WASHINGTON STATE
DEPARTMENT OF
ECOLOGY

Setting Standards for the Bacteriological Quality of Washington's Surface Water

Draft Discussion Paper and Literature Summary

Revised December 2002
Publication Number 00-10-072

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Prepared by:

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Water Quality Program

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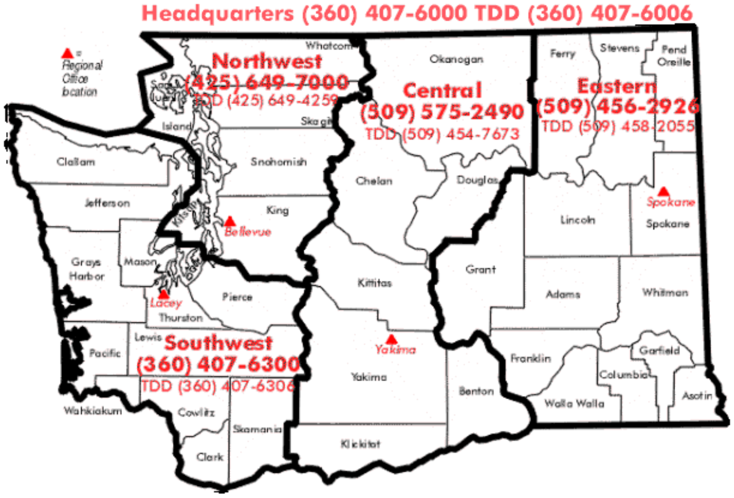

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Abstract

The Surface Water Quality Standards for the State of Washington (Chapter 173-201A WAC) contain criteria to reduce the chance of people becoming ill from eating shellfish or from swimming or wading in natural waterbodies. The state's current criteria for bacterial pollutants is based on the use of fecal coliform as an indicator of contamination by humans and other warm blooded animals. In 1986, the United States Environmental Protection Agency (USEPA) recommended to states that they should no longer use fecal coliform as an indicator of the bacterial health of water. Based on studies conducted by USEPA, it was recommended that states either use *Escherichia coli* (*E. coli*) or enterococci for their bacterial indicator criteria in freshwaters, and use only enterococci in marine waters. Washington, along with many other states, did not adopt the newly recommended criteria. In the summer of 1996, the Washington State Department of Ecology (Ecology) convened a technical work-group to examine the technical merits of the state's bacterial criteria. This report documents the technical and policy issues evaluated by the initial work-group and a later predecessor group. The information prepared with the assistance of the technical work-groups was used to focus discussions with numerous advisory panels both internal and external to Ecology. This process has resulted in the following key recommendations:

1) To protect people who work or play would result in water ingestion or exposure to their eyes, ears, nose, or throat; a primary contact criteria would be set:
    a) In fresh waters, *E. coli* criteria would be set at a concentration of 100/100 ml as a geometric mean with no more than 10% of samples exceeding 200/100 ml.
    b) In marine waters, enterococci criteria would be set at a concentration of 35/100 ml with no more than 10% of samples exceeding 104/100 ml.

2) In marine waters, meeting a fecal coliform level of 14/100 ml (the current standard to protect consumption of shellfish) would be considered equal in compliance to the enterococci standard of 35/100 ml. Thus waters shown to be safe for shellfish harvesting would also be considered safe for water contact use.

3) In waters not designated for primary contact protection, a secondary contact criteria would be set:
    a) In fresh waters, *E. coli* criteria would be set at 200/100 ml as a geometric mean with no more than 10% of samples exceeding 400/100 ml.
    b) In marine waters, enterococci criteria would be set at 70/100 ml with no more than 10% of samples exceeding 208/100 ml.

4) A narrative statement would be included prohibiting the discharge of untreated waste to all surface waters of the state.

5) The state would rely on the fecal coliform standards and the associated certification programs established under the National Shellfish Sanitation Program and used by the Washington State Department of Health as the basis for determining if people who eat shellfish are being adequately protected.

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I want to gratefully acknowledge the assistance that was provided by the technical work-groups established to evaluate the state’s bacteria standards:

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I. Summary and Recommendations

The Surface Water Quality Standards for the State of Washington (Chapter 173-201A WAC) contain criteria to reduce the chance of people becoming ill from eating shellfish or from swimming or wading in waters of the state. The state's criteria for bacteriological pollutants is based on the use of fecal coliform as an indicator of contamination by humans and other warm blooded animals. The use of fecal coliform as an indicator of bacterial contamination has been questioned by members of the public, the regulated community, and the United States Environmental Protection Agency (USEPA) on technical grounds. Most of this debate has focused on the use of fecal coliform as an indicator of potential health threats to swimmers, however, its use as an indicator of the safety of eating shellfish has also been brought into question. It is occasionally suggested that Washington should be using *Escherichia coli* (*E. coli*) or enterococci as indicators to protect swimmers, and should be testing for individual viruses in shellfish. With the help of a technical work-group, the Washington State Department of Ecology (Ecology) critically examined its existing bacteriological standards. This paper documents Ecology's review of its criteria and the information provided by technical work-group.

Bacteria Indicator Criteria Recommended for Adoption by Ecology:

The following recommendations were made with the assistance of the technical work-groups and advisory panels established to review the state's surface water standards for bacterial pollutants.

1. Adopt *E. coli* criteria for fresh waters, and enterococci criteria for marine waters to protect water contact activities, with a conditional option for using the fecal coliform shellfish standards to protect water contact recreation in marine waters.

2. Continue to use fecal coliform as the indicator bacteria in the surface water quality standards to protect commercial and recreational shellfish harvesting.

3. Recognize the Department of Health remains responsible for classification and approval of shellfish production areas in accordance with the national shellfish water quality standards.

4. When averaging bacterial indicator sample data over time for comparison to the geometric mean, the period of averaging should generally not exceed 12 months, and should generally have sample collection dates well distributed throughout the reporting period. It is preferable, though not specifically required, for the reporting periods to represent distinct climatic regimes (e.g., seasons, or summer versus winter) where 5 or more data collection events occur within each period.

5. When determining compliance with the geometric mean or single sample bacterial criteria in or around small sensitive areas such as popular swimming beaches, it is generally recommended that multiple samples be taken across homogeneous portions of the individual sites during each visit. Such multiple samples should be arithmetically averaged together (to reduce concerns with low bias when the data is later used in calculating a geometric mean) to reduce sample variability and to create a single representative data point.

6. The technical work-groups recommended not establishing a separate secondary contact recreation criteria (secondary contact refers to water contact other than from swimming, such as wading or fishing). Even though the risks of illness should be lower, it was believed that all recreational contact (swimming, wading, fishing, boating) of water posed a risk due to skin illnesses and due to cross contamination, and that there was not a scientifically defensible basis for setting a secondary contact criteria. Ecology, however, is proposing to continue having a secondary contact use in the water quality standards, even though it was not recommended by the technical work-groups. The criteria for such a use would be set at twice that established for primary contact use, and would be limited to waters where intentional contact with the water for recreation or work would be unexpected.

7. The technical work-groups recommended exempting certain waterbodies from numeric bacterial criteria. They recommended that waterbodies be exempted from the numeric criteria when location and physical characteristics would make even incidental contact an unlikely use. After further discussion on this issue with the USEPA, Ecology used this recommendation to create proposed exemptions for upland private farm ponds and waterbodies created by humans and managed for the removal or containment of pollution.

8. The department should establish site-specific bacterial standards for the mouths of rivers and streams where such waters are identified as causing or significantly contributing to the decertification or conditional certification of commercial or recreational shellfish harvest areas.

Other options considered for the choice of indicator bacteria included:

- Adopt enterococci for the protection of both fresh and marine waters.
- Using only a single value of 14/100ml fecal coliform in all marine waters to protect both shellfish harvesting and water contact activities.
- Adjusting the values for *E. coli* criteria recommendations to approximate the multiple levels of protection now provided by the existing fecal coliform standards at 50, 100 and 200/100ml.
- Adopting less protective limits under the assumption it would be a good economic tradeoff to allow a higher percentage of people to become sick since the absolute numbers will remain fairly small due to the relatively low numbers of people who recreate in our state's colder waters.

None of the above alternatives, including the recommended approach, will completely eliminate the risks of people becoming ill from coming in contact with the state's waters -- no indicator-based standard is completely risk-free. The selection of the final recommendation was based heavily on trying to maintain the generally high quality of our state's waters and on obtaining formal approval from the U.S. Environmental Protection Agency (USEPA). USEPA wants the states to only use either *E. coli* or enterococci in freshwaters, and only enterococci in marine waters to protect water contact activities; and additionally wants the states to use fecal coliform as an additional standard to protect shellfish growing areas. Any variations to their desired criteria create a risk of formal disapproval. USEPA has further announced their intention to force states to adopt their recommended standards within the next few years. While the state-established technical work-group was not convinced that USEPA's recommendations were indisputable, it did generally conclude that USEPA's recommended indicators could be used to effectively protect public health and should be adopted as the state's bacterial standards.

Proposed Regulatory Language:

The following language was created by Ecology in response to the technical work-group and advisory panel recommendation process. This language is proposed to be included in the surface water quality standards to control bacterial pollution in fresh and marine waters:

(1) Fresh Waters.

(a) The following table lists the bacteria criteria to protect water contact uses for fresh water.

Water Contact Bacteria Criteria in Fresh Water	
Category	Bacteria Indicator
Primary Contact Uses	*E. coli* organism levels must not exceed a geometric mean value of 100/100 mL, with not more than 10 percent of all samples (or any single sample when less than ten sample points exist) obtained for calculating the geometric mean value exceed 200/100 mL.
Secondary Contact Uses	*E. coli* organism levels must not exceed a geometric mean value of 200/100 mL, with not more than 10 percent of all samples (or any single sample when less than ten sample points exist) obtained for calculating the geometric mean value exceed 400/100 mL.

(i) Averaging of data collected beyond a thirty-day period, or beyond a specific discharge event under investigation, is not permitted when such averaging would skew the data set so as to mask noncompliance periods.

(ii) When averaging bacteria sample data for comparison to the geometric mean criteria, the period of averaging should not exceed 12 months, and should have sample collection dates well distributed throughout the reporting period.

(iii) It is preferable to average by season and include five or more data collection events within each period.

(iv) When determining compliance with the geometric mean and single sample bacteria criteria in or around small sensitive areas, such as popular swimming beaches, it is recommended that multiple samples are taken across homogeneous portions of the individual sites during each visit. Such multiple samples should be arithmetically averaged together (to reduce concerns with low bias when the data is later used in calculating a geometric mean) to reduce sample variability and to create a single representative data point.

(v) The department will, at its discretion, establish site-specific bacteria criteria for rivers and streams that cause, or significantly contribute to, the decertification or conditional certification of commercial or recreational shellfish harvest areas even when the pre-assigned bacteria criteria for the river or stream are being met.

(vi) Where information suggests that sample results are due primarily to sources other than warm-blooded animals (e.g., wood waste), alternative indicator criteria may be established on a site-specific basis by Ecology.

(vii) Toxic, radioactive, or deleterious material concentrations must be below those which have the potential, either singularly or cumulatively, to adversely affect characteristic water uses, cause acute or chronic conditions to the most sensitive biota dependent upon those waters, or adversely affect public health (see WAC 173-201A-240, Toxic Substances, and 173-201A-250, Radioactive Substances).

(viii) Aesthetic values must not be impaired by the presence of materials or their effects, excluding those of natural origin, which offend the senses of sight, smell, touch, or taste (see WAC 173-201A-230 for guidance on establishing lake nutrient standards to protect aesthetics).

(ix) Runoff from nonpoint sources (such as from animal and human wastes or soil erosion from land-use activities) are not allowed to drain or be discharged into surface waterbodies of the state, except when controlled with best management practices or treated with waste treatment technology, as approved by the department.

(2) Marine Waters.

(a) The following table lists the bacteria criteria to protect water contact uses for marine water.

Water Contact Use Bacteria Criteria in Marine Water	
Category	Bacteria Indicator
Primary Contact Use	Enterococci organism levels must not exceed a geometric mean value of 35/100 mL, with not more than 10 percent of all samples (or any single sample when less than ten sample points exist) obtained for calculating the geometric mean value exceeding 104/100 mL.
Secondary Contact Use	Enterococci organism levels must not exceed a geometric mean value of 70/100 mL, with not more than 10 percent of all samples (or any single sample when less than ten sample points exist) obtained for calculating the geometric mean value exceeding 208/100 mL.
Shellfish Growing Areas	Fecal coliform organism levels must not exceed a geometric mean value of 14 colonies/100mL, and not have more than 10 percent of all samples (or any single sample when less than ten sample points exist) obtained for calculating the geometric mean value exceeding 43 colonies/100mL

(i) Fecal coliform levels for shellfish growing areas will be viewed by Ecology as also being fully protective of primary and secondary water contact uses.

(ii) Shellfish growing areas approved for unconditional harvest by the state Department of Health are fully supporting the shellfish harvest goals of this chapter, even when comparison with the criteria contained in this chapter suggest otherwise.

(iii) *Notes (1)(a)(i)-(ix) listed previously for water contact criteria in fresh water also apply to marine water.*

(2) **Human-Created Waters Managed for Pollutant Removal**. Numeric criteria established in this chapter for bacterial pollutants and for aquatic life protection are not intended for application to waterbodies created by humans and subsequently managed for the removal or containment of pollution, as well as to private farm ponds created from upland sites that did not incorporate natural waterbodies. However, such waters must not posses conditions of quality and access that create unreasonable health risks to either humans or wildlife. Such waters must also be managed so as to ensure compliance with the criteria and standards established for downstream or adjacent waters.

II. Background

1. History of this Rulemaking Effort:

The Washington State Department of Ecology administers the state's surface water quality standards regulations. These regulations establish minimum requirements for the quality of water that must be maintained in lakes, rivers, streams and marine waters. This is done to ensure that all of the beneficial uses associated with these waterbodies are protected. These beneficial uses include aquatic life and wildlife habitat, fishing, shellfish collection, swimming, boating, domestic and industrial water supplies, and aesthetic enjoyment. The protection of swimmers and shellfish consumption is the focus of this paper.

To reduce the risk of illness to swimmers and people who eat shellfish, the state needs to set limits on the amount of disease-causing organisms that can be added to the surface waters. This is currently done in Washington by limiting the maximum concentration of fecal coliform bacteria allowed in fresh and marine waters. The presence of fecal coliform is one indicator that contamination from the waste of humans and other warm blooded animals may exist. While indicator bacteria may not in themselves be capable of directly causing disease (pathogenic) in people, their presence indicates the water may be contaminated by pathogenic bacteria and viruses. Some indicators, however, such as some types of *Escherichia coli* (*E. coli*) can be both directly pathogenic as well as being general indicators of the probable presence of other pathogens (Chordash, 1978).

The use of fecal coliform as an indicator has been questioned on technical grounds by members of the public, the regulated community, and the United States Environmental Protection Agency (USEPA). Most of this debate surrounds the use of fecal coliform as an indicator of potential health threats to swimmers; significantly less debate exists about the use of fecal coliform as a criterion to protect consumers of shellfish.

In October 1994, Ecology began a public review of its water quality criteria through use of a large broad-based advisory panel. From October, 1994, through May, 1996, the advisory panel evaluated the relationship between the current water quality standards and their protection of beneficial uses. This work was based on the use of questionnaires that were sent through the mail as part of a project referred to as the Use-Based Reformatting of the Water Quality Standards. One of the outcomes of this process was that Ecology received a strong level of encouragement to technically re-evaluate its use of fecal coliform as an indicator. In response, Ecology set up a work-group of technical specialists to review the issue. The discussions and recommendations of that technical group form the basis for this paper.

This discussion paper is intended to provide sufficient information for interested members of the public to use to assess the probable implications of any proposed changes to the state's current fecal coliform standards. The first part of this paper will discuss the use of bacterial indicators to protect swimming and water contact recreation, and the second part will discuss the role of indicators in protecting the health of people who consume shellfish. The more detailed information in the appendices is provided to supplement and elaborate on the key issues brought up in the body of the paper.

III. Protection for Recreational Contact

1. Development of the Existing Bacterial Indicator Criteria:

The U.S. Environmental Protection Agency has served as a leader for establishing and recommending criteria for the protection of surface water. States generally follow the recommendations of USEPA when it comes to setting water quality standards. The establishment of Washington's water quality standards for bacterial indicators, and the reason for this current review of those indicators, is strongly linked to the development and revision of such standards by USEPA.

Federal water quality criteria recommendations for bacterial pollutants were first proposed in 1968 by the National Technical Advisory Committee (NTAC) of the Federal Water Pollution Control Administration, a forerunner of EPA. The original criteria were based on disease studies that were conducted in the late 1940's and early 1950's by the U.S. Public Health Service. These studies were conducted at well-used bathing beaches and in one case a swimming pool. Gastrointestinal, respiratory, and other symptoms such as skin irritations were recorded by volunteers who swam in these waters. The water quality was measured using "total coliform bacteria" as the indicator organism (USEPA, 1986; Stevenson, 1953). The results of these studies showed a greater illness rate in individuals who swam on the three days when the geometric mean coliform density was 2,300/100mL when compared to swimmers who swam when the geometric mean was less.

In the mid 1960's the U.S. Public Health Service translated the original "total coliform" criterion to a "fecal coliform" criterion. This was reportedly done so that the criterion used would be more feces-specific. Based on an estimate that 18 percent of the coliforms are typically fecal coliforms, the previous guideline of 2,300 total coliforms was multiplied by 0.18 to create a comparable fecal coliform standard of approximately 400. Thus it was assumed that a detectable health risk would occur when fecal coliform concentrations reached 400/100mL. Since a detectable health effect was undesirable, the NTAC proposed to divide the 400/100mL concentration in half. The following summarizes their recommendation (USEPA, 1986):

> "Fecal coliforms should be used as the indicator organism for evaluating the microbiological suitability of recreation waters. As determined by multiple-tube fermentation or membrane filter procedures and based on a minimum of not less than five samples taken over not more than a 30-day period, the fecal coliform content of primary contact recreation waters shall not exceed a log mean of 200/100mL, nor shall more than 10% of total samples during any 30 day period exceed 400/100mL."

In 1972, the USEPA initiated a series of studies at marine and freshwater bathing beaches. These studies were conducted to try to respond to criticisms that had developed regarding their earlier swimming studies. The results suggested that fecal coliform was a poor indicator of swimming-related illness (The correlation coefficients are shown in Appendix B). *E. coli* was shown in the studies to be the best indicators of disease in freshwaters (correlation of 0.80) and enterococci was the best indicator in marine waters (correlation of 0.96). Enterococci actually performed very well in both marine and fresh waters (0.74). In response to this new information, USEPA revised its recommendations for bacterial standards to what they are today. Currently, USEPA recommends that states use *E. coli* as the indicator for freshwaters and enterococci for marine waters, or use enterococci for both marine and fresh waters.

Washington currently uses fecal coliform as its indicator bacteria. The levels established vary between different waterbodies based on their assigned classification and designated beneficial uses. The waters most protected for swimming have a fecal coliform criterion of 50/100mL (Class AA), the next most protective class has 100/100mL (Class A). Currently, wading is assigned a level of protection of 200/100mL, which equates to the original fecal coliform level of protection established to protect swimming by USEPA.

The Ecology archive records were searched to investigate the basis used in establishing our existing criteria. In a 1976 revision to the water quality standards, a discussion paper on changing the bacteria standards noted it was “desirable to have the fecal coliform level as low as possible to have the safest level of water to accommodate swimming and shellfish harvest”. So in setting bacterial standards, the department based their decision in large part on what levels of these bacteria were already being attained in the waters. The department’s investigation of existing data reportedly showed that: Class AA and A freshwaters were under 50 fecal coliform units per 100mL 76.3% of the time; Class B freshwaters were under 200/100mL 73.7% of the time; and lakes greater than 20 acres had less than 10/100mL 92.3% of the time. Class AA and A marine waters were less than 14/100mL 76.3% of the time; and Class B and C marine waters were less than 50/100mL 60.4% of the time. At the time, Ecology believed it was appropriate to set standards that were not being met in all waters at that time. This was based on the assumption that water quality would improve further because of improvements in wastewater discharge technology, and that more advanced wastewater treatment techniques would be used in the future.

IV. Use of Indicator Organisms Versus Pathogens

From time to time it is suggested that states should be directly measuring the pathogens in the water rather than measuring indicators which may not directly indicate or quantify the presence of pathogenic bacteria and viruses (Fugate, 1975; Grabow *et al.,* 1989; Bitton, 1980). This issue has probably existed since the time when the use of indicator organisms were first put in practice. In 1983, Cabelli listed several reasons why the use of indicators was a sound practice. These reasons remain sound today:

(i) A large number of pathogenic bacteria and viruses are potentially present in municipal sewage, and each has its own probability of illness associated with a given dose;
(ii) Routine monitoring for each of the pathogens would be a Herculean task;
(iii) Enumeration methods for some of the more important pathogens are unavailable (e.g., hepatitis, rotaviruses and parvo-like viruses), and for the rest are difficult;
(iv) Pathogen density data are difficult to interpret because the methodology generally is imprecise and inaccurate and because of the meager dose-response data available; and
(v) On theoretical grounds, the intent is not to index the presence of the pathogen but rather its potential to be there in sufficient numbers to cause unacceptable health effects.

Fleisher et al. (1993) examined the relationship between enterococci (actually measured as the similar though slightly broader fecal streptococci group) and enterovirus levels in marine recreational waters. The Fleisher et al. research estimated that the probability that a 100ml sample of water contained no enterovirus was higher than the probability it would contain a possible or probable infectious dose of enterovirus up to a enterococci density of 1,000/100ml. Further, the probability of zero enterovirus remained higher than the probability that a 100ml sample of seawater contained one or more enteroviruses up to an enterococci concentration of 450/100ml. Considering epidemiological studies have showed excess gastroenteritis at enterococci concentrations of as little as 32/100ml, the authors suggested the use of enterovirus assays may be of limited value in assessing the quality of marine recreational waters. Haile et al. (1996) in a study of bather disease in Santa Monica Bay, California found it necessary to concentrate 100 liter samples of seawater to successfully isolate viruses. This work further supports the opinion that setting water column standards based on direct measurement of virus may be problematic and ineffectual.

V. Evaluation of Indicator Organisms

Several sources of information contribute to our understanding and concern over various pathogenic organisms and indicator bacteria. We have defined these as clinical studies, outbreak studies, and field studies. Clinical studies, for our purposes, mean observational studies conducted in hospitals and clinics. Outbreak studies are investigations that follow-up on outbreaks of illness traced back to swimming in contaminated waters. Field studies refer to studies planned in advance. In field studies, data are collected on the concentrations of indicator organisms at recreational swimming beaches. This data is compared with information obtained on the amount of swimmers and non-swimmers who became ill in the following weeks. A statistical analysis is performed to determine what (if any) relationship exists between the illnesses observed in these two groups of people and the concentration of the various indicator organisms in the water.

Clinical studies were not identified for evaluating the risks of swimming in bacteriologically contaminated waters. It was believed that clinical studies do not adequately represent the exposure patterns of healthy swimmers. Outbreaks also have not been identified and used in this analysis. Outbreak studies can be useful in identifying the causes of swimming-associated illness. This is done by associating a specific group of people to an activity and location, such as people who swam at a given beach on a given day. Outbreak studies do not, however, provide information that can be used in developing a relationship between a measure of bacterial quality and the rate or incidence of disease. This is primarily because water quality is not actually monitored until well after the exposure period has occurred. Thus, while outbreaks can be useful for identifying waterborne pathogenic organisms, the use of controlled epidemiological field (retrospective) studies is the most appropriate information to use in developing water quality standards.

1. Epidemiological Field Studies

Marine Studies:

New York, Massachusetts, and Louisiana

Marine studies were conducted on behalf of the U.S. Environmental Protection Agency at bathing beaches in New York City, Boston, and Lake Pontchartrain, near New Orleans (Cabelli, 1983). While eleven different indicators were tested at the New York beaches, only fecal coliform, *E. coli* and enterococci were tested at beaches in Boston and Lake Pontchartrain. This USEPA study concluded that there is an increased risk of gastroenteritis associated with swimming in waters more (as opposed to less) polluted with sewage, and that increased risks existed even in waters that met the USEPA criteria of 200 fecal coliform per 100mL. Enterococci was determined to be the best indicator of highly credible gastrointestinal symptoms in recreational water quality (correlation coefficients of 0.72 - 0.75). *E. coli* was the next best indicator (with correlations of 0.52 - 0.54). Fecal coliform demonstrated a poor correlation with highly credible gastrointestinal illness.

At enterococcus densities of both 70 and 10/100mL, respectively, the rates for "total gastrointestinal illness" and for "highly credible gastrointestinal illness" symptoms among swimmers were twice those for non-swimmers. The symptoms were determined to be the same at about 1/100mL. Cabeli also found that greater rates for vomiting and diarrhea occurred with swimmers at the heavily and moderately polluted beaches, and that children under the age of ten were affected most by illness. USEPA used the Cabeli study to recommend that enterococci not exceed 35/100mL in marine waters to avoid having greater than 19 of every 1,000 swimmers contracting significant gastrointestinal disorders.

Santa Monica Bay, California

Haile et al. (1996) conducted a study to determine the possible health effects of swimming near stormwater outfalls in Santa Monica Bay, California. This study examined total and fecal coliforms, enterococci, *E. coli*, and enteric viruses. The authors determined the risk of becoming ill from swimming near the drain versus at 400+ yards for various cutoff points (which can generally be related to existing water quality standards recommendations). No associations with illness were found for *E. coli* using the lower cutoff points of 35 and 70/100mL. When days in which *E. coli* concentrations above the cutoff point of 320/100mL were evaluated, the relative risk of earache was about 46 percent higher and the relative risk of runny nose was about 24 percent higher. Only skin rash was significantly higher with total and fecal coliforms using the cutpoints of 10,000 and 400/100mL, respectively. The higher cutpoint of 106 cfu for enterococci was associated with producing a 423 percent increase in the relative risk of diarrhea with blood and a 44 percent higher risk of highly credible gastrointestinal illness. Using the cutoff point of five for the total to fecal coliform ratio, the authors found a relative increased risk of diarrhea of 28 percent, and an 87 percent increase for significant and highly credible gastrointestinal illness.

While the authors found no indicator to be fully predictive of disease, enterococci showed statistically significant correlations with more of the observed health effects. The reduced correlation that was found when the data set excluded days when enterococcus concentrations were below 35/100mL provides some support for the EPA recommendation that 35/100mL will be protective of swimmers.

Great Britain I

Fleisher *et al.* (1993) conducted a study on the health effects of fecal coliform and fecal streptococci at two beaches in Great Britain. The authors found no association with gastroenteritis at fecal coliform exposures below 200/100mL. They additionally found that the rate of illness between swimmers and non-swimmers was indistinguishable at fecal streptococci concentrations below 40/100mL.

Great Britain II

Kay *et al.,* (1994) studied gastrointestinal illness rates in adults at four beaches over a four year period in Great Britain. Water samples were analyzed for total and fecal coliform, fecal streptococci, and *Pseudomonas aeruginosa*. Total staphylococci were counted at three of the locations. Of the indicators examined, only fecal streptococci was correlated with rates of gastroenteritis. Fecal coliform was considered to have very little public health value as an indicator in the waters they tested. The conclusion of the study was that a concentration of fecal streptococci of 33/100mL represented the threshold of increased risk.

Great Britain III

Fleisher (1996) conducted a study at four beaches in Great Britain over four swimming seasons to examine total coliform, fecal coliform, fecal streptococci, total staphylococci, and *Pseudomonas aeruginosa*. The purpose of the study was to evaluate relationships between indicators and the incidence of non-gastrointestinal illness. The study evaluated acute febrile respiratory illness; and ear, eye, and skin ailments.

Only fecal streptococci exposure was reported as showing any evidence of a statistically significant trend with acute febrile respiratory illness, and only fecal coliform showed an increasing trend in the incidence of ear ailments. The authors estimated the threshold where excess illness in swimmers was statistically significant to be 60 fecal streptococci for acute febrile respiratory illness, and 100 fecal coliform for ear ailments. They also suggested that their study argued against the use of a single indicator to establish water quality standards, since individual indicators may be may be better at predicting specific types of illnesses.

Sydney, Australia

The South Wales Health Department initiated a study of adults using 12 popular bathing beaches in the Sydney area (Corbett et al., 1993). The study evaluated their existing fecal coliform criteria of 300/100mL, and made a comparison with fecal streptococci. The authors found that swimmers were almost twice as likely as non-swimmers to report symptoms, and that increases in respiratory, ear, and eye symptoms accounted wholly for the increase in illness observed. As the concentration of fecal bacteria increased, the reports of all symptoms, except gastroenteritis, also rose. People who swam for longer than 30 minutes were 4.6 times more likely to develop gastrointestinal symptoms; however, there was no correlation with increasing concentrations of fecal coliforms and increasing symptoms of gastroenteritis. The study also showed symptoms were elevated at beaches that met their current health standard of 300 fecal coliform units/100mL. The authors concluded in their study that fecal coliforms are marginally better predictors of reported symptoms than fecal streptococci.

Hong Kong

In a two-phase study, Cheung et al. (1989) studied nine marine beaches for fecal coliform, *E. coli*, *Klebsiella spp*., fecal streptococci, enterococci, staphylococci, *Pseudomonas aeruginosa*, *Candida albicans* and total fungi. There was a significant excess of total illness for swimmers at each of the nine beaches. The highly credible gastroenteritis (HCGI) symptom rate was five times higher for swimmers. Eye or fever symptoms were four times higher. Gastrointestinal, skin, respiratory, or total illness rates were two-three times higher. High correlation was found between observed illness rates and the concentrations of fecal coliforms, *E. coli*, fecal streptococci and enterococci. Low correlations were found between illness rates and the concentrations of the various microbial indicators (*Pseudomonas aeruginosa*, *Candida albicans* and total fungi). The authors found high correlation with HCGI and skin symptoms combined for both fecal coliform (0.71) and *E. coli* (0.73) in marine waters. Fecal streptococci, and enterococci showed lower correlation with HCGI or skin symptom rates. Staphylococci was significantly correlated with ear (0.66) and sore throat (0.56) symptom rates. When compared to other microbial indicators, staphylococci showed the highest correlation with total illness (0.36); and was the only indicator with a positive correlation with respiratory symptom rates (0.56).

The authors contend that their study points to the need to have more than one indicator, since staphylococci was highly correlated to ear, respiratory and total illness, but *E. coli* was superior for skin and highly credible gastroenteritis. Their suggestion to use both *E. coli* and staphylococci is also based on data that shows that the two indicators are poorly correlated with one another.

The authors separated health risks into four categories based on concentrations of *E. coli* and the rate of gastroenteritis and skin symptoms:

1) Good = 0 symptoms/1,000 swimmers at 24/100mL,
2) Acceptable = 10 symptoms/1,000 swimmers at 180/100mL,
3) Barely acceptable = 15 symptoms/1,000 swimmers at 610/100mL, and
4) Unacceptable = any concentration of *E. coli* above 610/100mL.

Geometric mean densities of 180 *E. coli* per 100mL and 1,000 staphylococci per 100mL were found to be the threshold values which statistically differentiated beaches that were considered barely acceptable from those considered to be relatively unpolluted. Fecal coliform levels above 410 per 100mL were also shown to be associated with beaches determined to be barely acceptable.

Freshwater Studies:

Lake Erie and Tulsa, Oklahoma

Dufour (1984) studied the incidence of illness at swimming beaches on behalf of the USEPA in Lake Erie at Erie, Pennsylvania, and in Keystone Lake outside of Tulsa, Oklahoma. Only fecal coliform, *E. coli*, and enterococci were examined. Symptom rates for swimmers was generally higher for all the categories of illness examined. The symptom rates for non-enteric related illness, however, were typically not considered statistically significant ($p < 0.05$). Significant swimmer-related illness rates tended to occur at the beaches that had the poorer water quality, and as with the USEPA marine studies, children under ten years of age had the highest rates of gastrointestinal illness.

The author found that highly credible gastrointestinal illness was highly correlated with concentrations of both *E. coli* (0.804) and enterococci (0.744). Fecal coliform levels were not found related to the rate of gastrointestinal illness. USEPA used Dufour's work to suggest a freshwater criteria of 126/100mL for *E. coli,* which should allow no more than 8 in every 1,000 swimmers to experience symptoms of a highly credible gastrointestinal illness.

Ontario, Canada

Seyfried et al. (1985) studied ten fresh water beaches in Ontario, Canada to evaluate fecal coliform against several other potential indicator organisms: fecal streptococci, heterotrophic bacteria, *Pseudomonas aeruginosa*, and total staphylococci. A relationship between total illness and surface water isolates of staphylococci, fecal coliform, and fecal streptococci was noted. Total staphylococci also related to eye and skin illness, which was not true with any of the other indicators. The correlation coefficients for total staphylococci, fecal coliform, and fecal streptococci versus total illness were 0.439, 0.284, and 0.166 respectively. Crude morbidity rates were 69.6 per 1,000 swimmers versus 29.5 per 1,000 non-swimmers (i.e., out of 2,743 swimmers seven percent became ill compared to three percent of the 1,794 non-swimmers). Swimmers experienced respiratory ailments most frequently, followed by gastrointestinal, eye, ear, skin, and allergenic symptoms. Immersion of the head was reported as related to higher ear illness.

Ardeche basin

Ferley et al. (1989) studied eight beaches in the Ardeche basin of France. The study evaluated total coliform, fecal coliform, fecal streptococci, *Pseudomonas aeruginosa*, and *Aeromonas spp*. Swimmers suffered skin ailments much more frequently than non-swimmers (3.7 to 1). Gastrointestinal illness had an occurrence rate of 2.4 to 1 for the two groups. Fecal streptococci was concluded to be the best indicator because of its higher correlation with acute gastrointestinal disease (AGID) symptoms. Correlations with AGID was 0.55 for fecal streptococci, 0.33 for fecal coliform, and 0.30 for total coliform. *Aeromonas* and *Pseudomonas* both had negative correlations for AGID, however, they correlated well with skin disease. For skin disease, fecal streptococci has a negative correlation and all of the other indicators had a moderate to strong correlations (fecal coliform 0.67, total coliform 0.46, *Aeromonas* 0.51, and *Pseudomonas* 0.73). The authors also found good correlation between fecal coliform and total disease (0.51), and found that skin disease is more prevalent in swimmers than in non-swimmers at fecal coliform levels greater than 120/100mL.

To prevent acute gastrointestinal disease (AGID) in swimmers, it was recommended that fecal streptococci be kept below 20/100mL and that fecal coliform be kept below 800/100mL. To prevent total gastrointestinal illness, not just acute symptoms, these values would be lowered to 7 fecal streptococci/100mL and 270 fecal coliform/100mL.

2. Discussion on Evaluating Studies and Selecting an Indicator Organism

Each of the bather studies examined above were conducted in a slightly, or in some cases a significantly, different manner from one another. The indicators evaluated the following:

- The number of participants,
- The nature of the control population,
- The sampling regime,
- The sources of the bacterial pollution (disinfected versus raw sewage, or animal waste), and
- The statistical analyses used .

This does not provide an ideal framework for determining which bacterial indicators are best. Further, while the EPA studies were conducted in U.S. waters, they were conducted largely in waters very different from those in the state of Washington. While the exposed study populations would be expected to be similar in their sensitivity to diseases as Washingtonians, no specific evidence was found that demonstrates this fact or shows the various pathogens of concern are found in similar numbers all across the U.S. Further, Washington’s waters (particularly our marine waters) are in general significantly colder than the waters used in any of the USEPA tests. This is an important difference since the survival of bacterial indicators as well as the pathogens themselves are influenced by water temperature.

All of the bather studies rely on individuals to recognize and recollect after a period of at least several days that they had experienced the symptoms of illness after swimming. It has been noted in the literature, however, that not everyone infected by an enteric virus will show clinical signs of illness. Asymptomatic infections are reported as common among some enteroviruses (Rose, 1993). Whether or not someone infected by an enteric virus develops clinical symptoms depends on factors such as: the immune status of the host, the host’s age, the virulence of the micro-organisms, and the route of infection.

Whether disease occurs from swimming or wading depends upon the type of pathogen and the route and extent of exposure. The immersion of a swimmers head and the amount of time spent in the water are obviously important exposure factors. They are not, however, predictably related to the amount of water consumed nor to the quantity of the viral or bacterial pathogen ingested. Oral ingestion is also not the only route for pathogenic infections. Exposure of the eyes, ears, and nose, as well as just through skin exposure can all lead to waterborne illnesses.

The route of exposure may be an important consideration in the selection of an indicator. It has been suggested, for example, that bather-to-bather transmission is the main source of major outbreaks of disease (ODEQ, 1995). Chaeng (1990) examined bather density in comparison to sources of the pollutants and the incidence of disease in swimmers and found that illness rates were higher among swimmers at both high and low bather densities, but were highest when bather densities were also high.

Indicators which measure the bacterial contamination from the mouth, nos, and skin (non-fecal) of bathers have generally received little attention in bather studies, but these sources may be quantitatively examined and may be consistent predictors of swimming-related illness (Favero, 1985). Several of the bathing beach studies have suggested that a significant portion of the illness associated with swimming is morbidity associated with the upper respiratory track, eyes, and ears (Seyfried, 1985; Chaeng, 1990; Chaeng, 1989). Indicators found to be correlated with morbidity associated with the eyes and respiratory tract include staphylococci which is not fecal specific and may be contributed from, and inoculated on, the skin, throat, nose, and eyes of bathers. The follow-up analysis conducted in association with the Hong Kong study showed a good correlation between bather density and morbidity associated with the eyes and respiratory tract, and further established the best correlation between these symptoms and staphylococcal densities (Chaeng, 1990). The U.S. studies only tested staphylococci in their first year at two beaches, where it had a good correlation (0.60) in the data grouped by trials.

The importance of the statistical procedures used to examine illness in the bather studies must also be carefully considered. Through statistics we can describe how confident we are that any one value is different from or related to another. Anytime there is naturally high variability in a factor, that variability translates into a higher standard deviation and a more stringent requirement for demonstrating significance. While some study authors carefully measured and compared the concentrations of indicators at the time specific participants were in the waters against the observed illnesses in those people, other studies generalized these relationships more broadly. In the USEPA bather studies, for example, data on bacterial concentrations and illness rates were averaged across entire summer seasons, and control groups were combined from studies on different beaches. These type of practices seriously detract from the strength of a study’s conclusions.

The above are just a few examples of factors that make evaluating bathing studies difficult. The technical work-group evaluating bacterial indicators considered these factors in reaching its recommendations. An additional factor that has played an important role in the recommendation process is the need to obtain final approval by USEPA.

The technical work-group generally concurred that enterococci concentrations less than 35/100mL, *E. coli* less than 126/100mL, and fecal coliform less than 100/100mL would each be adequately protective of swimmers in both fresh and marine waters. Enterococci was generally thought to be the best indicator overall, particularly if only one indicator were to be selected for both marine and freshwaters, however, the group found the benefits of more simplified analysis and the more fecal-specific nature of *E. coli* to also give it high value as an indicator. While fecal coliform has performed rather poorly in most bather studies in predicting rates of gastrointestinal illness, the fact that statistically significant increases in illness are not typically observed at concentrations below 100/100ml and the fact that fecal coliform has been shown in some studies to be a sound indicator for skin, eye, and respiratory illnesses was a persuasive factor in continuing to consider its use. Continuing to use fecal coliform was noted to also have some unique benefits. These included the ability to continue conducting trend analysis, since fecal coliform data has been collected now for about twenty years; the ability to use the least expensive and least complex analytical method; and to better enable pollution control programs to model riverine bacterial loading levels that will protect shellfish growing areas that are classified for protection based on fecal coliform levels. These additional benefits associated with staying with fecal coliform, however, are also more available if the state changes to using *E. coli*, since in Washington most (typically 95-98%) of the fecal coliform concentration is actually comprised of *E. coli* bacteria.

One concept that was introduced into the recommendations pertains to marine water protection. It was suggested that any indicator chosen should include an equivalency option using the shellfish consumption criteria that is based on fecal coliform. As an example, if enterococci is chosen as a bathing criteria, then either meeting an enterococci concentration of 35/100mL or meeting a fecal coliform concentration of 14/100mL, both expressed as a geometric mean, would demonstrate compliance.

For whatever reasons, bather studies have sometimes resulted in opposing conclusions regarding what constitutes the best indicator for determining the suitability for water contact recreation. It is very likely that the specific sources and waterbody characteristics weigh heaviest in determining which indicator is best for any specific waterbody, and even if there is a best indicator in general, many other indicators may be very suitable for any given waterbody. In other words, even if *E. coli* or enterococci are most consistently found to be strongly correlated with disease, in any given waterbody a third indicator such as fecal coliform or staphylococci may also be a very good.

Some authors have suggested that two or more bacterial indicators should be used in combination to ensure full protection of recreational contact. For example, in the Hong Kong studies *E. coli* and staphylococci were recommended in combination; and in both British (Fleisher, 1996) and French studies (Ferley et al., 1989), fecal coliform and enterococci were recommended to be used in combination. Studies recommending the use of multiple indicators often suggest that certain indicators are better for individual symptomatic illnesses. For example, fecal coliform tends to be strongest in predicting the occurrence of respiratory and eye infections, and skin ailments; while enterococci and *E. coli* tend to be better at predicting the occurrence of serious gastrointestinal disorders.

Even if we could select a single best indicator, or best combination of indicators, their use would not eliminate the risk of waterborne pathogens. While we can statistically describe concentrations of an indicator bacteria at which illness is generally not detected or is predicted to be very infrequent, we can never be absolutely sure that swimmers or waders will not become ill from coming in contact with waterborne contaminants. This basic fact is true whether we are talking about a pristine mountain lake or a river that receives treated wastewater.

Staphylococcus was dropped from consideration both because it was judged to be an inconsistent performer overall in predicting illness, and because there is no standard test for staphylococcus and it is complex to differentiate in a laboratory. It was noted as worthy of consideration by the work-group, however, because in a couple of cases it showed very good correlation with illnesses where other indicators performed poorly.

The choice of indicators that were good predictors of the rate of illness originally came down to a selection of enterococci or *E. coli.* The work-group initially rejected the use of fecal coliform because of its general lack of correlation with severe intestinal illness. Later, however, the work-group re-examined the value of using fecal coliform and reconsidered its use as an indicator based on its practical values and our ability to identify concentrations below which, increases in disease are rarely observed.

Recognizing that several indicators would be effective in protecting bathers, the work-group became more focused on the practical aspects of applying and administering any bacterial standards chosen. There are a number of factors that were considered important to the selection of an indicator organism. The key element considered was how well the indicator correlates with (or predicts) observed illness rates in swimmers; but other factors related to the practicality of using the various indicators were also considered important. These other factors included:

- The indicator should be specific to sewage or fecal sources;
- It should not enumerate bacteria considered to have little or no sanitary significance such as *Klebsiella* species*;*
- The indicator should mimic the survival characteristics of the pathogenic viruses and bacteria of concern (See Appendix I for technical discussion on viruses);
- Sample results should be able to be analyzed rapidly to get feedback on health threats; and
- Contract and private laboratories should be able to produce reliable and cost effective analyses.

Specificity to Fecal Sources:

In order of specificity to the feces of warm blooded animals, *E. coli* is most specific, closely followed by enterococci and then weakly followed by fecal coliform. While *E. coli* is essentially entirely fecal specific, the technical work-group acknowledged that it can also grow in industrial wastewater lagoons having the proper nutrients, pH, and temperature after inoculation by human or animal sources.

Enterococci is not specific to fecal sources, and may come from both insects and plants, however, contributions from warm-blooded animals typically makes up the majority of the enterococci measured in natural waters.

This is a good point to discuss the analytical method that measures the enterococci group of bacteria. The enterococcus test will enumerate concentrations of the species *E. faecalis, E. faecium, E. gallinarum, and E. avium*. It does not enumerate either *E. equinus or E. bovis* like the fecal streptococcus test does. Since *E. bovis* and *E. equinus* are a major species in the intestinal track of many large animals, concern may develop that the enterococci test will under identify the waste from farm animals. However, while these two species of bacterium are dominant in the gut of farm animals, they do not survive at all well outside the animals and thus die off very rapidly in the environment. This die off may mean that these two species cannot be expected to be enumerated from samples of water regardless of the test method chosen (Franson, 1992; and Brenner, 2000).

In a study by Rutkowski and Sjogren (1987), enterococci were found to be present in much greater numbers in human (38 to 78%) than non-human wastes (0.0 to 25.17%). The authors examined water from six sites, three heavily influenced by human sewage and three streams draining a diverse watershed. The species isolates were primarily made up of *S. faecalis, S. faecium, and S. avium.* (80 to 91% of the total streptococcal species). They also examined the species isolates in five animal species. Streptococcal species that would be enumerated as enterococci made up only a small percentage of most species with the exception of chickens (beaver 0%, sheep 1.2%, horse 3.7%, cow 29%, and chicken 98.8%). Using the work of others, Geldreich (1978) estimated that human feces contains enterococcus species 74-76% of the time, fecal streptococcus 100%, *Escherchia coli* 87-100%, *Enterobacter-Klebsiella* strains 0-98%, and *Klebsiella pneumoniae* 26-30% of the time.

In a study by Niemi and Niemi (1991), it was found that the relationship between presumptive fecal streptococci and confirmed fecal streptococci was strong in treated wastewater (82%) and weaker in agricultural and pristine areas (44%). It is noteworthy that the mean/median values of presumptive *E. coli* were 12/0 for pristine areas 3,610/283 for agricultural areas, and 20,639/9,100 for treated wastewater. The mean/median values for confirmed fecal streptococci was 26/0 in pristine areas, 495/106 in agricultural areas and 15,970/10,000 in treated wastewater.

Milligan (1986) examined various bacterial indicators to determine if the high fecal coliform levels observed in Bear Creek could be confirmed as a health problem in light of USEPA changing their focus to enterococci and *E. coli*. They found an average standard deviation in replicate testing of *E. coli* of 11.3 and 14.7 for enterococci. They also noted high correlation coefficients between enterococci and *E. coli* (0.81) and fecal coliform (0.79), and between fecal coliform and *E. coli* (0.91). It should be noted that such high correlations between enterococci and either *E. coli* or fecal coliform is not commonly reported.

The greatest situation of exception to the general rule of enterococci being related to fecal sources is most likely to occur in association with discharges containing wood waste. For example, Duncan and Razzell (1972) examined samples of water, soil, needles, and bark from three different forest environments, and from a pulp and paper mill. Forest water samples were less than 2/100mL for fecal coliform, and with the exception of a wood samples taken from a log pond that received untreated wastewater (<20->2,000/100mL) and one sample of grand fir needles (55/100mL), all of the other 27 forest samples were at or below the reported detection limit of 20/100mL. In identification of the isolates the authors found that 71% were *Klebsiella* and 2% was *E. coli*. Joe Joy, as part of the work-group's discussions, also noted finding enterococci criteria values exceeded in non-contact cooling waters. This suggests that such warmwater sources may serve as reservoirs for enterococci in freshwaters.

It is worth restating that while the primary source of concern involves pathogens associated with fecal pollution, non-fecal contamination associated with bather to bather transmissions of illness remains a health concern.

Does not Enumerate Klebsiellae:

The work-group was unanimous in the opinion that it is acceptable, if not preferable, to have an indicator which does not include *Klebsiellae* bacteria. Most species of *Klebsiellae* are commonly considered to be opportunistic and low risk pathogens that have not been associated with any disease outbreaks in swimmers. Neither enterococci nor *E. coli* testing enumerates *Klebsiellae* bacteria, while fecal coliform testing often does.

Klebsiellae can make up a significant or dominant portion of any sample analyzed procedurally as fecal coliform. A high fecal coliform count may be of less sanitary significance in cases where much or most of that count is based on *Klebsiellae* bacteria. Gregory Ma (Metro/King Co. Env. Health Lab.), as part of the work-group discussions, noted that his agency had observed about 50% *E. coli* and 50% *Klebsiellae* in samples taken from pristine waters and analyzed for fecal coliform. As they moved downstream, the proportion of *E. coli* tended to raise often making up almost all of the fecal coliform value. Nancy Jensen (1982), laboratory microbiologist with the Ecology laboratory, noted that out of eleven samples analyzed for fecal coliform and KES plate counts, KES ranged from 6.7 to 100% of the fecal coliform concentration. The median concentration was 48% KES. Of the KES positive colonies, with rare exception they were comprised of *Klebsiella pneumoniae*. A more detailed technical discussion on *Klebsiellae* is provided in Appendix D.

Mimics Survival of Pathogenic Viruses

Enterococci is considered to be the better mimic for the survival characteristics of viral pathogens in chlorinated wastewater, as well as subsequent survival in natural waters, particularly marine. While occasional strains of *E. coli* can be pathogens themselves, the more rapid die-off of *E. coli* compared to many of the virulent pathogens in chlorinated effluents and marine waters, may limit its performance as an indicator (see Appendix I for a more detailed discussion). However, research conducted by Ecology indicates no greater problem exists in deactivating enterococci than exists with either fecal coliform or *E. coli* using current methods of sewage disinfection and treatment (see Appendix H).

Speed of Obtaining Sample Results

E. coli can be analyzed in 24 hours but it has traditionally taken 48 hours to analyze for enterococci. If confirmation testing is required, the time period for *E. coli* increases another 24 hours and that for enterococci another 24-48 hours. However, more rapid analysis methods have recently been established for enterococci, such as the enterolert® method developed by IDEXX and USEPA's recently approved "method 1600". Both of these methods can reduce analysis time to 24 hours making it similar to *E. coli*; although, at present the IDEXX method is not approved by the USEPA.

Except for the possible exception of shellfish protection area studies, however, the work-group did not consider the time for analysis to be a significant issue. Most sampling programs do not have a mechanism to get results back to the sampler immediately, and the transient nature of spikes in bacteria concentrations means that in most cases you are taking action on events which have passed. Further, most monitoring programs are not directed towards emergency beach closures, but are instead ambient monitoring programs looking for water quality trends or trying to validate suspected problems. A description of the various types of monitoring programs is provided in Appendix E.

Complexity of Laboratory Procedures

E. coli requires the least change in equipment and procedures for laboratories already conducting analyses for fecal coliform. A different agar medium and only one additional step in the process is required. Enterococci may present some more serious cost and complexity problems, particularly for some small laboratories associated with wastewater treatment facilities. Two different agar media, separate incubators for initial analysis (41°C) and confirmation testing (10°C), and more complex microbiological assessments can be associated with enumeration of enterococci. The work-group saw these increased difficulties for enterococci as minor overall, and believed the laboratories that would have trouble are primarily those already having trouble running the fecal coliform test.

In a recent review by the state of Oregon, it was suggested that laboratories have problems enumerating enterococci in samples of chlorinated effluents. They suggested that a significant percentage of atypical colonies developed, due perhaps to chlorine stress. It was noted that confirmation testing of these stressed colonies takes greater microbiological expertise than for fecal coliform tests. It was also noted that effluents having moderate to high suspended solids tend to cause poor precision (the larger the sample volume filtered, the poorer the recovery of colonies). They reported that samples split among different laboratories have resulted in reported concentrations that vary by 29 to 66 percent of the mean (coefficient of variation). Thus, they are concerned that sample results may result in a high probability of false positive tests (ODEQ, 1995). No similar review was conducted for *E. coli* for comparison. The Washington work-group agreed that it requires greater expertise to confirm enterococci tests. The group could not, however find evidence to either support or refute the contention that greater chlorine stress of enterococci occurs than would occur with *E. coli*.

The cost for doing fecal coliform, *E. coli* and enterococci are all fairly comparable. The following shows the range of prices quoted by four contract labs and one government lab in the Tacoma/Seattle region:

Fecal Coliform:	$14, $25, $25, $35, $41
E. coli:	$14, $25, $35, $40, $41
Enterococci	$---, $25, $25, $55, $55

One laboratory did not conduct enterococci testing, and all but one enterococci quote was based on the Most Probable Number (MPN) method using 3 to 5 dilutions and 5 tubes (Franson, 1992). Costs between membrane filter (MF) and the 5-tube MPN method for enterococci were the same for all labs that did both. The costs for fecal coliform analysis varied, with some labs charging more for MPN tests. Prices quoted for fecal coliform were for MPN where available. It is worthy of mentioning that Ecology's laboratory currently charges $27 for enterococci testing, but that the analytical labs with the lower-ranged price quotes for enterococci ($25-35) cited above had noted the prices may be lower than they should be.

A particular problem identified with using the USEPA approved standard method for determining enterococci concentrations is that the procedure may create a state listed hazardous waste, sodium azide, as a reagent byproduct. This factor might increase the cost and complexity of conducting analysis for enterococci. The work-group considered this possibility to be worthy of some caution in choosing enterococci as an indicator bacteria.

3. Relative Strengths and Deficiencies of *E. coli*

Strengths:

- Sample analysis can typically be completed within 24 hours, providing an opportunity to provide more timely feedback to recreationalists.

- There are only several minor additional steps to determine *E. coli* as compared to the currently used fecal coliform standard.

- Shellfish are regulated using fecal coliform. Since *E. coli* can be correlated well with fecal coliform levels in specific waterbodies, using *E. coli* as a freshwater standard would allow for effective comparisons and modeling of the riverine inputs of fecal coliform to shellfish beds.

- Costs of laboratory analysis are similar or identical to fecal coliform analysis.

- *E. coli* is highly specific to fecal sources and does not enumerate *Klebsiellae* species.

- EPA strongly supports the use of *E. coli* as a freshwater indicator.

- Bather studies often show *E. coli* to be an effective indicator of the sanitation of freshwaters, and sometimes for marine waters.

- Its use would be compatible with neighboring states' standards, allow for continued trend analysis using historic fecal coliform data, and better correlate with fecal coliform standards used to protect shellfish harvesting in marine waters.

Weaknesses:

- EPA strongly discourages using *E. coli* as a marine water indicator organism.

- *E. coli* does not consistently predict the sanitary quality of marine waters.

- *E. coli* is more quickly eliminated from wastewater and ambient waters in response to chlorine, salts, and inhospitable temperatures than are many of the pathogens of concern.

4. Relative Strengths and Deficiencies of *enterococci*

Strengths:

- Sample analysis can now be completed within 24 hours using approved standard methods; providing an opportunity to provide more timely feedback to recreationalists.

- Enterococcus is an excellent indicator of the sanitary quality of both fresh and marine waters. It is the most consistently recommended indicator in studies with marine waters.

- Enterococci survive better in the environment than the indicators of fecal coliform or *E. coli*, and survive as well as many enteroviruses and many of the pathogens of greatest concern.

- Enterococci seems to better simulate many viral pathogens with regard to greater chlorine resistance than either *E. coli* or fecal coliform.

Weaknesses:

- Laboratory analysis costs may sometimes be greater than for either *E. coli* or fecal coliform.

- Most laboratories would need to obtain new equipment and would have more difficulty gaining experience with the more complicated analysis procedure than with either *E. coli* or enterococci.

- The need to conduct confirmation testing may be greater than for either *E. coli* or fecal coliform thus expanding the costs and the time for receiving sample results.

- The USEPA approved laboratory methods produce a hazardous waste by-product.

- The recommended criteria levels of 33 and 35 are very close to the lower end of the analytical countable range of 20. This results in very wide confidence limits for measured concentrations near the criteria limit. For example, it may be difficult to statistically defend that a measured concentration of 30/100mL is actually different than a measured concentration of 80/100mL.

- Enterococci can be contributed from vegetative sources in quantities that can become significant in waters influenced by the discharge of pulp mill wastes.

- Since shellfish will continue to be regulated using fecal coliform, using enterococci in some marine waters will result in needing to analyze for two very different indicators. This would increase monitoring program and compliance costs. If enterococci is used in marine waters, and *E. coli* in freshwaters, as recommended by EPA, than three indicators would need to be in effect within the state and all three may need to be in use in areas where rivers enter marine waters.

- Using enterococci in marine waters as swimming criteria would result in situations where waters are unconditionally approved for shellfish harvest, based on fecal coliform analysis, yet identified as unfit for water contact recreation based on enterococci concentrations.

- Using enterococci in marine waters would make it difficult to model contributions from freshwater sources if they are monitored for *E. coli*.

5. Relative Strengths and Deficiencies of Continuing to Use Fecal Coliform

Benefits of using fecal coliform at 100/100mL to protect recreational contact:

- No evidence that concentrations less than 100/100mL would result in a significant increase in illness rates.

- Laboratories are already set up and experienced in doing the fecal coliform tests.

- Fecal coliform sampling and analysis costs are the lowest of all indicators.

- Continuing with fecal coliform will allow long term data trend analysis to continue.

- Sample results could be directly compared to the fecal coliform shellfish standards.

- Compliance costs and difficulties would not increase in the majority of marine areas.

Costs of using fecal coliform to protect recreational contact:

- USEPA has informed Washington they will not approve the state's standards if it does not use enterococci in marine waters and either *E. coli* or enterococci in freshwaters.

- Rising fecal coliform levels are not as consistently correlated with increases in disease as is enterococci or *E. coli* (fecal coliform is not very useful for predicting the number of excess illness that will occur at a given contamination level).

- Fecal coliform testing also enumerates *Klebsiellae* and thus could possibly overstate health risks, particularly of bathing in waters with a high wood waste component.

6. Selection of a Recommended Bacterial Indicator

The technical work-group found little reason to conclude that any one indicator bacteria was sufficiently superior in all respects to justify their absolute support. The work-group could support the use fecal coliform at concentrations below 100/100mL, or *E. coli* and enterococci at or below the EPA recommended levels of 126/100mL and 33-35/100mL. It is believed any of these criteria would be adequately protective of swimming in both fresh and marine waters.

The work-group found strength in the familiarity, low cost, and low complexity aspects of continuing to use fecal coliform as the state indicator bacteria. They also recognized the value of having a single indicator organism for both fresh and marine waters, and since fecal coliform will continue to be required to monitor and approve shellfish growing areas, using it also to protect swimming creates a more efficient monitoring program.

The work-group found strength in the consistently good correlation with illness that has been found with the use of enterococci in both fresh and marine waters. They also recognized the superiority of enterococci in mimicking the environmental resistance exhibited by pathogenic viruses of concern. The group was very concerned however, about the greater complexity and wider confidence limits imposed with the analytical methods used to enumerate enterococci, and were uncomfortable with mandating the use of testing which generated a state hazardous waste as a byproduct. The question became, is there reason to believe that enterococci is so superior in protecting the health of swimmers that it justifies the added environmental and programmatic costs.

The work-group found strength in the general good correlations with illness that have been found with the use of *E. coli*, and particularly liked the fact that it is the most fecal specific of the three indicator bacteria under consideration. Using *E. coli* would remove some of the primary concerns that exist with fecal coliform, that of enumerating *Klebsiellae* and non-fecal and non-animal bacterial species. In considering the use of *E. coli* at the EPA recommended level of 126/100mL, however, the work-group noted that this change would result in allowing an approximate 40-140 percent increase in bacterial levels in our state's waters in comparison to our existing fecal coliform standards. This is because *E. coli* makes up typically between 90-99 percent of the measured fecal coliforms in most analyses considered by the work-group and our current fecal coliform standards are set at 50/100mL (Class AA) and 100/100mL (Class A).

In order of preference, the work-group preferred fecal coliform be the only bacterial indicator used in marine waters for both shellfish protection and swimming. The value could be set to be consistent with the shellfish standards of 14/100mL or separate swimming criteria could be set at 100/100mL. If USEPA could not accept our use of fecal coliform, the work-group suggested they would next prefer the use of *E. coli* in marine waters since *E. coli* can be more effectively compared with fecal coliform levels, which would allow better modeling of the impacts to shellfish areas. If *E. coli* were used in marine waters, it would also allow effective modeling of riverine inputs. If USEPA will not allow the use of *E. coli* in marine waters, then the group agreed it would support the use of enterococci, but emphasized the importance of getting USEPA to approve or develop less problematic and more reliable analytical methods. In freshwater, the work-group preferred the use of *E. coli*, but thought that either the enterococci standard developed by USEPA or a low fecal coliform standard (<100/100mL) would be acceptable substitutes.

Since the conclusion of the involvement by the work-group, Ecology has been in dialogue with the USEPA. They have stated directly that they will not any longer approve any bacterial standards that do not use their 1986 recommendations. They clarified that this means using only enterococci in marine waters, and using either *E. coli* or enterococci in freshwaters to protect water contact uses. After carefully weighing the benefits and costs of the various indicators, Ecology has determined that the best overall approach is to establish *E. coli* in freshwaters and enterococci in marine waters to protect people who work and play in the water. Where waters are designated for shellfish harvesting use, however, the fecal coliform criteria (associated with protecting that more sensitive use) would be the primary indicator used to assess the bacterial health of the water.

VI. Discussion of Risk

Any numerical value chosen for an indicator organism is associated with at least some theoretic level of risk. There may always be some natural level of viral and bacterial pathogens in our waters or residual levels that cannot be fully removed through wastewater and stormwater treatment. We cannot create an environment free of all risk of disease, but we can define and reduce these risks through setting standards and taking control actions.

While a single criterion may be chosen in association with a known level of risk, the actual risk to swimmers is not static. Actual risks change constantly over time and between individuals. This variability is due to factors that relate both to the individual, the waterbody, and the source of the bacterial pollutants. Some important factors that affect a person's actual risk include:

- Different pathogens may occur at different times, and not all pathogens are equally virulent to humans;
- Water temperature, light, predators, organics, and salinity can all affect the die-off rates of both indicator organisms and pathogens;
- The concentration of pathogens may be higher or lower at different times even if the indicator concentration is the same;
- Epidemics and outbreaks in the local community may increase the level of pathogens in the receiving waters;
- Wastewater and stormwater discharges would be expected to have highly variable concentrations of pathogens;
- Both young and old people tend to be more susceptible to illness; young because they have not yet developed any immunity and old because of a general loss of immunity;
- Healthy people tend to be more resistant to illness;
- Previous exposure to a pathogen either in a community setting or from swimming may provide added immunity;
- Some people swim longer or more frequently than others, or their experience level may cause them to ingest more or less water; and
- Different sites on the body have more or less vulnerability than others (Jett, 1994), so a pathogen that tries to adhere to some sites may be unsuccessful.

The complexity created by these risk variables makes it impossible to accurately predict how many people will get sick from swimming. So in setting standards, we use statistics to establish the level of illness expected based on the rates of illness actually observed among swimmers.

Table 1 below provide examples of the statistical relationship between enterococcus and *E. coli* densities and illness rates at a statistical 95 percent confidence level. It is based on illness observed at swimming beaches in the United States.

The issue of setting a numerical limit at some defined level of potential illness suggests that there can be an acceptable level of risk. This means we would consider some number of illnesses in a given population to be acceptable. Setting such risk levels is very common in establishing water quality standards both for toxic chemicals and for bacterial pollutants.

Contributing to the discussion regarding illness from bacterial contaminants is the relatively low level of concern with some of these pathogens. Most of the waterborne illnesses in the United States are generally considered relatively benign; not resulting in hospitalization or serious complications. While there are some notable exceptions that are cause for serious concern, there are also notable costs associated with trying to completely remove these pathogens from the water. Many people argue that, even if it were feasible, the economic cost of controlling bacterial and viral pathogens, particularly for sources such as stormwater, are extreme and unjustified to reduce already minor risks.

Table 1. 95% confidence limits for swimming-associated gastrointestinal symptom rates predicted from the observed mean bacterial indicator densities for marine and fresh waters.

Enterococci in Freshwater[1]		***E. coli* in Freshwater**[2]		**Enterococci in Marine Water**[3]	
Illness Rate per 1000 people	Geometric Mean	Illness Rate per 1000 people	Geometric Mean	Illness Rate per 1000 people	Geometric Mean
1	5.9	1	22.7	1	1.2
2	7.6	2	29.0	2	1.4
3	9.7	3	37.0	4	2.1
4	12.4	4	47.3	8	4.4
5	15.8	5	60.4	10	6.4
6	20.2	6	77.1	12	9.3
7	25.9	7	98.5	14	13.6
8	**33.0**	7.06	100.0	16	19.9
9	42.2	**8**	**125.9**	18	29.0
10	53.9	9	160.8	**19**	**35.1**
11	68.9	10	205.5	20	42.4
12	88.0	12	335.4	22	61.8
15	184	15	699.3	24	90.3
20	625	20	2380	26	132
25	2126	25	8100	28	192
30	7237	30	27569	30	281
35	24631	35	93830	35	724
40	83831	40	319341	40	1864
45	285311	45	1086852	45	4799
50	971033	50	3699007	50	12360

Source: “Ambient Water Quality for Bacteria: 1986”, Environmental Protection Agency.

USEPA suggests that their previous fecal coliform criteria of 200/100mL carries a theoretical risk of 8 illnesses per 1,000 swimmers in freshwater and 19 illnesses per 1,000 swimmers in marine water (USEPA, 1986). USEPA did not document the derivation of these risk levels for fecal coliform in the 1986 report, however, and in that document they suggest that measures of fecal coliform cannot be used to predict illness rates. While these seemingly contradictory statements remain unresolved at this time, USEPA takes the position that the risks of illness associated with the previous fecal coliform criteria are considered acceptable by the public because of the widespread use of the fecal coliform criteria. Based on the view that these risk levels are widely acceptable, USEPA proposed criteria levels for *E. coli* and enterococci indicators at these same risk levels. It is probably important to restate that the original EPA coliform criteria were initially described as being chosen specifically so as not to have a statistically discernable increase in illness (USEPA, 1986), thus acceptability may be based on states not finding objection with the levels of illness observed in swimmers when waters were meeting the previously recommended fecal coliform criteria.

For comparison purposes, it is worth noting that if the enterococci criteria were set at an 8 in 1,000 risk level for marine water (as EPA has done for fresh waters) the criteria would change from the currently recommended value of 35/100 mL to only 4.4/100 mL. Also, just to show how the criteria values change based on changing the allowable risk, if the enterococci criteria were reduced to a 1 in 1,000 risk level, the freshwater criterion would be 6/100mL and the marine water criterion would be 1/100mL (USEPA, 1986). The previous discussion has focused on estimating risks based on epidemiological studies of exposed populations, however, risks may also be estimated theoretically. By knowing the estimated infectious dose of a virus or other pathogen (i.e., how many individual virus units are typically needed to overcome the body's immune system), the level of exposure (e.g., how much water is consumed), and the concentrations of those pathogens observed in a water sample; the risk of someone contracting a disease can be estimated. While the technical work-group believed that epidemiological studies should be used to establish criteria recommendations, some researchers have used traditional risk assessment techniques to study waterborne pathogens. Gerba *et al.,* (1996) examined the human risks from drinking and recreating in waters containing human rotavirus. Rotavirus is considered to be the most common cause of gastroenteritis worldwide, is highly infectious, survives for long periods, and is resistant to disinfection. Since rotavirus may occur in large numbers in human feces, it is considered a significant source of waterborne disease risk. Using the methodology and assumptions of the authors, the risk of acquiring a rotavirus infection from swimming in recreational waters with the concentrations typically observed would range from 1 in 10 to 1 in 100 for each swimming event. This assumes that all rotavirus would be infectious, even though the authors note that most rotaviruses are less than 50 percent infectious. The risk they calculated can be compared to the 8 in 1,000 to 19 in 1,000 risks associated with the recommended USEPA swimming criteria. Rose *et al.,* (1996) used similar techniques to estimate the risks from reuse of reclaimed wastewater. Under the assumption of a 100mL consumption of water per year, the risk of illness associated with using highly treated and disinfected wastewater as landscape irrigation water ranged from 1 in 1,000,000 to 1 in 100,000,000. It is interesting to note that most of this risk was the consequence of the parasitic protozoans *Giardia* and *Cryptosporidium*, rather than from viruses. Their presence in many of the samples is a consequence of their strong resistant to disinfection.

Grabow *et al.,* (1989) conducted a risk assessment similar to that carried out by Gerba. The authors made recommendations for water quality criteria that were based on the concentrations of viruses typically observed at corresponding concentrations of indicator organisms; as compared to the relative health risks calculated in association with the recorded concentrations of the virus. It was recommended that to protect swimming, fecal coliform levels should not exceed 100/100mL, fecal streptococci should not exceed

40/100mL, coliphages should not exceed 50/100mL, and human viruses should not be detectable in more than 50 percent of the samples taken.

VII. Setting a Duration Component

In establishing a criterion, it is necessary to decide how it will be expressed and how monitoring data will be used to determine compliance. Some of the issues that were considered by the work-group included:

- Whether or not the criterion should be based upon a single sample value, or if the criterion should instead be based on an average of sample values?

- If an averaged criteria value is chosen, should there be a minimum number of samples for determining compliance?

- Should enforcement and control actions be based on exceeding any single sample, or only when there is a demonstrated trend of exceedence?

1. Expression as an Average of Samples Over Time

In discussing the issues surrounding the implementation of a bacteria standard, the consensus of the work-group was to establish the standard as a geometric mean of multiple samples. Indicator concentrations are highly variable, both spatially and temporally (daily and seasonally). High variability is also common between aliquots of a single sample, further demonstrating the characteristic variability of indicator concentrations. Given this variability, a single sample may not represent the overall quality of the waterbody or exposure to recreationalists. Failure to comply with a protective average of multiple sample values, however, may represent a clear ongoing risk to public health which warrants taking enforcement and control action. In addition to considering the variable nature of indicators in general, the work-group also based its recommendation on the design of the USEPA epidemiological studies themselves. The statistical analyses used by the USEPA were based on indicator concentration data which had been averaged over days, beaches, and by rank and season. All these factors combine to support establishing a bacterial criterion that is based on an average of individual sample values.

The USEPA recommendation of no fewer than five samples evenly spaced over any 30-day period, however, was believed to be an unnecessarily restrictive requirement that would preclude the use of data from all but the most intense site-specific studies. Most of the data collected throughout the state are at best weekly measurements, and more typically monthly sampling events, which could not be used to compare with the geometric mean-based criteria as recommended by USEPA. Except in the most highly frequented beaches, increasing the number of samples each month to five or greater was believed to be unjustified, as well as being cost prohibitive.

The recommendation of the work-group is: (a) When averaging samples over time for comparison to the geometric mean, the period of averaging should not exceed 365 days, and should generally have sample collection dates well distributed throughout the reporting period. It is considered optimal for the reporting periods to represent distinct climatic regimes (e.g., seasons, or summer versus winter) where five or more data collection events occur within each period. (b) When determining compliance with the geometric mean or single sample bacterial criteria in or around relatively small sensitive areas such as popular swimming beaches, it is generally recommended that multiple samples be taken across homogeneous portions of the individual sites during each visit. Such multiple samples should be geometrically averaged together to reduce sample variability and to create a single representative data point".

2. Expression as Single Sample Values

While the work-group believed that a geometric average-based criterion was the best way to implement the indicators, it was also believed that high single-sample values should be made useable. The desire to use single samples is related to the nature of the monitoring programs used (See Appendix E for discussion on monitoring programs) and to allow control of significant pollution events. Monitoring typically occurs at a frequency of only once per month. In recognition of this fact, it is often suggested that criteria should include a single value that cannot be exceeded in even one sample.

Epidemiological field studies do not provide ideal support for selecting a health-based single sample value. We can, however, establish a statistically-based single sample value. USEPA originally recommended single sample values based on four separate confidence levels (95%,90%, 82%, and 75%). They recommended applying different values based on how frequently the waterbody was used by swimmers. Their approach would mean that waters that were heavily used for swimming would have a more stringent single-sample value than waters seldom used, since the chances are that more people will be put at risk. There was no apparent basis for these statistical divisions, and the work-group did not support using USEPA's multiple confidence level approach. However, the work-group did support the use of a statistically derived single sample limit.

We can use a statistical confidence level to determine whether or not a single sample value is more likely to be the result of sample variability than it is an exceedence of the geometric mean-based criterion. In other words, we can statistically describe a set of samples using the standard deviation of the sample distribution. Using the geometric mean-based criterion value as the population mean, and by applying the standard deviation found from the sample distribution, we can statistically identify the highest sample value we would expect to find in a population that was in compliance with the geometric mean-based value.

For example, the USEPA recommended criterion of 35 enterococci per 100/mL as a geometric mean value was calculated from a sample population of data having a 0.7 $\log_{10}$ standard deviation. If we use the upper 90th percentile level to set a single sample criterion, a single sample action level of 276 would be derived for protecting swimming in marine waters. What this means statistically is that 90 percent of the individual sample values would be below 276/100mL in a waterbody with a geometric mean of 33/100mL and having a standard deviation of 0.7. If we think ten percent is too great a chance of taking enforcement-type action when a violation may not be occurring, then we could use five percent (i.e., the upper 95% confidence level). This would result in a single sample limit of 500. Alternatively, if we think ten percent creates too great of a chance of not taking action when a health threat may exist we could allow 25 percent (i.e., the 75% confidence level) of the samples to be above a single sample action level of 104 units/100mL.

In putting together both the geometric mean and single sample criteria values, we can create a reasonable and effective water quality standard. Using the EPA freshwater recommendation for *E. coli* as a basis for an example, a revised water quality standard to protect swimming may be: "*E. coli* organism levels must not exceed a geometric mean value of 126 colonies/100mL with not more than 10 percent of all samples (or any single sample when less than ten sample points exist) obtained for calculating the geometric mean value exceeding 406 colonies/100mL (*the estimated upper 90th percentile for a population of bacterial samples with a geometric mean of 126 and a* $\log_{10}$ *standard deviation. of 0.4*).

VIII. Other States' Standards for Bacteria

Since state programs are constantly being reviewed and changed, it is difficult to do an accurate analysis of what other states are doing to regulate bacterial and viral pollutants. Appendix F contains information compiled from phone interviews with the other states conducted in 2000. Based on this review, it appears that the vast majority of states are continuing to use fecal coliform organism levels to indicate the relative safety of the water.

IX. Prohibition on the Discharge of Untreated Waste

The direct discharge of poorly treated or untreated waste of both human and animal origin is viewed to produce unreasonable risks to the recreational public. As a result, the work-group strongly supported adopting a narrative standard against the direct discharge of untreated waste of human or animal origin.

The recommended narrative statement prohibiting the direct discharge of unacceptably treated sewage and animal waste is:

> *Runoff from nonpoint sources (such as from animal and human wastes or soil erosion from land-use activities) are not allowed to drain or be discharged into surface waterbodies of the state, except when controlled with best management practices or treated with waste treatment technology, as approved by the department.*

While the group was unanimous in the opinion that waste from other warm blooded animals poses a risk to humans through recreation, drinking water, and shellfish consumption routes of exposure, it was also unanimous that this risk was probably less than that caused by the discharge of human waste. This view is supported by the studies examined in this review where the possible bacterial indicators present in both human and animal feces have been examined (Stelma and McCabe, 1991; Geldreich, 1969, Cheung, 1989). The group strongly supported the continued practice in applying water quality standards of assuming that animal waste has the same relative risk as waste from human sources. It is believed, however, that this position should be reconsidered at some future date if information is developed that allows quantification of the separate risk from animal wastes, and when practical methods become available to distinguish between animal and human waste in ambient waters.

X. Secondary Contact Recreation Criteria

While primary contact is generally considered to be swimming, secondary contact is generally viewed as being use only for wading or incidental contact such as that associated with fishing or boating. The technical work-group unanimously opposed having the department establish secondary contact criteria for the following reasons:

1. There is no epidemiological basis for making a distinction between primary and secondary contact.

2. Waters that are used by some for wading may be used by others for complete immersion. Children, who are also less resistant to illness than adults, commonly immerse themselves in waters that adults would use only for wading or incidental contact.

3. The Department of Health has documented cases of disease (e.g., Giardia) in anglers exposed without full body immersion.

Although the technical work-group was generally unsupportive, the department plans to include a secondary contact use in the water quality standards. The secondary contact use would be protected at criteria set above that considered appropriate for primary contact recreation. A paramount reason the department is proposing to keep a secondary contact use is to prevent the need to upgrade the use designations in the waters across the state that are currently designated only for secondary contact use protection. Nine waterbodies are currently designated Class B in Washington and are only designated for the protection of secondary water contact. While changes to primary contact protection may occur at some future date, the department believes such changes should be made only after consideration of the appropriateness of the waters to support a higher beneficial use. The department also recognizes that some types of waterbodies pose little risk of human contact (e.g., seasonal watercourses that are not near residential areas) and in those situations a less stringent secondary contact criteria may be appropriate to help prevent unnecessary financial expenditures for entities that contribute human or animal waste at low concentrations.

While the department is including a secondary contact use, it is doing so in recognition of the technical workgroup’s concerns. This is reflected in setting the criterion at only twice the concentration used to protect primary contact uses (as it is done currently in the state standards). Based on the risk rates calculated by the USEPA for enterococci and *E. coli* indicators, this approach would only allow a very minor increase in risks (roughly 3-4 more illnesses per 1,000 users) even if the waters were unexpectedly used for primary contact. Yet this approach would double the amount of bacterial pollutants that could be allowed in such waters before the department would need to ask for greater levels of control or treatment.

XI. Wet Weather and Seasonal Exemptions

It is frequently suggested that storm water and combined sewer overflow pollution results in short-term pulses in bacterial concentrations, which cannot be realistically controlled, but which also do not have associated real-world health risks. These factors are commonly suggested as reasons why these sources of bacteria should be allowed or legitimized in any standards set by the state. It is also frequently suggested that standards should not apply during or immediately after a rainstorm since people will not be swimming, and that summer season-only criteria are appropriate since swimming rarely occurs in the winter.

In spite of these arguments, people fish, swim, scuba dive, surf, wind surf, boat, and collect shellfish in our waters year round. While the risk of a major outbreak is certainly less in the winter for recreational contact sports, setting seasonal criteria would result in higher risks to those people who participate in aquatic recreation and work in and on the water in the rainy and cooler periods of the year. Additionally, suspending standards during times of precipitation would not realistically be correlated with swimmer or recreational activities. People resume swimming soon after rains have ceased, and recreational activities (such as surfing and wind surfing) may occur intentionally during and immediately after stormy periods precisely because waves and winds are more severe. Bacterial and viral pathogens, however, can remain infectious in the water, sediments, and shellfish for days to months after storm periods. Wyer *et al.* (1996) found that even short pulses of stormwater significantly increased the concentrations of bacteria in recreational and shell fishing waters and that the stormwater component comprised a major fraction of the annual bacterial budget for the rivers and marine waters tested. Rose and Sobsey (1993) found that stormwaters with and without direct sewer inputs contained enteric viruses in levels ranging from 69-2,800 PFU/100 L. Additionally, pathogens that settle into the sediments may be stirred up again into the water column, and can be further concentrated in shellfish. Ecology (1985) assessed the contribution resuspended sediments have on concentrations of bacterial indicators. Subsequent to three days of rainfall totaling 0.57 inches, sediment disturbance experiments were conducted. Eight of nine sites had elevated concentrations of fecal coliform after disturbance. Two that met state water quality standards prior to disturbance, failed afterwards. A sediment sample taken at a stagnant point in the stream below several large heavily grazed pastures had greater than 240,000/100mL 6 days after the rain event had ceased. Michaud (1987) examined the sources of bacterial contamination to Oakland Bay in Puget Sound, Washington. They determined that stormwater and nonpoint sources were the primary source of bacteria problems. Haile, R.W., et al. (1996), in studying people who swam near stormwater outfalls into Santa Monica Bay, California, found that even during dry weather periods the incidence of illnesses increased notably near the outfall structures.

On the other hand, Gregory Ma reported during the work-group meetings that King County/METRO experimented with stirring up sediments prior to opening swimming beaches for the summer season. Where they had stirred up these freshwater sediments, they did not find an increase in enterococci counts. He also noted that in general they have not noticed increased concentrations in marine sediment samples.

The criteria recommended by the work-group is primarily based on a geometric mean-based value. This averaging factor allows for some short-term runoff related excess in bacterial concentrations, and the work-group concluded that further exemptions are not justified based on either scientific or epidemiological evidence.

XII. Oregon's Experience with Waste-Water Compliance Issues

In a recent rule revision in the state of Oregon, the state adopted enterococci as their state indicator standard for swimming protection. They were soon challenged by an association of wastewater plant operators on the grounds that there would be compliance problems with enterococci that currently did not exist with fecal coliform and which would be much less frequent if *E. coli* were adopted instead. Permitees were particularly concerned that short-term spikes in concentrations will result in enforcement measures that may be complicated and costly, yet not result in identification of practices which need to be changed. Based on the opinion that no increased risk in human illness would be associated with switching to *E. coli*, they successfully petitioned Oregon to rescind its newly adopted enterococci standard. (See Appendix G for data on Oregon treatment plant compliance). The Oregon work-group suggested that treatment plants without nutrient removal technology would have more compliance problems with enterococci. This is due to the greater complexation of ammonia ion into chloramine compounds in association with chlorine (i.e., effectively reducing the disinfection power). Citing one study, it was noted that *E. coli* may be inactivated by greater than four orders of magnitude within t10 seconds of exposure to free chlorine, while an exposure time of 15 minutes was required to achieve an equivalent inactivation using monochloramine. *Enterococcus faecium* was noted as requiring 60 seconds for free chlorine and 60 minutes for monochloramine. This was then compared to treatment plants, which are designed to have contact times typically between 45 to 60 minutes. While they believed this would be sufficient time to disinfect *E. coli* it was considered only marginal for achieving enterococci disinfection.

The Oregon work-group stated that with the enterococci standard:

- It would be more likely that higher chlorine dosages would be used by most treatment facilities to meet the standard; or solids removal would be required at most plants.
- Higher chlorination may mean that the plant would then need to dechlorinate the wastewater to meet aquatic life toxicity standards.
- Higher chlorination may also result in higher levels of toxic chlorination byproducts (halogenated compounds).

The Association of Clean Water Agencies (ACWA) estimated the frequency that their facilities would be out of compliance in the state of Oregon. They estimated that properly operated facilities using state of the art processes would be out of compliance with the enterococci standard for monthly averages 36 percent of the time, and exceed single sample limit on 37 percent of the tests performed. It should be noted, however, that we were unable to obtain estimates on the frequency to which the Oregon facilities would have been out of compliance with the *E. coli* standard.

In response to the concerns raised in Oregon, Ecology conducted a study designed to determine if a switch to enterococci as an indicator would increase the rates of non-compliance of Washington's sewage treatment plants. Nine facilities that use a variety of treatment and disinfection techniques were examined three days per week over a seven-week period. Samples were tested for fecal coliform, *E. coli*, and enterococci bacteria. The results, which are shown in Appendix H, indicate that Washington's wastewater treatment plants would not have any discernible increase in non-compliance if the state changed to using enterococci as the indicator bacteria. All of the facilities examined consistently complied with the USEPA enterococci criteria in 100 percent effluent.

XIII.Shellfish Consumer Protection

1. Background on the Use of Indicators in Shellfish Programs

Indicator bacteria have been used since the beginning of the twentieth century to evaluate the safety of foods. Concern over the potential for fish and shellfish to carry human pathogens resulted in extensive investigations. It was noted that fish and shellfish that live in unpolluted waters do not carry the kinds of enteric bacteria commonly found in warm-blooded animals. While less concern exists over fish and other crustaceans transmitting human pathogens, this is largely due to the more thorough cooking methods used for these foods. Shellfish are considered to have a large potential to act as carriers of food-borne disease (Matches, 1983) both due to traditional methods of shellfish food preparation, and also due to the physiologic nature of shellfish (Furfari, 1982). Shellfish are filter feeders and in the course of feeding they filter large volumes of water. This filtration action removes the bacterial and viral pathogens from the water, and accumulates and concentrates these disease-causing agents in the tissues of the shellfish.

Many of the issues which were discussed previously regarding the appropriateness of using indicator organisms to determine swimming safety, also apply to the issue of shellfish consumption safety. Ideally, we would like to be able to know if any viral or bacterial pathogens are present in shellfish that will make consumers ill. Jaykus (1994) condensed these issues into the following statements: “Methods for detecting enteric viruses and pathogenic bacteria in water and shellfish are considered too unreliable, complex, expensive, and time-consuming to be used for routine monitoring and surveillance purpose. Consequently, the fecal coliform index is still used as a sanitary quality indicator for shellfish and their harvesting waters. This index is considered appropriate because fecal coliforms are normal inhabitants of the gastrointestinal tract of warm-blooded animals and are excreted in the feces in large numbers. Their presence is taken as evidence of recent fecal pollution”.

The current fecal coliform standard of 14/100mL was derived through investigations by the states and the Public Health Service in the 1920’s. These studies indicated that typhoid fever and other enteric diseases would not ordinarily be attributed to shellfish harvested from water in which not more than 50 percent of the 1cc portions of water examined were positive for coliforms. This was found to be equivalent to about 70 total coliforms per 100mL. Using a total coliform to fecal coliform correlation rate of about 5:1, the fecal coliform standard of 14/100mL was derived (Meriwether, 1997).

The adequacy of bacteriological indicators to indicate the virological quality of shellfish is sometimes questioned. Viruses can be isolated from shellfish harvested in approved waters (Fugate, Cliver, and Hatch 1975; Goyal, Gerba, and Melnick 1979; Vaughn *et al.,* 1979b, 1980; Ellender *et al.,* 1980; Wait *et al.,* 1983). A recent paper by Rose and Sobsey (1993) noted that of 58 pooled samples, 19 percent were found to be positive for viruses. Their work estimated that individuals consuming raw shellfish from approved waters in the U.S.

might have an average risk of 1 in 100 of becoming infected with an enteric virus. When they made a subsequent estimate using the more infective rotavirus as the model, the risk rose to 50 in 100. The authors contend there is significant evidence that bacterial indicators do not adequately predict all microbial health risks, and suggest no correlation between indicator bacteria and the presence or absence of enteric viruses has been demonstrated in shellfish or the growing waters. They noted that viral outbreaks from shellfish harvested in approved waters continues to occur, and that a recent National Academy of Science report on “Seafood Safety” concluded that the fecal coliform indicator is inadequate for determining the microbial quality and safety of marine waters and shellfish. Like most studies of its kind, Rose and Sobsey noted that the concentrations of viruses were greater in more polluted waters (28-63% of ”closed areas” had enteric viruses compared to 9-40% in open areas). An important factor in the occurrence of viruses in approved waters is that shellfish concentrate viruses to much higher levels than in the water column. Most accumulations are reported to be within the range of 10 to 100 times the concentration in the ambient waters (Jaykus, 1994).

2. Consistency with Other State and Federal Programs

While using fecal coliform as an indicator of shellfish safety does not strongly correlate with the presence of viral and other pathogens (See Appendix I), it is still a reasonably useful indicator for shellfish and there is a very strong administrative reason for continuing its use. Setting a standard that is consistent with other state and federal requirements for shellfish bacterial quality is considered to be an overriding factor by the work-group.

The United States Food and Drug Administration (USFDA) has jurisdiction over the state shellfish control authorities and administering the National Shellfish Sanitation Program. Under this ongoing program, water quality standards are established for certification of shellfish growing areas, and tissue standards are set to allow the interstate marketing of shellfish meats. The National Shellfish Sanitation Program tissue standards apply to shellfish that will be marketed across state boundaries and are based on fecal coliform concentrations. They are also applied in evaluating the acceptance of shellfish marketed to the United States from other countries. The national program also establishes water column values for fecal coliform as the basis for determining the acceptance of shellfish growing areas. There is no expectation the USFDA will be changing indicators.

In Washington, the Department of Health (DOH) is charged with the responsibility of implementing the national standards for shellfish programs. The DOH has established rules on the certification of shellfish growing areas for commercial and recreational harvesting. Like the federal program, the state shellfish program uses fecal coliform as the principal indicator of water quality pollution.

With no expectation that the federal rules on shellfish protection will be changed in the near future, there is not any expectation that the state program will be changed. So, the main focus of this surface water quality standards rule revision in regards to shellfish consumer protection is to ensure that the Ecology rules compliment the State Department of Health and national shellfish programs.

The current Ecology water quality standards to protect shellfish are:

> "fecal coliform organism levels shall both not exceed a geometric mean value of 14 colonies/100mL, and not have more than 10% of all samples obtained for calculating the geometric mean value exceeding 43 colonies/100mL."

While the threshold levels in Ecology's standard matches those of the Department of Health and the USFDA, Ecology's standards do not specify a minimum number of samples. As little as two high sample results over a three-year period can result in a waterbody being placed on a federal Clean Water Act list [Section 303(d)] as being impaired for shellfish harvesting. The Department of Health, however, has a more intensive monitoring program that is used to evaluate shellfish harvest areas. The work-group has identified that the main goal for changing Ecology's bacterial standards for shellfish consumption protection should be to: a) increase compatibility between the surface water standards and the DOH shellfish certification program, and b) to minimize the chances that Ecology would classify a waterbody as not protecting shellfish harvesting that has been approved through the more detailed monitoring programs of the State Department of Health.

3. Work-group Recommendations for Shellfish Protection

The recommendations for changing the bacterial standards for shellfish protection in the Ecology standards are:

- Continue to use the current fecal coliform criteria of 14/100mL as a geometric mean, with not more than 10% of samples exceeding 43/100mL.

- Include language that clarifies that determinations on the acceptability of shellfish growing areas made in compliance with the regulations established by the Department of Health have precedence over data collected independently for measuring compliance with the state surface water quality standards.

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Appendix A: Membership of Technical Work-Group

This paper was developed with the assistance and review of the following members of a specially created technical work-group:

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Appendix B: Correlation Coefficients from U.S. Studies

Correlation Coefficients for Swimming-Associated Gastroenteritis Rates Against Mean Indicator Densities at Marine and Fresh Water Bathing Beaches (from Table 1. USEPA, 1986).

Water Type	Indicator[5]	Correlation Coefficients[1] Data by Summers	 Data by Grouped Trials[2]
Marine[3]	**enterococci**	**.75**	**.96**
	E. coli	**.52**	**.56**
	Klebsiella	.32	.61
	Enterobacter/Citrobacter	.26	.64
	Total Coliforms	.19	.65
	C. perfringens	.19	.01
	P. aeruginosa	.19	.59
	Fecal Coliform	**-.01**	**.51**
	A. hydrophila	-.09	.60
	V. parahemolyticus	-.20	.42
	Staphylococci	-.23	.60
Fresh[4]	**enterococci**	**.74**	
	E. coli	**.80**	
	Fecal Coliform	**-.08**	

Notes: [1] A correlation coefficient is a statistical measure that compares one factor to another. The closer the value is to 1.0 the better the correlation. Higher correlation values indicate a strong relationship between the concentration of the indicator organism and the occurrence of disease associated with swimming.

[2] Groups of trials (days) with similar mean indicator densities during a given summer.

[3] Data from trials conducted at New York City beaches 1973-1975 in Cabelli, 1976.

[4] Data from Cabelli, 1982.

[5] Discussion of Table 1. The two studies that form the basis for Table 1 did not test all of the same indicators and the data was not examined identically. The freshwater study did not compare data from individual exposure periods to the rates of reported illness in the populations that recreated during those periods. It instead averaged concentrations and reports of illness over the entire study period. The “grouped by trial” data is the most preferable for comparing cause and effect, however, strong correlations in the data by summers is considered effective as well. The marine water test showed that indicators that had strong correlations in the data by trials also had the strongest correlations in the data by summers. However, indicators with moderate correlations in the data by trials often showed very poor or negative correlations in the grouped by summer analysis. This suggests that indicators may be under-rated in the grouped by summer analyses, sometimes significantly so. This concern may be important when making comparisons between the U.S. studies by Cabelli and studies conducted in other countries by different authors.

Appendix C: Discussion of Epidemiological Studies Considered

United States:

Marine Studies:

New York, Massachusetts, and Louisiana:

Marine studies were conducted on behalf of the U.S. Environmental Protection Agency at bathing beaches in New York City, Boston, and Lake Pontchartrain, near New Orleans (Cabelli, 1983). Two beaches were selected at each site, with an attempt to have one represent little or no contamination and another whose water quality was barely acceptable with respect to local recreational standards. Studies were carried out on weekend days and excluded people who swam in the weeks before or after the survey. Symptoms were grouped into gastrointestinal (GI); respiratory; eye, ear, and nose; and "other" categories. In addition, a new symptom was created called highly credible gastrointestinal symptoms (HCGI).

The study concluded that there is an increased risk of gastroenteritis associated with swimming in waters more as opposed to less polluted with sewage, and that increased risks exist even in waters that met the USEPA criteria of 200 fecal coliform per 100mL. Enterococci was determined to be the best indicator of highly credible gastrointestinal symptoms in recreational water quality (correlations of 0.75 for data grouped by individual trials and 0.72 when data was averaged by summers), *E. coli* was the next best indicator (correlations of 0.54 for data grouped by individual trials and 0.52 when data was averaged by summers), and fecal coliform demonstrated a poor correlation with disease (0.51 for data grouped by individual trials and -.0 when data was averaged by summers). The better performance of enterococci compared with *E. coli* may indicate that enterococci better matches the survival of the pathogens causing illness in treated wastewater and the marine environment.

At enterococcus densities of both 70 and 10/100mL, respectively, the rates for total and HCGI symptoms among swimmers were twice those for non-swimmers. The symptoms are the same at about 1/100mL. The author suggested that the etiologic agent(s) responsible for the observed GI symptoms may be present in sewage in large numbers; and that it is highly infective and/or that it survives sewage treatment, disinfection and/or transport better than the indicator.

Other conclusions included: Greater differences in the rates for vomiting and diarrhea among swimmers relative to non-swimmers were obtained at the heavily and moderately polluted beaches. Children under the age of ten were affected most by illness. Frequency of swimming tended to reduce the illness rate (i.e., people who were regular swimmers tended not to get as ill). Statistically significant differences were reportedly obtained only for vomiting, diarrhea, stomachache, earache, and skin complaints. Enterococcus densities were better correlated with the GI symptom rates and was considered superior to *E. coli* as a recreational water quality indicator. In a summary of the study, USEPA reported that statistically significant swimming-related gastrointestinal illness rates were not observed at any of the relatively unpolluted beaches studied (USEPA, 1986). Using the Cabeli study, it is observed that at the relatively unpolluted beaches mean fecal coliform densities were 21.5 and 18/100mL in 1973 and 1974 respectively. Enterococcus densities were 21.8 and 3.6/100mL, and *E. coli* densities were 24.8 and 2.2/100mL.

Some deficiencies were identified with the USEPA study. It appears that the actual USEPA recommendations are based primarily upon the data from the New York study (USEPA, 1986). Additionally, while eleven different indicators were tested at the New York beaches, only fecal coliform, *E. coli* and enterococci were tested at beaches in Boston and Lake Pontchartrain. Further, documentation does not show the actual relationships found with eye, ear, throat, and respiratory infections, but generally states that it was not good. Concern over USEPA's statistical analysis has been documented elsewhere (Fleisher, 1991). It also appears that the control group - non-swimmers - included people who played in the water or who swam but did not fully immerse their heads. This possible inclusion would bias the sample population as some of these people may be poor swimmers who still ingest water even while they are trying not to put their head underwater, and it certainly would confound information on skin irritations. Despite these concerns and deficiencies, however, the USEPA studies have sufficient merit to include in an evaluation of the effectiveness of indicator organisms. It is also worth noting that Fleisher, who critically reviewed and questioned the marine criteria developed by USEPA later took part in two other studies of marine water risks to swimmers. These other studies were conducted in a manner to remove the concerns expressed with the USEPA studies. Fleisher's conclusions included the condemnation of the use of fecal coliform as an indicator for marine waters, and support for the use of fecal streptococci, an indicator that is procedurally comparable to enterococci. Both of these additional studies resulted in recommendations that paralleled those proposed by USEPA. USEPA had proposed 35/100mL enterococci while the two subsequent British studies proposed 32/100mL and 40/100mL fecal streptococci (Fleisher, 1993; Kay, 1994). It is also worth noting that within the New York City beach trials, excess gastrointestinal illness rates were ascribed to swimming when fecal coliform concentrations were as low as 18-21.6/100mL; although the data used to make this assumption was not addressed directly in the text and may not have been statistically significant.

Santa Monica Bay, California

Haile et al. (1996) conducted a cohort study to determine the possible health effects of swimming in Santa Monica Bay, California. The study was intended to answer two questions: 1) What are the relative risks of specific adverse health effects in subjects bathing at 0, 1-50, and 51-100 yards from a storm drain compared to subjects bathing beyond 400 yards away? 2) Are the illnesses observed associated with the measured levels of bacterial indicators or viruses?

Three beaches and 11,686 bathers who immersed their heads were used in the study. Study participants did not include persons who bathed within seven days of the study date or on multiple days during the study. Water samples were taken at ankle depth at 0, 100, and 400 yards from the storm drains in the mornings of the days that subjects were recruited. These samples were analyzed for total and fecal coliforms, enterococci, and *E. coil*. Samples were also taken in the storm drain (0 yards) on Friday, Saturday, and Sunday and analyzed for enteric viruses. Research subjects were interviewed nine to fourteen days after the exposure date to find out the occurrence of fevers, chills, eye discharge, earache, ear discharge, skin rash, infected cuts, nausea, vomiting, diarrhea, diarrhea with blood, stomach pain, coughing, coughing with phlegm, nasal congestion, sore throat, and a group of symptoms indicative of highly credible gastrointestinal illness (HCGI) and significant respiratory disease (SRD).

The study found statistically significant increases in illness in swimmers who swam at 0 versus 400+ yards from the drain. For example the relative risk of highly credible gastrointestinal illness (HCGI) for all three sites combined was 2.11 and that for significant respiratory disease (SRD) was 1.66. When days were removed from the analysis in which the total coliform to fecal coliform ratio was greater than 5 for the water samples taken at 400 yards away, the relative risks for the negative health outcomes all increased, and significant increases in risk were then observed for health effects at distances of 1-50 and 51-100 yards, compared to 400+ yards from the drain. This additional evaluation was made to eliminate those days in which the 400 yard site was a poor “control” to use for comparison.

The authors evaluated the effects of using the various bacterial indicators. They determined risk ratios (the risk of becoming ill from swimming near the drain versus at 400+ yards) for various cutoff points (which can generally be related to existing water quality standards recommendations). Data was excluded from analysis below each of these cutoff points to see if the observed relationships would be strengthened. No associations were found for *E. coil* using the lower cutoff points of 35/100mL and 70/100mL. When days in which *E. coil* concentrations were above the cutoff point of 320/100mL were independently evaluated, the relative risk (RR) of earache was 1.46 (about 46% higher) and the RR for runny nose was 1.24 (about 24% higher) when swimming near the outfalls. Only skin rash was significantly higher with total and fecal coliforms using the cutpoints of 10,000 and 400/100mL, respectively. The higher cutpoint of 106 cfu for enterococci was associated with diarrhea with blood RR=4.23 and HCGI-1 RR=1.44. Using the cutoff point of 5 for the total to fecal coliform ratio, the authors found a RR=1.28 for diarrhea and RR=1.87 for HCGI-2.

To supplement the discrete cutpoint estimates, the authors also calculated odds ratios from categorical (based on quintiles) and continuous models. The categorical models were reported to have given results similar to that observed with the dichotomous cutoff points. The continuous models generally showed more positive associations, particularly for enterococci. Fever, skin rash, and HCGI-1 were associated with fecal coliforms. Skin rash, nausea, and stomach pain were associated with *E. coli*. Fever, skin rash, nausea, diarrhea, stomach pain, coughing, runny nose, and HCGI-1 were associated with enterococci.

The authors found significant correlation between the number of days the storm drain samples tested positive for viruses and the health outcomes noted in swimmers within 50 yards of the drain. As examples: fever RR=1.53, vomiting RR=1.89, HCGI-1 RR=1.74, and HCGI-2 RR=2.26. The authors also calculated a cumulative estimate of risk for swimmers in front of the storm drain versus swimmers at least 400 yards away. They found the number of additional cases reporting at least one symptom that was 373 per 10,000 exposed subjects. They found the corresponding attributable number of HCGI-2 or SRD to be 314 per 10,000 exposed.

This study was not designed to recommend specific health-based criteria; however, it does provide some useful supporting observations. A possible caution, however, to using the findings for evaluating criteria should be noted that involves the control group used. The control group was swimmers at 400 yards or more away from the drains. While these individuals were typically exposed to lower concentrations of bacteria, they were still exposed individuals and as such may have also experienced health effects due to their exposure to waterborne pathogens. The authors tried to reduce this effect by their use of cutoff points, but this approach also had the effect of reducing the population numbers used in the analyses. While the authors found no indicator to be fully predictive of disease, enterococci showed statistically significant correlations with more of the observed health effects. The reduced correlation that was found when the data set excluded days when enterococcus concentrations were below 35/100mL provides some support for the EPA recommendation that 35/100mL will be protective of swimmers. When data was used for days when enterococcus was above the cutoff of 106/100mL (a value almost identical an EPA recommended single sample limit), statistically significant illness was observed.

When days that fecal coliform concentrations were below 200/100mL were excluded from their analysis, the authors found no statistically significant increase in illnesses. However, when days that fecal coliform levels were below 400/100mL were excluded from the analysis, a relative risk of 1.88 (1.21-2.94) was found for skin rash. This relationship was supported by the author's use of a categorical model, where the odds ratio for skin rash was 2.04 (1.09-3.81) for the first quintile. When the authors used a continuous model, significant effects were observed for fever, skin rash, and HCGI1.

This suggests it is very likely that skin rash is a health outcome that can be associated with fecal coliform levels, and that exposure levels below 400/100 have such sufficiently reduced risks of illness that their inclusion in the data base can change the outcome. Since only two cutoff points were used, we can not state whether some additional cutoff between 200 and 400/100mL would have also changed the outcome. But this study suggests that illness was primarily associated with fecal coliform concentrations above 400/100mL.

Freshwater Studies:

Lake Erie and Keystone Lake

The freshwater studies were conducted on behalf of the USEPA in Lake Erie at Erie, Pennsylvania, and on Keystone Lake outside of Tulsa, Oklahoma (Dufour, 1984). The studies included two sites at each location. The methodology in the freshwater studies essentially mirrored those used in the USEPA marine studies, discussed previously, with the exception that only fecal coliform, *E. coli*, and enterococci were examined. Symptom rates for swimmers was generally higher for all the categories of illness examined. The symptom rates for non-enteric related illness, however, were typically not considered statistically significant ($p < 0.05$). Significant swimmer-related illness rates tended to occur at the beaches that had the poorer water quality. As in the marine studies, children under ten years of age had the highest rates of gastrointestinal illness.

The author evaluated the relationship between the indicators and illness using three measures: the slope of the regression line, the standard variance from that line, and the correlation coefficient. The conclusions of the study were as follows:

1. Swimming-related gastrointestinal illness is related to the quality of the bathing water. A direct linear relationship was observed between highly credible gastrointestinal illness and bacterial densities of two indicators of fecal contamination, enterococci, and *E. coli*. The correlation for *E. coli* was 0.804 and that of enterococci was 0.744.

2. The relationship between the rate of swimming-related illness and bacterial indicator density was almost identical for two of the indicators examined, *E. coli* and enterococci. Fecal coliforms showed no relationship to the rate of gastrointestinal illness.

3. The criterion developed for marine bathing waters is not applicable to fresh water. At equivalent indicator densities, the swimming-related illness rate was approximately three times greater in marine water swimmers relative to that in freshwater swimmers. The author suggested this factor precludes having the same indicator density for freshwater as used in marine water. However, EPA actually ended up recommending essentially the same criteria value for marine and freshwaters, considering the higher risk level in marine water to be acceptable because of fewer bathers, (It should be noted that the Washington technical work-group was split on the issue of whether or not it was acceptable to have a standard for marine waters that carried a higher risk.)

Some deficiencies have been identified with the USEPA freshwater study. Due to small control groups at each beach, USEPA pooled the non-swimming populations from each beach within a single season to form a single control population. The lack of adequate sample sizes also resulted in USEPA not conducting an analysis of individual exposure periods, and only considered a summer average from each of the four beaches over the study years. As can be seen from the marine studies the correlations for individual trials was different from summer averaged correlations for various indicators. For specific indicators, such averaging significantly reduced or completely eliminated correlations in the marine water studies.

An attempt was made to select matched sets of beaches at each location, where one would be of good quality and the other of poor quality. The results, however, show that actual concentrations of indicator organisms were generally low at all beaches. This may contribute to the difficulty of demonstrating statistically significant differences. Data from other studies suggest that rates of illness can be quite comparable between moderate and low indicator densities (Cabelli, 1986; Cheung, 1989).

Comparing the marine and freshwater studies; the illness rates among bathers in marine waters were higher than those in fresh waters at the same indicator densities (Dufour, 1984). The mean of the highly credible G.I. symptom rate (15.2 per 1,000) grouped by beach and year was 2.67 times greater than the mean for the highly credible G.I. illness rates in freshwater swimmers (5.7 per 1,000). Dufour reported that this difference can partly be explained by the different die-off rates of indicator bacteria and pathogens in fresh and marine waters. The time it takes for indicators to die-off in seawater has been noted to be much faster than in freshwater (e.g., time for 90% of indicator to die-off was 2.2 versus 57.6 hours for coliform, 18 versus 110 hours for *E. coli*, and 47 versus 71 hours for enterococci). It was suggested that die-off rates of the actual pathogens is similar in freshwater and marine water and that this combined with the differential die-off rate of the indicators may account for the difference in illness rates between marine and freshwater swimmers. In other words, in marine waters the indicator may die-off faster than the actual pathogens when compared to these die-off relationships in freshwater. So, at similar indicator densities, there would be a higher amount of pathogenic organisms in marine water and thus higher observed illness rates.

Ontario Beaches: A study was carried out on ten fresh water beaches in Ontario, Canada to evaluate the Ontario fecal coliform indicator against several other indicator organisms: fecal streptococci, heterotrophic bacteria, *Pseudomonas aeruginosa*, and total staphylococci (Seyfried et al., 1985). During the study, the surface water of the lakes were within the acceptable guidelines of 100 fecal coliforms/100mL. Water and sediment samples were taken two to three times per day. A comparison was made between the levels of the bacterial indicators on individual days of the study to the reported incidence of illnesses for 4,537 individuals.

A relationship between total illness and surface water isolates of staphylococci, fecal coliforms, and fecal streptococci was noted. Total staphylococci also related to eye and skin illness, which is not true of the other indicators. The correlation coefficients for total staphylococcal, fecal coliform, and fecal streptococci versus total illness were 0.439, 0.284, and 0.166 respectively. Crude morbidity rates were 69.6 per 1,000 swimmers versus 29.5 per 1,000 non-swimmers (i.e., out of 2,743 swimmers 7% became ill compared to 3% of the 1,794 non-swimmers). Swimmers experienced respiratory ailments most frequently, followed by gastrointestinal, eye, ear, skin, and allergenic symptoms. Immersion of the head was reported as related to higher ear illness.

Sydney Beaches: In response to local physicians reporting an increase in ear infections, gastroenteritis, and other viral illnesses attributed to ocean bathing, the South Wales Health Department initiated of study of 12 popular bathing beaches in the Sydney area (Corbett et al., 1993). The study evaluated their existing fecal coliform criteria and made a comparison with fecal streptococci. Participants were 15 years of age and older. Swimming included any full immersion of the face and head, and the participants were asked to estimate the amount of time spent in the water. Water samples were taken on the same days at the same beaches on which interviews were conducted. The variables of the duration in the water and the measure of bacterial count in the water were evaluated. Bacterial concentrations were separated into the following categories: 10-300; 300-1,000; 1,000-3,000; and >3,000 fecal coliform units/100mL (the existing standard is 300 fecal coliform units/100mL). Symptoms evaluated separately included: a) any reported symptoms, b) respiratory symptoms, c) fever, d) eye symptoms, e) ear symptoms, and f) gastrointestinal symptoms. Only 303 of the 8413 initial volunteers could be used for the statistical analysis for various reasons. Reasons for exclusion included swimming within five days of the study, illness existing at the time of the study, and failure to respond to follow-up contact.

Swimmers were almost twice as likely as non-swimmers to report symptoms. As the concentration of fecal bacteria increased, the reports of all symptoms except gastroenteritis also rose. People who swam for longer than 30 minutes were 4.6 times more likely to develop gastrointestinal symptoms; however, there was no correlation with increasing concentrations and increasing symptoms of gastroenteritis. The authors indicate that increases in risk of respiratory, ear, and eye symptoms account wholly for the increases in illness observed. It was noted that enteroviruses, the most common virus present in sewage effluent, can cause respiratory symptoms. While the authors did not address this issue directly, it is important to note that increased symptoms were noted at beaches that met their current health standard of 300 fecal coliform units/100mL.

The authors concluded in their study that fecal coliforms are marginally better predictors of reported symptoms than fecal streptococci. They suggest the discrepancy between their study and other studies may be due in part by the different relative survival of these micro-organisms in effluent that is not chlorinated and in oceans that are warmer than those around North America. They also note finding an improvement in the correlation when the arithmetic mean, rather than the geometric mean, was used. Two possible factors that may have affected the results are the small statistical population used in the analysis, and the generally good bacteriologic quality of the water at all beaches during the study. It should also be noted that the illness observed was almost wholly for respiratory, ear, and eye symptoms, without significant increases in gastrointestinal disorder. As the authors noted, the results may have been affected by excluding children from the study even though they may in fact be more sensitive to gastrointestinal illnesses than adults.

Hong Kong: In a two phase study, Cheung et al. (1989) studied nine marine beaches for fecal coliforms, *E. coli*, *Klebsiella spp*., fecal streptococci, enterococci, staphylococci, *Pseudomonas aeruginosa*, *Candida albicans* and total fungi. In the first phase of the study, (the pretest), 4 beaches and 5114 beach-goers were included in the study. In the second phase, 9 beaches and 18,741 beach-goers were included. Beaches were separated into categories of pollution based on the measured concentrations of *E. coli*. Samples were taken at three locations at each beach every two hours from 9 am to 5 PM on weekend days.

There was a significant excess of total illness for swimmers at each of the nine beaches. The highly credible gastroenteritis (HCGI) symptom rate was five times higher for swimmers. Eye or fever symptoms were four times higher. Gastrointestinal, skin, respiratory, or total illness rates were two-three times higher. High correlation was found among fecal coliforms, *E. coli*, fecal streptococci and enterococci. Low correlations were found amongst the various microbial indicators. Except for one beach that was mainly polluted by livestock waste, significant swimming-associated gastrointestinal symptoms were observed for all of the most polluted beaches. Mean *E. coli* densities were correlated with swimming-associated HCGI (0.51) and skin (0.55) symptoms. The highest correlation (0.73) was found between *E. coli* and combined swimming-associated HCGI and skin symptom rates. Fecal coliforms, fecal streptococci, and enterococci showed lower correlation with HCGI or skin symptom rates. Staphylococci was significantly correlated with ear (0.66) and sore throat (0.56) symptom rates. When compared to other microbial indicators, staphylococci showed the highest correlation with total illness (0.36); and was the only indicator with a positive correlation with respiratory symptom rates (0.56).

The authors of the Hong Kong study suggested some possible explanations why the studies in North America showed enterococci as a superior indicator and their study showed it to be a poor indicator. It was considered possible that local swimmers have developed some immunity to enteric viruses due to repeated exposure since very early age. The authors contend that individual countries need to conduct their own epidemiological studies, so that the individual characteristics of their populations and waters can be considered. They also suggest that their study points to the need to have more than one indicator, since staphylococci was highly correlated to ear, respiratory and total illness, but *E. coli* was superior for skin and highly credible gastroenteritis. Their suggestion to use both *E. coli* and staphylococci is also based on data that shows that the two indicators are poorly correlated with one another.

Geometric mean densities of 180 *E. coli* per 100mL and 1,000 staphylococci per 100mL were found to be the threshold values which statistically differentiated beaches that were considered barely acceptable from those considered to be relatively unpolluted. Beaches considered barely acceptable showed significant excess of swimming-related gastroenteritis, highly credible gastroenteritis, skin, respiratory, and total illness symptoms.

The authors separated health risks into four categories based on concentrations of *E. coli* and the rate of gastroenteritis and skin symptoms:

1) Good = 0 symptoms/1,000 swimmers at 24/100mL,
2) Acceptable = 10 symptoms/1,000 swimmers at 180/100mL,
3) Barely acceptable = 15 symptoms/1,000 swimmers at 610/100mL, and
4) Unacceptable was any concentration of *E. coli* above 610/100mL.

The Hong Kong study was used to produce some other useful information on bacterial indicators that was published separately (Cheung, 1990). In this follow-up paper, it was concluded that *E. coli* concentrations were influenced by tide (dilution), and staphylococci concentrations were influenced more by bather numbers. It is noted that care must be taken in interpreting staphylococci data from natural beach areas since it can also be contributed from outside sources such as sewage and livestock waste. So, at some beaches, staphylococci is serving more as an indicator of fecal pollution rather than contaminants from bathers. They suggested that staphylococci may serve as a better indicator of bather density and the risk of cross-infection amongst bathers when the staphylococci to *E. coli* ratio is considerably higher than 3.

The work-group noted some problems with using the Hong Kong study results for Washington. Primarily the concerns relate to the warmer water temperature, the use of untreated wastewater, differing cultural traits, and different mixes of intestinal flora.

It is worthy of noting that the authors found high correlation with HCGI and skin symptoms combined for both fecal coliform (0.71) and *E. coli* (0.73) in marine waters. *E. coli* was found to represent 57 percent of the fecal coliform group on average in this study. Fecal coliform levels above 410 were shown to be associated with beaches determined to be barely acceptable. In this context "barely acceptable" means "the microbial density beyond which the risks of swimming-related diseases are expected to increase significantly." As used in association with their final recommendations for *E. coli*, barely acceptable had a risk of illness of 15 per 1,000 bathers in association with a seasonal geometric mean of 610/100mL.

Ardeche Basin:

Ferley et al. (1989) conducted a retrospective follow-up study using 5,737 tourists at eight holiday beaches in the Ardeche basin, France. Participants were questioned as to their swimming habits and the occurrence of illness during the previous week. This information was compared against samples taken twice per week during the same period at five beaches near holiday camps. The study evaluated total coliforms, fecal coliforms, fecal streptococci, and the two pathogens *Pseudomonas aeruginosa* and *Aeromonas spp*.

Total morbidity was 2.1 to 1 comparing swimmers to non-swimmers. Gastrointestinal illness was the major type of illness and had an occurrence rate of 2.4 to 1 for the two groups. Swimmers suffered skin ailments much more frequently than non-swimmers, 3.7 to 1. Fecal streptococci was concluded to be the best indicator because of its higher correlation with acute gastrointestinal disease (AGID) symptoms. Correlations with AGID was 0.55 for fecal streptococci, 0.33 for fecal coliforms, and 0.30 for total coliforms. *Aeromonas* and *Pseudomonas* both had negative correlations for AGID, however, they correlated well with skin disease. For skin disease, fecal streptococci has a negative correlation and all of the other indicators had moderate to strong correlations (total coliform 0.46, fecal coliform 0.67, *Aeromonas* 0.51, and *Pseudomonas* 0.73). The authors also found good correlation between fecal coliform and total disease (0.51), and found that skin disease is more prevalent in swimmers than in non-swimmers at fecal coliform levels greater than 120/100mL.

To prevent acute gastrointestinal disease (AGID) in swimmers, it was recommended that fecal streptococci be kept below 20 fecal streptococci/100mL and that fecal coliforms be kept below 800 fecal coliform units/100mL. To prevent total gastrointestinal illness, not just acute symptoms, these values would be lowered to 7 fecal streptococci/100mL and 270 fecal coliform units/100mL. The authors did not make recommendations based on skin disease and the concentrations of the various indicators.

The work-group identified several potential weaknesses to the Ardeche basin study. Foremost was the use of recall on disease and swimming habits, the small number of water samples taken, the use of non-residents, and the incomplete characterization of water quality at specific beaches used by the study group.

Great Britain I:

Fleisher *et al.* (1993) conducted a study on the health effects of bathing in marine waters contaminated with human sewage. This study was intended to overcome the weaknesses of earlier studies and focused on fecal coliform and fecal streptococci. Two intervention follow-up studies were conducted at beaches in Great Britain. Both bathing beaches passed the European bathing water directive but failed the directives guide level of having 80% of the samples be less than 100 fecal coliform/100mL. Langland Bay had a mean of 31/100mL with a range of 0-1310/100mL; and Moreton had a mean of 145/100mL with a range of 0-556/100 ml. The authors compared fecal coliform exposures below and above 200/100mL. They found no association with gastroenteritis when this threshold evaluation was included.

The study randomly assigned 484 people to swimmer and non-swimmers groups. Three sampling depths were included and were sampled at 20 minute intervals. The study also examined the foods consumed to look for confounding effects on the levels of gastroenteritis. The result of the study was that at both beaches only the samples at chest depth had a mathematical relationship between fecal streptococci and gastroenteritis. The authors noted that the non-water related risk factors confounded the relationship between fecal streptococci and gastroenteritis among bathers. They suggest this finding supports the need to randomize the participants into bather and non-bather groups. They additionally found that the rates of illness between swimmers and non-swimmers was indistinguishable at fecal streptococci concentrations below 40/100mL. This was true for both levels of symptoms evaluated.

Great Britain II:

Kay *et al.,* (1994) conducted a series of studies on the occurrence of gastroenteritis in people who swam in marine waters. Four beaches were studied over a four year period and included 1216 adults. Water samples were analyzed for total and fecal coliforms, fecal streptococci, and *Pseudomonas aeruginosa*. Total staphylococci were counted at three of the locations. Samples were taken every 20 minutes at 30 cm below the surface. Of the indicators examined only fecal streptococci was correlated with rates of gastroenteritis. Fecal coliform was considered to have very little public health value as an indicator in the waters they tested. The conclusion of the study was that a concentration of fecal streptococci of 33/100mL represented the threshold of increased risk. They do note their results may not apply to younger bathers since only adults were used as volunteers.

Great Britain III:

Fleisher (1996) summarized a study using 1,216 adult volunteers (>18 years, mean age 31.65) at four beaches in Great Britain over four swimming seasons. The water quality at the beaches all met the European Community bathing water quality criteria for swimming. Three samples were taken at each location at 30-minute intervals for the following five bacteriological indicators: total coliform, fecal coliform, fecal streptococci, total staphylococci, and *Pseudomonas aeruginosa*. The purpose of the study was to evaluate relationships between indicators and the incidence of non-gastrointestinal illness. The study evaluated acute febrile respiratory illness; and ear, eye, and skin ailments. Bathers spent an average of about 13 minutes in the water, and each bather was required to completely immerse their head at least three times. Interviews were conducted two-three days prior to each trial, trial day, at seven days, and at 21-days after exposure. People who had symptoms before exposure or who swam within a couple of days of the exposure period were not included in the analysis.

Only fecal streptococci exposure was reported as showing any evidence of a statistically significant trend with acute febrile respiratory illness. Only fecal coliform showed an increasing trend in the incidence of ear ailments with increasing fecal coliform concentrations. While bathers experienced greater rates of eye ailments, there was no reported evidence of a trend in incidence related to increasing indicator density. Also, no trend was noted with skin ailments and no statistical differences existed between the highest and lowest exposure concentrations. In conclusion, the authors estimated the threshold where excess illness in swimmers was statistically significant to be: 60 fecal streptococci for acute febrile respiratory illness and 100 fecal coliform for ear ailments. The authors noted that relationships between sample concentrations and illness held only for estimates of density derived from samples taken at or near the point of actual head immersion. They also suggested that their study argued against the use of a single indicator to establish water quality standards, since individual indicators may be specific in the illnesses, which they can predict.

Appendix D: Waterborne Illness and *Klebsiella*e Bacteria

Klebsiellae species are very common in natural waters and are produced in high numbers in process wastewater from pulp and paper mills. They have also been found to be a major factor in the fecal and total coliform counts from forest environments (Duncan and Razzel, 1972). Between 10 to 40 percent of human and animal populations may have *Klebsiellae* as an intestinal bacterium (Storm, 1981; Duncan, 1988). When analyzing water samples for fecal coliform, *Klebsiellae* bacteria are enumerated even though these bacteria do not always originate from the intestinal tract of warm blooded animals. This inclusion of *Klebsiella*e in fecal coliform test results is controversial. The controversy involves the issue of whether or not environmental exposure to *Klebsiellae* bacterium poses a legitimate risk to humans.

Our work-group was unanimous in the belief that the risk illness from environmental exposure is low, and that *Klebsiellae* is an opportunistic pathogen that primarily acts upon people who are already in an immune-challenged condition. Further, it is believed that other pathogens will tend to out-compete *Klebsiella*e in infecting wounds, and infections caused by *Klebsiella*e would have been infected by some other bacterial pathogen if *Klebsiella*e were not present. The belief of the work-group was that we should not make a decision on an indicator organism based on any perceived need to enumerate and consider the amount of *Klebsiella*e present. The remainder of this section elaborates on some of the issues and conflicts regarding the importance of *Klebsiella*e as a human pathogen.

*Klebsiella*e has not been reported as a causative agent in any waterborne disease outbreaks, though it has been found in association with other organisms that were implicated. *Klebsiellae* is considered by most analysts to have pathogenic propensities for man, but to cause serious infections only when the resistance of the human host is impaired (Duncan, 1988; Storm, 1981).

While *Klebsiella*e has not been documented as causing any illness in swimmers, it is a common pathogen causing infections in hospitalized patients, and has been documented as causative agent in food-borne outbreaks of gastroenteritis in healthy individuals (Rennie, 1990). In individuals who are of old age, who have had their resistance reduced through antibiotic treatment or who otherwise have compromised immune systems, there is certainly an increased chance of developing a secondary infection from *Klebsiella*e. Such infection is not necessarily the result of exposure after the immune system has been compromised, and may be the result of *Klebsiella*e that had already long since colonized the intestinal tract finding an opportunity to grow (Seidler, 1977). This long delay between colonization and infection would of course make it all the more difficult to demonstrate the epidemiological significance of *Klebsiella*e in surface waters.

Duncan, in a 1988 summary on *Klebsiella*e, reported that the infections typically found in healthy people are mainly the result of urinary infections or intra-abdominal infections, but that there is no evidence to suggest that any of these commonly acquired infections are related to exposure to *Klebsiellae* strains in the natural environment. He further suggested that workers in pulp and paper mills are routinely exposed to high concentrations of *Klebsiella*e, however, there is no evidence available to suggest that colonization rates are particularly high or that colonization is followed by serious disease. Duncan concludes that concerns regarding environmental strains of *Klebsiella*e seem largely based on the failure of the authors of such papers to appreciate that hospital findings on *Klebsiellae* do not apply in the community setting. On the other hand, Rennie (1990) implicated *Klebsiella pneumoniae* as the causative agent in lunch-room outbreak caused by eating turkey.

It has been inferred in some reviews that environmental strains of *Klebsiella*e may be less virulent than those that result in infections in hospital settings. In a 1977 study, however, Seidler tested the pathogenicity of 97 *Klebsiellae* isolates of pathogenic and environmental origin using mice. The results suggest that "*Klebsiella* from diverse environmental origins, regardless of fecal coliform response or biotype, are potentially as pathogenic as *Klebsiella* of known clinical origins and potentially more pathogenic than other environmentally-derived gram negative bacteria." While Seidler also considered *Klebsiellae* to be an opportunistic pathogen, he suggested that contamination of food and water may lead to increased enteric colonization and subsequent greater chances of secondary clinical infection. Thus, he suggested that environmental exposure and clinical manifestation may be separated in time. The work of Seidler, though important, still does not authoritatively answer the question of disease in human populations originating from environmental exposure.

While the complete picture on the long-term role of environmental exposure to *Klebsiellae* is still unclear, there is certainly no reason to suspect that swimming in water containing *Klebsiella*e presents any immediate or significant long-term risks to healthy individuals. Thus, in the absence of any definitive information to the contrary, the technical work-group concluded that we should not to be concerned with any indicator that would not include or enumerate *Klebsiella*e bacteria.

Appendix E: Monitoring Programs for Bacterial Quality

With the exception of programs for shellfish harvest areas and those with the sole purpose of monitoring swimming area quality, most monitoring programs do not provide proactive protection for public health. Programs typically are oriented either toward monitoring areas where problems with bacterial quality are already known to exist, or they do not have a mechanism to provide timely feedback to the people who may be recreating in the waters. These factors make prevention the most critical component for providing public health protection. The reliance on prevention is often at the heart of the debate over the need to take a more protective stance when setting surface water standards and discharge control requirements. The remainder of this section outlines the general types of monitoring programs that evaluate bacterial quality.

There are several ways the bacterial quality of waters can be assessed. State, federal and local agencies; tribes; private interest groups; and businesses may all have programs that collect data on water quality. While the purposes of these monitoring programs can vary significantly, they usually fit into one of the following four basic programs: 1) direct monitoring of swimming beaches, 2) special monitoring studies, 3) state-wide or jurisdiction-wide ambient monitoring programs, and 4) data collection by permittees.

<u>Direct monitoring of swimming beaches</u> to determine if swimmers are being adequately protected sometimes occurs. Overall it could be said that it is very rare for water quality to be tested on a routine basis at popular swimming areas. Where sampling does occur, it is typically a county or local government agency that conducts these sampling programs. These entities will usually take several samples from the swimming area to determine if a health risk exists sufficient to warrant posting the area as unsafe.

<u>Special monitoring studies</u> are sometimes conducted for swimming beaches by the state Department of Ecology as well as other governmental entities. Special studies usually focus on assessing the extent of contamination, and identifying and controlling the sources of that contamination. Typically these type of studies are well planned out and conducted where problems are known to exist. Further, more often or not they are focused on a large portion of a waterbody rather than a discrete swimming area.

<u>State-wide or jurisdiction-wide ambient monitoring programs</u> are an ongoing method of gauging the quality of our states surface waters. Fixed stations are established which are monitored on a regular, often monthly basis. Rotating stations are also established, which are typically monitored every other year; having rotating stations helps provide more sample sites than could be funded with just fixed stations. The sampling that accompanies these jurisdiction-wide ambient monitoring programs typically is made up of single samples, and the stations are not established to be in conformance with the locations of popular swimming beaches. The information produced from these programs is used to determine overall trends in the quality of our state's waters and sometimes results in problems being identified for special monitoring and control programs.

Data Collected by Permittees usually is done in compliance with the monitoring requirements established in formal permits to allow discharges of wastewater. These monitoring programs typically are limited to directly monitoring the wastewater before it is discharged to surface waters that may be used for swimming or shellfish harvesting. The data can be used to determine what concentrations are being released from a facility and thus give some idea on the relative risk of contamination posed.

Appendix F: Summary of Indicators Used in Other States

The following is a summary of the bacterial indicators in use in other states that was obtained by phone interview in late 2000 (Andrew Kolosseus, Washington State Department of Ecology):

	What indicator is the state using?[i]	*Technology-Based Limits*	*Concerns w/ methods?*	*Satisfied?*
Alabama	Freshwater: fecal coliform. Marine: fecal coliform at 100 (mean) and enterococci at 104 (single). The state monitors both to determine the correlation.	Fecal coliform is used.	Respondent did not know.	Marine: moving to enterococci. Freshwater: conducting some E. coli monitoring.
Alaska	Fecal coliform at 20-200 (mean) and 40-400 (10%).	Fecal coliform is used.	The state is not set up for E. coli or enterococci. Fecal coliform is believed to be cheaper and easier.	The state is satisfied with fecal coliform. They believe E. coli and enterococci may not be appropriate for Alaska.
Arizona	Fecal coliform at 200-1000 (mean). E. coli at 130 (mean) and 580 (single) for 1° contact.	The state does not have primacy for NPDES. They expect EPA's permits will change when WQS change.	The respondent was not aware of any concerns.	The state is in their triennial review and is looking at repealing fecal coliform. They might use E. coli at 126 (mean) and 235 (single for 1°) or 576 (single for 2°).
Arkansas	Fecal coliform at 200 (mean) and 400 (10%) from April-Sept. and 1000 (mean) and 2000 (10%) year-round.	Fecal coliform is used.	N/A	The state is studying a consideration to switch to E. coli.

	What indicator is the state using?[i]	*Technology-Based Limits*	*Concerns w/ methods?*	*Satisfied?*
California	Freshwater: each district sets their standards. Most use fecal coliform and some also use enterococci. Marine: fecal coliform at 200 (mean) and 400 (10%) and monitoring requirements for enterococci.	N/A	The respondent was not aware of any concerns. However, anecdotal evidence suggests that enterococci values less than 100 are not reliable.	For freshwater, there are no statewide plans to change indicators. For marine water, the plans will be updated and the staff-preferred option is to add enterococci.
Colorado	Fecal coliform at 200 and 325 (means) for 1° contact and 2000 for 2°. E. coli at 126 and 205 (means) for 1° contact and 630 for 2°. For ambient monitoring and 303(d) listing, E. coli trumps fecal coliform.	Dischargers can choose either fecal coliform or E. coli.	E. coli is no more difficult than fecal coliform. E-coli-alert™ seems to minimize human error.	The state is moving to E. coli. Fecal coliform seems to be more stringent than E. coli.
Connecticut	Freshwater and marine, 1° contact: enterococci at 33 (mean) and 61 (single). Freshwater, other: fecal coliform at 200 (mean).	No technology base limits. Considering using E. coli.	Department of Health does the analysis using a MPN test. The respondent was not aware of any concerns.	The state is proposing to use E. coli for freshwater at 126 for swimming. The state believes E. coli is closer to fecal coliform than enterococci (which has been used for 10 years).
Delaware	Enterococci: freshwater at 100 (mean) and marine at 10 (mean).	Respondent did not know.	Procedure works well.	No plans to change.
Florida	Freshwater and marine: fecal coliform at 200 (mean), 400 (10%), and 800 (single). Shellfish areas: fecal coliform at 14 (mean), 43 (10%), and 800 (single).	N/A	N/A	No changes are planned at this time. The state desires that FDA and EPA recommend the same standard. The state believes EPA's range for enterococci may not be appropriate for warmer climates.

	What indicator is the state using?[i]	*Technology-Based Limits*	*Concerns w/ methods?*	*Satisfied?*
Georgia	Freshwater: fecal coliform at 200, 300, or 500 (means) from May-Oct. and 1000 (mean) from Nov-April. Marine: fecal coliform at 100 (mean).	Fecal coliform is used. They have not addressed this issue when considering changes in WQS.	N/A	The state is reviewing potential changes, but immediate changes are not expected.
Hawaii	Freshwater: fecal coliform at 200 (mean) and 400 (10%). Marine: enterococci at 7 (mean).	Technology-based indicators match WQS.	The respondent was not aware of any concerns.	The state would have preferred to use different indicators.
Idaho	E. coli at 126 (mean) and 406 (single for 1º contact) or 576 (single for 2º contact).	The state is currently using fecal coliform and E. coli, and plans to change to exclusive use of E. coli.	The respondent was not aware of any concerns.	The WQS have a trigger level that obligates the agency to collect five samples to determine a monthly mean. This can be labor intensive in remote areas.
Illinois	Fecal coliform.	N/A	N/A	The indicator will change, probably to E. coli.
Indiana	E. coli at 125 (mean) and 235 (single).	E. coli is used (and possibly limited use of fecal coliform).	It takes 24 hours to obtain results.	They are satisfied with E. coli, but might change the numeric criteria.
Iowa	Fecal coliform.	Fecal coliform (this will probably not change).	N/A	The state is considering enterococci or E. coli.
Kans	Fecal coliform at 200 (mean) and 400 (10%) for contact (April to Oct.) and 2000 for non-contact (year-round).	Fecal coliform (this will probably not change).	N/A	The state hopes to change to E. coli. They have also attempted to adopt a 921 (single) fecal coliform standard for recreation.
Kentucky	Fecal coliform.	Fecal coliform is used.	N/A	The state kept fecal coliform in a recent triennial review. They are considering a fecal coliform – E. coli "either or" standard.

	What indicator is the state using?[i]	*Technology-Based Limits*	*Concerns w/ methods?*	*Satisfied?*
Louisiana	Fecal coliform.	N/A	The Health Department Laboratory does not want to change. The state's turbid waters make analyzing E. coli and enterococci difficult.	The state is considering E. coli and enterococci. They would prefer to use just enterococci. EPA has not indicated it would be a problem.
Maine	Freshwater: E. coli (in summer). Marine: fecal coliform.	Yes.	The respondent was not aware of any concerns.	Yes.
Maryland	Freshwater: E. coli at 126 (mean) and 235 (single). Enterococci at 33 (mean) and 61 (single) are optional. Fecal coliform is also still used.[ii] Marine: enterococci at 35 (mean) and 104 (single) and fecal coliform for shellfish at 14 (mean).	Fecal coliform is used by NPDES. Changing to E. coli or enterococci may be postponed until a less expensive laboratory method is approved.	For non-NPDES work, they use Entero-alert™ or E-coli-alert™. These methods are faster and better than fecal coliform methods. The approved NPDES method is slower and more expensive.	The current standard expires in December 2000. The state will decide what numeric criteria to use and if they will drop fecal coliform.
Massachusetts	Freshwater: fecal coliform at 20-1000 (means) and 100-4000 (singles). Marine: fecal coliform at 14 (mean) and 43 (single) for shellfish and 200 (mean) and 400 (single) for other waters.	Fecal coliform is currently used. The state has not decided if it will change indicators when WQS are changed.	N/A	The state will be changing to E. coli and enterococci.

	What indicator is the state using?[i]	*Technology-Based Limits*	*Concerns w/ methods?*	*Satisfied?*
Michigan	E. coli at 130 (mean) and 300 (single) for 1º contact and 1000 (single) for 2º contact.	Fecal coliform is used.	The respondent was not aware of any concerns.	There are no plans to change.
Minnesota	Fecal coliform at 200 (mean) and 400 or 2000 (10%) from April 1- Oct 30.	The state uses fecal coliform. They will probably keep fecal coliform even if WQS change to E. coli.	N/A	The state plans to change to E. coli. They do not know if they would adopt EPA's recommended criteria of 126.
Mississi	Fecal coliform.	N/A	N/A	The state is undergoing a triennial review in 2001 and will not change indicators at that time. They will probably eventually change to E. coli and enterococci.
Missouri	Fecal coliform at 200 (mean) from April 1-Oct 30 for waterbodies not affected by stormwater runoff.	If WQS indicator is changed, technology based limits would also probably change.	N/A	EPA is reviewing the current standards. In a few years, the agency will need to decide if it wants to change indicators.
Montana	Fecal coliform at 200 (mean) and 400 (10%) when the water temperature is above 60ºF.	The state would probably change to E. coli when the WQS change.	N/A	The state is planning to change to E. coli, and will probably follow EPA's numeric recommendation.
Nebraska	Fecal coliform at 200 (mean) and 400 (10%) from May 1 – Sept 30.	Fecal coliform is used.	The agency believes the analysis of E. coli is more expensive and the lab QA is not as good. This has deterred them from using E. coli.	The state is satisfied with fecal coliform. If the cost and QA of fecal coliform matched E. coli, they would consider changing. The state has determined that E. coli at 126 is more stringent than fecal coliform at 200.

	What indicator is the state using?[i]	*Technology-Based Limits*	*Concerns w/ methods?*	*Satisfied?*
Nevada	Fecal coliform at 200 (mean) and 400 for contact recreation. Lake Tahoe has numerous standards, including E. coli at 126 (mean).	Fecal coliform is used. It is unknown if it will change when the WQS change.	The respondent was not aware of any concerns.	The state will be changing to E. coli.
New Hampshire	Freshwater: E-coli at 47-126 (mean) and 88-406 (single). Marine: enterococci at 35 (mean) and 104 (single) for swimming and fecal coliform for shellfish.	E. coli at 1000 is used for point sources. Fecal coliform is used for shellfish-related discharges.	The respondent was not aware of any concerns.	The state is satisfied. They are considering situations where stormwater is violating standards due to animal waste, and they are evaluating the appropriateness of the numeric criteria.
New Jersey	Freshwater: enterococci at 33 (mean) and 61 (single). Marine: enterococci at 35 (mean) and 104 (single). Fecal coliform at 50, 200, 770, and 1500 (means) in fresh and marine water.	Enterococci are used.	There are no problems.	The state is generally satisfied, although the regulated community does not fully support the enterococci standard.
New Mexico	Fecal coliform at 100-1000 (mean) and 200-2000 (single).	Fecal coliform is used.	N/A	The state will probably change indicators in three years.
New York	Freshwater: fecal coliform at 200 and total coliform. Marine: fecal coliform at up to 2000 and total coliform.	N/A	N/A	The state has agreed to discuss issues with EPA. There are no immediate plans to change. The agency questions the advantages of changing.

	What indicator is the state using?[i]	*Technology-Based Limits*	*Concerns w/ methods?*	*Satisfied?*
North Carolina	Fecal coliform at 200 (mean) and 400 (20%).	N/A	N/A	The state is considering changing indicators. They question if the gains from changing are worth loosing the fecal coliform historic database.
North Dakota	Fecal coliform at 200 (mean).	Fecal coliform is used.	N/A	The state does not plan to change during this revision. The state might change indicators in three years.
Ohio	Bathing: fecal coliform at 200 (mean) and 400 (10%), E. coli at 126 (mean) and 235 (10%). 1° Contact: fecal coliform at 1000 (mean) and 2000 (10%), E. coli at 126 (mean) and 298 (10%). 2° Contact: fecal coliform at 5000 (10%), E. coli at 576 (10%).	The state is changing to E. coli.	The cost of E. coli analysis has declined. There is not as much controversy with E. coli now as there has been in the past.	The state is planning to change to just E. coli. They have found that the E. coli standard is more stringent than fecal coliform.
Oklahoma	Fecal coliform at 200 (mean) and 400 (10%). E. coli at 125 (mean) and 235 (single) for lakes or 406 (single) for streams. Enterococci at 33 (mean) and 61 (single) for lakes or 108 (single) for streams.	NPDES dischargers can choose one of the three indicators, but must use it for the life of the permit.	They had a problem with the six-hour holding time, so they extended it to 24 hours.	Yes. The state plans to keep all three indicators.
Oregon	Fresh and estuarine water: E. coli at 126 or 406 (mean). Marine and shellfish water: fecal coliform at 14 (mean) and 43 (10%).	E. coli and total coliform are used.	The respondent did not know.	Yes.

	What indicator is the state using?[i]	*Technology-Based Limits*	*Concerns w/ methods?*	*Satisfied?*
Pennsylvania	Fecal coliform at 200 (mean) for 1º contact (May 1 to Sept. 30).	The respondent was not sure.	N/A	The state is considering changes.
Rhode Island	Freshwater: fecal coliform at 200 (mean) and total coliform. Marine: fecal coliform at 14-50 (mean) and total coliform.	The respondent did not know.	N/A	The state will probably change to E. coli and enterococci and retain fecal coliform for shellfish and during a transition period.
South Carolina	Fecal coliform at 200 (mean) and 400 (10%) for both freshwater and marine. Fecal coliform at 14 (mean) for shellfish.	N/A	N/A	The state is in a triennial review and is not proposing to change indicators. The state will evaluate data over the next three years and make a determination.
South Dakota	Fecal coliform at 200 (mean) from May 1 – Sept. 30.	The state will probably switch from fecal coliform to E. coli when the WQS change.	N/A	The triennial review is due in 2001. The state will probably switch to E. coli at that time.
Tennessee	Fecal coliform at 200 and 1000 (mean) and 1000 and 5000 (single), E. coli at 126 (mean).	The state will change to E. coli when fecal coliform is phased out.	The laboratory says everything is okay.	Fecal coliform will be phased out. E. coli seems to be working.

	What indicator is the state using?[i]	*Technology-Based Limits*	*Concerns w/ methods?*	*Satisfied?*
Texas	Freshwater: E. coli at 126 (mean) and 394 (single) for contact and 605 (mean) for non-contact. Marine: enterococci at 35 (mean) and 89 (single) for contact and 168 (mean) for non-contact. Fecal coliform is still used for shellfish. Fecal coliform can still be used at 200 (mean) and 400 (single) for contact and 2000 (mean) and 4000 (single) for non-contact.	Technology based limits are still open. Dischargers can still use fecal coliform.	The Entero-alert™ and E-coli-alert™ tests are well received, especially with field staff with long travel times.	The current standards were approved by the state in July 2000. The state will continue to evaluate indicators. The respondent indicated that their studies show E. coli, and to a lesser extent enterococci, are less variable than fecal coliform and are a closer match to expectations.
Utah	Fecal coliform at 200 (mean).	If E. coli is adopted into the WQS, dischargers will probably be able to choose fecal coliform or E. coli.	N/A	Before adopting E. coli, the agency desires more guidance and discussion with EPA and other states.
Vermont	E. coli is used in recreational areas at an instantaneous standard of 77.	E. coli is used.	E. coli has been used since 1986 with no problems.	The agency has attempted to change the 77 standard set by a board to 126 (mean).
Virginia	Fecal coliform at 200 (mean), 1000 (single), and 14 for shellfish waters.	Respondent believed they would change the technology-based limit to match the WQS.	N/A	The state will change to some combination of E. coli and enterococci. They are still in the early stages of the process.
West Virginia	Fecal coliform at 200 (mean) and 400 (10%).	N/A	N/A	The state will be evaluating indicators next year, with the option of adopting enterococci or E. coli.

	What indicator is the state using?[i]	*Technology-Based Limits*	*Concerns w/ methods?*	*Satisfied?*
Wisconsin	Fecal coliform.	N/A	N/A	The state expects it will not change until 2003.
Wyoming	Fecal coliform.	Respondent believed the technology-based limits mirrored the WQS.	N/A	Wyoming is doing the triennial review and plans to keep fecal coliform. The state will probably eventually change to E. coli.

Appendix G: Performance of Oregon Wastewater Plants

Exhibit A:

The following are effluent concentrations of bacterial indicators reported for 16 Oregon wastewater treatment plants[1]. The data are grouped according to the frequency of samples that exceeded the USEPA single-sample recommendation of 61 enterococci per 100mL, and two levels of fecal coliforms (100 and 200/100mL). It is important to note that neither USEPA nor the state of Washington has a single-sample criterion for bacteria that applies to undiluted effluent. Oregon, however, applies their bacterial criteria at the point of discharge with no allowance for ambient dilution.

Facility Name	**Percentage of Samples Exceeding Indicator Levels** %>61 Ent.	%>100 FC	%>200 FC
Albany	13%	2.3%	2.3%
Corvallis	59.5%	0%	0%
Columbia	50.8%	49.2%	28%
The Dalles	36.1%	8.3%	5.6%
Durham	20.4%	0%	0%
Eugene	28.2%	5.9%	0.6%
Forest Grove	4.2%	4.2%	2.1%
Gresham	3.4%	3.8%	0%
Hillsboro	4.1%	0%	0%
Clackamas	24.1%	24.1%	13%
McMinville	88.9%	26.3%	16.7%
Medford	7.4%	0%	0%
Rock Cr.	33%	14.3%	4.1%
Salem	67.4%	7.4%	4.4%
Clackamas	18.42%	11.8%	5.3%
Tryon	90%	3.4%	1.7%

[1] Summary of Data Supplied by Janet A. Gillespie. Oregon Association of Clean Water Agencies, August 15, 1996.

Exhibit B:

Comparison of fecal coliform, enterococci and *E. coli* indicator bacteria concentrations at three wastewater treatment facilities in the state of Oregon[2]. Equivalent USEPA criteria would be 200 for fecal coliform, 33 for enterococci, and 180 for *E. coli*. In the data set below, none of the samples exceeded either the fecal coliform or *E. coli* criteria, while 41 percent of the samples exceeded the criteria for enterococci.

Eugene/Springfield Wastewater Treatment Plant

Date	Fecal coliform	Enterococci	E. coli
27-Mar	2	680	1
31-Mar	2	>800	0
3-Apr	2	170	1
7-Apr	1	1800	0
10-Apr	1	1020	3
14-Apr	0	35	0
22-Apr	2	2	2
24-Apr	0	1	2
28-Apr	2	5	3
1-May	3	4	0
5-May	8	25	4
8-May	6	26	6
12-May	24	16	7
15-May	10	3	8
19-May	3	2	1
22-May	1	7	2
2-Jun	6	1	2
5-Jun	99	19	18
9-Jun	24	10	16
16-Jun	122	8	85
19-Jun	135	6	57
23-Jun	4	5	4
26-Jun	2	2	1
30-Jun	2	2	0
3-Jul	1	1	0
7-Jul	21	115	22
10-Jul	1	14	5
14-Jul	6	86	1
17-Jul	7	7	1
21-Jul	7	14	3
24-Jul	2	2	0
28-Jul	4	6	0
31-Jul	6	11	2
4-Aug	1	8	1
7-Aug	1	1	2

Corvallis Wastewater Treatment Plant

Date	Fecal coliform	Enterococci	E. coli
2-Jun	<3	80	<3
9-Jun	6	33	<3
16-Jun	<3	3	<3
23-Jun	<3	136	<3
30-Jun	3	67	6
7-Jul	6	80	<3
14-Jul	<3	150	<3
21-Jul	<3	150	<3
28-Jul	3	67	9

Willow Lake Treatment Plant

Date	Fecal coliform	Enterococci	E. coli
22-Jul	0	50	0
27-Jul	0	20	0
29-Jul	0	60	0
3-Aug	0	75	0
5-Aug	0	95	4

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[2] Summary of data supplied by Francis Kessler, City of Salem, Oregon. February 26, 1997. Data originated from the Association of Clean Water Agencies' study on enterococcus compliance.

Appendix H: Performance of Washington Wastewater Plants

Summary of the draft Ecology report: "*2001 POTW Disinfection Study*"

Purpose: In May and June, 2001, nine publicly owned sewage treatment plants (POTWs) in Washington participated in a comparative disinfection study conducted by Washington Department of Ecology. The purpose of the study was to determine whether a variety of POTWs (Table 1) would be able to comply with effluent limits based on proposed criteria for bacteria. These criteria were for the following indicators: enterococci, *E. coli*, and fecal coliform. Of particular interest was whether ultra-violet (UV) (used at 4 of the plants) or chlorine disinfection (used at 5 of the plants) would be more effective at reducing numbers of bacteria in the effluents.

Table 1. Treatment plant information

Discharge location	Ultra-violet disinfection	Chlorine disinfection
Freshwater	3	2
Marine water	1	3

Methods: The POTWs collected and sent (by overnight express) disinfected effluent samples to Manchester Environmental Laboratory (MEL) over a period of seven weeks. Sample bottles, ice, and ice chests were supplied by MEL. Each POTW sent in approximately 3 samples per week, and field duplicates were also taken during the study. Each sample was analyzed for the three bacterial indicators. *E. coli* was run as a separate test, and not simply as a subset of the fecal coliform test. Samples were run within 24 hours of collection.

One treatment plant supplied two sets of samples that were analyzed within both the recommended 6-hour holding limit for bacterial samples as well as at 24 hours. This extra run was done to determine whether the increased holding times used in the study would influence the bacterial counts. Because National Pollutant Discharge Elimination System (NPDES) permit-specified analytical methods call for samples to be run within six hours, these samples are not appropriate for compliance assessment of existing NPDES permit limits for bacteria. They are useful, however, as a relative comparison of plant performance and as an estimator of compliance with hypothetical water quality-based limits for the three bacterial indicators.

Results: Analysis of data from the 6-hour and 24-hour comparison showed no statistical differences for the three bacterial indicators. Comparative data available from two treatment plant laboratories indicate that interlaboratory differences may greatly effect counts for fecal coliform and enterococci. Because of these differences, hypothetical compliance scenarios were developed using worst-case data estimated from the differences between the MEL and the treatment plant laboratory analyses, while relative differences among plants were analyzed using unaltered MEL data.

Compliance assessment: Water quality-based effluent limits were developed for the nine treatment plants using the general formula:

> Limit = (dilution ratio at the edge of the chronic mixing zone) x (candidate bacterial indicator criteria)

The dilution factors were obtained from either the most recent fact sheet of a facility's NPDES permit or directly from the permit writer responsible for drafting the facility's NPDES permit. The spatial dimensions of the chronic mixing zone vary with the type of water receiving the discharge (WAC 173-201A). Candidate bacterial indicator criteria are summarized in Table 2.

The fecal coliform counts from a subset of the treatment plants were unexpectedly high. Fortunately, two treatment plants collected duplicate samples for their own in-house analysis of fecal coliform and enterococci. The samples run at the treatment plant laboratories had much lower counts for fecal coliform than the samples run at MEL. The enterococci values from the treatment plant labs were in general higher than the values from MEL.

Findings are summarized in Table 2. Based on the comparison of fecal coliform data from the two POTW laboratories with MEL analyses, use of data from MEL to assess compliance with fecal coliform limits presents a worst-case compliance scenario. Using this worst-case approach, three out of four POTWs complied with the hypothetical water quality-based limits for the proposed marine fecal coliform criteria. The POTW that would possibly be unable to meet the hypothetical limit was one of the POTWs that ran analyses of duplicate samples, and their own in-house data showed compliance with the hypothetical limit.

Based on the duplicate samples run in-house at the two POTW laboratories, the enterococci data from MEL were adjusted (increased using a 168% conversion factor) to be representative of a near-worst case scenario for compliance with hypothetical limits based on the proposed enterococci criteria. Using this approach, all marine and freshwater POTWs participating in the study complied with the hypothetical limits.

No comparative data were available for *E. coli*. Based on data from MEL, all plants were able to comply with the hypothetical water quality-based limits for the proposed freshwater *E. coli* criteria.

Disinfection technology: The effluents treated with UV had statistically significantly lower bacterial counts than the effluents treated with chlorine. This held true for all three bacterial indicators. This finding may be confounded by the capacity at which the POTWs were running during the sampling. The UV plants in general are newer, and are running at a much lower capacity than the chlorine plants. This may influence the effective exposure of pathogens to UV radiation. This issue is addressed in the draft report "*2001 POTW Disinfection Study*".

Table 2. Summary of dischargers' potential compliance with water quality-based limits for dischargers. A 168 percent conversion factor was applied to enterococci counts to estimate plant performance based on average percent difference between Manchester and treatment plant laboratory enterococci counts of all split samples analyzed in May and June 2001. Fecal coliform compliance assessment indicates a worst-case scenario, based on split samples analyzed by Manchester two treatment plant laboratories. Potential non-compliance indicated by bold **X**s. Shaded areas indicate areas where criteria do not apply (for instance, marine criteria do not apply to the freshwater discharges). POTWs in bold-face treat with ultra-violet, others treat with chlorine.

Proposed indicator organism and uses protected	Potential compliance for 9 marine and freshwater dischargers. Enterococci compliance incorporates a 168% conversion factor.								
	1	**2**	**6**	**3**	**4**	**5**	**7**	**8**	**9**
Freshwater									
Enterococci **Use: Freshwater Recreation**		▨	▨	▨		▨			
E. coli **Use: Freshwater Recreation**		▨	▨	▨		▨			
Marine									
Fecal coliform **Use: Marine Shellfish,**	▨	*X*			▨		▨	▨	▨
Enterococci **Use: Marine Recreation**	▨				▨		▨	▨	▨
Enterococci **Use: Marine Clam, Oyster Harvesting**	▨				▨		▨	▨	▨

Appendix I: Survival Characteristics of Indicators and Pathogens

Data on Survival in the Absence of Chlorine Disinfection:

Survival data can be derived from studies that isolate bacteria and virus from water, sediments, soil, and tissues. It is difficult, however, to compare the various studies with each other. This is primarily due to the technical problems associated with measuring and determining the viability of viruses, as well as the significant differences that exist between the test conditions and media used (Vaughn *et al.,* 1979, 1980; Cliver, 1988). Some tests were conducted *in situ* and measured the effects from actual wastewater discharges, while others were derived in laboratory waters using pure strains of virus. Variations in pH, temperature (Ahmed and Sorensen, 1995), turbidity, planktonic blooms, light intensity (Bellair *et al.,* 1977), and to some extent salinity, can all affect the survival characteristics in tests, both in laboratory and in natural water settings. The effects of these variables on bacteria and virus survival characteristics are not yet fully understood, and the results of tests conducted under different conditions can not be adjusted and directly compared. One fact which is inescapable is that temperature is an environmental variable that greatly influences survival rates of both bacteria and virus (Niemela and Vaatanen,1981; Lo *et al.,* 1976.

Even with these complicating factors, however, there are general patterns that hold constant throughout most of the scientific literature that can aid in making comparisons between indicators and viral pathogens. The purpose of this discussion is to summarize some of the conclusions of research done on virus and bacteria survival to help establish a general trend to this issue. For the reasons discussed above, however, it was determined inappropriate to use these studies in combination to estimate specific survival rates for the bacteria and viruses themselves.

Human feces may contain a large variety of viruses, many of which are considered to be infectious through waterborne routes of exposure. These viruses may remain infectious for several weeks or longer after discharge into receiving waters (Cliver, 1988). The work by Lo et al. (1976), for example, showed that of three viruses tested (coxsackievirus B5, echovirus type 6, and poliovirus), all remained stable and infectious after being held for 46 weeks at 4°C. Their *in situ* studies, conducted in free flowing marine waters, showed survival for several months, and found CB-5 to be the most stable. This longevity in natural waters allows sufficient time for them to directly infect recreational water users and to be transported to coastal shellfish growing areas. Once inside the shellfish or deposited in the sediments, the survival of bacteria and viruses may be further prolonged (Van Donsel and Geldreich, 1971; Vaughn, Landry *et al.,* 1979a, b). The maximum accumulation of viruses in shellfish can far exceed levels present in the surrounding water and can occur within a few hours of exposure (Gerba *et al.,* 1978). Further, in addition to mollusks, crustaceans, including important west coast crabs, have been shown to accumulate viruses which can survive in tissue three to six times longer than coliform bacteria (Morris *et al.,* 1976). Cliver (1988) suggested that a single gram of human feces may contain at least 10^4 - 10^{10} infectious doses of virus.

A number of studies have been reviewed that compare the virological and bacteriological characteristics of shellfish harvest areas. Much of this work has been oriented towards investigating differences in viral concentrations between growing areas considered open or closed based on coliform concentrations in the water column. While in some cases growing areas that were approved for harvest had notably lower levels of viruses in the shellfish tissue analyzed (Sobsey *et al.,* 1980), these differences were not always statistically significant. The general consensus of the publications examined in this review is that indicator bacteria measured in the water column do not correlate well with the level of viruses in shellfish tissue (Gerba et al, 1980; Ellender *et al.,* 1980; Wait *et al.,* 1982; Vaughn and Landry *et al.,* 1979a, b; Goyal *et al.,* 1979). There also seems to be a general lack of correlation with viral concentrations found in sediments (Van Donsel and Geldreich, 1971), and a concern that the sediments may serve as sinks for pathogens which may be resuspended and ingested by humans or accumulated in shellfish or crustaceans. Although the general tendency is for the research to show a lack of correlation, this tendency is not absolute. Watkins and Cabelli (1985) showed the occurrence of *Vibrio parahaemolyticus* correlated well with two key indicator bacteria (0.81 for *E. coli* and 0.70 for enterococci).

In addition to greater survival in tissues, viruses and bacteria have also been shown to survive for significantly longer periods of time in the sediments than in the water column. The sediments can act as sinks for the storage of bacterial indicators as well as infectious pathogens. Marino and Gannon (1991) found that storm drain sediments acted as reservoirs for both fecal coliforms and fecal streptococci, with populations remaining stable for five to seven days during warm dry periods. Blanc and Nasser (1996) demonstrated that pathogenic viruses are capable of surviving for long periods of time in soil at ambient temperatures. No die off was found for any of the viruses studied (hepatitis A virus, poliovirus 1, and MS2 and PRD-1 bacteriophages) after 20 days at 10°C in soil saturated with treated wastewater. At a soil temperature of 23°C, MS2bacteriophage had the greatest die-off (as much as 5 $\log_{10}$ after 20 days), with intermediate die off for poliovirus 1 (less than 2 $\log_{10}$), and only negligible die-off for PRD-1 bacteriophage (1 $\log_{10}$) and hepatitis A virus (less than 1 $\log_{10}$). Van Donsel and Geldreich (1971) studied the relationship of salmonellae to total coliforms, fecal coliforms, and fecal streptococci in aquatic sediments. They found much higher densities of fecal coliforms and salmonellae in the mud than in the overlying waters. The results of their study additionally suggested that in sediments the survival of fecal coliforms closely paralleled that of salmonellae. In tests of surface soil, Van Donsel and Geldreich (1967) found that fecal coliform concentrations were reduced more rapidly in the autumn than fecal streptococci (13.4 versus 20.1 days), but that in the summer, fecal streptococci decayed somewhat faster than fecal coliforms (2.7 versus 3.7 days).

Several studies were conducted in completely frozen rivers in Alaska to assess the longevity of fecal indicator bacteria from a wastewater treatment plant that discharged unchlorinated primary effluent. The results of these studies were very comparable and showed survival rates downstream after seven days to be approximately 3.2-8.4% for total coliforms, 2.1-15.7% for fecal coliforms, and 18.1 to 37.3 for fecal streptococci. In a similar study, Van Donsel (1973) studied six salmonella serotypes and found that after a seven day travel time, they were still measurable in the presence of 60 fecal coliforms/100mL.

Gerba *et. al.* (1980) conducted a series of studies in marine waters to statistically compare virological data with bacterial indicators. They were unable to find a strong correlation between viruses in oysters to viruses in the overlying waters, and found high concentrations of viruses in waters which met bacteriological standards. In their studies, viruses were detected 43% of the time in recreational waters considered acceptable as judged by total coliform standards and 44% of the time when judged by fecal coliform standards. Viruses were detected in waters that met acceptable standards for shellfish harvesting 35% of the time. The authors also opined that ". . . current epidemiological methods are not sensitive enough to effectively detect viral disease transmission through water, because clinically observable illness occurs only in a small number of people who become infected and because of the widely varying incubation periods." This view was used in support of the position that the presence of any enteric virus in water is indicative of a potential for viral disease hazard.

Chlorination and its Effects on Bacteria and Virus Survival:

Gerba (1988) noted that the number of virus-associated outbreaks of gastroenteritis caused by shellfish was on the rise in the United States, and suggested that bacterial indicators currently used to assess the sanitary quality of shellfish are not adequate to prevent viral disease. Human enteric viruses were considered the major cause of outbreaks. Gerba suggested that the greater resistance of enteric viruses to chlorination was likely the cause of the reduced effectiveness of bacteria indicators in preventing virus-related disease. The following discussion looks at some of the literature findings on the issue of chlorine effectiveness.

Watkins and Cabelli (1985) determined using field studies that *E. coli* can be inactivated at rates greater than accompanying viral pathogens in the presence of chlorinated effluent. In examining laboratory and environmental isolates of several poliovirus and coxsackievirus to determine their rate of inactivation by chlorination, Payment *et al.* (1985) exposed several common viral pathogens to 0.4 mg/L residual chlorine for up to 1,000 minutes. Coxsackievirus B5 isolates were found to be more resistant than coxsackievirus B4, followed by poliovirus 1,2, and 3 in order of decreasing resistance. Additionally, environmental isolates of CB-5 were more resistant than the laboratory strain tested, and for two strains, 12 and 22% of the virus was still infectious after 100 minutes. Although CB-4 isolates were less resistant overall to chlorine than CB-5, after 1,000 minutes of contact, 0.01% of the virus was still infectious.

In the presence of chlorine, Keswick *et al.* (1985) found Norwalk virus to be more resistant than poliovirus type 1, human rotavirus, simian rotavirus, and f2 bacteriophage. A 3.75-6.5 mg/L dose of chlorine for 30 minutes of contact at 25°C was found to be effective against all of the viruses tested except the Norwalk virus, which remained infectious for five of eight volunteers. Norwalk virus treated with 10 mg/L chlorine produced illness in only one, and failed to induce seroconversion in any of eight volunteers. The authors contend that the strong resistance to chlorine may help explain why Norwalk is implicated in outbreaks of waterborne disease.

Hepatitis A virus (HAV) is a waterborne pathogen of concern. The inactivation of hepatitis A by chlorine was tested by Peterson *et al*. (1983) who concluded that HAV is somewhat more resistant to chlorine than are other enteroviruses. Using 0.5, 1.0, and 1.5 mg/L free residual chlorine per liter and a contact time of 30 minutes, the levels of hepatitis infection were 14, 8, and 10 percent in the animals tested. Inoculum treated with 2.0 or 2.5 mg of free residual chlorine was not infectious and did not result in seroconversion in the 13 animals tested after 30 minutes of chlorine contact.

It should be noted that the results of Peterson et al. (1983) discussed above conflict with those of Grabow *et al.* (1983) who concluded that free chlorine residuals were successful in inactivating HAV, SA-11 rotavirus, and reovirus-3. The conclusions of Grabow *et al.* strongly support the use of indicator organisms such as *E. coli* and enterococci to determine the effectiveness of chlorination for inactivating virus in wastewater. Grabow et al. examined the survival of *E. coli* and *S. faecalis* in chlorine-demand-free buffers at pH 6.0, 8.0, and 10.0 at 25°C. In a phosphate buffer at pH 6.0 *E. coli* had only an approximate 2 log inactivation in 15 minutes while *S. faecalis* had a 4 log inactivation in 4 minutes. However, in a phosphate buffer at a pH of 8.0, both *S. faecalis* and *E. coli* had 4 log inactivation but it took 8 minutes for *E. coli* and 13 minutes for *S. faecalis*. And in a borate buffer at pH 10.0, *S. faecalis* had just over a 2 log inactivation in 15 minutes compared with a 4 log inactivation in 2 minutes of *E. coli*. Free chlorine began at approximately 0.41 mg/L in all three tests, but was at 0.06, 0.08, and 0.28 in all three of the test pH's (6, 8,10). Monochloramine varied from 0.13/0.19, 0.24/0.30, and 0.32/0.22 in all three tests from start to 15 minutes. The authors note that "the relative survival of the same organisms may differ extensively in water which contains predominantly chloramines, as in the case of chlorinated wastewater". From the Grabow et al. work, we observe that pH may influence the relative survival of *E. coli* and enterococci, and that this may help explain why enterococci seems more difficult to remove from chlorinated effluents. Wastewater pH tends to be in the range of 6.9-7.1 (personal communication with Paul Jue, LOTT). The work of Grabow et al. found that as the pH increases from 6.0 to 10.0 the relative resistance of enterococci to disinfection decreases. While pH of 7.0 was not tested, at 6.0 enterococci (or at least *S. faecalis*) was significantly more resistant than *E. coli* and at 8.0 it remained more resistant but much less so. This suggests enterococci may still be notably more resistant at the intermediate pH of 7.0. It may be important, however, to note that the work by Grabow et al. was conducted at 25°C, a notably higher temperature than most of the other studies examined.

Vaughn *et al.* (1986) studied the inactivation of simian rotavirus SA-11 and human rotavirus type 2 at various levels of chlorination and pH. The authors concluded that there should be little difficulty in inactivating rotaviruses in water treatment facilities that maintain chlorine concentrations of 1 to 3 mg/L. These results were repeated in studies by Berman and Hoff (1984) who found that 99.99% of simian rotavirus SA11 was inactivated in less than 15 seconds at pH 6. Sproul (1974) noted times for 99.99% removal of 25 human enteric viruses with 0.5 mg/L free chlorine in river water with a pH 7.8 and temperature of 2°C. Inactivation ranged from 2.7 minutes for Reovirus 1 to more than 120 minutes for coxsackievirus A6. The author concluded that free chlorine residuals of 1 to 2 mg/L with contact times of one to two hours would be required for extensive inactivation in waters with pH values of about 7.8. Peterson *et al.* (1983) noted that the American Water Works

Association Committee in 1979 recommended that to ensure drinking water disinfection, there should be a free chlorine residual of 1.0 mg of HOCl per liter for at least 30 minutes at pH of less than 8.0. This is assumed to reduce the enterovirus numbers by two orders of magnitude in less than five minutes.

In a review of the literature, Clausen, Green and Litsky (1977) reported that fecal streptococci appear more persistent than either fecal or total coliforms. The authors concluded that the studies that showed fecal coliform and fecal streptococci reduced with equal efficiency related to differences in chlorine residual and contact time. They cited a study that indicated that *S. faecalis* persist significantly longer than either fecal coliforms or *Enterobacter aerogenes* in stormwater, but that *S. bovis* and *S. equinus* died off rapidly. Miescier and Cabelli (1982) sampled nine wastewater treatment plants to examine the concentrations of total coliforms, fecal coliforms, *E. coli*, enterococci, *A. hydrophila*, and *P. aeruginosa*. The authors found the standard deviations from 16 samples of influent to be 0.25 for enterococci, 0.41 for *E. coli*, and 0.44 for fecal coliform. The authors also found that fecal coliform and *E. coli* had 4.763 and 4.726 mean $\log_{10}$ reductions after chlorination while enterococci was “markedly less”, about 3.573. The two pathogens examined, *P. aeruginos*a and *A. hydrophila,* were reduced by less than one order of magnitude by chlorination, though in most instances this brought levels down to below the detection limit. The authors concurred with the generally held view that enterococci may better simulate the viral pathogens with regard to chlorine sensitivity.

While few studies were examined on the effectiveness of nonchlorine disinfection methods on enteric viruses and bacterial indicators, the work by Chang (1985) may provide some important insights. Simian rotavirus and poliovirus were found to be three to four times more resistant to ultraviolet (UV) radiation than were the vegetative bacteria studied. Bacterial spores and protozoan cysts tested were nine and fifteen times more resistant respectively to vegetative bacteria. The authors suggest it is more difficult to inactivate *E. coli*, bacterial spores, and protozoan cysts using chlorine disinfection than using UV disinfection, and with some exceptions this relationship may be true for enteric viruses. Neither *E. coli* nor total coliforms was considered effective as a quantitative model for disinfection of viruses, spores, or cysts. Chang et al., found that *S. faecalis* required about a 1.4 times higher dose of ultraviolet light to result in a three log inactivation in comparison to most vegetative bacteria (*E. coli, S. aureus, S. sonnei, and S. typhi*).

Oppenheimer et al., (1997) found ultraviolet light capable of meeting reclamation standards of less than 2.2/100ml MPN total coliforms for a seven-day period in secondary treated wastewater (mean turbidity was reported as 0.6 NTU and TSS typically below 4.0 mg/L). An ultraviolet dose of 120 mW s/cm^2 inactivated total coliform, fecal coliform, fecal streptococci, enterococci, and viruses below detection limits; however, as much as one or two logs of heterotrophic plate count (HPC) could be present at this disinfection dose. A four log reduction in HPC was accomplished with a mean dose of 91 mW s/cm^2. A four log reduction in total coliform, fecal coliform, and enterococci occurred with median values in the range of 57 to 75 with total coliform requiring the highest dose. It required a dose of 68 mW s/cm^2 to cause a four log reduction in seeded poliovirus. In comparing chlorination performance estimates in inactivating each target organism below the method detection limit, the authors cited <43 mg/min/L for total coliform; <30 mg/min/L for fecal coliform; <5 mg/min/L for fecal streptococci and enterococci; and >160 mg min/L for HPC. A four log reduction in seeded poliovirus with chlorine required 63 mg min/L. This article, as well as the work previously cited by Grabow et al. (1983), provides evidence that enterococci is not always more resistant to disinfection than fecal coliforms. Joan Oppenheimer, the primary author, was contacted to validate the determination. Ms. Oppenheimer suggested the information should be used with caution as it was based on only one analysis using wastewater from one facility with its unique complex of micro-organisms. She suggested facilities that need to meet a performance standard on a consistent basis may find that changing wastewater characteristics are what create the difficulty or perhaps variability in the inactivation of enterococci.

Kashimada et al. (1996) found the photoreactivation rate in raw sewage by near-UV light or visible light to be higher for fecal coliform and heterotrophic bacteria than for either *E. coli B* or *E. coli K12 A/t(F+).* It was noted that photoreactivation of *E. coli* has been shown in other studies at bandwidths not tested in their study. Further, it was shown that for fecal coliform, reactivation ceased in about 15 minutes and then sunlight acted as a disinfectant and began to deactivate bacteria.

In a report released by the U.S. Environmental Protection Agency (1977), ozone was considered superior to chlorine for inactivating viruses. It was noted that 99% of seeded poliovirus was inactivated in clean water in less than ten seconds with a residual ozone concentration of 0.3 ppm. They compared this to 100 seconds required to inactivate poliovirus by chlorine under similar conditions, and noted that lowering the temperature did not appear to reduce the rate of disinfection using ozone. The authors suggested that ozone rapidly and effectively inactivated viruses in wastewater effluent, with ozone bubbling causing a 99.999% reduction in two minutes at an ozone residual of about 0.6 ppm. *E. coli* was inactivated at concentrations as low as 0.04 ppm O_3.

As demonstrated above, a number of studies have been conducted to assess how effective chlorination, ultraviolet light, and ozonation are in inactivating viral pathogens as well as common bacterial indicators. From these studies, we can conclude that while there are several viruses which are very resistant to disinfection, overall, these various forms of disinfection are very effective in reducing the concentration of viruses in wastewater as long as the dose and contact time are carefully controlled. We can also conclude that enterococci is more often, though not always, a better mimic for the survival capability of the more resistant viral pathogens than is fecal coliform or *E. coli* in wastewater.

Appendix J: Examples of Ambient Data on Bacteria Indicators

Exhibit A: Statewide Monitoring of Fecal Coliform and Enterococci

From October 2000 to September 2001, the Department of Ecology collected water samples at 85 freshwater ambient monitoring stations. These stations are on rivers throughout the state. Ecology took samples monthly and analyzed them for fecal coliform and enterococci. The results were compared against the current fecal coliform criteria and EPA's proposed criteria for enterococci. A river was about four times more likely to violate the proposed enterococci criteria than the current fecal coliform criteria.

Compliance Rates for Fecal Coliform and Enterococci

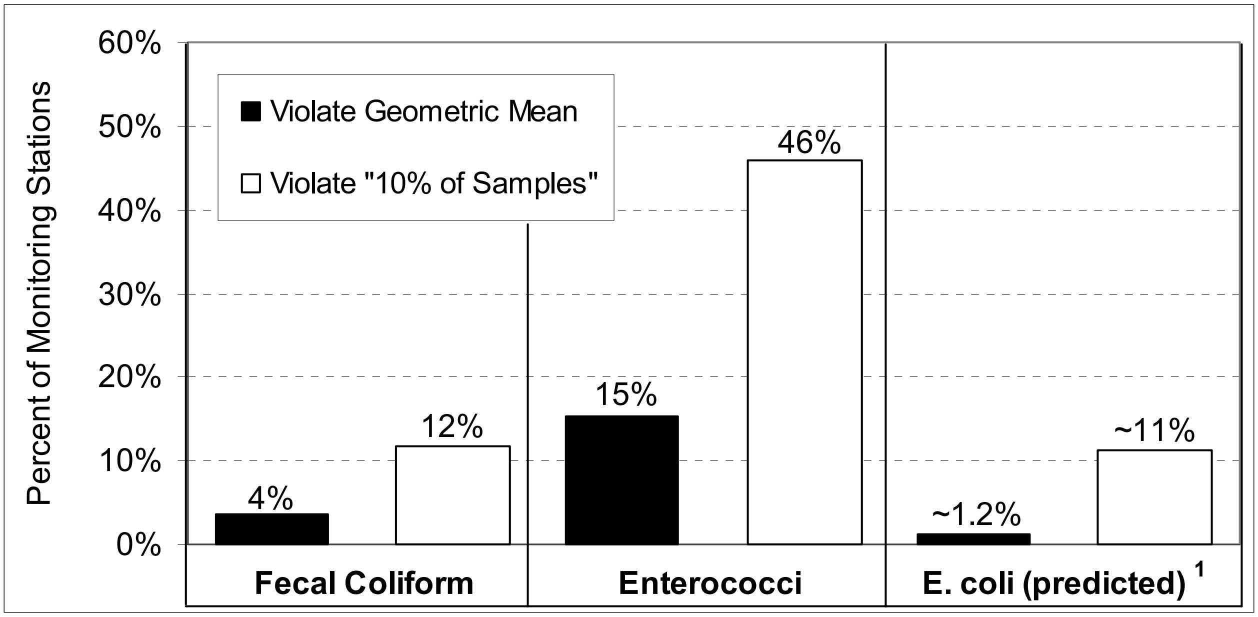
	Fecal Coliform		**Enterococci**	
	Geometric Mean Criterion	10% of Samples Criterion	Geometric Mean Criterion	10% of Samples Criterion
Total number of stations in violation (out of 85)	3	10	13	39

What about *E. coli*?

E. coli is a subset of fecal coliform. In theory, the concentration of *E. coli* should always be less than the concentration of fecal coliform. Studies conducted by the Department of Ecology during the last few years and Metro King County's beach monitoring from 1998-2000 show that, on average, 90-100% of fecal coliform is *E. coli*.

Compliance Rates for Each Bacterial Indicator

Using the monitoring data for enterococci and fecal coliform, and the knowledge that 90-100% of fecal coliform is *E. coli*, compliance rates can be calculated. EPA's recommended criteria for *E. coli* were used to determine compliance.



[1] The predicted levels of compliance for *E. coli* assumes that 90-100% of fecal coliform is *E. coli*.

Compliance by Classification

The 85 monitoring stations are on Class AA, A, and B rivers. The following table is a comparison of compliance by classification. Enterococci criteria were violated more frequently in all three classes. *E. coli* and fecal coliform compliance rates were similar in all three classes.

	AA (15 Sites)			**A (65 Sites)**			**B (5 Sites)**		
	Fecal Coliform	Entero cocci	*E. coli*	Fecal Coliform	Entero cocci	*E. coli*	Fecal Coliform	Entero cocci	*E. coli*
Number of stations violating the 10% of samples criterion	0	2	0	10	33	8	0	4	1

Seasonal Variation

The following table shows the fecal coliform and enterococci variation by season. The highest concentrations of fecal coliform and enterococci occurred during the summer. Fecal coliform concentrations dropped off dramatically during winter while enterococci concentrations stayed more constant.

Arithmetic Average for Each Season				
	Spring	Summer	Fall	Winter
Fecal Coliform	55	206	43	16
Enterococci	65	88	44	77

Data complied by Andrew Kolosseus, Washington State Department of Ecology, 2001.

Exhibit B: Relationship between fecal coliform and *E. coli* in the Nooksak River in 1997. Data supplied by Joe Joy, Department of Ecology.

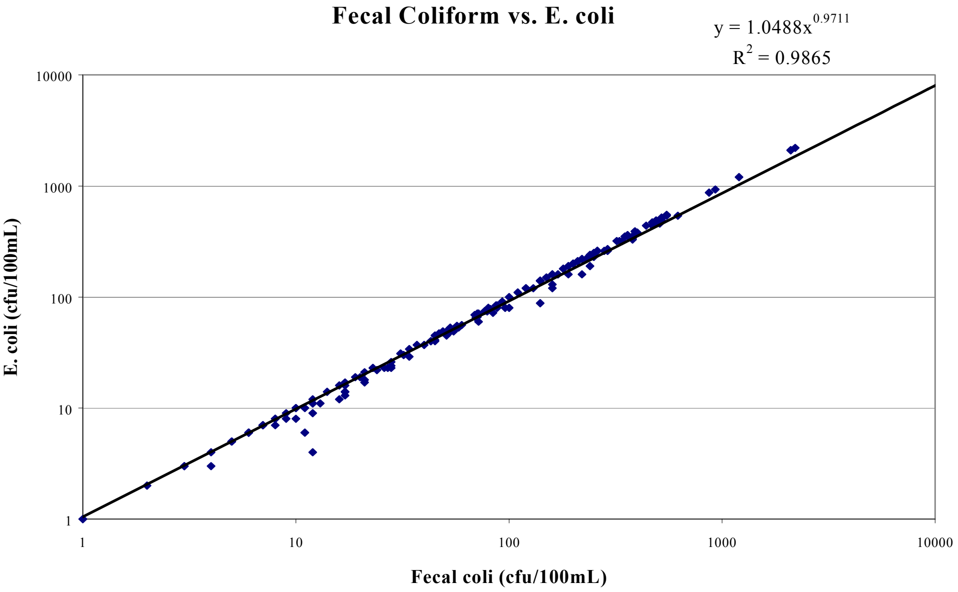
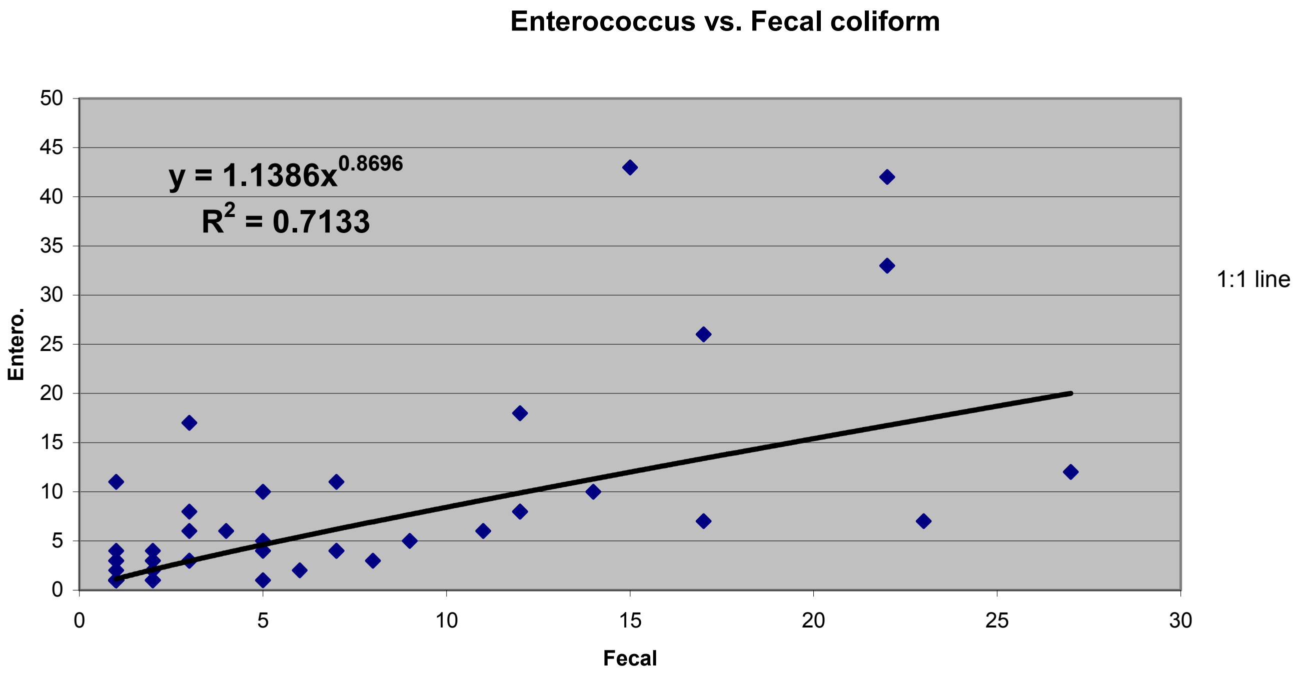


Exhibit C: Relationship between enterococci and fecal coliform concentrations in marine waters in Washington State over the water year 2001 using Ecology ambient monitoring data.



Based on ambient monitoring data supplied and summarized by Jan Newton, Washington State Department of Ecology, 2001.

Using the relationship shown above, a fecal coliform concentration of 14/100 ml (the current absolute value for shellfish harvesting protection) would be equivalent to an enterococci concentration of 11.3/100 ml. A fecal coliform concentration of 50/100 ml (the current Class AA criterion) would be equivalent to an enterococci concentration of 34.2/100 ml. Knowledge of these general relationships is useful for understanding the relative change in protection that is associated with the proposed changes to the states marine water quality criteria.

Exhibit D: Relationship between fecal coliform and enterococci in marine waters. Data supplied by Greg Ma (Metro/King County Environmental Lab) and Stuart Whitford (Bremerton - Kitsap County Health Department).

By combining data supplied from two sources, 1189 records were created where there was duplicate sample results for both fecal coliform and enterococci from the marine waters of Puget Sound.

Of the 1189 paired samples comparing fecal coliform to enterococci:

- 81% had enterococci levels <36/100ml
- 89% had enterococci levels <104/100ml
- 91% had enterococci levels <158/100ml

- 64% had fecal coliform levels <15/100ml
- 78% had fecal coliform levels <44/100ml
- 80% had fecal coliform levels <50/100ml
- 86% had fecal coliform levels <100/100ml
- 91% had fecal coliform levels <200/100ml

Of the 64% of paired samples with fecal coliform values <15/100ml (the shellfish protection criteria) 99% had enterococci levels <36/100ml. However, of the 81% of paired samples with enterococci values <36/100ml (the recreational criteria) 78% had fecal coliform values less than 15/100ml. Thus being in compliance with the fecal coliform shellfish criteria generally means that the water is in compliance with the recreationally-based enterococci criteria. However, the reverse is not as true; being in compliance with the recreationally-based enterococci criteria may still result in shellfish waters being out of compliance a significant amount of the time. Thus the fecal coliform criterion of 14/100ml may better protect swimmers than the 35/100ml enterococci criterion in Washington's Puget Sound.

What can also be ascertained from this data base is that the level of compliance with the existing Class AA standards for fecal coliform (50/100ml) is almost identical to that which would occur under the USEPA recommended enterococci criterion (35/100ml).

Further, a greater frequency of compliance occurs with the recommended single sample values for both enterococci and fecal coliform then occurs with the geometric mean-based standards. The 75th percent and 82% confidence level-based values for enterococci were out of compliance for 11 and 9% of the samples, respectively, considered as independent site samples (the standards would technically require examining sites individually which would likely reduce the number of sites in violation to below 10% for either confidence level-based criteria).