Applying knowledge to improve water quality
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Presenting Bacteria Data Effectively

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Sharing and Displaying Bacteria Data

Making bacteria data available and understandable to the public helps people make informed choices about where to swim and where not to. It can also be invaluable for helping decision makers better understand the impacts of activities in the watershed, or to target restoration efforts. However, there are some unique challenges involved in presenting bacteria data effectively. This factsheet, the third in a series about monitoring bacteria, provides guidance to help display your bacteria data effectively, allowing you to share your results with diverse audiences.

Determining how best to display your data should be based on your target audience, your data objectives and data users as well as on the story that your data tells. If you have sufficient resources, inclusion of tables, charts and maps highlighting various features of your data strengthens the utility of the information, and appeals to a wide range of data users and types of learners. (Our module "From the Trenches – Tips and Tools for Better Presentations" (http://www.volunteermonitoring.org/pdf/GuideBook/PresentationsX.pdf) provides detailed information and extensive resources for data presentation in general.)

Reporting Requirements

Waterborne fecal indicator bacteria have been associated with pathogens, which are disease causing organisms (USEPA, 1986). Unlike other parameters often monitored by volunteers, such as dissolved oxygen or macroinvertebrates, bacterial monitoring can directly determine potential human health risks of water exposure. In fact, based on data from health risk studies, federal and state standards have been established for drinking and recreational waters, typically with very specific monitoring protocol, lab analysis and reporting requirements. Posting bacterial data for public use can help people to assess the potential health risk of water exposure. However it is important to provide the relevant metadata, data about your data, or cautionary information with your data if your sites are not meeting all applicable state and federal regulations related to fecal indicator bacteria sampling and analysis protocols.

For example, the URI Watershed Watch (URIWW) program includes the phrase "URIWW data are intended for screening purposes only" with its bacteria data because its sampling protocols do not *exactly* match those used by the Rhode Island Department of Health (RIHealth) for beach closures. The URIWW data can't be used to close a beach, but high values may result in RIHealth conducting follow-up monitoring to determine if an area ought to be closed. This screening data also caution recreational users about potential risks, and provides impetus for watershed groups to investigate causes. Clarifying how the data were generated and how they can be used can reduce confusion with the public and conflicts with agencies. Working with your local or state agency to develop your monitoring and report protocols helps build trust and broaden the value of your data.

This is the fifteenth in a series of factsheet modules which comprise the **Guide for Growing Extension Volunteer Monitoring Programs,** part of the *National Facilitation of Extension Volunteer Monitoring Efforts* project. Funded through the USDA National Institute of Food and Agriculture (NIFA), the purpose of this project is to build a comprehensive support system for Extension volunteer water quality monitoring efforts nationally. The goal is to expand and strengthen the capacity of existing Extension volunteer monitoring programs and support development of new groups. Please see http://www.volunteermonitoring.org/for more information.

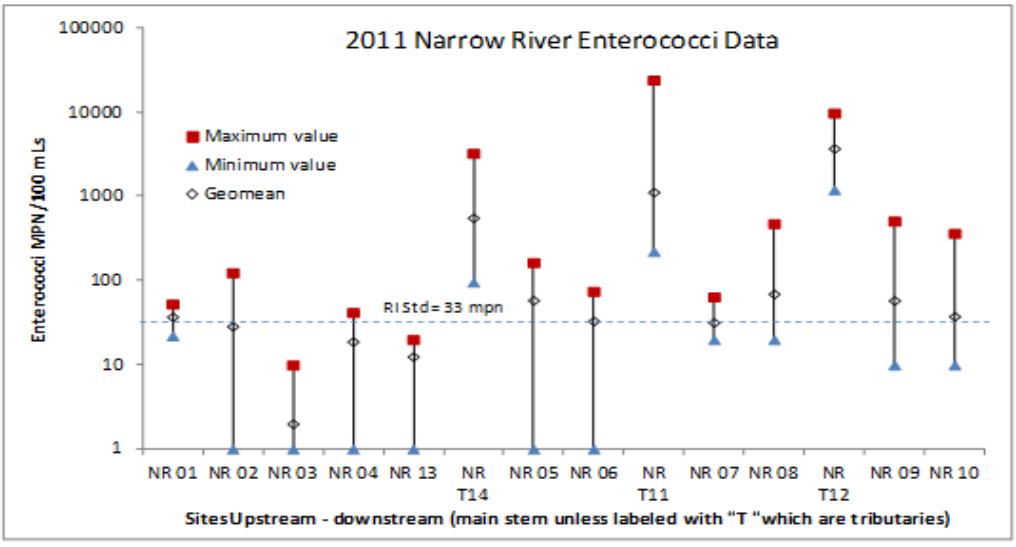
Handling Concentration Variations Across Space and Time

Bacteria concentrations vary significantly, often exponentially, from location to location, whether feet apart at a sampling site, hundreds of meters or miles apart between sampling sites within the same waterbody or between sampling events. Bacteria concentration fluctuations are generally related to proximity in space and time to the source. But unique localized conditions can allow bacteria to reproduce, be diluted, or die off. This results in bacteria levels that can vary from day to day, and even within a beach area at the same time (Pachepsky & Shelton, 2011).

The tremendous variation inherent with bacteria monitoring has resulted in state bacteria standards tending to be based on a **geometric mean** for a number of samples over a particular length of time, usually five observations over a thirty day period. A geometric mean (geomean), unlike an arithmetic mean, dampens the effect of very high or low values, reducing bias of single extreme values. The geomean is calculated by multiplying the numbers (n) in the dataset, and taking the nth root of the result. The geometric mean allows the central tendency of a site to be assessed, making it easier to compare different sites or trends over time. Most spreadsheet programs can handle this calculation or see Buzzard's Bay National Estuary Program's Geometric Mean Calculations webpage (http://www.buzzardsbay.org/geomean.htm) for additional information. One caution about using a geometric mean is that while it will tell you whether a particular site typically has higher or lower bacteria concentrations, it may not reflect true conditions at the site at a particular time (Sigler, 2007). Thus, single sample values are gaining use by state and federal agencies for assessing swimming beaches (USEPA BEACH).

Understanding bacteria concentration dynamics can be improved if the geomean and the range of sample values are reported. For instance, in addition to reporting the geomeans, presenting maximum and minimum values can be very useful. Excel's "Stock" chart format can be modified to plot the maximum, minimum and geomean values (see box 1 for details). The 'High', 'Low' and 'Closing' values are replaced with the max, min and geomean to create a chart like the one in figure 1. The Water Quality Data Report for the Norwalk River (http://norwalkriver.org/wp-content/uploads/2014/11/NR-winter-report-Oct-2010-through-April-2011.pdf) has excellent examples of the use of these modified charts for bacteria and other parameters.

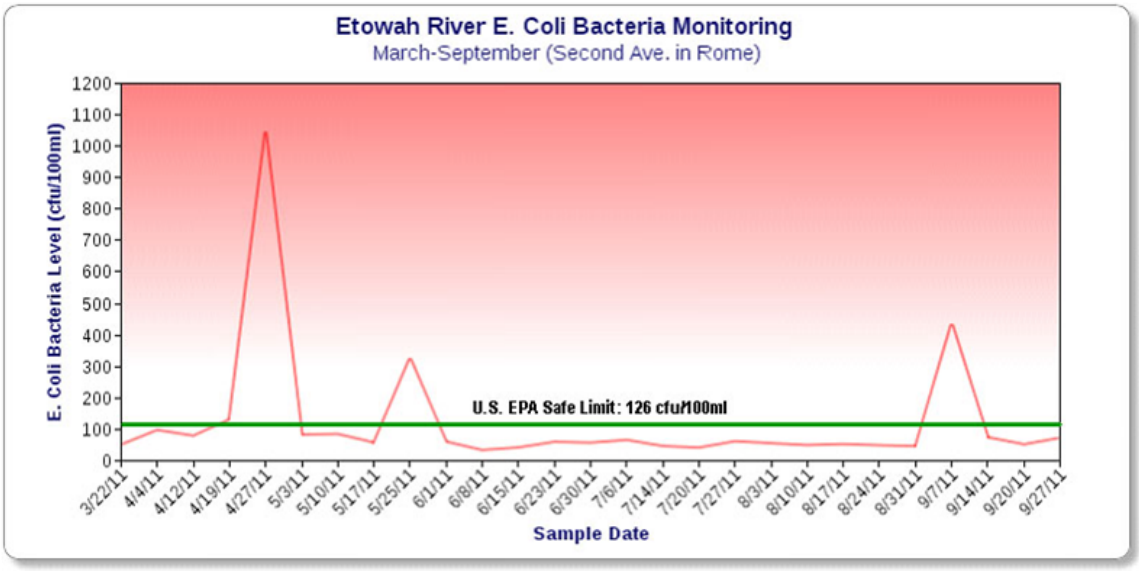
Figure 1. Example of a Stock Chart Modified for Use with Bacteria Data



Other Effective Ways to Present Bacteria Data

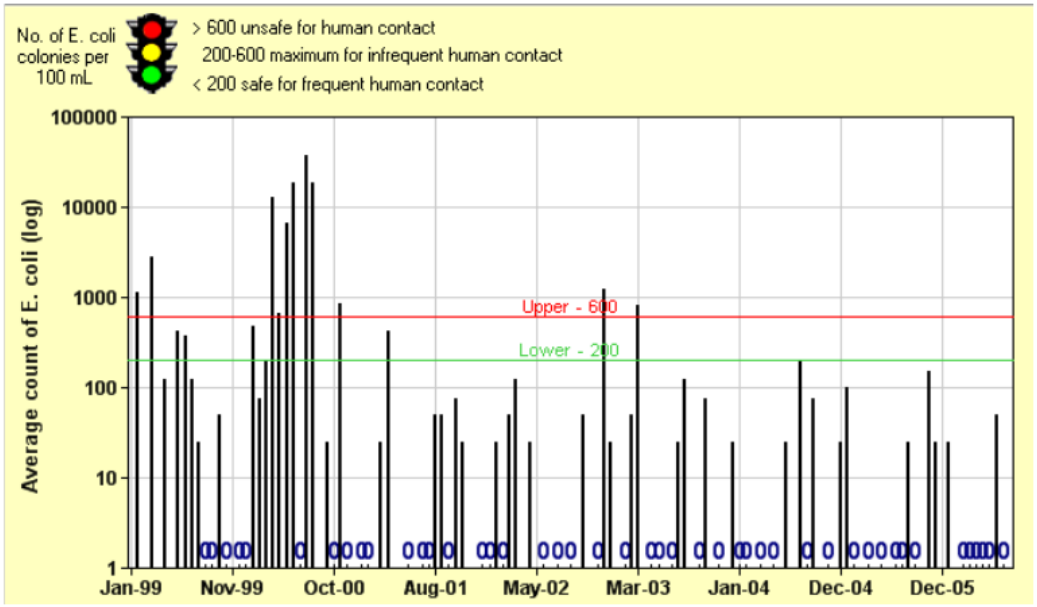
Other common bacteria graph formats include line charts, which can be effective for showing trends and relationships over a period of time or space (figure 2). However because bacteria levels can vary so much over time and distance, the use of line charts should be limited to sites where daily or very regular monitoring occurs, or perhaps as sites are displayed upstream to downstream during a "snapshot" monitoring event where a number of samples are collected during a brief time period. If your data don't meet one of these criteria, consider using another format to present your results. Column charts are often a much better choice for presenting bacteria results (figure 3). Columns effectively display the variability, while not implying linear patterns that may not exist.

Figure 2. Etowah River *E. coli* Line Graph



Etowah River Bacteria Monitoring Program - http://www.coosa.org/issues-actions/water-monitoring

Figure 3. *E. coli* testing of Wolf Creek Column Graph



(WBWW site 04012010 — Alabama Water Watch)

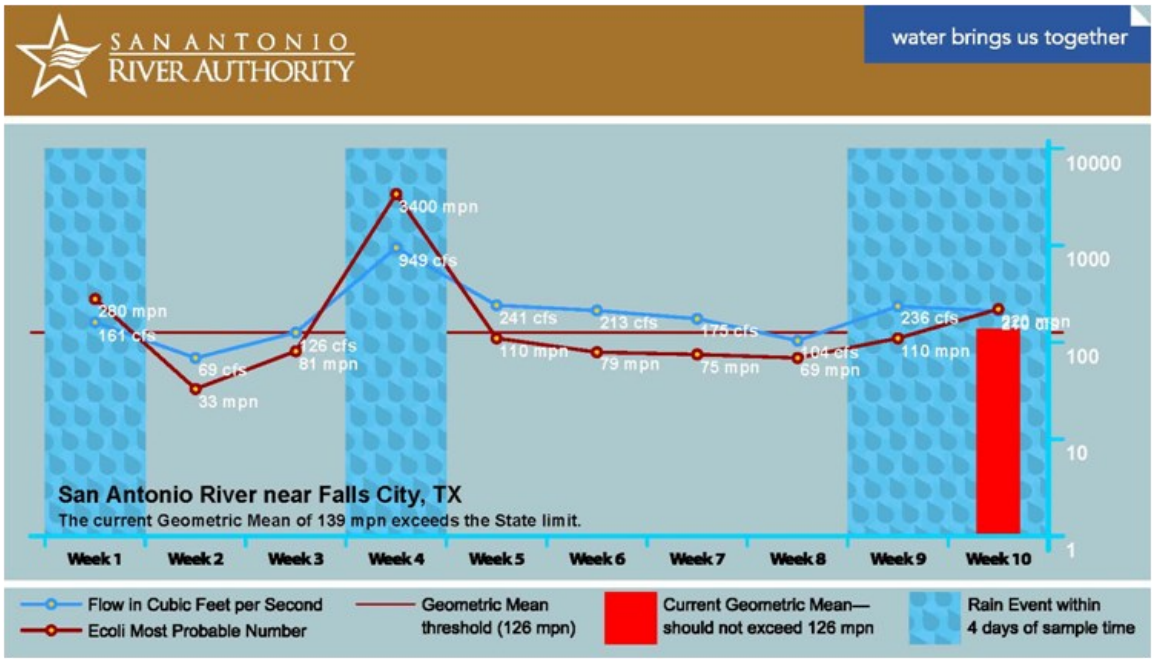
Box: 1. Modifying an Excel "Stock" Chart template for Use with Bacteria Data

1) Calculate the **minimum**, **maximum** and **geomean** value for data (by either sites or sampling dates depending on your study design).
2) Arrange data in columns with labels in this order from left to right: Site/date, Max, Min, Geomean
3) Insert a row beneath the column labels, and enter your data id (Site or date), High, Low and Close (these fields are needed to get Excel to create a stock chart – you'll change them later).
4) Select data, click on 'Insert', select 'Other Charts', select 'Stocks', use 'High-Low-Close'
5) Modify chart (zooming into the chart will be really helpful):
   a) Select series (max, min or geomean), and change the cells that series names link to. (i.e. Close to geomean).
   b) Modify y (vertical) axis – select logarithmic scale if necessary (if your range of values is large this will expand the data series significantly making them much easier to see and work with). Label as appropriate.
   c) Modify each data series. Select the geomean series by clicking on the "-"that will appear on the vertical line. Select the marker of your choice and color.
   d) Modify the max and min series markers by clicking on each end of the vertical line and select markers and colors of your choice.
6) Label the chart and x (horizontal) axis appropriately.

Presenting Bacteria Data (continued)

As noted earlier, bacteria concentrations are also closely linked to rainfall events. So when presenting results it is generally useful to also include rainfall data. The San Antonio River Authority has created a particularly interesting graph that pulls together not only the bacteria results and rainfall events, but also stream flow measured in cubic feet per second (figure 4).

Figure 4. San Antonio River near Falls City Bacteria Results



(San Antonio River Authority: https://www.sara-tx.org/apps/bacteria_charts/ecoli_chart_logrithm.php))

Good charts help to easily visualize the information, are particularly useful for a public audience because they are easily understood, and can be especially helpful for identifying hot spots. Unfortunately it can be difficult to include enough auxiliary information in a chart or graph to provide the full context of the data without cluttering the chart or graph too much.

For audiences requiring or preferring numeric values, such as decision makers or regulatory agencies, bacteria data can be presented in tabular form (table 1). Tables have the advantage of providing numeric values, and additional information can be included to provide greater context. The disadvantage of tables is that it can sometimes be more difficult to visualize what the data are saying about the watershed. Additional levels of color-coding or indication of samples collected during rainfall or within a designated period of rainfall can also be more easily noted table (see http://northbrooklynboatclub.org/assets/WQ_sheet_sm.pdf for an example). If weather data are available, relevant precipitation information can help to explain variations in bacteria results (see http://www.riverkeeper.org/water-quality/citizen-data/ for more examples).

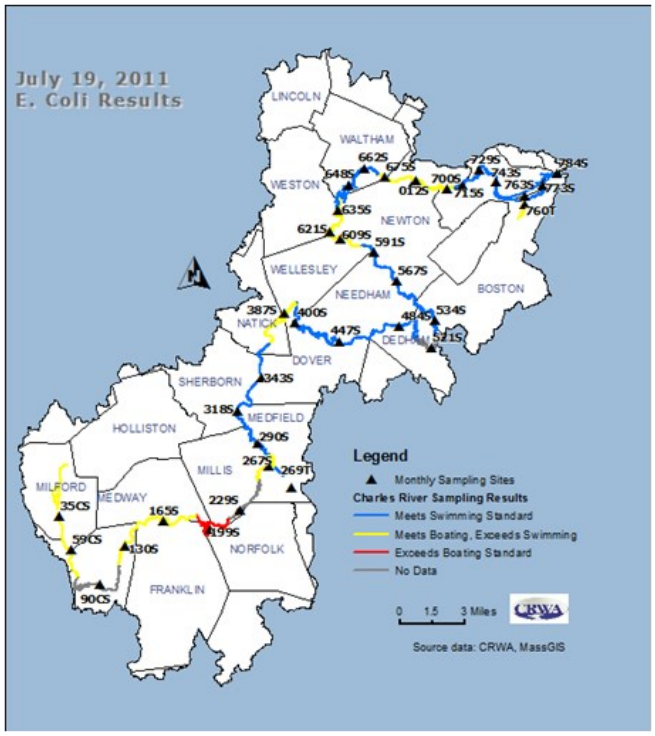
Table 1. Example of a Bacteria Data Table

Narrow River Watch Sites								
Watershed code	MONITORING LOCATION	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	GEOMEAN
(arranged upstream to downstream)		----	Most Probable Number of Enterococci per 100 mL					----
PE	NR 01- Gilbert Stuart *	53	51.2	34.2	-	22.2	-	37.9
PE	NR 02 - Upper Pond	20	20	124	20	<10	20	16
PE	NR 03 - Lower Pond A	<10	<10	<10	10	<10	-	<10
PE	NR 04 - Lower Pond B	42	31	10	10	<10	-	11
PE	NR 13 - Near Lakeside Rd.	10	10	<10	20	<10	<10 / 75	<10
PE	NR 14 - Lakeside Stormwater outfall	96	3265.6	Dry	Dry	-	- / 14136	1643
PE	NR 05 - Lacey Bridge	10	137	<10	164	53	-	26
PE	NR 06 - Mettatuxet Beach	31	75	<10	10	53	-	17
PE	NR 11 - Mettatuxet Brook *	222.4	24196	1549.2	976.8	225.2	-	1129
PE	NR 07 - End of Narrows	42	64	20	20	31	-	32
PE	NR 08 - Middlebridge	20	478	20	124	-	-	70
PE	NR 12 - Mumford Brook *	1642.4	4352	9804	8664	1198	-	3736
PE	NR 09 - Pettaquamscutt	512	64	10	207	10	-	58
PE	NR 10 - Sprague Bridge	10	364	20	20	53	-	38
						# / ## - before / after rain		
RI Department of Environmental Management Shellfish Standards: Not to exceed 14 fecal coliform per 100 mL.								
RI Department of Health standards for recreational contact (i.e.swimming):								
Single Sample Not to exceed: 61 enterococci per 100 mL Fresh Waters * / Marine Waters 104 enterococci per 100 mL.								
Freshwater Geometric Mean Density: 54 enterococci per 100 mL non-designated beach / 33 per 100 mL designated beaches.								
Marine (salt water) Geometric Mean Density: 35 enterococci per 100 mL.								

Presenting Bacteria Data (continued)

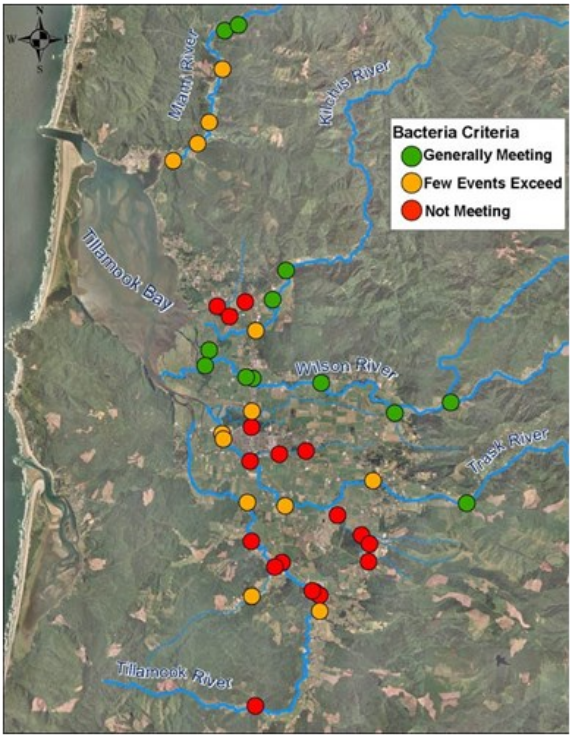
Targeting "hotspots" is often the focus of volunteer monitoring programs, so presenting bacteria data on maps can be especially useful. Maps can show single sampling events with results color-coded to show segments meeting various criteria (figure 5) or summary results indicating the regularity with which a site exceeds criteria (figure 6). Maps are also effective for guiding source tracking or to focus restoration efforts.

Figure 5. Charles River Watershed Association



http://www.crwa.org/field-science/monthly-monitoring/water-quality-data

Figure 6. Tillamook Estuaries Partnership Bacteria Results



http://www.tbnep.org/map.php for current interactive maps

Summary

Presenting complex water quality data in a way that is easily understood by diverse audiences can be a challenge. Fecal indicator bacteria data can be especially complicated. There are potential human health concerns associated with exposure to contaminated water, but significant variations are often found in bacteria levels in response to range of factors – so a single sample doesn't tell us the whole story. The careful use of maps, charts and tables can help the public identify, sites with clean water as well as problem areas, enabling them to make informed choices, and hopefully work toward restoring contaminated waterbodies.

Box 2: Other Guide to Growing Programs - Bacteria Modules

See *Volunteer Monitoring of Bacteria*, to learn more about:

- What are Bacteria
- Why Monitor Fecal Indicator Bacteria
- Which Bacteria Should You Monitor
- Emerging Indicators

See *Monitoring Bacteria – Methods* to learn more about:

- Sampling for Bacteria Analyses
- Bacteria Testing Laboratory Basics
- Laboratory Methods

References and for additional information on bacterial monitoring:

California Source Water Ambient Monitoring Program – Clean Water Team Citizen Monitoring Program – Compendium for Watershed Monitoring and Assessment (3.4. Bacteria Pathogen Indicators http://www.swrcb.ca.gov/water_issues/programs/swamp/cwt_guidance.shtml

E. coli Project. Building Capacity of *E. coli* Monitoring By Volunteers: A Multi-State Effort http://www.usawaterquality.org/volunteer/Ecoli/

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Heufelder, G. 1997. Interpreting Fecal Coliform Data: Tracking Down the Right Sources. The Volunteer Monitor. Vol. 9, No. 2. http://water.epa.gov/type/rsl/monitoring/upload/2004_10_13_monitoring_volunteer_newsletter_volmon09no2.pdf

Köster et al. 2003, 'Analytical methods for microbiological water quality testing', http://www.who.int/water_sanitation_health/dwq/en/9241546301_chap8.pdf

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Pachepsky, Y.A. & D.R. Shelton. 2011. *Escherichia Coli* and Fecal Coliforms in Freshwater and Estuarine Sediments. Critical Reviews in Environmental Science and Technology, 41:1067-1110.

Pathogen Indicators of Recreational Water Quality (a PowerPoint Presentation) http://www.state.nj.us/dep/wms/Recreational%20Indicators%20Overview.pdf.

Stedtfeld et al. 2007. Detection and Occurrence of Indicator Organisms and Pathogens. Water Environment Research. Vol. 79, No. 10, Literature Reviews (2007), pp. 1085-1108 http://www.jstor.org/stable/29763262

Turin, D..& M. Liebman. 2002. Keeping Posted: Communicating Health Risks at Public Beaches. Journal of Urban Technology 9:45-69.

USEPA. 1986. The Ambient Water Quality Criteria for Bacteria – 1986. EPA440/5-84-002 January, 1986

USEPA. Beaches Environmental Assessment and Coastal Health (BEACH) Program http://www2.epa.gov/beaches

USEPA. Water: Monitoring & Assessment 5.11 Fecal Bacteria http://water.epa.gov/type/rsl/monitoring/vms511.cfm.

USGS Field Manual – Fecal indicator bacteria: http://water.usgs.gov/owq/FieldManual/Chapter7/7.1_ver2.0.pdf.

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