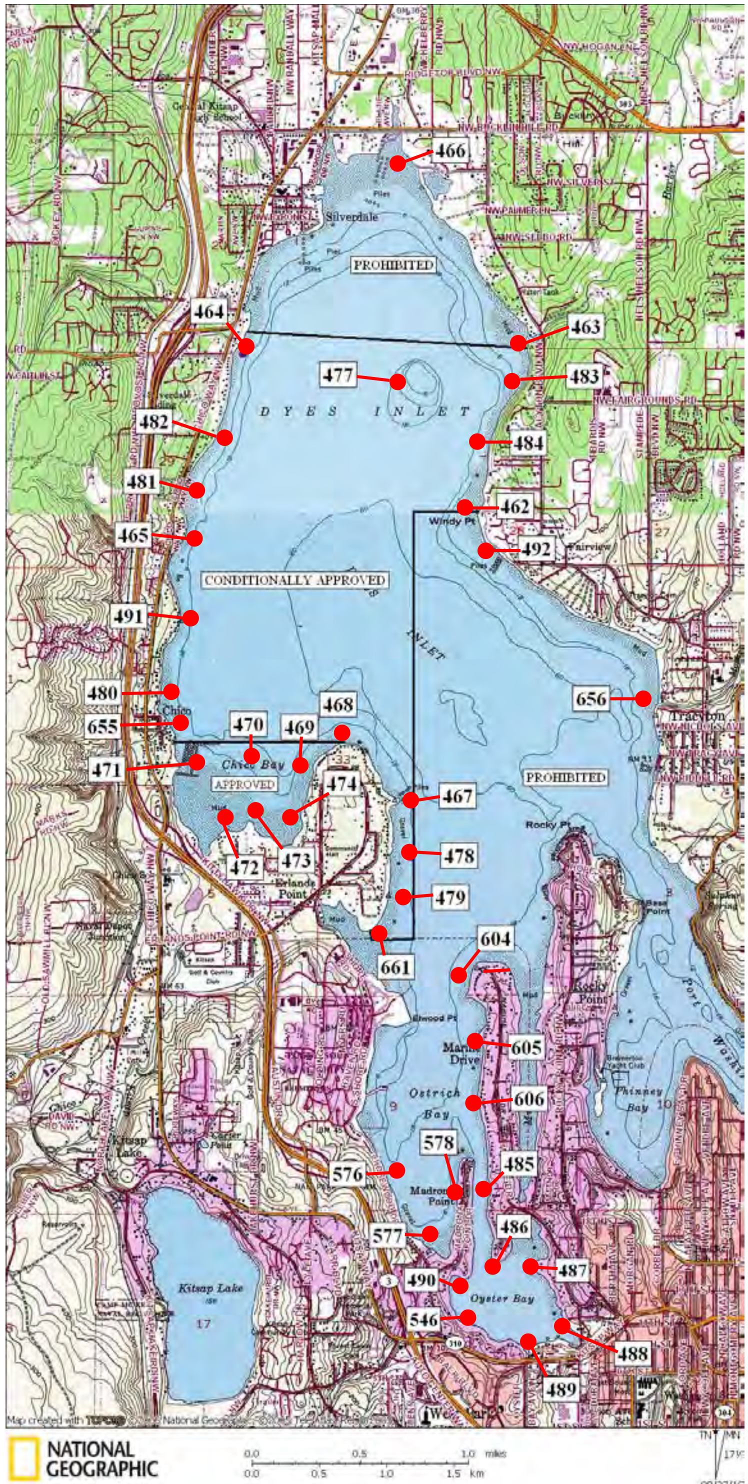
Status and Trends Summary

Fecal Coliform Pollution in Dyes Inlet: Year 2009



October 2010

Washington State Department of Health

PSAMP
Puget Sound Assessment and Monitoring Program

Remedial Action Summary in Dyes Inlet

The State ordered shellfish harvest in Dyes Inlet to cease in the 1950s due to nonpoint sources and raw sewage discharges. Over the years, direct discharges of raw sewage have been greatly reduced. At this time, discharges of sewage occur only through combined sewer overflows (CSOs) following heavy rains. In early 1993, the Washington State Department of Health (DOH) started sampling in Chico Bay leading to its reclassification to Restricted to permit relay of shellfish to cleaner waters.

The Dyes Inlet watershed supports a wide range of land uses: rural, suburban, high density residential and commercial. Potential fecal pollution sources include failed onsite sewage systems, waste from farm animals, combined stormwater-sewer overflows (CSOs), and contaminated stormwater runoff. Kitsap County and the City of Bremerton, guided by rigorous water quality monitoring and a U.S Navy water quality modeling study, found and fixed numerous fecal pollution sources. In 2003, DOH reopened 1500 acres of shellfish grounds following intensive local remedial action. Recent projects include:

- reduction of untreated CSO discharge (City of Bremerton);
- inspection and repair of failed onsite sewage systems (Kitsap County Health District);
- improved manure management (local rural landowners and Kitsap Conservation District), and stormwater system maintenance and source control.

Harvest is closed after excessive discharge of treated or untreated effluent through the remaining CSOs. The north and southeastern ends remain classified as Prohibited. (See boundaries on cover.)

Monitoring Fecal Pollution in Shellfish Growing Areas

DOH protects consumers from eating shellfish contaminated by pollution. The Department continually monitors marine water for fecal pollution in shellfish growing areas and searches for pollution sources on shorelines and adjacent uplands.

Systematic Random Sampling (SRS). The Department uses a systematic random sampling (SRS) method mandated by the National Shellfish Sanitation Program (NSSP) to monitor shellfish growing areas. DOH measures levels of fecal bacteria in water samples collected at sampling stations in each area. Under SRS, samples are collected at relatively even intervals over time. SRS purposely avoids targeting specific environmental factors, such as season, weather, tide, etc. SRS also requires substantial data (30 results) to calculate statistics used to classify growing areas. Thus, DOH data represents a wide range of environmental conditions encountered in the growing area. SRS ensures that unbiased, high-quality data are available for DOH tasks.

NSSP Growing Area Criteria. DOH uses the data gathered under SRS to classify shellfish beds according to level of fecal pollution. DOH applies the following NSSP criteria exclusively to areas potentially affected by nonpoint fecal pollution sources:

- The concentration of fecal coliform bacteria cannot exceed a geometric mean of 14 organisms per 100 milliliters (ml) in water (applied in all cases).
- The estimated 90th percentile cannot exceed 43 organisms per 100 ml of water

The Department uses a minimum of 30 results to calculate the criteria. Appendix A (page 11) explains how DOH uses NSSP criteria to classify shellfish growing areas.

DOH has reported status and trends for the Puget Sound Assessment and Monitoring Program (PSAMP) since 1998. The Department also uses the information to report progress on local remedial action programs.

Status and Trends Analysis for Dyes inlet

To analyze status and trends in Dyes Inlet, DOH selected stations with the longest, most complete record of fecal coliform data. DOH calculated NSSP statistics (geometric means and 90th percentiles) for these stations from the earliest date possible (i.e., those stations with the minimum required 30 results: see paragraph above) and for all subsequent sampling dates through the end of calendar year 2009.

DOH takes the same initial analytical step for long-term status and trends analysis as it takes to classify a growing area. However, data analysis for classification may require additional sorting and editing of the data to evaluate the effect of short-term pollution factors. For example, it is sometimes necessary to evaluate the impact of environmental effects, such as rainfall, on the classification of a growing area (see Appendix A, “Classifying Shellfish Growing Areas”, page 9).

DOH uses 90th percentiles to make inferences about status and trends because 90th percentiles are more sensitive to changes in pollution conditions than geometric means. Note that the time-series graphs in Figure 2 (pages 6-9) show both geometric means and 90th percentiles.

Status of fecal pollution at each station in Dyes Inlet in 2009.

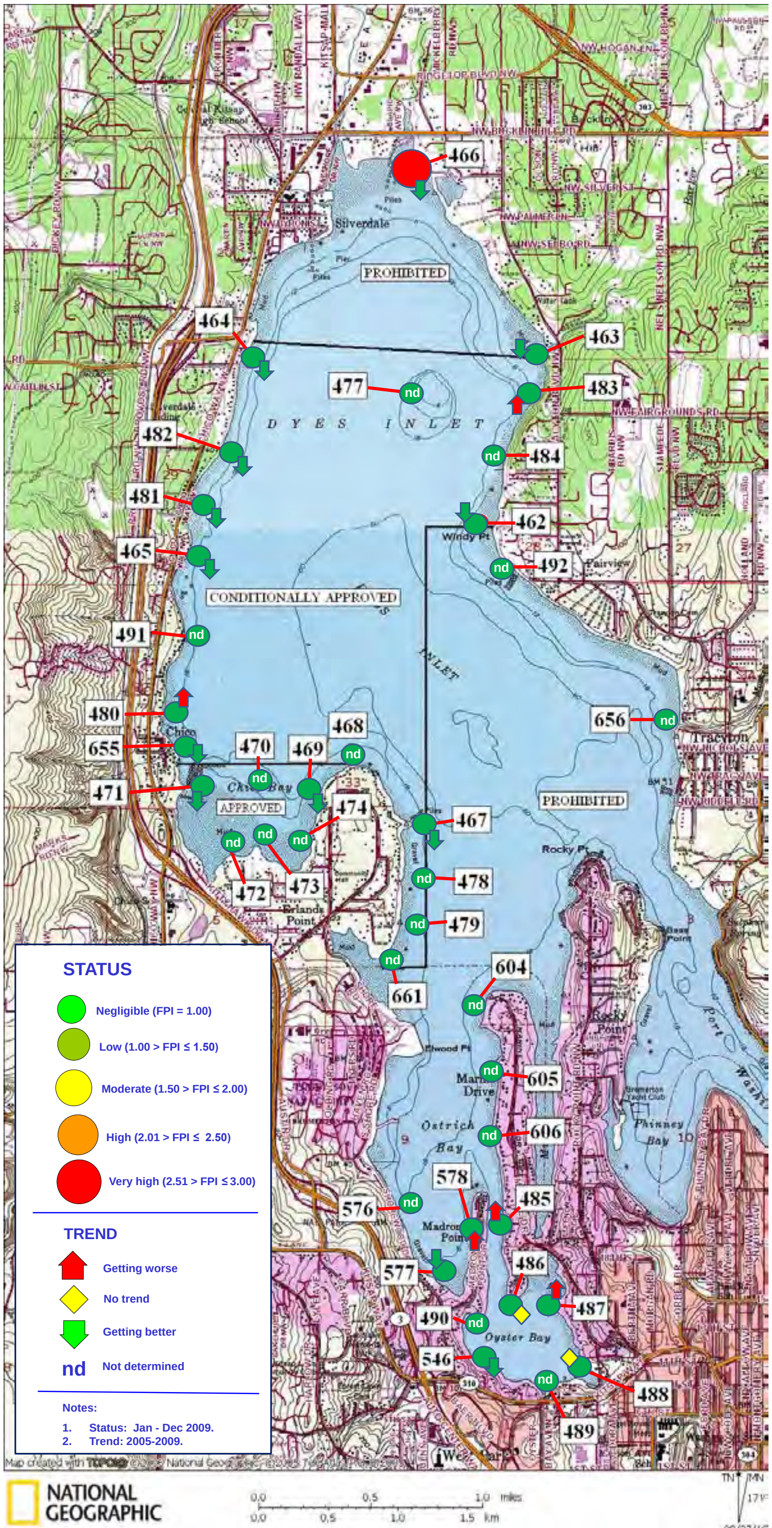
DOH developed a “Fecal Pollution Index” (FPI) to provide a single value to describe the annual status of fecal pollution. The FPI ranges from 1.0 (100% of stations show negligible pollution) to 3.0 (100% of stations show maximum pollution). Appendix B (page 13) shows the how the FPI is derived. The FPI can be applied at several geographic levels (sampling station, growing areas, regions within Puget Sound, or Puget-Sound wide). Figure 1 shows the status of fecal pollution at each station in Dyes Inlet for calendar year 2009 according to its annual FPI.

Trend of fecal pollution at each station in Dyes Inlet 2004-2009.

Figure 1 also shows the trend in fecal pollution at each station for the most recent 5-year period (2005-2009). A green arrow pointing down means fecal pollution decreased. A red arrow pointing up means fecal pollution increased. A yellow diamond means no significant change occurred. The abbreviation "nd" means that trend was not determined because the 90th percentiles were too low (less than 10 MPN per 100ml), or the record of 90th percentiles was too short (less than 3 years long). (Some stations in the "nd" category had both very low 90th percentiles and short records.) "Spearman's Rho" (a "nonparametric" test based on ranked data) statistically tested the significance of the 5-year trends (significant at $p<0.05$).

Figure 2 shows graphs of NSSP statistics (geometric means and 90th percentiles) for seven selected stations in Dyes Inlet for the period from 1998 through 2009. The selected stations were among those most significantly affected by fecal pollution over the decade.

Figure 1. Status and trends in fecal pollution at Dyes inlet through 2009.



General Observations from Figure 1:

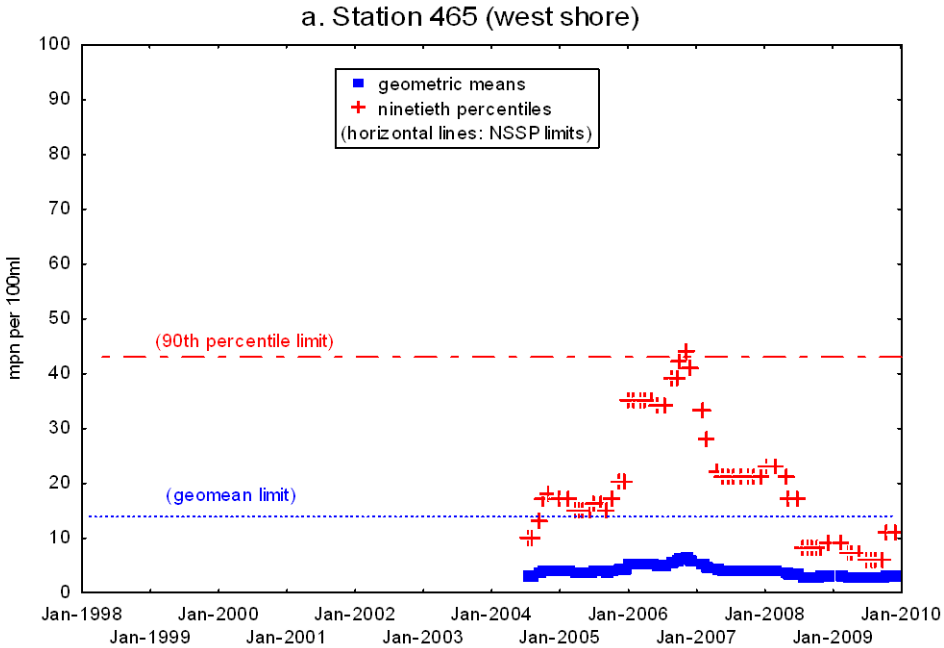
- All stations but one showed negligible fecal pollution (FPI = 1.00) during 2009. Station 466 (Clear Creek mouth near Silverdale) showed very high pollution (FPI = 2.89).
- A third of 30 stations showed reduced pollution in the last 3-5 years, including Station 466 (Clear Creek mouth near Silverdale).
- Five stations showed increasing trend, although fecal pollution at these sites was negligible.
- Trend at nearly half the stations was not determined because 90th percentiles were too low to justify analysis (less than 10 MPN per 100ml).

Trends Analysis for Selected Individual Stations in Dyes Inlet

Initial screening (using box plots of 90th percentiles) showed seven sites among all stations in Dyes Inlet to have exceeded the threshold level of fecal pollution for trend analysis (10 MPN per 100ml) sometime in the last five years. These stations were selected for graphical analysis of trend. Figure 2 shows graphs of NSSP statistics (geometric means and 90th percentiles) at each of the seven stations for the period 1998 through 2009. Station 466 (the most affected) is located at the northern end of Dyes Inlet near Silverdale. Four stations (stations 471-473, 655) are located either in or very near Chico Bay. The sixth station (Station 465) lies along the west shore roughly a third of the way between Chico and Silverdale. A seventh site (Station 577) is in the south end of Ostrich Bay. (See Figure 1 for locations of the stations).

Note that the 90th percentiles show a greater response to changing pollution conditions than the geometric means. Thus, DOH used 90th percentiles to analyze trends.

Figure 2. Trend in geometric means and ninetieth percentiles (NSSP statistics) from 2000 through 2009 at selected DOH stations in Dyes Inlet.



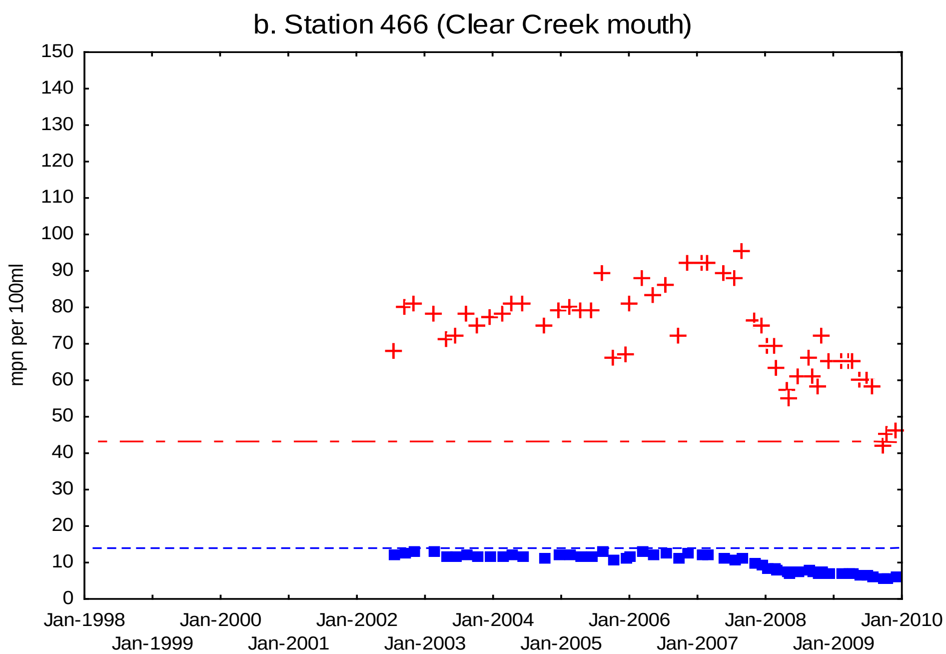
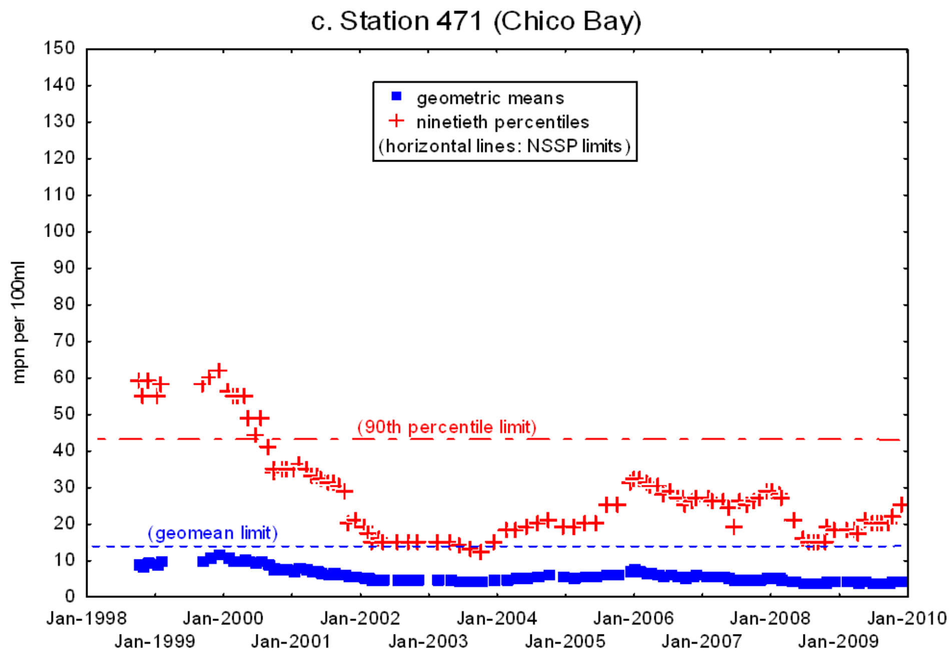


Figure 2. (Cont.)



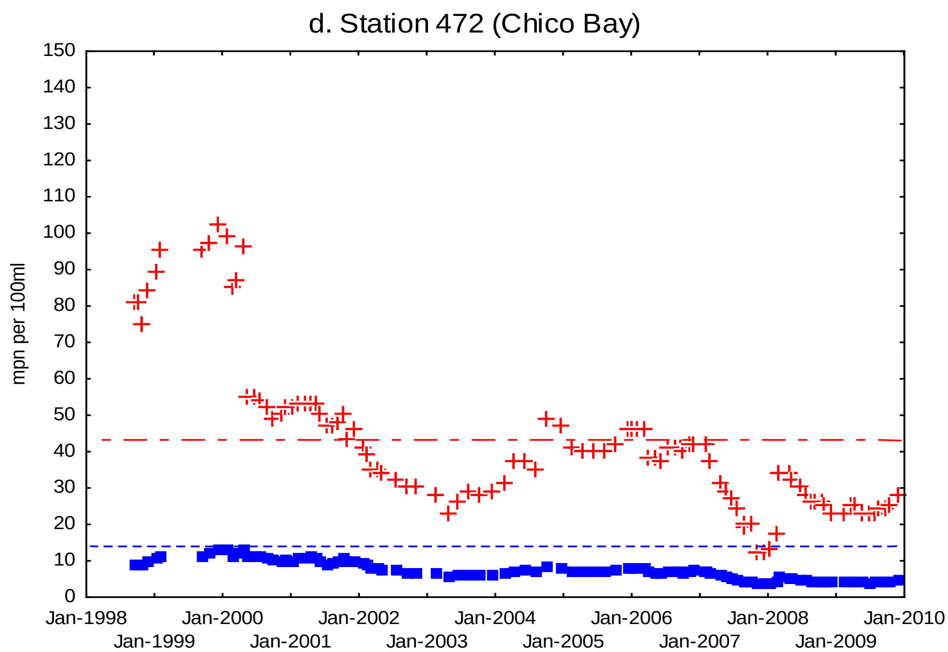
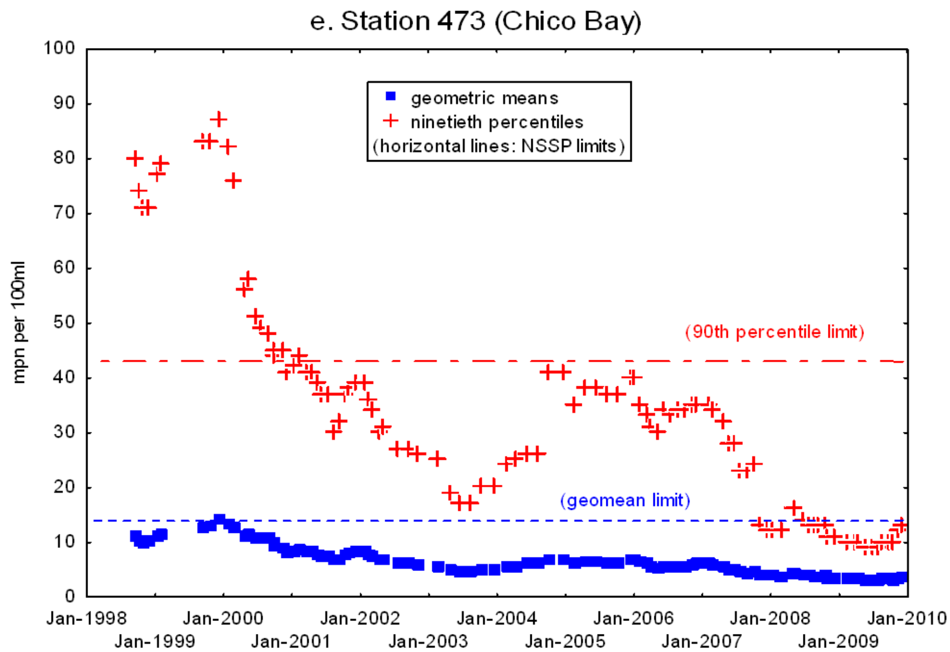


Figure 2. (Cont.)



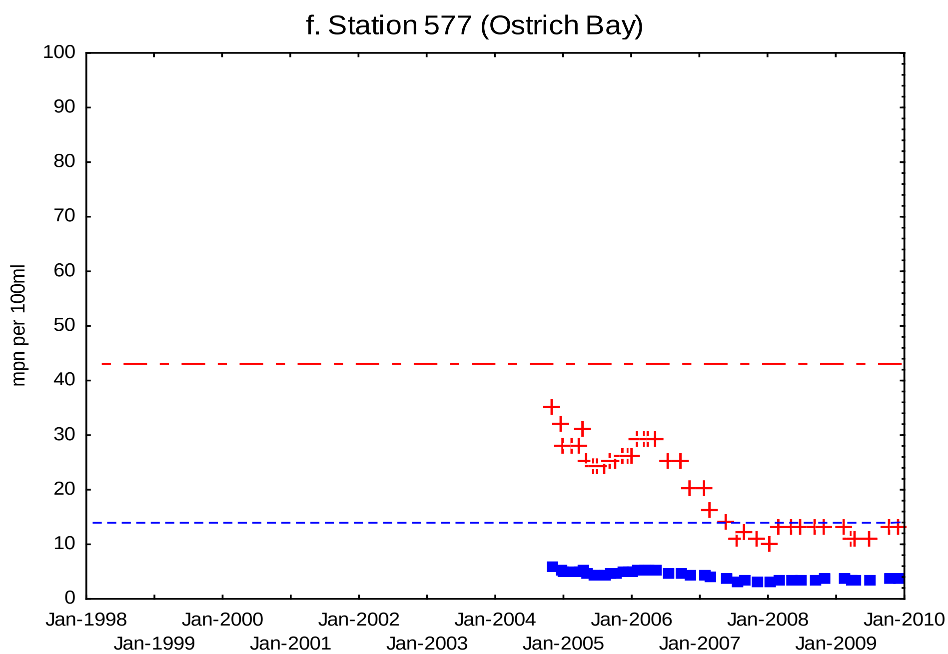
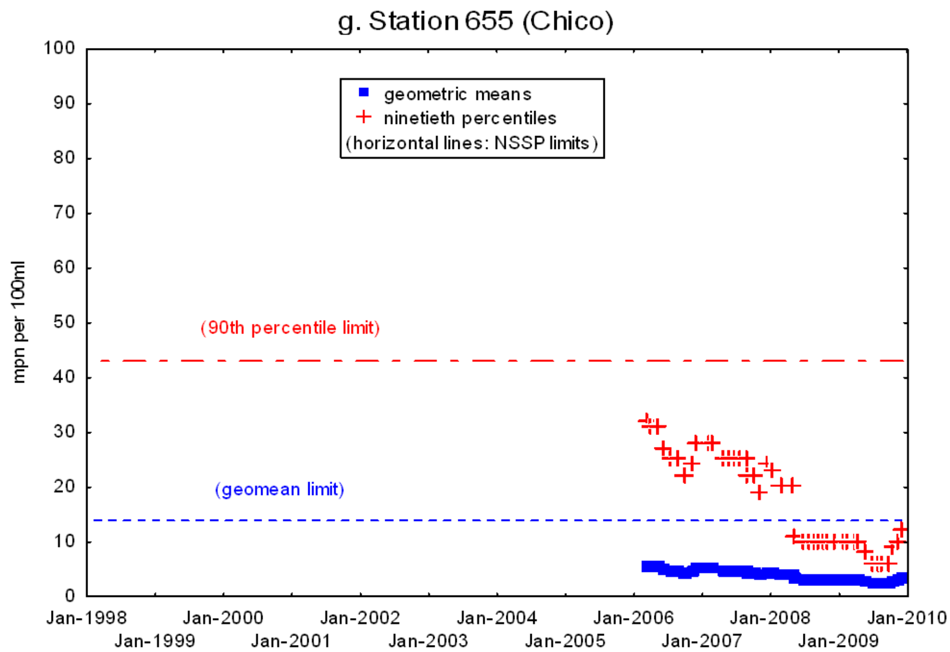


Figure 2. (Cont.)



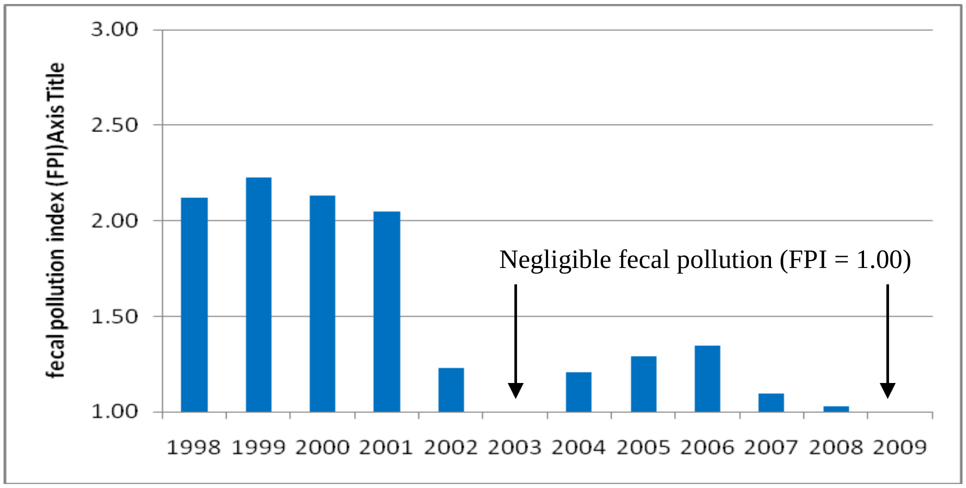
General Observations from graphs in Figure 2:

- Fecal pollution at Station 466 (Clear Creek near Silverdale) was substantial from 2002 through 2007. Although still very high, fecal pollution may have dropped in the last two years. The significance of this drop is yet uncertain.
- Stations in Chico Bay (stations 468-474) have the longest record of 90th percentiles in Dyes Inlet. All stations show overall decline in fecal pollution during the past decade.
- The Chico Bay stations and Station 465 show that overall reduction in fecal pollution was interrupted by a period of less intensive contamination in the period 2005-2007.
- Although the records of 90th percentiles at stations 465, 577 (Ostrich Bay), and 655 (near Chico) have relatively short records, the plots suggest reduced fecal pollution.

Fecal Pollution Trend in Chico Bay, Dyes Inlet 1998-2009

Figure 3 extends the concept of the Fecal Pollution Index (FPI) to all “historical” stations in Dyes Inlet. “Historical” stations are those with NSSP statistics for the entire period of interest (1998-2009). The “historical” stations in Dyes Inlet are limited to those in Chico Bay. In Chico Bay, an annual FPI was calculated from 90th percentiles pooled from all dates and stations for each year from 1998 through 2009 (see Appendix B, page 13).

Figure 3. Trend in fecal coliform pollution in Chico Bay, Dyes Inlet 1998-2009. Fecal pollution was negligible (FPI = 1.00) in 2003 and 2009).



General Observations from Figure 3:

- Fecal pollution in Chico has dropped substantially over the past decade.
- There appears to have been a period of significant secondary fecal pollution during the mid-2000s. The cause is unknown.

Appendix A. Classifying Shellfish Growing Areas

DOH applies guidelines set by the National Shellfish Sanitation Program (NSSP). Each harvest area is classified into one or more of four categories:

- An area is classified **Approved** for unlimited harvest if water quality criteria are met and significant pollutant sources are absent.
- An area is classified **Conditionally Approved** if water quality criteria are met, except during pollution events that are e*pisodic* and *predictable*, such as rain-related runoff. Harvests from Conditionally Approved areas require a "Conditionally Approved Area Management Plan" (or CAAMP).
- An area is classified **Restricted** if it is subject to limited pollution. Shellfish from Restricted areas cannot be harvested directly. They may be "relayed" under strict supervision to clean waters for natural cleansing.
- If an area receives pollution that is *chronically excessive* and/or *unpredictable*, it is classified **Prohibited** (P).

To classify a growing area, DOH evaluates two questions:

1. Does the area comply with the NSSP requirements for unlimited harvest of shellfish (Approved)?
2. If unlimited harvesting is not possible, are there conditions under which harvesting can be done (Conditionally Approved)?

Question 1: Does an area comply with Approved classification? DOH collects water samples in the growing area according to SRS (see **Introduction** on page 3). NSSP requires at least 30 samples be collected from each sampling station in a growing area. DOH calculates a geometric mean and a 90th percentile from the 30 results. These are compared to the NSSP criteria. Both the geometric mean and 90th percentile must meet the NSSP criteria.

1. The concentration of fecal coliform bacteria cannot exceed a geometric mean of 14 organisms per 100 milliliters (ml) in water (applied in all cases).
2. The estimated 90th percentile cannot exceed 43 organisms per 100 ml of water (applied to areas potentially affected by only nonpoint sources); OR not more than ten percent of the samples are to exceed 43 organisms per 100 ml of water (applied where point sources are present).

Besides the collection of fecal pollution data, DOH carries out a "shoreline survey" of the upland watershed and the marine shoreline to find and assess pollution sources. DOH cannot approve an area if the shoreline survey reveals pollution that presents a public health hazard, even if the water quality meets the NSSP criteria. If statistics from all stations meet the NSSP criteria and the shoreline survey does not reveal significant pollution that presents a public health hazard, DOH classifies the area Approved.

Question 2. Can a growing area be classified Conditionally Approved? If a shellfish growing area cannot be classified as Approved, DOH looks at the data to see if it can be classified Conditionally Approved. If conditions are found that would allow safe harvest, DOH prepares a "Conditionally Approved Area Management Plan" (CAAMP) for the area.

DOH examines the affect of various pollution factors in a growing area. Pollution factors include rainfall, seasonality, river flooding, or seasonal boat activity. The most common Conditionally Approved classification is based on 24-hour rainfall. To set the rain-related condition, statistics are recalculated from edited data (i.e., fecal coliform results from the rainiest days are removed) to see if an upper limit on 24-hour rainfall exists below which harvest can be done. DOH puts the rainfall limit into a "Conditionally Approved Area Management Plan" (CAAMP) for the area. DOH removed the rainfall-based CAAMP in 1998 when Dyes Inlet was reclassified from Conditionally Approved to Approved.

Appendix B. Derivation of the Annual Fecal Pollution Index (FPI)

The fecal pollution index (FPI) is a single number that describes the annual status of fecal pollution. FPIs can be applied to any level of resolution: sampling station, growing area, region, or all of Puget Sound.

We will use Dungeness Bay in 2008 as an example to show how to derive the FPI, and show how the FPI can be used to show annual impact at an individual sampling station, at the level of the growing area, or trend on the growing area. To begin, we calculate the estimated 90th percentiles for each station and sampling date in 2008.

After the 90th percentiles are calculated, we follow the steps described below (cross-referenced with color-coded text in Table B-1 (next page).

Step 1. NUMBERS. Sort the estimated 90th percentiles from each station into categories:

- "GOOD" (90th percentiles ≤ 30 mpn/100ml)
- "FAIR" (30 mpn/100ml < 90th percentiles ≤ 43 mpn/100ml)
- "BAD" (90th percentiles > 43 mpn/100ml)

Table D-1 shows that Station 113 had **four** GOOD 90th percentiles, **four** FAIR 90th percentiles, and **4** BAD 90th percentiles during 2008 (in columns b-d in Table D-1).

Step 2. FRACTIONS. For each station, divide the number of estimated 90th percentiles in each category by the total 90th percentiles in all categories. For Station 113, **four** GOOD 90th percentiles (column b) ÷ **12** total 90th percentiles (column e) = **0.33** (in column f).

Step 3. WEIGHTED FRACTIONS. Now, "weight" each fraction by multiplying it by a weighting factor:

- "GOOD" fractions × 1.00
- "FAIR" fractions × 2.00
- "BAD fractions" × 3.00

For example, for Station 113: the weighted FAIR fraction (**0.33** in column g) × 2.00 = **0.67** (in column j).

Step 4. FPI. Finally, add the weighted fractions. The sum is the fecal pollution index for each station. The FPI will range from 1.00 (100% of estimated 90th percentiles are GOOD) to 3.00 (100% of 90th percentiles are BAD). For example, the FPI for Station 113 (column l): (**0.33** + **0.67** + **1.00**) = **2.00**.

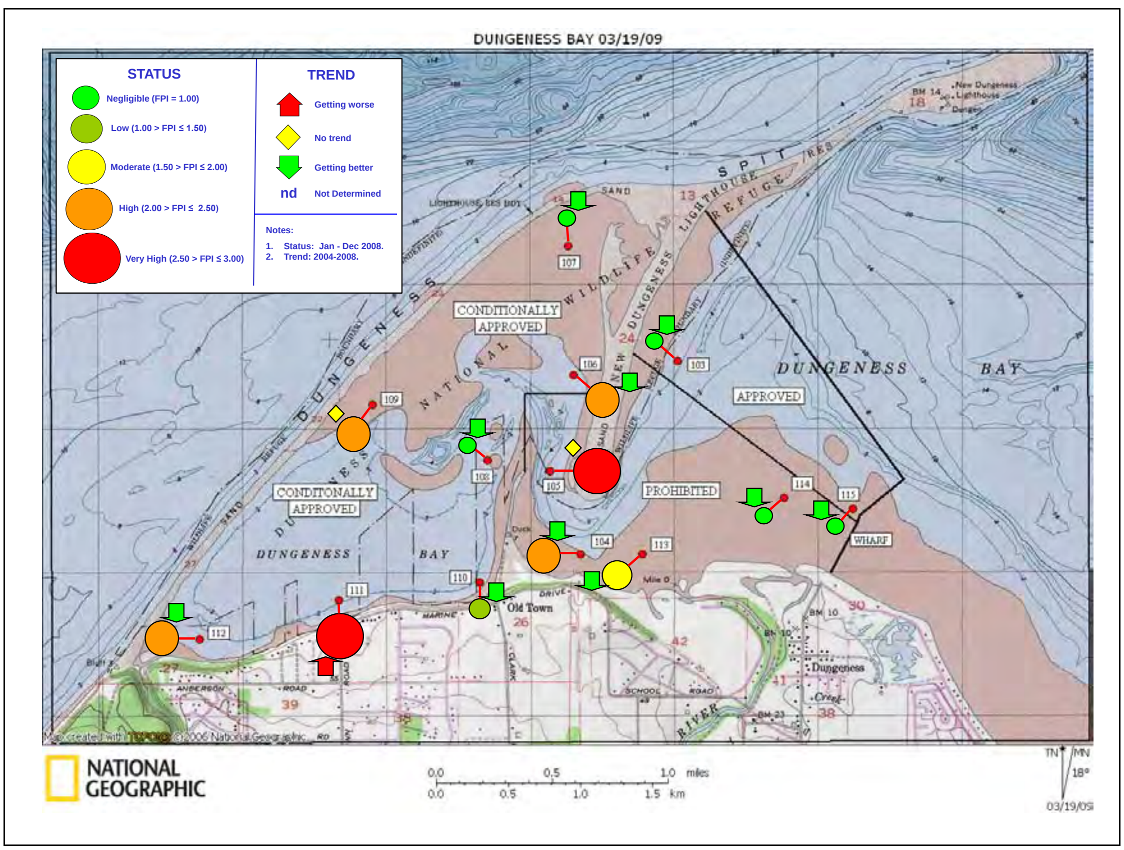
Figure B-1 uses the fecal pollution index at sampling stations in Dungeness Bay to characterize how fecal pollution was distributed in 2008.

Growing Area and Puget Sound FPI. To calculate the annual FPI for Dungeness Bay in 2008, we sum the numbers within each category for *all* stations (TOTAL DB line in Table B-1) and repeat the steps described above. The annual FPI for Dungeness Bay in 2008 was **1.57**. By extending the method to all stations in all Puget growing areas, the annual FPI for Puget Sound in 2008 was **1.16**.

Table B-1 summarizes FPI calculations for Dungeness Bay and Puget Sound in 2008.

(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)	(k)	(l)
	NUMBERS				FRACTIONS			WEIGHTED FRACTIONS			
STATION	GOOD	FAIR	BAD	TOTAL	GOOD	FAIR	BAD	GOOD	FAIR	BAD	FPI
103	11	0	0	11	1.00	0.00	0.00	1.00	0.00	0.00	1.00
104	0	0	12	12	0.00	0.00	1.00	0.00	0.00	3.00	3.00
105	6	6	0	12	0.50	0.50	0.00	0.50	1.00	0.00	1.50
106	0	12	0	12	0.00	1.00	0.00	0.00	2.00	0.00	2.00
107	11	1	0	12	0.92	0.08	0.00	0.92	0.17	0.00	1.08
108	8	4	0	12	0.67	0.33	0.00	0.67	0.67	0.00	1.33
109	11	1	0	12	0.92	0.08	0.00	0.92	0.17	0.00	1.08
110	7	6	0	13	0.54	0.46	0.00	0.54	0.92	0.00	1.46
111	0	8	4	12	0.00	0.67	0.33	0.00	1.33	1.00	2.33
112	11	0	0	11	1.00	0.00	0.00	1.00	0.00	0.00	1.00
113	4	4	4	12	0.33	0.33	0.33	0.33	0.67	1.00	2.00
114	12	0	0	12	1.00	0.00	0.00	1.00	0.00	0.00	1.00
115	12	0	0	12	1.00	0.00	0.00	1.00	0.00	0.00	1.00
TOTAL DB	81	42	20	143	0.57	0.29	0.14	0.57	0.59	0.42	1.57
TOTAL PS	7962	436	506	8897	0.89	0.05	0.06	0.89	0.10	0.17	1.16

Figure B-1 shows fecal pollution impact at each sampling station in in Dungeness Bay in 2008.



Temporal Trend Using FPI. The method is modified slightly to calculate annual "historical" FPIs for tracking change over time. "Historical" means that we use only 90th percentiles from stations with a continuous sampling history. We eliminate 90th percentiles from stations that were either dropped or added over time. Following the initial edit, we calculate an annual FPI for each year (1998 through 2008). Figure B-2 (below) shows the trend in "historical" FPIs in Dungeness Bay from 1998 through 2008.

Figure B-2. Fecal Pollution impact in Dungeness Bay 1998-2008.