charge Question 5(a). Conclusion (3) in section 1.4.3. and Section 5.5 WETLANDS: SYNTHESIS AND IMPLICATIONS contains useful information supported by the available science. However, Conclusion (3) in section 1.4.3. and Section 5.5 WETLANDS: SYNTHESIS AND IMPLICATIONS need a complete rewrite and reorganization to recognize the systematic approach to determine the structure and function of unidirectional wetlands, or how to conceptualize the wetland hydrology in the supporting case histories discussed in Chapter 5 Sections 5-6 thru 5-9. This is not new science for hydrogeologists, surface water and groundwater hydrologists, who have the tools and conceptual models to determine qualitatively and quantitatively the connectivity of both surface and subsurface hydrological systems to unidirectional wetlands. Most of these types of wetlands exist spatially and temporally because of the geology, geomorphology, hydrogeology, and groundwater systems caused by these three aspects of the landscape. Conclusion (3) in section 1.4.3. and Section 5.5 WETLANDS: SYNTHESIS AND IMPLICATIONS should be rewritten with the rewritten Chapter 2 and Chapter 3 as context.

The following are specific comments referring to Conclusion (3) in section 1.4.3. and Section 5.5 WETLANDS: SYNTHESIS AND IMPLICATIONS of the Report, and sections and contain/reiterate a few of the main problems with clarity and technical accuracy stated in Charge Question 5(a). In addition, Conclusion (3) in section 1.4.3. and Section 5.5 WETLANDS: SYNTHESIS AND IMPLICATIONS of the Report should be edited to remove the informal "we" and "our" as this is a technical document, and the ubiquitous usage of ambiguous pronouns need to be removed. Finally, Conclusion (3) in section 1.4.3. and Section 5.5 WETLANDS: SYNTHESIS AND IMPLICATIONS of the Report should be edited for one style as the current draft reads like a conglomeration of vastly different styles.

1.4.3 Conclusion (3); Unidirectional Wetlands

Comment #12: P 1-10 Line 29: Retention of sediments should be mentioned. Many of these wetlands are groundwater driven, particularly in the arid, semi-arid, subhumid systems of the western US. Many of these wetlands have a downstream exit to the surface hydrologic system, and are an important water source (flow) with specific water chemistry and water biology at the wetland source, and wetland exit. Most of the sediment is derived from non-channel sources (mass wasting processes or overland flow, for example).

Comment #13: P 1-11 Line 30: Unidirectional wetlands can also serve as a source for pollutants as well. The groundwater quality of the groundwater discharge determines the chemistry in many cases. The bedrock system, including both natural and altered hydrogeochemistry is an important variable.

Comment #14: P 1-12 Lines 12 – 33: Conclusions d, e. Conclusion d is close to the truth. Conclusion e needs to state clearly the importance of hydrologic systems analysis and a conceptual model for determining connectivity. Most of these unidirectional wetlands are connected in some way to the larger system. There are some exceptions, such as the Nebraska potholes, that these depression wetlands once were the termination of the hydrologic system. Some of the Nevada playa lakes similarly function in this manner.

5.5 WETLANDS: SYNTHESIS AND IMPLICATIONS

5.5.2. Unidirectional Wetlands

P 5-37 Line 20 "flats" is a formal classification of wetlands? Line 21 "These" is vague. Line 25 Omit "we examined". Lines 27 – 30: Omit sentences with "The problem, then…..explicitly" since conversational and not needed. Lines 31-35 Omit all sentences as this is not necessarily true or meaningful. P 5-38 Line 1 Take sentence beginning with "the purpose of this review….." and attach to P 5-37 Line 27 as second sentence.

P 5-39 Table 5-4 Comments and edits:

Omit "truly"; Omit "can also play a role"; "recharge" should be "recharge and discharge"; "over various time frames" should be "spatially and temporally"; Omit "Insofar as they often act as"; add to "nutrient delivery and water quality "of downstream waters""; "vectors" can have many meanings – assume "show the direction of"; Omit "their" as ambiguous.

General edits continued: P 5-40 Line 7 Omit "our" and "we conclude"; Line 10 Omit "which"; Line 11 Omit "they" as ambiguous. Line 13,14 Omit "our overall conclusions". Line 19 Do wetlands "spill"? Replace "spill" with "that have outlets". Line 21 Omit "it" as ambiguous. Line 24 Omit "they" as ambiguous. Line 30, 31 Omit "we", replace "-" with ","s. Line 35 Omit "does not tell us". P 5-40 and 5-41 need to be completely rewritten.

General Comment #66: Section 5.5 WETLANDS: SYNTHESIS AND APPLICATION: This section needs a complete rewrite and reorganization. This is an important section, and it is apparent that the section as written does not recognize the systematic approach to determine the structure and function of unidirectional wetlands, or how to conceptualize the wetland hydrology in these cases. This is not new science for hydrogeologists, surface water and groundwater hydrologists, who have the tools and conceptual models to determine the connectivity of both surface and subsurface hydrological systems to unidirectional wetlands. Most of these types of wetlands exist spatially and temporally because of the geology, geomorphology, hydrogeology, and hydrologic systems caused by these three aspects of the landscape. This section should be written with these systems as the foundation.

Other provided references (copyright protected materials not provided)

American Society for Testing and Materials. 1996. Standard Guide for Conceptualization and Characterization of Ground-Water Systems. Designation: D 5979-96 (Reapproved 2002). ASTM International, West Conshohocken, PA.

Kolm, K.E., van der Heijde, P.K.M., Downey, J.S., and Gutentag, E.D.. 1996. Conceptualization and Characterization of Ground-Water Systems, In: Subsurface Fluid-Flow (Ground-Water and Vadose Zone) Modeling, ASTM STP 1288, Joseph D. Ritchey and James O. Rumbaugh, Eds., American Society for Testing and Materials, 1996.

Available at:

http://books.google.com/books?hl=en&lr=&id=hF_PhPxIDIwC&oi=fnd&pg=PA60&dq=conceptualization+and+characterization+of+groundwater+flow+systems&ots=7VfPH_-dEp&sig=7qumo5lmnxeXD11CLoxCOhMIP9g#v=onepage&q=conceptualization%20and%20characterization%20of%20groundwater%20flow%20systems&f=false

Dr. Judith Meyer

Preliminary Comments from Judy Meyer

Charge question 1

This is an extensive and thorough review of the peer-reviewed scientific literature that is relevant to the assessment of the connection between small streams and wetlands and downstream waters. It is well organized and clearly presented. Although I have provided numerous specific comments below, my overall impression is that the review accurately presents and interprets the scientific literature on this topic.

Comments on Executive Summary (Chapter 1)

1-5, 25: The effects of nutrient spiraling are not necessarily "beneficial" to downstream ecosystems. Depending on circumstances, nutrient removal in the headwaters could reduce nutrient availability in downstream ecosystems, rendering them less productive. I would just remove the normative term "beneficial." 1-8, 5 and 6: same comment on "beneficial." The sentence could be written to provide an example of where the transformation would be beneficial (e.g., with large inputs of nutrients, reducing eutrophication in downstream waters), but all transformations are not necessarily beneficial to downstream waters.

Figure ES1 calls unidirectional landscapes geographically isolated wetlands. It would be more useful if the labels in that figure were consistent with the terminology used in the text of the report.

1-11, 27: "low" precipitation is pretty vague – can you provide a value – e.g. < x cm/yr? similarly "low" stream density is vague. What does "low" mean?

1-14, 22 and 24: I question the use of the term "might." "is likely to" is a more accurate descriptor. The concept of the cumulative or aggregate effect is crucial to get across in this document.

Charge question 2

Chapter 3 adequately and accurately conveys the complexity of water flow in river systems and the connectivity between surface and subsurface waters. Identifying the five types of functions by which streams and wetlands impact downstream waters is a useful way to categorize and convey these impacts.

The discussion of stream order needs to address the issue of map scale. Using maps of different scale results in assigning very different stream orders to a reach. This is addressed in other parts of the review, but it is important that it be included in this initial discussion of stream order. It is critical that readers of this document understand the problem of the failure of many databases to include small streams and the magnitude of the problem. In a North Carolina watershed 0.8 km of stream channel are shown on a 1:500,000 scale map whereas 56 km of stream channel are shown on a 1:7200 scale map; only 21% of stream channel length is shown on a 1:24000 scale map in another watershed (Meyer and Wallace 2001, already included in the review). Figures like this shown the magnitude of the problem.

Documenting the impact of an individual ephemeral, intermittent or headwater stream on a large river is a daunting task; yet the cumulative or aggregate effect of these water bodies has been clearly demonstrated in the scientific literature. The importance of evaluating connectivity by considering the cumulative or aggregate effect of ephemeral, intermittent and headwater streams on larger rivers is mentioned in this chapter (e.g., 3-27, 20-27), but it deserves its own section. The concept of cumulative/aggregate input is extremely important and should be given treatment in a separate section rather than scattered about as it is. The significance of the connection between small streams and large rivers hinges on cumulative effect, so it should be addressed clearly and in one place and that discussion carried over to the Executive Summary and to the conclusions (Chapter 6). Cumulative or aggregate impact is part of the conceptual basis for this document and needs to be more clearly articulated. It is an important aspect of the context needed to interpret the information presented in later chapters.

Specific Comments on Chapter 3

3-1, 29: why the statement that impermeable stream bottoms are not included? The LA River is bounded in cement, but still a river.

3-1, 32: The up and down gradient sections may be connected although not necessarily through a surface connection, so it is unclear why the word “surface” is included in this sentence.

Figure 3-1: Perhaps link magnitude could be included in this figure as well.

Figure 3-2: Include a description of what the grey area is showing (i.e. floodplain).

3-10, 3: formations ARE divided

3-10, 31-36: The difference between Payne and Woessner vs. Winter definitions is not clear. Is it just that Winter lumps all together whereas the other subdivides them by rate of flow?

3-12, 14: It sounds as though intermediate groundwater flow system is a separate category and should be printed in bold at first mention. Perhaps this sentence belongs later in the paragraph.

3-16, 24: Figure 3-9 C shows a very different percentage of headwater stream length across geographic regions and climates. The sentence should either say that or say the percentage is similar WITHIN geographic regions and climates. It is not correct as written.

Figure 3-12 would be improved by further explanation in the legend. How did weather conditions vary on the two dates? What is the reader supposed to notice in the two figures? Very little is said about this figure in the text so some additional explanation in the figure legend is definitely needed.

Table 3-1: The arrows are somewhat misleading, e.g. in the fish example for a sink, the flow is from the river to the sink. I realize that the footnotes say the arrows are illustrative and don't represent flow directions, but they are confusing. It would be clearer if the term "river" were not included as part of the figure; the figure is showing magnitude of input vs output and that would be more clearly shown if the term river were not included.

3-28, 6-10: The distinction between the two concepts of connectivity is not clear. Further elaboration is necessary to make this point.

3-29, 30-32: Benthic bacteria do not consume FPOM. They consume DOM and convert it to FPOM. Many benthic invertebrates consume FPOM. This sentence has to be corrected as it is WRONG.

3-31, 3: Recognize that this estimate is probably an underestimate given the scale of maps upon which this assessment is based.

Figure 3-17: The distinction between permeable and impermeable soil is not clear – color differences not great enough.

3-43. 23: representative of what?

3-50, 22-25: The Hammersmark et al. example doesn't fit with the topic sentence. How does this represent an adverse effect on downstream waters?

Charge question 3 a

Chapter 4 includes the most relevant scientific literature, which has been accurately characterized. Although I have made suggestions below, my overall impression is positive.

Charge question 3b

The conclusions presented in section 1.4.1 are supported by the literature reviewed in Chapter 4.

Specific comments on Chapter 4

4-9, 10: transmitted sediment is also essential for maintaining downstream beaches and tidal wetlands.

4-13, 2: is this sediment accumulation or wood accumulation rate?

4-16, 26: map scale for these first order streams should be noted in parentheses. A footnote noting the limitations of the data set used, as on p. 4-61 would be useful.

4-17, 8-10: This sentence is not particularly informative. So what if they modeled it? What did the models show? If the study is going to be cited, the reader needs to be told more about it.

4-18, 3: Again, include map scale for this in parentheses. A footnote noting the limitations of the data set used, as on p. 4-61 would be useful.

4-20, 4: Include the phosphorus numbers in this as well since three forms are mentioned in the sentence.

4-20, 12: I question "much in their original form." That certainly is not the case for P.

4-20, 17: downstream effects of what – impaired cycling? This implies greater downstream effects when cycling is impaired, and that doesn't make much sense.

4-20, 18: The major function of spiraling is to deliver transformed nutrients downstream. The examples that follow that statement show transformed nutrients not nutrients that have been regenerated in the same form in which they entered the stream.

4-22, 24-26: Benthic leaf litter is not only a source of FPOM; it is also a significant source of DOC. Leaves in the streambed leach DOC, which is easily transported to downstream reaches. For example, benthic leaf litter provided 30 % of daily exports of DOC in a S Appalachian headwater stream (Meyer et al. 1998. *Ecosystems* 1: 240-249).

4-23 – A study on the Ogeechee River in Georgia is worth considering here or perhaps more appropriately in the chapter on bidirectional wetlands. We looked at metabolism and turnover length along that river continuum from second to sixth order reaches in a system with extensive floodplains. Metabolism becomes increasingly dependent on allochthonous C sources with increasing stream order (because of floodplain contributions); first through third order streams represent 32% of the channel area of the sixth order basin, but only 9% of basin wide community respiration occurs in them. Although higher order streams have longer turnover lengths and are less efficient in organic C processing, they are responsible for most of the metabolic activity in this river basin because of the importance of exchanges with the floodplain (Meyer and Edwards. 1990. Ecosystem metabolism and turnover of organic carbon along a blackwater river continuum. *Ecology* 71: 668-677.)

4-24, 1-15: I question the value of these calculations. Too many assumptions are made, and the number calculated is an average value with little meaning. For example, the proportion of carbon from allochthonous sources is hugely variable across the country, so assuming a single number makes little sense.

4-26, 24-33: The contribution of this study is very unclear. The paragraph is written as though the reader has read the paper. What is the point that the reader is supposed to be getting from this paper?

4-27: The discussion of transport from headwaters and impact of metals on downstream systems could be bolstered by literature on mercury contamination in the Sacramento-San Joaquin Delta and San Francisco Bay foodwebs. Methyl mercury contamination of those foodwebs is the result of gold mining in the Sierras a century ago; yet we see the problem today in mercury contamination. This provides a good example of long distance and long time frame transport of contaminants. There are many papers on this topic; here is one: Gehrke et al. 2011. Sources of mercury to San Francisco Bay surface sediment as revealed by mercury stable isotopes. *Geochimica et Cosmochimica Acta* 75: 691-705.

4-31, 27: predictors of what measure of fish assemblage structure?

The title of 4.7.3 is strange – evidence of what? Evidence of connectivity would be a better title.

4-46, 24: Clarify that this is referring to the 1965 flood.

4-50, 14: rephrase "non-point land uses"

4-56, 8: Note scale of NHD, i.e. this is clearly an underestimate of the percent of intermittent streams. Could refer to Figure 4-8 where this is clearly articulated. Or use footnote as did well on 4-61.

4-57, 17: a parenthetical explanation of basin and range (i.e. states included) would help the non-geologist reader. Also Basin and Range is capitalized elsewhere.

4-67, 23: a footnote like that on 4-61 would be appropriate here.

Charge question 4 a

I provide a couple suggestions in my specific comments on Chapter 5 (below) on papers that could be included, but overall this is a thorough review of the relevant literature, correctly summarized.

Charge question 4b

The conclusions presented in section 1.4.2 are supported by the literature reviewed in Chapter 5.

Charge questions 5 a and b

I am less familiar with the literature on unidirectional wetlands, so will not comment on the thoroughness of this literature review. The conclusions presented in section 1.4.3 are supported by the literature reviewed in Chapter 5.

Specific comments on Chapter 5

5-8, 24-32: Trees falling in from the floodplain banks are a significant contribution of wood to the Ogeechee River, Georgia, and this wood provides the habitat for the highest macroinvertebrate productivity in the river (Wallace and Benke. 1984. Quantification of wood habitat in subtropical Coastal Plain streams. *Canadian Journal of Fisheries and Aquatic Sciences* 41: 1643-1652.)

5-9, 1: do you mean groundwater and riparian soil <u>temperature</u>?

5-11, 2-3: The importance of DOC coming from riparian leaf litter was clearly shown in the litter exclusion study (Meyer et al. 1998, cited above).

5-14, 17: also residual mercury from earlier eras, e.g. gold mining in the Sierras (see comment above about 4-27).

5-13, 25: This statement is not true in river systems with extensive floodplains like the Ogeechee River. In addition to the metabolism study cited above (Meyer and Edwards 1990) showing the increasing importance of allochthonous inputs from floodplains to metabolism in higher order streams, floodplains are also significant sources of bacteria (see Wainwright et al. 1992. Fluxes of bacteria and organic matter into a blackwater river from river sediments and floodplain soils. *Freshwater Biology* 28: 37-48.) to foodwebs in the river.

Glossary

The glossary is very useful. Sodium adsorption ratio (4-26, 28) needs to be defined in it.

Dr. Mark Murphy

TECHNICAL CHARGE QUESTIONS - - M.T. Murphy

1.) Overall Clarity and Technical Accuracy of the Draft Report

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.

I have confined my response to Charge Question 1 to general comments, without numerous citations. The studies that I feel would improve the report are cited in the answers to Charge Questions 2 to 5.

Overall, I was highly impressed with the quality of the report. I think that the organization and general writing contributed to a clear understanding of the state of the science and establishes the argument for the importance and need for this effort. The integration of water quality management and protection undoubtedly benefits from a watershed approach and this conclusion has been reached by numerous federal and academic policy researchers (see NRC 2009 for a good summary). Just as clearly, this integration needs to include agreement among public and private land managers on a consistent approach to long-term planning and conservation of watersheds.

The report leaves no doubt that the potential exists for a 'significant nexus' between long-lived tributaries and navigable waters at all scales in a functional watershed. Watersheds physically structure the movement of water and advectively deliver energy/momentum, chemical components, microbial and higher biota, and genetic material to downstream waters. In addition, the aquatic and riparian habitat creates migratory movement of vertebrate life and connectivity of both species and populations - - in effect, a web of habitat. In short, healthy downstream rivers depend fundamentally on healthy watersheds (Bennett 2003).
The conceptual model developed in this report has excellent scientific support as a description of the potential, even the probable, connectivity within a watershed. My main disappointment is that the significance of the potential connectivity that it so carefully describes is not given equal weight. This shortcoming limits the strength of the report and its suitability as the foundation to a rule on jurisdictional waters.

Significance has a fundamental meaning in science, being the measure of the plausibility of a hypothesized cause-and-effect couple. This is usually assessed through a series of statistical tests that attempt to demonstrate the unreasonableness of the null hypothesis, i.e. that the causal connection is highly unlikely. Significance in ecology also carries a temporal component in addition to a spatial component. The cause/effect couple must occur within a time scale that is reasonable for the transport processes of the watershed. I found many of the time-scale assumptions in the paper unstated or vague.

The arguments made in this report lean heavily upon a deterministic conceptualization of streamflow. For unregulated, perennial streams at flows less than bankfull, continuous and smoothly varied transport mechanisms are often a good approximation. This is the basis of the River Continuum principle (Vannote, et al 1980) For rainfall limited streams (ephemeral, intermittent or interrupted), streams controlled by externalities (e.g., human regulation or flood events), connectivity becomes discontinuous (Montgomery 1999, Ward and Stanford 1989, 2006) and cause and effect are best modeled in a discontinuous or probabilistic fashion.

Much of environmental science already relies on the idea that a significant causal connection is best idealized probabilistically. The exposure analysis paradigm from ecological risk assessments is that exposure is defined by a probability of contaminant (or trophic element) being transported along a physics-based pathway from a potential source to a target organism or population; this is a mature rationalization of exposure to harm (NRC 1983). The exposure analysis paradigm might offer a better methodology to quantify ecological significance within specific time and space scales. Adoption of the scientific basis of ecological risk assessments (Norton, 1992; Barnthouse, 1994; Pastorok et al., 2003; Suter, 2008), probabilistic hydrology (Beven 1993) and ecotoxicity, would greatly improve this study. Further discussion of the exposure analysis paradigm can be found in the response to Charge Question 5a.

And one final general comment - - the study is very sparse in the discussion of the connectivity of avian habitat. The migratory use of both flowing and still aquatic environments by waterfowl seems well covered; however, the use of both riparian and upland wetlands and floodplains by terrestrial birds is also an important source of connection among potential waters of the US. I cite specific studies in Sections 3a, 4a and 5a, but, in general, a number of studies suggest that the fluvial structure is an important qualification for transitory riparian habitat for migratory songbirds and many endangered birds. For example, Arriana Brand and co-workers (2011, 2013) demonstrate in both the Rio Grande and San Pedro River how the fluvial complexity of the riparian corridor provides necessary habitat that supports the entire river basin.

Avian connectivity also supports the movement of biochemical components, including genetic diversity, nutrients and microbial life. Higher than expected levels of E. coli bacteria are found in some watersheds and genetic tracing of the micro-organisms suggests that bird feces are the vector (Edge and Hill, 2007; Wright et al., 2009).

With all this in mind, the watershed basis for the definition of connectivity, as previously stated, is clearly supported by the existing text and the support for this opinion is extensive. This clearly implies that events significantly affecting the chemical, physical, and biological integrity of these headwaters could impact downstream navigable waters. I believe that the report makes an excellent start towards defining the nature of connectivity; however, in order to effectively support protection, the argument needs to extend beyond the potential for impact to the probability of harm.

2.) <u>Section 3 - Conceptual Framework: An Integrated, Systems Perspective of Watershed Structure and Function</u>

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.

This section provides a good basis for understanding the general nature of watershed function. The primary emphasis seems to be establishing the basic gravitational basis of water movement, as attenuated by landform modification, seepage and other dissipative processes. There are several ideas, mentioned in the response to Charge Question 1, that have a direct impact on the conceptual basis of subsequent chapters.

I was confused by the ambivalent way that time scales are evaluated in Section 3. In several parts of the discussion, connectivity seems to be fixed in time, at least relative to stream flow; however, in Section 3.3.2.2 there is an excellent discussion of flood-pulse expansion of stream networks. Despite this, I did not get a clear picture of the time scales most relevant to the author's arguments.

A more extensive discussion of hydrologic disturbance as an ecological control on habitat connectivity would be helpful, using, for example, the work of Fisher et al. (1982), Niemi et al. (1990), Sedell et al. (1990), Lytle and Poff (2004) and Stromberg (2007). Particularly useful would be a conceptual methodology for distinguishing human-initiated, long-term disturbance, which is often extirpating, from natural catastrophes and periodic events. This is a spot where the use of the exposure analysis paradigm (see Response 1) could provide a better defined spatial and temporal time scale for disturbance. It is important to evaluate how disconnection in highly regulated rivers can disrupt the existing biotic communities (Sedell et al., 1990).

Many of these issues converge in the list of connective processes and material fluxes outlined in Table 3-1 and referenced throughout the report. The terms, *source, sink, refuge, lag and transformation,* as defined by the report, imply that some sort of scaling factor, a Δx or Δt is used to assure that the processes are comparable to the flux terms (Maher 2011). For example, a sink is ecologically meaningless if it isolates pollutants on a time scale that is significantly shorter than the critical exposure time of an organism. This fundamental issue was not clearly discussed in the text. There was occasional use of words, 'often,' 'commonly,' 'rarely' and even, 'frequently;' however, there was little explanation of what these words mean in context.

In other places, spatially -dependent words are used that may have meaning in a regulatory sense but are not well grounded in science. For example, the use of the phrase 'geographically isolated wetlands' is not conceptually helpful, particularly when the document glossary admits that the phrase implies no hydrologic or biological isolation. While geography is a science, there is little meaning to geographic isolation in this usage, as has been pointed out by several authors (Tiner, 2003; Leibowitz, 2003). There is clear scientific meaning to 'interior drainage' as a hydrological concept and a classic example are the playa lakes of the Basin and Range Province (Lichvar et al., 2006; French et al., 2006). Playa lakes only discharge during very rare rainfall events with infinitesimal probability.

This is not semantic pedantry in that one can calculate and predict the weather conditions leading to discharge by predicting the runoff rates as a function of increasingly rare occurrence probability (return period). Thus, a particular basin can be evaluated as hydrologically open or closed if a probability of occurrence can be calculated. I was disappointed by Section 3.4.1; in that, the title seemed to promise some consideration of 'Climate-Watershed Characteristics' but on page 3-35 seemed to drift off in another direction.

I was hoping for a discussion of how rainfall estimates are used to predict runoff. The location and amount of rainfall, particularly geographically discontinuous, convective storms that prevail in summer cannot, and probably never will, be predicted by any deterministic model. In addition, the abstraction of rainfall to interception, evaporation and infiltration is difficult to generalize. When these factors conspire it becomes very difficult to generalize rainfall/runoff processes. I had hoped that the discussion would tackle these problems as they impact where, when and how much runoff is produced in a watershed.

The publications of RH Hawkins of the University of Arizona discuss of the hydrologically singular nature of rainfall/runoff processes (Hawkins, 1978; Hawkins et al, 1985; Hawkins and Cundy, 1987; Hawkins 1993; Woodward et al, 2004 and many others). Despite these inherent difficulties, the probabilistic prediction of runoff is a mature science; probabilistic rainfall/runoff models (for example, HEC-HMS), also have usefully informed ecological impact investigations (Poff et al 2010). In point of fact, the hydrologically derived pathways are often the best characterized risks because of the robust nature of the field of probabilistic hydrology.

In summary, although I thought that the conceptual model was both clear and scientifically correct in outlining the importance and potential for connectivity in a watershed. Despite this, without a better discussion of the conceptual basis of ecological significance, the usefulness of the model and subsequent applications is unnecessarily constrained. I wanted to see more acknowledgement of the probabilistic basis of rainfall/runoff processes. The time scales and likelihood of transport processes need to be better defined and integrated into the conceptual model.

3.) Section 4 - Lotic Systems: Ephemeral, Intermittent, and Perennial Streams

3a.) 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.

Note typo at line 3, page 4-67, replace 'Abo and Tijera Arroyos' with 'Abo and Tijeras Arroyos'

In many ways, this is the best section of the report. This may be because the science of stream ecology is so extensively developed. The sections give numerous examples of studies that support the conclusion that a potentially significant connection exists throughout most well-integrated[1] watersheds. This would mean that the section primarily addresses watersheds that are continuously delivering water, energy, chemical components and biotic material in a smooth fashion under conditions of perennial or intermittent flow.

I was particularly impressed by the sections (4.7 and 4.8) on prairie and Southwestern streams, two lotic ecosystems with which I am familiar. While my suggestions might strengthen the arguments, I feel these sections do quite well on their own and show that the authors understand the main technical problems that bedevil resource managers. I would suggest discussing the term 'interrupted stream' (Meinzer, 1923; Levick, 2008; RWRD, 2002) in this section. Stream flow that varies in space (i.e. from reach to reach) creates a different sort of connectivity than stream flow that varies in time (intermittent).

My most serious question with this section concerns the limits of channelized flow in a watershed. In other words, where and when does upland sheet flow end and a headwater stream begin? What are the criteria for the transition of transient rills and gullies to a functional integrated drainage? On this vexing subject, the chapter does not provide clear guidance. The implication in this document is that watershed connectivity extends right up to the point of raindrop impact and, in a sense, that is true. However, the unintended regulatory consequences of this are a nightmare.

The science of landscape evolution has a goal of predicting topographic form using geomorphic principles (Hopp and McDonnell 2009). Landscape evolution theory has developed a very full body of morphological research that began with Horton (1945) and has evolved into field-calibrated, physics-based landscape elevation computer models (LEMs) (see Morgan and Nearing, 2011). LEM codes were developed to provide three-dimensional projections of soil erosion and sediment transport and the definition of stability under various quasi-equilibrium states (Willgoose and Hancock, 2010). All LEM models use a digital elevation model (DEM) as

[1] I use the term integrated drainage in the sense of Horton (1945) and Strahler (1957) as a disturbed landscape measurably trending towards an ideal morphometry where erosion and deposition are in quasi-equilibrium on a specific time scale.

an initial condition and track the evolution of the land form against that initial profile. Most LEMs also use fluvial process, relating discharge/unit width, to simulate erosion. Thus, erosion is more pronounced in areas of channel flow as they transition to stable drainage networks (subwatersheds).

Two LEM codes that have received the most attention from geomorphologists are the SIBERIA (Willgoose et al., 1991; Hancock et al., 2000, 2008, 2009) and the Cellular Automaton Evolutionary Slope And River, or CAESAR (Coulthard, 1999; Coulthard and Van Der Wiel, 2006) codes. These codes have been combined with LIDAR topographic data to provide predictive estimates of landscape stability (Hancock et al., 2008; Hancock et al., 2011).

These models can provide a basis for predicting the potential for hydrologic connectitiy. Hydrologic connectivity is a subject of intense research scrutiny, mostly from a geostatistical perspective (Western et al., 2001; Knudby and Carrera, 2005; Ver Hoef et al 2006; Bracken and Croke 2007; Michaelides and Chappell, 2009). Both Western and co-workers (2001) and James and Roulet (2007) relate hydrologic connectivity to antecedent soil moisture, the degree of shallow saturation and transmission losses through channel seepage. This relationship is key to the question of whether an observed surface water channel is an actual channel under a presumed rainfall event. Finally, Reaney and co-workers (2007) develop these concepts into an integrative model to access runoff connectivity in headwater catchments.

Obviously, these investigations were not set up to address the questions of the Connectivity study; however, these ideas could be used to clarify the difference between integrative headwater streams and temporary rills and gullies that, although *potentially* connected to downstream waters, would not be expected to impact downstream waters of the US in any significant way. Exploratory use of LEM and hydrologic connectivity theory could provide quantitative tests of evolving headwater landscapes and establish the scales for headwater processes important to watershed connectivity.

Section 4 could also be improved by discussing at greater length floodplain complexity and internal fluvial connectivity. Ecologically active floodplains are generally considered those used by events in excess of the annual flood, the 1.5 year flood in many cases (Wolman and Miller, 1960; Junk et al., 1989; Poff et al., 1997); however, important ecological connectivity may exist between the active and abandoned floodplains (Richter and Richter, 2000), particularly when fish habitat is dynamic (Polivka 1999). Boudell and Stromberg (2008) found wetland obligate seed in patches of abandoned floodplain completely colonized by upland species (mesquite scrub). This demonstrated that terrain with no surface evidence of flow had nevertheless been connected to the active channel in the recent past. Seed bank studies might provide a critical discriminator between time scales in the location of active and inactive channels.

In Section 4.4, there should be discussion of how metal bioavailability varies with major ion chemistry, specifically calcium and magnesium (Di Toro, 2001). This is the basis of the EPA Biotic Ligand Model. Also, if the discussion of radionuclide transport in the Rio Grande is used, it should be updated to reflect recent work by the USGS (Falk et al., 2011), New Mexico

Environment Department (Englert et al., 2007) and Los Alamos Scientific Laboratory (Fresquez and Jacobi, 2012).

Finally, as mentioned in the response to Charge Question 1, there is insufficient discussion of migratory bird use of riparian and aquatic habitat. This is a very important connective process that exhibits a great deal of complexity. Use of riparian corridors by migratory songbirds is clearly important (Skagen et al., 1998, 2005; Machtans et al., 1996; Scott et al., 2003; Gillies and St. Clair, 2008). Many of these studies point out that not all riparian areas are equal in ecological usefulness. Primarily, the degradation of avian habitat occurs with development within the riparian area (Fisher and Goldney, 1997) or when the habitat was discontinuous ('stepping stone' habitat) (Kondo and Nakagoshi, 2002). Thus, useful connectivity of bird habitat across watersheds may require more temporal and spatial complexity than simple static refugia.

3b.) Please comment on whether the conclusions and findings in Section 4 are supported by the available science. Please suggest alternative wording for any conclusions and findings that are not fully supported.

Section 4 conclusions are supported by the available science. Additional useful conclusions might be possible by expanding the discussion to include the upland/headwater transition and provide a scientific basis for establishing the limits of channelized flow in watersheds.

4.) <u>Section 5.3 -Lentic Systems: Wetlands and Open Waters with the Potential for Non-tidal, Bidirectional Hydrologic Flows with Rivers and Lakes</u>

4a.) *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.*

Section 5.3 is probably the most clear-cut section in the report. Riparian wetlands are clearly significantly connective to downstream waters. They provide critical water quality functions that protect downstream water uses and are essential habitat, in and of themselves. Although Section 5.3 provides excellent scientific support for these and its own conclusions, a better functional definition of riparian wetlands is needed. For example, I don't see an important distinction in the literature (or practice) between 'floodplain' and 'riparian' wetlands. Wetlands in a floodplain are almost always a functional part of the riparian ecotone, to some degree, and need to be evaluated within that context.

A stronger definition of riparian wetlands is particularly important to the assessment of ephemeral streams, where floodplain and bank storage of ephemeral water is crucial for the long-term survival of the ecosystem (Richter and Richter, 2000; Stromberg, 2001; Tockner et al., 2010). I was disappointed to see a reliance on Cowardin et al. (1979), which does not adequately discuss wetlands associated with non-perennial rivers and is, in any case, outdated. I am not even sure a regulatory definition is needed for riparian/floodplain wetlands; if the stream is jurisdictional, the connected wetland would also be jurisdictional, regardless of the definition. Other than this, my only reservation with Section 5.3 is, again, the neglect of the role of birds in ecological connectivity and transport of bacteria, both of which apply here even more critically than in the Charge Question 3.

4b.) *Please comment on whether the conclusions and findings in section 5.3 are supported by the available science. Please suggest alternative wording for any conclusions and findings that are not fully supported.*

The conclusions of Section 5.3 are scientifically valid for the discussion preceding it.

5.) Section 5.4 - Lentic systems: Wetlands and Open Waters with Potential for Unidirectional Hydrologic Flows to Rivers and Lakes, Including "Geographically Isolated Wetlands"

5a.) *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.*

In many ways, Section 5.4 deals with the most difficult issue of the entire report. It may even be the part of the report that deals with the most critical issue of the study - - what defines connectivity for wetlands that have no topographically obvious flow path to navigable waters. Section 5.4 takes a useful step in the direction of a solution and lays the groundwork for a good discussion but it punts in the final quarter and this is not acceptable.

The problem begins in the introduction, never clearly defining unidirectional wetlands. If the system is part of a surface water channel then it's not isolated; if it is ground water derived, a seep in the usage of Springer and Stevens (2009) and Springer et al. (2008), then the source (regional ground water or shallow alluvial aquifer) of the discharge is critical to the question of connectivity and must be defined.

Section 5.4.2.2, concerning ground water flow, further confuses the issue with a mangled description of Darcy's Law. Hydraulic head drives porous media flow and is opposed by the inverse of hydraulic conductivity. Therefore, without a negative head difference there can be no unidirectional groundwater connectivity between a wetland and a stream. The hydraulic connectivity defines the significance of that flow as a transport process for energy, nutrients or contaminants. In other words, if it takes 10,000 years for a naturally attenuating pollutant to reach the stream, the wetland is effectively isolated from the stream, with respect to that stressor.

Much of the confusion in section 5.4 is predestined from the fact that connectivity is, once again, only defined deterministically (see my response to Charge Question 1). Being so defined, topographically closed basins can never be connected, except along a groundwater pathway. Any closed basin could, theoretically, become an open basin given enough rain; however, minus a biblical deluge, it is highly unlikely that many would ever spill to downstream waters. The significance of this circumstance is something that can be evaluated through the return period of the rainfall event, based upon the statistical record of precipitation and the losses to seepage and evaporation of the produced surface runoff.

The occurrence of runoff sufficient to connect unidirectional wetlands to downstream waters would thus follow a return period (for example, 1 year out of 100, or the 100-year event). It is curious that Section 5.4.2.1 cites three separate studies, Rains et al. (2008), Wilcox et al. (2011) and Leibowitz and Vining (2003) that produce some sort of probability of discharge for unidirectional wetlands. In fact, Wilcox and co-workers (2011) even discuss the application of their method to the definition of jurisdictional waters. Despite this, the report does not follow their lead.

Other studies add to this idea. Benke and co-workers (2000, 2001) evaluated invertebrate habitat in the Ogeechee River basin (GA) using a regression analysis of a 58-y period of record to predict inundation depths. Sommer and co-workers (2004, 2005) used hydrologic modeling of the Yolo Bypass in the Sacramento River delta (CA) to calculate what they called an 'idealized hydraulic residence time' and 'idealized mean velocity' that could be compared to *Onchyrhynchus spp.* habitat requirements. Howard and Cuffey (2003) used the HEC RAS hydraulic model (and probabilistic rainfall estimates) to predict the most likely distribution for the mussel population of the South Fork of the Eel River (CA). All of these studies were based upon statistically significant, peak and average runoff estimates for the upland watersheds. Nilsson and co-workers (2012) completed a probabilistic assessment of closed basins in Florida, using the metric 'inundation frequency' to classify their hydroperiod.

There are other useful ways of looking at the potential for hydrologic connectivity in these closed surface water bodies. In the 1990's, Pacific Northwest National Laboratory developed a program, the Multimedia Environmental Pollutant Assessment System (MEPAS) (Whelan et al., 1992), that analyzed the physics-based exposure risk of human and ecological targets based upon independent, coupled mechanistic models and stochastically determined parameters. The scientific basis of the program was not as innovative as the combination of these two disciplines, stochastic hydrology and quantitative risk assessment.

MEPAS has since evolved, under the direction of the EPA, Office of Research and Development, National Exposure Research Laboratory into a system of integrated models called Framework for Risk Analysis in Multimedia Environmental Systems (FRAMES) (Whelan et al., 2007), that is used to develop pathway analysis of stressors on exposed environments and individual targets. Of significance to this discussion is the integration of surface water transport models, such as the Soil & Water Assessment Tool (SWAT) (Arnold et al., 1998). The essence of this approach is to define the significance of conceptual risk within conventional exposure probabilities.

One particularly intriguing use of FRAMES involved the simulation of downstream aquatic habitat conditions in the Albemarle-Pamlico basin (NC and VA). Johnston and co-workers (2011) describe using a physiographically stratified sample of headwater streams (50) to characterize the sources of chemical and physical stressors to the aquatic ecosystem. The resulting methyl mercury concentrations in fish tissue were simulated and compared to regulatory limits.

Whelan and co-workers (2010) are using the Quantitative Microbial Risk Assessment module of FRAMES to evaluate transport of pathogens (*Cryptosporidium*, *E. coli*, and *Salmonella*) downstream of land application and pasture-derived manure sources. This kind of analysis could provide spatial/temporal limits for the significance of pathogen loading in watersheds of high agricultural use.

The point of this sidebar is not to promote FRAMES or any other analytical tool, but to simply provide a way of getting past the ambiguities of Section 5.4. The connectivity of 'geographically-isolated' water bodies cannot be deterministically evaluated. The difficulty disappears if a probabilistic, risk-based definition is used. Simply stated, a Section 5.4 water body is connected to downstream waters only if its probability of delivering environmental stressors or resources exceeds some acceptable risk to human and ecological receptors, which could be a water quality standard, a TMDL or another regulatory limit.

> 5b.) *Please comment on whether the conclusions and findings in section 5.4 are supported by the available science. Please suggest alternative wording for any conclusions and findings that are not fully supported.*

The conclusions of Section 5.5 are reasonable with regard to the evidence provided by Section 5.3 riparian and floodplain wetlands; however, the conclusions of Section 5.4 unidirectional wetlands, while reflective of the discussions of Section 5, are unacceptably open-ended, and it is difficult to imagine how they will be useful to resolving the current problems in defining the jurisdictional extent of the Clean Water Act.

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Dr. Duncan Patten

Comments on Various Sections and Issues in the Connectivity Report.... Patten
The first few pages of this comments document are some general thoughts and findings. These are followed by a discussion on structure of the report and then a review of the framework section.

What is Document's Purpose? The purpose of this document is to review and synthesize available evidence in the peer-reviewed scientific literature pertaining to three questions:

1. What are the physical, chemical, and biological connections to and effects of ephemeral, intermittent, and perennial streams on downstream waters?
2. What are the physical, chemical, and biological connections to and effects of riparian or floodplain wetlands and open-waters (e.g., riverine wetlands, oxbow lakes) on downstream waters?
3. What are the physical, chemical, and biological connections to and effects of wetlands and certain open-waters that lack bidirectional hydrologic exchanges with downstream waters (e.g., most prairie potholes, vernal pools), hereafter referred to as unidirectional wetlands, on downstream waters?

Question: Does the document clearly achieve the purpose and is it organized appropriately with similar organization and presentation throughout?

Answer: In general the document addresses the primary issues using appropriate literature and discussion. As expected, there are many statements that can be questioned or expanded to be more accurate or complete. For some issues, ideas or thoughts are presented. Section 3 dealing with the Framework is more fully discussed.

Issues raised relative to the report.

Magnitude of Connectivity. The report uses science to show the connectivity of water and other components between various water bodies within a watershed context, with emphasis on "rivers" as the receptor of water from other entities. Based on this, the report relates to types and directionality of connectivity but has limited discussion on magnitudes of connectivity which may be important to eventual assessment of the "significance" of connectivity.

Interconnections between water bodies. The following statement "The Information about connections among water bodies of the same type (e.g., wetland-wetland, headwater stream-headwater stream) that do not influence the condition of downstream waters, *are considered out of scope" of this report*, seems to forget the cumulative effects of small headwater streams, for example, on other small headwater streams that together may have a cumulative effect. How does this statement relate to two first order streams that together become a second order stream but influence each other in the integration? How does this statement relate to two bidirectional wetlands on headwater streams, one above the other, that influence each other down slope?

Does this statement ignore cumulative effects which may magnify the magnitude of the connectivity?

Weight of Evidence. In order to "justify" a connection, Weight of Evidence approach is used when connections are not obvious. The report states that "This approach, which borrows from weight-of-evidence approaches in causal analysis (Suter et al., 2002), is an effective way to synthesize the diversity of evidence needed to address questions at regional and national scales."

Does "weight of evidence" give credence to justifying a connectivity between smaller water bodies and rivers?

Human Altered Water Bodies (relates mostly to rivers in the SW). Some issues... . How does the report address rivers that once were perennial that now are intermittent (or perhaps ephemeral) in some of the lower reaches due to factors such as irrigation take out or groundwater pumping? Mentioned but not discussed in much detail but quite typical of SW rivers.

How does the report address rivers that once may have been perennial but now have flows maintained because of "artificial" means, for example, inflow of effluent, groundwater recharge near river? Common in SW rivers (e.g., a high percentage of Arizona rivers are effluent dominated).

Are rivers "connected" if a river has no flow, except perhaps high flood events that extend the "apparent" perennial nature of the river. River may have been dried up artificially to start with or may have been perennial before human influence.

"Human "intervention"... can make some water bodies "connected" to others when they weren't prior to intervention. For example, the statement page 3-50 "groundwater withdrawal also can increase connectivity in areas where that groundwater is applied or consumed." One assumes that "applied" means used for irrigation and tail-water from irrigation may flow to river (thus groundwater is connected to river???). Consumed would mean, for example, used in a city and the effluent from that city thus flows to a river??
This statement seems to imply that pumping groundwater and transporting it via "pipes, etc." will create a "connection" between the groundwater and some river where the applied or consumed water might reach.

The report does address restoration of "connectivity" giving dam removal as an example. Certainly, the connectivity of water above and below dams was never "broken" but sediment transport was altered and dam removal would restore this. This addresses the "importance" of non-water components of hydrology when considering connectivity.

Comments and Questions on components of connectivity and influencing factors.

In addressing connectivity as a concept, the report states "Water movement through the river system is the primary, but certainly not the only, mechanism providing physical connectivity within river networks." Examples of no water movement include aquatic food webs which connect terrestrial ecosystems, streams, wetlands, and downstream waters. Here connectivity includes terrestrial parameters that are distant from waters other then aerial connective pathways. This essentially means that any watershed or ecosystem parameter that at some point may "interact" with the stream, wetland or river can be used to determine connectivity. Should the panel comment on this?

In addition, if one follows the thinking of the following statement, almost parameter in and about a watershed is possible for evaluating connectivity. The statement reads "Climate, watershed topography, soil and aquifer permeability, the number and types of contributing waters, their spatial distribution in the watershed, interactions among aquatic organisms, and human alteration of watershed features can act individually or in concert to influence stream and wetland connectivity to, and effects on, downstream waters." Should connectivity be so all inclusive when considering guidelines for regulations which this report will be used for?

In addition, an interesting statement that implies limited connection between water and its components may be confusing. This statement is: " Importantly, our use of these landscape settings based on hydrologic directionality should not be construed as suggesting directionality of geochemical or biological flows." (page 1.2 ln 16). Since geochemical and biological factors are used, in part, to demonstrate connectivity, how is the statement above intended to be interpreted?

Literature Used in the Report

Overall, the report presents an extensive cross section of the pertinent literature on each topic, remembering that there was a cutoff date when the initial report was produced and literature published after that date could not be considered. Some literature used may stretch the findings of the publication but overall interpretation of data and findings seem appropriate.
Question about literature used: Only peer reviewed literature is used. Question: Are all books cited peer reviewed. One assumes that if a publisher publishes a book, it has gone to outside experts for review of the book or chapters. Are all government reports cited peer reviewed? If a chapter in a book is used for information, the chapter should be cited, not the book and the book should also be cited.

Suggested Additional Literature:

Unidirectional wetlands:

Stevens, L.E. and V.J. Meretsky (eds). 2008. Aridland Springs in North America: Ecology and Conservation. Arizona-Sonoran Desert Museum Studies in Natural History. University of Arizona Press, Tucson, AZ. (individual chapters may be appropriate for water bodies that lack bidirectional flows).

Bidirectional wetlands:

Brinson, M. M. 1993. Changes in the functioning of wetlands along environmental gradients. Wetlands 13:65-74.

Naiman, R. J., H. Decamps, and M. Pollock. 1993. The role of riparian corridors in maintaining regional biodiversity. Ecological Applications 3:209-212.

Terminology Issues

Aquitard only used where it prevents water percolating into ground and not where it constrains upward movement of groundwater and is critical to development of artesian wells and springs. Glossary should have term. The report uses aquiclude (some consider this the same as aquitard but it is a layer that does not give up water readily and/or reduce infiltration deep and cause to move through permeable soils on top (sounds like aquitard). The one in glossary should refer to other.

Are terms such as "terminal stream" (fig 3.18) or "terminal source stream" as in glossary commonly used in literature?

Figure In Executive Summary . Figure 1.1 caption and figure. There should be a red line between saturated zone and isolated wetlands as many isolated wetlands receive water from groundwater sources. This is discussed in text under unidirectional wetlands. The assumption from this figure is that isolated wetlands receive water only from surface inputs which is incorrect and is correctly addressed in text.

Review Comments on Connectivity Report Structure by Patten

Comments on Structure ... The overall structure of the report proceeds logically after executive summary and introduction from conceptual framework through hydrological types (i.e., streams, wetlands, and conclusions). The stream and wetland sections are presented in several subsections, the stream section presents an overview with synthesis followed by case studies, while the wetland section presents different wetland types followed by case studies. This section is much more expansive than the river section as it not only covers riparian and floodplain bidirectional wetlands but also unidirectional wetlands some of which may be isolated. The wetland section also offers many more case study examples of wetland types including those from mesic and arid regions, a format that should have been used in the stream section.
Each section steps through various influences or effects of the "wetland type"... including water (various aspects of water such as quality, etc.), sediment, organic matter, various biota, etc. Each discussion is designed to support a "connectivity theme". Is there an effort to "find connectivity" even where it may not exist?

Each section ends with a Synthesis and Implications section which is essentially a summary of findings (conclusions???). This is useful.

Wrap up tables at end of sections is a good idea and helpful (is this true for all sections???) Found in wetland section but elsewhere???

The whole document ends with Conclusions and Discussion (similar to those in Exec summary).

Assessment of Document Objectives/Goals: The apparent goals and/or objectives of this document are to demonstrate that connectivity "comes in many sizes and factors and/or attributes". Using this as the goal, the document demonstrates connectivity between variable water sources, even some that appear to have no direct hydrological connections. This raises the question of what is meant by "connectivity". If it is only an open water connection, then many of the cases and examples used do not meet that test. If it includes attributes that in some way connect hydrological units whether they be physical, chemical or biological, then the "connectivity" test may be achieved. Apparently, groundwater connections are considered a "direct" water connection but at what level. For example, if groundwater feeds a spring that does not flow into a river and also a spring that does, are these all connected to the river?

Use of Case Studies.

Case studies are a good approach to demonstrating some detail about rivers and/or wetlands. However, in this report the case studies of streams report on "unusual" types of streams from either a functional or geographic perspective and there is no detailed explanation of the reasons behind the selection of various case studies. For example, case studies for Streams (section 4) are arid stream systems, for example, prairie streams and southwestern intermittent and ephemeral streams. In the latter, the San Pedro is selected because it has been closely studied (and was part of the EPA EMAP program which may not have been a reason for selection). There is no mention of how the San Pedro might compare to other streams in the region where there have also been extensive studies (e.g., Gila, Hassayampa, Santa Cruz). Is the San Pedro really representative of streams from this region and should the report explain this representative nature of the San Pedro?

In addition, for comparison and a better understanding of function and connectivity of the case study streams, the report should also have a case study (or two) of an eastern and/or midwestern stream. How does the reader understand the relative uniqueness of SW streams without this comparison? Also, how does the reader understand the processes that influence determination of connectivity in eastern and/or midwestern streams without a case study with detail like those presented in the prairie and southwestern case studies?

Case studies presented in the wetland section (section 5) include a greater variation of wetland types and geographical settings than the streams section. As mentioned above, this greater variation in case studies might improve the stream section.

The case studies are presented as "stand alone" sections with their own abstracts. This is both good and bad as the information found in the case studies is not mentioned in the abstract for the overall section, and yet, it allows for a more detailed abstract for the case study. My recommendation would be to include a brief summary of the case studies in the section abstract.

Framework Section. (see following review).

Streams Section (no review**)**

Wetland Sections

Some of the following comments may also be found in review of Framework section.

The riparian and floodplain wetland subsection within Wetlands section is what one would expect to be presented in this report as these wetlands are directly associated with streams. There might be a better distinction between the riparian system that is adjacent to the river but above the saturation zone and riparian wetlands that are within the saturation zone along the river. In most cases riparian ecosystems are not considered to be a wetland. To address this, the report attempts to explain that most of the literature on riparian ecosystems may not be on riparian wetlands as determined by Cowardin system but the literature for this was included in this report as it is important to understanding the connectivity of this zone along a stream. The report also states that some riparian wetlands can be isolated and surrounded by uplands. By definition, riparian systems are on the edge of bodies of water (rivers, lakes, etc.) and thus cannot be surrounded solely by uplands. An edge must be along the body of water.

Unidirectional wetlands uniqueness. Bidirectional wetlands (i.e., riparian and floodplain wetlands) have direct connections with streams and thus may be considered as functional unit of the stream. Unidirectional wetlands deliver water to streams if there is sufficient water. However, some unidirectional wetlands, especially those in arid regions where groundwater springs or seeps may create the wetland, may never produce enough flow to reach a stream or river and thus are geographically isolated. Their role in groundwater connections with streams is tenuous and thus demonstrating any connectivity with rivers may be difficult. If groundwater is withdrawn from the spring area and used for surface irrigation or other uses, potential connectivity may be created (see comments on reports statement on use of groundwater "groundwater withdrawal also can increase connectivity in areas where that groundwater is applied or consumed."

No mention of artesian spring fed unidirectional wetlands (may be geographically isolated). This means no mention of aquitard (see terminology comments) although the confined aquifer is discussed in framework section.

Comments on Section 3. Conceptual Framework

Overall, this section lays out an understandable, and comprehensive organization of the river system (or watershed) on which the report is based. Throughout it, however, there are many points that need clarification or for which there are questions. These follow:

Channels. Should "constructed" passageways or depressions be included in description of "channels" that convey water down gradient? (pg 3-1). This is a point of contention among those discussing connectivity of waters.

Rivers and Streams. These have the same description except for the volume of flow. One has large volume and one small volume. When is there a distinction?

Headwater streams. Why are "headwater streams" first to third order? Because researchers designated them that or is there a scientific reason? How far out of "headwater" landscape does a stream have to flow to no longer be headwater?

Figure 3.1 should have citation as to whose system this configuration follows.

River System. What is the difference between this and a watershed which is, according to the text, the basis on which connectivity will be determined. Figure 3.2 looks like a watershed diagram.

Figure 3.2. Caption discusses unidirectional wetland but figure uses geographically isolated wetland. If these are indistinguishable, then text should support this. This figure uses "drainage basin" with heading "river system". Why not stick with watershed which is claimed to be the foundation of the whole report?

Note: On page 3.5 the report slips from riparian and floodplain into wetlands without highlighting this shift. This shift follows with an extensive discussion of description and directionality of flow. Somewhere this shift should be highlighted.

Wetland description. This report uses Cowardin and not federal regulatory designation of wetland. Although the report describes wetlands as including areas such as swamps, bogs, fens, marshes, ponds, and pools, under this designation, riparian areas can be considered wetlands because they may have hydrophytic plants (only one designator of wetlands under fed). However, under description of bidirectional wetlands the following description of riparian wetlands is used: "Riparian wetlands are portions of riparian areas that meet the Cowardin et al. (1979) three-attribute wetland criteria (i.e., having wetland hydrology, hydrophytic vegetation, or hydric soils)". No detailed discussion of why the report follows Cowardin, with this exception and why this exception because this shift is critical to understanding the importance and potential protection of riparian areas. ***This whole area of how to describe wetlands needs to be clarified as it is a point of contention.***

Directionality of hydrologic flows.

Unidirectional wetland description *should include possible sources of water* that maintain the wetland and also flows to stream or river. Is this also the place in the text where there is a description of wetlands that have a water source but that do not have outlets that flow far enough to reach river or stream? (see figure 3-19, page 3-39 for some discussion on this).

Geochemical flux. Should geochemical fluxes that are not part of hydrological connectivity be considered? (pg. 3-8). E.g., salmon carcasses...a geochemical fluxes that is decoupled from hydrologic flows. Mentioned but may be considered a part of "connectivity" if one expands the concept.

Bidirectional wetlands that are isolated. The discussion and description of this which includes a hydrological connection via occasional flooding tends to leave out the potential alluvial aquifer connection that these isolated wetlands may have with river. The report does consider the difficulty of determining these connections.

Sub Section on River System Hydrology. (3.2.2).

Confined aquifers. The diagram (3-4) used to describe zones (saturated and unsaturated) is too simple. Need some combination of fig 3-5 and 3-4 as 3-5 is somewhat confusing. The text discusses aquiludes a layer which gives up little water and confined aquifers (confined by aquitards), it states that the confined aquifer has less influence to surface that unconfined aquifer, which may be true, but in many areas confined aquifers can be significant sources of water via natural artesian water which support wetlands and and the water may flow to rivers.
Regional groundwater is discussed with connections to local groundwater. Both can be critical water sources in arid regions and *thus a water source for local streams* when artesian flow is sufficient. Artesian flow from regional groundwater to surface may pass through local groundwater layer but not necessarily.

Alluvial groundwater and hyporheic exchange.(3-14). This is a relatively good discussion of the processes and importance of these features.

Perennial and intermittent flows. (3-14) In this discussion flows are measurable surface flows, however, in the arid west many streams may flow perennially above and below surface but are measured as intermittent as some seasons the *flows are subsurface*. This affects aquatic organisms but not necessarily riparian vegetation.

Stream expansion and contraction discussion. (3-19, 3-20). The discussion uses *snowmelt events as ephemeral events* (same as a rain event), however, in much of mountain country snowmelt occurs over a long period and can be a source of water for much of the year (creating perhaps an intermittent flow), especially if snow fall was above normal. This includes small headwater streams as well as larger headwater and mainstem streams.

Riverine wetland (3-21). These can be both bi and unidirectional as discussed but what are small single source wetlands that are unidirectional and produce an output flow? Still riverine wetlands? Needs clarification.

Subsection 3.3 Influence of Streams and Wetlands.

The following statement (pg 3-25) is the essence of this section. It is also perhaps one of the more controversial ideas of connectivity as it extends beyond just water connections. Relative to the CWA it is an important statement and one which review of the report must keep in mind. "Thus, the fundamental way in which streams and wetlands affect river structure and function is by altering fluxes of materials to the river. This alteration of material fluxes depends on two key factors: functions within streams and wetlands that affect material fluxes, and connectivity (or isolation) between streams and wetlands and rivers that allows (or prevents) transport of materials between the systems."

Note: The discussion of connectivity (3-28) in this section should be discussed in the review as it may build on connectivity within or between biotic units, for example, which may not be considered connectivity between hydrologic units by many readers of the report.

Rivers as conduits. The following statement page 3-29, "As noted in Section 3.2.3, streams and rivers are not pipes" raises the issue of transport of withdrawn groundwater and "applying or consuming" it which the report states page 3-50 "groundwater withdrawal also can increase connectivity in areas where that groundwater is applied or consumed." How does one move water to be applied or consumed? Pipes???

Connectivity (non-aquatic)... Figure 3-14 and associated discussion creates a connectivity through aerial connections between wetlands and river, etc. The review should address this type of connectivity and its appropriateness as this is a potentially controversial issue.

Time and Space. The following statement (pg 3-31) brings up an important topic that should be discussed and supported in review. "When assessing the effects of connectivity/isolation and the five general functions (sources, sinks, refuges, lags, and transformation; see Table 3-1) on downstream waters, dimensions of time and space must be considered."

Types of hydrologic connections and examples.

Water sources San Pedro example (3-40). The following statement appears to contradict itself. "because a major proportion of water reaching the San Pedro River originates as overland flow to ephemeral streams that ultimately flow to the mainstem river, baseflow is limited. In other San Pedro River mainstem reaches, baseflow is supported by groundwater flow from regional and alluvial aquifers (Dickinson et al., 2010)." What is primary water source of river? Actually both...

Distance to river network.
Examples (3-43) given show dispersion of wetland types from some of the case studies in Section 5. This is a good connectivity between framework and other report sections. This connection is not obvious here.

Biotic Connections...needs close review by those considering this section as this is another contentious issue.

Human Alteration. Good to have this section in here but does it change one's perception of connectivity if humans alter the systems where connectivity is considered.

Dr. Mark Rains

General

Bidirectional-Unidirectional Wetlands

I don't particularly like terminology used to describe this distinction. This represents a departure from existing terminology, and I'm not entirely convinced that the departure is necessary or even accurate. If I understanding correctly, bidirectional wetlands are simply wetlands of all hydrogeomorphic classes in riparian and/or floodplain settings, while unidirectional wetlands are all other wetlands. I appreciate the distinction – the former have a two-way exchange of water and water-borne materials between the rivers and the wetlands and the latter have only a one-way exchange of water and water-borne materials from the wetlands to the river. However, couldn't you just call these riparian/floodplain wetlands and non-riparian/non-floodplain wetlands? That would more explicitly explain the distinction. Furthermore, it might more accurately describe the wetlands, because bidirectional and unidirectional are indicative of hydrologic and passive hydrologically related connectivity but are wholly not indicative of active biological connectivity. I think this is a big problem – either active biological connectivity doesn't matter, in which case bidirectional and unidirectional might be accurate and the entire active biological connectivity discussion should be removed from the report, or active biological connectivity does matter, in which case bidirectional and unidirectional don't accurately describe the ways in which these wetlands are connected to the broader hydrological landscape.

Geographically Isolated Wetlands

I've never liked this terminology. I don't know anyone else who does, either. However, I'm softening a bit, because I'm coming to grip with the strict definition – a wetland surrounded by uplands. Still, I'm pretty smart, I've thought about this a lot, I'm weary of the arguments, and I'm just a pinhead academic and not an on-the-ground regulator. Therefore, I'm probably not the person you should be convincing. For most people, this remains a problematic term that creates marbles-in-the-mouth moments for people trying to explain connectivity to the regulated public. Consider a depressional wetland in west-central Florida. Surface-water levels are higher than the surrounding uplands on some occasions and lower than the surrounding uplands on other occasions, leading to a switching behavior with the wetland sometimes the source of local groundwater recharge and sometimes the recipient of local groundwater discharge. It's underlain by a leaky confining unit and the head in the underlying regional aquifer is lower, so it always serves as a source of regional groundwater recharge. Though surrounded by uplands and not on the active floodplain, it nevertheless is extremely close to a navigable-in-fact river and is therefore ruled to be adjacent and subject to jurisdiction under the CWA. In explaining this to the regulated party – likely under contentious circumstances – the regulator has to explain how this is a unidirectional wetland that performs important functions because the water flows in three dimensions (huh?) and is hydrologically connected even though it is geographically isolated (wait, what?). I get that the term has a history and is a bit entrenched. However, I still think you should use this opportunity to argue that this term needs to be replaced.

Chapter 1

P. 1-2, Figure 1-1

One of the problems with the creation of new terminology is that it's not entirely clear how it relates to existing terminology. I know that this is a technical report, and I've argued in the past that it should be grounded in a scientific basis, but it should at least conveniently dovetail with existing regulatory terminology. Here, I'm wondering how this classification system corresponds to the concept of adjacency. "Bordering" and "contiguous" wetlands seem pretty easy to fit into this classification system – they would likely all be riparian/floodplain wetlands. But what about "neighboring" wetlands? A "neighboring" wetland – and, therefore, an adjacent wetland – can be outside of the riparian/floodplain zone, and can be completely surrounded by uplands, or at least that's what we're seeing in practice in some parts of the country, including west-central Florida. Therefore, by your terminology, a geographically isolated wetland can be an adjacent wetland. Is that your intent?

P. 1-3, l. 6—p. 1-4, l. 24, Summary of Major Conclusions

I think that you need an additional summary conclusion that represents a broader vision of how rivers and wetlands collectively fit into the hydrologic landscape. I think that this needs to be either first or last; regardless, it needs to send a strong message that rivers and wetlands cannot be accurately considered as independent features separate from the broader hydrologic landscape, and instead must be more accurately considered integrated elements of a broader hydrologic unit that we commonly call a watershed. Functional connectivity can then be seen as the norm, with functional isolation being the exception to the norm. This need not imply a significant nexus – only the opportunity for a significant nexus.

P. 1-6, l. 24—p. 1-13, l. 2, Discussion of Major Conclusions

See immediately above (i.e., P. 1-3, l. 6—p. 1-4, l. 24, Summary of Major Conclusions). Also, it's a bit early in the current format because you haven't yet introduced it, but it might be useful to tie your individual key findings to your conceptual model of functions being source, sink, refuge, transformation, and lag. For example, Section 1.4.1., Key Finding b.: "Headwaters convey water into local storage compartments…" is an example of a lag function. It's not a direct and easy fit – some key findings span multiple functions and some fit only awkwardly at all. Still, it might usefully tie your key findings into a conceptual model that otherwise hangs out there on its own a bit.

P. 1-14, l. 20-36

Nowhere in the report do you discuss the partial source area concept, where the headwater contributing areas contract and expand with recent conditions. Here is an example of where it might be appropriate – there are many others throughout the report—because vernal pools are excellent examples of this phenomenon, being dry and surface-water disconnected during the dry season but inundated and surface-water connected during the wet season. In other words, the source area expands during the wet season, with the vernal pools and swales serving as the headward extent of the source area at that time. This idea is central to watershed hydrology, going all the way back to the famous and well-cited paper by Dunne and Black (1970). [Dunne, T, Black, RD. 1970. Partial area contributions to storm runoff in a small New England watershed. Water Resources Research 6:1296—1311.] This expansion of the source area makes these areas, which might otherwise be considered geographically isolated, ephemerally or intermittently parts of what you elsewhere call the river network (i.e., "a hierarchical, interconnected population of channels that drains surface and subsurface water…from a drainage basin to a river and includes the river itself"). You do make the case for functional connectivity for these types of unidirectional wetlands – but that case can be strengthened by linking it to this foundational concept in watershed hydrology.

Chapter 2

NA

Chapter 3

P. 3-1, l. 1—p. 3-52, l. 15, Effects of Streams and Wetlands on Downstream Waters: A Conceptual Framework

This entire chapter is filled with excellent detail. Though I have some suggestions to improve the technical accuracy and breadth of the details, these existing details nevertheless can be part of an excellent chapter outlining the conceptual framework under which the remaining chapters can be presented and understood. However, the chapter lacks what it centrally promises – a conceptual framework. Lacking a unifying theme, the details are hard to categorize and I found myself forgetting what I had read and not able to anticipate what I was going to read next. Consider the analogy of building a house. One first lays a foundation and then builds a frame. Thereafter, the details are added. I feel like this chapter lacks that foundation and frame, so the details – e.g., the siding, the sheetrock, the paint – cannot be hung on that frame and therefore remain in neatly organized but separate piles.

The good news is that I think that the conceptual framework can simply be added on the front end, and the details for the most part will easily link back to that framework with very little additional effort. (Though some effort will be required.) You currently start with the river itself, which forces the reader to also focus on the river system for the remainder of the discussion. After a few pages, you briefly mention drainage basins, but really only in passing. Thereafter, you try to show how wetlands might be connected to that river system, but lack the explicit conceptual framework that would allow you to easily do so. I suggest that you reorganize, beginning with a very clear discussion watersheds, noting that watersheds are integrated hydrological landscapes through which water and water-borne materials move from ridges to outlets through surface-water and groundwater flowpaths, and also noting that uplands, unidirectional wetlands, and rivers and their associated bidirectional wetlands are all integrated components of watersheds and watershed flowpaths. You might do this best by discussing the watershed water budget:

$$P - ET + \Delta SW + \Delta GW = \Delta S$$

where P is precipitation, ET is evapotranspiration, ΔSW is the change in surface-water flow (i.e., surface-water inflow – surface-water outflow), ΔGW is the change in groundwater flow (i.e., groundwater inflow – groundwater outflow), and ΔS is the change in storage. Doing this might help the reader focus on the surface-water and groundwater flows that connect the watershed from the ridge to the outlet, and therefore better understand the roles that all parts of the watershed might play in maintaining the chemical, physical, and biological integrity of downstream waters. After all, most people inherently understand that the chemical, physical, and biological integrity of the mainstem river would be diminished even if we protected every single wetland and river but paved over every single upland.

Once that broader conceptual framework is established – i.e., that the chemical, physical, and biological integrity of any river is a function of the chemical, physical, and biological integrity of that river's watershed, and that wetlands and rivers are all part of that watershed – then it will be easier to connect all of the specific details already in this chapter about the role that connectivity plays in maintaining the overall chemical, physical, and biological integrity of the downstream, navigable-in-fact waters. It will also be easier to discuss the differences between hydrological connectivity and biological connectivity, with the latter in some circumstances being over large enough spatial scales to link watersheds.

You might also take the time here to discuss some important ecological concepts that are currently missing from the overall discussion, with an emphasis on how connectivity relates to these ecological concepts. There are large bodies of literature on, for example, subsidies and resilience that fit directly into the connectivity framework. You currently have five references with subsidies in the title and one reference with resilience in the title, though more of your references explicitly or implicitly discuss these foundational ecological concepts. Including a discussion of these – and perhaps others – will better enable you to connect your details to these foundational ecological concepts and a broader vision of how proper ecosystem functioning is at least partly a function of proper ecosystem connectivity.

P. 3-6, Figure 3-3

The dark shaded deposits probably should be defined. Also, there is an error. In A, I'd make the dark hillsides bedrock, then I'd make a small alluvial deposit around and underlying the stream. In B, the error is that the terrace is not on alluvium – there certainly are terraces not on alluvium or perhaps on alluvium from a different source than the river, but commonly terraces are formed on older alluvium from the same river. Therefore, in B, I'd make the dark bedrock, and I'd have it remain the same on the right but remain at the same depth as the bottom of the channel and exit the figure at that depth on the left, then I'd extend the alluvium and have it exit the figure at that same thickness on the left.

P. 3-10, l. 3

Change “is” to “are”.

P. 3, l. 5-7

These also can be called perching layers, an important distinction here because perching often supports shallow groundwater in environments where the regional groundwater is otherwise well below the surface.

P. 3-10, l. 8-10

I suggest you rewrite everything following the colon: “water can flow in small, interconnected voids in sediments (i.e., porous-media flow), in small, interconnected fractures in a low-permeability bedrock matrix (i.e., fracture-flow), or in large, interconnected voids in in a low-permeability carbonate rock matrix (i.e., karst flow).”

P. 3-10, l. 10-13

Water flows down a gradient in hydraulic head, where hydraulic head is the sum of the pressure head (which you mention) and elevation head (which you don’t mention). Therefore, this sentence is incorrect in only talking about hydraulic pressure.

P. 3-10, l. 14-27

There is one key difference that you fail to mention. Unconfined aquifers have a water table that is free to rise and fall. This results in variably saturated conditions over the range of the water-table variation and a variable thickness of the unconfined aquifer. Perched aquifers are a special case of unconfined aquifers, being unconfined aquifers underlain by a perching layer and having an unsaturated zone between the bottom of the perching layer and a deeper aquifer. Confined aquifers are overlain by a confining unit and do not have a water table free to rise and fall, instead having a potentiometric surface that represents the level to which water would rise above the confining unit if the confining unit were not present. This results in permanently saturated conditions and a constant thickness of the confined aquifer.

P. 3-11, l. 1-2

Why limit the discussion to unconfined aquifers? Both unconfined and confined aquifers interact with the surface environment, though in different ways. Unconfined aquifers interact with the surface wherever the water table is expressed at the surface, which might be expressed in topographic lows (e.g., where the water table might be expressed as surface-water stage in a depressional wetland) or on slopes (e.g., where a perched aquifer might outcrop and water might discharge along seeps, forming the headwater extent of slope wetlands). Confined aquifers can also interact with the surface if the confining unit is breached, which might be expressed in springs (e.g., where water flows upward through the breach and is expressed as focused flow out of the subsurface) or also on slopes (e.g., where a confined aquifer might outcrop and water might discharge along seeps, forming the headwater extent of slope wetlands).

P. 3-11, l. 13-15

Change these two sentences to begin with (1) "A groundwater recharge area…" and (2) "A groundwater discharge area…".

P. 3-12, l. 2-4

Stream reaches can also change from losing to gaining over time.

P. 3-12, l. 23-24

Not all deep, regional flow systems discharge to the surface. Therefore, add "may" between "systems" and "also".

P. 3-12, l. 32-36; P. 3-13, Figure 3-6

I suggest that you rewrite this paragraph and figure to be a full and correct description of hillslope hydrology. There are four pathways that water can take from the hillslope to a receiving water body: infiltration-excess overland flow, saturated overland flow, interflow, and saturated groundwater flow. These are individually described below. Also, return flow is used almost exclusively to refer to water that is taken from a river, used in irrigation, and then returned to the river after it has infiltrated and flowed back to the river.

Infiltration-Excess Overland Flow: This is the overland flow that occurs when the rainfall rate exceeds the infiltration rate, so excess rainfall runs overland even though the water table is still below the ground surface. This is also known as Horton overland flow because it was first described in the literature by RE Horton. [Horton, RE. 1945. Erosional development of streams and their drainage basins; Hydrophysical approach to quantitative morphology. Geological Society of America Bulletin 56:275–370.]

Saturated Overland Flow: This is the overland flow that occurs when the water table rises to the surface, so all additional rainfall runs overland. This is also known as Dunne's mechanism because it was first described by T Dunne. [Dunne, T, Black, RD. 1970. Partial area contributions to storm runoff in a small New England watershed. Water Resources Research 6:1296—1311.]

Interflow: This is rapid lateral flow in the unsaturated zone. It commonly occurs because there are interconnected macropores above a low-permeability layer, so infiltrating rainfall is intercepted and channeled into the interconnected macropores where it flows in what is essentially a subsurface pipe.

Saturated Groundwater Flow: This is the normal saturated groundwater flow, where infiltrating rainfall makes it to the water table and then flows laterally along with the general flow in that aquifer.

This entire discussion should emphasize that these are important flowpaths that can connect uplands, unidirectional wetlands, and rivers and their associated bidirectional wetlands. If I were writing this section, I might include it, at least briefly, as part of the earlier presentation of watershed connectivity at the beginning of the chapter. See my comment above (i.e., Pp. 3-1—3-52, Effects of Streams and Wetlands on Downstream Waters: A Conceptual Framework). This could be a convenient way to discuss how water enters channels and be immediately followed by a simple discussion of how channel networks route channel flow through watershed and to the outlet, with that water interacting laterally with riparian/floodplain wetlands along the way.

P. 3-14, l. 12-13

You might consider sticking with the terminology you use for flows, i.e., ephemeral, intermittent, and perennial.

P. 3-14, l. 20-21 and 33-35

If you're going to use "intermediate" in the first sentence, you also should use it in the second sentence.

P. 3-16, l. 8-11

You might consider sticking with the terminology you use for flows, i.e., ephemeral, intermittent, and perennial.

P. 3-18, Figure 3-9

Figures 3-9B and 3-9C are from Nadeau and Rains (2007b). These are identical to those figures, even down to the ranges in the legends. Therefore, Nadeau and Rains (2007b) should be cited as the source.

P. 3-22, l. 15-17

This is a poorly worded sentence. This also, by the way, is the saturated overland flow I previously described. See my comment above (i.e., P. 3-12, l. 32-36; P. 3-13, Figure 3-6).

P. 3-23, l. 1-2

At the very least, this needs to be described differently. Elevation is height above some datum. Commonly, we use elevation relative to a datum of sea level, so this sentence sounds like it is about a difference between high-mountain and lowland streams. Here, you're using elevation relative to something local – perhaps the stream bed, I suppose. Regardless, that datum is not standardized nor is it even locally clear. However, I think the sentence is only partly true, even if you clarify your datum. Flood storage is a complex function of the recurrence intervals of flows that access different parts of the floodplain; the available depressional storage on the floodplain, which has lateral and vertical dimensions, the roughness of the floodplain, and many other factors.

P. 3-23, l. 6

Change Bencala (2011) to Bencala et al. (2011). You might want to search elsewhere in the document to see if this mistake occurs elsewhere.

P. 3-27, l. 28

It's not just the frequency of an input – it's the frequency of an input relative to the frequency of all inputs. Rivers in the arid southwest US, for example, might receive most of their water and water-borne materials from infrequent ephemeral flows following monsoonal rainfalls. [Izbicki, JA. 2007. Physical and temporal isolation of headwater streams in the western Mojave Desert, Southern California. Journal of the American Water Resources Association 43:26—40.]

P. 3-28, l. 3-15

I don't see the difference between the definitions of connectivity presented here. I think you're trying to say that your idea of connectivity doesn't require flow or exchange; rather, can be something like a simple driving force. For example, water need not flow from a wetland to a stream; rather, the fact that the wetland supports a higher water table which creates a hydraulic gradient that is expressed as groundwater discharge to the stream is sufficient to demonstrate connectivity. Am I correct? If so, this doesn't come through in this paragraph, in which your definition of connectivity still sounds like there has to be flow or exchange.

P. 3-29, l. 29-32

I think the process to which you're referring is that DOC is converted to FPOM by bacteria. [Kerner, M, Hohenberg, H, Ertl, S, Reckermann, M, and Spitzy, A. 2003. Self-organization of dissolved organic matter to micelle-like microparticles in river water. Nature 422:150—154.]

P. 3-32, l. 13-14

You might consider sticking with the terminology you use for flows, i.e., ephemeral, intermittent, and perennial.

P. 3-33, l. 19—p. 3-41, l. 3, Climate-Watershed Characteristics

I suggest you use the Hydrologic-Landscape Region (HLR) concept introduced by Wolock et al. (2004). [Wolock, DM, Winter, TC, and McMahon, G. 2004. Delineation and evaluation of Hydrologic-Landscape Regions in the United States using Geographic Information System tools and multivariate statistical analyses. Environmental Management 34:S71—S88.] This could be a key organizational concept around which you can build this entire discussion. When you do so, you'll still lead with climate but will thereafter follow with geology and relief rather than the more generic and vague term of watershed characteristics. [Note that this would affect numerous sections in the report.] You already do this at times (e.g., p. 3-33, l. 20-21), so this doesn't really represent a change in your logic. Rather, it just gives you an organizational concept around which to build the entire discussion.

P. 3-33, l. 23-25

You focus only on climate in this sentence. However, geology and relief play equally important roles.

P. 3-34, Figure 3-15

Is this normalized runoff, i.e., discharge/watershed area? It must be, but it's not clear from the axis titles or the caption. Also, this fits right in with the HLR concept introduced by Wolock et al. (2004) – note, for example, that the runoff patterns are explicitly attributed to climate, geology, and relief in the caption. Last, this also fits in with the Natural Flow Regime concept introduced by Poff et al. (1997). See below (i.e., P. 3-40, l. 30—3-41, l. 3).

P. 35, l. 5-13

You only describe one of two overland flow mechanisms here, i.e., infiltration-excess overland flow. As previously noted, there also is saturated overland flow. See my comment above (i.e., P. 3-12, l. 32-36; P. 3-13, Figure 3-6).

P. 3-37, Figure 3-17; p. 3-38, l. 20-30

I suggest that this figure and the text that refers to this figure be rewritten in terms of a full and correct description of hillslope hydrology. See my comment above (i.e., P. 3-12, l. 32-36; P. 3-13, Figure 3-6). Also, replace "impermeable" with "low permeability", as it makes no sense for there to be any flow at all in an impermeable layer.

P. 3-38, l. 16-18

This is true only under a given hydraulic gradient. Therefore, this sentence might more correctly be written if it ended with "…under a given hydraulic gradient."

P. 3-40, l. 30—3-41, l. 3

This seems a good time to discuss the Natural Flow Regime concept (Poff et al., 1997) in the context of the HLR Concept (Wolock et al., 2004). See my comment above (i.e., P. 3-34, Figure 3-15). Flows can be characterized by frequency, magnitude, timing, duration, and rate of change, and these characteristics are naturally functions of climate, geology, and relief. The hypothesized importance is that biota are typically adapted to the Natural Flow Regime, so deviations to the Natural Flow Regime due to climatic and/or anthropogenic changes might be expected to create flow regimes no longer conducive to the life history strategies of native biota. [Poff, NL, Allan, JD, Bain, MB, Karr, JR, Prestegaard, KL, Richter, BD, Sparks, RE, and Stromberg, JC. 1997. The natural flow regime. BioScience 47:769—784.]

P. 3-42, l. 16-18

Why would this be true? It seems to me that one can't generalize about the relative roles of these kinds of wetlands. As you have no substantiating reference, I suggest that this be omitted.

P. 3-42, l. 20-23

This is an oversimplification that is only true if all other things are equal. Distance is only one factor – so, too, are leakiness (i.e., due to ET or infiltration), driving force (e.g., surface slope in the case of surface-water flows and hydraulic gradient in the case of groundwater flows), and roughness/conductance (e.g., surface roughness like that expressed by Manning's n in the case of surface-water flows and subsurface conductance like that expressed in permeability or hydraulic conductivity in the case of groundwater flows).

P. 3-42, l. 27—p. 3-43, l. 2

As previously discussed, elevation is probably not the correct way to describe flooding. See my comment above (i.e., P. 3-23, l. 1-2). Also, this isn't really how floodplains flood. Instead, floodplain flooding is a complex process during which microtopographic lows, especially abandoned channel features, flood both from rising water tables and from point-source flows from the channel. This is all described extremely well by Tockner et al. (2000), which is already in your references.

P. 3-43, l. 5-7

Again, this is an oversimplification that is only true if all other things are equal. See my comment above (i.e., P. 3-42, l. 20-23). A similar argument could be made here regarding how propagules or organisms move across a landscape.

Chapter 4

P. 4-4, l. 19-21

Discharge is a rate by definition, so "rate of discharge" is redundant. Therefore, change "rate of discharge" to "discharge".

P. 4-10, l. 13-16

Why does the transport distance associated with these floods matter at all? Sediment transport is always a batch process, with high flows moving sediment downstream, where it is deposited in short-term storage zones awaiting a subsequent high flow. This is happening all along a river network, with the sediment stored closest to the outlet providing the sediment discharged from the watershed but also being replenished from reaches just upstream.

P. 4-12, l. 3-5

Debris flows are mechanisms by which headwaters export large woody debris and sediment in large batches, with these large batches often playing important roles in creating the characteristic geomorphology and habitat quality on receiving rivers. [Montgomery, DM, Massong, TM, and Hawlet, SCS. 2003. Influences of debris flows and log jams on the locations of pools and alluvial channel reaches, Oregon Coast Range. Geological Society of America Bulletin 115:78—88.]

P. 4-13, l. 29—p. 4-14, l. 13

Groundwater discharge controls stream temperatures proximal to the location of the groundwater discharge. However, once in the channel, the groundwater quickly equilibrates with the air temperatures that it was buffered from when it was in the subsurface, and therefore quickly trends toward ambient surface-water temperatures in the absence of additional groundwater discharge. A study showing this is currently in review – and has been since August 2013 – but should be published by the time this report is finalized and ready to go to copy editing. [Callahan, MK, Rains, MC, Bellino, JC, Walker, CM, Baird, SJ, King, RS, and Whigham, DF. In Review. Trends and controls on surface water temperatures in headwater streams in two common geomorphic settings, Kenai Peninsula, Alaska. Journal of the American Water Resources Association.]

P. 4-24, l. 2-15

This is an acceptable back-of-the-envelope calculation, but it assumes that all allochthonous C is input to headwater streams which certainly isn't true – think about all of the allochthonous C input to the mainstem river during overbank flows, for example. Therefore, this assumption needs to be clearly stated and the results need to be clearly hedged.

P. 4-24, l. 6-7

This isn't a sentence.

P. 4-29, l. 8—p. 4-35, l. 22

What about vegetation? I know that you deal with it below in bidirectional wetlands, but it seems hard to ignore it here, since seeds and propagules are commonly transported by streamflows and able to establish and persist only under certain streamflow combinations. There is a great deal of literature on the establishment and persistence of riparian colonizers, e.g., cottonwood and willow, including a Special Issue in Wetlands in 1998. In general, seeds or propagules of these riparian colonizers move downstream during high flows, coming to rest on surfaces that have been scoured or buried with sediment. These seeds and propagules can establish if they have access to shallow groundwater in that first year, which commonly requires that river stages not fall too quickly or too far below the ground surface. These seedlings can then persist if these same areas aren't scoured or buried with sediment by high flows in the immediately following years. I suppose that one could argue that his is largely happening in the adjacent bidirectional wetlands – but that certainly isn't always the case (i.e., not all riparian colonization is in wetlands) and the broader effects are commonly on the channels themselves (e.g., changing local-scale hydraulics, which changes local-scale sediment transport and deposition and habitat quality). Doesn't this need to be addressed here? [Fetherston, KL, Naiman, RJ, and Bilby, RE. 1995. Large woody debris, physical processes, and riparian forest development in montane river networks of the Pacific Northwest. Geomorphology 13:133—144. AND Hupp, CR, and Osterkamp, WR. 1996. Riparian vegetation and fluvial geomorphic processes. Geomorphology 14:277—295. AND Scott, ML, Auble, GT, and Friedman, JM. 1997. Flood dependence of cottonwood establishment along the Missouri River, Montana, USA. Ecological Applications 7:677—690. AND Auble, GT, and Scott, ML. 1998. Fluvial disturbance patches and cottonwood recruitment along the upper Missouri River, Montana. Wetlands 18:546—556. AND Mahoney, JM, and Rood, SB. 1998. Streamflow requirements for cottonwood seedling recruitment—An integrative model. Wetlands 18:634—645. AND Kemp, JL, Harper. DM, and Crosa, GA. 2000. The habitat-scale ecohydraulics of rivers. Ecological Engineering 16:17—29. AND Gurnell, A, and Petts, G. 2006. Trees as riparian engineers: The Tagliamento River, Italy. Earth Surface Processes and Landforms 31:1558—1574.]

P. 4-36, l. 5-7

Another way that losing streams might contribute to downstream waters is that water lost by groundwater recharge on upstream reaches might be gained by groundwater discharge on downstream reaches. This is particularly common in karst environments, with the Santa Fe River, Florida, being a good example. There, streamflow is lost by groundwater recharge to the Floridan aquifer but soon thereafter gained by groundwater discharge from the Floridan aquifer, with as much as 62% of discharge from Devil's Ear Spring being from returning streamflow. [Kincaid, TR. 1998. River water intrusion to the unconfined Floridan aquifer. Environmental and Engineering Geoscience IV:361—374.]

Chapter 5

P. 5-1, l. 12-15

As previously noted, floodplain flooding is a complex process during which microtopographic lows, especially abandoned channel features, flood both from rising water tables and from point-source flows from the channel. This is all described extremely well by Tockner et al. (2000), which is already in your references. One thing that seems clear is that the effect of floods on the floodplain is not a strict function of distance from the main channel.

P. 5-4—p. 5-5, Figure 5.1

This should be moved to the end of the section on bidirectional wetlands to mirror the format of the sections on rivers and unidirectional wetlands.

P. 5-7, L. 7-15

Streamflow reductions due to ET losses from riparian wetlands was also shown by Hammersmark et al. (2008), which is already in your references.

P. 5-7, l. 18-19

This sentence doesn't make sense.

P. 5-8, l. 4-6

Sediments move by suspension in the water column and by sliding, rolling, and saltating on the bed. Therefore, replace "in the water column in suspension" with "in motion".

P. 5-8, l. 12-14

A particularly good reference for the effects of roots on streambank erosion is Smith (1976), with the roots in the study being hydrophytic grasses and sedges. [Smith, DG. 1976. Effect of vegetation on lateral migration of anastamosed channels of a glacier meltwater river. Geological Society of America Bulletin 87:857—860.]

P. 5-10, l. 32-34

The classic paper – cited ~1500 times – that describes the role of riparian wetlands in removing nutrients from inflowing waters is Peterjohn and Correll (1984), which is already in your references.

P. 5-11, l. 17-18

DIN concentrations in streams is correlated with alder cover in the watershed in the Kenai Lowlands, Alaska. [Shaftel, RS, King, RS, and Back, JA. 2012. Alder cover drives nitrogen availability in Kenai Lowland headwater streams, Alaska. Biogeochemistry 107:135—148.]

P. 5-18, l. 33-34

What effect can beaver have on fish species? The sentence doesn't say. If I recall the paper that is referenced correctly, beaver dams can help create slack-water habitats that increase coho salmon production.

P. 5-21, l. 5—p. 4-42, l. 4

This is your most difficult section, because you are making the case that these all exist on a continuum of connectivity and isolation, and that both might matter to the chemical, physical, and biological integrity of downgradient, navigable-in-fact waters. I think you could probably benefit from laying out this vision in a clear conceptual model up front, rather than diving straight into the details. As it is, you relate unidirectional wetlands to commonly known hydrogeomorphic classes, then launch right into the details under a section titled Surface Water Connections, and later begin to weave in that isolation might also matter. This creates a winding and confusing argument.

P. 5-21, l. 7-28

I like this section in which you relate unidirectional wetlands to hydrogeomorphic classification. It certainly helps with the confusion created by developing new terminology. Could you do the same for bidirectional wetlands? Or should you perhaps do this for both in the Introduction at the beginning of the chapter (p. 5-2, l. 24—p. 5-3, l. 14)?

P. 5-22, l. 12-14

Relace “transient” with “intermittent”.

P. 5-23, l. 22-33

Groundwater flow through conditions have also been identified in vernal pools on hardpan soils by Rains et al. (2006), which is already in your references.

P. 5-24, l. 2-5

This also has been more recently described for cypress domes in Florida. [McLaughlin, DL, and Coen, MJ. 2013. Realizing ecosystem services: wetland hydrologic function along a gradient of ecosystem condition. Ecological Applications 23:1619–1631.]

P. 5-24, l. 18-20

This is an oversimplification that could lead to erroneous assumptions, that can be easily corrected with another sentence or part of a sentence coupled with a reference. There are commonly fast flowpaths that develop in macropores in otherwise fine-grained, low-permeability deposits. This creates a dual permeability system – a low-permeability matrix that does, indeed, behave as you say, and high-permeability fast flowpath system that allows extremely rapid transport, perhaps even more rapid than in some coarse-grained, high-permeability deposits. This has been shown to link uplands and wetlands at the local and landscape scale on clay-rich, mine spoils deposits in the phosphate mining district, Florida. [Murphy, KE, Rains, MC, Kittridge, MG, Stewart, M, and Ross, MA. 2008. Hydrological connectivity between clay settling areas and surrounding hydrological landscapes in the phosphate mining district, peninsular Florida, USA. Journal of the American Water Resources Association 44:980–995.]

P. 5-28, l. 2-3

Aren't "hydrologic" and "physical" the same thing? If so, then one should be dropped.

P. 5-28, l. 13-28

This discussion on unidirectional wetlands as sources for downstream waters starts here with a discussion of how their exports can include methylmercury, to the detriment of the receiving waters. This seems an odd way to start this discussion. I suggest you start with some known beneficial effects of these exports, e.g., DOC (p. 5-28, l. 31—p. 5-29, l. 24). Thereafter, you can link to the potential negative effects, e.g., methylmercury, especially inasmuch as methylmercury can adsorb to DOC.

P. 5-31, l. 33—p. 5-32, l. 2

Do you really mean "geographically isolated wetlands" or do you instead mean "unidirectional wetlands"? I think you mean the latter, even though you say the former. Especially with all of this new – and, as I've previously argued, confusing – terminology, you need to be careful not to interchange terms that aren't really interchangeable.

P. 5-37, l. 20-21

I think this is one of the key areas where there remains confusion about the new terminology. Here, you say that "Unidirectional wetlands consist of depressional, slope, and flats wetlands that lack surface water inlets." As examples, you list vernal pools, among others. But most vernal pools do have surface water inlets and outlets. Commonly, only the headwardmost vernal pool in a vernal pool complex lacks an inlet – all other vernal pools have both inlets and outlets, commonly leading to intermittent headwater streams. By your logic, at least as expressed here, only the headwardmost vernal pool would be unidirectional – all other vernal pools would be bidirectional, basically serving as wetlands embedded in a headwater setting with focused flows in swales spreading out into vernal pools in a steady flow down the river network. Again, as I said in my general comments, this wouldn't be a problem if we used older established terminology, like riparian/floodplain wetlands and all other non-riparian/non-floodplain wetlands.

P. 5-37, l. 31-34

This case was explicitly made by Nadeau and Rains (2007b), which is already in your references.

P. 5-66, l. 36—p. 5-67, l. 4

Toward the end of this sentence, on p. 5-67, l. 3, replace "without" with "with".

P. 5-67, l. 29-31

This sentence only covers southern California and northern Baja. However, vernal pools are known to occur throughout central and northern California and southern Oregon, probably occurring in the highest density and overall coverage in central and northern California. [Holland, RF. 1998. Central Valley vernal pool distribution, photorevised 1996. Pp. 71-75 In CW Witham, ET Bauder, D Belk, WR Ferren, Jr., and R Ornduf (eds), Ecology, Conservation, and Management of Vernal Pool Ecosystems, California Native Plant Society, Sacramento, California.]

P. 5-70, l. 9-11

I don't really understand this sentence.

P. 5-70, l. 13—p. 5-71, l. 17

Rains et al. (2006), which is already in your references, also looked at N, P, and DOC dynamics, showing that water flowing into vernal pools is relatively high in N and P and relatively low in DOC, while water flowing out of vernal pools is relatively low in N and P and relatively high in DOC. In this specific case, the effects weren't measurable well downgradient at the intermittent stream, but they hypothesized that this was because vernal pools were a small part of this particular sub-basin and that the effect would be more apparent in vernal pool sub-basins in which vernal pools were more prevalent.

Chapter 6

P. 6-7, l. 1-16

It seems like you have made a pretty strong case for unidirectional wetlands being important, either through connectivity or isolation. Therefore, it seems a bit weak to end by saying that you can't generalize and that assessing on a case-by-case basis is technically challenging. It would seem more appropriate if you instead referenced the strong case you've made, and suggest that we should assume that unidirectional wetlands are important if we want to err on the side of caution.

Chapter 7

P. 7-9, l. 16-17

I only spot checked the references. While doing so, I searched on my name to at least make sure that all of my references were correct. In doing so, I found "Rains" in this reference. It doesn't belong and should be removed.

Dr. Amanda Rodewald

Rodewald Comments

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*.**

The authors of the report should be commended for conducting such a thorough and well-written scientific review. Clearly, a tremendous amount of effort has been invested in preparing the report. Although the breadth of the report sufficiently covers the topic, there could be additional depth in terms of the level of detail. In particular, the report would be more useful if it were to quantify, whenever possible, the degree of connectivity, the nature and magnitude of impacts on downstream waters, and the spatial and temporal scales at which connectivity manifests. Throughout the report, connectivity was often treated as a binary property – there was or was not connectivity. Establishing only the presence of connectivity without describing the magnitude or effect of that connectivity on downstream waters makes the report less useful and informative than it would otherwise be. Likewise, the authors would frequently refer to a "significant" or "strong" connection or impact without better qualifying or quantifying what that actually meant. For example, page 1-6, line 27 states that streams have a "strong influence on the character and functioning of downstream waters". Can more detail be added to statements such as these (e.g., effect sizes)? Information about the strength of evidence would also be helpful; e.g., 23 of 28 reviewed studies…". Additional information on the spatial and temporal scales and scopes of the studies reviewed would provide important context for findings. A better description of how the weight of evidence approach was applied would be helpful.

A greater amount of synthesis would provide stronger support than the sequential listing of findings of various studies or reporting of select examples. For instance, one could summarize the findings of multiple studies in sentences like the following: "In the eastern US, headwater streams provide 40-60% (mean +/- SE, n = x studies) of water volume to navigable waters." There also were several places where specific numbers were used without any point of reference, leaving the reader uncertain how important the finding was (e.g., on 5-11 and 5-12, is 45 kg of N per ha and year a lot or a little?).

Two fundamental principles that are key to evaluating the connectivity of geographically isolated wetlands are (1) the importance of examining ecological processes, connectivity, and impacts at the watershed scale (2) the need to consider wetlands in aggregate. These principles could be better supported in the text and better highlighted in the conclusions. For example, what is the rationale for considering the watershed to be the most appropriate ecological unit for analysis?

What constitutes connectivity and distinguishes a connected from isolated water needs additional clarity. Connectivity was defined as "the degree to which components of a system are joined, or connected, by various transport mechanisms" and something that is "determined by the characteristics of both the physical landscape and the biota of the specific system". In some places the report seems to consider connectivity from a hydrologic perspective alone. If the biota is also considered to play an important role in connectivity, then greater emphasis should be placed upon food webs and the needs of animals across the life cycle (i.e., breeding and non-breeding habitats). For example, birds and mammals can affect plant and animal communities of navigable waters by virtue of their transport of seeds and spores, vegetation, and invertebrates. Likewise, certain species that comprise part of the biological community of navigable waters may depend upon intermittent streams, floodplains, or geographically isolated wetlands during parts of their life cycle. Examples include salmon and trout that rely upon headwater streams for spawning, and waterfowl that breed in prairie potholes.

Were all studies examining connectivity included, or were only those that found evidence of connectivity used in the report? The latter is suggested by the description on page 2-1 "Approach", but it should be explicitly stated. If studies finding no evidence of connectivity were excluded, then the conclusions are subject to bias. Including the proportion of studies reporting specific results of interest would be very helpful in drawing conclusions from the report. Also, what was considered peer-reviewed literature? It appears that several government reports and conference proceedings were included as well. In addition, the literature review should be updated with recent references (i.e., late 2012 and 2013).

Depending upon how extensively the report is expected to be used by decision-makers and as a reference to support the regulatory process, the authors might consider organizing the material differently. As written, the volume of material made it easy for important points to get buried in the text. An alternative organization might be to state the main conclusion/finding as section headings (e.g., "Headwater streams have strong impacts on downstream waters") and then have key supporting lines of evidence elaborated below (perhaps even in bullet form). On a similar note, the case studies would be more effective if they were framed to address explicit questions, rather than relatively dense and descriptive accounts of different systems.

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.**

This was a comprehensive and nicely written overview.

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.

Is it appropriate to jointly consider ephemeral and intermittent waters, especially in the arid Southwest?

Is specific discussion of ditches used for agriculture and in road construction warranted?

The connectivity of headwaters and small tributaries to fish communities in downstream waters could be better emphasized. For many fishes (including economically important ones like trout and salmon), the headwaters provide the cold-water habitat required for spawning as well as refuge from disturbance.

p. 4-68 and 4-69, the text focuses on adaptations of insects to flow regime, but the link to connectivity is unclear.

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.

Supported, but it could use additional detail. The synthesis section about streams (p 4-35, line 25) states that "a substantial body of evidence unequivocally demonstrates connectivity…". Can this be quantified (e.g., >80% of studies reviewed).

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

The report would benefit from more discussion of forested wetlands, including bottomland hardwoods, given their ecological importance, rate of loss, and unique attributes.

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

Supported but could be better quantified or more specifically described.

Lentic systems: Wetlands and Open Waters with Potential for Unidirectional Hydrologic Flows to Rivers and Lakes, Including "Geographically Isolated Wetlands"

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.

Two fundamental principles that are key to evaluating the connectivity of geographically isolated wetlands are (1) the importance of watershed level processes and impacts and (2) the need to consider the effect of wetlands in aggregate. These principles could be better explained in the text.

Some of the language implies that unidirectional wetlands are less connected than bidirectional wetlands, but that is not necessarily the case.

When evaluating the biological integrity of navigable waters, it is critical to consider the full life cycle of migratory species. Many animals will use navigable waters during one period of the life cycle and then depend upon geographically isolated wetlands during another – even outside of the actual migratory period (ie., not when migrating proper). If the critical wetland habitats were lost, then the biological integrity of the navigable waters would be diminished. Waterfowl provide a powerful demonstration of the importance of geographically isolated wetlands to the biological integrity of downstream navigable waters. Migratory birds are part of the biological communities of navigable waters during specific times of their life cycle (e.g., nearly the entire population of Redheads winter in navigable waters of Texas). Because many of these same species are dependent upon prairie potholes for breeding habitat, loss of pothole wetlands would result in the loss of certain waterfowl from the navigable waters. Similar examples exist for amphibians and fish.

Do arctic systems (e.g., permafrost wetlands in Alaska) need separate discussion given their unique attributes?

P. 5-32, lines 14-16: the authors interpret a pattern whereby closer wetlands have more similar plant communities than more widely separated wetlands as evidence of connectivity. However, the pattern might also result from similar microclimates, soils, or other environmental attributes.

Table 5-3 lacks the references to particular sections of the report that were included in other tables.

p. 5-60, lines 30-34: the information about waterfowl and other taxa using prairie potholes has not been conceptually linked in the text. The link should be made explicit.

p. 6-2, line 15 specifies hydrologic connectivity, but the definition used in the report indicates that connectivity can arise from physical or biotic mechanisms.

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

The language used in the conclusions seemed weak relative to the amount of discussion and number of studies described that demonstrated connectivity.

The conclusions about unidirectional, geographically isolated wetlands seem to emphasize connectivity from a hydrologic perspective, rather than a biological one and also in terms of functional connectivity. For example, capture and storage of nutrients, sediments, and contaminants in hydrologically-isolated wetlands would affect the functioning of the downstream waters.

Ecologists have long recognized the importance of a systems approach to science and management. Although some geographically isolated wetlands may not be amenable to generalization, there are certain ecosystems comprised of geographically isolated wetlands where the degree of connectivity can be generalized. Prairie pothole and playa lake ecosystems are examples of systems where the wetlands should be considered in aggregate as components of a larger functional ecosystem tha timpacts navigable waters.

Dr. Emma Rosi-Marshall

Initial Response to Charge Questions

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Charge Question 1. Overall impressions of the clarity and technical accuracy of EPA's draft Report.

Overall this report provides substantial review of the current scientific literature and documents the links between headwater and wetland systems to downstream waters. The report is technically accurate and is well organized. The "Key Findings" of the report are supported by available science and are credible. The characterization the headwater and wetland systems are connected to downstream waters via hydrological, chemical and biological connections is well grounded in the scientific understanding of these systems. The draft report provides a literature review and case studies to describe scientific findings that demonstrate these connections.

Charge Question 2. Comments on the clarity, technical accuracy, and usefulness of the conceptual framework describing the hydrologic elements of a watershed and the physical, chemical, and biological connections linking these elements.

The conceptual framework presented in the document describes the connectivity of waters via hydrological, chemical, and biological connections. This framework is appropriate and based on the current scientific understanding of the numerous connections among these ecosystems. It is scientifically valid to describe multiple facets that connect these ecosystems and the report appropriately reviews studies that demonstrate the hydrological, chemical and biological connections that occur.

The presentation of river ecosystem components and the definitions provided are well grounded in the current science. The figures to illustrate these connections are effective and are based on current understanding of these systems.

There is more available literature on some of these connections than was cited in Table 3-1. This table provides examples of the functions by which streams and wetlands influence material flux to downstream waters. The functions described in column 1 are appropriate, but the examples provided in Column 3 could be greatly expanded with literature cited later in the report or additional review of the literature.

The text of the report appropriately emphasizes that time and space should be considered;

however, the section on Spatial and Temporal variability of connectivity would benefit from some additional clarification. It would be very useful to provide additional review of the scientific literature to clarify how/whether the extent to which these systems are connected in space and time to downstream waters influences their connectivity overall.

Charge Question 3(a). Comments on EPA's review and characterization of the literature on the directional (downstream) connectivity and effects of ephemeral, intermittent, and perennial streams (including flow-though wetlands).

Chapter 4 of the USEPA Connectivity report discusses the hydrological, chemical, and biological connection between headwater streams and downstream waterbodies. The document uses a wide array of scientific literature to provide a review of these connections. The literature review that describes these three fundamental connections of headwaters to downstream systems is generally well supported.

On Page 4-2, the report highlights how headwater streams are scientifically defined and how many databases and topographic maps underestimate the number of headwater streams that occur in a basin. The report accurately describes the numerous scientific studies that demonstrate that headwater streams are largely not portrayed on standard topographic maps. An additional figure with a map to illustrate this point would be helpful.

The report provides adequate detail about the extent to which water inherently connects headwater streams to downstream waterbodies. The extent to which downstream discharge is comprised of water that originated or passed through headwater streams is accurately described and well supported with scientific literature. The report provides details about how the hydrology of downstream waterbodies is connected to headwater streams. The describes how even though headwater streams are periodically dry, over an annual cycle they can contribute a large fraction of the water in downstream ecosystems; however, this could be expanded in the text. In the current draft, there is not a specific paragraph that describes explicitly how ephemeral streams are linked with downstream flow, but this seems warranted in this section of the report.

The discussion of hydrologic dispersion was useful and presented definitions and examples from the literature. However, in its current form, this section of the report does not address what happens when headwater streams are altered (piped, filled in or when drainage is increased, e.g. via tile drainage). There is evidence in the literature to suggest that alterations in hydrologic flowpaths can have effects on the flow regime of downstream waterbodies and it seems appropriate to highlight these in this section of the report or refer back to specific sections of Chapter 3 that discuss this.

The paragraph about dams (line 14, page 4-11) is weakly supported by available literature. It has been long understood that dams disrupt the flow of sediments into downstream waters and it seems that this paragraph is suggesting that sediments from tributaries ameliorate this effect of dams on rivers. If this is indeed the intent of this paragraph, then it is necessary to provide a more extensive review of the available literature.

The text describing the influence of stream temperature on downstream ecosystems does not address the interactions between land use of headwater streams and temperature. Changes in headwater stream thermal regimes because of land use change may have a disproportionate affect on the temperature of downstream ecosystems. This section could be improved by additional consideration of changing land use in streams and the potential concomitant effects on downstream thermal regimes.

The paragraph on Line 18, Page 4-17 seems to be focused on the importance of underlying geology influencing nutrients in headwaters and consequently on downstream waters. The importance of geology to stream chemistry has been widely investigated and a more thorough review of this topic is warranted.

Charge Question 3(b). Comments on whether EPA's findings and conclusions concerning the directional (downstream) connectivity and effects of ephemeral, intermittent, and perennial streams (including flow-thorough wetlands) are supported by the available science.

The findings and conclusions on the directional connectivity are appropriate and sound.

Suggested rewording of Key Findings:

a. Change "only in direct response to precipitation" to "as a result of precipitation"

d. Suggest editing the sentence: "The connections formed by surface and subsurface streamflows act as a series of complex physical, chemical, and biological alterations that occur as materials move through different parts of the river ecosystem." To "As water moves through surface and subsurface streamflows materials in the water can be physically, chemically, and biologically altered." It would be also useful to highlight the important role for nutrient removal processes as well as nutrient spiraling in this section. For example, denitrification that occurs throughout a river network will result in nitrogen removal from the bioavailable pool and improve water quality.

Charge Question 4(a). Comments on EPA's review and characterization of 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.

The EPA's review covered appropriate topics and included relevant scientific literature. One shortcoming of the text in section 5.3.2.2 is the reliance on one article (Vidon et al. 2010). This article was one of only three articles referenced in this section, but this article has been cited 48 times since its publication and there may be other papers to include. It would also be worthwhile to include additional discussion of the evidence that riparian zones influence nitrogen removal.

The review is somewhat confusing about which areas are included in this section of the report. The introduction seems to include riparian/floodplain wetlands and the report includes a justification for a relatively broad inclusion of literatures that deals with riparian/floodplain wetlands on page 5-3. However, some of the literature included was conducted in the riparian zones of forested headwater streams (e.g. Section 5.3.2.4) and it is unclear from the Key Conclusions listed in Table 5-3 whether this section is focused on riparian/floodplain wetlands or riparian/floodplain zones in general. Including studies that focused on stream riparian zones may be appropriate, if the report is intended to cover all riparian zones. However, the introduction to this section indicates that it is focused on riparian and floodplain *wetlands* and that a broader review was needed to capture these systems that may have not been termed "wetlands". Additional details about the specific studies mentioned are needed to provide a context for whether a study represents a likely "riparian or floodplain wetland".

In general, additional clarification is needed to establish exactly what this section of the report is focused on and what is covered in the section about riparian/floodplain wetlands. If Figure 3-2 is the guide to this, then a riparian wetland is a wetland that is occurring adjacent to a river in the riparian zone. Therefore, review of literature about riparian zones adjacent to streams that are not wetlands may not be appropriate. Otherwise additional clarification is needed in the text of the review to highlight these studies and why they provide appropriate research that sheds light on riparian wetlands.

Charge Question 4(b). Comments on whether EPA's findings and conclusions concerning the directional (downstream) connectivity and effects of wetlands and certain open waters subject to non-tidal, bidirectional hydrologic flows with rivers and lakes are supported by the available science.

As mentioned in the answer to Charge Question 4(a), there is some confusion about the inclusion of riparian/floodplain areas in general versus riparian/floodplain wetlands in this section. The conclusions are presumably based on the review chapter on wetlands. The title "Riparian/Floodplain Waters" is broadly inclusive, but the "Conclusion 1.4.2. section" suggests by the first sentence that this section is about wetlands.

The conclusion fails to provide a clear scope of whether this section is considering all riparian/floodplain areas, or riparian/floodplain wetlands. This results in some confusion, especially considering that the details of review are found in Chapter 5 that is titled "Wetlands: physical, chemical..". For example, the Key Finding a. states that "Riparian areas act as buffers…" and in the second sentence focuses on "riparian wetlands". The additional sections refer to "riparian and floodplain areas". The report would benefit from a more explicit statement about what is being considered in this section of the report and more consistent use of terminology.

Charge Question 5(a). Comments on EPA's review and characterization of 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. (Section 5.4)

The EPA's review and characterization of this topic was based on the available literature, but the report points out that generalizing the effects of "unidirectional wetlands" may be limited by the literature available. The report provides the context for distinguishing between geographic isolation and lack of connectivity due to surface, subsurface flowpaths, links to groundwater and important biological connections. The report provides a review of the connections that exist between unidirectional wetlands and downstream waters.

Charge Question 5(b). Comments on whether EPA's findings and conclusions concerning 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 are supported by the available science.

The general findings about the role of "unidirectional wetlands" are sound. The wording on some of the key finding paragraphs should be tightened up. Unlike the other Key Findings listed in other sections of the report, these include more site-specific details from the literature that are described elsewhere in the report. The key findings should be general statements rather than specifics from the literature review. For example, in Key Finding a, the general statement about how water storage by wetlands can affect streamflow is supported by the literature presented in section 5.4. However, the subsequent sentences that focus on specific locations and studies are not appropriate here and the text should be more general. This is also the case for Key Finding b.

Dr. Jack Stanford

Jack Stanford's Comments on EPA Aquatic Connectivity Report

General comments

Overall, I think the report is darn good, given that it has to deal with almost all aspects of river and wetland ecology in order to nail down the fact that connectivity (and complexity, although that is not emphasized) is a foundational aspect of freshwater ecology. However, the report may be excessively long. A lot of the concepts are repeated to some extent in all of the chapters. This probably emerges from the fact that many people have written sections. I would give this thing to a committee of the three best editors in the field with a charge to shorten the text by 30% and more clearly state the main points and conclusions. I'd use boxed text to highlight key principles. The case studies are great but they are long because much of the conceptual material in the main chapters is reiterated in making the case and therefore it should be possible to substantially shorten them. However, again, it is much better than I expected and does the job in some ways that surprised me (e.g., inclusion of vernal ponds as an example of connected wetlands). Good job, I hope the workshop helps hone the message.

The summary is too long and has too many vague terms in it. For example I read the summary first and was really thrown by inclusion of vernal pools as connectors. I always considered them as totally isolated but I was enlightened by the text in Chapter 4. So, in the summary it is important to make it clear why vernal pools were used as examples of how seemingly isolated and seasonally watered pools are in fact influential on downstream waters. I have commented at length below. My main point is that the summary is what will be read by the pundits and it has to be written in less scientific language than the main body of the report. The key points need to be brief and hard hitting (not a verbatim repeat of what is given at length in the conclusions and discussion chapter (6). The current version is pretty short of the mark andneeds work. I hope my suggestions below will help.

The conceptual framework chapter works well for me with the exception that the 3 dimensional nature of all streams and rivers too routinely is omitted. I have pointed out key places that I recommend including text about the importance of groundwater flow paths (alluvial aquifers especially) as connectors and transformers in the longitudinal continuum. Also, the role of primary succession of woody vegetation on flood scoured surfaces is left out entirely. That must be corrected.

I endorse the segregation of directionality that is used throughout the report. That is a very good way to show that even seemingly isolated wetlands are connected structurally and functionally to downstream waters at least during wet periods. Chapter organization is fine and the review of the literature is sufficiently complete to underscore the main conclusions.

That said, the report is not very well organized and complete with respect to anthropogenic influences. In some sections human effects are explicitly referred to but in others it is notably missing. A main purpose of the report is to say that scientific world is unified on the fact that freshwaters are interconnected from ridge to reef and that interconnection clearly means that processes upstream strongly influence conditions in receiving waters downstream. This fundamental principle has big implications for management and conservation of freshwater. Perhaps human effects on connectivity merits its own chapter (so much for my recommendation to shorten the report however).

Specific comments.

Summary.

Page 1-2. Fig 1.1. Good one for the summary but extend the floodplains further upstream. Page 2-3 Line 33 Primary conclusion 2 – The role of water moving through the landscape via groundwater flow paths is the primary process by which wetlands and open waters are maintained. The flows usually are bi-directional over an annual hydrologic cycle. Without clarity that groundwater flux from channel, riparian and phreatic zones of the landscape is a primary connecting process, this conclusion is incomplete. The phrase “temporary storage of local groundwater that supports baseflow in rivers” does not provide the needed clarity because groundwater in shallow aquifers usually is permanent not temporary, although depth to water table and volume of the aquifer and its vadose and hyporheic zones may vary with climate hydrology. Also in this paragraph, for clarity eliminate the word “they” when referring to wetlands.

Page 1-4. Lines 8-14. This text seemly contradicts the opening statement of this primary conclusion or is at least not clear. What is a gradient of connectivity? The North Temperate Lakes LTER is a unidirectional wetland system with isolated seepage lakes connected by unidirectional flow paths and the research clearly shows that upstream processes and conditions strongly influence downstream conditions and processes. I think the last half of this conclusion starting at line 8 should be deleted and left for elaboration in the wetlands chapter.

Page 1-5 Line 27-30. This statement lacks sufficient clarity. What is meant by river “health?” I prefer “ecological (or biophysical) integrity” which is used pointedly in the discussion (Fig 6-1). But more importantly, flooding is a fundamental landscape forming process in rivers and riparian systems and even wetlands. Floods are not infrequent. Big floods are infrequent. The point is that floods move fine and coarse (small and large) sediment and wood around in ways that maintain a dynamic landscape (riverscape) structure and hence floods strongly control connectivity all points in the longitudinal hydraulic continuum above and below ground from ridges to the ocean. Temporary disconnections in the three dimensional flow paths simply add variance to the dynamic nature of river structure and function. Maintenance dynamic exchanges in 3D and through time is the foundation of connectivity and integrity in the context of this report (e.g., the 4 dimensional, self-organizing character of rivers, see (Ward 1989, Ward 1997)

Page 1-6, Line 13-22. The example here should focus on potential and actual removal of EXCESS nitrogen. I doubt there is ever a case where nitrogen flux is zero. Near zero perhaps, but not zero.

Page 1-9. Key Findings. e. Why do you not say that riparian zones of expansive river floodplains are hot spots of biodiversity? This should be highlighted I would think because there is lots of literature on the issue and biodiversity in a regional context at least arises from connectivity.
Page 1-10. Line 35 on. Same problem as described above for page 1-4. Text is repeated here and clarity is not improved. I think this contradiction should be removed from the summary. The issue is sufficiently described on 1-12, point e. Leave it at that.
Page 1-13. Line 17. This statement is confusing, what is meant by “outside the river” if they originate upstream (as said in the next sentence). Perhaps the idea is that rivers are drainage networks that move and transform materials that originate in the terrestrial landscape.
Page 1-14. Line 24. I think the term “vernal” is misused here. Such pools occur in swales all right but they are vernal because of the seasonality of hydrology. They fill in spring and are dry by midsummer. A little clarification needed. Also, this is the last paragraph in the summary andit lets the report sort of “die on the vine.” I suggest enlarging the text that starts at line 29 into a final paragraph that brings home connectivity in a watershed (catchment basin) context. That water quality and quantity at any point from the ridge to the ocean is in some way influenced by the sum of all interconnections upstream is the key point to leave with the reader.
Page 2-1. Introduction. Purpose and Scope. Seems fine. Points are clear.
Page 3-4. Line 28. Please add that terraces are surfaces that no longer receive floodwaters even during the highest contemporary flows. Or something like that. The word terrace is often badly misused in describing what should be described as riparian benches of expansive floodplains (see Stanford et al. 2005). In Figure 3-3 you correctly show a natural levee, I think. Trouble is that levee means man-made to most people. Not sure how to clarify except to say natural levee but they certainly are present on most unregulated rivers.
Page 3-13 Line 24. Bears carrying salmon into a riparian area is not a geochemical flux. Biophysical perhaps. The example is ok for the point you are trying to make, but include a geochemical example as well…wind blown sediments on floodplains perhaps?
Page 3-13. I have rarely seen an upland in a floodplain setting unless you mean a drumlin or some other glacial structure left in an outwash floodplain. Suggest some clarity here.
Page 3-17. Fig 3-8. Panel B is difficult to understand so don’t use it. I assume you mean the

rain fall event is as in panel a. Perhaps show a constrained channel and a floodplain in base and flood flow to give a better idea of expansion and contraction. Fig 3-12 works well.
Page 3-25. Line 8. Consider adding here that flux also is time dependent in that connectivity of lack of it can change in short time periods as emphasized above as expansion and contraction of the stream network in relation to flow events (or lack of them).
Page 3-27. Line 16. The ideas in this paragraph are re-iterated in the summary and my comments about excess N apply here as well.
Page 3-27. Define woody debris…. Drift wood?

Page 3-36. Fig 3-16. I understand that a playa is a shallow lake basin with no outlet, usually dry. An interior basin means that water flows into a lake with no outlet, like the Great Salt Lake. Ground water inputs do not dominate as shown in the figure. Clarify.
Page 3-41. Line 14. Add that water can be lost from the channel into the alluvial aquifer… very different than bank storage.
Page 3-43. Line 4. For example the likelihood that a prey organism will be killed by a predator increases with distance. Way you have it does not make sense.
Page 4-11. 4.3.3 (and on page 4-10, Line 9) This section is about wood recruitment into streams… this is drift wood. I have never liked calling it woody debris. But the section about DEAD wood as given here is ok, but what about live wood? Actually sediment transport in foodplain rivers is more influenced by plant succession on newly formed gravel bars than drift wood. Where is the section on LIVE WOOD?
Page 4-14 Line 26-30. Ebersole found cold patches that exceeded tolerances in summer? Does not make sense. You mean that he found cold patches from groundwater discharge (outwelling) in an otherwise very warm river during late summer. Ebersole and others found that spring brook streams from ground water outwelling in dry flood channels provided cool water to the main channel. This is related to my next comment.
Page 4-15. Line 19. This section on temperature needs a bit added about how temperature can vary dramatically across floodplains owing to gw-sw exchanges and varying water flux through lateral habitats that are only connected to the channel by hyporheic flux. Thus different physicalhabitats such as spring brooks and ponds on the floodplain usually have dramatic differences in temperature patterns which promotes productivity and biodiversity.
Page 4-16, Line 15-19. This paragraph is vague and probably wrong. The effect of tributary streams on mainstem river water temperatures…..tributary streams are often cooler than the main channel and can be important as refugia for mainstem biota. They are not constant temperatures unless they are springs.
Page 4-29. 4.5.1 Invertebrates. This section needs to include invertebrates contributed to downstream waters from alluvial aquifers (e.g., Stanford et al., 2005)
Page 4-31. 4.5.2. Fishes. This section needs to include a discussion of the importance of floodplain habitats such as spring brooks and ponds that juvenile fishes move into from the main channel (e.g., Eberle and Stanford 2010, cited in the report).
Page 4-33. 4.5.3. Genes. This section some considerations of human effects but anthropogenic influences were not included in the sections above, at least some pointed considerations of the influences of dams, diversions, pollution.
Page 4-34. 4.6 Streams:Synthesis. This section forgets to include the fundamental importance of gw-sw exchanges on physical, chemical and biological connectivity. It does not have to be long but it has to be there. Most of the sections above do include these considerations so the synthesis is not complete…. Also, since there is a synthesis section, I don't see the utility of an abstract. The paper is long enough as is.
Pages 4-38. The case studies are very well done and I like the selection because they are examples of perhaps the least connected systems but nonetheless underscore the main point of the report. However, given that big rivers are the main conduits of continental water, perhaps a large floodplain river should be included as an example to complete the

story. I would use the Columbia or one of its most studied tributaries, such as the Flathead. Or at least have a section on the book, Rivers of North America, as a summary of rivers nationwide. Most of the chapters in that book illustrate upstream downstream connections.

Page 5-2. 5.1 Abstract. Line 8. Riparian wetlands also are hydrologically (and biologically) connected to rivers via the alluvial aquifer. This is especially important on expansive floodplain rivers where the hyporheic zone is equivalent to the alluvial aquifer because the aquifer recharge is predominately from the river (see Stanford et al., 2005). But it exists to some extent on all rivers even though in small streams the flux is often thought of as bank storage. In any case, riparia do not exist without the presence of saturated bedsediments. Most of the wetland environments of floodplains are predominately maintained by groundwater flux from the river. Since you are including floodplains in this chapter as key wetland environments, the importance of the alluvial aquifer and water (and invertebrate) flux through the hyporheic zone must be referred to properly throughout this chapter down to 5.4.2 (this comment is not as germane to uni-directional wetlands). Processes in the alluvial aquifers influence temperatures, nutrient and pollutant concentrations, organic matter and biota in downstream waters. In the summary table

5-3, you need to add the phrase "above and below ground" in the appropriate summary sentences where connectivity is the point, e.g., point 1 – Riparian areas are highly connected to streams and

rivers above and below ground. I am biased but the best empirical citation for all of this is Stanford et al., 2005. Boulton et al. (2010) is a thorough review of most of these concepts and must be worked into the riparian portion of this chapter.

Page 6-1. Major Conclusions. This text is exactly as in the summary. Therefore the comments I have above about the summary also apply here. However, I recommend abstracting (short and hard hitting) the major conclusions in the summary and leaving the text intact here (but please note the comments given above).

Page 6-6. Figure 6-1. This is the most important figure in the paper. Do not leave a question mark in it when referring to metrics. Give some bullets to illustrate what they are and say in the legend that this is the area where research is needed. But, don't leave the impression that no metrics for integrity and resilience exist.

Page 6-7 End of the discussion. The discussion dies on the vine as I commented above about the summary. Something like this is needed at the end of the summary and at the end of the discussion in the report: The main point of this report is fundamentally that water runs downhill – above and below ground – creating the full range of aquatic habitats, including alluvial aquifers and saturated soils, inhabited by aquatic and semi-aquatic biota. All of these environments are interconnected via hydrologic and/or biotic flow paths that may be uni-directional (upstream to downstream) or bi-directional (direction of flows may reverse in time and space) as illustrated in Figure 6-1. But, in all cases, the science is very clear: biogeochemical structural and functional processes in upstream areas strongly determine outcomes in downstream environments. All riverine, lacustrine and wetland environments in one way or another are connected to downstream waters and must be managed in that context.

Boulton, A. J., T. Datry, T. Kasahara, M. Mutz, and J. A. Stanford. 2010. Ecology and management of the hyporheic zone: stream–groundwater interactions of running waters and their floodplains. Journal of North American Benthological Society **29**:20–40.

Stanford, J. A., M. S. Lorang, and F. R. Hauer. 2005. The shifting habitat mosaic of river ecosystems. Verh. Internat. Verein. Limnol. **29**:123–136.

Ward, J. V. 1989. The four-dimensional nature of lotic ecosystems. J. N. Am. Benthol. Soc. **8**:2–8.

Ward, J. V. 1997. An expansive perspective of riverine landscapes: pattern and process across scales. GAIA **6**:52–60.

Dr. Mazeika Sullivan

Preliminary Comments from Mazeika Sullivan
12.07.2013

I have provided preliminary overview comments and suggested discussion points for all technical charge questions. Additionally, I have provided detailed comments on Charge Question 4(b) (as assigned to me by the Panel Chair). I have included a small set of references along with my comments, but there are several additional papers that may help inform our discussion and I can provide these at the meeting. I have a number of minor editorial suggestions, which I can also provide at the meeting. As these are preliminary comments, I look forward to further discussion at the SAB Panel meeting (Dec. 16-18th, 2013) to formulate more definitive conclusions.

CHARGE QUESTION #1 - Overall Clarity and Technical Accuracy of the Draft Report

Overall, I found the draft document, "*Connectivity of Streams and Wetlands to Downstream Waters: A Review and Synthesis of the Scientific Evidence*" to be comprehensive and nicely organized. My first impression is that the review and synthesis of the literature is extensive and that the salient conclusions are generally defensible from a scientific perspective. Two major paradigms are presented in the review: (1) the watershed scale is the most appropriate context for addressing biological, chemical, and physical connections among water bodies, and (2) the effects of small water bodies in a watershed need to be considered in aggregate in order to understand their effects on downstream waters. These concepts are generally accurate and appropriate based on the available evidence. Relative to the first paradigm, I also suggest explicit consideration of the growing macroecological emphasis. In particular, more explicit treatment of macrosystem ecology could help place the concept of water body connectivity in appropriately broad spatiotemporal scales (see Thorp 2013). Relative to the second paradigm, we may also want to further consider the relative distribution of water bodies in the catchment as well as catchment shape and structural characteristics (e.g., drainage density), which might also be expected to be important relative to connectivity.

The categorization of wetlands (i.e., wetlands in unidirectional and bidirectional landscape settings) appears to be appropriate within the context of the report. We may want to discuss how these terms align with commonly used terminology in management, regulatory, and other relevant contexts.

Striking a balance between broad patterns of connectivity and site-specific, regional, and temporal variability in patterns is challenging, but my initial reaction is that the authors successfully draw on material from a broad variety of primary literature representing an extensive geographic scope, strengthening the generality of the findings. Nonetheless, we might consider further integrating data from high northern latitudes, urban systems, and less-disturbed systems into the report. The case studies nicely complement the broader thematic discussions, and help provide nuance to the broader themes addressed in the document.

As with any review of this nature where the body of literature is vast, there will always be potential omissions. I commend the authors on a thorough review, although there are instances where relevant references may be missing or the argument at hand may be overly dependent on a single/couple citation/s. We also may want to consider requesting additional detail related to the methodology used in the literature review, as this may help clarify the use of some literature that does not seem to be peer-reviewed (e.g.; Dahl 1990, Winter et al. 1998), as well as any other potential reference-related inconsistencies. In the Summary of Major Conclusions (P24-25), as well as elsewhere in the document, I encourage additional consideration of variability in biological connectivity across spatial scales. In particular, the review may benefit from further detail relative to birds and other organisms that spatially integrate the landscape (both within and among watersheds) more broadly. The importance of food webs to water body connectivity is stated early in the document and again in the Conclusions (P26, L8-9 and P235, L28-29 – "Similarly, aquatic food webs connect terrestrial, ecosystems, streams, wetlands, and downstream waters."), but we may want to consider a more explicit treatment of the mechanisms of food-web mediated connectivity in each of the major sections. I found the Major Conclusions (Sec 1.4) to be generally supported, although am prepared to offer additional perspectives at the Panel meeting.

CHARGE QUESTION #2 - Conceptual Framework: An Integrated, Systems Perspective of Watershed Structure and Function

My overall impression is that this section provides a useful context for the material presented in the following sections about the individual watershed components. The material is clearly presented with definitions provided (as well as in Appendix A: Glossary) to assist readers that may not be familiar with some of the technical terms. My initial reaction is that the material presented in this chapter is technically sound, with some points that could use additional clarification. I offer the following for consideration for further discussion:

1) P39, L17-18 – I would be interested in hearing the panel's thoughts on the variability of headwater stream definitions found in the literature (e.g., Meyer et al. 2007).
2) P42, L12-13 – I encourage further discussion relative the description of wetlands as "transitional areas between terrestrial and aquatic ecosystems". Although wetlands can experience spatial and temporal variability in features, it is my understanding that they can be viewed as aquatic ecosystems in their own right.
1) P68, L1-3: Organisms such as mammals, amphibians, and birds can also be vectors of contaminants from wetlands to rivers, even with hydrological isolation.
2) P84, L20: We may also want to note that lateral hydrological connectivity can increase riverscape diversity, not just create additional habitat for those taxa found in the mainstream (e.g., Sullivan and Watzin 2009).
3) P84, L31 – Perhaps explicit mention of non-aquatic taxa that link aquatic systems can be considered.
4) P85, L22-24 – The following statement may be somewhat misleading: "Upstream of large dams, riparian areas are permanently inundated, increasing lateral hydrologic connectivity." Although riparian areas upstream of impoundments may be inundated, this may not translate to functional connectivity, as found in systems with (more) natural flow regimes.
5) P87, L4 – Irrigation canals and ditches, common in agricultural landscapes can indeed provide connectivity among water bodies, but we may want to further address the quality and function of the link. The *actual* vs. *potential* function presented on P64 may be a helpful framework in which to do this.
6) P87, L22 – Also consider citing Stanley and Doyle (2002).

CHARGE QUESTION #3 (a and b): Lotic Systems: Ephemeral, Intermittent, and Perennial Streams

Overall, I found this section to be comprehensive and the literature clearly summarized. The case studies on prairie and southwestern streams contribute to refining the more general information presented in the earlier sections of this chapter and serve as examples of the variability that can exist in patterns of connectivity. I offer the following specific points for further consideration:

1) P94, L20-21 – We may want to consider the impacts of synchronous vs. asynchronous tributary flows/inputs on downstream systems.
2) P98, Sediment – Additional detail relating to the impacts of sediment loading on aquatic biota could strengthen the sediment discussion.
3) P99, L15-19 – Although transport distance of sediment after individual floods in ephemeral systems may not be linked to perennial rivers, it is my understanding that the cumulative impact of many floods could represent a significant sediment pulse to receiving systems.
4) I found the discussion on large wood to be light on the biological side, especially in terms of the habitat provided for certain life-stages of organisms and as refuge areas for various fishes.
5) P111, L11 – Benfield (1997) draws evidence from a variety of stream systems, including coniferous and deciduous. The variability in the contribution of organic matter among systems should be recognized.
6) P115-118, Contaminants – This section would benefit from a brief discussion of the role of organisms as biovectors of contaminants (Sullivan and Rodewald 2012).
7) P118 – We may want to discuss including examples of organisms besides fish and invertebrates in discussion of biological connections. For example, headwater streams are important habitat for birds such as the northern waterthrush, Louisiana waterthrush, and American dipper. Resident American dipper populations link headwater streams and rivers through seasonal movements: nesting (headwaters) and overwintering (rivers).
8) P118-120, Invertebrates – There is no discussion of biological connections via the adult life stage and subsequent aerial dispersal of aquatic insects (e.g., Bogan and Boersma 2012).

CHARGE QUESTION #4 (a and b): Lentic Systems: Wetlands and Open Waters with the Potential for Non-tidal, Bidirectional Hydrologic Flows with Rivers and Lakes

In general, I found this section to clearly outline how bidirectional wetlands are connected to streams and downstream water bodies and to be generally supported by the available science. However, my initial reaction was that the overlapping discussion between the role of riparian and floodplain wetlands and the role of purely riparian areas (i.e., irrespective if there are wetlands associated with them or not) could be clarified. For example, the discussion about inputs of large wood (P167, 3rd par) indicates that riparian vegetation (via inputs of wood) shapes stream geomorphology, but the specific contribution of wood from riparian and floodplain *wetlands* is unclear. I recognize that limiting the literature review to articles that describe the riparian area as a wetland would have been too restrictive (as explained on P162) and appreciate the authors' approach. Nonetheless, I wonder if further highlighting the specific contributions of bidirectional wetlands within the broader riparian framework may be a useful approach. Additionally, the location, size, and other physiographic characteristics of wetlands relative to the receiving system may be important in fully understanding their potential contribution to receiving waters. Lastly, we may want to consider more explicit treatment of forested wetlands (bottomland hardwood forests), as these wetlands represent a significant portion of remaining US wetlands.

<u>Table 5-1 (P163-164)</u>

- 7th Source Function bullet: Riparian/floodplain wetlands can also be sources of birds to downstream waters.
- 8th Source Function bullet: In addition to provisioning habitat for riverine organisms,

riparian/ floodplain wetlands can also increase fish community diversity.

- 1st Transformation Function bullet: It is my understanding that the production of methylmercury in waters largely occurs via transformation of oxidized mercury vs. elemental mercury.
- Lag function: We may want to consider an additional bullet to address potential changes in nutrient spiraling length affected by riparian/floodplain wetlands.

<u>The Physical Influence of Riparian Areas on Streams</u>

Hydrology

I suggest that we further discuss the residence time of water (also see similar comment relative to N and P, below). Powers et al. (2012) point out that aquatic ecosystem components that have relatively high nutrient processing rates may not contribute substantially to total ecosystem retention unless enabled by hydrological connections. The idea of biogeochemical hotspots (zones of disproportionately high nutrient reaction rates relative to surrounding matrix) has received significant attention (McClain et al. 2003), yet some hot spots may not contribute substantially to nutrient retention within the entire river network. Hotspots that are highly connected hydrologically to nutrient sources have an increased capacity (relative to poorly connected hotspots) to influence ecosystem-level nutrient retention and may alter nutrient transport.

Geomorphology (Sediment-Vegetation Dynamics)

P167, 1st par – In some landscape contexts, riparian wetlands may also functionally contribute to a reduction in main channel coarse substrate by reducing local flood flows and scour and leaving more fines in the channel (Riseng et al. 2011).

P167, L14-16 – The report states that streambanks that are devoid of vegetation can be susceptible to channel widening. It may also be relevant to note that herbaceous riparian vegetation (vs. forest) can stabilize stream banks and trap sediment, which leads to narrower channels than those found in forested reaches (Davies-Colley and Quinn 1998, Sweeney et al. 2004), but that these changes result in loss of in-stream habitat and ecosystem services.

Temperature and Sunlight

The statement, "Net primary productivity is greatest in open reaches and less in forested reaches …" (P168, L27-28) strikes me as being a bit overly generalized. We may want to consider adding the caveat, *all other features being similar.*

<u>The Chemical-Nutrient Influence of Riparian Areas of Streams</u>

Nitrogen and Phosphorus

It is my understanding that water residence time in riparian/floodplain wetlands can be an important factor in mediating nutrient fluxes to receiving waters. Powers et al. (2012) underscore that nutrient retention is the result of a balance among uptake efficiency, water residence time, and the strength of the hydrological connections between nutrient sinks and sources. We may also want to explicitly point out that the destruction of riparian wetlands has been shown to exacerbate nutrient loading from agricultural lands by reducing or eliminating riparian nutrient uptake, dentrification, and sedimentation of adsorbed phosphorus (e.g., Verhoeven et al. 2006).

Carbon and Allochthonous Inputs

My initial impression is that the evidence in this section may be strengthened by explicit consideration of alternative and/or complementary concepts to the longitudinally-based RCC. A number of concepts have been proposed (Townsend 1996, Thorp et al. 2006, Poole 2010). In particular, patch dynamics concepts that recognize discontinuous patterns have emerged with important potential implications for water-body connectivity (Montgomery 1999, Thorp et al. 2006, Poole 2010, Sullivan 2013). We may also want to consider additional vectors of additions of autochthonous material including wind and organisms (e.g., beaver).

Mercury
In addition to waste incineration and coal combustion as mercury sources to the atmosphere, we also may want to mention other sources that have recently been shown to be important (e.g., industrial processes, mining, and others). We may want to also mention the multiple pathways of heavy metal movement through food webs, including large-scale contaminant transport as well as other consumers affected by mercury.

<u>Biological Connections Between Riparian Areas and Streams</u>

P174, L10 – We may want to consider additional citations relative to importance of floodplains for fish.

Vascular Plants and Phytoplankton
P175, L20 – There are multiple other lines of evidence supporting effects of invasion by nonnative plants that we may want to consider.

P176, 1st par – The report states that "phytoplankton communities in river networks can be bolstered by high productivity conditions in temporarily connected floodplain wetlands." We might further consider the mechanisms and importance of this function. For example, in large river-floodplain systems, Tockner et al. (1999) present a conceptual model linking hydrology with ecological processes (floodplain shifts from a closed and primarily biologically controlled system, Phase I) to an increasingly open and more hydrologically controlled system (Phases II and III). Phase II exhibits high nutrient inputs to the floodplain and high water residence times and therefore favors the development of phytoplankton biomass ('primary production phase'). The 'transport phase' refers to short flood pulses above bankfull that move particulate matter between the floodplain and main channel.

Vertebrates
I suggest highlighting the role of vertebrates as nutrient movers between water bodies. For example, birds can be key movers of nutrients, plants (seeds), and invertebrates between wetlands (and downstream waters) across ranges of lateral and spatial connectivity. Green et al. (2008) suggest that birds are likely to be particularly important in facilitating the recolonization of invertebrates and plants with limited drought resistance in arid climates. Waterfowl play an important role in dispersal of organisms in aquatic environments via internal transport (Figuerola et al. 2003).

P177, 2nd par – We may want to consider moving this paragraph elsewhere (perhaps to introduction to *Biological Connections Between Riparian Areas and Streams*). The function of this paragraph is to illustrate that riparian/floodplain wetlands can influence stream integrity/health, which can be measured via multiple metrics beyond invertebrates. Also, a broader landscape perspective may be useful to consider. For example, Riseng et al. (2011) found that landscape context can be an important mediator of the influences of riparian/floodplain wetlands on stream biological integrity.

Invertebrates

My initial read leaves me with the impression that this section would benefit from a more bidirectional perspective, especially relative to river-to-wetland movement of organisms.

CHARGE QUESTION #5 (a and b): Lentic systems: Wetlands and Open Waters with Potential for Unidirectional Hydrologic Flows to Rivers and Lakes, Including "Geographically Isolated Wetlands"

As with previous sections, the authors drew from a variety of literature to support their conclusions. The case studies on oxbox lakes, Carolina and Delmarva bays, prairie potholes, and vernal pools offer important site- and/or regionally-specific details and incorporate a range of geographic perspectives for both wetlands in bidirectional and unidirectional settings. Relative to the discussion of surface-water connectivity (e.g., P181, L34), we might want to consider the implications of potential climatic shifts (temperature, precipitation). Additional points to consider relative to broader concepts of connectivity of unidirectional wetlands with downstream water bodies could be the predictable movement of birds from/to unidirectional wetlands, the potential importance of unidirectional wetlands to metapopulation dynamics and genetic diversity of biotic populations, and the potential role of mammals in connecting these wetlands with receiving systems. Lastly, the report appears to be somewhat ambiguous on the broader conclusions relative to unidirectional wetlands (e.g., P161, L8-22), which I propose we further discuss.

Synthesis and Conclusions

My overall impression of the Synthesis and Applications section (P196-201) is that it is perhaps a bit light in terms of biological connectivity (in particular, relative to organisms that may spatially integrate the landscape over larger spatial scales). I offer the following thoughts on Table 5.3 (P197-198):

- 1st Physical Connectivity and Function bullet – It may be important to note that the influence of riparian/floodplain wetlands is not a unidirectional influence, but that streams also influence riparian zones
- 4th Chemical Connectivity and Function bullet – I suggest we revisit this statement as increased turbidity in downstream reaches can decrease primary productivity and overland flood pulses can bring allochthonous material into the channel.

From my initial read, I think that the Conclusions and Discussion (P234-240) accurately reflect the material presented in the document and are largely defensible. For Conclusion #2 (P234), we may want to consider emphasizing that wetlands with bidirectional hydrologic exchanges are intimately linked to streams and rivers through biological connections (including integrated wetland-river food webs) that operate across a range of temporal and spatial scales. Also, we may want to more clearly distinguish between our current capabilities to measure and monitor ecologically-relevant connections and new tools and metrics that would enhance these capabilities (P240).

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Dr. Jennifer Tank

Preliminary Written Comments to Technical Charge Questions: *Connectivity of Streams and Wetlands to Downstream Waters*

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Charge Question 1. Overall impressions on the clarity and technical accuracy of EPA Draft Report.

General Comments: I found that the draft report on the physical, chemical, and biological connections of streams and wetlands to downstream waters to be accurate and clearly written. Using a comprehensive review, the report summarizes the body of peer-reviewed literature supporting the hydrological, chemical, and biological linkages between streams and wetlands to downstream waters.

Specific comments to strengthen and/or clarify text of section 1. Executive Summary: (specified as page number, followed by line numbers)
P1-6, L26-27: Brief mention of how connectivity changes over time with changing flow (e.g., storms, seasonality) is warranted here, rather than waiting until later (P1-13).
P1-8, L 25-27: An additional sentence explaining how excess nutrients lead to hypoxic conditions, through algal blooms, subsequent death and decomposition, is needed.
P1-9, L15: "Riparian area" could be replaced by "Riparian floodplains/wetlands" to be more precise.
P1-12, L1-3: Summary statement on conclusions about unidirectional wetlands for nutrient removal and reduction and attenuation on flooding (P1-13, L35-36) suggest string evidence for connectivity and yet these seem contradictory to earlier statements on inconclusive nature of literature review (P1-10, L39).
P1-13, L10-15: Last half of 1st paragraph of the Closing Comments is very confusing and needs to be clarified.

Charge Question 2. Comments on the clarity, technical accuracy, and usefulness of the conceptual framework describing the hydrologic elements of a watershed and the physical, chemical, and biological connections linking these elements.

General Comments: The conceptual framework was clear, accurate, and provides a necessary foundation describing how water and materials move in a watershed. This context is integral for the subsequent detailed summary of the peer-reviewed literature regarding connectivity of streams, floodplain/riparian wetlands, and unidirectional wetlands. Additionally, the figures were useful in illustrating key concepts that are then referred to throughout the report. Finally, Table

3-1 was helpful in delineating the 5 major functions by which streams and wetlands alter material fluxes to downstream waters.

Specific comments to strengthen and/or clarify text of section 3. Conceptual Framework:
P3-2, L5-6: Minor clarification on the definition of channel: use of phrase "hampers the colonization and persistence of terrestrial vegetation" may be oversimplification. For example, vegetation such as annual grasses are often key primary producers in headwater streams and create the diffuse boundary between stream channel and riparian zone.
P3-9, L15-17: There should be some mention of the temporal variation in the delineation of saturated and unsaturated zones.
P3-14, L7-8: Inaccurate statement that denitrification in riparian zone "filters water" before it reaches the stream channel. Water with dissolved nitrate comes in contact with bioreactive soils/sediments in riparian zone and subsequent microbially-mediated denitrification can reduce nitrate concentrations.
P3-18, Fig. 3-9 and text on P3-16, L24-26: Legend for figure could be clarified as it is unclear whether panel C for headwater streams represents the sum of perennial and intermittent stream lengths. For text on P3-16, clarifying difference between intermittent and ephemeral which are combined in Panel B.
P3-25, L27-28: It would be accurate to include nutrients in this list materials carried by streams during high flows.
P3-27, L13-15: The paradox mentioned about degraded streams and wetlands getting more protection than less impacted systems is not clearly described; confusing as written.
P3-27, L28-30: These statements about frequency of material delivery and supposed effects are overgeneralizations and confusing.
P3-27, L35: Overstatement; replace "keystone" with "important" as salmon are not keystone species in all systems using accepted definition of keystone.
P3-29, L24: It would be helpful to add "requiring the use of watershed modelling approaches" to the end of this sentence about quantitative assessment of the roles of streams and wetlands on downstream export.
P3-29, L28-32: The given example of a "lag effect" is somewhat confusing and not appropriately cited as it is not clear to me how cations convert DOM to FPOM. Perhaps using sediment retention or nutrient retention during pulsed storm events would be more conceptually straightforward?
P3-30, Fig 3-14: I agree that a conceptual figure about sequential transformation is useful but this figure is lacking in that it depicts mostly food webs, rather than the specifics about the transformation of material. Examples that could be more effective include CPOM (i.e., leaves) to FPOM and DOM or dissolved inorganic ammonium to N biomass in organisms and then excretion as DON.
P3-31, L19-25: The end of Section 3.3.2.1 Connectivity and Isolation could be better summarized compared to the current text, which is very confusing.
P3-31, L28-35; P3-32, L8-20: This text seems repetitive to previous text on hydrology; could omit or refine.
P3-33 L4-6: This section on connectivity ends with a lost opportunity to mention connectivity in context of nutrients and biogeochemistry and instead the previous paragraphs focus primarily on

organisms (termed "biota"), and only mention nutrient dynamics in these last lines with vague example about drying.
P3-34, Fig 3-15 and text P3-40, L3-6: Choice of 5 rivers to examine variation in annual runoff omits Midwest and Mississippi River Basin all together; consider adding two panels in middle of country to expand scope.
P3-35, L12-13 and P3-37, Fig 3-17: If you are going to mention human alterations (i.e., impermeable surfaces) then you should also mention the influence of agriculture on water flow. For example, flow regimes for headwater streams in the agricultural Midwest are strongly influenced by the prevalence of subsurface tile drainage and channelization, which causes significantly altered and "flashy" hydrographs. This example could also be added to text in Fig 3-17 legend.
P3-41, L11-29: This paragraph linking hydrologic connectivity and material transformations is awkward. For example (L16) water cannot be diluted, and the shift to coverage on material flow (L18) is also rough. These are important concepts and should be re-phrased for increased clarity, focusing on topic of section which is variation in the spatial distribution of headwaters.
P3-42, Fig 3-19: Not sure how useful this figure of "major basin shapes (n=2) is as stands. This would likely be considered an oversimplification by a fluvial geomorphologist and could be augmented to reflect current understanding.
P3-43, L3-7: Paragraph on biological connectivity seems out of place here and does not support previous or subsequent text.
P3-47, L5-8: The term "biota" is unclear to me here. Is this section summarizing "macro-biota" only? Microbes and their associated functions (production, assimilation, and transformation) are a significant part of biota as well. This should be clarified if term biota is being used differently here.
P3-48, L5: It would be helpful to separate the reduced connectivity examples from the example of enhanced connectivity as these are important concepts and they are getting lost in very long sentences. Also "piping" (L6) could be more accurately defined as tile drainage occurring in agricultural landscapes.
P3-50, L-1-2: This paragraph would be improved with a few sentences introducing how continuous wetland drainage is achieved through the installation of subsurface tile drains (as depicted in "artificial drainage" panel in Fig 3-21B. Tile drains are mentioned later in the report as well and would benefit from introduction.
P3-50, L-7: Insert "excess nutrients from fertilizer" after "(2) increases delivery of sediment" as they are currently not mentioned in the effects of enhanced hydrologic connectivity. This section could be enhanced with results from research has shown that agricultural drainage ditches are crucial links between fields and downstream receiving waters (Moore et al. 2011, Sharpley et al. 2007)
P3-50, L24-5: Also restoration of floodplains in formally channelized streams enhances ecosystem function (e.g., N removal via denitrification, Roley et al. 2012a, 2012b).

Charge Question 3(a). Comments on EPA's review and characterization of the literature on the directional (downstream) connectivity and effects of ephemeral, intermittent, and perennial streams.

General Comments: The review and characterization of the literature supporting the downstream connectivity of all streams, including perennial, intermittent and ephemeral systems, was generally clear, accurate, and provided strong support for their role in retaining, transforming, and transporting materials to downstream systems. Additionally, the case studies on arid southwestern and prairie streams emphasize the downstream connectivity of ephemeral/intermittent systems. The literature review could be strengthened through the addition of studies employing a watershed modeling approach to more effectively to support the summary of field studies. The report provided strong evidence that streams can act as both sinks and sources for nitrogen to downstream ecosystems, via assimilatory uptake, transformation, and export, but the their role in P cycling and stream metabolism of carbon (via primary production and community respiration) would add additional support for stream connectivity.

Specific comments to strengthen and/or clarify text of 4. Streams: physical, chemical and biological connections to rivers:
P4-1, L9-12: Phosphorus should also be added to this statement, both in source and sink examples.
P4-2, L34-35: IN noting that databases and maps do not accurately reflect true extent of headwaters, and thus these resources should not be used, it does not say what resources should be used as better alternative.
P4-4, L14-15: I don't know what "variation in river hydrologic response over space" means; consider rephrasing.
P4-6, L20-21 and P4-7, L9-10 then further explained in P4-8 L4 onwards: Consider introducing the idea of "variable residence times" earlier to explain why tracer dyes disperse as they move downstream. I don't think is only the effect of travel distance over larger spatial scales that causes dispersion, as noted on P4-8 L4.
P4-11, L1-2: I don't recall the definition for symmetry ratio being presented earlier; perhaps it should be presented here.
P4-11, L29-32: Wood also provides a substrate for potentially important microbial biofilms for nutrient uptake and as a food resource for higher trophic levels (e.g., Tank and Webster 1998, Eggert and Wallace 2007).
P4-16, L25-35: This paragraph introducing nutrients as examples of how streams and rivers are chemically connected relies heavily on Alexander et al 2000 and 2007 which focus on results from the SPARROW model. To demonstrate breadth of the literature review, other modeling studies examining same topic but used contrasting modeling approaches should also be reported (e.g., Seitzinger et al. 2002, Donner et al. 2004, Wollheim et al 2006, Wollheim et al. 2008).
P4-17, L24-27: Concentrations in uM should be converted to ug/L to be consistent with the rest of the report.
P4-18, L19-23: The characterization of the LINXI study (Lotic Intersite Nitrogen eXperiments, as summarized in Peterson et al. 2001, and site-specific studies contained therein) could be improved in this text. Stable isotope tracer additions using ^{15}N-NH_4 in 12 streams located in different biomes were used to demonstrate how ammonium in headwaters streams is efficiently retained (via assimilatory uptake) and transformed (via nitrification).
P4-19, L1-6: Again, the characterization of the results from the Helton et al. 2011 paper could be refined, as currently the description distracts from, rather than supports, the nutrient connection

between headwaters and rivers. Helton et al. reports on the results from a network model parameterized using empirical measurements of nitrate removal using $^{15}N\text{-}NO_3$ tracer additions as part of the LINXII study (reported in Mulholland et al. 2008), combined with synoptic sampling of nitrate concentrations in 8 watersheds with varying land-use conditions. The results from the modeling effort suggested that it is important to include interactions with the floodplain, wetlands, riparian zone and hyporheic zone in order to accurately predict nitrate export from watersheds.

P4-20, L9-17: It should be noted in the context of spiraling theory, nutrients are cycled, as well as transformed, multiple times as they move downstream; by mentioning only cycling, one loses the important role of transformation (as emphasized in Peterson et al. 2001) which is especially efficient in headwater streams with high bioreactive surface area to water volume ratios. As written now, the text in this paragraph does not link well with following that highlights transformations (L18).

P4-20, L31-33: It is erroneous to characterize the main result of nitrification as reducing the potential for ammonium toxicity, and that it only occurs in undisturbed streams. In fact microbially-mediated nitrification is ubiquitous in streams (Mulholland et al. 2000, Kemp and Dodds 2001, Strauss et al. 2002, Findlay and Sinsabaugh 2003, Starry et al. 2005) and is an integral link in the N cycle, providing substrate for the rate-limiting step (nitrate availability) for denitrification which is important permanent sink for N.

P4-21, L5-10: The role of denitrification in agriculturally impacted headwater streams needs to be clarified and the invoked role of altered hydrology is unclear. Microbial denitrification in agriculturally impacted streams is very high due to high nitrate availability along with anoxic conditions, and organic rich sediments (e.g., Mulholland et al 2008, Kemp and Dodds 2002, Bohlke et al. 2004, Laursen and Seitzinger 2004, Schaller et al. 2004, Inwood et al. 2005, Arango et al. 2007, Roley et al. 2012) Yet, although transformation rates are high, nitrate loads are usually excessive, and denitrification cannot keep pace with loading (as articulated in Royer et al. 2004). The effect of altered hydrology (tile-drainage and channelization) increases loading, but the term “through-put mode” as used in the text implies the biology is not functioning which is not the case.

P4-21, L11-17: The role of headwater streams as a source and sink for both dissolved and particulate phosphorus is not adequate. In this report only 2 studies are described; Meyer (1979) where a budget approach was used in a forested stream and Simmons (2010) reporting on sediment P dynamics in a stream with acid mine drainage. Significant contributions about the role of headwater streams in retaining dissolved phosphate should be described to bolster this section including Mulholland et al. 1990, Webster et al. 1991, Marti and Sabater 1996, Hall et al. 2002, Hall and Tank 2003.

P4-21, L35-36: In covering the dynamics of carbon processing along river networks, it would be good to include a diagram illustrating the River Continuum Concept (Vannote et al. 1980).

P4-22, L25-26: The mention of primary production here is the one and only place it is mentioned throughout and its role in carbon cycling as well as the fundamental link to nutrient cycling should be noted (e.g., Hall and Tank 2003). As written, mention of metabolism in headwater streams seems tacked on and unsupported and there is rich literature supporting this role (reviewed in Tank et al. 2010, meta-analysis in Marcarelli et al. 2011).

P4-22, L27-33: The role of microbial processing in the decomposition of organic matter, and subsequent role in supporting stream and river food webs could be described more clearly. As written references referring to processing or course and fine particulate organic matter are interspersed and the continuum concept is lost. Also some citation classics should be mentioned that provided foundation for these concepts (e.g., Minshall et al. 1983, Cummins 1974).
P4-23, L23-28: The role of increasing discharge on the estimation of spiraling length has not been discussed and has a strong influence via increasing velocities and depths associated with increasing size.
P4-25, L4-16: The conclusion paragraph on the importance of headwater streams on organic matter dynamics downstream river network could be improved. As presented, this paragraph is somewhat confusing and speculative.
P4-26, L4-14: Section 4.4.4 on Contaminants could be strengthened by adding breadth to the contaminants that are covered in this section. As presented, the section that would include discussion on contaminants from urban land sue (in this case wastewater treatment) is only mentioned in a single line with one reference (Rowan et al. 1995). The rest of the section (through P4-29) is devoted to contaminants from predominantly mining activities. Although the examples detailed are also excellent examples of connectivity, there is an opportunity to expand the contaminants section to include urban contaminants in general; for example a starting point for review of urban stream contaminants is given in Paul and Meyer 2011.
P4-29, L6: The section on contaminants would benefit from some concluding or summary statements.
P4-33, L18; Section 4.5.3 on Genes would benefit from a clarification of genes from what particular types of organisms are being described- on which organisms has this work been done? For example P4-34, L18: Statement refers to “stream populations”; what organisms are referred to here (e.g., fishes, macroinvertebrates)?
P4-35, L12: Paragraph on overland dispersal from headwater organisms to maintain genetic diversity at watershed scale could be expanded to include other studies; this is a rapidly growing area of interest (examples Krosch et al. 2011 and citations therein, MacNeale et al 2005).
P4-36, L15: “Nitrogen and carbon” should be replaced with “Nutrients” as the cycling of phosphorus from streams to rivers should not be omitted.
P 4-42, L28-33: It may be an overgeneralization to say that all streams and rivers in the central US contain elevated nutrient loads (as N and P); perhaps better to say “majority”?
P4-50, L1-2: Statement would be better placed in context if noted that headwater streams in the agricultural Midwest of MRB contribute even more of the N load to the Gulf of Mexico.
P4-66, L31: Section 4.8.5 on Other Southwestern Rivers is quite limited and could be expanded to better support the case study of the San Pedro River. Huge body of work on desert streams of southwest beginning way back with classics like Fisher et al 1982, Grimm 1987, Grimm 1988, to more recent publications like Fellows et al 2001, Sponseller and Fisher 2006.

Charge Question 3(b). Comments on whether EPA’s findings and conclusions concerning the directional (downstream) connectivity and effects of ephemeral, intermittent, and perennial streams are supported by the available science.

General Comments: In general, the document outlined strong scientific support for the conclusions concerning the connectivity of ephemeral, intermittent and perennial streams to downstream ecosystems via their role in retaining, transforming, and transporting materials. The case studies on prairie streams and arid streams of the southwest especially supported the downstream connectivity of ephemeral and intermittent streams.

Charge Question 4(a). Comments on EPA's review and characterization of 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.

General Comments: The review and characterization of the literature supporting the downstream connectivity of riparian and floodplain wetlands was generally clear, accurate, and provided strong support for their role in retaining, transforming, and transporting materials to downstream systems. The review could be improved by additional support from the literature quantifying the role of floodplains in mitigating downstream nutrient/sediment transport to rivers. The text that generally reviewed riparian zones could be narrowed to riparian wetlands in order to provide a more focused treatment and better understanding of the role of wetlands in the transport and retention of nutrients and other materials. In addition, the review on the role of wetlands/floodplains in processing, retaining and exporting carbon to downstream water bodies needs to be expanded, and should tap into a rich literature base that also covers dissolved organic matter dynamics.

Specific comments to strengthen and/or clarify text of section 5.3 Riparian and Floodplain Wetlands:

P5-6, L17: The restoration of the Kissimmee River and its associated floodplain habitats is a strong example of downstream linkages, but would be strengthened by inclusion of literature on the results of the restoration after 1995. A bibliography on the restoration with many publications is available at the South FL Water Mgmt Dist http://www.sfwmd.gov/portal/page/portal/xrepository/sfwmd_repository_pdf/kissim_bibliography2008.pdf

P5-9, L 25-34: The section on the influence of riparian shading on stream primary production is out of place and should be located in Section 4, perhaps to be included in the carbon cycling section or as a link between nutrients and carbon cycling. Additionally the text is limited to just a few references and could be expanded considerably. Suggestions are given in my comments above about P4-22, L25-26.

P5-10, L1: The introduction to section 5.3.2 could be clarified. It is unclear whether the following text focuses on riparian zones in general or riparian wetlands specifically. Additionally comments about links between hyporheic zone and riparian wetlands are unclear (L9). Finally, I would suggest that key processes known to be significant in wetlands (e.g., denitrification) should be mentioned specifically, not in vague terms like "redox reactions" (L17).

P5-11, L7: The section on nitrogen cycling in wetlands could be strengthened with a review of the role of floodplain and riparian wetlands on N cycling and export to downstream waters, rather than general riparian literature. The following citations (and citations therein) could be included to support the role of wetlands in cycling nitrogen, mostly via denitrification

(Hernandez and Mitsch 2007, Forshay and Stanley 2005, Fennessy and Cronk 1997, Hayock and Pinnay 1993, Mitsch and Gosselink 2000, Groffman et al. 1991, Jordan et al. 1993, Lowrance et al. 1984, Mayer et al. 2007, Roley et al. 2012).
P5-12, L4: The section on phosphorus cycling in wetlands could be strengthened with an expansion of the literature reviewed. The following citations (and citations therein) could be included to support the role of wetlands in cycling phosphorus (Craft and Casey 2000, Johnston et al 2001, Osborne and Kovacic 1993, Noe and Hupp 2005, Vought et al. 1994). In addition, some clarification about which studies examined the removal/cycling of particulate P vs. dissolved P in wetlands/floodplains would strengthen this section.
P5-13, L7-31: This section of text describes the dynamics of allochthonous inputs to streams and is not best placed in the wetland section. This text is better placed in the organic matter cycling section of section 4: streams. Thus the literature review on the role of wetlands/floodplains in processing, retaining and exporting carbon to downstream water bodies needs to be revisited, and should tap into a rich literature base including dissolved organic matter as well.
P5-18, L33-34: It is not clear how beaver dams have an effect on coho salmon and this statement could be expanded.
P5-19, L1-13: The example of the elk-mediated trophic cascade and its influence on riparian vegetation could be more succinctly stated in the Vertebrate section.
P5-20, L6-12: The summary of the results from Jenkins and Boulton (2003) are indented and numbered, which throughout the rest of the document, is reserved for section summaries or conclusions. Current formatting gives unnecessary weight to this study and points could be incorporate into normal text body.
P5-20, L26: Replace “riparian areas” with “floodplains/wetlands” to better reflect focus of section/task.

Charge Question 4(b). Comments on whether EPA’s findings and conclusions concerning the directional (downstream) connectivity and effects of wetlands and certain open waters subject to non-tidal, bidirectional hydrologic flows with rivers and lakes are supported by the available science.

General Comments: In general, the document outlined strong scientific support for the conclusions concerning the connectivity of riparian and floodplain wetlands to downstream ecosystems via their role in retaining, transforming, exchanging, and transporting materials which include nutrients, other chemicals, and organisms.

Charge Question 5(a). Comments on EPA’s review and characterization of 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.

General Comments: The review and characterization of the literature supporting the downstream connectivity of unidirectional wetlands was accurate and provided evidence that they influence downstream systems either through periodic connections or when isolated in the landscape. Additionally, they provide ecosystem services similar to those of bidirectional wetlands in that they retain, transform, and sometimes transport materials (including chemicals and organisms) to downstream systems.

Specific comments to strengthen and/or clarify text of section 5.4 Unidirectional Wetlands:
P5-27, L14: Avoid term “pollutant” here as nitrogen and phosphorus are only pollutants when occurring in excess of biological demand.
P5-27, L32: Does “Nitrogen” refer to particulate or organic N here? Otherwise it is redundant with ammonium and nitrate in list.
P5-28, L16: Mercury is not “created” by wetlands and should be reworded.
P5-28, L29-30: The statement about wetland-derived DOM having negative influence on downstream waters due to its interaction with contaminants is overstated- it occurs under certain conditions.

Charge Question 5(b). Comments on whether EPA’s findings and conclusions concerning 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 are supported by the available science.

General Comments: The document outlined scientific support that unidirectional wetlands are connected to downstream ecosystems through their functional attributes that benefit downstream ecosystems. They perform similar functions as bidirectional wetlands in that they retain, transform, and periodically transport water and materials. I did not agree with the conclusion that the scientific literature did not provide sufficient support regarding connectivity and feel this conclusion was somewhat in opposition to the literature review contained in section 5.4. In addition, the case studies of the Prairie Pothole Region and the Carolina and Delmarva Bays demonstrates times and places where unidirectional wetlands are connected to downstream systems, as well as times and places where isolation of these systems serves a beneficial function to downstream systems (e.g., dampening flood pulse during precipitation events).

Specific comments to strengthen and/or clarify text of section 5.5 Wetlands Synthesis and Implications and Sections 5.6-5.9 Case Studies:
P5-38, Table 5.3: The table could be improved by focusing more on the specifics functions of riparian wetlands and floodplains rather than including statements about riparian zones in general. Although valid, it distracts from support for specific linkages of wetlands by being overly general.
P5-40, L30: This paragraph surprised me as it seems to back-peddle on all that has been presented previously about the connectivity of unidirectional wetlands. The reviewed literature as presented provided times and places where connectivity was demonstrated clearly.
P5-41, L22-33: This text appears repetitive in that the points about how wetlands can be miscategorized as geographically isolated was just presented P5-46, L18. Restating in brief is preferable.

P5-51, Fig 5-1: A timescale for this figure should be included in the legend. Is this for present day?
P5-57, L18-20: This statement identifying a lack of connectivity seems to contradict the evidence presented as part of the case study.
P5-64, L19-21: It would be helpful to add that more empirical studies and monitoring data are needed in addition to modeling studies, particularly because these data are needed to parameterize models.
P5-73, L3-5: This is an important statement/topic about climate variation, but a citation is needed to support the statement.

Specific comments to strengthen and/or clarify text of section 6. Conclusions and Discussion:
P6-1, L36: Replace "playa lakes" with "ponded depressional wetlands" (e.g., Prairie Potholes and Carolina Bays) so as to include what was covered in the case studies. If vernal pools = playa lakes then their inclusion is redundant in list.
P6-2, L9-1: Previously stated disagreement with this conclusion.
P6-2, L14-15: Equivocal wording is confusing.
P6-2, L34-36: This is an unclear statement about the role of nutrient spiraling in linking streams and downstream ecosystems.

Dr. Maurice Valett

1) Overall Clarity and Technical Accuracy of the Draft Report

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.

Specific issues relevant to Chapters 1& 2:

A few technical issues exist in Chapter #1 that should be addressed:

Page 1-1, Line 20&21: The Executive Summary suggests the 'watershed scale' as 'appropriate' for the conceptual framework. At the same time, watershed is a confusing word that is used differently by different disciplines (e.g., watershed vs. catchment). Later (Page 1-1, Line 30) the report addresses
'landscape settings' relevant to wetlands. I propose that the 'landscape scale' is the more appropriate reference to use on Line 20&21 for reasons the report itself employs.

Page 1-3, Line 26&27: This line needs to be reworded as 'assimilation and transformation' do not in and of themselves alter 'nutrient loading' without specifically addressing the 'transformation' as a 'removal' process (e.g., denitrification).

Page 1-3, Lines 35-38: These lines argue that wetlands 'serve an important role' because of their influence as sinks for materials that could 'otherwise negatively impact' conditions. The importance of their role as a sink lies in their influence on the quantity and quality of materials supplied to downstream environments regardless of its 'good or bad' influence. The important thing is to note that 'sinks' alter fluxes that link elements of the drainage system. No 'good or bad' judgment is required.

Page 1-3 & 1-4 – Major Conclusion #3: The logic employed for the above argument is directly relevant to the conclusion reached for 'isolated' wetlands. Their role as a sink influences the magnitude and character of linkages to down-gradient elements of the landscape.

General Comments:

In general, I found the report to be well written, well organized, and informative. The review of the literature reflects a good deal of effort and a broad perspective.

I have deduced that the case studies were chosen to reflect conditions under which linking waters of interest to down-gradient system is comparatively problematic given temporal and spatial variability in the most visibly evident component of connection, i.e., water flow. The chosen examples are appropriate and logical. In general, those cases are well presented. I do feel, however, that a substantial body of work on semi-arid water ways relevant to the

connectivity issue has been overlooked. I am referring to the seminal work of SG Fisher and NB Grimm at Sycamore Creek, AZ. These efforts address the spatial and temporal character of nexus in a representative 'desert stream'. Accordingly, they are most appropriately applicable to Chapter #4 and I address them specifically in that section below. There I provide a series of suggestions
as to how their work is relevant to the issues of downstream connections in general, and how it pertains directly to intermittent system case studies.

Regarding the applicability of the literature reviewed, I did not find any literature cited or studies addressed to be 'irrelevant' and thus inappropriate. I did find some of the terminology employed to be initially puzzling, but more readily understood when addressed under the context of the wording employed by the rulings relevant to the CAB's charge.

The scope of the effort provided by the ORD is broad and daunting. Scientific assessment of all of the areas relevant for consideration does exist; it is evident, however, that the expressed interest suggests a broad need for continued funding for this work. The US harbors an extensive talent in this area. Its productivity and service to the government of the US, however, is under-utilized and it is ironic that the work is in place and eager to engage, but unable to do so based on short-sighted financial perspectives.

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

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.

Valett comments:

I found this chapter to be well constructed with arguments and conclusions strongly rooted in the literature presented. I have included some suggestions for inclusion and consideration below.

From the onset (Page 3-1, Line 10) the framework employs a 'systems' approach at a 'landscape' scale. I believe this to be a strength of the framework as the connections of interest can be viewed as 'emergent properties' not readily perceived at smaller scales.

Page 3-5, Lines 13-17: The definition of a wetland employed herein is consistent with that originally published by Cowardin in 1979 and again emphasized in Cowardin and Golet (1995) as used by the US Fish and Wildlife Service 1979 wetland classification protocol (Vegetatio

118:139-152). In the context of wetland management, therefor, the applied definition is appropriate.

Page 3-7: Here the conceptual framework identifies 'unidirectional' and 'bidirectional' conditions as
'landscape settings'. Such an approach employs a broader-based assessment of wetlands than is applied through wetland classification (See Page 3-8, Lines 11 & 12). As such, it avoids taxonomy and emphasizes 'function' with particular focus on connectivity. The report does a good job of avoiding circularity when addressing the extent and character of connection within these broad settings.

Page 3-8; Lines 27-35: The term 'geographically isolated' is identified here in the context of being surrounded by 'uplands'. With a strong scientific basis, the concept is rendered relatively inapplicable as the degree of 'isolation' is recognized to be a gradient without distinct 'categories'. As such, its usefulness is limited, but perhaps required given past terminology.

Page 3-25,Lines 1-11: While this paragraph makes the cogent argument that 'most' materials in a stream are provided 'from either the upstream river network or other components of the river system', this statement fails to recognize the influence of 'in-stream production' on many materials. That production is intimately coupled to the upstream supplies emphasized in this paragraph, but in many systems (e.g., deserts, prairies) in-stream production can be of comparable magnitude to other vectors of supply.

Page 3-25, Lines 18-21: Table 3-1 provides 5 robust functions through which streams and wetlands may link to downstream locations and conditions. This is a strong and well-argued approach to take. It is a strength of the conceptual framework. Clarification of 'potential function' is critical here as it pertains to protection under law and is an appropriate inclusion criterion.

Page 3-28, Lines 6-8: Emphasis on the combined influences of 'connectivity and function' is a strong basis
for the conceptual framework for the report. It combines the essence of many approaches to understanding the nature of linked systems (see Valett et al. 1996, Limnol. Oceanogr. 41:333-345).

3) 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.

Valett comments:

Chapter #4 is a strong chapter. It uses the literature well, but I have also identifed a a number of sources of work that need to be included here.

Page 4-4, Lines 14-34: Use of scaling laws here is a good way to address the 'regionalization' issues associated with generalizing characterizing connectivity. This may help with some sense of the magnitude of physical linkage.

Page 4-8; Line 5: Should be rewritten to read '...areas are characterized by *little* and highly variable...'. Low and high refer to elevation, despite popular usage.

Page 4-9, Lines 1&2: The interception of channel flow in semi-arid landscapes not only recharge alluvial aquifers but promote subsurface 'streams' that influence the structure and function of adjacent and downstream above-ground streams (Stanley, E. H., and H. M. Valett. 1992. Interactions between drying and the hyporheic zone. Troubled waters of the greenhouse earth. P. Firth & S.G. Fisher (eds.), pp.
234-249. edition. Springer Verlag,
New York.)

Page 4-18: 16-18: This area of research focuses on biological influences on chemical pattern and how these patterns reflect upstream-downstream linkages. This area of work was the focus of research by SG Fisher and NB Grimm in the Sycamore Creek watershed outside of Phoenix, AZ. There are a number of excellent papers produced by this group that are directly relevant to the issues addressed in this section of the report (i.e., Chapter 4). They should be presented in the numerous places that they are relevant. I will point them out as they occur in my review.

Lines 16-18: Dent et al. (1999; Dent, C. L., and N. B. Grimm. 1999. Spatial Heterogeneity of Stream Water Nutrient Concentrations over successional time. Ecology **80(7)**:2283-229) use geospatial statistics to show how longitudinal linkages in chemical structure vary with season and discharge in Sycamore Creek.

Page 4-19; Lines 29-31: The contention that the spiral length can be represented by the 'uptake length' is good only for systems where most of the nutrient in transport is inorganic. Not good for larger systems, nor those that are more autotrophic in character.

Page 4-20, Lines 11 & 12: Cycling tends to accumulate organic forms that are transported long distances compared to inorganic forms (i.e., nutrient in organic form are less labile than inorganic forms). This is really true when comparing small organic particles (and their associated nutrients) with inorganic dissolved solutes (Webster, J. R., E. F. Benfield, T. P. Ehrman, M. A. Schaeffer, J. L. Tank, J. J. Hutchens, and D. J. D'angelo. 1999. What happens to allochthonous material that falls into streams? A synthesis of new and published information from Coweeta. Freshwater Biology **41**:687-705.).

Page 4-20; Line 26: This is true for some conditions, but as indicated the increased storage is temporary and steady-state must occur both logically and as expressed by mass-balance. We showed how this characterizes most headwater systems and thus necessitates downstream linkage (Brookshire, E.N., **H.M. Valett**, and S. Gerber. 2009. Maintenance of terrestrial nutrient loss signatures during in-stream transport. Ecology. 90:293-299).

Page 4-26 – Contaminants: Shouldn't there be some 'rotenone' examples in here? I am sure they will illustrate linkage. Wiley, R. W. 2008. The 1962 Rotenone Treatment of the Green River, Wyoming and Utah, Revisited: Lessons Learned. Fisheries **33**:611-617.

Page 4-27: Metals literature is really important here. More longitudinal studies exist that help with this argument. Will Clement's work on the Arkansas showed longitudinal linkage to inputs and Bryant Kimball and Rob Runkel's work on synoptic sampling (Kimball, B. A., R. L. Runkel, K. Walton-Day, and K. E. Bencala. 2002. Assessment of metal loads in watersheds affected by acid mine drainage by using tracer injection and synoptic sampling: Cement Creek, Colorado, USA. Applied Geochemistry **17**:1183-1207.; Runkel, R. L., and B. A. Kimball. 2002. Evaluating remedial alternatives for an acid mine drainage stream: application of a reactive transport model. Environmental Science & Technology **36**:1093-1101.)

Page 4-30; Line 12: This statement is not well constructed. Populations do not 'compensate' for anything. Rewording is necessary.

Page 4-34; Lines 24-28: Sokol et al. 2011 (Sokol, E. R., E. F. Benfield, L. K. Belden, and H. M. Valett.
2011. The assembly of ecological communities inferred form taxonomic and functional composition. American Naturalist **177**:630-644.) showed linkage among aquatic invertebrates across multiple watersheds.

Page 4-35; Lines 17-22: Data exist on the distances over which organisms are genetically linked in stream systems (Bunn, S.E. and J.M. Hughes 1997. Dispersal and recruitment in streams: evidence from genetic studies. Journal of the North American Benthological Society. 16:338-346.

Page 4-37; Table 4-1: Source function should include 'disturbance' in the sense that streams are the origin of down-gradient floods that act, not just as floods, but as agents of disturbance. See comments on page #6 of this document.

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.

Section 1.4.1 provides six ‘key findings’ related to the topic of *connectivity and effects of ephemeral, intermittent, and perennial streams.* In ascending order: 1) stream are hydrologically linked to downstream waters – This finding is very well documented by the literature reported; 2) Headwaters convey flow into temporary storage zones that support base flow at later times – This pattern of behavior is well documented in the literature and is frequently addressed using ‘transient’ modeling to show temporary accumulation of water in alluvial storage associated with headwater stream behavior (e.g., Wroblicky, G. J., M. E. Campana, H. M. Valett, and C. N. Dahm. 1998. Seasonal Variation in Surface-subsurface Water Exchange and Lateral Hyporheic Area of Two Stream-aquifer Systems. Water Resources Research **34**:317-328.). The Wroblicky et al 1998 work is in semi-arid headwater streams in New Mexico. 3) Infrequent flows are important in transmitting materials – Work in semi-arid systems like Sycamore Creek, AZ shows how material accumulates between floods, but is then transported to downstream reaches during infrequent, high-magnitude flows (Fisher, S. G., L. G. Gray, N. B. Grimm, and D. E. Busch. 1982. Temporal succession in a desert stream ecosystem following flash flooding. Ecological Monographs **43**:421-439.) 4) Linkage provides opportunity for sequential processing – This is solidly rooted in the nutrient spiraling concept as described. 5) Headwater streams act as sources and/or sinks of N – This finding is very well documented across space and time in studies of lotic ecosystems in multiple countries and biomes. 6) Headwater streams are critical habitat for organisms capable of moving throughout the riverscape– This is the observation that started the field of stream ecology and remains central to many of its ideas.

One critical component of the ecology of prairie and semi-arid systems, and of lotic systems in general, that is not particularly well fleshed out relates to the implications of disturbance for longitudinal linkage and, in particular, the role of floods in this regard. The idea is addressed on Page 4-10, Line 5 when the report points out that ‘during disturbance’ small streams may have large effects on rivers. That should really read ‘during flooding’. On the other hand, the theory of ‘disturbance ecology’ suggests that systems ‘open up’ as the result of disturbance and those disturbance effects are carried greater distances downstream (Likens et al. 1978). Those disturbances can arise from outside of the system (as mentioned in the report for wood recruitment, Pages 4-9 to 4-11), but in the case of flooding the influences are two-fold:
1) the creation of a very strong down-gradient linkage vector, and 2) the removal of biological processes responsible for retaining materials....and thus shortening the scope of downstream linkage (e.g., shorter spiraling or processing lengths). These ideas are central to research on Sycamore Creek and can be found in Grimm (1987; Grimm, N. B. 1987. Nitrogen dynamics during succession in a desert stream. Ecology **68**:1157-1170), Marti et al. (1997: Marti, E., N. B. Grimm, and S. G. Fisher. 1997. Pre- and post-flood retention efficiency of nitrogen in a Sonoran Desert stream. Journal of the North American Benthological Society **16**:805-819), and Fisher et al. 1989 (Fisher, S. G., N. B. Grimm, E. Marti, R. M. Holmes, and J. B. Jones. 1998. Material Spiraling in Stream Corridors: A Telescoping Ecosystem Model. Ecosystems **1**:19-34) and Fisher (2004; Fisher, S. G., R. A. Sponseller, and J. B. Heffernan. 2004. Horizons in stream biogeochemistry: Flowpaths to progress. Ecology **85**:2369–2379.

In general, the linkage that occurs during flooding seems to be underrepresented herein. Surely there are examples of downstream erosion and or deposition that can be added to the notion of flood wave transmission. The idea that water from headwater streams causes disturbance in larger systems is a substantial example of linkage.

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

Valett comments:

I though this chapter was well constructued and organized. I agree with the logic behind these 'types'. I agree with the broadly based decision to address 'landscape settings'as an approach to understanding, or perhaps more accurately, addressing the distinction applied to wetlands found within the active channel (i.e., that zone flooded annually by a flow of some specified recurrence interval) and those that occur outside of this realm. I, again, think that the issue of disturbance is relevant here. I recognize, however, that these ideas (succession and linkage changes during biotic recovery) are less well developed for wetlands in comparison to streams or rivers.

Page 5-3; Line 33&34: I think the decision to survey broadly the riparian literature is strongly justifiable. Indeed, the riparian zone began as a unit studied by botanists; it is now addressed by biogeochemists, hydrologists, engineers, and ecologist without being characterized as a 'wetland'. This fact does not reflect whether it actually serves as a wetland.

Page 5-6 & 5-7: The role of wetland storage of water is well described here within the stream network. Would it help to broaden this perspective and recognize that this is an established function for wetlands in all settings (e.g., coastal wetlands and storm surges)?

Page 5-7; Lines 32-34: The classic paper for this is Peterjohn and Correll (1984). It isn't quoted until much later (Page 5-11, Line 15).

Page 5-8, Lines 3-10: A recent paper by Noe et al. (2013; Noe, G. B., C. R. Hupp, and N. B. Rybicki. 2013. Hydrogeomorphology Influences Soil Nitrogen and Phosphorus Mineralization in Floodplain Wetlands. Ecosystems **16**:75-94) is an excellent study showing the sediment retention process for a river in Virginia. Should be added here.

Page 5-9, Line 33: This is poorly worded. Limiting to 'what'? How about 'Shading can cause light availability to limit rates of primary productivity in streams (....'

Page 5-10; Line 33: Again, the classic is Peterjohn and Correll (1984).

Page 5-11: Nitrogen – For whatever reason, discussion of the 'riparian wetlands' in respect to N has focused almost entirely on sub-surface influences. Innundation of the floodplain during high flows and the retention of N (and P) at this time is a critical part of the story. This is true throughout the drainage as
'floodplains' occur in a scaled manner along the continuum. Valett et al. (2005) illustrate how a floodplain does this for the Rio Grande using nutrient budgets. The same process happens in headwater systems as
shown by Brookshire and Cwyer (2003) for riparian wetlands in low-order systems of Oregon (Brookshire, E. N. J., and K. A. Dwire. 2003. Controls on patterns of coarse organic particle retention in headwater streams. Journal of the North American Benthological Society **22**:17-34).

Page 5-11; Lines 3&4: The better reference for DOC pulse from autumnal leaves is Lush, D. L., and H. B. N. Hynes. 1978. The uptake of dissolved organic matter by a small spring stream. Hydrobiologia
60:271-275.

Page 5-11; Line 4: Better reference for water quality management is Naiman and DeCamps (1990) and certainly Vidon et al. (2010) since the terms are in the title.

Page 5-11; Lines 30-36: Vidon et al. (2010) seems to be referenced a great deal in the context of subsurface nutrient removal. There is a broad and varied literature to pull from here. This seems like the wrong place to be referencing a review article.

Hyporheic zones associated with floodplains are lost somewhere between Chapters 4 & 5. This is true for a great deal of work that addresses 'near-stream' flow paths that penetrate riparian systems. Stanford and Ward (1988) point out that the entire alluvial aquifer of the Flathead River is part of the hyporheic zone and is part of the floodplain wetland. Where does that literature get fit into this perspective of riparian zones?

Page 5-12; Lines 34 & 35: Maybe I am missing something here regarding the reduction of terminal electron acceptors. In any case, the sentence seems to suggest that liberation of carbon dioxide results in more alkaline conditions. Doesn't seem correct.

Page 5-13; Lines 25-31: Declining riparian C inputs co-occur with enhanced floodplain interaction.

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

Valett comments:

Across the board, I find these to be conservative and appropriate conclusions derived from Chapter 5's address of bi-directional wetlands (i.e. Section 1.4.2).

5) Lentic systems: Wetlands and Open Waters with Potential for Unidirectional Hydrologic Flows to Rivers and Lakes, Including "Geographically Isolated Wetlands"

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.

Valett comments:

This is a good section addressing an important landscape setting for wetlands. The links described rely on integration and distinction (i.e., isolation and uniqueness). It would be easy to say that those without strong material flows are not 'connected', but the connections occur in altering critical material budgets for down-gradient systems. In this way, the links contain 'information', a historical currency for systems assessment.

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

Valett comments:

The conclusions offered in Section 1.4.3 accurately portray the findings of the literature provided in Chapter 5's assessment of unidirectional wetlands. I again state my support for the 'landscape' perspective employed in this context. Key Finding (a) points out that 'isolated' wetlands are often ‘connected’ and influence transmission of flood waters. Importantly, finding (d) addressing the issue of ‘isolation’ and makes the distinction between geographic and ‘functional’ isolation. Finally, Finding (f) is an important point to keep in mind. The nexus that exists for a complex of ‘isolated’ elements may occur at a very different scale than is expected from behavior of those individual elements. This is a critical point for all assessment of linkage between and among elements of a larger system (e.g., wetlands and tributaries within a broader drainage system).

Dr. Ellen Wohl

Wohl preliminary written comments in response to charge question 3(b)

The EPA's findings and conclusions concerning directional (downstream) connectivity and the effects of ephemeral, intermittent and perennial streams, as stated in section 1.4.1, are very thorough, clearly written, and supported by the available science. I do not have any alternative wording to suggest for any conclusions or findings. On the contrary, I believe that this portion of the text represents an excellent balance between being concise, and thoroughly and carefully explaining the available science and the implications of that science in terms of understanding the effects of ephemeral, intermittent and perennial streams on directional connectivity