

# Beach Management Guidance Document, 2014

This document is in support of the Recreational Water Protocol, 2014  
(or as current) under the Ontario Public Health Standards

Public Health Policy and Programs Branch  
Public Health Division

Ministry of Health and Long-Term Care

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## Preamble

This guidance document supports implementation of the *Recreational Water Protocol, 2008* (or as current)<sup>1</sup> of the Safe Water Program, developed as part of the Ontario Public Health Standards.<sup>2</sup> Under the Safe Water Program, Boards of Health (BOHs) are required to conduct surveillance of public beaches and assess associated risk factors and emerging trends related to illnesses and injuries in order to reduce the risk of illness or injury to the public. BOHs are also required to respond to complaints and reports of adverse events related to recreational water use at public beaches. This response is required within 24 hours of notification and includes determining the level of potential impact and the appropriate corrective response.

## Purpose

The purpose of this guidance document is to support the BOH in meeting the minimum expectations of the Safe Water Program's *Recreational Water Protocol, 2008* (or as current), to reduce the risk of water-borne illness and injury related to recreational water use at public beaches.

Specifically, this guidance document will assist BOHs to:

- Collect and assess relevant information about environmental conditions that may influence recreational water quality;
- Apply appropriate methods for collecting water samples reflective of the conditions at the time of sampling;
- Calculate the geometric mean for assessing recreational water quality and guiding public health actions, including communicating risk to the public; and,
- Effectively respond to adverse events at public beaches.

## Guidance for Board of Health Staff

### Data Collection and Methodology for Recreational Water Sampling

Prior to the bathing season, as defined in the *Recreational Water Protocol, 2008* (or as current), boards of health shall conduct and complete an environmental survey of all public beaches in their area, and review local historical and epidemiological data. BOHs can adapt the *Environmental Survey – Field Data Report* (Appendix A) to assist in field data collection.

During an environmental survey, BOHs are to:

- Confirm the inventory of public beaches that require monitoring by determining if the site meets the definition of a public beach;
- Determine the suitability of the site for public recreational use supported by a water sampling program and appropriate level of surveillance, in collaboration with the owner/operator;
- Analyze previous years' data on public bathing area water conditions and bacterial quality, and where appropriate, use other surveillance tools to assist in identifying predictive influences on water quality (e.g., predictive modeling); and,

- Identify possible contaminant sources, and where appropriate, collaborate with local stakeholders, municipalities, and other surrounding landowners, to reduce or eliminate any potential impact on the quality and safety of the water for public recreational use.

Water samples should be collected to assess water quality prior to commencement of the bathing season, or can be taken during the environmental survey.

The BOH should take immediate action to address any hazardous condition observed during the course of the environmental survey or routine beach surveillance.

During the course of the bathing season, additional environmental surveys may be carried out if:

- Subsequent bacterial testing of the water demonstrates a significant, unexpected deterioration in water quality;
- Historical and/or epidemiological evidence demonstrates a possible association between the public beach and a water-borne illness; or
- There are reports or evidence of chemical, biological, physical contamination, including fish/bird die off, or other contaminants that may affect public beach water quality.

The duration of the recreational water quality sampling program may vary by health unit, depending on local operations and weather conditions.

## Laboratory Services

It is important that BOHs consult with Ontario Public Health Laboratories prior to commencement of the water quality sampling program. BOHs are to follow the Ontario Public Health Laboratories' procedures and protocols for the submission of samples and the communication of lab results. Samples submitted should be identified as a public beach so the appropriate analytical method is used, and may be submitted as part of an environmental survey or for routine beach surveillance.

## Sampling Points

During the bathing season, as defined in the *Recreational Water Protocol, 2008* (or as current), the BOH shall conduct a minimum of one set of five samples per week. Where possible, the samples should be collected on the same day of the week, at approximately the same time of day, for consistency of data collection.

Water samples and any subsequent resamples for routine surveillance should be collected from the same general locations at the public beach which represent the water conditions for the majority of the bathing area. This practice will support consistency for analyzing trends in water quality.

To determine and record sampling points, BOHs should prepare a diagram of the public beach area and include:

- Approximate length of the beach;
- Approximate depth of the water in the public beach area;

- Possible sources of pollution and the distances to the bathing area, where applicable; and
- Numbered sampling points and the sequence in which the samples should be collected.

Water sampling points are determined by length of the bathing area as follows:

**Table 1: Water sampling points**

<b>Length of beach</b>	<b>Number of sampling points</b>
1000 meters or less	5 points
Over 1000 meters	1 point per 200 meters
Over 5000 meters	1 point per 500 meters

### Sampling Frequency

Based on a risk assessment, more frequent sampling may be carried out for public beaches that are prone to changes due to variations in environmental conditions. Routine sampling may be reduced to once per month where historical data of the geometric mean and environmental surveys indicate that water quality has been consistently within water quality limits for an entire bathing season.

The frequency of water sampling may also be reduced to once per month for public beaches that consistently fail to meet water quality limits for an entire bathing season. In this case, the medical officer of health should implement a communication strategy to minimize its use by the public (e.g., permanent posting).

### Water Sample Collection

*When collecting recreational water samples at public beaches, staff should be trained and adhere to all health and safety precautions to prevent injury or illness.*

Where the depth of water is 1 to 1.5 meters, samples for bacteriological analysis must be obtained 15 to 30 centimeters below the water surface. When the depth of water is less than 1 meter, samples should be obtained as far off shore as possible within the bathing area.

Water samples for bacteriological analysis are collected using sterile bottles approved by and available through Ontario Public Health Laboratories.

#### Procedure for Collecting Recreational Water Samples at Public Beaches:

The sampling bottle is to be kept unopened until the time at which it is required for filling.

1. Complete the required information on the requisition form.
2. Remove one barcode from the bottle and apply it to the top copy of the requisition in the “barcode” field.
3. Examine the lid of the bottle.
4. Remove cap and ensure it is kept away from sources of contamination.
5. Plunge bottle downward into water to 30cm – turn bottle in direction point of current.
6. Remove bottle from the water. If the bottle is filled to the top, remove some of the water so it is filled to 200mL line.
7. Replace cap immediately.
8. Store and transport samples between 1 °C and 10 °C (preferably 4 °C) within one calendar day of collection.

Samples must be collected in a manner that ensures that they are representative of the water being tested and have not been contaminated during collection.

## Water Sample Preservation and Transport to Laboratory

Immediately after collection, water samples should be properly labelled and stored in an insulated or refrigerated cooler for delivery to the nearest Ontario Public Health Laboratory, preferably on the day of collection. Samples must reach the laboratory and be analyzed within one calendar day of sample collection. Samples submitted must meet Ontario Public Health Laboratories acceptance criteria or they will not be accepted by the laboratory for analysis. For further guidance on sample collection and submission, refer to Public Health Ontario's *Public Health Inspector's Guide to the Principles and Practices of Environmental Microbiology*.<sup>3</sup>

## Routine Public Beach Surveillance Report

A Routine Public Beach Surveillance Report may be modeled after the *Environmental Survey – Field Data Report* (Appendix A) to document observations and data when recreational water quality samples are collected throughout the bathing season. The report documents conditions at the beach that may be observed and recorded during routine public beach sampling. These include:

- Water and ambient air temperature;
- Rainfall;
- Rain intensity;
- Sky conditions (e.g. cloudy, sunny);
- Wind speed and direction;
- Water clarity/turbidity;
- Wave height; and,
- Pollution sources, such as: waterfowl, industrial waste discharges, storm water outflows, septic system discharges, algal blooms and agricultural run-off.

These factors can contribute to microbiological quality of recreational water at public beaches. The list above captures the minimum parameters that should be observed and/or measured and recorded at the time of sampling. The parameters listed are not exhaustive and BOHs should document other factors that may be locally significant. Data collected should be analyzed to determine factors that may be influencing water quality, in order to inform decisions about communications, posting of beaches, and other actions that may be warranted to protect public health.

## Predictive Modeling

Predictive modeling is a statistical equation tool that BOHs may use to predict *E. coli* levels within public beach water, based upon factors such as turbidity, rainfall, wave height, wind speed, and air and water temperature, and may be used to make same day predictions about microbiological water quality.

The predictive modelling approach is currently being used by some BOHs on a pilot basis and requires many prerequisites in order to be effective. Not all beaches are successful candidates for this method. For further details, refer to the *Feasibility of Predictive Modeling for Beach Management in Ontario*.<sup>4</sup>

## Geometric Mean for Recreational Water Samples

Assessment of the bacterial quality of recreational water requires more than a single result. Due to the uneven distribution of bacteria throughout a liquid medium, the count of microorganisms in a single "grab sample" does not represent the average concentration in a particular body of water. A random sample may demonstrate a concentration that is far above or below the average. In obtaining an accurate assessment of the quality of recreational water, the results of a number of samples must be combined in such a way that a random, unrepresentative sample will not unduly influence the average. For this reason, scientific publications setting bacterial standards for water quality usually require either that a large proportion of the readings fall below a certain maximum permissible value, or that the geometric mean of all samples falls below such a maximum value. The *Recreational Water Protocol, 2008* (or as current) uses the latter approach with respect to public beaches in Ontario. The BOH must review the bacterial test results, as calculated using the geometric mean, along with other environmental factors of the particular public beach, to determine the appropriate course of action.

BOHs monitoring public beaches must test for and report *E. coli* bacteria concentrations. The data must be calculated as a geometric mean of all the test results obtained during the reporting period. The geometric mean, rather than the arithmetic average, is used in these calculations, because it tends to minimize the effect of very high or low values on the average. For example, the arithmetic average of five counts of <10, > 1000, <10, 30, and 240 is 258, while the geometric mean is 59. For sample calculations on how to calculate the geometric mean refer to Appendix B. The single high reading may indicate an error or sporadic occurrence, the cause of which should be investigated. However, use of the arithmetic average, when incorporating an uncommon high reading, results in an exaggerated or inaccurate estimate of average conditions.

Use of the geometric mean which is a log-transformation of data permits more meaningful statistical evaluations.

## Responding to Adverse Events at Public Beaches

The BOH must establish communication strategies with partner agencies to provide clear and timely information to the public regarding potential risks associated with the use of public beaches. Communication may include, but is not limited to, posting information on the BOH website, disseminating written materials, issuing media releases to the local media, and informing local stakeholders, including municipalities.

This section assists BOHs to establish local operating procedures for responding to and reporting potentially hazardous spills and adverse events (e.g., suspected microbiological, chemical, physical or radiological agents) at public beaches.

Response may involve posting beach signage for a swimming advisory or a beach closure.

## Beach Posting

Posting of a beach means to communicate advisories and/or place signs in response to a swimming advisory or beach closure. Postings are typically communicated through an update on the local health unit's website or through local media/newspapers. Beach postings inform the public about potential risks to health and safety, based on an assessment of those risks. The owner/operator of the beach is primarily responsible for posting and removing the advisory/signs as conditions warrant.

## Swimming Advisory

A Swimming Advisory may be issued when beach water quality is not suitable for recreational use. For example, exceedance of the recreational water accepted value for *E. coli* bacteria.

## Beach Closure

A Beach Closure may be ordered under Section 13 of the Health Protection and Promotion Act (HPPA)<sup>3</sup> in circumstances that present a serious and immediate health risk for bathers. Beach closures should be issued when the level of bacterial contaminants in recreational water far exceeds acceptable values (e.g., a sewage or manure spill) or when other conditions occur that render public beaches unsafe or unsuitable for use by the public.

## Beach Signage

Where there is evidence that a public beach is potentially dangerous to the health of bathers, the BOH must ensure that signs are displayed in prominent locations at the public beach, indicating the nature of the risk. The signs should be clear, concise, and recommend a course of action to the public based on specific risk. Considerations with respect to sign posting should include:

- Evidence to support the posting of signs may be based on bacteriological analysis, assessment of historical, environmental and epidemiological data, or the physical quality of the water;
- Signs placed at conspicuous locations along the affected public beach or shoreline;
- Signs containing universal symbols that are easily identifiable, and correspond to the results indicating safe or unsafe swimming conditions; and,
- Signs left in place for as long as deemed necessary and promptly removed when the adverse condition no longer exists.

The duration of the beach posting should:

- Take into account any available evidence and historical data related to the public beach in question;
- Continue until surveillance of the water quality demonstrates that any risk to a bather is at a level considered acceptable by the BOH; and,
- Remain in effect until additional tests conducted show satisfactory results or the observations leading to the action are no longer present or have been satisfactorily addressed.



Where beach water contamination follows heavy rainfall or other environmental factors known to influence recreation water quality, beach postings may be removed when previous experience suggests that sufficient time has elapsed for water quality to have recovered. Signage may be permanently posted at the beach where historical data shows that the bacterial counts consistently either exceed or fluctuate above the limits set for recreational use. Monthly sampling to provide background data may be continued at the discretion of the BOH. After any remedial work is completed that may affect water quality, regular weekly sampling should resume, to re-assess the posting requirement.

## Communication

The BOH is responsible for communicating to the owner/operator (e.g. the municipality) of a public beach about:

- Water sample test results and recommended actions;
- Placement and removal of signs about potential risks to health or safety; and,
- Set-up and dismantle of barriers/barricades when a beach should be closed or re-opened.

BOHs that receive complaints or reports of adverse events related to recreational water use at public beaches should conduct a preliminary assessment, based on available information, within 24 hours of notification, to determine the level of potential impact and the appropriate response required.

## Adverse Event Examples

### Chemical, Oil, Manure or Sewage Spill

*A public beach posting should be issued until the public beach is determined to be acceptable for public use.*

BOH staff should collaborate with the local office of the Ministry of Environment (MOE), the conservation authority, the municipality, and any other relevant agencies where applicable, to investigate the issue. The nature and extent of the potential adverse effect will determine the appropriate response. An action plan to resolve the issue and assess any other potential environmental impacts should be developed, in collaboration with the MOE, the municipality and the conservation authority, and any other relevant agencies. In some cases, re-opening of the public beach will be contingent on testing and obtaining satisfactory results for the spilled materials or residues, in addition to considering other observations.

### Waste Water Treatment Plant Bypass (unintentional or controlled)

*A public beach posting should be issued, depending on the nature and extent of the potential adverse effect, if there is sufficient evidence that the bypass or overflow may have adversely affected the bacterial quality of the public beach.*

Considerations should include:

- Proximity of the bypass or overflow to the public beach;
- Volume, dilution and level of treatment of effluent (secondary or tertiary bypass);
- Circumstances surrounding release (e.g., heavy rain event, plant failure, overload); and,

- Location of the outflow in relation to the beach.

The preliminary assessment can be based on telephone communications with the owner/operator. BOH staff should collaborate with the local public works department, local office of the MOE, and the conservation authority, where applicable, to investigate, develop an action plan to resolve the issue, and assess other potential environmental impacts. Further assessment may require a site visit by BOH staff that includes water sampling to verify the bacterial quality of the recreational water.

#### **Blue-Green Algae Bloom (confirmed by visual observation or laboratory test)**

Blue-green algae are a natural phenomenon that may persist for a significant part of the bathing season.

*A public beach posting should be issued until a complete risk assessment can determine the acceptability of using the beach for bathing.*

MOE, the Ministry of Natural Resources (MNR), the conservation authority and the local municipality should be involved in investigating and managing the adverse event. A swimming advisory is sufficient if the presence of blue-green algae is confirmed by visual observation.

A beach closure may be warranted if the presence of cyanobacteria toxin is confirmed by laboratory tests, depending on the type and level of cyanobacteria toxin found.

#### **Heavy Algae Growth or Accumulation**

*A public beach posting should be issued if the growth of plant life at the bathing area could cause entanglement or could prevent the ability to see someone in distress.*

If the problem is extreme, a beach closure should be considered by the beach owner, depending on the location and extent of the plant life or dead and decaying accumulated algae. Although the presence of the material, in and of itself, may not be considered a health hazard, an assessment may be needed to determine if it is of sufficient quantity and in a location that may directly affect the health and safety of swimmers. Heavy accumulation of dead and decaying algae usually accompanied by odour, typically deters beach use.

#### **Fish or Other Wildlife Die-off at the Beach**

*A public beach posting should be issued indicating that the water is unsuitable for swimming or wading.*

MNR should be notified to determine any action it may deem necessary. MOE, MNR, the conservation authority, and the local municipality should be involved in investigating and managing the clean-up operation.

#### **Visible Debris, Metal or Sharp Objects in Water or Beach Area**

*A public beach posting should be issued depending on the extent and risk of the debris or objects to users.*

The beach owner/operator should be contacted and the material removed from the beach area by the owner/operator before the postings are removed.

### Exceedance of Bacterial Recreational Water Standard

*A public beach posting should be issued if water sample test results exceed the recreational water level for E. coli when calculated using the geometric mean and an assessment of other environmental factors supports such action.*

Beach postings may occur anytime during the bathing season. As part of the routine monitoring program of public beaches, beach postings may be required where exceedance of recreational water quality levels and other environmental data supports the need for posting. Gathering environmental data using the *Routine Public Beach Surveillance-Field Data Report* will provide important information to predict possible bacterial levels under certain conditions (e.g., heavy rainfall, wave action).

### Other Situations

A variety of other situations may arise at public beaches that require an assessment by the BOH, and subsequent action. In determining the most appropriate action, BOHs must meet the applicable requirements under the HPPA and the *Recreational Water Protocol, 2008* (or as current) and should take this guidance document into account.

Notification systems should be established with local public works, parks and recreation, MOE, MNR, and conservation authorities, and any other relevant agencies in order to effectively respond to and manage adverse events in a timely manner.

## Glossary

**Adverse Condition:** a situation that may be potentially harmful to the health and safety of beach and recreational water users.

**Advisory:** a precautionary notice that informs members of the public about specific risks to health and safety to allow them to take measures to protect themselves.

**Bathing Area:** the area at a public beach used for bathing. The bathing area should be determined in collaboration with the beach owner/operator.

**Bathing Season:** the period of time each year that a public beach is used for bathing. Bathing season generally begins in June and ends the first weekend of September. The duration of the recreational water quality sampling program may vary by health unit, depending on local operations.

**Beach Closure:** to cause restriction/elimination of public access to a beach or specific beach areas where a significant risk to health and safety has been identified. The BOH will direct the owner/operator of the beach to post signage and/or erect barriers/barricades at appropriate locations to reduce the risk of public exposure to the health hazard.

**Environmental Survey:** an inspection of the physical beach area to identify changes to existing structures, installation of new structures (e.g., drainage lines, storm water outfalls, signs, etc.), changes in beach landscape that affects runoff, potential pollution sources, garbage or debris

collection, and any other environmental factor that has the potential to impact water quality, water safety, and/or public health.

**Geometric Mean Calculation:** for the purposes of this guidance document, the geometric mean is a calculation used to average the bacterial levels of *E. coli* in samples collected from recreational water.

**Beach Posting:** posting of a beach means to communicate advisories and/or place signs in response to a swimming advisory or beach closure. Postings are typically communicated through an update on the local health unit's website or through local media/newspapers. Beach postings inform the public about potential risks to health and safety, based on an assessment of those risks. The owner/operator of the beach is primarily responsible for posting and removing the advisory/signs as conditions warrant.

**Public Beach:** includes any public bathing area owned/operated by a municipality to which the general public has access, and where there is reason to believe that there is recreational use of the water (e.g., beach signage, sectioned off swimming area, water safety/rescue equipment, lifeguard chairs, etc.), which may result in waterborne illness or injury as determined by the local medical officer of health.

## References

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2. Ontario. Ministry of Health and Long-Term Care. Ontario Public Health Standards. Toronto, ON: Queen's Printer for Ontario; 2008 [revised 2014 May 1; cited 2014 May 1]. Available from: [http://www.health.gov.on.ca/en/pro/programs/publichealth/oph\\_standards/docs/ophs\\_2008.pdf](http://www.health.gov.on.ca/en/pro/programs/publichealth/oph_standards/docs/ophs_2008.pdf)
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## Appendix A: Sample Report

Table 2: Sample Report

Environmental Survey - Field Data Report	
Name of Beach:	Beach ID Number:
Surveyor Name:	Posted at time of sampling: <input type="checkbox"/> Yes <input type="checkbox"/> No
Address/Location:	Latitude: _____ Longitude: _____
Date of Sampling:	Time at Sampling:
Name of Water Body:	Length of Bathing Area (m):
Are maps of the beach area attached? <input type="checkbox"/> Yes <input type="checkbox"/> No Are maps of the watershed attached? <input type="checkbox"/> Yes <input type="checkbox"/> No	Owner/Operator:
Part I: General Beach Conditions	
Air Temperature: _____ <input type="checkbox"/> C <input type="checkbox"/> F	Water Temperature: _____ <input type="checkbox"/> C <input type="checkbox"/> F
Rain Intensity: <input type="checkbox"/> Light (<2.5mm/hr.) <input type="checkbox"/> Medium (2.6-7.5mm/hr.) <input type="checkbox"/> Heavy (>7mm/hr.) <input type="checkbox"/> None	Rainfall: <input type="checkbox"/> <24 hrs. _____ cm rainfall measured/reported <input type="checkbox"/> <48 hrs. _____ cm rainfall measured/reported <input type="checkbox"/> <72 hrs. _____ cm rainfall measured/reported <input type="checkbox"/> >72 hrs. _____ cm rainfall
Water Clarity (Turbidity): <input type="checkbox"/> <100 cm <input type="checkbox"/> >100 cm Value (NTU): _____	
Wave Height (cm): _____	
Sky Conditions: <input type="checkbox"/> Sunny <input type="checkbox"/> Mostly Sunny <input type="checkbox"/> Partly Cloudy <input type="checkbox"/> Mostly Cloudy <input type="checkbox"/> Cloudy	
Wind Direction: <input type="checkbox"/> None <input type="checkbox"/> Away from Shore <input type="checkbox"/> Toward Shore <input type="checkbox"/> Parallel to Shore Wind Speed: _____	
Beach Materials/Sediments: <input type="checkbox"/> Sandy <input type="checkbox"/> Mucky <input type="checkbox"/> Rocky <input type="checkbox"/> Other (specify) _____	
Subsurface Conditions: Does the bottom consist of material that is easily stirred up? <input type="checkbox"/> Yes <input type="checkbox"/> No Are the slopes gentle? <input type="checkbox"/> Yes <input type="checkbox"/> No Is the bottom free of large rocks, sharp objects and other obstructions? <input type="checkbox"/> Yes <input type="checkbox"/> No Is the bottom free of weeds? <input type="checkbox"/> Yes <input type="checkbox"/> No Is the beach susceptible to undertows or rip currents? <input type="checkbox"/> Yes <input type="checkbox"/> No	
Comments/Observations:	

Part II: Use of Beach			
Type: <input type="checkbox"/> Residential <input type="checkbox"/> Industrial <input type="checkbox"/> Commercial <input type="checkbox"/> Agricultural <input type="checkbox"/> Other (specify) _____			
Water Body Uses: <input type="checkbox"/> Boating <input type="checkbox"/> Fishing <input type="checkbox"/> Windsurfing <input type="checkbox"/> Bathing/Swimming <input type="checkbox"/> Recreational Camp <input type="checkbox"/> Aquatic Classes <input type="checkbox"/> Scuba Diving <input type="checkbox"/> Other (specify) _____			
Approximate number of people observed in the water: _____		Approximate number of people using the beach but not in the water at time of observation: _____	
Part III: Potential Pollutants			
Type of Source	Concern		Describe how this source might contribute to beach pollution and its frequency of contribution
Wildlife/Waterfowl	<input type="checkbox"/> Yes	<input type="checkbox"/> No	
Domestic Animals	<input type="checkbox"/> Yes	<input type="checkbox"/> No	
Waterwaste Discharges	<input type="checkbox"/> Yes	<input type="checkbox"/> No	
Sewage Overflows	<input type="checkbox"/> Yes	<input type="checkbox"/> No	
Septic Systems	<input type="checkbox"/> Yes	<input type="checkbox"/> No	
Stormwater/Natural Outfalls	<input type="checkbox"/> Yes	<input type="checkbox"/> No	
Agricultural/Urban Runoff	<input type="checkbox"/> Yes	<input type="checkbox"/> No	
Watercraft Access/Boat Dockage	<input type="checkbox"/> Yes	<input type="checkbox"/> No	
Seasonal Watercourse	<input type="checkbox"/> Yes	<input type="checkbox"/> No	
Chemical Hazards	<input type="checkbox"/> Yes	<input type="checkbox"/> No	
Prone to Algal blooms	<input type="checkbox"/> Yes	<input type="checkbox"/> No	
Part IV: Water Quality			
Sample Number	Sample Point	Parameter: <input type="checkbox"/> E. coli <input type="checkbox"/> Other (specify)	Comments
Geometric Mean:			
Surveyor Signature:			
Part V: Diagram of Sampling Location and Pollution Sources			
Include location of: sample points, pollution sources, marinas, boat dockage, fishing, bathing/swimming, jetty, sanitary facilities, restaurants/bars, playground, parking lot(s), etc. *Remember to show North			

## Appendix B: Calculating the Geometric Mean

**Definition of Geometric Mean:** An averaging method used to reduce the effect of a single high reading.

**Mathematical Definition:** the  $n^{\text{th}}$  root of the product of  $n$  values.

**Practical Definition:** the average of the logarithmic values of a data set, converted back to a base 10 number.

The geometric mean could be thought of as the average of the logarithmic values, converted back to a base 10 number.

The formula for the geometric mean is:

$$\text{Geometric Mean} = ((X_1)(X_2)(X_3)\dots(X_n))^{1/n}$$

where  $X_1, X_2$ , etc. represent the individual data points and  $n$  is the total number of data points used in the calculation.

### Calculating the Geometric Mean

To calculate a geometric mean:

1. Compute the natural logarithm (ln) of each sample result.
2. Add the logarithm of each sample result together.
3. Divide the result by the number of samples.
4. Convert this product (logarithm of the geometric mean) back to an arithmetic value by computing the antilog of the product.

The formula for the logarithm of the geometric mean is:

$$\text{Logarithm of Geometric Mean} = ((\ln X_1) + (\ln X_2) + (\ln X_3) + \dots + (\ln X_N))/n$$

The following example illustrates how this is done:

Where <10, >1000, <10, 30, and 240 are sample data results of colony-forming units (cfu) per 100 ml of water, calculate the geometric mean. This calculation can be performed on a scientific calculator using the “log” key. For example, enter “10” on the calculator and then press the “log” key.

**Table 3: Example Geometric Mean Calculation**

Sample #	Sample Result	Logarithms
Sample 1	<10	$\ln(10) = 2.303$
Sample 2	>1000	$\ln(1000) = 6.908$
Sample 3	<10	$\ln(10) = 2.303$
Sample 4	30	$\ln(30) = 3.401$
Sample 5	240	$\ln(240) = 5.481$

Average of logarithms = 4.079

Antilog of average = 59

In this example, the geometric mean for the data is 59 cfu/100ml of water. Public health inspectors would use this value in addition to other public health factors to determine the necessity for posting or other advisory actions.

