Rapid Response Water Quality Monitoring and Public Awareness

Final Report

by

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Executive Summary

The University of Massachusetts Water Resources Research Center (WRRC), working in collaboration with Targeted Watershed Initiative (TWI) partners Pioneer Valley Planning Commission (PVPC), Franklin Regional Council Of Governments (FRCOG), and the Connecticut River Joint Commissions (CRJC), designed a water quality study that involved sampling 16 sites (drawn from a list of 26 sites) twice a week in two urbanized reaches of the river in Massachusetts, Chicopee to Holyoke and Turners Falls to Greenfield; and one mixed urban/suburban/rural reach in New Hampshire and Vermont, from Lebanon and Wilder to Cornish and Weathersfield, during the high-use summer recreation months of 2008 and 2009. All sites sampled are considered to receive a high degree of use for swimming, boating, fishing and other river recreation. Samples were analyzed at four local wastewater treatment plants and a private laboratory.

This study focused only on potential health impacts related to possible disease bearing organisms. We did not attempt to examine other issues such as nutrient loadings, toxic substances, or other potential problems. All findings, conclusions and recommendations pertain solely to health-related use of the river for recreational purposes.

Our major findings are that relative to *E. coli* bacteria:

- Water quality appears to be worse on wet days than on dry days.
- Vermont and New Hampshire sites generally support contact recreation in both wet and dry weather conditions.
- With the exception of site Barton Cove (MAG4), the northern Massachusetts sites were supportive of contact recreation during dry weather, and partially supportive during wet weather. Site MAG4 exhibited high bacteria levels on several occasions, during both wet and dry weather in 2009. Further study of this site is warranted, to determine the cause of the high bacteria levels.
- The more urbanized southern Massachusetts reach frequently exceeded primary contact recreation limits during wet weather and occasionally did so in dry weather at some sites. Site North End/Bassett Marina (MAC1) is of particular concern, as this site usually exceeded the contact limit, regardless of weather conditions.

Introduction

The Connecticut River is not meeting Class B, fishable/swimmable standards in many urbanized areas, due to elevated bacteria levels from combined sewer overflows (CSOs) and urban stormwater. Little information is available to the public on whether the river is safe for water-based recreation at any given location or time. Limited water quality sampling recently undertaken by consultants for the Connecticut River Clean-up Committee in the Holyoke-Springfield, MA reach of the river showed average *E. coli* bacteria levels during wet weather events of 7480 in Holyoke, 1800 in Chicopee and 1267 in Springfield, well above the water quality upper limit of 126 colonies/100ml indicating impaired river water and failure to meet water quality standards for recreational uses.

A 2004 water quality assessment of the Upper Connecticut River by New Hampshire Department of Environmental Services (NH DES), found that 13.8 miles of the river from Hartford, Vermont to Cornish, New Hampshire, do not support primary contact recreation (swimming) due to the influence of combined sewer overflows from Lebanon, NH and White River Junction, VT. Midway in this segment is Sumner Falls in Hartland, VT, some of the most popular technical kayaking water on the entire main stem, where recreational users are regularly immersing themselves in the river. Due to lack of good water quality data, public officials faced with costly clean-ups are constantly debating sources of pollution and bacteria and whether their community is responsible.

The Rapid Response Water Quality Monitoring and Public Awareness program was designed to address these issues. The University of Massachusetts Water Resources Research Center (WRRC), working in collaboration with TWI partners Pioneer Valley Planning Commission (PVPC), Franklin Regional Council Of Governments (FRCOG), and the Connecticut River Joint Commissions (CRJC), designed a water quality study that involved sampling 16 sites (drawn from a list of 26 sites) up to twice a week (three times per week for Chicopee sites in 2008) in two urbanized reaches of the river in Massachusetts, Chicopee to Holyoke and Turners Falls to Greenfield; and one mixed urban/suburban/rural reach in New Hampshire and Vermont, from Lebanon and Wilder to Cornish and Weathersfield, during the high-use summer recreation months (May-October) of 2008 and 2009. Some sites were sampled every sample event; others were sampled on a roving basis. Volunteers from these areas were recruited to collect samples and transport them to five laboratories participating in the program (Aquacheck Incorporated of Weathersfield VT, Greenfield MA water pollution control facility, United Water Incorporated for the city of Holyoke MA, Premier Laboratory Incorporated for the city of Chicopee MA (one sample per week), and Chicopee's own waste water treatment plant (WWTP) laboratory (2 times/week)). WRRC prepared a quality assurance project plan (QAPP) for all phases of the sampling program. Results were posted within 24 hours of completed laboratory analysis on a new Connecticut River website established for this project (http://www.cesd.umass.edu/TWI/TWI_Projects/Water_Quality_Monitoring/index.html), in order to alert recreational users to water quality conditions and identify pollution hot spots. This report describes the program.

Methods

Site Selection

WRRC, PVPC, FRCOG and CRJC selected 26 water quality sampling sites along the main stem of the Connecticut River; including 7-11 sites in each of three river reaches, including Wilder to Weathersfield, Vermont and Lebanon to Cornish, NH; font change Turners Falls-Greenfield, Massachusetts; and Chicopee-Holyoke, Massachusetts. Sites were selected based on proximity to public recreation access points, and best options for sampling access for volunteers. A master site list was drawn up for each river reach. In Holyoke and Chicopee, the same 4 sites were sampled each event. In the VT/NH and northern MA reaches, the master list consisted of a core list and a supplementary list of sampling sites for each reach. Sites were sampled according to a schedule arranged by WRRC in communication with PVPC, CJRC, FRCOG and all laboratories. One of the primary research objectives of this project was to evaluate the impact of bacterial pollution on recreational use of the river. This objective influenced the selection of sites (i.e. public access sites) and sampling dates. The target sampling season in both years (2008 and 2009) was from just prior to Memorial Day to just after Labor Day, considered as the beginning and end of the high use recreational season. Administrative delays in project start delayed sampling efforts until late July 2008. As a consequence, the 2008 sampling season was extended until early October in most reaches. Because water temperatures are colder in the Vermont/New Hampshire region, sampling concluded earlier in 2008 (9/22) and began later in 2009 (6/22) than in the other reaches. In both years, the City of Chicopee began sampling in April, well before the startup of the Targeted Watershed Initiative volunteer monitoring program. The early season Chicopee data are included in the raw data tables in Appendix B. However, for consistency with the overall program, these early Chicopee results are not included in the data analysis and discussion found in this document, except where specifically noted. Sampling site list and maps are found in Appendix A.

Organization

For purposes of organizing and facilitating communication among volunteers and laboratories, a coordinator was assigned to each of the three main reaches: CJRC for VT/NH; FRCOG for northern MA, and PVPC for southern MA, with WRRC assuming role of overall coordination. River sampling was in most cases done by volunteers. Chicopee WWTP personnel collected samples from the Chicopee reach. Volunteers were trained at sessions held at the beginning of the 2008 and 2009 sampling seasons, separately held in Vermont and in Massachusetts.

Sampling and Analysis

It was the intent of this program to conduct both wet and dry weather sampling, with a target of at least 5 wet weather events each season. Wet weather sampling was defined as at least 0.1" rain in the 24 hours prior to sampling. Because both 2008 and 2009 were relatively wet years during the sampling seasons, it was not necessary to organize any special wet weather sampling events; we were able to produce a sufficient number each year using the sampling

schedule set at the beginning of each season. In general sample events were scheduled for Monday and Thursday (four sites in the Chicopee MA area were also sampled on some Wednesdays). The rationale for this was as follows: labs were not open on weekends; making allowances for weather fluctuations, Monday sampling events provided a reasonable estimate of the most recent weekend's conditions, and Thursday sampling events, reported by Friday afternoon, provided a reasonable forecast of conditions for the upcoming weekend.

Samplers were given a cooler, freezer pack, thermometer, sterilized sample bottles, instructions sheets and field data sheets. Instructions directed samplers to put their freezer pack in their home freezer the night before collection day, and put it in their cooler just before leaving for sampling. Once at their site, samplers were asked to make observations on the current weather, past 48-hours weather, water color and odor, presence or absence of debris and wildlife, and types of recreation observed at time of sampling. They would then record air temperature, water temperature, and take a river sample in the sterilized bottle. Samples were transported directly to the assigned laboratory for each reach – or in some cases to a reach coordinator for transportation. Samples were analyzed at the laboratories for *E. coli* following EPA method 1603 or variation, as documented by each laboratory in standard operating procedures (SOPs) submitted to EPA as part of the QAPP process. The participating laboratories included:

- Aquacheck, Incorporated of Weathersfield VT for the VT and NH sites;
- Greenfield MA water pollution control facility for the northern MA sites
- United Water Incorporated for Holyoke MA sites
- Premier Laboratory Incorporated (one sample per week), and the Chicopee MA wastewater treatment plant laboratory (2 times/week)) for Chicopee sites.

Data Management

Laboratories emailed analysis reports to WRRC staff, who transcribed these to a web site jointly operated by WRRC and the UMass Center for Educational Software Development (CESD). In most cases, results were posted within 24 hours of the completion of analyses. Results were posted in two formats: a table showing all sites together, and map/graph form. The map/graph format contains a map of the project area with icons showing the location of the sampling sites. By clicking on an icon, web site users were able to access a graph showing current and recent sample results for that site. For many of the sites, photographs of the sampling location are also shown. Both the table and map/graph forms use color codes to indicate whether each site has exceeded the relevant state's water quality criteria. See results discussion below for more details. Data were also sent to local media in the project area.

Data were entered in a format compatible with STORET (STOrage and RETrieval), EPA's data management system, and submitted to EPA after the end of each sampling season.

Quality Control

A Quality Assurance Project Plan was written before the onset of the project and sent to EPA for review. Approval was granted prior to the beginning of sampling. The major points of the quality control program were:

- Volunteer monitors were trained by WRRC in sample collection.
- Monitor performance was evaluated through a field check: WRRC staff observed volunteers at several times during the sampling season and provided correction as necessary.
- Lab analysts were professional lab technicians and needed no further training. Laboratories did submit their Standard Operating Procedures as part of the QAPP.

Documentation and Records

Volunteers sent field data sheets directly to WRRC or via coordinators. These were entered in the sampling database by WRRC staff. Chain of custody forms were used to follow the samples from collection to analysis. Lab sheets were filled out at the lab and emailed to WRRC.

Equipment Testing

Before each sampling season, thermometers were compared with a certified thermometer owned by the UMass Environmental Analytical Laboratory (EAL); any that departed from EAL by > 1 degree Celsius were not used.

Quality Control for sample collection and analysis

A.Field QC Checks

One or two field QC checks per week were assigned to volunteers. Field QCs consisted of either field duplicates or field blanks, according to a schedule set by WRRC. For *Field Duplicates*, a volunteer would take 2 samples sequentially at the same location. For *Field Blanks*, a volunteer would beforehand be given a bottle of de-ionized water (furnished by the UMass EAL); at the sampling site, the volunteer would pour the de-ionized water into an empty sample bottle. This would be done in addition to taking a normal field sample. Both types of field QC samples were labeled in a way to disguise the QC type and the sample site location from the lab personnel. Laboratory results for these QC samples were later reconciled with appropriate date and location by WRRC staff.

B. Laboratory QC Checks

Lab Duplicates and Blanks were done at each lab, in accordance with their respective SOPs.

C. Data Analysis of QC Checks

WRRC staff compared QC data to the quality objectives stated in the QAPP (e.g. blanks show no colonies, duplicates show $\leq$ 30% relative per cent (RPD) difference for log10 transformed data).

Results

Regulatory context

From a legal perspective, the Connecticut River flows largely through two states in the project area. North of the Massachusetts border, the river is considered by law to be within New Hampshire boundaries except where the river is impounded behind dams constructed after 1938 and its waters inundate parts of Vermont; upon reaching Gill, MA, it is within the jurisdiction of the Commonwealth of Massachusetts. New Hampshire and Massachusetts have established different criteria for E. coli levels. New Hampshire water quality standards apply to the Connecticut River.

In both states, the river is designated as a Class B waterway; criteria below reflect that classification, except where noted.

Table 1. Water Quality Criteria

New Hampshire Criteria for *E. coli* (Escherichia coli; units = colonies/100ml)		
Geometric mean[1]	Single sample maximum	Appropriate Recreational Use
≤ 126	406	Suitable for primary contact (swimming)
127 - 630	407 - 2030	Secondary contact only (boating, no swimming)
> 630	> 2030	Unsuitable for recreational contact
Massachusetts Criteria for *E. coli* (Escherichia coli; units = colonies/100ml)		
Geometric mean[1]	Single sample maximum	Appropriate Recreational Use
≤ 126	235	Suitable for primary contact
> 630	1260	Unsuitable for recreation[2]

1. Geometric mean of 3 samples (NH: for MA, 5 or more samples) taken within a 60 day period (NH: for MA, samples taken within the same bathing season for bathing beaches, otherwise samples taken within most recent 6 months).
2. MA has no criteria for class B waters, secondary contact. For comparison purposes, the numbers listed in this row pertain to MA criteria for Class *C* waters.

Quality Control Results

Quality Control results are summarized here, and listed in Appendix C. In the Chicopee reach (sites MAC1-4 (see table 4, p. 15 for site names), analyzed at Premier Lab), 21 quality control (QC) checks were run in 2008: 3 field blanks, 18 field duplicates. All but 1 passed: < 1 colony for 2 blanks, one blank reported as <10. Result for this date and site was flagged, but not discarded. All duplicates were ≤ 28% relative percent difference (RPD) for log10 transformed data. In 2009, 19 QC samples were run – 15 duplicates, 4 blanks. All passed: blanks < 1 colony, all field duplicates were ≤ 10.4% RPD.

In the Holyoke reach (sites MAH1-4, analyzed at United Water), 12 QC checks were run in 2008: 10 blanks, 2 duplicates. All passed: blanks were 0, duplicates were ≤ 6.9% RPD. In 2009, 41 checks were run: 28 blanks, 13 duplicates. All passed: blanks showed no counts, duplicates were ≤ 9.3% RPD.

In the Greenfield reach (sites MAG1-7, analyzed at Greenfield WWTP lab), 24 QC checks were run in 2008: 17 blanks, 7 duplicates. All blanks passed (0 colonies). One of the 7 duplicates showed a 59.7% RPD; however, counts for the sample and duplicate were 13 and 4 respectively. At this low level, higher RPDs might be expected. Data for this date and site are flagged, but not discarded. Otherwise, all duplicates showed ≤ 20% RPD. In 2009, 42 QC checks were run: 29 blanks and 13 duplicates. All samples passed (blanks were 0, duplicates were ≤ 16.3% RPD.

In the Vermont/New Hampshire reach (sites NHA1-7 and VTA1-4, analyzed at Aquacheck Lab), 10 QC checks were run in 2008: 7 field duplicates, 3 blanks. All passed: blanks < 1 colonies, duplicates ≤11% RPD. Nine QC checks were run in 2009: 6 field duplicates, 3 blanks. All blanks passed (0 colonies). Two of the 6 field duplicates exceeded the 30% RPD goal set in the QAPP: On August 20, the field sample and duplicate were 8 and 4 colonies, respectively, for a 40% RPD of the log-transformed data; the September 8 sample and duplicate of 10 and 2 colonies respectively

translate to a 107% RPD. However, on both dates the absolute difference between the two counts (i.e. 4 and 8 counts, respectively) was small, counts were on the low end of the possible range, and well below the primary contact standard. These data are flagged, but not discarded.

Weather Data

A major study question was the impact that wet weather has on bacteria levels in the Connecticut River, particularly at the high-use recreational access points selected as sampling sites. For purposes of distinguishing wet weather sample collections from dry weather events, a value of 0.1" rain in the 24 hours prior to sampling was chosen as the minimum qualifying amount. Rainfall data were obtained from records contained on the weather underground web site (www.wunderground.com). Data were obtained from the following weather stations (station ID codes in parentheses): North Hartland VT (MNHDV1), Airport Hill, Claremont NH (KNCLARE2), Brattleboro VT (MBBOV1), Northfield/Mt Hermon MA (KMAMTHER2), Chicopee MA (KMACHICO6) and Easthampton MA (MC0845). Data from these stations were reviewed for day of sampling (taking care to note start time and duration of rainfall, in order to ascertain that rainfall occurred prior to time of sampling) and the previous day. In a few borderline cases (i.e. where rainfall totals were just at or around 0.1"), rainfall data from 2 days prior to sampling were also consulted. If these showed high rainfall amounts (e.g. > 0.5") a designation of wet was assigned to the sample event. Data were consulted from these several weather stations in recognition of the widespread geographic distribution of sampling sites, and of the likelihood that there would be some days when runoff conditions were significantly different in the different reaches of the river. This variability is reflected in the results. Appendix B contains wet/dry indicators for each sample date and site, along with sample results. Wet/dry designations were assigned to each site. In almost all cases, wet/dry conditions for sites within a reach were uniformly wet or dry for a given sample date. Reaches are defined for this purpose as the VT/NH reach, the Northern MA reach, and the Southern MA reach (comprising samples collected for both the Chicopee and Holyoke laboratories). One stated objective of the study design was to collect at least 5 wet and 5 dry samples in each year of the program. By reach, this objective was met, except for in 2008 in the Northern MA reach, when only 4 wet weather sample events occurred. Sampling did not begin on this reach until August 4; three July wet weather dates that were sampled in other reaches were missed in this reach. Those sites in the VT/NH and Northern MA reaches that were designated as secondary sites (see section on site selection, above) were not sampled on every sample date; and thus did not get sampled at least 5 times per season on either a wet or dry basis. Some sites generated no wet weather samples for a given year.

Table 2. Sampling events, wet weather vs. dry weather.

	2008		2009	
Reach	**# of wet events**	**# of dry events**	**# of wet events**	**# of dry events**
VT/NH	7	11	7	12
Northern MA	4	15	12	18
Southern MA	9	12	12	18

E. coli results discussion

Full results are listed in Appendix B.

Results were analyzed from three different perspectives:

1) Comparison of wet weather and dry weather results for all sites, all reaches.
2) Comparison of results among the different reaches.
3) Review individual site data; identify, attempt to explain outliers (i.e. results that were unusually high or low for given conditions).

Wet weather vs. dry weather.

Geometric means were calculated for wet weather and dry weather results for each site and each of the three reaches for each sampling year and for 2008 and 2009 combined.

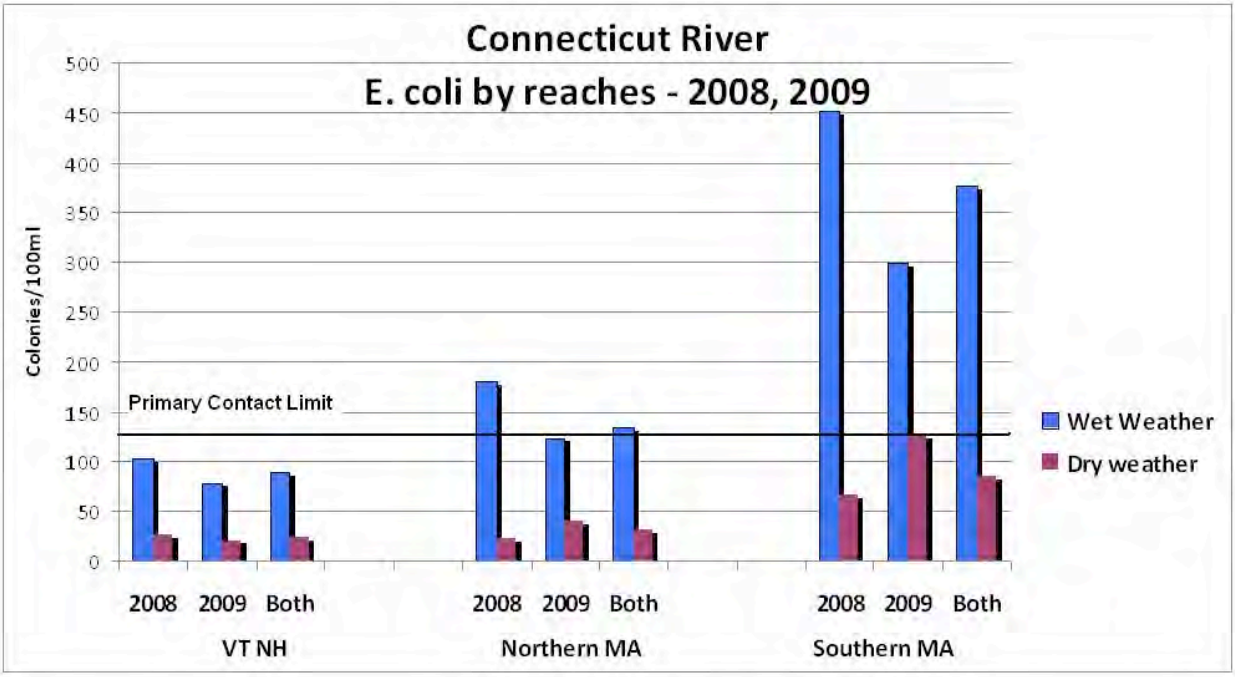


Figure 1. Geometric mean of *E. coli* results by reaches

Figure 1 illustrates that *E. coli* levels were much higher in wet weather than in dry. This disparity occurs in all three reaches, in both years. The wet weather geomeans in the Vermont / New Hampshire reach were well below the primary contact limit of 126 colonies / 100 ml water in both years. In the Northern Massachusetts reach, the geomean for 2008 was 181 colonies, well above the 126 standard. In 2009, the geomean for this reach was 123, just below the limit. The two-year geomean of 134 was slightly above the limit. In the Southern Massachusetts reach, geomeans were well above the limit for both years. In dry weather, the Southern Massachusetts reach yielded a geomean of 126 in 2009, exactly at the limit. For all other reaches, dry weather results were well below the limit for both 2008 and 2009.

We also computed the number of times the *single sample* maximum was exceeded at each site, for both wet and dry conditions. The single sample maximum is more liberal than the geomean standard: 235 colones/100ml in Massachusetts, 406 in New Hampshire (including Vermont sites). For this analysis, the relevant state's standard was used, although we also provide in Table 3 the number of exceedences that would have occurred in the Vermont and New Hampshire sites if the stricter Massachusetts standard was used. For all sites combined, 38% of the wet weather samples

exceeded the standards in 2008, vs. 7% of the dry weather samples. In 2009, 23% of the wet weather samples exceeded the limit vs. 9% of the dry weather samples. Combining both years, we find that 29% of wet weather vs. 8% of dry weather samples exceeded the standard. These numbers are skewed somewhat by the more urbanized Chicopee sites. When these 4 sites are eliminated from the calculation, exceedences drop to 17% for wet, 0% for dry in 2008 and 15% for wet, 5% for dry in 2009.

Table 3. Number of times primary contact limit exceeded

Number of times single sample standard was exceeded					
	2008		2009		Total #
Site	Wet	Dry	Wet	Dry	Exceeded/Sampled
VTA4	0/2	0/1	0/4	0/6	**0/13**
NHA7	1/2	0/2	0/3	0/6	**1/13**
VTA3	1/2/2	0/3/1			**1/5**
NHA6	0/2	0/2	0/3	0/6	**0/13**
NHA5	0/6	0/12	1/3	0/6	**1/27**
NHA4	0/0	0/4			**0/4**
NHA3	0/0	0/4	0/3	0/6	**0/13**
VTA2	0/6/2	0/12	0/4/1	0/6	**0/28**
NHA2	0/0	0/3	0/4/1	0/5	**0/12**
NHA1	0/2	0/2			**0/4**
VTA1	0/2	0/3	0/4	0/6	**0/15**
MAG7	2/5	0/11	2/4	0/11	**4/31**
MAG5	1/2	0/4	3/9	0/20	**4/35**
MAG4	2/3	0/3	6/9	8/20	**16/35**
MAG3	1/5	0/11	0/4	0/10	**1/30**
MAG2	0/2	0/8	0/4	0/9	**0/23**
MAG1	0/1	0/8	0/5	0/10	**0/24**
MAH4	0/1	0/4	0/11	0/15	**0/30**
MAC4	6/10	0/15	3/9	2/14	**11/48**
MAH3	0/3	0/6	0/11	0/18	**0/36**
MAC3	6/10	1/15	3/9	2/14	**12/48**
MAC2	4/10	0/15	3/9	0/14	**7/48**
MAC1	9/10	12/15	8/9	8/14	**37/48**
MAH2	0/1	0/6	3/11	2/18	**5/38**
MAH1	0/1	0/7	1/11	0/18	**1/37**

Maximum allowable single sample value for primary contact in MA: 235 colonies.
Maximum allowable single sample value for primary contact in NH: 406 colonies.
All MA samples are compared against MA standard. All VT/NH samples are compared against NH standard. Note however, that some VT/NH exceedence results show a third number (e.g. 1/2/2). This number is the number of exceedences that would have occurred if stricter MA standard were used. For example, Site VTA2 exceeded the NH standard 0 times out of 6 wet weather samples in 2008, but would have exceeded it 2 times if the MA standard were used. In 2009, it exceeded the NH standard 0 out of 4 wet weather samples, but would have exceeded it one time if the MA standard were used.

Collectively, these data support the finding that the Connecticut River is adversely affected by polluted runoff during wet weather events. In the Vermont and New Hampshire Reaches tested, this impact is not severe enough to compromise the river's ability to support primary contact recreation. In the Northern Massachusetts reaches, it does compromise the river's ability to do so during wet

weather, and in the Southern Massachusetts reaches, it prevents the river from supporting contact recreation during wet weather.

Results by Reach

VT- NH Reach

Approximately 14 miles of the Upper Connecticut River, from Hartford, VT to Cornish, NH do not support primary contact recreation due to the influence of combined sewer overflows from Lebanon, NH and White River Junction, VT, according to NH DES's 2004 water quality assessment. Since that sampling year, the Town of Hartford invested in improvements that have most likely eliminated the last combined sewer overflow in White River Junction. Therefore, the only remaining CSOs are associated with Lebanon, NH, discharging just above the confluence of the Mascoma River.

Most of the VT and NH sites selected for the Rapid Response Water Quality Monitoring Project were chosen to test whether this condition still exists. Sites VTA4 and NHA7 are immediately above this reach. Site VTA3 lies above the CSOs, but does receive runoff from urban areas of Hartford VT and from the White River. It is not used in the following analysis, which focuses on possible CSO impacts. Sites NHA6, NHA5, NHA3, NHA2, and site VTA2 are all within this stretch, and could be expected to register impacts from the CSO outfalls. Site NHA4 is located on Hanchett Brook, a tributary to the Connecticut. It would not be expected to exhibit any influence from pollutants coming from upstream locations of the river, and is not used in this analysis. This site is discussed further below, in the results by site section.

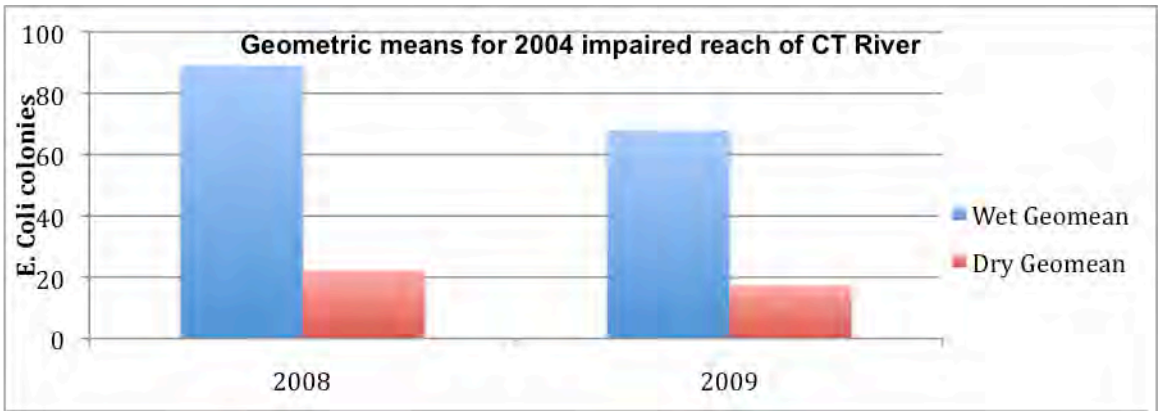


Figure 2. Geometric means for sites NHA6, NHA5, NHA3, NHA2 and VTA2.
(these sites were found to be impaired in 2005 NH DES report)

As shown in Figures 1 and 2, annual geometric means for the reach that was impaired in 2008, as well as for all Vermont and New Hampshire sampling locations were below the primary contact limit (126 colonies for the geometric mean) for wet and dry conditions. Only 3 samples of out 147 exceeded the single sample limit of 406 colonies. The highest recorded result was 520 colonies at site NHA7 (located above the CSO outfalls) during a wet weather event. These data suggest that the river now supports primary contact recreation in this reach. This issue is discussed further in the results by site section below.

Northern MA Reach

Wet weather *E. coli* levels were moderately higher in the Northern Massachusetts reach than the Vermont/New Hampshire reach. The annual wet weather mean of 181 exceeded the primary contact standard in 2008, and was just below (123 colonies) in 2009. However, it should be noted that only 18 wet weather samples were collected from this reach in 2008, compared to 45 samples in 2009. Dry weather *E. coli* levels were minimally higher in the Northern Massachusetts reach than in Vermont/New Hampshire. They were actually slightly lower (23 vs. 26 colonies) than in the Vermont/New Hampshire reach in 2008, and slightly higher (39 vs. 21 colonies) in 2009. Only one site in the Northern Massachusetts reach had any dry weather results above the Massachusetts single sample limit of 235 colonies. This site (MAG4, Barton Cove) had numerous high counts in both wet and dry weather in 2009. This is discussed further below. It is worth noting that this reach produced several samples well in excess of single sample limits. There were seven samples in a range between 1000 and 3067 colonies. Five of these were wet weather samples. Four of the seven were from MAG4 (Barton Cove), two of which were dry weather samples.

Southern MA Reach

The Southern Massachusetts reach had significantly higher bacteria levels than either Vermont/New Hampshire or Northern Massachusetts, in both wet and dry conditions. Results for this reach were somewhat skewed by consistently high bacteria levels at site MAC1, a boat launch near the North End Bridge. This site generally exceeded contact limits in both wet and dry weather. Three other sites in this reach exceeded limits 30% to 60% of the time in wet weather, but during dry weather exceedences were rare in all sites other than MAC1: 7 out of 179 dry weather samples exceeded limits, with no site exceeding more than twice out of 14 samples in any one year. There were 36 samples that exceeded 1000 colonies over the duration of the project, including 14 that occurred during dry weather. The highest level found was 13,286 colonies. This occurred in wet weather; the highest dry weather result was 6,533 colonies. Other than site MAC1, which generally did not support contact recreation, this reach can be characterized as not supporting contact recreation during wet weather, and occasionally not supporting it during dry weather.

Individual site results

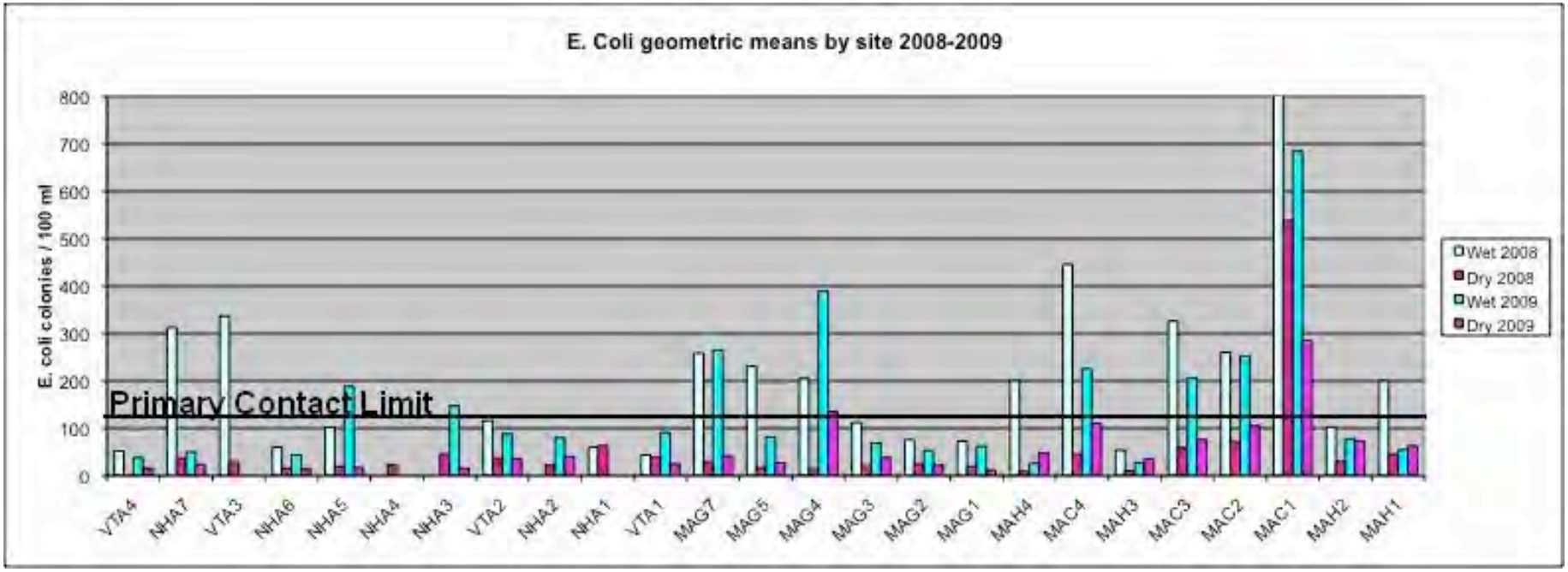
Table 4 and Figure 3 are used in this discussion. In both, sites have been sorted from north to south, to give the reader a better understanding of conditions moving upstream to downstream. To reiterate, site names link them to the laboratories where they are analyzed. The Southern Massachusetts sites, although analyzed at two different labs (Holyoke (MAH sites) and Chicopee (MAC sites), are intermingled geographically.

It is useful to note that all Vermont samples are taken at sites located on the west bank of the river; all New Hampshire sites are located on the eastern side. NHA4 is located on Hanchett Brook, near its mouth. In Massachusetts, the following sites are on the west bank: MAG5, MAG4, MAG1, and MAH3. Site MAC2 is located on the north bank of the Chicopee River, near the mouth.

E. coli results		2008		2009	
Site #	Site name	Wet Geomean	Dry Geomean	Wet Geomean	Dry Geomean
VTA4	Wilder Picnic Area, Hartford	*52*	*1*	*38*	15
NHA7	East Wilder Boat Launch, W. Lebanon	***313***	*37*	*50*	24
VTA3	Lyman Point Park, Hartford	***337***	*29*		
NHA6	Lebanon CSO Outfall, W. Lebanon	*60*	*15*	*44*	13
NHA5	Blood Brook Canoe Launch, Lebanon	102	18	***188***	17
NHA4	Hanchett Brook, Plainfield		*23*		
NHA3	Riverview Farm, Plainfield		*46*	***147***	16
VTA2	Sumner Falls, Hartland	116	37	88	36
NHA2	Cornish Boat Launch, Cornish		*23*	*80*	40
NHA1	North Star Canoe Rentals, Cornish	*60*	*63*		
VTA1	Wilgus State Park, Weathersfield	*44*	*39*	*91*	25
MAG7	Northfield Boat Ramp, Northfield	**259**	29	***265***	41
MAG5	Munn's Ferry, Gill	***231***	*16*	82	27
MAG4	Barton Cove, Gill	***205***	*13*	**389**	**135**
MAG3	Rock Dam, Montague	112	21	*69*	38
MAG2	Sunderland Bridge, Sunderland	*76*	*25*	*53*	22
MAG1	Hatfield Boat Ramp, Hatfield	*73*	19	62	12
MAH4	Brunelle's Marina, S. Hadley	***200***	*9*	26	48
MAC4	Berchulski Fisherman Access, S. Hadley	**446**	45	**226**	110
MAH3	Jones Ferry, Holyoke	*54*	10	27	36
MAC3	Medina St. Boat Ramp, Chicopee	**326**	59	**206**	76
MAC2	Davitt Bridge, Chicopee	**260**	71	**253**	105
MAC1	North End Bridge, Springfield	**2770**	**538**	**684**	**286**
MAH2	Pynchon Point Park, Springfield	*103*	30	78	73
MAH1	Pioneer Valley Yacht Club, Agawam	***200***	46	54	63

Table 4. Geometric means by site

Blue background: dry weather geomean > wet weather geomean for that year.
Bold red: Exceeded contact limit (for geometric mean) of 126 colonies.
Bold Italics: Geometric mean calculated on fewer than 5 samples. See table 3 for numbers.



Wet weather geomeans are shown in shades of blue. Dry weather geomeans are shown in shades of red or magenta.

Figure 3 Geometric means by site for each year, separated into wet and dry conditions.

Caution is advised in interpreting the values in Table 4 and Figure 3. Several of the geomean values are calculated from between one and four data points, as shown in Table 3. It is generally preferable to have at least 5 data points for a geometric mean, to give the number a higher degree of statistical rigor. Whether using a geometric mean or individual data points (see Appendix B), it is also advisable to use caution in extrapolating from a small number of data points when drawing broad conclusions about general conditions at any given site or reach. For example, Figure 3 shows that sites NHA7 and VTA3 violate the primary contact limit in 2008 (using the geometric mean limit of 126 colonies), as do sites NHA5 and NHA3 to a lesser extent in 2009. Table 5 isolates these sites, dates and conditions.

Table 5 Selected wet weather results

Site	Date	Result	Geomean
NHA7	7/25/08	188	
NHA7	8/7/08	520	313
VTA3	7/25/08	236	
VTA3	8/7/08	480	337
NHA3	7/9/09	160	
NHA3	7/24/09	86	
NHA3	7/30/09	232	147
NHA5	7/9/2009	134	
NHA5	7/24/2009	120	
NHA5	7/30/2009	416	188

Only two or three wet weather samples were collected for these sites in the years indicated. Looking at individual sample results, and applying the New Hampshire single sample contact limit of 406 colonies, it is shown that only three of the 10 wet weather samples in this set exceeded the limit; no site reported more than one exceedence. Similar examples of fewer than five data points comprising a season's worth of wet or dry data are found throughout the data set. Thus, Table 3 is useful when interpreting any of the tables or figures in this report.

In the above discussion of river reaches, it was demonstrated that the 2004 impaired reach did not appear to violate the primary contact limit in the 2008 and 2009 sampling years. The following discussion focuses on sites immediately in the vicinity of the urban areas where the CSOs are located. White River Junction, Vermont and Lebanon, New Hampshire lie in close proximity, on opposite sides of the Connecticut River, at the confluence of the White and Connecticut Rivers. Figures 3 and 4 in Appendix A show Vermont and New Hampshire sampling locations. Of particular interest for this discussion are sites VTA4, VTA3, NHA7, NHA6 and NHA5. Sites VTA4 and NHA7 are both just upstream of the impaired reach listed in the 2004 water quality assessment. These two sites served as control sites for the hypothesis that CSOs cause an increase in bacteria levels in the river. Sites NHA6 and NHA5, just downstream from the CSO outfalls, were considered prime candidates for high bacterial levels. NHA6 is located immediately below the Lebanon outfall, and NHA5 is approximately 4 miles downstream of NHA6. These serve as impact sites that would provide the best contrast with VTA4 and NHA7. Comparing these control and impact sites provides us with another test of our hypothesis. However, it is quite possible that even though NHA6 is physically located just below the outfall, the pollutants discharged so close above are delivered in such a way that the current does not bring this water close to the shore at NHA6; the thalweg is on the VT side here. The current does, however, come close to the shore (after some mixing) at NHA5. We did not include VTA3 in this test. It lies just at the top of the impaired reach, above the CSOs of interest, but still receiving some urban runoff from Hartford, VT, and possibly reflecting conditions in the White River. It was thus unclear at the outset of the study whether VTA3 would exhibit bacteria levels more similar to the control sites or to the assumed impaired sites.

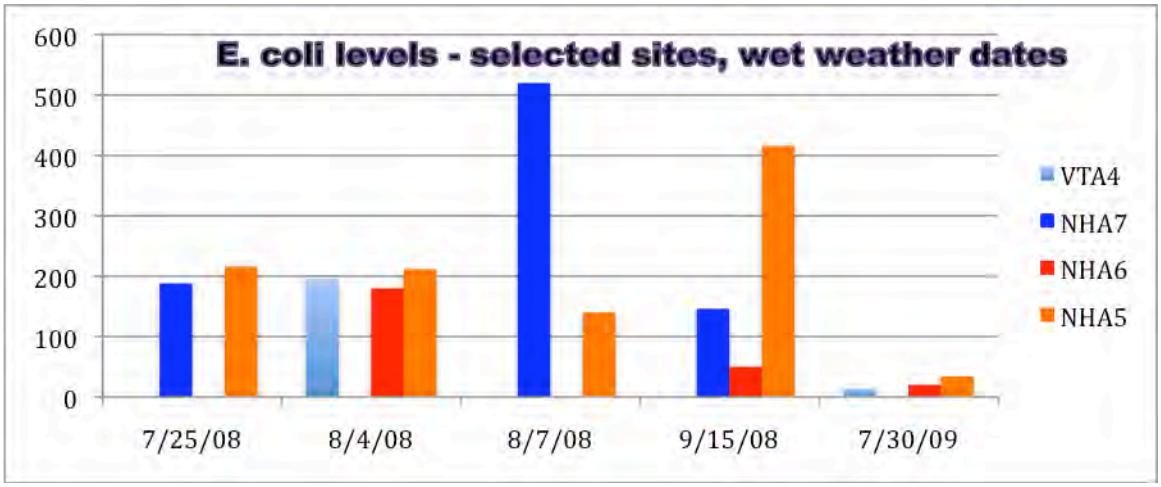


Figure 4. VT/NH sites above (blue) and below (red, orange) CSOs, wet weather events.

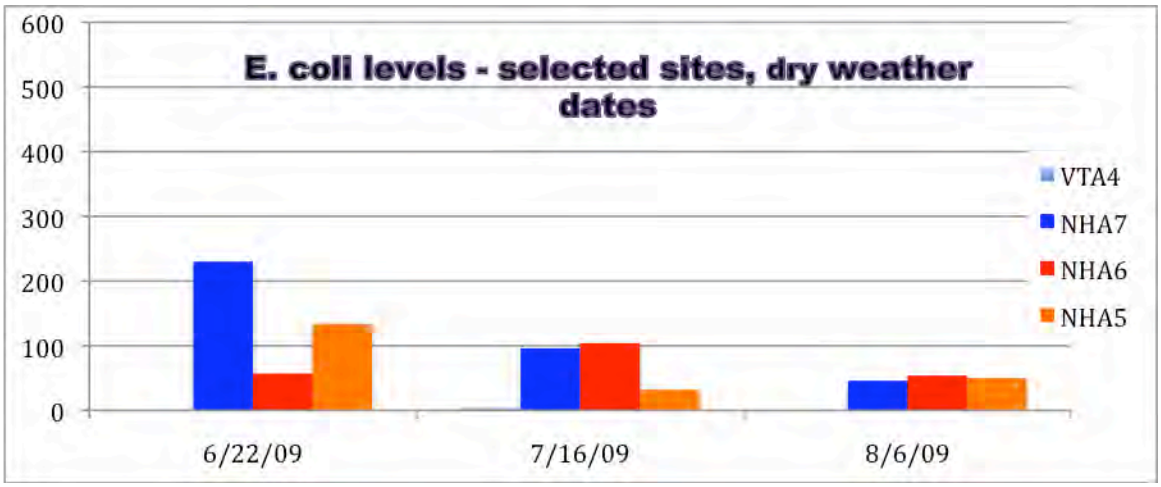


Figure 5. VT/NH sites above (blue) and below (red, orange) CSOs, dry weather events.

In Figures 4 and 5 the control sites (i.e. above CSOs) are shown in shades of blue, while those just below the CSOs are in red/orange. Figure 4 shows all wet weather dates when at least one of the two control sites (VTA4 and NHA7) and at least one of the impact sites (NHA6 and NHA5) were sampled. Figure 5 shows 3 representative dates where the same control/impact comparisons could be made. There were 3 additional dry weather dates, in August and September 2009, where paired comparisons were possible. All of the additional dates produced results similar to 8/6/09: low values (i.e. < 20 colonies) and no significant difference in results for control and impact sites. Neither of these charts reveals a pattern of higher bacteria levels in the impact sites than in the control sites. Neither these data nor the geometric mean data shown in Table 4 support the hypothesis that the CSOs contribute significantly to the impairment of the Connecticut River in this urbanized reach of the river. As discussed above, wet weather does appear to increase *E. coli* levels in the Vermont/New Hampshire sites; however, the absence of a discernable increase in the vicinity of the CSOs suggests that other types of stormwater runoff – perhaps from urban and/or agricultural land uses – are the causal factor.

TABLE 5 does show that four individual sites (NHA7, VTA3, NHA5 and NHA3) each produced wet weather geometric means in one of the two sampling years in excess of the 126 colony limit.

However, these cannot confidently be attributed to CSOs. Furthermore, given that the means were calculated on only 2 or 3 samples, we cannot conclude that these sites are in violation of the primary contact standard. These sites are good candidates for further study.

Site NHA4 was different from the other sites in that it was situated on Hanchett Brook (near its mouth), not on the Connecticut. It was monitored in 2008 because it was thought to possibly be adversely affected by agricultural runoff in the brook. Although it was not sampled in wet weather, all 5 dry weather samples taken in 2008 revealed low bacteria levels (highest single value was 58 colonies), and the site was dropped for the 2009 season.

None of the remaining Vermont / New Hampshire sites appear to pose bacteria-related health risks.

In the Massachusetts portion of the river, Figure 3 reveals two apparent clusters of high bacteria levels: the 3 northernmost sites in the state (MAG7, MAG5 and MAG4) and in the Holyoke/Springfield region. MAG7 exceeded the wet weather geomean limit in both years (with 2 of 4 single sample exceedences in 2008, 2 of 5 exceedences in 2009). MAG5 exceeded the wet weather geomean in 2008 (one single sample exceedence out of two samples taken) and did not in 2009 (but it did have 3 single sample exceedences out of 9 samples – note that the MA single sample limit of 235 colonies is stricter than the NH limit of 406). Both sites had low bacteria levels at all times during dry weather. The wet weather values were generally higher in MAG7 than in MAG5. MAG7 had three samples between 1000 and 1467 colonies; the highest MAG5 reading was 778 colonies. MAG7 is at the Northfield Boat ramp. It is the northernmost site in MA and lies above all urban areas in MA. It is about 10 or 12 miles downstream of Brattleboro, VT, and approximately 12-15 miles below Keene NH (via the Ashuelot River). It is not known if these areas contributed to the high readings at site MAG7, nor are there other known reasons for the occasional high levels found. MAG5, at Munn's Ferry, is approximately 7 miles downstream of MAG7. It is also above Greenfield, with no known significant bacteria sources. It may be that MAG5 is exhibiting the impacts of the same sources that affect MAG7, somewhat diminished by dilution from streams entering the river between the site, and by normal in-stream self-cleaning processes.

MAG4, at Barton Cove in Gill, MA, was something of a surprise. It exceeded the primary contact geometric mean for both years in wet weather, and in dry weather in 2009 (albeit by a small amount: 135 colonies vs. the limit of 126). In 2008, 2 of 3 samples exceeded the single sample limit, with 370 and 240 colonies, respectively. The three dry weather samples taken in 2008 were all quite low: 13, 21 and 8 colonies respectively. *E. coli* levels were considerably higher in 2009, in both wet and dry conditions. It exceeded the single sample maximum 6 of 9 wet weather sample dates, including three results of 900, 1433, and 3067, respectively. It also exceeded the single sample limit 8 of 20 dry weather dates, including three results of 650, 2133, and 1133 colonies. MAG4 also lies above the city of Greenfield, with no urban areas in the upstream vicinity. There are no known obvious sources of pollution in the vicinity. The sample site is a well-used public boat ramp on a cove of the river. Because it lies out of the main flow of the river, it is likely that water does not circulate well there; any introduced pollutants are not as likely to be flushed downstream as they would be if the site were located closer to the main current. There is a portable toilet on the property, maintained by the Department of Environmental Conservation. It appears to be well-maintained, and is not considered a likely source of contamination. Nor were any pipes or other likely contributors observed in visual inspection of the site by project volunteers. There is a property approximately 200 feet from the sample site that contains several fenced emus. This also appears to be well maintained, with no noticeable pathway that might contribute runoff from this property to the sample site. The fact that high levels were appearing in both dry and wet weather seems to contradict any hypothesis

that stormwater runoff is the culprit. When the high bacteria levels began to appear in 2009, project personnel began more active observational efforts, including those mentioned above, to try to locate likely sources. It was observed on several occasions that a large number of geese and other wildfowl were present. The dates of high waterfowl use seemed to correspond to high bacteria levels. However, this is only a tentative qualitative finding, because the presence of geese was only documented after several of the high bacteria events were recorded. No attempt was made to carefully quantify the number of wildfowl or the duration of their presence. Nor were paired sampling events attempted (e.g. purposefully sample on dates with/without geese present in certain numbers). This site bears further study. A study that is designed to evaluate the impact of wildfowl on bacteria levels is advised.

In the following discussion two caveats are offered regarding interpretation of data from the Holyoke sites.

1) There were five instances of data reported as TNTC (too numerous to count), which the laboratory stated should be interpreted as 200 colonies, for purposes of statistical analysis. This number was used in all charts, tables and means calculated on the Holyoke sites. It is possible that actual bacteria counts were either higher or lower than 200 for these dates and sites: MAH1 and MAH4 on 9/29/08, MAH2 and MAH3 on 7/2/09, and MAH4 on 7/30/09. Adjusting these numbers upward or downward would of course affect the geometric means calculated, and might change the number of exceedences occurring at these sties.
2) On 6/15/09 and 6/22/09, all four Holyoke sites produced unusually low bacteria counts (0-8 colonies). These were both wet weather dates, on which other reaches produced higher numbers. On 6/15/09, the Chicopee sites weren't sampled, but the northern MA sites were, with results between 44 and 279 colonies. On 6/22/09, Chicopee and northern MA reaches were both sampled, with results between 88 and 270 (Chicopee) and 28 and 320 (northern MA). On this date, Holyoke results were either 0 or 1 colony. It is interesting to note that on 6/18/09 (between the 2 dates in question) samples were taken in both the Holyoke and northern MA sites, with no unusual disparity as occurred on 6/15 and 6/22. Quality Control samples run by United Water (the Holyoke lab) for these two dates consisted of blanks; both passed. We contacted the lab about these results, and were informed that nothing in their records indicated any problems that might have compromised sample integrity. We have flagged but not discarded the Holyoke data for these two dates/

The second major cluster of high bacteria levels is in the Holyoke/Chicopee, which also includes the cities of Springfield and West Springfield and surrounding urban areas. Collectively, this is the most urbanized reach of the river tested in this project. As shown on the maps and in figure 3, the upstream to downstream sequence of these sites is MAH4, MAC4, MAH3, MAC3, MAC2 (on the lower Chicopee River), MAHC1, MAH2 and MAH1.

MAH4, located below Northampton but above the more heavily settled parts of the Greater Springfield area, produced the abovementioned TNTC results on the wet weather dates of 9/29/08 and 7/30/09, but was otherwise relatively clean. This does not appear to be a problem site.

MAC4, the Berchulski Fisherman Access in South Hadley, exhibited wet weather bacteria impacts. It exceeded the geometric mean limit in wet weather in both 2008 and 2009, with nine single-sample exceedences out of 15 wet weather dates sampled over the project period. These include seven samples with *E. coli* levels between 1040 and 4000 colonies. This site also experienced significant bacterial pollution on several dates in 2008 prior to the beginning of the TWI volunteer monitoring

program. As mentioned above, the City of Chicopee's participation in this project included water quality sample collection by city employees. In both 2008 and 2009, Chicopee's sample collection began in April; earlier than the TWI sampling start dates of 7/24/2008 and 5/21/2009. For the most part, these additional samples have not been included in the results analysis and discussion. However, as Appendix B shows, site MAC4 produced *E. coli* levels between 1600 and 4400 colonies five times in a one month period, between 6/7/2008 and 7/2/2009 (one other sample had 430 colonies). These high levels were not found in the early season 2009 sampling for this site. This pattern of high early-season bacteria levels in 2008 was also found in sites MAC1 and MAC3, although not as consistently as in site MAC4. It is noteworthy that site MAC2, which is located on the Chicopee river, did not demonstrate similar high levels during this point. It is not known what caused these high bacteria levels in sites MAC1, MAC3 and MAC4.

MAH3, Jones Ferry on the west bank of the river in Holyoke, is approximately 5 miles downstream of site MAC4. MAH3 tested healthy throughout the project. There was one wet weather TNTC result (interpreted as 200 colonies). Otherwise, no samples produce *E. coli* levels as high as 150 colonies, in either wet or dry weather.

Results as site MAC3, the Medina Street Boat Ramp in Chicopee, were similar to those found at MAC4, although wet weather bacteria levels were not quite as high as those found at site MAC3.

Site MAC2, below the Davitt Bridge on the Chicopee River in Chicopee, had lower wet weather bacteria levels than at either site MAC4 or MAC3, but with similar or slightly higher levels during dry weather. The dry weather results at MAC2 are not considered a problem – the site never experienced a dry weather result above the single sample primary contact limit.

MAC1, at the North End Bridge in Springfield, was the most polluted site in the study. It had the highest single reading (13,286 colonies on a wet weather day), the highest wet weather and dry weather geometric means in both years, and the greatest number of single sample exceedences in both wet and dry conditions both years; in all, 37 of 48 samples exceeded the single sample primary contact limit. It is not known why this site was so consistently more polluted than other sites, nor why the dry weather results were so consistently high. This site is a prime candidate for further study. A visual inspection of the river and shoreline upstream of this site might be in order, to see if any previously unknown pollution sources are discharging in the vicinity.

Site MAH2, Pynchon Point Park, is approximately one mile downstream of MAC1 on the same side of the river, generally tested much cleaner than MAC1. Bacteria remained at healthy levels throughout 2008. There were three wet weather and two dry weather exceedences in 2009, but annual geomeans were within safe limits for both wet and dry conditions.

Site MAH1, the Pioneer Valley Yacht Club on the west bank of the river in Agawam, is the southernmost sampling site in the project, downstream of the most urbanized areas along the river. MAH1 is approximately 7 miles downstream of MAH2. The Westfield River and the Mill River (Springfield) join the Connecticut between site MAH1 and MAH2. MAH1 had one wet weather TNTC result in 2008 (interpreted as 200 colonies), and one wet weather exceedence in 2009 (633 colonies); otherwise all samples, wet and dry, were below the single sample primary contact limit.

Collectively, the results for the Chicopee and Holyoke reach display results that are fairly typical of urbanized rivers. Wet weather bacteria levels are very high at times, some sites also produce high dry weather levels, and bacteria increases as the river flows through the most urbanized reaches,

recovering to some degree as the river leaves the urban areas, and where tributary flows enter the river. These data show that problems remain, particularly in wet weather, at several sites on the river. Recreational use of this stretch of the river during wet weather does not appear to be wise; however, with the exception of site MAC1, dry weather conditions were supportive of contact recreation on more than 90% of dates sampled.

APPENDIX A. *E. coli* sampling sites

Site numbering convention; example NHA1
NH = state of sampling location
A = abbreviation for laboratory that will analyze samples
1 = number of site. Site numbers ascend going south to north.

Table 1: Massachusetts *E. coli* Sites

* indicates primary sites. Others were sampled less frequently, on a roving basis determined by monitoring coordinator in consultation with reach coordinators.

Chicopee/Holyoke Sites				Geo Coordinates. Datum NAD83 / WFS84		
Site #	**Site Name**	**Town**	**River**	**Site Rationale**	**Lat**	**Long**
MAH1*	Pioneer Valley Yacht Club	Agawam	CT		42.063513	-72.59329
MAH2*	Pynchon Point Park	Springfield	CT		42.0833	-72.585449
MAC1*	North End Bridge/Bassett Marina	Springfield	CT	Boat launch site	42.1100833	-72.6128833
MAC2*	Davitt Bridge / Granby Rd	Chicopee	Chicopee River	Fishing access/Boat launch site	42.1504	-72.6069167
MAC3*	Medina St. Boat Ramp	Chicopee	CT	Boat launch site	42.1533833	-72.6253833
MAH3*	Jones Ferry	Holyoke			42.172379	-72.629898
MAC4*	Berchulski Fisherman Access S. Hadley	South Hadley	CT	Boat launch site	42.1945333	-72.59985
MAH4*	Brunelle's Marina	South Hadley	CT	Boat launch site	42.2632	-72.5996333

Greenfield / Turner Sites				**Geo Coordinates. Datum NAD83 / WFS84**

Site #	Site Name	Town	River	Site Rationale	Lat	Long
MAG1	Hatfield Boat Ramp	Hatfield	CT	Boat Launch, recreation site	42.3940513	-72.5901675
MAG2	Sunderland Bridge	Sunderland	CT	Boat Launch site, DEP sampling point	42.4674	-72.583
MAG3*	Rock Dam	Montague	CT	Swimming, fishing site	42.5816333	-72.5789833
MAG4	Barton Cove	Gill	CT	River Recreation site	42.6015667	-72.5315
MAG5	Munn's Ferry	Gill	CT	River Recreation site	42.6523	-72.481
MAG6	Route 10 Bridge	Northfield	CT	DEP sampling site		
MAG7*	Northfield / Pauchag Boat Ramp	Northfield	CT	Boat launch, recreational site	42.7157	-72.45255

Figure 1: MA *E. coli* Sites (southern)

VV

Figure 2: MA *E. coli* Sites (northern)

Table 2: Vermont/New Hampshire *E. coli* Sites

Vermont Sites					Geo Coordinates. Datum NAD83 / WFS84	
Site #	**Site Name**	**Town**	**River**	**Site Rationale**	**Lat**	**Long**
VTA1	Wilgus State Park	Weathersfield (near Ascutney village)	CT	River recreation site	43.390819	-72.404494
VTA2*	Sumner Falls	Hartland	CT	River recreation site	43.5675138	-72.3799444
White River Junction Outfall	Potential impact - not a sampling site	Hartford	CT			
VTA3	Lyman Point Park	Hartford	CT	Above CSOs	43.6495667	-72.31525
VTA4	Wilder Picnic Area	Hartford (Wilder village)	CT	Swimming area, above CSOs	43.6797667	-72.3030167

* indicates primary sites. Others were sampled less frequently, on a roving basis determined by monitoring coordinator in consultation with reach coordinators.

New Hampshire Sites					Geo Coordinates. Datum NAD83 / WFS84	
Site #	**Site Name**	**Town**	**River**	**Site Rationale**	**Lat**	**Long**
NHA1	North Star Canoe Rentals	Cornish	CT	Recreation access point	43.432255	-72.393877
NHA2	Cornish Boat Launch	Cornish	CT	Recreation access point	43.4804277	-72.3793611
NHA3	Riverview Farm	Plainfield	CT	Below CSOs and unnamed trib with possible ag impacts	43.5855	-72.35122222
NHA4	Hanchett Brook	Plainfield	Tributary of CT	Possible agri. Impacts	43.594411	-72.335508
NHA5*	Blood Brook Canoe Launch	Lebanon	CT	Below CSOs; Recreation Access Site	43.6064667	-72.3268167
NHA6	Lebanon CSO Outfall	West Lebanon	CT	Immediately below CSO outfall	43.6374	-72.3225333
NHA7	East Wilder Boat launch	West Lebanon	CT	Swimming area, above CSOs	43.67532333	-72.29905

* indicates primary sites. Others were sampled less frequently, on a roving basis determined by monitoring coordinator in consultation with reach coordinators.

Figure 3: VT/NH *E. coli* Sites (southern)

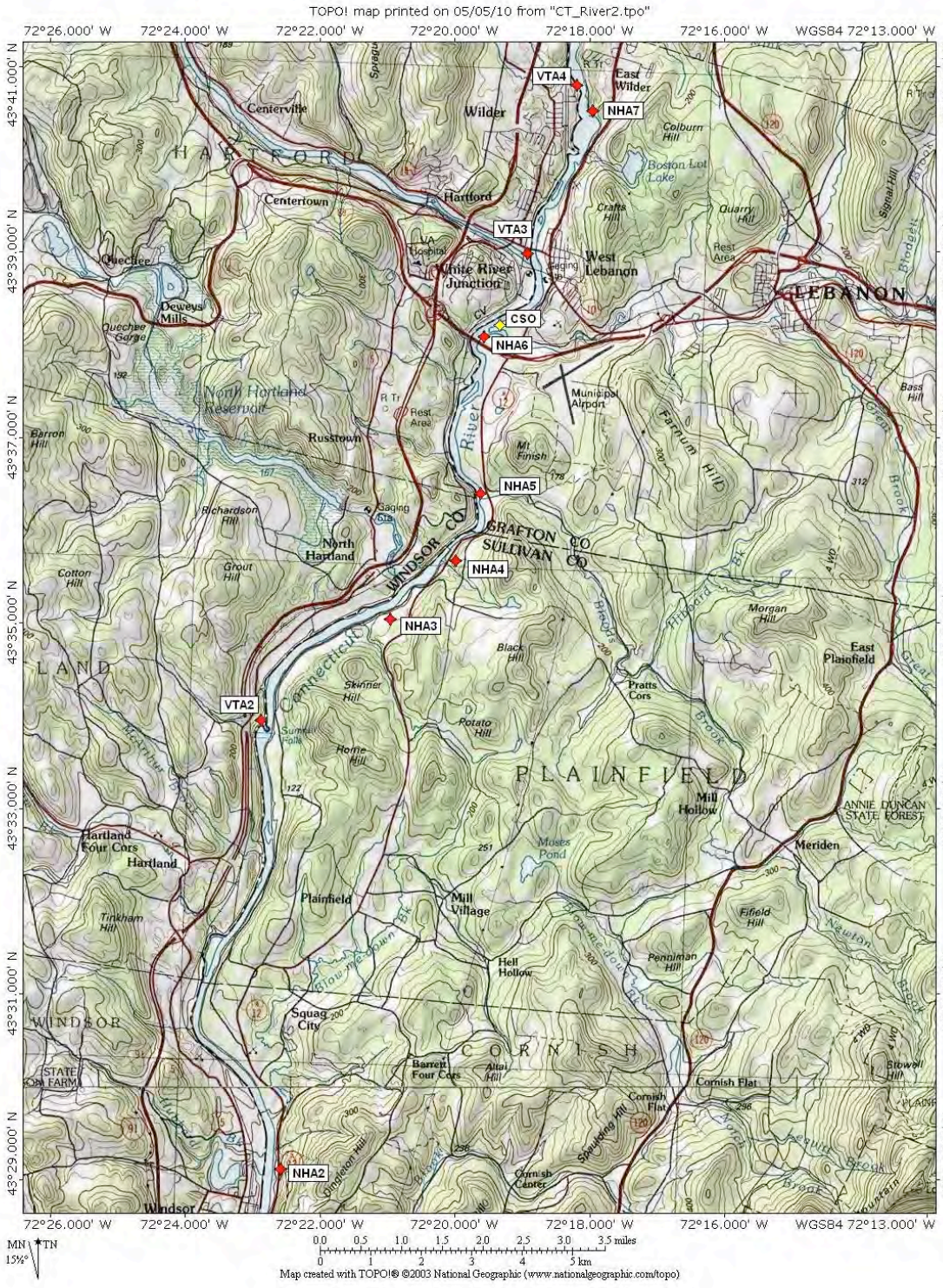


Figure 4: VT/NH *E. coli* Sites (northern)