A Total Maximum Daily Load Analysis for the Quinnipiac River Regional Basin

FINAL – June 4, 2008

This document has been established pursuant
to the requirements of Section 303(d)
of the Federal Clean Water Act

_____ _____

Amey Marrella, Deputy Commissioner
Air, Waste & Water Programs — Date

_____ _____

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TABLE OF CONTENTS

TABLES

FIGURES

APPENDICES

INTRODUCTION

A Total Maximum Daily Load (TMDL) analysis was completed for indicator bacteria in the Quinnipiac River Regional Basin. The waterbodies included in the TMDL analysis are the Harbor Brook, Misery Brook, Quinnipiac River, and Sodom Brook (Figure 1). These waterbodies are included on the *2006 List of Connecticut Waterbodies Not Meeting Water Quality Standards*[1] (*2006 List*) due to exceedences of the indicator bacteria criteria contained within the State *Water Quality Standards* (WQS) [2]. Segment CT5200-00_05 in the Quinnipiac River is not included on the 2006 *List*, however is included in the TMDL analysis because available data indicates exceedences of indicator bacteria criteria. Under section 303(d) of the Federal Clean Water Act (CWA), States are required to develop TMDLs for waters impaired by pollutants that are included on the *2006 List* for which technology-based controls are insufficient to achieve water quality standards. Please refer to the *2006 List* for more information on impaired waterbodies throughout the State. The *2006 List* is included as Appendix C in the *2006 Integrated Water Quality Report to Congress*[3], which contains information regarding all assessed waterbodies in the State.

In general, the TMDL represents the maximum loading that a waterbody can receive without exceeding the water quality criteria, which have been adopted into the WQS for that parameter. In this TMDL, loadings are expressed as the average percent reduction from current loadings that must be achieved to meet water quality standards. The United States Environmental Protection Agency's (EPA) November 15, 2006 memorandum entitled *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*[4], recommends that TMDL submittals express allocations in terms of daily time increments. The percent reduction TMDLs for the Quinnipiac River Regional Basin are applicable each and every day until recreational use goals are attained. Federal regulations require that the TMDL analysis identify the portion of the total loading which is allocated to point source discharges (termed the Wasteload Allocation or WLA) and the portion attributed to nonpoint sources (termed the Load Allocation or LA), which contribute that pollutant to the waterbody. In addition, TMDLs must include a Margin of Safety (MOS) to account for uncertainty in establishing the relationship between pollutant loadings and water quality. Seasonal variability in the relationship between pollutant loadings and WQS attainment is also considered in this TMDL analysis.

The Quinnipiac River Regional Basin extends into the Connecticut municipalities of Farmington, Bristol, New Britain, Plainville, Southington, Berlin, Wolcott, Waterbury, Middletown, Meriden, Cheshire, Middlefield, Prospect, Wallingford, Durham, Hamden, New Haven, North Haven, East Haven and North Branford. Within these municipalities are designated urban areas, as defined by the US Census Bureau [5] (Figure 2). Such municipalities are required to comply with the General Permit for the Discharge of Stormwater from Small Municipal Separate Storm Sewer Systems (MS4 permit). The general permit is applicable to municipalities that contain designated urban areas (or MS4 communities) and discharge stormwater via a separate storm sewer system to surface waters of the State. The permit requires municipalities to develop a program aimed at reducing the discharge of pollutants, as well as to

protect water quality. The permit includes a provision requiring towns to focus their stormwater plans on waterbodies for which TMDLs have been developed. Such a program must include the following six control measures: public education and outreach; public participation; illicit discharge detection and elimination; construction stormwater management (greater than 1 acre); post-construction stormwater management; and pollution prevention and good housekeeping. Specific requirements have been developed within each of these control measures. Additional information regarding the general permit can be obtained on the Department of Environmental Protection (DEP) website at http://www.ct.gov/dep/cwp/view.asp?a=2721&q=325702& depNav_GID=1654.

TMDLs that have been established by states are submitted to the Regional Office of the Federal Environmental Protection Agency (EPA) for review. The EPA can either approve the TMDL or disapprove the TMDL and act in lieu of the State. TMDLs provide a scientific basis for local stakeholders to develop and implement Watershed Based Management Plans (WBMP), which describe the control measures necessary to achieve acceptable water quality conditions. Therefore, WBMPs derived from TMDLs typically include an implementation schedule and a description of ongoing monitoring activities to confirm that the TMDL will be effectively implemented and that WQS are achieved and maintained where technically and economically feasible. Public participation during development of the TMDL analysis and subsequent preparation of WBMPs is vital to the success of resolving water quality impairments.

TMDL analyses for indicator bacteria in the Quinnipiac River Regional Basin are provided herein. As required in a TMDL analysis, load allocations are determined, a margin of safety is included, and seasonal variation is considered. This document also includes recommendations for a water quality monitoring plan, as well as a discussion of guidance for TMDL Implementation.

PRIORITY RANKING

Table 1. The status of impairment for each of the subject waterbodies as well as the TMDL development priority based on the 2006 *List*.

Waterbody Name	Waterbody Segment ID	Waterbody Segment Description	303(d) Listed (Yes/No)	Impaired Use Cause	Priority*
Harbor Brook	CT5206-00_01 CT5206-00_02	From mouth at confluence with Quinnipiac River upstream to culvert entrance (upstream of Mill Street crossing), Meriden.	Yes	Recreation *Escherichia coli*	H
Misery Brook	CT5203-00_01	From mouth at Quinnipiac River (Cheshire/Southington border) upstream to Slopers Pond outlet dam, Southington.	Yes	Recreation *Escherichia coli*	H
Quinnipiac River	CT5200-00_1 CT5200-00_2 CT5200-00_3 CT5200-00_4 CT5200-00_5 CT5200-00_6 CT5200-00_7	From Clintonville Road crossing, North Haven upstream to headwaters at Dead Wood Swamp, Farmington.	Yes **	Recreation *Escherichia coli*	H
Sodom Brook	CT5205-00_01	From mouth at confluence with Quinnipiac River upstream to headwaters, Meriden.	Yes	Recreation *Escherichia coli*	H

* "H" indicates that the waterbody is a high priority because assessment information suggested a TMDL may be needed to restore the water quality impairment and a TMDL was planned for development within 3 years.

** Segment CT5200-00_05 in the Quinnipiac River is not included on the 2006 *List*, however is included in the TMDL analysis because data available since the development of the *2006 List* indicates exceedences of indicator bacteria criteria.

DESCRIPTION OF THE WATERBODY

See "Site Specific Information" in Appendix A.

POLLUTANT OF CONCERN AND POLLUTANT SOURCES

Potential sources of indicator bacteria include point and nonpoint sources, such as stormwater runoff and illicit discharges/hook ups to storm sewers. Potential sources that are tentatively identified based on land-use (Figure 3) for each of the waterbodies are presented in Table 2.

Table 2. Potential sources of bacteria for each of the subject waterbodies.

Waterbody Name	Nonpoint sources	Point Sources
Harbor Brook	Stormwater runoff, Source Unknown	Regulated stormwater runoff, Illicit connections/Hook ups to storm sewers, Sanitary collection system failures
Misery Brook	Stormwater runoff, Source Unknown	Regulated stormwater runoff
Quinnipiac River	Stormwater runoff, Source Unknown	Regulated stormwater runoff, Illicit connections/Hook ups to storm sewers
Sodom Brook	Stormwater runoff, Source Unknown	Regulated stormwater runoff

Four municipal wastewater treatment plants (Cheshire WPCF, Meriden WPCF, Southington WPCF, and Wallingford WPCF) and one industry (Cytec Industries Inc.) that discharge to the Quinnipiac River receive indicator bacteria limits in their National Pollutant Discharge Elimination (NPDES) Permits. Disinfection required under the NPDES Permit is sufficient to reduce indicator bacteria densities to below levels of concern in the effluent when in use and functioning properly (See Numeric Water Quality Target for further explanation).

APPLICABLE SURFACE WATER QUALITY STANDARDS

Connecticut's WQS establish criteria for bacterial indicators of sanitary water quality that are based on protecting recreational uses such as swimming (both designated and non-designated swimming areas), kayaking, wading, water skiing, fishing, boating, aesthetic enjoyment and others. Indicator bacteria criteria are used as general indicators of sanitary quality based on the results of EPA research[5] conducted in areas with known human fecal material contamination. The EPA established a statistical correlation between levels of indicator bacteria and human illness rates, and set forth guidance for States to establish numerical criteria for indicator bacteria organisms so that recreational use of the water can occur with minimal health risks. However, it should be noted that the correlation between indicator bacteria densities and human illness rates varies greatly between sites and the presence of indicator bacteria does not necessarily indicate that human fecal material is present since indicator bacteria occur in all warm-blooded animals.

The applicable water quality criteria for indicator bacteria to the Quinnipiac River Regional Basin are presented in Table 3. These criteria are applicable to all recreational uses established for these waters. However, it should be noted that the water quality classification and target criteria should not be considered as a certification of quality by the State or an approval to engage in certain activities such as swimming. Full body contact should be avoided immediately downstream of wastewater treatment plants, in areas known to have high levels *E.coli*, and during times when *E.coli* levels are expected to be particularly high, such as during and following storm events.

Table 3. Applicable indicator bacteria criteria for the subject waterbodies.

Waterbody	Waterbody Segment ID	Class	Bacterial Indicator	Criteria
Harbor Brook	CT5206-00_01 CT5206-00_02	B	*Escherichia coli* (*E. coli*)	Geometric Mean less than 126/100ml Single Sample Maximum 576/100ml
Misery Brook	CT5203-00_01	A		
Quinnipiac River	CT5200-00_1 CT5200-00_2 CT5200-00_3 CT5200-00_4 CT5200-00_5 CT5200-00_6 CT5200-00_7	C/B, A		
Sodom Brook	CT5205-00_01	B/A, A		

NUMERIC WATER QUALITY TARGET

TMDL calculations are performed consistent with the analytical procedures presented in the guidelines for *Development of TMDLs for Indicator Bacteria in Contact Recreation Areas Using the Cumulative Frequency Distribution Function Method* (Guidelines)[7] included as Appendix B. All data used in the analysis and the results of all calculations are presented in Appendix A. The results are summarized in Table 4 below.

Table 4. Summary of TMDL analysis.

Waterbody	Waterbody Segment Description	Segment ID	Monitoring Site	Average Percent Reduction to Meet Water Quality Standards			
				TMDL	WLA	LA	MOS
Harbor Brook	From mouth at confluence with Quinnipiac River upstream to exit of box culvert, Meriden.	CT5206-00_01	101	95	95	95	Implicit
		CT5206-00_02*					
Misery Brook	From mouth at Quinnipiac River upstream to Slopers Pond outlet dam, Southington.	CT5203-00_01	1417	65	74	59	Implicit
Quinnipiac River	From Rt. 5, North Haven upstream to headwaters at Dead Wood Swamp, Farmington.	CT5200-00_01	1421	68	73	64	Implicit
		CT5200-00_02	289	64	73	58	Implicit
		CT5200-00_03*	1422	84	88	80	Implicit
		CT5200-00_04					
		CT5200-00_05	294	75	80	71	Implicit
		CT5200-00_06	1423	82	85	80	Implicit
		CT5200-00_07	1424	78	83	75	Implicit
Sodom Brook	From mouth at confluence with Quinnipiac River upstream to headwaters, Meriden.	CT5205-00_01	1418	92	92	91	Implicit

*Current data is unavailable to conduct a TMDL analysis for segments CT5200-00_03 and CT5206-00_02 in the Quinnipiac River and Harbor Brook, respectively. However, these small segments (~1 ¼ and ¼ linear miles, respectively) and are located adjacent to segments that require percent reductions. Therefore, it is reasonable to presume that the same percent reduction applies to these segments.

The numeric target allocated to NPDES permitted discharges is "0% reduction" because disinfection reduces bacteria densities to below levels of concern as stated in the Guidelines[7]. The current NPDES permits for the four municipal wastewater treatment plants (WWTPs) and Cytec Industries Inc. requires disinfection from May 1 - September 30 (See Seasonal Analysis below). Under the NPDES Permits, indicator bacteria (fecal coliform) cannot exceed a geometric mean of 200 col/100mLs over a 30-day period or a single sample maximum of 400 col/100mLs. The indicator bacteria used in this TMDL is *E.coli*, which is one of several species that make up the fecal coliform group. Therefore, only a portion of fecal coliform densities account for *E.coli* in the sample and *E.coli* densities are always lower than total fecal coliform densities. Based on this information, NPDES Permit limits for the WWTPs and Cytec Industries Inc. are sufficient to reduce *E.coli* to below levels of concern and do not need to be reduced further as part of the waste load allocation. Also, WWTPs and industrial dischargers are required to sample effluent through the disinfection period and submit monitoring reports to DEP. DEP reviews the monitoring reports and takes action to mitigate any problems when there are consistent violations of the Permit. Based on monitoring reports submitted to DEP during the

past year, there were no consistent violations of the indicator bacteria permit limits for WWTPs or Cytec Industries Inc. in the Quinnipiac River Regional Basin.

MARGIN OF SAFETY

TMDL analyses are required to include a margin of safety (MOS) to account for uncertainties regarding the relationship between load and wasteload allocations, and water quality. The MOS may be either explicit or implicit in the analysis.

The analytical approach used to calculate the TMDLs incorporates an implicit MOS. Sampling results that indicate quality better than necessary to achieve consistency with the criteria are assigned a percent reduction of "zero" instead of a negative percent reduction. This creates an excess capacity that is averaged as a zero value thereby contributing to the implicit MOS. In addition, the indicator bacteria criteria used in this TMDL analysis were developed exclusively from data derived from studies conducted by EPA at high use designated public bathing areas with known human fecal contamination[6]. Therefore, the criteria provide an additional level of protection when applied to waters not used as designated swimming areas or contaminated by human fecal material. As a result, achieving the criteria results in an "implicit MOS". Additional explanation concerning the implicit MOS incorporated into the analysis is provided in the Guidelines[7] (Appendix B).

SEASONAL ANALYSIS

The TMDLs presented in this document are applicable during the typical disinfection (summer) season from May 1 to September 30. Previous investigations by the DEP into seasonal trends of indicator bacteria densities in surface waters indicates that the summer months typically exhibit the highest densities of any season (*Water Quality* Summary)[9]. This phenomenon is likely due to the enhanced ability of indicator bacteria to survive in surface waters and sediment when ambient temperatures more closely approximate those of warm-blooded animals, from which the bacteria originate. In addition, resident wildlife populations are likely to be more active during the warmer months and more migratory species are present during the summer. These factors combine to make the summer, recreational period representative of "worst-case" conditions. Achieving consistency with the TMDLs through the summer months will result in achieving full support of recreational uses throughout the remainder of the year.

TMDL IMPLEMENTATION GUIDANCE

The percent reductions established in this TMDL can be achieved by implementing control actions where technically and economically feasible that are designed to reduce *E. coli* loading from nonpoint sources (Load Allocation) and point sources (Waste Load Allocation). These actions may be taken by State and Local government, academia, volunteer citizens groups, and individuals to promote effective watershed management.

It is important to note that the TMDLs are effective for the entire watershed because they are a measurement of compounded impacts at a single point. As such, corrective actions must be

undertaken at the source(s) whether it is a tributary or illicit discharge pipe, in order to achieve the required percent reductions. Also, the approach to TMDL Implementation is anticipated to be on a watershed wide scale, which will require that all sources within the regional basin that are contributing to the in-stream impairment be addressed. The DEP advocates that a watershed based plan for the Quinnipiac River Regional Basin be developed to implement the TMDLs. The plan should follow guidelines provided by the EPA and include participation for all watershed towns. The following guidance offers suggestions regarding BMP implementation, however the goal is to allow responsible parties flexibility in developing a TMDL implementation plan (watershed based plan). The DEP supports an adaptive and iterative management approach where reasonable controls are implemented and water quality is monitored in order to evaluate for achievement of the TMDL goals and modification of controls as necessary.

Potential point sources of *E. coli* to the Quinnipiac River Regional Basin include regulated stormwater. Control actions for regulated stormwater include the General Permit for the Discharge of Stormwater from Small Municipal Separate Storm Sewer Systems (MS4 Permit). Under this permit, municipalities are required to implement minimum control measures in their Stormwater Management Plans to reduce the discharge of pollutants, protect water quality, and satisfy the appropriate water quality requirements of the Clean Water Act. The six minimum control measures are:

- Public Education and Outreach
- Public Participation/Involvement
- Illicit Discharge Detection and Elimination
- Construction Site Runoff Control
- Post-construction Runoff Control
- Pollution Prevention/Good Housekeeping

The minimum control measures include a number of Best Management Practices (BMP) for which an implementation schedule must be developed and submitted to the DEP as Part B Registration. Under the MS4 permit, all minimum control measures must be implemented by January 8, 2009. Information regarding Connecticut's MS4 permit can be found on the DEP's website at http://www.ct.gov/dep/lib/dep/Permits_and_Licenses/Factsheets_Water_Discharges /MS4_factsheet.pdf. In addition, the EPA has developed fact sheets, which provide an overview of the Phase II final rule and MS4 permit, and provide detail regarding the minimum control measures, as well as optional BMPs not required in Connecticut's MS4 permit. The fact sheets can be found on the EPA's website at: http://cfpub.epa.gov/npdes/stormwater/swphases.cfm. Some of the information includes guidance for the development and implementation of Stormwater Management Plans, as well as guidance for establishing measurable goals for BMP implementation.

Section 6(K) of the MS4 Permit requires the municipality to modify their Stormwater Management Plan to implement the TMDL within four months of TMDL approval by EPA. It is recommended that municipalities focus their revised Stormwater Management Plans on the TMDL waterbodies for Section 6(a)(1)(A)(i) - implement public education program, Section 6(a)(3)(A)(i, ii, iii) and 6(a)(3)(A)(i, ii, iii, iv) - illicit discharge detection, Section 6(a)(6)(A)(iv)

- stormwater structures cleaning, and Section 6(a)(6)(A)(v) - prioritize stormwater structures for repair or upgrade, of the MS4 permit.

The DEP encourages all local stakeholders to continue their efforts by working together to formulate a watershed based plan to implement the TMDL. A watershed based plan formulated at the local level will most efficiently make use of local resources by assigning tasks to responsible parties and serving as an agreed roadmap to reducing bacteria levels in the Basin.

The TMDLs establish a benchmark to measure the effectiveness of BMP implementation. Achievement of the TMDLs is directly linked to incorporation of the provisions of the MS4 permit by municipalities, as well as the implementation of other BMPs to address nonpoint sources. Potential nonpoint sources include domestic animal waste, wildlife and surface water base flow. BMPs for the management of nonpoint sources include nuisance wildlife control plans and pet waste ordinances. Nuisance wildlife information can be found on the DEP's website at http://www.ct.gov/ dep/cwp/view.asp?a=2723&q=325944&depNav_GID=1655. Pet waste information can be found on the CT River Coastal Conservation District website at http://www.conservect.org/ ctrivercoastal/give_a_bark_resources.shtml. As progress is made implementing BMPs, the "percent reduction" needed to meet criteria will decrease.

In addition, the DEP's watershed coordinator will continue to provide technical and educational assistance to the local municipalities and other stakeholders, as well as identify potential funding sources, when available, for implementation of the TMDL and monitoring plan.

WATER QUALITY MONITORING PLAN

A comprehensive water quality monitoring program is necessary to guide TMDL implementation efforts. The monitoring program should be designed to accomplish two objectives: source detection to identify specific sources of bacterial loading and direct BMP implementation efforts with fixed station monitoring to quantify progress in achieving TMDL established goals. The MS4 Permit that is the basis of TMDL implementation efforts in MS4 communities includes the following monitoring requirement:

> *"Stormwater monitoring shall be conducted by the Regulated Small MS4 annually starting in 2004. At least two outfalls apiece shall be monitored from areas of primarily industrial development, commercial development and residential development, respectively, for a total of six (6) outfalls monitored. Each monitored outfall shall be selected based on an evaluation by the MS4 that the drainage area of such outfall is representative of the overall nature of its respective land use type."*
>
> Section 6(h)(A) MS4 Permit

This type of monitoring may be referred to as event monitoring because it is scheduled to coincide with a stormwater runoff event. Event monitoring can present numerous logistical difficulties for municipalities and may not be the most efficient way to measure progress in achieving water quality standards. This is particularly true for streams draining urbanized watersheds where many sources contribute to excursions above water quality criteria. However,

the municipality may request written approval from the DEP for an alternative monitoring program:

> *"The municipality may submit a request to the Commissioner in writing for implementation of an alternate sampling plan of equivalent or greater scope. The Commissioner will approve or deny such a request in writing.*
>
> Section 6(h)(B) MS4 Permit

The DEP encourages municipalities faced with implementing a TMDL to request approval for an alternative monitoring program. Monitoring may be performed by municipal staff, citizen volunteers, or contracted to an environmental consulting firm. The program must include sampling to address both objectives (source detection and progress quantification). Source detection monitoring may include such activities as visual inspection of storm sewer outfalls under dry weather conditions, event sampling of individual storm sewer outfalls, and monitoring of ambient (in-stream) conditions at closely spaced intervals to identify "hot spots" for more detailed investigations leading to specific sources of high bacteria loads.

Progress in achieving TMDL established goals through BMP implementation may be most effectively gauged through implementing a fixed station ambient monitoring program. DEP strongly recommends that routine monitoring be performed at the same sites used to generate the data used to perform the TMDL calculations. Sampling should be scheduled at regularly spaced intervals during the recreational season. In this way the data set at the end of each season will include ambient values for both "wet" and "dry" conditions in relative proportion to the number of "wet" and "dry" days that occurred during that period. As additional data is generated over time it will be possible to repeat the TMDL calculations and compare the percent reductions needed under "dry" and "wet" conditions to the percent reductions needed at the time of TMDL adoption.

All pollutant parameters must be analyzed using methods prescribed in Title 40, CFR, Part 136 (1990). Electronic submission of data to DEP is highly encouraged. Results of monitoring that indicate unusually high levels of contamination or potentially illegal activities should be forwarded to the appropriate municipal or State agency for follow-up investigation and enforcement. Consistent with the requirements of the MS4 permit, the following parameters should be included in any monitoring program:

pH (SU)
Hardness (mg/l)
Conductivity (umos)
Oil and grease (mg/l)
Chemical Oxygen Demand (mg/l)
Turbidity (NTU)
Total Suspended Solids (mg/l)
Total Phosphorous (mg/l)
Ammonia (mg/l)
Total Kjeldahl Nitrogen (mg/l)
Nitrate plus Nitrite Nitrogen (mg/l)

E. coli (col/100ml)
precipitation (in)

DEP will continue to explore ways to provide funding support for monitoring efforts linked to TMDL implementation or other activities that exceed the minimum requirements of the MS4 permit. DEP is also committed to providing technical assistance in monitoring program design and establishing procedures for electronic data submission.

REASONABLE ASSURANCE

The MS4 Permit is a legally enforceable document that provides reasonable assurance that the municipalities will take steps towards achieving the target TMDLs and reducing point sources of stormwater containing bacteria.

The DEP further supports the development of a watershed based plan specific to bacteria reductions and source mitigation in order to implement the TMDLs. Such a plan may also make projects aimed at reducing nonpoint sources of bacteria in the Quinnipiac River Regional Basin eligible for funding, as along as such projects are not used for permit compliance.

PROVISIONS FOR REVISING THE TMDLs

The DEP reserves the authority to modify the TMDLs as needed to account for new information made available during the implementation of the TMDLs. Modification of the TMDLs will only be made following an opportunity for public participation and will be subject to the review and approval of the EPA. New information, which will be generated during TMDL implementation includes monitoring data, new or revised State or Federal regulations adopted pursuant to Section 303(d) of the Clean Water Act, and the publication by EPA of national or regional guidance relevant to the implementation of the TMDL program. The DEP will propose modifications to the TMDL analysis only in the event that a review of the new information indicates that such a modification is warranted and is consistent with the anti-degradation provisions in Connecticut Water Quality Standards. The subject waterbodies of this TMDL analysis will continue to be included on the *List of Connecticut Water bodies Not Meeting Water Quality Standards* until monitoring data confirms that recreational uses are fully supported.

PUBLIC PARTICIPATION

The Quinnipiac River Regional Basin TMDL document was noticed for public comment in the in the Meriden Record, Hartford Courant, and New Haven Register on February 1, 2008. In addition, the municipalities, as well as several interested parties were notified by mail of the comment period. At the close of the public comment period, the DEP received two comment letters. The final TMDL document was modified to reflect any reasonable requests submitted in the comment letters.

REFERENCES

(1) Connecticut Department of Environmental Protection, 2006. Appendix C: List of Connecticut Water bodies Not Meeting Water Quality Standards. In: *Integrated Water Quality Report to Congress. Bureau of Water Protection and Land Reuse*, 79 Elm Street, Hartford, CT 06106-5127.

(2) Connecticut Department of Environmental Protection, 2002. *Connecticut Water Quality Standards*. Bureau of Water Management, 79 Elm Street, Hartford, CT 06106-5127.

(3) Connecticut Department of Environmental Protection, 2006. *Integrated Water Quality Report to Congress*. Bureau of Water Protection and Land Reuse, 79 Elm Street, Hartford, CT 06106-5127.

(4) United States Environmental Protection Agency, 2006. *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*.

(5) U.S. Census Bureau, March 2002. www.census.gov/geo/www/ua/ua_2k.html.

(6) United States Environmental Protection Agency, 1986. *Ambient Water Quality Criteria for Bacteria -1986.* EPA 440/5-84-002.

(7) Connecticut Department of Environmental Protection, 2005. *Development of TMDLs for Indicator Bacteria in Contact Recreation Areas Using the Cumulative Frequency Distribution Function Method*. Bureau of Water Protection and Land Reuse, 79 Elm Street, Hartford, CT 06106-5127.

(8) Connecticut Department of Environmental Protection, 2002. *Water Quality Summary Report for Sasco Brook, Mill River, Rooster River, Fairfield County Connecticut*. November 2002.

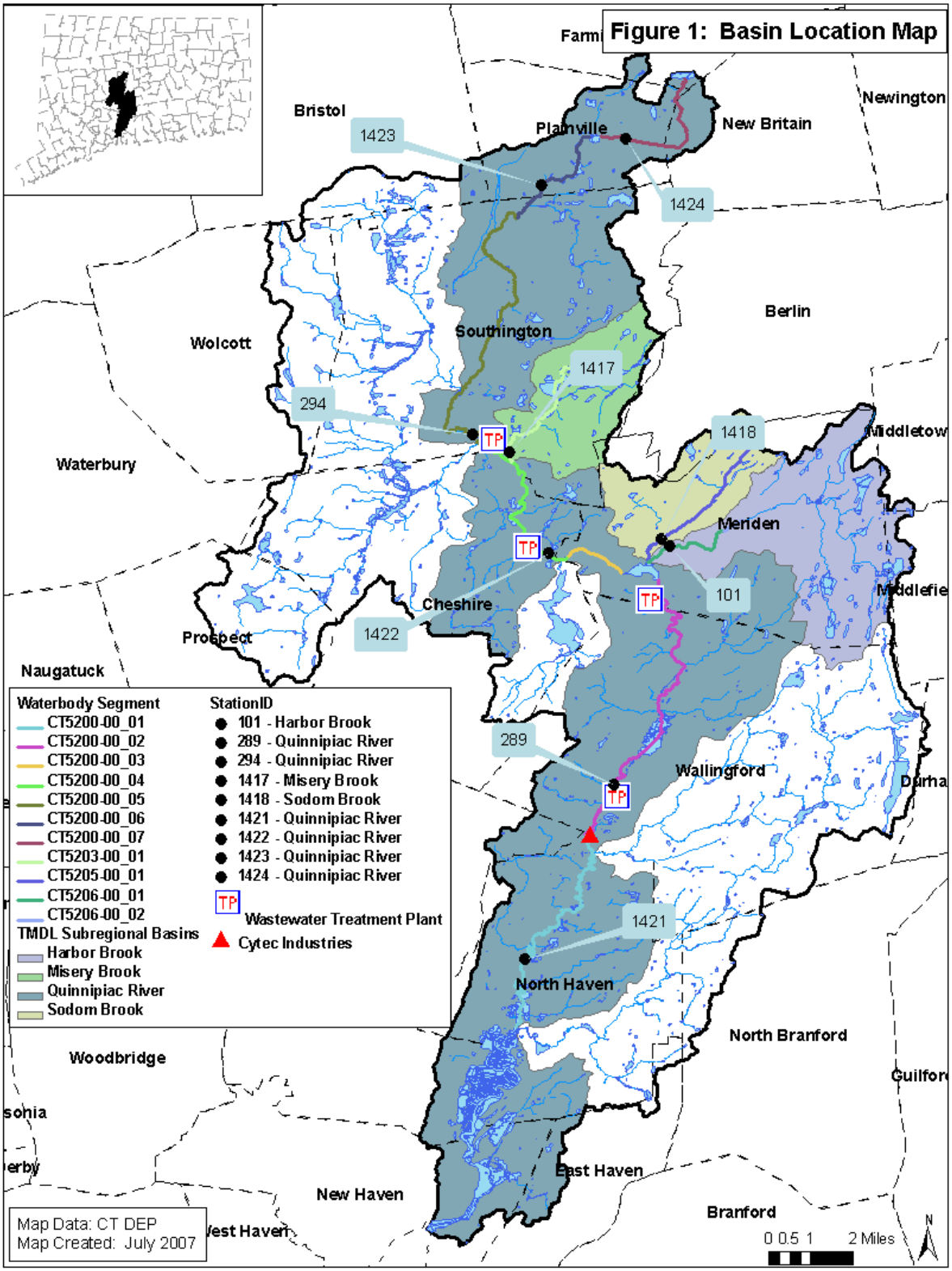


Figure 1: Basin Location Map
Bristol
Plainville
New Britain
Newington
Berlin
Southington
Wolcott
Waterbury
Cheshire
Prospect
Naugatuck
Meriden
Middletown
Middlefield
Wallingford
Durham
North Haven
North Branford
Guilford
Woodbridge
East Haven
New Haven
Branford
1423
1424
1417
294
1418
101
1422
289
1421
Waterbody Segment
CT5200-00_01
CT5200-00_02
CT5200-00_03
CT5200-00_04
CT5200-00_05
CT5200-00_06
CT5200-00_07
CT5203-00_01
CT5205-00_01
CT5206-00_01
CT5206-00_02
TMDL Subregional Basins
Harbor Brook
Misery Brook
Quinnipiac River
Sodom Brook
StationID
101 - Harbor Brook
289 - Quinnipiac River
294 - Quinnipiac River
1417 - Misery Brook
1418 - Sodom Brook
1421 - Quinnipiac River
1422 - Quinnipiac River
1423 - Quinnipiac River
1424 - Quinnipiac River
TP
Wastewater Treatment Plant
Cytec Industries
Map Data: CT DEP
Map Created: July 2007
0 0.5 1 2 Miles
N

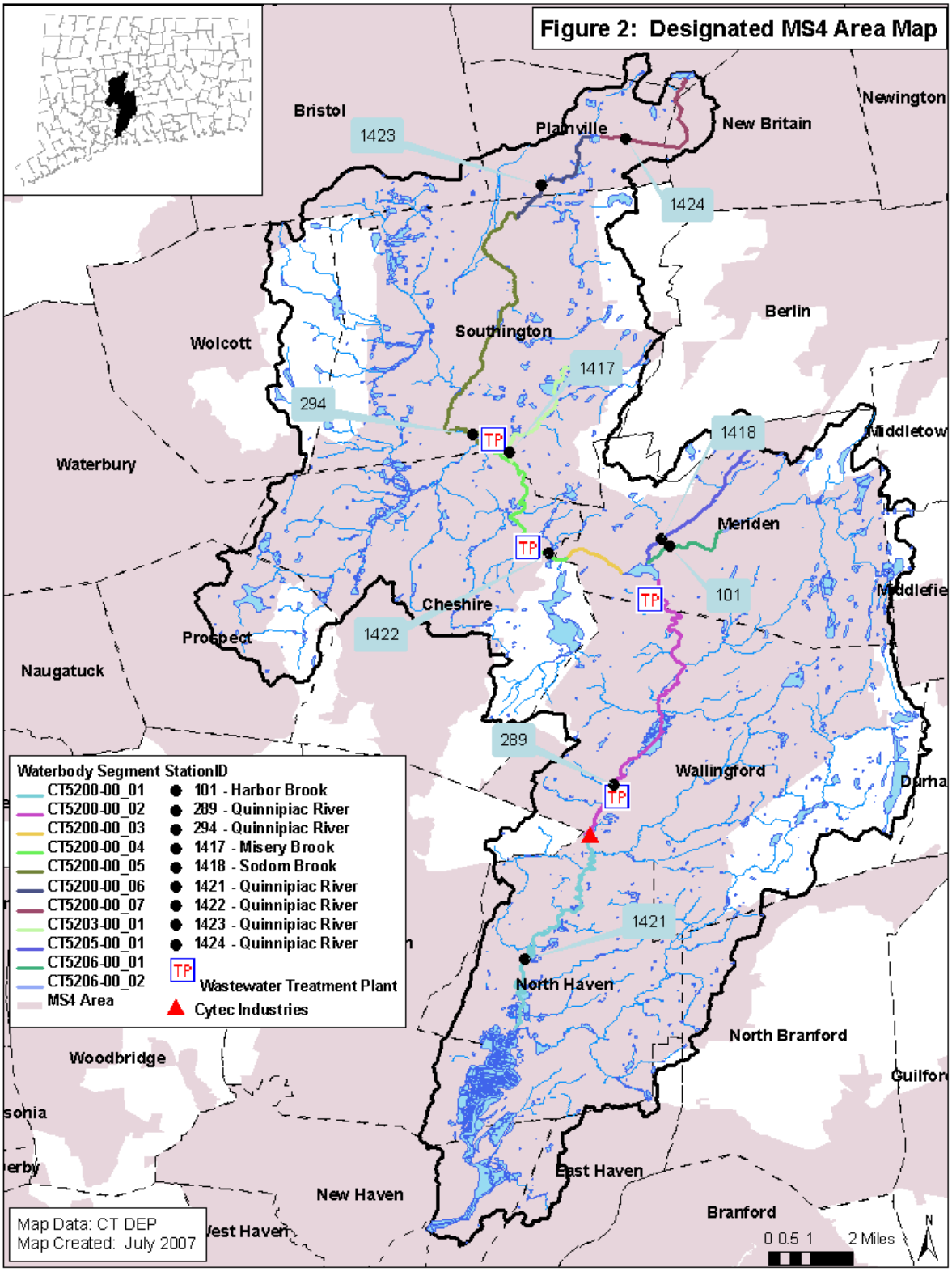


Figure 2: Designated MS4 Area Map
Bristol
Plainville
New Britain
Newington
1423
1424
Berlin
Southington
Wolcott
1417
294
1418
Middletow
Waterbury
Meriden
TP
101
Middlefie
Cheshire
Prospect
1422
Naugatuck
289
Wallingford
Durha
1421
North Haven
North Branford
Woodbridge
Guilfor
East Haven
New Haven
Branford
Waterbody Segment StationID
CT5200-00_01
CT5200-00_02
CT5200-00_03
CT5200-00_04
CT5200-00_05
CT5200-00_06
CT5200-00_07
CT5203-00_01
CT5205-00_01
CT5206-00_01
CT5206-00_02
MS4 Area
101 - Harbor Brook
289 - Quinnipiac River
294 - Quinnipiac River
1417 - Misery Brook
1418 - Sodom Brook
1421 - Quinnipiac River
1422 - Quinnipiac River
1423 - Quinnipiac River
1424 - Quinnipiac River
Wastewater Treatment Plant
Cytec Industries
Map Data: CT DEP
Map Created: July 2007
0 0.5 1 2 Miles
N

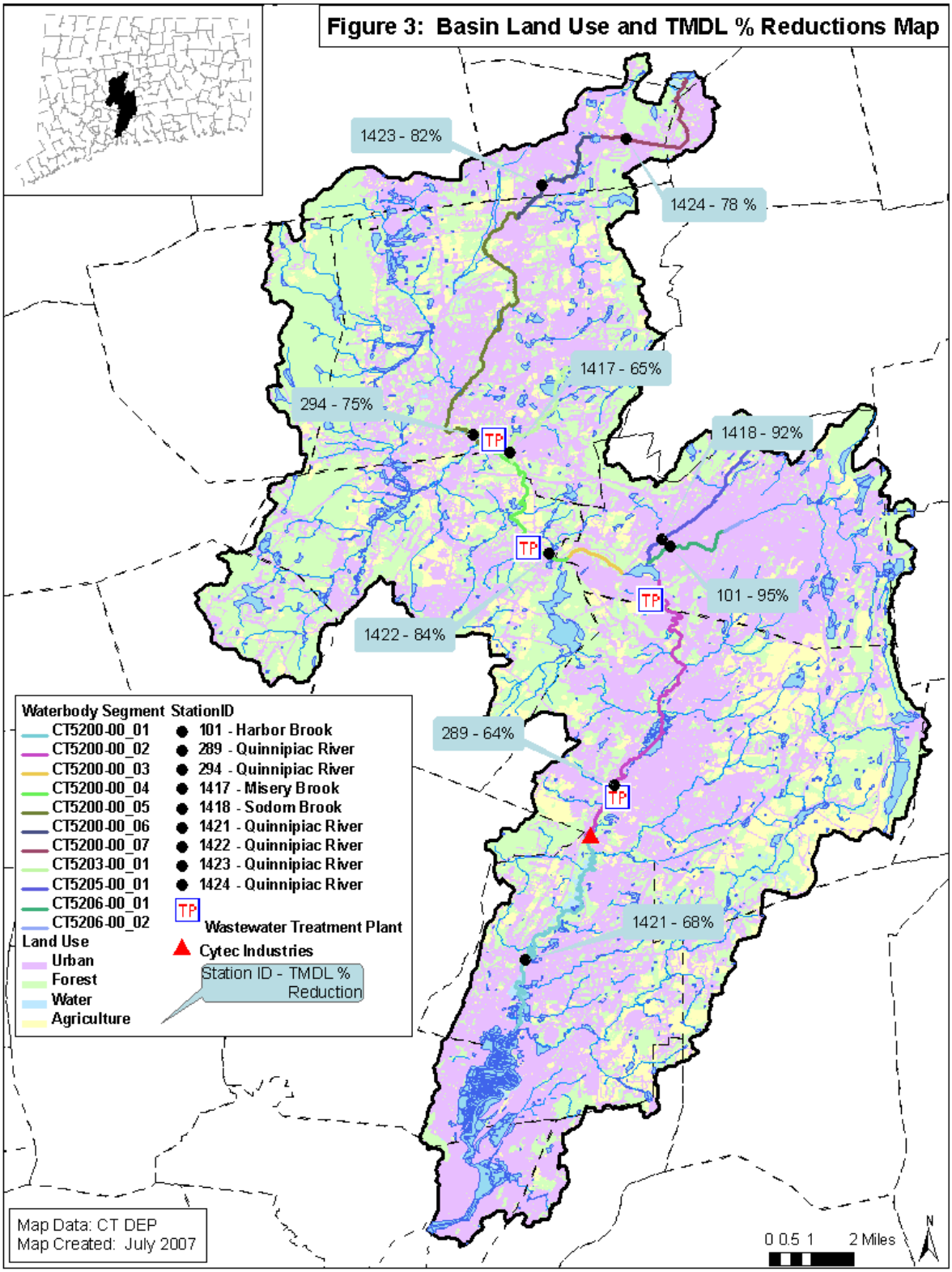


Figure 3: Basin Land Use and TMDL % Reductions Map
1423 - 82%
1424 - 78 %
1417 - 65%
294 - 75%
1418 - 92%
101 - 95%
1422 - 84%
289 - 64%
1421 - 68%
TP
Waterbody Segment
CT5200-00_01
CT5200-00_02
CT5200-00_03
CT5200-00_04
CT5200-00_05
CT5200-00_06
CT5200-00_07
CT5203-00_01
CT5205-00_01
CT5206-00_01
CT5206-00_02
Land Use
Urban
Forest
Water
Agriculture
StationID
101 - Harbor Brook
289 - Quinnipiac River
294 - Quinnipiac River
1417 - Misery Brook
1418 - Sodom Brook
1421 - Quinnipiac River
1422 - Quinnipiac River
1423 - Quinnipiac River
1424 - Quinnipiac River
Wastewater Treatment Plant
Cytec Industries
Station ID - TMDL % Reduction
Map Data: CT DEP
Map Created: July 2007
0 0.5 1 2 Miles
N

Appendix A

Appendix A-1
Quinnipiac River
Waterbody Specific Information

Impaired Waterbody
Waterbody Name: Quinnipiac River
Waterbody Segment ID: CT5200-00_1, CT5200-00_2, CT5200-00_3, CT5200-00_4, CT5200-00_5, CT5200-00_6, CT5200-00_7
Waterbody Segment Description: From Rt. 5, North Haven upstream to headwaters at Dead Wood Swamp, Farmington.

Impairment Description:
Designated Use Impairment: Recreation
Size of Impaired Segment: 36.98 linear miles
Surface Water Classification: Class C/B, A

Watershed Description:
Total Regional Drainage Basin Area: 165.55 square miles
Tributary To: New Haven Harbor
Subregional Basin Name & Code: Quinnipiac River, 5200
Regional Basin: Quinnipiac River
Major Basin: South Central Coast
Watershed Towns: Berlin, Bristol, Cheshire, Durham, East Haven, Farmington, Hamden, Meriden, Middlefield, Middletown, New Britain, New Haven, North Branford, North Haven, Plainville, Prospect, Southington, Wallingford, Waterbury, Wolcott
Phase II GP applicable? : Berlin - yes, Bristol - yes, Cheshire - yes, Durham - yes, East Haven - yes, Farmington - yes, Hamden - yes, Meriden - yes, Middlefield - yes, Middletown - yes, New Britain - yes, New Haven - yes, North Branford - yes, North Haven - yes, Plainville - yes, Prospect - yes, Southington - yes, Wallingford - yes, Waterbury - yes, Wolcott - yes
Applicable Season: Recreation Season (May 1 to September 30)

Landuse:

Land Use Category	Percent Composition
Forested	35.5%
Urban/Developed	46.9%
Water/Wetland	5.6%
Agriculture	12%

Data Source: Connecticut Land Use Land Cover Data Layer LANDSTAT (2002) Thematic Mapper Satellite Imagery.

Appendix A-1
Quinnipiac River
TMDL Summary

The TMDL analysis for the Quinnipiac River was conducted at six sites, which are representative of seven waterbody segments. Current data is unavailable to conduct a TMDL analysis for segment CT5200-00_03 in the Quinnipiac River. However, this small segment (1 ¼ linear miles) is located in between two segments that require reductions. Therefore, it is reasonable to presume that the same percent reduction applies to this segment. The analysis indicates that the sites are influenced by sources of bacteria active under both wet weather and dry weather conditions. The Waste Load Allocation (WLA) is applicable to regulated stormwater. Reduction in the WLA can be achieved through the detection and elimination of illicit discharges to the storm sewers, as well as, the installation of engineered controls to reduce the surge of stormwater to the river, promote groundwater recharge, and improve water quality. Nonpoint sources, such as domestic animal waste and wildlife, may contribute to the Load Allocation. It is important to note that the percent reductions required at the sites in segments CT5200-00_3, CT5200-00_4, CT5200-00_5, CT5200-00_6, and CT5200-00_7 are slightly higher than those in segments CT5200-00_1 and CT5200-00_2. This may be attributed to the fact that Hanover Pond is located upstream of segments CT5200-00_1 and CT5200-00_2, which may act as a retention and settling basin for bacteria associated with particulate material.

Quinnipiac River-01

CT5200-00_01

Data Used in the Analysis

Monitoring Site: 1421, From Rt 5 N. Haven, US to Tolles Rd, Wallingford.

Date	Precip.(in)[1]			Condition[2]	E. coli	Rank	Proportion	Criteria	%
	24h	48h	96h	(WET/DRY)	(col./100 ml)			Value	Reduction
6/10/04	0.09	0.09	0.09	DRY	220	9.0	0.3600	91	59
6/16/04	0.00	0.00	0.18	DRY	180	4.0	0.1600	50	72
6/23/04	0.00	0.03	0.03	DRY	230	11.0	0.4400	110	52
6/30/04	0.00	0.19	0.19	DRY	370	15.0	0.6000	159	57
7/8/04	0.01	0.01	1.03	DRY	220	9.0	0.3600	91	59
7/14/04	0.10	0.43	0.46	**WET**	580	18.0	0.7200	216	63
7/21/04	0.00	0.01	0.14	DRY	200	6.5	0.2600	70	65
7/28/04	1.30	1.33	1.33	**WET**	2600	24.0	0.9600	576	78
8/4/04	0.00	0.00	0.66	DRY	380	16.0	0.6400	175	54
8/5/04	0.19	0.19	0.19	**WET**	2100	23.0	0.9200	460	78
8/11/04	0.13	0.13	0.13	**WET**	450	17.0	0.6800	194	57
8/17/04	0.45	0.49	1.55	**WET**	1200	20.0	0.8000	274	77
8/18/04	0.01	0.46	1.55	**WET**	280	12.0	0.4800	120	57
8/25/04	0.01	0.01	1.08	DRY	320	13.0	0.5200	132	59
9/1/04	0.00	0.01	0.02	DRY	340	14.0	0.5600	145	57
9/8/04	0.73	0.74	0.74	**WET**	41	1.0	0.0400	25	39
9/9/04	0.71	1.44	1.45	**WET**	9200	25.0	1.0000	576	94
9/16/04	0.17	0.17	0.18	**WET**	1800	21.0	0.8400	315	83
9/20/04	0.00	1.81	1.82	**WET**	16000	9.0	0.3600	91	99
9/22/04	0.00	0.00	1.81	DRY	960	19.0	0.7600	241	75
9/27/04	0.01	0.03	0.04	DRY	200	6.5	0.2600	70	65
8/2/05	0.00	0.00	0.00	DRY	180	4.0	0.1600	50	72
8/10/05	0.00	0.00	0.00	DRY	120	2.0	0.0800	35	71
8/15/05	0.11	0.11	0.11	**WET**	1900	22.0	0.8800	372	80
9/7/05	0.01	0.01	0.01	DRY	180	4.0	0.1600	50	72

Statistics

# Samples DRY	**14**
# Samples WET	**11**
# Samples Total	**25**
Geomean	**508**
Log std deviation	**0.6000**

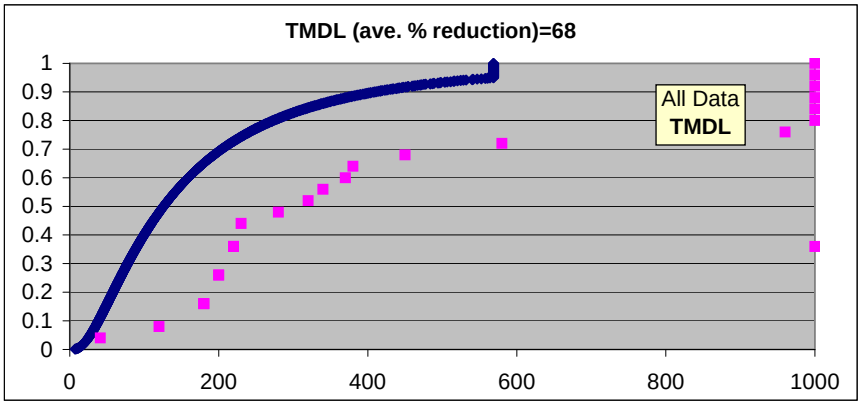
Avg % Reduction

Wet (WLA)	**73**
Dry (LA)	**64**
Total (TMDL)	**68**

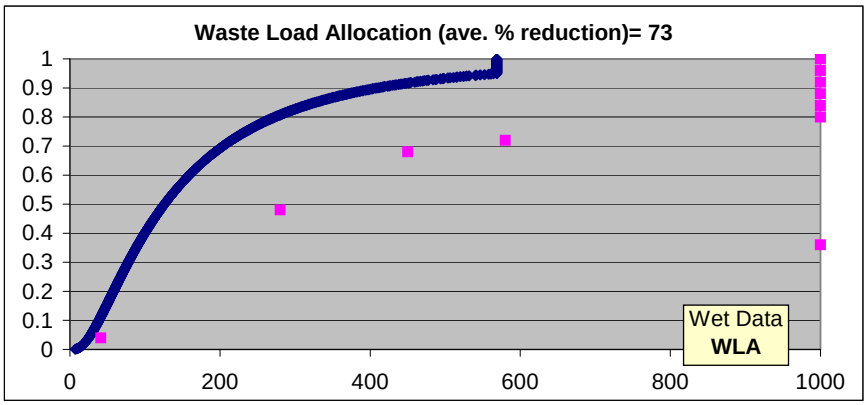
Precipitation and E. coli data provided by NOAA and CT DEP, respectively.
WET Condition defined as greater than 0.1" precipitation in 24 hours or 0.25" precipitation in 48 hours, or 2.0" precipitation in 96 hours.

Quinnipiac River-01 Criteria Curve for Monitoring Site 1421

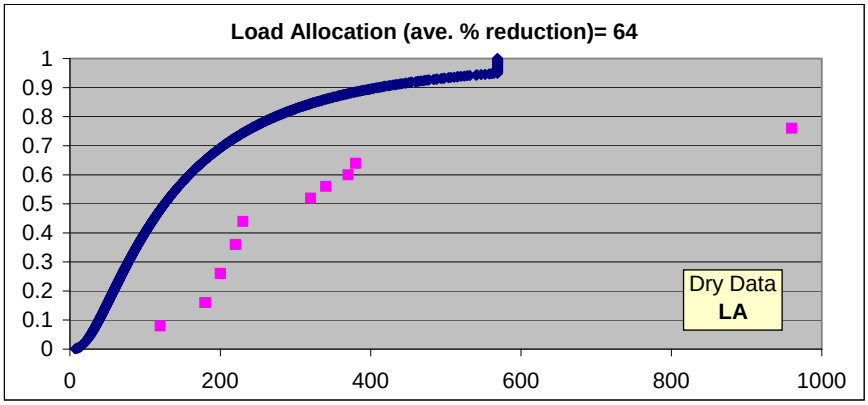
y axis = cumulative frequency; x axis = *E.coli* (col/100mL)



TMDL needed from current condition (magenta squares) to meet criteria (blue line). Current condition based on dry and wet weather data.



Waste Load Allocation (WLA) needed from current condition (magenta squares) to meet criteria (blue line). Current condition based on wet weather data.



Load Allocation (LA) needed from current condition (magenta squares) to meet criteria (blue line). Current condition based on dry weather data.

Quinnipiac River-02

CT5200-00_02

Data Used in the Analysis

Monitoring Site: 289, From Tolles Rd., US to Hanover Pond outlet dam, Meriden

Date	Precip.(in)[1]			Condition[2]	E. coli	Rank	Proportion	Criteria	%
	24h	48h	96h	(WET/DRY)	(col./100 ml)			Value	Reduction
6/10/04	0.09	0.09	0.09	DRY	170	7.5	0.3000	78	54
6/16/04	0.00	0.00	0.18	DRY	160	5.0	0.2000	58	64
6/23/04	0.00	0.03	0.03	DRY	200	10.0	0.4000	100	50
6/30/04	0.00	0.19	0.19	DRY	150	4.0	0.1600	50	66
7/8/04	0.01	0.01	1.03	DRY	370	15.0	0.6000	159	57
7/14/04	0.10	0.43	0.46	**WET**	490	17.0	0.6800	194	60
7/21/04	0.00	0.01	0.14	DRY	180	8.0	0.3200	82	55
7/28/04	1.30	1.33	1.33	**WET**	4100	23.0	0.9200	460	89
8/4/04	0.00	0.00	0.66	DRY	310	12.0	0.4800	120	61
8/5/04	0.19	0.19	0.19	**WET**	3700	22.0	0.8800	372	90
8/11/04	0.13	0.13	0.13	**WET**	120	2.0	0.0800	35	71
8/17/04	0.45	0.49	1.55	**WET**	1200	21.0	0.8400	315	74
8/18/04	0.01	0.46	1.55	**WET**	320	13.5	0.5400	138	57
8/25/04	0.01	0.01	1.08	DRY	390	16.0	0.6400	175	55
9/1/04	0.00	0.01	0.02	DRY	320	13.5	0.5400	138	57
9/8/04	0.73	0.74	0.74	**WET**	47	1.0	0.0400	25	47
9/9/04	0.71	1.44	1.45	**WET**	4900	24.0	0.9600	576	88
9/16/04	0.17	0.17	0.18	**WET**	630	19.0	0.7600	241	62
9/20/04	0.00	1.81	1.82	**WET**	24001	7.5	0.3000	78	100
9/22/04	0.00	0.00	1.81	DRY	580	18.0	0.7200	216	63
9/27/04	0.01	0.03	0.04	DRY	160	6.0	0.2400	66	59
8/2/05	0.00	0.00	0.00	DRY	130	3.0	0.1200	43	67
8/10/05	0.00	0.00	0.00	DRY	220	11.0	0.4400	110	50
8/15/05	0.11	0.11	0.11	**WET**	750	20.0	0.8000	274	64
9/7/05	0.01	0.01	0.01	DRY	190	9.0	0.3600	91	52

Statistics

# Samples DRY	**14**
# Samples WET	**11**
# Samples Total	**25**
Geomean	**436**
Log std deviation	**0.6147**

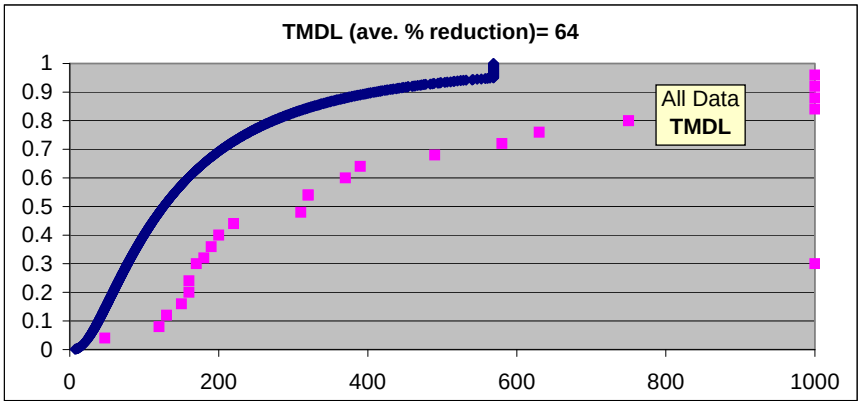
Avg % Reduction

Wet (WLA)	**73**
Dry (LA)	**58**
Total (TMDL)	**64**

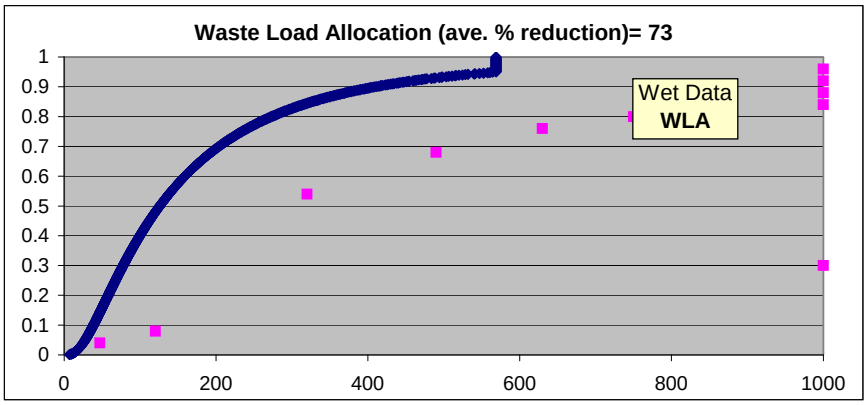
Precipitation and E. coli data provided by NOAA and CT DEP, respectively.
WET Condition defined as greater than 0.1" precipitation in 24 hours or 0.25" precipitation in 48 hours, or 2.0" precipitation in 96 hours.

Quinnipiac River-02 Criteria Curve for Monitoring Site 289

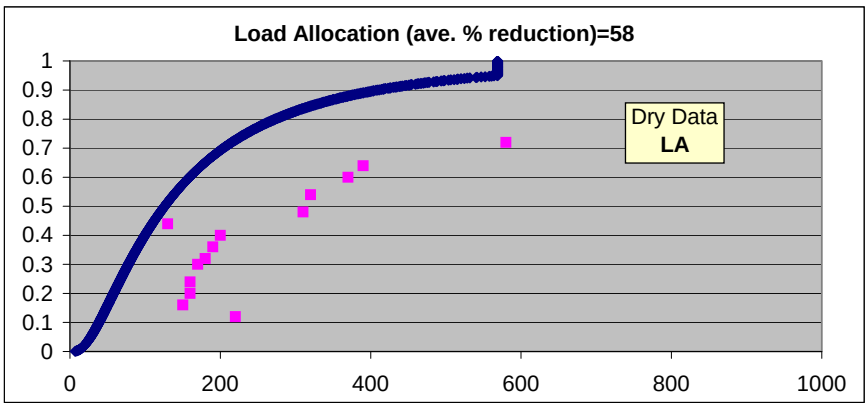
y axis = cumulative frequency; x axis = *E.coli* (col/100mL)



TMDL needed from current condition (magenta squares) to meet criteria (blue line). Current condition based on dry and wet weather data.



Waste Load Allocation (WLA) needed from current condition (magenta squares) to meet criteria (blue line). Current condition based on wet weather data.



Load Allocation (LA) needed from current condition (magenta squares) to meet criteria (blue line). Current condition based on dry weather data.

Quinnipiac River-04

CT5200-00_06

Data Used in the Analysis

Monitoring Site: 1422, From Rt 10 Southington, US to Hamlin Pond, Plainville.

Date	Precip.(in)[1]			Condition[2]	E. coli	Rank	Proportion	Criteria	%
	24h	48h	96h	(WET/DRY)	(col./100 ml)			Value	Reduction
6/10/04	0.09	0.09	0.09	DRY	440	10.0	0.4000	100	77
6/16/04	0.00	0.00	0.18	DRY	320	7.0	0.2800	74	77
6/23/04	0.00	0.03	0.03	DRY	1105	16.0	0.6400	175	84
6/30/04	0.00	0.19	0.19	DRY	1700	17.5	0.7000	204	88
7/8/04	0.01	0.01	1.03	DRY	290	4.0	0.1600	50	83
7/14/04	0.10	0.43	0.46	**WET**	2100	21.0	0.8400	315	85
7/21/04	0.00	0.01	0.14	DRY	960	15.0	0.6000	159	83
7/28/04	1.30	1.33	1.33	**WET**	4900	24.0	0.9600	576	88
8/4/04	0.00	0.00	0.66	DRY	580	13.0	0.5200	132	77
8/5/04	0.19	0.19	0.19	**WET**	2300	22.0	0.8800	372	84
8/11/04	0.13	0.13	0.13	**WET**	740	14.0	0.5600	145	80
8/17/04	0.45	0.49	1.55	**WET**	3700	23.0	0.9200	460	88
8/18/04	0.01	0.46	1.55	**WET**	1700	17.5	0.7000	204	88
8/25/04	0.01	0.01	1.08	DRY	460	12.0	0.4800	120	74
9/1/04	0.00	0.01	0.02	DRY	410	8.0	0.3200	82	80
9/8/04	0.73	0.74	0.74	**WET**	2000	19.0	0.7600	241	88
9/9/04	0.71	1.44	1.45	**WET**	7700	25.0	1.0000	576	93
9/16/04	0.17	0.17	0.18	**WET**	180	1.0	0.0400	25	86
9/20/04	0.00	1.81	1.82	**WET**	3400	10.0	0.4000	100	97
9/22/04	0.00	0.00	1.81	DRY	440	10.0	0.4000	100	77
9/27/04	0.01	0.03	0.04	DRY	220	3.0	0.1200	43	81
8/2/05	0.00	0.00	0.00	DRY	310	6.0	0.2400	66	79
8/10/05	0.00	0.00	0.00	DRY	300	5.0	0.2000	58	81
8/15/05	0.11	0.11	0.11	**WET**	2050	20.0	0.8000	274	87
9/7/05	0.01	0.01	0.01	DRY	215	2.0	0.0800	35	84

Statistics

# Samples DRY	**14**
# Samples WET	**11**
# Samples Total	**25**
Geomean	**873**
Log std deviation	**0.4744**

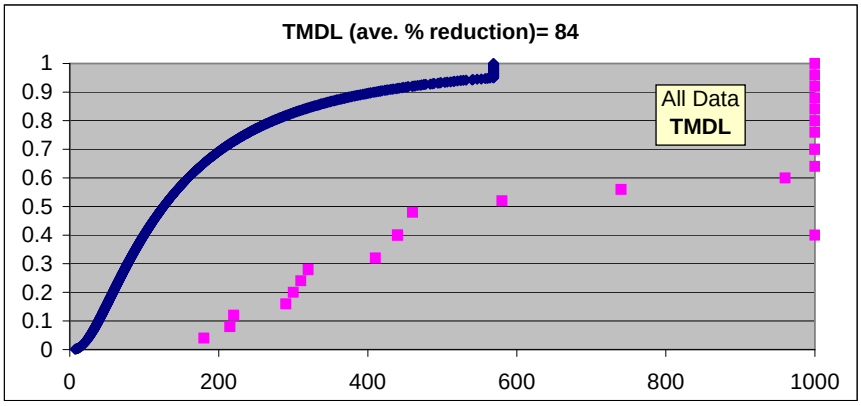
Avg % Reduction

Wet (WLA)	**88**
Dry (LA)	**80**
Total (TMDL)	**84**

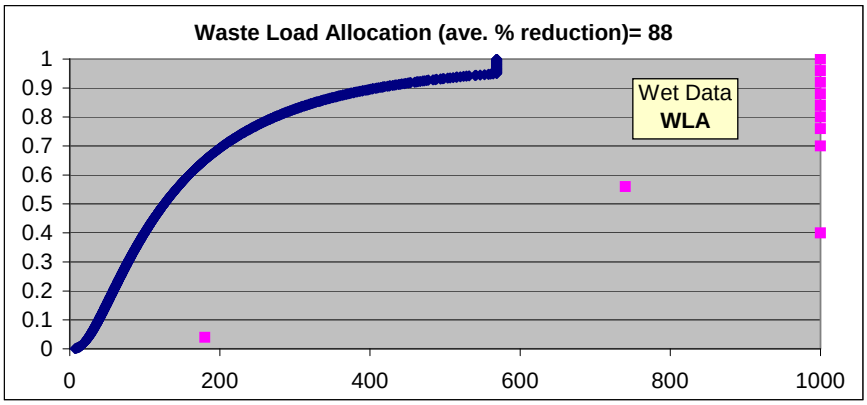
Precipitation and E. coli data provided by NOAA and CT DEP, respectively.
WET Condition defined as greater than 0.1" precipitation in 24 hours or 0.25" precipitation in 48 hours, or 2.0" precipitation in 96 hours.

Quinnipiac River-04 Criteria Curve for Monitoring Site 1422

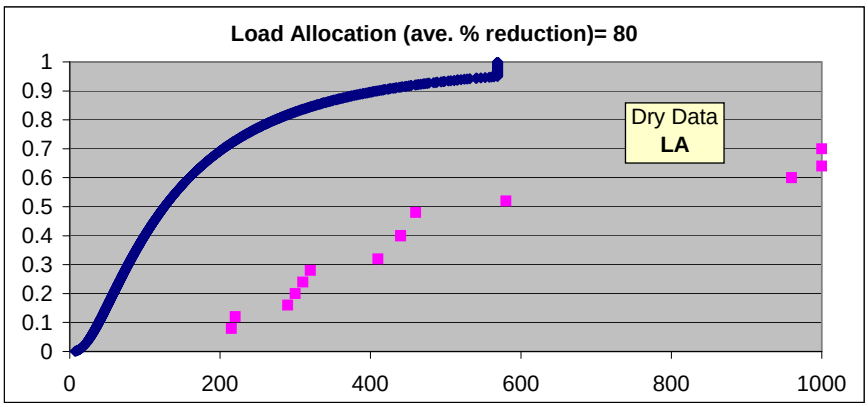
y axis = cumulative frequency; x axis = *E.coli* (col/100mL)



TMDL needed from current condition (magenta squares) to meet criteria (blue line). Current condition based on dry and wet weather data.



Waste Load Allocation (WLA) needed from current condition (magenta squares) to meet criteria (blue line). Current condition based on wet weather data.



Load Allocation (LA) needed from current condition (magenta squares) to meet criteria (blue line). Current condition based on dry weather data.

Quinnipiac River-05

CT5200-00_05

Data Used in the Analysis

Monitoring Site: 294, From confluence with Tenmile R. US to RT 10 Southington.

Date	Precip.(in)[1]			Condition[2]	E. coli	Rank	Proportion	Criteria	%
	24h	48h	96h	(WET/DRY)	(col./100 ml)			Value	Reduction
6/10/04	0.09	0.09	0.09	DRY	350	9.5	0.3800	95	73
6/16/04	0.00	0.00	0.18	DRY	220	5.0	0.2000	58	74
6/23/04	0.00	0.03	0.03	DRY	480	15.5	0.6200	167	65
6/30/04	0.00	0.19	0.19	DRY	480	15.5	0.6200	167	65
7/8/04	0.01	0.01	1.03	DRY	300	7.0	0.2800	74	75
7/14/04	0.10	0.43	0.46	**WET**	1300	20.0	0.8000	274	79
7/21/04	0.00	0.01	0.14	DRY	640	17.0	0.6800	194	70
7/28/04	1.30	1.33	1.33	**WET**	1900	21.0	0.8400	315	83
8/4/04	0.00	0.00	0.66	DRY	440	14.0	0.5600	145	67
8/5/04	0.19	0.19	0.19	**WET**	2600	22.0	0.8800	372	86
8/11/04	0.13	0.13	0.13	**WET**	310	8.0	0.3200	82	74
8/17/04	0.45	0.49	1.55	**WET**	800	19.0	0.7600	241	70
8/18/04	0.01	0.46	1.55	**WET**	670	18.0	0.7200	216	68
8/25/04	0.01	0.01	1.08	DRY	410	12.5	0.5000	126	69
9/1/04	0.00	0.01	0.02	DRY	170	3.5	0.1400	47	73
9/8/04	0.73	0.74	0.74	**WET**	3700	24.0	0.9600	576	84
9/9/04	0.71	1.44	1.45	**WET**	7300	25.0	1.0000	576	92
9/16/04	0.17	0.17	0.18	**WET**	170	3.5	0.1400	47	73
9/20/04	0.00	1.81	1.82	**WET**	1400	9.5	0.3800	95	93
9/22/04	0.00	0.00	1.81	DRY	360	11.0	0.4400	110	70
9/27/04	0.01	0.03	0.04	DRY	130	2.0	0.0800	35	73
8/2/05	0.00	0.00	0.00	DRY	280	6.0	0.2400	66	77
8/10/05	0.00	0.00	0.00	DRY	410	12.5	0.5000	126	69
8/15/05	0.11	0.11	0.11	**WET**	2800	23.0	0.9200	460	84
9/7/05	0.01	0.01	0.01	DRY	120	1.0	0.0400	25	79

Statistics

# Samples DRY	**14**
# Samples WET	**11**
# Samples Total	**25**
Geomean	**581**
Log std deviation	**0.4728**

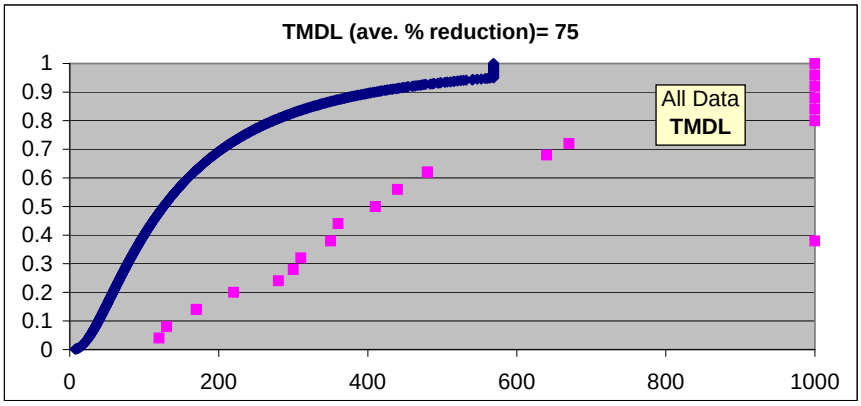
Avg % Reduction

Wet (WLA)	**80**
Dry (LA)	**71**
Total (TMDL)	**75**

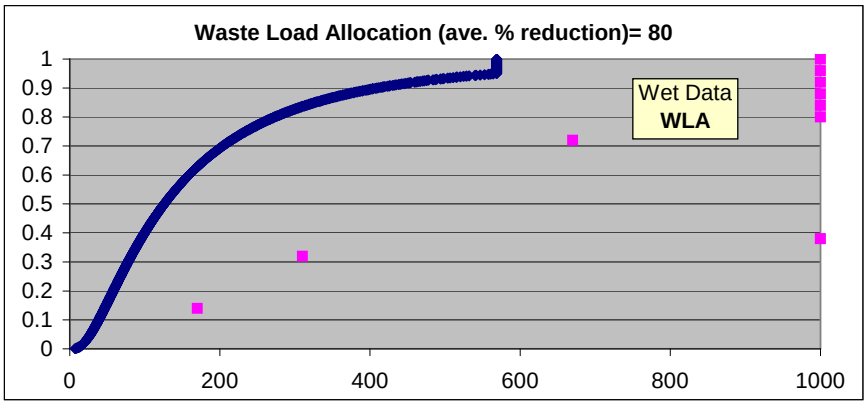
Precipitation and E. coli data provided by NOAA and CT DEP, respectively.
WET Condition defined as greater than 0.1" precipitation in 24 hours or 0.25" precipitation in 48 hours, or 2.0" precipitation in 96 hours.

Quinnipiac River-05 Criteria Curve for Monitoring Site 294

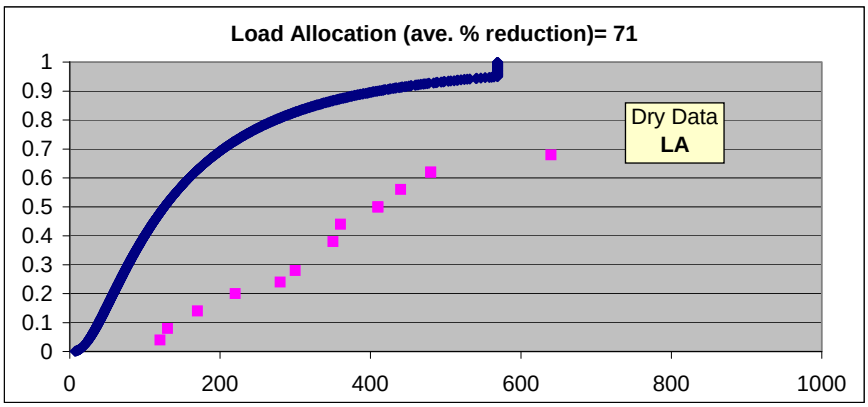
y axis = cumulative frequency; x axis = *E.coli* (col/100mL)



TMDL needed from current condition (magenta squares) to meet criteria (blue line). Current condition based on dry and wet weather data.



Waste Load Allocation (WLA) needed from current condition (magenta squares) to meet criteria (blue line). Current condition based on wet weather data.



Load Allocation (LA) needed from current condition (magenta squares) to meet criteria (blue line). Current condition based on dry weather data.

Quinnipiac River-06

CT5200-00_06

Data Used in the Analysis

Monitoring Site: 1423, From Rt 10 Southington, US to Hamlin Pond, Plainville.

Date	Precip.(in)[1]			Condition[2]	E. coli	Rank	Proportion	Criteria	%
	24h	48h	96h	(WET/DRY)	(col./100 ml)			Value	Reduction
6/10/04	0.09	0.09	0.09	DRY	910	14.5	0.5800	152	83
6/16/04	0.00	0.00	0.18	DRY	370	11.0	0.4400	110	70
6/23/04	0.00	0.03	0.03	DRY	1100	18.0	0.7200	216	80
6/30/04	0.00	0.19	0.19	DRY	990	16.0	0.6400	175	82
7/8/04	0.01	0.01	1.03	DRY	345	8.0	0.3200	82	76
7/14/04	0.10	0.43	0.46	**WET**	1055	17.0	0.6800	194	82
7/21/04	0.00	0.01	0.14	DRY	580	13.0	0.5200	132	77
7/28/04	1.30	1.33	1.33	**WET**	2250	20.0	0.8000	274	88
8/4/04	0.00	0.00	0.66	DRY	1615	19.0	0.7600	241	85
8/5/04	0.19	0.19	0.19	**WET**	11000	24.0	0.9600	576	95
8/11/04	0.13	0.13	0.13	**WET**	350	9.0	0.3600	91	74
8/17/04	0.45	0.49	1.55	**WET**	540	12.0	0.4800	120	78
8/18/04	0.01	0.46	1.55	**WET**	320	7.0	0.2800	74	77
8/25/04	0.01	0.01	1.08	DRY	250	5.0	0.2000	58	77
9/1/04	0.00	0.01	0.02	DRY	310	6.0	0.2400	66	79
9/8/04	0.73	0.74	0.74	**WET**	8200	23.0	0.9200	460	94
9/9/04	0.71	1.44	1.45	**WET**	3900	21.0	0.8400	315	92
9/16/04	0.17	0.17	0.18	**WET**	122	1.0	0.0400	25	79
9/20/04	0.00	1.81	1.82	**WET**	1350	14.5	0.5800	152	89
9/22/04	0.00	0.00	1.81	DRY	190	2.0	0.0800	35	82
9/27/04	0.01	0.03	0.04	DRY	210	4.0	0.1600	50	76
8/2/05	0.00	0.00	0.00	DRY	24000.5	25.0	1.0000	576	98
8/10/05	0.00	0.00	0.00	DRY	200	3.0	0.1200	43	79
8/15/05	0.11	0.11	0.11	**WET**	4400	22.0	0.8800	372	92
9/7/05	0.01	0.01	0.01	DRY	360	10.0	0.4000	100	72

Statistics

# Samples DRY	**14**
# Samples WET	**11**
# Samples Total	**25**
Geomean	**860**
Log std deviation	**0.6045**

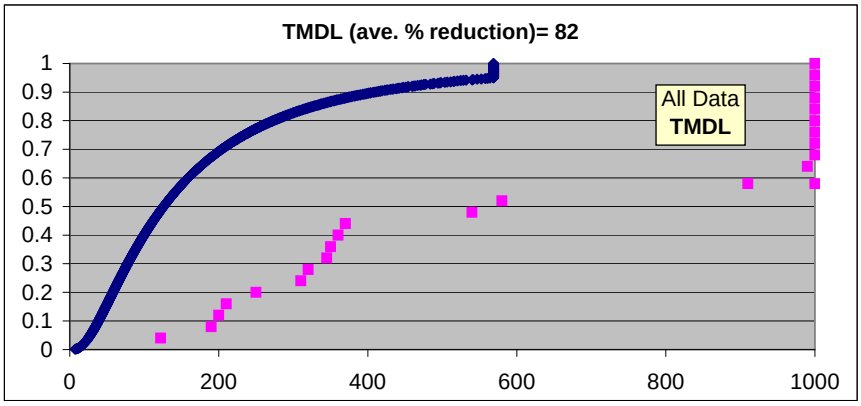
Avg % Reduction

Wet (WLA)	**85**
Dry (LA)	**80**
Total (TMDL)	**82**

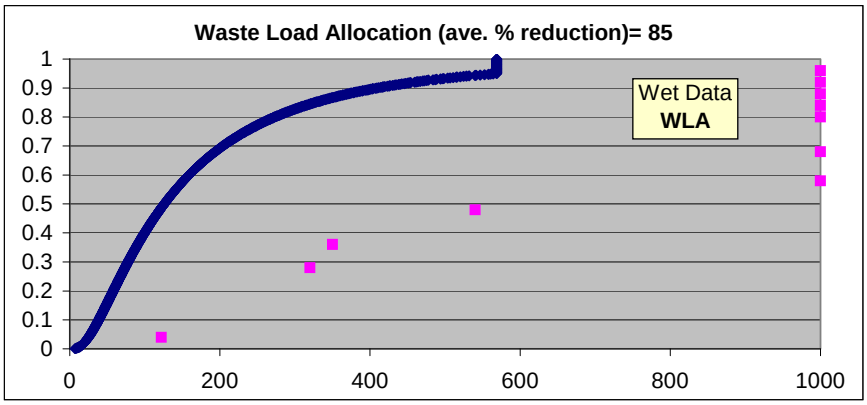
Precipitation and E. coli data provided by NOAA and CT DEP, respectively.
WET Condition defined as greater than 0.1" precipitation in 24 hours or 0.25" precipitation in 48 hours, or 2.0" precipitation in 96 hours.

Quinnipiac River-06 Criteria Curve for Monitoring Site 1423

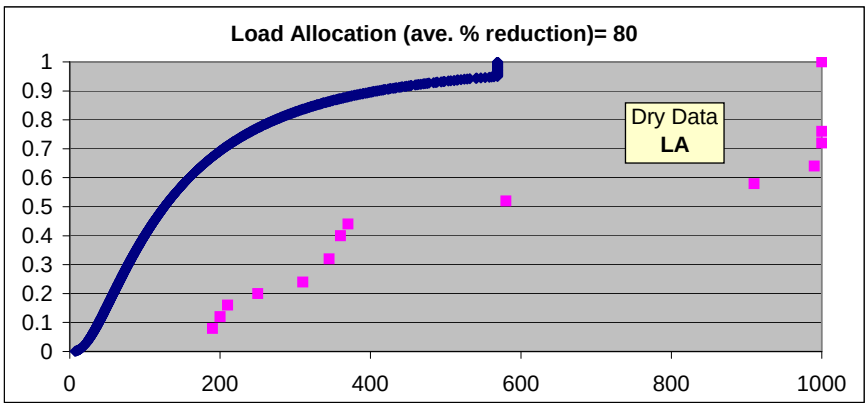
y axis = cumulative frequency; x axis = *E.coli* (col/100mL)



TMDL needed from current condition (magenta squares) to meet criteria (blue line). Current condition based on dry and wet weather data.



Waste Load Allocation (WLA) needed from current condition (magenta squares) to meet criteria (blue line). Current condition based on wet weather data.



Load Allocation (LA) needed from current condition (magenta squares) to meet criteria (blue line). Current condition based on dry weather data.

Quinnipiac River-07

CT5200-00_07

Data Used in the Analysis

Monitoring Site: 1424, From Hamlin Pond US to headwaters.

Date	Precip.(in)[1]			Condition[2]	E. coli	Rank	Proportion	Criteria	%
	24h	48h	96h	(WET/DRY)	(col./100 ml)			Value	Reduction
6/10/04	0.09	0.09	0.09	DRY	420	13.5	0.5400	138	67
6/16/04	0.00	0.00	0.18	DRY	3900	21.0	0.8400	315	92
6/23/04	0.00	0.03	0.03	DRY	230	4.0	0.1600	50	78
6/30/04	0.00	0.19	0.19	DRY	460	15.0	0.6000	159	65
7/8/04	0.01	0.01	1.03	DRY	350	7.0	0.2800	74	79
7/14/04	0.10	0.43	0.46	**WET**	380	9.5	0.3800	95	75
7/21/04	0.00	0.01	0.14	DRY	385	11.0	0.4400	110	72
7/28/04	1.30	1.33	1.33	**WET**	1600	20.0	0.8000	274	83
8/4/04	0.00	0.00	0.66	DRY	170	1.0	0.0400	25	85
8/5/04	0.19	0.19	0.19	**WET**	4400	22.0	0.8800	372	92
8/11/04	0.13	0.13	0.13	**WET**	180	2.0	0.0800	35	81
8/17/04	0.45	0.49	1.55	**WET**	320	6.0	0.2400	66	79
8/18/04	0.01	0.46	1.55	**WET**	730	18.0	0.7200	216	70
8/25/04	0.01	0.01	1.08	DRY	380	9.5	0.3800	95	75
9/1/04	0.00	0.01	0.02	DRY	370	8.0	0.3200	82	78
9/8/04	0.73	0.74	0.74	**WET**	13000	24.0	0.9600	576	96
9/9/04	0.71	1.44	1.45	**WET**	14000	25.0	1.0000	576	96
9/16/04	0.17	0.17	0.18	**WET**	300	5.0	0.2000	58	81
9/20/04	0.00	1.81	1.82	**WET**	410	13.5	0.5400	138	66
9/22/04	0.00	0.00	1.81	DRY	520	17.0	0.6800	194	63
9/27/04	0.01	0.03	0.04	DRY	200	3.0	0.1200	43	79
8/2/05	0.00	0.00	0.00	DRY	1200	19.0	0.7600	241	80
8/10/05	0.00	0.00	0.00	DRY	510	16.0	0.6400	175	66
8/15/05	0.11	0.11	0.11	**WET**	6500	23.0	0.9200	460	93
9/7/05	0.01	0.01	0.01	DRY	390	12.0	0.4800	120	69

Statistics

# Samples DRY	**14**
# Samples WET	**11**
# Samples Total	**25**
Geomean	**715**
Log std deviation	**0.5677**

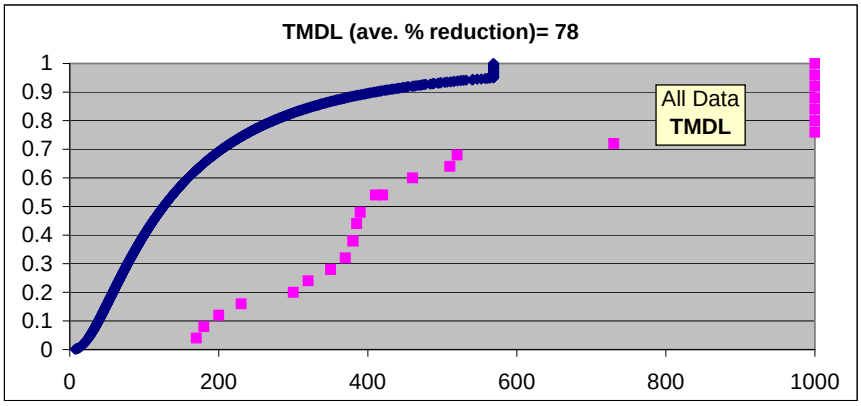
Avg % Reduction

Wet (WLA)	**83**
Dry (LA)	**75**
Total (TMDL)	**78**

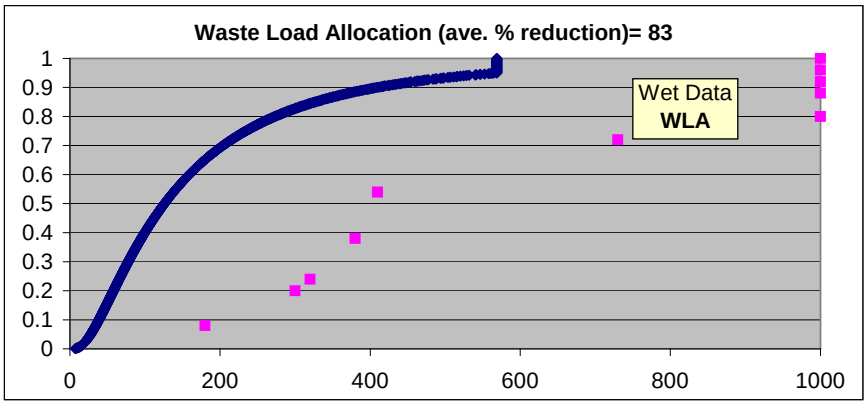
Precipitation and E. coli data provided by NOAA and CT DEP, respectively.
WET Condition defined as greater than 0.1" precipitation in 24 hours or 0.25" precipitation in 48 hours, or 2.0" precipitation in 96 hours.

Quinnipiac River-07 Criteria Curve for Monitoring Site 1424

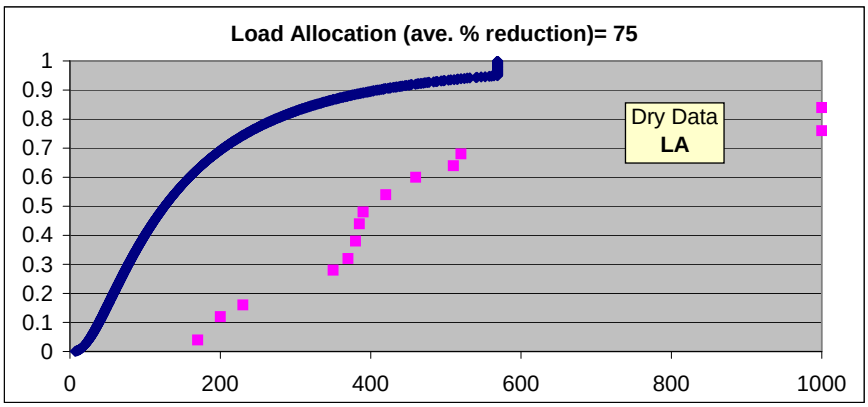
y axis = cumulative frequency; x axis = *E.coli* (col/100mL)



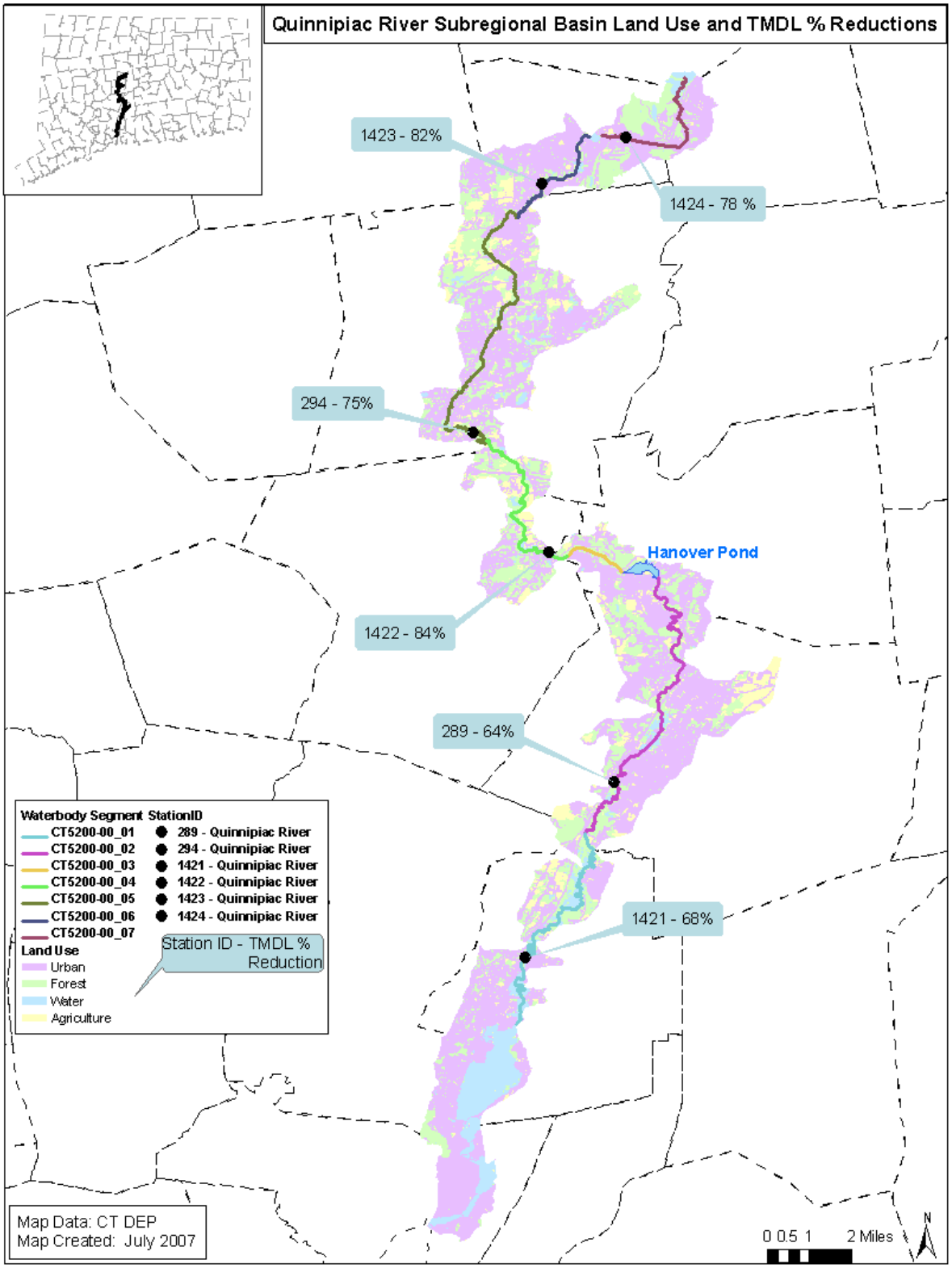
TMDL needed from current condition (magenta squares) to meet criteria (blue line). Current condition based on dry and wet weather data.



Waste Load Allocation (WLA) needed from current condition (magenta squares) to meet criteria (blue line). Current condition based on wet weather data.



Load Allocation (LA) needed from current condition (magenta squares) to meet criteria (blue line). Current condition based on dry weather data.


Quinnipiac River Subregional Basin Land Use and TMDL % Reductions
1423 - 82%
1424 - 78 %
294 - 75%
Hanover Pond
1422 - 84%
289 - 64%
1421 - 68%
Waterbody Segment StationID
CT5200-00_01
CT5200-00_02
CT5200-00_03
CT5200-00_04
CT5200-00_05
CT5200-00_06
CT5200-00_07
289 - Quinnipiac River
294 - Quinnipiac River
1421 - Quinnipiac River
1422 - Quinnipiac River
1423 - Quinnipiac River
1424 - Quinnipiac River
Land Use
Urban
Forest
Water
Agriculture
Station ID - TMDL % Reduction
Map Data: CT DEP
Map Created: July 2007
0 0.5 1 2 Miles
N

Appendix A-2
Harbor Brook
Waterbody specific information

Impaired Waterbody
Waterbody Name: Harbor Brook
Waterbody Segment IDs: CT5206-00_01, CT5206-00_02
Waterbody Segment Description: From mouth at confluence with Quinnipiac River upstream to exit of box culvert, Meriden.

Impairment Description:
Designated Use Impairment: Recreation
Size of Impaired Segments: 2.42 linear miles
Surface Water Classification: Class B

Watershed Description:
Drainage Basin Area: 12.12 square miles
Tributary To: Quinnipiac River
Subregional Basin Name & Code: Harbor Brook, 5206
Regional Basin: Quinnipiac River
Major Basin: South Central Coast
Watershed Towns: Berlin**,** Meriden, Middlefield, Middletown, Wallingford
Phase II GP applicable? Berlin - yes**,** Meriden - yes, Middlefield - yes, Middletown – yes, Wallingford - yes
Applicable Season: Recreation Season (May 1 to September 30)

Landuse:

Land Use Category	Percent Composition
Forested	22.9%
Urban/Developed	63.2%
Water/Wetland	5.6%
Agriculture	8.3%

Data Source: Connecticut Land Use Land Cover Data Layer LANDSTAT (2002) Thematic Mapper Satellite Imagery.

Appendix A-2
Harbor Brook
TMDL Summary

The TMDL analysis for Harbor Brook was conducted at one site, which is representative of two waterbody segments. Current data is unavailable to conduct a TMDL analysis for segment CT5206-00_02 in Harbor Brook. However, this small segment (1/4 linear mile) is located adjacent to a segment that requires reductions. Therefore, it is reasonable to presume that the same percent reduction applies to this segment. In addition segment CT5206-00_02 is channelized and travels underneath the City of Meriden. A study* conducted under a Clean Water Act Section 319 grant indicated that there are likely illicit discharges to the storm sewers and failed sanitary infrastructure in this underground section that contribute to the impairment in the waterbody segment downstream (CT5206-00_01). The TMDL analysis indicates that the sites are influenced by sources of bacteria active under both wet weather and dry weather conditions. Reductions in the Waste Load Allocation can be achieved through the detection and elimination of illicit discharges to the storm sewers or directly to the brook and the upgrade of failed sanitary infrastructure, as well as, the installation of engineered controls to reduce the surge of stormwater to the brook, promote groundwater recharge, and improve water quality. Since illicit discharges and failed sanitary collection systems may also be active under dry conditions, it is likely that corrective actions aimed at eliminating these sources will also reduce the Load Allocation (LA). Other contributors to the LA include as domestic animal waste, wildlife, and stormwater input as sheet flow.

* Anisfeld, Shimon, 2004. *Quinnipiac Watershed Bacterial Contamination Assessment*. Section 319 Project #00-20e.

Harbor Brook-01

CT5206-00_01

Data Used in the Analysis

Monitoring Site: 101, From mouth at Quinnipiac R. US to exit of box culvert, Meriden.

Date	Precip.(in)[1]			Condition[2]	E. coli	Rank	Proportion	Criteria	%
	24h	48h	96h	(WET/DRY)	(col./100 ml)			Value	Reduction
6/10/04	0.09	0.09	0.09	DRY	1900	7.5	0.3261	83	96
6/16/04	0.00	0.00	0.18	DRY	1800	5.0	0.2174	61	97
6/23/04	0.00	0.03	0.03	DRY	2900	13.5	0.5870	154	95
6/30/04	0.00	0.19	0.19	DRY	5200	18.0	0.7826	259	95
7/8/04	0.01	0.01	1.03	DRY	3100	15.0	0.6522	181	94
7/28/04	1.30	1.33	1.33	**WET**	7700	20.0	0.8696	355	95
8/4/04	0.00	0.00	0.66	DRY	3900	17.0	0.7391	227	94
8/5/04	0.19	0.19	0.19	**WET**	5800	19.0	0.8261	299	95
8/11/04	0.13	0.13	0.13	**WET**	2900	13.5	0.5870	154	95
8/17/04	0.45	0.49	1.55	**WET**	1200	2.5	0.1087	40	97
8/18/04	0.01	0.46	1.55	**WET**	1700	4.0	0.1739	53	97
8/25/04	0.01	0.01	1.08	DRY	1200	2.5	0.1087	40	97
9/1/04	0.00	0.01	0.02	DRY	2200	11.0	0.4783	120	95
9/8/04	0.73	0.74	0.74	**WET**	16000	23.0	1.0000	576	96
9/9/04	0.71	1.44	1.45	**WET**	8200	21.0	0.9130	441	95
9/16/04	0.17	0.17	0.18	**WET**	3400	16.0	0.6957	202	94
9/20/04	0.00	1.81	1.82	**WET**	1900	7.5	0.3261	83	96
9/22/04	0.00	0.00	1.81	DRY	2800	12.0	0.5217	132	95
9/27/04	0.01	0.03	0.04	DRY	515	1.0	0.0435	26	95
8/2/05	0.00	0.00	0.00	DRY	1900	7.5	0.3261	83	96
8/10/05	0.00	0.00	0.00	DRY	2000	10.0	0.4348	108	95
8/15/05	0.11	0.11	0.11	**WET**	13000	22.0	0.9565	576	96
9/7/05	0.01	0.01	0.01	DRY	1900	7.5	0.3261	83	96

Statistics

# Samples DRY	**13**
# Samples WET	**10**
# Samples Total	**23**
Geomean	**2918**
Log std deviation	**0.3480**

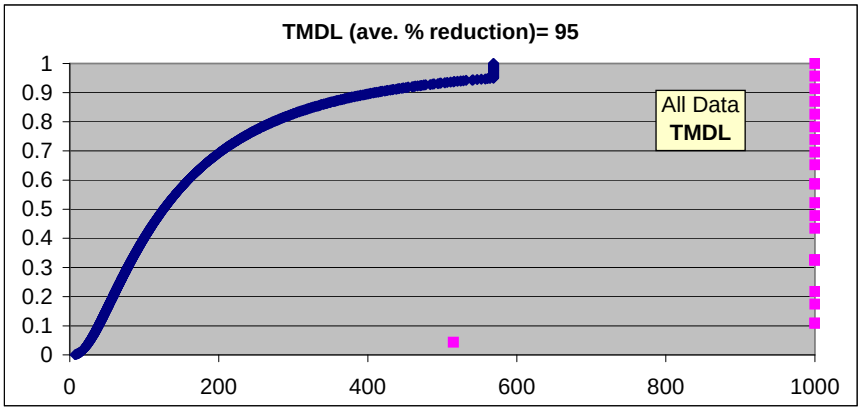
Avg % Reduction

Wet (WLA)	**95**
Dry (LA)	**95**
Total (TMDL)	**95**

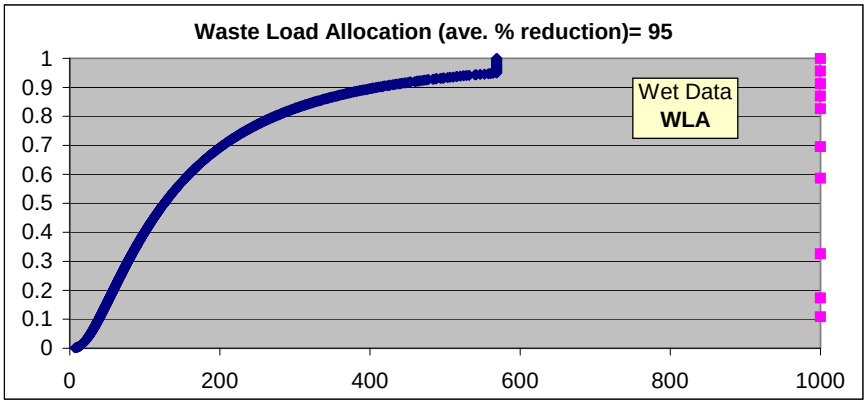
Precipitation and E. coli data provided by NOAA and CT DEP, respectively.
WET Condition defined as greater than 0.1" precipitation in 24 hours or 0.25" precipitation in 48 hours, or 2.0" precipitation in 96 hours.

Harbor Brook-01 Criteria Curve for Monitoring Site 101

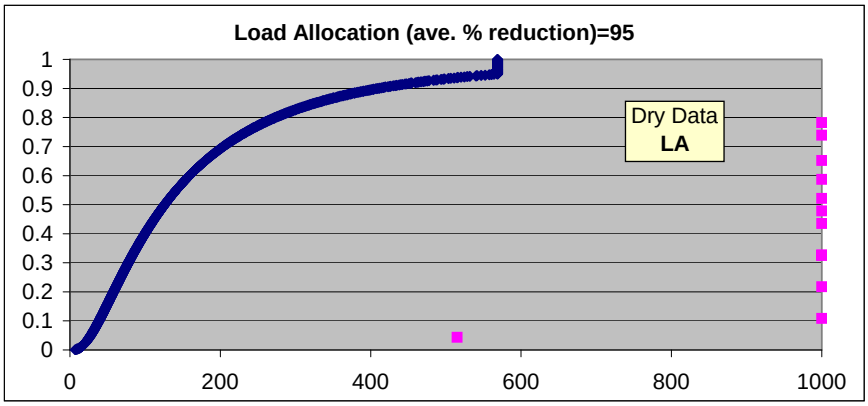
y axis = cumulative frequency; x axis = *E.coli* (col/100mL)



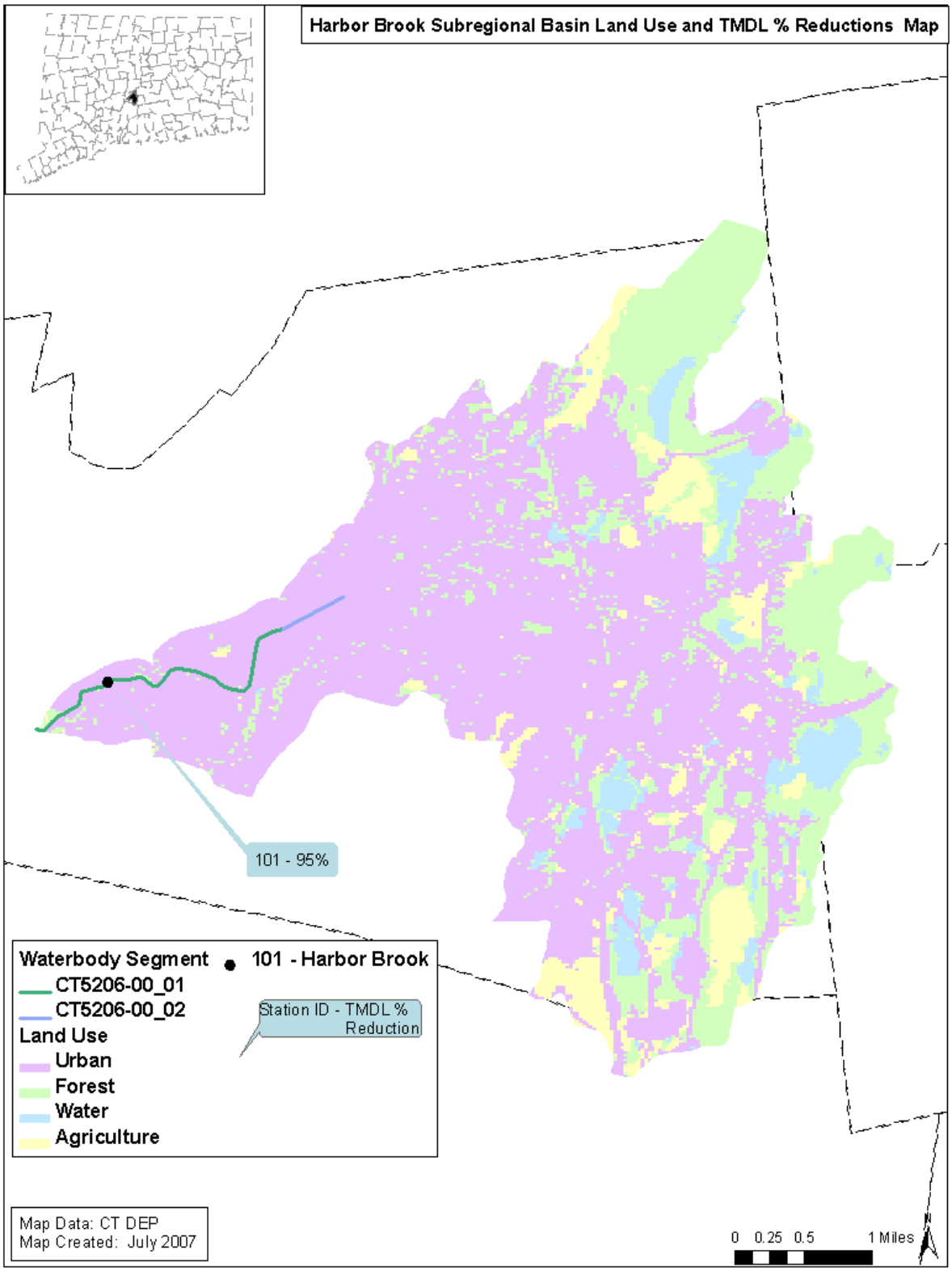
TMDL needed from current condition (magenta squares) to meet criteria (blue line). Current condition based on dry and wet weather data.



Waste Load Allocation (WLA) needed from current condition (magenta squares) to meet criteria (blue line). Current condition based on wet weather data.



Load Allocation (LA) needed from current condition (magenta squares) to meet criteria (blue line). Current condition based on dry weather data.


Harbor Brook Subregional Basin Land Use and TMDL % Reductions Map
101 - 95%
Waterbody Segment
CT5206-00_01
CT5206-00_02
Land Use
Urban
Forest
Water
Agriculture
101 - Harbor Brook
Station ID - TMDL % Reduction
Map Data: CT DEP
Map Created: July 2007
0 0.25 0.5 1 Miles

Appendix A-3
Misery Brook
Waterbody specific information

Impaired Waterbody
Waterbody Name: Misery Brook
Waterbody Segment IDs: CT5203-00_01
Waterbody Segment Description: From mouth at Quinnipiac River upstream to Slopers Pond outlet dam, Southington.

Impairment Description:
Designated Use Impairment: Recreation
Size of Impaired Segments: 4.23 linear miles
Surface Water Classification: Class A

Watershed Description:
Drainage Basin Area: 6.25 square miles
Tributary To: Quinnipiac River
Subregional Basin Name & Code: Misery Brook, 5203
Regional Basin: Quinnipiac River
Major Basin: South Central Coast
Watershed Towns: Berlin, Meriden, Southington
Phase II GP applicable? Berlin – yes, Meriden – yes, Southington - yes
Applicable Season: Recreation Season (May 1 to September 30)
Landuse:

Land Use Category	Percent Composition
Forested	39%
Urban/Developed	45.2%
Water/Wetland	6.4%
Agriculture	9.4%

Data Source: Connecticut Land Use Land Cover Data Layer LANDSTAT (2002) Thematic Mapper Satellite Imagery.

Appendix A-3
Misery Brook
TMDL Summary

The TMDL analysis for Misery Brook was conducted at one site, which is representative of one waterbody segment. The TMDL analysis indicates that the site is influenced by sources of bacteria active under both wet weather and dry weather conditions. The Waste Load Allocation (WLA) (74%) was higher than the Load Allocation (LA) (59%). This indicates that this waterbody segment is more strongly influenced by point source stormwater than nonpoint sources. Reduction in WLA can be achieved through the installation of engineered controls to reduce the surge of stormwater to the brook, promote groundwater recharge, and improve water quality, as well as, detection and elimination of illicit discharges to the storm sewers. Nonpoint sources, such as domestic animal waste and nuisance wildlife may contribute to the LA.

Misery Brook-01

CT5203-00_01

Data Used in the Analysis

Monitoring Site: 1417, From mouth at Quinnipiac R, US to Slopers Pond, Southington.

Date	Precip.(in)[1]			Condition[2]	E. coli	Rank	Proportion	Criteria	%
	24h	48h	96h	(WET/DRY)	(col./100 ml)			Value	Reduction
6/10/04	0.09	0.09	0.09	DRY	280	12.5	0.5208	132	53
6/16/04	0.00	0.00	0.18	DRY	200	6.0	0.2500	68	66
6/23/04	0.00	0.03	0.03	DRY	220	8.5	0.3542	89	59
6/30/04	0.00	0.19	0.19	DRY	230	10.5	0.4375	109	53
7/8/04	0.01	0.01	1.03	DRY	350	15.0	0.6250	169	52
7/14/04	0.10	0.43	0.46	**WET**	280	12.5	0.5208	132	53
7/21/04	0.00	0.01	0.14	DRY	230	10.5	0.4375	109	53
7/28/04	1.30	1.33	1.33	**WET**	4100	23.0	0.9583	576	86
8/4/04	0.00	0.00	0.66	DRY	380	16.0	0.6667	187	51
8/5/04	0.19	0.19	0.19	**WET**	1700	21.0	0.8750	363	79
8/11/04	0.13	0.13	0.13	**WET**	200	6.0	0.2500	68	66
8/17/04	0.45	0.49	1.55	**WET**	460	18.0	0.7500	235	49
8/18/04	0.01	0.46	1.55	**WET**	150	1.0	0.0417	26	83
8/25/04	0.01	0.01	1.08	DRY	170	4.0	0.1667	52	70
9/1/04	0.00	0.01	0.02	DRY	560	19.0	0.7917	266	52
9/8/04	0.73	0.74	0.74	**WET**	9200	24.0	1.0000	576	94
9/9/04	0.71	1.44	1.45	**WET**	3300	22.0	0.9167	450	86
9/16/04	0.17	0.17	0.18	**WET**	220	8.5	0.3542	89	59
9/20/04	0.00	1.81	1.82	**WET**	1600	20.0	0.8333	307	81
9/22/04	0.00	0.00	1.81	DRY	430	17.0	0.7083	209	51
9/27/04	0.01	0.03	0.04	DRY	160	2.5	0.1042	40	75
8/2/05	0.00	0.00	0.00	DRY	160	2.5	0.1042	40	75
8/10/05	0.00	0.00	0.00	DRY	200	6.0	0.2500	68	66
9/7/05	0.01	0.01	0.01	DRY	290	14.0	0.5833	153	47

Statistics

# Samples DRY	**14**
# Samples WET	**10**
# Samples Total	**24**
Geomean	**429**
Log std deviation	**0.4981**

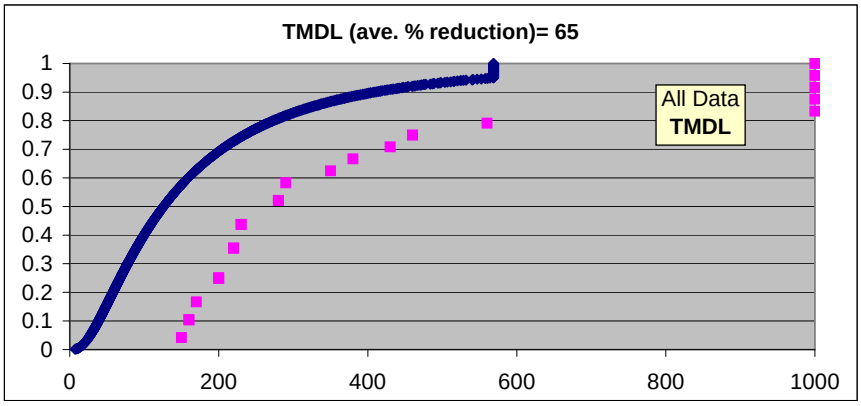
Avg % Reduction

Wet (WLA)	**74**
Dry (LA)	**59**
Total (TMDL)	**65**

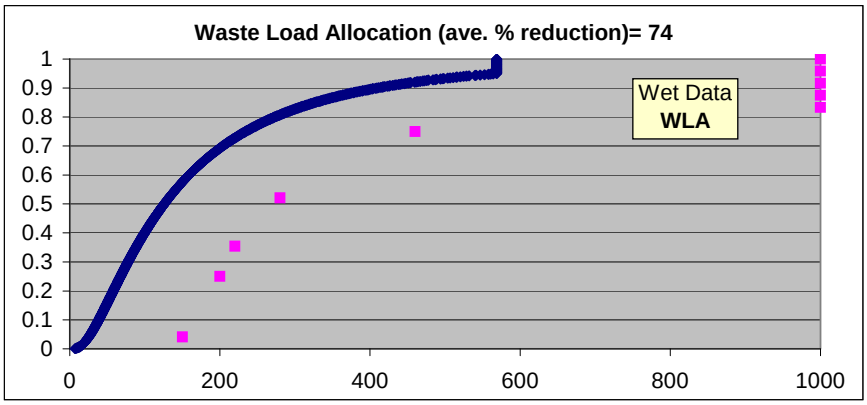
Precipitation and E. coli data provided by NOAA and CT DEP, respectively.
WET Condition defined as greater than 0.1" precipitation in 24 hours or 0.25" precipitation in 48 hours, or 2.0" precipitation in 96 hours.

Misery Brook-01 Criteria Curve for Monitoring Site 1417

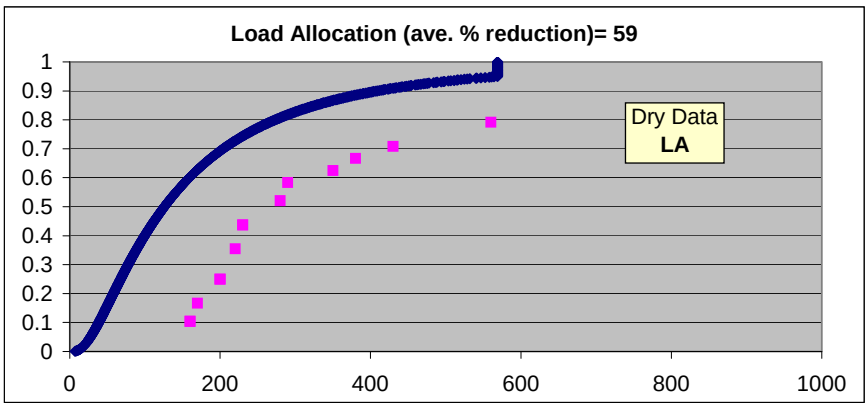
y axis = cumulative frequency; x axis = *E.coli* (col/100mL)



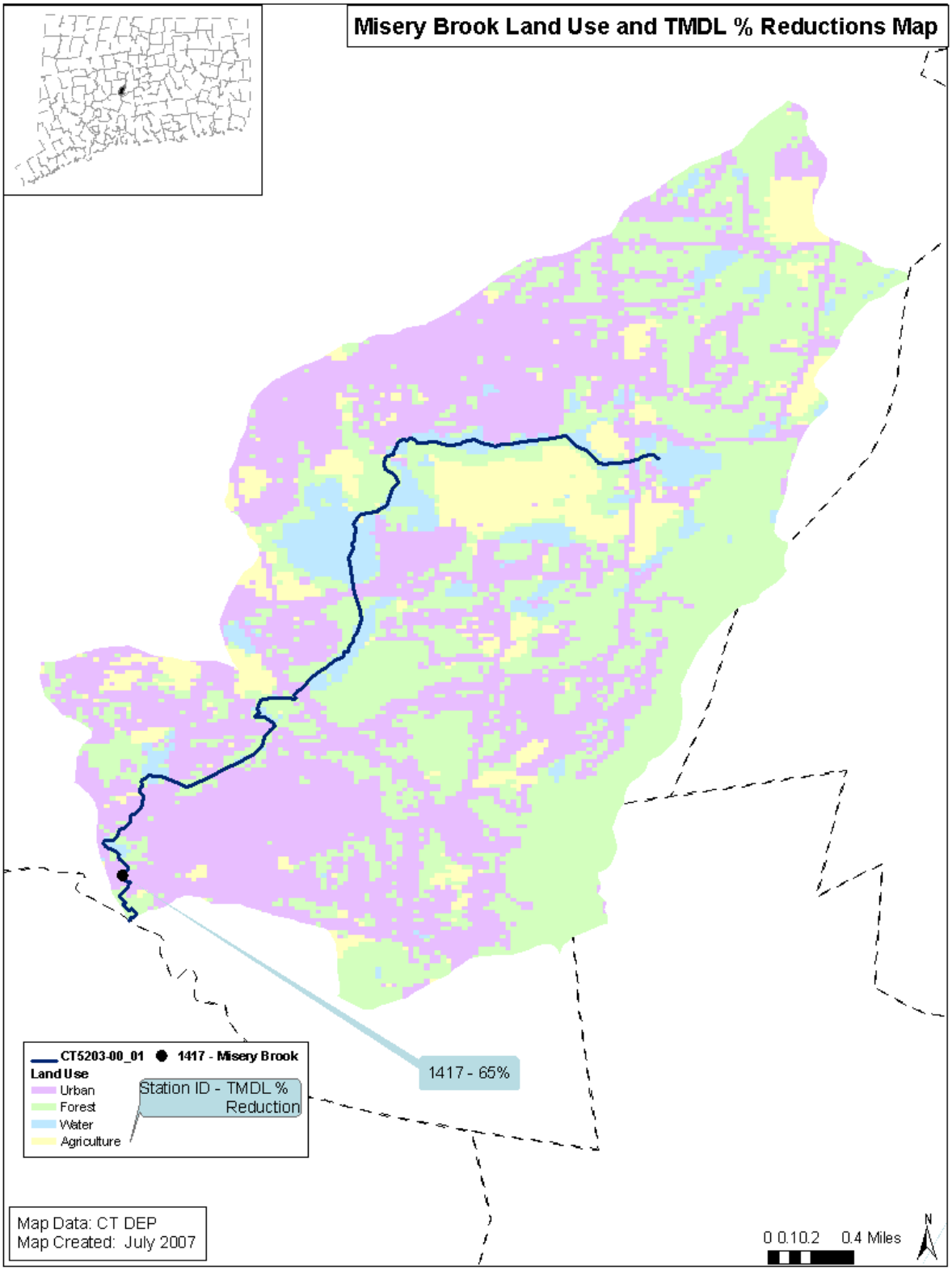
TMDL needed from current condition (magenta squares) to meet criteria (blue line). Current condition based on dry and wet weather data.



Waste Load Allocation (WLA) needed from current condition (magenta squares) to meet criteria (blue line). Current condition based on wet weather data.



Load Allocation (LA) needed from current condition (magenta squares) to meet criteria (blue line). Current condition based on dry weather data.


Misery Brook Land Use and TMDL % Reductions Map
CT5203-00_01
1417 - Misery Brook
Land Use
Urban
Forest
Water
Agriculture
Station ID - TMDL % Reduction
1417 - 65%
Map Data: CT DEP
Map Created: July 2007
0 0.10.2 0.4 Miles
N

Appendix A-4
Sodom Brook
Waterbody specific information

Impaired Waterbody
Waterbody Name: Sodom Brook
Waterbody Segment ID: CT5205-00_01
Waterbody Segment Description: From mouth at confluence with Quinnipiac River upstream to headwaters, Meriden.

Impairment Description:
Designated Use Impairment: Recreation
Size of Impaired Segment: 4.16 linear miles
Surface Water Classification: Class B

Watershed Description:
Total Regional Drainage Basin Area: 5.28 square miles
Tributary To: Quinnipiac River
Subregional Basin Name & Code: Sodom Brook, 5205
Regional Basin: Quinnipiac River
Major Basin: South Central Coast
Watershed Towns: Berlin, Meriden, Southington
Phase II GP applicable? Berlin – yes, Meriden – yes, Southington - yes
Applicable Season: Recreation Season (May 1 to September 30)
Landuse:

Land Use Category	Percent Composition
Forested	38.8%
Urban/Developed	52.3%
Water/Wetland	2.5%
Agriculture	6.4%

Data Source: Connecticut Land Use Land Cover Data Layer LANDSTAT (2002) Thematic Mapper Satellite Imagery.

Appendix A-4
Sodom Brook
TMDL Summary

This TMDL analysis for Sodom Brook was conducted at one site, which is representative of one waterbody segment. The analysis indicates that the sites are influenced by sources of bacteria active under both wet weather and dry weather conditions. The Waste Load Allocation is applicable to regulated stormwater. Reduction is the WLA can be achieved through detection and elimination of illicit discharges to the storm sewer, as well as, the installation of engineered controls to reduce the surge of stormwater to the brook, promote groundwater recharge, and improve water quality. Nonpoint sources, such as domestic animal waste and wildlife, may contribute to the Load Allocation.

Sodom Brook-01

CT5205-00_01

Data Used in the Analysis

Monitoring Site: 1418, From confluence with Quinnipiac R, US to headwaters.

Date	Precip.(in)[1]			Condition[2]	E. coli	Rank	Proportion	Criteria	%
	24h	48h	96h	(WET/DRY)	(col./100 ml)			Value	Reduction
6/10/04	0.09	0.09	0.09	DRY	1200	8.0	0.3200	82	93
6/16/04	0.00	0.00	0.18	DRY	1500	14.0	0.5600	145	90
6/23/04	0.00	0.03	0.03	DRY	910	4.5	0.1800	54	94
6/30/04	0.00	0.19	0.19	DRY	1900	17.5	0.7000	204	89
7/8/04	0.01	0.01	1.03	DRY	1400	12.0	0.4800	120	91
7/14/04	0.10	0.43	0.46	**WET**	1900	17.5	0.7000	204	89
7/21/04	0.00	0.01	0.14	DRY	1400	12.0	0.4800	120	91
7/28/04	1.30	1.33	1.33	**WET**	5500	23.0	0.9200	460	92
8/4/04	0.00	0.00	0.66	DRY	1700	15.0	0.6000	159	91
8/5/04	0.19	0.19	0.19	**WET**	4100	22.0	0.8800	372	91
8/11/04	0.13	0.13	0.13	**WET**	2000	20.0	0.8000	274	86
8/17/04	0.45	0.49	1.55	**WET**	1400	12.0	0.4800	120	91
8/18/04	0.01	0.46	1.55	**WET**	790	3.0	0.1200	43	95
8/25/04	0.01	0.01	1.08	DRY	1300	9.5	0.3800	95	93
9/1/04	0.00	0.01	0.02	DRY	1300	9.5	0.3800	95	93
9/8/04	0.73	0.74	0.74	**WET**	17000	25.0	1.0000	576	97
9/9/04	0.71	1.44	1.45	**WET**	3700	21.0	0.8400	315	91
9/16/04	0.17	0.17	0.18	**WET**	1100	7.0	0.2800	74	93
9/20/04	0.00	1.81	1.82	**WET**	1000	6.0	0.2400	66	93
9/22/04	0.00	0.00	1.81	DRY	370	2.0	0.0800	35	91
9/27/04	0.01	0.03	0.04	DRY	230	1.0	0.0400	25	89
8/2/05	0.00	0.00	0.00	DRY	910	4.5	0.1800	54	94
8/10/05	0.00	0.00	0.00	DRY	1900	17.5	0.7000	204	89
8/15/05	0.11	0.11	0.11	**WET**	7700	24.0	0.9600	576	93
9/7/05	0.01	0.01	0.01	DRY	1900	17.5	0.7000	204	89

Statistics

# Samples DRY	**14**
# Samples WET	**11**
# Samples Total	**25**
Geomean	**1643**
Log std deviation	**0.3859**

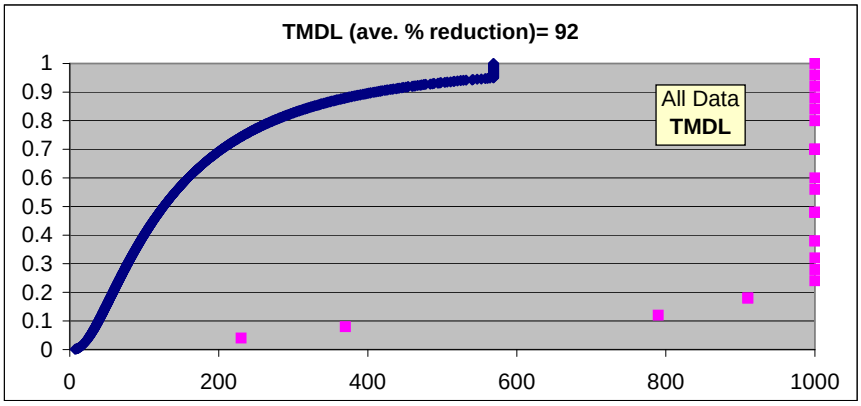
Avg % Reduction

Wet (WLA)	**92**
Dry (LA)	**91**
Total (TMDL)	**92**

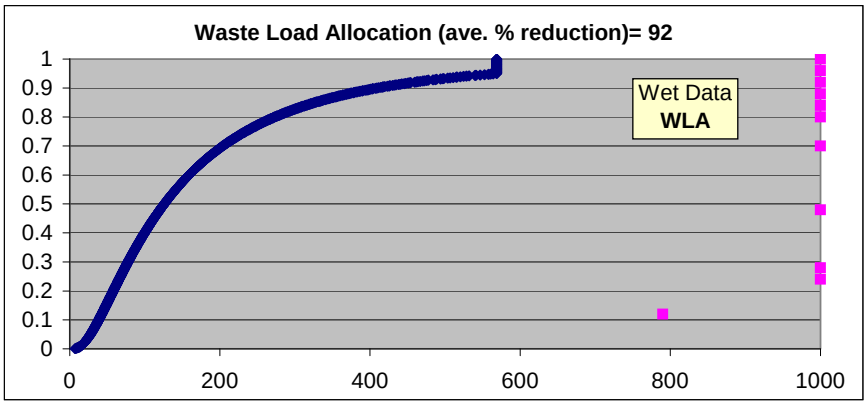
Precipitation and E. coli data provided by NOAA and CT DEP, respectively.
WET Condition defined as greater than 0.1" precipitation in 24 hours or 0.25" precipitation in 48 hours, or 2.0" precipitation in 96 hours.

Sodom Brook-01 Criteria Curve for Monitoring Site 1418

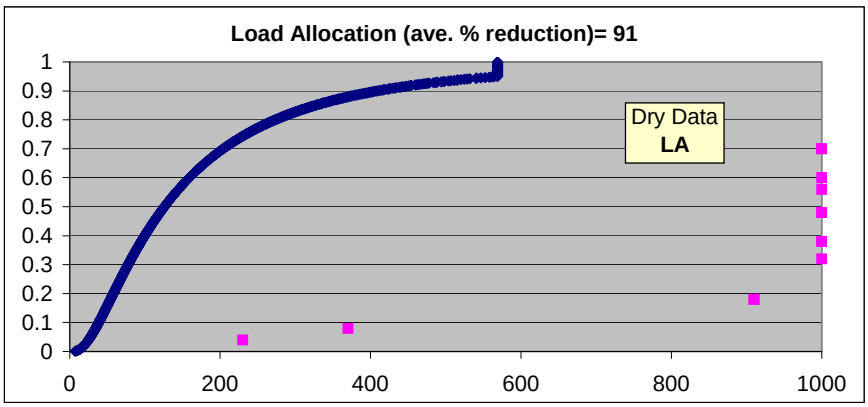
y axis = cumulative frequency; x axis = *E.coli* (col/100mL)



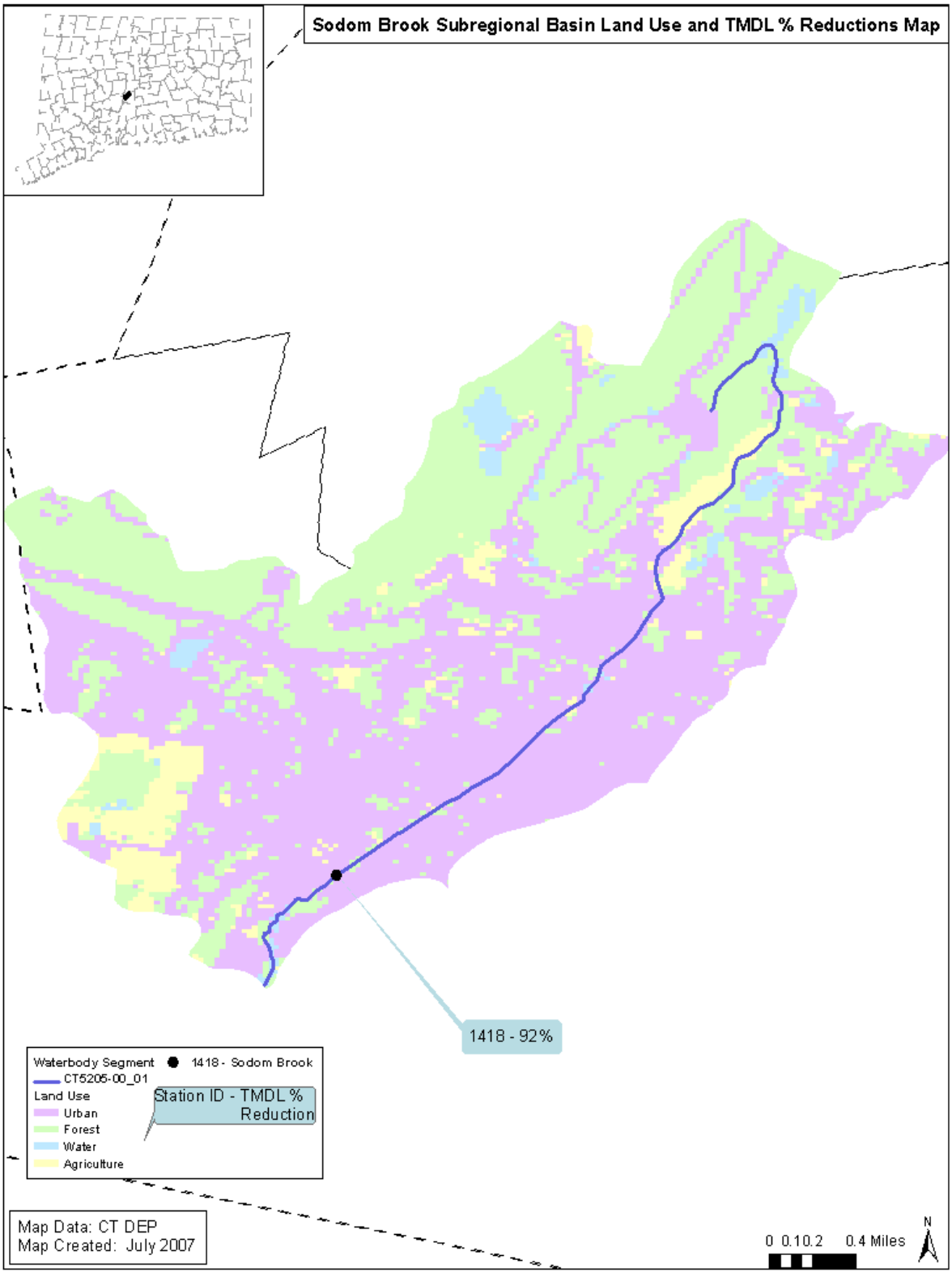
TMDL needed from current condition (magenta squares) to meet criteria (blue line). Current condition based on dry and wet weather data.



Waste Load Allocation (WLA) needed from current condition (magenta squares) to meet criteria (blue line). Current condition based on wet weather data.



Load Allocation (LA) needed from current condition (magenta squares) to meet criteria (blue line). Current condition based on dry weather data.


Sodom Brook Subregional Basin Land Use and TMDL % Reductions Map
1418 - 92%
Waterbody Segment
1418 - Sodom Brook
CT5205-00_01
Land Use
Urban
Forest
Water
Agriculture
Station ID - TMDL % Reduction
Map Data: CT DEP
Map Created: July 2007
0 0.10.2 0.4 Miles
N

Appendix B
Technical Support Document for the Cumulative Distribution Function Method

DEVELOPMENT OF TOTAL MAXIMUM DAILY LOADS (TMDLs) FOR INDICATOR BACTERIA IN CONTACT RECREATION AREAS USING THE CUMULATIVE FREQUENCY DISTRIBUTION FUNCTION METHOD

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Mary E. Becker, Environmental Analyst
CT Department of Environmental Protection
Total Maximum Daily Load Program

Last revised: November 8, 2005

OVERVIEW OF APPROACH

The analytical methodology presented in this document provides a defensible scientific and technical basis for establishing TMDLs to address recreational use impairments in surface waters. Representative ambient water quality monitoring data for a minimum of 21 sampling dates during the recreational season (May 1 – September 31) is required for the analysis. The reduction in bacteria density from current levels needed to achieve consistency with the criteria is quantified by calculating the difference between the cumulative relative frequency of the sample data set and the criteria adopted by Connecticut to support recreational use. Connecticut's adopted water quality criteria for indicator bacteria (*Escherichia coli*) are represented by a statistical distribution of the geometric mean 126 and log standard deviation 0.4 for purposes of the TMDL calculations.

TMDLs developed using this approach are expressed as the average percentage reduction from current conditions required to achieve consistency with criteria. The procedure partitions the TMDL into wet weather allocation and dry weather allocation components by quantifying the contribution of ambient monitoring data collected during periods of high stormwater influence and minimal stormwater influence to the current condition. The partition is used to determine the effect of high stormwater influence on the contribution of sources to the waterbody. TMDLs developed using this analytical approach provide an ambient monitoring benchmark ideally suited for quantifying progress in achieving water quality goals as a result of TMDL implementation.

APPLICABILITY

The methodology is intended solely for use in developing TMDLs for waters that are identified as impaired on the *List of Connecticut Water Bodies Not Meeting Water Quality Standards* [1]. It is expected that implementation of these TMDLs will be accomplished through implementing the provisions of the Small Municipal Separate Storm Sewer System general permit (MS4 permit) [2] in designated urban areas, as well as through measures that address non-point sources. The method as described here is not intended for use as an assessment tool for purposes of identifying use attainment status relative to listing or delisting of waterbody segments pursuant to Section 303(d) of the federal Clean Water Act. Assessment of use support is performed in accordance with the Department's guidance document, *Connecticut Consolidated Assessment and Listing Methodology (CT-CALM)* [3].

BACKGROUND

TMDLs are established by the State in accordance with the requirements established in the federal Clean Water Act. Section 303(d) of the Act requires the State to perform an assessment of waters within the State relative to their ability to support designated uses including recreational use. The procedure used by the Department to assess use attainment is described in the guidance document, *CT-CALM* [3]. The list of waterbody segments in Connecticut that do not currently support recreational use is updated to incorporate the most recent monitoring information by the Department every two years. As a result of this process, waterbodies may be added to or deleted from the list of impaired waters in accordance with the *CT-CALM* guidance. Once complete, the list is submitted to the Regional office of the federal EPA for approval. Section 303(d) of the Act requires the State to establish TMDLs for each pollutant contributing to the impairment of each waterbody segment identified on the list.

WATER QUALITY CRITERIA FOR INDICATOR BACTERIA

Connecticut's adopted water quality criteria for the indicator bacteria *Escherichia coli (E.coli)* in the CT Water Quality Standards [4] include a geometric mean and upper confidence limit (i.e. single sample maximum), which are based on three recreational use categories. The categories include designated swimming, non-designated swimming, and all other recreational uses. 'Designated swimming' includes areas that have been designated by State or Local authorities. 'Non-designated swimming' includes waters suitable for swimming but have not been designated by State or Local authorities, as well as water that support recreational activities where full body contact is likely, such as tubing or water skiing. 'All other recreational uses' include waters that support recreational activities where full body contact is infrequent, such as fishing, boating, kayaking, and wading. The recreational uses and applicable criteria are provided in the following table.

Recreational Use Category	Indicator Bacteria	Geometric Mean	Single Sample Maximum Upper Confidence Limit
Designated Swimming	*E.coli*	126col/100mls	256col/100mls 75th Percentile
Non-designated Swimming			410col/100mls 90th Percentile
All Other Recreational Uses			576col/100mls 95th Percentile

Table 1. Applicable indicator bacteria (*E.coli*) water quality criteria for recreational uses

The indicator bacteria, *E. coli*, is not pathogenic, rather its presence in water is an indicator of contamination with fecal material that may also contribute pathogenic organisms. Connecticut's criteria are based on federal guidance [5]. In this guidance, the basis for the criteria and the relationship between the geometric mean criterion and the single sample maximum criterion is explained in detail.

The geometric mean criterion was derived by EPA scientists from epidemiological studies at beaches where the incidence of swimming related health effects (gastrointestinal illness rate) could be correlated with indicator bacteria densities. EPA's recommended criteria reflect an average illness rate of 8 illnesses per 1000 swimmers exposed. This condition was predicted to exist based on studies cited in the federal guidance when the steady-state geometric mean density of *E. coli* was 126 col/100ml. The distribution of individual sample results around the geometric mean is such that approximately half of all individual samples are expected to exceed the geometric mean and half will be below the geometric mean.

EPA also derived a single sample maximum criterion from this same database to support decisions by public health officials regarding the closure of beaches when an elevated risk of illness exists. Because approximately half of all individual sample results for a beach where the risk of illness is considered "acceptable" are expected to exceed the geometric mean criteria of 126 col/100ml, an upper boundary to the range of individual sample results was statistically derived that will be exceeded at frequencies less than 50% based on the variability of sample data. The mean log standard deviation for *E. coli* densities at the freshwater beach sites studied by EPA was 0.4. The single sample maximum criterion of 235 col/100mls, 410 col/100mls, and 576 col/100mls adopted by Connecticut represents the 75^{th}, 90^{th}, and 95^{th} percentile upper confidence limit, respectively, for a statistical distribution of data with a geometric mean of 126 and a log standard deviation of 0.4 as recommended by EPA [5].

Consistent with the State's disinfection policy (Water Quality Standard #23), the critical period for application of the indicator bacteria criteria is the recreational season, defined as May 1 through September 30. For waters that do not receive point discharges of treated sewage subject to the disinfection policy, a review of ambient monitoring data contained in the State's Ambient Monitoring Database [6] confirms that bacteria densities are typically highest during the summer months. Consistency with criteria during the summer is indicative of consistency at all times of the year. Lower densities reported during other portions of the year are most likely a result of several environmental factors including more rapid die-off of enteric bacteria in colder temperatures and reduced loadings from wildlife and domestic animal populations. Further, human exposure to potentially contaminated water is greatly reduced during the colder months, particularly exposure that results from immersion in the water since cold temperatures discourage participation in recreational activities that typically involve immersion.

Connecticut's adopted criteria are based on federal guidance and reflect an idealized distribution of bacteria monitoring data for sites studied by EPA that can be represented by statistical distribution with a geometric mean of 126 col/100ml and a log standard deviation of 0.4. The criteria can therefore be expressed as a cumulative frequency distribution or "criteria curve" as shown in figures 1a through1c for each of the specified recreational uses in Connecticut's bacteria criteria.

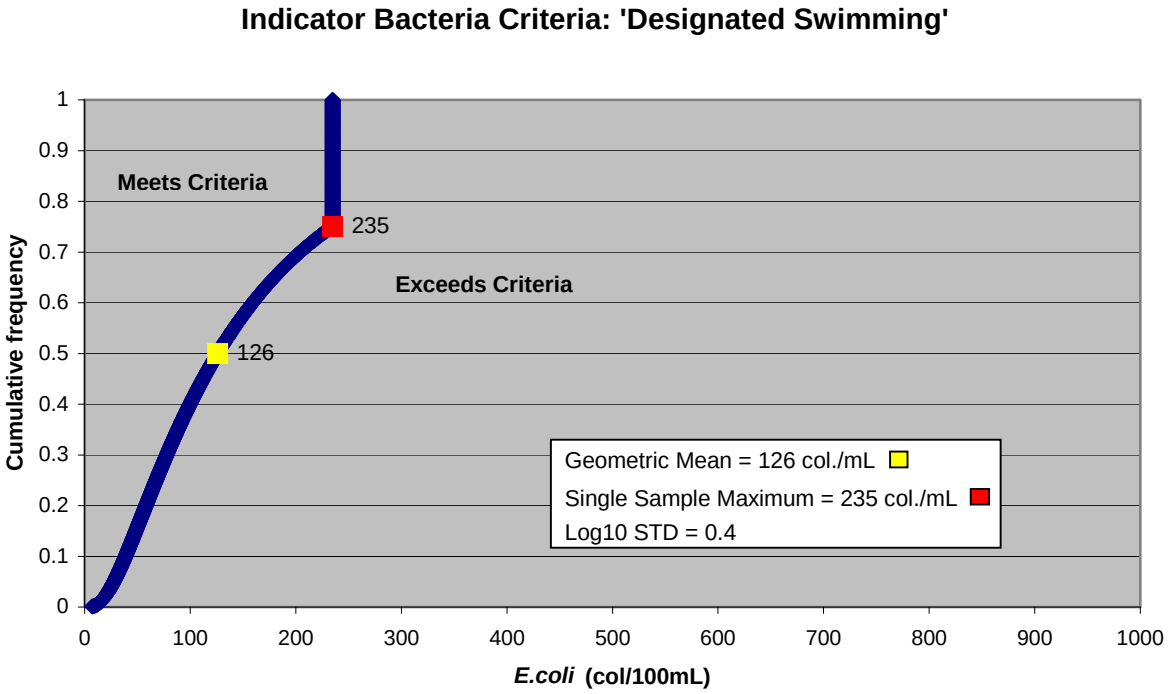

Figure 1a. Cumulative Relative Frequency Distribution representing water quality to support designated swimming use.

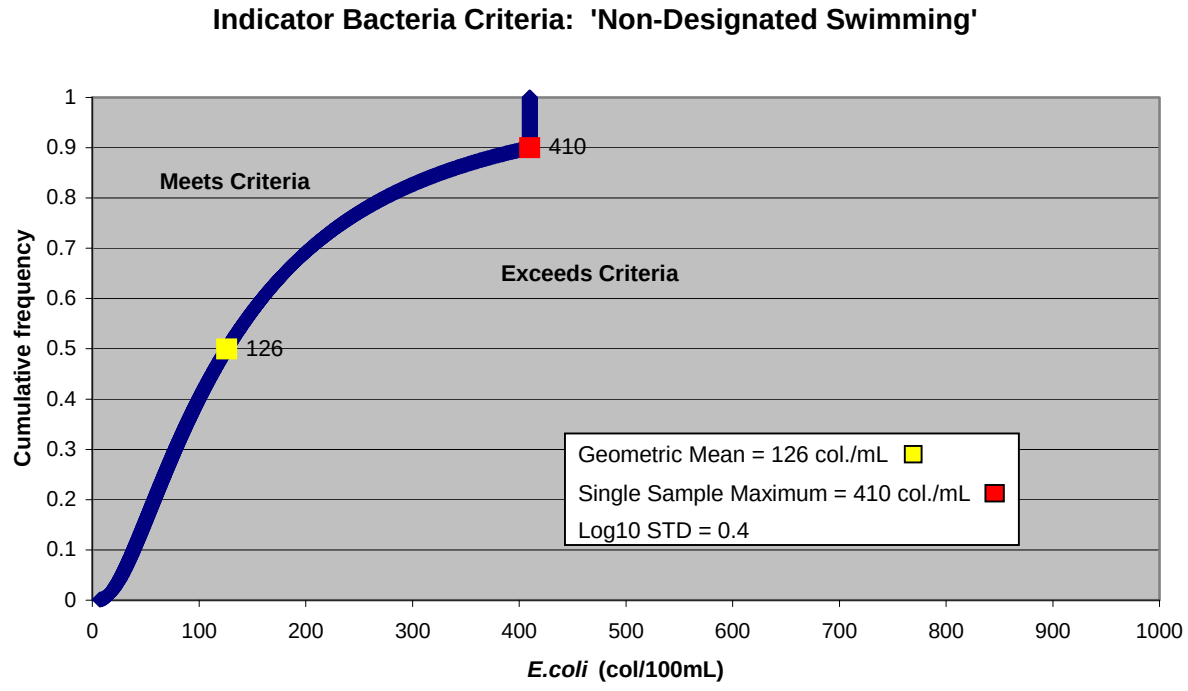

Figure 1b. Cumulative Relative Frequency Distribution representing water quality to support non-designated swimming use.

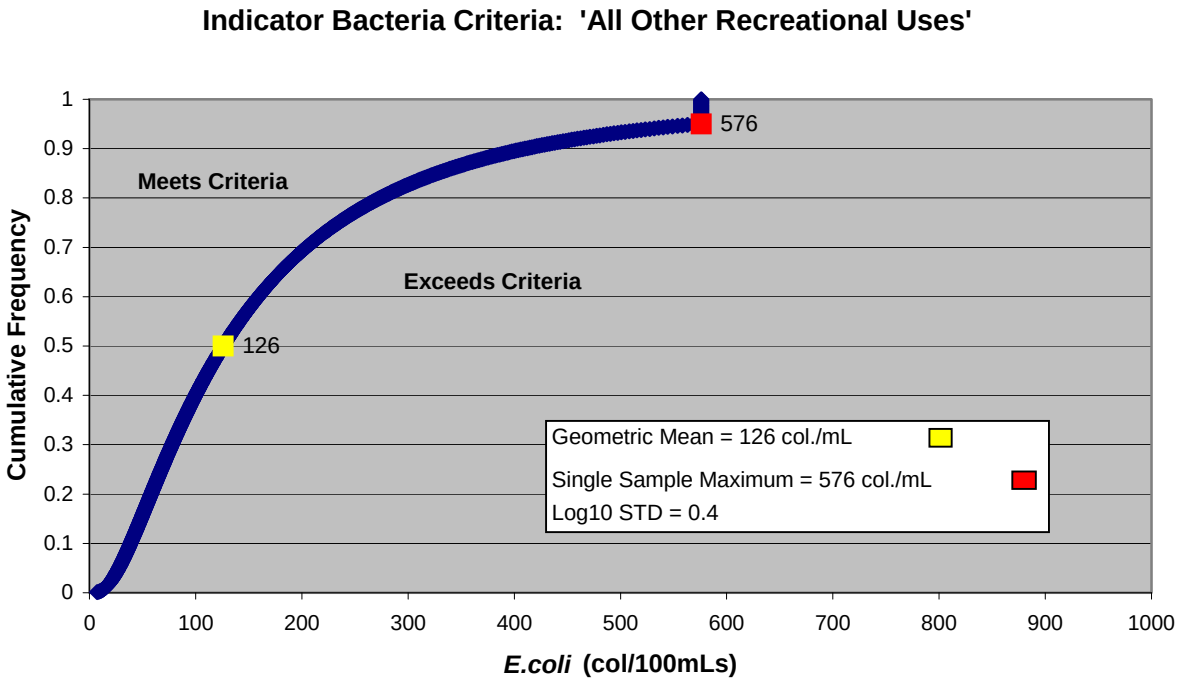

Figure 1c. Cumulative Relative Frequency Distribution representing water quality criteria to support all other recreational uses.

TMDL

As with the cumulative relative frequency curves representing the criteria shown in Figure 1a through 1c, a cumulative relative frequency curve can be prepared using site-specific sample data to represent current conditions at the TMDL monitoring site. The TMDL for the monitored segment is derived by quantifying the difference between these two distributions as shown conceptually in Figures 2a through 2c. This is accomplished by calculating the reduction required at representative points on the sample data cumulative frequency distribution curve and then averaging the reduction needed across the entire range of sampling data. This procedure allows the contribution of each individual sampling result to be considered when estimating the percent reduction needed to meet a criterion that is expressed as a geometric mean.

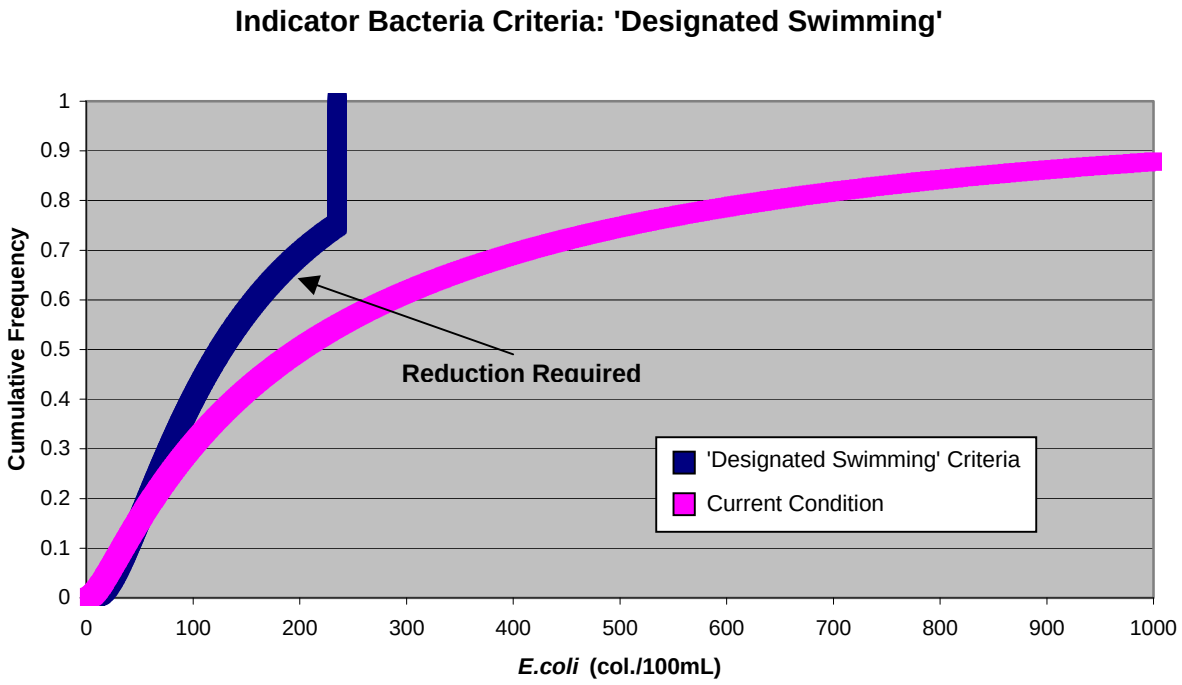

Figure 2a. Reduction indicator bacteria density needed from current condition to meet 'designated swimming' criteria based on cumulative relative frequency distribution.

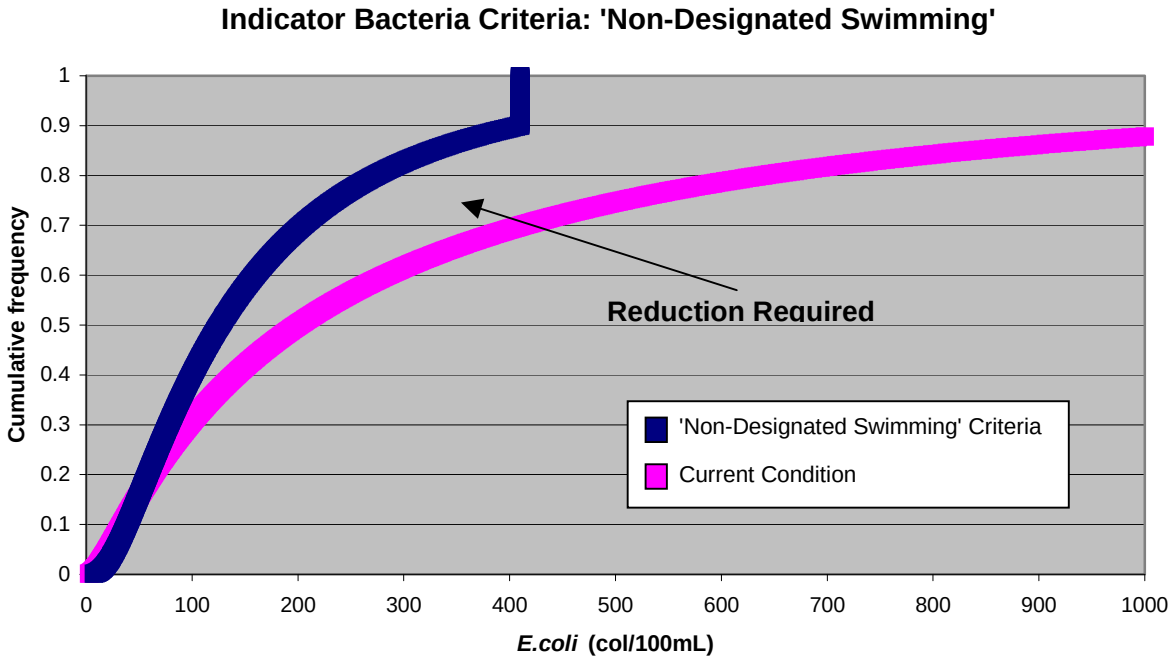

Figure 2b. Reduction indicator bacteria density needed from current condition to meet 'non-designated swimming' criteria based on cumulative relative frequency distribution.

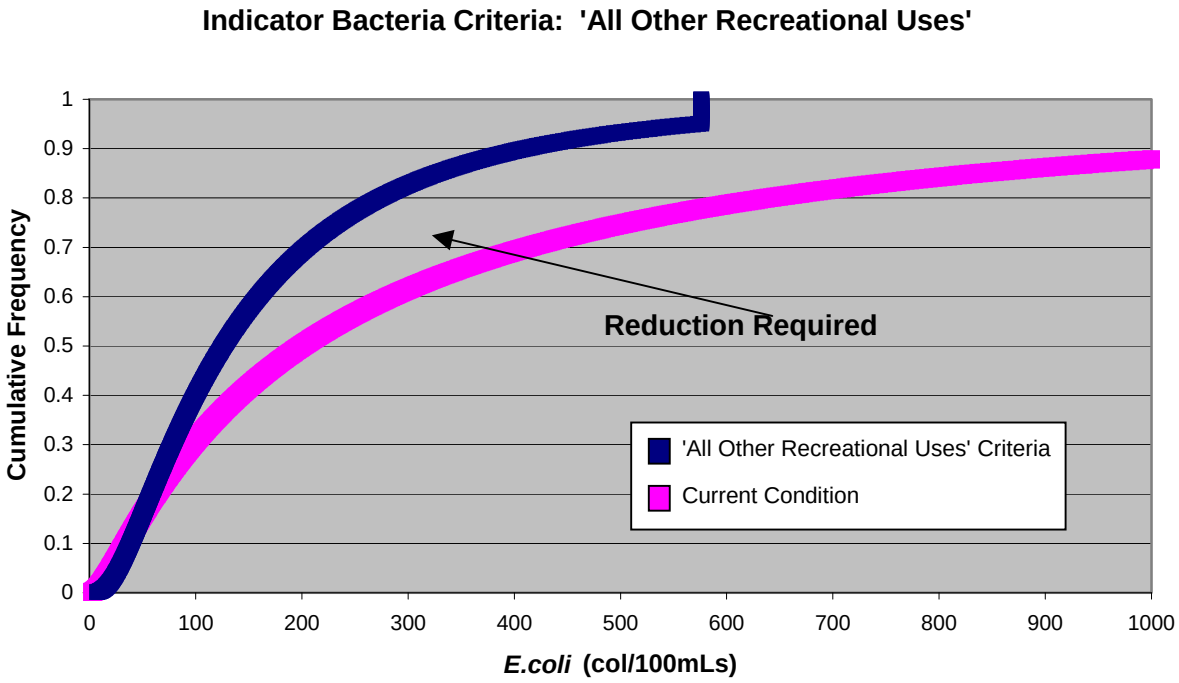

Figure 2c. Reduction indicator bacteria density needed from current condition to meet 'all other recreational uses' criteria based on cumulative relative frequency distribution.

TMDL ALLOCATIONS

Federal regulations require that the TMDL analysis identify the portion of the total loading which is allocated to point source discharges and the portion attributed to non-point sources, which contribute that pollutant to the waterbody. Stormwater runoff is considered a point source subject to regulation under the NPDES permitting program in designated urbanized areas. Designated urban areas, as defined by the US Census Bureau [7], are required to comply with the General Permit for the Discharge of Stormwater from Small Municipal Separate Storm Sewer Systems (MS4 permit). The general permit is applicable to municipalities that contain designated urban areas (or MS4 communities) and discharge stormwater via a separate storm sewer system to surface waters of the State. TMDLs for indicator bacteria in waters draining urbanized areas must therefore be partitioned into a WLA to accommodate point source stormwater loadings of indicator bacteria and a LA to accommodate non-point loadings from unregulated sources. One common characteristic of urbanized areas is the high percentage of impervious surface. Much of the impervious surface is directly connected to nearby surface waters through stormwater drainage systems. As a result, runoff is rapid following rain events and flow in urban streams is typically dominated by stormwater runoff during these periods. Monitoring results for samples collected under these conditions are strongly influenced by stormwater quality. During dry conditions, urban streams contain little stormwater since urban watersheds drain quickly and baseflows are reduced due to lower infiltration rates and reduced recharge of groundwater. At baseflow, urban stream water quality is dominated by non-point sources of indicator bacteria since stormwater outfalls are inactive.

A WLA for stormwater discharges is not warranted in non-designated urbanized areas and in waterbody segments where there are no stormwater outfalls. As such, sources of bacteria in these waterbodies segments are attributed solely to nonpoint sources. However, wet weather and dry weather percent reductions are partitioned in the LA analysis to demonstrate the effect of stormwater events on the contribution of nonpoint sources of bacteria to the waterbody.

The relative contribution of indicator bacteria loadings occurring during periods of high or low stormwater influence to the geometric mean indicator density is estimated by calculating separate averages of the reduction needed to achieve consistency with criteria under "wet" and "dry" conditions. In urbanized areas, the reduction needed under "wet" conditions is assigned to the WLA and the reduction needed under "dry" conditions is assigned to the LA. In non-designated urbanized areas, the LA is comprised of "wet" and "dry" conditions, which are partitioned into separate reduction goals. Separate reduction goals are established for baseflow and stormwater dominated periods that can assist local communities in selection of best management practices to improve water quality. The technique also facilitates the use of ambient stream monitoring data to track future progress in meeting water quality goals.

The sources contributing to the WLA and LA can be further subdivided depending on knowledge of sources present in the watershed (Table 2). Some existing sources such as dry weather flows from stormwater collections systems, illicit discharges to stormwater systems, and combined sewer overflows are allocated "100 percent reduction" since the management goal for these sources is elimination. Permitted discharges of treated and disinfected domestic wastewater (sewage treatment plants) are allocated "zero percent reduction" since disinfection required by the NPDES permit is sufficient to reduce indicator bacteria levels to below levels of concern. Natural sources such as wildlife are also allocated a "zero percent reduction" since the management goal is to foster a sustainable natural habitat and stream corridor to the extent practicable. Management measures to control nuisance populations of some wildlife species that can result in elevated indicator bacteria densities such as Canadian geese however should be considered in developing an overall watershed management plan. The management goal for point sources in designated swimming areas is elimination when the source is determined to be the main contributor of bacteria to the swimming area. This is consistent with the United States Environmental Protection Agency's (EPA) advisory for swimmers to avoid areas with discharge pipes [8] and a recent study indicating an increased potential for health risk to people swimming in areas near storm drains [9].

Source	Critical Conditions	Assigned To
On-Site Septic	Baseflow (DRY)	LA
Domestic Animal	Baseflow (DRY)	LA
Natural (Wildlife)	Baseflow (DRY)	LA
Wastewater Treatment Plants	Baseflow (DRY)	WLA
Regulated Urban Runoff/Storm Sewers	Wet Weather Flow (WET)	WLA
Dry Weather Overflow	Baseflow (DRY)	None
Illicit Discharges	Baseflow (DRY)	None
Combined Sewer Overflow	Wet Weather Flow (WET)	None

Table 2: Establishing WLA and LA Pollutant Sources

MARGIN OF SAFETY

Federal regulations require that all TMDL analyses include either an implicit or explicit margin of safety (MOS). The analytical approach described here incorporates an implicit MOS. Factors contributing to the MOS include assigning a percent reduction of "zero" to sampling results that indicate quality better than necessary to achieve consistency with the criteria. The increase in loadings on those dates that could be assimilated by the stream without exceeding criteria is not quantified (as a negative percent reduction) and averaged with the load reductions needed on other sampling dates. Rather, this excess capacity is averaged as a zero value thereby contributing to the implicit MOS.

The means of implementing the TMDL also contributes to the MOS. The loading reductions specified in the TMDL for regulated stormwater discharges and nonpoint sources must be sufficient to achieve water quality standards since confirmation that these reductions have been achieved will be based on ambient monitoring data documenting that water quality standards are met. Further, achieving compliance with the requirements of the MS4 permit includes elimination of high loading sources such as illicit discharges and dry weather overflows from storm sewer systems. Eliminating loads from these sources, as opposed to allocating a percent reduction equal to that given other sources, contributes to the implicit MOS. Further assurance that implementing the TMDL will meet water quality standards is provided by the iterative implementation required for compliance with the MS4 permit. This approach mandates that additional management efforts must be implemented until ambient monitoring data confirms that standards are met.

Many of the best management practices that are implemented to address either wet or dry weather sources will have some degree of effectiveness in reducing loads under all conditions. For example, the TMDL allocates all the percent reduction needed to meet standards under wet weather conditions to the WLA. However, reductions resulting from best management practices implemented to reduce dry weather loads (LA) will provide some benefit during wet weather conditions as well. These reductions also contribute to the implicit MOS.

DATA REQUIREMENTS

Ambient monitoring data for a minimum of 21 sampling dates during the recreational season (May 1 – September 30) is required. Data collected at other times during the year are excluded from the analysis. In addition to data on indicator bacteria density, precipitation data for each sampling date and the week prior to the sampling is necessary. Sampling dates should be selected to insure that representative data is available for both wet and dry conditions. This may be accomplished most easily by selecting sampling dates without prior knowledge of the meteorological conditions likely to be encountered on that date.

Data must reflect current conditions in the TMDL segment. The monitoring location where data is collected must therefore be sited in an area that can be considered representative of water quality throughout the TMDL segment. Data obtained under unusual circumstances may be excluded from the analysis provided the reason for excluding that data is provided in the TMDL. Potential reasons for excluding data may include such things as evidence that a spill, upset in

wastewater treatment, or sewer line breakage occurred that resulted in a short-term excursion from normal conditions. Data that represent conditions during an extreme storm event that resulted in widespread failure of wastewater treatment or stormwater best management practices may also be excluded. However, data for periods following typical rainfall events must be retained. Reasons for excluding any data must be provided in the TMDL Analysis.

All data must be less than five years old. If circumstances in any watershed suggest that conditions have changed during the most recent five-year period, the analysis may be restricted to more recent data in order to be representative of the current status provided the minimum data requirements are met.

Assurance of acceptable data quality must be provided. Typically, all data should be collected and results analyzed and reported pursuant to an EPA approved Quality Assurance Project Plan (QAPP). Data collected in the absence of a QAPP may be acceptable provided there is evidence that confirms acceptable data quality.

ANALYTICAL PROCEDURE – TMDL

1.

The *E. coli* monitoring data is ranked from lowest to highest. In the event of ties, monitoring results are assigned consecutive ranks in chronological order of sampling date. The sample proportion (p) is calculated for each monitoring result by dividing the assigned rank (r) for each sample by the total number of sample results (n):

$$p = r / n$$

2.

Next, a single sample criteria reference value is calculated for each monitoring result according to the specified recreational use (designated swimming, non-designated swimming, or all other) in a waterbody segment from the statistical distribution used to represent the criteria following the procedure described in steps **3 - 6** below:

3.

Designated Swimming	**Non-Designated Swimming**	**All Other Recreational Uses**
If the sample proportion is ≥ 0.75, the single sample criteria reference value is equivalent to the single sample criterion adopted into the Water Quality Standards (235 col/100ml)	If the sample proportion is ≥ 0.90, the single sample criteria reference value is equivalent to the single sample criterion adopted into the Water Quality Standards (410 col/100ml)	If the sample proportion is ≥ 0.95, the single sample criteria reference value is equivalent to the single sample criterion adopted into the Water Quality Standards (576 col/100ml)

4.

Designated Swimming	Non-Designated Swimming	All Other Recreational Uses
If the sample proportion is less than 0.75, and greater than 0.50, the single sample criteria reference value is calculated as:	If the sample proportion is less than 0.90, and greater than 0.50, the single sample criteria reference value is calculated as:	If the sample proportion is less than 0.95, and greater than 0.50, the single sample criteria reference value is calculated as:

$$\textit{criteria reference value} = \text{antilog}_{10}\,[\log_{10} 126 \text{ col/100ml} + (F * 0.4)]$$

N.B. 126 col/100ml is the geometric mean indicator bacteria criterion adopted into Connecticut's Water Quality Standards, *F* is a factor determined from areas under the normal probability curve for a probability level equivalent to the sample proportion, 0.4 is the $\log_{10}$ standard deviation used by EPA in deriving the national guidance criteria recommendations (Table 4).

5.

Designated Swimming	Non-Designated Swimming	All Other Recreational Uses
If the sample proportion is equal to 0.50, the single sample reference criteria value is equal to the geometric mean criterion adopted into the Water Quality Standards (126 col/100 ml)		

6.

Designated Swimming	Non-Designated Swimming	All Other Recreational Uses
If the sample proportion is less than 0.50, the single sample reference criteria value is calculated as:		

$$\textit{criteria reference value} = \text{antilog}_{10}\,[\log_{10} 126 \text{ col/100ml} - (F * 0.4)]$$

7. The percent reduction necessary to achieve consistency with the criteria is then calculated following the procedure described in steps **8 - 9** below:

8. If the monitoring result is less than the single sample reference criteria value, the percent reduction is zero.

9. If the monitoring result exceeds the single sample criteria reference value, the percent reduction necessary to meet criteria on that sampling date is calculated as:

$$\textit{percent reduction} = [(\textit{monitoring result} - \textit{criteria reference value})/\textit{monitoring result}]*100$$

10. The TMDL, expressed as the average percent reduction to meet criteria, is then calculated as the arithmetic average of the percent reduction calculated for each sampling date.

ANALYTICAL PROCEDURE – WET AND DRY WEATHER EVENTS

Precipitation data is reviewed and each sampling date is designated as a "dry" or "wet" sampling event. Although a site-specific protocol may be specified in an individual TMDL analysis, "wet" conditions are typically defined as greater than 0.1 inches precipitation in 24 hours or 0.25 inches precipitation in 48 hours, or 2.0 inches precipitation in 96 hours.

In designated urbanized areas the average percent reduction for all sampling events used to derive the TMDL that are designated as "wet" is computed and established as the WLA. The average percent reduction for all sampling events used to derive the TMDL that are designated as "dry" is computed and established as the LA.

In areas that do not have point sources, the average percent reduction for all sampling events used to derive the TMDL that are designated "wet" is computed as the wet weather LA, and the average percent reduction for all sampling events used to derive the TMDL that are designated as "dry" is computed as the dry weather LA.

ANALYTICAL PROCEDURE – SPREADSHEET MODEL

An Excel$^{(tm)}$ spreadsheet has been developed that performs all calculations necessary to derive a TMDL using this procedure. Copies of the spreadsheet in electronic form may be obtained from DEP by contacting Thomas Haze at (860) 424-3734 or by email at thomas.haze@po.state.ct.us.

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