

Gibbons Creek Data Summary

Part 1 –Effectiveness and Trend Monitoring by Volunteers

July 2006

Background

Gibbons Creek Watershed

Gibbons Creek is located in eastern Clark County and flows into the Columbia River just east of the town of Washougal (Figure 1). Land use in the watershed consists largely of rural residential development along the slopes of the Columbia River Valley. Many of these residences keep a small number of horses and/or cattle. The town of Washougal extends into the western portion of the watershed encompassing most of Campen Creek, and includes a school, golf course, and new residential development. Only part of the area is serviced by city sewer, but the city plans to service all residents.

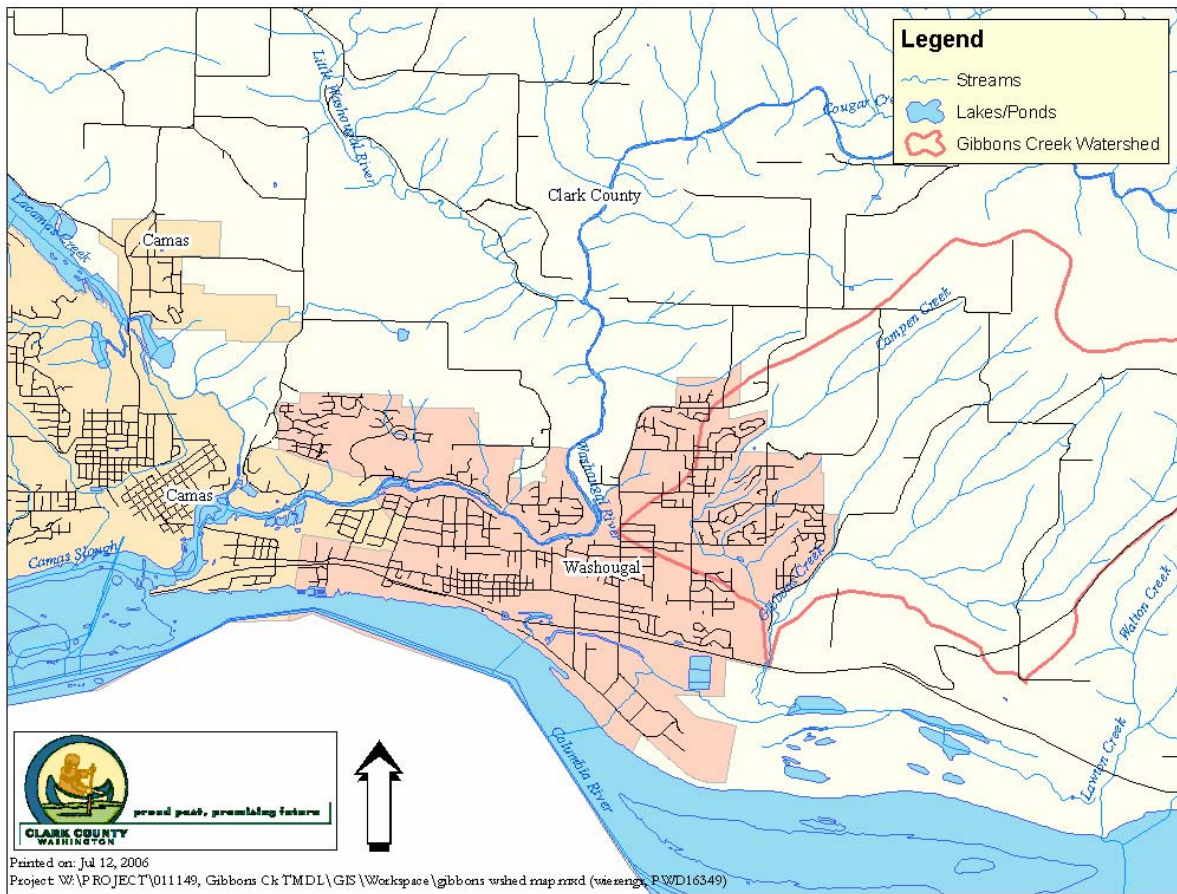


Figure 1. Map of Gibbons Creek and vicinity in Clark County.

Gibbons Creek is classified as Class A for water quality standards and therefore shall meet or exceed the requirements for all or substantially all of the following characteristic uses: domestic, industrial, and agricultural water supply; stock watering; salmonid and other fish migration, rearing, spawning, and harvesting; clam, oyster, and mussel rearing, spawning, and harvesting (Ch. 173-201A WAC).

History of the TMDL Program in Gibbons Creek

Gibbons Creek has received intermittent attention over the years. The Washington State Department of Ecology (Ecology) initially sampled Gibbons Creek at the Evergreen Highway crossing from October 1991 to September 1992, during the 1992 Ambient Monitoring Project (Ehinger, 1993).

Water quality standard violations for fecal coliform placed Gibbons Creek on the State's 303d list for impaired waterways. A TMDL assessment was conducted in late 1994 and early 1995 with the goal of establishing fecal coliform limits and identifying potential implementation activities. The TMDL implementation activities on p. 23 of the assessment report included the following (Nocon and Erickson, 1996):

- An inventory of farm animals in the basin;
- An assessment of animal waste systems and identification of farms that are likely to be contributing excess levels of fecal coliform to Campen Creek, particularly between stations GC2 and GC3 (which is the golf course);
- A septic survey to identify failing septic tanks, especially in Campen Creek;
- A land use analysis of the entire basin to identify other potential sources of fecal coliform;
- Recommend focusing on summer problems to protect primary contact recreation beneficial use;
- Verify water right holders are not using the creek for drinking water;
- Monitor Campen Creek in the summer and possibly winter to assist in identifying the sources of fecal coliform and to monitor improvements in water quality as pollution controls are implemented;
- Monitor upper Gibbons Creek watershed in summer to better determine source and extent of fecal coliform problems.

There was a several year gap in activity after the TMDL assessment report was issued in 1996. Ecology initiated the TMDL process again for Gibbons Creek in February 2000, by committing to the development of a TMDL implementation plan. Ecology developed a 'Water Cleanup Plan' in 2000, which discussed how the waters covered in the TMDL will achieve water quality standards over time (Post, 2000). It also included a description of the activities conducted to date and the process of how a 'Detailed Implementation Plan' (DIP) would be developed.

During the 2002 water year, Ecology again monitored Gibbons Creek at the Evergreen Highway crossing, as well as the mouth of Campen Creek, as part of the ambient monitoring program. Data showed that the lower mainstem Gibbons Creek and Campen Creek continued to violate water quality standards for fecal coliform, showing levels similar to data collected a decade earlier.

In early 2004, Ecology initiated a collaborative effort with the City of Washougal, and Clark County to develop a monitoring strategy to again assess fecal coliform levels in the Gibbons Creek watershed. Under the TMDL requirements of the Clean Water Act, monitoring is required to track the effectiveness of implementation activities and to determine if pollution reduction targets are being met. To meet this requirement, a project plan was made to monitor the Gibbons Creek watershed in three parts (Post, 2005). The purpose of dividing the monitoring was to increase public participation, spread monitoring costs among monitoring participants, and provide adequate data to determine the effectiveness of implementation activities. This division of responsibility also closely followed areas of expertise of the participants.

Part 1 of the study, carried out by Clark County Public Works and City of Washougal Wastewater Treatment plant staff, and by trained volunteer monitors, has the following objectives:

- Initiate preliminary source identification of fecal coliform and turbidity.
- Track relative fecal coliform and turbidity levels in various tributaries in the watershed.
- Involve the local community in water cleanup planning and monitoring.
- Determine effectiveness of previous TMDL implementation activities on water quality.

Fecal Coliform Levels in Gibbons Creek

Water quality data for the Gibbons Creek watershed primarily consist of those measured by Washington State Department of Ecology's Ambient Monitoring Program (Ehinger, 1993; unpublished data 2002) and those from Environmental Assessment Program's TMDL assessment (Nocon and Erickson, 1996), as well as data collected by the U.S. Fish & Wildlife Service (USFWS, 2003). Historical fecal coliform data is summarized in Table 1 below.

Table 1. Summary of fecal coliform data from previous monitoring programs.

Monitoring Station	Monitoring Date Range	Range of Fecal Coliform Concentration	Geometric Mean Fecal Coliform Concentration	90 th Percentile Fecal Coliform Concentration
Gibbons Creek at Evergreen Highway (Ecology ID 28G070)	October 1991-September 1992	37-900 cfu/100mL	230 cfu/100mL	705 cfu/100mL
Gibbons Creek at Evergreen Highway (Ecology ID 28G070)	October 2001-September 2002	6-1,300 cfu/100mL	119 cfu/100mL	635 cfu/100mL
Campen Creek mouth above confluence (Ecology ID 28H070)	October 2001-September 2002	12-1,200 cfu/100mL	158 cfu/100mL	1,052 cfu/100mL

Project Methods

A collaborative effort between local jurisdictions and volunteers was used to implement this monitoring project. Project guidance, equipment, and volunteer coordination were provided by Clark County Public Works Department staff through the Volunteer Monitoring Program and Resource Center. Analytical services were provided by the City of Washougal Public Works' Wastewater Department at their treatment plant laboratory. The lab is accredited by Ecology and routinely analyzes samples in accordance with their wastewater discharge permit.

Clark County staff conducted the first monitoring survey in April 2004. A training event was held for volunteers in May 2004. Additionally, trained volunteers instructed other volunteers that later joined the project over time. 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 county staff to ensure equipment availability. 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. Arrangements needed to be made for staff to work according to volunteers' schedules, which often included weekends. Volunteers reported to the treatment plant to pick up field equipment kits. Typically the Gibbons Creek sample stations were visited first, followed by Campen Creek sample stations, and

samples were collected within 1-2 hours of each other. The station name, and sample date and time uniquely identified the samples collected by volunteers.

The monitoring surveys utilized seven monitoring stations that were visited by volunteers at approximately monthly intervals for two years (see Figure 2 for a map of stations). Water samples were analyzed for bacteria and turbidity. Water temperature was monitored continuously using data loggers during summer of the first season. 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	Monthly	Standard Methods (SM) 9222D Membrane Filtration	NA	100-mL	250-mL sterile HDPE	30 hours
Turbidity	Monthly	EPA 180.1 Nephelometric	Hach 2100P	10-mL	15-mL glass vial	48 hours
Temperature	Continuous 1-hr interval	EPA 170.1	Hobo Water Temp Pro datalogger	NA	NA	NA

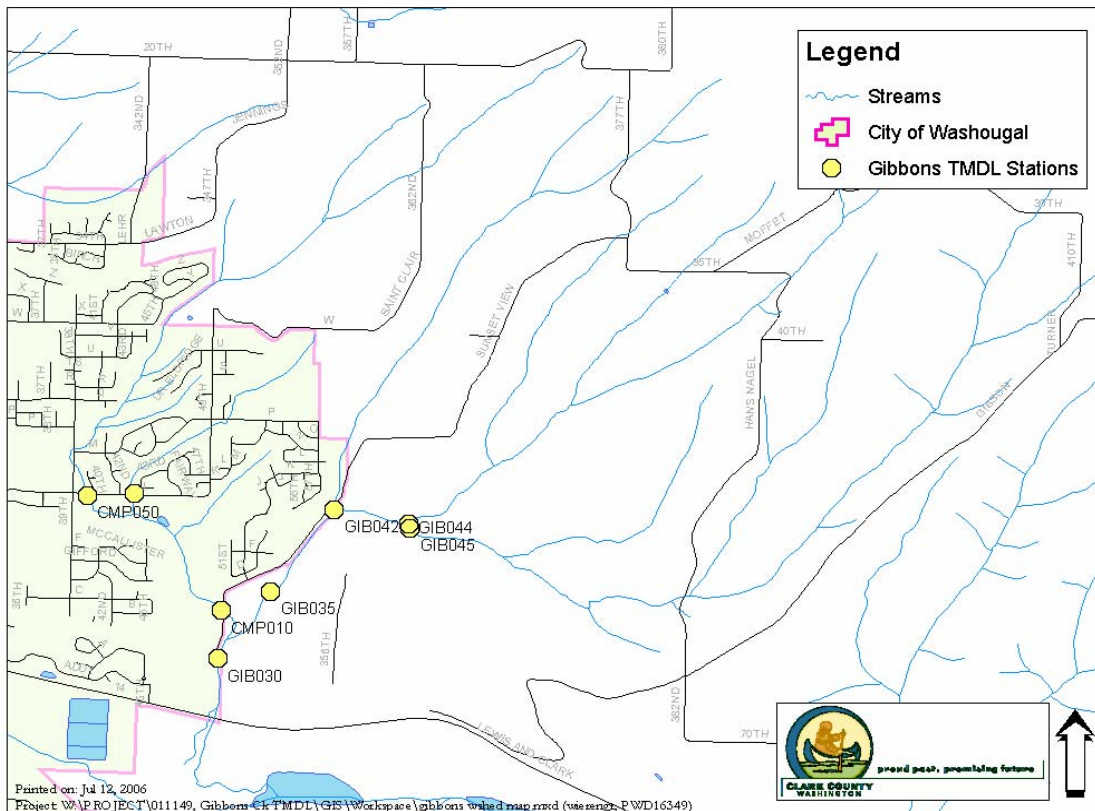


Figure 2. Map showing the layout of volunteer monitoring stations.

Data Summary

Activity Summary

In all, a dedicated team of volunteers monitored the creek's water quality for two years, completing 24 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 below. Water quality criteria for a Class A water body in Washington State maintain that "Fecal coliform organism levels must not exceed a geometric mean value of 100 colonies /100 mL, with not more than 10 percent of all samples (or any single sample when less than ten sample points exist) obtained for calculating the geometric mean value exceeding 200 colonies /100 mL" (WAC173-201A-200). 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 most of the monitoring stations in the watershed exceeded one or both of the water quality criteria over the two-year monitoring period. Four of the seven stations violated both fecal coliform water quality criteria.

Along the Gibbons Creek mainstem, the two stations representing the upper watershed, GIB044, located at the Wooding Road tributary, and GIB045, the upstream-most sample station on Gibbons Creek, nearly met both criteria. The GIB042 station on a tributary draining the northern part of the watershed that runs along Sunset View Road, however, showed occasionally high levels of fecal coliform and exceeded the 90th percentile criterion nearly three-fold. The downstream-most location at GIB030, Gibbons Creek at the Evergreen Highway, had consistently higher bacteria levels than the other Gibbons Creek stations.

Each of the monitoring stations in the Campen Creek drainage showed poor water quality. The monitoring station on the lower mainstem Campen Creek, located near the creek's confluence with Gibbons Creek, had a geometric mean concentration nearly three times the water quality criterion and a 90th percentile value nearly 10 times the criterion. Stations located in upper Campen Creek also showed degraded conditions, with the upper mainstem station at CMP050 typically having higher fecal coliform levels than the tributary represented by station CMP038.

Table 3. Summary of fecal coliform sample data from April 2004 to April 2006; highlighted values indicate cases where the Class A 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	90 th Percentile Fecal Coliform Concentration cfu/100 mL
CMP010	22	1-6,080	317	2075
CMP038	23	2-3,520	181	656
CMP050	22	1-1,030	188	922
GIB030	23	20-5,260	159	564
GIB042	22	1-2,960	97	602
GIB044	22	1-2,160	35	158
GIB045	22	1-640	32	219

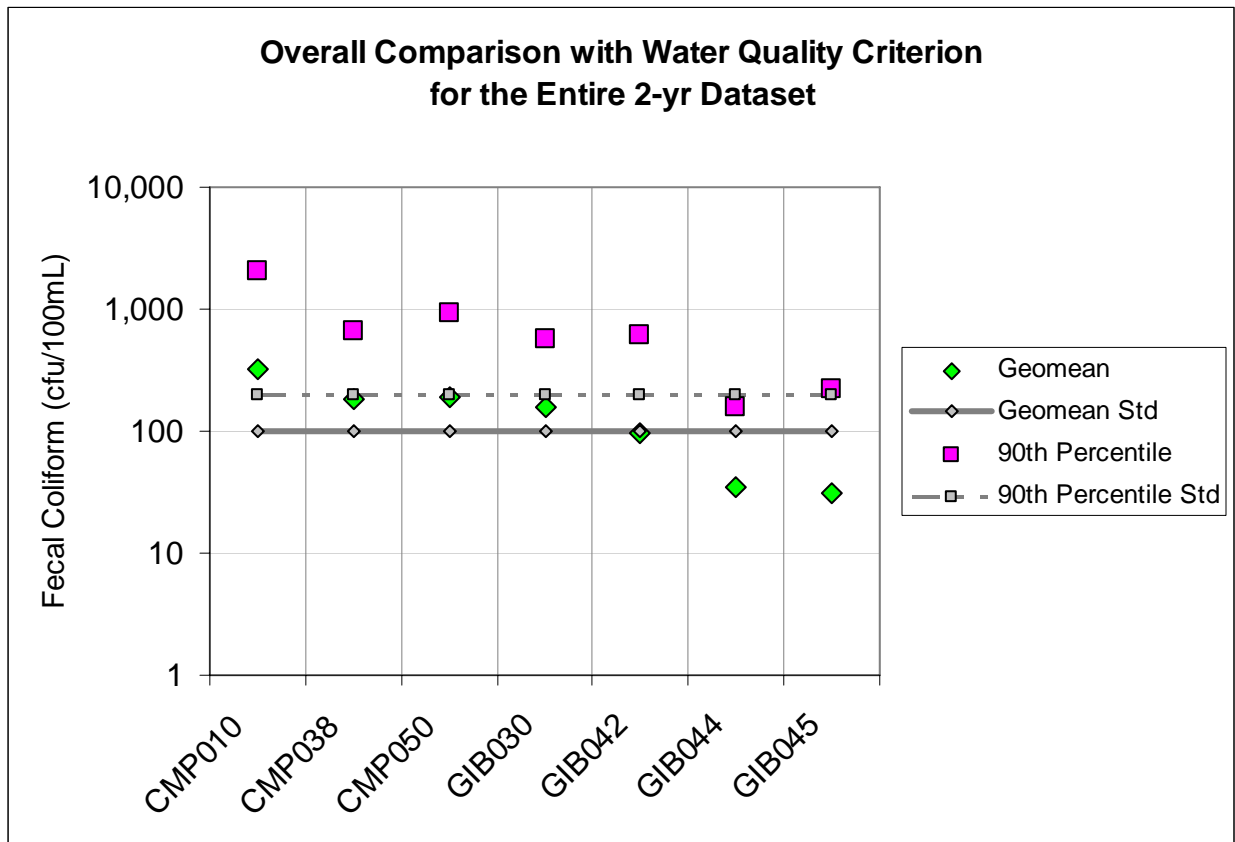


Figure 3. Summary of fecal coliform data from April 2004 to April 2006. Calculations of the geometric mean (GeoMean) concentrations and 90th percentile concentrations are shown as symbols; the lines show the Washington State Class A water quality criteria for each calculation.

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.

Although the sampling dates were chosen arbitrarily by volunteers, the sites were distributed somewhat evenly among the categories, with a few more events taking place in wet weather relative to dry weather, and in the wet season relative to the dry season (see totals in Table 5 below).

Table 4. Summary of conditions during sample over the two 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)
04/28/04	Dry Weather	Wet Season	< 0.01	< 0.01
05/22/04	Wet Weather	Wet Season	0.22	0.22
06/19/04	Dry Weather	Dry Season	< 0.01	< 0.01
07/24/04	Dry Weather	Dry Season	< 0.01	< 0.01
08/22/04	Wet Weather	Dry Season	1.19	1.19
09/18/04	Wet Weather	Dry Season	0.98	1.64
10/23/04	Wet Weather	Dry Season	0.53	0.63
12/18/04	Dry Weather	Wet Season	< 0.01	< 0.01
01/22/05	Wet Weather	Wet Season	< 0.01	0.13
02/16/05	Dry Weather	Wet Season	< 0.01	< 0.01
03/19/05	Wet Weather	Wet Season	0.41	0.41
04/30/05	Dry Weather	Wet Season	0.03	0.04
06/02/05	Wet Weather	Dry Season	0.33	1.74
06/26/05	Dry Weather	Dry Season	< 0.01	< 0.01
07/16/05	Dry Weather	Dry Season	< 0.01	< 0.01
08/23/05	Dry Weather	Dry Season	< 0.01	< 0.01
09/11/05	Wet Weather	Dry Season	0.44	0.46
10/31/05	Wet Weather	Dry Season	2.52	2.84
11/19/05	Dry Weather	Wet Season	< 0.01	< 0.01
12/17/05	Dry Weather	Wet Season	< 0.01	< 0.01
01/18/06	Wet Weather	Wet Season	0.88	2.17
02/24/06	Wet Weather	Wet Season	0.58	0.84
03/21/06	Wet Weather	Wet Season	0.22	0.22
04/21/06	Dry Weather	Wet Season	0.07	0.07

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

Event Category	Event Count	Geometric Mean Value	90 th Percentile Value	Number of Observations
Dry Weather/Dry Season	5	240	640	31
Wet Weather/Dry Season	6	367	2726	34
Dry Weather/Wet Season	7	37	292	29
Wet Weather/Wet Season	6	81	476	42

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

- Although geometric mean and 90th percentile fecal coliform values are higher during wet weather than dry weather, the difference is not statistically significant*.
- Fecal coliform levels are significantly higher during the dry season than the wet season*.
- Wet weather during the dry 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 the Gibbons and Campen Creek watersheds (Figure 4 and Table 6 below). Exceptions include the geometric mean value at CMP010, the mouth of Campen Creek, where values were lower for wet weather during the wet season compared to dry weather. Another exception is at the uppermost Gibbons Creek station, GIB045, where fecal coliform levels in wet weather during the dry season were lower compared to dry weather. These exceptions to the general pattern of wet weather coinciding with high levels of fecal coliform may indicate the presence of continuous, dry weather sources of bacteria, for example illegal connections of sewer to drainage ways or perhaps failing septic systems.

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

Event Category	CMP010	CMP038	CMP050	GIB030	GIB042	GIB044	GIB045
	Geometric Mean Value						
Dry/Dry	508	289	319	257	269	77	162
Wet/Dry	1,043	501	623	484	432	121	121
Dry/Wet	216	79	<i>100</i>	<i>74</i>	<i>24</i>	7	<i>5</i>
Wet/Wet	133	139	114	103	72	46	32
	90th Percentile Value						
Dry/Dry	885	632	812	496	380	175	437
Wet/Dry	4,520	2,246	914	3,484	2,024	1,334	466
Dry/Wet	376	264	734	<i>172</i>	<i>100</i>	30	<i>34</i>
Wet/Wet	1,400	1,160	460	377	395	<i>110</i>	90

* 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 .

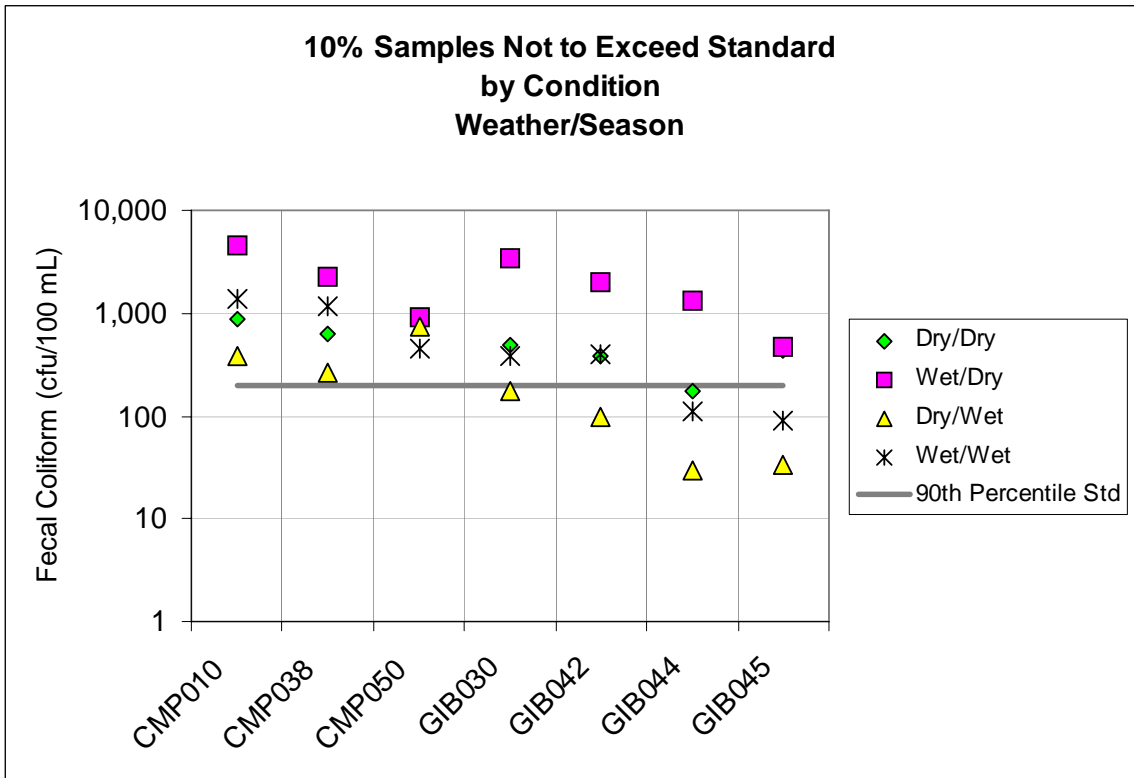
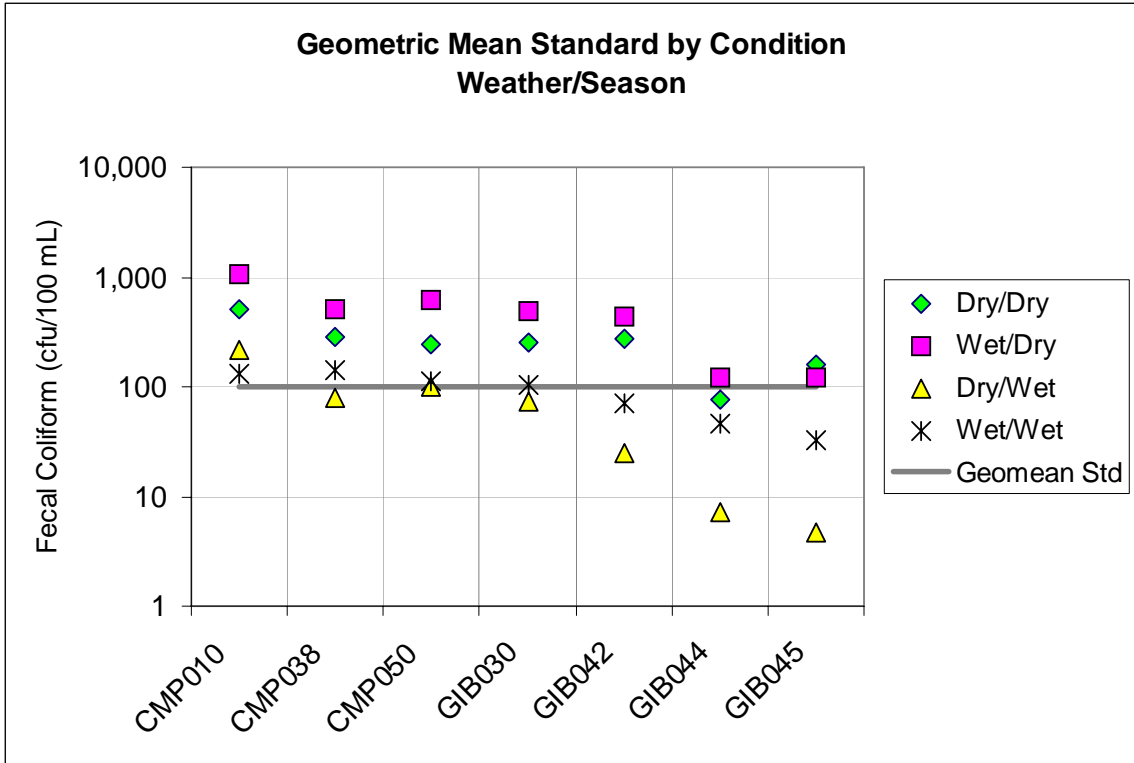


Figure 4. Fecal coliform levels for each of the stations showing data grouped into categories of weather and season, for example, 'Dry/Dry' is the category for 'Dry Weather during the Dry Season'. Dry and wet weather were determined with a 48-hr rainfall total of 0.1 inches, and dry and wet seasons were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

Time series for the geometric mean fecal coliform levels throughout the calendar year are shown in the figure below. Individual station data were grouped by month for stations in/along the Gibbons and Campen Creek mainstem prior to calculating the geometric mean. While the events per month ranged from a single to three events, most of the months had at least two sample events over the two 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 a gradual increase in fecal coliform levels throughout the summer, with occasionally large values observed in late summer due to rain events carrying pollutants accumulating on infrequently washed surfaces. Lower values are typically observed during the winter months. Additionally, it is evident from the graph that fecal coliform levels in Campen Creek may be similar to levels in Gibbons Creek throughout much of the winter, but are routinely higher throughout the rest of the year. It is important to note that the downstream-most station in Gibbons Creek, which was grouped into the Gibbons Creek stations, is located below the Campen Creek confluence and is strongly influenced by its bacteria levels. When the station is removed from the Gibbons Creek group, the separation of the plotted lines in Figure 5 is more pronounced, indicating routinely higher levels of bacteria in Campen Creek relative to upper Gibbons Creek.

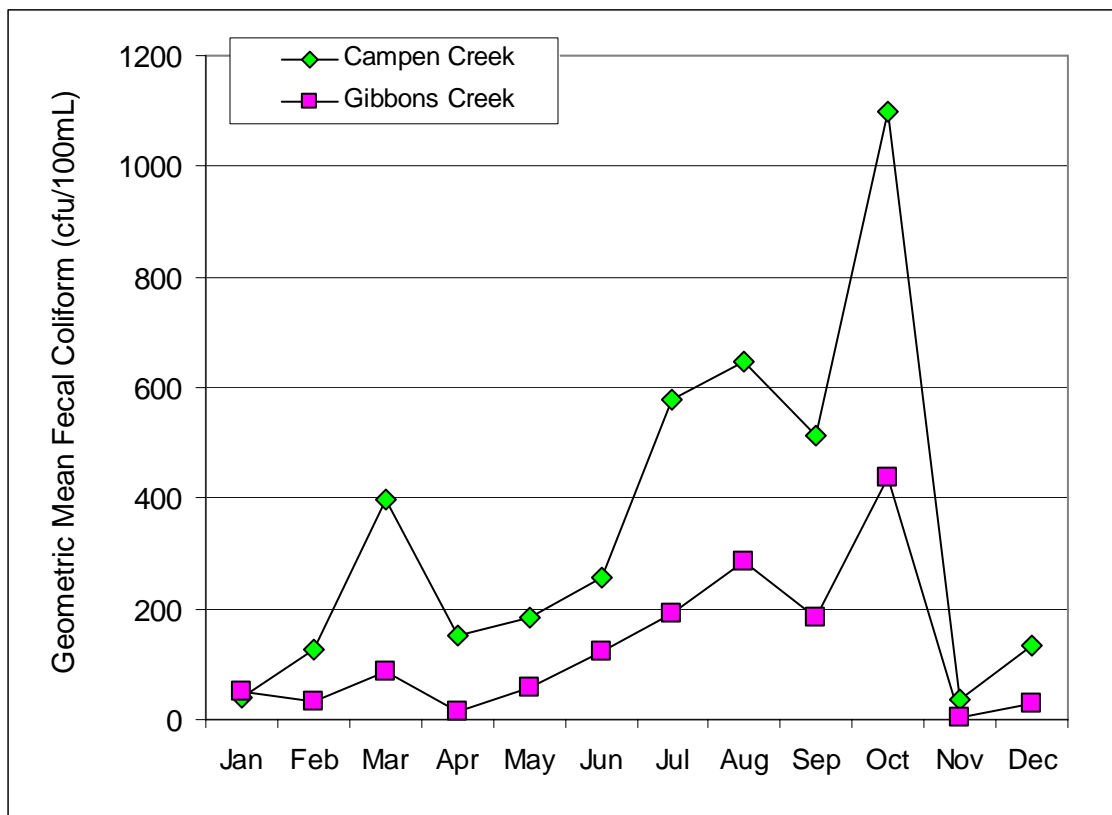


Figure 5. Geometric mean fecal coliform levels for Gibbons and Campen Creek stations, grouped by month. Several of the months showed distributed weather conditions.

Turbidity

Water quality criteria for a Class A water body in Washington State maintain 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 that is between 1-5 NTU is realistic.

Turbidity values are summarized in Table 7. Typically, the observed values were low; the median value at each of the monitoring stations was between 2-5 NTU. But, occasionally, very high values of turbidity were observed at each of the monitoring stations in both Gibbons and Campen Creek. If background turbidity was conservatively assumed to be about 1 NTU, then Campen and Gibbons Creeks would exceed the criteria of 6 NTU about 40-70% of the time, indicating a turbidity problem throughout most of the drainage.

Table 7. Summary of turbidity sample data from April 2004 to April 2006.

Monitoring Station Code	Number of Samples	Range of Turbidity Values NTU	Median Turbidity NTU
CMP010	23	3.4-85.0	16.6
CMP038	24	3.9-337.0	23.6
CMP050	24	2.2-92.4	14.0
GIB030	24	1.8-96.8	10.5
GIB042	23	2.0-95.4	16.1
GIB044	23	2.7-63.9	14.2
GIB045	23	1.7-103.0	14.2

As with the fecal coliform data described previously, individual sampling events 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 Gibbons 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 significantly higher during wet weather in the dry season than wet weather during the wet season*.
- Turbidity levels are *not* significantly higher during dry weather in the dry season than dry weather during the wet season*.

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

Event Category	Event Count	Range of Turbidity Values NTU	Average Turbidity NTU	Number of Samples
Dry Weather/Dry Season	5	2.5-13.1	6.1	31
Wet Weather/Dry Season	6	4.0-96.8	25.6	42
Dry Weather/Wet Season	8	1.7-13.8	5.3	49
Wet Weather/Wet Season	6	2.8-337.0	23.2	42

* 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 .

The data summarized in Table 8 indicates that typical turbidity during wet weather is similar among seasons. But the statistical analysis summarized above indicates that weather is a driving factor behind turbidity levels, and that levels are significantly higher during the dry season relative to the wet. It is interesting to note, that a single intense rain event on March 19, 2005 skews the statistics for the 'wet weather during the wet season' category. The magnitude of turbidity values during this event masks general patterns for the influence of weather and season.

With this outlier removed from the dataset, typical turbidity levels for 'wet weather during the wet season' are lower and more similar to dry weather levels during both seasons, with a range of 2.8-14.6 NTU and an average turbidity value of 6.9 NTU. Taking this outlier into account reinforces the observation that turbidity values are higher in 'wet weather during the dry season' relative to the wet season, and that the critical period for turbidity appears to be wet weather during the summer, from June to October. These observations generally held true for the individual sample stations in the Gibbons and Campen Creek watersheds.

Water Temperature

Water quality criteria for a Class A water body in Washington State maintain that “Temperature shall not exceed 64.4 deg-F (freshwater) or 60.8 deg-F (marine water) due to human activities” (WAC173-201A-200). A station or waterbody’s evaluation is based on the calculation of the maximum 7-day moving average of the daily maximum water temperature.

Water temperature statistics calculated from the continuous data logger records are shown in Figure 6. Data loggers were not deployed at the upper Campen Creek stations due to logistical constraints. Gibbons and Campen Creek both exceeded water quality criteria for water temperature. The Gibbons Creek tributary stations at GIB042 and GIB044 were close to the 64.4 deg-F standard, while the other main stem sites at GIB030 and GIB045 were three to five degrees above the standard. Campen Creek, near its confluence with Gibbons Creek, was about four degrees above the standard, similar to the downstream station at GIB030.

The GIB010 station, located at the mouth of Gibbons Creek at the Columbia River, was established for a cooperative project with the Steigerwald Lake Wildlife Refuge, US Fish and Wildlife Service. Maximum water temperature at the GIB010 station was much higher than the other stations. Prior to 1992, the lower reach of Gibbons Creek flowed westerly for the lower mile before discharging into the Columbia River. Since 1992, this channel has been significantly modified and it drains nearly due south from the highway crossing, through the wildlife refuge, to the Columbia River. For most of this lower mile, the creek flows through an artificial, elevated channel before discharging into the Columbia River through a fish ladder structure. Because this portion of the channel is elevated (built on a dike), the surrounding land does not drain into Gibbons Creek, but instead drains into the old remnant channel. Therefore, no land south of Highway 14, including the wildlife refuge, industrial park, and agricultural areas contributes runoff to Gibbons Creek.

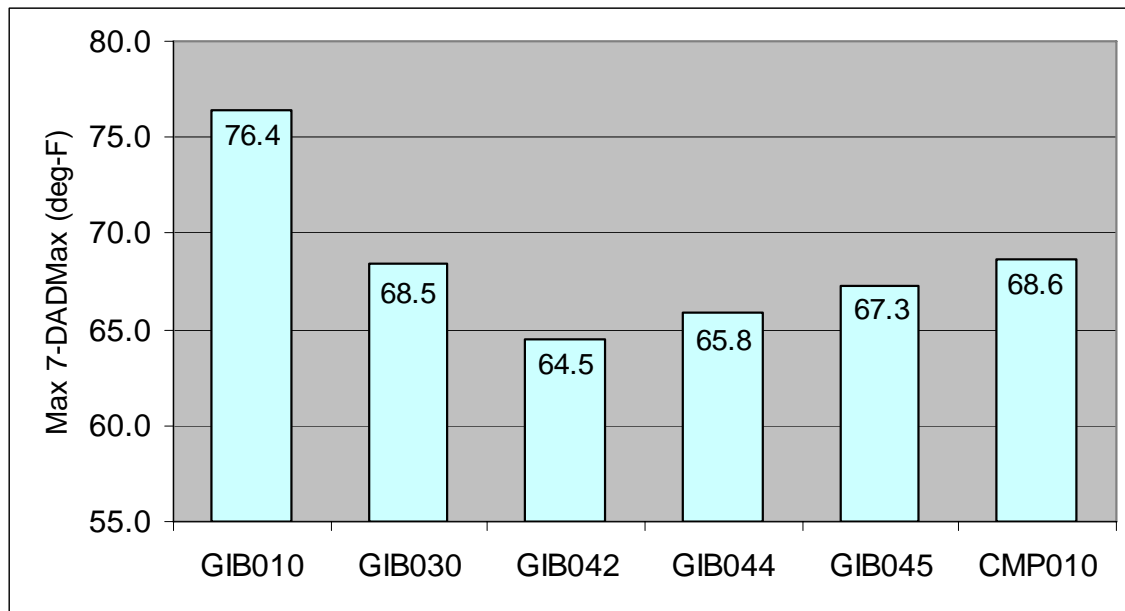


Figure 6. Water temperature data statistics for the Gibbons Creek watershed from May to October 2004. Data reported is the maximum 7-day moving average of the daily maximum (Max 7-DADMax) water temperature.

Quality Control Summary

Data completeness

There were 24 sampling events scheduled from April 2004 to April 2006. Both the fecal coliform and turbidity data were over 90% complete, with between 22 and 24 events sampled. 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.

Water temperature data loggers were deployed at five of the seven sample sites for about 70% completeness. Loggers were not deployed in the upper Campen Creek tributaries because no secure data logger locations were found. In early 2005 volunteers were equipped with a handheld temperature probe to collect temperature data during grab sampling events. An additional data logger was deployed at the mouth of Gibbons Creek outside the project area in cooperation with the US Fish and Wildlife Service.

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 Water Resources staff in accordance with the manufacturer's instructions. Secondary standards for turbidity were used to verify the calibration of field meters. A NIST-certified thermometer was used to verify the accuracy of the temperature sensors prior to and after field deployment. Calibration logs were completed during each calibration and were archived in Water Resources' files.

Laboratory QC samples were analyzed in accordance with the Washougal 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 two 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 of the fecal coliform QC samples met this objective, as the RSD ranged from less than 1% to 22%.

Twenty one turbidity measurements were replicated in the field by the volunteer teams to estimate precision. During a few sampling events near the beginning of the program volunteers did not collect QC replicate measurements for turbidity. The data quality objective for the replicate turbidity measurements was an RSD of 10% (Table 10). Sixteen of the 22 QC measurements met the objective, while five had RSDs between 10 and 15%; most of which were near the lower end of the method reporting limit and in each case the difference was less than 2.0 NTU.

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

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

The Washougal Wastewater Treatment Plant laboratory did not report any problems or cases of contamination in sample blanks that were run with each batch of samples. No side-by-side monitoring by WA Department of Ecology occurred as had been directed in the QAPP (Post, 2005).

Conclusions and Recommendations

Conclusion

This collaborative monitoring effort addressed an important data gap. The previous work by the Washington Department of Ecology had provided insight into how fecal coliform levels varied through the year and from year to year, but only at the most downstream locations on Gibbons and Campen Creeks. When compared to previous efforts, sampling in 2002 showed that the situation had not improved significantly since the early 1990's. Assessments done by Ecology in the mid-1990's provided information at more locations in the watershed, but only for three sample events in the late-summer and winter. This most recent effort by local jurisdictions and community volunteers provided the first multi-season look at fecal coliform and turbidity levels for the major branches of Gibbons Creek.

The results showed that the upper mainstem and tributaries of Gibbons Creek are in good condition relative to the other tributaries. Sources of bacteria certainly exist in the upper drainages; however, expending resources locating and removing these sources is currently not as crucial as in other locations. Campen Creek and the Gibbons Creek tributary following Sunset View Road should be the focus of future monitoring and source removal programs. Campen Creek, at stations in both the lower and upper reaches, consistently had higher levels of bacteria than upper Gibbons Creek.

The patterns observed in the data also indicate that there are likely multiple sources of fecal coliform pollution entering the creeks. Bacteria and turbidity levels were often higher during rain events, particularly the late summer and early fall events. Therefore stormwater runoff appears to be an important pathway for conveying pollutants accumulating on impervious surfaces to the waterways. Furthermore, routinely high fecal coliform levels during dry weather in the dry season indicate continuous, non-stormwater runoff related sources of bacteria, such as illegal discharges and failing septic systems. July through October appears to be the most critical period for controlling large pulses of fecal coliform and turbidity to the creeks.

The results of this project will help the agencies and local jurisdictions direct limited resources for improving conditions in Gibbons 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. Implementing source assessment and control activities at this point is voluntary and not a requirement of the TMDL for these waterways. Much of the work may fall under the existing programs of local jurisdictions. For example, Clark County's NPDES MS4 permit requires detecting and removing sources of pollution to the storm sewer system, as well as implementing and enforcing erosion and development regulations required by Clark County code.

Recommendations include:

1. Perform a watershed analysis to describe the natural and developed characteristics of the drainage that create vulnerable conditions for surface water pollution, and to identify potential sources of pollution, such as parking lots, septic systems, and farming operations.
2. Assess both privately and publicly owned storm water infrastructure (conveyance, storage, and treatment features) with desktop and field assessment tools.
3. Monitor fecal coliform and turbidity levels during both dry and wet weather from July to October, particularly during or after intense storms in the early fall. Monitoring stations should be densely located along reaches where higher levels of bacteria have been observed, such as the Gibbons Creek tributary along Sunset View Road and throughout Campen Creek.
4. Initiate source assessment activities, such as storm sewer outfall screening, septic system surveys, and stream assessments.

5. Coordinate with the Clark County Public Health for septic system inspection, survey, and education in drainages showing high levels of fecal coliform (a TMDL implementation activity).
6. Continue quarterly monitoring at the volunteer site located on Gibbons Creek near the Jemtegaard Middle School.
7. Establish a long-term stream flow monitoring gauge on Gibbons Creek for water quality monitoring and fisheries management activities.
8. Coordinate with the Clark County Conservation District to identify potential riparian improvement/restoration sites for decreasing water temperatures and filtering out pollutants in storm water runoff from agricultural and open areas. Potential locations in lower Gibbons and Campen Creeks include the reach running along Jemtegaard Middle School and upstream along Sunset View Road, and along the Orchard Hills Golf Course. Locations in upper Gibbons Creek, above Hans Nagel Road, may also be ideal for riparian habitat improvement projects.

Acknowledgements

Thank you to the members of the monitoring team for volunteering their time for this project: Christine Roggenkamp, George Pollock, Pauline Rule, Sherian Wright, Malcom Wright, Steve Roberts, Terry Arvidson, Wendi Allen, Ray Allen, and Cesilie Cocks.

Volunteer monitoring is supported by the Clark County Public Works, Clean Water Program. Volunteer Coordinator is Jason Wolf, and Ron Wierenga analyzed the data and wrote this report.

This project was made possible by the partnership with the City of Washougal Wastewater Treatment Lab. Many thanks to the supervisor, Trevor Evers, and to the lab technicians Ryan Baker and Trever Munsch.

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