Appendix C

E. coli Bacteria Allocations and Daily Loads for the Potomac River and Tributaries

February 2013

Contents

Introduction

The purpose of this document is to revise the original 2004 *Final Total Maximum Daily Load for Fecal Coliform Bacteria in Upper Potomac River, Middle Potomac River, Lower Potomac River, Battery Kemble Creek, Foundry Branch, and Dalecarlia Tributary* (DDOH 2004). The revision incorporates a new water quality standard (WQS) for *Escherichia coli* (*E. coli)* that the District of Columbia (District) promulgated in October 2005 after the approval of the original total maximum daily loads (TMDLs). The allocations specified in the original TMDL are still in effect; this revision provides a translation of those loads to *E. coli*, the parameter on which the existing standard is based. The translation was performed using a translator equation developed from analysis of paired fecal coliform/*E. coli* sampling data collected from waters in the District.

In addition, daily loading expressions for the new *E. coli* allocations are provided. This has been done to comply with the U.S. Environmental Protection Agency (EPA) obligations under the 2006 court case, *Friends of the Earth vs. the Environmental Protection Agency, 446 F.3d 140, 144* (D.C. Cir. 2006) which requires establishment of a daily loading expression in TMDLs in addition to any annual or seasonal loading expressions previously established in the TMDL.

Anacostia Riverkeepers, Friends of the Earth, and Potomac Riverkeepers filed a complaint (Case No.: 1:09-cv-00098-JDB) on January 15, 2009, because certain District TMDLs did not have a daily load expression established. EPA settled the complaint by agreeing to an established schedule that both the court and the plaintiffs to the case approved. The settlement agreement requires establishment of daily loads in the District. Bacteria TMDLs referenced in Paragraphs 24a, 24c, 24g, 24i, 24j, and 24l of the plaintiffs' complaint by December 2014. This TMDL revision satisfies that requirement for the 2004 *Final Total Maximum Daily Load for Fecal Coliform Bacteria in Upper Potomac River, Middle Potomac River, Lower Potomac River, Battery Kemble Creek, Foundry Branch, and Dalecarlia Tributary* (Paragraph 24i of complaint).

Applicable Water Quality Standards

The Potomac River and the tributaries were listed on the District's 1996 303(d) lists because of excessive counts of fecal coliform bacteria that exceeded the District's WQS. The District WQS, Title 21 of the District of Columbia Municipal Regulations (DCMR) Chapter 11, 49 D.C. Reg. 3012 and D.C. Reg. 4854, specifies the categories of beneficial uses as

1. Class A. primary contact recreation
2. Class B. secondary contact recreation
3. Class C. protection and propagation of fish, shellfish, and wildlife
4. Class D. protection of human health related to consumption of fish and shellfish
5. Class E. navigation

WQS are derived from EPA recommendations on the basis of risk levels associated with swimming. Under the WQS that were in place at the time of the original TMDL, Class A and Class B waters were required to achieve or exceed the WQS for bacteria as measured by fecal coliform as the indicator organism. Fecal coliforms are microbes that live in the intestinal tracts of warm-blooded animals, whose presence indicates the potential for pathogens in the water.

When the original 2004 fecal coliform bacteria TMDL was developed for the Potomac River and its tributaries, the standard for Class A waters was a maximum 30-day geometric mean of 200

MPN, where *MPN* is a statistically derived estimate of the Most Probable Number of bacteria colonies in a 100 milliliter sample. This statistical estimate is often called a *count*, although it is represented as a concentration. The geometric mean is based on a minimum of five samples within the 30-day period. The standard for Class B waters was a 30-day geometric mean of 1,000 MPN. However because all the waterbodies were designated as Class A waters, which were subject to the more restrictive bacteria standard, the 200 MPN for Class A designation was used as the not-to-exceed criterion for all the waterbodies in the original 2004 TMDL.

Effective January 1, 2008, the District bacteriological WQS changed from fecal coliform to *E. coli*. The current Class A water standards are a geometric mean of 126 MPN and 410 MPN for a single sample value. The geometric mean is based on a minimum of five samples within the 30-day period and is used in both water quality trend assessments and permits. The single sample value is valid for use only in assessing water quality trends. Class B and Class C waters do not have an *E. coli* standard. Currently, all waters subject to this TMDL including the Potomac mainstem and all tributaries, are designated as Class A waters (DCMR, WQS, 21-1101.2), see Table 1.

Table 1. Classification of the District's waters

Surface waters of the District	Use classes	
	Current use	**Designated use**
Potomac River	B, C, D, E	A, B, C, D, E
Potomac River tributaries (except as listed below)	B, C, D	A, B, C, D
Battery Kemble Creek	B, C, D	A, B, C, D
C&O Canal	B, C, D, E	A, B, C, D, E
Rock Creek	B, C, D, E	A, B, C, D, E
Rock Creek tributaries	B, C, D, E	A, B, C, D, E
Tidal Basin	B, C, D, E	A, B, C, D, E
Washington Ship Channel	B, C, D, E	A, B, C, D, E
Oxon Run	B, C, D	A, B, C, D
Anacostia River	B, C, D, E	A, B, C, D, E
Anacostia River tributaries (except as listed below)	B, C, D	A, B, C, D
Hickey Run	B, C, D	A, B, C, D
Watts Branch	B, C, D	A, B, C, D
Wetlands	C, D	C, D

Source: DCMR 1101.2

The waterbodies addressed by this revision are the same waterbodies that received allocations under the original TMDL, the Upper, Middle, and Lower Potomac River mainstem and the Potomac River tributaries of Battery Kemble Creek, Foundry Branch, and Dalecarlia Tributary.

Translation of Fecal Coliform Values to *E. Coli*

A *translator* is a mathematical equation that allows one parameter to be translated into another consistently and in a scientifically defensible manner. To support the TMDL revision, EPA and the District of Columbia Department of the Environment developed a District-specific translator using the statistical relationship between paired fecal coliform and *E. coli* data collected in the District's waters (LimnoTech 2011 and 2012).[1] The data used to develop the DC translator was composed of paired fecal coliform and *E. coli* instream monitoring measurements for DC and adjacent waters collected by three agencies: DDOE, the Virginia Department of Environmental Quality (VDEQ), and the Maryland Department of the Environment (MDE). The dataset includes ambient instream water quality monitoring data as well as end-of-pipe data collected by DC Water at separate storm water system (SSWS) outfalls. CSO data were excluded from the dataset and were not used in the development of the translator. *E.coli* allocations for CSO's were not calculated using the translator (See Section CSO section below). The translator is representative of ambient and stormwater bacteria concentrations and was used to convert the original fecal coliform TMDL allocations into *E. coli* values. The District-specific translator equation is shown in Equation 1 below.

$$\text{Log2}(E.\ coli) = 0.9377[\text{Log2}(\text{fecal coliform})] - 0.4614 \qquad [1]$$

Use of the translator allowed for converting original fecal coliform annual load allocations to the current WQS for *E. coli*, while still relying on the original modeling and analysis.

Compliance with Revised WQS

Using the District-specific translator, a fecal coliform value of 200 MPN (the original District standard for bacteria) is associated with an *E. coli* value of approximately 104 MPN, which is below the 126 MPN *E. coli* criteria.

It is important to consider that under the original modeling analysis, reductions to sources of fecal bacteria were made until the waterbodies met the fecal coliform geometric mean standard of 200 MPN at all times. Therefore, under the original modeling analysis, fecal coliform loads translated to *E. coli* loads will result in loads that are more protective than WQS. The *E. coli* reductions in this TMDL meet approximately a geometric mean of 104 MPN, while the current bacteria standard is 126 MPN.

Translation Methodology

This TMDL revision translates the existing annual fecal coliform loads into equivalent annual *E. coli* loads. The original March 2004 TMDL provides loads for the MPN of colonies of fecal coliform calculated for various sources. Sources specified include: upstream sources (representing the in-stream and watershed loads delivered at the District's boundaries); direct runoff or lateral flows (LAT), separate storm sewers (SW), combined sewer overflows (CSOs),

[1] Documentation related to development of the translator is in LimnoTech's 2011 Memorandum, *Final Memo Summarizing DC Bacteria Data and Recommending a DC Bacteria Translator (Task 2)* and Limno Tech's 2012 Memorandum, *Update on Development of DC Bacteria Translators*.

the Blue Plains Wastewater Treatment Plant (WWTP); Rock Creek, the Anacostia River, and small tributary loads (Battery Kemble Creek, Dalecarlia Tributary, Foundry Branch). Available model files also provide daily existing condition fecal coliform concentrations and flows for all mainstem sources except for the CSOs.

Information from the original TMDL and input files to the Potomac model (Dynamic Estuary [Potomac] Model [DEM][2]) were used to develop the revised *E. coli* allocations. The methodologies used to calculate the revised *E. coli* allocation for each source are more fully described below. For calculations and information supporting the translations, please see Appendix D.

Potomac Mainstem

CSO

The *E. coli* loads for CSO's were not calculated using the equation 1 translator but were developed using the Long Term Control Plan (LTCP) based event meant concentration (EMC) for *E. coli*, which was established from data gathered during the development of DC Water and Sewer Authority 's Combined Sewer System Long Term Control Plan (DC WASA 2002). The LTCP-based EMC for *E. coli* (686,429 MPN / 100 mL) and the predicted flow volume under full implementation of the LTCP were used to calculate the revised CSO *E. coli* allocation as follows.

1. Obtained the predicted flow volumes from the Potomac CSOs for 1988-1990 under the LTCP implementation scenario.
2. Multiplied the flow volumes by the LTCP-based *E. coli* EMC value of 686,429 MPN/ 100 mL to derive the daily CSO loads.
3. Calculated the average by summing the loads and dividing by three to derive the annual CSO allocation for the modeled three year period.

Upstream, Direct Stormwater Runoff, Tributary Stormwater, Rock Creek and Anacostia Sources

Equation 1 was applied to fecal coliform concentrations to develop the revised E. coli allocation for the upstream, direct stormwater runoff (LAT), tributary storm runoff (SW), Rock Creek, and Anacostia River sources as follows.

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[2] The Potomac River was simulated using the EPA's Dynamic Estuary (Potomac) Model (DEM), a one-dimensional model that simulates both hydrodynamics and water quality explicitly (USEPA 1979). The DEM was developed by the Interstate Commission for the Potomac River Basin (ICPRB).

1. From available original model files, obtained the time series of the flow and fecal coliform loads for the existing condition. Calculated the fecal coliform concentrations using the load and flow (concentration = load / flow).
2. Multiplied each fecal coliform concentration value by the percent reduction required for that source in the original TMDL (see Table 2 **Error! Reference source not found.**) to derive the 'TMDL' condition daily fecal coliform concentrations[3].
3. Applied Equation 1 to the TMDL daily fecal coliform concentrations to derive the TMDL daily *E. coli* concentrations.
4. Multiplied the daily *E. coli* concentrations by the flow volumes to derive the *E. coli* TMDL daily load time series.
5. From the daily load time series, calculated the average annual *E. coli* TMDL load allocation by summing the daily loads and dividing the total by three to account for the three-year simulation period.

Table 2. Required percent reductions to Potomac Sources (original fecal coliform TMDL)

Source	% Reduction Required		
	Upper Potomac	Middle Potomac	Lower Potomac
Upstream	50.46	52.03	72.81
Separate Storm Water (SW)	50.48	50.51	50.48
Direct Storm Runoff (LAT)	50.50	50.50	50.47
Rock Creek	NA	67.15	NA
Anacostia River	NA	NA	74.45

Blue Plains Wastewater Treatment Plant

The revised Blue Plains WWTP allocation was calculated based on the existing *E. coli* WQS and the design flow of the WWTP. The assumption of this TMDL is that the WLA for Blue Plains WWTP is an aggregate for outfalls 001 and 002 and is based on discharging at criteria end of pipe.

1. The average daily waste load from Blue Plains was calculated by multiplying the permitted design flow of 370 MGD by the permitted *E. coli* limit of 126 MPN / 100 mL.
2. The average annual WLA for Blue Plains was calculated by multiplying the average daily load by the 365.

Potomac Tributaries

Equation 1 was directly applied to original fecal coliform load allocations to develop the revised *E. coli* allocation for the tributaries to the Potomac River including Battery Kemble Creek,

[3] The required percent reductions were calculated based on the original TMDL's listed existing loads and TMDL loads.

Dalecarlia Tributary, and Foundry Branch. Total allocations were translated and then distributed among the sources in the same proportion as they were allocated in the original TMDL.

Allocations

The original March 2004 TMDL used a series of computer simulations to determine the level of annual load reductions needed to meet WQS. The WQS were considered to be met if no model segment in the District had a fecal coliform maximum 30-day geometric mean exceeding the 200 MPN Class A standards. Exceedance is expressed in the number of months exceeding the geometric mean. However, this revised TMDL considers standards to be met when all portions of the waterbody do not exceed the *E. coli* maximum 30-day geometric mean of 126 MPN Class A standard. Because the bacteria translator provides a means to calculate an equivalent *E. coli* load, under a given scenario that meets the fecal coliform standard, the equivalent *E. coli* standard will also be met. The tables below present the TMDL expressed in equivalent *E. coli* annual loads.

Mainstem

The following *E. coli* wasteload allocations are made for the Potomac mainstem (Table 3).

Table 3. Potomac River average annual *E. coli* allocations (MPN)

Source	Upper Potomac	Middle Potomac	Lower Potomac
Upstream	7.09E+15	7.46E+15	9.58E+15
CSO	2.70E+13	1.78E+15	2.55E+14
Separate Storm Water	2.35E+14	1.24E+13	2.65E+14
Direct Storm Runoff	1.10E+14	1.37E+14	3.77E+14
Blue Plains WWTP	0.00E+00	0.00E+00	6.45E+14
Rock Creek	0.00E+00	1.87E+14	0.00E+00
Anacostia River	0.00E+00	0.00E+00	1.83E+15
1% MOS[a]	7.51E+11	3.40E+10	2.49E+11
Total	7.46E+15	9.58E+15	1.29E+16

a. The original TMDL applies the 1% MOS to all sources except CSOs. The CSO's have an implicit MOS.

Tributaries

The following *E. coli* wasteload allocations are made for the Potomac tributaries (Table 4). Total allocations were developed by translating the total fecal allocation into a total *E. coli* allocation. Then source allocations were assigned based on proportions used in the original TMDL.

Table 4. Potomac River tributaries *E. coli* annual wasteload allocations (MPN)

	Total load	Storm water	Direct runoff	MOS
Battery Kemble Creek	1.17E+11	7.04E+10	2.50E+09	4.37E+10
Foundry Branch	1.12E+11	6.85E+10	5.82E+09	3.71E+10
Dalecarlia Tributary – DC	5.61E+11	4.01E+11	0.00E+00	1.60E+11
Dalecarlia Tributary – MD	1.96E+10	1.39E+10		5.58E+09

Daily Loads Calculation Methodology

In November 2006, EPA issued the memorandum *Establishing TMDL Daily Loads in Light of the Decision by the U.S. Court of Appeals for the D.C. Circuit in Friends of the Earth, Inc. v. EPA et. al., No. 05-5015 (April 25, 2006) and Implications for NPDES permits*, which recommends that all TMDLs and associated load allocations and wasteload allocations include a daily time increment in conjunction with other appropriate temporal expressions that might be necessary to implement the relevant WQS. In compliance with that recommendation, this section presents corresponding daily load expressions for the long-term load allocations for the Potomac mainstem and tributaries described in Table 3 and Table 4, above. These daily loads were developed in a manner consistent with the following assumptions in EPA's *Draft Options for Expressions of Daily Loads in TMDLs* (Daily Loads Guidance) (USEPA 2007):

1. Methods and information used to develop the daily load should be consistent with the approach used to develop the loading analysis.
2. The analysis should avoid added analytical burden without providing added benefit.
3. The daily load expression should incorporate terms that address acceptable variability in loading under the long-term loading allocation. Because many TMDLs are developed for precipitation-driven parameters, one number will often not represent an adequate daily load value. Rather, a range of values might need to be presented to account for allowable differences in loading because of seasonal or flow-related conditions (e.g., daily maximum and daily median).
4. The methodologies are applicable to a wide variety of TMDL situations; however, the specific application (e.g., data used, values selected) should be based on knowledge and consideration of site-specific characteristics and priorities.
5. The TMDL analysis on which the daily load expression is based fully meets the EPA requirements for approval, is appropriate for the specific pollutant and waterbody type, and results in attainment of water quality criteria in a manner that is consistent with the underlying analysis that was used to develop the original TMDLs.

For mainstem sources (excluding the Blue Plains WWTP) representative average and maximum daily loads were derived on the basis of the modeled time series data derived from input files to the original model. For the tributaries, a statistical approach was applied to the annual *E. coli* allocations on the basis of recommendations in the Daily Loads Guidance. For the Blue Plains

WWTP, a statistical multiplier was applied to the average daily load on the basis of recommendations in EPA's *Technical Support Document for Water Quality-based Toxics Control* (TSD).

Daily Load Calculation Approach for Potomac Mainstem Sources

For the mainstem sources (excluding Blue Plains), daily load allocations were developed on the basis of the translated *E. coli* daily load time series for the simulation period (1988-1990). From these time series, EPA identified the average and maximum daily load values for each source. The specific steps are summarized below:

1. Used the TMDL scenario *E. coli* daily load time series for sources (CSO, lateral flows, direct drain, upstream) to the Potomac mainstem model (Dynamic Estuary [Potomac] Model [DEM][4]).

2. Analyzed the time series for each source to identify the maximum *E. coli* daily load over the 3 year period of simulation.

3. Next, from the same time series, calculated the *E. coli* average daily load (for non-zero loading days) over the 3 year period of simulation for each source category. Average daily loads were calculated by summing all the simulated daily loads for each source and dividing the sum by the number of data points.

Daily Load Calculation Approach for Potomac River Tributaries

EPA's draft guidance document, *Options for Expressing Daily Loads in TMDLs* (USEPA 2007), recommends a statistical approach as another appropriate way to develop daily maximum load values, specifically when long periods of continuous simulation data are not available. EPA's TSD (USEPA 1991) describes a statistical approach to identifying a maximum daily load in such circumstances. The statistical daily load expression incorporates acceptable variability in loading under the long-term loading allocation.

Equation 2 below relates the maximum daily load (MDL) to the long-term average (LTA) as

$$MDL = LTA \cdot \exp\left(Z_p \sigma_y - 0.5\sigma_y^2\right) \qquad [2]$$

where

Z_p = *p*th percentage point of the standard normal distribution, as above
CV = coefficient of variation of the untransformed data
$\sigma_y = \sqrt{\ln\left(CV^2 + 1\right)}$.

Table 5-2 of the TSD provides pre-calculated multipliers for the LTA depending on coefficient of variation and the Z-statistic used. The 99th percentile was used, and the default coefficient of variation of 0.6 was assumed according to recommendations in the TSD.

For the Potomac tributary loads, the calculation steps are summarized below:

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[4] The Potomac River was simulated using the EPA's Dynamic Estuary (Potomac) Model (DEM), a one-dimensional model that simulates both hydrodynamics and water quality explicitly (USEPA 1979). The DEM was developed by the Interstate Commission for the Potomac River Basin (ICPRB).

1. Divided the annual *E. coli* load allocation for each tributary in Table 4 by 365 (average daily load) to calculate the LTA.

2. Multiplied the LTA by 3.11 (the 99th percentile Z-statistic from Table 5-2 in the TSD) to derive the corresponding MDL.

Daily Load Calculation Approach for Blue Plains WWTP

Daily load values for the Blue Plains WWTP were developed using the statistical approach outlined above but used a CV value calculated from facility discharge data rather than an assumed CV value.

1. From available model files, obtained the flow time series for the Blue Plains WWTP over the simulation period 1988–1990. Flows included CSO/stormwater and treatment facility flows.

2. Calculated the coefficient of variation (CV) for the time series of total flows from the facility for the period 1988-1990 and identified the corresponding 99^{th} percentile z statistic (CV = .138 and z statistic = 1.25).[5]

3. Calculated the maximum daily load by multiplying the average daily load (370 MGD x 126 #/ 100 mL) by a factor of 1.25 (the 99th percentile Z-statistic from Table 5-2 in the TSD) (USEPA 1991).

E. coli Daily Loads

Table 5 presents the *E. coli* daily loads for the mainstem Potomac by source. Table 6 presents the *E. coli* daily loads for the tributaries.

[5] CV was based on facility total flows and not discharge concentrations because it is assumed the TMDL discharge concentration is a constant 126 / 100 mL. Therefore, the variation is associated with the flows from the facility.

Table 5. Mainstem daily loads (*E. coli*) (MPN)

Source	Allocation	Upper	Middle	Lower
Upstream	Max daily	2.69E+14	2.70E+14	2.40E+15
	Avg daily	1.94E+13	2.04E+13	2.62E+13
CSO	Max daily	7.16E+13	1.99E+15	4.11E+14
	Avg daily	2.70E+13	4.11E+14	1.27E+14
Tributary Storm Runoff (SW)	Max daily	2.98E+13	1.38E+12	1.44E+13
	Avg daily	6.97E+11	6.48E+10	7.92E+11
Direct Storm Runoff (Lateral)	Max daily	3.95E+12	7.34E+12	1.43E+13
	Avg daily	3.08E+11	1.14E+12	1.06E+12
Blue Plains WWTP	Max daily	0	0	2.21E+12
	Avg daily	0	0	1.77E+12
Rock Creek	Max daily	0	1.67E+14	0
	Avg daily	0	5.11E+11	0
Anacostia River	Max daily	0	0	1.68E+15
	Avg daily	0	0	5.00E+12

Table 6. Tributaries daily loads (*E. coli*)

Source/tributary	Allocation	MPN
Battery Kemble Creek	Max daily	9.93E+08
	Avg daily	3.19E+08
Foundry Branch	Max daily	9.50E+08
	Avg daily	3.06E+08
Dalecarlia Tributary	Max daily	4.95E+09
	Avg daily	1.59E+09

Other Sources

The March 2004 TMDL provides zero allocations of fecal coliform to boats, ships, houseboats, and floating residences. This TMDL revision also provides a zero allocation to these sources as part of the *E. coli* allocations.

Assurance of Implementation—Daily Loads

The approach used to calculate daily loads in this TMDL identifies a representative maximum daily or average daily load for the annual TMDL for each source identified in the original report. The approach does not presume that the MDL provided could be discharged every day and still meet the in-stream WQS. While expressions of daily loading values are useful in illustrating the variability in loading that can occur under a TMDL scenario, the annual average load must also be met to comply with the TMDL.

Note that federal regulations at Title 40 of the *Code of Federal Regulations* section 122.44(d)(1)(vii)(B) require that, for a National Pollutant Discharge Elimination System permit for an individual point source, the effluent limitations must be consistent with the assumptions and requirements of any available wasteload allocation for the discharge prepared by the jurisdiction and approved by EPA. There is no express or implied statutory requirement that effluent limitations in NPDES permits necessarily be expressed in daily terms. The Clean Water Act definition of *effluent limitation* is quite broad (effluent limitation is "any restriction on quantities, rates, and concentrations of chemical, physical, biological, and other constituents which are discharged from point sources …"), see Clean Water Act section 502(11). Unlike the Clean Water Act's definition of TMDL, the Clean Water Act definition of *effluent limitation* does not contain a *daily* temporal restriction. National Pollutant Discharge Elimination System permit regulations do not require that effluent limits in permits be expressed as maximum daily limits or even as numeric limitations in all circumstances, and such discretion exists regardless of the time increment chosen to express the TMDL. For further guidance, see Benjamin H. Grumbles' memo of November 15, 2006, titled *Establishing TMDL Daily Loads in Light of the Decision by the U.S. Court of Appeals for the D.C. Circuit in Friends of the Earth, Inc. v. EPA, et al., No. 05-5015 (April 25, 2006) and implications for NPDES Permits.*

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