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Ministry of Environment

Lower Mainland Region

Assessment of Bacteriological Indicators in False Creek

With Recommendations for Bacteriological Water Quality Objectives for Recreational Uses

FINAL REPORT

August 2006

ENVIRONMENTAL QUALITY

Assessment of Bacteriological Indicators in False Creek

With Recommendations for Bacteriological Water Quality Objectives for Recreational Uses

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EXECUTIVE SUMMARY

Designated water uses for False Creek were identified in the 1990 Burrard Inlet Water Quality Objectives report. At that time, it was decided that the appropriate water uses to be protected throughout the inlet included aquatic life and wildlife, as well as primary-contact recreation at the bathing beaches, the nearest one to False Creek being Sunset Beach. In 2000, the Friends of False Creek (FoFC) requested that the Ministry of Environment (MoE) (then the Ministry of Environment, Lands and Parks) revisit False Creek's water uses, and that primary- and/or secondary-contact recreation be considered as protected water uses. The MoE deemed this reassessment was justified due to both the observed increase in kayaking, canoeing and dragon boat racing within False Creek, as well as the ongoing South East False Creek developments, which are likely to continue to support these increasing recreational uses. The water quality review was composed of four parts: determining existing water uses of the inlet; collecting and analyzing False Creek water quality data; and comparing this data to existing water quality guidelines. Recommendations were then made based on these analyses.

Water Usage

In order to determine the current recreational water uses of False Creek, a survey was distributed to members of the FoFC recreational users' database, as well as at two live-aboard marinas, the False Creek Community Centre, and a number of businesses throughout False Creek. Eighty-four people responded to the survey, with the activities they reported falling within two major categories. One category included activities not involving water contact such as jogging, cycling and walking around the False Creek walkways. The other category included non-motorized vessel use such as dragon boating, rowing, and kayaking. A few respondents also reported occasionally seeing swimmers in the inlet. Based on existing definitions of primary- and secondary-contact recreation, the majority of activities reported would be defined as secondary-contact. Respondents reported little variability in seasonal usage of the inlet, and tended to recreate regardless of the weather.

Water Quality Data

There were two main sources of water quality data assessed in order to determine trends in bacteriological contaminants in False Creek. Data from the Greater Vancouver Regional District's weekly fecal coliform sampling at shoreline sites, which began in 1985, was one source. As well, data from a coordinated sampling program including the Friends of False Creek and the Ministry of Environment were also used. The Friends of False Creek, in conjunction with MoE, sampled a number of mid-channel sampling sites in 2001. Weekly sample collections at the mid-channel sites were coordinated with the GVRD's shoreline sampling program. For the duration of this coordinated sampling program, both fecal coliform and enterococci analyses were conducted on each sample. Enterococci analyses were added as enterococci are the preferred indicator of fecal contamination in marine waters as they are more long-lived than fecal coliforms, and are a better viral indicator (most marine diseases being of viral origin). For these reasons, enterococci are better correlated with gastrointestinal symptoms in marine users than are fecal coliforms.

Potential relationships between the bacteriological indicator data and a number of factors were analyzed. These included spatial, temporal and seasonal trends, rainfall amounts, combined-sewer outfall (CSO) releases, and salinity. It was found that bacterial concentrations almost invariably increased in a west to east direction, with the highest concentrations typically being found near the Plaza of Nations and Science World.

Bacterial concentrations over the period of record considered in this report (1990 – 2002) tended to increase between the early and mid 1990's, and then gradually decreased. As part of a second temporal analysis, data were divided into summer (April to September) and winter (October to March) months, representing the recreation and non-recreation seasons as defined in the 1990 objectives document. While more westerly sites showed significantly higher concentrations of coliforms during the winter season, there was no statistically significant difference between seasons at the easterly sites. When data from each month was considered separately for each sampling location, bacteriological concentrations tended to be lowest in the early spring, increased gradually over the summer, and peaked in the fall and winter months.

Precipitation, salinity and CSO releases were not correlated well enough with bacteriological concentrations to be used as predictors of elevated bacteria levels. A strong correlation was found between precipitation events and CSO discharges, and therefore rain events could be used to predict elevated coliform concentrations associated with these discharges. There were, however, also periods during which elevated coliform levels occurred that did not appear to be directly related to environmental conditions.

Guidelines

Water quality guidelines for bacteriological indicators from a number of different agencies, including B.C. MoE, the Canadian Council of Ministers of the Environment (CCME), Health and Welfare Canada, the US Environmental Protection Agency (EPA) and the World Health Organization (WHO), were compared to determine how they were derived and what their recommended guidelines were for recreational water uses. The review found that all jurisdictions recommended the same indicator (enterococci for marine recreational waters) and, that the method used to derive their numeric guidelines was similar for most of the jurisdictions.

The B.C. MoE, CCME, Health and Welfare and the EPA all used the same regression formula to derive their guidelines. The guidelines differed only in the level of risk of gastrointestinal disease that was deemed acceptable. These agencies also use the same methods to determine attainment with the guidelines, namely the geometric mean of not less then five samples collected within a 30-day period. MoE uses a risk level of 1.6% illness (16 users in 1000 experiencing illness), while CCME (1999), Health and Welfare (1992) and the EPA (1986) use a risk level of 1.9%. These risk levels result in primary-contact guidelines of 20 enterococci/100mL (geometric mean) for MoE and 35 enterococci/100 mL (geometric mean) for the CCME, Health and Welfare and the 1986 EPA guidelines. The EPA has recently reviewed their 1986 guidelines and the resulting 2002 guidance document now recommends that acceptable illness rates for marine water be lowered to be between 0.8-1.4 percent. This recommendation results in primary contact guidelines of between 8 - 14 enterococci/100 mL (geometric mean).

For primary contact recreation waters, the EPA, CCME, Health and Welfare and B.C. MoE have also established maximum concentrations allowed in any single sample. These values ranged between 63-195 enterococci/100 mL for EPA's 2002 guidelines, 70 enterococci/100 mL for CCME and Health and Welfare, 284/100 mL for B.C. MoE and 501/100 mL for the 1986 EPA guideline.

Agencies which recognize secondary contact guidelines (MoE and EPA) suggest using a conversion factor of five (five times the primary objective) to derive the secondary-contact guideline. This results in guidelines of 100 enterococci/100 mL (MoE), and 175 enterococci/100 mL (1986 EPA guideline). The more recent EPA guidance document results in secondary-contact guidelines of between 40 - 70 enterococci/100 mL.

The WHO approach differs from the other jurisdictions as it uses a classification matrix to determine relative levels of water quality acceptability. The classifications are based on the 95th percentile of enterococci concentrations and the results of a sanitary inspection. WHO considers only primary-contact recreation, in the form of bathing beaches. In this way, individual bathing beaches are assigned a category ranging from very poor to very good, each of which require specific recommendations to users as well as a specific sampling regime.

Attainment

Attainment of the data with the MoE secondary-contact guideline (geometric mean of 100 enterococci/100 mL) ranged from 53% at a few sites in the eastern basin to 100% at the majority of the more western sites. Attainment with the 1986 EPA secondary-contact guideline (geometric mean of 175 enterococci/100 mL) ranged from 73% for one of the mid-channel sites in the east to 100% at the majority of the other sites. Attainment with the 2002 EPA guideline (at 1.4% acceptable risk of illness) ranged 28% for one of the shoreline sites in the eastern basin (21C) to 100% at seven of the other sites. The WHO ranking for the various False Creek sites ranged from poor to very poor.

Recommendations-

Objectives

Based on the results of the recreational survey and an analysis of the existing water quality data, a recommendation was made to include secondary-contact recreation as a protected water use in False Creek, and to adopt a guideline of a geometric mean of less than 100 enterococci/100 mL for at least five samples collected within a 30-day period. The single-sample maximum based on this guideline would be 1420 enterococci/100 mL. The ministry approval of these recommendations will be deferred until the new Canadian Recreational Water Quality Guidelines are released. These are expected in 2007. It is anticipated that these new guidelines will establish enterococci as the recommended indicator in marine waters and that guidance regarding secondary contact activities and guidelines will also be established. The Ministry will attempt to be consistent with the national approach with respect to the guideline values as well as the guideline parameter.

If, in the future, it is determined that primary-contact recreation is a desirable use for False Creek, and if infrastructure is developed to accommodate these activities, a long-term objective should be established for primary-contact recreation.

Investigations

Under the GVRD's Liquid Waste Management Plan, the ministry has also required the GVRD to post signs at combined sewer overflow outfall locations in order to warn the public of their presence. This notification to the public of the direct discharges into recreational waters allows the public to make informed personal choices about using the area for recreational activities according to potential risk. These signs are to be posted at CSO outfall locations in False Creek by the summer of 2006.

Consistent with the approach of providing information to allow the public to make informed personal choices, an environmental health assessment/sanitary survey as outlined in the Canadian Water Quality and WHO guidelines, as discussed by the Canadian Health and Welfare and WHO guidance documents, should be conducted in False Creek. A part of this effort should include an investigation to determine alternate sources of bacteriological contamination of False Creek, and to reduce these if viable. More research and investigations would also be useful for understanding a number of other pertinent factors affecting False Creek water quality. Some of these include the timing of the release of any identified alternate bacteriological sources; the conditions affecting circulation and mixing within False Creek; and the survival times of bacteria within the inlet. This information would provide a better understanding of the sources of the contaminants and how best to minimize their impacts on recreational uses. The information gathered could be used to guide management actions.

As many of the side effects that people recreating in False Creek reported in the survey were skin rashes and irritations, and since enterococci is not well correlated with these, a specific investigation into the occurrence and sources of *Pseudomonas* (which is better correlated with skin irritations) may also be useful. It is recommended that *Pseudomonas aeruginosa* concentrations be monitored throughout the inlet over a two-year period. If at that time it appears that *Pseudomonas* concentrations are high enough to cause concern, and the concentrations are mainly anthropogenic in origin, an objective for *Pseudomonas* may be proposed.

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ACKNOWLEDGEMENTS

This report would not have been possible without the contributions of numerous individuals. Volunteer sampling of the mid-channel sites was conducted by Kevin and Doug of Feathercraft Folding Kayaks for the duration of the 2002 monitoring program. Fred Mah of the Friends of False Creek collected the samples from the volunteers and delivered them to the laboratories for analysis. Funding for sample analysis was provided in part by the Georgia Basin Ecosystem Initiative (GBEI). A number of members of the GVRD Liquid Waste Management Plan Environmental Monitoring Committee contributed comments on the draft report, including Andrew Lewis of the Greater Vancouver Regional District, Peter Judd and Steve McTaggart of the City of Vancouver, Dominic Losito and Alfred Guthrie of the Vancouver Coastal Health Authority, Fred Mah of the Friends of False Creek, and Les Swain of MoE, Victoria. Brent Moore and Jennifer McGuire of MoE, Surrey also contributed valuable input to the report development.

1.0 INTRODUCTION

1.1 BACKGROUND

In 1990, a water quality objectives (WQOs) report for Burrard Inlet was published by the then Ministry of Environment, Lands and Parks (MELP) (now the Ministry of Environment, MoE). The Medical Health Officer of the time recommended against primary-contact recreation as a designated water use in the False Creek area, except at bathing beaches located at its mouth (Nijman and Swain, 1990b). Based on this recommendation, the Ministry determined that the designated water uses to be protected in False Creek were for the protection of aquatic life and wildlife, as well as primary contact recreation at the beaches at the mouth of False Creek during the summer recreation season (May – September).

A letter from the Friends of False Creek (FoFC) to the MoE in September 2000, requested that the 1990 Burrard Inlet water quality objectives specific to False Creek be reviewed. The Minister of Environment, Lands and Parks supported this request. A Memorandum of Agreement (MoA) between the FoFC, the Clean Water division of Environment Canada's Georgia Basin Ecosystem Initiative (GBEI) and the Ministry was developed with one of the goals being to gather data on False Creek water quality. A subsequent coordinated water quality monitoring agreement included the Greater Vancouver Regional District (GVRD), the City of Vancouver, and the Vancouver-Richmond Health Authority (now the Vancouver Coastal Health Authority) as partners.

In this report water quality data collected as a result of these recent water quality initiatives, as well as data collected by the GVRD since 1990 are assessed, and current and foreseeable recreational uses of False Creek are examined. Short-term and long-term water quality objectives for recreation in this area are then proposed.

1.2 THE AREA

False Creek is the largest natural harbour in the Vancouver area outside of Vancouver Harbour itself (Figure 1, Figure 2). The inlet is approximately 3 km long and varies between 100 and 400 m in width. This area has historically been used for industrial activities, with sawmills, foundries, shipbuilding, metalworking, warehousing and the City's public works yard operating around the inlet at various times since the late 1800's. Discharges and runoff from these and other industries have resulted in elevated concentrations of cadmium, mercury and lead in False Creek inlet sediments, as well as levels of total copper, iron, lead, mercury, nickel and zinc in the water column that exceed aquatic life guidelines (Nijman and Swain 1990b).

Current discharges to False Creek inlet include two industrial discharges, five combined sewer overflows, ten stormwater discharges and discharges from boats utilizing the inlet (including commercial craft, tour boats and live-aboards not connected to marina septic systems). It is primarily the latter three discharges that contribute to the bacteriological contamination of the inlet and have the greatest potential impact on recreational uses. In addition, warm-blooded wildlife, including waterfowl and domestic animals, especially dogs, may be significantly contributing to the bacteriological contamination of the inlet.

The effect of these discharges is exacerbated by the low flushing rate of the False Creek inlet. The inlet's relatively large size and long, narrow shape, coupled with the relatively low inflow of fresh water, results in very little water circulation or mixing with outside waters. In addition, while the majority of the basin has a mean depth of approximately 5 metres, there is a sill under the Cambie Street Bridge which reduces the mean depth to about 3 metres at this location. This reduces the circulation between the east and west basins of False Creek (Nijman and Swain, 1990b).

1.3 RATIONALE FOR REVIEWING WATER QUALITY OBJECTIVES

Recreational use of False Creek has increased significantly since 1990 and, with further development of the shoreline, pressure to expand this use will likely continue to increase in the years to come. At the same time, water quality in the inlet is generally believed to have improved since 1990 due to a number of initiatives undertaken by the City of Vancouver to reduce discharges to False Creek. Consequently, a review of the 1990 Burrard Inlet water quality objectives for possible future inclusion of recreation as a designated water use in the False Creek area was deemed to be justified.

Water quality objectives have been established for a number of different parameters in False Creek, including suspended solids and turbidity, ammonia, a number of metals in both sediments and the water column, polychlorinated biphenyls (PCBs) in fish and sediments, and polycyclic aromatic hydrocarbons (PAHs) in sediments. Any impact on human health from most of these contaminants requires the ingestion of a significant amount of water, or the consumption of resident bottomfish, on an on-going basis. As recreational users are usually only exposed to the water column and possibly sediments for relatively short periods of time, and bottomfish consumption is limited, this water quality objective review focuses on the microbiological objectives. Microbiological contamination is often the most likely impact to recreational users from water pollution since the ingestion of even small amounts of such contaminated water can cause serious illness.

Fecal coliform bacteria, *E. coli*, and enterococci concentrations are used to determine the likelihood of becoming ill from exposure to contaminated waters. Fecal coliforms originate in the intestines of warm-blooded mammals and thus their presence indicates the presence of fecal-derived material. Untreated, improperly treated or incompletely treated and disinfected sewage containing human fecal wastes is the primary source of infectious water-borne diseases (Warrington, 1988). While fecal coliform bacteria are generally not pathogenic in themselves, they are indicators of the potential presence of other pathogens. Various pathogens, including bacteria, viruses, fungi, protozoa, roundworms and tapeworms can result in diseases or infections of eyes, ears, nose, throat, skin, gastrointestinal tract and vagina. Monitoring waters for all of these types of pathogens would be prohibitively expensive and almost impossible to coordinate. Microbiological indicators are therefore used as surrogates for these pathogens.

Although fecal coliforms are not pathogenic, *E. coli* and enterococci are both pathogenic (especially some strains of *E. coli*). Both are good indicators of the risk of gastroenteritis to swimmers in fresh water. In marine waters, however, enterococci are the better indicators of this risk (Warrington, 1988). This is due to the much shorter survival time of *E. coli* than of other pathogens associated with fecal contamination. Enterococci, like other pathogens, survive much longer than *E. coli* and are thus the recommended indicator of microbiological contamination in marine water (Warrington, 1988). In addition, most marine diseases are of viral origin, and enterococci are much better viral indicators than *E. coli* (Warrington, 1988).

1.3.1 Increased Recreational Use

Since the Burrard Inlet WQO report was published in 1990, recreational use of False Creek has increased significantly, and includes activities such as kayaking, rowing, and dragon boating. Dragon boat racing began in False Creek in 1986 with 28 teams, each team consisting of 22 paddlers and four spares. By 2002, this number had increased to 186 teams representing over 4,800 individuals (Mah, pers com. 2003). Teams typically begin their training seasons in late February and continue to practice and/or race until late October. Each team generally practices once per week during the beginning of the season, increasing to as much as three times per week or more during May and June (Chu, pers. com. 2003). As dragon boat practices generally last one to two hours, a conservative estimate of annual hours that dragon boaters spend on False Creek would be 150,000 person hours.

Ecomarine Ocean Kayak Centre is a kayaking company that operates an instructional school and offers kayak rentals from their offices on Granville Island. They have a fleet of approximately 65 kayaks on Granville Island, and another 50-60 kayaks at their Jericho Beach location. The company has been operating since 1983, and rents kayaks to approximately 2000 people per year from their facilities on Granville Island (Ladner, pers. comm. 2003). In addition to the kayak rentals, approximately 3500 people per year participate in their twice-daily tours from both Granville Island and Jericho Beach. The primary season for kayak rentals is between June and September, and evenings and weekends are the busiest times during this period. Ecomarine also operates a kayak club program from their facilities on Granville Island every Thursday evening, in which about a dozen people participate regularly.

The False Creek Community Centre offers a number of kayaking and canoeing programs that utilize False Creek. Approximately 140 to 150 people take part each year in the 'Introduction to Kayaking' program, while another 40 to 50 people participate in canoeing lessons (Peterson, pers. comm. 2003). Approximately 90% of the people participating in the kayaking lessons also join the kayak users group, which allows them to utilize community centre kayaks on False Creek. There is also a seniors' dragon-boating course that teaches approximately 17 people per year. Another six people partake in the seniors' kayak and canoe course. While water contact in all of these programs is limited (rolls and recoveries are taught in a swimming pool), it is greater than in other programs. The Waterworld Explorers course, which teaches a number of activities including kayaking and canoeing each summer to 160 children between the ages of 10 and 13, tends to result in considerably more water contact (Peterson, pers. comm. 2003).

Full-contact activities such as swimming are not common in False Creek except at the mouth of the inlet (at Sunset Beach). Swimmers are, however, occasionally seen utilizing other areas of the inlet.

1.3.2 Future Development in False Creek

South East False Creek (SEFC) is the last remaining tract of undeveloped waterfront land near downtown Vancouver. Historically this area was heavily used for industrial and commercial purposes. The City of Vancouver redevelopment plans for SEFC include the use of the site as the 2010 Olympic Athlete's Village, followed by the area becoming a mixed-use community to include a significant amount of family housing (Southeast False Creek Policy Statement, 1999). The 2010 Olympic Athlete's Village in SEFC will bring people from all over the world in close proximity to the False Creek inlet. With this large influx of people for both 2010 and afterwards, recreational use of the inlet is likely to increase significantly, and there will be a huge increase in ferry traffic and the number of people walking around the inlet. As False Creek is one of the focal points of the 2010 Olympics in Vancouver, it is likely to have a large impact on peoples' perception of Vancouver all over the world.

The City of Vancouver's vision for the SEFC community that will exist after the Olympics places a large focus on the False Creek inlet. Section twelve of the SEFC policy statement addresses the water basin and shoreline. Common themes of accessibility to the waterfront and the encouragement of non-motorized boating activities are found throughout the various policy categories in this section. More specifically, the following are the objectives and intent outlined in the SEFC Policy Statement (Section 12.3):

- To maintain the extent of the water basin.
- To enhance the recreational uses and ecological quality of the water's edge in SEFC.
- To ensure that the waterfront zone is designed to be accessible and well linked with surrounding areas.
- To ensure that any changes to the existing shoreline are beneficial to the aesthetic, recreational and ecological quality of False Creek.
- To enable the SEFC development to support the uses of non-motorized craft in False Creek.

These objectives are also incorporated in the further development stages that have been outlined, such as the Rezoning Phases Policies. These policies state that:

- the waterfront should be designed to be publicly accessible (Section 12.4(6)), and
- active, water-oriented recreational opportunities in SEFC should be encouraged through provision of a pier along the waterfront, as well as facilities, possibly associated with a community centre, to accommodate non-motorized craft, such as kayaks, dragon boats, native canoes and small sailboats (Section 12.4 (7)).

This later concept is captured in Section 12.4(3) of the Official Development Plan (ODP) phase policies which states that ‘Any marinas or boating facilities in SEFC should cater to non-motorized craft.’ The proposed community and boating centre that is to be open for the 2010 games is intended for dragon boating, rowing, canoeing and kayaking.

The theme of increasing the water-based recreation opportunities in False Creek continues in the Development and Design Directives of the policy statement. Section 12.4 (13) suggests exploring the possibility of creating a beach along or adjacent to the SEFC waterfront as a park amenity. In the ODP that was approved by City Council as a by-law in 2005, the Shoreline Concept figure shows a small beach east from the Granville Street Bridge (City of Vancouver 2006). Post-Development Initiatives further the idea of primary-contact activities occurring in False Creek by mentioning the idea of swimming in the inlet. These initiatives state that when the water in False Creek meets swimming standards, the possibility of having swimming rafts should be considered (Section 12.4 (14)).

The SEFC post-development initiatives also encourage the City to continue to pursue sewer separation work and to give the east end of False Creek a high priority for these initiatives.

Many of the initiatives in the SEFC Policy Statement, including the development of a pier along the waterfront, the creation of a beach and the introduction of swimming rafts, would encourage primary-contact recreational activities such as wading and swimming. There is already evidence that primary-contact recreation is occurring in False Creek without these organized facilities, with survey respondents observing occasional swimmers. In 1990, these activities were not recognized as protected water uses by the Ministry of Environment nor were they recommended to be occurring in False Creek by the Medical Health Officer.

1.3.3 Changes to Effluent Discharges

There are currently two permits issued by the Ministry of Environment that allow discharges to False Creek. One permit (PE 2300) allows Ocean Construction Supplies Ltd. (a concrete facility on Granville Island) to discharge stormwater as well as cooling water from their property. The second permit (PE 7164) allows the Plaza of Nations to discharge cooling water from their facility. Neither of these discharges are expected to contribute fecal material to False Creek.

As mentioned in Section 1.2, discharges currently contributing to bacteriological contamination of False Creek include combined sewer outfalls (CSOs), stormwater discharges, and discharges from pleasure craft and other vessels. The sewer system in Vancouver dates back over 100 years, and as recently as in the mid-1980's, raw sewage was discharged directly into parts of False Creek. These direct discharges have been eliminated with the exception of five CSOs which remain in the False Creek area (see Figure 3). During periods of high rain, stormwater runoff raises the levels of flow in the combined sewage system above the capacity of the pipes designed to carry flow to the treatment plant. This excess flow during storm events (a mixture of untreated sewage and stormwater) is then released directly into False Creek through the CSOs.

In the early 1970's, the City of Vancouver implemented a program to replace the combined sewer system with a separated one. This would reduce, and eventually eliminate, CSOs by replacing old sewers on a life-cycle basis. This process does not simply replace the CSO itself, but requires that sanitary and storm sewers, as well as connections to them through the entire drainage area, be modified. In 1995, the Drake Street combined overflow was eliminated by separating sewers and stormwater drains in the Yaletown drainage basin. In 1999, the Downtown South Granville drainage basin was separated, thus eliminating the Granville Street combined overflow. Prior to this, both the Drake Street CSO and the Granville Street CSO flowed into False Creek. Under the current GVRD Liquid Waste Management Plan, the City of Vancouver has targeted complete elimination of all False Creek CSOs by the year 2040, with four of the five existing CSOs to be eliminated by 2013. This will result in a 50% reduction in discharges by 2013, with only the Heather Street CSO remaining until 2040 (City of Vancouver, 2002).

There are also ten stormwater outfalls that discharge into False Creek. Urban stormwater discharges have a limited potential to contribute to bacteriological contamination as long as there are no sanitary sewer cross connections. As all flow contributions come directly from surface water runoff from roads and sidewalks, fecal material on the roads from pets, wildlife, and other animals may be carried into the stormwater system, and eventually discharged into False Creek. When the 1990 water quality objectives report was prepared, the volume of stormwater discharging into False Creek was minor in comparison with that released by combined sewer outfalls (Nijman and Swain, 1990a). This, however, has likely changed with the elimination and future elimination of CSO discharges. Stormwater contributions would thus account for a larger proportion of the overall discharges into the inlet.

1.3.4 Potential Discharges from Boats

There are a large number of pleasure craft that utilize False Creek. These craft can be classified under two main categories: boats anchored throughout False Creek proper (both short and long-term), and boats moored at marinas. The primary concern regarding fecal coliform contamination from these boats is the discharge of raw sewage, either from holding tanks (when these exist) or directly from toilet facilities on the boat (when no holding tank is present).

In 2003, there were approximately 55 pleasure craft moored throughout False Creek outside of marinas. These boats were concentrated primarily in and around the small bay to the east from Spruce Harbour Marina, between the Heather Civic Marina and the Cambie Street Bridge, and east from the Plaza of Nations. It is difficult to estimate the number of boats that are live-aboards; however, it is likely in the neighborhood of 10 boats. It is not known if any of the live-aboards have holding tanks for their sewage. As well, those that do have holding tanks are unlikely to travel to pump-out facilities each time the tanks are full. It is more likely that they discharge sewage directly into the inlet.

It is very difficult to determine the potential volume of sewage being contributed to False Creek from these boats due to incomplete information on the number of individuals living on boats, the length of time they spend on their boats, the volume of water available to users of the boat and the frequency with which they use the heads on their boats.

A walking survey of False Creek, coupled with searches of telephone directories and the internet, resulted in a list of 12 marinas operating in False Creek. The newest of these, Quayside Marina, opened in 2002. Both the False Creek Yacht Club and Concord Pacific (the developers of Quayside Marina) are considering the addition of a number of slips near the False Creek Yacht Club.

Table 1 shows a summary of the total number of boats moored at each marina, as well as the number of live-aboards. There are over 1,600 boats moored within False Creek, of which at least 82 are live-aboards. Those marinas that report live-aboards (Heather Civic Marina and Spruce Harbour Marina) both have individual hook-ups to the city sewer system for each boat. These craft are therefore not likely contributing any fecal contamination to False Creek. It is likely, however, that people occasionally overnight on their boats at all of the marinas, including those without hook-ups. Therefore, unless the boat has a holding tank, usage of the head during these stays could result in direct fecal depositions into False Creek.

Table 1. Marina facilities operating within False Creek (arranged clockwise around the harbour, from northwest to southwest).

	Slips owned by marina or individual	Total number of boats	Number of live-aboards	No. of trailered boats	No. of kayaks/ canoes	No. of rowing shells	Pump-out facilities?
Beach Avenue Marina Ltd.	Individual						
Yacht Harbour Marina							
False Creek Yacht Club		85					Yes
Quayside Marina	Individual	115	0				Yes
Plaza of Nations Marina	Marina	20					No
Heather Civic Marina	Marina	257	27				Yes
Spruce Harbour Marina	Marina	115	55				Yes
Pelican Bay Marina		33					
Granville Isl. Market and Marina		300					
False Creek Harbour Authority	Marina	250	0				No
Burrard Bridge Civic Marina	Marina	430	0	150	33	100	Yes
Heritage Harbour							
Totals		1605	82	150	33	100	5

In addition, 65% of the boats moored at the False Creek Harbour Authority (Fisherman's Wharf) are commercial fishing boats, which generally do not have holding tanks. Fisher's often stay on these boats, especially during the various commercial seasons. There are washrooms and shower facilities provided by the False Creek Harbour Authority, however, it is likely that the washroom facilities on these boats are occasionally used during these stays and therefore contribute to fecal contamination of False Creek.

There are also a number of evening cruises that take place in False Creek, primarily in the summer months, from the Plaza of Nations Marina. It is not known if these cruise boats have holding tanks, or if the tanks are emptied within False Creek.

Currently, the City of Vancouver can remove boats if they are considered to be unsafe (*e.g.*, a fire hazard, or dragging their anchor), if they are in the navigable portion of the inlet, or if they are causing an environmental impact (discharging sewage or litter, or causing excessive noise pollution). The City of Vancouver, in conjunction with the Coast Guard, has also attempted to develop regulations that would limit the time that a boat could be moored within False Creek. This would make the inlet more accessible to transient boaters and ensure that it is not being monopolized by a few individual boats. In August 1999, the City of Vancouver installed 12 mooring buoys in Charleson Bay for short-term moorage for transient boaters. Mooring was permitted for up to 72 hours, and a daily fee of $15 was charged. In August 2000, the number of buoys was reduced to five, and they were placed under the management of the City of Vancouver Parks Board staff. However, as some boat owners refused to pay the daily fee and did not respect the 72-hour maximum stay, the mooring buoys were eventually removed.

In 2005 the City of Vancouver subsequently applied to the federal government for a new Boating Restriction Regulation specific to False Creek. This regulation is to be administered and enforced in the spring of 2006. The new regulation requires boats anchoring in False Creek for more than 8 hours between 9 AM and 11 PM, or anytime between 11 PM and 9 AM the following day, to obtain a permit. Permits are free and allow boaters to anchor a maximum of 14 full or partial days of 30 days during high season (April 1 – September 30) and 21 days of 40 days in low season (October 1 – March 31). This regulation and permit system will provide a safer and less congested environment and allow more equitable access for all boaters who want to use the waterway (http://www.city.vancouver.bc.ca/engsvcs/streets/blueways/anchoring.htm). Boating discharges are not addressed in this regulation.

The Vancouver Coastal Health Authority has attempted to address concerns regarding the discharge of raw sewage from pleasure boats into False Creek. In 1998, the Director of Environmental Health for the Vancouver/Richmond Health Board submitted a request to have both False Creek and English Bay designated a "no sewage discharge area" under the Pleasure Craft Sewage Pollution Prevention Regulation of the *Canada Shipping Act* (CSA 2001, Bill C-14). During this process, a number of concerns were expressed by pleasure craft operators regarding the lack of pump-out facilities. If the area were to be designated a "no sewage discharge area" under the Pleasure Craft Sewage Pollution Prevention Regulation, then commercial craft would also be prohibited from releasing sewage in the area under the Non-Pleasure Craft Sewage Pollution Prevention

Regulation. Commercial operators were worried about the commercial impact of further designations and the lack of technology for suitable alternatives such as on-board treatment systems. As approximately 160 of the boats moored at the False Creek Harbour Authority belong to commercial fishers, and they make an important economic contribution to the area, this was a concern.

Although the applications for the re-designation of both False Creek and English Bay were denied, there have been plans to re-submit the applications, focusing first on only the False Creek area. False Creek would be the focus of the new effort due to the fact that it should be easier to designate as a no-sewage discharge area. This is because of the large concentration of pleasure craft, the poor tidal flushing, and the high concentration of recreational users in False Creek (City of Vancouver, 2002). This would hopefully result in the elimination of pleasure craft sewage discharges, both at marinas and at anchorages throughout the inlet in the future. This re-application may be unnecessary, however, due to the anticipated changes to the Canada Shipping Act (CSA 2001, Bill C-14), including a common set of Sewage Pollution Prevention Regulations for both pleasure and non-pleasure craft alike. The new Prevention of Pollution from Vessels Regulation may automatically designate coastal zones (including False Creek) as no sewage discharge areas. This new regulation being developed to support the new CSA, is to be updated in 2006 (http://www.tc.gc.ca/marinesafety/rsqa/CSA2001RegRefSite/menu.htm).

2.0 DISCUSSION OF CURRENT RECREATIONAL USE OF FALSE CREEK

As mentioned in Section 1.3.1, recreational use of False Creek has increased significantly in recent years, and is likely to increase further with the redevelopment of South East False Creek. In an attempt to quantify the recreational use of False Creek, input from users of the inlet was solicited. This information was used to enumerate the types and frequencies of recreational usage in False Creek. In February 2003, a brief survey was distributed by the FoFC to a number of individuals and locations (see Appendix 1 for survey questions and complete answers). Surveys were distributed to individuals on the False Creek Roundtable users database. This database was established for the distribution of information to people interested in recreation and water quality in the False Creek area and the possible formation of a roundtable to discuss these issues. Surveys were also left at the two live-aboard marinas in False Creek, the False Creek Community Centre, Ecomarine, and at the Fishboat Dock between the Granville and Burrard bridges. Finally, dragon boat clubs were also contacted.

2.1 SUMMARY OF FINDINGS FROM THE RECREATIONAL SURVEY

There were 84 responses to the False Creek Recreational Survey. From the respondents, it was found that there are two major user groups that frequent False Creek for recreation: those that walk, jog, bicycle, rollerblade, or bird-watch around the seawall and along the inlet, and those that paddle, row, sail, kayak or otherwise boat on the inlet. Three respondents reported that mooring their boats and/or living on their boats in the inlet year-round was their major use, while another reported frequently swimming at the beaches near the mouth of the inlet during the summer months. Six respondents reported seeing individuals swim in False Creek on occasion. Table 2 summarizes the number of respondents reporting their participation in each category of activity, as well as the season(s) when the activity occurred, and the frequency with which they participated in the activities.

Recreational activities are generally placed in one of three classifications: primary and secondary contact, as well as aesthetic use which includes activities which entail no contact. Primary-contact recreation consists mostly of swimming, diving and other activities where there is a high risk of water ingestion or extensive bodily contact with the water, such as white-water rafting, board and wind-surfing, and white-water kayaking. Secondary-contact recreation includes sailing, boating, fishing, and canoeing, as well as other activities where there is limited bodily contact with the water and a very low risk of ingesting an infectious dose of any pathogen (Warrington, 1988). Survey respondents reported that the most common activities on False Creek were dragon boating, rowing and kayaking. These activities would most likely fall into the category of secondary-contact, as complete body immersion would occur only on an accidental basis. Some ingestion of water might occur while participating in these activities, but as the exposure scenarios are different than would occur during complete immersion, extrapolations for illness rates cannot be made. Some activities, such as wind-surfing or jet-skiing, could be classified as either primary or secondary contact, based on the skill level of the participant. Beginners are generally more likely to be immersed and ingest water than experienced individuals. A third class of recreational use is termed aesthetic use, and does not entail any contact with the water. Examples of this type of recreation would include photography, painting and other activities which draw their inspiration from the water, as well as walking beside the water or simply viewing lakes, rivers or other vistas which include water. The vast majority of the activities discussed in Section 2.1 fall under the definition of either secondary-contact recreation or aesthetic use, with complete immersion only occurring accidentally. Activities involving secondary-contact with the waters of False Creek are summarized in Figure 4. The current accessibility and lack of deterrents do however also result in some people using False Creek for primary contact activities.

It should be noted that respondents to these surveys do not represent a statistical representation of the community at large – those that chose to participate did so because they are particularly interested in recreation in False Creek and/or have strong views about the perceived water quality of the inlet. Therefore, the actual proportions of respondents answering in a specific way do not have any statistical relationship to the percentage of the general public or stakeholders that may share that view.

2.1.1 Activities and Water Contact

As would be expected, those people that participate in land-based activities (walking, jogging etc.) reported no contact or very limited contact with the water. Paddlers, on the other hand, reported contact ranging from minimal to complete submersion. In total, twelve percent of respondents reported no water contact, 42% reported minimal contact, 41% reported some contact (head and face, as well as arms), and 5% reported complete submersion during their recreational activities. Therefore, from the responses received, 88% of people participating in recreational activities in the False Creek area experience water contact ranging from minimal to complete submersion (Figure 5). As such, 83% of participants would be classified as participating in secondary-contact activities, and 5% would be considered as participating in primary-contact activities. The remaining 12% would be classified as aesthetic users.

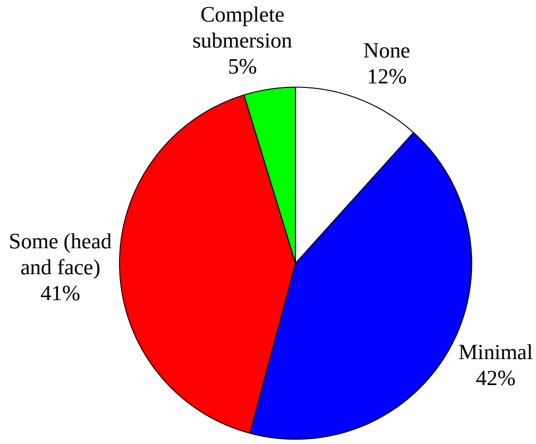

Figure 5. Extent of contact with water while recreating in or around False Creek reported by survey respondents.

2.1.2 Effects of Precipitation on Recreational Activities

Almost all respondents reported that rain did not affect their participation in recreational activities in False Creek. Eighty-five percent of the respondents stated that they recreate during the rain while 92% reported recreating immediately after rains. The two respondents that said they avoided the inlet during rains stated they would participate in their activities any time from immediately after the rainfall stopped, to 12 hours after the rainfall ceased. Of the different users, dragon boaters invariably stated that they paddled rain or shine, while those that avoided the inlet during rains were generally pedestrians. The fact that people recreate in the inlet regardless of weather conditions suggests one of four things: the thought of a safety concern does not enter the minds of the individuals who participate in these events; individuals do not perceive an increased threat of contamination or illness associated with rain events; their scheduled activities require that they ignore this potential threat; or they know what the risks are and are willing to accept them.

2.1.3 Seasonal Nature of Activities

The False Creek Racing Canoe Club (FCRCC) reported that it puts an average of 300 paddlers a day on False Creek during the summer months, and at least 50 people per day the remainder of the year. The majority of respondents that reported dragon boating as their main recreational activity reported that they paddled frequently (at least a few times a week) all year round. Therefore, for most people recreating on the water in False Creek, the time of year does not appear to influence their participation.

2.1.4 Perceived Health Effects

Benefits from undertaking recreational activities in False Creek were reported by 40% of respondents. All of these were related to increased fitness and personal well-being due to the exercise from recreating on the inlet. Approximately 60% of respondents that reported minimal to some contact with the water also reported negative health effects, usually rashes or itchy skin, but occasional gastro-enteritis problems as well. While individuals reporting negative health effects believed that water contact was responsible for their ailment, this has not been substantiated and there may be other factors responsible for the symptoms they experienced. In addition, allergic reactions rather than the presence of specific pathogens may have been responsible for some of the skin irritations reported. Regardless, a large number of paddlers reported that they avoided contact with water when possible, and showered or rinsed off as soon as possible after leaving the water.

Table 2. **Summary of recreational survey responses (activities and locations).**

Season/ Frequency*	Number of respondents* per activity type per location[+] per season			
Winter	**Rollerblading, running, walking, biking, bird-watching, tennis**	**Paddling, dragon boating, outrigger, sailing, rowing**	**Moor boats, live aboard**	**Swimming, diving**
Very often (daily)	5a, 2w	30a, 3ew, 1wm, 1e	3w	1a
Often (weekly)	1a, 1wm, 1ew, 2w, 1m	8a, 5ew, 1w		
Occasionally (Monthly)	3a, 1w	2a, 1ew, 2w, 1wm, 1m		
Seldom (a few times a year	2e, 1wm			
Spring				
Very often (daily)	5a, 2w	31a, 4ew, 1wm, 1e	3w	
Often (weekly)	1a, 2wm, 3w, 1ew, 1m	9a, 8ew, 1wm, 1w, 1e		
Occasionally (Monthly)	1wm, 4a	3a, 2w, 1e, 1wm, 1m		
Seldom (a few times a year				
Summer				
Very often (daily)	5a, 2w	31a, 4ew, 1wm, 1e	3w	1m
Often (weekly)	2a, 2wm, 3w, 1ew, 1e, 1m	10a, 8ew, 2e, 1wm, 1w		
Occasionally (Monthly)	3a, 1wm	2a, 2w, 1ew, 2wm, 1m		
Seldom (a few times a year				
Fall				
Very often (daily)	5a, 2w	31a, 3ew, 1wm, 1e	3w	
Often (weekly)	1a , 2wm, 3w, 1ew, 1m	8a, 8ew, 1wm, 1w, 1e		
Occasionally (Monthly)	4a, 1e	3a, 2w, 1e, 1wm, 1m		
Seldom (a few times a year	1wm			

Notes:

* Numbers represent the number of respondents participating in those activities in the different areas.
\+ Locations: e = East (Science World to Cambie Bridge), w = West (Cambie Bridge to Burrard Bridge), m = Mouth (Burrard Bridge to Sunset Beach), a = All areas.

2.1.5 Perceived Water Quality and Water Quality Trends

Ninety-five percent of respondents said that they felt that the water quality of False Creek was poor, while only 5% (two people), classified it as good. Sixty-nine percent of the respondents said that they believed that False Creek water quality was improving, while 31% said they felt that it was getting worse. The most common perception thus appears to be that the False Creek water quality is poor but improving. Those that reported improvements pointed to increased populations of sea birds, seals and fish, while those who stated that the water quality was poor and getting worse noted increasing garbage, oil slicks, raw sewage (as evidenced by floating feces, condoms and tampons) and algal growth as evidence. A number of respondents mentioned seeing “squatters” on illegally-moored boats dumping sewage directly into the inlet, or acting in a threatening or menacing manner.

3.0 ASSESSMENT OF FALSE CREEK BACTERIOLOGY

3.1 SUMMARY OF BACTERIOLOGICAL SAMPLING, 1990-2002

Table 3 summarizes the GVRD and FoFC sampling schedules and locations.

Table 3. Comparison of locations which have been sampled since 1985 as well as the corresponding site identifiers used by the GVRD and FoFC in sampling programs (site locations are shown on Figure 2).

1985-1992 GVRD	1993-1994 GVRD	1995-2002 GVRD	2001 FoFC/ MoE	2002 Coordinated (FoFC/GVRD)	Site references used in report	Site Descriptor
16	BFC-01-16	BFC-01-16		BFC-01-16	16	Burrard Bridge Civic Marina
17	BFC-01-17	BFC-01-17	17	BFC-01-17	17	Heather Civic Marina
18	BFC-01-18	BFC-01-18		BFC-01-18	18	NE Granville Island
22	BFC-01-22	BFC-01-22		BFC-01-22	22	False Creek Yacht Club
23	BFC-01-23	BFC-01-23		BFC-01-23	23	N. shore Granville St. Bridge
19	BFC-02-19	BFC-02-19	19	BFC-02-19	19	S. shore, E. of Cambie St Bridge
20	BFC-02-20	BFC-02-20	20	BFC-02-20	20	Near Science World
21	BFC-02-21	BFC-02-21	21			Near Plaza of Nations
		BFC-02-20A	20A	BFC-02-20A	20A	Near Science World
		BFC-02-20B	20B			Near Science World
		BFC-02-20C	20C			Near Science World
		BFC-02-21A	21A	BFC-02-21A	21A	Near Plaza of Nations
		BFC-02-21B	21B	BFC-02-21B	21B	Near Plaza of Nations
		BFC-02-21C	21C			Near Plaza of Nations
			F2		F02	Mouth of English Bay
			F3	BFC-04-F03	F03	Off Sunset Beach
			F4	BFC-04-F04	F04	Below Burrard St. Bridge
			F5	BFC-04-F05	F05	Between FCHA and Granville Isl.
			F6	BFC-04-F06	F06	Below Granville St. Bridge
			F7	BFC-04-F07	F07	N. of Spruce Harbour Marina
			F8	BFC-04-F08	F08	S. of Granville Isl. Comm. Centre
			F9	BFC-04-F09	F09	N. shore bay between Granville Bridge and Cambie Bridge
			F10	BFC-04-F10	F10	E. of Heather Civic Marina
			F11	BFC-04-F11	F11	Off Quayside Marina
			F12	BFC-04-F12	F12	NE of Heather Civic Marina
			F13	BFC-04-F13	F13	Below Cambie St. Bridge
			F14	BFC-04-F14	F14	E. of Cambie St. Bridge
			F15	BFC-04-F15	F15	Near Plaza of Nations
			F16	BFC-04-F16	F16	Near Plaza of Nations
			F17	BFC-04-F17	F17	Near Plaza of Nations
			F18	BFC-04-F18	F18	Near Science World

Between 1990 and 1994 eight shoreline sites were sampled once per week. Starting in 1995, fecal coliform samples were collected throughout False Creek by the GVRD approximately once a week at fourteen shoreline sites. Sampling frequencies were occasionally reduced during January and February to one sample every two weeks. All

GVRD fecal coliform samples were analyzed at the GVRD microbiological lab at the Lake City Operations Centre in Burnaby. Samples were kept on ice in a cooler and transported to the laboratory on the same day that they were collected.

In November 2001, the FoFC and the MoE initiated an independent sampling program during which 27 sites were sampled for both fecal coliforms and enterococci. The sites comprised a mix of shoreline (10 sites) and mid-channel locations (17 sites). Samples were collected by volunteers using kayaks. For shoreline sites, kayaks were positioned as close to shore as possible to simulate sample collection from shore and allow comparisons with shoreline sampling conducted by the GVRD. The FoFC collected fecal coliform samples between November 14, 2001 and March 14, 2002, and enterococci samples between January 24, 2002 and March 14, 2002 at the shoreline and mid-channel sites.

In May 2002, the FoFC, MoE, GVRD, City of Vancouver and VCHA designed and initiated a coordinated sampling program. The FoFC collected mid-channel samples and the GVRD collected shoreline samples weekly during this project. Both the FoFC and GVRD collected fecal coliform and enterococci samples following the Canadian Recreational Water Quality Guidelines standard methods for sample collection (Health and Welfare, 1992). Samples were collected on Wednesdays and shipped on ice to the respective laboratories where they were received no later than 13:00 hours on the same day. Samples were collected on Wednesdays for the entire period between May 29, 2002 and December 18, 2002.

Beginning in January 2003, the sampling program was reduced to 10 shoreline sites (Sites 16, 17, 18, 19, 20, 20A, 21, 22, 23, and 24) sampled by the GVRD for fecal coliforms.

The GVRD laboratory at the Lake City Operations Centre in Burnaby conducted the fecal coliform analyses, while enterococci samples were analyzed by CanTest Laboratories. Fecal coliform analyses were conducted using the multiple-tube fermentation technique to determine the most probable number (MPN). Enterococci samples were analyzed using the membrane filtration technique with a selective media (mE agar) and incubated for 48 hours at 41°C. The filters were then transferred onto EIA media for 20 minutes at 41°C.

3.2 Summary of Bacteriological Data

Recreational water quality objectives for microbiological indicators such as fecal coliforms and enterococci are expressed as the geometric mean of at least five samples collected at a site within a 30-day period (see Section 3.4). Geometric means, rather than a simple mean, are used to assess objectives, due to the high potential variability in bacteriological populations and the tendency for microbes to "clump" together on particles. By calculating a geometric mean, the effect of a single very high or very low value is minimized.

The geometric mean is calculated by multiplying together the bacteriological concentrations of all individual samples (n=number) collected in the past 30 days (minimum of five) and then taking the n^{th} root of this calculated value. This is expressed by the following equation:

$$GM_{\bar{y}} = \sqrt[n]{y_1 y_2 y_{3.} \ldots y_n}$$

The majority of the data discussed in this report are expressed as rolling geometric means. Rolling geometric means are calculated by applying this formula to values 1 through 5, values 2 through 6, etc., from a site as long as no more than 30 days separate the first and fifth value. If more than five values were available for a site in a 30-day period, then that number of values would be multiplied together and the number of values (for example, six) would be used as the root.

Another method used by some agencies such as the World Health Organization (WHO) is the 95% compliance level (*i.e.*, 95% of sample measurements collected must lie below a specific value to meet the standard). Both the geometric mean method and the 95^{th} percentile method have benefits and drawbacks. "*The geometric mean is statistically a* *more stable measure, but this is because the inherent variability in the distribution of the water quality data is not characterized in the geometric mean. However, it is this variability that produces the high values at the top end of the distribution that are of greatest public health concern. The 95% compliance system, on the other hand, does reflect much of the top-end variability in the distribution of water quality data and has the merit of being more easily understood. However, it is affected by greater statistical uncertainty and hence is a less reliable measure of water quality, thus requiring careful application to regulation*" (WHO, 2001).

3.3 Factors Affecting Bacteriological Concentrations

A number of potential factors that could influence bacteriological concentrations throughout the False Creek inlet were examined. These factors included general spatial and temporal effects, environmental parameters such as precipitation and salinity, and information regarding releases from CSO's. A number of these factors are related (for example, both precipitation and tides will affect salinity throughout the inlet), and these relationships are discussed.

Enterococci are generally the preferred indicator of fecal contamination in marine waters due to the fact that they generally survive longer than other bacteriological indicators in saltwater. As well, enterococci are better correlated with gastrointestinal symptoms in recreational users than are fecal coliforms (Kay *et al.* 1994; Fleisher *et al.* 1996). The B.C. Water Quality Guidelines provide guidelines for both primary and secondary-contact recreation for enterococci, but only for primary-contact recreation for fecal coliforms. For this reason, geometric means of fecal coliforms can only be compared with primary-contact guidelines, which may be more stringent than necessary for the activities occurring in False Creek. Enterococci samples, however, were collected in False Creek only between January and December, 2002. A longer period of record for fecal coliforms exists due to the GVRD shoreline sampling program which dates back to 1990 and earlier.

Comparisons of trends for fecal coliforms and enterococci data from duplicate samples collected at the same sites in 2002 show strong correlations between the two indicators. Although the concentrations of the two indicators can be an order of magnitude different, the trends are similar. For example, Figures 6, 7 and 8 show a comparison of fecal coliform and enterococci concentrations at sites F3, F12 and F15. These sites were chosen for their relatively high correlation values, as well as because they represent a good spatial distribution throughout the inlet. Correlation factors calculated between fecal coliform and enterococci data collected at the same sites ranged from 0.42 ($p = 0.024$) at Site F13 to 0.90 ($p < 0.001$) at Site F4 (Table 4). Examining all of the data resulted in a mean correlation of 0.71 ($p < 0.001$) for all sites. Due to the larger database of fecal coliform concentrations and the strong correlation between fecal coliforms and enterococci, fecal coliforms, rather than enterococci will most often be used, to examine the various relationships mentioned above.

Table 4. Correlation coefficients, standard errors and p values for fecal coliform / enterococci relationships at mid-channel sites in 2002.

Site	Correlation coefficient (r)	p
F03	0.883	< 0.001
F04	0.900	< 0.001
F05	0.740	< 0.001
F06	0.706	< 0.001
F07	0.807	< 0.001
F08	0.851	< 0.001
F09	0.539	0.003
F10	0.707	< 0.001
F11	0.700	< 0.001
F12	0.813	< 0.001
F13	0.419	0.024
F14	0.778	< 0.001
F15	0.791	< 0.001
F16	0.604	< 0.001
F17	0.586	< 0.001
F18	0.622	< 0.001

3.3.1 Spatial and Temporal Trends in Bacteriological Indicators

3.3.1.1 Fecal Coliforms

From all of the data collected between 1990 and 2002, geometric means were calculated for any instance when there were a minimum of five fecal coliform samples collected within a 30-day period (Table 5). Since there is a much larger data set from the shoreline sites, data was separated into mid-channel or shoreline sites for many of the analyses.

Temporal Trend Analysis

An analysis of temporal trends in the geometric means of fecal coliform concentrations at the various shoreline sites throughout False Creek shows considerable variability, both annually and over the period of record. The general trend appears to be a slight increase in coliform concentrations between 1991 and 1995, followed by a gradual decrease between 1995 and 2001 (*e.g.* sites 17 and 19, Figures 9 and 10). With the separation of the Granville Street CSO in 1999, one might have expected to see decreasing coliform concentrations associated with the nearest site (Site 23). However, the data appears to indicate that coliform concentrations at this site may have actually increased slightly after the CSO closure (Figure 11), although the relatively few samples collected after 1999 make this difficult to confirm.

In an attempt to examine temporal trends at the shoreline sites, percent attainment of the primary-contact recreation guideline (200 /100 mL) was calculated for each site for each year. Table 6 shows a summary of these calculations, with the total number of rolling geometric means calculated for all sites during a given year summed and compared with the number of these geometric means that failed to meet the primary-contact guideline. Exceedences generally increased between 1990 and 1995 and then decreased from 1995 to 2002.

Table 5. Range of geometric mean values calculated from fecal coliform concentrations at each of the sampling locations, and attainment of B.C. primary-contact recreation guideline (geometric mean < 200 /100 mL).

	Number of geometric means calculated	Minimum geometric mean	Maximum geometric mean	Average geometric mean	% of geometric means meeting B.C. 1° contact recreation guideline (200/ 100 mL)
16	560	20	863	86	94%
17	543	20	2123	172	78%
18	547	20	955	134	81%
22	571	20	2623	206	73%
23	540	20	1276	327	85%
19	514	20	6207	393	56%
20	510	20	4765	640	37%
20A	291	20	1522	240	64%
20B	266	20	1732	318	50%
20C	292	23	6122	651	24%
21	429	20	16000	1006	12%
21A	282	52	6417	720	10%
21B	293	29	7189	845	12%
21C	264	20	3691	513	35%
F03	16	23	263	89	94%
F04	16	20	227	90	75%
F05	16	91	728	263	38%
F06	16	31	435	144	75%
F07	16	26	496	134	69%
F08	16	20	533	163	69%
F09	16	20	1259	317	69%
F10	16	30	922	317	56%
F11	16	33	3448	738	63%
F12	12	66	1157	374	58%
F13	16	47	7833	1410	63%
F14	16	47	5373	977	56%
F15	16	49	1900	520	44%
F16	16	33	2952	789	50%
F17	16	51	2680	600	44%
F18	16	232	3364	1190	0%

Table 6. Comparison of geometric means exceeding primary-contact guideline for fecal coliforms on an annual basis between 1990 and 2002 for all of the shoreline sites on False Creek.

Year	Number of geometric means	Number of geometric means exceeding 200/100 mL	Percentage of geometric means exceeding 200/ 100 mL
1990*	207	67	32%
1991*	309	56	18%
1992*	313	79	25%
1993*	380	97	26%
1994*	491	185	38%
1995**	819	544	66%
1996**	580	259	45%
1997**	641	360	56%
1998**	735	324	44%
1999**	182	75	41%
2000**	288	99	34%
2001**	211	86	41%
2002**	232	100	43%

* Eight sites
** Fourteen sites

Spatial Trend Analysis

Figure 12 shows the average of all geometric mean values calculated for fecal coliform samples collected from each shoreline site between 1990 and 2002. The following assessments are based on averages of geometric means which in themselves are already averages. Consequently, the effect of high values has been greatly reduced by two averaging calculations. As well, these values are not the true data which should be compared to the geometric mean criteria. However, this is still a useful way to examine the data for spatial trends, as it enables us to compare coliform concentrations for the period of record along the entire inlet.

There is a general increase in fecal coliform concentrations from west to east along the length of False Creek (Figure 12). The lowest fecal coliform concentrations were typically found near the mouth of the inlet and higher values were in the east end of the inlet. The highest concentrations occurred at sites 21 and 21B (located near the Plaza of Nations), and sites 20 and 20C (near Science World). A subset of the shoreline fecal coliform data (from 1999 to 2002) was also analyzed, to determine if there has been any significant change in trends since the closure of the Granville Street CSO. These data showed an almost identical trend, with sites 21B, 21C and 20C having higher average fecal coliform concentrations than the other sites.

Fecal coliform data were collected at the mid-channel sites over a much shorter period (May 29, 2002 to December 18, 2002). These data, however, showed a similar trend to that shown at the shoreline sites, with concentrations generally increasing in a west to east direction (Figure 13). The highest average geometric mean and variability of the mid-channel sites occurred at Site F13, beneath the Cambie Street Bridge, rather than further east near the Plaza of Nations where the highest shoreline geometric mean values occurred. Since the maximum fecal coliform concentrations at this site occurred during the winter, they are likely a result of precipitation events that triggered releases from the Crowe CSO. The Crowe CSO is located between sites F13 and F14 east of the Cambie Street Bridge (see Figure 3).

Figure 14 shows geometric means for fecal coliform concentrations at both shoreline and mid-channel sites for their respective periods of record in a west-east direction. Concentrations of fecal coliforms were similar between the mid-channel and shoreline sites, although the two highest values both occurred at mid-channel sites (F13 and F18). Site F18 is located near the Terminal CSO, which may account for the occasional very high fecal coliform concentrations at this site.

3.3.1.2 Enterococci

Enterococci data were collected only in 2002, and therefore represent a much smaller data set than the fecal coliform data. However, they represent the most recent data, and considering the changes that have occurred in False Creek over the past decade, are likely the most relevant data.

Similar spatial trends are seen in the enterococci samples collected in False Creek at both shoreline and mid-channel sites in 2002 (Figures 15 through 18). Enterococci concentrations in the samples collected at the mid-channel stations generally increased from west to east along the length of the inlet. The mean values and variability are higher in the May to December sampling period (Figure 17) than the January to March period (Figure 15). The May to December mid-channel data (Figure 17) shows the east-west trend more clearly with sites F10 and west having lower means and variability than sites F12 and eastward. Site F10 is located approximately mid-way between the Granville and Cambie bridges. The January to March data are less clear with mid-inlet sites showing more variability than the other sites. This could be a consequence of more variable weather during the winter season. Some of the higher means and variability during both sampling periods appears at sites in close proximity to CSOs, such as F06 (near the Granville Island CSO), F09 (near the Laurel CSO), F12 (near the Heather CSO), F13 and F14 (near the Crowe CSO) and F18 (near the Terminal CSO). Other sites such as F11, F16 and F18, which are all located in embayments, also had elevated means and variability. The small bays may hinder mixing and flushing.

The May to December shoreline data (Figure 18) are of comparable range to the mid-channel data and, like the mid-channel data, show higher means and variability than the January to March data (Figure 16). Figure 18 also shows that enterococci concentrations are higher at the eastern sites than western sites, and that the Crowe CSO (near Site 19) did not appear to have a large influence on water quality data (mean and variability of enterococci geometric means were similar to other more westerly sites). This may have been a result of 2002 being a dry year and consequently having fewer CSO events. Both Figures 16 and 18 show sites along the eastern basin with high means and variability. The sites around Plaza of Nations (sites 21, 21A and 21B) and near Science World (sites 20, 20A, 20B, 20C) had high means during the 2002 sampling program. This suggests that there may be an intermittent source of fecal contamination such as the Terminal CSO affecting these areas. While this would primarily affect the Science World sites, the lack of circulation in the end of the inlet may also result in effects being measured at the Plaza of Nations sites. As well, or instead, fecal contamination from other areas of the inlet may be depositing here by tidal and wind action. The relatively poor circulation, coupled with the sill located beneath the Cambie Street Bridge may be restricting flow, not allowing this material to be readily flushed from False Creek.

Trends in both fecal coliform at the shoreline sites (12 years of data) and fecal coliform and enterococci data for the mid-channel sites (one year of data) show that bacteriological concentrations increase from west to east in False Creek. The highest concentrations typically occurred between the Cambie Street Bridge and the Plaza of Nations. Enterococci concentrations were typically an order of magnitude lower than those measured for fecal coliforms. Mid-channel sites showed similar trends to those observed at shoreline sites despite the much shorter period of record for these sites. While some of the sites with the highest coliform concentrations were associated with CSOs (such as F13 near the Crowe CSO and 20, 20A, 20B and 20C near the Terminal CSO), not all of the peak locations were located near CSOs. The sites around the Plaza of Nations do not appear to be directly associated with CSOs, however they did show consistently high concentrations.

3.3.2 Seasonal Trends in Bacteriological Indicators

Figures 19 through 21 show raw fecal coliform data collected between 1990 and 2002 at three shoreline sites (sites 16, 20 and 21). These sites were chosen to provide information about the seasonal trends in different spatial locations in the inlet. As the complete GVRD data set dating back to 1990 was used, only fecal coliform data from shoreline sites could be used to examine the seasonal trends. The data in the figures are displayed according to season. Data collected between April and September (the recreation season as defined in the 1990 objectives document) is compared with data collected between October and March. Data in all seasons was collected on a weekly basis, except for occasional bi-weekly sampling in January and February.

At Site 16, near the mouth of the inlet, fecal coliform concentrations were significantly higher during winter months than during the summer (Figure 19). The arithmetic average of fecal coliform concentrations during the winter months (between October and March) over the period of record (1990 – 2002) was 265/100 mL (n=300), while the average for the summer samples (between April and September) for the same period was 153 /100 mL (n=369) ($p = 0.009$). Peaks in the winter data occurred in 1997 and 1998. Winter averages were also significantly higher than summer averages at Sites 17, 18 and 23. The average winter concentration at Site 18 was 647 /100 mL while the summer average was 279 /100 mL ($P = 0.002$); the winter average at Site 17 was 1375 /100 mL compared with a summer average of 346 /100 mL ($P < 0.001$); and the winter average at Site 23 was 725 /100 mL while the summer average was 390 /100 mL ($p = 0.035$). Winter concentrations were also higher than summer averages at Site 22 (821 /100 mL versus 551 /100 mL), although not statistically significant ($p = 0.179$).

Sites 20 near Science World (Figure 20) and 21 near the Plaza of Nations (Figure 21), did not show significant differences in recent years between winter and summer fecal coliform concentrations. At both sites during the early 1990's, fecal coliform concentrations were higher in the summer than during the winter months. The fecal coliform concentrations at both of these sites were consistently greater than at Site 16 west from the Burrard Street Bridge. The average summer concentrations were 1697 /100 mL (n=344) at Site 20 and 1944 /100mL at Site 21 (n=285). These results are higher than their respective average winter concentrations of 1310 /100 mL (n=289) and 1800 /100 mL (n=253), however, not statistically significant ($p = 0.138$ for Site 20, and $p = 0.630$ for Site 21). Mean summer fecal coliform concentrations at both 20 and 21 were significantly higher than mean summer fecal coliform concentrations at Site 16 ($p < 0.0001$).

These averages are conservative estimates of the true fecal coliform concentrations since the laboratory method used does not allow for an actual value determination for fecal coliform concentrations greater than 16,000 /100 mL (which were recorded a number of times at both sites 20 and 21). The means are therefore estimated using a concentration of 16,000 /100 mL for these samples. The true fecal coliform concentrations in these samples, however, are unknown and may have been significantly higher than this.

In general, fecal coliform concentrations were found to be lowest in the early spring (March-April), and to peak in August (Site 20) or September (Site 21), with a secondary peak around December (Figure 22). The fecal coliform concentrations at Site 16 were much lower and more stable throughout the year. Peak concentrations were seen in

November and December at this westerly site. Near the mouth of the inlet, fecal coliform concentrations appear to be higher during winter months than during the summer. There does not appear to be a similar seasonal correlation in the eastern portion of False Creek.

3.3.3 Relationship between Bacteriological Indicators and Precipitation

Figures 23 through 25 compare fecal coliform concentrations at three sites with the precipitation volume from the previous 24 hours (Site 16, near the mouth of False Creek, Site 20, near Science World, and Site 21, near the Plaza of Nations). Precipitation data used for the comparison was collected at the GVRD rain gauge site SVA-13, located in Stanley Park. This location was selected as it had the most complete period of record of those sites located nearest False Creek.

Due to the relatively small size of the drainage basins around False Creek, water travel times through the system (from catch-basins near the top of the drainage, through the sewer system, into False Creek if an overflow situation is occurring), is on the order of one hour or less (McTaggert, pers. comm. 2003). A 24-hour period was therefore selected since rainfall in the preceding twenty-four hours is likely to affect bacterial levels if a CSO event has been triggered. Precipitation occurring more than one day prior to the microbial sample collection may not be pertinent, due to the short survival-time of bacteria in marine waters. Rainfall data collected over this time period correlated ($r = 0.53$, $p < 0.001$) with CSO releases from the Heather Street Station, the only CSO for which discharge records are available (Figure 26).

In Figures 23 through 25, it can be seen that there is some correlation between rainfall and fecal coliform concentrations, especially at Site 16. Correlation coefficients between coliform concentrations and precipitation in the preceding 24-hours for the three sites ranged from 0.085 ($p = 0.028$, Site 20) to 0.383 ($p < 0.001$, Site 16). There were also a significant number of high fecal coliform readings that did not correspond with any significant rainfall in the previous two days. For example, 35% of fecal coliform values over 200 /100 mL measured at Site 16 occurred when there was less than 5 mm of cumulative precipitation in the previous two-day period. This number increases to 57%

of all fecal coliform samples over 200 /100 mL at Site 20, and to 63% at Site 21. The 200 /100 mL cut-off was used for this analysis as it represents the primary-contact recreation guideline, and concentrations below this do not represent an impact. The fact that elevated coliform levels occur in the absence of precipitation may indicate that for at least some of the time, there are sources of fecal contamination other than direct CSO contributions that are responsible for the elevated fecal coliform levels.

A possible explanation may be that there are cross-connections between sewers and stormwater drains for one or more of the nine stormwater discharges located in the east basin of False Creek. There could also be other significant sources of contamination, such as live-aboards, contributing to coliform concentrations in the eastern basin of False Creek.

3.3.4 Relationship between Bacteriological Indicators and CSO Releases

The GVRD measures and records the discharges from the major of the CSO's in Vancouver. Of the CSO's that discharge into False Creek, the Heather Street CSO is the only one that has a record of discharge events available. The Heather Street CSO generally discharges almost half of the overall CSO discharge volume into False Creek (see Table 7).

Table 7. Estimated annual discharge volumes for False Creek CSO's (City of Vancouver, 2002).

CSO Outfall Location	Estimated Annual Sanitary Discharge (millions of litres)	Estimated Completion Date for Separation (Elimination of CSO)
Heather Street	60	2040
Crowe Street	46	2013
Granville Island	22	2007
Laurel Street	6	2009
Terminal Avenue	2	2011
Total:	136	

Figure 1 shows discharge volumes from the Heather Street CSO compared with enterococci concentrations at two mid-channel sites (sites F10 and F12, near the Heather

Street CSO discharge). As with the previous parameters examined, enterococci concentrations appear to be directly related to some individual CSO discharge events, but not all, as elevated concentrations also occurred when CSO discharges were not recorded. There were also a number of instances where discharges occurred and there was no apparent increase in enterococci concentrations.

Samples were often not collected on the date of a CSO discharge; therefore, the only correlation analyses conducted used the sampling date that was closest to a possible discharge event. The correlations were extremely weak from this analysis and ranged from -0.01 (Site F10, $p = 0.929$) to 0.02 (Site F12, $p = 0.867$). Possible explanations for the lack of correlation may be that fecal coliform samples were seldom collected on the same day that a discharge occurred, some or all of the other CSOs may be discharging into False Creek at lower levels of precipitation than those necessary to cause the Heather Street Station to overflow, or there are other significant sources of bacteriological contamination not related to the CSOs, such as pleasure craft.

3.3.5 Relationship Between Bacteriological Indicators and Salinity

Another potentially significant relationship is between bacteriological indicators and salinity. Salinity affects the survival time of bacteria, and therefore increases in salinity would also result in a more rapid die-off of coliform bacteria, further supporting the hypothesis of a negative correlation between these factors.

Salinity in False Creek is affected by two primary factors – inflow of freshwater from precipitation, storm water runoff and CSOs, and mixing with ocean water, primarily due to tidal activity. A negative correlation (increased fecal coliforms with decreased salinity) might be expected from CSO discharges that would reduce the salinity while contributing raw sewage that in turn would increase fecal coliform concentrations. Similarly, increased tidal circulation could result in relatively uncontaminated seawater mixing with False Creek water, thereby decreasing the concentration of fecal coliforms present in the inlet. This latter scenario would not be valid if some of the water entering the inlet through tidal action is the Fraser River water and its associated contaminants (as is suspected by the GVRD, City of Vancouver and Vancouver Coastal Health Authority).

Figures 28 through 30 compare fecal coliform concentrations at three sites with the salinity concentrations at the time of sample collection. A correlation analysis of the data at the three sites does not show a consistent trend or strong relationship between fecal coliforms and salinity (Site 16: $r = 0.007$, $p = 0.851$; Site 20: $r = 0.022$, $p = 0.567$; Site 21: $r = 0.090$, $p = 0.038$). It is therefore not possible to say that trends in salinity are a good indicator of fecal coliform concentrations.

3.3.6 Summary of Factors Affecting Bacteriological Concentrations

While it was found that fecal coliform and enterococci concentrations almost invariably increase in a west to east direction along the inlet, it does not appear that the relationship between fecal coliform concentrations and other environmental conditions (*i.e.* seasonal changes, precipitation, CSO discharges or salinity) is strong enough to use any of these for predictive purposes. There is a strong correlation between precipitation events and CSO discharges (Figure 26), and rain events could therefore be used to predict elevated coliform concentrations associated with these discharges. However, there are also periods during which elevated coliform levels occur that do not appear to be directly related to environmental conditions.

More research and investigations are needed to understand a number of pertinent factors, including the relative contributions of contaminants from various sources within the inlet, and the timing of these releases, as well as conditions affecting circulation and mixing within False Creek and the survival times of bacteria within the inlet. This information could lead to a better understanding of the sources of the contaminants and how best to minimize their impacts on recreational uses.

3.4 Water Quality Attainment of Various Recreational Bacteriological Guidelines

Various jurisdictions recommend slightly different bacteriological guidelines, depending on the acceptable level of risk and methods for summarizing the data (geometric means versus 95^{th} percentiles). The following sections discuss the guidelines recommended by B.C., Canada, the U.S., and the World Health Organization, and determine the attainment of False Creek data with each guideline.

3.4.1 British Columbia Guidelines

Water quality objectives, as established by the Ministry of Environment in British Columbia, are usually based on an analysis of the natural, pristine condition of a given watershed and the application of water quality guidelines (also called criteria) developed by various provincial, federal and international agencies. As objectives are not meant to require that water quality be rehabilitated to a condition better than that which occurs naturally, it is important to examine the natural condition of a watershed. This should ensure that water quality objectives are not more stringent than natural conditions. For a given water quality parameter, numeric guidelines are established for different types of water uses (for example, drinking water, the protection of aquatic life or wildlife, irrigation, etc.). Due to the large number of variables that can affect the toxicity or potential for harm from a given contaminant, guidelines have an inherent safety factor built in to them, to ensure that a given water use is protected.

In British Columbia, water quality guidelines for a number of microbiological indicators have been established for recreational water uses including both primary and secondary-contact activities (Warrington, 1988). The guidelines apply to both marine and fresh waters since there is no epidemiological evidence to justify different levels in British Columbia waters (Warrington, 1988).

The most common indicators of fecal contamination are fecal coliforms, *E. coli* and enterococci. While there is a correlation between *E. coli* and/or enterococci concentrations and fecal coliforms, this correlation is not consistent and therefore the use of either *E. coli* or enterococci concentrations are recommended in fresh water (EPA, 1986). Enterococci is the preferred indicator in marine waters, as it is much more robust in this environment than fecal coliforms or *E. coli* (EPA, 1986; Health and Welfare Canada, 1992), and has the best correlation with gastrointestinal symptoms at marine beaches (Health and Welfare Canada, 1992).

The enterococci guideline for primary-contact recreation (where there is a good likelihood of ingesting water) is not more than 20 colonies/100 mL (geometric mean) while the fecal coliform guideline is not more than 200 colonies/100 mL (geometric mean). The geometric mean is based on a statistically sufficient number of samples (generally not less than five samples equally spaced over a 30-day period). These guidelines are based on an acceptable risk level of 1.6% in marine waters or 16 people in 1000 becoming ill from exposure to these levels of streptococci (a category of bacteria which includes enterococci). The guideline recommends immediate re-sampling at a sufficient number of sites when the concentration of enterococci in a single sample exceeds 284 colonies/100 mL, to determine whether the sample was simply a high value from the same population or if the water quality had deteriorated. The guideline for fecal coliforms and primary-contact recreation states that resampling should occur when any sample exceeds 400 colonies/100 mL. These guidelines are based on the same rationale as that used by the Federal-Provincial Advisory Committee on Environmental and Occupational Health in their 1983 *Guidelines for Canadian Recreational Water Quality*.

Secondary-contact guidelines are derived by multiplying the primary-contact guidelines by five (Warrington, 1988). While no secondary-contact guideline has been proposed for fecal coliforms, the secondary-contact guideline for enterococci is 100 colonies/100 mL, or five times the primary-contact guideline.

The presence of fecal indicators such as fecal coliforms or enterococci give only an indication of the likelihood of contracting gastrointestinal diseases from recreational activities in the subject waters. Gastrointestinal diseases account for only about 20% of the illnesses caused by swimming in sewage-contaminated waters (Warrington, 1988). The remaining illnesses reported include eye, ear, nose and throat (50% of illnesses reported) as well as skin and other infections (30% of illnesses reported). Indicators of the pathogens that cause these types of illnesses are species such as *Streptococcus spp.*, *Staphylococcus aureus* and *Pseudomonas aeruginosa*. These species have not been sampled in False Creek. The B.C. guidelines to protect from ear and skin infections are that 75% of at least five samples collected in a 30-day period should not have concentrations of *Pseudomonas aeruginos*a exceeding 10 colonies /100 mL (secondary-contact recreation), and should not exceed 2 colonies /100 mL (primary-contact recreation).

While no specific guidelines have been established for the following organisms, their presence in large numbers in bathing waters indicates a health hazard: *Candida albicans*, *Shigella*, *Mycobacterium tuberculosis*, *Clostridium perfringens*, *Flavobacterium*, *Acinetobacter*, *Klebsiella*, *Serratia*, *Vibrio parahaemolyticus*, *Salmonella*, enteric viruses and *Staphylococcus aureus* (Warrington 1988).

3.4.2 Canadian Guidelines

The B.C. bacteriological guidelines for recreation are based on the data and recommendations put forth in the Canadian Water Quality Guidelines (CCREM 1987). The enterococci guideline recommended in these documents is that the geometric mean of five samples collected in a 30-day period not be more than 20 colonies /100 mL (for primary-contact recreation). More recent documents, however, by the CCME (formerly the CCREM) and Health and Welfare Canada's 'Guidelines for Canadian Recreational Water Quality', (Health and Welfare Canada 1992) use the guidelines recommended by the US EPA in 1986. As discussed in Section 3.4.3, the primary difference between the guidelines recommended by B.C. and the CCREM versus those recommended by the more recent CCME, Health and Welfare Canada and the EPA are <u>the acceptable levels of risk of infection</u>. The guidelines recommended by B.C. and CCREM (1.6% risk of illness) are more conservative than the CCME, Health and Welfare Canada and 1986 EPA guidelines (1.9% risk of illness). The guideline recommended by the CCME for marine waters is a maximum geometric mean for five samples collected in a 30-day period of not more than 35 /100 mL, and resampling when any sample exceeds 70 /100 mL.

The Canadian Water Quality Guidelines also recommend an annual environmental health assessment prior to the recreational season, in order to identify potential sources of contamination and physical hazards that could affect the recreational area (Health and Welfare Canada, 1992). Key points of such an assessment include:

- a determination of the risk of inadequately treated sewage, fecal matter, or chemical substances entering the water;
- a knowledge of all outfalls and drainages in the area that may contain sewage, including urban storm water and agricultural waste or runoff;
- an inspection of the area for physical hazards;
- an assessment of the seasonal variability of hazards, bather density, water temperature, water circulation, water depth and occurrences of algal blooms;
- an examination of the effect of rainfall on water quality; and
- a reporting mechanism to ensure that health authorities are informed of any malfunction or change in waste treatment facilities in the area that might affect recreational water quality.

Finally, it is recommended that bather illness and injury be monitored and reported on, and that surveillance be increased if there have been reports of suspected illness or injuries.

3.4.3 Environmental Protection Agency Guidelines

In 2002, the U.S. Environmental Protection Agency (EPA) published a draft document intended to provide direction to states and tribes within the U.S. on the adoption and implementation of the 1986 ambient bacteriological water quality criteria set to protect waters designated for recreation (EPA, 1986). This 2002 draft document reviewed previous epidemiological studies as well as the more current science. The EPA reached the conclusion of recommending the same 1986 guidelines (with enterococci as the marine indicator) with the exception of recommending a lowering of the acceptable risk of illness rate for marine waters. Many states and authorized tribes have not yet made the transition from using total or fecal coliforms to *E. coli* and enterococci (as was recommended by the EPA in 1986). States and tribes have primarily resisted this transition due to their large existing fecal coliform databases (EPA, 2002). As of 2002, only 18 states, three territories and six authorized tribes had adopted *E. coli* and/or enterococci guidelines to protect recreational waters.

In the U.S., all waters are to be protected for primary-contact recreation uses unless it can be shown that these uses are not attainable or that the water is inaccessible. Waters are considered inaccessible if they are: surrounded by fencing; located in an urban waterbody that also serves as a shipping port or has close proximity to shipping lanes; if water is not present during the months when recreation would otherwise take place; or if the waterbody is not in close proximity to residential areas (EPA, 2002).

The EPA guidelines for bacteria in recreational waters are based on a formula similar to the one used in British Columbia, and can be described by the following equation:

For Marine Waters:

Enterococci guideline: log(geometric mean) = (0.0827 x illness rate) – 0.0164

In addition, the EPA has established Single Sample Maximum (SSM) allowable densities that would limit the maximum allowable concentration of enterococci to be present in a single sample. Therefore, if the geometric mean is not exceeded but the SSM is, the waterbody would not meet EPA criteria. These SSM enterococci densities are based on the frequency of water use – designated beach areas would use a 75% confidence level, while areas used infrequently for primary-contact recreation (such as False Creek) would be allowed a 95% confidence level. Consequently, more conservative levels are used in areas that are frequently used for recreation, while those areas that are seldom used or have lower levels of contact may be given less restrictive single-sample limits. The formula used to calculate SSM values is described by the following equation:

$$\text{Log (SSM)} = (\text{Log (Geometric Mean Value)}) + ((\text{Confidence Level Factor}) \times (\text{Log Standard Deviation})),$$

where Confidence Level Factors are: 75% = 0.68
82% = 0.94
90% = 1.28
95% = 1.65

and the Log Standard Deviation for marine waters = 0.7

Based on the above formula, Table 8 describes geometric mean densities as well as single sample maximum allowable densities for illness rates between 0.8% and 1.9%.

Table 8. Enterococci water quality criteria for marine recreational waters (from EPA 2002).

Illness Rate (per 1000)	Geometric Mean Density	Single Sample Maximum Allowable Density			
		Designated Beach Area 75% C.L.	Moderate Full Body Contact Recreation 82% C.L.	Lightly Used Full Body Contact 90% C.L.	Infrequently Used Full Body Contact 95% C.L.
8	4[1]	13	20	34	63
9	5	16	24	42	76
10	6	19	29	50	91
11	8	23	35	61	110
12	9	28	42	73	133
13	11	33	51	89	161
14	14[2]	40	61	107	195
15	16	49	74	129	235
16	20[3]	59	90	156	284
17	24	71	108	189	343
18	29	86	131	228	415
19	35[4]	104	158	276	501

[1] EPA's new guideline based on the lowest acceptable illness rate (0.8%)

[2] EPA's new guideline based on the highest acceptable illness rate (1.4%).

[3] B.C. Primary-contact Recreation Guideline.

[4] EPA's guideline based on it's 1986 recommended illness rate.

The 1986 EPA guideline for enterococci concentrations for primary-contact recreation in marine waters is a geometric mean of 35 enterococci/100 mL (based on an acceptable risk level of 1.9%). This EPA guideline differs from the B.C. guideline only in the level of acceptable risk. Using the B.C. level of acceptable risk of 1.6%, the EPA criteria match B.C.'s designated primary-contact enterococci criteria of 20 enterococci / 100 mL (geometric mean). In the most recent EPA implementation guideline, recommendations are that states and authorized tribes adopt guidelines based on the same risk levels in both fresh water and marine waters (EPA 2002). As their guidelines for primary-contact recreation in fresh waters are based on illness rates of 0.8%, they recommend adopting both freshwater and marine guidelines based on rates between 0.8% and 1.4%. The upper threshold (1.4%) is based on the fact that the epidemiological data used to support the relationship between illness rates and fresh water bacteriological conditions is based on an observed illness rate range of up to 14 illnesses per 1000 swimmers and thus does not support extrapolation beyond that point (EPA, 2002). The result is a recommended marine water primary-contact recreation guideline of between 4 enterococci/100 mL and

14 enterococci/100 mL (geometric mean) (Table 8). These values are lower than both the B.C. and Canadian guidelines.

The EPA has not established a national criterion for secondary-contact recreation. This is due to the fact that the exposure data collected in the key epidemiological studies were associated with swimming-related activities involving immersion. They do not have data from secondary-contact recreation activities which generally only involve incidental immersion (*e.g.* slipping and falling into the water or having water splash in one's face). As these are different exposure scenarios and involve different exposure routes, the EPA has not derived a national criterion for secondary-contact recreation based on the existing data. In their 2002 draft report, however, the EPA recognized that there is a need for epidemiological research to determine appropriate criteria to be protective of secondary-contact recreation activities. The EPA plans to undertake such studies in the future. As part of EPA's requirements under the Beaches Environmental Assessment and Coastal Health Act (BEACH Act) amendments and commitments made to its Beach Action Plan, the EPA intends to gather additional data and investigate the development of water quality guidelines for transmission of organisms that cause skin, eye, ear, nose, respiratory illness, or throat infections (EPA, 2002). Some elements of this study may be applicable to secondary-contact uses.

Despite the lack of epidemiological studies to support definitive secondary contact guidelines, the EPA does still provide guidance in the 2002 document. In some instances (*i.e.* when primary contact recreation is not an existing use and the water quality necessary to support the use is not attainable based on chemical, physical and biological analyses, as well as economic considerations), the EPA allows states and authorized tribes to apply for secondary-contact recreation status for a specific waterbody. The EPA suggests that until conclusive research is conducted, states and authorized tribes may wish to adopt a secondary-contact criterion of five times that of the geometric mean of the primary-contact recreation guideline (EPA, 2002). This is the same method used to designate the secondary-contact guideline in B.C. and Canada. Based on this recommendation, the EPA enterococci guideline for secondary-contact recreation would be 175 /100 mL, (using their 1986 acceptable risk level of 1.9%). Adopting the more conservative illness levels recommended in their 2002 document results in their secondary-contact guidelines falling between 20 /100 mL and 70 /100 mL. This is considerably lower than the 100 /100 mL guideline recommended by B.C. for secondary-contact recreation in marine waters. The EPA single-sample maximum appropriate for False Creek would be calculated by applying a 95% confidence limit. This would result in a primary-contact single sample maximum guideline of 284 enterococci per 100 mL and a secondary-contact single sample maximum guideline of 1420 enterococci per 100 mL (calculated by multiplying the primary-contact SSM by a factor of five).

3.4.4 World Health Organization Guidelines

The World Health Organization (WHO 2001) also bases its marine water microbiological guidelines on the estimated risk of illness. Rather than using geometric means of enterococci samples, however, the World Health Organization (WHO) recommends the use of a 95th percentile value. 95th percentiles are based on at least 100 raw numbers, preferably the most recent data available, and are calculated by ranking the values in ascending order. The 95th percentile is then simply the 95th value, and represents the level which 95% of values would fall below. This method, compared with the geometric mean system, reflects much of the top-end variability in the distribution of water quality data and is more easily understood. There is, however, a higher degree of statistical uncertainty associated with this value, and therefore it is less reliable and the data requires more caution when interpreting.

Table 9 shows WHO guideline values for marine recreational waters, which are based on the same epidemiological studies used by the EPA (*i.e.*, Kay *et al.* 1994 and Fleisher *et al.* 1996). The WHO bases their analyses on enterococci, as it is the only indicator that showed a dose-response relationship for both gastrointestinal illness and acute febrile respiratory illness (AFRI). Guidelines are based on bathing waters (primary-contact recreation) only, as the WHO feel that there are insufficient epidemiological data to present a parallel analysis for other types of exposure. As the WHO does not recognize secondary contact activities and therefore do not have corresponding guidelines, False Creek waters were assessed according to the primary-contact recreation guidelines.

Table 9 defines limits for bacterial contamination (as represented by enterococci concentrations) on the basis of acceptable risk in a method similar to that of the EPA and British Columbia. However, all of these agencies identify shortcomings with this type of analysis. For example, the measurement of indicator bacteria provides a retrospective assessment of what water quality was. As 25 hours is usually necessary to incubate samples and determine densities, the results are thus descriptive of what conditions were. As well, some thermo-tolerant bacteria used as indicators of fecal contamination can have sources outside of fecal material, such as some industrial wastes. The selection of specific bacteria such as enterococci helps to address this concern to some extent as enterococci are less likely to be in industrial wastes.

Table 9. World Health Organization guideline values for microbiological quality of marine recreational waters (from WHO 2001)*.

95^{th} % ile value of enterococci/100 mL	Basis of derivation	Estimated Risk[3]
=40	This value is below the NOAEL in most epidemiological studies	**<1% GI illness risk[1]** **<0.3% AFRI risk** This related to an excess illness of less than 1 incidence in every 100 exposures[2]. The AFRI burden would be negligible.
41-200	The 200/100 mL value is above the threshold of illness transmission reported in most epidemiological studies that have attempted to define a NOAEL or LOAEL for GI illness and AFRI.	**1-5% GI illness risk** **>1.9% AFRI illness risk** The upper 95^{th} percentile values of 200 relates to an average probability of one case of gastroenteritis in 20 exposures. The AFRI illness rate at this water quality would be 19 per 1000 exposures, or approximately 1 in 50 exposures.
201-500	This level represents a substantial elevation in the probability of all adverse health outcomes for which dose-response data are available.	**5-10% GI illness risk** **1.9-3.9% AFRI illness risk** This range of 95^{th} percentiles represents a probability of 1 in 10 to 1 in 20 of gastroenteritis for a single exposure. Exposures in this category also suggest a risk of AFRI in the range of 19-39 per 1000 exposures, or a range of approximately 1 in 50 to 1 in 25 exposures.
>500	Above this level, there may be a significant risk of high levels of minor illness transmission	**>10% GI illness risk** **>3.9% AFRI illness rate** There is a greater than 10% chance of illness per single exposure. The AFRI illness rate at the 95^{th} percentile point of 500 enterococci per 100 mL would be 39 per 1000 exposures, or approximately 1 in 25 exposures.

*Notes:

1. Abbreviations used: AFRI – acute febrile respiratory illness; GI = gastrointestinal; LOAEL = lowest observed adverse effect level; NOAEL = no-observed adverse effect level
2. The "exposure" in the key studies was a minimum of 10 min bathing involving three immersions. It is envisaged that this is equivalent to many immersion activities of similar duration, but it may underestimate risk for longer periods of water contact or for activities involving higher risks of water ingestion (see also note 7).
3. The "estimated risk" refers to the excess risk of illness (relative to a group of non-bathers) among a group of bathers who have been exposed to fecally-contaminated recreational water under conditions to those in the key studies.
4. The functional form used it the dose-response curve assumes no excess illness outside the range of the data (*i.e.*, at concentrations above 158 enterococci/100 mL). Thus, the estimates of illness rate reported above are likely to be underestimates of the actual disease incidence attributable to recreational-water exposure.
5. This table would produce protection of "healthy adult bathers" exposed to marine waters in temperate north European waters.
6. It does not relate to children, the elderly or immuno-compromised, who would have lower immunity and might require a greater degree of protection. There are no available data with which to quantify this, and no correction factors are therefore applied.
7. Epidemiological data on fresh waters or exposures other than bathing (*e.g.*, high-exposure activities such as surfing, dinghy boat sailing or white-water canoeing) are currently inadequate to present a parallel analysis for defined reference risks. Thus, a single microbiological value is proposed, *at this time*, for all recreational uses of water, because insufficient evidence exists at present to do otherwise. However, it is recommended that the severity and frequency of exposure

encountered by special interest groups (such as bodysurfers, board riders, windsurfers, sub-aqua divers, canoeists and dinghy sailors) be taken into account.

8. Where disinfection is used to reduce the density of indicator bacteria in effluents and discharges, the presumed relationship between enterococci (as indicators of fecal contamination) and pathogen presence may be altered. This alteration is, at present, poorly understood. In water receiving such effluents and discharges, enterococci counts may not provide an accurate estimate of the risk of suffering from mild gastrointestinal symptoms or AFRI.
9. Risk attributable to exposure to recreational water is calculated after the method given by Wyer et a. (1999), in which a $\log_{10}$ standard deviation of 0.8103 was assumed. If the true standard deviation for a beach were less than 0.8103, then reliance on enterococci would tend to overestimate the health risk for people exposed above the threshold level, and vice versa.
10. Note that the values presented in this table do not take account of health outcomes other than gastroenteritis and AFRI. Where other outcomes are of public health concern, then the risks should be assessed and appropriate action taken.
11. Guideline Values should be applied to water used recreationally and at the times of recreational use. This implies care in the design of monitoring programs to ensure that representative samples are obtained. It also implies that data from periods of high risk may be ignored if effective measures were in place to discourage recreational exposure.

Due to the concerns identified, WHO recommends a proactive approach with two key elements associated with beach bathing waters:

1. A classification scheme based on an inspection of various sources of fecal contamination (*i.e.*, a sanitary survey), determining the extent to which feces affect beach waters (by identifying factors such as nearby rivers or stormwater outlets that may be influenced by rainfall events or sewer overflows), and the density of fecal indicator bacteria in beach water samples, and
2. The possibility of reclassifying a beach to a higher class if effective management interventions are instituted to reduce exposure and thereby lower the risk of swimming-associated illness.

A classification matrix for recreational water environments, as shown in Table 10, has been adopted by the WHO. Classifications are based upon both environmental hazard assessments (*i.e.* sanitary surveys) and microbiological water quality assessment components. The classification scheme enables local management to respond to sporadic or limited areas of pollution and thereby upgrade a recreational-water environment's classification. This is achieved by discounting data collected during periods when actions to discourage recreational-water use were deployed and shown to be effective.

Table 10. World Health Organization classification matrix for recreational water environments (from WHO, 2001).

		Microbiological Assessment Category (95^{th} percentile indicator counts)				Exceptional circumstances
		A <40	**B** 40-200	**C** 201-500	**D** >500	
Sanitary Inspection Category (susceptibility to fecal influence)	Very Low	Very good	Very good	Follow up*	Follow up+	
	Low	Very good	Good	Fair	Follow up+	
	Moderate	Follow up*	Good	Fair	Poor	
	High	Follow up*	Follow up*	Poor	Very poor	
	Very High	Follow up*	Follow up*	Poor	Very poor	
Exceptional circumstances						

Notes:

1. * indicates unexpected results requiring investigation (bacterial concentrations are lower than would be expected based on Sanitary Inspection Category (SIC)
   + implies non-sewage sources of fecal indicators (*e.g.*, livestock) and this should be verified (bacterial concentrations are higher than would be expected based on SIC).
2. In certain circumstances, there may be a risk of transmission of pathogens associated with more severe health effects through recreational-water use. The human health risk depends greatly on specific (often local) circumstances. Public health authorities should be engaged in the identification and interpretation of such conditions. The need for reassessment of risk may be triggered by various factors. Accounting for such risks may lead to the reclassification of a location, unless recreational-user access can be controlled
3. Exceptional circumstances relate to known periods of higher risk, such as during an outbreak with a pathogen that may be waterborne, trunk sewer/combined sewer rupture in the beach catchment, etc. Under such circumstances, the classification matrix would be superseded.

This classification scheme, as opposed to a pass/fail system, would provide incentive to local management actions and pollution abatement. In addition, it provides recreational users with a generic statement regarding the level of risk involved and thus allowing them to make informed personal choices regarding the utilization of the resource. The classification also indicates the principal management and monitoring actions likely to be appropriate to ensure that key periods of sensitivity are identified. Managers may then focus their efforts on determining the sources of contaminants during these critical periods and reducing or eliminating the sources. As well, monitoring schedules may be focused on periods when it would be most useful and relevant.

3.5 FALSE CREEK GUIDELINE ATTAINMENT

False Creek enterococci and fecal coliform data from the period of record are compared to the B.C., CCME, Health and Welfare Canada, EPA and WHO guidelines for attainment in Table 11. Evaluation of attainment of the B.C., Canadian and EPA guidelines, is based on the percentage of rolling geometric mean values at each site that meet the various guidelines presented in the table. Evaluation of the WHO guideline is based on the assignment of a classification (A – D) based on the 95th percentile of all enterococci values at each site.

The current data analysis approach used by the GVRD and the Vancouver Coastal Health Authority (VCHA) is to pool all data from all of the sites in the east, west and central basins and calculate a single geometric mean value for each basin. The east basin consists of sites 20, 20A, 20B, 20C, 21, 21A, 21B and 21C. The central basin consists of sites 17 and 19. The western basin consists of sites 16, 18, 22 and 23. Prior to May 29, 2002, data were divided into only two basins (east and west), with the sites from the central basin divided between these (Site 17 was considered part of the west basin, while Site 19 was considered to be part of the east basin). This methodology still relies on five samples being collected within a 30-day period, however instead of calculating geometric means for each site, data for all of the sites in a basin are pooled and used to calculate one geometric mean for the area. The western basin now contains four sites, each with one sample collected weekly in a 30-day period. The resulting 20 values are pooled and a single geometric mean value is then calculated for the basin.

In general, attainment of the various guidelines decreased along the length of the inlet, with the highest attainment occurring at the mouth of False Creek and the lowest attainment occurring near the eastern end of the inlet (where recreational use is highest).

3.5.1 B.C. Guideline Attainment

When comparing the enterococci data from the shoreline sites to the primary contact guideline (20 /100 mL(geometric mean)), the attainment with the guideline ranged from 0% at sites near the Plaza of Nations (sites 21, 21A, 21B and 21C) to 80% near Sunset Beach (Site F03). When comparing the same data to the secondary contact guideline (100 /100 mL geometric mean), the attainment ranged from 53% (21A, 21B, 20 and F18) to 100% (sites 16, 18, 20B, 20C, 21, 21C, F02, F03, F04 and F10).

A consistent trend is that the Plaza of Nations and Science World sites often exceed the secondary-contact enterococci guideline while sites to the west were consistently lower than the guideline. A frequency histogram (Figure 31) shows the attainment with the B.C. secondary-contact enterococci guideline at each of the sites in a west to east direction. The highest levels of non-attainment were centered around the Plaza of Nations.

When comparing the fecal coliform data from each site to the B.C. primary contact guideline, attainment ranged from 0% (Site F18) to 94% (Site 16 and Site F02). These results are similar to those found for enterococci, with sites in the western basin meeting the guideline more often than the eastern sites.

The single sample maximum value (1420 /100 mL based on a 95% confidence level) for secondary-contact recreation was exceeded by three enterococci samples: 1500 /100 mL, 2350 /100 mL, and 2370 /100 mL, on May 29, 2002, June 5, 2002 and August 7, 2002, respectively, all at Site 20 (near Science World).

3.5.2 EPA, Health and Welfare Canada and CCME Guideline Attainment

Attainment of the enterococci data with the primary contact marine recreation guidelines of the CCME, Health and Welfare Canada and the EPA (1986) (35 enterococci/100 mL) ranged from 0% (Site 21) to 100% (sites 20 and F02) at the shoreline sites. When comparing this data to the B.C. secondary-contact enterococci guidelines (100 enterococci/100 mL), attainment at the shoreline sites ranged from 73% at Site F18 to 100% at the majority of the other shoreline sites. A frequency histogram (Figure 32) shows the attainment with the 1986 EPA secondary-contact enterococci guideline (175 enterococci/100 mL at an illness rate of 1.9%) at each of the sites, in a west to east direction. The highest levels of non-attainment were centered near the Plaza of Nations. The secondary-contact single sample maximum value of 2505 enterococci/100 mL was not exceeded by any enterococci samples (value derived from a conversion of five times the primary contact single sample maximum guideline, at a risk level of 1.9% and a 95% confidence level).

A second histogram (Figure 33) shows attainment with the 2002 EPA secondary-contact enterococci guideline (70 enterococci/100 mL based on an illness rate of 1.4%). Non-attainment ranged from 28% at one site in the eastern basin, to 100%. The single sample maximum coinciding with the 1.4% illness rate is 975 enterococci (based on a conversion of five times the primary contact SSM guideline at a risk level of 1.4% and a 95% confidence level). This maximum value was exceeded by 18 individual samples on seven separate dates between May 29 and December 19, 2002.

Table 11. Attainment of False Creek enterococci and fecal coliform data with B.C., CCME, Health and Welfare Canada, EPA and WHO marine contact recreation guidelines.

	Enterococci							Fecal coliforms
Shoreline Stations	**# of Geometric means**	***< 20[1]***	***< 35[2]***	***< 100[3]***	***< 175[4]***	***95th %ile***	***WHO Ranking***	***< 200[1]***
16	26	46%	81%	100%	100%	341	C	94%
17	30	70%	73%	87%	100%	453	D	78%
18	26	65%	81%	100%	100%	448	D	81%
22	26	38%	46%	88%	92%	760	D	73%
23	26	50%	69%	92%	100%	630	D	85%
19	30	67%	70%	90%	100%	528	D	56%
20	4	25%	100%	100%	100%	845	D	36%
20A	30	7%	13%	93%	100%	370	D	64%
20B	4	50%	50%	100%	100%	158	B	50%
20C	30	7%	10%	53%	87%	148	B	24%
21	4	0%	0%	100%	100%	140	B	12%
21A	30	0%	7%	53%	83%	635	D	10%
21B	30	0%	7%	53%	87%	849	D	12%
21C	29	0%	7%	55%	86%	214	C	35%
Mid-channel stations								
F02	4	75%	100%	100%	100%	104	C	No fecal data
F03	30	80%	93%	100%	100%	314	C	94%
F04	30	60%	80%	100%	100%	412	D	75%
F05	30	13%	37%	93%	100%	518	C	38%
F06	30	47%	57%	90%	100%	348	D	75%
F07	30	53%	67%	97%	100%	676	D	69%
F08	30	53%	67%	93%	100%	777	D	69%
F09	30	47%	57%	90%	100%	680	D	69%
F10	30	57%	77%	100%	100%	760	D	56%
F11	30	27%	50%	77%	90%	800	D	63%
F12	30	43%	60%	83%	87%	616	D	58%
F13	30	53%	70%	93%	100%	690	D	63%
F14	30	40%	60%	87%	97%	692	D	56%
F15	30	13%	47%	83%	93%	586	D	44%
F16	30	23%	33%	80%	87%	530	D	50%
F17	30	20%	40%	83%	100%	730	D	44%
F18	30	3%	10%	53%	73%	963	D	0%

[1] B.C. primary-contact recreation guideline
[2] EPA, CCME & Health and Welfare Canada primary-contact recreation guideline
[3] B.C. secondary-contact recreation guideline
[4] EPA, CCME & Health and Welfare Canada secondary-contact recreation guideline (with 1.9% risk of illness)

3.5.3 WHO Categorization

Calculation of the 95th percentile (for the enterococci data) for each False Creek station generally resulted in rankings of D. The 95th percentile is based on WHO's primary-contact beach classification as they do not have any other classifications for recreational waters. All of the mid-channel stations east from the Granville Street Bridge were categorized as D (see Table 11). Shoreline sites 02-20B, 02-20C and 02-21 received the highest rankings in False Creek, with a value of B. Rankings, however, were based on a maximum of 39 values which is well below the 100 values recommended by WHO.

Based on WHO recommendations that sanitary inspections be carried out when there are sources of direct releases of raw sewage, False Creek falls into the sanitary inspection category of high to very high (Table 11). This is a result of the presence of CSO's, and pleasure boat releases, as well as stormwater discharges. The microbiological assessment categories of C and D, coupled with the sanitary inspection categories of high or very high result in False Creek being rated as poor to very poor for most of the sampled stations as well as for the inlet as a whole. It should be noted that the methods used by the WHO are based on primary, rather than secondary-contact recreation, which explains why their rankings tend to be lower than the other methods discussed.

3.5.4 Current Data Assessments

Currently, data collected by the GVRD are pooled into east, west and middle basins of False Creek prior to calculating geometric means (as described in Section 3.5). This data was compared with the range of geometric mean values calculated for each of the individual sites within the basin. Table 13 shows a comparison of the methodologies for enterococci data collected at the shoreline sites between May 29 and December 18, 2002. The comparison shows that the geometric mean reported for the basin as a whole is significantly lower than the average of each of the geometric mean values reported for the individual sites comprising the basin. This is not surprising given the tendency of geometric mean calculations to "dampen" higher values. The actual range of percent-differences between the pooled values and the average of the individually calculated values ranged from slightly more than 0% to a maximum of 69%, with an average of

10%. Therefore, it would appear that the pooling method would slightly underestimate the average risk of exposure to enterococci at specific locations within the basin, compared with calculating individual geometric means for each sampling location within the basin. As this approach reflects the method used at bathing beaches, the Ministry accepts the pooling of data. However, as this method can downplay bacteriological levels at localized hotspots, the need to inform the public of potential health risks is emphasized. Consequently, the Ministry has required the GVRD and/or member municipalities to post signs at combined sewer overflow outfall locations in order to provide this type of public notification. These signs are to be posted by the summer of 2006.

3.5.5 Comparison of Guideline Methodologies for Various Jurisdictions

All of the methodologies used for interpreting bacteriological data by the various jurisdictions (including the WHO ranking system) are based on the same key studies (*i.e.* Kay *et al.* 1994; Fleisher *et al.* 1996). These studies were conducted in the United Kingdom, and were designed to overcome biases in earlier epidemiological studies. Key biases reflected in the earlier studies included misclassifications, which involved attributing a daily mean water quality to all bathers, rather than reporting coliform concentrations from the same time and location that the individual bathing took place. Another important bias was self-selection, wherein the past volunteers were allowed to decide if they were to be in the “bather” or “non-bather” class, which would tend to result in more healthy people in the bather group. In the newer studies, volunteers were randomly assigned to a “bather” or “non-bather” group. Both of the biases mentioned above would have resulted in underestimates of the illness rates, and both of these biases were eliminated in the more recent studies (*i.e.* Kay *et al.* 1994; Fleisher *et al.* 1996).

Differences in the interpretation of these studies by each jurisdiction relate to:

- how the data are summarized (B.C., Canada and the EPA use geometric means, while the WHO uses 95^{th} percentiles), and
- the acceptable risk of illness levels (B.C. and CCREM use an illness rate of 1.6%, while the older EPA and Health and Welfare Canada use a level of 1.9%).

The B.C. guidelines are therefore more conservative than those advocated by the CCME, Health and Welfare Canada and the older EPA guidelines. In the new draft EPA implementation guideline (EPA, 2002), however, the EPA is recommending that states and authorized tribes adopt a new more stringent guideline due to problems with data extrapolation beyond 1.4% (see Section 3.4.3). Adoption of these recommendations would result in an illness rate (and therefore guideline level) lower than that currently used by B.C. (Table 12).

Table 12. Comparison of primary- and secondary-contact guidelines and single-sample maximums recommended by various agencies.

	B.C. and CCREM	1986 EPA, Health & Welfare, CCME	2002 EPA
1° Contact Guideline (Enterococci / 100 mL)	20	35	4 - 14
1° Single Sample Maximum (Enterococci / 100 mL)	284	501	63 - 195
2° Contact Guideline (Enterococci / 100 mL)	100	175	20 - 70
2° Single Sample Maximum (Enterococci / 100 mL)	1420	2505	315 - 975
Acceptable Level of Risk	**1.6%**	**1.9%**	**0.8% - 1.4%**

Another key difference between methodologies used by the various jurisdictions is their recognition of secondary contact guidelines. While B.C. and the EPA recognize the application of secondary-contact guidelines (based on a factor of five times the primary-contact guideline), the WHO guidelines are recommended solely for bathing beaches (*i.e.,* primary-contact guidelines). The WHO justifies this single classification based on the fact that insufficient studies have been conducted to be able to recommend an appropriate secondary-contact guideline. Similarly, Health Canada and the CCME do not differentiate between different types of recreation based on water contact.

4.0 PROPOSED WATER QUALITY OBJECTIVES FOR BACTERIOLOGY

4.1 CURRENT RECREATIONAL USE OF FALSE CREEK

Results from the recreational surveys discussed in Section 2 show that there are a significant number of individuals partaking in recreational activities on False Creek on a year-round basis. Dragon-boaters appear to be the largest recreational group, and participation rates do not appear to vary according to either weather or season. Spatially, usage appears to be slightly higher in the eastern basin and decreases in a westerly direction.

Based on information provided by respondents to the False Creek Recreational Survey, it appears that the vast majority of people that participate in activities on the water do so with activities that would be classified as secondary-contact recreation. The exception to this would be swimming. While swimming generally takes place only at the mouth of False Creek at Sunset Beach, (where the primary-contact recreation guideline of the Burrard Inlet Water Quality Objectives apply) swimmers are occasionally observed throughout the inlet. There are a number of potential risks associated with swimming in False Creek at the present time besides the water quality. These include heavy boat traffic (posing a significant risk to swimmers) as well as submerged garbage and debris that swimmers could cut themselves on or become entangled in. Finally, stormwater runoff and CSO discharges may contain contaminants other than bacteria that may be a concern to swimmers health. Currently, primary-contact recreation should be discouraged until such a time as all factors affecting the safety of swimmers (designated no-boating areas, construction of a beach or other area where debris is removed from the substrate, and consistent water quality attainment of primary-contact recreation guidelines) are addressed.

For all other activities reported, full submersion (where there is a likelihood of ingesting water) occurs only accidentally or incidentally. As such, a water quality objective for secondary-contact recreation is proposed for False Creek

4.2 Recommended Objectives for Bacteriological Indicators in False Creek

4.2.1 Short-term Objective

The selection of an appropriate secondary-contact water quality objective for False Creek was derived from the water quality data assessment and examination of the guidelines used by other jurisdictions. All of the jurisdictions discussed in this report base the development of primary-contact water quality guidelines in a marine environment on the same methodology (*i.e.*, a regression formula based on the acceptable illness risk and the concentration of enterococci). Differences exist in the application of the guidelines such as how the enterococci data are summarized (geometric means versus 95^{th} percentiles), and the acceptable risk of illness. Recommendations for acceptable illness levels range from 0.8% to 1.9%. At the illness level currently deemed acceptable by the MoE (1.6%, or 16 in every 1000 people suffering from gastro-intestinal or AFRI symptoms), the primary-contact guideline would allow a maximum geometric mean of 20 enterococci per 100 mL sample.

Determining an acceptable guideline for secondary-contact recreation is not as easy since there is a lack of science investigating the risks from these types of exposures. Consequently, there is a lack of data and science available to be used for setting standards. The 1988 MoE guideline document states that while experience indicates that an acceptable health risk for secondary-contact activities results from using a ratio of five times the primary-contact guideline, there is no good epidemiological evidence to support this ratio. The EPA concurs, stating that they are unable to develop a national criterion for secondary-contact recreation based upon existing data until more scientific studies have been completed (EPA, 2002). If a secondary contact guideline is necessary however, the EPA also recognizes that the adoption of a guideline five times that of the primary-contact guideline may be suitable.

Until studies are conducted to provide a more scientifically-defensible guideline, the current B.C. MoE secondary contact guideline of a maximum geometric mean of 100 enterococci per 100 mL should be adopted as a water quality objective for False Creek. In addition, the EPA’s additional single sample maximum (SSM) allowable concentration guideline should be established (as discussed in Section 3.4.3). A 95% confidence limit should be used and a secondary-contact recreation guideline obtained by multiplying the primary-contact single sample maximum by a factor of five. This would result in a SSM of 1420 /100 mL. The False Creek objective would therefore state that the geometric mean of not less than five samples collected within a 30-day period should not exceed 100 enterococci per 100 mL and no single sample should have a concentration exceeding 1420 enterococci per 100 mL. The ministry approval of these recommendations will be deferred until the new Canadian Recreational Water Quality Guidelines are released. These are expected in 2007. It is anticipated that these new guidelines will establish enterococci as the recommended indicator in marine waters and either establish secondary contact criteria, or provide guidance on how to deal with secondary contact activities.

Modifications to the bacteriological water quality monitoring program in False Creek are also recommended. Enterococci samples should be collected in False Creek on a weekly basis during the recreation season, and perhaps once or twice a month outside of the recreation season. Based on survey results included in this report, the recreation season might be considered the period from March through October, with the period of November through February representing much-reduced levels of recreational activity. Ideally, samples would be collected at all of the mid-channel sites sampled as part of this project, as these most closely reflect the environment that recreational users such as rowers, kayakers and dragon-boaters would come in contact with. Shoreline sites in areas often accessed by recreational users (docks, etc.) should also be sampled. The relatively good correlation between shoreline sites and mid-channel sites suggests that only the shoreline sites could be used, however, if this were a more cost-effective method of monitoring.

4.2.2 Long-term Objective

If, in the future, it is determined that primary-contact recreation is a desirable use for False Creek, and if infrastructure is developed to accommodate these activities, a long-term objective should be established for primary-contact recreation. The timing for implementation of this long-term objective should be based on many factors, possibly including the removal of all CSOs, and determining what other sources of bacteriological contamination need to be addressed prior to formally adopting this long-term goal. Other risks, such as boat traffic and other contaminants besides those that are bacteriological would also need to be assessed prior to the implementation of the long-term objective. Additional information may also indicate that achieving this long-term objective is not practicable; however, such a decision would likely not be made at a purely technical level.

4.3 Recommendations for Future Work

In addition, the majority of health complaints regarding False Creek water that were reported in the survey results are associated with skin irritation (rashes, infections). These types of illnesses are not well correlated with fecal coliforms or enterococci. Therefore, an indicator such as *Pseudomonas aeruginosa* (which is better correlated with skin irritations) should also be regularly sampled to help determine the risk of ear and skin infection. If *Pseudomonas* concentrations do not appear to be well correlated with incidents of skin irritation, an attempt should be made to determine a better indicator organism. Once sufficient background data has been collected to determine trends and ambient levels of these indicator bacteria (likely over a two-year period), an objective may be proposed based on B.C. guidelines for secondary-contact recreation in marine environments.

Currently False Creek does not consistently meet the secondary-contact objective throughout the year, or in a given season. It also does not appear that all values that exceed the objective are linked to precipitation and CSO releases (see Section 3.3.5). More work should therefore be conducted to determine the sources of fecal contamination in False Creek. This should fall within a larger process such as an environmental health assessment outlined in the Canadian Water Quality Guidelines or a classification approach as identified in the WHO Guidelines. These steps in either of these approaches may include:

- a sanitary inspection, which identifies sources of fecal contamination (including sewage outfalls, CSO's, stormwater drains, pleasure boat discharges, and bather shedding);
- an analysis of the physical characteristics of the area and the data on microbiological water quality (the latter is discussed in this report); and
- an identification of factors likely to yield fecal contamination events (for example, rainfall levels resulting in releases from CSO's, increased pleasure boat traffic and therefore discharges during warm weather).

This could result in a classification for the area or other management actions, and would allow users to make informed choices about using the area for recreational activities according to the potential risk. Consistent with the approach of providing information to the public, the MoE has required the GVRD and/or member municipalities to post the locations of CSO outfalls. Under their LWMP the GVRD must now post signs on the shoreline adjacent to CSO outfalls that discharge into waters used for recreation. This will include CSO outfalls discharging into False Creek.

Reduce Discharges

As the eastern basin of False Creek (between the Cambie Street Bridge and Science World) consistently has the highest concentrations of enterococci and fecal coliforms, and yet is the most widely used portion of the basin recreationally, the majority of effort to isolate and minimize fecal contamination should be centered on this area. Outside of reducing discharges from CSO's and pleasure craft, as discussed earlier in this document, potential methods that would directly reduce existing levels of contaminants in the water should be examined. Feasibility studies for any methods to reduce fecal contamination would have to be conducted prior to implementation to determine their cost-effectiveness and likely benefits to the reduction of fecal contaminant levels.

Future Usage

Over the last 15 years, water uses in False Creek have changed substantially, as secondary contact recreational activities have become very popular in the waterbody. At this stage it appears appropriate to establish water quality objectives that are protective of such uses and user groups. As any future change in water use -such as moving to primary contact recreation- is difficult to predict at this time, it may be necessary for the Ministry and other stakeholders to periodically review the level of future recreational use, and whether further water quality objectives are warranted.

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Table 13. Comparison of GVRD/VHCA pooling geometric means for each basin with geometric means calculated for individual sites.

Western Basin (16, 18, 22, 23)		Geometric mean for individual sites (16, 18, 22, 23)					
Date of last sample	Pooled geometric means	Minimum	Maximum	Average	Difference (average - pooled)	% Difference	% Individual geometric means exceeding pooled geometric mean
Jun 26,2002	51.6	25.1	92.2	58.8	7.2	13.9%	50%
Jul 03,2002	24.4	12.9	37.6	26.4	2.0	8.2%	50%
Jul 10,2002	25.3	5.8	54.6	33.1	7.8	30.9%	75%
Jul 17,2002	22.4	9.3	49.1	26.4	3.9	17.6%	75%
Jul 24,2002	26.6	14.2	51.4	29.6	3.0	11.2%	50%
Jul 31,2002	23.8	17.6	47.6	26.1	2.3	9.8%	25%
Aug 07,2002	31.3	20.5	63.8	34.6	3.3	10.6%	25%
Aug 14,2002	26.4	17.9	35.7	27.5	1.0	3.9%	50%
Aug 21,2002	23.1	16.3	36.9	24.2	1.1	4.7%	25%
Aug 28,2002	17.2	14.2	20.0	17.2	0.0	0.2%	50%
Sep 04,2002	18.9	11.7	39.3	21.4	2.4	12.8%	50%
Sep 11,2002	15.8	13.0	23.6	16.8	0.9	6.0%	50%
Sep 18,2002	12.6	9.7	15.2	12.7	0.1	0.7%	50%
Sep 25,2002	13.0	9.2	46.5	20.1	7.2	55.3%	50%
Oct 02,2002	11.0	7.6	46.5	18.5	7.5	68.5%	50%
Oct 09,2002	9.8	7.7	23.5	12.0	2.3	23.1%	25%
Oct 16,2002	8.2	6.5	9.5	8.4	0.2	2.1%	75%
Oct 23,2002	9.6	6.7	14.6	10.0	0.3	3.5%	50%
Oct 30,2002	7.4	5.2	9.2	7.5	0.1	1.0%	50%
Nov 06,2002	13.6	9.1	19.1	14.2	0.6	4.3%	50%
Nov 13,2002	25.6	19.6	35.3	26.5	0.9	3.4%	50%
Nov 20,2002	58.8	44.9	90.5	61.2	2.4	4.1%	50%
Nov 27,2002	53.2	35.0	84.4	55.9	2.7	5.1%	50%
Dec 04,2002	64.1	33.5	137.6	74.9	10.7	16.7%	50%
Dec 11,2002	83.9	46.2	187.8	98.7	14.8	17.7%	50%
Dec 18,2002	98.3	60.2	189.2	110.4	12.2	12.4%	50%

Table 13 (continued)

Central Basin (17, 19)		Geometric mean for individual sites (17, 19)					
Date of last sample	Pooled geometric means	Minimum	Maximum	Average	Difference (average - pooled)	% Difference	% Individual geometric means exceeding pooled geometric mean
Jun 26,2002	35.8	14.1	90.9	52.5	16.7	46.8%	50%
Jul 03,2002	13.1	4.8	36.0	20.4	7.2	55.1%	50%
Jul 10,2002	9.9	5.1	18.9	12.0	2.2	21.9%	50%
Jul 17,2002	7.3	4.5	11.8	8.1	0.9	12.0%	50%
Jul 24,2002	6.7	4.2	10.7	7.4	0.7	10.9%	50%
Jul 31,2002	7.3	5.4	9.7	7.6	0.3	4.3%	50%
Aug 07,2002	11.7	9.7	14.2	12.0	0.2	1.9%	50%
Aug 14,2002	7.8	5.7	10.8	8.3	0.4	5.1%	50%
Aug 21,2002	9.8	9.7	10.0	9.8	0.0	0.0%	50%
Aug 28,2002	10.2	9.5	10.9	10.2	0.0	0.2%	100%
Sep 04,2002	8.9	8.0	9.9	9.0	0.1	0.6%	50%
Sep 11,2002	4.4	4.1	4.6	4.4	0.0	0.2%	100%
Sep 18,2002	4.4	3.5	5.5	4.5	0.1	2.6%	100%
Sep 25,2002	3.2	3.1	3.4	3.2	0.0	0.1%	100%
Oct 02,2002	3.2	2.9	3.5	3.2	0.0	0.5%	100%
Oct 09,2002	3.4	2.9	4.0	3.4	0.0	1.4%	100%
Oct 16,2002	4.2	3.8	4.7	4.2	0.0	0.6%	50%
Oct 23,2002	6.1	5.3	7.1	6.2	0.1	1.1%	50%
Oct 30,2002	8.8	6.7	11.7	9.2	0.4	4.0%	100%
Nov 06,2002	17.6	14.1	22.0	18.0	0.4	2.5%	100%
Nov 13,2002	39.7	33.0	47.9	40.4	0.7	1.7%	100%
Nov 20,2002	92.4	62.2	137.2	99.7	7.3	7.9%	50%
Nov 27,2002	84.6	60.6	118.3	89.4	4.8	5.7%	50%
Dec 04,2002	91.6	88.6	94.7	91.7	0.0	0.1%	0%
Dec 11,2002	118.5	113.5	123.7	118.6	0.1	0.1%	0%
Dec 18,2002	124.8	123.7	126.0	124.8	0.0	0.0%	50%

Table 13 (continued)

Eastern Basin (20, 20A, 20C, 21A, 21B)		Geometric mean for individual sites (20, 20A, 20C, 21A, 21B))					
Date of last sample	Pooled geometric means	Minimum	Maximum	Average	Difference (average - pooled)	% Difference	% Individual geometric means exceeding pooled geometric mean
Jun 26,2002	149.3	50.4	237.2	158.3	9.0	6.0%	50%
Jul 03,2002	117.2	31.9	206.4	152.9	35.7	30.4%	75%
Jul 10,2002	92.6	36.9	159.7	110.1	17.5	18.9%	50%
Jul 17,2002	91.3	36.6	163.6	104.0	12.7	13.9%	75%
Jul 24,2002	103.2	36.2	214.8	124.6	21.4	20.7%	50%
Jul 31,2002	106.0	33.4	219.2	130.6	24.6	23.2%	50%
Aug 07,2002	166.4	93.4	239.4	176.3	9.9	5.9%	75%
Aug 14,2002	159.1	69.3	263.7	177.2	18.1	11.4%	75%
Aug 21,2002	176.1	57.2	365.9	214.1	38.0	21.6%	75%
Aug 28,2002	115.5	50.4	205.2	131.3	15.8	13.7%	50%
Sep 04,2002	124.9	66.0	401.0	165.1	40.3	32.2%	25%
Sep 11,2002	67.3	41.6	162.6	79.5	12.2	18.1%	50%
Sep 18,2002	58.7	38.7	124.7	65.8	7.1	12.1%	25%
Sep 25,2002	47.4	34.7	84.9	50.9	3.5	7.3%	50%
Oct 02,2002	56.9	31.6	154.5	70.6	13.7	24.1%	50%
Oct 09,2002	71.5	51.8	95.3	73.2	1.7	2.4%	50%
Oct 16,2002	84.5	66.9	131.5	87.8	3.4	4.0%	50%
Oct 23,2002	80.4	75.9	87.0	80.5	0.1	0.2%	50%
Oct 30,2002	44.1	35.7	52.5	44.6	0.5	1.2%	50%
Nov 06,2002	43.6	37.4	57.6	44.2	0.6	1.5%	25%
Nov 13,2002	52.3	40.9	71.1	53.5	1.2	2.3%	50%
Nov 20,2002	74.2	60.7	105.3	76.1	1.9	2.6%	50%
Nov 27,2002	50.8	38.5	59.4	51.5	0.7	1.3%	75%
Dec 04,2002	80.9	74.5	90.0	81.1	0.3	0.3%	50%
Dec 11,2002	111.8	106.6	120.2	112.0	0.1	0.1%	25%
Dec 18,2002	124.5	115.3	139.3	124.8	0.3	0.3%	50%