ATTACHMENT D

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A Scientific Response to EPA's Conclusion that Restoration of the Housatonic Rest of River Will Be Fully Effective and Reliable

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September 26, 2014

1. INTRODUCTION

EPA's "Comparative Analysis of Remedial Alternatives" for the Housatonic Rest of River inaccurately portrays ecosystem restoration as a straightforward undertaking with predictable results, as summarized in these three sentences (p. 26, lines 31-36):

"There is a significant body of knowledge with respect to ecosystem restoration that documents the ability to reestablish the pre-remediation conditions and functions of the affected habitats (see Appendix D of the 2011 Site Information Package). Accordingly, restoration is expected to be fully effective and reliable in returning these habitats, including vernal pool habitat, to their pre-remediation state. As a result, the likelihood of effective restoration is equal under any of the alternatives."

This document explains why EPA's claims about the effectiveness and reliability of ecological restoration are inconsistent with what we know about the limitations of this endeavor, especially in a complex ecosystem like that of the Housatonic Rest of River. We provide a detailed critique of Attachment 12 to the Comparative Analysis (which was Appendix D to the EPA's Region's 2011 Site Information Package and is referred to herein as EPA's Appendix D), including a shorter critique of Attachment 11 to the Comparative Analysis. We also include as exhibits to this document a number of papers on ecosystem restoration.

First, we will provide a brief overview of our perspective on this topic by parsing the four elements of EPA's conclusion repeated above and responding to each.

1. *"There is a significant body of knowledge with respect to ecosystem restoration..."*

We generally agree. With over 10,000 scientific articles on the topic, and three specialty journals steadily publishing more research, this is a reasonably well-studied discipline. However, it is notable that it is also a fairly young discipline with virtually no published research before 1990, and over 90% of the articles published on the topic since 2000. This significantly constrains the ability to assess the long-term efficacy of restoration projects to date. It is notable that three major review articles regarding the attempted restoration of wetlands, rivers, and vernal pools have been produced recently (Moreno-Mateo et al. 2012, Palmer et al. in press, Calhoun et al. 2014, respectively) that provide a fairly comprehensive overview of relevant issues.

2. *"[This literature] documents the ability to reestablish the pre-remediation conditions and functions of the affected habitats."*

This statement implies that the ability to reestablish ecosystems is well-founded, but that is inconsistent with the body of knowledge referenced above. A better generalization would be that ecosystem restoration can improve the structure and function of degraded ecosystems and can occasionally, under the right circumstances, re-establish some approximation of the previous ecosystem. We will show that EPA's own statements contradict its claim that it is feasible to re-establish the pre-remediation conditions and functions of critically important elements of the Rest of River ecosystem, such as mature forests, vernal pools, and river dynamism.

3. *"Accordingly, restoration is expected to be fully effective and reliable in returning these habitats, including vernal pool habitat, to their pre-remediation state."*

We will also show that this statement is inaccurate and unsupported by the very body of knowledge to which EPA refers. At best it would be reasonable to say that restoration may be partly effective at returning some types of habitats to some semblance of their pre-remediation state after an extended period that cannot be predicted with any certainty.

4. *"As a result, the likelihood of effective restoration is equal under any of the alternatives."*

This statement is illogical unless you accept the premise that restoration is perfectly effective, and we will show that this is not the case. Because the impacts of the Rest of River remediation alternatives differ greatly and the required restoration will be far less than perfect, the ultimate result – that is, the extent and degree of ecosystem alteration – would differ markedly depending on the alternative selected and its impacts.

2. CRITIQUE OF EPA'S APPENDIX D (ATTACHMENT 12 TO COMPARATIVE ANALYSIS): RIVER AND FLOODPLAIN RESTORATION

2.1 RESTORATION TRAJECTORY – RESTORING THE FUTURE

Section 2.1 of EPA's Appendix D states (p.1 lines 31-35): *"Active ecological restoration 'sets the stage' for natural, passive restoration processes to take over, and can reduce the time needed for recovery from many decades to that of years."*

This generalization is misleading because the time frame for "recovery" depends very much on the type of ecosystem in question and can range into centuries for forests like those at the center of the Rest of River ecosystem in which large trees, snags, and logs are key components

(Lindenmayer et al 2012). Certainly ecosystem restoration can accelerate recovery, sometimes significantly, but there are important limitations. For example, one might subtract only 10 years from the 100-200 years it takes to grow a very large silver maple by planting a sapling rather than waiting for seed-based recruitment. In any event, as Fig. 1 (copied from EPA's own Appendix D) makes clear, the term "restoration" is a bit of a misnomer because the "ecological restoration" results in a "novel ecosystem," not the restoration of the "original" ecosystem as it would have naturally evolved.

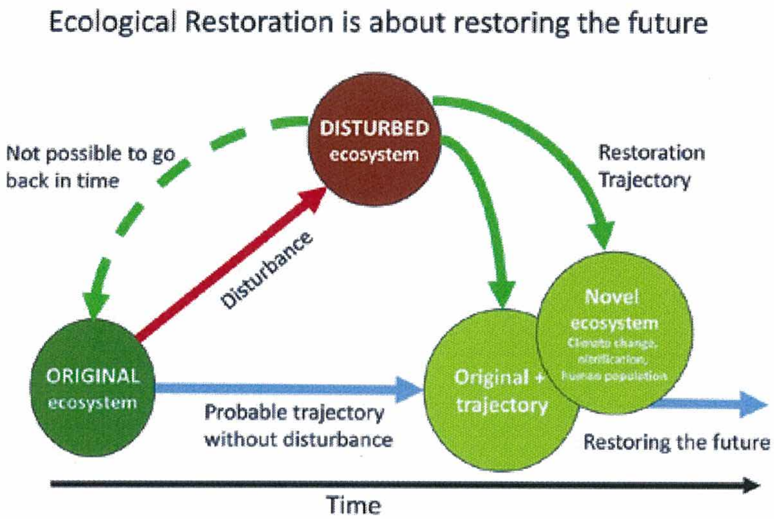

Fig. 1 Ecosystem restoration trajectories through time from EPA Comparative Analysis, Appendix D.

We agree with the ideas depicted in this figure. However, those ideas are inconsistent with EPA's statements about *"reestablish[ing] pre-remediation conditions and functions" or "returning these habitats...to their pre-remediation state"* because, as the figure makes clear, it is impossible to restore the original ecosystem. As EPA's figure recognizes, disturbance and attempted restoration will result in a "novel ecosystem" with a profoundly different species composition, including many non-native plant species. Further, EPA's figure underestimates the time necessary to generate a realistic novel ecosystem. Therefore, a revision of EPA's figure consistent with the "significant body of knowledge" to which EPA refers would look more like this:

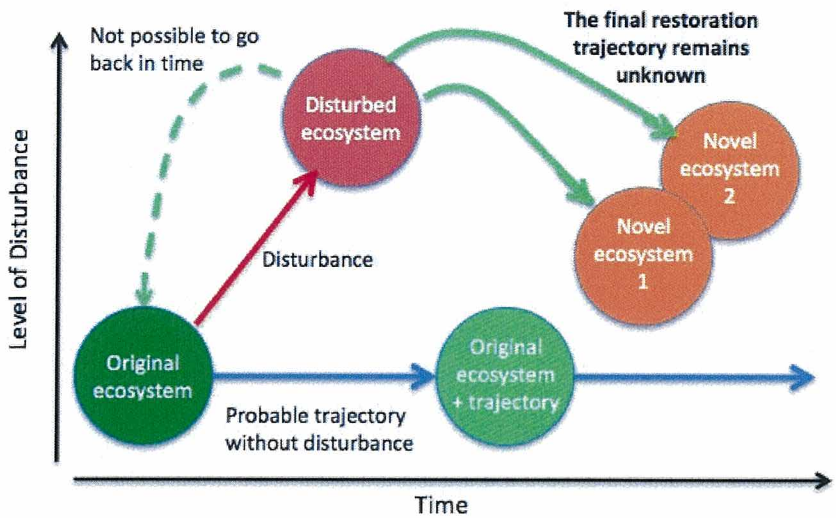

Fig. 2. A modification of Figure 1 displaying more realistic scenarios (Novel Ecosystems 1 & 2) for the likely trajectory for the Housatonic Rest of River if the proposed remediation plans are implemented. Note we have labeled the Y-axis Level of Disturbance, which was implicit in the original EPA figure. In the original EPA figure, the resultant Novel Ecosystem was unrealistically close to a likely natural trajectory for the original ecosystem following remediation of the kind and scope proposed. It is impossible to know just where the actual novel ecosystem will fall but it is likely to be higher on the Disturbance Axis and take longer to reach that state, so we have depicted some alternative, more realistic locations as Novel Ecosystems 1 & 2.

2.2 ELEMENTS OF A SUCCESSFUL RESTORATION PLAN

Among the eight items described in Section 2.2 of EPA's Appendix D, there are seven that merit comment.

--*"A clear rationale as to why restoration is needed."*

It is noteworthy that, unlike most restoration projects in which historical ecological damage is being remedied (see again EPA's figure), in this case EPA is advocating the disturbance that would require the attempted restoration.

--*"A statement of goals and objectives of the restoration project."*

The apparent goal of this project to "*reestablish the pre-remediation conditions and functions*" is not realistic for reasons that will be elaborated on below for each component of restoration.

--*"A designation and description of the reference."*

The uniqueness of the Housatonic River and floodplain make this impossible. We note that EPA hasn't identified any system that is anything like a reasonable analog that might serve as a reference system.

-- *"An explanation of how the proposed restoration will integrate with the landscape and its flows of organisms and materials."*

The extent of the proposed remediation raises the specter of landscape fragmentation. Within the lowlands of the Housatonic Valley south of Pittsfield, the Housatonic River and its floodplain currently represent a remarkably intact corridor along which organisms can move up and down the valley. This corridor will be severed by the excavation and access roads and staging areas proposed by EPA and restoration cannot be relied upon to repair this fragmentation in any predictable time frame. (See more detailed analysis in our Ecological Impacts document.)

-- *"Explicit plans, schedules, and budgets for site preparation, installation, and post installation activities include a strategy for prompt mid-course corrections."*
-- *"Well-developed and explicitly stated performance standards, with monitoring protocols by which the project can be evaluated."*
-- *"Strategies for long-term protection and maintenance of the restored ecosystem."*

These three items cover details that are premature at this stage, but it is noteworthy how the banner of "we will restore the ecosystem" is waved with no recognition of the complexity of this process and the limitations that will constrain it. To quote a comprehensive review of 644 river restoration projects: *"Restoring the ecological integrity of degraded waterways is tough, complicated work"* and outcomes of river restoration tend to be *"disappointing"* (Palmer et al. in press).

2.3 RIVER RESTORATION PLANNING

Many important items are touched upon in Section 2.3 of EPA's Appendix D and we will comment on several here and below.

-- *"...re-establishing river and floodplain processes ..."*

Dynamic river processes are already established in the Rest of River. What is being proposed is to interrupt those processes, destroying the existing system with its varied habitats and communities, and then attempt to restore them with techniques designed to minimize sediment movements – from the substrates, banks, floodplains, and in the water column. Minimizing the movement of sediment is fundamentally antithetical to restoring river and floodplain dynamism. That objective will not allow natural, dynamic river and floodplain processes to occur, and hence, the existing, productive ecosystems currently present will be lost. See further discussion below.

-- *"...providing for landscape linkages ..."*

As indicated above, the proposal would sever existing linkages rather than providing for their enhancement.

--"*The composition and structure of vegetation provides the basis for riparian habitat.*"

This is true, and is a very worrisome aspect of the proposal given the profound difficulty of reestablishing many species of native plants and of controlling exotic invasive plant species, especially in an aquatic environment, as will be discussed below.

--*"The morphology of the channel provides the basis for in-stream habitat."*

This is a partially true statement. However, one also needs to be cognizant of the importance of other riverine ecosystem elements, such as bank condition, bank and floodplain vegetation, and inputs from the surrounding and upstream landscape. That said, the proposed remediation approach of attempting to stabilize the channel to minimize bank erosion will not restore in-stream habitats to their prior, productive condition as discussed in Section 2.6 below.

--*"... ensures the future health and integrity of the river... without requiring external assistance."*

EPA acknowledges the need for extensive control of invasive plant species, which contravenes this idea and will not be successful in this circumstance in any case. See further discussion of exotic plants below.

--*"Include adaptive management"*

Adaptive management is explicitly mentioned by EPA, particularly in the context of vernal pool restoration (see pp. 6, 8, & 34 of EPA's Comparative Analysis), but the proposed time frame of eight years for Reaches 5A, 5B, and 5C and their associated backwaters is grossly inadequate for acting, monitoring, learning, revising, and acting again required of adaptive management. See further details below in Section 2.5.

2.4 HISTORY OF RIVER RESTORATION

The brief history presented in Section 2.4 of EPA's Appendix D omits some critically important recent attempts to assess the success of river restoration detailed below.

The section concludes with five criteria from Palmer et al. (2005) that are useful to consider:

1. A guiding image exists: a dynamic ecological endpoint is identified a priori and used to guide the restoration (within present regional context).

EPA's "guiding image" seems to be the riverine ecosystem in its current condition, or at least as close to that as feasible, but this overlooks the reality that it is the proposed excavation and dredging that would degrade the ecosystem and thus generate the need for restoration.

2. Ecosystems are improved: the ecological conditions of the river are measurably enhanced and move toward the guiding image.

This criterion will definitely not be met relative to the current state of the Rest of River ecosystem, as acknowledged by EPA: "*Remediation and restoration of the river and floodplain at this scale cannot be accomplished to any meaningful level without impacts to the present state of the river and floodplain*" (p. 6 of Appendix D, lines 23-24). As discussed below, it is far more likely that imperfect restoration will not rectify the degradation of the riverine ecosystem caused by the excavation and dredging inherent in EPA's proposal. A review of 644 river restoration projects found that only 16% showed any improvement in biodiversity following restoration activities (Palmer et al. in review) and these comparisons were relative to the degraded state of the ecosystems, not their condition prior to the degradation that required restoration. Certainly there will be no improvement in biodiversity relative to the Rest of River's current state.

3. Resiliency is increased: the river ecosystem is more self-sustaining than before.

Similar to Criterion 2, the Housatonic River ecosystem will be far less self-sustaining after proposed remediation and restoration, for decades at a minimum. Fundamentally, many species are likely to be extirpated or have severely reduced populations during this lengthy period. This is related to many driving factors discussed below.

4. No lasting harm is done: implementing the restoration does not inflict irreparable harm.

This criterion is particularly problematic if the project contributes to regional extinction of some listed species, as seems likely, given the difficulty of restoring endangered species populations and their habitats. In particular, implementation of the proposal would directly disturb approximately 374 acres of designated Priority Habitat of state-listed species, resulting in 25 takes, 9 of which would be of significant portions of the local populations of those species (see Table 12 and Attachment E of GE's comments on the proposed remedy).

5. Ecological assessment is completed: some level of pre- and post-project assessment is conducted and the information is shared.

This criterion will presumably be met, although it will be critically important to tie post-project monitoring and assessment both to measures taken prior to remediation and to "as-built" conditions immediately following construction. Some improvements compared to "as-built" conditions are likely but the negative changes compared to the pre-project conditions are certain to be profound. As discussed in the next section, the time frame for both completing the work, and presumably the assessment, is far too short.

2.5 CONSIDERATION OF TEMPORAL SCALE

In Section 2.5 of Appendix D, EPA emphasizes the dynamism of the Housatonic River and particularly its recovery from past disturbances. We concur that it is important to appreciate the role of river dynamics and below we highlight some of the potential conflicts between river dynamism and EPA's proposed bank restoration. Here we focus on two other temporal issues.

First, contrary to EPA's suggestion, any meaningful ecological recovery of certain elements of the Rest of River ecosystem will take, at best, decades beyond the timeframe of the remediation. This point is particularly salient where the dominant vegetation comprises large silver maples. These trees are currently tall enough to support canopy-dwelling birds, have crowns wide enough to shade the river and backwaters and have trunks robust enough to provide dens for cavity-dwelling mammals and birds and to become large woody debris in the river. These forests also provide critical post-breeding habitat for amphibians during summer, fall, and winter. However, if remediation proceeds in the manner proposed by EPA, these trees will be entirely replaced with saplings that will take at least 50 years to reach mature tree height, and probably over 100 years for full-size crowns and boles.

Second, despite EPA's claim that *"[r]emediation and restoration would progress incrementally from upstream to downstream, affecting small stretches of the river and floodplain at any given time."* (p. 26 of EPA's Comparative Analysis), all of the remediation in Reaches 5A, 5B, and 5C and their associated backwaters is scheduled to be completed in just 8 years (Fig. 3). This means that extensive areas will essentially be simultaneously denuded of their natural vegetation.

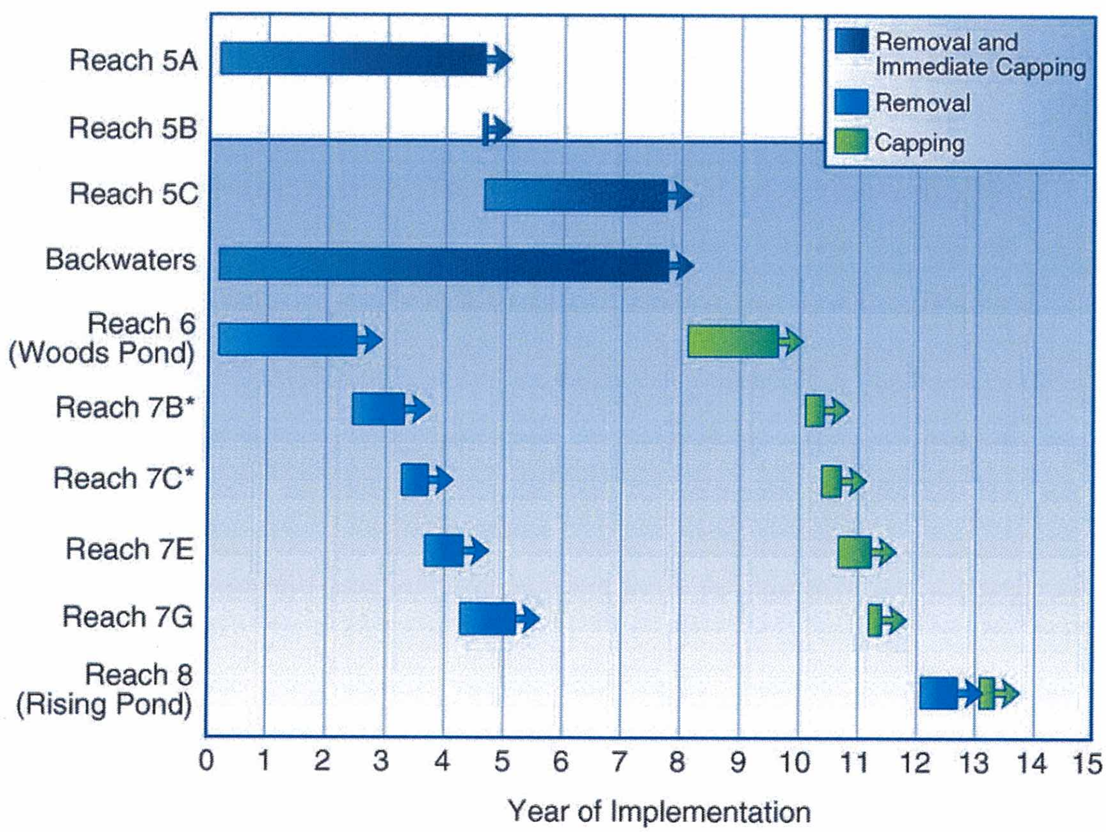

Fig. 3. EPA's estimated timeline for cleanup activities (taken from Figure 5 of EPA's Statement of Basis).

If the goal is to affect only "*small stretches ... at any given time,*" then one would remediate a small portion of the total area and wait until the vegetation has largely recovered before proceeding to the next portion. Translating "small portion" and "largely recovered" into two reasonable numbers (10% to constitute a "small portion" and the minimum of 50 years to achieve mature tree height to constitute "largely recovered") would generate a 500-year time frame for the entire undertaking (10 portions of 10% each x 50 years). This number highlights just how ill-advised it is to suggest that one can substantially mitigate the impact of the proposed remediation if it is conducted within an 8-year time frame. Even if you "pushed the envelope" very hard, the proposed 8 years is completely inadequate (for example, remediating 25% of the area per period and assuming trees were large enough after 20 years leads to an 80-year time frame, ten times longer than the proposal).

The fact is that adaptive management requires significant time, especially when dealing with slow ecological processes like the growth and succession of vegetation. The fundamental feature of adaptive management is learning from past experience, and that requires time to: monitor the results or outcomes of actions; assess if goals were met and unintended consequences incurred; and develop new approaches based on lessons learned. In the context of vegetation restoration it is likely to take at least 5-10 years just to be able to judge if the restoration effort is on track to be successful (e.g., planted trees are surviving and the site is not overrun with exotic species.) Thus, even at sites where the goal is to restore fast-growing plants, like annuals, rather than trees or shrubs, it is not reasonable to suggest that in just 8 years one can make multiple trips around the cycle of adaptive management (Fig. 4).

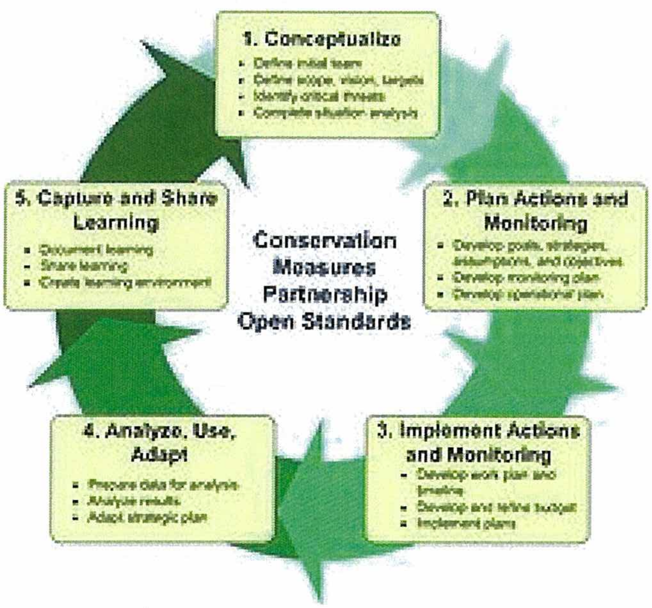

Fig. 4. Adaptive management requires cycles of action, monitoring, and learning.

2.6 RESTORATION TECHNIQUES SUPPORTING DIVERSE HABITAT

Section 2.6 of EPA's Appendix D discusses restoration techniques and presents EPA's view of successful restoration examples. A meta-analysis comparing 621 wetland restoration sites to 551 reference wetlands (Moreno-Mateos et al. 2012) speaks to the challenges of restoration ecology in general and is specifically relevant to floodplain restoration:

"Our results ... from throughout the world show that even a century after restoration efforts, biological structure (driven mostly by plant assemblages), and biogeochemical functioning (driven primarily by the storage of carbon in wetland soils), remained on average 26% and 23% lower, respectively, than in reference sites. Either recovery has been very slow, or post-disturbance systems have moved towards alternative states that differ from reference conditions."

Similarly, these lines appear in the conclusion of a review of 644 river restoration projects (Palmer et al. in press): *"While outcomes of river restoration based on our review of published studies may be disappointing, it is important to remember that stream restoration science is very young compared to, say, forest or prairie restoration. Researchers and practitioners are still developing methods, and the problematic ecological outcomes of many or most structurally based restoration projects are only now becoming more widely acknowledged. A unified perspective on how to succeed in restoring rivers has yet to take hold."*

In the following subsections we provide an overview of some key constraints on restoration ecology for each of four habitat types. A more detailed analysis appears in our Ecological Impacts document.

2.6.1 River

We refer back to the four statements from EPA's Comparative Analysis described above to evaluate their relevance to ease of restoring the river that is the heart of the Rest of River.

1. There is a significant body of knowledge with respect to ecosystem restoration.

Recent reviews have summarized what is known about the success, and lack thereof, for river restoration (e.g., Palmer et al. 2005, Bernhardt and Palmer 2011, Palmer et al. 2014, Palmer et al. in press). We summarize the findings from key papers in the next few sections.

2. *[The literature] documents the ability to reestablish the pre-remediation conditions and functions of the affected habitats.*

Recent review papers repeatedly call attention to the lack of river restoration success. Palmer et al. (in press) state: "*Yet, ecologists have pointed out that while restoration of hydro-geomorphology is a critical consideration in restoring many streams, it is typically not sufficient for degraded channels and it can even lead to worsening the ecological condition of the stream; i.e., may be viewed as a disturbance itself (Louhi et al. 2011, Tullos et al. 2009). For example, if in the process of restoring floodplain overflow potential, riparian trees are removed* *from a previously closed-canopy stream, the underlying energy regime may change from allochthonous resources to one driven by primary production, which may shift the stream further away from the desired ecological state often toward algae dominated streambeds and higher temperatures (Sudduth et al. 2011). Similarly, if the hydrologic regime is restored but there is no nearby source of invertebrate colonists, then the in-stream communities remain unrestored (Sundermann et al. 2011).*"

3. *Accordingly, restoration is expected to be fully effective and reliable in returning these habitats . . . to their pre-remediation state.*

For riverbeds, based on an extensive review of river restoration projects, this statement is simply not true. Palmer et al. (in press) found that: "*A strong focus on channel morphology has led to approaches that involve major earth-moving activities such as channel re-configuration with the unmet assumption that ecological recovery will follow.*" The same review "*showed there remains a major emphasis on the use of dramatic structural interventions such as completely re-shaping a channel despite growing scientific evidence that such approaches do not enhance ecological recovery and the data we assembled (Table 2) suggest they are generally ineffective in stabilizing channels when that is the primary goal.*" Thus, it is highly unlikely that, following the implementation of EPA's proposal (which would directly impact 126 acres of aquatic riverine habitat and at least 3.5 miles of riverbank in Reach 5A, as shown in Table 11 of GE's comments), the Rest of River could be restored to its current high level of biodiversity and productivity, and it is nearly certain this highly functioning set of reaches will become further degraded and lose valued riverine habitats, decreasing the diversity of species now present (see Table 12 and Attachment E of GE's comments).

4. [T]he likelihood of effective restoration is equal under any of the alternatives.

The remediation alternatives considered by the Comparative Analysis vary considerably in how they will alter the existing riverine ecosystem. Therefore, it is incorrect to suggest that the "*likelihood of effective restoration is equal*" unless, by being equal, it is assumed that any restoration outcomes will be suboptimal and ineffective in any alternative implemented, as a review of the literature suggests.

2.6.2 Riverbanks

We again refer back to the four statements from EPA's Comparative Analysis described above to evaluate their relevance to ease of restoring riverbanks in the Rest of River.

1. There is a significant body of knowledge with respect to ecosystem restoration.

As described in Attachment 11 (Bank Erosion/Restoration) to EPA's Comparative Analysis, there are accepted methods in the literature to stabilize and/or repair severely eroded riverbanks. What is not sufficiently acknowledged in EPA's analysis of alternatives are the system-wide, negative impacts that will result due to the extensive spatial extent of riverbank remediation – 3.5 miles of riverbank for Reach 5A alone. In addition, it is important to recognize that in most rivers of this type, a portion of the banks will be eroding as part of the natural process of forming meanders where the outer cut bank maintains a near-vertical face of exposed sediments and soil. Several species have adapted to or require this type of habitat (e.g., belted kingfisher, bank swallow, denning otter or mink, etc.). In the eastern U.S., when the dominant forest cover is intact, steep banks are stabilized by the root masses of trees living at the top of the bank. When steep, eroding riverbanks are not pervasive (and they are not pervasive in the Housatonic), then the negative impacts of erosion and sedimentation in the riverine ecosystem can be readily absorbed . Thus, the primary question that should be asked and answered is, what is the minimum length of eroding riverbank that should be, and can be, stabilized to reduce targeted riverbanks erosion problems without causing harm to the overall riverine ecosystem? We believe it is far less than 3.5 miles.

2. *[The literature] documents the ability to reestablish the pre-remediation conditions and functions of the affected habitats.*

We agree that "*[o]ver time, the Housatonic River will move toward a state of uniform energy dissipation that will result in reduced bank erosion, a reduction in bar formation, and fewer channel processes that form and maintain the oxbows*" (Attachment 11, page 2). We also agree that there are a series of standard techniques to stabilize severely eroding riverbanks (e.g., live staking, fascines, tree/log revetments, log or rock cross vanes, plant mats, geotextile applications, etc) (Eubanks and Meadows, no date). In degraded rivers, conducting selected stabilization or repair of highly eroded riverbanks is a common practice. What is of great concern for the Housatonic Rest of River is the excessive number and length of riverbanks designated for remediation. If a few sections were remediated, the consequences to the riverine ecosystem would be minor. If extensive sections are remediated, then negative impacts – loss of shade, increasing temperatures, loss of critical breeding, resting, and overwintering habitats – will cause significant changes to the Housatonic, damaging the ecological integrity of the system.

3. *Accordingly, restoration is expected to be fully effective and reliable in returning these habitats . . . to their pre-remediation state.*

This claim is incorrect for the riverbanks. As stated in the Section 2.6.1 on rivers, wholesale disturbance of the river channel along lengthy reaches can have undesirable impacts on the adjacent riverbanks and do not necessarily enhance the ecological recovery of the riverine ecosystem (Palmer et al. in press). Another factor of concern for the proposed remediation derives from EPA's statements that, because the objective is to permanently stabilize the remediated riverbanks, their angle of repose would be quite low, eliminating many of the vertical or steep banks. Also, there would be a sustained effort to keep the banks free from mature trees, the concern being that tree roots would dislodge some of the stabilizing structures. As a consequence, these remediated banks would not serve the same functions of the existing natural banks, that is, providing shade, habitat, and contributing coarse wood debris into the riverine ecosystem. Most of Reach 5 is designated as habitat for many state-listed species, and these impacts would be devastating to those valued populations.

4. [T]he likelihood of effective restoration is equal under any of the alternatives.

If only the most severely eroded riverbanks were stabilized – a much smaller proportion than proposed – then the natural recovery of the river could proceed unabated, since the few stabilized banks would likely not affect the overall recovery. If more than a small proportion of the riverbanks are disturbed during remediation, then this recovery would be set back for decades, since the stabilized banks themselves would be permanently altered and this would undermine or preclude the prospects of returning to overall pre-remediation conditions along the river.

2.6.3 Floodplain

We again refer back to the four statements from EPA's Comparative Analysis described above to evaluate their relevance to ease of restoring floodplain habitats in the Rest of River.

1. There is a significant body of knowledge with respect to ecosystem restoration.

The overwhelming majority of the literature on river restoration is focused on reclaiming the dimensions of the river channel and immediate banks. Few studies are directed specifically at floodplain restoration, and thus, there is not "*a significant body of knowledge*" concerning the potential restoration of this vital component of the riverine ecosystem.

2. *[The literature] documents the ability to reestablish the pre-remediation conditions and functions of the affected habitats.*

The literature on river restoration, and the relatively few successful examples, are most applicable to reaches where the channel and associated riverbanks and floodplains have been severely altered by channelization, filling and/or drainage of aquatic features of the floodplain, or encroachment of urban and industrial developments. These alterations, in turn, cause drying of the floodplain, loss of flood storage capacity, and elimination of suitable habitats for many floodplain species. Implementation of EPA's proposal would cause these types of destruction. Although the wholesale reconfiguration of channels, beds, and banks was appropriate for the Upper 2 Miles of the Housatonic River where severe alterations had previously occurred, they are highly inappropriate for the Rest of River where more natural hydrodynamics and the resultant productive habitats currently exist.

Palmer et al. (2014) describe the intentional shift in urban headwater streams toward highly engineered functions for stormwater management. These projects rarely achieve the intended functions (ecosystem services). In an earlier review paper, Palmer et al. (2010) stated: "*The findings indicate that physical heterogeneity should not be the driving force in selecting restoration approaches for most degraded waterways. Evidence suggests that much more must be done to restore streams impacted by multiple stressors than simply re-configuring channels and enhancing structural complexity with meanders, boulders, wood, or other structures.*" More recently, Palmer et al. (in press) state: "*A strong focus on channel morphology has led to approaches that involve major earth-moving activities such as channel re-configuration with the unmet assumption that ecological recovery will follow*"; and "*Our review showed there remains a major emphasis on the use of dramatic structural interventions such as completely re-shaping a channel despite growing scientific evidence that such approaches do not enhance ecological recovery and the data we assembled (Table 2) suggest they are generally ineffective in* *stabilizing channels when that is the primary goal.*" Therefore, it is clear that given its large spatial extent, limited period, and available techniques, EPA's proposal is unlikely to be successful in establishing pre-remediation ecological conditions or services. As stated previously, and shown in our revision of EPA's trajectory figure (Fig. 1), a novel ecosystem will develop over an extended time period of decades, but it will be one that is quite different from the current riverine ecosystem (Fig. 2).

3. *Accordingly, restoration is expected to be fully effective and reliable in returning these habitats . . . to their pre-remediation state.*

For floodplain habitats, this is not true for multiple reasons, many of which were covered in detail in Sections 5-8 of the Revised CMS. Here, we offer four examples from the literature of why restoration will not reliably return floodplain habitats – forested wetlands, emergent wetlands, riparian areas – to their pre-remediation states.

Jansson et al. (2007) found that animal and plant species affected before or during restoration of rivers do not necessarily return after restoration, and that an inability to manage invasive plants leads to novel ecosystems: "*Species that have been lost from a stream cannot be assumed to recolonize spontaneously, calling for strategies to ensure the return of target species to be integrated into projects. Possible effects of invasive exotic species also need to be incorporated into project plans, either to minimize the impact of exotics, or to modify the expected outcome of restoration in cases where extirpation of exotics is impractical.*"

Moreno-Mateos et al. (2012) and Gebo and Brooks (2012) compared multiple wetland mitigation projects to reference wetlands and found that neither the structure nor function of wetlands were being replaced with current restoration or mitigation practices. In a meta-analysis of 621 wetland restoration projects, Moreno-Mateos et al. (2012) found that: "*Ecological restoration to recover critical ecosystem services has been widely attempted, but the degree of actual recovery of ecosystem functioning and structure from these efforts remains uncertain.*" Gebo and Brooks (2012) showed that fringing wetlands along lakes had the highest probability of successful replacement, whereas vegetated depressions and forested wetlands were most vulnerable to failure. Under EPA's proposal, 14 acres of emergent wetland and 36 acres of forested wetland will be destroyed (see Table 11 of GE's comments on proposed remedy); and with a low likelihood of successful replacement of structural and functional features, the ecological value of these areas of the Rest of River floodplain will decline substantially.

Bernhardt and Palmer (2011), in summarizing river restoration practices, stated that "*given that a number of studies have now found no ecological improvement from channel reconfiguration projects and, in some cases, even found evidence of increased degradation (e.g., Tullos et al.2009), future restoration approaches should keep earthmoving activities to a minimum, particularly if they include the removal of trees.*"

Buchanan et al. (2012) offered extensive recommendations on how to critically model and monitor the complex hydrodynamics of river restoration projects, but they also realized how in-stream processes interact with restoration of floodplains: "*Problems with stream restoration projects involving floodplain creation, regrading, or clearing have been largely attributable to low hydraulic roughness over the floodplain.*" The authors expressed these concerns for relatively short reaches on a single river. What should be of significant concern for the Rest of River are the extensive areas of river channel, riverbank, and floodplain that will be disturbed simultaneously during the remediation process (see Section 2.5). Even if work is performed on short reaches or small areas, the cumulative floodplain and wetland revegetation efforts will not have sufficient time to produce "roughness" across the floodplain to counter the inevitable heavy rainfall and flooding events that will occur during the first few years of vegetation establishment. Newly planted areas, even after several years, will have reduced rooting masses, with less chance of resisting erosion and loss of soil during harsh weather events. Non-forested open areas will dominate any remediated floodplain areas, translating to loss of mature forest habitat and species, and fragmentation of the forested riverine corridor. Large trees in a forested floodplain are irreplaceable and without them, shade is reduced, water and land surface temperatures increase, species dependent on large trees are lost, and opportunistic invasive plants will proliferate, further degrading the ecological integrity of the system.

4. The likelihood of effective restoration is equal under any of the alternatives.

Under EPA's proposed remedy, the types and spatial extent of remediation activities will not be able to "*keep earth-moving activities to a minimum*" (Bernhardt and Palmer 2011) or produce sufficient native vegetation cover to protect land surfaces from erosion. The objective of reducing sedimentation will be negated by increased losses of sediment and soil from newly constructed riverbeds, riverbanks, and floodplains. These types of post-remediation problems will lead to even more damage to aquatic ecosystems in the Rest of River than the actual remediation process.

2.6.4 Vernal Pools

We again refer back to the four statements from EPA's Comparative Analysis described above to evaluate their relevance to ease of restoring vernal pools in the ROR.

1. There is a significant body of knowledge with respect to ecosystem restoration.

There is a fair amount of information about creating vernal pools and we recently reviewed the state-of-the-art of pool creation in a peer-reviewed paper (Calhoun et al. 2014) that is attached as Exhibit D-4 hereto. Our review of the literature indicates that vernal pool creation is an imperfect science (Calhoun et al. 2005, Windmiller and Calhoun 2008, Denton and Richter 2013). There is a lot of gray literature (not peer-reviewed) on pool creation methods (i.e., how-to guidance books for pool creation), but the peer-reviewed scientific studies that evaluate the success of pool creation raise serious doubts about the efficacy of these methods in conserving target pool-breeding species.

2. *[The literature] documents the ability to reestablish the pre-remediation conditions and functions of the affected habitats.*

Collectively, the peer-reviewed literature cautions against assuming pool creation will successfully create suitable habitat for obligate or target vernal pool species. It suggests that the key to effective vernal pool creation is attention to context: For example, what was the historical landscape distribution of wetlands and vernal pools and what is the current distribution? What are the target species of concern? Where will source populations come from if pools fail? What is the condition of the post-breeding habitat (e.g., the adjacent forest)? EPA's statement that the literature "*documents the ability to reestablish pre-remediation conditions and functions*" of vernal pools habitats is unfounded given: (a) the destruction of all or parts of numerous pools in the floodplain and clear cutting of mature forest and soil removal in adjacent post-breeding forested habitat; (b) the current pool context (a series of high functioning vernal pools that are connected through mature forested corridors and are habitat for target species that are sensitive to this type of destruction, such as wood frogs and fairy shrimp); and (c) the difficulty in re-establishing natural hydroregimes and soil substrates in artificially constructed pools.

3. *Accordingly, restoration is expected to be fully effective and reliable in returning these habitats, including vernal pool habitat, to their pre-remediation state.*

There are many reasons why this statement is invalid (e.g., difficulty in recreating appropriate hydroperiods, soil conditions and suitable post-breeding habitat) and these restoration liabilities have been discussed in depth in previous documents (e.g., in the response to vernal pool remediation in the Revised CMS, our vernal pool White Paper shared with EPA in 2012, and the pool creation literature review published by Calhoun et al. 2014). We focus on two key factors here: (1) EPA's use of the Massachusetts Natural Heritage and Endangered Species Program (NHESP) measure of success for vernal pool certification is inappropriate; and (2) the experience with the restoration of one vernal pool in the floodplain upstream of the Rest of River provides no basis for the conclusion that the vernal pool network of the Rest of River can be recreated in the highly degraded and/or deforested river floodplain that will exist following the implementation of EPA's proposal.

First, the evidence of breeding by any vernal pool amphibian sufficient for certification of a vernal pool under the Commonwealth's regulations is not appropriate to evaluate the potential population-wide effects on pool-breeding amphibians by destruction of both pool and terrestrial habitat at the scale proposed by EPA for the Rest of River. The MA NHESP's evidence-of-breeding criterion for certification is designed to protect vernal pools with this modest showing, not to maintain the population persistence of more diverse populations of pool-breeding amphibians or to maintain other vernal pool ecosystem services (e.g., resting and foraging sites for mammals, birds, and other herpetofauna (Mitchell et al. 2008), biogeochemical services including nutrient cycling and transformations (Capps et al. in press), or hydrologic functions (Mushet et al. in revision). These guidelines were NOT intended or crafted for determining whether a remediated pool meets the goal of sustaining current population levels of pool-breeding amphibians or other landscape-scale pool functions (see Lichko and Calhoun 2003, Calhoun et al. 2014).

Second, EPA's experience with the remediated and "restored" vernal pool known as 8-VP-1 is no evidence that the over 40 vernal pools that could be affected by EPA's proposal (as an upper-bound estimate) can be effectively restored. The single remediated vernal pool does now provide appropriate breeding habitat for wood frogs in some years (following a dry-down year) but also serves as a potential sink in years when hydrologic conditions allow green frogs to successfully breed there, which is devastating for sensitive vernal pool species. This mixed result tells us nothing about the effect of the remediation proposed by EPA for the Rest of River.

The relevant study would require baseline research on amphibian breeding populations of an analogous section of river with multiple pools and associated terrestrial habitat followed by a recovery study. Given that this is not possible, one needs to rely on broader scale studies that compare reference pools to mitigated pools with sample sizes large enough to be statistically significant (Calhoun et al. 2014). Findings from these studies are more relevant to guiding decision-making with respect to pool integrity in this system than are findings from a single, relatively undisturbed site where there is a strong local population of pool-breeders to recolonize a pool.

We have already summarized that body of literature in Calhoun et al. 2014. In short, vernal pool functions (within the pool footprint and as related to adjacent terrestrial habitats and ecosystem connections) cannot be adequately replaced in most cases and most certainly should not be used as a rationale for justifying destruction of intact breeding and post-breeding amphibian habitats, particularly at the scale currently proposed for the Rest of River.

4. The likelihood of effective restoration is equal under any of the alternatives.

Given that the degree of vernal pool remediation varies significantly among alternatives and that there is a high likelihood of vernal pool restoration failure, this is not true. Success of creation efforts hinges strongly on successful recreation of hydrology, soil conditions, adjacency of mature forest suitable for post-breeding habitat and connections to other wetlands, and healthy source populations from nearby pools, none of which will be available in the current proposed remediation for the Rest of River. The level and extent of habitat destruction vary greatly among remediation plans and are of supreme relevance to the level of restoration success.

2.6.5 EPA's Restoration Examples

We reviewed the case studies provided in EPA's Appendix D for relevance to potential success of the proposed remediation and restoration activities in the Housatonic. None of the case studies cited as examples of successful restoration is appropriate for comparing the potential outcomes of the proposed remediation and restoration efforts in the Rest of River (see Woolsey et al. 2007 on the importance of closely matching proposed restoration outcomes specifically with relevant reference metrics for each critical ecosystem function). The Rest of River is an ecologically vibrant reach of river as described below:

The Housatonic River watershed is critical to biological conservation in Massachusetts. The Western New England Marble Valleys ecoregion that spans the lowlands of the Housatonic watershed is characterized by calcium-rich conditions that support some of the rarest plants, animals, and natural communities in the state. The watershed currently contains 110 plant species and 51 animal species protected by the Massachusetts Endangered Species Act (MESA) (NHESP 2010).

The EPA proposal would cause extensive damage to a river and floodplain that winds for more than 10 miles through a diverse ecosystem that includes an extensive complex of riverbed, riverbank, wetland, floodplain, and backwater habitats. That complex system includes a largely unfragmented forested floodplain corridor and provides exceptional habitat for many wildlife and plant species, including over 50 rare species listed by the State. By contrast, the Provo

River, Kissimmee River, Big Spring Creek, Nine Mile Run, and Clark Fork River restoration projects identified by EPA were focused on rivers that were physically, chemically, and biologically degraded either in urban (Clark Fork, Nine Mile Run) or agricultural (Provo, Kissimmee) settings, and/or largely in semi-arid riparian settings in the western U.S. (Clark Fork, Provo, Big Spring Creek). In all of these cases, the river sections had been channelized, dammed, or otherwise physically and/or chemically compromised and restoration efforts consisted of removing point and non-point source pollutants and restoration or complete creation of the physical structure of the systems (restoring stream banks, meanders, hydrologic flows to floodplains, etc.). None had intact floodplain and bank ecosystems well connected to a diversity of other wetland resources, with the biodiversity and ecological integrity of the Rest of River. In addition, some of the restoration activities are still in progress and assessment of successes is premature.

2.6.5.1 Provo River Project, UT (URMCC 2011, cited in EPA's Appendix D)

Prior to restoration, the Provo River consisted of a highly altered river system that was created during the 1940s and 1950s when the river was dammed, channelized, and placed between dikes as part of federal water reclamation projects. It was a straight river channel running through agricultural land. The goal of the restoration project was to realign the river to a more natural, meandering pattern and provide a protected corridor along the river – or, in other words, to make it more like the current Rest of River. This is very different from attempting to re-establish the conditions of a highly productive natural ecosystem.

Relevance to Housatonic: The 12-mile Provo River section that was remediated was highly physically degraded in a landscape dominated by agriculture and semi-arid landscape riparian vegetation. **This project was a physical restoration to remediate past structural degradation of a river system.**

2.6.5.2 Kissimmee River, FL (Mossa 2009, cited in EPA's Appendix D)

Similar to the Provo River, the Kissimmee River prior to restoration consisted of a channelized canal that was created for flood protection in the 1960s by cutting and dredging a 30-foot deep straightaway through the river's former meanders. The restoration project included backfilling approximately 8 miles of the canal to reconnect and restore flow to the former river channel, and the removal of existing levees, water control structures, and various infrastructure improvements within the project area, including a number of headwater lakes. This project re-established flow to much of the former river channel and associated wetlands. This is much different from the promised restoration of the Rest of River because it involved a completely different setting and did not involve the reconstruction of riverbanks or adjacent wetland or other floodplain habitats. The continuation of the project is currently (as of August 2014) stalled in court.

Relevance to Housatonic: The Kissimmee River Basin is dominated by agriculture and marshes. A river that was dammed by flood control structures and drained has been restored to re-flood marsh land and re-establish the expansive wetland area associated with the Everglades. **This project involved a physical restoration to emulate past conditions.**

2.6.5.3 Big Spring Creek, MT (Inter-fluve 2011, cited in EPA's Appendix D)

This project addressed a small (2,600-foot-long) reach of Big Springs Creek that had been channelized and straightened in 1912, with the adjacent floodplain used for numerous industrial purposes until the mid-1980s. The work involved constructing a 4,000-foot-long meandering channel adjacent to the man-made channel while water continued to flow down the artificial channel.

Relevance to the Housatonic: This project provides no precedent for restoration of the 10+ miles of meandering river and densely wooded riparian floodplain corridor in the Rest of River. Further, the relevance of this project for riverbank reconstruction is undermined by the fact that it was performed in the dry, whereas EPA's proposal would involve riverbank restoration through flowing water, which would preclude use of several bioengineering restoration techniques. **The only commonality was an issue with PCBs** (see page 120 of the Inter-fluve report for PCB contaminant details), **but the banks, streambed, and floodplains of the river were *not* excavated. The stretch of river remediated was already highly degraded and physically and chemically and biologically compromised.**

2.6.5.4 Nine Mile Run Restoration Project, PA (see Powerpoint available at http://www.fws.gov/chesapeakebay/masrc/MASRC%20PDFs/A_session_web/9_A_Anderson.pdf)

This project addressed a two-mile reach of Nine Mile Run in Pittsburgh, which was a completely urbanized stream that had been subjected to 90 years of abuse from urban activity. According to one account, it was "polluted into lifelessness, buried in culverts, insulted with trash, gouged by flash floods, and stripped of its floodplain by vast piles of slag," and "was as close to biological death as a stream could get" ("Nine Mile Rerun," *Landscape Architecture*, Nov. 2007). The restoration project included removal of rocks, channel reconfiguration, creation of riffle and pool sequences, riverbank stabilization, and installation of native plantings.

Relevance to Housatonic: Restoration of biologically dead streams like this, where anything is better than its prior condition, is no precedent for efforts to restore the complex existing system of diverse environments and their wildlife that would be required if the EPA proposal is implemented in the Rest of River. Such efforts are much less likely to succeed than restoring a dead stream to life. Most of the work was to reduce source pollutants, re-introduce structure into the stream, and to stabilize the highly eroded and degraded banks. No river floodplain, banks, or streambeds were removed.

2.6.5.5 Loring Air Force Base, ME (see site visit summary report by Brooks et al. dated April 27, 2010 and Powerpoint presentation prepared for September 2012 meeting with EPA, attached as Exhibits D-30 and D-31)

This project in northern Maine involved restoration of 2.5 miles of a small streambed and 35 acres of riparian wetlands after remediation to remove PCB contaminated soils and sediments.

Relevance to Housatonic: The Loring "unnamed stream" drains just one square mile and has a minimal floodplain as is typical of 1st and 2nd order streams. In contrast, the Housatonic River is a large, dynamic river (draining approx. 180 sq miles above the Rest of River) with extensive floodplains and riparian wetlands characteristic of a 5th order river. Reaches 5A and 5B of the Housatonic River are characterized by high, undercut banks whereas the Loring AFB stream is characterized by low, primarily stony banks. Wetlands in much of the Rest of River are dominated by vegetation adapted to regular flooding, notably an understory of ferns and herbs under a tall forest canopy. Wetlands at the Loring site are dominated by species that do not tolerate flooding, notably tall shrubs such as alders and coniferous trees. The Rest of River has an array of at least 58 productive, naturally occurring vernal pools (or wetland depressions). The Loring restoration site had no documented vernal pools prior to restoration. Created pools visited in 2010 showed minimal pool-breeding amphibian activity. **In summary, Loring is an unsuitable comparison for the Housatonic due to differences in: watershed size and river hydraulics; number and type of banks and vernal pools; plant communities and soil types; and sensitive habitats of rare species.**

2.6.5.6 Clark Fork River, MT (MNRDP 2008; CERTAC 2009; EPA 2011 – cited in EPA's Appendix D; also see updates to this project at: http://www.cfrtac.org/061913.html).

This project has three components. The first component, and the only portion where restoration has been completed, was a headwater creek that was totally dead due to metals contamination from mining waste; it contained no living plants or aquatic life whatsoever. In that creek, the contaminants were removed, a new substrate was placed, and plantings were installed. The second component, involving the Clark Fork itself, is ongoing (see below), so cannot be a precedent for successful restoration. The third component is the Milltown Reservoir, where the dam was removed, the metals in sediments were cleaned up, and the State is restoring 2.5 miles of river upstream from the dam. An update (the project is still ongoing) and photos can be found at the Clark Fork River restoration website: http://www.cfrtac.org/061913.html.

Relevance to Housatonic: As noted above with respect to Nine Mile Run, restoration of the dead headwater stream is irrelevant to EPA's suggestion that the thriving ecosystem of the Rest of River could be restored after the widespread damage inherent in implementation of EPA's proposal. In addition, comparisons to remediation efforts for a static reservoir are irrelevant to remediation of a flowing river. Furthermore, the Clark Fork River is situated in a semi-arid region where the floodplain is dominated by willows and shallow river banks. The context and ecological function of this system and the Housatonic are not comparable. **This project involves the attempted restoration of a historic river channel and highly toxic reach of river through excavation and recreation. The clean-up is still ongoing and results of the efficacy of the project in restoring ecological functions, except for difficulty in revegetating the floodplains, remain to be seen.**

2.6.6 Attributes of a Restored Ecosystem

Section 2.6.4 of EPA's Appendix D presents nine attributes of a restored ecosystem based on the SER International Primer on Ecological Restoration (SER 2004). We respond to two of these in detail (Attributes 1 and 2), and for the other seven attributes we make summary observations based on our responses elsewhere in this document.

1. The restored ecosystem contains a characteristic assemblage of the species that occur in the reference ecosystem and that provide appropriate community structure.

As mentioned above, only 16% of the river restoration projects reviewed by Palmer et al. (in press) showed improvement. In the case of the Housatonic ecosystem, the most appropriate reference ecosystem is the current ecosystem, prior to the proposed remediation, that will necessitate restoration. Revegetating the bare substrate remaining after major earthworks is not too challenging, because "nature abhors a vacuum." However, there is world of difference between making a site green and restoring some semblance of the native flora, the suite of plant species indigenous to a particular environment. That difference is obvious from an analysis of 249 cases of restoring 172 plant species (Godefroid et al. 2011) in which only 29% of efforts were deemed successful by the people who undertook the restoration, despite using a low bar for success based simply on survival rather than reproduction. Also, germane to the "time required for adaptive management" issue discussed above, the authors found that metrics of success actually declined through time after a restoration. For example, percent of individuals flowering (one key to long term persistence) diminished steadily through time and averaged only 6% after 4 years. One study of restoring native plants is of particular interest because it was executed in Massachusetts and had a substantial sample size: almost 30,000 propagules in 596 plots. Fifteen years after a reintroduction project at two reserves outside Boston, Drayton and Primack (2011) revisited reintroduced populations of eight plants species and discovered that six species were entirely gone, one had limited success, and only one was well established. Ecosystem restoration proponents generally assume that animal species will recolonize a site on their own. This is unlikely in the case of many riverine animal species in the Rest of River, given the vast extent of the proposed intervention and the rather different environments upstream and downstream of the remediation areas, which are unlikely to harbor the same suite of species.

2. The restored ecosystem consists of indigenous species to the greatest practicable extent.

There is a high risk of greatly increasing the abundance of exotic invasives in the Rest of River. Exotic plants are already prevalent with 18 problematic species listed. Conditions will improve substantially for most exotic invasive species with extensive areas of exposed soil (both backfill and new sediments), less competition from native species removed during remediation, and more sunlight following forest canopy removal (a factor relevant to both aquatic and terrestrial species). Furthermore, access roads, staging areas, and the movement of vehicles and soil will all increase invasions of propagules. EPA documents imply that controlling exotics is straightforward, but this is not the case. One analysis (Kettenring and Adams 2011) examined 335 research papers covering control of 110 invasive plants species and reported: "*Regardless of control method, our meta-analysis revealed that few studies produced gains in native plant cover, density or biomass*." The authors also warned about the negative ecosystem impacts of invasive control: "*Herbicide was the most commonly implemented and, according to our meta-analysis, the most effective control method for reducing invasives. However, native species response to herbicide was highly variable, probably because this broad-scale approach can hinder native species establishment through seed limitation.*" In fact, there can be unintended consequences of using particular techniques to control invasive exotics (see Skurski et al. 2013).

3. All functional groups necessary for the continued development and/or stability of the restored ecosystem are represented, or, if they are not, the missing groups have the potential to colonize by natural means.

As detailed throughout this document and the Revised CMS, many functional groups will be impaired by the proposed work. To take but one example, sizable trees, notably silver maples, will take many decades to restore, especially the largest trees that have special functional significance (Lindenmayer et al. 2012).

4. The physical environment of the restored ecosystem is capable of sustaining reproducing populations of the species necessary for its continued stability or development along the desired trajectory.

As detailed throughout this document and the Revised CMS, profound changes to the physical environment will be widespread. Three of the most significant are diverse changes in the microclimate due to vegetation removal that affect all aspects of the ecosystem, changes in soil chemistry and hydrology due to the massive amount of earth moving proposed, and major changes to the structure and dynamism of the riverbanks.

5. The restored ecosystem apparently functions normally for its ecological stage of development, and signs of dysfunction are absent.

Because function is tied to the species composition of the ecosystem, this attribute will not be fully achieved because of issues raised above regarding loss of native species and increased populations of invasive species. Regardless of species composition, the restored ecosystem will not function normally because bank stabilization efforts will severely constrain the natural dynamism of the river, as described above.

6. The restored ecosystem is suitably integrated into a larger ecological matrix or landscape, with which it interacts through abiotic and biotic flows and exchanges.

This attribute will not be achieved because the proposed remediation and restoration efforts will lead to fragmentation in two ways. First, the river and its floodplain, which currently constitute a remarkably intact corridor, will be severed. Second, the Rest of River downstream of the more urbanized Upper 2-Mile Reach that was remediated previously will not have the benefit of colonization by plants and animals from upstream because the Upper 2-Mile Reach has only an impoverished biota.

7. Potential threats to the health and integrity of the restored ecosystem from the surrounding landscape have been eliminated or reduced as much as possible.

The key issues in this respect are tied to the access roads, staging areas, and footprint of remediation activities, all of which will result in significant, long-lasting changes in the landscape which will decrease the habitat suitability of the restored ecosystem for the species that currently rely on it and increase the success of invasive species, and other impacts.

8. The restored ecosystem is sufficiently resilient to endure the normal periodic stress events in the local environment that serve to maintain the integrity of the ecosystem.

The ecosystem's resiliency is likely to be significantly compromised by all the issues discussed above.

9. The restored ecosystem is self-sustaining to the same degree as its reference ecosystem, and has the potential to persist indefinitely under existing environmental conditions. Nevertheless, aspects of its biodiversity, structure, and functioning may change as part of normal ecosystem development, and may fluctuate in response to normal periodic stress and occasional disturbance events of greater consequence. As in any intact ecosystem, the species composition and other attributes of a restored ecosystem may evolve as environmental conditions change.

We acknowledge that ecosystems are not static as emphasized in the last two sentences above. Nevertheless, to be self-sustaining, an ecosystem must be resilient and cannot be challenged too severely. The proposed remediation will constitute an overly severe challenge that cannot be rectified by restoration attempts.

3. SUMMARY

As explained throughout this document, the science and practice of ecosystem restoration provide only a tenuous foundation for undertaking a vast, complex project such as the proposed remediation and restoration of the Housatonic Rest of River. To quote Palmer et al. in review again: "*...it is important to remember that stream restoration science is very young... [and that] a unified perspective on how to succeed in restoring rivers has yet to take hold.*" EPA has repeatedly minimized the difficulties involved, for example, by presenting an unrealistically short time-line, by minimizing the impacts of fragmentation, by implying that exotic invasive species will be readily managed, and much more. Perhaps EPA's most fundamental mistake is to assert boldly that "*restoration is expected to be fully effective and reliable in returning these habitats ... to their pre-remediation state.*" No student of restoration ecology would make such an assertion and indeed EPA contradicts itself on this basic issue. If EPA's proposed remedy is implemented, the Rest of River will be severely impaired for many decades, perhaps centuries, and restoration efforts will constitute just a small Band-Aid on a gaping wound.

4. REFERENCES

The literature review for EPA's Appendix D is very limited relative to what is available. Most notably only 6 out of 23 citations by EPA are from peer-reviewed scientific journals (noted by * in Section 4.1 below); 12 papers are from the so-called "gray literature," chiefly reports about particular projects written by the people who undertook them. This is potentially significant because, according to Bernhardt and Palmer (2011): "*Despite a lack of measurable ecological improvement..., most restoration practitioners consider their projects to be successful.*" (Also see Bernhardt et al. 2007.) It is also notable that the literature review is currently rather out-of-date, with no peer-reviewed articles since 2009, and only 5 project reports in 2010 and 2011. To provide some context for the "thinness" of Appendix D's literature, we performed a search of Web of Science using this keyword string – (River* or Stream* or Floodplain*) Restor* – and generated 9,874 references on July 17, 2014. Even if we eliminate citations after 2011, the total is 7,645. Clearly, most of these thousands of papers are only tangentially relevant to the Housatonic remediation and restoration proposal, but many of them are relevant, particularly those that provide an overview evaluation of earlier projects, but unfortunately they do not seem to have provided a foundation for EPA's Appendix D. In the next two subsections, we review the EPA's literature, then provide an annotated set of citations for 30 directly relevant papers that EPA did not cite.

4.1 REVIEW OF REFERENCES ON ECOSYSTEM RESTORATION CITED BY EPA

The papers cited in EPA's Appendix D represent a slim and dated reflection of the literature. Most are on methodologies and guidelines for restoration. The scientific papers cited there all suggest that river restoration is relatively young and a controversial and risky business that is very site-specific and, foremost, should be ecologically based. Thus, Appendix D does not reflect some of the key concepts set forth in the papers that it cites.

We have reviewed all of the papers cited in Appendix D and provide some brief annotations in italics. References about the case studies described in Appendix D are covered in Section 2.6.5 above.

*Bernhardt, E.S., M.A. Palmer, J.D. Allan, G. Alexander, K. Barnas, S. Brooks, J. Carr, S. Clayton, C. Dahm, J. Follstad-Shah, D. Galat, S. Gloss, P. Goodwin, D. Hart, B. Hassett, R. Jenkinson, S. Katz, G.M. Kondolf, P.S. Lake, R. Lave, J.L. Meyer, T.K. O'Donnell, L. Pagano, B. Powell, and E. Sudduth. 2005. Synthesizing U.S. River Restoration Efforts. Science 308:636-637. *(Paper concludes that river restoration is difficult, and more recent literature by Bernhardt and Palmer (2011) and Palmer et al. (in press) raises further concerns regarding river restoration.)*

Field, D.J. 2011. Housatonic River Historical Changes in River Morphology. Field Geology Services, Farmington, ME. March 2011. (*This publication on the straightened section of Rest of River states that there have been historical changes to the river, concluding that the river has already suffered major disturbances and "recovered." This is no justification for the drastic disturbances or destruction of habitat proposed by EPA and no evidence that repairing the resulting damage is likely.)*

Fischenich, J.C., and S. Dudley. 2000. Determining Drag Coefficients and Area for Vegetation. EMRRP-SR-08. (*A technical paper on method of determining drag coefficients.*)

*Kondolf, G.M., M.W. Smeltzer, and S.F. Railsback. 2001. Design and Performance of a Channel Reconstruction Project in a Coastal California Gravel-Bed Stream. *In*: Environmental Management, Vol. 28(6), pp. 761-776. (*This paper illustrates that implementing the concept of channel stability is often a failure and does not meet the goal of channel restoration as it is based on poor assumptions.*)

*Kondolf, G.M. 2006. River Restoration and Meanders. Ecology & Society, Vol. 11(2):42 *(Same conclusions as 2001 work.)*

Lave, R. 2008. The Rosgen Wars and the Shifting Construction of Scientific Expertise. Dissertation, Geography. University of California at Berkeley, Berkeley, CA. (*There is significant controversy over Rosgen Natural Channel Design and its emphasis on bank stability in restoration projects. This paper highlights that the science is still new and there are few new research initiatives. All studies should be very case specific; note the NRCS publications, listed below, are based on Rosgen river classifications.)*

*Lave, R. 2009. The Controversy Over Natural Channel Design: Substantive Explanations and Potential Avenues for Resolution. Journal of the American Water Resources Association (JAWRA), Vol. 45(6). pp. 1519-1532. (*See notes on Lave 2008.*)

Leopold, L.B., and T. Maddock, Jr. 1953. The Hydraulic Geometry of Stream Channels and Some Physiographic Implications. U.S. Geological Survey Professional Paper 252. U.S. Government Printing Office, Washington, DC. pp. 117-127. *(Luna Leopold did pioneering work on fluvial processes; this is a technical review of limited relevance to the Rest of River beyond foundational science.)*

Leopold, L.B., G.M. Wolman, and J.P. Miller. 1992. Fluvial Processes in Geomorphology. Dover Publications, Inc., Mineola, NY. (*An update to Leopold's earlier work.)*

NHESP (National Heritage and Endangered Species Program). 2010. Rare Species and Natural Community Surveys in the Housatonic River Watershed of Western Massachusetts. Massachusetts Division of Fisheries and Wildlife. July 2010. *(A key description of the Housatonic's special ecological status.)*

NRCS (Natural Resources Conservation Service). 2001. Stream Corridor Restoration Principles, Processes, and Practices. (*These are the guidelines discussed in Lave 2008 re: the Natural Channel Design controversy.)*

NRCS (Natural Resources Conservation Service). 2007. Stream 1 Restoration Design, National Engineering Handbook, Part 654, Des Moines, IA. *(Same as above.)*

*Palmer, M.A., E.S. Bernhardt, J.D. Allan, P.S. Lake, G. Alexander, S. Brooks, J. Carr, S. Clayton, C.N. Dahm, J.F. Shah, D.L. Galat, S.G. Loss, P. Goodwin, D.D. Hart, B. Hassett, R. Jenkinson, G.M. Kondolf, R. Lave, J.L. Meyer, T.K. O'Donnell, L. Pagano, and E. Sudduth. 2005. Standards for Ecologically Successful River Restoration. Journal of Applied Ecology, Vol. 42(2). pp. 208-217. *(This paper emphasizes that river restoration is very controversial; it highlights the importance of allowing for a dynamic system and "doing no harm.")*

SER (Society for Ecological Restoration International). 2004. *The SER International Primer on Ecological Restoration.* Science and Policy Working Group. (*This paper is cited because EPA's Appendix D uses their definition of "restoration.")*

*Shields, F.D., R.R. Copeland, P.C. Klingeman, M.W. Doyle, and A. Simon. 2003. Design for Stream Restoration. Journal of Hydraulic Engineering, Vol. 129(3). pp. 575-584. *(Paper concludes that research addressing problems associated with stream corridor ecosystem restoration is beset by numerous problems. First, terms referring to restoration are loosely*

defined. Secondly, stream ecosystems are not amenable to rigorous experimental design because they are governed by a host of independent variables that are heterogeneous in time and space, they are not scalable, and their response times are often too long for human attention spans. These problems lead to poorly controlled or uncontrolled experiments with outcomes that are not reproducible.)

Smith, S.M. 1997. Changes in the Hydraulic and Morphological Characteristics of a Relocated Stream Channel" MS thesis, University of Maryland, College Park, MD. (*We found the publication that came from this work (Smith and Pestegaard 2005 cited below) and it describes the reasons for failure of one stream rehabilitation project.)*

USFWS (U.S. Fish and Wildlife Service). 2008. Natural Channel Design Review Checklist. (*This checklist is based on traditional river restoration stabilization literature; see Bernhardt 2005, 2006 for illumination of the controversy around stabilizing banks.)*

4.2 A COMPILATION OF 30 SCIENTIFIC PAPERS ON ECOSYSTEM RESTORATION NOT CITED BY EPA

New papers referred to below are attached as Exhibits D-1 through D-29 to this document (excluding the paper by Mushet et al., which has not yet been published). An * denotes peer-reviewed papers.

*Bernhardt, E.S., E.B. Sudduth, M.A. Palmer, J.D. Allan, and J.L. Meyer. 2007. Restoring rivers one reach at a time: Results from a survey of U.S. river restoration practitioners. Restoration Ecology 15(3):482–93. *(Results of a survey of 317 river restoration managers indicate two-thirds of them judge their projects to be successful even though less than half had measurable objectives.)*

*Bernhardt, E.S., and M.A. Palmer. 2011. River restoration: The fuzzy logic of repairing reaches to reverse catchment scale degradation. Ecological Applications 21:1926–1931. *(A brief summary of the river restoration literature and introduction to a collection of papers on the topic that explore the significant limitations on river restoration.)*

*Buchanan, B.P., M.T. Walter, G.N. Nagle, and R.L. Schneider. 2012. Monitoring and assessment of a river restoration project in central New York. River Research Applications 28:216–33. (*A case study that proposes a set of technical monitoring and assessment measures in an effort to assess success and discern failures in river restoration.*)

*Calhoun, A.J.K., J. Arrigoni, R.P. Brooks, M.L. Hunter, and S.C. Richter. 2014. Creating Successful Vernal Pools: A Literature Review and Advice for Practitioners. Wetlands DOI 10.1007/s13157-014-0556-8. (*Review of relevant scientific studies on the science of vernal pool creation concluding that vernal pool functions cannot be adequately replaced in most cases. The authors include two primary researchers in the field of pool creation and restoration, two scientists whose research focus is pool breeding amphibians, and one scientist who has expertise in wetland mitigation, floodplain ecology, and wetland hydrodynamics.)*

*Calhoun, A.J.K., N. Miller, and M.W. Klemens. 2005. Conserving pool-breeding amphibians in human-dominated landscapes through local implementation of Best Development Practices. Wetlands Ecology and Management 13:291-304. (*Recommendations for conserving vernal pools, including taking a landscape approach that incorporates issues of connectivity.)*

Calhoun, A.J.K., M.L. Hunter, and R.P. Brooks. 2012. A review of literature on issues regarding restoring, creating, and mitigating vernal pools. Unpublished white paper (included in EPA's Administrative Record for the Rest of River, #522325).

*Capps, K.A., R. Rancatti, N. Tomczyk, T. Parr, A.J.K. Calhoun, and M.L. Hunter Jr. In press. Biogeochemical hotspots in forested landscapes: The role of vernal pools in denitrification and organic matter processing. Ecosystems. *(A study of nutrient dynamics in four New England vernal pools suggesting they may be hotspots of high levels of biogeochemical cycling in terrestrial landscapes.)*

*Denton, R.D., and S.C. Richter. 2013. Amphibian communities in natural and constructed ridge top wetlands with implications for wetland construction. Journal of Wildlife Management 77:886–889. (*Researchers documented a high failure rate of created pools, which are often inadequate for species more sensitive to hydroperiod including wood frogs.)*

*Drayton, B., and R.B. Primack. 2012. Success rates for reintroductions of eight perennial plant species after 15 years. Restoration Ecology 20: 299–303. *(Only one of 6 plant reintroductions was successful.)*

Eubanks, C.E., and D. Meadows. 2002. Soil Bioengineering Techniques. Chapter 5 in A Soil Bioengineering Guide for Streambank and Lakeshore Stabilization. U.S. Forest Service Technology and Development Program, San Dimas, CA. http://www.fs.fed.us/publications/soil-bio-guide/guide/chapter5.pdf). (*A detailed federal agency report, well illustrated, on the rationale and techniques for bank and shore stabilization.*)

*Gebo, N.A., and R.P. Brooks. 2012. Hydrogeomorphic (HGM) assessments of mitigation sites compared to natural reference wetlands in Pennsylvania. Wetlands 32:321-331. (*In Pennsylvania, 72 wetland mitigation projects were compared to 222 reference wetlands on the same hydrogeomorphic type, which showed mitigation projects displayed a significantly lower potential to perform functions than reference wetlands.*)

*Godefroid, S, C. Piazza, G. Rossi, et al. 2011. How successful are plant species reintroductions? Biological Conservation 144: 672-682. *(Plant reintroductions are not very successful [29% at best] based on a review of 249 examples.)*

*Jansson, R., C. Nilsson, and B. Malmqvist. 2007. Restoring freshwater ecosystems in riverine landscapes: The roles of connectivity and recovery processes. Freshwater Biology 52:589–596. (*A paper that highlights the importance of longitudinal, lateral, and vertical connectivity if recolonization of restored reaches is to occur within a reasonable period of time; all aspects of life cycles should be considered in restoration plans.*)

*Kettenring, K.M., and C. R. Adams. 2011. Lessons learned from invasive plant control experiments: A systematic review and meta-analysis. Journal of Applied Ecology 48: 970-979. *(A review of 331 papers covering 110 invasive species found disappointing results, especially as measured by native species response.)*

*Lichko, L., and A.J.K. Calhoun. 2003. An evaluation of vernal pool creation attempts in New England: Project documentation from 1991-2000. Environmental Management 32:141-151. *(A review of vernal pool creation efforts that cites weak standards of success as a major threat to effective pool conservation.)*

*Lindenmayer, D.B., W.F. Laurance, and J.F. Franklin. 2012. Global decline in large old trees. Science 338:1305-1306. *(Global review of the special ecological role of large old trees.)*

*Louhi, P., H. Mykrä, R. Paavola, A. Huusko, T. Vehanen, A. Maki-Petays., and T. Muotka. 2011. Twenty years of stream restoration in Finland: Little response by benthic macroinvertebrate communities. Ecological Applications 21:1950–1961. *(Stream restoration increased habitat diversity but did not enhance benthic biodiversity.)*

*Mitchell, J.C., P.W.C. Paton, and C.J. Raithel. 2008. The importance of vernal pools to reptiles, birds, and mammals. *In* Calhoun, A.J.K., and P.G. deMaynadier (eds), Science and Conservation of Vernal Pools in Northeastern North America, pages 169-190. CRC Press, Boca Raton, FL. *(Researchers reviewed the literature on functions of vernal pools for resting, foraging, and cover habitat for wildlife that are not obligate pool breeders.)*

*Moreno-Mateos, D., M.E. Power, F.A. Comin, and R. Yochteng. 2012. Structural and functional loss in restored wetland ecosystems. PLOS Biology 10(1):e1001247. (*A meta-analysis comparing 621 wetland restoration sites to 551 reference wetlands worldwide concludes significant structural and functional shortcomings exist in many projects.*)

*Mushet, D.M., A.J.K. Calhoun, L.C. Alexander, M.J. Cohen, E.S. deKeyser, L. Fowler, C.R. Lane, M.W. Lang, M.C. Rains, and S.C. Walls. In revision. Geographically isolated wetlands: Rethinking a misnomer. Wetlands. *(The authors argue that so-called "isolated" wetlands, including ephemeral wetlands, are hydrologically and/or ecologically linked to both other wetlands and adjacent terrestrial ecosystems. They highlight the importance of landscape context in evaluating pool functions.)*

*Palmer, M.A., K.L. Hondula, and B.J. Koch. In press. Ecological restoration of streams and rivers: Shifting strategies and shifting goals. Annual Review of Environment and Resources (in press). (*A paper that evaluates 644 river restoration projects points to the strong focus on channel reconfigurations as leading to incomplete and relatively unsuccessful river restoration projects.*)

*Palmer, M.A., H.L. Menninger, and E.S. Bernhardt. 2010. River restoration, habitat heterogeneity and biodiversity: A failure of theory or practice? Freshwater Biology 55(1):205–222. *(A review of 78 river restoration projects that concludes that managers should not focus primarily on physical channel characteristics if ecological recovery is the goal.)*

*Palmer, M.A., S. Filoso, and R.M. Fanelli. 2014. From ecosystems to ecosystem services: Stream restoration as ecological engineering. Ecological Engineering 65:62–70. *(An analysis of costs and benefits of urban stream restoration to enhance specific ecosystem services.)*

*Skurski, T.C., B.D. Maxwell, and L.J. Rew. 2013. Ecological tradeoffs in non-native plant management. Biological Conservation 159:292-302. *(Describes decrease of native species and increase of non-target exotic species after herbicide use.)*

*Smith, S.M., and K.L. Prestegaard. 2005. Hydraulic performance of a morphology-based stream channel design. Water Resources Research 41(11):W11413:1-17. *(Describes reasons for failure of one stream rehabilitation project.)*

*Sudduth, E.B., B.A. Hassett, P. Cada, and E.S. Bernhardt. 2011. Testing the field of dreams hypothesis: Functional responses to urbanization and restoration in stream ecosystems. Ecological Applications 21:1972–1988. *(A comparison of ecosystem metabolism and nitrate uptake kinetics in four stream restoration projects.)*

*Sundermann, A., S. Stoll, and P. Haase. 2011. River restoration success depends on the species pool of the immediate surroundings. Ecological Applications 21:1962–1971. *(Analysis of 24 German stream restorations indicating they did not improve the benthic invertebrate community quality.)*

*Tullos, D.D., D.L. Penrose, G.D. Jennings GD, and W.G Cope. 2009. Analysis of functional traits in reconfigured channels: Implications for the bioassessment and disturbance of river restoration. Journal of the North American Benthological Society 28:80–92. *(Research on channel reconfiguration shows taxa in restored sections are still those tolerant of disturbance.)*

*Windmiller, B., and A.J.K. Calhoun. 2008. Conserving vernal pool wildlife in urbanizing landscapes. *In* Calhoun, A.J.K., and P.G. deMaynadier (eds), Science and Conservation of Vernal Pools in Northeastern North America, pages 235-247. CRC Press, Boca Raton, FL. *(The authors argue for the importance of maintaining a diversity of pool types and hydroperiods in any given landscape and speak to the importance of pool context.)*

*Woolsey, S., F. Capelli, T. Gonser, E. Hoehn, M. Hostmann, B. Junker, A. Paetzold, C. Roulier, S. Schweizer, S.D. Tiegs, K. Tockner, C. Weber, and A. Peter. 2007. A strategy to assess river restoration success. Freshwater Biology 52: 752–769. *(This paper presents guidelines for assessing river restoration success based on 49 indicators and 13 specific objectives.)*