WQGIT Approval DRAFT

Consensus Recommendations to Improve Protocols 2 and 3 for Defining Stream Restoration Pollutant Removal Credits

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October 8, 2020

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Executive Summary

Two groups of more than 25 stream experts have worked over the last year on how to better apply protocols 2 and 3 to integrated stream and floodplain restoration projects (FR) (*Section 1*).

Floodplain restoration can be achieved using two basic techniques to reconnect incised streams to their floodplains. The first approach, termed legacy sediment removal (FR-LSR), removes sediments to lower the floodplain surfaces, increasing out-of-bank flow and re-establishing the hyporheic exchange zone by reconnecting the floodplain with the hyporheic aquifer.

The second approach, known as raising the stream bed (RSB), involves several techniques to raise the elevation of an incised stream channel and shallow groundwater, thereby increasing the volume of runoff diverted into the floodplain for treatment. These two approaches are often used in combination. The group came to consensus on the key terms, definitions and qualifying conditions for both floodplain restoration design approaches (*Section 3*).

The groups reviewed the considerable research conducted over the last decade on the sediment and nutrient dynamics associated with FR projects (*Section 4*) and concluded that:

Denitrification can be enhanced when the hyporheic exchange zone is expanded, floodplains are connected to hyporheic aquifers and runoff, and roots and other organic matter provide a carbon source. Denitrification rates are variable in space and time, but tend to increase with greater geomorphic and floodplain complexity, greater supply of nitrogen, and where mature and natural floodplain plant communities exist.

Both sediment and nutrients are effectively trapped by floodplains during larger storms, where they may be stored for many decades. Most of the trapping research has occurred in un-restored floodplains of the Chesapeake Bay watershed, but there is strong evidence that FR projects that increase the annual volume of storm flow diverted to the floodplain can mimic this function of natural floodplain trapping zones.

The groups recommended changes to the existing crediting protocols to improve their accuracy and reliability in estimating pollutant reduction for floodplain restoration projects.

Protocol 2 (P-2): Hyporheic Box (*Section 5)*

While the 2014 Stream Restoration Expert Panel intended for the dimensions of the hyporheic box to be variable – applying to sections of the stream where hyporheic exchange could be documented and verified – the 5 ft depth was frequently applied as a default. The groups concluded that the fixed unit dimensions (5 ft) of the original hyporheic box were not consistent with recent stream research and field measurements

and needed to be replaced with an "effective hyporheic zone" or EHZ, defined by actual site conditions.

The EHZ may extend across the full width of the restored floodplain, corresponding to a typically very shallow Hyporheic Exchange Zone (HEZ) where surface water and groundwater interact with the channel banks and the plant root zones in the floodplain. The lateral boundaries of the EHZ are defined by the restored floodplain elevations above the channel bed or low flow water elevation as confirmed by field measurements and shown on post-construction plans.

The groups also agreed on an updated unit area denitrification rate to apply to the EHZ that reflects the current research consensus. A new equation was also developed to adjust the unit rate to account for individual site differences, such as baseflow conditions, hyporheic aquifer conductivity and floodplain soil saturation.

The bank height ratio (≤1) requirement established by the original expert panel for Protocol 2 was eliminated, since it does not typically apply to low-bank FR projects. The group also developed design examples to show how the changes to Protocol 2 would apply to typical floodplain restoration projects.

Protocol 3 (P-3): Floodplain Reconnection (Section 6).

Both groups agreed on improved methods to define the extent of the floodplain treatment zone (FTZ), model flow diversions from the stream to floodplain, and compute sediment and nutrient reductions achieved in the floodplain by individual projects.

The groups concluded that hydraulic modeling that computes critical flow velocities in the floodplain could be used to define the boundaries of the FTZ. Further, they concluded that the crediting cap that limited nutrient and sediment reductions to the first one foot of water on the floodplain can be relaxed in certain circumstances for projects that otherwise meet the qualifying conditions.

They also agreed that downstream methods provide superior estimates of the annual volume of storm runoff diverted into the floodplain for treatment, and provided more detail on how to apply them to individual FR projects. These include standard baseflow channel definitions, acceptable techniques for separating storm flow from baseflow and methods to select and process appropriate USGS flow gage data.

Both groups also endorsed the use of the floodplain pollutant removal rates contained in the recently approved expert panel reports on non-tidal wetland (NTW) restoration, creation and rehabilitation. The project load reduction is computed by multiplying the nutrient and sediment loads delivered to the floodplain in the FTZ treatment volume by the most appropriate removal rate, given the wetland conditions encountered at individual floodplain restoration/rehabilitation projects.

Lastly, the groups decided to eliminate the upstream watershed to floodplain surface area ratio (>1) requirement. The original expert panel used this requirement to adjust the FTZ load reduction downward in certain upstream watershed situations, but the new groups concluded it was not needed.
Environmental Considerations and Practice Verification (*Section 7*).

The groups established new environmental and verification qualifying conditions for FR projects to help ensure they minimize unintended environmental consequences and maintain their intended functions over time. Based on an extensive research review on environmental impacts, the groups recommended more than 20 “best practices” to follow during project assessment, design, construction, and operation. The groups also developed specific indicators for verifying the long-term performance and functions of individual projects. FR projects require careful field assessment and use of best practices during design and construction to minimize detrimental environmental impacts.

The goal of this section is to create awareness of potential impacts, as well as existing research gaps, to help inform the assessment of potential project sites and restoration designs to maximize functional uplift and minimize unintended consequences. In all cases, the appropriate local, state and federal regulatory authorities retain the final decision regarding whether any proposed stream restoration project aligns with their priority restoration and natural resource objectives.

Note on Non-Urban Practices

The Water Quality Goal Implementation Team approved the Recommendations for Improving the Application of the Prevented Sediment Protocol (Group 3, 2020) for urban stream restoration practices only. To provide consistency with that decision, the stream restoration methods and practices described in these protocols also currently apply only to urban stream restoration practices.

The Chesapeake Bay Program’s Agriculture Workgroup has been separately charged with convening an expert panel to evaluate NRCS stream restoration practices that do not adhere to the stream restoration protocols developed by the Urban Stormwater Workgroup and refined within this guidance document.

Note on Grandfathering of Existing Projects

The group recommends that all new definitions, qualifying conditions and changes to Protocol 2 and 3 methods take effect on July 1, 2021. This “ramp-up” period will allow practitioners the opportunity to adjust to meet the new guidelines set forth in this document. Any projects already implemented or under contract as of July 1, 2021 have the option to follow the new recommendations, but may continue to adhere to the definitions, qualifying conditions and Protocol 2 and 3 calculations laid out in the Stream Restoration Expert Panel Protocols (2014) unless these newer guidelines are adopted by the project team. The final authority for making crediting decisions for qualifying projects falls to the appropriate state regulatory agencies.

Table of Contents

The following memo documents proposed modifications for how pollutant reduction credits are calculated using the stream restoration protocols for denitrification within the hyporheic zone and pollutant removal due to floodplain treatment as outlined by policy approved by the Urban Stormwater Work Group (USWG, 2016).

1. Charge and Roster of the Working Group

In its report, "Recommendations of the Expert Panel to Define Removal Rates for Individual Stream Restoration Projects", the original expert panel recommended ways to define pollutant removal credits for several classes of stream restoration including LSR, NCD and RSC projects (USR EP, 2014). Over the last five years, a diverse group of stream restoration stakeholders requested that the original protocols be revisited, and four groups were formed in late 2018 to do so (USWG, 2018). The Urban Stormwater Workgroup (USWG) convened an ad hoc team to review the protocols, update the science and provide additional guidance on their application. The members of the team are provided in Table 1.

While the original expert panel recognized the critical importance of floodplain reconnection in the design of stream restoration projects, the panel had low confidence in the methods for how to effectively estimate the pollutant removal credits. Stakeholders from both the public and private sector have sought to re-examine protocols 2 and 3 to make sure they effectively capture the interaction of a stream and its floodplain.

Table 1. Roster for Group 4

Name	*Affiliation*	*E-mail Address*
Joe Berg	Biohabitats	jberg@biohabitats.com
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The group was charged to review and recommend in the following areas:

- Determine if any pollutant reduction protocols from past or current CBP expert panels on wetland creation/restoration can be used to address floodplain reconnection and wetland dynamics.

- Ensure protocols reflect our current understanding of stream and floodplain dynamics and investigate potential standard methods to define post-restoration floodplain storage and sediment trapping capacity within the project reach.

- Determine how far the hyporheic box can be extended from the stream channel into the adjacent floodplain, especially when the project restores or rehabilitates floodplain wetlands.

- Evaluate how landscape position influences the pollutant reduction capability of floodplain reconnection projects (i.e., the relationship between the contributing upland watershed, the original and proposed stream reaches and degree that they both interact with the adjacent floodplain).

- Assess any new qualifying conditions needed to ensure that floodplain protocols are properly applied.

As Group 4 deliberated, it became apparent that a specialized team should be formed to assess floodplain restoration projects involving the removal of legacy sediments (Table 2). Individual team members were interviewed in October and a day-long team workshop was conducted in York, PA on 11/6/19. Recommendations were finalized in response to e-mails comments and conference calls in 2019 and 2020. The recommendations were presented to Group 4 on 2/28/20 for consideration. Many recommendations were incorporated into this memo, while several excerpts were retained in their entirety in Appendix C.

Table 2. Members of the LSR Crediting Team

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2. Background on Protocols 2 and 3

The Need for New Protocol 2 and 3 Guidance

Stream restoration projects that qualify for credit using Protocol 2 (Denitrification in the Hyporheic Zone) and Protocol 3 (Floodplain Treatment Volume) are designed to reconnect degraded and incised streams with their floodplain throughout the restoration reach. By restoring the stream flow access and groundwater interaction with the floodplain, the restorations promote natural nutrient and sediment processes in the floodplain while reducing erosive flow velocities within the project area and downstream. A detailed description of how the original expert panel defined Protocol 2 and Protocol 3 is available in Appendix A.

Since the release of the first expert panel report (USR EP, 2014), hundreds of miles of new stream restoration projects have been implemented across the Chesapeake Bay watershed. When the expert panel developed its recommendations, Natural Channel Design (NCD) was the predominant design approach being used in the Chesapeake Bay Watershed. Therefore, many of the recommendations focused on the NCD approach.

In recent years, other approaches, including stream and floodplain restoration with legacy sediment removal (FR-LSR) and regenerative stormwater conveyance (RSC) have become more common, and research and monitoring results to assess their effectiveness are now available. Any of these design approaches may succeed in restoring stream flow access to the floodplain and enhance surface water/groundwater exchange and qualify for nutrient and sediment reductions under Protocols 2 and 3. With 5 years of additional experience, several key needs were identified to improve upon the original protocols:

- Guidance for how floodplain treatment may differ across design approaches (NCD, FR-LSR, RSC)
- Re-evaluation of the hyporheic box dimensions
- A protocol that more accurately estimates the pollutant removal credits for designs that restore natural floodplain processes and provide re-connection during frequent, small storm events
- Better alignment with the new Phase 6 Chesapeake Bay Watershed Model

Section 3. Key Practice Definitions and Qualifying Conditions

3.1 Common Terminology

The group agreed on the terms and acronyms and definitions in Table 3 to guide their discussions.

Table 3: Glossary of Key Project Crediting Terms

EHZ	*Effective Hyporheic Zone:* The area of restored channels and floodplain wetlands used to calculate nitrogen reduction credits using P-2.
FTZ	*Floodplain Trapping Zone* where low energy conditions encourage trapping and filtering of sediments and organic matter in the floodplain during and shortly after storm events. Extends from the floodplain surface to one foot above the baseline floodplain elevation, unless a higher elevation is justified by local H&H modeling.
HA	*Hyporheic Aquifer:* An aquifer within the HEZ with a high hydraulic conductivity that underlies a floodplain soil layer, and where shallow groundwater exchange with the surface water occurs.
HEZ	*Hyporheic Exchange Zone:* Subsurface zone where nitrogen processing is highest and where denitrification credits are produced. The HEZ is where surface water and groundwater interact with the channel banks and the plant root zones in the floodplain soil layer. The HEZ occurs where a hyporheic aquifer underlays, and is in direct contact with the floodplain root zone, and the channel planform supports surface and groundwater exchange with the hyporheic aquifer. The HEZ will typically be shallow, often only 9 to 18 inches deep for most projects. Depths exceeding 12 inches would typically only occur in project reaches with large watersheds and/or large spring baseflows.

*Note: D*efinitions for terms specific to the original expert panel report (Hyporheic Box, NCD, RSC), are found in the Urban Stream Restoration Expert Panel (2014).

FR projects can be applied to many sub-watersheds. The restoration sites with the greatest potential occur where there is sufficient space available to restore a naturally wide floodplain. The technique can be highly effective at legacy sediment “hotspots” with high downstream sediment delivery (e.g., active streambank erosion upstream of breached mill dams; incised and overwide channels formed through unconsolidated sediments; upstream sub-watersheds that are rapidly urbanizing and delivering more storm runoff to the stream valley, Fleming et al, 2019). The FR approach has been effectively implemented in watersheds with urban, agricultural and forested land uses.

FR practices have been successfully applied in all physiographic regions of the Chesapeake Bay watershed, including the Piedmont, Coastal Plain, Ridge and Valley and Alleghany plateau provinces. These practices have also been successful in both carbonate and non-carbonate watersheds. The design for individual projects is adjusted to account for differences in underlying watershed geology.

3.2 Two Strategies for Floodplain Restoration: LSR and RSB

Table 4: Comparison of the Two Major Floodplain Restoration Strategies

Factor	Floodplain Restoration Strategy [1]	
	LSR Legacy Sediment Removal	**RSB** Raised Stream Bed
Strategy	"Lower the Floodplain"	"Raise the Stream"
Design Approach	Legacy sediments are removed to restore the floodplain, which reduces bank heights, expands hyporheic exchange, and reconnects a stream or increases existing connection of a stream to its floodplain and aquifer	Raise the stream bed either by (a) filling incised channels and/or (b) installing riffle/grade control practices To effectively lower bank heights, raise the shallow groundwater into the root zone, and more frequently access the floodplain
Boundaries and Zones	Both share common zones such as EHZ and FTZ, but use different indicators and field methods to define their precise vertical and lateral boundaries	
Project Qualifying Conditions	● Project EHZ and FTZ boundaries based on field investigations ● Avoid extended ponding/inundation of the floodplain	
	● Legacy sediment deposits are present ● LS removal primary restoration technique ● Floodplain reconnected to hyporheic aquifer by removal of fine-grained sediment	● Upstream and downstream grade controls to maintain intended stream invert ● Maintain or improve pre-restoration baseflow characteristics
Floodplain Plant Community	Restore historical floodplain plant community (often wet meadow complexes)	Wider range of potential floodplain habitat outcomes, e.g., could also be forest, scrub-shrub, wet meadow, or emergent wetlands
Protocol 2: Adjustments	Both approaches use the same methods to define the dimensions of the EHZ and calculate the total annual areal denitrification rate. Monitoring and verification are important for both methods.	
Protocol 3 Adjustments	Both approaches use the same methods to define the extent of the FTZ, model flow diversions from the stream to floodplain, and calculate the sediment and nutrient removal rate for the floodplain	

A decade ago, many urban stream restoration designs focused on channel geometry to accommodate the flows and sediment inputs to the project reach. While floodplain reconnection was often considered, reconnection in these designs only occurred several times a year during larger storm events. Over time, scientists and practitioners have realized the importance of reconnecting the stream with its floodplain. If space is available along the stream corridor, designers seek to restore streams and floodplains together, using a diversity of design approaches borrowed from NCD, LSR, RCS and other sources.

For purposes of crediting, however, the wide diversity in floodplain restoration projects can be divided into two broad strategies to reconnect streams with their floodplains:

- **Legacy Sediment Removal (FR-LSR):** a stream and floodplain restoration approach where legacy sediments are removed from the floodplain to lower the floodplain surfaces, enhancing hyporheic zone functions and increasing the annual stream runoff volume diverted into the floodplain. The primary goal, when feasible, is to reconnect the floodplain to the hyporheic aquifer, re-establishing the hyporheic exchange zone.
- **Raising the Stream Bed (RSB):** a restoration approach that raises the surface water level in an incised or degraded stream channel through two primary techniques. One technique fills the incised channel with native materials to elevate the stream invert, thereby increasing the annual stream runoff volume diverted into the floodplain. A second technique uses a series of elevated riffle grade control structures or beaver dam analogues to slow flow velocities and promote floodplain access during storm events.

These two strategies are depicted in Figures 1 and 2, respectively. In addition, Tables 8 and 12 provide a more detailed comparison of the two strategies in the context of the recommendations of this memo.

Figure 1. Floodplain Restoration Using Legacy Sediment Removal (Courtesy: Jeff Hartranft, PA DEP and Art Parola, University of Louisville)

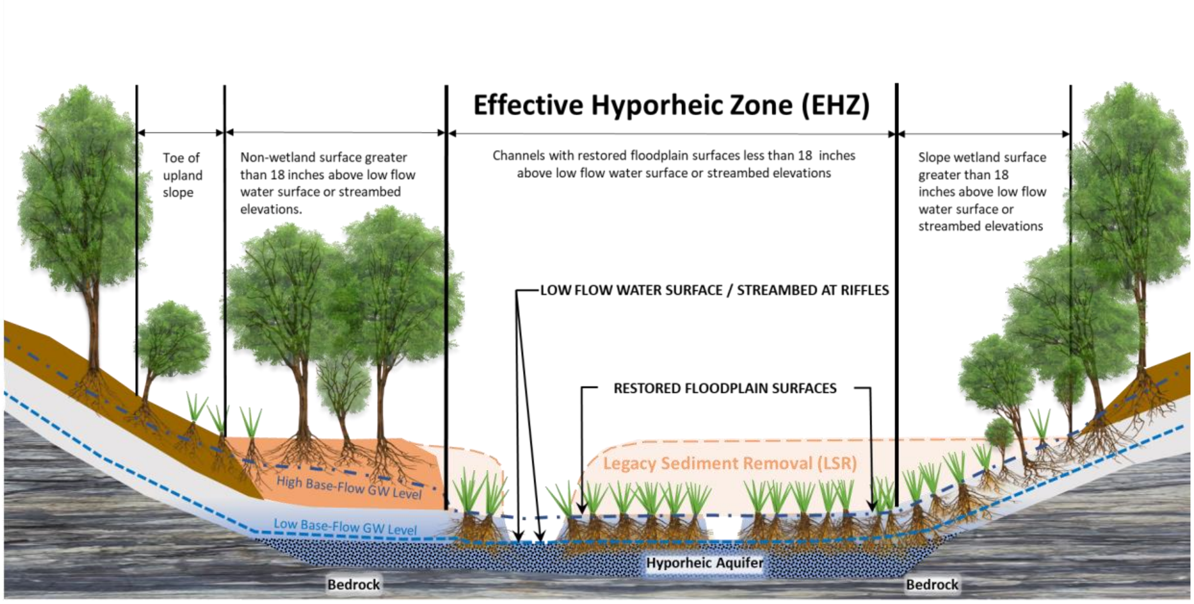
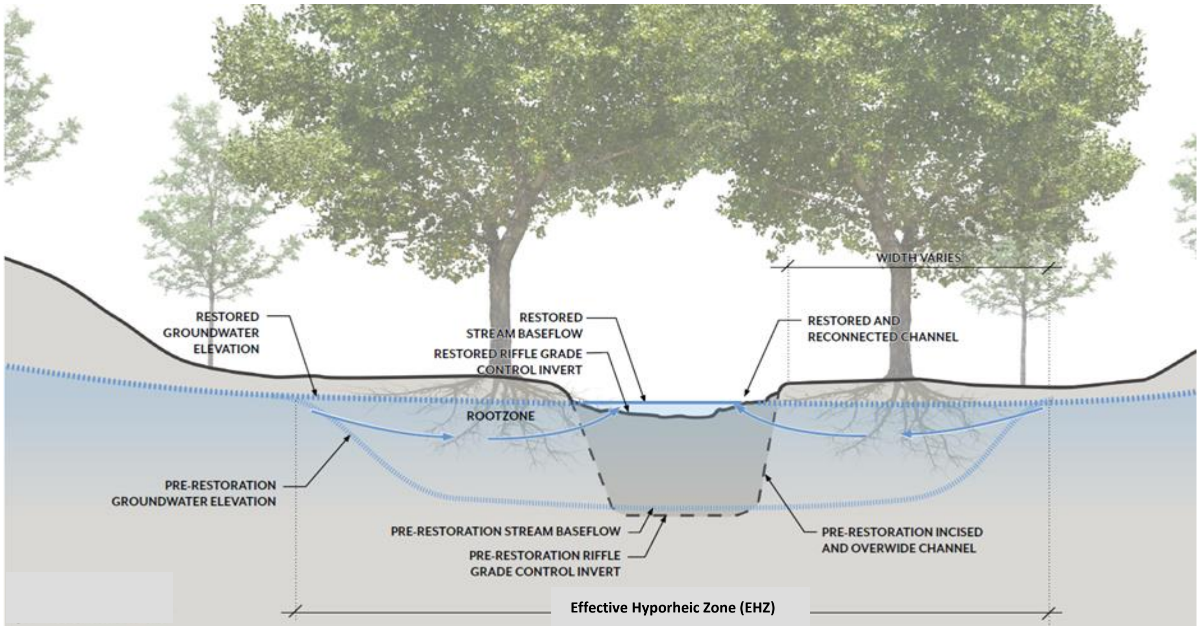


Figure 2. Floodplain Restoration by Raising the Stream Bed (Courtesy: Joe Berg, Biohabitats)



3.3 Existing Qualifying Criteria

The Stream Restoration Expert Panel (2014) outlined a series of qualifying conditions that must be met for a project to be eligible for Chesapeake Bay TMDL reductions. The qualifying conditions were designed to promote a watershed-based approach for screening and prioritizing stream restoration projects to improve stream function and habitat. Qualifying conditions from the original expert panel report will still apply and are outlined, in their entirety, in Appendix B.

3.4 New Qualifying Criteria

In addition, the following new qualifying conditions and clarifications have been added for all FR projects:

1. *Project must meet applicable floodplain management requirements in the stream corridor*. Any individual stream restoration project should be assessed with hydrologic and hydraulic models to demonstrate whether it increases water surface elevations or has adverse downstream flooding impacts. In general, these analyses are based on design storm events and flood risk conditions established by the appropriate local or state floodplain management agency (e.g., the 100-year storm event).
2. *Project must evaluate the duration of floodplain ponding in the context of the restoration goals*. Micro pools and long-duration ponding of water on the floodplain is essential for amphibian habitat, but large open water features may adversely impact the desired riparian vegetative community. In evaluating a potential restoration site and design, consider the potential adverse effects of extended open water ponding based on the soil characteristics, plant community, amphibian and other aquatic habitat goals.
3. *Project must demonstrate consideration of potential unintended consequences of the restoration (Outlined in Section 7)*. The project should document that a site impairment exists and that the interventions or restoration work proposed are appropriate to address the impairment. The proposed design should demonstrate that a positive ecological functional uplift (or change) for the stream and associated riparian system will result. Decisions related to the evaluation of existing, high functioning stream and riparian habitats, as well as other unintended consequences such as aquatic passage and potential water quality loss, will be made on a state-by-state basis by the appropriate regulatory agencies.

There are also several qualifying conditions specific to the different design approaches:

FR-RSB Qualifying Conditions

There are three additional qualifying conditions that apply to FR-RSB projects, as defined by Group 4. Those conditions are outlined below:

1. *Project must demonstrate that it either provides, or is tied into existing upstream and downstream grade controls* to ensure the project reach can maintain the intended stream access to the floodplain.
2. *Project must clearly define the boundary of the effective hyporheic zone*. For FR-RSB projects the EHZ is a maximum of 18 inches deep in the floodplain soil profile, and extends only to those areas that are regularly inundated after the streambed is raised. The actual dimensions must be confirmed by site

investigations that define stream flow conditions, root zones, aquifer conditions and the pre-project water table conditions (see Section 5 for details).

3. *Project must demonstrate that baseflow conditions are not reduced as a result of the restoration (ex. change from perennial to seasonal intermittent flow).*

FR-LSR Qualifying Conditions

There are four additional qualifying conditions that apply to FR-LSR projects, as defined by Team 5. They are summarized below. For more detail please see Appendix C.

1. Confirm the presence of legacy sediment deposits
2. Demonstrate that the design approach restores channel and floodplain connection with the hyporheic aquifer and restores processes within a hyporheic exchange zone. The EHZ is a maximum of 18 inches deep in the floodplain soil profile. When modern site constraints prevent directly connecting the restored channel and floodplain to the hyporheic aquifer, the design should include measures to interrupt flow within the hyporheic aquifer and elevate the hyporheic exchange zone into the restored floodplain.
3. Defined EHZ boundaries across channels/floodplain
4. Legacy sediment removal is the primary floodplain restoration technique

4. Summary of Recent Research

Since the most recent version of the Stream Restoration Expert Panel Report (2014), there has been a rapid increase in stream restoration projects often motivated by the desire to achieve nutrient and sediment reductions for the Chesapeake Bay TMDL. In the past, many projects emphasized the prevented sediment approach to reduce bank erosion within the stream channel (Group 1, 2020). More recent efforts focus on stream restoration designs that reconnect stream channels with their floodplains and promote more interaction between stream flows and groundwater.

This section provides a synthesis of recent research on the nutrient and sediment dynamics of reconnected streams and floodplains. The group also reviewed recent research on potential unintended environmental consequences of stream and floodplain restoration projects, which is profiled in Section 7.

Denitrification in the hyporheic zone

There are several recent studies measuring how streambed and floodplain denitrification rates are influenced by stream and floodplain restoration. The recent research generally supports the conclusions of the original expert panel, but also has refined our understanding of where and when denitrification occurs in stream and floodplain restoration projects. Table 5 summarizes some of the key recent denitrification studies that were reviewed by both groups, and supports the following general conclusions:

- *There is ample support for updating the fixed dimensions of the hyporheic box.* Clay lenses or bedrock layers often restrict hyporheic exchange and the depth of these layers can vary by physiographic region. Denitrification is also less likely to occur deeper below the floodplain surface due to distance from the root zone, which provides a critical carbon source for promoting denitrification (Mayer et al 2010, Hester et al 2016, Doll et al 2018, Duan et al 2019, Hartranft 2019).

- *Enhanced denitrification can occur in floodplain soils as well as in the channel.* Recent research also supports a shift from a hyporheic box focused primarily on the streambed to an expanded hyporheic zone that extends across the restored floodplain. Denitrification not only occurs within and below the stream channel, but also in hotspots throughout the restored floodplain. Denitrification can be enhanced when the hyporheic exchange zone is restored, floodplains are re-connected to hyporheic aquifers or wetlands, and plants provide an active carbon source. Denitrification rates are variable in space and time, but tend to increase at restoration sites with high hydraulic conductivity, connectivity to stream channel surface water, and mature floodplain plant communities (Kaushal et al 2008, Craig et al 2008, Mulholland et al 2008, Mayer et al 2010, Harrison et al 2011, WEP 2016, CBP 2019, Forshay et al 2019, Hartranft 2019).

- *Increasing the geomorphic complexity of the stream/floodplain system promotes greater denitrification.* Restored streams that increase the connectivity of the floodplain and restore greater geomorphic complexity are often linked to higher denitrification rates. This complexity can involve increasing channel sinuosity, restoring multi-thread channels, and installing instream wood and riffle structures to reduce flow velocities and increase in-stream transient storage (Cluer and Thorne, 2014, Tuttle et al 2014, Hester et al 2018, Lammers and Bledsoe 2017).

- *A strong technical foundation exists to derive an average unit area denitrification rate for the hyporheic zones associated with restored streams and reconnected floodplains.* More than a hundred denitrification research studies from across the Chesapeake Bay watershed and globally provide a basis for updating the estimated hyporheic denitrification rate formulated by the original expert panel (see Table 5).

Table 5: Denitrification in Hyporheic Zones

Summary: Restoring stream channels by increasing floodplain connectivity increases denitrification rates compared to unrestored streams. Increased denitrification occurs in a series of hot-spots and hot-moments, driven by factors including floodplain connectivity with the hyporheic zone, hydraulic residence time, nitrate concentrations and the available supply of organic carbon.

Citation	*Region*	*SR Type*	*Duration*	*Key Measurements*
Kaushal et al 2008	CB	NCD	1-2 yr	Denitrification rates in reconnected floodplains
Mulholland et al 2008	CB, OCB	NRS	1-2 yr	Uptake and denitrification as a function of stream nitrate concentrations
Klocker et al 2009	CB	NCD	1-2 yr	Nitrate uptake in restored and unrestored streams
Mayer et al 2010	CB	NCD	2-5 yr	Factors that influence denitrification rates in restored streams
Harrison et al 2011	CB	NCD	1-2 yr	Denitrification rates in urban floodplain wetlands
Weller et al 2011	CB	NRS	1-2 yr	Stream nitrate levels as a function of riparian buffers
Tuttle et al 2014	OCB	NCD	1-2 yr	Denitrification rates in streambed sediments
Hester et al 2016 & 2018	CB	FR	N/A	Model simulated nitrate removal in hyporheic zone and floodplain
Newcomer-Johnson et al 2016	CB, OCB	FR	N/A	Meta-analysis of nutrient uptake in restored streams.
Lammers and Bledsoe 2017	CB, OCB	FR	N/A	Meta-analysis of streambed and riparian denitrification rates
Mcmillan and Noe 2017	OCB	NCD	1-2 yr	Sedimentation and nutrient processing in restored floodplains
Audie 2019	CB	LSR	5+ yr	Groundwater residence time, groundwater nitrogen
Duan et al 2019	CB + Lab	RSC	< 1 yr	Effect of carbon inputs on nitrogen retention
Forshay et al 2019	CB	LSR	5+ yr	Stream and groundwater nitrate vs. denitrification

Key

CB: Chesapeake Bay Watershed OCB: Outside the Chesapeake Bay Watershed	NCD: Natural channel design LSR: Legacy sediment removal RSC: Regenerative stormwater conveyance NRS: Non-restored stream FR: Floodplain restoration	Duration >1 yr 1-2 yr 2-5 yr 5+ yr

Floodplain Trapping and Attenuation

Stream restoration designs that restore floodplain reconnection and floodplain soils can achieve additional nutrient and sediment attenuation. Recent research, summarized in Table 6, supports the following takeaways:

- *Sediment and nutrient trapping rates in reconnected floodplains can be similar to "natural" floodplains*. A series of comprehensive monitoring studies, conducted as part of the Chesapeake Floodplain Network, have measured long-term sediment and nutrient trapping rates for floodplains across the Bay watershed (Noe 2013, Noe et al 2019a). The research indicates that both sediment and organic nutrients are effectively trapped by floodplains during larger storms, where they may be stored for many decades. While most of the research has occurred in un-restored floodplains, there is some evidence that FR projects that increase storm flow diverted to floodplains can mimic or replicate trapping function (McMillian and Noe 2017, Noe et al 2019b).

- *Trapping can occur across a wide range of storm events but can be highly variable*. Another finding from recent research is that there is support for refining the treatable floodplain volume cap imposed by the original expert panel. This new research shows that sediment and nutrient retention occurs in the floodplain at a similar rate, regardless of the size of the storm event (Noe et al 2019a). On the other end of the spectrum, deposition can also occur in the frequent, small storm events for highly reconnected systems (McMillan and Noe 2017, Langland et al., 2020). Other studies have shown more mixed results. Filoso et al. (2015) reported that storm events larger than 1 inch resulted in net TSS export from the reach.

- *Restoring the stream and floodplain system will ultimately improve nutrient and sediment retention capacity in well-designed restoration projects*. In addition to trapping, restoration projects that restore floodplain/geomorphic complexity and promote overbank flooding can enhance filtering and microbial uptake removal mechanisms in the floodplain (Noe et al 2013, Hilderbrand et al. 2014, WEP 2016, CBP 2019).

Table 6. Sediment and Organic Trapping in the Floodplain

Summary: Recent literature provides a good understanding of sediment trapping dynamics within un-restored floodplains. Restored streams that promote floodplain reconnection are inferred to provide trapping rates similar to these systems across a wide range of storm events.

Citation	*Region*	*SR Type*	*Duration*	*Key Measurements*
Hupp et al 2013	CB	NRS	2-5 yr	Bank erosion and floodplain deposition rates
Noe et al 2013	CB	NRS	1-2 yr	Soil net ammonification, nitrification, N, and P mineralization
Donovan et al 2015	CB	NRS	N/A	Gross erosion and deposition rates
Gellis et al 2017	CB	NRS	2-5 yr	Erosion and deposition rates in channels and floodplains
McMillian and Noe 2017	OCB	NCD	1-2 yr	Sedimentation and nutrient processing in restored floodplains
Gillespie et al 2018	CB	NRS		Inputs, cycling and losses of nutrients and sediment
Pizzuto et al 2018	CB	NRS		Sediment transport and storage
Noe et al 2019	CB	NRS	5+ yr	Sedimentation rates and nutrient deposition
Noe et al 2019b	CB	NRS	5+ yr	Sedimentation rates and nutrient deposition

Key

CB: Chesapeake Bay OCB: Outside the Chesapeake Bay Watershed	NCD: Natural Channel Design LSR: Legacy Sediment Removal RSC: Regenerative Stormwater Conveyance NRS: Non-Restored Stream	Duration >1 yr 1-2 yr 2-5 yr 5+ yr

Pollutant Dynamics in Restored Stream Channels

Fewer studies are available to demonstrate the actual change in pollutant loads as they pass through an individual stream restoration project. These experiments are very difficult, as they require long-term monitoring of very complex and dynamic systems over a wide range of flow conditions. Nutrient sampling is needed at the top and bottom of the reach, but may also be needed in the hyporheic zone, floodplain or aquifer to fully capture the nutrient transformations occurring in space and time. Lastly, the upstream nutrient and sediment loads delivered to the stream reach can be extremely variable and are not dictated by the stream restoration approach. Further, within reach contributions of nutrients from stormwater or groundwater sources complicate pollutant load comparisons.

Several notable long-term studies on pollutant dynamics in restored stream channels are summarized in Table 7 and outlined below:

- *Upstream and site conditions are an important factor in determining the in-stream nutrient levels of a restored reach.* Incoming nitrate concentrations are one of the most important factors in determining denitrification rates within a stream restoration. Further, the capacity of restored stream systems to trap and retain sediments and nutrients in the long-term may depend on the magnitude of sediment loads originating upstream and the physical setting (gradient, watershed position) of the restoration (Tuttle et al 2014, Filoso et al 2015, Filoso 2020, Mueller-Price et al 2016, Lammers and Bledsoe 2017).

- *Restored streams are dynamic systems and adjustments are expected over time.* The age of restoration can be an important factor in nutrient removal performance. This is particularly true for sites where new riparian vegetation was planted in disturbed areas following construction. As vegetation becomes stable and more robust, carbon availability improves, increasing microbial activity (McMillian and Noe 2017, Forshay 2019; Hartranft, 2019)

Table 7. Nutrient Dynamics in Restored Stream Channels

Summary: Nutrient treatment and retention in restored stream systems are dynamic and variable based on site-specific conditions. Upstream nutrient and sediment loads as well as nutrient loads supplied through groundwater sources play a significant role in in-stream loads at restoration sites and measured reductions can potentially change over time as channels adjust and newly vegetated riparian corridors mature.

Citation	*Region*	*SR Type*	*Duration*	*Key Measurements*
Tuttle et al 2014	OCB	NCD	1-2 yr	Denitrification rates in streambed sediments
Filoso et al, 2015	CB	RSC	2-5 yr	Input-output budgets of suspended sediment in a restored reach
Mueller-Price 2016	OCB	NCD/NRS	1-2 yr	Transient storage and nitrate uptake
Forshay et al 2019	CB	LSR	5+ yr	Surface water and groundwater nitrate and denitrification rates
Langland et al 2020	CB	LSR	5+ yr	N, P and TSS removal

Key

CB: Chesapeake Bay OCB: Outside the Chesapeake Bay Watershed	NCD: Natural Channel Design LSR: legacy sediment removal RSC: Regenerative Stormwater Conveyance NRS: Non-Restored Stream	Duration >1 yr 1-2 yr 2-5 yr 5+ yr

Big Spring Run Project

One of the most comprehensive long-term monitoring studies of a floodplain restoration project is the Big Spring Run project in Pennsylvania, which investigated ecosystem responses to a project that removed legacy sediments from the valley bottom. The initial research findings are described in a series of papers and presentations by Langland et al. (2020), Forshay et al. (2019), Hartranft et al. (2011) and Hartranft (2019), Fleming et al. (2019), and are reviewed in detail in Appendix C.

5. Recommendations for Modifying Protocol 2

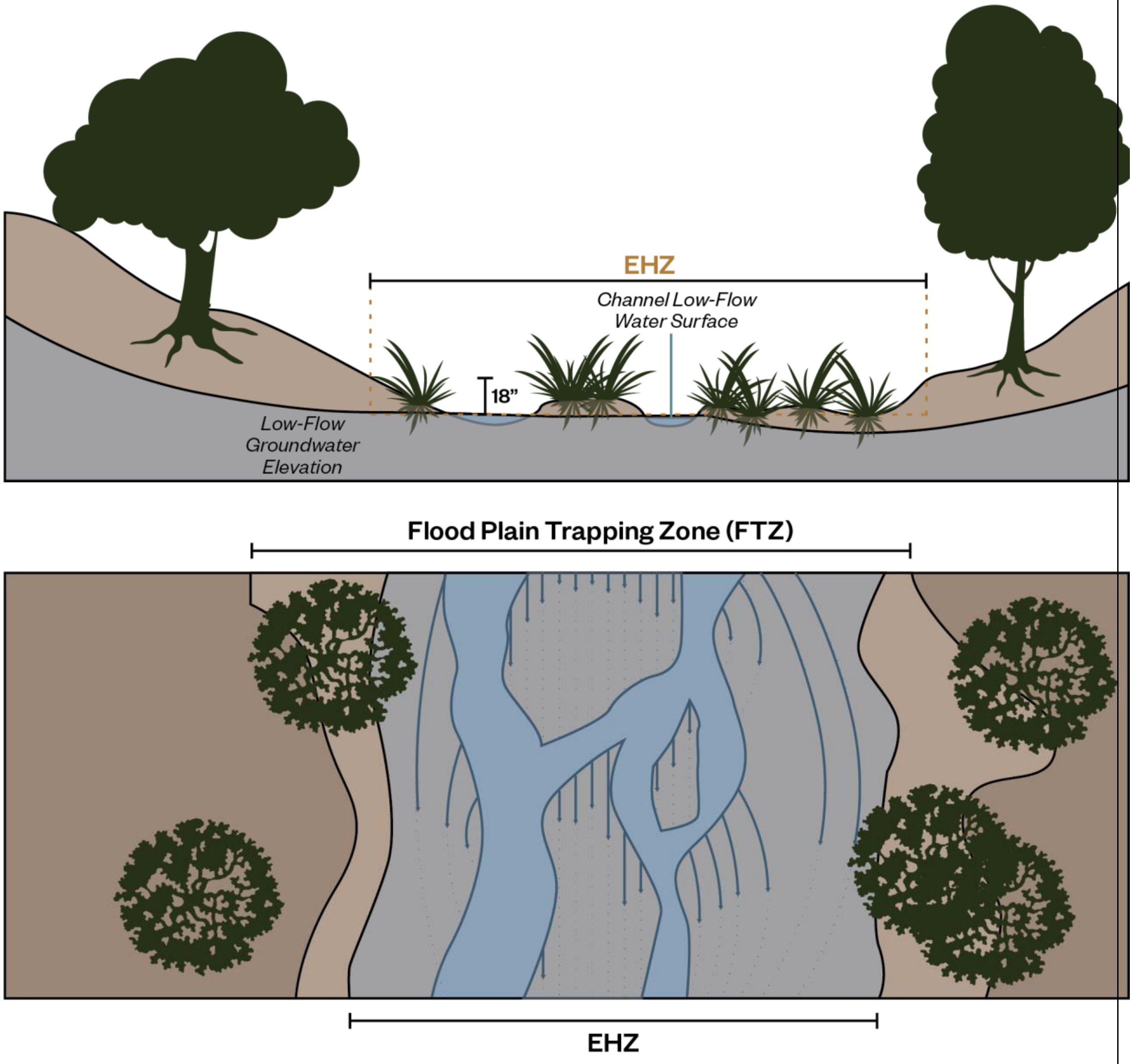
The group found many areas of consensus for how to apply Protocol 2 to FR projects, which are profiled in Table 8.

Table 8. Summary of Areas of Consensus for Protocol 2

For All FR Projects:

- Replace the existing Hyporheic Box with an area-based "Effective Hyporheic Zone". The lateral dimensions of the EHZ are defined by locations where the restored floodplain elevations are less than 18 inches above the low flow water elevations and confirmed through on-site soil/groundwater investigation (see Figure 3).
- Define how the lateral boundaries for the EHZ should be measured in the field and shown on post-construction plans.
- Guidance for on-site soil/groundwater testing to define EHZ
- Replace the existing denitrification rate (1.95 x 10^{-4} lbs/ton/day) with a new rate (2.69 x 10^{-3} lbs NO_3/sq ft/year) based on the latest science and adjust it based on site factors, such as seasonal streamflow, floodplain soil saturation and the underlying materials in the hyporheic aquifer (i.e., the Parola Equation).
- Eliminate the bank height ratio (≤1) requirement, since these don't typically apply to most low-bank FR projects.
- Final nitrogen reduction should reflect the difference between pre- and post-restoration conditions.

Figure 3. Depiction of EHZ boundaries cross-section and plan view



Graphics Credit: Cassie Frye, Hazen and Sawyer

The Effective Hyporheic Zone

The group recommends replacing the existing hyporheic box with the concept of an area-based, effective hyporheic zone (EHZ). The dimensions of the EHZ are as follows, and as shown in Figure 3.

- The floodplain area eligible for P-2 credit includes the region below and alongside a stream where there is an exchange and mixing of shallow groundwater and the surface water in the channel. This region corresponds with the lateral extent of a hyporheic aquifer composed of a porous medium, typically gravel, sand or fractured/degraded bedrock. The hyporheic aquifer also includes a thin layer of floodplain soils above this base layer and is encompassed with in the hyporheic exchange zone (HEZ). Increasing the geomorphic complexity of the stream/floodplain system promotes greater surface water/shallow groundwater interaction throughout the EHZ and should be encouraged. This complexity can involve increasing channel sinuosity, creating multi-thread channels, and installing instream wood and riffle structures to reduce flow velocities and increase in-stream transient storage.

- Operationally, the EHZ extends laterally across all areas of the channel and floodplains that are less than 18 inches above the channel bed or low flow water elevations. Any area of high floodplain (i.e., elevation greater than 18 inches above channel bed or low flow water elevation) are excluded from any P-2 credit. See Figure 3. The 18-inch floodplain elevation is a nutrient crediting-based threshold and represents the typical root zone that facilitates hyporheic exchange and provides a carbon source for denitrification. Most of the root mass is within 12 inches of the ground surface but may extend to 18 inches (National Research Council, 1995). Few floodplain wetland species have significant root mass below 18 inches. The experimental values for rates of denitrification have come from saturated zones within 18 inches of the surface.

- The actual dimensions of the EHZ should be determined by site investigations to confirm that the intended water table elevations have been achieved. These validation sites should be shown on construction plans as field indicators for future verification efforts. Designers should assess site factors to demarcate the EHZ across the valley bottom, such as hydric or saturated soils, presence of carbon sources and/or active root zones, or other floodplain stratigraphy that is less than 18 inches above the channel bed or low flow water elevations. These factors are used to accurately map the lateral EHZ boundaries at the project site. These investigations can include:

    - Trenches, direct push coring, observation of exposed stream banks, and/or tile probing analyses of exposed streambanks to document soil stratigraphy and identify buried floodplain soils, basal gravels, bedrock or groundwater elevations.
    - Direct push coring provides similar information to trenches, but can cover more area with somewhat less precision
    - Tile probes can identify depths to gravel and bedrock over a larger area in less time, but are limited to “feel” rather than sight.
    - Radiocarbon dating of organic material combined with magnetic resonance imaging can constrain the ages of floodplain stratigraphy and target restored floodplain elevations.

- Methods should be tailored to reach conditions when defining the target elevations and boundaries for the project EHZ. Photogrammetric survey or

LIDAR methods also may be used to create a digital elevation terrain model to assist in identifying the lateral boundaries of the EHZ.

Revisiting the denitrification rate

Since the original expert panel report was published, several new studies have reviewed nitrogen removal rates in restored streams. Their findings are summarized in Table 9.

Table 9. Comparison of several nitrogen removal studies published since 2012.

Study	*Sites*	*Unrestored*	*Restored*	*Method*	*Units*
Newcomer Johnson et al 2014	4	43.3 – 490.8	8.5 – 588.7	Denitrification	µg N/kg soil/day
Newcomer Johnson et al 2016	12, 32	median: 0.42	median: 1.8	Nitrate uptake	$\mu g/m^2/s$
Lammers and Bledsoe 2017	69	--	1.85	Denitrification	$mg\ N/m^2/hr$
Hester et al 2016	1	--	-3.1%	Change in N received by reach due to denitrification	Percent change

The group decided to replace the old denitrification rate (1.95×10^{-4} lbs TN/ton/day) with a new, areal rate of 1.49 mg $NO_3/m^2/hr$ (2.69×10^{-3} lbs NO_3/sq ft/year). The new rate is based on the difference in median nitrate uptake rate between restored and unrestored streams from Newcomer-Johnson et al. (2016) -- 4.96 mg $NO_3/m^2/hr$. The rate was then adjusted to assume that 30% of this uptake is from denitrification based on data on urban streams from Mulholland et al. (2008).[1]

The old rate was based heavily on in-situ denitrification studies in restored streams within the Baltimore metropolitan area (Kaushal et al., 2008; Striz and Mayer, 2008). The new rate combines the most up to date, comprehensive review of nitrate uptake literature, with the most comprehensive denitrification study to produce a more defensible rate. Furthermore, this areal denitrification rate provides a more relevant metric for calculating nitrogen removal based on the area of the EHZ.

Adjusting the Base Denitrification Rate for Site Conditions

The group's review of the recent research (summarized in Section 4) emphasized the importance of site-specific factors that appear to influence denitrification capacity within the reconnected floodplain.

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[1] Calculation for the final areal denitrification rate: 1.8-0.42 = 1.38 $\mu g/m^2/s$ = 4.96 mg $NO_3/m^2/hr$ (from Newcomer Johnson et al. 2016). 4.96 x 0.3 = 1.488 mg $NO_3/m^2/hr$ (from Mulholland et al. 2008).

Parola et al. (2019) developed a simple equation to adjust the base denitrification rate to account for these site-specific factors, which is shown in Table 10. Guidance is also provided on how to estimate reduction factors for baseflow, floodplain height and aquifer conductivity at individual sites. The group recommends that this equation be used to adjust the denitrification rate for <u>all</u> floodplain restoration projects.

Table 10: Site Specific Discount Factors for Adjusting the Denitrification Rate (Parola et al, 2019)

Effective Hyporheic Zone N credit = (Base Rate) (EHZ) (B_f) (H_f) (A_f)

Baseflow Reduction Factor (B_f)		Floodplain Height Factor [1] (H_f)		Aquifer Conductivity Reduction Factor [2] (A_f)	
Perennial baseflow	1.0	0-0.75 ft	1.0	cobbly gravel, gravel, gravelly sand, sand and peat	1.0
Baseflow in all but late summer/fall	0.75	0.76 ft – 1.00 ft	0.75	gravelly silt, silty sand, or loamy sand, sandy loam, and organic silt with no coarse material layer connected to the streambed	0.60
Baseflow in winter/spring	0.50	1.01 ft – 1.25 ft	0.50	clayey gravel, sandy silt, or sandy clay loam, loam, silt loam, and silt with no coarse material layer connected to the streambed	0.40
Baseflow only during wet seasons	0.25	1.26 ft – 1.50 ft	0.10	sandy clay, clay loam, silty clay loam, organic clay with no coarse material layer connected to the streambed	0.10
Flow only during runoff events	0.10	>1.50 ft	0.00	silty clay and clay with no coarse material layer connected to the streambed	0.01

[1] The floodplain height factor is determined by the restored floodplain height (Hf) above the streambed riffle elevations or low flow water surface elevations. Additional streambed feature elevations, like those at a run in sand bed channels or streambeds comprised of silty clay, also may be used to determine the restored floodplain height. Low base-flow (lowest 10% of flows) could also be used as a suitable alternative.

[2] This refers to an aquifer capacity factor based on the dominant materials within the streambed and below the floodplain soil of the EHZ (Figure 4). Where coarse grain aquifer layers are not directly connected to the channel, the factor should be determined based on the soil texture at the elevation of the streambed using NRCS standard texture classifications (Schoeneberger, et al., 2012).

“Base Rate” is the mean areal floodplain denitrification rate (lbs/sq foot/yr), as recommended by Group 4.

The first factor relates to the soil texture in the hyporheic aquifer beneath the proposed EHZ. In general, groundwater movement is enhanced by direct hydraulic connection with a coarse grain layer or peat layer that extends beneath the floodplain. While channels without direct hydraulic connection to an underlaying coarse grain material layer can still be credited, surface water/groundwater exchange is more constrained when the aquifer is composed of tighter silts and clays (which were often deposited in the legacy sediment layer). Under most low gradient conditions the residence time in clean gravels and sands is sufficient for denitrification (6-12 hours), and additional residence time would not further enhance denitrification.

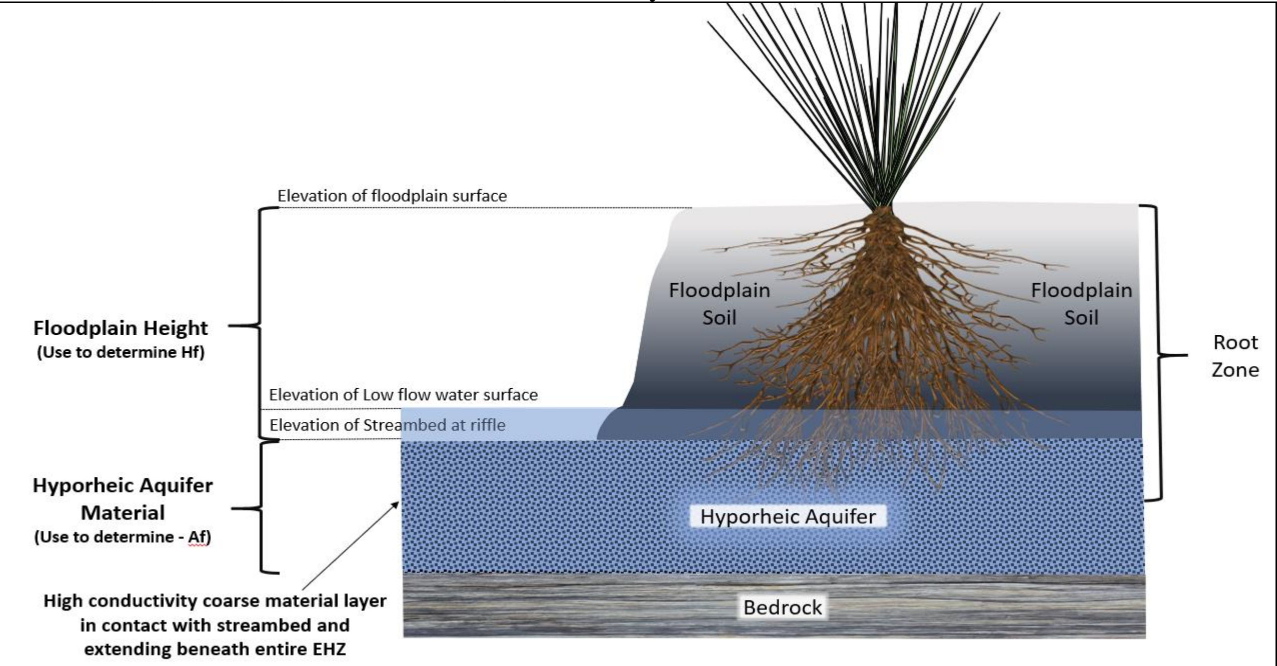
Strict use of soil lateral conductivity would lead to extremely low rates of lateral transfer of hyporheic water through silt and silty soils and would not reflect the importance of the cycling of root biomass and root architecture for establishing preferential flow paths and enhancing lateral hydraulic conductivity (Ghestem et al., 2011; Lu et al., 2020; Newman et al., 2004; Noguchi et al., 1997; Wang et al., 2020). Therefore, the aquifer conductivity reduction factor is based on the relative differences in material hydraulic conductivity between soil types (Domenico and Schwartz, 1990), adjusted to account for the impact of root mass.

The second factor, floodplain height, is based on the importance of sustained saturated soil in the rootzone. Prolonged soil saturation creates anaerobic conditions important for denitrification (Martens, 2005). One way to estimate groundwater elevations in the floodplain is to use the height of the riffle crest profile, or low baseflow (lowest 10% of flow) elevation. If the groundwater table remains within 9” of the floodplain for most of the year, it is an indicator that the ideal conditions for denitrification are present across the extent of the EHZ.

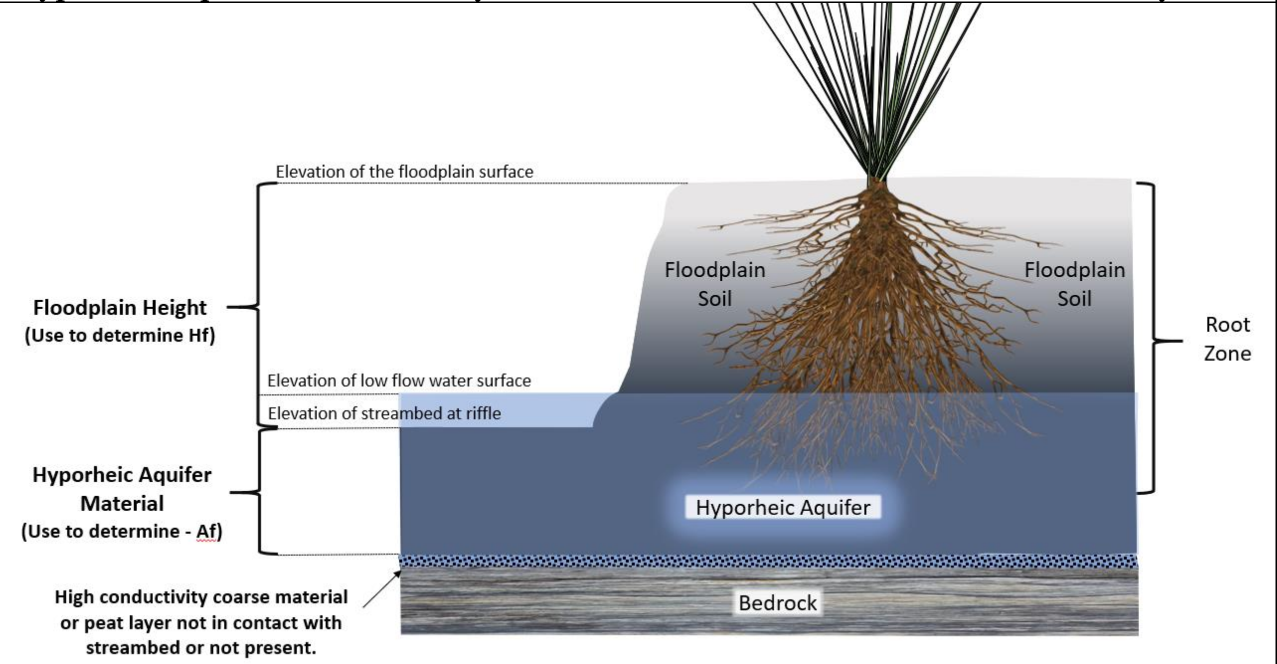
The last factor includes the seasonality of streamflow within the hyporheic zone, which varies depending where the reach is located in the stream network. The reduction factors are based on the proportion of the year in which baseflow is present. The importance of valley slope was also considered as a factor but was excluded to avoid further complication.

These factors are illustrated in Figure 4 and a step-by-step example of how to calculate Protocol 2 for a hypothetical project is included in Table 11.

Figure 4. Illustration of site-specific discount factors for Protocol 2 (Courtesy: Jeff Hartranft, PA DEP; and Art Parola, University of Louisville).



Hyporheic Aquifer with Direct Hydraulic Connection to Coarse Grain Material Layer.



Hyporheic Aquifer without Direct Hydraulic Connection to Coarse Grain Material Layer.

Table 11. Simplified design examples to show how the revised P2 works for LSR and RSB projects

Design Example[1]

A 1,000 linear ft FR project is completed. It meets all qualifying criteria outlined in Sections 3.3 and 3.4. The resulting stream-wetland complex has the following characteristics:

- Single-threaded meandering channel with perennial baseflow.
- The post-restoration floodplain surface is 6” above the riffle crest for an area that extends an average of 100 ft laterally, for the entire length of the restoration. The channel itself is 5 ft wide. (These dimensions are later confirmed by groundwater monitoring).
- The predominant post-restoration soil type is a silty-sand.

<u>*Step 1.* Define the Extent of the EHZ.</u>

Calculate the area of the restored floodplain. It is helpful to separate out the channel area to make the following steps simpler:

- Floodplain: 1,000 ft x 95 ft = 95,000 sq ft
- Channel: 1,000 ft x 5 ft = 5,000 sq ft

<u>*Step 2.* Apply the Denitrification Rate to the EHZ</u>

- Floodplain: 95,000 sq ft x 0.00269 lbs/sq ft/year = 256 lbs NO_3/year
- Channel: 5,000 sq ft x 0.00269 lbs/sq ft/year = 13 lbs NO_3/year

<u>*Step 3.* Apply the Site Specific Discount Factors</u>

The site has perennial baseflow, 6” floodplain height and a silty-sand aquifer throughout the restored floodplain. Use Table 10 to identify the appropriate adjustments.

- Floodplain: 256 lbs/year x 1.0 x 1.0 x 0.6 = 154 lbs NO_3/year
- Channel: 13 lbs/year x 1.0 x 1.0 x 1.0 = 13 lbs NO_3/year

<u>*Step 4.* Calculate the Total Nitrate Removed</u>[2]

In this example, the pre-restoration condition was an incised, highly degraded channel. Fine grained legacy sediments in the floodplain and the lack of contact between the hyporheic aquifer and the root zone meant that there was assumed to be negligible denitrification in the hyporheic zone during baseflow conditions[3]. Therefore, the sum of the post-restoration denitrification rate in the channel and floodplain represents the total nitrate removal under Protocol 2.

- 154 + 13 = **167 lbs NO3/year**

[1] Design example represents a simplified hypothetical project site to demonstrate how the nutrient reductions are calculated.

[2] Protocol 2 is based on nitrate (NO_3) removal due to denitrification. The Chesapeake Bay Program only accepts total nitrogen (TN) as a reportable unit. The value calculated in Step 4 should be reported as TN, without further adjustment. This is the most accurate way to report the removal efficiency as calculated in Protocol 2, while also serving as a conservative estimate of

the TN removed in the hyporheic zone during baseflow.

[3] If the pre-restoration floodplain area includes existing wetlands or areas that are within 18” of the low flow water elevation, practitioners and reviewers should check to ensure that the project meets the qualifying condition that the stream is highly degraded and actively degrading. If the qualifying conditions are met, the Protocol should be run on both the pre- and post-restoration conditions, and credit is earned for the difference.

6. Recommendations for Modifying Protocol 3

The group explored options to modify P-3 to improve how it estimates pollutant reduction achieved by FR projects due to increased connection between the stream and its floodplain. The group recommended three key changes to overhaul P-3, summarized in Table 12.

Table 12. Summary of Areas of Consensus for Protocol 3
For All FR Projects: ● Define the vertical and lateral dimensions of the floodplain trapping zone (FTZ) to reflect a project’s increased floodplain reconnection. ● Replace the “upstream” method of using rainfall-runoff models to determine the amount of stream flow that is diverted into the floodplain, with a “downstream” method that uses scaled, representative USGS gauge stations to calculate overbank flow. ● Apply updated annual nutrient and sediment removal rates to the pollutant loads in streamflow that accesses the FTZ. The new rates reflect the latest science from recent expert panel reports that investigated pollutant removal by non-tidal wetland restoration projects, and is based on the predominant floodplain wetland conditions (See Tables 14 and 15). ● Floodplain wetlands that are restored, created, or rehabilitated as part of a comprehensive stream and floodplain restoration project (as described in this memo) should be reported using Protocol 3. All other floodplain wetland projects should be reported using the NTW Expert Panel (NTW EP, 2019). They should not be reported twice. ● Remove the upstream watershed to floodplain surface area ratio reduction. ● Nutrient and sediment reductions are only applied to overbank flow. ● Final nitrogen reduction should reflect the difference between pre- and post-restoration conditions.

Defining the Dimensions of the Floodplain Trapping Zones:

The group specified the on-site data needed to establish channel flow and floodplain capacity and define the future boundaries of the floodplain trapping zone. These methods can include spatial data from field-run topographic field surveys, LIDAR data or drone surveys to delineate the above-ground FTZ volume within the project reach. The group agreed that modeled hydraulic parameters such as critical shear stress velocities could be used to define FTZ boundaries.

The 2014 expert panel implemented a one-foot floodplain elevation cap for crediting purposes. This was based on the assumption that suspended sediments more than one foot above the floodplain surface would not settle out onto the floodplain. Based on new research summarized in Section 4, the team now recommends replacing the one-foot floodplain elevation cap for crediting with a variable cap based on critical floodplain velocities. The group recommends that the upper limit of the floodplain trapping zone be defined by floodplain elevations that remain below critical floodplain velocities, as defined by 1-D HEC-RAS or 2-D hydrodynamic models. [2]

The one-foot maximum floodplain elevation limit would remain as the default but can be relaxed when modeled floodplain flow velocities are below 2 ft/sec (up to 3 feet or the 10-year water surface elevation, whichever is lower). To standardize this assessment, an assumed Manning's n roughness on the floodplain of 0.07 and in the stream channel of 0.035 should be used. A summary of the analysis that led to this recommendation, conducted by Coleman and Altland (2020) is presented in Appendix D.

A Downstream Approach to Diversion Modeling

There are two contrasting approaches to model how stream flow is diverted into the floodplain. The "upstream" approach relies on upstream watershed models to compute flows to the project site using long-term rainfall/runoff statistics, whereas the "downstream" approach relies on scaling USGS flow data measured at long-term gages. The USGS gage(s) may be located in the same watershed or within an adjacent or nearby watershed with similar land use or geology.

The group recommends replacing the upstream approach that is currently embedded in Protocol 3 of the expert panel report (2014), with the downstream approach. In the short term, the team suggests that it is acceptable to use existing upstream rainfall models, but they should be phased out by the end of the "grandfathering" period.

The Group concluded that upstream methods tend to under-estimate annual reconnection volumes for low-bank projects that are highly reconnected to their

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[2] The floodplain elevation cap is intended as a nutrient and sediment removal crediting construct and does not represent a specific design recommendation. Practitioners should still follow the qualifying conditions described in Section 3, regarding consideration of unintended consequences and duration of floodplain ponding.

floodplain, and that downstream methods provide more accurate estimates since they rely on measured baseflow and runoff rates from gage data.

Upstream Approach. The upstream approach is the one currently embedded in P-3 (USR EPR, 2014). Over the last five years, practitioners have created many spreadsheet models to simplify the upstream design approach, which vary greatly in terms of the hydrologic models and technical assumptions employed.

The two most common upstream methods include the rainfall to runoff method and the discrete method developed by Medina (Method 1 and 2 in USR EPR, 2014). Uncertainty is created by these methods, however, because they rely on standard hydrologic models to compute runoff that are best suited to predict large infrequent storm events and not the smaller, more common flow events that are important in floodplain reconnection.

Downstream Approach. The downstream approach estimates the floodplain diversion volume using stream flow data derived from USGS 15-minute interval flow gages that have similar watershed characteristics as the project site being evaluated.

The range of flow statistics are then related to the channel capacity of the project reach to compute the estimated overflow frequency and volume to the floodplain, given its new channel/floodplain dimensions. Several methods have been explored by Altland et al (2019), Doll et al (2018) and Lowe (2016).

Each downstream method uses flow duration curves, hydrograph separation and other flow processing techniques to define a range of flow conditions using USGS gage data. The key flow conditions include: baseflow, channel flow, treatable floodplain flows (w/in one foot of floodplain invert) and untreatable floodplain flows (that are more than a foot deep). States and practitioners have the flexibility to adapt one of the existing methods referenced above, or develop their own downstream flow diversion models, but should use the following guidance to ensure consistency:

- USGS gauge data with minimum 15-minute time step
- USGS gauge data with 10+ year flow record
- USGS gauge from watershed in the same physiographic region with similar land cover, slope, and percent karst
- USGS gauge data scaled by comparing the drainage area of gauge site to project site drainage area
- Define the baseflow discharge for the 50% recurrence interval
- Use HEC-RAS or a similar model, to determine the channel flow (the flow that would just fill the existing channel without overtopping its banks) and the floodplain flow at maximum creditable floodplain inundation depth (1 ft is the default unless modeling shows velocities below the threshold described previously).

Altland et al (2019) compared upstream vs. downstream models for computing the annual volume diverted into the reconnected floodplain for multiple FR-LSR projects of various scales and conditions, including the BSR project that has been extensively monitored. They concluded that upstream methods tend to under-estimate annual reconnection volumes for low-bank LSR projects, and that downstream methods provide more accurate estimates since they rely on measured baseflow and runoff rates from gage data (and compared well with treatment rates measured at the BSR site). A summary of their modeling results for five projects can be found in Table 13.

Table 13: Comparison of Floodplain Treatment Volume for 5 Projects Using Different Upstream and Downstream Methods

Site Factors	FR-LSR Restoration Projects				
	Israel Creek	Bens Branch	Talbot Branch	Furnace Ck	Big Spring Run
Drainage Area (mi^2)	29.1	2.4	0.3	1	1.9
IC (%)	5.0%	5.4%	1.0	45.9	14.0
Length (ft)	3666	4180	3392	4753	2592
Method	Percent of Annual Flow Volume Diverted to Floodplain for Treatment				
Upstream 1	8.6%	11.2	19.9	12.7	14.1
Upstream 2	20.4%	78.6	81.0	78.7	84.4
Downstream 1	48.1%	30.6	19.1	64.6	83.1
Wetland RR	0.2%	2.8	14.3	7.6	2.1

Modeling analysis by Altland et al (2019).

Altland et al (2019) suspects the USGS gage approach may be more sensitive to differences in flow distributions due to varying watershed characteristics (e.g., carbonate vs. non-carbonate watersheds, rural, suburban or urban watersheds). Consequently, the group developed more guidance on improved methods to derive regional flow curves from USGS gage data to estimate floodplain flow diversions (see Appendix E). The new methods can be used for all projects in a region to standardize the computation methods and reduce credit variability. At the present time, resources are not available to develop standardized curves, but the group recommends this as a priority moving forward.

Selecting an Annual Floodplain Wetland Removal Rate

The original expert panel report reasoned that floodplain pollutant removal from overbank flow would behave in the same fashion as a restored floodplain wetland and thus relied on wetland removal rates and technical assumptions largely developed by Jordan (2007). In the original formulation of P-3, the pollutant load treated by the floodplain was multiplied by a base wetland removal rate.

Since then, two new panels conducted a comprehensive literature review of the pollutant removal capability of non-tidal wetland restoration practices (WEP 2016; NTW EP 2019). The expanded data analyses contained in these two reports provide new insight into the nutrient and sediment removal capability of floodplain wetlands, and a stronger technical foundation to support base wetland removal rates.

The pollutant removal studies evaluated by the WEP (2016) and NTW EP (2019) were based on surface water input loads from the immediately adjacent land uses, and include trapping, settling and denitrification processes. Because the pollutant removal rates will only be applied to overbank flow in Protocol 3, there will not be double-counting of denitrification with Protocol 2, which only considers denitrification during baseflow. The removal rates established for three different categories of non-tidal wetland "restoration" are shown in Table 14.

Table 14. Floodplain Wetland Removal Rates in Prior CBP Expert Panel Reports

Wetland BMP Category	Pollutant Removal Rate (compared to pre-restoration)		
	Total N	Total P	TSS
NTW Restoration	42%	40%	31%
NTW Creation	30%	33%	27%
NTW Rehabilitation	16%	22%	19%

[1] as outlined in expanded lit review and recently approved Expert Panel Report(NTW EP, 2020)

[2] rates are applied to the stream bed and bank load delivered to the project reach (see Table 16 and Appendix H for example). The "upland acres treated" factors from the NTW EP do not apply for Protocol 3.

Group 4 recommends that the pollutant removal rate applied to the floodplain treatment volume should reflect the predominant floodplain wetland category(s) present at the site, as defined in Table 15. Any wetlands that fall within the boundaries of the FTZ and are reported for credit under Protocol 3 should not also be reported using the Non-Tidal Wetlands Expert Panel, as it would double-count nutrient and sediment reductions from these practices.

Wetland delineations are normally required as part of the stream restoration permit approval process. Consequently, designers should have adequate field delineation data to determine how much project floodplain area falls into each restoration category and choose the correct rate to calculate pollutant removal within its FTZ.

Table 15. Definitions of Restoration Categories from NTW EP (2020)

Restoration: Manipulate physical, and biologic characteristics of a site with the goal of returning natural/historic functions to a former wetland:

- No wetland currently exists or has been extensively degraded
- Hydric soils are present
- "prior converted"

Creation: Manipulate site characteristics to develop a new wetland that did not previously exist at the site:

- No wetland currently exists
- Hydric soils are not present
- Functional gain due to new wetland features

Rehabilitation: Manipulate site characteristics with the goal of repairing natural/historic functions to a degraded wetland:

- Wetland present
- Wetland condition or function is degraded

Lastly, Group 4 found no evidence in the most recent series of NTW restoration expert panel reports to justify the continued use of Step 4 (from the 2014 Expert Panel Report) for P-3. The original stream restoration panel (USR EPR, 2014) added Step 4 to adjust the FTZ load reduction downward in situations where the upstream watershed to floodplain surface area ratio was less than one. The group noted that sediment and nutrient trapping in the FTZ was governed more by actual flow velocities in the FTZ that occur during storm events which are considered in the new methods to define its boundaries.

Table 16. Simplified design example to show how the revised P3 works for FR projects

Design Example[1]

A 4,000 ft FR project is completed. It meets all qualifying criteria outlined in Sections 3.3 and 3.4. The project has the following characteristics:

- Single-threaded meandering channel with perennial baseflow.
- Has a FTZ defined by LiDAR (or other topographic field data) and hydraulic modeling
- The project is located within the Piedmont, with a 2.5 sq mile watershed that is 15% impervious, with little to no karst.
- The floodplain contained hydric soils, demonstrating evidence of historic wetlands that had been buried or degraded by legacy sediment infill.
- The FTZ includes 80% restored wetlands and 20% rehabilitated wetlands.

Step 1. Determine the treatment depth in the FTZ

- Hydraulic modeling showed an average flow velocity of 2.5 fps at one foot of flow depth in the FTZ, so the 1 ft elevation cap is applied.

Step 2. Identify the channel flow, floodplain flow at the treatment depth in the FTZ, and mean baseflow

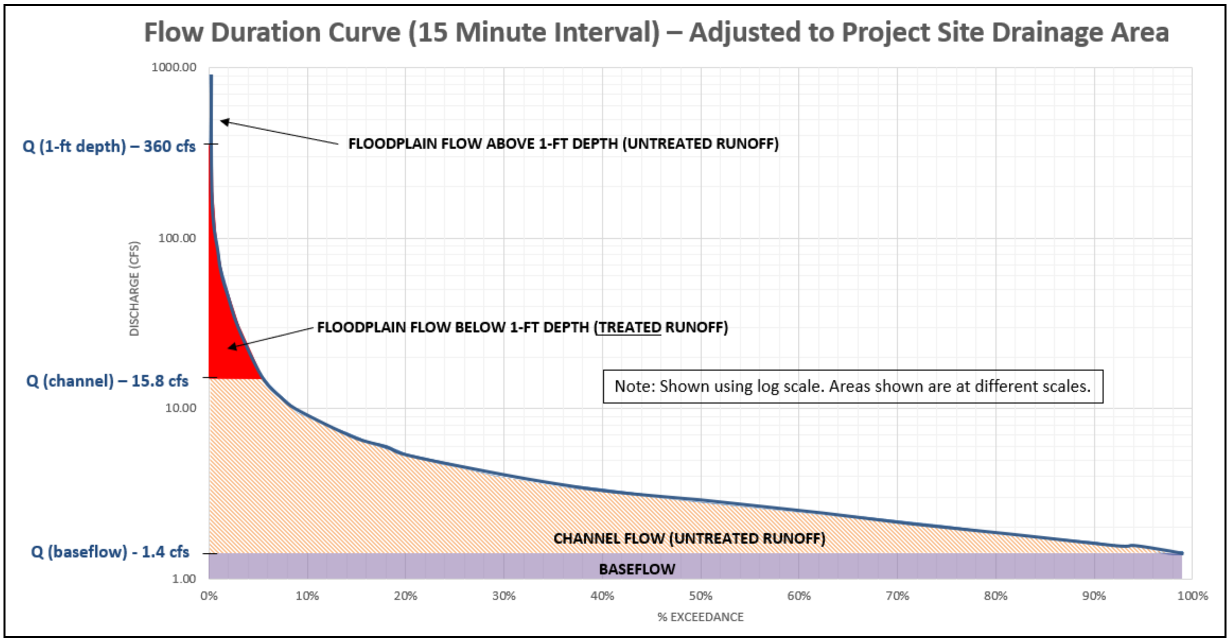
- In this example, the practitioner's hydraulic modeling determined that the top of bank channel capacity is 15.8 cfs.
- Similarly, hydraulic modeling of the flow at 1 ft of depth in the FTZ yielded 360 cfs.
- The 50% exceedance baseflow is 1.4 cfs, as determined by hydrograph separation analysis using USGS HySep computer program, which is incorporated in the Groundwater Toolbox program as outlined in Appendix E.

Step 3: Develop an appropriate flow duration curve from comparable USGS gauge station.

- The practitioner selected a USGS gauge station within the Piedmont with 20% impervious cover in a 5 sq mile drainage area.
- A flow duration curve was developed using methodology presented in Appendix E, adjusting discharges by watershed area.

Step 3. Determine the treatable flow

- Channel flow, floodplain flow at 1' depth and mean baseflow were plotted on the representative flow duration curve below.



- Treatable flow = (Total flow) – (channel flow) – (flow over 1 ft) + (baseflow)
- Convert to % flow treated (area under curve between Q(1-ft depth) and Q(channel)

divided by total area under curve above baseflow) = 43.5%

- Using the same flow duration curve, the same process was repeated for existing conditions. Treatable flow in existing conditions = 6.2%
- Difference between existing and proposed conditions is 43.5 – 6.2 = 37.3% treatable flow as a result of the project improvements.

<u>Step 4. Determine the load delivered to the project site</u>

- Using CAST (See Appendix H) determine the total load delivered to the project site
- Load delivered to site (using CAST): 1,570 lbs TN, 329 lbs TP, and 692 tons TSS
- Multiply the percent of treatable flow that is in the FTZ by the pollutant load delivered to the reach
- Treatable Load = Total Load x % treatable flow from Step 3 = 586 lbs TN, 123 lbs TP, and 258 tons TSS

<u>Step 5. Apply the appropriate Wetland Pollutant Removal Efficiencies.</u>

- Using Table 14 determine weighted wetland removal efficiency rate for project (80% wetland restoration and 20% wetland rehabilitation) = 36.8% TN, 36.4% TP, and 28.6% TSS
- TN Removed = Treatable TN Load x 0.368 = 215.6 lbs/yr
- TP Removed = Treatable TP Load x 0.364 = 44.7 lbs/yr
- TSS Removed = Treatable TSS Load x 0.286 = 73.9 tons/yr

[1] Design example represents a simplified hypothetical project site to demonstrate how the nutrient reductions are calculated.

7. Environmental Considerations for Stream and Floodplain Restoration Projects

7.1 Key Findings on Unintended Environmental Consequences

Stream restoration projects have the potential to exert unintended environmental consequences, particularly if they are poorly assessed, located, designed or constructed. The group reviewed the most recent monitoring and research studies that identified potential unintended consequences of stream restoration projects in the Chesapeake Bay watershed and discussed how these potential impacts can be managed by adopting "best practices" during restoration project planning, design, and construction. The group offers the following caveats about their recommendations:

- The guidance provided on the environmental impacts of stream restoration projects is advisory in nature and is intended to promote best practices to minimize potential impacts for individual projects to the extent to which they apply.
- State and federal permitting agencies reserve the discretion to apply this guidance to support better permit decisions and always retain the authority to make permit decisions and/or establish permit conditions for TMDL-driven stream restoration projects. Likewise, decisions about how to weigh the potential for temporary adverse impacts on existing site environmental qualities against the long-term environmental benefits is left to the appropriate regulatory agencies.
- While this section primarily focuses on floodplain restoration projects, some of the research reviewed was drawn from other types of stream restoration projects or from unrestored streams or floodplains in the Chesapeake Bay watershed.

The group listened to more than a dozen presentations from researchers and regulators on the unintended environmental consequences and co-benefits associated with stream restoration projects. Many of the presentations involved floodplain reconnection projects, and all are included in Appendix G.

All stream restoration design approaches (i.e., NCD, RSC, LSR and their variants) have the potential to cause unintended consequences that degrade the quality of streams and/or floodplains. These consequences have been documented in a series of recent research studies in the mid-Atlantic region and elsewhere, which are profiled in Table 17.

Unintended environmental impacts have been observed in restored stream channels, floodplains and downstream ecosystems. Some common examples are shown in Figure 5. A more comprehensive summary of the scientific literature supporting Table 17 can be found in Appendix F.

Table 17: Review of Potential Unintended Consequences Associated w/ Floodplain Restoration Projects [1]

Project Stream Channel		
Impact [2]	*Evidence*	*Notes*
Depleted DO	M, P [3,4]	Associated with stagnant surface waters and high dissolved organic carbon. Often observed as seasonal.
Iron Flocculation	M, P	Observed in both restored and unrestored streams. Associated with high dissolved organic carbon, anoxic conditions and the use/presence of ironstone.
Warmer Stream Temps	M, P	Associated with loss of tree canopy in the riparian corridor. Stream and floodplain connection to groundwater in the hyporheic aquifer can mitigate increased temperatures.
More Acidic Water	M, E	Associated with disturbance of channel and floodplain soils during construction.
More Primary Production	M, P	Associated with loss of canopy cover in the riparian corridor.
Benthic IBI Decline	M, P	Associated with construction disturbance, with recovery to pre-project levels in some cases.
Construction Turbidity	M, E	Sediment erosion during construction, especially when storm flows overwhelm instream ESC practices
Floodplain/Valley Bottom		
Project Tree Removal	M, P	Riparian/floodplain forest losses are common due to clearing for design and construction access.
Post-Project Tree Loss	M, P	Field and lab studies show that long-term soil inundation results in mortality and morphological changes in tree species.
Invasive Plant Species	M	Construction disturbance and frequent inundation of the floodplain can serve as vectors for invasive species along restored and unrestored streams.
Change in Wetland Type or Function	M	Changes in vascular plant communities as a result of floodplain inundation are expected and may be desirable or undesirable depending on the habitat outcome.
Downstream Ecosystems and Infrastructure		
Increased Flooding	E	Well-designed floodplain restoration projects should result in local flood stage reductions
Infrastructure Damage	E	Well-designed floodplain restoration projects should result in avoidance of flood damages to local infrastructure. Damage due to failure can occur in restored and unrestored streams.
Downstream Benthic Decline	M	Associated with changes in habitat conditions, and construction disturbance. Changes may be temporary.
Blockage of Fish Passage	M	Incision, large drops or structure failures can impede passage. More study needed

Notes:

[1] Adapted from summaries presented by Clearwater (2019), Guignet (2019), Mayer (2019) and Williams (2019).

[2] Impacts are defined in relation to the stressors measured in a comparable unrestored urban stream/floodplain system.

[3] Evidence includes impact (M): observed or monitored at many restoration sites or (P): documented in a scientific report/paper or (E): observed at some project failures.

[4] References profiled in Appendix F.

Figure 5: Un-intended Environmental Impacts Caused by Poor Stream Restoration Projects

(a) Riparian Tree Loss Can be Severe During Construction unless Extreme Care is taken to Preserve and Protect Existing Trees

(b) Upstream Passage of Fish and other Aquatic Life can be Impeded by PoorlyDesigned In-stream Structures that Create Vertical Drops

(c) Excessive Pooling or Higher Groundwater Levels Can Kill Remaining Trees in the Floodplain that are not Adapted to the Changed Conditions

(d) Poor Designs Can Cause Water Quality Impacts to the Restored Stream Channel, such as stream warming, lower DO and iron flocculation (shown above)

Photo sources: (a-c) CSN files (d) courtesy M. Williams (2019)

Strong variability is frequently observed in the severity of impacts at individual projects. This variability is often related to:

- Site-specific or reach factors
- Exposure to extreme flow events, and
- Care taken during project assessment, design and construction.

It is generally acknowledged that restoration project construction often exerts short-term adverse environmental impacts. Depending on the pre-restoration condition and level of construction disturbance, years of ecosystem maturation may be needed before a project fully meets its long-term restoration objectives and realizes its full environmental benefits. There are few long-term monitoring studies specific to these types of projects available to confidently state the probability of long-term adverse impacts, though some failures are anticipated. There are also a handful of lab and field studies, referenced below, that can help reasonably evaluate the potential for adverse impacts.

Perhaps the most visible project impacts involve vegetation disturbance and tree loss through either direct removal during construction or mortality afterwards due to increased groundwater elevations and/or extended inundation of the floodplain, compaction and root disturbance from construction activities, or a variety of other reasons. A substantial literature review documents the response of forest and wetland plant species to changes in floodplain inundation frequency and root saturation. Some examples include Angelov et al (1996), Anderson and Pezeshki (1999), Pezeshki and Delaune (2012), Folzer et al (2006), Garssen et al, (2015), Teskey and Hinckley (1977 a,b, 1978) and Simon and Collison (2002).

Kaushal et al. (2019) provisionally demonstrated that tree removal during stream restoration construction can trigger sub-surface fluxes of nutrients out of the riparian zone and into the stream. The significance and duration of these fluxes and their influence on stream nutrient dynamics is still be investigated. In addition, water quality impacts have been observed in some restored stream channels, including lower dissolved oxygen, iron flocculation and stream warming. Appendix F provides a more detailed summary of available research on each of these impacts.

7.2 Best Practices for Floodplain Restoration Projects

The original expert panel recognized the potential for unintended consequences and outlined a set of general environmental qualifying conditions for all stream restoration projects (USR EPR, 2014—excerpted in Appendix A). These general recommendations were designed to promote a watershed-based approach to screen restoration projects to improve their stream function and habitat.

While Group 4 concurs and reaffirms the prior expert panel recommendations, they concluded that future projects should apply a specific list of “best practices” to reduce the potential for un-intended environmental impacts. Further, the group agreed that best practices need to be applied over the entire project life-cycle – beginning with initial site assessment, project planning and design, construction, and operation over the lifetime for which the credit is generated.

Our current understanding of best practice is always evolving as new science sheds light on how aquatic ecosystems respond to restoration interventions along the stream and its floodplain. At this time, the group strongly recommends adoption of the following best practices for stream and floodplain restoration projects:

Best Practices During Project Planning and Design

1. Planners should evaluate options for combining stream and floodplain restoration with stormwater, forestry and agricultural BMPs in the contributing watershed area. It is generally accepted that individual stream and floodplain restoration projects are more effective when pollutant loads delivered from the contributing watershed also are reduced. The CBP has developed numerous BMP options that can be applied for pollutant reduction credit within contributing watershed areas:

    - Stormwater retrofits (of ponds, ditches and new practices)
    - Impervious cover disconnection or removal
    - Landscaping practices, such as rain gardens and conservation landscapes
    - Tree planting and reforestation projects
    - Urban nutrient plans for managed turf
    - Street and storm drain cleaning
    - Investigations at stormwater outfalls to trace pollutant discharges

2. Identify and remedy site-specific source(s) of impairment in the stream and floodplain (e.g. sedimentation, flow alterations and/or habitat degradation). Use both reference form and processes to assess impairment and provide the basis for restoration designs. Individual project designs should apply the restoration principles outlined by EPA (2000).
3. Follow guidance from the appropriate federal, state or local regulatory authority regarding assessment of existing high-quality habitat and ecosystem functions. The following are considerations that may be required:

    - Assess existing habitat characteristics and functions across the project during project planning and design phases and compare with predicted post-construction conditions to evaluate uplift
    - Conduct intensive surveys when high quality stream or wetland resources are identified within or immediately downstream of the project reach to assess potential impacts to these resources
    - Avoid restoration projects at sites where aquatic assessment metrics indicate that the stream is currently in good or excellent condition.
    - Avoid restoration projects at sites where floodplain or wetland metrics indicate that the current floodplain plant community is functioning well.

- Carefully survey existing forests minimize tree clearing during construction and identify individual trees that should be saved.

4. Give special consideration to protecting freshwater mussels and their host fish if they are present within or immediately downstream of the project reach. Common, rare, threatened and endangered species all deserve conservation consideration per the findings of Kreeger et al (2018). The site should be surveyed for mussels as soon as possible. Freshwater mussels can be inconspicuous and as such a thorough survey is important. Site designs should consider the presence of live mussels and avoid disturbances. It may be helpful to view their presence similar to infrastructure or wetlands (Blevins et al. 2019). Mussels represent one of the priority species of conservation in these ecosystems, and as such stream restoration designs which leads to known disturbance of these organisms would be counterproductive and inappropriate.

5. Ensure that all aquatic life (e.g. fish, eels, etc.) can safely pass through the project reach through careful design of instream structures. Passage may be accomplished by aquatic life moving through, over, or around instream structures.

6. Avoid designs that:

    - Create stagnant pools within the stream channel and long-term inundation or ponding across the floodplain width. Creation of vernal and temporary pools within the floodplain as a habitat feature is acceptable.
    - Rely on extensive bank armoring using rock or other fixed structures and disregard the maximum armoring limits adopted by Group 3 (2020).
    - Dewater perennial stream channels. Rather, irrigation curtains and other techniques can be used to maintain consistent baseflow conditions.

7. Clearly describe how the proposed project will affect local and downstream elevations of the 100-year floodplain, and conform to federal and state floodplain management requirements through appropriate H&H modeling.

8. Assess potential for toxics contamination in floodplains located within highly urban areas or brownfields and watersheds that have a history of potential contamination through soil investigations. Avoid disturbing acidic soils if they are present at the project site.

Best Practices During Project Construction

1. Reduce the use of "iron-stone" rock or sand and other iron-rich construction materials when raising the streambed to avoid iron flocculation during anoxia.

2. Decrease the use of labile organic matter added to the stream bed (e.g., compost) to avoid mobilization of metals or phosphorus.

3. If required by the appropriate federal, state or local regulatory authority, minimize removal of mature trees in the existing riparian zone, as specified in the project's forest conservation plan.

4. Minimize disturbance caused by construction access and use appropriate equipment to reduce compaction of the stream's bed, banks and floodplain.

5. Work "in the dry" during project construction to reduce potential for downstream bed sedimentation or turbid discharges.

6. Recycle wood from any trees cleared during construction to introduce carbon sources and restore habitat features within the restoration project site.

Best Practices for Post Construction Phase

1. Verify that stream restoration projects continue to meet their performance objectives for hyporheic exchange and floodplain reconnection functions. Individual floodplain restoration projects should be inspected every five years using the visual indicators, numeric triggers and failure thresholds outlined by Group 1 (2019). Some of the key indicators for this class of projects focus on maintaining the:

    - Pre-restoration baseflow conditions in the stream channel
    - Intended bank heights along the project reach to achieve the desired frequency of floodplain reconnection
    - Desired density and species targets in the restored floodplain plant community.

2. Implement a vegetation management plan to maintain the post-restoration vegetation target for the banks and floodplain (including invasive species management). Also consider potential mosquito management needs if the project is in close proximity to residential or public access.

3. Allow for adjustment of structures that affect water elevations if they are responsible for unacceptable inundation or pooling over the surface of the floodplain. If this is a concern, the inspection frequency may need to be increased.

7.3 Project Verification and Measuring Functional Uplift

The original expert panel did not outline procedures for verifying the performance of stream restoration projects built for pollutant removal credit. This was rectified in 2019, when the USWG approved procedures for field verification of stream restoration projects, after their original construction permit monitoring requirements expire (Group 1, 2019).

The new field verification approach utilizes a two-stage inspection process of the entire project reach. The first stage involves a rapid inspection to assess project condition, relying on simple visual indicators. The second stage involves a forensic inspection to diagnose the nature and cause(s) of the failure and whether project functions can be recovered by additional work.

While Group 4 supports the visual indicators developed by Group 1 for P2 and P3, it does suggest a few specific modifications to account for the unique low-bank conditions of FR projects. The modifications help ensure that the desired elevation(s) for stream/floodplain reconnection are maintained in the face of future upstream storm flows or head-cuts advancing from downstream. These modifications are shown in Tables 18 and 19, respectively.

Table 18. Defining Loss of P-2 Pollutant Reduction Function for FR Projects (Denitrification in the EHZ) [1]

Criteria	*Key Visual Indicators for FR Projects*
Evidence that the reach does not meet the design assumptions for the EHZ (such as when channel incision reduces access to hyporheic zone).	● Less than 80% of ground or canopy cover established in the project's EHZ ● Stream lacks any observable baseflow during normal dry weather conditions ● Bank height (floodplain height over streambed) greater than 18 inches, due to post-construction floodplain deposition or channel incision ● Failure of riffle-grade control practices (where present) used to raise water levels

[1] Modified from Group 1 (2019)

Table 19. Defining Loss of P-3 Pollutant Reduction Function for FR Projects [1]

Criteria	*Key Visual Indicators for FR Projects*
Channel incision or floodplain sediment deposition increases effective bank height, thereby reducing intended annual stream flow volume diverted to floodplain	● Inability to meet 80% ground or canopy cover targets within the project's designed FTZ ● No evidence of overbank deposition and floodplain retention, as signified by a lack of sediment deposition, terraces, wrack-lines or leaf clumps in floodplain ● Restored floodplain elevation (floodplain height over streambed) greater than 18 inches above channel or low flow water elevation due to post-construction floodplain deposition or channel incision ● Incision or downcutting of channel fill that causes an increase post-restoration bank height ● Failure of channel grade control practices used to raise water levels (if using RSB approach)

[1] Modified from Group 1 (2019)

The group also recommended that:

- Field crews observe indicators in a manner that adequately cover the surface area of any EHZ or FTZ created for the project to ensure it is still functioning as originally designed.

- Post-construction as-built plans should clearly show EHZ or FTZ areas to assist in future verification and define average bank elevations.

7.4 Measuring Functional Uplift at Floodplain Restoration Projects

The original expert panel report emphasized the importance of demonstrating functional uplift within a stream as part of any TMDL restoration project (USR EPR, 2014). The expert panel reviewed several methods to measure uplift, and ultimately adopted the functional pyramid approach developed by Harman et al (2011).

The group concurs with the need to measure functional uplift but notes that this assessment should be done across the entire reconnected stream and floodplain together. In addition, the reference condition to measure functional improvement should be the entire valley bottom ecosystem, with an emphasis on the connection of the root zone to the groundwater/aquifer.

Several recent assessment tools developed by Starr and Harman (2015 a,b) and Starr et al (2016) may be useful for measuring functional uplift at floodplain restoration projects, possibly in combination with traditional wetland functional assessment methods such as FHWA, HGM, WET and others.

The group agreed that basic research to define and test new metrics to effectively measure functional uplift in floodplains was an urgent management priority.

Critical Research to Fill Priority Management Needs:

The group agreed on four research priorities that can fill gaps in our understanding of how stream restoration projects can be improved to enhance their ecosystem functions:

- Long-term, interdisciplinary research studies on how streams and floodplains respond to innovative design approaches that emphasize how sediment and nutrient dynamics and ecosystem functions change in projects over time. A good example of the scope for effective multi-year investigations is the Big Spring Run research project, which is profiled in Appendix B-2 of Group 5 (2020).

- Short and long term research efforts focused on the effectiveness of specific best practices in mitigating unintended environmental impacts caused by stream restoration projects. One of the most urgent research priorities is measuring how stream nutrient dynamics respond to different levels of riparian tree loss during and after construction.

- Detailed forensic investigations to identify the causes of failure for projects that do not pass their post-construction verification inspections, per Group 1 methods.

- Basic research to define and test new metrics that can effectively predict and measure the degree of functional uplift and/or functional losses achieved by floodplain restoration projects over short- and longer time frames.

8. Tracking and Reporting Stream Restoration Practices in CAST

The following information is needed to report Stream Restoration BMPs to the Chesapeake Bay Program Office:

- *BMP Name:* Stream Restoration
- *Final Calculated Reductions:* Protocol 2 lbs TN; Protocol 3 lbs TN; Protocol 3 lbs TP; Protocol 3 lbs TSS
- *Project Location:* Qualifying NEIEN geographies including: Latitude/Longitude; or County; or County (CBWS Only); or Hydrologic Unit Code (HUC12, HUC10, HUC8, HUC6, HUC4, State (CBWS Only)
- *Date of Implementation:* Year

In addition, the group recommends the following information be tracked to assist in future verification efforts:

- Project length
- Primary design approach
- EHZ and FTZ dimensions
- Site conditions used to determine Protocol 2 adjustment factors (baseflow, soil saturation, soil texture).
- Documentation of the credit calculations, specifically the flow characteristics used for Protocol 3 (flow duration curve used, baseflow, channel flow, flow at 1ft floodplain elevation)
- Justification for selected floodplain wetland type in Protocol 3

It is best practice for the installing agency to maintain an extensive project file for each stream restoration project installed (i.e., construction drawings, as-built survey, credit calculations, photos, post construction monitoring, inspection records, and maintenance agreement). The file should be maintained for the lifetime for which the load reduction will be claimed.

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APPENDIX A. CONDENSED SUMMARY OF ORIGINAL PROTOCOLS 2 and 3 (USR EPR, 2014)

Summary of Protocol 2: Denitrification in the Hyporheic Zone

Stream restoration designs that increase hyporheic exchange between the floodplain rooting zone and the stream channel help promote biological nutrient processing. To account for the additional denitrification occurring in these restoration projects, the original expert panel developed Protocol 2. The method assumed that most of the denitrification occurs in a “box” that runs the length of the restored reach. The box extends 5 feet beneath the stream invert and 5 feet to either side of the streambank of the median baseflow channel. The full method is summarized in Table A-1.

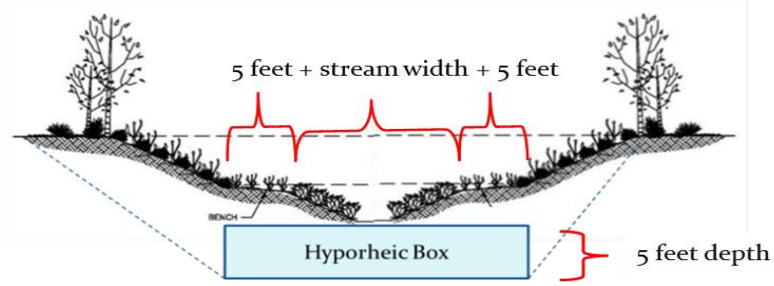
Table A-1: Summary of Protocol 2: Denitrification in the Hyporheic Zone

Step 1: Determine the total post construction stream length that has been reconnected using a bank height ratio of 1.0 or less (for NCD projects) or the 1.0 inch storm (other design approaches).

The bank height ratio is an indicator of floodplain connectivity and is a useful proxy for how much of the stream length is interacting with the root zone. It is defined as the lowest bank height of the channel cross section divided by the maximum bank full depth.

Step 2. Determine the dimensions of the hyporheic box.

The cross-sectional area is determined by adding 10 ft (2 times 5 ft) to the width of the channel at median baseflow depth (as determined by gage station data) and multiplying the result by 5 ft. This assumes that the stream channel is connected on both sides, which is not always the case.



Next, multiply the cross-sectional area by the length of the restored connected channel from Step 1 to obtain the hyporheic box volume.

Step 3. Multiply by the unit denitrification rate

Measure the bulk density of the soil to determine the tons of sediment within the hyphorheic box volume you calculated in Step 2. Then, multiply the sediment load by 1.06 x 10-4 pounds/ton/day of soil to determine your total nitrogen reduction.

Summary of Protocol 3: Floodplain Reconnection Volume

Stream restoration projects that reconnect the stream channel to its floodplain over a range of storm events promote settling and filtering processes that remove sediments and nutrients. Protocol 3 was developed to calculate the annual mass sediment and nutrient removal based upon the volume of annual flow that is effectively in contact with the floodplain. The full method is summarized in Table A-2.

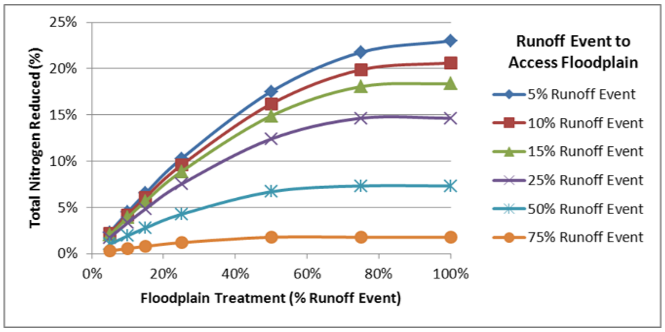
Table A-2: Summary of Protocol 3: Floodplain Reconnection

Step 1: Estimate the floodplain connection volume.

Designers conduct detailed hydrologic and hydraulic modeling (or post restoration monitoring) of the subwatershed, stream and floodplain to estimate the increase in runoff volume diverted from the stream to the floodplain compared to pre-restoration conditions.

Step 2: Estimate the nutrient and sediment removal rates.

A series of curves show pollutant removal as a function of floodplain storage volume for several runoff events that allow runoff to access the floodplain. The removal rates are based on the wetland pollutant removal efficiencies from Jordan (2007).



Step 3: Compute the annual N, P and TSS load delivered to the project

The Chesapeake Bay Program modeling tools (CAST) estimate the pollutant loads being delivered to the project site based on land use loading rates and existing upland BMPs.

Step 4. Multiply the pollutant load by the project removal rate

If the wetland to watershed ratio is less than 1.0% the removal rates should be adjusted.

Appendix B. Condensed Summary of Original Qualifying Conditions for Stream Restoration (USR EPR, 2014)

The Stream Restoration Expert Panel (2013) outlined the following qualifying conditions that a project must meet to be eligible for nutrient and sediment reductions under the Chesapeake Bay TMDL:

- The stream reach must be greater than 100 feet in length and be still actively enlarging or degrading in response to upstream development or adjustment to previous disturbances in the watershed (e.g., a road crossing and failing dams). Most projects will be located on first- to third-order streams, but if larger fourth and fifth order streams are found to contribute significant and uncontrolled amounts of sediment and nutrients to downstream waters, consideration for this BMP would be appropriate, recognizing that multiple and/or larger scale projects may be needed or warranted to achieve desired watershed treatment goals.

- The project must utilize a comprehensive approach to stream restoration design, addressing long-term stability of the channel, banks, and floodplain.

- Special consideration is given to projects that are explicitly designed to reconnect the stream with its floodplain or create wetlands and instream habitat features known to promote nutrient uptake or denitrification.

- In addition, there may be certain project design conditions that must be satisfied in order to be eligible for credit under one or more of the specific protocols.

The 2013 Expert Panel also outlined the following environmental considerations:

- Each project must comply with all state and federal permitting requirements, including 404 and 401 permits, which may contain conditions for pre-project assessment and data collection, as well as post-construction monitoring.

- Stream restoration is a carefully designed intervention to improve the hydrologic, hydraulic, geomorphic, water quality, and biological condition of degraded urban streams, and must not be implemented for the sole purpose of nutrient or sediment reduction.

- There may be instances where limited bank stabilization is needed to protect critical public infrastructure, which may need to be mitigated and does not qualify for any sediment or reduction credits.

- A qualifying project must meet certain presumptive criteria to ensure that high functioning portions of the urban stream corridor are not used for in-stream stormwater treatment (i.e., where existing stream quality is still good). These may include one or more of the following:
  - Geomorphic evidence of active stream degradation (i.e., BEHI score)

  - An IBI of fair or worse
  - Hydrologic evidence of floodplain disconnection
  - Evidence of significant depth of legacy sediment in the project reach

- Stream restoration should be directed to areas of severe stream impairment, and the use and design of a proposed project should also consider the level of degradation, the restoration needs of the stream, and the potential functional uplift.

- In general, the effect of stream restoration on stream quality can be amplified when effective upstream BMPs are implemented in the catchment to reduce runoff and stormwater pollutants and improve low flow hydrology.

- Before credits are granted, stream restoration projects will need to meet post-construction monitoring requirements, exhibit successful vegetative establishment, and have undergone initial project maintenance.

- A qualifying project must demonstrate that it will maintain or expand existing riparian vegetation in the stream corridor, and compensate for any project-related riparian losses in project work areas as determined by regulatory agencies.

- All qualifying projects must have a designated authority responsible for development of a project maintenance program that includes routine maintenance and long-term repairs. The stream restoration maintenance protocols being developed by Starr (2012) may serve as a useful guide to define maintenance triggers for stream restoration projects.

Appendix C.
Excerpts of Group 5 Memo for Crediting Floodplain Restoration Projects Involving Legacy Sediments Not Directly Incorporated into Main Memo

Drew Altland, Ted Brown, Jason Coleman,
Ben Ehrhart, Ward Oberholzer, Art Parola,
Bill Stack, Joe Sweeney and Jeff White

Released: April 10, 2020

Background:

In recent years, a diverse group of stream restoration stakeholders have sought to revisit the original protocols, and four groups were formed in late 2018 to do so (USWG, 2018). As these four groups deliberated, however, it was apparent that a specialized team was needed to assess floodplain restoration projects involving the removal of legacy sediments. Recommendations were finalized in response to comments and conference calls held in 2019 and 2020. The consensus findings contained in their memo were incorporated into the final decisions to modify the crediting protocols presented in the main body of this report.

Floodplain Restoration Involving Legacy Sediment Removal:

Floodplain restoration involves careful modifications to valley bottoms that contain legacy sediments to increase the interaction of the stream with its floodplain and the hyporheic aquifer. This usually involves restoring smaller baseflow channel(s) and removing legacy sediments to effectively lower the floodplain to promote interaction of surface flows with the underlying hyporheic aquifer, which produces riparian wetland conditions over much of the floodplain.

This class of projects is defined in several ways:

1. The projects modify the vertical profile of floodplain sediments that often follows a prescribed sequence from top to bottom: surface vegetation, legacy sediments, organic layer, gravel layer and bedrock.

2. The projects reduce the elevation of the floodplain which, in turn, reduces the height of stream banks, enabling stream runoff to access the floodplain more frequently, expansively and for longer periods.

3. The width and depth of the existing channel are typically reduced in size, and anastomosing baseflow channels are allowed to develop over time within the floodplain.

4. The project restores a vegetative community that includes a diverse mosaic of herbaceous plants, shrubs and water-loving trees and less continuous and drier floodplain forest cover. The restored vegetative community seeks to mimic the natural reference condition for the valley bottom that is supported by historical accounts.

5. The design of floodplain restoration projects is often influenced by the upstream contributing drainage area (in relation to available floodplain project area), as well as any adjacent drainage area.

6. After initial adjustment, the restored floodplain conditions act to enhance sediment and nutrient removal in both the stream and floodplain during storm flow events and baseflow.

Minimum Qualifying Conditions for FR-LSR Projects

To qualify for credits, the team agreed that all projects should meet the following minimum qualifying conditions:

1. *Presence of legacy sediment deposits or other floodplain impairment.* Legacy sediments must be present in the project reach to a depth that has impaired aquatic ecosystem function. Legacy sediment includes any deposits that have occurred since European settlement, including very recent sediment deposits, often created by features such as mill dams, road embankments, floodplain fill and other kinds of stream corridor impairment.

   The presence of legacy sediments should be confirmed by on-site investigations of soil stratigraphy and other evidence that characterize stream valley bottom materials (e.g., such as buried hydric soils, woody material or leaf pack, etc.).

   Other information that can corroborate legacy sediments includes land records, historical atlases and maps, past aerial photographs or current LIDAR measurements. Land Studies (2017) provides a good example of how historical research methods were used to define and interpret legacy sediments for a valley bottom restoration project in Brubaker Run, PA.

2. *Floodplain connection to valley bottom aquifer.* The design objective is to restore a plant/groundwater connection within the floodplain, so that most of the root mass of the floodplain vegetation is in direct contact with the underlying hyporheic aquifer. In cases where the historic hyporheic aquifer cannot be accessed due to modern controls (i.e., culverts or utility crossings), the objective is to plug the flow of the underlying aquifer so as to create a new hyporheic zone using cobbles, gravel and/or sandy materials.

   For effective root zone interaction, the streambed should be on or within the underlying hyporheic aquifer and the surface of the floodplain should not extend more than 18 inches above either the channel bed (in riffles) or residual pool water surface elevation (i.e., during minimal flow).

Field investigations may be needed to identify the current groundwater elevations relative to hydric soils, existing root zones and the stratigraphy of the floodplain.

3. *Defined boundaries for the channel(s), floodplain and valley bottom*. The restored channel and floodplain dimensions are based on field testing that define the key vertical and lateral sediment boundaries of the existing floodplain and the hyporheic aquifer beneath it.

   These boundaries can be measured by a combination of the following methods: direct push soil coring, trenching, test wells, LIDAR surveys, photogrammetry or other site investigations. The objective is to define conditions at critical soil layers in the floodplain profile, and document how the active root zone of the plant community will be connected to the hyporheic aquifer during sustained baseflow periods.

4. *Removal of legacy sediments is the primary means to restore floodplain reconnection at most sites*. This memo applies to projects that primarily remove LS to reconnect the floodplain, and not projects that primarily do so by raising the streambed.

5. *Meet applicable floodplain management requirements in the stream corridor*. Any individual stream restoration project should be assessed with hydrologic and hydraulic models to demonstrate whether it increases water surface elevations or adverse downstream flooding impacts. In general, these analyses are based on design storm events and flood risk conditions established by the appropriate local or state floodplain management agency (e.g., the 100-year storm event).

Summary of Big Spring Run (BSR) Research Findings

A team of researchers investigated the long-term improvements in ecosystem functions in floodplain restoration projects featuring removal of legacy sediments. The impaired stream reach was about 3,000 feet in length and had a contributing drainage area of about 1,000 acres (Figure 9). Approximately 22,000 tons of legacy sediment were removed from the BSR site. The BSR monitoring program and research findings are described in a series of papers by Langland, (2019), Hartranft et al (2011), Hartranft (2019) and in https://chesapeakestormwater.net/download/9913/

The restoration project was designed in the context of a wider research program on how legacy sediments have influenced stream and floodplain functions in Pennsylvania valley bottoms. Some notable references include Merritts et al (2010, 2011), Walters et al (2007) and Walter and Merritts (2008). Another watershed perspective on floodplain connection research was summarized in a recent Chesapeake Bay Program STAC workshop (Miller et al, 2019). The following section summarizes key research findings on how the BSR restoration project performed in capturing and treating runoff, sediment and nutrients.

Flow and groundwater dynamics in the channel and floodplain. Three years after restoration, surveys confirmed that the wetland-floodplain surface remained stable and there was minimal change in ground elevation (Hartranft, 2019). H&H models showed lower shear stress across the restoration reach during storms and more frequent overtopping of banks by floodwaters, at both lower flow stages and over a greater area than pre-restoration conditions (Parola and Merritts, 2014). The peak discharge rate for storms was extended by 17 minutes following restoration (Walter et al, 2019).

Changes in groundwater residence time were highly variable following floodplain restoration, with several wells showing an increase in residence time and others showing a decrease (Audie, 2019). Groundwater monitoring indicated that groundwater nitrate concentrations decreased after the third year following restoration, and in response to increased storage in relation to groundwater nitrogen concentrations (Forshay, 2019).

Summary of nutrient and sediment reductions reported for the Big Spring Run restoration project

Pollutant	*Reduction*	*Percent Reduction*	*Source*
TSS Load	600 tn/yr	71%	Langland, 2019
TSS Concentration	482 mg/L/yr	87%	Langland, 2019
TP Load	1,380 lb/yr	71%	Walter et al, 2019
TP Concentration	0.15 mg/L	79%	Langland, 2019
Soluble Reactive P Load	--	37%	Forshay et al, 2019
TN Load	1,740 lb/yr	71%	Walter et al, 2019
Nitrate-N Load	--	32%	Forshay et al, 2019

Sediment and nutrient removal efficiency. Monitoring of surface water quality was conducted by USGS and EPA for three years prior to restoration and five years afterward. Prior to restoration, the stream bank erosion rate averaged 875 ton/yr across the BSR reach (Langland, 2019). The BSR project was found to highly effective in reducing both the concentration and mass loads of upstream nutrient and sediments.

Decreases in suspended sediment and dissolved phosphorus were observed the year immediately following restoration (Langland 2019; Forshay, 2019), while surface water nitrate decreased gradually over the five-year monitoring period. Nitrate removal is closely tied to organic carbon availability; the delayed nitrate improvements were attributed to the lag time for floodplain vegetation to develop and mature after restoration (Forshay, 2019).

Local Co-Benefits of Floodplain Reconnection

When done properly, floodplain restoration can create many environmental co-benefits in the riparian corridor beyond pollutant removal, when compared to pre-restoration conditions. Many of these local co-benefits have been documented at Big Spring Run and other PA LSR restoration sites (Appendix B-2 and Hartranft, 2019) and may include:

- Surface water thermal regulation (i.e., cooler summer stream temperatures, Land Studies, 2016)
- Improved stream clarity (i.e., reduced turbidity)
- Detention of extreme flood events (Land Studies, 2017)
- Lower flood peak discharges from floods (Land Studies, 2017).
- Carbon sequestration in the floodplain and particulate carbon retention in stream channel
- Restoration of stream, wetland and riparian aquatic ecosystems
- Restored native plant and animal species diversity and habitat
- Wetland bird, wildlife and pollinator habitat restoration
- Increased groundwater recharge rates
- Increased baseflow in stream and more resilience to drought
- Increased hydrophytic vegetation biomass and species richness
- Restored habitat for threatened and endangered species, such as bog turtles

Other community co-benefits that are often associated with well-designed FR-LSR projects include:

- Reduced damage to public infrastructure, such as roads and sewers
- Reduced flood water surface elevations especially for more frequent storm events
- Creation of an open space amenity and potential greenway/trail corridor
- Can be a cost-effective option in relation to other urban BMPs used to meet MS4 sediment and nutrient pollutant reduction targets (Fleming et al, 2019)

Obviously, the degree of environmental and community benefits created by any floodplain restoration project are strongly influenced by site conditions and how it is assessed, designed, constructed and managed over time.

Appendix D. Restored Floodplain Velocity Case Study Analysis

RK&K
Responsive People • Creative Solutions

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MEMORANDUM

To: David Wood, Tom Schueler
From: Jason Coleman, Drew Altland
Date: February 7, 2020
Subject: Restored Floodplain Velocity Case Study Analysis

RK&K performed an analysis to evaluate the velocity of 2 feet per second (ft/s) as an upper limit velocity for floodplain treatment above one foot of depth. Five floodplain restoration sites were evaluated hydraulically using HEC-RAS to estimate velocities at different depths in the restored condition. All sites used for this analysis removed legacy sediment to restore the floodplains and incorporate a small baseflow sized channel that accesses the restored floodplain area during most runoff events.

A range of discharges were entered into the model to produce a rating curve of depth versus velocity at each modeled cross section. Therefore, the discharges don’t necessarily represent a yearly return interval. One cross section for each project reach was selected to assess the reach-wide representative depth and velocity. For each project comparisons are provided for the average floodplain velocity at 1’ of depth, 3’ of depth, and at the depth produced by the 100-year discharge. The results are summarized in the following table:

Project	Valley Slope	Ave. FP Velocity @ 1' Depth (ft/s)	Ave. FP Velocity @ 3' Depth (ft/s)	Ave. FP Velocity @ 100-Year Depth (ft/s)	Notes	Recommended Treatment Depth (ft)
Israel Creek	0.21 %	0.41	0.84	2.31	3' depth occurs at ~1-yr discharge	3'
Furnace Creek	0.40 %	1.33	2.65	2.79	3' depth is between 50- and 100-yr discharges	~2'
Bens Branch	1.10 %	1.60	3.35	4.07	3' depth occurs at ~25 yr discharge	~1.5'
Talbot Branch Trib	1.50 %	2.45	n/a	2.72	100-year depth is ~1.3'	1'
Piscataway Creek Trib	6.00 %	n/a	n/a	2.93	100-year depth is ~0.5'	1'

All sites analyzed used a floodplain Manning's n roughness of 0.07 in the floodplain and 0.035 in the channel. Therefore, the velocity is primarily dependent on valley slope and depth. The floodplains with steeper slopes, such as the Talbot Branch Trib and Piscataway Creek Trib case studies, often produce higher velocities that exceed 2 ft/s. However, since these streams have smaller watersheds, the flow depths, even at the 100-year discharge, are minimal. In these conditions, it is expected that the filtering in the floodplain is enhanced due to the shallow flood depths and the increased contact with vegetation. As the valley slopes decreased, velocities generally decrease, and depth increases. As the velocity decreases, increased sediment trapping occurs along with the filtering.

Based on this case study analysis, the floodplain treatment to one foot of depth seems to be a reasonable default depth for all projects. Additionally, floodplain treatment up to three feet of depth also seems reasonable in settings where the energy slope is low and additional trapping can occur. The threshold of 2 ft/s seems to be a reasonable upper limit for velocity based on this case study analysis and observed deposition and filtering at these case study sites that have been constructed.

Appendix E. Developing regional flow diversion curves

This appendix provides guidance on improved methods to estimate floodplain flow diversions for a particular project reach. The new methods are based on the work by Altland (2019) and "scale" down regional flow gage data for individual projects, using available USGS hydrograph separation methods. This appendix also outlines how post-restoration channel dimensions for FR projects are defined, using baseflow statistics.

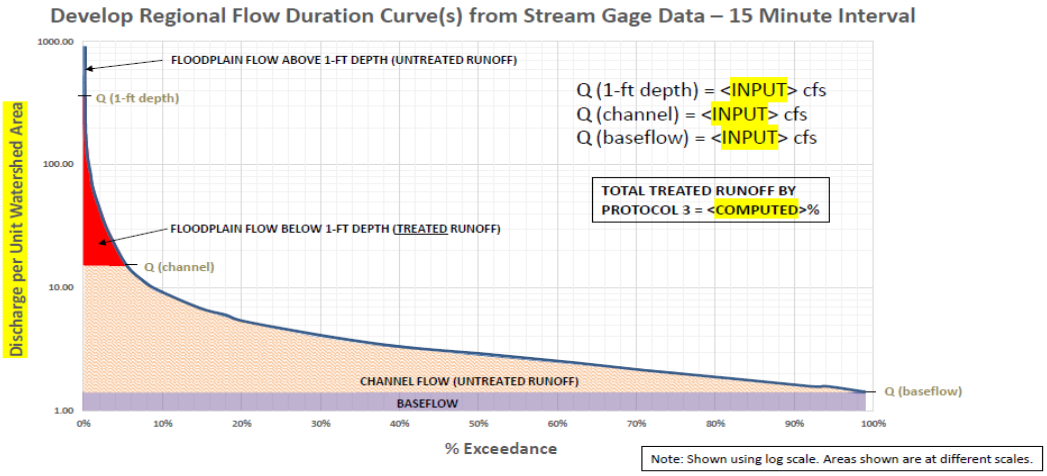
The Regional Flow Curve Approach

For this approach, 15-minute flow data from USGS gage stations would be used to create a series of curves that represent stream discharge as a function of the size of the storm event. Unique curves would be developed for each physiographic region in the Chesapeake Bay Watershed, and for different watershed land use conditions so they are representative of the project site conditions.

By adjusting these curves to the specific project site drainage areas and developing companion spreadsheet tools to run the pollutant removal calculations, a 3-step process can be used to determine the treatable flow:

1. Select the appropriate regional flow duration curve and regional baseflow curve for your project site. Use the baseflow curve to define the baseflow discharge for the 50% recurrence interval.
2. Using HEC-RAS or a similar model, determine the channel flow (the flow that would just fill the existing channel without overtopping its banks) and the floodplain flow at 1ft floodplain inundation depth.
3. Input the channel flow, flow at 1 foot of floodplain inundation, and baseflow into a spreadsheet tool to calculate the percent of flow that can be treated by the floodplain.

Figure E-1. *Flow Duration Curve for calculating floodplain treatment (Altland 2019).*



Note: Shown using log scale. Areas shown are at different scales.

Developing the Regional Flow Duration Curves

Regional flow duration curves would be developed for the Piedmont, Coastal Plain, and Ridge & Valley provinces using the best available or most appropriate USGS gage data (evaluation of up to 50 total gages). Stations with 15-minute or better and 10+ years of data are preferred when feasible. The data are scaled by comparing the drainage area of gage site to project site drainage area.

From these 50 gage sites, one curve per province would be developed; however, more than one curve may be needed for each province to address varying watershed conditions. Other critical parameters that would be assessed include: similar watershed land cover, watershed slope, and percent karst. It is assumed that no more than 3 curves would be required for each province to address these varying conditions.

For the same 50 gage sites, average base flow values will be developed using hydrograph separation methods for the 50% exceedance interval. Hydrograph separation can be performed using the USGS HySep computer program, which is part of the Groundwater Toolbox program. There are 8 different methods to perform the HySep computations, which can be averaged for this computation.

Finally, a series of spreadsheet tools would then be produced to easily compute Protocol 3 treatment efficiency as described in Step 3 above. The spreadsheets would allow users to input the channel flow, baseflow, and flow at 1ft depth above the floodplain in order to calculate the treatment efficiency. There would be one spreadsheet per regional flow duration curve. It is estimated that the development of all of these products would require between 200 and 250 hours and approximately $35,000.

Appendix F. Review of References for Potential Impacts of Stream Restoration Projects

<table>
<tr><td colspan="5"><i>Depleted Dissolved Oxygen</i></td></tr>
<tr><td colspan="5"><i>Summary:</i> Seasonal, low dissolved oxygen has been observed in some restoration projects. Low DO is associated with stagnant surface waters and high dissolved organic carbon.</td></tr>
<tr><td><i>Reference[1]</i></td><td><i>Region</i></td><td><i>Duration</i></td><td><i>Type</i></td><td><i>Method Notes</i></td></tr>
<tr><td>Williams et al (2017)</td><td>CB</td><td>1-2 yr</td><td>RSC</td><td>Daily avg DO concentrations. Post-construction only</td></tr>
<tr><td>Duan et al (2019)</td><td>CB + Lab</td><td>< 1 yr</td><td>RSC</td><td>Field: restoration vs paired control
Lab: Change with increasing DOC</td></tr>
<tr><td colspan="5"><i>Iron Flocculation</i></td></tr>
<tr><td colspan="5"><i>Summary:</i> Iron flocculation has been observed in both restored and unrestored streams. Iron flocculation is associated with high dissolved organic carbon, anoxic conditions and the use/presence of ironstone.</td></tr>
<tr><td><i>Reference</i></td><td><i>Region</i></td><td><i>Duration</i></td><td><i>Type</i></td><td><i>Notes</i></td></tr>
<tr><td>Williams et al (2016)</td><td>CB</td><td>2-5 yr</td><td>RSC</td><td>Pre-post. Causes of mobilization</td></tr>
<tr><td>Duan et al (2019)</td><td>CB + Lab</td><td>< 1 yr</td><td>RSC</td><td>Field: restoration vs paired control
Lab: Change with increasing DOC</td></tr>
<tr><td colspan="5"><i>Warmer Stream Temperatures</i></td></tr>
<tr><td colspan="5"><i>Summary:</i> Increased surface water temperatures following a restoration are associated with loss of tree canopy in the riparian corridor. Exposure of groundwater seeps can mitigate increased temperatures.</td></tr>
<tr><td><i>Reference</i></td><td><i>Region</i></td><td><i>Duration</i></td><td><i>Type</i></td><td><i>Notes</i></td></tr>
<tr><td>Lessard and Hayes (2003)</td><td>OCB</td><td>1-2 yr</td><td>NRS</td><td>Impact of small dams on downstream temps</td></tr>
<tr><td>Johnson (2004)</td><td>OCB</td><td><1 yr</td><td>NRS</td><td>Impacts of shading and substrate on stream temperature</td></tr>
<tr><td>Moore et al (2005)</td><td>OCB</td><td>N/A</td><td>NRS</td><td>Impact of riparian forest harvesting on stream temperatures</td></tr>
<tr><td>Cristea and Janisch (2007)</td><td>OCB</td><td>N/A</td><td>NRS</td><td>Modeled impact of riparian vegetation on stream temperature</td></tr>
<tr><td>Fanelli and Lautz (2008)</td><td>OCB</td><td>1-2 yr</td><td>NRS</td><td>Streambed temperature upstream and downstream of log dam structure</td></tr>
<tr><td>Hildebrand et al (2014)</td><td>CB</td><td></td><td>NRS</td><td>Thermal sensitivity of stream systems</td></tr>
<tr><td>Mbaka et al (2015)</td><td>OCB</td><td>N/A</td><td>NRS</td><td>Impact of small impoundments on stream temperature.</td></tr>
<tr><td>Land Studies Inc (2016)</td><td>CB</td><td>2-5 yr</td><td>LSR</td><td>Pre-Post. Change in stream sensitivity to thermal radiation</td></tr>
<tr><td>Weber et al (2017)</td><td>OCB</td><td>5+ yr</td><td>NRS</td><td>Impact of natural beaver dam and beaver dam analogues on stream temperature</td></tr>
<tr><td>Dugdale et al (2018)</td><td>OCB</td><td>1-2 yr</td><td>NRS</td><td>Impact of riparian plant community on stream temperature</td></tr>
<tr><td>Fanelli et al (2019)</td><td>CB</td><td>1-2 yr</td><td>RSC</td><td>Monthly temperatures in restored vs</td></tr>
</table>

				degraded channels.
Water pH				
Summary: Lower pH following restoration is associated with disturbance of channel and floodplain soils during construction.				
Reference	*Region*	*Duration*	*Type*	*Notes*
Mayer (2019)	CB	< 1 yr	RSC	Restoration vs paired control
Primary Production				
Summary: Increase in primary production in restoration sites is associated with loss of canopy cover in the riparian corridor.				
Reference	*Region*	*Duration*	*Type*	*Notes*
Potopova et al (2016)	CB		LSR	Pre-post Change in diatom diversity
Levi and McIntire (2020)	OCB	<1 yr	NCD	GPP in restored vs paired control
Local Benthic IBI				
Summary: Local benthic IBI does not consistently show improvement following restoration activities. Local benthic decline has been observed, associated with construction disturbance, with recovery to pre-project levels in some cases.				
Reference	*Region*	*Duration*	*Type*	*Notes*
Revetta 2014	OCB	1-2 yr	LSR	Change in biomass and community structure
Fanelli et al (2019)	CB	1-2 yr	RSC	Aquatic insect assemblage in restored and degraded channels.
Project Tree Removal				
Summary: Riparian/floodplain forest losses are common due to clearing for design and construction access.				
Reference	*Region*	*Duration*	*Type*	*Notes*
Palmer et al (2014)	CB	1-2 yr	RSC	Measuring hydrologic changes and nutrient removal. Tree removal noted but not quantified.
Kaushal et al (2019)	CB	N/A	Mixed	Area of trees cleared at restoration sites
Post Project Tree Loss				
Summary: Lab studies show that long term soil inundation results in mortality and morphological changes in tree species.				
Reference	*Region*	*Duration*	*Type*	*Notes*
Teskey and Hinckley (1977a)	CB + OCB	N/A	NRS	Describes species ability to survive inundation
Angelov (1996)	OCB	Lab	N/A	Impact of permanent pooling on survival of upland seedling species
Pezeshki et al. (1999)	OCB	Lab	N/A	Impact of 70 day inundation on seedling elemental uptake
Anderson and Pezeshki (1999)	OCB	Lab	N/A	Impact of intermittent flooding on seedling survival

Folzer et al. (2006)	OCB	Lab	N/A	Impact of flooding on tree morphology
Pezeshki and DeLaune (2012)	OCB	Lit Review	N/A	Impact of soil flooding in wetlands on plant morphology
Garsson et al. (2015)	OCB	Lit Review	N/A	Impact of time of inundation on seedling survival
Invasive Plant Species				
Summary: Construction disturbance and frequent inundation of the floodplain can serve as vectors for invasive species.				
Reference	*Region*	*Duration*	*Type*	*Notes*
Coastal Resources Inc (2000)	CB	< 1 yr	Mixed	Post-restoration plant survey
Cuda et al (2017)	OCB	< 1 yr	NRS	Plant survey
Change in Wetland Type or Function				
Summary: Changes in vascular plant communities as a result of floodplain inundation are expected and may be desirable or undesirable depending on the habitat outcome.				
Reference	*Region*	*Duration*	*Type*	*Notes*
Fleming et al (2019)	CB	5+ yr	LSR	Pre-post. Change in vascular plant community structure
Change in Aquatic Habitat Quality				
Summary: No references at this time				
Reference	*Region*	*Duration*	*Type*	*Notes*
Salant et al (2012)	OCB	5+ yr	NCD	Pre-post. Change in macroinvertebrate community and native trout habitat.
Garsson et al (2015)	OCB	Lit Review	N/A	Impact of time of inundation on riparian plant community
Hale and Swearer (2017)	OCB	Lit Review	N/A	Identifying criteria for successful and unsuccessful habitat restoration
Increased Flooding				
Summary: Well-designed floodplain restoration projects should result in local flood stage reductions. Changes to floodplain elevations resulting from the project should be reported to the appropriate regulatory authority.				
Reference	*Region*	*Duration*	*Type*	*Notes*
Jacobson et al (2015)	OCB	Modeled Study	FR	Modeled floodplain storage
Cizek et al (2017)	OCB		RSC	Surface flow conversion to seep out
Koryto et al (2017)	OCB	1-2 yr	RSC	Surface flow conversion to media flow
Infrastructure Damage				
Summary: Well-designed floodplain restoration projects should result in avoidance of flood damages to local infrastructure.				
Reference	*Region*	*Duration*	*Type*	*Notes*
Miller and Kochel (2010)	OCB	1-2 yr	NCD	Likelihood of failure of in-stream structures
Hawley et al (2013)	OCB	Lit Review	NRS	Cost data on infrastructure failure due

				to channel instability
Jacobson et al (2015)	OCB	Modeled Study	FR	Modeled floodplain storage
Biological Diversity				
Summary: Changes in benthic community structure may result from stream restoration projects. Those changes are associated with changes in habitat conditions, and construction disturbance. Changes may be temporary and may be desirable or undesirable depending on project goals.				
Reference	*Region*	*Duration*	*Type*	*Notes*
Lessard and Hayes (2003)	OCB	1-2 yr	NRS	Shift in macroinvertebrate and fish species composition downstream of small dams
Brown and Conway (in prep)	CB	5+ yr	LSR	Pre-post. Amphibian captures
Fanelli et al (2019)	CB	1-2 yr	RSC	Aquatic insect assemblage in spring in degraded and restored streams
Blockage of Fish Passage				
Summary: Special consideration should be given to protecting freshwater mussels and their host fish if they are suspected to be present in the restoration reach.				
Reference	*Region*	*Duration*	*Type*	*Notes*
Noonan et al (2012)	OCB	Lit Review	FR	Passage efficiency of different fish species through in-stream passage structures
Kreeger et al (2018)	CB	Lit Review	NRS	Summary of freshwater mollusk capacity to provide WQ benefit
Key: NRS = Non-Restored Stream RSC = Regenerative Stormwater Conveyance NCD = Natural Channel Design LSR = Legacy Sediment Removal FR = Floodplain Reconnection (unspecified design approach)				Key: CB: Chesapeake Bay Watershed OCB: Outside CB Watershed
[1] Full citations available in Section 8 of this memo.				

Appendix G. CBP Presentations on Unintended Environmental Consequences and Co-benefits of Stream Restoration Projects: 2018/2019

Presentation	Link
June 2018	
Presenter: Rebecca Cope (EPA) *Title:* RSC Introduction and Monitoring Results	https://www.chesapeakebay.net/channel_files/25884/epa_1_rcope_rsc_uswg.pdf
Presenter: Paul Mayer (EPA) *Title:* Effects of RSC on Water Quality	https://www.chesapeakebay.net/channel_files/25884/epa_3_mayer_etal_-_uswg_webinar_-_19_june_2018.pdf
Presenter: Kyle Hodgson (MD DNR) *Title:* Water Quality and Macroinvertebrates in Muddy Creek	https://www.chesapeakebay.net/channel_files/25884/epa_4_muddy_creek_ppt_061018_epa.pdf
March 2019	
Presenter: Tom Jordan (SERC) *Title:* Effects of a Stream Restoration on Water Quality and Fluxes of Nutrients and Suspended Solids	https://www.chesapeakebay.net/channel_files/32639/jordan_muddycr_urbanstormwaterworkgroup.pdf
October 2019	
Presenter: Michelle Audie (EPA) *Title:* Influence of groundwater residence time on biogeochemical transformations after legacy sediment removal from a headwater stream in Lancaster County, Pennsylvania	https://www.chesapeakebay.net/channel_files/37046/bsr_graphs_10.2019_v3.pdf
Presenter: Ken Forshay (EPA) *Title:* Restoring stream-floodplain connection with legacy sediment removal increases denitrification and nitrate retention, Big Spring Run, PA USA	https://www.chesapeakebay.net/channel_files/37046/chesapeakebc2019fin.pdf
Presenter: Sujay Kaushal (UMD) *Title:* Tree Trade-Offs in Stream Restoration Projects: Impact on Riparian Groundwater Quality	https://chesapeakestormwater.net/download/9857/
November 2019	
Presenter: Jeff Hartranft (PADEP) *Title:* Big Spring Run Restoration Project Background & Monitoring Results	https://chesapeakestormwater.net/events/big_spring_run_research/
Presenter: Dave Guignet (MDE) Title: Community Floodplain Regulations to Participate in NFIP	https://chesapeakestormwater.net/download/9861/
Presenter: Denise Clearwater (MDE) *Title:* Floodplain Reconnection Unintended Consequences	https://chesapeakestormwater.net/download/9865/
Presenter: Paul Mayer (EPA) *Title:* Unintended Consequences of Urban Stream Restoration	https://chesapeakestormwater.net/download/9869/
Presenter: Michael Williams (UMD) *Title*: Unintended/Negative Consequences of Stream Restoration	https://chesapeakestormwater.net/download/9873/

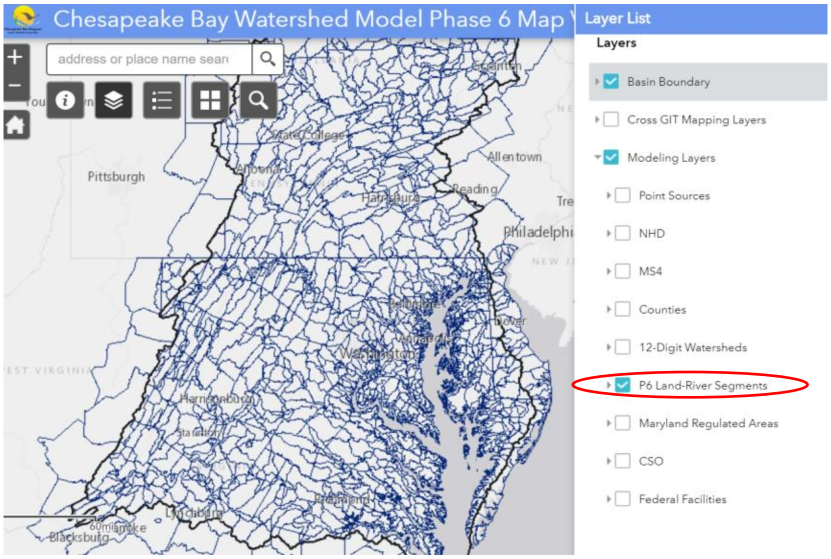
Appendix H. Using CAST To Determine Load Delivered to Project Reach for Protocol 3

Purpose:

Protocol 3 applies a treatment efficiency to the nutrients and sediments in the streamflow that accesses the restored floodplain. To determine the pounds of TN, TP and TSS in the overbank flow, practitioners must use CAST. The 6-step procedure is provided below:

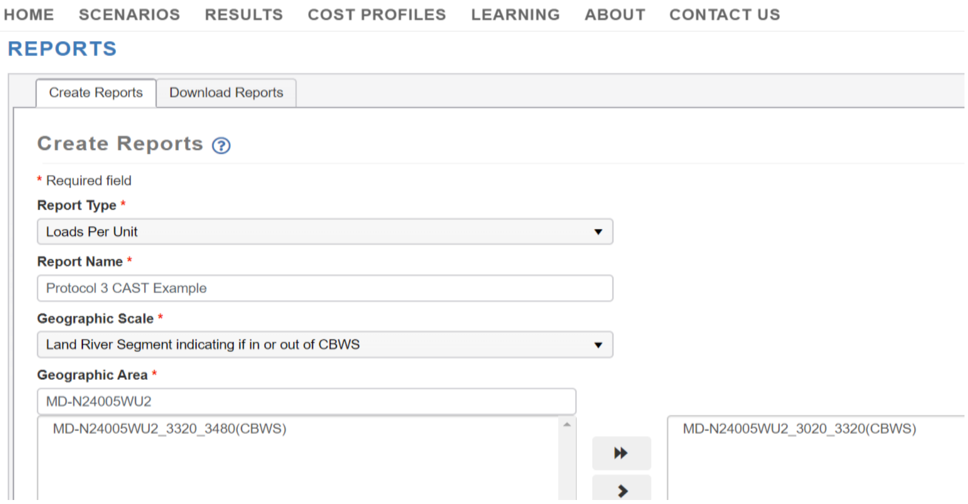
Step 1. Determine the Land-River Segment where your project is located using the Chesapeake Bay Watershed Model Phase 6 Map Viewer.

- Turn on the P6 Land-River Segment Layer as shown below and search the project address.



Step 2. Generate a "Loads Per Unit" Report for your LR Segment

- Log into CAST and select Results > Reports
- Select "Loads Unit Report"
- Name your project
- Select Land River Segment for the scale
- Enter the LR segment from Step 1
- Select the most recent Progress Year for the "Scenario"
- Select "Source – All Agencies" for the Aggregation



Create Reports

* Required field

Report Type *: Loads Per Unit

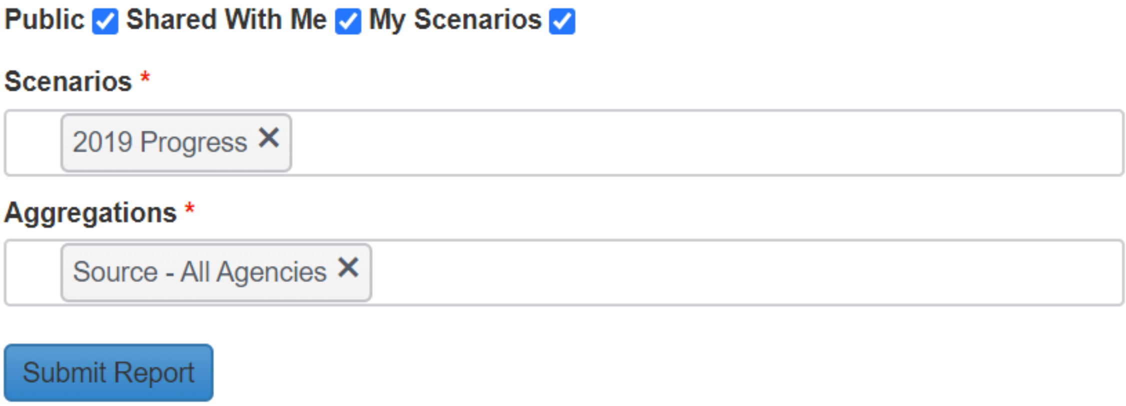
Report Name *: Protocol 3 CAST Example

Geographic Scale *: Land River Segment indicating if in or out of CBWS

Geographic Area *: MD-N24005WU2

MD-N24005WU2_3320_3480(CBWS)

MD-N24005WU2_3020_3320(CBWS)

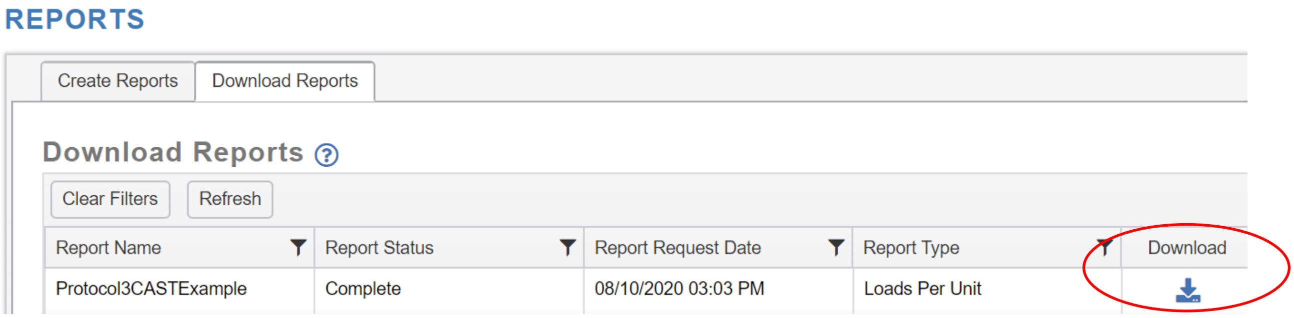


Public ☑ Shared With Me ☑ My Scenarios ☑

Scenarios *: 2019 Progress

Aggregations *: Source - All Agencies

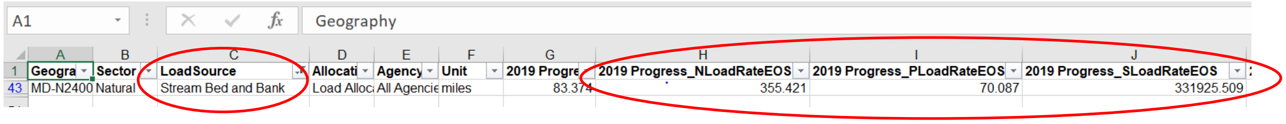
Step 3. Download the report.



Download Reports

Report Name	Report Status	Report Request Date	Report Type	Download
Protocol3CASTExample	Complete	08/10/2020 03:03 PM	Loads Per Unit	

Step 4. Filter the table for the “Stream Bed and Bank” LoadSource to find the loading rate (lbs/mile of stream)



A1 Geography

	Geogra	Sector	LoadSource	Allocati	Agency	Unit	2019 Progre	2019 Progress_NLoadRateEOS	2019 Progress_PLoadRateEOS	2019 Progress_SLoadRateEOS
43	MD-N2400	Natural	Stream Bed and Bank	Load Alloc	All Agencie	miles	83.374	355.421	70.087	331925.509

Step 5. Determine the total linear miles of stream upstream of the project reach. This can be done in-house by the practitioner, or CAST has a "Stream Layer" available for download.

- To download the "Stream Layer" in CAST, go to the Home page, select the Map Tools and Spatial Data button on the bottom left of the page. Scroll all the way down to find the Stream Layer.

Step 6. Multiply the miles of stream upstream of the project by the loading rates from the downloaded report to determine the loads delivered to the project.

Step 7 (Optional): Once you have finished calculating your load reductions from the Stream Restoration Protocols, you can enter them into a CAST Scenario to determine the final load reductions. This may be useful if you are interested in the impact of other BMPs on the reductions, or how sediment delivery influences loads reaching the Chesapeake Bay.

Appendix I. Response to Comments

The following appendix documents comments received during the Chesapeake Bay Program Partnership's open comment period between May 19, 2020 and June 19, 2020. Responses were developed and approved by Group 4 members and corresponding revisions are reflected in the August UWSG Approval Draft of the memo.

Maryland Department of the Environment

1. Inundation levels: The Department is concerned that promised clarifying language was not included related to the proposed raising of inundation levels in the floodplain in some circumstances, from 1 foot to 3 feet. This clarification is necessary for the Department's further review, as the substantial increase in flooding is more likely to affect adjacent properties, as well as existing resources.

Response: The floodplain elevation cap is a nutrient and sediment crediting construct, not a design criteria or design recommendation. The group supported the relaxation of the floodplain elevation cap under the described circumstances based, on the findings of Noe et al (2019a) that the additional inundation levels do not diminish the nutrient trapping and sedimentation rates on the floodplain during storm events, which was the reason for the initial cap. Stream restoration projects are required to do an upstream and downstream HH analysis for their Nationwide permit. Note the protocol only allows a higher elevation if HH analysis indicates this can occur without affecting nearby properties. The appropriate local, state and federal permitting authorities retain final decisions on whether proposed stream restoration designs will produce inundation levels in conflict with restoration and natural resource objectives. Clarification to this effect has been added to the memo.

2. Legacy sediment removal: In addition to comments on protocols 2 and 3, the Department has further comments on the Group 5 Memo for Crediting Floodplain Restoration Projects Involving Legacy Sediments. Some language from the protocol 2 and 3 memo, and an appendix, shares or summarizes language in the Group 5 memo. Language should be consistent between the two documents. The Department would also like to further discuss the Group 5 memo and share comments in greater detail.

Response: Group 5 was advisory in nature, and final decisions regarding their recommendations and how they are incorporated lie with Group 4. To avoid redundancy, the full Group 5 memo was removed as an appendix and specific excerpts were selected to provide additional clarity regarding definitions that were not fully covered in the body of the Group 4 memo.

The Department is concerned that the definition of "legacy sediment", when it includes any sediment generated from human activities, is so broad that it would include all of Maryland, given the State's history of farming, logging, and development. This means that some of Maryland's existing highest quality resources would be considered as unnatural areas of legacy sediment deposition, thus should be excavated to restore to some level of "pre-colonial" condition. Maryland values and manages many water/natural resources according to their current condition and benefits.

The Department also finds that descriptions of resources and soils in the legacy sediment document do not reflect Statewide condition, particularly in the Coastal Plain. The Department strongly recommends including its revisions to more accurately describe effects and benefits of legacy sediment removal projects, particularly when the practice is promoted as being appropriate for any physiographic region.

Response: The legacy sediment definition is largely consistent with that of the Scientific and Technical Advisory Committee (STAC) Workshop findings (Miller et al 2019), which concluded, "For the purposes of Bay management, we define legacy sediment as sediment stored in upland and lowland portions of the Bay's tributary watersheds as a byproduct of accelerated erosion caused by landscape disturbance following European settlement, most prominently in the Piedmont and Coastal Plain provinces." A citation was added to further support the definition.

3. Table 10 on page 25: The Department has major concerns with Table 10 and the use of vegetation as a surrogate for soil saturation. The Department strongly recommends using actual soil data, which is readily available. Based on past disturbance and management, any of these vegetation communities could exist on these soils.

The hydraulic conductivity rates in soil surveys apply to both lateral and horizontal movement, and should be used. The Department also provided an example from the Natural Resources Conservation Service for Howard County of how soil information can be used in TMDL calculations. The Department suggests that similar information be used for the calculations.

Response: Following consideration of several alternative options, the group reached a decision to replace the vegetation surrogate with a floodplain height factor.

The soil survey information and evaluation of soils prior to restoration represent pre-restoration conditions. The duration of soil saturation and the depth of soil saturation will most often be different after restoration; therefore, groundwater levels and soil characteristics that indicate saturation prior to restoration will not be representative of the conditions after restoration.

Strict use of soil lateral conductivity would lead to extremely low rates of transport of lateral transfer of hyporheic water through silt and silty soils, resulting in insignificant rates of nitrogen removal compared to the nitrogen load in the water passing by in the channels. Dead and dying root matter in the floodplain root zones increase lateral conductivity in these soils and is therefore an added consideration in Table 10 that is unaccounted for in soil survey data. Research is needed to improve the accuracy of the discount factors for all types of soils and could include information about the plant community and its effect on lateral conductivity.

4. Test Drive Period: The Department requests that a test drive period be incorporated into this expert panel process and utilize field data for real world projects. This will allow better understanding of the calculation procedures and clarify questions pertaining to development of the requisite data inputs. A lengthy test drive period was afforded to the original stream restoration expert panel and a similar period along with a comparison of results of old versus new methods is needed for further evaluation. A test drive period will assist the Department in understanding internal training, data tracking, and technical methods and modeling needs for developing procedures for effective oversight of these projects.

Response: A test drive period is not recommended due to the time and resource constraints involved. The revisions to Protocols 2/3 are scientifically more robust that the original protocols. Several practitioners were on the Group and saw no issues with the suggested changes. A comparison of calculations using the old and new recommended methods was provided to the commenter, but was not included in the memo because the differences will vary considerably due to site-specific conditions and the group did not want the examples to be erroneously used as defaults. Further, additional detail on the tracking and reporting needs has been added to the report, along with improved design examples.

5. Scope: The document should clarify application of natural channel design and regenerative stormwater conveyance methodologies for using the new protocols. Do the new protocols only apply to floodplain reconnection projects, and if so, what is the technical threshold distinguishing a floodplain reconnection project from a natural channel design, etc? Do the old protocol 2 methods still apply for natural channel design projects? These issues are not clear.

Response: Floodplain reconnection is better described as a design objective than a unique design approach. Natural channel design and regenerative stormwater conveyance can both achieve floodplain reconnection and may use “LSR” or “RSB” designs principles to meet this objective. In fact, Natural Channel Design Priority 1 and 2 Designs are candidates for Protocols 2/3. This has been clarified in the memo.

6. Applicability in rural streams: The Department believes that the new protocols should be applicable for rural streams. The Department relies on expert panel recommendations to support review decisions associated with oversight of stream restoration implementation. Therefore, maintaining consistency with expert panel recommendations will ensure consistent implementation of these practices in the State of Maryland and in the Bay watershed.

Much of the information developed for the legacy sediment removal recommendations is supported by the monitoring data from the Big Spring Run restoration project. Pictures published of this project indicate this is not an urban stream. If the Big Spring Run project was not performed in an urban stream, yet the results are used to inform the new protocols, the Department questions the exclusion of the protocols in rural streams. Please consider clarifying that application of the protocols can include rural areas to avoid this inconsistency and allow Department review to align with expert panel recommendations.

Response: The group believes that the underlying science and principles outlined in the Group 4 memo are applicable to both urban and rural streams. However, during the review of the Group 3 memo, concerns were raised about data availability for NRCS funded practices that may prevent proper evaluation of whether the projects meet the recommended qualifying conditions. Therefore, the previous memo was only approved by the Water Quality Goal Implementation Team (WQGIT) for application in urban stream restoration projects. The language was clarified to be more consistent with the language approved by the WQGIT.

7. Comparing old protocol design examples: To complete the review of the new calculation procedures, a comparison of calculations of old versus new protocol calculations for a specific project is requested.

Response: A comparison was conducted and provided to the commenter, however, results will vary based on site-specific conditions.

8. Protocol 3: A design example needs to be provided for protocol 3. This information is required in order for the Department to completely review the implications of the new design process. It is not clear how the new procedures will impact the former calculation process. In place of an actual design example, the reader is referred to Appendix E. The

discussion includes a three step process for determining the amount of flow that is treated on the channel floodplain using new regional flow duration curves. The Department has numerous questions regarding this calculation process. Provision of a design example that includes specific modeling methods needed to determine the input data for these calculations is needed before the Department can review the new procedures in sufficient detail.

Response: A design example has been included for Protocol 3. The basic approach using the "down-stream method" which involves the use of flow-duration data from gauging stations can be found in a study published by North Carolina State https://www.chesapeakebay.net/channel_files/30006/nutrient_credit_evaluation_final_report_ncsu_9-17-18.pdf This study also compared the down-stream method to the original protocol 3 (up-stream approach). Further, Table 12 also compares the results using 2 upstream methods (existing Protocol 3) with the down-stream method.

In addition, the memo does not indicate who will develop the protocol 3 regional curves and associated spreadsheets and does not provide a timeline. The regional curves should be developed concurrent with this document and should be reviewed and approved in the same process.

Response: The intent was for the curves to be developed prior to the end of the “grandfathering period” that ends July 1, 2021, contingent upon available funding. The group does not currently have the funding to develop these curves. Therefore, additional language has been provided to clarify this point. Until funding and resources are available for regional curve development, states may allow curves to be developed by practitioners per the guidance in Appendix E or allow other comparable approaches such as USGS’s method to convert gauge flow data to nearby sites based on scaling factors. This flexible approach is consistent with the approach taken by the 2014 expert panel, which provided examples of upstream methods, but allowed practitioners the flexibility to develop in-house models to conduct the analysis.

9. Design examples, pages 26 and 27: The LSR design example states that a “1,000 ft FR-LSR project is completed.” In addition, the RSB design example states that a “1,000 ft FR-RSB project is completed.” This implies that the calculation process does not occur until after construction and not at the design stage. Of note, the site characteristics and data used in the calculation process are related to post restoration conditions. The memo should clarify that the actual credit determined for a project will not occur until after project completion and the requisite field data is compiled post restoration. In the case of the RSB design example, page 22 notes that groundwater testing should take place within one year after project construction. The memo should also clarify that the actual credit for a given project under protocol 2 may not be determined for up to one year after project completion.

Response: Agreed. Language has been added that credits are generated upon completion of the project based on site-specific conditions.

10. Default rates: The regulated community will need an upfront estimate of the amount of credit a proposed stream restoration project may generate. This information is essential for establishing budgets and local planning processes. Please consider establishing default rates – which may include using prior protocols, so that local governments can plan and budget accordingly.

Response: Group 4 supports the conclusions of Group 3 and the 2014 expert panel. There is no scientific basis for the development of default nutrient and sediment reductions. To the extent that planning level estimates are needed, the default efficiencies developed by the 2014 expert panel may still be used.

11. Why is the hydraulic conductivity reduction factor for gravel and sand equal to 1 in the Parola Equation? The higher the hydraulic conductivity, the less the residence time would be. Therefore, the denitrification rate should be lower. Increased residence times should lead to higher denitrification rates.

Response: The hydraulic conductivity coefficient was developed this way to ensure that there is sufficient surface water/groundwater exchange in and out of the HEZ. The values are relative and based on material conductivity and then adjusted upward to account for porosity added by root density. Under most low gradient conditions the residence time is sufficient for denitrification in clean gravels and sands (6-12 hours). Residence times significantly longer than this are not helpful in removing nitrogen. Gravel will not remain clean because roots and soil will invade and fill voids reducing the hydraulic conductivity such that it is closer to sand with roots. The residence time in silt and silty soils is longer than necessary and low lateral hydraulic conductivity results in lower transfer rates from the channel and back to the channel.

12. For the baseflow reduction factor in the Parola Equation, do some of the classifications even constitute projects that classify as stream restoration. If a project is done in a reach that has no baseflow, would this represent stream restoration?

Response: Zero order streams (intermittent and ephemeral) are eligible for stream restoration credit, per the original Expert Panel. While Dry Channel RSC projects are commonly applied at these sites and receive credit using the Runoff Reduction curves, the table was developed in this manner for the sake of completeness.

13. Does the protocol 2 methodology assume that the prior denitrification rate of the project was de minimis? The protocol load reduction methodology is based solely on post construction conditions. An accurate estimate of the actual load reduction from the project would be equal to the mass of denitrification pre construction minus the mass of denitrification post construction.

Response: This is correct. Further clarification has been added that Protocol 2 should represent the increase in denitrification over pre-restoration conditions.

14. In the new protocol 3, how is the volume of water treated in the floodplain converted to a nitrogen, phosphorus, and sediment load reduction? The report indicates that the new nontidal wetland reduction efficiencies should be used, but what load should they be applied to? Is there a 1:1 assumption between total discharge in the modeling segment treated in the floodplain to segment load?

Response: This was an oversight in the draft report. New language has been added on how to use CAST, in combination with the new “downstream approach” to calculate the TN, TP and TSS loads delivered to the project floodplain that should be used to calculate the final load reductions for Protocol 3.

15. What processes is the nontidal wetland reduction efficiency applied in protocol 3 reflective of? Does it reflect denitrification or the settling and capture of particulate nitrogen in the Floodplain Trapping Zone? If it reflects denitrification, does that mean there is overlap between the nitrogen reduction processes being accounted for between protocols 2 and 3?

Response: The nontidal wetland reduction efficiency applied in protocol 3 is of both settling of particulate nitrogen as well as denitrification. The difference between Protocol 2 and Protocol 3 is that Protocol 2 represents denitrification occurring within the HEZ during baseflow conditions. Protocol 3 represents treatment that occurs during storm events. Due to the calculation method, any flow that remains within the channel is excluded from treatment under Protocol 3.

16. Where are the revisions to protocol 1 in the Legacy Sediment memo now published, if the entire Legacy sediment memo is not included as an appendix to this document?

Response: The intent is to produce a single, comprehensive document that includes the recommendations from all four approved stream restoration memos. The Protocol 1 revisions would be incorporated into that document.

17. In Figure 3, please consider using a detail that does not have the name of a specific practitioner. This affords the specific practitioner a competitive advantage as the Department will be referring our stakeholders to this document.

Response: This change has been made.

18. Defining the effective hyporheic zone for RSB: Qualifying conditions require a clearly defined effective hyporheic zone. The actual dimensions must be confirmed by site investigations that define stream flow conditions, root zones, aquifer conditions, and pre-project water table conditions. Because the credit under protocol 2 is based on the accurate delineation of the hyporheic zone, an example of the required site investigations is needed for further review.

Response: The delineation of confining layers to better define the hyporheic channel dimensions was also required under the existing Protocol 2. This level of detail was left to the states to determine. Multiple examples of potential methods are included in the report.

19. Defining the effective hyporheic zone for LSR: Methods are included on page 20. Please provide examples of how these methods are used in the field to delineate the hyporheic zone for further review of this process.

Response: Please see prior response.

20. Differences between LSR and RSB hyporheic zones: The differences between how to delineate the hyporheic zones in LSR and RSB projects should be more clearly demonstrated by an explicit comparison in the narrative or in table format.

In addition, Figures 2 and 3 do not clearly illustrate these differences. Labels that reflect the narrative descriptions, including the 18 inch criteria, would provide greater understanding.

Response: The definition of the EHZ is the same, regardless of the design approach. There are differences in how restoration of the hyporheic exchange zone is achieved LSR and RSB, but the site-specific elements necessary to promote enhanced denitrification are accounted for in the standard definition and adjustment factors. This has been clarified in the report, and new figures were added to better illustrate the EHZ and HEZ.

21. Reporting Requirements: Section 7 of the original expert panel report provided a detailed list of reporting requirements associated with each protocol. The revisions for protocols 2 and 3 make the reporting of numerous parameters from the original expert panel report obsolete. The expert panel should clarify which parameters should continue to be reported to the CBP and include a list of additional parameters required under the revisions in the memo. This information is necessary for the Department's oversight of future stream restoration implementation.

Response: Agree, this has been added to the memo.

Pennsylvania Department of Environmental Protection

1. Page 4 includes the following note on non-urban practices:

"These recommendations do not apply to non-urban stream restoration practices, often associated with NRCS or federal farm bill conservation programs. The Chesapeake Bay Program's Agriculture Workgroup has been separately charged with convening an expert panel, or similar group, to evaluate NRCS stream restoration practices that do not adhere to the stream restoration protocols developed by the Urban Stormwater Workgroup and refined within this guidance document."

What is meant by "non-urban" in the statement above is not defined in the expert panel report. I assume that the intent of this section is to stipulate that areas which are not designated as a "developed" NLCD land use are ineligible to use Protocols 2 and 3. I do not agree with this restriction and recommend that the language be changed to allow the state regulatory agencies to use their discretion when determining if the use of the protocols will be allowable within their state and for which sectors. The crediting process is driven by the channel and floodplain geomorphic and process characteristics and therefore it does not matter if the land use of restoration site is urban or non-urban.

Further it is stated on page 9 that:

"The restoration sites with the greatest potential occur where there is sufficient space available to restore a naturally wide floodplain and incised and overwide channels have formed through unconsolidated sediments.... The FR approach has been effectively implemented in watersheds with urban, agricultural and forested land uses."

Given the space requirements of floodplain reconnection projects, it seems that most of these projects will be occurring outside the urban sector. Therefore, restricting the use of the protocols to only urban locations will severely limit the number of credit eligible restoration projects.

Response: The group believes that the underlying science and principles outlined in the Group 4 memo are applicable to both urban and rural streams. However, during the review of the Group 3 memo, concerns were raised about data availability for NRCS funded practices that may prevent proper evaluation of whether the projects meet the recommended qualifying conditions. Therefore, the previous memo was only approved by the Water Quality Goal Implementation

Team (WQGIT) for application in urban stream restoration projects. The language was clarified to be more consistent with the language approved by the WQGIT.

2. The last paragraph of Section 3.2 states that the legacy sediment removal and raising the stream bed design strategies are depicted in Figures 2 and 3 (page 11). I don't see these figures, were they removed? Including pictures/diagrams will increase the clarity of the restoration techniques presented.

Response: The figures in the report have been updated.

3. It is understood that the best case scenario is one in which the lateral extent of horizontal sediments are identified and removed to full restore the floodplain, however this is not always feasible, particularly in urban environments. A frequent challenge for MS4 permitting is that permittees are only required to achieve a certain load reduction so if a project is estimated to exceed the load reduction requirement, the permittee will likely only be interested in completing the portion of the project that will achieve their load reduction requirement. Can language be added to speak to the minimum design criteria that a project should follow in instances where a full site restoration will not be implemented (i.e. modeled shear stress on the floodplain during a 100-yr storm no greater than 2 lbs/sqft).

Response: The memo provides guidance on best practice for implementation and crediting, which includes comprehensive restoration approaches that address existing impairments and provide functional uplift. It is up to the appropriate regulatory agencies to make decisions about what is allowable or not in the described instance.

4. What reference was used for the NO_3 to TN conversion? (page 26 Step 4)

Response: This conversion was an error in the draft report. Protocol 2 is designed specifically to calculate NO3 removal due to denitrification. Because CAST requires nitrogen reductions to be reported as TN, the pounds of NO3 removed in Protocol 2 will be reported as TN without further conversion. This approach aligns with the best current scientific understanding of denitrification within the hyporheic zone, provides a conservative estimate of TN removal, and reduces the potential for double-counting nitrogen removal between the Protocols.

5. The layout of tables 10 and 11 work very well to illustrate the use of Protocol 2, can something similar be added to show an example for how to apply Protocol 3?

Response: Yes, a corresponding summary table has been added for Protocol 3.

6. The expert panel report for Nontidal Wetland Creation, Rehabilitation and Enhancement (2019) also includes discussion of floodplain wetlands. The addition of langue to distinguish between when the use of crediting through the Wetland expert panel is appropriate and when Protocol 3 should be used, would help avoid confusion and prevent possible double counting.

Response: It is recommended that floodplain wetlands that are restored or rehabilitated as part of a stream restoration project be reported using Protocol 3, while floodplain wetlands restored or rehabilitated independent of a stream restoration project be reported as NTW BMP. They should not be reported twice. Clarifying language has been added to the report.

7. The Workgroup 4 Memo Presentation included discussion of the following adjustment to Protocol 1:

"Option 1: Divide the Bank Erosion Zone (BEZ) into two components: Remaining low-bank sediments and removed legacy sediments from the higher bank. Remaining sediments are subject to the 50% discount, whereas removed sediments are not subject to any discount (i.e., 100% credit)."

I agree with this recommendation, but I did not see it in the Draft Protocol 2 and 3 Memo. How will this recommendation be implemented

Response: The intent is to produce a single, comprehensive document that includes the recommendations from all four approved stream restoration memos. The Protocol 1 revisions would be incorporated into that document.

District Department of Energy and Environment

1. In the calculation for nutrient removal for Protocol 2, the examples show a conversion of NO3 to TN at the end of the process. I did not see much discussion in the text about that conversion or where the 4.42 number comes from. Is it possible to add more background on that to the document?

Response: This conversion was an error in the draft report. Protocol 2 is designed specifically to calculate NO3 removal due to denitrification. Because CAST requires nitrogen reductions to be reported as TN, the pounds of NO3 removed in Protocol 2 will be reported as TN without further conversion. This approach aligns with the best current scientific understanding of denitrification within the hyporheic zone, provides a conservative estimate of TN removal, and reduces the potential for double-counting nitrogen removal between the Protocols.

2. In the determination of the denitrification zone for Protocol 2, an 18” distance from low flow water elevations is used as criteria. I did not see much discussion on where this 18” value was taken from. Is it possible to add documentation on what publication that number was derived from?

Response: This value is based on based on the best professional judgment of the group. Most of the root mass is within 12 inches of the ground surface but may extend to 18 inches. Only a few species have significant root mass below 18 inches. Contact with the root zone is critical for denitrification because of the carbon input provided by the root systems. The experimental values for rates of denitrification have come from saturated zones within 18 inches of the surface. The data that does exist for deeper groundwater rates is much lower.

3. I find it very useful to see examples how to apply the protocols. Two examples seem to be provided for Protocol 2, but I did not see an example for Protocol 3. Could one be added?

Response: Agreed, a design example has been added for Protocol 3.

4. Was any work done to compare the nutrient removal credits from this BMP with those for the forest buffer BMP? It seems there is growing interest in considering performance compared to other BMPs. For example, if the scientific community believes a riparian wetlands installed for Protocol 2 is likely to remove more nitrogen than a forest buffer, will the calculations show that difference using expert panel calculations for the two BMPs.

Response: This comparison has not been conducted and is outside the scope of this group. Due to the site-specific nature of the recommended protocol calculations, it is expected that the relative benefits will differ from site to site.

EPA Region 3

1. Group 3 recommended to replace the existing "hyporheic box" with an "effective hyporheic zone" defined by site specific conditions. I see this as an improvement over past practice. The question was; Does this replacement apply to FR projects only or would this apply also to RSC, NCD? Does the Parola equation apply to all projects or just FR approach?

Response: Yes to both questions -- floodplain reconnection is a design objective, not a design approach. Natural channel design and regenerative stormwater conveyance can both achieve floodplain reconnection and may use "LSR" or "RSB" designs principles to meet this objective. Therefore, the recommended protocols apply to any qualifying project regardless of design approach. This has been clarified in the memo.

Paul Mayer (EPA ORD)

2. **EHZ and HEZ:** The change from hyporheic box to EHZ and HEZ is significant and I think it will take some time to absorb this. Hence, it's critical that the definitions be made very clear. First, how are they different? If I were to read this document for the first time, I may be confused. In table 3, the definitions of EHZ and HEZ are quite similar and are described as the are used to calculate N or denitrification credits. Is there some wording or explanation to make these terms distinct?

Response: The HEZ is the subsurface volume where denitrification occurs, while the EHZ is the surface area directly above the HEZ that is used to calculate the nitrogen reduction. We have added new figures and language to the memo to better illustrate this point.

3. **Table 8:** I suggest also that you check the descriptions be clarified; for example in table 8, is the EHZ ≤18" <u>above</u> the stream bed? Is the HEZ 9-18" <u>below</u> the stream bed? A picture is worth a thousand words, so perhaps these can be made clearer in Figure 3 by showing the above and below stream bed contrast more clearly. Then, to avoid further confusion, fig 4 should be similarly labeled identifying EHZ and HEZ. As is, figure 4 seems to show a HEZ that is **much** bigger and deeper than the 5' hyporheic box because the lines seem to extend far below the root zone.

In table 8, it appears that there are really no differences in the bulleted points for LSR and RSB projects and therefore, one could combine all of these points for all FR projects.

Response: Clarifications have been made to Table 8 and to the figures to better represent the defined terminology.

4. **Figure 2** is a poor sketch because it's not clear or well labeled.

Response: Each of the figures have been removed and replaced to better represent the described zones.

5. **Table 11.** I'm concerned that the calculation of the reconnected floodplain may contain a loophole that would promote straight channel designs instead of more sinuous designs if sinuous designs are credited only with a connection that extends the amplitude of the sine wave created by the channel which is only 30 ft in the FR-RSB example. The straight channel stream, in the FR-LSR example is credited with

connecting floodplain 100 ft on either side of the stream. Why wouldn't the sinuous stream also be credited similarly?

Response: The amplitude of the sine wave created by the channel is not used in the crediting calculations. The EHZ is determined by delineating the area of the floodplain that is within 18" of the low flow water elevation, regardless of channel sinuosity. The design example has been revised to make the process for defining the EHZ more clear. Further, language has been added to further emphasize the importance of sinuosity and geomorphic complexity for promoting exchange between the surface water and groundwater.

6. **Nitrate to TN conversion:** why is there conversion from nitrate to TN in the Table 11 examples? Where is this conversion factor derived? TN should be at least as great as nitrate total. Yet, in these examples, the amount of TN is only a quarter of the amount of nitrate. Am I missing something here?

Response: This conversion was an error in the draft report. Protocol 2 is designed specifically to calculate NO3 removal due to denitrification. Because CAST requires nitrogen reductions to be reported as TN, the pounds of NO3 removed in Protocol 2 will be reported as TN without further conversion. This approach aligns with the best current scientific understanding of denitrification within the hyporheic zone, provides a conservative estimate of TN removal, and reduces the potential for double-counting nitrogen removal between the Protocols.

Chris Becraft (Underwood and Associates)

1. Overall, Underwood & Associates would suggest that the document stay in line with our understanding of the charge of providing background information about the crediting process and methodology for identifying and calculating floodplain, wetland, and stream restoration projects. As an example we would suggest efforts be made to elaborate on allowable flow and extent of floodplain inundation likely to create biogeochemical conditions that would satisfy the current specified removal rate. In this way we also feel subsequent iterations of the document could be more easily modified per the best available science and technology.

Response: The group is comfortable with the scope of the recommendations provided. The memo makes recommendations for improving the calculation of nutrient and sediment reductions using Protocols 2 and 3 based on their review of recent science and practitioner experience. All recommendations are in support of the key qualifying conditions and objectives of the Stream Restoration BMP as defined by the Chesapeake Bay Program.

2. We suggest that Section 7 be removed from the document, perhaps addressed in a separate effort. For example, the restoration community in general sees the use of sandstone/ironstone and the reference to flocs formed by iron oxidizing bacteria as an education opportunity. Restoration projects use many different refractory materials such as granite, coarse woody debris, and/or sandstone. In any case, the projects may have extensive iron flocs if there are iron ore rich soils - not related to the material used in the restoration. Furthermore, most stream restorations that initially have flocs exhibit dissipation over time, and are unlikely to exceed the EPA regulated maximum of 1.0 mg/L Fe. WIth that said, topics like these may be better addressed separately from this effort. Lastly , the topic of unintended consequences and impacts is an important matter. However, like the topics above, we feel would be better addressed in another document.

Response: The inclusion of Section 7 is necessary to achieve the consensus approval of the memo by the Chesapeake Bay Program partnership. While the group was not designated as an official expert panel, it sought to remain consistent in addressing the key elements that all BMP expert panels must address, including consideration of potential unintended consequences.

3. Protocols 2 and 3 seem quite interrelated. Is there some way to more clearly articulate
what the goal of each is?

Response: Protocol 2 represents denitrification in the EHZ during baseflow conditions. Protocol 3 represents trapping, settling and denitrification occurring in overbank flow during storm events. Due to the calculation method, any flow that remains within the channel is excluded from treatment under Protocol 3. The group considered consolidating the two protocols but ultimately decided to keep them separate to maintain consistency with the original expert panel crediting structure.

4. "1/ Recommendations for Modifying Protocol 2" has a "quick look" Table 8 but why does" 2/ Recommendations for modifying Protocol 3" not ALSO have the bulleted table associated with it? Maybe not necessary but nice for consistency and comprehension of protocols.

Response: Agreed, a summary table has been added to Protocol 3.

5. The document mentions physiographic regions and underlying geology but does not address any related specifics. Is it critical to the Protocols? The comment about "carbonate vs. non-carbonate watersheds” may be a similar situation.

Response: One of the reasons for the shift to the EHZ over the hyporheic box, was to replace what many practitioners had come to consider a fixed-dimension hyporheic box, with an EHZ that is measured on site for each project. Further, Protocol 3 will use regional flow duration curves that will be produced for each physiographic province to account for differences in slope and geology.

6. Under Section 2 page 8 "key needs": “Better alignment with Phase 6 Chesapeake Bay Watershed Model,” Specifics aren’t mentioned anywhere how this document better aligns? But maybe is implied by the overall change in context?

Response: Correct. A section has also been added to the revised memo that provides additional information on new tracking and reporting needs based on the recommended changes to the protocols and the new Phase 6 Model.

7. Page 15: Might Table 5 include actual values relevant to denitrification? Are added citations for RSC desirable?

Response: Table 9 provides a summary of actual denitrification values.

8. Pages 21 and 22: Figures 2, 3 and 4 seem very important yet are not easy to read. Figure 2 is a hybrid of LSR and RSB and contains EHZ and FTZ, but only for LSR, RSB uses old terminology of HB for some reason. Figures 3 has HEZ and EHZ but Figure 4 only specifically labels HEZ. The Text says that EHZ and FTZ are expressed

in Figures 2 and 4 but there's no FTZ in figure 4. Would it be useful to have same type of figure style for both plan view and section view and accurately refer to terms contained in figures in text? In addition, FTZ is only discussed in Protocol 3 - best to have a few robust, complete diagrams to which the two "Protocol" sections refer if possible.

Response: This comment is based upon an outdated version of the report. The figures have been removed and replace to better represent the defined terminology used throughout the report.

9. Table 6 - same comment as Table 5 (suggest addition of actual values)
10. Table 7 - Same comment as Table 5 (suggest addition of actual values)

Response: These tables were provided to demonstrate the breadth of literature reviewed by the group and used to improve the understanding of the removal processes on which the recommended protocols were based. The bulk of the available literature on trapping and sedimentation dynamics were conducted on unrestored floodplains. While these studies helped inform the processes underlying the protocol methods, because they were not from restoration sites, they were not considered directly applicable to a BMP removal rate.

11. Tables in general – suggest more specific connection to how they apply to/serve articulation of Protocols might be helpful. Sometimes they are not referred to in the body of text (Table 11 is one example).

Response: This comment appears based on an outdated version of the report. All tables were referred to within the body of the text except for Table 11, which has been amended.

12. Table 8 - If there is a blanket denitrification rate for all projects then is it important to separate types of FR projects?

Response: This has been clarified in the report.

13. Page 21 and 22: Is mention of radio-carbon dating, bulk density and soils data collection complete for all LSR projects?

Response: It is not clear what is meant by this comment.

14. Table 9 - why are we revisiting the denitrification rate (and finally looking at values) when we looked at denitrification in Table 5? If there is so much literature on this why is there not a larger matrix of values and literature?

Response: Table 9 was located in Section 5 to draw a more direct link to the updated denitrification rate. Tables 5, 6 and 7 represented foundational literature that informed the pollutant removal processes underlying the updated protocols. Three of the four studies presented in Table 9 were literature review studies, representing a collection of over 100 sites where denitrification rate data was collected.

15. Table 10 – Might include supporting values from peer reviewed literature rather than just one citation.

Response: Table 10 and the supporting text have been updated to address multiple comments received. Table 10 is based upon the best professional judgment of the group members in an effort to develop a method that is technically sound but not overly burdensome. However, the concepts and processes accounted for in Table 10 are supported by peer reviewed research as described in Section 4.

16. Table 11 - Once P2 is articulated and cited with tables and supporting literature, calculations for several FR case studies could be shared rather than just one of LSR and one of RSB?

Response: Table 11 is provided to demonstrate how the Protocol calculation method works. They are hypothetical examples for illustrative purposes only.

17. Recommendations for Modifying Protocol 3 - Just a little more information or introduction about the goal of Protocol 3, as well as a similar summary table as Protocol 2, could shape this section up - but I do like that they have three key changes to do the "overhaul" as they call it (language too informal?) for P3. Perhaps the discussion of downstream vs. upstream might be shorter and part of an Appendix so that the primary “meat” of the protocol can get through? Same with the Table 12.

Response: A summary table has been added for Protocol 3.

18. Don't understand why there aren't more citations considered for wetland removal rate other than Jordan 2017?

Response: Jordan 2007 was the basis for the original wetland removal rates. The new wetland removal rates are based on WEP (2016); NTW EP (2019). Each of those expert panels reviewed several hundred references to develop their pollutant removal rates.

19. Table 13 – Suggest citations for more species of T, P, and TSS, or at least a range?

Response: See prior response.

20. Table 14 - Could be very powerful but the Impacts in Section 7 conflict with this Table?

Response: The intent of this comment is not clear.

21. Section 7.1 which is also part of Section No. 3 (General Comment: I'm not sure you want to have large overall numbers and then section numbers?

Response: This comment appears to be based on an outdated version of the report.

22. Table 15 - somehow Table 15 appears in Section 7.1 but the content, without the Table number, reappears again after Appendix C, maybe this was a printing/editing error?

Response: Appendix C is excerpted from a report developed by a sub-group of Group 4 focused only on LSR projects and was advisory in nature. Group 4 expanded upon the table and broadened the scope to include both LSR and RSB projects. The table has been removed from Appendix C to avoid confusion.

23. Much of Part 3 Section 7.1 does not appear constructive to the goals of the protocols and may be beyond the scope of - the Draft Consensus document.

Response: It is not clear what section of the report is being referred to in this comment.

24. Appendix A and B - seem fine however very unusual that neither were cited or referenced in the main body of the document.

Response: Appendix A is referenced on page 35. Appendix B is referenced on page 11.

25. Appendix C, also not referenced in body of main text. This is primarily about a singular LSR project Big Spring Run. It seems a subset of this information would be part of the background to Protocols and then cited – although I think it is a "star" example of LSR and I understand people wish to share and inform. TN, TP and TSS much higher than the NTW data, but somehow not relevant enough to cite in body of text?

Response: Appendix C is referenced on page 13 and page 18. Studies of Big Spring Run are referenced in Table 5 and Table 7. TN, TP and TSS removal data from Big Spring Run differ from the NTW data because it includes reductions due to prevented sediment (P1), denitrification in the EHZ (P2) and floodplain treatment (P3) combined.

26. Appendix D IS referenced in Section 6 (Mods to Protocol 3). Since they are taking the 2 feet per second from one study (albeit with a number of different slopes so that is good - but we don't know anything more about the watersheds?). Also unfortunate, Coleman and Altland (2020) is cited as if a peer reviewed study but that study is not in the "Lit Cited" section so we don't know anything further other than the raw data in Appendix D.

Response: A citation has been added to the References section of the report.

27. Appenidix E. Similar deal to Appendix D. Is spring baseflow "low baseflow"? I thought that was in more drought conditions in summer and in spring groundwater was generally higher?

Response: The example method in Appendix E uses baseflow discharge for the 50% recurrence interval. This has been clarified.

28. Appendix F - If the "impacts section" is going to be kept in this document, my preference would be to have peer reviewed literature only cited, not a presentation to a group (Jordan 2019). Also I'd prefer for the "potential impacts" to be from research that is more conclusive than Duan et al. (2019) or Williams et al (2016). There were conflicting results in these studies and the Duan study only measured in lab microcosms at 30 deg C, not a representative temperature. In addition, the table is incomplete, such as the entry for Fanelli and Lautz (2008) and others. It's not that this section is unimportant, again, it may not be appropriate to a BMP crediting document.

Response: The intend of Appendix F was only to include peer reviewed studies. The Jordan 2019 reference has been removed. The empty cells in the table have been filled in.

29. Appendix G - Same comment as above. This is a lot of important information and it needs to be discussed by a separate, balanced group to educate, clarify, understand fully and possible be mitigated, repaired or fixed in future or current projects.

Response: The group stands by its decision to include Appendix G to provide further evidence of the comprehensive nature of their review of potential unintended consequences. Care was taken to not conflate these citations with peer reviewed literature, and thus they feel the inclusion is warranted.

Jeff Hartranft (PA DEP)

1. Multiple clarifying edits to create more consistent terminology.

Response: All clarifying edits were accepted.

2. Page 2 -- The research being referenced here is not identified. If it is referencing some of the studies that I am familiar with and cited elsewhere in this document, I don't think the floodplains or channels can be referred to as "natural" in accordance with the restoration criteria and recommendations in this document. They are more likely to be located within legacy sediment zones of storage and erosion, and these channel/floodplain conditions, as well as the full range of current processes, are un-natural (Walter and Merritts, 2008; etc.)

I think "un-restored" is an appropriate characterization and can be used in this sentence to support the overall idea of this paragraph. Even this term doesn't really convey the idea that the research on natural or reference conditions and processes are severely lacking or non-existent for the Bay Watershed.

Response: Reference to "Natural" channels has been removed.

3. Page 7 -- I recommend this change to allow for "wiggle room". This edit is inserted to provide flexibility should the outcome of other or future efforts result in consensus with this Memo. It actually may apply based on the outcome of current or future efforts. As written, this language is <u>not consistent</u> with "Recommendations" as is in the title and the intent of this document. As written, this eliminates current and future flexibilities in applying the recommendations. NRCS is not the only entity doing restorations in the Chesapeake Bay in "non-urban" streams, and as written this is too broadly restrictive of all stream restoration practices. NRCS is just an example and specific. It is up to the jurisdictions to decide where to apply these recommendations. PA believes that these recommendations may apply to stream restoration in non-urban sectors that are not related to NRCS programs and we wish to maintain that discretion. The 2014 recommendations have been applied to non-urban stream restoration.

Response: The group believes that the underlying science and principles outlined in the Group 4 memo are applicable to both urban and rural streams. However, during the review of the Group 3 memo, concerns were raised about data availability for NRCS funded practices that may prevent proper evaluation of whether the projects meet the recommended qualifying conditions. Therefore, the previous memo was only approved by the Water Quality Goal Implementation Team (WQGIT) for application in urban stream restoration projects. The language provided has been updated to ensure consistency with the language approved by the WQGIT.

4. Page 7: This also sounds over-reaching. Nobody should "be subject to" recommendations.

Response: Throughout the document, revisions have been made to consistently apply language that avoids regulatory connotation.

5. Table 3: recommend this edit to remove confusion that the Hyporheic Aquifer is restricted to the "bed and banks of the stream channel". The hyporheic aquifer underlies the entire EHZ area, including the bed and banks. It actually occurs within the full extent of the floodplain soil layer, which includes the banks. The banks are a small area of the floodplain soil layer.

Response: The recommended edit has been accepted.

6. This recommended edit simply provides more clarity. HEZ is a representative zone for denitrification, but it is not a specific term used in Protocol 2 and the equations/calculations. This edit removes some of the confusion that may lead people to think that the HEZ is a term/metric applied in the P2 calculation. Essentially, this term is a zone representative of the "Hyporheic Box" that was part of the 2014 protocols that are being revised here. This box is still referenced in the document, but it has been eliminated from the Protocol 2 calculation that is simplified by this Memo to use area instead of volume and as has been discussed in detail above.

Response: The recommended edit has been accepted.

7. Page 11: I'm not sure what happened to these figures? But we have recommended in previous comments and on previous drafts that current examples should explicitly demonstrate the concepts of connection to hyporheic aquifer and an aquatic ecosystem approach to restoration, where wetlands, floodplains, and channels are integrated into a fully functional aquatic ecosystem. One design example is Big Spring Run. Contact Landstudies, Inc for permissions/design drawings of Big Spring Run, or any number of their projects that demonstrate the application of the Principles for the Ecological Restoration of Aquatic Resources (USEPA, 2000).

Response: New figures have been added to the memo.

8. Page 11: I went back through the 2014 report and the "qualifying conditions" do not explicitly reference Chesapeake Bay TMDL reductions. In the 2014 document, the qualifying conditions are relevant to whether or not the individual projects are eligible for credit using the protocols and recommendations of the expert panel. The qualifying conditions in the 2014 document also refer to whether individual projects produce functional uplift for local streams.

Response: All BMP expert panel reports are written for the explicit purpose of defining protocols for crediting nutrient and sediment reductions to track progress towards the Chesapeake Bay TMDL.

9. Page 13: I have had numerous and extensive conversations with many colleagues about using planform as a criteria. To be clear for FR-LSR projects only, I do not agree that planform/belt width of the restored channel should be a criteria. The justification for this position is based on the results from the Big Spring Run demonstration project (Figure 1 below). The documented and confirmed EHZ for Big Spring Run extends well beyond the design planform/belt width and also well

beyond the evolved/mature anastomosing planform/belt width. The Big Spring Run example, if using design planform, would result in approximately 1/3 less EHZ area than the documented/confirmed EHZ for this project. That reduction is not appropriate as confirmed by this cornerstone project that underlies the development of these FR-LSR crediting efforts.

Response: Channel planform is not part of the determination of the EHZ. As described in Appendix C: "The restored channel and floodplain dimensions are based on field testing that define the key vertical and lateral sediment boundaries of the existing floodplain and the hyporheic aquifer beneath it. These boundaries can be measured by a combination of the following methods: direct push soil coring, trenching, test wells, LIDAR surveys, photogrammetry or other site investigations. The objective is to define conditions at critical soil layers in the floodplain profile, and document how the active root zone of the plant community will be connected to the hyporheic aquifer during sustained baseflow periods."

10. Table 10: Table 10 provides adjustment factors for the base denitrification credit, to be used within the Parola et al, 2019 equation. Supporting documentation and explanation for the method and its numeric adjustments was requested previously, in comments generated for the April 14, 2020 draft documents. The previous comment is: "Since the Parola et al (2019) reference is not peer-reviewed/published, a summary of the study (appendix?) is warranted. Without some background concerning methods and results it is impossible to assess the general applicability to restoration crediting." Little additional documentation was provided in any subsequent draft reports. Of the three discount factors, only the Aquifer Conductivity Reduction Factor appears susceptible to evaluation without additional supporting information. Table 10 values for Aquifer Conductivity Reduction Factor cover a 3-orders-of-magnitude range between highest rating (sand, gravel, and sand/gravel mixtures) and lowest (clay). Typical permeability coefficient range for these soil types covers a minimum of 5 orders of magnitude, and probably closer to 7 orders of magnitude. Table 10 values presumably incorporate a rooting adjustment, as suggested in the text. However, there is no supporting documentation for the magnitude of the adjustment. The only support provided for an adjustment is the statement that the factor was "adjusted based on best professional judgment to account for additional porosity added by the floodplain root zone." Furthermore, any rooting-induced porosity does not necessarily indicate a proportional increase in bulk soil permeability.

Response: Table 10 and the supporting text have been updated to address multiple comments received. Table 10 is based upon the best professional judgment of the group members in an effort to develop a method that is technically sound but not overly burdensome. However, the concepts and processes accounted for in Table 10 are supported by peer reviewed research as described in Section 4.

11. Table 11: The EHZ is better described as a width across the restored valley in plan view. The boundaries of this width are determined by the height above the stream channel or low flow water elevation being less than 18 inches.

Response: This change has been made.

12. Many of the assumptions made by Jordon (2007) were disproven at Big Spring Run. These assumptions were directly tested at BSR, where the ratio of the restoration area to drainage area is less than 0.5%. Effectively, the restoration area is relatively

small compared to the watershed area and these relationships assumed by Jordon did not hold. Drew Altland provided a comparison of projects and included measured/monitored results from BSR. The results indicate that only P and TSS relationships are valid for Protocol 3. Again, this is based on real data from an extensively monitored FR-LSR site that is the cornerstone of these protocols. This "discounting" is a further reduction that does not apply to FR-LSR projects. It may be applied to wetland areas outside of the EHZ which are subject to crediting under the Wetlands Expert Panel report. Review Figure 2 as revised above that shows slope wetlands outside of the EHZ. That is where this would apply, but is not necessary for these Protocols. Adding this is likely to increase confusion for practitioners. Also, the problem of double dipping is clearly delineated by separating these crediting methods.

Response: The group did agree to eliminate the upstream watershed to floodplain surface area ratio (>1) requirement. To clarify, the wetland treatment efficiency does not represent a "discount factor", it represents the Protocol 3 treatment efficiency. The downstream method determines the volume of flow that accesses the floodplain. Because 100% of TN, TP and TSS in the overbank flow does not settle out onto the floodplain, a treatment efficiency must be applied. The group felt that using the rates developed by the NTW expert panel provided consistency with the structure of the original expert panel and is based on an extensive literature review. Clarification has been added to the report to distinguish when to report a NTW BMP versus a stream restoration BMP.

13. Page 37: This new language is crucial to PA DEP: However, the key management question is not whether floodplain reconnection will temporarily impact the existing site environmental qualities, but whether or not the project will restore long-term environmental benefits to the site and address the existing impairments.

Response: This language does not necessarily represent the key management question in all jurisdictions. A statement has been added to clarify that decisions about how to weigh the potential for temporary adverse impacts on existing site environmental qualities against the long-term environmental benefits is left to the appropriate regulatory agencies.

14. Aquatic diversity metrics are not a good indicator, in and of themselves, of a stream's geomorphic condition. Diversity metrics in streams have generally been shown to be related to water quality, not physical characteristics. The goal of FR is restoration of the physical characteristics to increase the frequency of flow access to the floodplain. This in turn provides water quality and habitat benefits when appropriately designed. For instance, a sample of macroinvertebrates may be taken from the only riffle in a 2000 foot section of a stream. The sample may indicate high aquatic diversity in that riffle. But this is the only riffle in the entire length being evaluated because of the severely degraded geomorphic characteristics of the stream. Again, diversity metrics are not a good indicator particularly as it relates to geomorphic conditions that are the targets of FR. If anyone is persistent on this point, then they need to provide references to support it. Otherwise, we will disagree and continue to oppose this language. This is a very very big obstacle for PADEP's final agreement in support of this Memo.

Response: This language is specifically included under the following statement: "Follow guidance from the appropriate federal, state or local regulatory authority regarding assessment of existing high-quality habitat and ecosystem functions. The following are considerations that may be required:" PA DEP has the discretion not to use aquatic diversity metrics in its evaluation of stream geomorphic conditions.

15. Table 17: These criteria are ambiguous because they don't indicate a measurable quantity. Since the processes are the same for LSR and RSB projects they should use the same criteria. The criteria for the LSR projects are quantitative and should be used for RSB projects.

Response: The table has been revised.

Art Parola (University of Louisville)

1. Table 8: There should be a planform limit. The mixing of the channel water and the hyporheic zone water is mostly driven by the channel planform – meander sinewave amplitude or braided area. Without this requirement, designers can make a straight channel and get credit for the entire valley bottom. This may be inexpensive.

Response: Language has been added to further emphasize the importance of sinuosity and geomorphic complexity for promoting exchange between the surface water and groundwater.

Kevin Du Bois (DoD)

1. Grandfathering: The report states, "Any projects already in the ground or under contract as of July 1, 2021 should not be subject to the new recommendations, but should adhere to the definitions, qualifying conditions and Protocol 2 and 3 calculations laid out in the Stream Restoration Expert Panel Protocols (2014) unless these newer guidelines are adopted by the project team." I appreciate that the report recommends that past projects should continue to receive credit based on the 2014 protocols, but I am concerned about the potential for jurisdictions to require that the new protocols and any associate requirements be applied retroactively for TMDL credit to stream restoration projects installed prior to July 1, 2021. The DoD CBP recommends that any proposed changes to the protocols be communicated to the Partnership's leadership and approved by the Executive Committee with the goal of ensuring consistency and predictability of crediting among jurisdictions for these projects prior to the recommendations taking effect.

Response: The memo will be approved through the Urban Stormwater Workgroup, Watershed Technical Workgroup and Water Quality Goal Implementation Team.

2. Confusion over Recommendations vs. Requirements for Credit Validation: Given my background in regulation, I personally found it difficult to understand when the report intended to recommend vs. require actions for credit validation. In particular, the mixed language used to discuss the 2014 Protocol qualifying conditions vs. these new protocols, new qualifying criteria and "best practices" leads to a sense of unpredictability regarding project validation requirements and TMDL credit to be achieved post July 1, 2021. In my view, words like "must" and "shall" connote requirements while words like "should" or "recommend" refer to non-mandatory conditions. When these terms are used inconsistently throughout a section that adds to my confusion.

Response: Throughout the document, revisions have been made to more consistently apply language regarding recommendations and requirements. While the entire memo represents recommendations for adoption by Chesapeake Bay Program partners, to remain consistent with the 2014 Expert Panel report, qualifying conditions retain "must", while all other recommendations are presented as "should".

3. Cost: As indicated in the report, if required, the need to determine the lateral boundaries of the EHZ with field measurements (Pg. 19), site investigations that define stream flow conditions, root zones, aquifer conditions and the pre-project water table conditions (Pg 12), post construction surveys, and any other new requirements adds to the cost of these restoration projects. The DoD CBP recommends that, prior to adoption, the group considers and reports on how increases in cost could affect the rate of implementation of these projects and the effect on the pace at which stream restoration goals and outcomes will be affected. In addition, the DoD CBP recommends that the group consider and report on the potential for allowing the level of required effort outlined in the 2014 Protocol to continue with associated levels of TMDL credit

Response: A detailed cost analysis is outside the scope of this group.

Katie Brownson and Sally Claggett (US Forest Service)

1. **Updated denitrification rate**: More information would be helpful to understand the updated denitrification rate and metrics for all FR projects. With the different units of measure presented between the original rate, the median rate derived from the Newcomer Johnson et al 2016 study, and the new rate, it is difficult to interpret the implications of the new rate. Will this change effectively increase or decrease the denitrification rates assigned for a "typical" project in the watershed? Perhaps calculations could be made and provided using the original methods for the Design Examples in Table 11. Given that the science is still uncertain regarding the impacts of these projects and the diversity of factors that can influence denitrification rates, we would not support any changes that would effectively increase the base denitrification rate. Finally, since the Newcomer Johnson et al. 2016 paper was a global review, it would be good to further justify why the median rate across all studies was used- wouldn't it be more justifiable to only use the rates associated with projects in similar ecoregions?

Response: A comparison of the original denitrification rate and the new, recommended denitrification rate has been conducted and can be provided to the commenters, but was not included in the report to avoid the concern that example values may be used as defaults. The differences in removal will vary across projects due to differences in site-specific conditions. The group believes that the recommended protocol revisions represent the best available science on denitrification within the hyporheic exchange zone and stands by its recommended rate.

2. **Discount factors for denitrification**: In Table 10 (page 25), a discount factor is assigned to reduce the denitrification rate for forested wetlands and non-wetland forests based on an unpublished study by Parola et al. 2019. We understand that vegetation is being used as a proxy for soil saturation and therefore denitrification, but by assigning this discount factor, we are concerned that this crediting system will incentivize designs that do not include trees. Restoring to non-forested systems can have adverse habitat and stream health impacts. Further, as is pointed out on page 35 of this report, removing trees can trigger sub-surface nutrient fluxes, so any gains in denitrification may be counteracted by other losses. These interactions are currently not well-understood; as this report point out on page 40: "One of the most urgent research priorities is measuring how stream nutrient dynamics respond to different levels of riparian tree loss during and after construction". It therefore does not appear that this reduced credit is

adequately justified by peer-reviewed science and we do not support a reduced credit for designs that restore to a forested condition.

Response: Following consideration of several alternative options, the group reached a decision to replace the vegetation surrogate with a floodplain height factor.

Judy Okay (J&J Consulting)

1. There is minimal mention of Hydro-geomorphic Provinces. The document is Coastal oriented regarding the concentration on wetlands and wide floodplains. P. 9 does have a paragraph regarding Floodplain Restoration successes across geo-morphic provinces of varying bed substrates. The substrate and stream morphology changes as piedmont areas are considered. **Non-tidal is mentioned on p. 3 where it says it was agreed to use the Wetland floodplain removal rates in "non-tidal" areas. Do these rates vary by stream order/hydrogeomorphic province variation?** Non-tidal and lower order streams with diverse bed substrates behave differently and maybe should be considered. Maybe some end notes or something could be inserted as hydrogeomorphic province considerations. Narrower floodplain areas with steeper slopes are in need of forests rather than just shrub and herbaceous vegetation.

Response: The stream restoration BMP only applies to non-tidal stream systems and is generally only applicable to 1st through 3rd order streams, per the qualifying conditions of the 2014 expert panel report. Tidal systems are credited under the Shoreline Management BMP. Protocol 3 will use regional flow duration curves that will be produced for each physiographic province to account for differences in slope and geology.

2. In Table 15 where environmental impacts are presented. One statement about Benthic decline should be reconsidered or reframed. It is presented that a decline in benthics may be temporary or not and may be desirable or not depending on the project goals? It should not be acceptable to end up with a decline in Benthic macro-invertebrates as a project goal.

Response: Agreed, the statement has been clarified.

Kevin Smith (Maryland Coastal Bays Program)

1. Unintended environmental impacts are important in planning and designing stream and floodplain restoration projects but, in my opinion, simply don't belong in this document. These are all highly site-specific and goal specific. These are considerations for a stream and floodplain restoration manual. The impact they play in pollutant removal is highly varied and, in many cases, not well understood. Finally, the inclusion of Best Management Practices in this document may seem like a good idea, but again, outside the scope of this groups charge. While many of the recommendations included appear on the surface to be correct and innocuous, some are simply wrong (e.g.; "Reduce the use of "iron-stone" rock or sand and other iron-rich construction materials when raising the streambed to avoid iron flocculation during anoxia"), not well-understood (e.g. the contribution of rehydrated floodplains in mitigating stream temperature) and contrary to other recommendations in the document (e.g; "Avoid the creation of stagnant pools within the stream channel and long-term inundation or ponding across the floodplain width.").

Response: The inclusion of Section 7 is necessary to achieve the consensus approval of the memo by the Chesapeake Bay Program partnership. While the group was not designated as an official expert panel, it sought to remain consistent in addressing the key elements that all BMP expert panels must address, including consideration of potential unintended consequences. The group stands by its summary of potential unintended consequences based upon the available literature reviewed.

Chris Spaur (USACE member of Stream Health Workgroup)

1. Glossary defines upper boundary of FTZ. Here or elsewhere as appropriate, consider clarifying lower boundary of FTZ, or explain why not defined/clarified

Response: For the purposes of nutrient and sediment removal crediting, the lower boundary of the FTZ is the floodplain elevation (height above low flow water levels). This has been clarified in the report.

2. To item 2, add “Consider mosquito management needs if in close proximity to human community”

Response: A bullet on mosquito management control has been added to Section 7 of the memo.

3. Consider adding some caution about creating anoxic stream waters

Response: The group feels this has been effectively addressed elsewhere within the memo including in the qualifying conditions and in Section 7.

4. Table 10: Should factor be adjusted to a bell curve shape with silt having highest crediting value?

Response: The hydraulic conductivity coefficient was developed this way to ensure that there is sufficient surface water/groundwater exchange in and out of the HEZ. The values are relative and based on material conductivity and then adjusted upward to account for porosity added by root density. Under most low gradient conditions the residence time is sufficient for denitrification in clean gravels and sands (6-12 hours). Residence times significantly longer than this are not helpful in removing nitrogen. Gravel will not remain clean because roots and soil will invade and fill voids reducing the hydraulic conductivity such that it is closer to sand with roots. The residence time in silt and silty soils is longer than necessary and low lateral hydraulic conductivity results in lower transfer rates from the channel and back to the channel.

5. Add new bullet something like “Avoid removing native vegetation in urban parks where such vegetation constitutes last remnants of native vegetation in area”

Response: The group felt that this concern has been sufficiently addressed throughout the Best Practices section of the report.

Kate Bennett (Montgomery County)

1. Protocol 3: For the downstream approach using the USGS gages, the expert panel report states “The USGS gage(s) may be located in the same watershed or within an adjacent or nearby watershed with similar land use or geology.” For watersheds without gages, it would be helpful to have an example of how they selected a suitable, nearby gage or a definition of what’s acceptable as “similar land use or geology.”

Response: An example is provided in the new Table 16. However, because there is considerable variability across site-conditions, practitioners will have some flexibility to select and defend their chosen representative gauge stations, working with the appropriate regulatory authority.

Neely Law and Matt Meyers (Fairfax County)

1. Please clarify floodplain connectivity as discussed as a part of Protocol 2 and its relationship to Protocol 3. Protocol 2 addresses denitrification for baseflow conditions but the protocol reads to provide information where stormflows inundate the floodplain to demarcate the EHZ. Will the area inundated an credited for Protocol 2 be the same as Protocol 3 given the different methods to determine its extent?

Response: Protocol 2 only provides crediting for the EHZ defined under baseflow conditions. The EHZ area and the total floodplain area inundated during storm events is not expected to be the same. Language will be added to the memo to clarify this point.

2. The definition of the HEZ and EHZ needs further clarification both in the narrative and Figure 3 and how it applies to RSB projects. Please see Figure 3 for further details.

Response: The HEZ is the subsurface volume where denitrification occurs, while the EHZ is just the surface area directly above the HEZ that is used to calculate the nitrogen reduction. It's essentially a scientific construct vs. a TMDL crediting construct. We have added new figures and language to the memo to better illustrate this point.

3. HEZ and how does it apply to RSB projects? The extent of the HEZ is unclear. From the draft report, "The floodplain area eligible for P2 credit in FR-RSB is defined as the region below and alongside a stream, occupied by porous medium where there is an exchange and mixing of shallow groundwater and the surface water in the channel. The dimensions of effective hyporheic zone are defined by…" 18" Criteria and its Interpretation

Response: The HEZ is applicable to both LSR and RSB projects. Monitoring is needed to establish that the HEZ is within 18 inches of the floodplain surface during low flow conditions to ensure consistent contact with the floodplain root zone regardless of design approach.

4. What is the basis for the 18"? It is assumed that it may be related to the depth used to characterize hydric soils for regulatory wetlands (e.g., (https://www.nab.usace.army.mil/Missions/Regulatory/Wetlands/); if so it may be worthwhile to add a citation for documentation of this value. This represents an average and will likely present a very strict limiting factor for credit or no credit. Given the more extensive data collection efforts that will be required to support the credit, it is suggested that the 18" may be used as a default, but to provide an option to include supporting data that may demonstrate hydric soils greater than 18"to some upward maximum.

Response: The 18 inch depth is used to represent consistent contact between the surface water and groundwater and the plant root zones in the floodplain. This value is based on based on the best professional judgment of the group. Most of the root mass is within 12 inches of the ground surface but may extend to 18 inches. Only a few species have significant root mass below 18 inches. Contact with the root zone is critical for denitrification because of the carbon input provided by the root systems. The experimental values for rates of denitrification have come from saturated zones within 18 inches of the surface. The data that does exist for deeper groundwater rates is much lower.

5. Please clarify the difference, if any, between the depth of the EHZ for the channel, the bank height and the depth to groundwater in the floodplain? Does the 18" provide an approximation for all three?

Response: The EHZ is the area where the groundwater is less than or equal to 18" below the floodplain surface. The entire channel area is included within the EHZ as well.

6. Request to reconsider the discount factor for forested wetlands. Wetland denitrification/nutrient reduction is quite variable and a 40% is quite steep given the variability and impact on credit. Suggestions are provided in the report comments. For example, using the two examples in the revised protocol (e.g. comparing the design examples with the existing protocol 2), it is estimated that LSR project would be reduced by 38% and the RSB project by 82% .

Response: Following consideration of several alternative options, the group reached a decision to replace the vegetation surrogate with a floodplain height factor. The discount factors were also adjusted in accordance with the new approach.

7. For credit, the example provided in Table 1 calculates the credit only on post-restoration condition. Similar to Protocol 1, does Protocol 2 credit account for pre-restoration conditions? If so, may it be assumed that the data is needed to demonstrate the EHZ is for both pre- and post-construction conditions. The Protocol 2 credit would apply to the change in the extent of the HEZ for FP-RSB projects. Please clarify. Further, groundwater levels to verify the groundwater table is within 18" of the floodplain soils is highly recommended. What mechanism or process is in place to provide this documents – via State agencies, CBP?

Response: Yes, Protocol 2 should represent the change from pre to post-restoration conditions. This has been clarified in the memo. It is agreed that the groundwater levels should be monitored to provide confidence in the boundaries of the EHZ. A determination on the appropriate mechanisms is beyond the scope of the group, but typically occurs as part of the BMP verification/QAPP process.

8. Overall, it may be helpful to provide a list of qualifying conditions and data needed to support eligibility for credit. Examples are provided below to initiate ideas. The "existing" column indicates if the information that may be readily obtained from current projects.

Response: A section on data tracking needs has been added to the memo.

Appendix J. Dissenting Opinion Regarding Table 10

The following letter was submitted by a member of Group 4 as a dissenting opinion regarding the use of Table 10 in Protocol 2.
September 14, 2020

Maryland
Department of
the Environment

Larry Hogan, Governor
Boyd K. Rutherford, Lt. Governor

Ben Grumbles, Secretary
Horacio Tablada, Deputy Secretary

September 14, 2020

TO: David Wood, Chesapeake Stormwater Network

FR: Denise Clearwater, Maryland Department of the Environment

RE: Dissenting Opinion Regarding Table 10, Consensus Recommendations
to Improve Protocols 2 and 3 for Defining Stream Restoration Pollutant Removal Credits

I am providing this dissenting opinion as a member of the work group charged with preparing the technical memo for revisions to Protocols 2 and 3 "Consensus Recommendations to Improve Protocols 2 and 3 for Defining Stream Restoration Pollutant Removal Credits." The dissent is specific to Table 10, Site Specific Discount Factors for Adjusting the Denitrification Rate. Additional background and a list of references are provided in Attachment 1.

The dissent focuses on the Floodplain height factor, which is the distance from the top of the floodplain to base flow as indicated by riffle, run, or other suitable alternative method.
In the proposed Table 10, there is no reduction factor for post-construction water levels at floodplain heights from 0.0 - 0.75 feet above the base flow, followed by the next category from 0.76 feet - 1.0 feet with a reduction multiplier of .75.

Denitrification requires both aerobic and anaerobic processes, which are accomplished by fluctuations in groundwater levels, resulting in alternating wet and drier periods. This in turn affects the microbial use of available oxygen, which is rapidly depleted in saturated conditions when organic matter is also present. Anaerobic processes then become more dominant.

Restoration designs which maintain continuously high groundwater levels would be expected to reduce the belowground denitrification by:

1) Reducing the area for the intermediate aerobic nitrification stage (ammonium converted to nitrate) for denitrification;
2) Reducing ability of surface water to enter floodplains soils due to their saturation and

resulting limited capacity in pore spaces;

3) Favoring ammonification. Under continuous saturation, the dominant form of nitrogen is ammonium, which cannot be reduced. Ammonium must first be converted by aerobic nitrification to nitrate for denitrification to occur. (Vasilas, personal communication and Hefting et al., 2004).

Recommendation: An improved approach would be to qualify that the highest floodplain height ranking is for 0-.75 feet for a more limited time during the growing season, e.g November through May, or switch the ranking scores for the proposed 0-.75 feet with the second score of .76-1 foot for summer baseflow.

See the attachment 1 below for additional background and references.

Please contact me at denise.clearwater@maryland.gov if you have any questions or need more information.

cc: Heather Nelson, MDE
Jeff White, MDE
Deborah Cappucitti, MDE,
Christina Lyerly, MDE
Raymond Bahr, MDE

Attachment 1

Dissenting Opinion Dissenting Opinion Regarding Table 10, Consensus Recommendations to Improve Protocols 2 and 3 for Defining Stream Restoration Pollutant Removal Credits

Additional Background

Denitrification in the hyporheic zone is requires the presence of nitrate, dissolved organic carbon, denitrifying bacteria, and anaerobic conditions. Further influences which have been described include hydraulic conductivity, hydraulic gradient, pH, soil texture, soil saturation, vegetation, stream sinuosity, and temperature. However, there are conflicting results in the literature for many of these factors. Denitrification in the hyporheic zone is a complex process and is site specific. In order to include a simple equation usable for crediting, many of the influencing variables have been omitted or are not readily collected from specific sites. It is recognized that this likely affects the accuracy of providing estimates of denitrification. However, there remain simple revisions which would improve accuracy of the model to predict denitrification which consider scientific findings.
In order to clarify some of the limitations which are not considered (for creation of a simple equation) the following are not addressed in this table:

Nitrogen removal by processes other than below ground denitrification in the hyporheic zone

Effects of channel bed complexity, organic matter, hydraulic gradient, pH, temperature, sinuosity, and structures on instream denitrification.

The hyporheic zone expands and contracts seasonally (Boano et al. 2014), primarily driven by groundwater influences and as streams shift from gaining to losing states and the hydraulic gradient reverses. During periods of low base flow, the hydraulic gradient in groundwater-supported riparian areas is toward the channel. Increases in stream flow from storms when groundwater levels are normally lower allow for entry into the stream banks.

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Appendix K. MDE Addendum: Application of Protocol 3 in Maryland

MDE provided the following statement on Maryland's authority to define the amount of treatment volume allowed for restoration crediting purposes under Protocol 3 for stream restoration projects implemented in Maryland:

Implementation of Protocol 3 in Maryland

The Maryland Department of the Environment (Department) thanks the Chesapeake Bay Program (CBP) for the opportunity to review and provide comment on the *Consensus Recommendations to Improve Protocols 2 and 3 for Defining Stream Restoration Pollutant Removal Credits*. The Department understands that numerous revisions and additional guidance have been incorporated and thanks CBP for the significant effort made in working with the Department and other stakeholders to address comments and include many of the suggested changes. The Department supports the Consensus Recommendations with reservation. At this time, the Department has remaining questions regarding assumptions associated with the treatable floodplain volume used in Protocol 3.

The research available does not provide sufficient scientific basis to support that the total volume of flow within the defined floodplain trapping zone is subject to pollutant reducing processes. Until the Department conducts the necessary research to support the pollutant reduction amounts as detailed in the report, it retains the authority to set or limit the amount of pollutant reductions used for total maximum daily loads and municipal separate storm sewer system (MS4) permitting requirements. The Department hopes that the result of this effort will add to the important work already completed. Ultimately, these efforts will allow the Department to offer additional guidance to stakeholders in Maryland that intend to implement the new stream restoration protocols.