A Department of Ecology Report

Grays Harbor Fecal Coliform Bacteria Monitoring to Characterize Water Quality in Urban Stormwater Drains

October 2011

Abstract

This report describes fecal coliform monitoring performed in 2010/2011 to characterize water quality in urban stormwater drains effecting Grays Harbor. The sites are located in the cities of Cosmopolis, Aberdeen and Hoquiam.

Grays Harbor is a large estuary in Southwest Washington (Figure 1) Water Resource Inventory Area 22. Grays Harbor was on the list of the Department of Ecology's (Ecology) impaired waters (303(d) list) for fecal coliform (FC) bacteria in 1996. This prompted Ecology's Environmental Assessment Program to conduct a Total Maximum Daily Load (TMDL) study during March 1997 – April 1998. Sampling of representative urban storm drains in the inner harbor was added as part of the TMDL. Samples from the storm drains were collected February through April 1998 (Pelletier et al., 2000). The TMDL set a loading reduction target for the drains as a whole based on the water quality criterion that allows for a geometric mean concentration of 100 colonies/100 mL, with no more than 10 percent of samples greater than 200 colonies/100 mL. The overall goal of the 2010/2011 monitoring project was to characterize FC bacteria concentrations in urban stormwater drains in the cities of Aberdeen, Hoquiam, and Cosmopolis during the wet season of 2010/2011 and compare them to the 1998 study. Statistical comparisons were not made between the study years due to the low number of samples in 1998. All 16 urban drain sites and both stream sites failed to meet the water quality criterion. Efforts should be made by all three cities to reduce sources of bacteria to the stormwater systems.

Publication Information

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Background

Introduction

Grays Harbor estuary is located in southwest Washington (Figure 1) Water Resource Inventory Area 22. The drainage area for Grays Harbor is approximately 2,550 square miles. The large tributaries include the Chehalis, Hoquiam, Wishkah, Humptulips, Johns, and Elk Rivers.

Grays Harbor was on the list of Ecology's impaired waters (303(d) list) for fecal coliform (FC) bacteria in 1996. This prompted Ecology's Environmental Assessment Program to conduct a Total Maximum Daily Load (TMDL) study during March 1997 – April 1998 (Pelletier et al., 2000). Fecal coliform sampling was conducted for both the inner and outer harbor. Details for sampling the urban drains from the Aberdeen, Hoquiam, and Cosmopolis area were not detailed in the original Quality Assurance Project Plan (QAPP) for the TMDL (Pelletier, 1997). However, high concentrations were found in an earlier study monitoring FC bacteria in urban drains during July 1987 (Pelletier et al., 1988). Additionally, shellfish growers in the outer harbor were experiencing repeated closures due to FC bacteria in concentrations higher than accepted limits. As a result, sampling of representative urban storm drains was added as part of the TMDL during the wet season, February 1998 – April 1998, in the inner harbor. The TMDL set a loading reduction target for the drains as a whole. The report states that a 98% reduction was needed to meet the water quality criterion (Pelletier et al., 2000). The criterion allows for a geometric mean concentration of 100 colonies/100 mL, with no more than 10 percent of samples greater than 200 colonies/100 mL (Ecology, 1997). Two streams, Mill Creek and Fry Creek, were also sampled for this study since they act as stormwater conveyances (Seiders, 2010), but they are not part of the urban drain load allocation. The water quality criterion for the streams is the same as for the urban drains.

Study purpose

Ecology conducted this study to follow-up on the high bacteria concentrations identified in the urban drains during the 1997/1998 TMDL.

The overall goal of the monitoring project was to characterize FC bacteria concentrations in select urban stormwater drains in the cities of Aberdeen, Hoquiam, and Cosmopolis during the wet season of 2010/2011.

The objectives established to meet this goal are:

1. Include the cities of Aberdeen, Hoquiam, and Cosmopolis in the study planning and invite them to participate in implementation.
2. Collect, analyze, and interpret FC bacteria data to determine if the standard by which the load allocation was based is being met. The criterion states that the geometric mean of the samples must not exceed 100 colonies/100mL with 10% of the samples not to exceed 200 colonies/100mL.
3. Compare data collected in 2010/2011 to the 1998 TMDL data set.
4. Make the data obtained from this study available to the cities of Aberdeen, Hoquiam, and Cosmopolis for their use in protecting water quality.

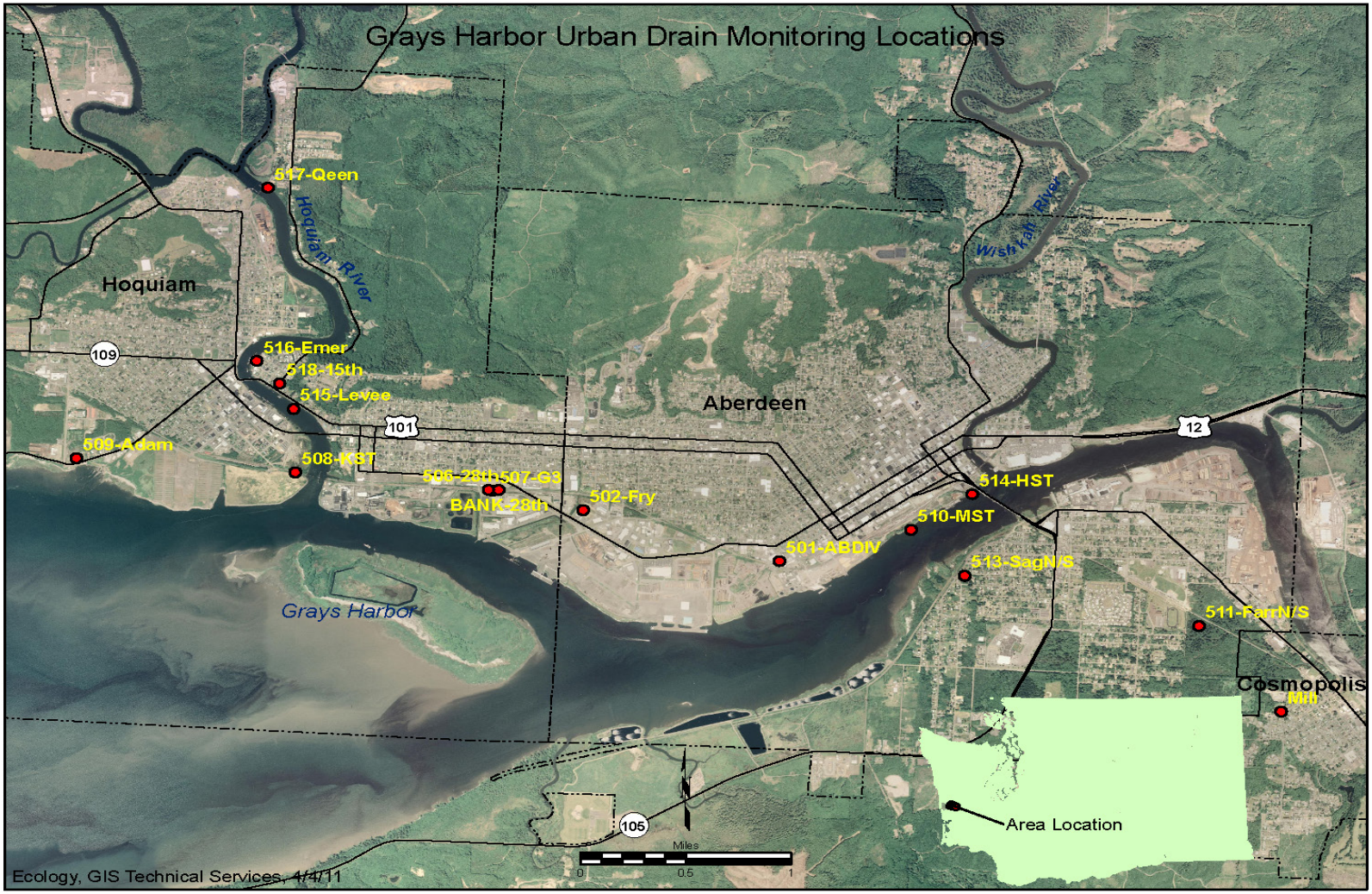

Figure 1. Sampling locations for this study.

Methods

Ecology project staff collected water quality data from 16 storm drains and two streams in Cosmopolis, Aberdeen, and Hoquiam. Water samples were collected for FC bacteria. The sites were chosen based on sites sampled in the previous TMDL (Pelletier et al., 2000). The city of Aberdeen staff was instrumental in choosing more representative and safer site locations as well as assisting with sampling. The sites are displayed in Figure 1 and described in Table 1. Thirteen sampling events were conducted from November 2010 to April 2011. However, samples were only collected at the sites with pump stations if the pump was on so that a representative sample could be collected (except at H Street in Aberdeen which had gravity flow and Mill Creek). Therefore, the number of samples collected for each site varied. The samples were analyzed at Ecology's Manchester Environmental Lab (MEL) using the membrane filter (MF) technique. More detailed information on the study and study design is available in the Quality Assurance Project Plan (Dickes, 2010).

Standard Ecology protocols were used for sample collection (Mathieu, 2006a). Grab samples for FC bacteria were collected directly into pre-cleaned polyethylene containers supplied by the laboratory and described in Manchester Environmental Laboratory (MEL, 2008). Water samples were collected using a sampling pole from below the surface of the water or from the outflow from the culvert or tide gate. Caution was used to prevent contamination of the sample with sediment or through touching the conveyance structure. The sampling was initiated at least an hour after high tide and extended to low tide as necessary. Each sample was labeled and immediately placed in a dark thermal cooler with ice. Samples were kept in conditions between 0°C and 4°C until the samples were processed by the laboratory. Samples arrived at MEL within 24 hours of collection, except for those mentioned in the Quality Control section below.

Results

Quality control

Data collected for the project were all considered useable based on the study objectives. However, some results were qualified based on failure to meet data quality objectives, such as holding time. A summary of data quality issues is provided below.

- On 11/30/2010 Manchester Environmental Laboratory (MEL) analyzed seven samples outside the 24-hour holding time. The first seven samples collected that day (514-HST, 510-MST, 501-ABDI, 513-SAGN, 513-SAG-S, 511- FARRN, 511- FARRS) were analyzed one to two hours over the holding time. The data were used but qualified as estimated values.

- One sample collected on 3/15/11, 513-SAG-S, was analyzed four minutes over holding time. The data value was used but qualified as an estimate.

- Laboratory blanks were all negative for bacterial growth.

- All laboratory duplicate relative percent differences (RPD) with plate counts greater than 20 colony forming units/100 mL (cfu/100 mL) were within the acceptable limits of a RPD of 40,

except for one duplicate pair on 4/27/11. A duplicate of site location 506-28th had a RPD of 42 instead of the acceptable RPD of 40. The data were used but qualified as an estimated value.

- Field replicates for bacteria met the quality objectives as per Mathieu (2006b) (Figure 2). Fifty percent of the replicate pairs were at or below 20% relative standard deviation (RSD) and 90% of the pairs were at or below 50% RSD. Replicates were averaged and used in data analyses.

- Conductivity data were not used for analyses, but were used to determine that freshwater was being sampled. Field replicates were not collected, but pre and post calibration was conducted successfully.

- Only 77% of the expected sample collection was completed which is less than the 95% expected. This was due to a combination of:

    - Pumps not turning on in time allotted for sampling, especially during short winter days.
    - Not having a tide low enough to adequately expose a tide gate for sampling.

- Bias was reduced by following sampling protocols and eliminating sample contamination with careful collection and handling.

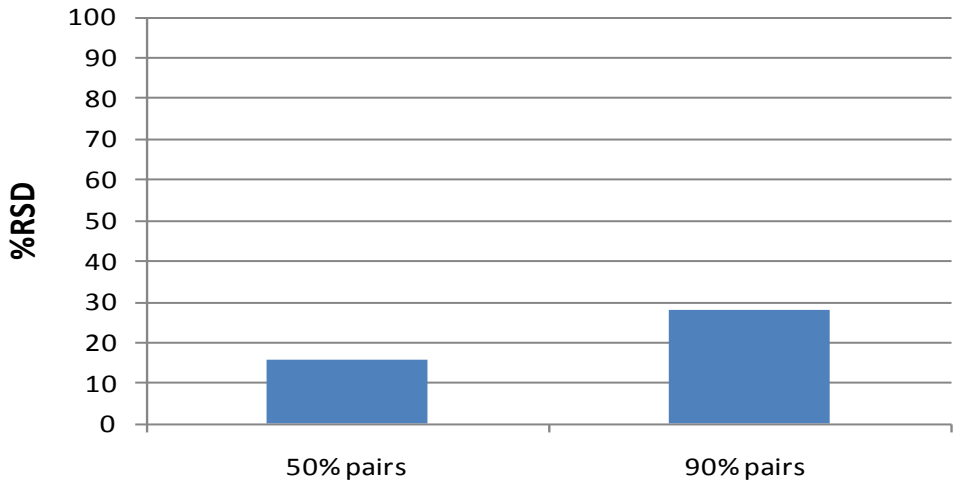

Figure 2. Precision for replicate pairs. *50% of the replicate pairs had a % RSD of 16 or below, 90% of the replicate pairs had a % RSD of 28 or below.*

Site locations

Table 1 provides site location description for the study. Some site locations were moved from the original Grays Harbor study locations based on recommendations from the city of Aberdeen and safety and logistical considerations.

- Mill Creek was sampled at the end of I Street and not via the main bridge on First Street.
- 514-HST was sampled at the H Street pump station manhole versus down at the mud flat tide gate and is named HST PMP in Ecology's Environmental Information Management System (EIM). The sample was collected from the elevated pipe coming in from the east in the manhole.
- 510-MST was sampled from the manhole at the M Street pump station instead of at the mud flat tide gate and is named MST PMP in EIM.
- 511-FARR was sampled separately at the north and south channels versus from the pump outflow. In EIM they are called 511-FARRN and 511-FARRS.
- 513-SAG was sampled separately at the north and south channels versus from the pump outflow. In EIM they are called 513-SAGN and 513-SAG-S.
- BANK-28TH was not sampled in the previous TMDL, but was included due to the proximity to the other two sites at 28th and Henderson Streets.

Table 1. Site location descriptions for sampling sites for this study.

SITE NAME	LOCATION	LATITUDE	LONGITUDE
Cosmopolis			
Mill	Mill Creek at I Street	46˚ 57' 22.14"	-123 46' 44.17"
Aberdeen			
511- FARRN	Farragut St Pump Station North Channel	46˚ 57' 45.72"	-123 47' 15.43"
511-FARRS	Farragut St Pump Station South Channel	46˚ 57' 45.72"	-123 47' 15.43"
513-SAGN	Saginaw Slough North Channel	46˚ 57' 57.67"	-123 48' 40.93"
513-SAG-S	Saginaw Slough South Channel	46˚ 57' 57.67"	-123 48' 40.93"
HST PMP	H Street Pump Station	46˚ 58' 20.99"	-123 48' 39.53"
MST PMP	M Street Pump Station	46˚ 58' 10.20"	-123 49' 1.09"
501-ABDI	Division Street Pump Station	46˚ 57' 59.90"	-123 49' 48.12"
502-FRY	Fry Creek Industrial Rd Pump Station - in stream	46˚ 58' 11.76"	-123 51' 4.30"
Hoquiam			
507-G3	28th Street Large 36 inch Culvert	46˚ 58' 17.22"	-123 51' 32.76"
506-28TH	28th Street Tide Gate	46˚ 58' 17’.22"	-123 51' 32.76"
BANK-28TH	28th Street Pipe from Bank	46˚ 58' 17.22"	-123 51' 32.76"
508-KST	K Street Pump Station outfall	46˚ 58' 20.17"	-123 52' 44.36"
515-LEVE	Under Levee Street Pump Station	46˚ 58' 38.24"	-123 52' 46.09"
509-ADAM	Adam Street Pump Station in-flow	46˚ 58' 21.86"	-123 54' 3.71"
518-15TH	15th Street Tide Gate on River bank	46˚ 58' 45.47"	-123 52' 51.67"
516-EMER	Emerson Avenue Pump Station at outfall	46˚ 58' 51.49"	-123 53' 0.31"
517-QEEN	Queen Avenue Pump Station at outfall	46˚ 59' 41.03"	-123 52' 59.38"

Fecal coliform data

A summary of site-specific information is provided below regarding the fecal coliform concentrations from samples collected during the 2010/2011 study. Summarized data for 2010/2011 can be found in Table 2 and Table A-1. Data are also provided for the 1998 (Pelletier et al., 2000) study in Table A-2, but the sample size was too small to make statistical comparisons between the two studies. Daily precipitation data are located in Appendix B. Precipitation data for 2010/2011 are from the Bowerman Basin Airport and were obtained from the Hoquiam Wastewater Treatment Plant. Charts showing the geometric mean values for the cities of Aberdeen and Hoquiam are presented in Appendix C; a chart for the city of Cosmopolis is not presented.

City of Cosmopolis

One stream site was sampled in Cosmopolis during this study; that site was located on Mill Creek at I Street. The water quality at this site tended to have low FC bacteria concentrations except during rain events on 11/17/2010 and 4/27/2011 when over 0.7 inches of rain fell. The geometric mean was 23 cfu/100 mL, but since two samples out of 12 (17%) were over 200 cfu/100 mL, the water quality criterion was not met (Table 2).

City of Aberdeen

Eight sites were sampled within the city limits of Aberdeen (Table 2) during the 2010/2011 study. Four of the sites (511-FARRN, 513-SAGN, 513-SAG-S, and 502-FRY) had a geometric mean below 100 cfu/100 mL. But, all sites had more than 10 percent of their samples exceeding 200 cfu/100mL. Therefore, none of the 8 sites met the water quality criterion.

511-FARRN and 511-FARRS were sampled upstream of the Farragut Pump Station in the north and south channels, respectively. Samples were collected only when the pump was running and the water was flowing. The south channel had 3 sample events when the channel did not appear to be flowing and thus was not sampled. 511-FARRN had a geometric mean of 59 cfu/100 mL, therefore meeting the first part of the criterion. However, 3 of 9 samples (33%) were above 200 cfu/100mL, so failed the second part of the criterion. The three high concentrations were during rain events of greater than 0.7 inches. Site 511-FARRS did not meet either part of the water quality criterion. High fecal coliform concentrations at this site also related to the rain events of over 0.7 inches.

513-SAGN and 513-SAG-S were only sampled when the pump was on and water flowing through the channels. The water quality criterion was not met at these sites. Both sites had a geometric mean below 100 cfu/100 mL, but both had more than 10% of their samples exceeding 200 cfu/100 mL. SAGN had 2 of 9 samples (22%) greater than 200 cfu/100 mL occurring on the 11/17/10 and 11/30/10 rain events. SAG-S had 1 of 9 samples (11%) over 200 cfu/100 mL on 11/17/2010.

HST PMP sample location was from the elevated pipe to the east from within the manhole. A sample was collected if water was flowing from the pipe even if the pump was not running. Both parts of the water quality criterion were exceeded at this site with a geometric mean of 269 cfu/100 mL and 8 out of 13 samples (62%) exceeding 200 cfu/100 mL. Of particular note is on 11/17/2010 when concentrations were 13,000 cfu/100mL during a 24-hour rain event of 0.82 inches.

MST PMP was a difficult location to sample. The pump rarely came on. When it did, it was unclear that the sample from the manhole would be representative. Therefore, only 6 samples were collected.

The geometric mean for the samples was 359 cfu/100 mL and 4 out of the 6 samples (67%) were above 200 cfu/100 mL. Therefore, this site did not meet the water quality criterion. The highest concentration 2000 cfu/100 mL was collected during the 11/17/2101 rain event.

501-ABDI was sampled only when the pump was running. Samples collected from the site did not meet either part of the water quality criterion with a geometric mean of 344 cfu/100 mL and 5 out of 9 samples (56%) exceeding 200 cfu/ 100 mL. The three highest concentrations were on the days of greater than 0.7 of rain on 11/17/10, 11/30/10, and 4/27/11.

502-FRY is a creek; however, it has a pump station. It was sampled when the pump was running and the water flowing. It had a geometric mean of 75 cfu/ 100 mL, but had 3 out of 13 samples (23%) exceeding 200 cfu/100 mL. The water quality criterion was not met. High FC bacteria concentrations on Fry Creek correlated to the rain events over 0.7 inches on 11/17/10, 11/30/10, and 4/27/11.

City of Hoquiam

Nine sites were sampled in the city of Hoquiam. All nine sites violated both parts of the water quality criterion for FC bacteria (Table 2).

507-G3 is the 36 inch pipe at 28th and Henderson. It was discharging during every event except for 1/3/11. The site had a geometric mean of 500 cfu/100 mL and all 11 samples exceeded 200 cfu/100 mL. There were high concentrations collected during the rain events over 0.7 inches, but concentrations were high even when there was little rain. For example, the concentration was 1700 cfu/100 mL on 1/18/11 with 0.05 inches of rain.

506-28TH was the tide gate at 28th and Henderson Street. Water from this site did not meet the water quality criterion with a geometric mean of 800 cfu/100mL and 4 out of 9 samples (44%) exceeding 200 cfu/100 mL.

BANK-28TH was the larger pipe coming from the north bank. It had a geometric mean of 220 with 5 out of 12 samples (42%) exceeding 200 cfu/100 mL, therefore not meeting the water quality criterion.

508-KST is located at the end of K Street. The sampling location was at the outfall from the pump station. Samples were collected when the pump was on and water flowing from the tide gate. FC bacteria concentrations were noticebly high (over 1000 cfu/100 mL) whether there was rain or not, except on 3/15/11 when the concentration was only 100 cfu/100 mL. Otherwise, this site had the most impaired water quality of all sites. It had the highest individual value of 37,000 cfu/100 mL on 4/11/11 with 0.06 inches of rain. It also had the highest geometric mean for the study period of 2452 cfu/100 mL. Twelve out of 13 samples (92%) were over 200 cfu/100mL.

515-LEVE was sampled under the Levee St pump station. It was difficult to access and the tide had to be quite low to get a sample. Samples from this site had a geometric mean of 170 cfu/100 mL and 5 out of 10 samples (50%) were over 200 cfu/100 mL.

509-Adam was sampled in the channel upstream of the grate at the end of Adams Street. Five out of the 13 samples (38%) were above 200 cfu/100 mL and resulted in a geometric mean of 170 cfu/100 mL. The water quality criterion was not met.

Table 2. 2010/2011 sampling locations and comparison with water quality criterion.

Site	Number of Samples	Minimum (cfu/100 mL)	Maximum (cfu/100mL))	Geometric Mean	Met Geometric Mean Standard	Percentage of Samples >200	Met 10 % Criterion ?
Cosmopolis							
Mill Creek	12	2	520	23	yes	17	no
Aberdeen							
511-FARRN	9	8	380	59	yes	33	no
511-FARRS	6	15	670	111	no	50	no
513-SAGN	9	18	970	66	yes	22	no
513-SAG-S	9	17	460	73	yes	11	no
HST PMP	13	8	13000	269	no	62	no
MST PMP	6	120	2000	359	no	67	no
501-ABDI	9	56	3100	344	no	56	no
502-FRY	13	15	1100	75	yes	23	no
Hoquiam							
507-G3	11	210	1700	500	no	100	no
506-28th	9	8	800	128	no	44	no
BANK-28TH	12	43	2200	220	no	42	no
508-KST	13	100	37000	2542	no	92	no
515-LEVE	10	12	2500	170	no	50	no
509-ADAM	13	26	2200	170	no	38	no
518-15TH	5	120	3100	484	no	60	no
516-EMER	9	77	2100	345	no	67	no
517-QEEN	12	130	7100	584	no	75	no

518-15TH was sampled 5 times. Three out of the 5 samples (60%) were above 200 cfu/100 mL resulting in a geometric mean of 484 cfu/ 100 mL. The water quality criterion was not met. The highest concentrations were found during the 11/17/10, 11/30/10, and 4/27/11 rain events.

516-EMER was located at the outfall to the Emerson Street pump station. Samples were collected when the pump was running. Six out of 9 samples (67%) exceeded 200 cfu/100 mL with a geometric mean of 345 cfu/100 mL. The highest concentrations were during the 11/17/10 and 4/27/11 rain events.

517-QEEN was located at the outfall to the Queen Street pump station. Samples were collected when the pump was running. The geometric mean was 584 cfu/100 mL with nine out of 12 samples (75%)

exceeding 200 cfu/100 mL. High concentrations were found during rain events, but also a sample with elevated concentration (2000 cfu/100 mL) was collected on 1/3/11 when no rainfall was recorded.

Conclusions and Recommendations

- All 16 urban drain sites and both stream sites exceeded the bacteria water quality criterion. Efforts should be made by all three cities to reduce sources of bacteria to the stormwater systems. This would include, but not be limited to, investigation and elimination of illicit discharges using water quality monitoring or other methods. Outreach and education regarding proper pet waste disposal, and garbage management should also be considered to prevent the potential concentration of pets and wildlife.

- The city of Aberdeen must continue to implement the requirements of its Ecology-issued Phase II Municipal Stormwater Permit.

- The site located at the end of K Street in the city of Hoquiam was the site of most concern. It had high concentrations throughout the study period whether there was rain or not; with the exception of the sampling event on 3/15/11 when the sample was 100 cfu/100 mL. This site also had the highest geometric mean for sampling sites in the 1998 study. The city of Hoquiam should investigate illicit connections in the lines leading to the pump station as well as review and eliminate other sources to the stormwater conveyance.

- Sample size in the 1998 study was low. This made it difficult to compare with the data collected in 2010/2011. Subsequent studies should plan for at least 10 sample events.

- Ecology should conduct effectiveness monitoring sampling after controls for bacteria sources have been implemented by the cities. Discharge should be estimated at the urban drain sampling sites to allow for comparison with the TMDL load allocation.

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Appendix A

Table A-1. Data for the 2010/2011 Grays Harbor urban drain study.

Location	Date	Time	Sample ID	FC (cfu/100 mL)	Data Qualifier
Cosmopolis					
MILL	11/17/10	11:20:00	1011019-05	520	
MILL	11/30/10	10:00:00	1012012-08	62	
MILL	12/20/10	12:20:00	1012013-01	8	
MILL	1/3/11	15:05:00	1101001-03	2	
MILL	1/18/11	12:50:00	1101002-01	52	
MILL	1/31/11	13:10:00	1102001-01	4	
MILL	2/15/11	12:15:00	1102009-04	7	
MILL	3/2/11	12:55:00	1103009-04	6	
MILL	3/15/11	10:55:00	1103010-05	32	J
MILL	3/29/11	11:40:00	1103011-05	13	
MILL	4/11/11	10:30:00	1104007-04	45	
MILL	4/27/11	13:30:00	1104008-01	230	
Aberdeen					
511-FARRN	11/17/10	10:55:00	1011019-03	380	
511-FARRN	11/30/10	9:40:00	1012012-06	50	J
511-FARRN	12/20/10	12:42:00	1012013-03	8	U
511-FARRN	2/15/11	12:00:00	1102009-03	40	
511-FARRN	3/2/11	17:25:00	1103009-17	43	
511-FARRN	3/15/11	10:39:00	1103010-04	43	
511-FARRN	3/29/11	11:21:00	1103011-04	11	
511-FARRN	4/11/11	10:15:00	1104007-03	310	
511-FARRN	4/27/11	16:35:00	1104008-17	210	
511-FARRS	11/17/10	11:00:00	1011019-04	240	
511-FARRS	11/30/10	9:45:00	1012012-07	250	J
511-FARRS	12/20/10	12:44:00	1012013-04	15	
511-FARRS	3/15/11	10:38:00	1103010-03	67	
511-FARRS	3/29/11	11:20:00	1103011-03	46	
511-FARRS	4/27/11	16:30:00	1104008-16	670	
513-SAGN	11/17/10	10:40:00	1011019-01	970	
513-SAGN	11/30/10	9:30:00	1012012-04	360	J
513-SAGN	12/20/10	12:56:00	1012013-05	38	
513-SAGN	1/18/11	13:10:00	1101002-02	22	
513-SAGN	2/15/11	11:35:00	1102009-01	18	
513-SAGN	3/2/11	12:30:00	1103009-01	21	
513-SAGN	3/15/11	10:25:00	1103010-01	52	

513-SAGN	3/29/11	11:08:00	1103011-01	61	
513-SAGN	4/11/11	10:00:00	1104007-01	65	
513-SAG-S	11/17/10	10:42:00	1011019-02	460	
513-SAG-S	11/30/10	9:32:00	1012012-05	200	J
513-SAG-S	12/20/10	12:58:00	1012013-06	23	
513-SAG-S	1/18/11	13:15:00	1101002-03	22	
513-SAG-S	2/15/11	11:37:00	1102009-02	160	J
513-SAG-S	3/2/11	12:35:00	1103009-02	17	
513-SAG-S	3/15/11	10:26:00	1103010-02	63	J
513-SAG-S	3/29/11	11:10:00	1103011-02	52	
513-SAG-S	4/11/11	10:01:00	1104007-02	150	J
514-HST	11/2/10	10:15:00	1011017-01	290	
514-HST	11/17/10	12:55:00	1011019-09	13000	J
514-HST	11/30/10	8:55:00	1012012-01	900	J
514-HST	12/20/10	13:15:00	1012013-07	930	
514-HST	1/3/11	13:30:00	1101001-01	38	
514-HST	1/18/11	14:05:00	1101002-04	520	
514-HST	1/31/11	13:50:00	1102001-02	8	U
514-HST	2/15/11	12:30:00	1102009-05	31	
514-HST	3/2/11	13:20:00	1103009-05	1000	J
514-HST	3/15/11	11:10:00	1103010-06	180	J
514-HST	3/29/11	11:55:00	1103011-06	845	
514-HST	4/11/11	10:45:00	1104007-05	19	
514-HST	4/27/11	13:45:00	1104008-02	860	
510-MST	11/2/10	10:30:00	1011017-02	280	
510-MST	11/17/10	13:00:00	1011019-10	2000	J
510-MST	11/30/10	9:00:00	1012012-02	730	J
510-MST	12/20/10	13:20:00	1012013-08	120	
510-MST	2/15/11	12:40:00	1102009-06	190	
510-MST	3/15/11	11:20:00	1103010-08	230	
501-ABDI	11/2/10	10:40:00	1011017-03	660	J
501-ABDI	11/17/10	11:40:00	1011019-07	3100	J
501-ABDI	11/30/10	9:15:00	1012012-03	1000	J
501-ABDI	12/20/10	16:00:00	1012013-09	100	
501-ABDI	2/15/11	13:15:00	1102009-07	72	
501-ABDI	3/2/11	14:15:00	1103009-06	56	
501-ABDI	3/15/11	12:40:00	1103010-09	64	
501-ABDI	3/29/11	13:00:00	1103011-08	515	
501-ABDI	4/27/11	14:00:00	1104008-04	2500	J
502-FRY	11/2/10	11:00:00	1011017-04	57	
502-FRY	11/17/10	12:05:00	1011019-08	840	J
502-FRY	11/30/10	10:50:00	1012012-09	800	

502-FRY	12/20/10	14:20:00	1012013-10	62	
502-FRY	1/3/11	14:20:00	1101001-02	17	
502-FRY	1/18/11	14:35:00	1101002-05	32	
502-FRY	1/31/11	14:15:00	1102001-03	15	
502-FRY	2/15/11	13:30:00	1102009-08	25	
502-FRY	3/2/11	15:00:00	1103009-08	18	
502-FRY	3/15/11	13:10:00	1103010-10	61	J
502-FRY	3/29/11	13:10:00	1103011-10	110	
502-FRY	4/11/11	11:05:00	1104007-07	26	
502-FRY	4/27/11	14:30:00	1104008-05	1100	J
Hoquiam					
507-G3	11/17/10	13:16:00	1011019-12	950	
507-G3	11/30/10	11:00:00	1012012-10	570	
507-G3	12/20/10	15:50:00	1012013-16	380	
507-G3	1/18/11	14:50:00	1101002-07	1700	J
507-G3	1/31/11	14:30:00	1102001-06	580	
507-G3	2/15/11	13:43:00	1102009-12	320	
507-G3	3/2/11	15:16:00	1103009-10	230	
507-G3	3/15/11	13:19:00	1103010-13	340	
507-G3	3/29/11	13:31:00	1103011-12	350	
507-G3	4/11/11	11:16:00	1104007-09	210	J
507-G3	4/27/11	14:35:00	1104008-06	1300	J
506-28th	11/17/10	13:17:00	1011019-13	650	
506-28th	11/30/10	13:35:00	1012012-19	100	
506-28th	12/20/10	15:55:00	1012013-17	460	
506-28th	1/3/11	16:40:00	1101001-10	29	
506-28th	2/15/11	13:42:00	1102009-11	29	
506-28th	3/2/11	15:17:00	1103009-11	800	J
506-28th	3/29/11	15:50:00	1103011-18	8	
506-28th	4/11/11	11:17:00	1104007-10	92	
506-28th	4/27/11	14:38:00	1104008-07	630	J
BANK-28TH	11/17/10	13:15:00	1011019-11	1400	
BANK-28TH	11/30/10	11:01:00	1012012-11	480	
BANK-28TH	12/20/10	15:40:00	1012013-15	1600	
BANK-28TH	1/3/11	16:30:00	1101001-09	77	
BANK-28TH	1/18/11	14:48:00	1101002-08	44	
BANK-28TH	1/31/11	14:25:00	1102001-05	43	
BANK-28TH	2/15/11	13:41:00	1102009-10	48	
BANK-28TH	3/2/11	15:15:00	1103009-09	420	
BANK-28TH	3/15/11	13:18:00	1103010-12	110	
BANK-28TH	3/29/11	13:30:00	1103011-11	180	
BANK-28TH	4/11/11	11:15:00	1104007-08	92	

BANK-28TH	4/27/11	14:14:00	1104008-08	2200	
508-KST	11/2/10	11:45:00	1011017-05	2000	J
508-KST	11/17/10	14:00:00	1011019-16	2300	J
508-KST	11/30/10	11:30:00	1012012-14	2300	
508-KST	12/20/10	14:55:00	1012013-13	1300	
508-KST	1/3/11	15:50:00	1101001-07	14000	J
508-KST	1/18/11	16:05:00	1101002-14	2600	
508-KST	1/31/11	14:55:00	1102001-08	17500	J
508-KST	2/15/11	14:15:00	1102009-14	1500	
508-KST	3/2/11	15:40:00	1103009-13	1000	
508-KST	3/15/11	13:45:00	1103010-15	100	J
508-KST	3/29/11	15:25:00	1103011-17	1900	J
508-KST	4/11/11	12:05:00	1104007-15	37000	J
508-KST	4/27/11	15:35:00	1104008-12	2000	
515-LEVE	11/17/10	14:10:00	1011019-18	860	
515-LEVE	11/30/10	13:15:00	1012012-18	50	
515-LEVE	1/18/11	16:15:00	1101002-15	920	J
515-LEVE	1/31/11	15:10:00	1102001-10	23	
515-LEVE	2/15/11	15:10:00	1102009-18	31	
515-LEVE	3/2/11	17:00:00	1103009-16	12	
515-LEVE	3/15/11	15:05:00	1103010-18	360	
515-LEVE	3/29/11	15:20:00	1103011-16	1300	
515-LEVE	4/11/11	12:30:00	1104007-16	50	
515-LEVE	4/27/11	15:45:00	1104008-14	2500	J
509-ADAM	11/2/10	12:00:00	1011017-06	355	
509-ADAM	11/17/10	13:50:00	1011019-15	1200	
509-ADAM	11/30/10	11:20:00	1012012-12	365	
509-ADAM	12/20/10	14:50:00	1012013-11	85	
509-ADAM	1/18/11	15:55:00	1101002-13	39	
509-ADAM	1/31/11	14:45:00	1102001-07	45	
509-ADAM	2/15/11	14:05:00	1102009-13	180	
509-ADAM	3/2/11	15:30:00	1103009-12	71	
509-ADAM	3/15/11	13:35:00	1103010-14	640	
509-ADAM	4/11/11	11:50:00	1104007-14	110	
509-ADAM	1/3/11	15:35:00	1101001-06	26	
509-ADAM	3/29/11	14:50:00	1103011-15	85	
509-ADAM	4/27/11	15:30:00	1104008-11	2200	J
518-15TH	11/17/10	14:45:00	1011019-20	3100	
518-15TH	11/30/10	13:50:00	1012012-20	800	
518-15TH	2/15/11	15:55:00	1102009-19	120	
518-15TH	3/29/11	16:05:00	1103011-19	130	
518-15TH	4/27/11	16:00:00	1104008-15	690	

516-EMER	11/17/10	13:40:00	1011019-14	1100	
516-EMER	11/30/10	12:00:00	1012012-15	250	
516-EMER	1/18/11	15:15:00	1101002-09	135	
516-EMER	2/15/11	14:35:00	1102009-16	210	
516-EMER	3/2/11	16:10:00	1103009-14	460	
516-EMER	3/15/11	14:05:00	1103010-16	170	
516-EMER	3/29/11	14:25:00	1103011-13	700	
516-EMER	4/11/11	11:30:00	1104007-11	77	
516-EMER	4/27/11	15:05:00	1104008-09	2100	J
517-QEEN	11/17/10	14:30:00	1011019-19	900	
517-QEEN	11/30/10	12:50:00	1012012-16	465	
517-QEEN	12/20/10	15:30:00	1012013-14	1200	
517-QEEN	1/3/11	16:15:00	1101001-08	2000	
517-QEEN	1/18/11	15:30:00	1101002-11	250	
517-QEEN	1/31/11	15:45:00	1102001-11	810	
517-QEEN	2/15/11	14:50:00	1102009-17	140	
517-QEEN	3/2/11	16:45:00	1103009-15	130	
517-QEEN	3/15/11	14:15:00	1103010-17	190	
517-QEEN	3/29/11	14:35:00	1103011-14	7100	J
517-QEEN	4/11/11	11:40:00	1104007-12	265	
517-QEEN	4/27/11	15:15:00	1104008-10	1200	

J=estimate

U= below detection

Table A-2. Urban drain data for the 1998 Grays Harbor FC TMDL.

Site	Date	Time	FC (MPN/100 mL)		geometric mean
Cosmopolis					
505-Mill	2/4/1998	1340	17		
	4/7/1998	1655	14		15
Aberdeen					
511-FARR	2/11/1998	1715	20		
513-SAG	2/11/1998	1845	110		
514-HST	2/11/1998	1930	3500		
	3/11/1998	1910	2400		
	4/7/1998	1740	79		872
510-MST	2/10/1998	1810	2400		
	3/11/1998	1950	130		
	4/7/1998	1800	7.8		135
501-ABDI	2/4/1998	1030	110		
	2/10/1998	1635	350		
	3/11/1998	1625	79		145
502-FRY	2/4/1998	1100	11		
	2/10/1998	1730	79		
	4/7/1998	1900	4.5		16
Hoquiam					
507-G3	2/4/1998	1540	1600		
	2/10/1998	1715	130		
	4/7/1998	1623	17000		1523
506-28TH	2/4/1998	1500	920		
508-KST	2/4/1998	1610	24000		
	2/10/1998	1545	1100		5138
515-LEVE	2/26/1998	1430	6.8		
509-ADAM	2/4/1998	1650	1700		
	2/10/1998	930	24000		
	4/7/1998	1455	920		3348
518-15TH	3/9/1998	1650	110		
516-EMER	2/26/1998	1450	240		
	3/9/1998	1505	2400		
	4/7/1998	1540	2400		1114
517-QEEN	3/9/1998	1520	540		

Appendix B

Precipitation

Table B-1. Precipitation data for the specific sampling days in 2010/11.
Data are from the Bowerman Basin Airport in Hoquiam.

Date	Precipitation (in)
11/2/2010	0.01
11/17/2010	0.82
11/30/2010	0.78
12/20/2110	0.40
1/3/2011	0.00
1/18/2011	0.05
1/31/2011	0.01
2/15/2011	0.05
3/2/2011	0.30
3/15/2011	0.32
3/29/2011	0.66
4/11/2011	0.06
4/27/2011	0.74

Table B-2. Precipitation data for the specific sampling days in 1998.
Data are from the Bowerman Basin Airport in Hoquiam.

Date	Precipitation (in)
2/4/1998	0.26
2/10/1998	0.51
2/11/1998	0.52
2/26/1998	0.00
3/9/1998	0.55
3/11/1998	0.03
4/7/1998	0.01

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Appendix C

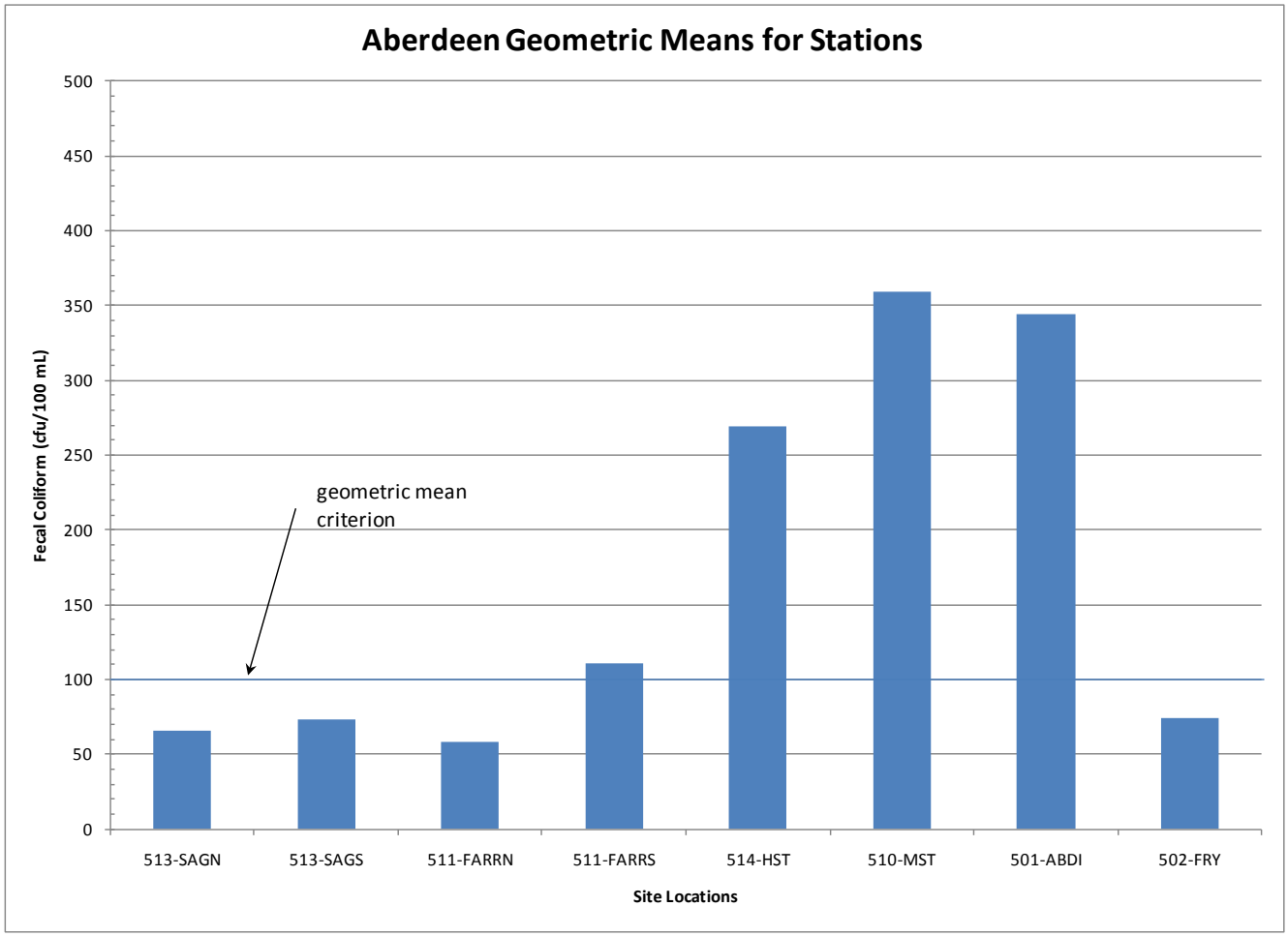

Figure C-1. Geometric mean values for the city of Aberdeen. *The geometric mean criterion is 100 cfu/100 mL.*

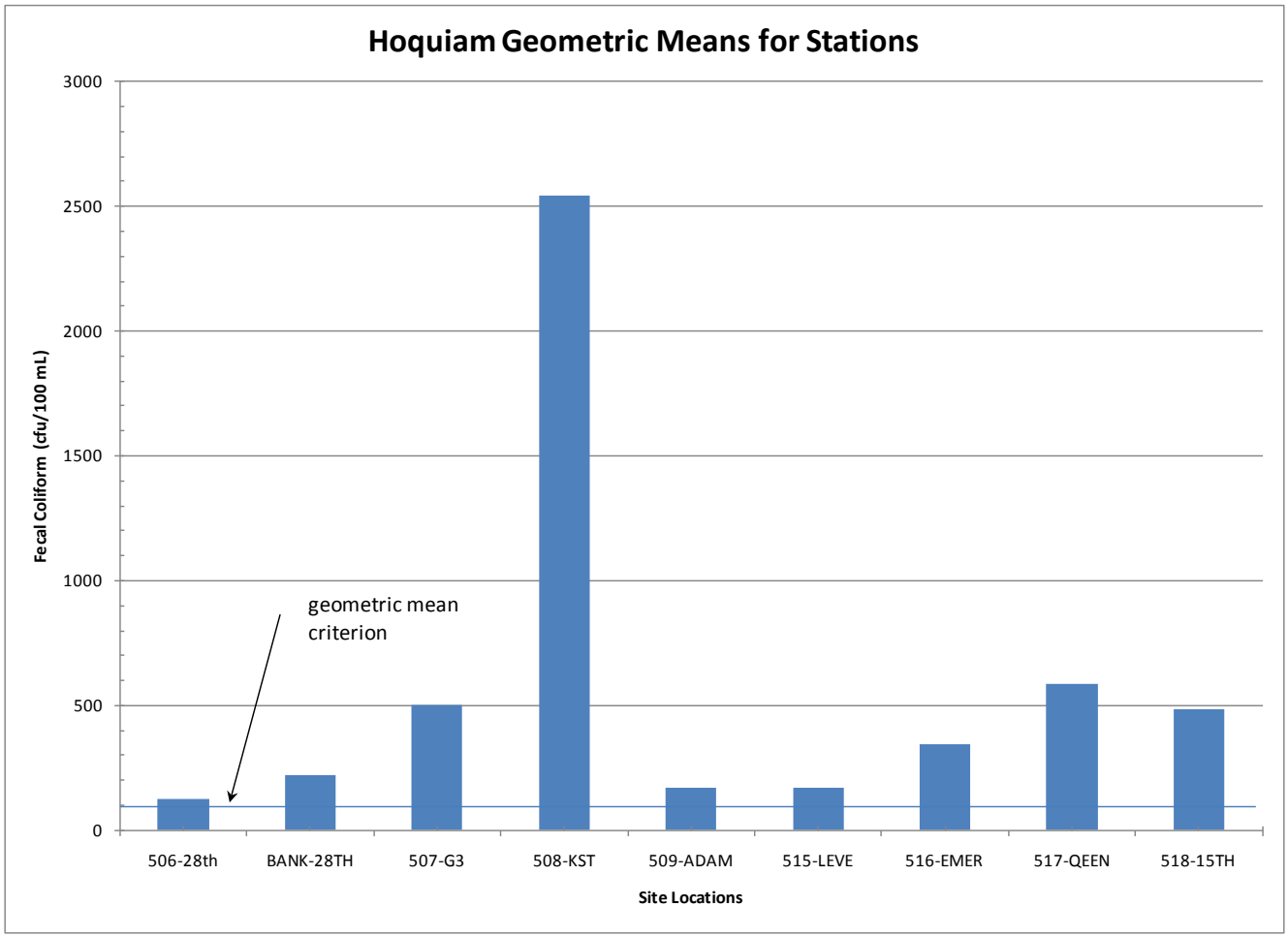

Figure C-2. Geometric mean values for the city of Hoquiam. *The geometric mean criterion is 100 cfu/100 mL.*