Developing Estimates of MS4 Load Reductions

TMDL development in the NY/NJ Harbor may involve the control of nutrients from diffuse sources such as urban stormwater runoff. The management of stormwater relies heavily on Best Management Practices (BMPs). The implementation of BMPs for the control of stormwater-associated pollutants is part of promulgated Phase II stormwater regulations. Phase II stormwater regulations pertain specifically to Municipal Separate Stormwater Sewer Systems (MS4s). MS4s are regulated through the National Pollution Discharge Elimination System (NPDES). NPDES permits for MS4s require Stormwater Pollution Prevention Plans (SWPPPs) incorporating BMPs to achieve six minimum control measures.

In general, BMP research is still a relatively young field and the number of studies is limited. As the number of studies increases, so will the confidence with which BMP performance can be reported. HydroQual has consulted existing literature reviews that examine the range of nitrogen and carbon runoff reductions associated with implementation of various programs and practices (e.g., the *National Pollutant Removal Performance Database* developed by the Center for Watershed Protection (Sept 2007) and O'Shea, M. L., Borst, M., and C. Nietch, The Role of Stormwater BMPs in Mitigating the Effects of Nutrient Overenrichment in the Urban Watershed. In: Proceedings of the 9th Triennial International Conference on Urban Storm Drainage, September 8-13th, 2002, Portland, OR, etc.).

Based on an analysis of the existing literature reviews and expert opinions, HydroQual is pleased to present the below technical memorandum recommending: 1) the level of nitrogen and carbon reduction expected from the current MS4 requirements that should be incorporated into the modeling analysis and 2) the plausible upper and lower limits of reduction for carbon and nitrogen for targeted BMPs that could occur in the future.

In summary the levels of reductions that we are suggesting include:

- HydroQual's recommendations for the plausible upper and lower limits of reduction for carbon for targeted BMPs that could occur in the future are 20% and 40%.
- HydroQual's recommendations for the plausible upper and lower limits of reduction for nitrogen for targeted BMPs that could occur in the future are 24% and 56%.
- HydroQual's recommendation for the level of nitrogen and carbon reduction expected from the current MS4 requirements that should be incorporated into the modeling analysis is 0%.

The technical basis for the recommended reductions is described more fully below.

Literature Review

As identified in O'Shea et al. 2002, there are two currently available stormwater BMP databases: the International Stormwater BMP database (ASCE 2001) and the Center for Watershed Protection's (CWP) National Pollutant Removal Performance Database for Stormwater Treatment Practices (Winer 2000). Both of these databases have been continually upgraded and updated since being identified by O'Shea et al., in 2002. Further, there are repetition and overlap between these databases. Each of the databases is described more fully below. Some general problems with both databases include:

- Reported removals are widely variable and considerable effort was expended by HydroQual in attempting to "tease out" appropriate ranges for NY/NJ Harbor.
- The variability of the data across forms of nitrogen dictated a separate consideration of each nitrogen species.
- Available documents summarizing the databases often omitted an analysis for carbon removal efficiencies.

International Stormwater BMP Database (ASCE 2001)

The National Stormwater BMP database is a joint effort between the American Society of Civil Engineers (ASCE) and USEPA and a number of other government agencies and professional societies. At the time of the O'Shea et al. 2002 review, the BMP database included detailed site, watershed, and removal data on approximately 135 BMPs nationally. This database is for the most part event mean and mean concentration based, rather than total mass loading based. In other words, changes between inflow and outflow of BMP's are reported as changes in event mean and mean concentrations rather than as changes in mass loadings. The National Stormwater BMP Database is currently under revision and is now the International Stormwater BMP Database. The contractors performing the revision are Wright Water Engineers, Inc., and Geosyntec Consultants. Based upon personal communications with the contractors, the fully updated database and online query functions, Version 5, will soon be fully available at

www.bmpdatabase.org. HydroQual downloaded the database as available in December 2007. Data are presented based on a statistical analysis showing median and quartile removal values for groupings of types of stormwater BMPs. Findings are described below following a discussion of another readily available database.

Center for Watershed Protection's (CWP) National Pollutant Removal Performance Database for Stormwater Treatment Practices (Winer 2000)

The CWP Performance Database summarized findings from 153 studies at the time of the O'Shea et al.2002 review. The publicly available Version 2 of this database (March 2000) includes 139 studies. Version 3 of the Database was last updated in September 2007. 27 studies published through 2006 were added to the database. Access is through www.cwp.org and www.stormwatercenter.net. The Version 3 data are presented based on a statistical analysis showing median and quartile removal values for groupings of types of stormwater BMPs. In this database, mass or load-based removal efficiencies are emphasized rather than concentration-based measurements when both types of measurements are available. HydroQual reviewed summaries of each of the 139 studies in Version 2 and attempted to review a large number of the 27 studies added for Version 3. Our findings are described in greater detail below.

Database Findings and Application to NY/NJ Harbor

Findings from searches of both databases are summarized below by nutrient.

Organic Carbon (TOC, BOD_5, COD)

For expected carbon removals for stormwater, we considered database information reported for organic carbon, BOD_5, and COD. The *National Pollutant Removal Performance Database, Version 3 September, 2007* by the Center for Watershed Protection does not report summary statistical analyses for BMP removals of either BOD_5, COD, or organic carbon from stormwater. HydroQual therefore had to examine the 166 BMP performance studies incorporated in the database individually. Fortunately, within the database, HydroQual identified 44 BMP studies that reported removal efficiencies for one or both of BOD_5 and TOC. This number is higher when COD is also included, about 56% of the studies. In version 2 of the database, almost all of the studies reporting carbon removals were conducted prior to 1996. Newer results examined were comparable. HydroQual took advantage of an excellent summary document (Center for Watershed Protection 1996) that summarized stormwater carbon removal performance.

According to the Center for Watershed Protection, "the ability of urban stormwater management practices to remove organic carbon or oxygen demanding material, while quite variable, was generally fairly modest, with median removal rates on the order of 20 to 40%. A noticeable

exception was water quality swales, which exhibited median removal rates in excess of 65%. It should be noted that some variability in carbon removal rates could be due to lumping of total organic carbon, BOD, and COD together." More specific information presented by the Center (see Table 3.6 of Winer 2000 and Table 3 of Center for Watershed Protection 1996) shows median removals for stormwater carbon for selected practice groups as 43% for wet ponds, 25% for dry ponds, 18% for wetlands, 54% for filtering practices, 88% for infiltration, 69% for swales, and 18% for ditches.

Unfortunately, the summary literature for the International Stormwater BMP Database (see GeoSyntec 2006) did not include a summary for organic carbon removal efficiencies. With the BMP database website still under development, HydroQual had to develop its own queries of the database. Many of the studies in this database overlapped with those from the Center for Watershed Protection database so we did not view this effort necessarily as generating new information, but rather as an additional check. For the sake of carbon removal efficiencies, we relied more heavily on the published Center for Watershed Protection results which are based on mass removal.

With the International Stormwater BMP Database, HydroQual performed queries with Microsoft Access specifically for carbon. 174 records were identified collectively for several parameters (i.e., BOD_5, TOC, COD) representing carbon. The 174 records included many different types of structural BMPs (i.e., detention basins, biofilters, hydrodynamic devices, media filters, retention ponds, wetland basins, wetland channels, etc.). There were instances of negative median removals for carbon within these records; however, collectively when median carbon removals were positive (i.e., 95 records) the medians averaged 38%, supporting the 20% to 40% identified by the Center for Watershed Protection.

Accordingly, HydroQual's recommendations for the plausible upper and lower limits of reduction for carbon for targeted BMPs that could occur in the future are 20% and 40%. Further, HydroQual's recommendation for the level of carbon reduction expected from the current MS4 requirements that should be incorporated into the modeling analysis is 0% based on the fact that only a handful of carbon removal efficiency measurements in either the Center for Watershed Protection National Pollutant Removal Performance Database for Stormwater Treatment Practices or the International Stormwater BMP Database are reported for projects in New York, New Jersey, and Connecticut. Further, the limited projects in the three States are not proximal to the NY/NJ Harbor and were conducted prior to 1995 when the SWEM field program was conducted and are structural in nature and therefore are not reflective of the incidental benefits of simply having MS4 requirements in place. These projects include: the Vortechs TM Stormwater

Treatment System in the Marine Village Watershed in Lake George, New York (BOD_5, only 2 events, dates not specified); a stormwater wet pond in Buckland, Connecticut (TOC, 7 events, 1989); and a stormwater wet pond in Unqua, New York (TOC, 8 events, 1983).

Nitrogen

The September 2007 National Pollutant Removal Performance Database Version 3 provides summary statistical information for measured load-based BMP removal efficiencies for total nitrogen, and nitrate plus nitrite nitrogen. These summary results are shown in Table 1. As shown in Table 1, broadly, with a great deal of variability and uncertainty, BMP's generally achieve 24% to 56% removal of total nitrogen from stormwater and -14% to 67% removal of nitrate and nitrite nitrogen from stormwater.

Table 1.
Summary of Measured Load-Based BMP Removal Efficiencies for Nitrogen
Center for Watershed Protection, September 2007

BMP	TOTAL NITROGEN 25^{TH} & 75^{TH} PERCENTILE AND MEDIAN REMOVAL EFFICIENCY	NITRATE + NITRITE 25^{TH} & 75^{TH} PERCENTILE AND MEDIAN REMOVAL EFFICIENCY
Dry pond (7 studies)	5 & 31 %; 24%	-2 & 36 %; 9%
Wet pond (22 - 29 studies)	16 & 41 %; 31%	24 & 67 %; 45%
Wetlands (24 - 33 studies)	0 & 55 %; 24%	22 & 80 %; 67%
Filtering (9 - 14 studies)	30 & 47 %; 32%	-70 & 21%; -14%
Biorention (8 - 9 studies)	40 & 55 %; 46%	16 & 67%; 43%
Infiltration (5 - 7 studies)	2 & 65 %; 42%	-100 & 82 %; 0%
Open channels (9 -16 studies)	40 & 76 %; 56%	14 & 65 %; 39%

The Center for Watershed Protection (Winer 2000) offers that differences in total nitrogen and nitrate plus nitrite nitrogen removals relate to nitrate and nitrite nitrogen being soluble. The solubility of nitrate and nitrite nitrogen also explains the large differences (i.e., -14% to 67%) in median removals across BMP methods. The Center (1996b) also suggests the concept of an "irreducible concentration" for nitrogen in stormwater. The existence of an irreducible concentration for nitrogen suggests that there are practical limits to improving treatment efficiency with additional stormwater practices after a certain point.

The Analysis of Treatment System Performance for the International Stormwater BMP Database for 1999-2005, prepared by GeoSyntec Consultants in 2006, provides summary statistics for total nitrogen, total Kjeldahl nitrogen (i.e., organic nitrogen and ammonia nitrogen), nitrate nitrogen, and nitrate plus nitrite nitrogen. The statistics include 95% confidence intervals and medians for average effluent and effluent event mean concentrations. For both average effluents and event mean concentrations, it is noted whether or not there is a significant difference between effluent and influent concentrations. These findings are summarized in Table 2.

Table 2
Summary of Statistically Significant Differences (Yes/No)
Between BMP Influents and Effluents for Nitrogen
International Stormwater BMP Database 1999-2005
GeoSyntec Consultants & Wright Water Engineers, Inc., February 2006

BMP	TOTAL NITROGEN	KJELDAHL NITROGEN	NITRATE NITROGEN	NITRATE + NITRITE NITROGEN
Detention Basin	No	No	No	No
Biofilter	No	No	No	No
Hydrodynamic Device	No	No	No	No
Media Filter	No	No	No	No
Retention Pond	No	Depends on average or EMC	Depends on average or EMC	Depends on average or EMC
Wetland Basin	No	Depends on average or EMC	Depends on average or EMC	Depends on average or EMC
Wetland Channel	Depends on average or EMC	No	No	Not Reported

The wide range of load-based removal efficiencies developed by the Center for Watershed Protection (Table 1) and the lack of statistically significance differences between nitrogen BMP influents and effluents calculated by GeoSyntec Consultants (Table 2) are both indicative that we can't estimate reliably expected removals for nitrogen or forms of nitrogen from stormwater either now as a result of MS4 actions since 1995 or in the future as a result of targeted BMP initiatives. On this basis, HydroQual does not recommend introducing nonpoint source loading

reductions for nitrogen based on BMPs into SWEM TMDL simulations for the NY/NJ Harbor, particularly for current MS4 commitments. For purposes of bounding future removals, the GeoSyntec calculations suggest that retention ponds and wetland basins might be the most promising for removing nitrogen from stormwater. The Center for Watershed Protection results suggest that bioretention and open channels are promising nitrogen removers.

Regarding the most local results (i.e., NY, NJ, and CT), the Center for Watershed Protection database includes a wet pond in Buckland, Connecticut (1989; 7 storms; 24% total Kjeldahl nitrogen mass removal and 22% nitrate plus nitrite mass removal). The International BMP Database includes two local projects: Marine Village Watershed Lake George, New York Vortechs TM System (9 samples, negative total nitrogen concentration removal, influent and effluent median concentrations not statistically different) and Timothy Edwards Middle School South Windsor, Connecticut Vortechs 5000 System (53 samples, 60% nitrate concentration removal, influent and effluent median concentrations statistically different, 57% ammonia median concentration removal, influent and effluent median concentrations statistically different, 10% median total Kjeldahl nitrogen concentration removal, influent and effluent median concentrations not statistically different).

HydroQual's recommendation based on the available data, with caveats as discussed above, for the plausible upper and lower limits of reduction for nitrogen for targeted BMPs that could occur in the future are 24% and 56%. Further, HydroQual's recommendation for the the level of nitrogen reduction expected from the current MS4 requirements that should be incorporated into the modeling analysis is 0%, based on the highly structural/deliberate nature of the BMPs for which removal efficiency data are available and the uncertainties in the reported removals.

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