Appendix G
Clarifications and Edits Resulting from the "Test Drive Period"

Background. This Appendix includes clarifications and edits resulting from the 6-month Test Drive. Because of the complexity of the stream restoration protocols, the Expert Panel decided there would be a "Test Drive Period" so that states and localities could "test" the protocols on actual projects. The results would identify sections of the reports that require clarification or editing to improve the protocols.

Five consulting firms (Williamsburg Environmental Group, Timmons Group, LandStudies, RK&K and AMEC Engineering) and one local government (Anne Arundel County) applied the protocols to ten different projects and provided suggestions on improvements that were agreed to by the Expert Panel. Additionally, four Maryland Counties (Anne Arundel, Carroll, Montgomery, and Prince George's), the Maryland State Highway and the Maryland Department of the Environment provided additional comments.

The results of the Test Drive varied widely. The biggest concerns are summarized below.

- The protocols are too complicated and difficult to use for planning purposes.
- The interim rate leads to load reductions that can exceed watershed loading rates and may preclude the use of more robust protocols.
- The BANCS method may not be accurate and regional curves have not been developed.
- The 50% efficiency requirement for Protocol 1 is too low.
- Certain types of projects result in load reductions that can exceed watershed loading especially for Protocol 2.
- The pre-restoration condition was not accounted for in Protocol 3.
- Confusion over how upstream BMPs will affect load to the project and subsequently the credit received.
- Some of the reviewers didn't understand how the sediment delivery factor was applied or understand which protocols were additive.
- The curves used to develop Protocol 3 are not accurate enough for design purposes.
- The protocols will bias Natural Channel Design Projects because the additional load reductions associated with floodplain reconnection projects is nominal.

While most of these issues are addressed in this appendix, a few recommendations were important enough to be added to the Expert Panel Report. These recommendations include a revised interim rate for projects that do not conform to the protocol requirements (Q-3) and a revised denitrification rate for Protocol 2 (Q-8).

This appendix includes one technical addendum:

- Technical Addendum A: Alternative Protocol 3 Curves

Part A
General Questions

Q-1: The Chesapeake Bay Watershed Model (CBWM) uses general parameters (i.e., urban impervious and urban pervious lands) to represent all urban areas. Conversely, the protocols for obtaining credit for an individual stream restoration project require very complex and detailed site analysis. Because the CBWM represents small watersheds in a very general scale, won't the credit reductions achieved using the protocols be out of proportion with Chesapeake Bay modeled loads?

A-1: The Chesapeake Bay Program recognizes that crediting for stream restoration projects is challenging because 0-3rd order streams are not specifically modeled by the CBWM. This makes the development of methodologies to credit individual stream restoration projects for sediment and nutrient reduction particularly challenging. Despite this challenge, there is a critical need to develop a methodology(s) so that managers can begin planning and implementing their strategies at the individual project site scale that can be translated to the CBWM scale. The Expert Panel believes despite the uncertainty and inaccuracies with the recommended protocol, the approximation of the credit associated with stream restoration using the Protocols is far superior to the previous rate that was approved by the Chesapeake Bay Program. Since load reductions are inputted into MAST at the County scale, it is believed that instances where load reductions from stream restoration projects exceed the watershed load will be averaged-out. As the Chesapeake Bay Program (CBP) Stream Restoration and Sediment Coordinator, the Center for Watershed Protection (CWP) is currently working with the Modeling Team to determine how to better represent these stream classes, as well as modeling sediment transport in the next phase of model development. This should enable more accurate estimation techniques to account for credits assigned to individual projects.

Q-2: How can a planning level estimate of nutrient and sediment load reductions be obtained when the Protocols are labor-intensive?

A-2: The interim rate should be used for planning level estimates. Based on feedback from the test drive period, we are confident that engineers can generate shortcut approaches for the Protocols to estimate nutrient and sediment load reductions.

Q-3: Why does the interim rate in some of the examples result in nutrient and sediment load reductions that are higher than the reductions calculated from the stream restoration protocols?

A-3: The interim rate resulted in higher load reductions than the protocols for several of the test drive examples. This prompted the Expert Panel to reevaluate the basis for the interim rate, which was based on stream data collected by Baltimore City under their Municipal Separate Storm Sewer System Permit. When the interim rate was developed, Baltimore City was using phosphorus as a benchmark pollutant. A 50% efficiency factor was applied to estimated phosphorus loading rates to account for reductions associated with stream restoration. Reduction efficiencies were not applied to TSS and TN.

Therefore the interim rates for TSS and TN should be adjusted to reflect the estimated reduction efficiency associated with restoration. The Expert Panel felt that the efficiencies for TSS and TN should be based on the same study used by Baltimore City to develop the initial rate (Stewart, 2008), which found that the restoration efficiencies for Spring Branch were 37.5% for TN and 80% for TSS. The Panel recommends applying these TN and TSS efficiencies to the interim rate (Row 3 of Table G-1) to bring the estimates more in line with those of the protocols described in Section 5 of the Panel report.

Table G-1. Edge-of-Stream 2011 Interim Approved Removal Rates per Linear Foot of Qualifying Stream Restoration (lb/ft/yr)

Source	TN	TP	TSS*
Interim CBP Rate	0.20	0.068	310 (54.25)*
Revised Interim Rate	**0.075**	**0.068**	**248 (43.4)***

Derived from six stream restoration monitoring studies: Spring Branch, Stony Run, Powder Mill Run, Moore's Run, Beaver Run, and Beaver Dam Creek located in Maryland and Pennsylvania
* The removal rate for TSS is representative of edge-of-field (EOF) rates and is subject to a sediment delivery ratio (SDR) in the CBWM to determine the edge-of-stream (EOS) removal rate. This sediment delivery ratio is approximately 0.175 and its application to the TSS EOF rate is noted in parentheses. The SDR should be used for planning purposes, however for reporting progress, load reductions using the actual EOF value should be used (248 lb/ft/yr). Scenario Builder will apply a more accurate SDR estimation to the EOF rate. Additional information about the sediment delivery ratio is provided in Appendix B.

Q-4: Why don't the protocols apply to projects designed to protect public infrastructure when some projects, such as outfall stabilization and bank stabilization, provide water quality benefits.

A-4: Although projects designed to protect public infrastructure can provide water quality benefits, the credited stream restoration projects were meant to be ones that are considered as part of a comprehensive watershed strategy. They were not meant to be installed solely for the purpose of nutrient and sediment load reduction, but instead should improve the hydrologic, hydraulic, geomorphic, water quality, and biological condition of urban streams. This is why the Expert Panel chose not to develop a separate Protocol for dry channel regenerative stormwater conveyance projects. A separate Expert Panel may be convened to consider projects that protect public infrastructure.

Q-5: Why are some projects subject to a 50% restoration efficiency when they have been documented to prevent, and in some cases completely eliminate bank erosion, such as legacy sediment removal projects?

A-5: In preparation of the Panel report, only one study (Stewart, 2008) could be found that included monitoring efficiencies for stream restoration projects. The Panel felt that monitoring data from Big Spring Run would provide information on the effectiveness of legacy sediment removal projects. Monitoring data from this project was presented by Dr. Dorothy Merritts from Franklin and Marshall College at the Mid-Atlantic Stream Restoration Conference (http://midatlanticstream.org/), which showed sediment reduction efficiencies of approximately 70%. The Panel felt that projects like Big Spring Run that include monitoring should be allowed to use reduction efficiencies greater than 50% if supported by monitoring data. This will hopefully encourage municipalities and localities to collect much needed data.

Part B
Protocol 1: Credit for Prevented Sediment During Storm Flow

Q-6: How can proper credit be received from Protocol 1 with the documented uncertainty using the BANCS method, such as not accounting for sediment erosion from incision and headcuts and the lack of region-specific curves?

A-6: The level of accuracy of the BANCS method is believed to be greater than that of the original stream restoration rate. The limitations of the BANCS method would result in errors that in many cases would be offsetting. For instance, the BANCS method can overestimate erosion from stream banks comprised of cohesive clays. However, the BANCS method can also under predict erosion resulting from channel incision and head cuts. This was discussed in a study of the Codorus Creek Watershed by the Codorus Creek Watershed Association (CCWA 2008, 2009, 2010), which used a modified version of the BANCS approach to predict stream bank erosion. In addition, the Panel report recommends that regional calibration curves be developed, however the Panel does not have resources to develop these curves. In the absence of region-specific curves, localities should use the Hickey Run curve.

To encourage further improvements to Protocol 1, the report gives states the flexibility to use alternative methods that can be calibrated to measured stream channel erosion rates, provided the methods are approved by the CBP. In addition, some of the design examples included the use of multiple methods (e.g., BANCS, bank pins) as is often done in stream restoration design. State and municipal governments should consider using multiple methods as a QA/QC check, especially if they are concerned about the accuracy of the BANCS method.

Q-7: How is the sediment delivery factor applied and how is it determined?

A-7: The sediment load reductions from these protocols are edge of field and will have to be adjusted with a sediment delivery factor to account for transport losses. Refer to Appendix F for information on how these adjustments will be made. For demonstration purposes an average sediment delivery factor of 0.175 was used in Section 6.5 of the Panel Report for the design examples.

Part C
Protocol 2: Credit for In-Stream and Riparian Nutrient Processing within the Hyporheic Zone During Base Flow

Q-8: Why is the nitrogen load reduction often higher than the load reduction from the interim rate and the watershed nitrogen load?

A-8: The denitrification rate used in protocol 2 was based on a study in Minebank Run, as documented in Appendix C. This rate was based on the average rate from low-bank restored sites. However, considering the variability in the measured denitrification rates at these sites, the Expert Panel has recommended a lower denitrification rate based on the mean of all restoration sites, including the high, non-connected bank sites. This lower rate reduces the original credit received from Protocol 2 by approximately half. Appendix C provides additional information about the denitrification rate.

In addition, the original methodology for Protocol 2 did not require a comparison of the TN credit received to the total TN load of the watershed. Upon review of the test drive results, the Panel felt applying a cap on the potential credit would help resolve the issue of the credit surpassing the watershed TN load. A qualifying condition was added so that the nitrogen removal credit obtained from this protocol cannot exceed 40% of the total watershed TN load. This credit cap is based on a study by Klocker et al. (2009), who found that 40% of the daily load of nitrate in Minebank Run could be removed through denitrification.

Q-9: What design guidelines should be followed to promote in-stream nitrogen removal for Protocol 2?

A-9: The Expert Panel was not charged with developing detailed design specifications, but rather basic qualifying conditions to encourage and allow flexibility in design. Angela Gardner Allen provided the following design guidelines based on a review of the literature on N removal rates driven by hyporheic exchange in restored streams. The guidelines were developed to maximize potential for nutrient removal, including varying hydraulic gradients, harvesting of hyporheic material, sizing of structures, and developing biogeochemical hot spots.

Pattern:

Establishing a meander pattern in a straightened stream is not always a possibility in urban restoration projects plagued by constraints such as utilities, roads, and infrastructure. However, hyporheic exchange through meander bends can account for 46-53% of total hyporheic exchanges in a stream system (Cardenas and Wilson 2004). In another study, Kasahara and Wondzel (2003) showed that removal of sinuosity from a channel would decrease exchanges by 12%.

Profile:

Geomorphic feature complexity along a stream reach will vary the vertical hydraulic gradient, thereby increasing zones of downwelling and upwelling in the channel. It is recommended to go beyond a simple riffle-pool sequence to include riffle-pool-step sequences or riffle-step-pool sequences. The steps will increase zones of downwelling that could overcome the natural hydrology of a gaining stream. The utilization of vanes and J-hooks can also create zones of downwelling and upwelling within the channel.

Hot Spots:

Design and research regarding biogeochemical hot-spots is at the forefront. Stream features and structures that can be constructed specifically with nutrient dynamics in mind are encouraged. This could be a small scale debris dams, brush material in riffles, brush sills, etc.

Materials:

Whenever possible, riffle material should be (1) harvested from the original stream channel or (2) harvested from native rock material on-site. The newly constructed stream will benefit from the natural heterogeneity of harvested material and the material will likely already contain the denitrifying bacteria. Harvesting native rock on site is preferable to hauling rock from a quarry. The rock is native to the stream system, and when harvested it is a heterogeneous mixture containing the largest material you specify down to fines. This heterogeneity will provide varied flow paths and potential anoxic microsites within the riffle. A heterogeneous riffle material will also encourage hyporheic exchanges, known as pumping, along the length of the riffle as pressure builds up on the upstream end of larger rocks and boulders.

The harvesting of existing hyporheic material in conditions such as a high-clay content piedmont site where the new channel is being constructed in a floodplain containing compacted clays should be considered. Over-excavating the new channel and placing in hyporheic material from the old channel could provide a more porous material for the stream bed.

Wood, as a carbon source to the system should be encouraged, especially in low gradient streams where rock isn’t necessarily needed or present in natural channels. In essence, don't use rock when wood will do. Incorporation of wood into riffles, such as packing branches into riffle material, and the creation of brush toe or brush mattresses along banks are good options.

Construction:

Compaction may be one of the largest issues in the first year for hyporheic exchange in newly constructed channels. Most construction plans specify what the compaction levels of floodplain and upland areas should be post construction and pre-planting, however they never include compaction of the channel bottom or banks during construction. This is a good opportunity to stress that in design plans.

Part D
Protocol 3: Credit for Floodplain Reconnection Volume

Q-10: Can the Protocol 3 curves be adapted to different hydrological methods that are typically used in stream restoration design?

A-10: The curves developed for Protocol 3 were based on the frequency distributions of rainfall from records from National Airport. To develop the curves, an assumption was made that runoff volume followed the same frequency distribution as rainfall. This assumption works for small LID type designs however does not hold for projects such as stream restoration that require more complicated hydrologic methods. Therefore the curves developed in the Expert Panel report are conceptual in nature and should only be used for planning purposes and not for design. However, the rationale and basis for developing the curves still should form the basis for estimating sediment and nutrient removal for projects that qualify for Protocol 3. The curves will have to be adjusted depending on the hydrologic method used.

This became evident in the test drive period of the stream restoration protocols which suggest that using rainfall data as a surrogate for runoff on the Protocol 3 curves significantly overestimates the annual runoff volume, thus underestimating treatment. While the fraction of total annual precipitation may be significant for smaller rainfall events, the fraction of total annual discharge resulting from those smaller rainfall events may be much lower, due to abstraction and interception which occurs in small events.

Technical Addendum A provides an example of how the curves can be adapted using the Soil Conservation service (SCS) Runoff Curve Number method. This method was chosen because it is one of the more popular hydrologic methods used in stream restoration design.

Q-11: How should the effect of upstream BMPs be accounted for when calculating the watershed load to the stream restoration project?

A-11: Refer to Appendix F for information on the effect of upstream BMPs and how they are accounted for in Scenario Builder.

Q-12: Why is the calculation of the minimum watershed to floodplain surface area necessary when the Protocol 3 curves already incorporate the volume in runoff? Since only the first 1 foot of volume on the floodplain is eligible for credit, wouldn't the minimum ratios have been established by default?

A-12: While the curves incorporate the volume, they do not account for hydraulic residence time. The TN, TP and TSS efficiencies used in this protocol are from Jordan

(2007), who found that water detention time is roughly proportional to the ratio of wetland area to watershed area because watershed discharge and wetland volume increase with their prospective areas. The Expert Panel felt that using a 1% wetland to watershed ratio was warranted to assure adequate hydraulic residence time within the floodplain wetlands. The recommendation of the 1.0 maximum depth was added as an additional safeguard to assure adequate retention time and maximum contact between the floodplain wetlands and runoff. Given the numerous concerns about not being able to meet the 1% ratio, the Expert Panel recommends that the minimum floodplain depth requirement be eliminated.

Q-13: Won't the protocols be biased towards Natural Channel Design Projects because the additional load reductions associated with floodplain reconnection projects is nominal?

A-13: As stated in the response to Question 8 in Part C, the Expert Panel has recommended a lower denitrification rate that would reduce the credit received from Protocol 2 by approximately half. This revision will put the credit for natural channel calculated from Protocol 2 more in line with the credit received for floodplain reconnection projects from Protocol 3.

Technical Addendum A
Alternative Protocol 3 Nutrient and Sediment Removal Rate Curves

The curves developed for Protocol 3 were based on the frequency distributions of rainfall from records from National Airport. To develop the curves, an assumption was made that runoff volume followed the same frequency distribution as rainfall. This assumption works for small LID type designs however does not hold for projects such as stream restoration that require more complicated hydrologic methods. Therefore the curves developed in the Expert Panel report are conceptual in nature and should only be used for planning purposes and not for design. However, the rationale and basis for developing the curves still should form the basis for estimating sediment and nutrient removal for projects that qualify for Protocol 3. The curves will have to be adjusted depending on the hydrologic method used.

This became evident in the test drive period of the stream restoration protocols which suggest that using rainfall data as a surrogate for runoff on the Protocol 3 curves significantly overestimates the annual runoff volume, thus underestimating treatment. While the fraction of total annual precipitation may be significant for smaller rainfall events, the fraction of total annual discharge resulting from those smaller rainfall events may be much lower, due to abstraction and interception which occurs in small events. The use of rainfall depths of 0.5 inch and 1 inch as the “baseline” value for applying the methodology may create practical challenges with the future application of the methodology, as conventional event-based hydrologic models such as TR-55 often predict little to no runoff associated with such small events and are not particularly well suited for evaluating small storm hydrology.

Based on these findings, the Protocol 3 curves were revised as follows so that they are based on the percentage of runoff as opposed to rainfall depths.

Various hydrologic methods can be used to revise the curves or flow records from gauged stream stations (more accurate) can be used. We chose to use the Soil Conservation Service Runoff Curve Number (RCN) because it is one of the more popular hydrologic methods. This method was used to estimate the runoff associated with a rainfall event occurring at Regan National Airport based on long term rainfall records. The rainfall runoff relationship depends on land use in all runoff estimation methods. The probability of resulting runoff due to each rain event was assessed for a number of curve numbers ranging from 70 to 95.

The absolute ability of each runoff event to reach the floodplain is different depending on the RCN used; however, the relative runoff trend is very similar. Using this information, relative relationships can be made entirely based on runoff probability. For example, a relationship can be made between Floodplain Treatment (as a percent runoff event) and Runoff Treated (as a percent of runoff) for a given Floodplain Access (as a percent runoff event). The Floodplain Treatment value represents the relative volume of water treated by restoring floodplain connectivity. The Floodplain Access value represents the relative amount of runoff required to access the floodplain. Relative values are based on the largest runoff event on record.

In order to represent these data in the most consistent manner, a second order polynomial regression between Floodplain Treatment and resulting Runoff Treated was made for six Floodplain Access values over four RCNs. These regressions were forced through zero, as no floodplain treatment would result in no runoff treated. A subsequent regression between the two parameters of the initial regressions was developed to determine the most appropriate equation for general application across the watershed. The result was the following equation.

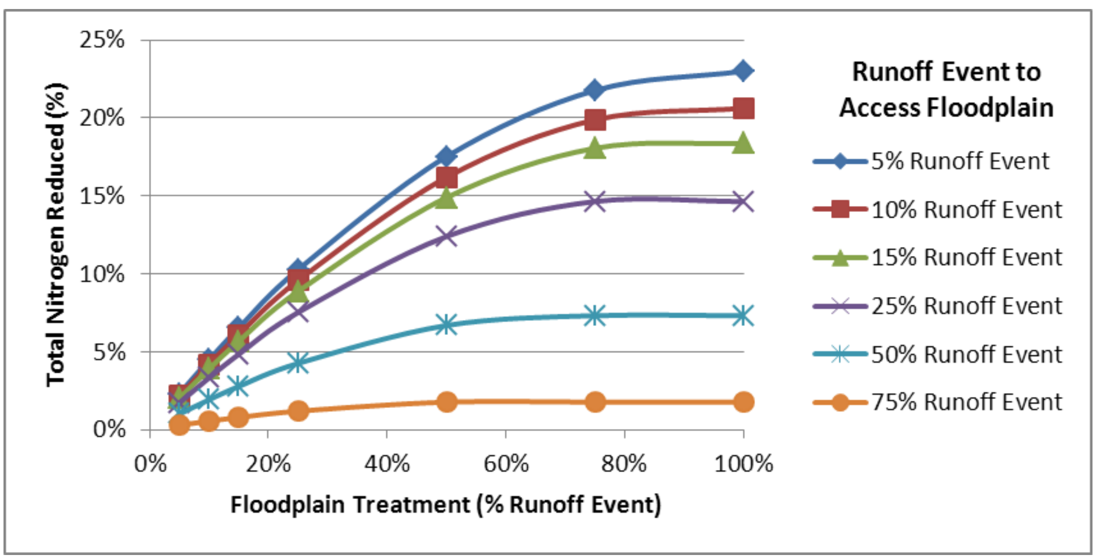
$$\%\,Water\ Treated = [(FA^2 + 0.3 * FA - 0.98) * FT^2 + (-2.35 * FA + 2) * FT] * 100$$

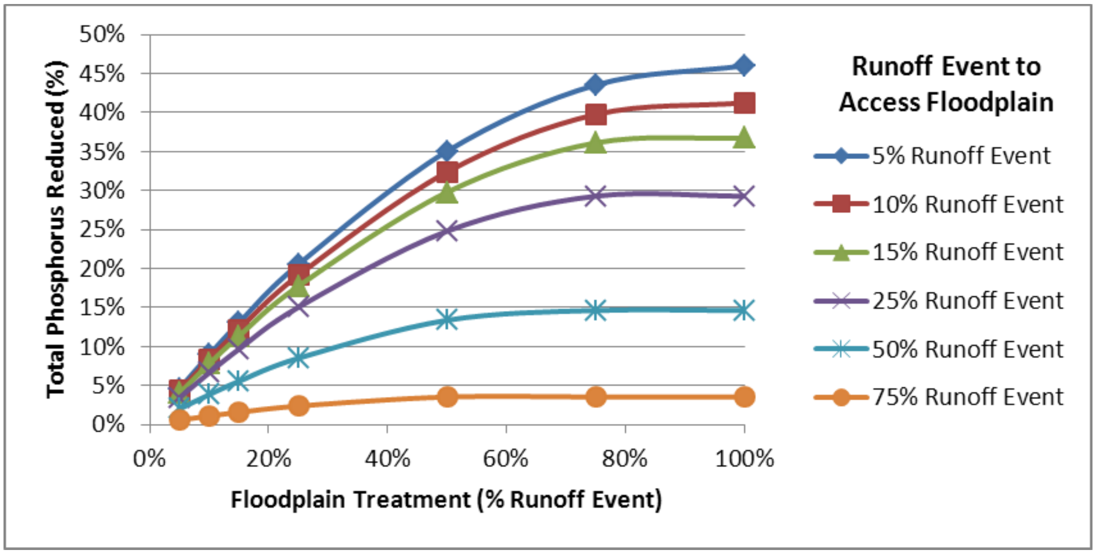
Where,

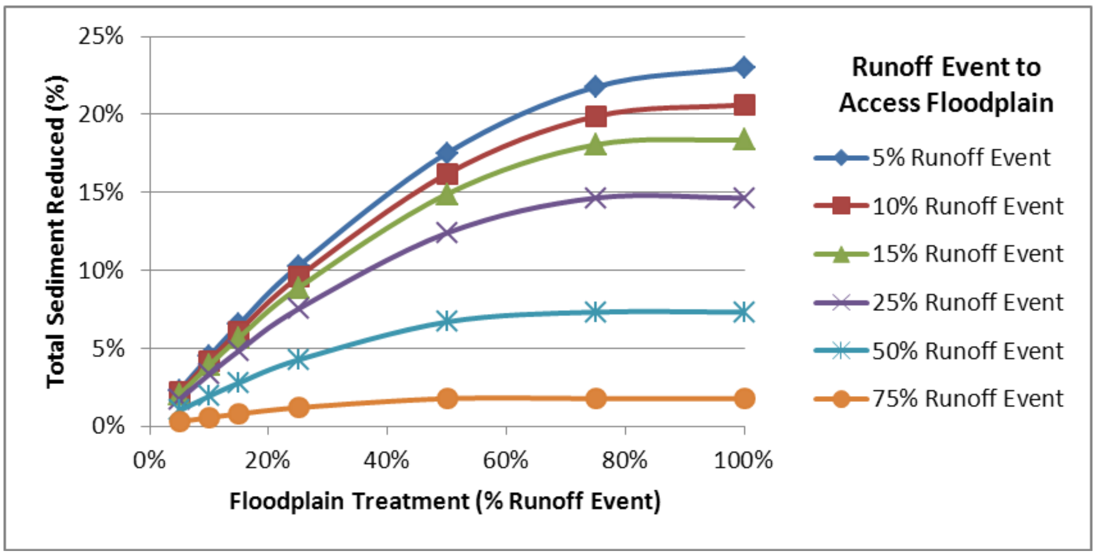
- FA is Floodplain Access (fraction of runoff) i.e. what percentage runoff event would be required to push water into the floodplain
- FT is Floodplain Treatment (fraction of runoff) i.e. what percentage runoff event is treated in the floodplain

As a product of the regressions, the above equation tends to turn down when Floodplain Access requires a large amount of runoff (greater than 25%) and Floodplain Treatment provided is large (greater than 75%). As such, if a large amount of Floodplain Treatment is provided with a stream restoration project, the maximum resulting runoff treatment value can be used.

Applying reduction efficiencies, resulting reduction trends for Total Nitrogen (25%), Total Phosphorus (50%), and Total Sediment (25%) are shown in the following figures:







Note: For the above 3 graphs, the 5% runoff event curve means that 95% of all runoff events will access the floodplain.

From Appendix C of the stream protocols with a few modifications

A detailed description of the spreadsheet analysis

1. Ordered the daily rainfall events for 30 years of data from least to greatest, and removed all events of 0.1" or less. Runoff based on various curve numbers between 70 and 95 were associated with each rainfall event.
2. Summed the total rainfall volume.
3. Set floodplain access depths (in fraction of runoff)
4. Set treatment volumes (in fraction of runoff)

5. Determine the value for each combination of floodplain access depth and treatment volume by:
    a. Adding up all of the runoff amounts between the floodplain access depth and the floodplain access depth + the treatment volume.
    b. Subtracting the floodplain access depth from each event in the above sum.
    c. Adding the treatment depth for all runoff amounts above the floodplain access depth + the treatment volume.
    d. Dividing the total of a-c above by the total runoff volume.
6. This value represents the percentage of the total runoff treated by a given combination of floodplain access depth and treatment volume.

An example using this method:

A floodplain does not begin to fill until the 10% runoff event occurs. The floodplain has the ability to treat volume from the runoff event associated with 25% of runoff events.

a. Add up all of the runoff above the 10% event.
b. Subtract the runoff associated with runoff happening before the 10% event since this portion does not access the floodplain. Additionally, the storage volume is only treating a fraction of the runoff events between the 10% and 25% events.
c. The full treatment volume is being utilized for runoff events 25% and above.
d. This results in approximately 38% of the runoff being treated.

Applying this method to an example using rainfall from Regan National Airport and estimated runoff using a CN of 80, yields an average annual runoff of approximately 3.4 inches with an average annual rainfall of approximately 37.5 inches. Access to the floodplain will occur at 0.001 inches of runoff (the 10% runoff event). The floodplain will provide 0.007 inches of treatment (the 25% runoff event). Over the period of record, the 38% of runoff would be treated. This equates to approximately 1.28 inches annually. This results in 9.6%, 19.1%, and 9.6% of the TN, TP, and TSS being reduced, respectively.

Another example:

Floodplain access at the 50% runoff event. Curve number of 70. Average annual runoff is approximately 1.14 inches with an annual average rainfall of 37.5 inches. The floodplain provides a treatment volume associated with the 15% runoff event. This scenario provides 0.13 inches of treatment annually (~11%). This results in 2.8%, 5.5%, and 2.8% of the TN, TP, and TSS being reduced, respectively.