Gee Creek Focused Assessment

Fecal Coliform and Turbidity

July 2008

Background

Gee Creek Watershed

Gee Creek is located in western Clark County and flows into the Columbia River northwest of the City of Ridgefield (Figure 1). Land use consists largely of rural residential development and agriculture in the upper watershed, while the City of Ridgefield urban growth boundary includes the majority of the lower watershed. Gee Creek is an important community asset, flowing through Abrams Park in downtown Ridgefield and continuing into the Ridgefield National Wildlife Refuge.

Under current Washington State water quality standards, Gee Creek is to be “protected for the designated uses of: Salmonid spawning, rearing, and migration; primary contact recreation; domestic, industrial, and agricultural water supply; stock watering; wildlife habitat; harvesting; commerce and navigation; boating; and aesthetic values” (WAC 173-201A-600).

Gee Creek contains segments that are Category 5 listed (polluted waters that require a TMDL) for fecal coliform, based on the state water quality criteria below:

Fecal Coliform Bacteria	Geometric mean fecal coliform concentration not to exceed 100 colonies/100mL, and not more than 10% of samples exceeding 200 colonies/100mL.

Fecal Coliform Levels in Gee Creek

Water quality data for the Gee Creek watershed primarily consists of data collected by the Clark County Public Works Clean Water Program (CWP) through ongoing ambient monitoring and volunteer monitoring programs. Historical fecal coliform data is summarized in Table 1 below.

Table 1. Summary of fecal coliform data from previous monitoring projects
Station GEE050

Year	2002 n=5	2003 n=12	2004 n=12	2005 n=11	2006 n=12	2007 n=12
Geometric mean (Standard = 100 CFU/ 100mL)	230	203	161	154	168	61
Exceedences over 200 CFU (not to be greater than 10%)	60%	50%	42%	33%	42%	17%
90th Percentile concentration	740	500	427	780	730	195

Station GEE030

Year	2003 n=4	2004 n=4	2005 n=4	2006 n=4
Geometric mean (Standard = 100 CFU/ 100mL)	129	146	245	454
Exceedences over 200 CFU (not to be greater than 10%)	50%	25%	75%	75%
90th Percentile concentration	440	681	422	1430

Project Methods

Volunteer monitors were used to implement this monitoring project. Project guidance, equipment, and volunteer coordination were provided by CWP staff through the Volunteer Monitoring Program and Resource Center. Analytical services were provided by the Salmon Creek Wastewater Treatment Plant laboratory. The lab is accredited by Ecology and routinely analyzes samples in accordance with their wastewater discharge permit.

CWP staff conducted the first monitoring survey in April 2007. A training event was held for volunteers in May 2007. The volunteers were trained to follow a general flow of sampling procedures. Monitoring dates were arranged by teams of two or three people and confirmed with CWP staff . Equipment was stored at the treatment plant for the duration of the project. Prior to sampling, arrangements were made with the treatment plant staff to drop off water samples, allowing sufficient time to analyze them within holding-time requirements. Volunteers reported to the treatment plant to pick up field equipment kits. Typically samples were collected beginning at the station furthest downstream and moving upstream through the watershed. All samples were collected within 1-2 hours of each other. The station name, sample date and time uniquely identified the samples.

The monitoring surveys utilized seven monitoring stations that were visited by volunteers at bi-monthly intervals for one year (see Figure 2 for a map of stations). Water samples were analyzed for fecal coliform bacteria and turbidity. The study design was intended to provide data representing seasonal variations and weather conditions, as well as spatial variation in the watershed. Methods for individual parameters are shown in Table 2.

Table 2. Methods for field measurements and lab parameters.

Field Activity Type	Sampling Frequency	Method	Equipment	Sample Size	Container Preservation	Holding Time
Fecal Coliform	Twice Monthly	Standard Methods (SM) 9222D Membrane Filtration	NA	111-mL	250-mL sterile HDPE	30 hours
Turbidity	Twice Monthly	EPA 180.1 Nephelometric	Hach 2100P	10-mL	15-mL glass vial	48 hours

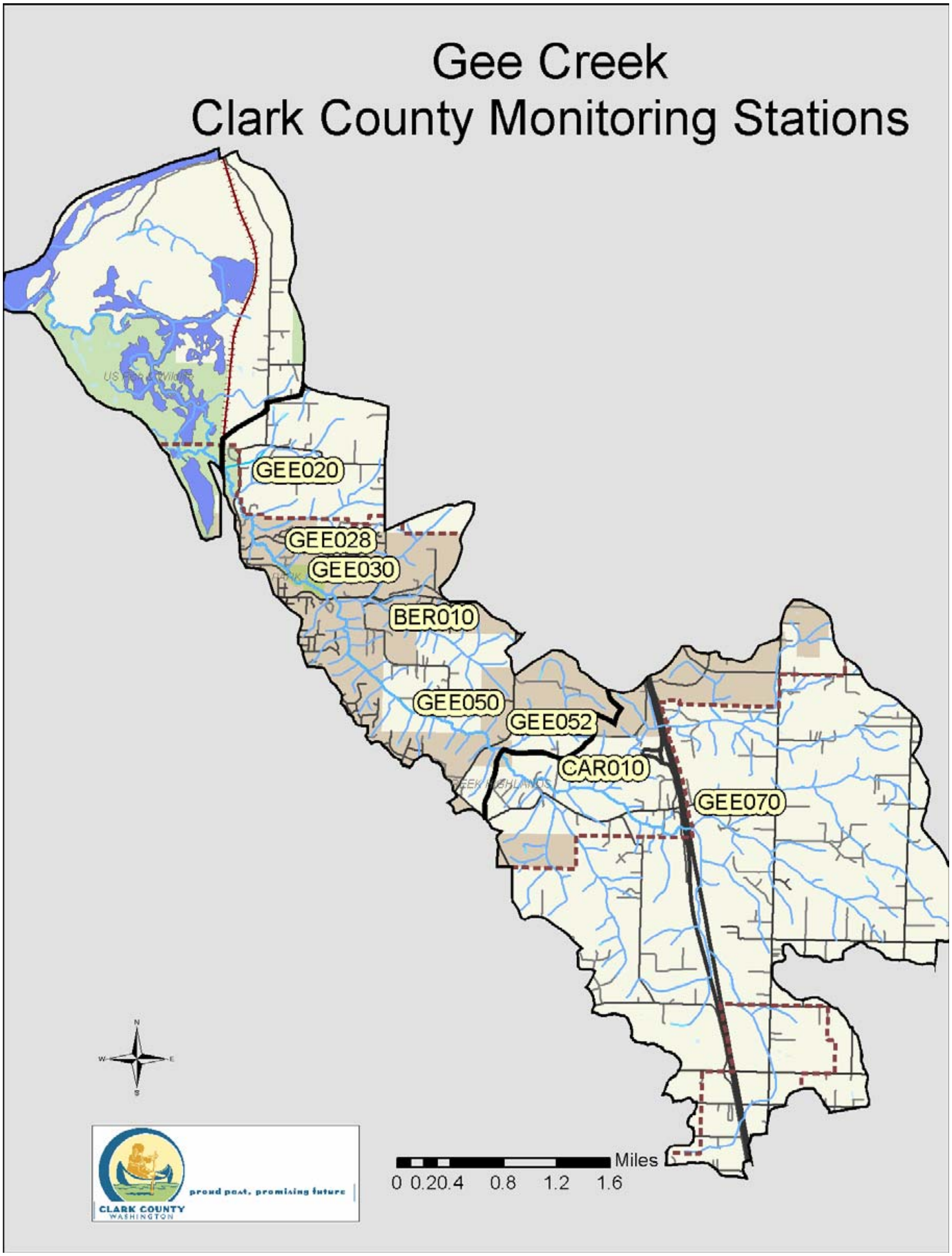


Figure 1. Map of Gee Creek and sampling stations.

Data Summary

Activity Summary

A team of six volunteers monitored water quality at each station for one year, completing 21 sampling events in a variety of weather conditions and seasons.

Fecal Coliform Bacteria by Location

A fecal coliform data summary is presented in Table 3 and in Figure 3. The complete data set is available from the CWP.

Geometric mean values and 90th percentile values (used to evaluate the 10 percent exceedances criterion) are calculated to evaluate the data relative to the water quality criteria.

Bacteria levels at all of the monitoring stations in the watershed exceeded one or both of the fecal coliform water quality criteria over the monitoring period. Six of the seven stations violated both criteria.

Stations GEE070 (Maple Crest Road) and GEE085 (Gee Creek rest area) in the upper watershed had the lowest overall geometric mean concentrations. Station GEE070 met the geometric mean criterion but failed to meet the 90th percentile criterion by three-fold, while GEE085 failed both criteria, exceeding the 90th percentile criterion by four-fold.

The Bertsinger Road station (BER010) had the lowest range of overall concentrations, yet the highest overall geometric mean, indicating consistently elevated concentrations but an absence of the occasional very high values seen at many other stations.

Conditions improved considerably between stations GEE030 (Abrams Park) and GEE020 (Main Street), with geometric mean value decreasing by nearly 100 cfu/100mL and a four-fold decrease in 90th percentile concentration. Several factors may contribute to this observed improvement, including dilution with additional tributary water or increased bacteria die-off due to increased solar exposure or time of travel.

The Carty Road station (CAR010) had the highest 90th percentile concentration, exceeding the criterion by more than ten-fold, a concentration nearly 1000 cfu/100ml higher than the next highest station, indicating more frequent occurrence of very high values at this location. Values from the next station downstream (GEE050) were frequently elevated as well, and likely tend to reflect inputs from the Carty Road tributary.

Table 3. Summary of fecal coliform sample data from April 2007 to March 2008; highlighted values indicate cases where the state water quality criteria were not met (WAC173-201A-200).

Monitoring Station Code	Number of Samples	Range of Fecal Coliform Concentrations cfu/100 mL	Geometric Mean Fecal Coliform Concentration cfu/100 mL	90th Percentile Fecal Coliform Concentration cfu/100 mL
BER010	21	41 - 1045	302	936
CAR010	21	11 - 4300	244	2100
GEE020	21	20 - 2200	174	500
GEE030	21	30 - 3700	271	1291
GEE050	21	28 - 6000	286	1036
GEE070	21	3 - 3000	71	618
GEE085	17	12 - 2600	148	867

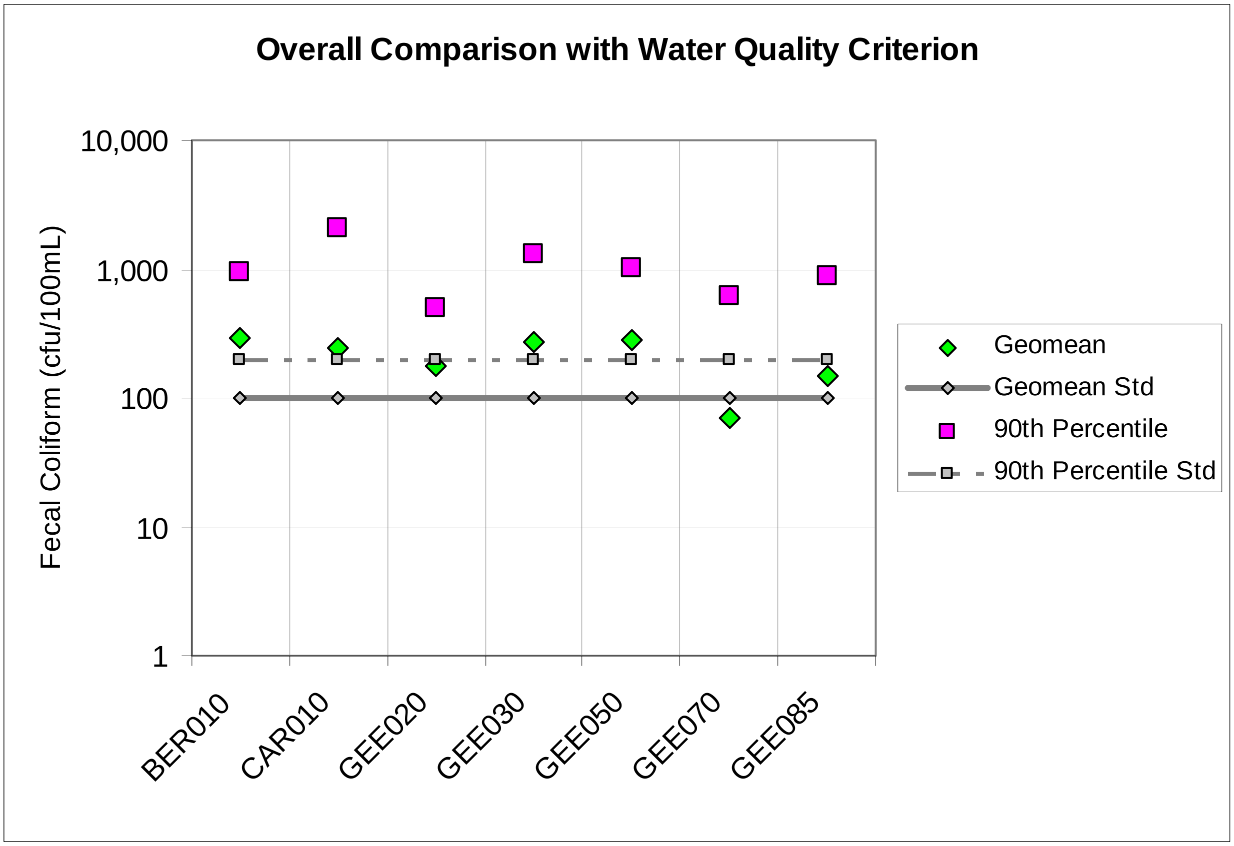


Figure 3. Summary of fecal coliform data from April 2007 to March 2008. Calculations of the geometric mean (GeoMean) concentrations and 90th percentile concentrations are shown as symbols; the lines show the Washington State water quality criteria for each calculation.

Fecal Coliform Bacteria by Weather and Season

Individual sampling events were classified by weather and season in order to describe critical periods for exceedances of water quality criteria. Utilizing data from a nearby precipitation gage, categories for weather were assigned by calculating the 48-hour total rainfall amount prior to each event. Precipitation totals greater than 0.10 inches indicated ‘wet’ weather, while other events were classified as ‘dry’ weather. Categories for season were assigned by the month of the sampling event. Events taking place from November through May were classified as ‘wet’ season, while events taking place from June through October were classified as ‘dry’ season. A summary of the classifications for the sampling events is shown in Table 4 below.

Tentative sampling dates were selected at random by staff, with final dates being subject to volunteer schedules and availability. Sampling events were distributed somewhat unevenly among the categories, with more overall events taking place in dry weather relative to wet weather, and only a single event occurring during wet weather in the dry season (see totals in Table 5 below).

Table 4. Summary of weather conditions during sampling over the one- year sampling period. The 48-hr precipitation totals were used to classify the sampling event as 'wet' or 'dry' weather; seasons were assigned using the month of sampling. The 24-hour, 2-yr model rainfall event is about 3".

Event Date	Weather (Rainfall)	Season (Time of Year)	24-hr Precip (inches)	48-hr Precip (inches)
4/12/2007	Dry Weather	Wet Season	0.09	0.09
4/25/2007	Dry Weather	Wet Season	0.06	0.07
5/17/2007	Dry Weather	Wet Season	0	0
6/2/2007	Dry Weather	Dry Season	0	0
6/15/2007	Dry Weather	Dry Season	0.02	0.02
7/7/2007	Dry Weather	Dry Season	0	0
7/21/2007	Dry Weather	Dry Season	0.05	0.07
8/3/2007	Dry Weather	Dry Season	0.01	0.01
8/18/2007	Dry Weather	Dry Season	0	0
9/1/2007	Dry Weather	Dry Season	0	0
9/23/2007	Dry Weather	Dry Season	0	0
10/7/2007	Dry Weather	Dry Season	0.02	0.02
10/20/2007	Wet Weather	Dry Season	0.51	0.95
11/4/2007	Dry Weather	Wet Season	0	0
12/2/2007	Wet Weather	Wet Season	0.97	1.04
12/16/2007	Wet Weather	Wet Season	0.01	0.12
1/6/2008	Wet Weather	Wet Season	0.25	0.55
2/2/2008	Wet Weather	Wet Season	0.4	0.61
2/29/2008	Dry Weather	Wet Season	0	0
3/15/2008	Wet Weather	Wet Season	0.09	0.48
3/29/2008	Wet Weather	Wet Season	0.08	0.36

Table 5. Fecal coliform calculations from all stations, grouped by categories or weather and season.

Event Category	Event Count	Geometric Mean Value	90th Percentile Value	Number of Observations
Dry Weather/Dry Season	9	173	592	58
Wet Weather/Dry Season	1	362	479	7
Dry Weather/Wet Season	5	57	220	35
Wet Weather/Wet Season	6	586	2960	42

After combining the data from all of the stations in the Gee Creek watershed, inferences about fecal coliform levels relative to weather and seasons are possible:

- Fecal coliform values are significantly lower during dry weather in the wet season than any other weather/season combination*.
- Dry weather fecal coliform values are significantly higher during the dry season than the wet season*.
- Wet weather fecal coliform values are *not* significantly different during the dry season and wet season*.
- Wet weather during the wet season resulted in the highest fecal coliform levels.
- Dry weather during the wet season resulted in the lowest fecal coliform levels.

These observations generally held for the individual sample stations in Gee Creek watershed (Figure 4 and Table 6 below). A notable exception is the Bertsinger Road tributary station (BER010), where dry weather during the dry season produced a much higher geometric mean and somewhat higher 90th percentile value versus other weather/season categories. This exception to the overall pattern of wet weather coinciding with high levels of fecal coliform likely indicates the presence of continuous, dry weather sources of bacteria on this tributary, for example illegal connections of sewer to drainage ways, failing septic systems, or direct livestock access to the stream.

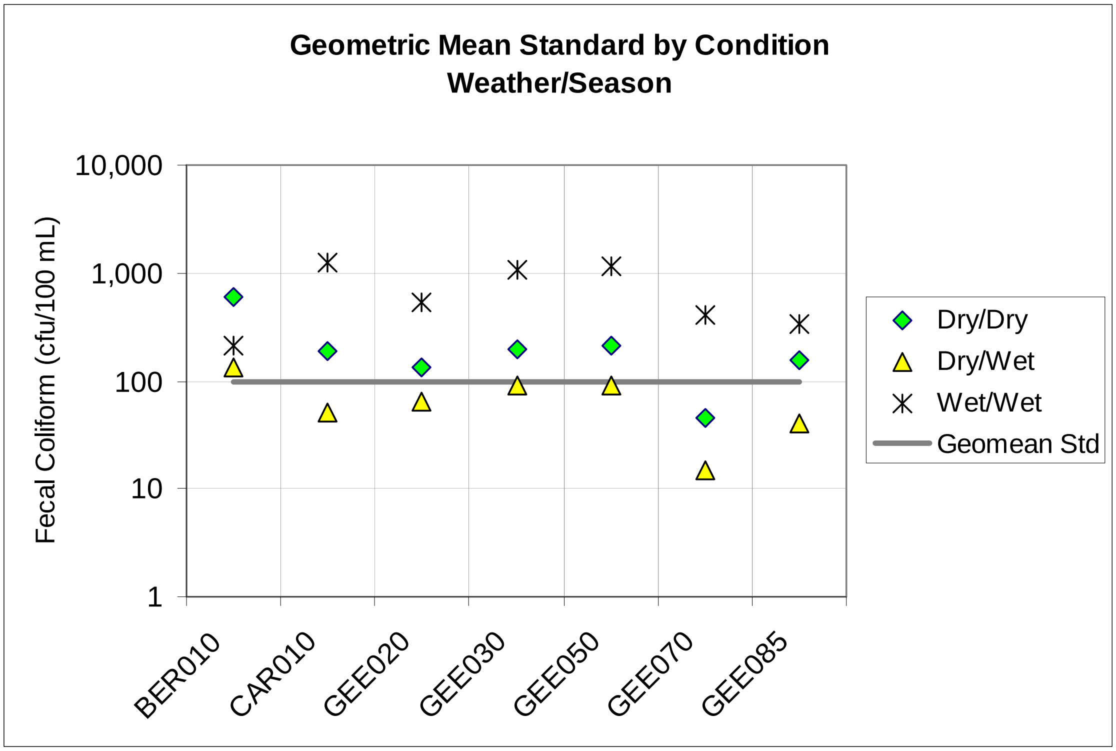
Only one sampling event (October 20, 2007) fell into the Wet Weather/Dry Season category. Geometric mean and 90th percentile values were not calculated. Data for each station during the October 20 event are shown in Table 7. Fecal coliform values were elevated and very similar for six of the seven stations during this event; the exception was the GEE085 station with a value nearly twice as high as the other stations.

Table 6. Fecal coliform level calculations for the Gee Creek stations, grouped by categories of weather and season. Values in *bold italics* meet water quality criteria for bacteria; event categories are listed according to weather/season.

Event Category	BER010	CAR010	GEE020	GEE030	GEE050	GEE070	GEE085
	Geometric Mean Value						
Dry/Dry	609	186	135	197	208	***45***	156
Wet/Dry**							
Dry/Wet	132	***51***	***65***	***90***	***91***	***15***	***40***
Wet/Wet	210	1265	543	1082	1137	402	332
	90th Percentile Value						
Dry/Dry	938	494	344	316	354	106	496
Wet/Dry**							
Dry/Wet	308	***156***	***166***	228	212	***41***	***67***
Wet/Wet	909	4150	1750	2850	4150	2205	1832

** Only one Wet/Dry event occurred during the monitoring period. Geometric mean and 90th percentile were not calculated.

* Minitab statistical software was used to run one-way ANOVA on ranked fecal coliform values, utilizing the Tukey-Kramer method to obtain confidence intervals for all pair-wise differences between rank means; differences between categories that were greater or less than zero were considered statistically significant.



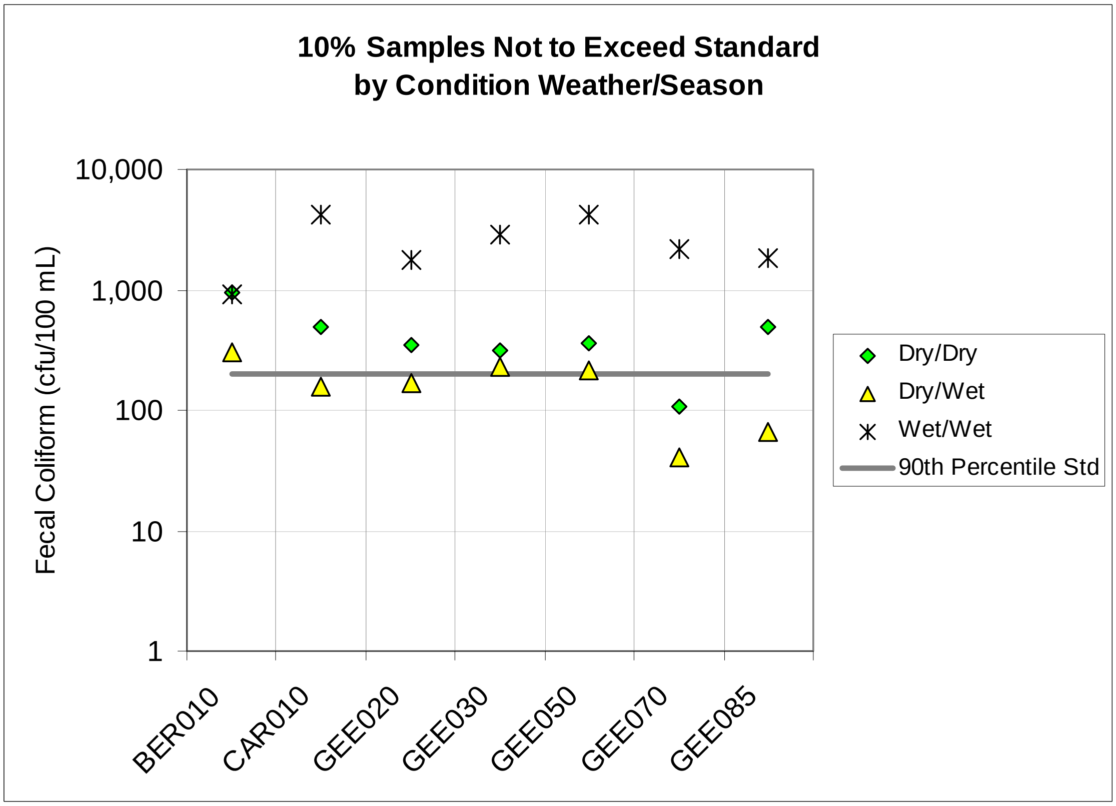


Figure 4. Fecal coliform levels for each of the stations showing data grouped into categories of weather and season, for example, ‘Dry/Dry’ is the category for ‘Dry Weather during the Dry Season’. Dry and wet weather were determined with a 48-hr rainfall total of 0.1 inches, and dry and wet seasons were determined by the sample month (June-October is the dry season).

Table 7. October 20, 2007 sample event data

Event Category	BER010	CAR010	GEE020	GEE030	GEE050	GEE070	GEE085
	Fecal Coliform (CFU/100mL)						
Wet/Dry	310	380	280	330	360	330	627

Time series for the fecal coliform levels throughout the calendar year are shown in Figure 5 below. Most months had two sample events over the one-year period for the analysis. While additional data may smooth out some of the variability in the graph, the general patterns would likely remain the same.

The graph shows higher fecal coliform levels throughout the winter for most stations, with the highest values during winter rain events which are likely carrying pollutants from a variety of sources. Lower values are typically observed during the summer months.

Notable findings at individual stations include:

- Values for the Bertsinger Road tributary were typically the highest for any station during the dry season.
- The three highest recorded values came from the Carty Road station (CAR010 -- 4000 CFU/100mL and 4250 CFU/100mL) and Royle Road station (GEE050-- 6000 CFU/100mL) during two wet weather events in the wet season, in both cases greatly exceeding the values from any other station.
- All stations except BER010 had maximum fecal coliform concentrations greater than 2000 CFU/100mL.

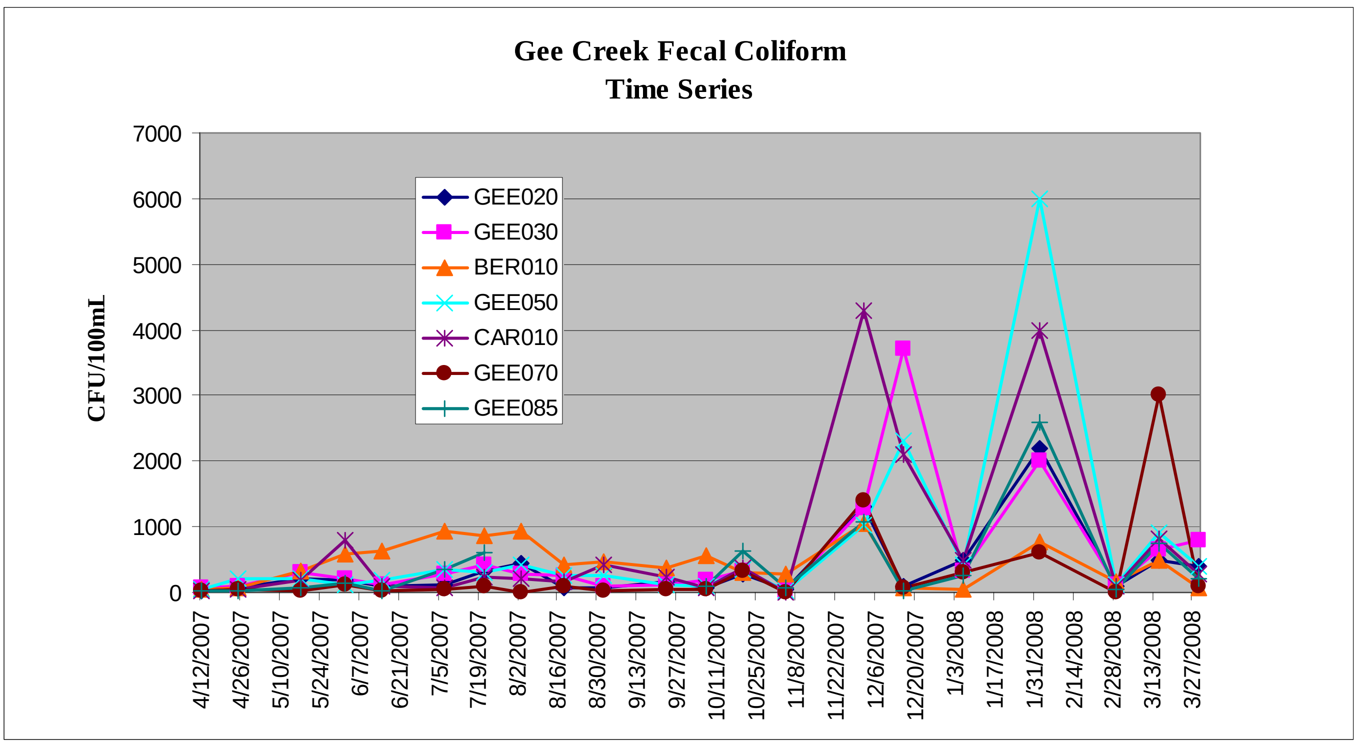


Figure 5. Fecal coliform levels for Gee Creek stations, time series.

Turbidity
Washington State water quality criteria for Gee Creek state that "Turbidity shall not exceed 5 NTU over *background* turbidity when the background turbidity is 50 NTU or less, or have more than a 10 percent increase in turbidity when the background turbidity is more than 50 NTU" (WAC173-201A-200)". Although background turbidity for these creeks has not been determined, it is likely similar to the lower range of values observed at the sample stations. A background turbidity between 1-5 NTU is realistic.

Turbidity values are summarized in Table 7. Typically, the observed values were somewhat elevated; the median value at each of the monitoring stations was between 6 - 12 NTU. Occasionally, very high values of turbidity were observed at each of the monitoring stations. If background turbidity was conservatively assumed to be about 3 NTU, then Gee Creek stations exceeded the criteria of 8 NTU from 26 - 89 percent of the time, indicating a turbidity problem throughout most of the drainage.

Considering a threshold of 8 NTU, the most consistently turbid station was GEE070 (Maple Crest Road), which exceeded 8 NTU during 17 of 19 sampling events (89%). However, the range of turbidity values was relatively narrow at station GEE070, with an absence of extremely high values. By a significant margin, the highest individual values were observed at the Bertsinger Road (BER010) and Carty Road (CAR010) stations. Four of the seven stations had median turbidity values >8 NTU.

Table 7. Summary of turbidity sample data from April 2007 to March 2008.

Monitoring Station Code	Number of Samples	Range of Turbidity Values NTU	Median Turbidity NTU
BER010	19	2.4 - 421	6.4
CAR010	19	4.1 - 224	12.1
GEE020	19	4.8 - 99	7.0
GEE030	19	3.3 - 130	6.1
GEE050	19	3.4 - 114	9.3
GEE070	19	5.5 - 63	11.7
GEE085	15	4.1 - 62	10.9

As with the fecal coliform data, turbidity results were classified by weather and season in order to describe possible critical periods for exceedances of water quality criteria (see Table 4 above for event classification).

Combining the data from all of the stations in the Gee Creek watershed, inferences about turbidity levels relative to weather and seasons are possible:

- Turbidity levels are significantly higher during wet weather than dry weather, in either season*.
- Turbidity levels are *not* significantly different between wet weather in the dry season and wet weather during the wet season*.
- Turbidity levels are *not* significantly different between dry weather in the dry season and dry weather during the wet season*.

* Minitab statistical software was used to run one-way ANOVA on ranked turbidity values, utilizing the Tukey-Kramer method to obtain confidence intervals for all pair-wise differences between rank means; differences between categories that were greater or less than zero were considered statistically significant .

Table 8. Turbidity calculations from all stations, grouped by categories of weather and season.

Event Category	Event Count	Range of Turbidity Values NTU	AverageTurbidity NTU	Number of Samples
Dry Weather/Dry Season	9	3.3 - 66	9	59
Wet Weather/Dry Season	1	12.1 - 42	23	7
Dry Weather/Wet Season	3	2.4 - 16	6	21
Wet Weather/Wet Season	6	5.4 - 421	51	42

The data summarized in Table 8 indicates that average turbidity during wet weather is significantly higher than dry weather. This pattern holds despite the presence of a single very high turbidity event during wet weather in the wet season. This event established the high end of the range for most stations, but simply reinforced the pattern seen in the remaining samples.

The general pattern of higher turbidity during wet weather also holds for individual stations, suggesting the absence of a seasonal critical period for turbidity. Rather, the critical period for turbidity appears to be during rain events, regardless of season.

Quality Control Summary

Data completeness

There were 24 sampling events scheduled from April 2007 to March 2008. Fecal coliform events were nearly 90% complete, with 21 events completed. Turbidity events were 80% complete, with 19 events completed. There were a few instances where data was either not collected or had to be discarded due to uncertainty from a mix-up of sample bottle numbers, analytical problems, volunteer and laboratory scheduling, and occasionally simply forgetting to collect a value. For several sampling events during late summer, there was no flow present at station GEE085 in the upper watershed.

Quality Control Results

This project's quality control (QC) sample types, frequencies, and definitions are listed in Table 9. The overall goal was to duplicate fecal coliform samples and field meter measurements at one sample site during each monthly survey.

Table 9. QC sample types, frequencies, and definitions required for the project.

QC Sample Type	Frequency	Definition
Field measurement replicate	One per monthly survey	Repeat field meter measurements
Sample duplicate	One per monthly survey	Duplicate sample collected for laboratory analysis

All meters were calibrated and maintained by CWP staff in accordance with the manufacturer's instructions. Secondary standards for turbidity were used to verify the calibration of field meters. Calibration logs were completed during each calibration and were archived in Water Resources' files.

Laboratory QC samples were analyzed in accordance with the Ecology accredited Salmon Creek Wastewater Treatment Plant Laboratory's quality assurance plan. Other than results from sample blanks there was no QC data provided by the lab with the data reports.

In summary, QC data for precision was very good. Twenty-one duplicate pairs of samples were used for fecal coliform QC analysis. The data quality objective for fecal coliform duplicate samples was 25% RSD on log-transformed data (Table 10). All but one fecal coliform QC sample met this objective, and the RSD ranged from less than 1.2% to 30%. The 30% value resulted from a duplicate pair with very low concentrations of fecal coliform: the original value was 2 CFU/100mL and the duplicate value was 3 CFU/100mL. Eliminating this value gives a range of RSD for twenty pairs of 1.2% to 19%.

Nineteen turbidity measurements were replicated in the field by the volunteer teams to estimate precision. The data quality objective for the replicate turbidity measurements was an RSD of 10% (Table 10). All of the 19 QC measurements met the objective, ranging from 0.0% to 3.1%.

The Salmon Creek Wastewater Treatment Plant laboratory did not report any problems or cases of contamination in sample blanks that were run with each batch of samples.

Table 10. Summary Measurement Quality Objectives (MQO's) of laboratory and field parameters.

Parameter	Accuracy	Precision	Bias	Required Reporting Limit
	Percent (%) deviation from true value or units of measurement	*Relative Standard Deviation*	*Percent (%) of true value*	*Concentration units*
Turbidity	25%	10%	5%	1 NTU
Fecal Coliform	NA	25% (log transformed data)	NA	2 MPN/100mL

Conclusions and Recommendations

Conclusion

Gee Creek is listed for fecal coliform on the 2008 Ecology 303(d) list. Previous monitoring by Clark County and community volunteers (2002-2007) provided insight into how fecal coliform levels varied through the year and from year to year at two locations in mid and lower Gee Creek.

This study provided greater detail describing fecal coliform distribution throughout the Gee Creek watershed and indicated potential areas where future source control efforts may be most productive.

The results suggest that fecal coliform water quality standard violations are widespread and frequent in Gee Creek. None of the seven stations studied during 2007 and 2008 were in compliance with the state water quality criteria for fecal coliform.

Conditions were relatively better at the upper watershed stations (GEE070 and GEE085), and at the furthest station downstream (GEE020). Interestingly, conditions improved considerably in a relatively short distance between stations GEE030 (Abrams Park) and GEE020. The Bertsinger Road tributary (BER010) had the highest overall geometric mean concentration and was consistently the most impacted station during the dry season. The Carty Road tributary station (CAR010) had the highest 90^{th} percentile concentration and showed several very high concentrations during wet weather. Turbidity values were relatively similar throughout the watershed, with no statistical difference between stations.

Overall, wet weather during the wet season (October - May) produced the highest fecal coliform values, while dry weather during the wet season produced the lowest. Turbidity values were typically much higher during wet weather, regardless of season.

Due to widespread fecal coliform problems, source removal efforts are needed throughout the watershed in order to meet state criteria. However, there are several areas where concentrated source control efforts may result in particularly significant improvements. These include the Bertsinger Road tributary upstream of station BER010, and the Carty Road tributary upstream of station CAR010.

The seasonal, weather-related, and geographic patterns observed in the data indicate that there are likely multiple types of fecal coliform pollution sources. Bacteria and turbidity levels were typically higher during rain events; therefore, stormwater runoff appears to be an important pathway for conveying pollutants to the waterways. This pattern was observed at most stations. Station BER010 had high fecal coliform levels during dry weather in the dry season, indicating continuous, non-stormwater runoff related sources of bacteria.

Overall, wet weather during the wet season appears to be the most critical period for controlling large pulses of fecal coliform and turbidity to the creek.

Recommendations

The following recommendations are possible next-steps for locating and removing sources of fecal coliform and turbidity to stormwater and surface water resources. Work in the near term will fall under the existing programs of local jurisdictions and groups. For example, Clark County's NPDES municipal stormwater permit requires detecting and removing sources of pollution to the storm sewer system, including ditches along county roads, as well as implementing and enforcing erosion and development regulations required by Clark County code.

During 2008, the Gee Creek watershed was included in Clark County's Stormwater Needs Assessment Program. Assessment activities included illicit discharge screening at 85 public stormwater outfalls and resulted in the removal of a serious ongoing source of fecal coliform pollution in the upper watershed.

Additional recommendations for stormwater and watershed improvement may be found in the 2008 Stormwater Needs Assessment Report for Gee Creek. Opportunities may exist for several agencies, jurisdictions, and groups to begin addressing the following recommendations, including City of Ridgefield, Clark Conservation District, Gee Creek Enhancement Committee, Clark County, and Ecology. This report will be shared with all of the above-listed groups.

Recommendations include:

1. Initiate specific technical assistance visits and public contacts at known locations with direct livestock access to streams. Initial priority should be given to those locations listed in the 2008 Stormwater Needs Assessment Report for Gee Creek.
2. Initiate additional source control activities, focused on the Bertsinger Road and Carty Road tributaries. These should include map-based research to locate potential pollution generating sites in these areas, site-specific technical assistance visits, focused mailings, mud/manure workshops and other activities.
3. Continue quarterly or monthly monitoring at the GEE050 (Clark County) and GEE030 (City of Ridgefield and/or Gee Creek Watershed Enhancement Group) stations.
4. Promote focused septic system inspection, education programs, and agricultural best management practice implementation directed at reductions in fecal coliform.

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Or, visit the Clean Water Program website:
www.clark.wa.gov/water-resources/index.html

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