Green-Duwamish Watershed Water Quality Assessment

Microbial Source Tracking Study Report

October 2006

King County
Department of Natural Resources and Parks
Water and Land Resources Division

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MICROBIAL SOURCE TRACKING STUDY

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Prepared for

King County Department of Natural Resources and Parks

October 24, 2006

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Prepared for

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Executive Summary

The Green-Duwamish River watershed, located in King County, Washington, has numerous stream segments throughout the watershed that are listed on the state's Clean Water Act Section 303(d) list of impaired water bodies for violations of water quality standards for fecal coliform bacteria (Ecology 2006). Section 303(d) of the Clean Water Act (CWA) requires the state to identify those water bodies that do not meet water quality standards, and to develop total maximum daily load (TMDL) values to improve water quality in the affected reaches.

In 2001, King County initiated a comprehensive study of the Green-Duwamish watershed, called the Green-Duwamish Watershed Water Quality Assessment (GDWQA) Comprehensive Monitoring Program. The primary purpose of the program was to collect and analyze water quality data within the Green-Duwamish watershed. As part of the GDWQA, King County implemented the current microbial source tracking (MST) study described herein to address bacterial contamination in the watershed and to better understand the relationship between land use and bacterial loadings. This document summarizes the findings of the Green-Duwamish MST study.

This MST study used a genetic fingerprinting methodology (molecular ribotyping) technique to identify fecal sources of bacterial contamination in the environment. This methodology involves identifying different *E. coli* strains from water samples and matching them to genetically identical strains isolated from known sources (e.g., domestic animals, humans, farms animals, etc.). The primary goal of the Green-Duwamish watershed MST study was to determine potential sources of the indicator bacteria *Escherichia coli* in the Green-Duwamish watershed.

To address this general goal, the following objectives were defined for the study:

- Provide information that may be used to improve understanding of, and describe the relationship between, bacterial sources and land use, hydrology, and season.
- Provide data that may be used to refine development of models used to simulate the dynamics of *E. coli* populations in the Green-Duwamish River.
- Determine the relative contribution of human and animal sources from each of the selected tributaries and reaches of the main stem Green-Duwamish River.
- Improve our understanding of the types and sources of *E. coli* populations at various locations in the main stem Green River that are attributable to the various land uses in representative subbasins.

To meet the study objectives, *E. coli* colonies were isolated from water samples and genetically typed using a molecular ribotyping technique to identify animal and human sources of fecal coliform bacteria. The ribotypes obtained from the water samples were compared to a ribotype library to determine the number of genetic matches between those ribotypes recovered from known sources and those recovered from the various water quality sampling stations monitored in this study.

Water samples were collected during 2003 and 2004 for the Green-Duwamish MST study during a total of eight storm events and seven base flow events at nine study locations, four on the main stem Green River and five at the mouth of tributaries of the Green River. Additional bacterial data from samples collected during 2001 and 2002 were used to supplement the study database. Overall, a total of 564 water samples were collected from five stream sites and four river sites. Thirteen percent of the samples were analyzed for fecal coliform bacteria and 27 percent of the samples were analyzed for *E. coli*. A total of 1,503 *E. coli* isolates were obtained from the samples and used in the ribotyping analysis to determine which source they originated from.

Bacteria concentration data were evaluated to test for differences in terms of hydrologic and seasonal conditions, as well as for compliance with water quality standards, to determine how bacteria concentrations vary in the Green River watershed. *E. coli* bacteria concentrations were significantly higher during storm flow conditions than base flow conditions at all stations except Soos Creek (A320), and generally exceeded the EPA water quality criterion at all but one station during base flow and all but two stations during storm flow. Summer bacteria concentrations were generally higher than winter concentrations; however, the differences observed were not statistically significant.

Bacteria data were also evaluated to assess the influence of location and land use on bacteria concentrations in the Green River watershed. Fecal coliform bacteria concentrations in the main stem Green River increased significantly from upstream to downstream, reflecting the increased amount of development and agricultural land use from upstream to downstream. Likewise, the highest fecal coliform bacteria concentrations were observed in those stream subbasins with the most development and agricultural land use, while the lowest concentrations were observed at the stream subbasin (Soos Creek) with the least development and agricultural land use.

The ribotyping analysis successfully matched 95 percent of 1,503 isolates obtained from the 564 water samples to known human or animal fecal sources. Proportions of bacteria sources generally varied with the land use present in the areas draining to each monitoring site. Human sources were most prevalent in areas of low density development (i.e., septic systems), canine/feline sources were most prevalent in areas of high density development, and livestock sources were most prevalent in agriculture areas. Bacteria sources among stations generally did not vary consistently with hydrologic condition (base flow versus storm flow) or season (winter versus summer).

Human bacteria sources represented 3.5 percent of the total *E. coli* isolates obtained, and were detected at all river and stream monitoring sites except Springbrook Creek (A317), suggesting that the 100 percent coverage of municipal sewer and the lack of on-site septic systems

effectively prevents the contamination of Springbrook Creek from human waste. Livestock (bovine and horse) bacteria sources represented 7.1 percent of the total isolates. The highest percentage of livestock isolates (24 percent) was observed at Newaukum Creek (0322), whose basin contains the highest percentage of agricultural land use (45 percent) of all the study sites. Canine sources represented 12.5 percent of all sources and were observed more frequently at stream stations (14.5 percent) than river stations (9.2 percent). In addition, at the stream sites, the percentage of canine bacteria sources increased with increasing developed land use, suggesting that a majority of the isolates originate from domesticated canines (dogs).

Avian bacteria sources represented the largest percentage (26.1 percent) of all ribotypes, and were the predominant source at eight of the nine monitoring stations. Rodent/beaver sources were the second most prevalent source observed (16.6 percent) and were observed more frequently at the stream stations (18.3 percent) than the river stations (13.8 percent). Deer/elk and raccoon sources were observed at a moderate frequency (9.3 and 7.5 percent, respectively), and were observed at all stream and river stations while bear, bobcat, coyote, muskrat, skunk, and squirrel were rarely observed at any station (less than 1 percent).

1.0 Introduction

The Green-Duwamish River watershed, located in King County, Washington, has numerous stream segments throughout the watershed that are listed on the state's Clean Water Act Section 303(d) list of impaired water bodies for violations of water quality standards for fecal coliform bacteria (Ecology 2006). Section 303(d) of the Clean Water Act (CWA) requires the state to identify those water bodies that do not meet water quality standards, and to develop total maximum daily load (TMDL) values to improve water quality in the affected reaches.

In 2001, King County initiated a comprehensive study of the Green-Duwamish watershed, called the Green-Duwamish Watershed Water Quality Assessment (GDWQA) Comprehensive Monitoring Program. The primary purpose of the program was to collect and analyze water quality data within the Green-Duwamish watershed. The data are being used to support King County and other agencies in capital planning projects, water resource inventory area (WRIA) 9 salmon conservation planning, stormwater management efforts, and TMDL studies. Seventeen sites were selected for monitoring to represent three water body types within the watershed: main stem Green River, major streams, and tributaries. The tributary sites were selected to represent different types of land use (i.e., density of development, agriculture, and forestry). The water quality data have been statistically evaluated and pollutant loadings were calculated to evaluate the influence of land use conditions on the occurrence of pollutants in the watershed (Herrera 2006a in press).

As part of the GDWQA, King County implemented the microbial source tracking (MST) study described herein to address bacterial contamination in the watershed and to better understand the relationship between land use and bacterial loadings. The primary purpose of this MST study is to determine potential fecal sources of indicator bacteria (i.e., *Escherichia coli*) in the Green-Duwamish watershed. This MST study used a genetic fingerprinting methodology (molecular ribotyping) technique to identify fecal sources of bacterial contamination in the environment. This methodology involves identifying different *E. coli* strains from water samples and matching them to genetically identical strains isolated from known sources (e.g., domestic animals, humans, farms animals, etc.). The results of this study will be used to better understand the relationship between bacteria sources and land uses contributing to bacterial loadings in the watershed.

This document summarizes the findings of the Green-Duwamish MST Study. The report that follows is organized into separate sections including: background information; project description; methods; results and discussion; and conclusions.

2.0 Background Information

2.1 Watershed Overview

The Green-Duwamish watershed is located in water resource inventory area 9 (WRIA 9), which is located entirely within King County, Washington (Figure 1). The watershed comprises a drainage area of approximately 484 square miles, consisting of the Puget lowland and Cascades ecoregions (Ecology 1995; King County 2002). The watershed extends from the crest of the Cascade Mountains at the headwaters of the Green River, west to the mouth of the Duwamish River where the river empties into Elliott Bay at the City of Seattle. The average areal precipitation is 59 inches per year within the watershed (Ecology 1995). The Green-Duwamish watershed is comprised of the following subwatersheds (Figure 1):

- Upper Green River subwatershed covering 220 square miles above river mile (RM) 64.5 at Howard Hanson Dam
- Middle Green River subwatershed covering 178 square miles from RM 64.5 to RM 32.0 at Auburn Narrows
- Lower Green River subwatershed covering 64 square miles from RM 32.0 to RM 11.0 at Tukwila
- Green-Duwamish Estuary subwatershed covering 22 square miles from RM 11.0 to RM 0.0 at Elliott Bay.

The study area encompasses 264 square miles of the Green-Duwamish watershed that extends from Howard Hanson Dam (RM 64.5) to the mouth of the Duwamish River (RM 0) (King County 2002). The Upper Green River sub-watershed (220 square miles) above Howard Hanson Dam is not included in this study because less than 1 percent of the area above the Howard Hanson Dam is developed and public access is restricted. Based on previous water quality data (Herrera 2004a, 2005a), fecal coliform bacteria concentrations always met state water quality standards, indicating that there are no significant sources of bacteria in this sub-watershed. Major cities that are located within the study area include Seattle, Renton, Kent, Auburn, Tukwila, and Enumclaw. Major streams draining to the Green River within the study area include Soos, Newaukum, Mill (Hill), and Springbrook Creeks.

Land use in the study area is presented in Figure 2. Land use in the Upper Green River watershed (not included in the study area) is dominated by forest and forestry practices, and serves as the drinking water supply watershed for the City of Tacoma. Land use in the Middle and Lower Green River subwatersheds is dominated by agriculture and low- to high-density residential development with some forested areas. The Green-Duwamish Estuary subwatershed is primarily an urban industrialized area serving the City of Seattle.

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Figure 1. Location of the Green-Duwamish watershed study area in WRIA9, Washington.

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Figure 2. Monitoring sites for the Green-Duwamish Watershed Water Quality Assessment.

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2.2 Project Background

King County (and previously the Municipality of Metropolitan Seattle) has conducted water quality sampling in the Green-Duwamish watershed since 1970. In the past, the goal of this monitoring has been to provide information about local surface waters in the Seattle/King County metropolitan area in support of programs designed to protect water quality and abate water pollution. Fourteen sites in the Green-Duwamish Watershed have been monitored since the mid-1970s. King County performed a detailed water quality assessment (WQA) in Elliott Bay and the Duwamish River in 1999 (King County 1999). One component of this study was an assessment of indicator bacteria (e.g., fecal coliforms) in the Duwamish River.

Indicator bacterial concentrations measured in the Green-Duwamish watershed have exceeded state standards. Numerous stream segments throughout the watershed are listed on the state's 303(d) list of impaired water bodies for violations of water quality standards for fecal coliform bacteria (Ecology 1998, 2006; King County 2002). Section 303(d) of the Clean Water Act (CWA) requires the state to identify those water bodies that do not meet water quality standards, and to develop TMDL values to improve water quality in the affected reaches. Accordingly, King County is investigating approaches to address bacterial contamination in the watershed.

Indicator bacteria concentrations in surface waters are monitored to evaluate the risk to human health from waterborne illnesses in those waters. The presence of indicator bacteria indicates the presence of fecal contamination from human and other warm blooded animals, but not necessarily the presence of pathogens that can be associated with fecal matter. Therefore, indicator bacteria concentrations in surface waters do not necessarily indicate a risk to human health. However, these indicator bacteria can be used for the early detection of problems that could lead to a risk to human health.

Indicator bacteria concentrations are evaluated by comparing concentrations observed in surface waters to water quality standards developed by state and federal agencies. The U.S. Environmental Protection Agency (U.S. EPA) uses *Escherichia coli* (*E. coli*), a member of the group comprising the fecal coliform bacteria, as an indicator of freshwater fecal contamination. The water quality criterion for *E. coli* bacteria in bathing (full body contact) recreational waters specifies that the geometric mean bacteria concentration must not exceed 126 CFU/100 mL (U.S. EPA 1986).

Currently, no Washington state surface water quality standard exists for *E. coli* bacteria in fresh waters. Washington State uses fecal coliform bacteria as an indicator of freshwater contamination and the criteria is based on the designated use of each water body as described in WAC 173-201. Except for the Upper Green River subwatershed, the Green-Duwamish MST study area is designated as primary contact recreation. The fecal coliform bacteria water quality criteria for primary contact recreation is: the geometric mean must not exceed 100 colony forming units per 100 mL (CFU/100 mL) with not more than 10 percent of the samples (i.e., the 90^{th} percentile) exceeding 200 CFU/100 mL. The Upper Green River subwatershed is

designated as extraordinary primary contact recreation, and the water quality criteria is: the geometric mean must not exceed 50 colony forming units per 100 mL (CFU/100 mL) with not more than 10 percent of the samples (i.e., the 90th percentile) exceeding 100 CFU/100 mL.

A review of the Green-Duwamish water quality data collected during storm events in 2001 and 2002 generally shows that loadings and concentrations of fecal coliform bacteria, including *E. coli* and *Enterococcus,* increase with storm flows (Herrera 2004a). These findings suggest that precipitation and stream flow are related to bacterial concentrations and loadings. However, no clear quantitative relationship between flow-related variables and bacterial concentrations has been established to date. These preliminary findings suggest that other unidentified factors may be associated with variations in bacterial concentrations in the Green River watershed. Results presented in the Green Duwamish Water Quality Assessment Year 2003 report (Herrera 2005a) reveal that fecal coliform bacteria geometric mean concentrations are highest during storm flow conditions. However, the 2003 study report also showed that the state water quality standard for fecal coliform bacteria was exceeded at most sites during both base flow and storm flow conditions. Geometric mean concentrations were highest at stations draining agricultural land uses. Monitoring stations in stream drainage basins dominated by urban and residential development also yielded high geometric mean concentrations of fecal coliform bacteria.

Collectively, these findings generated an interest in improving the understanding of the sources and land uses contributing to bacterial loadings in the watershed. And, the findings suggest that one of the primary factors associated with bacterial concentrations in surface waters is land use, which may determine the specific types of sources of bacterial loadings. It is plausible that land use/cover may be useful as a surrogate to predict these sources. Specific sources that may be related to land use include, but are not limited to, agricultural animals (pasture and agricultural land and hobby farms), septic systems (rural residential), pets (suburban areas) and wildlife/birds (forested and rural areas). In order to elucidate these potential relationships, it is necessary to identify the sources of bacteria in the Green River and its tributaries, and to correlate those sources with land use. This goal can be accomplished using microbial source tracking (MST) techniques.

Further, MST can be used to assist in setting and evaluating progress in achieving TMDLs for fecal coliform bacteria in the main stem reaches and in streams that are on the 303(d) list. Affected streams include Newaukum Creek, Springbrook Creek, and Soos Creek (Ecology 2006).

Microbial source tracking is a method that can be used to determine the source(s) of bacterial contamination in the environment. The methodology used for this MST study (molecular ribotyping) involves identifying different *E. coli* strains from water samples and matching them to genetically identical strains of known sources (e.g., domestic animals, humans, farms animals, etc.). *E. coli* isolates with matching genetic (ribotype) finger printings are more likely to originate from common sources, and therefore environmental isolates can be matched to those of a known source.

The King County Surface Water Management Division and the City of Seattle previously conducted two MST studies on Little Soos Creek and Piper's Creek, respectively (King County 1995; Herrera 1993). The Piper's Creek study was conducted to identify the sources of fecal contamination in this urban stream. In the Piper's Creek study, *E. coli* ribotypes isolated from water samples were compared to *E. coli* ribotypes isolated from fecal sources of known origin. The results of this study showed that the source of fecal contamination in Piper's Creek were of animal origin (primarily household pets).

Similarly, the Little Soos Creek MST study compared water derived *E. coli* isolates to isolates of known origin. The results of this study showed that the majority of water derived isolates originated from cattle, horses, and dogs, with human septage a minor component of the fecal contamination in Little Soos Creek.

The molecular ribotyping technique used for this investigation has been used for other studies to identify fecal sources in watersheds throughout western Washington (Herrera 1999, 2001, 2004b, 2005b, 2006b). The current MST study will build on these previous studies to accomplish more detailed objectives described below in the methods section.

A comprehensive independent study of 22 researchers using 12 different microbial source tracking methods was recently conducted by the Southern California Coastal Water Research Project (Griffith et al. 2003). This study included the ribotyping method (Method D) used by the Institute of Environmental Health (IEH) for this study as part of six microbial source tracking methods that are genotypic-based and require a host origin database (genotype library) (Myoda et al. 2003). The study found that the ribotyping method (Method D) performed well in several of the evaluation criteria (Myoda et al. 2003). Method D had high sensitivity rates, low false positive rates, and correctly identified the dominant source of contamination in 75 percent of all samples.

In addition to producing accurate and precise data, particularly when compared to other genotypic-based microbial source tracking methods, the ribotyping method employed by IEH has the appropriate sensitivity to discern all sources of fecal contamination. This level of specificity results in a low percentage of unknown sources and high confidence that the predominant sources of fecal contamination are correctly identified. Finally, the ribotyping method is cost effective because the genotypic library is complete and the collection of known source samples to develop a new database are not needed.

3.0 Methods

The primary goal of the Green-Duwamish watershed MST study was to determine potential sources of the indicator bacteria,, *Escherichia coli*, in the Green-Duwamish watershed (King County 2003). To address this general goal, the following objectives were defined for the study:

- Provide information that may be used to improve understanding of, and describe the relationship between, bacterial sources and land use, hydrology, and season.
- Provide data that may be used to refine development of models used to simulate the dynamics of *E. coli* populations in the Green-Duwamish River.
- Determine the relative contribution of human and animal sources from each of the selected tributaries and reaches of the main stem Green-Duwamish River.
- Improve our understanding of the types and sources of *E. coli* populations at various locations in the main stem Green River that are attributable to the various land uses in representative subbasins.

The study design and methods are summarized below. A detailed description of the study design, study methods, and quality assurance objectives and procedures can be found in the sampling and analysis plan (King County 2003).

3.1 Study Design

To meet the study objectives, *E. coli* colonies were isolated from water samples and genetically typed using a molecular ribotyping technique to identify animal and human sources of fecal coliform bacteria. The ribotypes obtained from the water samples were compared to a ribotype library to determine the number of genetic matches between those ribotypes recovered from known sources and those recovered from the water quality sampling stations.

According to the sampling and analysis plan (King County 2003), a total of 15 sampling events, including 8 base flow events and 7 storm flow events, were to be monitored at nine locations (see Figure 2) in the Green-Duwamish River watershed during 2003 and 2004. During each event, five water samples were to be collected, for a total of 675 samples. The ribotyping technique was to be applied to approximately two *E. coli* isolates from each of the 675 samples for a total of 1,350 total isolates. Quantitative *E. coli* and fecal coliform bacteria data were also to be collected on a periodic basis during 2003 and 2004.

A total of 15 monitoring events, including 7 base flow events and 8 storm flow events, were monitored during 2003 and 2004 for the MST study. A total of 491 water samples were collected and a total of 1,261 isolates were obtained from the samples collected during 2003 and 2004. Among the 491 samples collected during 2003 and 2004, a total of 82 water samples were analyzed for *E. coli* bacteria and 5 water samples were analyzed for fecal coliform bacteria. A total of 1,503 isolates were used in the analyses for this report. A total of 74 samples were analyzed for fecal coliform bacteria and 154 samples were analyzed for *E. coli*. Table 1 summarizes the numbers of samples and analyses for each monitoring station.

Table 1. Numbers of samples collected and analyses conducted during base and storm flow conditions for the Green-Duwamish watershed microbial source tracking study.

		Water samples			Fecal coliform bacteria analyses[a]			*E. coli* analyses[a]			*E. coli* isolates ribotyped[b]		
Site ID	Site location	base	storm	total	base	storm	total	base	storm	total	base	storm	total
E319	Upper Green River	21	26	47	6	3	9	10	8	18	40	67	107
B319	Middle Green River near 277th Street	22	27	49	0	0	0	4	4	8	38	70	108
D319	Middle Green River below Olson Creek	27	38	65	0	0	0	5	6	11	57	92	149
A310	Lower Green River	42	27	69	18	0	18	22	5	27	134	75	209
0322	Newaukum Creek	29	35	64	6	1	7	11	6	17	77	97	174
A320	Soos Creek	36	32	68	8	0	8	12	2	14	92	82	174
A315	Mill Creek	24	34	58	5	1	6	7	5	12	77	88	165
A317	Springbrook Creek	33	30	63	7	0	7	13	6	19	102	81	184
A307	Hamm Creek	50	31	81	19	1	20	22	6	28	153	81	238
Total		284	280	564	69	6	75	106	48	154	770	733	1,503

[a] Grab samples analyzed by King County Environmental Laboratory.
[b] *E. coli* isolates ribotyped and compared to known sources by the Institute for Environmental Health.

Deviations from the sampling and analysis plan did occur. In particular, fewer water samples were collected in 2003 and 2004 than designed, and as a result fewer isolates were obtained than were designed for the MST study. The issue was resolved by obtaining additional isolates from archived cultures of water samples that were collected for the GDWQA in 2001 and 2002. An additional 242 *E. coli* isolates were obtained from 72 samples collected in 2001 and 2002 as part of the GDWQA. These additional samples were collected during 7 base flow events and 6 storm events. In addition to exceeding the study target of 1,350 isolates, the inclusion of isolates collected during previous monitoring events increased the diversity of bacteria sources observed because the samples were collected during different hydrologic and seasonal conditions. Therefore, the number and diversity of *E. coli* isolates obtained from water samples met the basic objectives of the MST study design.

The study was designed to obtain an average of two isolates per sample. This low number of isolates per sample was targeted to obtain a diverse number of sources from a high number of samples because the diversity of sources is generally much lower in a small water sample than in

the water body. The average number of *E. coli* isolates ribotyped per sample ranged from 2.2 to 3.0 among the nine monitoring sites (see Table 1), which generally meets the study design of two isolates per sample. However, the actual number of isolates per sample ranged from 1 to 12 among all samples. Thus, high numbers of isolates were obtained from relatively few samples, and the objectives for representativeness and diversity of fecal source isolates collected for the study were generally met because the study target of 1,350 isolates was exceeded by 153 isolates.

3.1.1 Sampling Sites

The sampling sites were selected to represent the range of land uses and provide moderate geographic coverage within the Green-Duwamish River watershed (see Figure 2). The various reaches of the Green River and subbasins that drain into those reaches can generally be described to represent forested (Upper Green River), forested and agricultural/residential (Middle Green River), and commercial/industrial (Lower Green River/Duwamish Estuary) land uses. Table 2 identifies the drainage basin area and land-use types draining to each sampling site. The major river subbasins are described further below.

Table 2. Basin drainage area and land use by sampling site for the Green-Duwamish microbial source tracking study.

	River Sites[a]				Stream Sites				
	Upper Green River (E319)	Middle Green River (B319)	Middle Green River (D319)	Lower Green River (A310)	Newaukum Creek (0322)	Soos Creek (A320)	Mill Creek (A315)	Springbrook Creek (A317)	Hamm Creek (A307)
Basin Area (mi^2)	221.6	285.0	404.9	434.7	27.5	65.6	12.2	23.4	0.8
Effective Impervious Area (percent)	3.0	2.8	4.6	6.1	5.0	10.2	29.8	39.1	23.1
Sewered Area (percent)	- -	6.9	27.6	32.0	- -	83.2	82.5	100	83.4
Land Use/Cover (percent)									
Forest	85.8	85.3	72.6	69.2	30.9	52.9	23.3	16.7	26.4
Agriculture	- -	0.6	5.5	5.9	45.2	0	5.6	0.2	- -
Low Density Residential	- -	0.3	4.4	5.4	4.9	17.4	16.0	20.7	30.5
High Density Residential	- -	0	0.1	0.3	- -	0.2	0.7	0.9	0.4
Commercial/ Industrial	- -	0.1	0.5	1.3	0.7	1.5	17.9	29.2	10.2
Other[b]	14.2	13.7	16.9	17.9	18.3	27.9	36.5	32.4	32.5

[a] Basin areas and land use/cover percentages for the river sites extend from the river monitoring site up to Howard Hanson Reservoir, and do not include 213.1 square miles above the reservoir.
[b] Other describes land cover categories that do not fit into or overlap with the land use categories and may include grass; wetlands; water; roads; and bare ground/snow/rock/ice/shoreline.
Data source: Shotwell 2006.

The Upper Green River watershed (47 percent of the basin) is comprised of mountainous, forested areas that drain to Howard Hanson Reservoir where the U.S. Army Corps of Engineers operates a dam to control floods and augment instream flows. Downstream of this dam, the City of Tacoma operates a diversion dam to divert water for the City's municipal water supply. The middle portion of the watershed drains 35 percent of the total basin area. Major tributaries in the middle portion include Newaukum Creek draining the Enumclaw plateau and Soos Creek draining the Covington upland. Land use/land cover is mixed and includes forests, agricultural, residential, and commercial areas. The Green-Duwamish valley dominates the lower portion of the watershed (18 percent of the basin). Land use/land cover is mixed but includes substantial commercial and industrial areas within the cities of Auburn, Kent, Renton, Tukwila, and Seattle.

The Middle Green River (approximately 30 miles in length) is the most unconstrained segment of the main stem channel system. Consequently, avulsions (or changes in channel direction) occur where meandering is allowed. The two largest tributaries that drain into the middle Green River basin, Newaukum Creek (27 square miles) and Soos Creek (66 square miles), are distinctly different. The Newaukum Creek basin is composed of primarily flat agricultural and pasture land with a dense network of unidentified diversion ditches creating a complex drainage system, with no significant lakes. In contrast, the Soos Creek basin has multiple lakes with groundwater linkages, significant amounts of medium/high density development, and some pasturelands. Other, more minor drainages discharging to the Green River have high forest cover.

The Lower Green River differs from the Middle Green River with even higher levels of development and hydromodifications. Approximately 90 percent of the Lower Green watershed is developed, with 65 percent of that being urban commercial land use. As a result of the various flood protection plans, most of the commercial and rural developments rely on the constructed levee/revetment system. There are several significant tributaries in the Lower Green River Watershed, including Mill Creek, Mullen Slough and the Black River (Springbrook Creek). These tributaries experience backwater effects during high flow conditions in the Green River. High flow conditions on the Green River impede surface flow causing back-ups into farm fields and flooding along the West Valley Highway.

3.2 Sampling Schedule

Water samples were collected from January 2003 through May 2004 for the MST Study. Additional samples collected from November 2001 through December 2002 were used to supplement the MST study samples. Sampling dates for the MST study and additional samples are presented in Table 3 with the corresponding event type designations and daily precipitation totals. Storm flow sampling was to be conducted when the predicted rainfall amount for the study area was at least 0.35 inches for a 12-hour period. Base flow events required no measurable rain (less than 0.01 inches) for the 24-hour period prior to a sampling event. Samples were not collected at all sites on all dates. Although the base flow event conducted on August 6, 2002 had 0.02 inches of precipitation, the samples that were collected are still representative of base flow conditions because this very small amount of precipitation would not generate stormwater runoff.

Table 3. Sampling events schedule for the Green-Duwamish River watershed microbial source tracking study.

Sample Date(s)	Event type	Daily precipitation (inches)[a]
11/28/2001	storm	0.97
12/14/2001	base	0.0
1/25/2002	storm	0.98
2/14/2002	base	0.0
2/21/2002	storm	0.87
3/26/2002	base	0.01
4/25/2002	base	0.0
6/12/2002	base	0.0
6/28/2002	storm	0.84
8/6/2002	base	0.02
10/22/2002	base	0.0
11/6/2002	storm	0.45
12/4/2002	storm	0.14
1/22/03 - 1/23/03	storm	0.77[b]
2/12/03 - 2/13/03	base	0.0
2/25/03	base	0.0
3/9/03 - 3/10/03	storm (isolates only)	0.66
4/9/03	storm	0.11
4/29/03	base	0.0
6/2/03	base	0.0
6/9/03	base	0.0
8/26/03 - 8/27/03	base	0.01[b]
10/6/03 - 10/7/03	storm	0.34[b]
10/17/03 - 10/18/03	storm	0.16[b]
11/18/03 - 11/19/03	storm	1.47[b]
3/16/04	base	0.0
3/25/04	storm	0.41
5/26/04	storm	0.83

[a] Precipitation measured at King County rain gauge 32U, Lower Green River.
[b] 48-hour total presented for 2-day events.

3.3 Sample Collection Procedures

King County personnel collected grab samples according to U.S. EPA standards (U.S. EPA, 1996) during base flow and storm flow conditions. To adequately characterize *E. coli* populations at each sampling location, up to 5 water samples were collected at least two minutes apart. Samples were collected while facing upstream to minimize contamination from field equipment. All samples were collected using aseptic techniques, placed on ice, and transported to the King County Environmental Laboratory within 24 hours of sample collection.

3.4 Laboratory Analysis Procedures

3.4.1 Bacteria Analyses

Water samples were analyzed for the enumeration of *E. coli* and fecal coliform bacteria by the King County Environmental Laboratory (KCEL) using the membrane filter technique. The analysis methods, including quality control and quality assurance procedures, are outlined in King County Standard Operating Procedures (King County 2005a, 2005b), which are based on procedures described in *Standard Methods for the Examination of Water and Wastewater* (APHA et al. 1995). Routine quality control analyses for microbiology included procedures used to ensure the quality of each batch of media and sample containers, and included procedures used to monitor the method performance of each sample analysis batch or analysis session. A sample analysis batch consists of up to 20 samples of the same matrix that are prepared and analyzed together using the same reagents, media, and equipment. An analysis session consists of one or more batches done within a working day.

Each batch of media was tested to confirm pH, sterility, and positive and negative performance characteristics. After washing and sterilization, each batch of containers used for the collection of samples was evaluated for appropriate pH and sterility. The King County Standard Operating Procedures (King County 2005a, 2005b) describe the method performance evaluation procedures for each of the following quality control elements:

- Laboratory duplicates
- Positive controls
- Negative controls
- System controls
- Verification
- Corrective actions.

After enumeration, bacteria culture plates from samples analyzed as part of the MST study were either used to isolate and archive individual strains of *E. coli*, or were delivered directly to the Institute for Environmental Health (IEH) laboratory for isolation and ribotyping analysis. Archived cultures of *E. coli* from water samples that were collected in 2001 and 2002 were also delivered to the IEH laboratory for ribotyping analysis when it was determined that there was not a sufficient number of isolates from the water samples collected in 2003 and 2004.

3.4.2 Ribotyping Analysis

Bacteria culture plates and archived *E. coli* cultures were shipped overnight to the Institute for Environmental Health. Upon arrival, all samples were inspected for any signs of contamination and damage. Sample identifiers were also checked against the chain of custody forms accompanying the samples.

Five non-mucoid blue colonies were picked from culture plates corresponding to each water sample and were plated on MacConkey agar for purification. Archived *E. coli* cultures were

plated on MacConkey agar and incubated overnight at 35°C. The next day, 3 to 5 lactose fermenting, non-mucoid colonies were picked and replated on MacConkey agar for purification.

At this stage, each of the colonies picked from a given sample was assigned a provider Sample ID number and an accession letter. A single, well isolated non-mucoid colony was picked from each MacConkey plate and plated on Tryptic Soy Agar. After overnight incubation at 35°C, each culture was tested by spot indol test using appropriate positive and negative controls. Indol positive cultures were further tested for the ability to utilize citrate using the Simon Citrate media. Indol positive and citrate negative colonies were identified as *E. coli* and assigned isolate numbers.

Genomic DNA was isolated from each *E. coli* strain using a standard protocol. All reagents and buffers were made according to standard formulas. Reagents and buffers were tested for sterility.

Every batch of restriction enzyme reaction contains two reactions with the positive control strain that are included on two lanes of each gel. Agarose gel electrophoresis was conducted under standard conditions that control for agarose gel concentration, volume, buffer strength, pH, voltage, current, and electrophoresis time. Each agarose gel was assigned a number, and when more than one gel was run, the position of the first standard reference strain was changed in each gel (from the 1st lane on the first gel to the Nth lane on the Nth gel). After electrophoresis, two gels were stained in ethidium bromide in a single container. Of the two gels placed in the same container, one corner of the gel with the higher number was clipped and the labels for each gel transferred to the staining container. Each gel was then photographed and a hard copy of the print labeled with the gel sheet (containing the isolate numbers loaded on each lane, the restriction enzyme designation, date, gel number, voltage, current, gel strength, buffer strength, and electrophoresis time).

After photography, each gel was returned to the same staining container and denatured for Southern blotting. The Southern blotting protocol is detailed in the IEH Standard Operating Procedures (SOP). Each blotting apparatus was placed in a separate container, and labeled with the gel number. Each membrane filter was labeled with the gel number, restriction enzyme designation, date, and technician's initials.

The genetic fingerprints were analyzed manually using an algorithm developed by Dr. Samadpour of the Institute for Environmental Health. Type patterns were cut and catalogued and each pattern was compared side by side to the type pattern. New patterns were given appropriate identifiers and catalogued accordingly. The criterion established for the data analysis was 100 percent identity of the ribotype patterns.

3.5 Data Analysis Procedures

To facilitate a comparison between the Green-Duwamish MST study and GDWQA study bacteria data, geometric mean bacteria concentrations were calculated for base flow and storm flow conditions. The bacteria data were compared to determine if bacteria concentrations observed during the MST study are representative of conditions in the Green-Duwamish watershed as observed for the GDWQA study. Geometric mean bacteria concentrations for the MST study and the GDWQA study were also calculated for comparison to water quality standards.

The Green-Duwamish MST study bacteria data were statistically evaluated to test for significant differences in terms of hydrologic, seasonal, and spatial conditions to evaluate how bacteria concentrations vary environmentally in the Green River watershed. Because bacteria data typically do not exhibit a normal distribution, nonparametric statistical tests were employed. A two-tailed Mann-Whitney U test was used to test for differences between hydrologic conditions (i.e., base flow versus storm flow) and season (i.e., summer versus winter). The Mann-Whitney U test is a nonparametric analogue to the paired t-test. Differences between monitoring stations were tested using a Kruskal-Wallis analysis of variance (ANOVA). The Kruskal-Wallis test is a nonparametric rank-sum analysis-of-variance used to compare multiple groups of independent samples. All tests were conducted at a significance level (α) of 0.05. Results from the statistical analyses are presented in Appendix B.

A spatial comparison was performed separately for the river stations and the stream sites using the MST study data. This approach was used to detect any significant pattern in bacteria concentrations along the Green River and to determine if there are significant differences in bacteria concentrations among the streams that discharge to the Green River. To detect upward or downward trends in bacteria data, comparisons between river stations or stream stations were performed using the Kruskal-Wallis analysis of variance (ANOVA) to determine if there was a significant difference. If a significant difference was detected, a nonparametric multiple comparison test was performed to determine which stations were significantly different from the others. Statistical results are presented in Table B2 (Appendix B).

4.0 Results and Discussion

Results of the microbial source tracking study are discussed separately below for data validation, hydrology, bacteria concentrations, and ribotyping analysis. The MST study database is presented in Appendix A.

4.1 Data Validation

A detailed description of the quality assurance procedures for the King County Environmental Laboratory (KCEL) and the Institute for Environmental Health (IEH) can be found in the sampling and analysis plan (King County 2003) and are summarized above in the Laboratory Analysis Procedures section. Although quality control problems were identified, no data were rejected during the data review. Therefore, all collected data are considered to be of acceptable quality and are used here for evaluation purposes. Data validation results are summarized below for bacteria enumeration and ribotyping.

4.1.1 Bacteria Enumeration

The KCEL project coordinator reviewed the bacteria enumeration results for acceptability based on compliance with holding times, storage and testing conditions, positive and negative controls, filtration blank results, and conformance with both historical data and synoptic data. Corrective actions were taken whenever a quality control issue occurred. Unacceptable quality control results within a batch or session of analyses required that all samples associated with those batches and/or session be reviewed. The KCEL project coordinator determined if and how the samples should be qualified, and documented the resolution to any data qualification (i.e., if the data are acceptable for release or analysis). Once the results had been shown to meet all criteria the project coordinator approved the data. In general, very few data flags were assigned to the bacteria data collected for this study. A description of the data quality issues is presented below.

For the *E. coli* bacteria enumeration data, a total of 10 of the 165 water sample bacteria results (6.1 percent) were flagged. Seven (4.2 percent) were flagged with an "H" because a sample handling time criterion was not met prior to analysis. Two (1.2 percent) were flagged with an "E" because a standard method was used to estimate the number of microorganisms, rather than an actual count. One (0.6 percent) was flagged with a "C" because there was confluent growth, indicating that the actual value was greater than the reported value. These flagged values indicate relative bacterial abundance and were used in the data analysis.

For the fecal coliform bacteria data, a total of six of the 79 water sample bacteria results (7.6 percent) were flagged. All six were flagged with an "H" because a sample handling time criterion was not met prior to analysis.

4.1.2 Ribotyping

Ribotyping is a microbial source tracking technique that identifies sources of fecal coliform bacteria by comparing patterns in the genetic material of bacterial isolates to patterns from known sources. The method used by IEH includes various proprietary quality control procedures that provide data of the highest quality.

A comprehensive independent study of 22 researchers using 12 different microbial source tracking methods was recently conducted by the Southern California Coastal Water Research Project (Griffith et al. 2003). This study included the ribotyping method (Method D) used by the Institute of Environmental Health as part of six microbial source tracking methods that are genotypic-based and require a host origin database (Myoda et al. 2003). Blind, labeled water samples were prepared, and contained between one and three of five possible fecal sources (i.e., sewage, human, dog, cow, and gull), and were analyzed by each study participant.

The study of microbial source tracking methods found that the ribotyping method (Method D) performed well in several of the evaluation criteria (Myoda et al. 2003). Method D had high sensitivity rates (i.e., the percentage of time the source was correctly identified as present in the sample), at 88 percent for human and sewage sources and 81 percent for all sources. The false positive rates (i.e., the percentage of time the source was incorrectly identified as present in the sample) for Method D were low, at 17 percent for human and sewage sources and 23 percent for all sources. Method D correctly identified the dominant source of contamination in 75 percent of all samples.

Several study design issues were identified by Myoda et al. (2003) that might have underestimated the reliability of the methods. Only 50 isolates were examined, representing a small percentage of the bacterial sample population. Also, heterogeneity of sample preparation and differential bacterial die-off might have resulted in a misrepresentation of the bacteria population.

Although blind water samples containing known fecal sources were not prepared for the Green-Duwamish MST study, IEH recently analyzed blind water samples prepared for separate MST studies of the Willapa River (Herrera 2005b) and Thornton Creek (Herrera 2006b). IEH correctly identified the five *E. coli* isolates prepared from cow feces and the six *E. coli* isolates prepared from deer feces that were collected from the Willapa River watershed, which is located in southwestern Washington and is primarily comprised of forest and agriculture land uses. IEH correctly identified the three *E. coli* isolates prepared from goose feces and the three *E. coli* isolates prepared from dog feces that were collected from the Thornton Creek watershed, which is located in Seattle, Washington and is comprised of urban development. Thus, the sensitivity rate was 100 percent and the false positive rate was 0 percent for these recent MST studies.

4.1.3 Green-Duwamish MST

Because the study design was followed with only slight deviations (see methods section above), a large number of isolates (1,503) were obtained during a wide range of hydrologic and seasonal

conditions. In addition, a high percentage (95 percent) of those isolates matched known sources in the source library. The diverse bacterial population sampled and the high matching percentage obtained provides a high level of confidence that the dominant fecal sources and the relative proportion of fecal sources were correctly identified for the Green-Duwamish MST study.

Data management quality control issues were identified in the database received from the ribotyping laboratory. These issues included (with resolution in parentheses): King County sample identification number for a single sample was transcribed incorrectly from the sample tube to the chain of custody form (King County sample identification number was corrected); King County sample identification number for eleven samples was entered incorrectly into the ribotyping laboratory's database (King County sample identification number was corrected); and duplicate matching results for 15 isolates were entered into the ribotyping laboratory's database (the duplicate results for the 15 isolates were removed from the database). These issues were resolved prior to entry into the County's data management system. In addition, one quality control issue was identified in the database received from the County: matching results were not reported for five isolates. Those five isolates were removed from the study database prior to any analysis being conducted.

4.2 Hydrology

Precipitation and discharge data for the Green-Duwamish MST study are summarized below. Monthly precipitation data are presented for 2001 through 2004 and compared to historical averages for identification of the particularly wet or dry months during the study period. Discharge data are presented for sample comparison of the base and storm flow conditions at the river and stream sites.

4.2.1 Precipitation

Precipitation data were collected from the following rain gauges located within the Green-Duwamish watershed (see Figure 1):

- Lower Green River (gauge 32U)
- Soos Creek (gauge 54V)
- O'Grady Creek (gauge 40U)
- Covington Creek (gauge 09U).

Monthly and annual precipitation totals for 2001 through 2004 for the Lower Green River gauge are compared to historical averages in Table 4. These data indicate that precipitation totals measured in January, March, and October of 2003 were generally higher than historical averages, and precipitation totals measured in February and May through August of 2003 were substantially lower than historical averages. Thus, the summer of 2003 was unusually dry.

Table 4. Monthly and annual precipitation totals (in inches) from the Lower Green River gauge (32U) in the Green-Duwamish watershed for 2001 through 2004 compared to historical averages.

	Historical [a]	2001	2002	2003	2004
January	5.54	*2.76*	6.55	**7.65**	5.93
February	4.10	*2.59*	3.70	*1.83*	*2.61*
March	3.96	3.70	3.45	**5.04**	2.43
April	3.41	4.56	4.53	3.38	*0.82*
May	2.39	*1.95*	*1.63*	*1.22*	3.75
June	1.89	**4.12**	1.66	*1.53*	1.21
July	1.02	*0.63*	0.64	*0.01*	*0.11*
August	0.89	**1.86**	*0.11*	*0.42*	*3.83*
September	1.04	0.86	0.69	1.63	*3.91*
October	3.58	3.54	1.26	**7.96**	3.52
November	6.62	**10.11**	*2.67*	5.55	*3.52*
December	4.91	**6.00**	**5.67**	4.16	3.58
Total	39.35	42.68	32.56	40.38	35.22

[a] Based on average monthly precipitation totals measured over the period from 1989 through 2000.
Values in *italics* are below the 25th percentile value from the historical monthly or annual precipitation totals.
Values in **boldface type** are above the 75th percentile value from the historical monthly or annual precipitation totals.

4.2.2 Discharge

Summary statistics for discharge data collected for the GDWQA and the Green-Duwamish MST study are presented in Figure 3. The data are presented as box and whisker plots that show the median as a point, the 25th and 75th percentiles of the data as a box, and the 10th and 90th percentiles of the data as whiskers. Discharge rates measured at the time of sample collection are presented separately for base and storm flow samples. Discharge data associated with the bacteria samples collected for the MST study are compared to discharge data associated with all bacteria samples collected for the GDWQA. This comparison is made to determine if the hydrologic conditions sampled for the MST study are similar to the larger set of GDWQA samples. Discharge was not measured at either the Middle Green River site (D319 and B319) or the Lower Green River site (A310) for the GDWQA, but discharge data are available for some MST samples collected at one of the Middle Green River sites (D319). Discharge rates for the Green-Duwamish MST study were measured for 131 of the 564 bacteria samples collected.

For the GDWQA, median flow rates at the Upper Green River (E319) ranged from a minimum of 703 cubic feet per second (cfs) during base flow, to a maximum of 1,311 cfs during storm flow. For the stream sites, median flow rates during base flow ranged from 0.89 cfs at Hamm Creek to 105 cfs at Soos Creek. During storm flow, median flow rates at the stream sites ranged from 3.47 cfs at Hamm Creek to 150 cfs at Soos Creek.

Insert Figure 3

Figure 3. Discharge rates for base and storm flow samples collected at river and stream stations for the Green-Duwamish water quality assessment (WQA) and microbial source tracking (MST) study.

Discharge rates for the MST study samples compare favorably to those for the GDWQA. These results suggest that bacteria isolates collected for the Green MST were collected during representative hydrologic conditions. One exception is that the storm flow rates were statistically lower (based on results from a Mann Whitney U test, $p = 0.006$) at Newaukum Creek (0322) for the MST study than the GDWQA.

4.3 Bacteria Concentrations

Bacteria summary statistics for the MST study samples and for all GDWQA samples are presented in Figure 4. Summary statistics are presented separately for fecal coliform bacteria and *E. coli* bacteria in Tables 5 and 6, respectively. Data are summarized only for those sites that were part of both studies. The bacteria data in Figure 4 are summarized as box and whisker plots. Box and whisker plots show the geometric mean as a point, the 25th and 75th percentiles of the data as a box, and the 10th and 90th percentiles of the data as whiskers. In the following sections, fecal coliform and *E. coli* bacteria data for the MST study are compared to bacteria data from the GDWQA to establish water quality conditions during the MST study. Because of the limited amount of fecal coliform bacteria data for the MST study, the GDWQA study bacteria data are then discussed in terms of compliance with water quality standards. Finally, the MST study bacteria data are discussed in terms of station location, hydrologic conditions (i.e., base versus storm flow), and season of the year. The project database is presented in Appendix A.

Because more samples were collected from the MST study sites for the GDWQA than for the MST study, the MST bacteria data were compared to the GDWQA bacteria data. This statistical comparison was conducted for geometric mean bacteria concentrations to ensure that samples collected during the MST study may be considered representative of bacteria concentrations observed previously in the Green-Duwamish watershed. Among all samples collected at the nine MST study sites for the entire GDWQA, a total of 384 water samples were analyzed for fecal coliform bacteria and 400 water samples were analyzed for *E. coli*. In contrast, only 68 water samples were analyzed for fecal coliform bacteria and 135 samples were analyzed for *E. coli* for the MST study.

8 1/2 X 11 Insert Figure 4

Figure 4. Fecal coliform and *E. coli* bacteria concentrations during base and storm flow conditions for the Green-Duwamish microbial source tracking (MST) study and the Green-Duwamish water quality assessment (WQA).

Table 5. Fecal coliform bacteria summary statistics for the Green-Duwamish microbial source tracking (MST) study and the Green-Duwamish water quality assessment (GDWQA).

	MST Study			GDWQA		
Site/Event	Geometric Mean (CFU/100 mL)	Percent of samples >200[a]	No. of Samples	Geometric Mean (CFU/100 mL)	Percent of samples >200[a]	No. of Samples
Upper Green River (E319) all data	3	0	9	3	0	32
base	2	0	6	1	0	16
storm	7	0	3	8	0	16
Middle Green River (D319) all data	–	–	0	–	–	0
base	–	–	0	–	–	0
storm	–	–	0	–	–	0
Middle Green River (B319) all data	–	–	0	–	–	0
base	–	–	0	–	–	0
storm	–	–	0	–	–	0
Lower Green River (A310) all data	15	0	18	93	**39**	94
base	15	0	18	23	3	34
storm	–	–	0	**209**	**57**	60
Newaukum Creek (0322) all data	63	**14**	7	**631**	**72**	71
base	52	0	6	61	**11**	18
storm	**200**	**100**	1	**1,391**	**92**	53
Soos Creek (A320) all data	32	0	8	71	**18**	17
base	32	0	8	39	0	10
storm	–	–	0	**168**	**43**	7
Mill Creek (A315) all data	**269**	**67**	6	**476**	**71**	17
base	**177**	**60**	5	**166**	**56**	9
storm	**2,200**	**100**	1	**1,557**	**100**	8
Springbrook Creek (A317) all data	80	**14**	7	**655**	**80**	50
base	80	**14**	7	93	**17**	12
storm	–	–	0	**1,214**	**100**	38
Hamm Creek (A307) all data	**121**	**25**	20	**307**	**60**	103
base	**119**	**26**	19	**141**	**33**	36
storm	**160**	0	1	**468**	**75**	67

[a] The Washington State fecal coliform bacteria water quality standard is a geometric mean not to exceed 100 CFU/100mL with not more than 10 percent of samples used to calculate the geometric mean exceeding 200 CFU/100mL

Bold numbers indicate an exceedance of the state water quality standard.

Table 6. *E. coli* bacteria summary statistics for the Green-Duwamish microbial source tracking (MST) study and the Green-Duwamish water quality assessment (GDWQA).

Site/Event	MST Study		GDWQA	
	Geometric Mean (CFU/100 mL)	No. of Samples	Geometric Mean (CFU/100 mL)	No. of Samples
Upper Green River (E319) all data	3	18	3	38
base	2	10	2	20
storm	7	8	8	18
Middle Green River (D319) all data	50	11	–	0
base	13	5	–	0
storm	**154**	6	–	0
Middle Green River (B319) all data	9	8	–	0
base	2	4	–	0
storm	39	4	–	0
Lower Green River (A310) all data	21	27	70	99
base	13	22	18	42
storm	**165**	5	**185**	57
Newaukum Creek (0322) all data	86	17	**558**	77
base	36	11	65	23
storm	**427**	6	**1,391**	54
Soos Creek (A320) all data	46	14	72	17
base	36	12	38	10
storm	**208**	2	**177**	7
Mill Creek (A315) all data	**361**	12	**394**	17
base	**127**	7	107	9
storm	**1,560**	5	**1,708**	8
Springbrook Creek (A317) all data	**153**	19	**504**	54
base	76	13	85	16
storm	**692**	6	**1,068**	38
Hamm Creek (A307) all data	**133**	28	**261**	98
base	92	22	115	37
storm	**524**	6	**428**	61

Bold numbers indicate an exceedance of the *E. coli* water quality criterion (EPA recommended criterion of 126 CFU/100mL).

Bacteria concentrations observed for the GDWQA and MST study are summarized separately below for fecal coliform bacteria and *E. coli*. Comparisons are then made to water quality standards, between hydrologic conditions (i.e., base versus storm flow), between summer and winter seasons, and spatially among the river and stream sites. For a detailed assessment of the GDWQA bacteria data, see Herrera 2004a and 2005a.

4.3.1 Fecal Coliform Bacteria

For the GDWQA, geometric mean concentrations of fecal coliform bacteria ranged from 1.4 colony-forming units (CFU)/100 milliliters (mL) at the Upper Green River (E319) to 166 CFU/100 mL at Mill Creek (A315) during base flow. During storm flow, geometric mean concentrations ranged from 7.9 CFU/100 mL at the Upper Green River to 1,557 CFU/100 mL at Mill Creek (A315). The results presented in Figure 4 clearly show that fecal coliform bacteria geometric means are much higher during storm flow compared to base flow at all sites. Geometric means also increase downstream in the main stem river and are typically higher in the streams than in the river.

For the MST study, geometric mean concentrations of fecal coliform bacteria ranged from 1.9 CFU/100 mL at the Upper Green River to 177 CFU/100 mL at Mill Creek during base flow. During storm flow, geometric mean concentrations ranged from 6.7 CFU/100 mL at the Upper Green River to 2,200 CFU/100 mL at Mill Creek (A315) (see Table 5). As shown for the GDWQA results, geometric means for the MST study samples increase downstream in the river and are typically higher in the streams compared to the river. A comparison of fecal coliform bacteria concentrations for the GDWQA and the MST study in Figure 4 indicates that the bacteria data exhibit similar trends with regard to spatial and hydrologic influences. These results suggest that bacteria isolates analyzed for the Green-Duwamish MST study were collected during representative conditions.

4.3.2 *E. coli* Bacteria

Summary statistics for *E. coli* bacteria during base and storm flow are presented in Figure 4 and Table 6. For the GDWQA, *E. coli* bacteria geometric mean concentrations ranged from 1.5 CFU/100 mL at the Upper Green River (E319) to 114 CFU/100 mL at Hamm Creek (A307) during base flow. During storm flow, *E. coli* bacteria geometric mean concentrations ranged from 8.4 CFU/100 mL at the Upper Green River (E319) to 1,708 CFU/100 mL at Mill Creek (A315). As observed for fecal coliform bacteria, *E. coli* bacteria geometric means were much higher during storm flow compared to base flow. Geometric means also increased downstream in the river stations, and were higher in the streams than in the lower river.

For the MST study, base flow *E. coli* bacteria geometric mean concentrations ranged from 1.8 CFU/100 mL at the Upper Green River (E319) to 127 CFU/100 mL at Mill Creek (A315). During storm flow, *E. coli* bacteria geometric mean concentrations ranged from 7.1 CFU/100 mL at the Upper Green River (E319) to 1,560 CFU/100 mL at Mill Creek (A315). Similar trends observed in the GDWQA *E. coli* bacteria data were exhibited in the MST study data, including higher geometric means during storm flow compared to base flow, increasing geometric means downstream at river sites, and higher geometric mean concentrations in the streams. These results also suggest that MST bacteria isolates were collected during representative conditions.

4.3.3 Water Quality Standard Comparison

All stations except the Upper Green River (E319) are designated as primary contact recreation by the Washington state water quality standards (WAC 173-201A). The fecal coliform bacteria water quality standard for primary contact recreation is: the geometric mean must not exceed 100 colony forming units (CFU)/100 mL with not more than 10 percent of the samples (i.e., the 90th percentile) exceeding 200 CFU/100 mL. The Upper Green River station is designated as extraordinary primary contact recreation, and the fecal coliform bacteria water quality standard is: the geometric mean must not exceed 50 CFU/100 mL and the 90th percentile must not exceed 100 CFU/100 mL. Because of the limited amount of storm flow fecal coliform bacteria data available for the MST study, the fecal coliform bacteria standard has not been assessed for the MST study bacteria data.

As shown in Table 5 for the GDWQA study, the state water quality standard for fecal coliform bacteria was exceeded at all stream sites during base flow and storm flow with the exception of base flow at Soos Creek (A320). Among the river sites, fecal coliform bacteria standard was only exceeded during storm flow at the Lower Green River (A310), but fecal coliform bacteria were not analyzed for any of the samples collected at either Middle Green River site (B319 and D319).

Currently, no Washington state surface water quality standard exists for *E. coli* bacteria in fresh waters. However, the EPA recommends that states use either *E. coli* or enterococci as an indicator for freshwater contamination (U.S. EPA 2002). The U.S. Environmental Protection Agency (U.S. EPA) water quality criterion for *E. coli* bacteria in bathing (full body contact) recreational waters specifies that the geometric mean must not exceed 126 CFU/100 mL (U.S. EPA 1986). As shown in Figure 4 and Table 6, the EPA-recommended *E. coli* bacteria water quality criterion was exceeded during base flow only in Mill Creek (A315) and during storm flow at all sites except the Upper Green River (E319) and the Middle Green River near 277th (B319).

4.3.4 Hydrologic Comparison

As shown in Figure 4, fecal coliform and *E. coli* bacteria concentrations for the Green MST data were substantially higher during storm flow than base flow at all sites. Results from the Mann-Whitney U test of MST study data indicate that *E. coli* bacteria concentrations during base flow and storm flow conditions are statistically different at all sites except Soos Creek (A320) (see Table B1, Appendix B). The Mann-Whitney U test was not conducted for fecal coliform data associated with the MST study because of the low number of samples. Preliminary results for the Mann-Whitney U test using all GDWQA bacteria data show a significant difference between base and storm flow for fecal coliform and *E. coli* bacteria concentrations at all sites except Hamm Creek (A307) (Herrera 2006a). (Data for the Middle Green River sites were not analyzed for the GDWQA). These results clearly show that stormwater runoff is a significant factor affecting bacterial contamination in the Green-Duwamish River watershed.

4.3.5 Seasonal Comparison

The MST study bacteria data were assigned to one of two seasons to compare data collected during the summer or dry season (June through October) to data collected during the winter or wet season (November through May). This delineation of seasons was based on the more frequent occurrence of storm events during the period of November through May, and the lower occurrence of storm events during the period of June through October. Summary statistics for fecal coliform and *E. coli* bacteria by season are presented as box and whisker plots in Figure 5. Statistical results can be found in Table B1, Appendix B.

A non-statistical comparison of seasonal geometric means indicates that for most stations, fecal coliform and *E. coli* bacteria concentrations were higher during the summer than winter. Results from the Mann-Whitney U test of MST data for all sites indicate that summer and winter concentrations are significantly different for both fecal coliform bacteria ($p=0.0004$) and *E. coli* ($p=0.0096$). However, results for individual sites indicate that fecal coliform bacteria concentrations are not significantly different between seasons except at Springbrook Creek (A317) ($p = 0.0339$) and Hamm Creek (A307) ($p = 0.0275$). Similarly, results for individual sites indicate that *E. coli* bacteria concentrations are not significantly different in the summer compared to the winter except at the Lower Green River (A310) ($p = 0.0029$).

These results indicate that seasonal influences are a significant factor in describing bacteria contamination across the Green-Duwamish watershed, but that a large amount of data is required to show a statistical significance between stations. This lack of power is due to the inherently high variability of bacteria concentrations in water.

4.3.6 Spatial Comparison

For the Green River stations, bacteria concentrations generally increased from upstream to downstream (see Figure 4). Between the Upper Green River (E319) and Lower Green River (A310) sites, the geometric mean fecal coliform bacteria concentration increased downstream from 1.8 to 14.1 CFU/100 mL during base flow. (Storm flow fecal coliform bacteria data are not available for the Lower Green River site A310). Similarly, the geometric mean of *E. coli* bacteria concentrations increased from 1.8 to 13 CFU/100 mL during base flow and from 7.1 to 165 CFU/100 mL during storm flow at these sites.

Results from the Kruskal-Wallis ANOVA indicate that there were significant differences in fecal coliform bacteria and *E. coli* concentrations among both the river and stream sites. Fecal coliform bacteria concentrations were significantly higher at the Lower Green River (A310) than the Upper Green River (E319) ($P=0.0014$). A significant increasing pattern downstream was also detected for *E. coli* bacteria in the Green River, with bacteria concentrations at the Upper Green River (E319) significantly lower than concentrations at both the Middle Green River (D319) and Lower Green River (A310) ($p = 0.0074$). For the stream stations, both fecal coliform bacteria ($p = 0.0205$) and *E. coli* ($p = 0.0080$) concentrations were significantly higher at Mill Creek (A315) than at Soos Creek (A320), but no differences were observed between Newaukum Creek (0322), Springbrook Creek (A317), and Hamm Creek (A307).

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Figure 5. Fecal coliform and *E. coli* bacteria concentrations during summer (June through October) and winter (November through May) for the Green-Duwamish microbial source tracking study.

4.3.7 Land Use Comparison

A summary of land use for each basin was presented previously in Table 2. Percentages of designated land uses in each subbasin are separated into major land use categories that include forest and the following developed land uses: agriculture, low density residential, high density residential, and commercial/industrial. The remaining area of each basin includes undeveloped land cover categories (e.g., grass, wetlands, water, roads, and bare ground) that do not overlap with these land use categories.

Because land use designations in the study subbasins are generally mixed, the influence of specific land uses on bacteria concentrations is difficult to assess. Although an upstream or reference site was not established for each site, the Upper Green River (E319) can be used as a reference site for the remaining river and stream sites because less than 1 percent of the area draining to the Upper Green River (E319) contains developed land. Thus, the influence of land use as it transitions from forest to developed land uses can be characterized. As previously discussed, bacteria concentrations in the Green River increase from upstream to downstream. This increase is attributable to the decrease in forest and the increase in developed (i.e. residential and commercial/industrial) and agricultural land uses from upstream to downstream.

An overall comparison of land use in the stream basins shows that the highest fecal coliform bacteria concentrations (based on use of the GDWQA study data due to lack of MST storm flow bacteria data) were observed in those basins having the highest amount of developed land use. Springbrook Creek and Newaukum Creek, each with 51 percent combined agricultural and developed land use, exhibited the highest mean fecal coliform bacteria concentrations (see Table 5). Additionally, Mill Creek, with 40 percent combined agricultural and developed land use, exhibited the highest base flow and storm flow fecal coliform bacteria concentrations (see Figure 4 and Table 5). Hamm Creek, with 41 percent developed land use and no agricultural land use, exhibited the second highest base flow fecal coliform bacteria concentrations of the stream stations. In contrast, Soos Creek (A320), having the lowest amount of developed land use (19 percent) and no agricultural land use, exhibited the lowest mean fecal coliform bacteria concentrations among the monitored streams (see Figure 4 and Table 5). These results suggest that developed and agriculture land use is a significant factor influencing bacteria concentrations in the Green-Duwamish watershed.

4.4 Ribotyping

A total of 1,503 isolates were obtained for the Green-Duwamish MST study, including 1,266 isolates from samples collected specifically for the MST study, and an additional 242 isolates from samples collected for the GDWQA in 2001 and 2002. These isolates were then matched to the ribotype database maintained by the Institute for Environmental Health. Approximately 95 percent of all isolates obtained were matched to a known fecal source. This high matching rate and the large number of isolates obtained provides a high level of confidence that the major fecal sources were correctly identified for the study sites.

The ribotyping matching results are presented in Table 7. The number and percentage of isolates obtained are presented for each site and for all sites combined. Several identified categories were combined into one category for ease of interpretation. For example, the human category includes sources originating from human waste or sewage samples. The bovine category includes sources identified as cow or bovine. Bovine sources include bacteria strains that may be common to both cows and sheep. The deer/elk category includes sources identified as deer, elk, or deer/elk (i.e., bacteria strains considered to be common to both deer and elk). The canine category includes sources identified as dog, coyote, or canine (i.e., bacteria strains common to both domestic dog and coyote). The feline category includes sources identified as feline, which may have originated from domestic cats, bobcat, or cougar. For ease of discussion, the canine and feline categories are assigned to a general category of canine/feline, the sources of which could be wild (i.e., coyote/bobcat) and/or domesticated (i.e., dog/cat). The relative proportion of wild and domesticated canine/feline isolates is likely dependant on the relative proportions of forested and developed land use. The rodent/beaver category includes sources identified as rodent or rodent/beaver (i.e., bacteria strains common to both rodent and beaver). Rodents include rats, mice, bats, voles, moles, beavers and nutrias.

Figure 6 presents the percent matching results for each station represented as a pair of stacked bars. The pair of bars represent the percentage of those sources obtained from samples collected during base flow or storm flow. The number of isolates (n) associated with each bar is included at the top of the bar. Matching results are described below for the MST study. Results are summarized for the overall study, and are discussed generally in terms of the river and stream stations. Hydrologic, seasonal, and land use factors are also summarized and discussed.

Further analysis was initiated that evaluated the distribution of fecal sources from samples that either met or exceeded the EPA recommended *E. coli* water quality standard. The purpose of this analysis was to evaluate whether human or other sources of bacteria are more prevalent when bacteria concentrations are elevated and potentially pose a higher risk to human health. The EPA *E. coli* standard was selected rather than the Washington state fecal coliform bacteria standard because more samples were analyzed for *E. coli* bacteria (154 samples) than for fecal coliform (75 samples). However, because of the lack of data, the analysis was not included in this report. Only one-third of the total isolates (459 of 1,503 isolates) had *E. coli* bacteria concentrations associated with them, and several stations had too few isolates for a meaningful comparison.

4.4.1 Overall Matching Results

Human sources of *E. coli* bacteria represented 3.5 percent of the total number of isolates obtained from all stations in the MST study. Human sources were detected at all stations except for Springbrook Creek (A317), and were only present at the Upper Green River (E319) during storm flow conditions. The highest percentage of human isolates (6.7 percent) was found at both the Middle Green River (D319) and Lower Green River (A310). Human sources comprised 4.9 percent of the isolates from the river stations and 2.7 percent from the stream stations.

Livestock sources (bovine, horse, and llama) represented 7.1 percent of the total isolates obtained for the MST study. Bovine sources comprised the majority (65 percent) of the livestock sources compared to 34 percent horse and less than 1 percent llama. The highest percentage of bovine isolates (17.8) was found at Newaukum Creek (0322). Bovine isolates were observed at all stations except Springbrook Creek (A317). Livestock sources comprised 8.2 percent and 6.3 percent of the isolates from the river stations and stream stations, respectively.

Avian isolates comprised the largest percentage (26.1) of all sources and was the predominant source at eight of the nine stations. The highest percentage of avian isolates (37.6 percent) was found at Mill Creek (A315). Avian sources were found more frequently at the stream stations (28.6 percent) than the river stations (22 percent). Waterfowl sources were also present at all stations, comprising 8.7 percent and 5.8 percent of the isolates from river and stream stations, respectively.

Rodent and beaver sources were the second most prevalent sources observed (16.6 percent) and were observed more frequently at the stream stations (18.3 percent) than at the river stations (13.8 percent). Canine sources represented 12.5 percent of all sources, and were observed more frequently at stream stations (14.5 percent) than river stations (9.2 percent). Deer/elk and raccoon sources were observed at a moderate frequency (9.3 and 7.5 percent, respectively), and were observed at all stations. Feline sources represented less than 2 percent of all sources and were observed at all stations except the Upper Green River (E319). Bear, bobcat, coyote, muskrat, skunk, and squirrel were rarely observed (less than 1 percent). Isolates from unknown sources were observed at all stations except Mill Creek (A315), and were observed at a low frequency (5.2 percent) overall.

4.4.2 Hydrologic and Seasonal Evaluation

Generally, the percentages of fecal coliform bacteria sources did not exhibit consistent trends or vary substantially (i.e., greater than ten percent) with hydrologic condition or season at the river sites or stream sites. However, small differences are apparent from comparisons of these variables. Figure 6 presents the bacteria source matching results separated in terms of base flow and storm flow samples results from each station. Figure 7 presents the bacteria source matching results separated by summer and winter sample results from each site.

4.4.2.1 Hydrologic Comparison

At the Upper Green River (E319) and Mill Creek (A315), livestock bacteria sources were not present during base flow but were observed at a low frequency (3 to 10 percent) during storm flow. This suggests that stormwater runoff carries livestock waste to these water bodies rather than livestock having direct access to them. Canine/feline bacteria sources increased by 15 percent during storm flow conditions at the Lower Green River (A310), which suggests that stormwater runoff carries pet waste to water at this site. However, the canine and feline percentages exhibited a slight decrease during storm flow at Newaukum Creek (0322) (five percent) and Soos Creek (A320) (six percent). The lack of consistent differences in fecal source percentages among the sites for base and storm flow suggests that hydrologic conditions do not have a substantial influence on the fecal sources present at these sites.

Table 7. Number of *E. coli* bacteria isolates by fecal source category obtained for the Green-Duwamish River Watershed Microbial Source Tracking Study.

	River Sites								Stream Sites											
	E319 Upper Green River		B319 Middle Green River		D319 Middle Green River		A310 Lower Green River		0322 Newaukum Creek		A320 Soos Creek		A315 Mill Creek		A317 Springbrook Creek		A307 Hamm Creek		Sum of All Stations	
Fecal Source	No.	% of Total	No.	% of Total	No.	% of Total	No.	% of Total	No.	% of Total	No.	% of Total	No.	% of Total	No.	% of Total	No.	% of Total	No.	% of Total
Human	1	0.9%	3	2.8%	10	6.7%	14	6.7%	7	4.0%	8	4.6%	4	2.4%	0	0.0%	6	2.6%	53	3.5%
Canine/feline																				
Canine	16	15.0%	7	6.5%	13	8.7%	17	8.1%	15	8.6%	18	10.3%	29	17.6%	31	16.9%	42	17.9%	188	12.5%
Feline	0	0.0%	1	0.9%	5	3.4%	5	2.4%	3	1.7%	2	1.1%	1	0.6%	4	2.2%	6	2.6%	27	1.8%
Livestock																				
Llama	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	1	0.6%	0	0.0%	0	0.0%	0	0.0%	1	0.1%
Bovine	3	2.8%	9	8.3%	12	8.1%	8	3.8%	31	17.8%	3	1.7%	1	0.6%	0	0.0%	2	0.9%	69	4.6%
Horse	4	3.7%	4	3.7%	4	2.7%	3	1.4%	10	5.7%	8	4.6%	2	1.2%	0	0.0%	1	0.4%	36	2.4%
Avian																				
Avian	21	19.6%	20	18.5%	34	22.8%	51	24.4%	33	19.0%	41	23.6%	62	37.6%	65	35.5%	65	27.8%	392	26.1%
Waterfowl	9	8.4%	7	6.5%	9	6.0%	25	12.0%	7	4.0%	14	8.0%	12	7.3%	9	4.9%	12	5.1%	104	6.9%
Large Mammals																				
Bear	2	1.9%	1	0.9%	3	2.0%	1	0.5%	1	0.6%	2	1.1%	0	0.0%	0	0.0%	0	0.0%	10	0.7%
Deer/elk	16	15.0%	24	22.2%	17	11.4%	26	12.4%	19	10.9%	19	10.9%	12	7.3%	5	2.7%	2	0.9%	140	9.3%
Bobcat	2	1.9%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	1	0.6%	0	0.0%	0	0.0%	0	0.0%	3	0.2%
Coyote	1	0.9%	0	0.0%	2	1.3%	3	1.4%	2	1.1%	2	1.1%	1	0.6%	0	0.0%	2	0.9%	13	0.9%
Small Mammals																				
Rodent/beaver	12	11.2%	17	15.7%	25	16.8%	25	12.0%	27	15.5%	33	19.0%	33	20.0%	35	19.1%	42	17.9%	249	16.6%
Muskrat	1	0.9%	0	0.0%	0	0.0%	0	0.0%	1	0.6%	1	0.6%	0	0.0%	0	0.0%	1	0.4%	4	0.3%
Opossum	2	1.9%	1	0.9%	0	0.0%	1	0.5%	1	0.6%	3	1.7%	1	0.6%	1	0.5%	3	1.3%	13	0.9%
Raccoon	10	9.3%	9	8.3%	9	6.0%	17	8.1%	6	3.4%	9	5.2%	7	4.2%	19	10.4%	27	11.5%	113	7.5%
Skunk	1	0.9%	0	0.0%	0	0.0%	1	0.5%	1	0.6%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	3	0.2%
Squirrel	0	0.0%	0	0.0%	0	0.0%	1	0.5%	1	0.6%	2	1.1%	0	0.0%	1	0.5%	2	0.9%	7	0.5%
Unknown	6	5.6%	5	4.6%	6	4.0%	11	5.3%	9	5.2%	7	4.0%	0	0.0%	13	7.1%	21	9.0%	78	5.2%
Total	107	100.0%	108	100.0%	149	100.0%	209	100.0%	174	100.0%	174	100.0%	165	100.0%	183	100.0%	234	100.0%	**1503**	100.0%

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Figure 6. Percentage of *E. coli* isolates by source during base flow and storm flow conditions for the Green-Duwamish MST study.

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4.4.2.2 Seasonal Comparison

At the Middle Green River (D319) and Newaukum Creek (0322), waterfowl bacteria sources decreased by 2 percent each during the winter season compared to the summer season. Conversely, waterfowl bacteria sources increased during the winter season compared to the summer season at the Upper Green River (E319) (five percent), Lower Green River (A310) (seven percent), Mill Creek (A315) (three percent), and Springbrook Creek (A317) (five percent). These results possibly reflect the increased use by migratory waterfowl in those watersheds. Livestock bacteria sources decreased during the winter season compared to the summer season at the Middle Green River (B319) (nine percent) and the Lower Green River (A310) (five percent), but increased during the winter season at Soos Creek (A320) (four percent). Although small differences (i.e., less than 10 percent) were apparent at individual monitoring stations, no substantial differences or consistent trends in fecal source percentages were observed during summer and winter at the river or stream sites (see Figure 7). These results suggest that fecal sources do not vary substantially with seasons of the year.

4.4.3 Land Use Evaluation

The influence of land use on bacteria sources is discussed separately below for the river and stream sites. Land use in the Green-Duwamish River watershed includes developed (i.e. low density residential, high density residential, and commercial/industrial) and agriculture (see Figure 2 and Table 2). Generally, percentages of bacteria sources observed at the study sites reflected the land use present in each respective drainage basin. For example, the highest percentage of bovine fecal sources was observed at Newaukum Creek (17.8 percent), which has the highest proportion agricultural land use (45 percent). In contrast, the lowest percentage of bovine fecal sources was observed at Springbrook Creek, which drains the most developed basin (22 percent residential and 29 percent commercial/industrial) with very little (0.2 percent) agriculture.

For this evaluation, human bacteria sources are compared to the amount of developed land use, and livestock bacteria sources (i.e., bovine, horse, and llama) are compared to the amount of agricultural land use. Although canine/feline bacteria sources could be included as bacteria sources from developed and agricultural land uses, this category will be considered separately due to the potential presence of both wild and domestic canine/feline bacteria sources. Overall, human and livestock bacteria sources represented approximately 11 percent of the total isolates obtained, and ranged from 0 to 28 percent at the monitoring sites. The proportion of each source category observed at each site is shown schematically in Figure 8.

4.4.3.1 River Sites

The predominant land use in the Upper Green River subbasin (E319) is forest (87 percent cover), with no development and agricultural land use activity (see Table 2). Avian/waterfowl (28.0 percent) and deer/elk (15.0 percent) isolates represented the predominant fecal sources at this station. Human and livestock bacteria sources represented

7 percent of the isolates at this site. Only one isolate (0.9 percent) was attributed to humans, and seven isolates (6.5 percent) were attributed to livestock (bovine and horse) sources. Canine fecal sources represented 15 percent of the isolates at this site, and based on the lack of development and agricultural land use, these isolates are likely to be primarily from wildlife (i.e., coyote). The highest percentage of raccoon isolates (9.3) for the river sites was observed at the Upper Green River site (E319)

Land use in the Middle Green River subbasins (B319 and D319) consists of more agriculture and residential development than the Upper Green River subbasins (E319). Station B319 is located upstream of D319, in a section of the Green River basin with less agricultural land use, less residential land use, and a higher percentage of forested land cover than the D319 subbasin. Together, development and agriculture bacteria source isolates increased downstream between the upper Middle Green River (B319) (22.2 percent) and the lower Middle Green River (D319) (29.5 percent). Human isolate percentages increased nominally from B319 (2.8 percent) to D319 (6.7 percent).

Canine/feline isolate sources also increased from B319 (7.4 percent) to D319 (12.1 percent). Livestock isolate sources were similar at B319 (12.0 percent) and D319 (10.7 percent). Wildlife sources decreased downstream, representing 46.2 percent of the isolates at B319 and 34.6 percent of the isolates at D319. These findings reflect the relative position of each station along the main stem and the change in land use in the downstream reaches of the subbasin.

The Lower Green River subbasin (A310) consists of less agriculture and more development (residential/commercial/industrial land use) than the middle subbasins. The percentage of isolates from human (7 percent) and canine/feline (11 percent) sources from this site were similar to those observed at the Lower Middle Green River (D319). Livestock isolates continued to decrease downstream, representing 5 percent of the total isolates at the Lower Green River (A310). The percentage of waterfowl source isolates observed at the Lower Green River (A310) was twice that observed at the Lower Middle Green River (D319). Figure 7 shows this increase occurs during the winter season, suggesting increased use by migrating birds. Wildlife isolate percentages for large and small mammals did not change appreciably from the lower Middle Green River to the Lower Green River. Overall, matching results from the Lower Green River (A310) indicate less influence from agricultural land use and are a reflection of sources present in the entire Green River watershed.

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Figure 7. Percent of *E. coli* isolates by source during summer (June through October) and winter (November through May) for the Green-Duwamish River watershed MST Study.

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Figure 8. Schematic diagram of bacteria source percentages or each station for the Green-Duwamish MST study.

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4.4.3.2 Stream Sites

Land use in the Newaukum Creek subbasin (0322) is predominantly agriculture (45 percent) and includes a small amount of low-density residential use (5 percent). The highest percentage of bovine (17.8 percent) and horse (5.7 percent) isolates for the study were observed at this station. These findings suggest that agricultural land use activities are an important factor in predicting fecal coliform bacteria contamination from livestock bacteria sources. Canine/feline fecal sources comprised approximately 10 percent of the total isolates at this site, and likely originated from both wildlife (coyote and bobcat) and pets (dog and cat) because the basin includes both forest (31 percent) and development (5.6 percent) (see Table 2). Large mammal fecal sources comprised 13 percent of the total isolates, with the highest percentage of deer/elk isolates (11 percent) for the stream sites observed at this station. In contrast, the smallest percentages of small mammal (21.3 percent) and avian/waterfowl (23 percent) fecal sources for the study were observed at this predominantly agricultural site.

Land use in the Soos Creek subbasin (A320) is predominantly low-density (rural) residential (17 percent) development, and includes a substantial amount of forest (53 percent; see Table 2). This subbasin also has significant amounts of medium- to high-density development and includes some high-density residential and commercial development (2 percent), and less than 1 percent agriculture. This mixed land use is reflected in the distribution of fecal sources observed at this site. Human fecal sources represented 5 percent of the total isolates, livestock fecal sources represented 7 percent of the total, and canine/feline fecal sources represented 11 percent of the total. A substantial number of the canine/feline isolates may have originated from wild animals, particularly considering that coyote and bobcat isolates were obtained from this site. Avian and waterfowl fecal sources comprised 32 percent of the total isolates, and wildlife fecal sources, including deer/elk and rodent/beaver sources, comprised 42 percent of the total isolates observed (see Figure 8).

Developed land use in the Mill Creek subbasin (A315) is predominantly commercial/industrial (18 percent) and low-density residential (16 percent). Human and livestock fecal sources represented low percentages of the total isolates for this site (2 percent each). The low human percentage is indicative of an area with municipal sewer systems (in 83 percent of the basin) and limited on-site septic systems. The low livestock percentage reflects the low percentage of agriculture (5.6 percent) in the basin, which may be used more for crops than for grazing. The percentage of canine fecal sources (18 percent) was higher at this site than any of the other sites. Domestic dogs likely represent a large proportion of those canine sources, due to the relatively low proportion of forest (23 percent) and high proportion of development (35 percent) in the basin. The predominant fecal sources at this station were avian (38 percent) and rodent/beaver (20 percent). These percentages are the highest for avian and rodent/beaver fecal sources of all sites in this study.

Developed and agricultural land use in the Springbrook Creek subbasin (A317) is predominantly commercial/industrial development (29 percent) and includes a substantial amount of low-density residential development (21 percent). Human isolates were not observed at this site, suggesting that the 100 percent coverage by municipal sewers and wastewater treatment, and the

lack of on-site septic systems effectively prevents contamination of Springbrook Creek from human sources. Livestock isolates were also not obtained from this site, which agrees with the lack of (less than 1 percent) agricultural land use in the basin. The majority of the isolates obtained from this site include avian/waterfowl (40 percent), wildlife (33 percent), and canine/feline (19 percent) sources. It is likely that most of the canine fecal sources observed at this site originated from domestic dogs due to the larger proportion of development (50 percent) in the basin. Wildlife primarily included raccoon (10.4 percent) and rodent/beaver (19.1 percent) sources.

Developed and agricultural land use in the Hamm Creek subbasin (A307) is predominantly low-density residential (31 percent), and includes commercial/industrial development (10 percent) as well as a forested upper riparian corridor. Matching results are similar to Springbrook Creek, with the highest percentage of canine/feline sources (21 percent) in the study area and low percentages of human (2.6 percent) and livestock (1 percent) sources. Based on the high percentage of developed land use (41 percent), and the low percentage of forest (26 percent), it is likely that the canine/feline isolates originated primarily from domesticated animals. The forested upper basin also influences the isolates obtained from this site, with avian and small mammals (rodent/beaver and raccoon) comprising 65 percent of the sources. The highest percentage of raccoon fecal isolates (11.5 percent) for the MST study was observed at this site.

5.0 Conclusions

5.1 Bacteria Enumeration

Water samples were collected during 2003 and 2004 for the Green-Duwamish MST study during a total of eight storm events and seven base flow events at nine study locations, four on the main stem Green River and five at the mouth of tributaries of the Green River. Additional bacterial data from samples collected during 2001 and 2002 were used to supplement the study database. Overall, a total of 564 water samples were collected, 13 percent of the samples were analyzed for fecal coliform bacteria, and 27 percent of the samples were analyzed for *E. coli*. Additional bacteria enumeration data were collected for the water quality assessment. Conclusions reached from the bacteria enumeration data include the following:

- Fecal coliform bacteria concentrations for the GDWQA study exceeded the state water quality standard at all stream sites except Soos Creek (A320) during base flow conditions and at the Lower Green River (A310) during base and storm flow conditions. The state standard was not evaluated for the Middle Green River sites (B319 and D319) due to a lack of data.

- *E. coli* bacteria geometric mean concentrations exceeded the EPA-recommended water quality criterion at Mill Creek (A315) during base flow conditions and at all stations except the Upper Green River (E319) and the Middle Green River (B319) during storm flow conditions.

- *E. coli* bacteria concentrations were significantly higher during storm flow conditions than base flow conditions at all stations except Soos Creek (A320).

- Bacteria concentrations in the Green River increased significantly from upstream to downstream, reflecting the increased amount of human-related land use, (development and agriculture) from upstream to downstream.

- The highest fecal coliform bacteria concentrations were observed in those stream subbasins with the most development and agricultural land use, while the lowest concentrations were observed at the stream subbasin (Soos Creek) with the least development and agricultural land use.

- Fecal coliform and *E. coli* bacteria concentrations were significantly higher during the summer than during the winter when comparing the entire study dataset, but no seasonal differences in fecal coliform or *E. coli* bacteria concentrations were apparent when comparing bacteria concentrations observed at individual stations.

5.2 Ribotyping

The ribotyping analysis successfully matched 95 percent of 1,503 isolates obtained from the 564 water samples to known human or animal fecal sources. General conclusions reached from the ribotyping analysis performed for this study include:

- Human bacteria sources represented 3.5 percent of the total *E. coli* isolates obtained, and were observed at all river and stream monitoring sites except Springbrook Creek (A317). These results suggest that the 100 percent coverage by municipal sewers and wastewater treatment and the lack of on-site septic systems effectively prevent contamination of Springbrook Creek from human waste. The highest percentage of human isolates (6.7 percent) was observed at both the Middle Green River (D319) and the Lower Green River (A310).

- Livestock (bovine and horse) bacteria sources represented 7.1 percent of the total isolates. The highest percentage of livestock isolates (24 percent) was observed at Newaukum Creek (0322), whose basin contains the highest percentage of agricultural land use (45 percent) of all study sites.

- Avian bacteria sources represented the largest percentage (26.1 percent) of all ribotypes, and were the predominant source at eight of the nine stations.

- Rodent/beaver sources were the second most prevalent source observed (16.6 percent) and were observed more frequently at the stream stations (18.3 percent) that the river stations (13.8 percent).

- Canine sources represented 12.5 percent of all sources and were observed more frequently at stream stations (14.5 percent) than the river stations (9.2 percent).

- Deer/elk and raccoon sources were observed at a moderate frequency (9.3 and 7.5 percent, respectively), and were observed at all stream and river stations.

- Feline sources represented less than 2 percent of all sources and were observed at all stations except the Upper Green River (E319).

- Bear, bobcat, coyote, muskrat, skunk, and squirrel were rarely observed (less than 1 percent).

- Proportions of bacteria sources generally did not vary consistently among stations with hydrologic condition (base versus storm flow) or season (winter versus summer).

- Proportions of bacteria sources generally did vary with the land use present in the areas draining to each monitoring site. Human sources were most prevalent in areas of low density development (i.e., septic systems), canine/feline sources were most prevalent in areas of high density development, and livestock sources were most prevalent in agriculture areas.

- At the river sites, human bacteria sources generally increased downstream while wildlife bacteria sources generally decreased downstream, reflecting the relative position of each monitoring station along the main stem and the change in land use in the downstream reaches of the subbasin.

- At the river sites, livestock bacteria sources increased from the Upper Green River (E319) to the Middle Green River (B319 and D319), and then decreased from the Middle Green River (B319 and D319) to the Lower Green River (A310), reflecting the change (reduction) in agriculture land use downstream.

- The percentage of waterfowl bacteria sources at the Lower Green River was twice the percentage of waterfowl bacteria sources observed at the Lower Middle Green River, possibly reflecting the increased use by migrating birds.

- At the stream sites, human bacteria sources generally decreased somewhat downstream, reflecting a reduction in the use of on-site septic systems and an increase in the use of sewers and municipal wastewater treatment.

- At the stream sites, the percentage of canine bacteria sources increased with increasing developed land use, suggesting that a majority of the canine isolates originate from domestic dogs.

6.0 References

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APPENDIX A

Project Database

Table A-1. Project database for the Green-Duwamish watershed Microbial Source Tracking Study

Site ID	King County Sample ID	Collect Date	Collect Time	Hydrology	season	Isolate #	Bacteria Source	Bacteria Source Category	E. coli Bacteria (CFU/100 mL)	Data Flags	Fecal Coliform Bacteria (CFU/100 mL)	Data Flags	Flow (cfs)
E319	L22828-9	11/28/2001	1800	Base	winter	104168	raccoon	wildlife	1		2		
E319	L22976-44	12/14/2001	841	Storm	winter	104172	bobcat	wildlife	7		5		
E319	L22976-44	12/14/2001	841	Storm	winter	104169	deer/elk	wildlife	7		5		
E319	L22976-44	12/14/2001	841	Storm	winter	104170	rodent/beaver	wildlife	7		5		
E319	L22976-44	12/14/2001	841	Storm	winter	104171	canine	canine/feline	7		5		
E319	L23184-3	1/23/2002	1808	Base	winter	104176	deer/elk	wildlife	5	H	0	H	
E319	L23184-3	1/23/2002	1808	Base	winter	104177	deer/elk	wildlife	5	H	0	H	
E319	L23184-3	1/23/2002	1808	Base	winter	104174	opossum	wildlife	5	H	0	H	
E319	L23184-3	1/23/2002	1808	Base	winter	104173	raccoon	wildlife	5	H	0	H	
E319	L23184-3	1/23/2002	1808	Base	winter	104175	waterfowl	wildlife	5	H	0	H	
E319	L23373-7	2/21/2002	400	Storm	winter	104178	avian	wildlife	13		12		1101
E319	L23373-7	2/21/2002	400	Storm	winter	104179	bobcat	wildlife	13		12		1101
E319	L23947-3	4/24/2002	913	Base	winter	103577	canine	canine/feline	1		1		1392
E319	L23534-7	6/28/2002	1412	Base	summer	104181	raccoon	wildlife	5	H	2	H	799.2
E319	L23534-7	6/28/2002	1412	Base	summer	104182	rodent/beaver	wildlife	5	H	2	H	799.2
E319	L23534-7	6/28/2002	1412	Base	summer	104180	canine	canine/feline	5	H	2	H	799.2
E319	L25056-6	8/6/2002	933	Base	summer	103640	waterfowl	wildlife	2		2		238.7
E319	L25056-6	8/6/2002	933	Base	summer	103642	canine	canine/feline	2		2		238.7
E319	L25935-4	10/22/2002	945	Base	summer	103659	deer/elk	wildlife	2		0		
E319	L25935-4	10/22/2002	945	Base	summer	103658	skunk	wildlife	2		0		
E319	L24891-1	11/6/2002	1010	Base	winter	104183	canine	canine/feline	1		1		
E319	L24891-1	11/6/2002	1010	Base	winter	104184	canine	canine/feline	1		1		
E319	L24891-2	11/7/2002	1059	Base	winter	104185	avian	wildlife	1	H	5		
E319	L24891-2	11/7/2002	1059	Base	winter	104186	avian	wildlife	1	H	5		
E319	L26467-10	12/12/2002	1243	Storm	winter	104188	deer/elk	wildlife	5		5		
E319	L26467-10	12/12/2002	1243	Storm	winter	104187	raccoon	wildlife	5		5		
E319	L26887-38	1/22/2003	1003	Storm	winter	101602	avian	wildlife					
E319	L26887-39	1/22/2003	1006	Storm	winter	101603	avian	wildlife					
E319	L27361-11	2/25/2003	1025	Storm	winter	101627	human	human	1				1444
E319	L27361-12	2/25/2003	1027	Storm	winter	101647	waterfowl	wildlife					1444
E319	L27361-12	2/25/2003	1027	Storm	winter	104167	unknown	unknown					1444
E319	L27361-13	2/25/2003	1029	Storm	winter	101648	waterfowl	wildlife					1444
E319	L27361-13	2/25/2003	1029	Storm	winter	101654	waterfowl	wildlife					1444

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Site ID	King County Sample ID	Collect Date	Collect Time	Hydrology	season	Isolate #	Bacteria Source	Bacteria Source Category	E. coli Bacteria (CFU/100 mL)	Data Flags	Fecal Coliform Bacteria (CFU/100 mL)	Data Flags	Flow (cfs)
E319	L27826-14	4/29/2003	914	Base	winter	101744	deer/elk	wildlife					885.6
E319	L27826-14	4/29/2003	914	Base	winter	101743	canine	canine/feline					885.6
E319	L27783-11	6/2/2003	922	Base	summer	102889	unknown	unknown	2				757.8
E319	L27783-12	6/2/2003	923	Base	summer	101824	bear	wildlife					757.8
E319	L28447-12	6/9/2003	823	Base	summer	102894	opossum	wildlife					456.1
E319	L29246-12	8/27/2003	942	Base	summer	82304	deer/elk	wildlife					248.3
E319	L29246-14	8/27/2003	946	Base	summer	82305	avian	wildlife					248.3
E319	L29246-14	8/27/2003	946	Base	summer	82306	avian	wildlife					248.3
E319	L28018-41	10/6/2003	1054	Base	summer	83524	raccoon	wildlife	2				273.4
E319	L28018-41	10/6/2003	1054	Base	summer	83523	canine	canine/feline	2				273.4
E319	L28018-42	10/6/2003	1056	Base	summer	83525	deer/elk	wildlife					273.4
E319	L28018-43	10/6/2003	1058	Base	summer	83527	raccoon	wildlife					273.4
E319	L28018-43	10/6/2003	1058	Base	summer	83526	rodent/beaver	wildlife					273.4
E319	L28018-44	10/6/2003	1100	Base	summer	83531	avian	wildlife					273.4
E319	L28018-44	10/6/2003	1100	Base	summer	83528	deer/elk	wildlife					273.4
E319	L28018-44	10/6/2003	1100	Base	summer	83530	waterfowl	wildlife					273.4
E319	L28018-44	10/6/2003	1100	Base	summer	83529	canine	canine/feline					273.4
E319	L27770-41	10/17/2003	702	Storm	summer	85074	avian	wildlife	34				1233
E319	L27770-41	10/17/2003	702	Storm	summer	85075	avian	wildlife	34				1233
E319	L27770-41	10/17/2003	702	Storm	summer	85076	rodent/beaver	wildlife	34				1233
E319	L27770-42	10/17/2003	704	Storm	summer	85077	avian	wildlife					1233
E319	L27770-42	10/17/2003	704	Storm	summer	85078	avian	wildlife					1233
E319	L27770-42	10/17/2003	704	Storm	summer	85079	bovine	livestock					1233
E319	L27770-43	10/17/2003	706	Storm	summer	85080	avian	wildlife					1233
E319	L27770-43	10/17/2003	706	Storm	summer	85083	deer/elk	wildlife					1233
E319	L27770-43	10/17/2003	706	Storm	summer	85082	raccoon	wildlife					1233
E319	L27770-43	10/17/2003	706	Storm	summer	85081	horse	livestock					1233
E319	L27770-44	10/17/2003	708	Storm	summer	85084	canine	canine/feline					1233
E319	L27770-44	10/17/2003	708	Storm	summer	85085	canine	canine/feline					1233
E319	L27770-44	10/17/2003	708	Storm	summer	85086	canine	canine/feline					1233
E319	L27770-45	10/17/2003	710	Storm	summer	85089	bear	wildlife					1233
E319	L27770-45	10/17/2003	710	Storm	summer	85087	rodent/beaver	wildlife					1233
E319	L27770-45	10/17/2003	710	Storm	summer	85088	rodent/beaver	wildlife					1233

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E319	L30144-41	11/18/2003	1103	Storm	winter	86089	deer/elk	wildlife	43				5570
E319	L30144-41	11/18/2003	1103	Storm	winter	86091	deer/elk	wildlife	43				5570
E319	L30144-41	11/18/2003	1103	Storm	winter	86090	rodent/beaver	wildlife	43				5570
E319	L30144-42	11/18/2003	1104	Storm	winter	86094	avian	wildlife					5570
E319	L30144-42	11/18/2003	1104	Storm	winter	86093	avian	wildlife					5570
E319	L30144-42	11/18/2003	1104	Storm	winter	86092	canine	canine/feline					5570
E319	L30144-43	11/18/2003	1105	Storm	winter	86096	avian	wildlife					5570
E319	L30144-43	11/18/2003	1105	Storm	winter	86095	rodent/beaver	wildlife					5570
E319	L30144-43	11/18/2003	1105	Storm	winter	86097	rodent/beaver	wildlife					5570
E319	L30144-44	11/18/2003	1106	Storm	winter	86098	deer/elk	wildlife					5570
E319	L30144-44	11/18/2003	1106	Storm	winter	86099	unknown	unknown					5570
E319	L30144-45	11/18/2003	1107	Storm	winter	86102	raccoon	wildlife					5570
E319	L30144-45	11/18/2003	1107	Storm	winter	86100	rodent/beaver	wildlife					5570
E319	L30144-45	11/18/2003	1107	Storm	winter	86101	rodent/beaver	wildlife					5570
E319	L29825-13	3/16/2004	1248	Base	winter	90408	avian	wildlife					
E319	L29825-14	3/16/2004	1251	Base	winter	90410	avian	wildlife					
E319	L29825-14	3/16/2004	1251	Base	winter	90411	avian	wildlife					
E319	L29825-14	3/16/2004	1251	Base	winter	90409	deer/elk	wildlife					
E319	L29825-15	3/16/2004	1254	Base	winter	90412	unknown	unknown					
E319	L29940-41	3/25/2004	1106	Storm	winter	90842	avian	wildlife	2				
E319	L29940-41	3/25/2004	1106	Storm	winter	90840	unknown	unknown	2				
E319	L29940-41	3/25/2004	1106	Storm	winter	90841	unknown	unknown	2				
E319	L29940-42	3/25/2004	1109	Storm	winter	90843	waterfowl	wildlife					
E319	L29940-45	3/25/2004	1118	Storm	winter	90845	deer/elk	wildlife					
E319	L29940-45	3/25/2004	1118	Storm	winter	90844	waterfowl	wildlife					
E319	L31629-41	5/26/2004	1230	Storm	winter	93803	deer/elk	wildlife	5				
E319	L31629-41	5/26/2004	1230	Storm	winter	93802	raccoon	wildlife	5				
E319	L31629-41	5/26/2004	1230	Storm	winter	93801	waterfowl	wildlife	5				
E319	L31629-41	5/26/2004	1230	Storm	winter	93800	canine	canine/feline	5				
E319	L31629-42	5/26/2004	1232	Storm	winter	93805	rodent/beaver	wildlife					
E319	L31629-42	5/26/2004	1232	Storm	winter	93804	canine	canine/feline					
E319	L31629-42	5/26/2004	1232	Storm	winter	93806	horse	livestock					
E319	L31629-43	5/26/2004	1234	Storm	winter	93808	raccoon	wildlife					

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E319	L31629-43	5/26/2004	1234	Storm	winter	93807	canine	canine/feline					
E319	L31629-43	5/26/2004	1234	Storm	winter	93809	bovine	livestock					
E319	L31629-44	5/26/2004	1236	Storm	winter	93810	coyote	wildlife					
E319	L31629-44	5/26/2004	1236	Storm	winter	93812	bovine	livestock					
E319	L31629-44	5/26/2004	1236	Storm	winter	93811	horse	livestock					
E319	L31629-45	5/26/2004	1238	Storm	winter	93813	avian	wildlife					
E319	L31629-45	5/26/2004	1238	Storm	winter	93814	horse	livestock					
E319	L31629-45	5/26/2004	1238	Storm	winter	93815	muskrat	wildlife					
B319	L26887-13	1/23/2003	1211	Storm	winter	101590	rodent/beaver	wildlife					
B319	L27037-37	2/13/2003	1143	Base	winter	102904	unknown	unknown					
B319	L27361-16	2/25/2003	1141	Base	winter	101628	bovine	livestock	1				
B319	L27361-18	2/25/2003	1145	Base	winter	101655	raccoon	wildlife					
B319	L27361-18	2/25/2003	1145	Base	winter	101649	bovine	livestock					
B319	L27361-19	2/25/2003	1147	Base	winter	101650	avian	wildlife					
B319	L27361-19	2/25/2003	1147	Base	winter	101656	deer/elk	wildlife					
B319	L27361-20	2/25/2003	1149	Base	winter	101651	avian	wildlife					
B319	L27033-32	3/10/2003	1142	Storm	winter	101812	avian	wildlife					
B319	L27033-34	3/10/2003	1146	Storm	winter	101697	avian	wildlife					
B319	L27033-35	3/10/2003	1148	Storm	winter	101698	raccoon	wildlife					
B319	L27271-32	4/9/2003	911	Storm	winter	101727	waterfowl	wildlife					
B319	L27271-35	4/9/2003	917	Storm	winter	101728	avian	wildlife					
B319	L27826-16	4/29/2003	1155	Base	winter	101745	avian	wildlife	1				
B319	L27826-17	4/29/2003	1157	Base	winter	101746	rodent/beaver	wildlife					
B319	L27826-18	4/29/2003	1159	Base	winter	102930	opossum	wildlife					
B319	L27826-20	4/29/2003	1203	Base	winter	101748	deer/elk	wildlife					
B319	L27826-20	4/29/2003	1203	Base	winter	101747	unknown	unknown					
B319	L27783-16	6/2/2003	1114	Base	summer	101770	avian	wildlife	2				
B319	L27783-17	6/2/2003	1116	Base	summer	102890	canine	canine/feline					
B319	L28447-17	6/9/2003	1204	Base	summer	102895	deer/elk	wildlife					
B319	L28447-18	6/9/2003	1206	Base	summer	101791	avian	wildlife					
B319	L28447-18	6/9/2003	1206	Base	summer	102939	rodent/beaver	wildlife					
B319	L28447-19	6/9/2003	1208	Base	summer	102896	deer/elk	wildlife					
B319	L28447-20	6/9/2003	1210	Base	summer	102897	deer/elk	wildlife					

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B319	L29246-16	8/27/2003	1312	Base	summer	82309	deer/elk	wildlife	12				
B319	L29246-16	8/27/2003	1312	Base	summer	82308	bovine	livestock	12				
B319	L29246-16	8/27/2003	1312	Base	summer	82307	horse	livestock	12				
B319	L29246-17	8/27/2003	1314	Base	summer	82311	bear	wildlife					
B319	L29246-17	8/27/2003	1314	Base	summer	82310	canine	canine/feline					
B319	L29246-17	8/27/2003	1314	Base	summer	82312	human	human					
B319	L29246-18	8/27/2003	1316	Base	summer	82313	avian	wildlife					
B319	L29246-18	8/27/2003	1316	Base	summer	82314	raccoon	wildlife					
B319	L29246-18	8/27/2003	1316	Base	summer	82315	bovine	livestock					
B319	L29246-19	8/27/2003	1318	Base	summer	82318	deer/elk	wildlife					
B319	L29246-19	8/27/2003	1318	Base	summer	82316	horse	livestock					
B319	L29246-19	8/27/2003	1318	Base	summer	82317	horse	livestock					
B319	L29246-20	8/27/2003	1320	Base	summer	82321	raccoon	wildlife					
B319	L29246-20	8/27/2003	1320	Base	summer	82319	rodent/beaver	wildlife					
B319	L29246-20	8/27/2003	1320	Base	summer	82320	rodent/beaver	wildlife					
B319	L28018-31	10/7/2003	30	Storm	summer	83494	rodent/beaver	wildlife	76				
B319	L28018-31	10/7/2003	30	Storm	summer	83492	waterfowl	wildlife	76				
B319	L28018-31	10/7/2003	30	Storm	summer	83493	bovine	livestock	76				
B319	L28018-32	10/7/2003	32	Storm	summer	83496	deer/elk	wildlife					
B319	L28018-32	10/7/2003	32	Storm	summer	83497	waterfowl	wildlife					
B319	L28018-32	10/7/2003	32	Storm	summer	83495	canine	canine/feline					
B319	L28018-33	10/7/2003	34	Storm	summer	83498	deer/elk	wildlife					
B319	L28018-33	10/7/2003	34	Storm	summer	83499	deer/elk	wildlife					
B319	L28018-33	10/7/2003	34	Storm	summer	83501	waterfowl	wildlife					
B319	L28018-33	10/7/2003	34	Storm	summer	83500	human	human					
B319	L28018-34	10/7/2003	36	Storm	summer	83504	rodent/beaver	wildlife					
B319	L28018-34	10/7/2003	36	Storm	summer	83502	unknown	unknown					
B319	L28018-34	10/7/2003	36	Storm	summer	83503	unknown	unknown					
B319	L28018-35	10/7/2003	38	Storm	summer	83532	avian	wildlife					
B319	L28018-35	10/7/2003	38	Storm	summer	83505	rodent/beaver	wildlife					
B319	L28018-35	10/7/2003	38	Storm	summer	83506	rodent/beaver	wildlife					
B319	L28018-35	10/7/2003	38	Storm	summer	83533	waterfowl	wildlife					
B319	L28018-35	10/7/2003	38	Storm	summer	83507	bovine	livestock					

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Site ID	King County Sample ID	Collect Date	Collect Time	Hydrology	season	Isolate #	Bacteria Source	Bacteria Source Category	E. coli Bacteria (CFU/100 mL)	Data Flags	Fecal Coliform Bacteria (CFU/100 mL)	Data Flags	Flow (cfs)
B319	L27770-31	10/18/2003	1114	Storm	summer	85046	deer/elk	wildlife	42				
B319	L27770-31	10/18/2003	1114	Storm	summer	85044	canine	canine/feline	42				
B319	L27770-31	10/18/2003	1114	Storm	summer	85045	canine	canine/feline	42				
B319	L27770-32	10/18/2003	1116	Storm	summer	85049	deer/elk	wildlife					
B319	L27770-32	10/18/2003	1116	Storm	summer	85048	bovine	livestock					
B319	L27770-32	10/18/2003	1116	Storm	summer	85047	human	human					
B319	L27770-33	10/18/2003	1118	Storm	summer	85050	avian	wildlife					
B319	L27770-33	10/18/2003	1118	Storm	summer	85051	deer/elk	wildlife					
B319	L27770-33	10/18/2003	1118	Storm	summer	85052	rodent/beaver	wildlife					
B319	L27770-34	10/18/2003	1120	Storm	summer	85055	avian	wildlife					
B319	L27770-34	10/18/2003	1120	Storm	summer	85053	rodent/beaver	wildlife					
B319	L27770-34	10/18/2003	1120	Storm	summer	85054	bovine	livestock					
B319	L27770-35	10/18/2003	1122	Storm	summer	85056	deer/elk	wildlife					
B319	L27770-35	10/18/2003	1122	Storm	summer	85057	deer/elk	wildlife					
B319	L27770-35	10/18/2003	1122	Storm	summer	85058	deer/elk	wildlife					
B319	L30144-31	11/19/2003	1306	Storm	winter	86061	avian	wildlife	9				
B319	L30144-31	11/19/2003	1306	Storm	winter	86062	avian	wildlife	9				
B319	L30144-31	11/19/2003	1306	Storm	winter	86059	deer/elk	wildlife	9				
B319	L30144-31	11/19/2003	1306	Storm	winter	86060	raccoon	wildlife	9				
B319	L30144-32	11/19/2003	1308	Storm	winter	86063	avian	wildlife					
B319	L30144-32	11/19/2003	1308	Storm	winter	86064	avian	wildlife					
B319	L30144-33	11/19/2003	1310	Storm	winter	86065	rodent/beaver	wildlife					
B319	L30144-33	11/19/2003	1310	Storm	winter	86066	rodent/beaver	wildlife					
B319	L30144-34	11/19/2003	1312	Storm	winter	86067	rodent/beaver	wildlife					
B319	L30144-34	11/19/2003	1312	Storm	winter	86069	rodent/beaver	wildlife					
B319	L30144-34	11/19/2003	1312	Storm	winter	86068	canine	canine/feline					
B319	L30144-35	11/19/2003	1314	Storm	winter	86071	deer/elk	wildlife					
B319	L30144-35	11/19/2003	1314	Storm	winter	86072	deer/elk	wildlife					
B319	L30144-35	11/19/2003	1314	Storm	winter	86070	horse	livestock					
B319	L29825-17	3/16/2004	1405	Base	winter	90414	avian	wildlife					
B319	L29825-17	3/16/2004	1405	Base	winter	90413	deer/elk	wildlife					
B319	L29825-19	3/16/2004	1411	Base	winter	90415	avian	wildlife					
B319	L29825-19	3/16/2004	1411	Base	winter	90416	avian	wildlife					

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Site ID	King County Sample ID	Collect Date	Collect Time	Hydrology	season	Isolate #	Bacteria Source	Bacteria Source Category	E. coli Bacteria (CFU/100 mL)	Data Flags	Fecal Coliform Bacteria (CFU/100 mL)	Data Flags	Flow (cfs)
B319	L29940-32	3/25/2004	1249	Storm	winter	90822	waterfowl	wildlife					
B319	L31629-31	5/26/2004	1115	Storm	winter	93770	rodent/beaver	wildlife	83				
B319	L31629-31	5/26/2004	1115	Storm	winter	93769	waterfowl	wildlife	83				
B319	L31629-31	5/26/2004	1115	Storm	winter	93771	canine	canine/feline	83				
B319	L31629-32	5/26/2004	1117	Storm	winter	93772	avian	wildlife					
B319	L31629-32	5/26/2004	1117	Storm	winter	93773	deer/elk	wildlife					
B319	L31629-32	5/26/2004	1117	Storm	winter	93774	deer/elk	wildlife					
B319	L31629-33	5/26/2004	1119	Storm	winter	93777	rodent/beaver	wildlife					
B319	L31629-33	5/26/2004	1119	Storm	winter	93775	bovine	livestock					
B319	L31629-33	5/26/2004	1119	Storm	winter	93776	unknown	unknown					
B319	L31629-34	5/26/2004	1121	Storm	winter	93778	raccoon	wildlife					
B319	L31629-34	5/26/2004	1121	Storm	winter	93779	raccoon	wildlife					
B319	L31629-34	5/26/2004	1121	Storm	winter	93780	raccoon	wildlife					
B319	L31629-34	5/26/2004	1121	Storm	winter	93781	raccoon	wildlife					
B319	L31629-35	5/26/2004	1123	Storm	winter	93782	deer/elk	wildlife					
B319	L31629-35	5/26/2004	1123	Storm	winter	93783	deer/elk	wildlife					
B319	L31629-35	5/26/2004	1123	Storm	winter	93784	feline	canine/feline					
D319	L26887-41	1/22/2003	1210	Storm	winter	101605	canine	canine/feline					973.1
D319	L26887-41	1/22/2003	1210	Storm	winter	101604	bovine	livestock					973.1
D319	L26887-42	1/22/2003	1213	Storm	winter	101606	avian	wildlife					973.1
D319	L26887-42	1/22/2003	1213	Storm	winter	101607	avian	wildlife					973.1
D319	L26887-43	1/22/2003	1216	Storm	winter	101609	unknown	unknown					973.1
D319	L26887-44	1/22/2003	1219	Storm	winter	101610	human	human					973.1
D319	L27037-41	2/12/2003	1115	Base	winter	104135	rodent/beaver	wildlife	7				1199
D319	L27037-41	2/12/2003	1115	Base	winter	104136	rodent/beaver	wildlife	7				1199
D319	L27361-31	2/25/2003	953	Base	winter	101633	rodent/beaver	wildlife	16				1995
D319	L27361-31	2/25/2003	953	Base	winter	101632	bovine	livestock	16				1995
D319	L27361-32	2/25/2003	956	Base	winter	101667	feline	canine/feline					1995
D319	L27361-32	2/25/2003	956	Base	winter	101675	feline	canine/feline					1995
D319	L27361-33	2/25/2003	959	Base	winter	101668	feline	canine/feline					1995
D319	L27361-33	2/25/2003	959	Base	winter	101676	human	human					1995
D319	L27361-34	2/25/2003	1002	Base	winter	101677	raccoon	wildlife					1995
D319	L27361-34	2/25/2003	1002	Base	winter	101669	feline	canine/feline					1995

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D319	L27033-21	3/9/2003	1116	Storm	winter	102918	avian	wildlife					1227
D319	L27033-22	3/9/2003	1118	Storm	winter	101686	unknown	unknown					1227
D319	L27033-24	3/9/2003	1122	Storm	winter	101688	deer/elk	wildlife					1227
D319	L27033-24	3/9/2003	1122	Storm	winter	101687	canine	canine/feline					1227
D319	L27033-25	3/9/2003	1124	Storm	winter	101689	rodent/beaver	wildlife					1227
D319	L27033-25	3/9/2003	1124	Storm	winter	101690	canine	canine/feline					1227
D319	L27271-21	4/9/2003	855	Storm	winter	102928	avian	wildlife	35				1747
D319	L27271-22	4/9/2003	857	Storm	winter	101717	deer/elk	wildlife					1747
D319	L27271-23	4/9/2003	859	Storm	winter	101813	rodent/beaver	wildlife					1747
D319	L27271-24	4/9/2003	901	Storm	winter	101719	avian	wildlife					1747
D319	L27271-25	4/9/2003	903	Storm	winter	102886	rodent/beaver	wildlife					1747
D319	L27826-32	4/28/2003	1203	Base	winter	101755	bovine	livestock					1535
D319	L27826-33	4/28/2003	1206	Base	winter	101756	rodent/beaver	wildlife					1535
D319	L27826-33	4/28/2003	1206	Base	winter	101757	bovine	livestock					1535
D319	L27826-34	4/28/2003	1209	Base	winter	101766	raccoon	wildlife					1535
D319	L27826-34	4/28/2003	1209	Base	winter	101765	canine	canine/feline					1535
D319	L27826-35	4/28/2003	1212	Base	winter	101758	raccoon	wildlife					1535
D319	L27783-32	6/2/2003	838	Base	summer	101775	rodent/beaver	wildlife					1024
D319	L27783-32	6/2/2003	838	Base	summer	101776	rodent/beaver	wildlife					1024
D319	L27783-34	6/2/2003	842	Base	summer	101777	avian	wildlife					1024
D319	L27783-35	6/2/2003	844	Base	summer	101778	bear	wildlife					1024
D319	L28447-31	6/9/2003	929	Base	summer	101799	avian	wildlife	50				657.8
D319	L28447-32	6/9/2003	931	Base	summer	101800	avian	wildlife					657.8
D319	L28447-32	6/9/2003	931	Base	summer	101801	raccoon	wildlife					657.8
D319	L28447-33	6/9/2003	933	Base	summer	101803	avian	wildlife					657.8
D319	L28447-34	6/9/2003	935	Base	summer	101804	raccoon	wildlife					657.8
D319	L28447-35	6/9/2003	937	Base	summer	101823	rodent/beaver	wildlife					657.8
D319	L29246-31	8/26/2003	1120	Base	summer	82352	avian	wildlife	60				233.8
D319	L29246-31	8/26/2003	1120	Base	summer	82353	rodent/beaver	wildlife	60				233.8
D319	L29246-31	8/26/2003	1120	Base	summer	82351	human	human	60				233.8
D319	L29246-32	8/26/2003	1122	Base	summer	82354	avian	wildlife					233.8
D319	L29246-32	8/26/2003	1122	Base	summer	82355	avian	wildlife					233.8
D319	L29246-32	8/26/2003	1122	Base	summer	82356	avian	wildlife					233.8

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D319	L29246-33	8/26/2003	1124	Base	summer	82357	avian	wildlife					233.8
D319	L29246-33	8/26/2003	1124	Base	summer	82358	avian	wildlife					233.8
D319	L29246-33	8/26/2003	1124	Base	summer	82359	waterfowl	wildlife					233.8
D319	L29246-34	8/26/2003	1126	Base	summer	82360	canine	canine/feline					233.8
D319	L29246-34	8/26/2003	1126	Base	summer	82361	canine	canine/feline					233.8
D319	L29246-34	8/26/2003	1126	Base	summer	82362	bovine	livestock					233.8
D319	L29246-35	8/26/2003	1128	Base	summer	82365	deer/elk	wildlife					233.8
D319	L29246-35	8/26/2003	1128	Base	summer	82363	raccoon	wildlife					233.8
D319	L29246-35	8/26/2003	1128	Base	summer	82364	canine	canine/feline					233.8
D319	L28018-21	10/6/2003	2312	Storm	summer	83463	coyote	wildlife	610				307.4
D319	L28018-21	10/6/2003	2312	Storm	summer	83462	raccoon	wildlife	610				307.4
D319	L28018-21	10/6/2003	2312	Storm	summer	83464	human	human	610				307.4
D319	L28018-22	10/6/2003	2315	Storm	summer	83466	deer/elk	wildlife					307.4
D319	L28018-22	10/6/2003	2315	Storm	summer	83467	deer/elk	wildlife					307.4
D319	L28018-22	10/6/2003	2315	Storm	summer	83465	rodent/beaver	wildlife					307.4
D319	L28018-23	10/6/2003	2318	Storm	summer	83468	avian	wildlife					307.4
D319	L28018-23	10/6/2003	2318	Storm	summer	83470	canine	canine/feline					307.4
D319	L28018-23	10/6/2003	2318	Storm	summer	83469	human	human					307.4
D319	L28018-24	10/6/2003	2322	Storm	summer	83471	avian	wildlife					307.4
D319	L28018-24	10/6/2003	2322	Storm	summer	83472	human	human					307.4
D319	L28018-25	10/6/2003	2325	Storm	summer	83473	canine	canine/feline					307.4
D319	L28018-25	10/6/2003	2325	Storm	summer	83474	bovine	livestock					307.4
D319	L28018-25	10/6/2003	2325	Storm	summer	83475	unknown	unknown					307.4
D319	L27770-21	10/17/2003	817	Storm	summer	85015	avian	wildlife	340				824.3
D319	L27770-21	10/17/2003	817	Storm	summer	85013	bovine	livestock	340				824.3
D319	L27770-21	10/17/2003	817	Storm	summer	85014	horse	livestock	340				824.3
D319	L27770-22	10/17/2003	819	Storm	summer	85018	avian	wildlife					824.3
D319	L27770-22	10/17/2003	819	Storm	summer	85017	canine	canine/feline					824.3
D319	L27770-22	10/17/2003	819	Storm	summer	85016	human	human					824.3
D319	L27770-23	10/17/2003	821	Storm	summer	85021	avian	wildlife					824.3
D319	L27770-23	10/17/2003	821	Storm	summer	85019	deer/elk	wildlife					824.3
D319	L27770-23	10/17/2003	821	Storm	summer	85020	canine	canine/feline					824.3
D319	L27770-24	10/17/2003	823	Storm	summer	85023	deer/elk	wildlife					824.3

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D319	L27770-24	10/17/2003	823	Storm	summer	85024	rodent/beaver	wildlife					824.3
D319	L27770-24	10/17/2003	823	Storm	summer	85022	bovine	livestock					824.3
D319	L27770-25	10/17/2003	825	Storm	summer	85026	deer/elk	wildlife					824.3
D319	L27770-25	10/17/2003	825	Storm	summer	85025	waterfowl	wildlife					824.3
D319	L27770-25	10/17/2003	825	Storm	summer	85027	waterfowl	wildlife					824.3
D319	L30144-21	11/18/2003	1257	Storm	winter	86031	avian	wildlife	90				3211
D319	L30144-21	11/18/2003	1257	Storm	winter	86029	waterfowl	wildlife	90				3211
D319	L30144-21	11/18/2003	1257	Storm	winter	86030	feline	canine/feline	90				3211
D319	L30144-22	11/18/2003	1259	Storm	winter	86033	avian	wildlife					3211
D319	L30144-22	11/18/2003	1259	Storm	winter	86032	canine	canine/feline					3211
D319	L30144-23	11/18/2003	1301	Storm	winter	86035	deer/elk	wildlife					3211
D319	L30144-23	11/18/2003	1301	Storm	winter	86034	rodent/beaver	wildlife					3211
D319	L30144-23	11/18/2003	1301	Storm	winter	86036	horse	livestock					3211
D319	L30144-24	11/18/2003	1303	Storm	winter	86039	avian	wildlife					3211
D319	L30144-24	11/18/2003	1303	Storm	winter	86037	human	human					3211
D319	L30144-24	11/18/2003	1303	Storm	winter	86038	human	human					3211
D319	L30144-25	11/18/2003	1305	Storm	winter	86040	avian	wildlife					3211
D319	L30144-25	11/18/2003	1305	Storm	winter	86041	horse	livestock					3211
D319	L30144-25	11/18/2003	1305	Storm	winter	86042	unknown	unknown					3211
D319	L30144-25	11/18/2003	1305	Storm	winter	86043	unknown	unknown					3211
D319	L29825-31	3/16/2004	1157	Base	winter	90450	avian	wildlife	1				1298
D319	L29825-31	3/16/2004	1157	Base	winter	90448	deer/elk	wildlife	1				1298
D319	L29825-31	3/16/2004	1157	Base	winter	90449	deer/elk	wildlife	1				1298
D319	L29825-32	3/16/2004	1200	Base	winter	90452	deer/elk	wildlife					1298
D319	L29825-32	3/16/2004	1200	Base	winter	90451	rodent/beaver	wildlife					1298
D319	L29825-32	3/16/2004	1200	Base	winter	90453	unknown	unknown					1298
D319	L29825-33	3/16/2004	1203	Base	winter	90455	deer/elk	wildlife					1298
D319	L29825-33	3/16/2004	1203	Base	winter	90454	rodent/beaver	wildlife					1298
D319	L29825-33	3/16/2004	1203	Base	winter	90456	rodent/beaver	wildlife					1298
D319	L29825-34	3/16/2004	1206	Base	winter	90459	avian	wildlife					1298
D319	L29825-34	3/16/2004	1206	Base	winter	90457	raccoon	wildlife					1298
D319	L29825-34	3/16/2004	1206	Base	winter	90458	rodent/beaver	wildlife					1298
D319	L29825-35	3/16/2004	1209	Base	winter	90460	avian	wildlife					1298

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D319	L29825-35	3/16/2004	1209	Base	winter	90462	avian	wildlife					1298
D319	L29825-35	3/16/2004	1209	Base	winter	90463	deer/elk	wildlife					1298
D319	L29825-35	3/16/2004	1209	Base	winter	90461	bovine	livestock					1298
D319	L29940-21	3/25/2004	1328	Storm	winter	90790	deer/elk	wildlife	34				1581
D319	L29940-21	3/25/2004	1328	Storm	winter	90791	rodent/beaver	wildlife	34				1581
D319	L29940-21	3/25/2004	1328	Storm	winter	90792	bovine	livestock	34				1581
D319	L29940-22	3/25/2004	1330	Storm	winter	90795	bear	wildlife					1589
D319	L29940-22	3/25/2004	1330	Storm	winter	90793	coyote	wildlife					1589
D319	L29940-22	3/25/2004	1330	Storm	winter	90794	horse	livestock					1589
D319	L29940-23	3/25/2004	1332	Storm	winter	90797	avian	wildlife					1589
D319	L29940-23	3/25/2004	1332	Storm	winter	90798	rodent/beaver	wildlife					1589
D319	L29940-23	3/25/2004	1332	Storm	winter	90796	waterfowl	wildlife					1589
D319	L29940-24	3/25/2004	1334	Storm	winter	90801	avian	wildlife					1589
D319	L29940-24	3/25/2004	1334	Storm	winter	90802	avian	wildlife					1589
D319	L29940-24	3/25/2004	1334	Storm	winter	90799	bovine	livestock					1589
D319	L29940-24	3/25/2004	1334	Storm	winter	90800	bovine	livestock					1589
D319	L29940-25	3/25/2004	1336	Storm	winter	90803	avian	wildlife					1589
D319	L29940-25	3/25/2004	1336	Storm	winter	90804	avian	wildlife					1589
D319	L31629-21	5/26/2004	1002	Storm	winter	93737	deer/elk	wildlife	600				885.1
D319	L31629-21	5/26/2004	1002	Storm	winter	93738	deer/elk	wildlife	600				885.1
D319	L31629-21	5/26/2004	1002	Storm	winter	93739	rodent/beaver	wildlife	600				885.1
D319	L31629-22	5/26/2004	1004	Storm	winter	93740	waterfowl	wildlife					885.1
D319	L31629-22	5/26/2004	1004	Storm	winter	93741	waterfowl	wildlife					885.1
D319	L31629-22	5/26/2004	1004	Storm	winter	93742	waterfowl	wildlife					885.1
D319	L31629-22	5/26/2004	1004	Storm	winter	93743	waterfowl	wildlife					885.1
D319	L31629-23	5/26/2004	1006	Storm	winter	93744	bear	wildlife					885.1
D319	L31629-23	5/26/2004	1006	Storm	winter	93745	rodent/beaver	wildlife					885.1
D319	L31629-23	5/26/2004	1006	Storm	winter	93746	rodent/beaver	wildlife					885.1
D319	L31629-24	5/26/2004	1008	Storm	winter	93747	avian	wildlife					885.1
D319	L31629-24	5/26/2004	1008	Storm	winter	93748	rodent/beaver	wildlife					885.1
D319	L31629-24	5/26/2004	1008	Storm	winter	93749	rodent/beaver	wildlife					885.1
D319	L31629-25	5/26/2004	1010	Storm	winter	93750	raccoon	wildlife					885.1
D319	L31629-25	5/26/2004	1010	Storm	winter	93751	canine	canine/feline					885.1

Table A-1. Project database for the Green-Duwamish watershed Microbial Source Tracking Study

Site ID	King County Sample ID	Collect Date	Collect Time	Hydrology	season	Isolate #	Bacteria Source	Bacteria Source Category	E. coli Bacteria (CFU/100 mL)	Data Flags	Fecal Coliform Bacteria (CFU/100 mL)	Data Flags	Flow (cfs)
D319	L31629-25	5/26/2004	1010	Storm	winter	93752	human	human					885.1
A310	L23007-7	2/13/2002	1503	Base	winter	103509	deer/elk	wildlife	5		26		
A310	L23007-7	2/13/2002	1503	Base	winter	103510	opossum	wildlife	5		26		
A310	L23007-7	2/13/2002	1503	Base	winter	103508	raccoon	wildlife	5		26		
A310	L23007-7	2/13/2002	1503	Base	winter	103507	rodent/beaver	wildlife	5		26		
A310	L23007-8	2/13/2002	2303	Base	winter	103512	raccoon	wildlife	7		7		
A310	L23007-8	2/13/2002	2303	Base	winter	103511	rodent/beaver	wildlife	7		7		
A310	L23007-8	2/13/2002	2303	Base	winter	103514	rodent/beaver	wildlife	7		7		
A310	L23007-8	2/13/2002	2303	Base	winter	103513	human	human	7		7		
A310	L23007-9	2/13/2002	703	Base	winter	103515	avian	wildlife	5		1		
A310	L23007-9	2/13/2002	703	Base	winter	103516	avian	wildlife	5		1		
A310	L23007-9	2/13/2002	703	Base	winter	103517	avian	wildlife	5		1		
A310	L23007-9	2/13/2002	703	Base	winter	103518	canine	canine/feline	5		1		
A310	L23473-10,11,12	3/25/2002		Base	winter	103546	avian	wildlife					
A310	L23473-10,11,12	3/25/2002		Base	winter	103548	avian	wildlife					
A310	L23473-10,11,12	3/25/2002		Base	winter	103544	bear	wildlife					
A310	L23473-10,11,12	3/25/2002		Base	winter	103540	waterfowl	wildlife					
A310	L23473-10,11,12	3/25/2002		Base	winter	103547	waterfowl	wildlife					
A310	L23473-10,11,12	3/25/2002		Base	winter	103545	horse	livestock					
A310	L23473-10,11,12	3/25/2002		Base	winter	103543	human	human					
A310	L23473-10,11,12	3/25/2002		Base	winter	103542	human	human					
A310	L23945-10	4/24/2002	1056	Base	winter	103572	avian	wildlife	3		4		
A310	L23945-10	4/24/2002	1056	Base	winter	103573	canine	canine/feline	3		4		
A310	L23945-11	4/24/2002	1856	Base	winter	103574	deer/elk	wildlife	9	H	17	H	
A310	L23945-12	4/25/2002	256	Base	winter	103575	deer/elk	wildlife	14		18		
A310	L23945-12	4/25/2002	256	Base	winter	103576	rodent/beaver	wildlife	14		18		
A310	L24476-10	6/12/2002	1500	Base	summer	103598	avian	wildlife	21		18		
A310	L24476-10	6/12/2002	1500	Base	summer	103599	avian	wildlife	21		18		
A310	L24476-11	6/12/2002	2300	Base	summer	103604	avian	wildlife	41		43		
A310	L24476-11	6/12/2002	2300	Base	summer	103603	deer/elk	wildlife	41		43		
A310	L24476-11	6/12/2002	2300	Base	summer	103600	waterfowl	wildlife	41		43		
A310	L24476-11	6/12/2002	2300	Base	summer	103602	waterfowl	wildlife	41		43		
A310	L24476-12	6/13/2002	700	Base	summer	103605	avian	wildlife	58		68		

Table A-1. Project database for the Green-Duwamish watershed Microbial Source Tracking Study

Site ID	King County Sample ID	Collect Date	Collect Time	Hydrology	season	Isolate #	Bacteria Source	Bacteria Source Category	E. coli Bacteria (CFU/100 mL)	Data Flags	Fecal Coliform Bacteria (CFU/100 mL)	Data Flags	Flow (cfs)
A310	L24476-12	6/13/2002	700	Base	summer	103606	avian	wildlife	58		68		
A310	L24476-12	6/13/2002	700	Base	summer	103607	canine	canine/feline	58		68		
A310	L25054-3	8/6/2002	1155	Base	summer	103617	raccoon	wildlife	69		53		
A310	L25054-3	8/6/2002	1155	Base	summer	103616	rodent/beaver	wildlife	69		53		
A310	L25054-3	8/6/2002	1155	Base	summer	103620	rodent/beaver	wildlife	69		53		
A310	L25054-3	8/6/2002	1155	Base	summer	103615	bovine	livestock	69		53		
A310	L25934-10	10/23/2002	1115	Base	summer	103677	deer/elk	wildlife	42		68		
A310	L25934-10	10/23/2002	1115	Base	summer	103678	raccoon	wildlife	42		68		
A310	L25934-10	10/23/2002	1115	Base	summer	103679	raccoon	wildlife	42		68		
A310	L26567-10	12/3/2002	1500	Base	winter	103703	rodent/beaver	wildlife	27		32		
A310	L26567-10	12/3/2002	1500	Base	winter	103704	unknown	unknown	27		32		
A310	L26567-10	12/3/2002	1500	Base	winter	103705	unknown	unknown	27		32		
A310	L26567-11	12/4/2002	700	Base	winter	103706	unknown	unknown	47		43		
A310	L26567-11	12/4/2002	700	Base	winter	103707	canine	canine/feline	47		43		
A310	L26567-11	12/4/2002	700	Base	winter	103708	bovine	livestock	47		43		
A310	L27035-10	2/12/2003	1500	Base	winter	101616	avian	wildlife	5		8		
A310	L27035-11	2/12/2003	2300	Base	winter	102902	avian	wildlife	6		7		
A310	L27037-6	2/13/2003	1105	Base	winter	104073	avian	wildlife	12				
A310	L27037-6	2/13/2003	1105	Base	winter	104079	avian	wildlife	12				
A310	L27037-6	2/13/2003	1105	Base	winter	104080	avian	wildlife	12				
A310	L27037-6	2/13/2003	1105	Base	winter	104074	rodent/beaver	wildlife	12				
A310	L27037-6	2/13/2003	1105	Base	winter	104075	rodent/beaver	wildlife	12				
A310	L27037-6	2/13/2003	1105	Base	winter	104077	rodent/beaver	wildlife	12				
A310	L27037-6	2/13/2003	1105	Base	winter	104081	rodent/beaver	wildlife	12				
A310	L27037-6	2/13/2003	1105	Base	winter	104076	unknown	unknown	12				
A310	L27037-6	2/13/2003	1105	Base	winter	104078	horse	livestock	12				
A310	L27037-8	2/13/2003	1111	Base	winter	101615	avian	wildlife					
A310	L27361-10	2/25/2003	1200	Base	winter	104164	avian	wildlife					
A310	L27361-10	2/25/2003	1200	Base	winter	104165	avian	wildlife					
A310	L27361-10	2/25/2003	1200	Base	winter	101646	waterfowl	wildlife					
A310	L27361-10	2/25/2003	1200	Base	winter	101653	waterfowl	wildlife					
A310	L27361-10	2/25/2003	1200	Base	winter	104166	waterfowl	wildlife					
A310	L27361-6	2/25/2003	1148	Base	winter	104144	avian	wildlife	12				

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A310	L27361-6	2/25/2003	1148	Base	winter	104145	avian	wildlife	12				
A310	L27361-6	2/25/2003	1148	Base	winter	104143	rodent/beaver	wildlife	12				
A310	L27361-6	2/25/2003	1148	Base	winter	102910	unknown	unknown	12				
A310	L27361-6	2/25/2003	1148	Base	winter	104147	canine	canine/feline	12				
A310	L27361-6	2/25/2003	1148	Base	winter	104146	human	human	12				
A310	L27361-7	2/25/2003	1151	Base	winter	102915	avian	wildlife					
A310	L27361-7	2/25/2003	1151	Base	winter	104148	raccoon	wildlife					
A310	L27361-7	2/25/2003	1151	Base	winter	104149	raccoon	wildlife					
A310	L27361-7	2/25/2003	1151	Base	winter	101652	waterfowl	wildlife					
A310	L27361-7	2/25/2003	1151	Base	winter	104150	waterfowl	wildlife					
A310	L27361-8	2/25/2003	1154	Base	winter	104151	deer/elk	wildlife					
A310	L27361-8	2/25/2003	1154	Base	winter	104152	deer/elk	wildlife					
A310	L27361-8	2/25/2003	1154	Base	winter	104154	deer/elk	wildlife					
A310	L27361-8	2/25/2003	1154	Base	winter	104153	rodent/beaver	wildlife					
A310	L27361-8	2/25/2003	1154	Base	winter	101643	waterfowl	wildlife					
A310	L27361-8	2/25/2003	1154	Base	winter	104155	unknown	unknown					
A310	L27361-9	2/25/2003	1157	Base	winter	104140	avian	wildlife					
A310	L27361-9	2/25/2003	1157	Base	winter	104161	avian	wildlife					
A310	L27361-9	2/25/2003	1157	Base	winter	104162	deer/elk	wildlife					
A310	L27361-9	2/25/2003	1157	Base	winter	104157	raccoon	wildlife					
A310	L27361-9	2/25/2003	1157	Base	winter	104158	raccoon	wildlife					
A310	L27361-9	2/25/2003	1157	Base	winter	101644	waterfowl	wildlife					
A310	L27361-9	2/25/2003	1157	Base	winter	101645	waterfowl	wildlife					
A310	L27361-9	2/25/2003	1157	Base	winter	104141	waterfowl	wildlife					
A310	L27361-9	2/25/2003	1157	Base	winter	104156	waterfowl	wildlife					
A310	L27361-9	2/25/2003	1157	Base	winter	104159	canine	canine/feline					
A310	L27361-9	2/25/2003	1157	Base	winter	104160	bovine	livestock					
A310	L27361-9	2/25/2003	1157	Base	winter	104163	unknown	unknown					
A310	L27271-10	4/9/2003	1002	Storm	winter	102883	feline	canine/feline					
A310	L27271-8	4/9/2003	956	Storm	winter	101709	unknown	unknown					
A310	L27826-7	4/29/2003	1056	Base	winter	101736	unknown	unknown					
A310	L27826-8	4/29/2003	1059	Base	winter	101737	rodent/beaver	wildlife					
A310	L27826-9	4/29/2003	1102	Base	winter	101738	human	human					

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A310	L27783-8	6/2/2003	1054	Base	summer	101768	deer/elk	wildlife					
A310	L28447-7	6/9/2003	1136	Base	summer	102937	avian	wildlife					
A310	L28447-8	6/9/2003	1138	Base	summer	101787	human	human					
A310	L28447-8	6/9/2003	1138	Base	summer	101786	unknown	unknown					
A310	L28447-9	6/9/2003	1140	Base	summer	101788	deer/elk	wildlife					
A310	L28447-9	6/9/2003	1140	Base	summer	102938	waterfowl	wildlife					
A310	L29246-10	8/27/2003	1133	Base	summer	82300	avian	wildlife					
A310	L29246-10	8/27/2003	1133	Base	summer	82301	avian	wildlife					
A310	L29246-10	8/27/2003	1133	Base	summer	82303	feline	canine/feline					
A310	L29246-10	8/27/2003	1133	Base	summer	82302	bovine	livestock					
A310	L29246-6	8/27/2003	1121	Base	summer	82289	avian	wildlife	180				
A310	L29246-6	8/27/2003	1121	Base	summer	82288	deer/elk	wildlife	180				
A310	L29246-6	8/27/2003	1121	Base	summer	82290	raccoon	wildlife	180				
A310	L29246-7	8/27/2003	1124	Base	summer	82293	avian	wildlife					
A310	L29246-7	8/27/2003	1124	Base	summer	82291	rodent/beaver	wildlife					
A310	L29246-7	8/27/2003	1124	Base	summer	82292	human	human					
A310	L29246-8	8/27/2003	1127	Base	summer	82294	avian	wildlife					
A310	L29246-8	8/27/2003	1127	Base	summer	82295	waterfowl	wildlife					
A310	L29246-8	8/27/2003	1127	Base	summer	82296	human	human					
A310	L29246-9	8/27/2003	1130	Base	summer	82299	avian	wildlife					
A310	L29246-9	8/27/2003	1130	Base	summer	82297	rodent/beaver	wildlife					
A310	L29246-9	8/27/2003	1130	Base	summer	82298	bovine	livestock					
A310	L28018-10	10/7/2003	119	Storm	summer	83428	avian	wildlife					
A310	L28018-10	10/7/2003	119	Storm	summer	83429	bovine	livestock					
A310	L28018-10	10/7/2003	119	Storm	summer	83430	human	human					
A310	L28018-6	10/7/2003	107	Storm	summer	83418	avian	wildlife	380				
A310	L28018-6	10/7/2003	107	Storm	summer	83417	coyote	wildlife	380				
A310	L28018-6	10/7/2003	107	Storm	summer	83416	rodent/beaver	wildlife	380				
A310	L28018-7	10/7/2003	110	Storm	summer	83420	avian	wildlife					
A310	L28018-7	10/7/2003	110	Storm	summer	83421	avian	wildlife					
A310	L28018-7	10/7/2003	110	Storm	summer	83419	horse	livestock					
A310	L28018-8	10/7/2003	113	Storm	summer	83422	avian	wildlife					
A310	L28018-8	10/7/2003	113	Storm	summer	83424	avian	wildlife					

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A310	L28018-8	10/7/2003	113	Storm	summer	83423	canine	canine/feline					
A310	L28018-9	10/7/2003	116	Storm	summer	83427	deer/elk	wildlife					
A310	L28018-9	10/7/2003	116	Storm	summer	83425	human	human					
A310	L28018-9	10/7/2003	116	Storm	summer	83426	human	human					
A310	L27770-10	10/18/2003	1056	Storm	summer	84927	deer/elk	wildlife					
A310	L27770-10	10/18/2003	1056	Storm	summer	84928	deer/elk	wildlife					
A310	L27770-10	10/18/2003	1056	Storm	summer	84929	bovine	livestock					
A310	L27770-6	10/18/2003	1048	Storm	summer	84917	deer/elk	wildlife	180				
A310	L27770-6	10/18/2003	1048	Storm	summer	84915	canine	canine/feline	180				
A310	L27770-6	10/18/2003	1048	Storm	summer	84916	feline	canine/feline	180				
A310	L27770-7	10/18/2003	1050	Storm	summer	84920	avian	wildlife					
A310	L27770-7	10/18/2003	1050	Storm	summer	84918	deer/elk	wildlife					
A310	L27770-7	10/18/2003	1050	Storm	summer	84919	waterfowl	wildlife					
A310	L27770-8	10/18/2003	1052	Storm	summer	84921	deer/elk	wildlife					
A310	L27770-8	10/18/2003	1052	Storm	summer	84922	deer/elk	wildlife					
A310	L27770-8	10/18/2003	1052	Storm	summer	84923	rodent/beaver	wildlife					
A310	L27770-9	10/18/2003	1054	Storm	summer	84926	avian	wildlife					
A310	L27770-9	10/18/2003	1054	Storm	summer	84924	canine	canine/feline					
A310	L27770-9	10/18/2003	1054	Storm	summer	84925	unknown	unknown					
A310	L30144-10	11/19/2003	1116	Storm	winter	85999	deer/elk	wildlife					
A310	L30144-10	11/19/2003	1116	Storm	winter	85998	canine	canine/feline					
A310	L30144-6	11/19/2003	1104	Storm	winter	85988	avian	wildlife	190				
A310	L30144-6	11/19/2003	1104	Storm	winter	85987	deer/elk	wildlife	190				
A310	L30144-6	11/19/2003	1104	Storm	winter	85989	rodent/beaver	wildlife	190				
A310	L30144-7	11/19/2003	1107	Storm	winter	85992	raccoon	wildlife					
A310	L30144-7	11/19/2003	1107	Storm	winter	85990	waterfowl	wildlife					
A310	L30144-7	11/19/2003	1107	Storm	winter	85991	waterfowl	wildlife					
A310	L30144-8	11/19/2003	1110	Storm	winter	85994	avian	wildlife					
A310	L30144-8	11/19/2003	1110	Storm	winter	85995	avian	wildlife					
A310	L30144-8	11/19/2003	1110	Storm	winter	85993	rodent/beaver	wildlife					
A310	L30144-9	11/19/2003	1113	Storm	winter	85996	feline	canine/feline					
A310	L30144-9	11/19/2003	1113	Storm	winter	85997	feline	canine/feline					
A310	L29825-10	3/16/2004	1405	Base	winter	90406	avian	wildlife					

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A310	L29825-10	3/16/2004	1405	Base	winter	90405	deer/elk	wildlife					
A310	L29825-10	3/16/2004	1405	Base	winter	90407	raccoon	wildlife					
A310	L29825-6	3/16/2004	1352	Base	winter	90394	avian	wildlife	5				
A310	L29825-6	3/16/2004	1352	Base	winter	90393	coyote	wildlife	5				
A310	L29825-6	3/16/2004	1352	Base	winter	90392	squirrel	wildlife	5				
A310	L29825-7	3/16/2004	1355	Base	winter	90397	deer/elk	wildlife					
A310	L29825-7	3/16/2004	1355	Base	winter	90395	raccoon	wildlife					
A310	L29825-7	3/16/2004	1355	Base	winter	90396	raccoon	wildlife					
A310	L29825-8	3/16/2004	1358	Base	winter	90398	avian	wildlife					
A310	L29825-8	3/16/2004	1358	Base	winter	90399	rodent/beaver	wildlife					
A310	L29825-8	3/16/2004	1358	Base	winter	90400	rodent/beaver	wildlife					
A310	L29825-8	3/16/2004	1358	Base	winter	90401	rodent/beaver	wildlife					
A310	L29825-9	3/16/2004	1402	Base	winter	90402	avian	wildlife					
A310	L29825-9	3/16/2004	1402	Base	winter	90403	avian	wildlife					
A310	L29825-9	3/16/2004	1402	Base	winter	90404	rodent/beaver	wildlife					
A310	L29940-10	3/25/2004	1155	Storm	winter	90755	waterfowl	wildlife					
A310	L29940-10	3/25/2004	1155	Storm	winter	90756	waterfowl	wildlife					
A310	L29940-10	3/25/2004	1155	Storm	winter	90757	waterfowl	wildlife					
A310	L29940-6	3/25/2004	1147	Storm	winter	90743	deer/elk	wildlife	62				
A310	L29940-6	3/25/2004	1147	Storm	winter	90744	raccoon	wildlife	62				
A310	L29940-6	3/25/2004	1147	Storm	winter	90745	raccoon	wildlife	62				
A310	L29940-7	3/25/2004	1149	Storm	winter	90746	raccoon	wildlife					
A310	L29940-7	3/25/2004	1149	Storm	winter	90748	canine	canine/feline					
A310	L29940-7	3/25/2004	1149	Storm	winter	90747	human	human					
A310	L29940-8	3/25/2004	1151	Storm	winter	90750	avian	wildlife					
A310	L29940-8	3/25/2004	1151	Storm	winter	90749	waterfowl	wildlife					
A310	L29940-8	3/25/2004	1151	Storm	winter	90751	canine	canine/feline					
A310	L29940-9	3/25/2004	1153	Storm	winter	90754	avian	wildlife					
A310	L29940-9	3/25/2004	1153	Storm	winter	90753	canine	canine/feline					
A310	L29940-9	3/25/2004	1153	Storm	winter	90752	bovine	livestock					
A310	L31629-10	5/26/2004	838	Storm	winter	93711	deer/elk	wildlife					
A310	L31629-10	5/26/2004	838	Storm	winter	93712	canine	canine/feline					
A310	L31629-10	5/26/2004	838	Storm	winter	93710	human	human					

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A310	L31629-6	5/26/2004	830	Storm	winter	93698	avian	wildlife	150				
A310	L31629-6	5/26/2004	830	Storm	winter	93699	canine	canine/feline	150				
A310	L31629-6	5/26/2004	830	Storm	winter	93700	canine	canine/feline	150				
A310	L31629-6	5/26/2004	830	Storm	winter	93701	canine	canine/feline	150				
A310	L31629-7	5/26/2004	832	Storm	winter	93704	rodent/beaver	wildlife					
A310	L31629-7	5/26/2004	832	Storm	winter	93702	waterfowl	wildlife					
A310	L31629-7	5/26/2004	832	Storm	winter	93703	waterfowl	wildlife					
A310	L31629-8	5/26/2004	834	Storm	winter	93705	avian	wildlife					
A310	L31629-8	5/26/2004	834	Storm	winter	93706	coyote	wildlife					
A310	L31629-8	5/26/2004	834	Storm	winter	93707	human	human					
A310	L31629-9	5/26/2004	836	Storm	winter	93709	deer/elk	wildlife					
A310	L31629-9	5/26/2004	836	Storm	winter	93708	skunk	wildlife					
0322	L23007-13	2/13/2002	1027	Base	winter	103519	avian	wildlife	27		23		69.91
0322	L23007-13	2/13/2002	1027	Base	winter	103522	avian	wildlife	27		23		69.91
0322	L23007-13	2/13/2002	1027	Base	winter	103521	rodent/beaver	wildlife	27		23		69.91
0322	L23007-13	2/13/2002	1027	Base	winter	103520	bovine	livestock	27		23		69.91
0322	L23007-13	2/13/2002	1027	Base	winter	103523	bovine	livestock	27		23		69.91
0322	L23474-4	3/25/2002	1306	Base	winter	103550	avian	wildlife	57		61		85.78
0322	L23474-4	3/25/2002	1306	Base	winter	103551	avian	wildlife	57		61		85.78
0322	L23474-4	3/25/2002	1306	Base	winter	103549	bovine	livestock	58		61		85.78
0322	L23474-4	3/25/2002	1306	Base	winter	103552	horse	livestock	58		61		85.78
0322	L23947-4	4/24/2002	1245	Base	winter	103578	waterfowl	wildlife	80		88		57.62
0322	L23947-4	4/24/2002	1245	Base	winter	103579	waterfowl	wildlife	80		88		57.62
0322	L23947-4	4/24/2002	1245	Base	winter	103582	waterfowl	wildlife	80		88		57.62
0322	L23947-4	4/24/2002	1245	Base	winter	103580	horse	livestock	80		88		57.62
0322	L23947-4	4/24/2002	1245	Base	winter	103581	human	human	80		88		57.62
0322	L24477-4	6/12/2002	1501	Base	summer	103609	avian	wildlife	110		160		25.3
0322	L24477-4	6/12/2002	1501	Base	summer	103610	raccoon	wildlife	110		160		25.3
0322	L24477-4	6/12/2002	1501	Base	summer	103608	canine	canine/feline	110		160		25.3
0322	L25056-4	8/6/2002	1330	Storm	summer	103639	avian	wildlife	97		200		27.94
0322	L25056-4	8/6/2002	1330	Storm	summer	103638	deer/elk	wildlife	97		200		27.94
0322	L25056-4	8/6/2002	1330	Storm	summer	103637	bovine	livestock	97		200		27.94
0322	L25935-5	10/22/2002	1335	Base	summer	103661	avian	wildlife	27		39		14.11

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0322	L25935-5	10/22/2002	1335	Base	summer	103662	canine	canine/feline	27		39		14.11
0322	L25935-5	10/22/2002	1335	Base	summer	103663	bovine	livestock	27		39		14.11
0322	L26568-5	12/3/2002	1221	Base	winter	103711	avian	wildlife	25		25		13.17
0322	L26568-5	12/3/2002	1221	Base	winter	103712	canine	canine/feline	25		25		13.17
0322	L26568-5	12/3/2002	1221	Base	winter	103709	bovine	livestock	25		25		13.17
0322	L26568-5	12/3/2002	1221	Base	winter	103710	bovine	livestock			25		13.17
0322	L26887-17	1/23/2003	1338	Storm	winter	101591	bovine	livestock					90.61
0322	L26887-18	1/23/2003	1341	Storm	winter	101592	raccoon	wildlife					90.61
0322	L27037-16	2/13/2003	1117	Base	winter	101617	avian	wildlife	23				38.2
0322	L27037-16	2/13/2003	1117	Base	winter	104089	avian	wildlife	23				38.2
0322	L27037-16	2/13/2003	1117	Base	winter	104090	avian	wildlife	23				38.2
0322	L27037-16	2/13/2003	1117	Base	winter	104091	rodent/beaver	wildlife	23				38.2
0322	L27361-21	2/25/2003	1116	Base	winter	102911	avian	wildlife	49				55.68
0322	L27361-21	2/25/2003	1116	Base	winter	101629	human	human	49				55.68
0322	L27361-22	2/25/2003	1118	Base	winter	101811	avian	wildlife					55.68
0322	L27361-22	2/25/2003	1118	Base	winter	102877	canine	canine/feline					55.68
0322	L27361-23	2/25/2003	1120	Base	winter	101662	deer/elk	wildlife					55.68
0322	L27361-23	2/25/2003	1120	Base	winter	101658	unknown	unknown					55.68
0322	L27361-24	2/25/2003	1122	Base	winter	101663	muskrat	wildlife					55.68
0322	L27361-24	2/25/2003	1122	Base	winter	101659	canine	canine/feline					55.68
0322	L27361-25	2/25/2003	1124	Base	winter	101664	rodent/beaver	wildlife					55.68
0322	L27361-25	2/25/2003	1124	Base	winter	101660	unknown	unknown					55.68
0322	L27033-36	3/10/2003	1115	Storm	winter	102919	deer/elk	wildlife					215.7
0322	L27033-36	3/10/2003	1115	Storm	winter	101699	raccoon	wildlife					215.7
0322	L27033-37	3/10/2003	1116	Storm	winter	101700	unknown	unknown					215.7
0322	L27033-37	3/10/2003	1116	Storm	winter	102921	feline	canine/feline					215.7
0322	L27033-37	3/10/2003	1116	Storm	winter	102920	bovine	livestock					215.7
0322	L27033-38	3/10/2003	1117	Storm	winter	101703	waterfowl	wildlife					215.7
0322	L27033-38	3/10/2003	1117	Storm	winter	101702	canine	canine/feline					215.7
0322	L27033-39	3/10/2003	1118	Storm	winter	102922	skunk	wildlife					215.7
0322	L27033-39	3/10/2003	1118	Storm	winter	101704	human	human					215.7
0322	L27271-37	4/9/2003	854	Storm	winter	101729	avian	wildlife					93.08
0322	L27271-37	4/9/2003	854	Storm	winter	101730	bear	wildlife					93.08

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0322	L27271-38	4/9/2003	855	Storm	winter	102887	coyote	wildlife					93.08
0322	L27271-38	4/9/2003	855	Storm	winter	101732	squirrel	wildlife					93.08
0322	L27271-39	4/9/2003	856	Storm	winter	102923	rodent/beaver	wildlife					93.08
0322	L27826-21	4/29/2003	1125	Base	winter	102931	avian	wildlife	31				59.58
0322	L27826-22	4/29/2003	1126	Base	winter	101739	rodent/beaver	wildlife					59.58
0322	L27826-24	4/29/2003	1128	Base	winter	101818	bovine	livestock					59.58
0322	L27826-24	4/29/2003	1128	Base	winter	102929	horse	livestock					59.58
0322	L27826-25	4/29/2003	1129	Base	winter	101741	avian	wildlife					59.58
0322	L27826-25	4/29/2003	1129	Base	winter	101740	deer/elk	wildlife					59.58
0322	L27783-22	6/2/2003	1056	Base	summer	101772	waterfowl	wildlife					26.6
0322	L27783-23	6/2/2003	1057	Base	summer	101773	avian	wildlife					26.6
0322	L27783-25	6/2/2003	1059	Base	summer	101774	waterfowl	wildlife					26.6
0322	L29246-21	8/27/2003	1244	Base	summer	82322	deer/elk	wildlife	55				10.55
0322	L29246-21	8/27/2003	1244	Base	summer	82324	deer/elk	wildlife	55				10.55
0322	L29246-21	8/27/2003	1244	Base	summer	82323	bovine	livestock	55				10.55
0322	L29246-22	8/27/2003	1246	Base	summer	82325	deer/elk	wildlife					10.55
0322	L29246-22	8/27/2003	1246	Base	summer	82326	canine	canine/feline					10.55
0322	L29246-22	8/27/2003	1246	Base	summer	82327	feline	canine/feline					10.55
0322	L29246-23	8/27/2003	1248	Base	summer	82330	avian	wildlife					10.55
0322	L29246-23	8/27/2003	1248	Base	summer	82328	rodent/beaver	wildlife					10.55
0322	L29246-23	8/27/2003	1248	Base	summer	82329	feline	canine/feline					10.55
0322	L29246-24	8/27/2003	1250	Base	summer	82333	raccoon	wildlife					10.55
0322	L29246-24	8/27/2003	1250	Base	summer	82331	rodent/beaver	wildlife					10.55
0322	L29246-24	8/27/2003	1250	Base	summer	82332	rodent/beaver	wildlife					10.55
0322	L29246-25	8/27/2003	1252	Base	summer	82335	avian	wildlife					10.55
0322	L29246-25	8/27/2003	1252	Base	summer	82334	deer/elk	wildlife					10.55
0322	L29246-25	8/27/2003	1252	Base	summer	82336	rodent/beaver	wildlife					10.55
0322	L28018-36	10/7/2003	8	Storm	summer	83509	coyote	wildlife	250				12.27
0322	L28018-36	10/7/2003	8	Storm	summer	83508	bovine	livestock	250				12.27
0322	L28018-36	10/7/2003	8	Storm	summer	83510	bovine	livestock	250				12.27
0322	L28018-37	10/7/2003	9	Storm	summer	83512	rodent/beaver	wildlife					12.27
0322	L28018-37	10/7/2003	9	Storm	summer	83513	rodent/beaver	wildlife					12.27
0322	L28018-37	10/7/2003	9	Storm	summer	83511	bovine	livestock					12.27

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0322	L28018-38	10/7/2003	10	Storm	summer	83516	avian	wildlife					12.27
0322	L28018-38	10/7/2003	10	Storm	summer	83514	horse	livestock					12.27
0322	L28018-38	10/7/2003	10	Storm	summer	83515	horse	livestock					12.27
0322	L28018-39	10/7/2003	11	Storm	summer	83519	avian	wildlife					12.27
0322	L28018-39	10/7/2003	11	Storm	summer	83518	deer/elk	wildlife					12.27
0322	L28018-39	10/7/2003	11	Storm	summer	83517	rodent/beaver	wildlife					12.27
0322	L28018-40	10/7/2003	12	Storm	summer	83522	waterfowl	wildlife					12.27
0322	L28018-40	10/7/2003	12	Storm	summer	83520	bovine	livestock					12.27
0322	L28018-40	10/7/2003	12	Storm	summer	83521	bovine	livestock					12.27
0322	L27770-36	10/18/2003	1039	Storm	summer	85059	avian	wildlife	69				13.17
0322	L27770-36	10/18/2003	1039	Storm	summer	85060	human	human	69				13.17
0322	L27770-36	10/18/2003	1039	Storm	summer	85061	human	human	69				13.17
0322	L27770-37	10/18/2003	1040	Storm	summer	85063	canine	canine/feline					13.17
0322	L27770-37	10/18/2003	1040	Storm	summer	85062	bovine	livestock					13.17
0322	L27770-37	10/18/2003	1040	Storm	summer	85064	bovine	livestock					13.17
0322	L27770-38	10/18/2003	1041	Storm	summer	85066	deer/elk	wildlife					13.17
0322	L27770-38	10/18/2003	1041	Storm	summer	85065	bovine	livestock					13.17
0322	L27770-38	10/18/2003	1041	Storm	summer	85067	horse	livestock					13.17
0322	L27770-39	10/18/2003	1042	Storm	summer	85070	avian	wildlife					13.17
0322	L27770-39	10/18/2003	1042	Storm	summer	85068	raccoon	wildlife					13.17
0322	L27770-39	10/18/2003	1042	Storm	summer	85069	raccoon	wildlife					13.17
0322	L27770-40	10/18/2003	1043	Storm	summer	85073	avian	wildlife					13.17
0322	L27770-40	10/18/2003	1043	Storm	summer	85071	rodent/beaver	wildlife					13.17
0322	L27770-40	10/18/2003	1043	Storm	summer	85072	canine	canine/feline					13.17
0322	L30144-36	11/19/2003	1232	Storm	winter	86073	bovine	livestock	2300				81.08
0322	L30144-36	11/19/2003	1232	Storm	winter	86075	bovine	livestock	2300				81.08
0322	L30144-36	11/19/2003	1232	Storm	winter	86074	horse	livestock	2300				81.08
0322	L30144-37	11/19/2003	1233	Storm	winter	86077	avian	wildlife					81.08
0322	L30144-37	11/19/2003	1233	Storm	winter	86076	deer/elk	wildlife					81.08
0322	L30144-37	11/19/2003	1233	Storm	winter	86078	bovine	livestock					81.08
0322	L30144-38	11/19/2003	1234	Storm	winter	86081	avian	wildlife					81.08
0322	L30144-38	11/19/2003	1234	Storm	winter	86082	deer/elk	wildlife					81.08
0322	L30144-38	11/19/2003	1234	Storm	winter	86079	rodent/beaver	wildlife					81.08

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0322	L30144-38	11/19/2003	1234	Storm	winter	86080	bovine	livestock					81.08
0322	L30144-39	11/19/2003	1235	Storm	winter	86083	rodent/beaver	wildlife					81.08
0322	L30144-39	11/19/2003	1235	Storm	winter	86084	rodent/beaver	wildlife					81.08
0322	L30144-39	11/19/2003	1235	Storm	winter	86085	unknown	unknown					81.08
0322	L30144-40	11/19/2003	1236	Storm	winter	86086	rodent/beaver	wildlife					81.08
0322	L30144-40	11/19/2003	1236	Storm	winter	86087	rodent/beaver	wildlife					81.08
0322	L30144-40	11/19/2003	1236	Storm	winter	86088	canine	canine/feline					81.08
0322	L29825-21	3/16/2004	1345	Base	winter	90417	avian	wildlife	7				41.43
0322	L29825-21	3/16/2004	1345	Base	winter	90419	horse	livestock	7				41.43
0322	L29825-21	3/16/2004	1345	Base	winter	90418	horse	livestock	7				41.43
0322	L29825-22	3/16/2004	1347	Base	winter	90421	unknown	unknown					41.43
0322	L29825-22	3/16/2004	1347	Base	winter	90420	unknown	unknown					41.43
0322	L29825-22	3/16/2004	1347	Base	winter	90422	unknown	unknown					41.43
0322	L29825-23	3/16/2004	1349	Base	winter	90423	deer/elk	wildlife					41.43
0322	L29825-23	3/16/2004	1349	Base	winter	90425	rodent/beaver	wildlife					41.43
0322	L29825-23	3/16/2004	1349	Base	winter	90424	bovine	livestock					41.43
0322	L29825-24	3/16/2004	1351	Base	winter	90427	rodent/beaver	wildlife					41.43
0322	L29825-24	3/16/2004	1351	Base	winter	90428	rodent/beaver	wildlife					41.43
0322	L29825-24	3/16/2004	1351	Base	winter	90426	canine	canine/feline					41.43
0322	L29825-25	3/16/2004	1353	Base	winter	90431	deer/elk	wildlife					41.43
0322	L29825-25	3/16/2004	1353	Base	winter	90429	canine	canine/feline					41.43
0322	L29825-25	3/16/2004	1353	Base	winter	90430	bovine	livestock					41.43
0322	L29940-36	3/25/2004	1223	Storm	winter	90826	deer/elk	wildlife	360				46.53
0322	L29940-36	3/25/2004	1223	Storm	winter	90823	rodent/beaver	wildlife	360				46.53
0322	L29940-36	3/25/2004	1223	Storm	winter	90827	rodent/beaver	wildlife	360				46.53
0322	L29940-36	3/25/2004	1223	Storm	winter	90824	bovine	livestock	360				46.53
0322	L29940-36	3/25/2004	1223	Storm	winter	90825	horse	livestock	360				46.53
0322	L29940-37	3/25/2004	1225	Storm	winter	90830	rodent/beaver	wildlife					46.53
0322	L29940-37	3/25/2004	1225	Storm	winter	90828	canine	canine/feline					46.53
0322	L29940-37	3/25/2004	1225	Storm	winter	90829	canine	canine/feline					46.53
0322	L29940-38	3/25/2004	1227	Storm	winter	90833	avian	wildlife					46.53
0322	L29940-38	3/25/2004	1227	Storm	winter	90832	deer/elk	wildlife					46.53
0322	L29940-38	3/25/2004	1227	Storm	winter	90831	rodent/beaver	wildlife					46.53

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0322	L29940-39	3/25/2004	1229	Storm	winter	90836	deer/elk	wildlife					46.53
0322	L29940-39	3/25/2004	1229	Storm	winter	90835	bovine	livestock					46.53
0322	L29940-39	3/25/2004	1229	Storm	winter	90834	human	human					46.53
0322	L29940-40	3/25/2004	1231	Storm	winter	90838	avian	wildlife					46.53
0322	L29940-40	3/25/2004	1231	Storm	winter	90839	rodent/beaver	wildlife					46.53
0322	L29940-40	3/25/2004	1231	Storm	winter	90837	canine	canine/feline					46.53
0322	L31629-36	5/26/2004	1140	Storm	winter	93785	deer/elk	wildlife	4400	C			61.58
0322	L31629-36	5/26/2004	1140	Storm	winter	93786	deer/elk	wildlife	4400	C			61.58
0322	L31629-36	5/26/2004	1140	Storm	winter	93787	bovine	livestock	4400	C			61.58
0322	L31629-37	5/26/2004	1142	Storm	winter	93788	bovine	livestock					61.58
0322	L31629-37	5/26/2004	1142	Storm	winter	93789	bovine	livestock					61.58
0322	L31629-37	5/26/2004	1142	Storm	winter	93790	bovine	livestock					61.58
0322	L31629-38	5/26/2004	1144	Storm	winter	93792	avian	wildlife					61.58
0322	L31629-38	5/26/2004	1144	Storm	winter	93793	opossum	wildlife					61.58
0322	L31629-38	5/26/2004	1144	Storm	winter	93791	rodent/beaver	wildlife					61.58
0322	L31629-39	5/26/2004	1146	Storm	winter	93794	human	human					61.58
0322	L31629-39	5/26/2004	1146	Storm	winter	93795	unknown	unknown					61.58
0322	L31629-39	5/26/2004	1146	Storm	winter	93796	unknown	unknown					61.58
0322	L31629-40	5/26/2004	1148	Storm	winter	93797	avian	wildlife					61.58
0322	L31629-40	5/26/2004	1148	Storm	winter	93798	avian	wildlife					61.58
0322	L31629-40	5/26/2004	1148	Storm	winter	93799	avian	wildlife					61.58
A320	L23009-13	2/13/2002	1320	Base	winter	103489	deer/elk	wildlife	8	H	10	H	199.9
A320	L23009-13	2/13/2002	1320	Base	winter	103488	opossum	wildlife	8	H	10	H	199.9
A320	L23009-13	2/13/2002	1320	Base	winter	103487	bovine	livestock	8	H	10	H	199.9
A320	L23944-14	4/25/2002	850	Base	winter	103557	rodent/beaver	wildlife	21		30		145.6
A320	L23944-14	4/25/2002	850	Base	winter	103558	rodent/beaver	wildlife	21		30		145.6
A320	L23944-14	4/25/2002	850	Base	winter	103559	waterfowl	wildlife	21		30		145.6
A320	L25054-14	8/6/2002	830	Base	summer	103623	bobcat	wildlife	83		68		31.3
A320	L25054-14	8/6/2002	830	Base	summer	103622	deer/elk	wildlife	83		68		31.3
A320	L25933-17	10/22/2002	944	Base	summer	103651	deer/elk	wildlife	23		31		22.69
A320	L25933-17	10/22/2002	944	Base	summer	103653	llama	livestock	23		31		22.69
A320	L25933-17	10/22/2002	944	Base	summer	103652	human	human	23		31		22.69
A320	L25933-17	10/22/2002	944	Base	summer	103650	squirrel	wildlife	23		31		22.69

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Site ID	King County Sample ID	Collect Date	Collect Time	Hydrology	season	Isolate #	Bacteria Source	Bacteria Source Category	E. coli Bacteria (CFU/100 mL)	Data Flags	Fecal Coliform Bacteria (CFU/100 mL)	Data Flags	Flow (cfs)
A320	L25933-18	10/22/2002	958	Base	summer	103654	avian	wildlife	47		28		22.69
A320	L25933-18	10/22/2002	958	Base	summer	103657	coyote	wildlife	47		28		22.69
A320	L25933-18	10/22/2002	958	Base	summer	103656	raccoon	wildlife	47		28		22.69
A320	L25933-18	10/22/2002	958	Base	summer	103655	rodent/beaver	wildlife	47		28		22.69
A320	L26566-6	12/4/2002	935	Base	winter	103686	avian	wildlife	93		100		28.1
A320	L26566-6	12/4/2002	935	Base	winter	103687	avian	wildlife	93		100		28.1
A320	L26566-6	12/4/2002	935	Base	winter	103688	avian	wildlife	93		100		28.1
A320	L26566-6	12/4/2002	935	Base	winter	103685	raccoon	wildlife	93		100		28.1
A320	L26566-7	12/4/2002	945	Base	winter	103690	avian	wildlife	74		59		28.1
A320	L26566-7	12/4/2002	945	Base	winter	103689	rodent/beaver	wildlife	74		59		28.1
A320	L26566-7	12/4/2002	945	Base	winter	103692	canine	canine/feline	74		59		28.1
A320	L26566-7	12/4/2002	945	Base	winter	103691	horse	livestock	74		59		28.1
A320	L26887-31	1/22/2003	1000	Storm	winter	101596	raccoon	wildlife					147.3
A320	L26887-32	1/22/2003	1002	Storm	winter	101597	rodent/beaver	wildlife					147.3
A320	L26887-32	1/22/2003	1002	Storm	winter	101598	waterfowl	wildlife					147.3
A320	L26887-33	1/22/2003	1004	Storm	winter	101599	deer/elk	wildlife					147.3
A320	L26887-34	1/22/2003	1006	Storm	winter	101608	waterfowl	wildlife					147.3
A320	L26887-35	1/22/2003	1008	Storm	winter	101601	avian	wildlife					147.3
A320	L26887-35	1/22/2003	1008	Storm	winter	101600	canine	canine/feline					147.3
A320	L27034-10	2/12/2003	845	Base	winter	104134	avian	wildlife			11		131.8
A320	L27034-10	2/12/2003	845	Base	winter	104131	rodent/beaver	wildlife			11		131.8
A320	L27034-10	2/12/2003	845	Base	winter	104132	rodent/beaver	wildlife			11		131.8
A320	L27034-10	2/12/2003	845	Base	winter	104133	rodent/beaver	wildlife			11		131.8
A320	L27034-10	2/12/2003	845	Base	winter	104130	feline	canine/feline			11		131.8
A320	L27034-10	2/12/2003	845	Base	winter	104129	human	human	15		11		131.8
A320	L27037-33	2/12/2003	912	Base	winter	101624	opossum	wildlife					131.8
A320	L27037-35	2/12/2003	916	Base	winter	102905	unknown	unknown					131.8
A320	L27361-41	2/25/2003	1213	Base	winter	102913	rodent/beaver	wildlife	17				136.9
A320	L27361-41	2/25/2003	1213	Base	winter	102906	unknown	unknown	17				136.9
A320	L27361-42	2/25/2003	1215	Base	winter	101674	horse	livestock					136.9
A320	L27033-26	3/9/2003	918	Storm	winter	101692	deer/elk	wildlife					149.1
A320	L27033-26	3/9/2003	918	Storm	winter	101691	human	human					149.1
A320	L27033-27	3/9/2003	920	Storm	winter	101694	avian	wildlife					149.1

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A320	L27033-27	3/9/2003	920	Storm	winter	101693	human	human					149.1
A320	L27033-28	3/9/2003	922	Storm	winter	101695	avian	wildlife					149.1
A320	L27033-29	3/9/2003	924	Storm	winter	101696	rodent/beaver	wildlife					149.1
A320	L27271-27	4/9/2003	944	Storm	winter	101723	rodent/beaver	wildlife					195.9
A320	L27271-27	4/9/2003	944	Storm	winter	101722	canine	canine/feline					195.9
A320	L27271-28	4/9/2003	946	Storm	winter	101724	rodent/beaver	wildlife					195.9
A320	L27271-28	4/9/2003	946	Storm	winter	101725	unknown	unknown					195.9
A320	L27271-29	4/9/2003	948	Storm	winter	101726	unknown	unknown					195.9
A320	L27826-41	4/28/2003	930	Base	winter	101762	canine	canine/feline					131.8
A320	L27826-43	4/28/2003	936	Base	winter	101763	human	human					131.8
A320	L27826-44	4/28/2003	939	Base	winter	101764	canine	canine/feline					131.8
A320	L27783-41	6/2/2003	1146	Base	summer	101780	rodent/beaver	wildlife	50				56.71
A320	L27783-42	6/2/2003	1148	Base	summer	102935	canine	canine/feline					56.71
A320	L27783-44	6/2/2003	1152	Base	summer	101782	raccoon	wildlife					56.71
A320	L28447-41	6/9/2003	813	Base	summer	101807	avian	wildlife					46.1
A320	L28447-43	6/9/2003	817	Base	summer	101808	avian	wildlife					46.1
A320	L28447-44	6/9/2003	819	Base	summer	101809	canine	canine/feline					46.1
A320	L28447-44	6/9/2003	819	Base	summer	101810	muskrat	wildlife					46.1
A320	L29246-41	8/26/2003	859	Base	summer	82367	bear	wildlife					19.6
A320	L29246-41	8/26/2003	859	Base	summer	82368	bear	wildlife					19.6
A320	L29246-41	8/26/2003	859	Base	summer	82366	rodent/beaver	wildlife					19.6
A320	L29246-42	8/26/2003	901	Base	summer	82371	avian	wildlife					19.6
A320	L29246-42	8/26/2003	901	Base	summer	82369	raccoon	wildlife					19.6
A320	L29246-42	8/26/2003	901	Base	summer	82370	rodent/beaver	wildlife					19.6
A320	L29246-43	8/26/2003	903	Base	summer	82372	avian	wildlife					19.6
A320	L29246-43	8/26/2003	903	Base	summer	82373	canine	canine/feline					19.6
A320	L29246-43	8/26/2003	903	Base	summer	82374	canine	canine/feline					19.6
A320	L29246-44	8/26/2003	905	Base	summer	82376	avian	wildlife					19.6
A320	L29246-44	8/26/2003	905	Base	summer	82377	rodent/beaver	wildlife					19.6
A320	L29246-44	8/26/2003	905	Base	summer	82375	waterfowl	wildlife					19.6
A320	L29246-45	8/26/2003	907	Base	summer	82379	deer/elk	wildlife					19.6
A320	L29246-45	8/26/2003	907	Base	summer	82380	deer/elk	wildlife					19.6
A320	L29246-45	8/26/2003	907	Base	summer	82381	deer/elk	wildlife					19.6

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A320	L29246-45	8/26/2003	907	Base	summer	82378	opossum	wildlife					19.6
A320	L28018-26	10/7/2003	107	Base	summer	83476	avian	wildlife	310				23.28
A320	L28018-26	10/7/2003	107	Base	summer	83478	avian	wildlife	310				23.28
A320	L28018-26	10/7/2003	107	Base	summer	83477	rodent/beaver	wildlife	310				23.28
A320	L28018-27	10/7/2003	109	Base	summer	83479	avian	wildlife					23.28
A320	L28018-27	10/7/2003	109	Base	summer	83481	rodent/beaver	wildlife					23.28
A320	L28018-27	10/7/2003	109	Base	summer	83482	rodent/beaver	wildlife					23.28
A320	L28018-27	10/7/2003	109	Base	summer	83480	waterfowl	wildlife					23.28
A320	L28018-28	10/7/2003	111	Base	summer	83484	avian	wildlife					23.28
A320	L28018-28	10/7/2003	111	Base	summer	83483	rodent/beaver	wildlife					23.28
A320	L28018-28	10/7/2003	111	Base	summer	83485	rodent/beaver	wildlife					23.28
A320	L28018-29	10/7/2003	113	Base	summer	83486	rodent/beaver	wildlife					23.28
A320	L28018-29	10/7/2003	113	Base	summer	83487	rodent/beaver	wildlife					23.28
A320	L28018-29	10/7/2003	113	Base	summer	83488	unknown	unknown					23.28
A320	L28018-30	10/7/2003	115	Base	summer	83489	rodent/beaver	wildlife					23.28
A320	L28018-30	10/7/2003	115	Base	summer	83490	canine	canine/feline					23.28
A320	L28018-30	10/7/2003	115	Base	summer	83491	feline	canine/feline					23.28
A320	L27770-26	10/17/2003	640	Storm	summer	85028	avian	wildlife					46.09
A320	L27770-26	10/17/2003	640	Storm	summer	85029	canine	canine/feline					46.09
A320	L27770-26	10/17/2003	640	Storm	summer	85030	canine	canine/feline					46.09
A320	L27770-27	10/17/2003	642	Storm	summer	85032	rodent/beaver	wildlife					46.09
A320	L27770-27	10/17/2003	642	Storm	summer	85031	horse	livestock					46.09
A320	L27770-27	10/17/2003	642	Storm	summer	85033	horse	livestock					46.09
A320	L27770-28	10/17/2003	644	Storm	summer	85034	avian	wildlife					46.09
A320	L27770-28	10/17/2003	644	Storm	summer	85036	avian	wildlife					46.09
A320	L27770-28	10/17/2003	644	Storm	summer	85035	deer/elk	wildlife					46.09
A320	L27770-29	10/17/2003	646	Storm	summer	85038	avian	wildlife					46.09
A320	L27770-29	10/17/2003	646	Storm	summer	85039	avian	wildlife					46.09
A320	L27770-29	10/17/2003	646	Storm	summer	85037	waterfowl	wildlife					46.09
A320	L27770-30	10/17/2003	648	Storm	summer	85042	avian	wildlife					46.09
A320	L27770-30	10/17/2003	648	Storm	summer	85041	deer/elk	wildlife					46.09
A320	L27770-30	10/17/2003	648	Storm	summer	85043	waterfowl	wildlife					46.09
A320	L27770-30	10/17/2003	648	Storm	summer	85040	canine	canine/feline					46.09

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A320	L30144-26	11/18/2003	1036	Storm	winter	86045	waterfowl	wildlife					143.8
A320	L30144-26	11/18/2003	1036	Storm	winter	86044	horse	livestock					143.8
A320	L30144-26	11/18/2003	1036	Storm	winter	86046	human	human					143.8
A320	L30144-27	11/18/2003	1038	Storm	winter	86047	avian	wildlife					143.8
A320	L30144-27	11/18/2003	1038	Storm	winter	86048	deer/elk	wildlife					143.8
A320	L30144-27	11/18/2003	1038	Storm	winter	86049	deer/elk	wildlife					143.8
A320	L30144-28	11/18/2003	1040	Storm	winter	86051	avian	wildlife					143.8
A320	L30144-28	11/18/2003	1040	Storm	winter	86050	deer/elk	wildlife					143.8
A320	L30144-28	11/18/2003	1040	Storm	winter	86052	deer/elk	wildlife					143.8
A320	L30144-29	11/18/2003	1042	Storm	winter	86055	avian	wildlife					143.8
A320	L30144-29	11/18/2003	1042	Storm	winter	86053	rodent/beaver	wildlife					143.8
A320	L30144-29	11/18/2003	1042	Storm	winter	86054	waterfowl	wildlife					143.8
A320	L30144-30	11/18/2003	1044	Storm	winter	86057	avian	wildlife					143.8
A320	L30144-30	11/18/2003	1044	Storm	winter	86056	deer/elk	wildlife					143.8
A320	L30144-30	11/18/2003	1044	Storm	winter	86058	waterfowl	wildlife					143.8
A320	L29825-41	3/16/2004	1453	Base	winter	90479	raccoon	wildlife	12				113.7
A320	L29825-41	3/16/2004	1453	Base	winter	90480	rodent/beaver	wildlife	12				113.7
A320	L29825-41	3/16/2004	1453	Base	winter	90482	rodent/beaver	wildlife	12				113.7
A320	L29825-41	3/16/2004	1453	Base	winter	90481	horse	livestock	12				113.7
A320	L29825-42	3/16/2004	1456	Base	winter	90484	avian	wildlife					113.7
A320	L29825-42	3/16/2004	1456	Base	winter	90483	rodent/beaver	wildlife					113.7
A320	L29825-42	3/16/2004	1456	Base	winter	90485	canine	canine/feline					113.7
A320	L29825-43	3/16/2004	1459	Base	winter	90487	avian	wildlife					113.7
A320	L29825-43	3/16/2004	1459	Base	winter	90488	raccoon	wildlife					113.7
A320	L29825-43	3/16/2004	1459	Base	winter	90486	canine	canine/feline					113.7
A320	L29825-44	3/16/2004	1502	Base	winter	90489	avian	wildlife					113.7
A320	L29825-44	3/16/2004	1502	Base	winter	90490	canine	canine/feline					113.7
A320	L29825-44	3/16/2004	1502	Base	winter	90491	unknown	unknown					113.7
A320	L29825-45	3/16/2004	1505	Base	winter	90493	avian	wildlife					113.7
A320	L29825-45	3/16/2004	1505	Base	winter	90492	bovine	livestock					113.7
A320	L29940-26	3/25/2004	1340	Storm	winter	90805	raccoon	wildlife	54				120.2
A320	L29940-27	3/25/2004	1343	Storm	winter	90806	raccoon	wildlife					120.2
A320	L29940-27	3/25/2004	1343	Storm	winter	90807	rodent/beaver	wildlife					120.2

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A320	L29940-27	3/25/2004	1343	Storm	winter	90808	rodent/beaver	wildlife					120.2
A320	L29940-28	3/25/2004	1346	Storm	winter	90810	avian	wildlife					120.2
A320	L29940-28	3/25/2004	1346	Storm	winter	90811	avian	wildlife					120.2
A320	L29940-28	3/25/2004	1346	Storm	winter	90809	waterfowl	wildlife					120.2
A320	L29940-29	3/25/2004	1349	Storm	winter	90816	avian	wildlife					120.2
A320	L29940-29	3/25/2004	1349	Storm	winter	90812	deer/elk	wildlife					120.2
A320	L29940-29	3/25/2004	1349	Storm	winter	90815	deer/elk	wildlife					120.2
A320	L29940-29	3/25/2004	1349	Storm	winter	90813	waterfowl	wildlife					120.2
A320	L29940-29	3/25/2004	1349	Storm	winter	90814	unknown	unknown					120.2
A320	L29940-30	3/25/2004	1352	Storm	winter	90820	avian	wildlife					120.2
A320	L29940-30	3/25/2004	1352	Storm	winter	90821	avian	wildlife					120.2
A320	L29940-30	3/25/2004	1352	Storm	winter	90819	deer/elk	wildlife					120.2
A320	L29940-30	3/25/2004	1352	Storm	winter	90817	rodent/beaver	wildlife					120.2
A320	L29940-30	3/25/2004	1352	Storm	winter	90818	horse	livestock					120.2
A320	L31629-26	5/26/2004	1030	Storm	winter	93753	avian	wildlife	800				68.84
A320	L31629-26	5/26/2004	1030	Storm	winter	93755	rodent/beaver	wildlife	800				68.84
A320	L31629-26	5/26/2004	1030	Storm	winter	93754	canine	canine/feline	800				68.84
A320	L31629-27	5/26/2004	1032	Storm	winter	93757	avian	wildlife					68.84
A320	L31629-27	5/26/2004	1032	Storm	winter	93756	coyote	wildlife					68.84
A320	L31629-27	5/26/2004	1032	Storm	winter	93758	canine	canine/feline					68.84
A320	L31629-28	5/26/2004	1034	Storm	winter	93761	deer/elk	wildlife					68.84
A320	L31629-28	5/26/2004	1034	Storm	winter	93760	waterfowl	wildlife					68.84
A320	L31629-28	5/26/2004	1034	Storm	winter	93759	bovine	livestock					68.84
A320	L31629-28	5/26/2004	1034	Storm	winter	93762	human	human					68.84
A320	L31629-29	5/26/2004	1036	Storm	winter	93764	avian	wildlife					68.84
A320	L31629-29	5/26/2004	1036	Storm	winter	93765	avian	wildlife					68.84
A320	L31629-29	5/26/2004	1036	Storm	winter	93763	squirrel	wildlife					68.84
A320	L31629-30	5/26/2004	1038	Storm	winter	93766	waterfowl	wildlife					68.84
A320	L31629-30	5/26/2004	1038	Storm	winter	93768	horse	livestock					68.84
A320	L31629-30	5/26/2004	1038	Storm	winter	93767	human	human					68.84
A315	L23009-15	2/13/2002	1220	Base	winter	103490	avian	wildlife	22	H	23	H	
A315	L23009-15	2/13/2002	1220	Base	winter	103493	avian	wildlife	22	H	23	H	
A315	L23009-15	2/13/2002	1220	Base	winter	103491	raccoon	wildlife	22	H	23	H	

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A315	L23009-15	2/13/2002	1220	Base	winter	103492	rodent/beaver	wildlife	22	H	23	H	
A315	L25054-13	8/6/2002	1045	Base	summer	103618	avian	wildlife	480		490		
A315	L25054-13	8/6/2002	1045	Base	summer	103619	avian	wildlife	480		490		
A315	L25054-13	8/6/2002	1045	Base	summer	103621	avian	wildlife	480		490		
A315	L25933-16	10/22/2002	1115	Base	summer	103647	avian	wildlife	310		360		
A315	L25933-16	10/22/2002	1115	Base	summer	103649	avian	wildlife	310		360		
A315	L25933-16	10/22/2002	1115	Base	summer	103648	canine	canine/feline	310		360		
A315	L26566-5	12/4/2002	1150	Base	winter	103681	avian	wildlife	200		170		
A315	L26566-5	12/4/2002	1150	Base	winter	103682	avian	wildlife	200		170		
A315	L26566-5	12/4/2002	1150	Base	winter	103683	coyote	wildlife	200		170		
A315	L26566-5	12/4/2002	1150	Base	winter	103680	deer/elk	wildlife	200		170		
A315	L26566-5	12/4/2002	1150	Base	winter	103684	canine	canine/feline	200		170		
A315	L26884-11	1/22/2003	1210	Storm	winter	101611	avian	wildlife	2800		2200		
A315	L26887-27	1/22/2003	1232	Storm	winter	101595	rodent/beaver	wildlife					
A315	L27034-9	2/12/2003	1155	Base	winter	101618	raccoon	wildlife	240		250		
A315	L27037-27	2/12/2003	1213	Base	winter	104102	avian	wildlife					
A315	L27037-27	2/12/2003	1213	Base	winter	104103	avian	wildlife					
A315	L27037-27	2/12/2003	1213	Base	winter	104104	avian	wildlife					
A315	L27037-27	2/12/2003	1213	Base	winter	104106	avian	wildlife					
A315	L27037-27	2/12/2003	1213	Base	winter	101619	waterfowl	wildlife					
A315	L27037-27	2/12/2003	1213	Base	winter	104107	canine	canine/feline					
A315	L27037-27	2/12/2003	1213	Base	winter	104105	human	human					
A315	L27037-28	2/12/2003	1216	Base	winter	104108	avian	wildlife					
A315	L27037-28	2/12/2003	1216	Base	winter	104112	avian	wildlife					
A315	L27037-28	2/12/2003	1216	Base	winter	104113	avian	wildlife					
A315	L27037-28	2/12/2003	1216	Base	winter	104114	avian	wildlife					
A315	L27037-28	2/12/2003	1216	Base	winter	104111	deer/elk	wildlife					
A315	L27037-28	2/12/2003	1216	Base	winter	101620	waterfowl	wildlife					
A315	L27037-28	2/12/2003	1216	Base	winter	104109	waterfowl	wildlife					
A315	L27037-28	2/12/2003	1216	Base	winter	101623	canine	canine/feline					
A315	L27037-28	2/12/2003	1216	Base	winter	104110	canine	canine/feline					
A315	L27037-29	2/12/2003	1219	Base	winter	102903	avian	wildlife					
A315	L27037-29	2/12/2003	1219	Base	winter	104122	avian	wildlife					

Table A-1. Project database for the Green-Duwamish watershed Microbial Source Tracking Study

Site ID	King County Sample ID	Collect Date	Collect Time	Hydrology	season	Isolate #	Bacteria Source	Bacteria Source Category	E. coli Bacteria (CFU/100 mL)	Data Flags	Fecal Coliform Bacteria (CFU/100 mL)	Data Flags	Flow (cfs)
A315	L27037-29	2/12/2003	1219	Base	winter	104120	raccoon	wildlife					
A315	L27037-29	2/12/2003	1219	Base	winter	104118	rodent/beaver	wildlife					
A315	L27037-29	2/12/2003	1219	Base	winter	104119	rodent/beaver	wildlife					
A315	L27037-29	2/12/2003	1219	Base	winter	104121	rodent/beaver	wildlife					
A315	L27037-29	2/12/2003	1219	Base	winter	104115	canine	canine/feline					
A315	L27037-29	2/12/2003	1219	Base	winter	104117	human	human					
A315	L27037-29	2/12/2003	1219	Base	winter	104116	human	human					
A315	L27037-30	2/12/2003	1222	Base	winter	104124	avian	wildlife					
A315	L27037-30	2/12/2003	1222	Base	winter	104125	avian	wildlife					
A315	L27037-30	2/12/2003	1222	Base	winter	104126	deer/elk	wildlife					
A315	L27037-30	2/12/2003	1222	Base	winter	104128	deer/elk	wildlife					
A315	L27037-30	2/12/2003	1222	Base	winter	104123	rodent/beaver	wildlife					
A315	L27037-30	2/12/2003	1222	Base	winter	101622	waterfowl	wildlife					
A315	L27037-30	2/12/2003	1222	Base	winter	104127	canine	canine/feline					
A315	L27361-36	2/25/2003	1024	Base	winter	102912	avian	wildlife	200				21.57
A315	L27361-36	2/25/2003	1024	Base	winter	101634	rodent/beaver	wildlife	200				21.57
A315	L27361-37	2/25/2003	1027	Base	winter	101670	avian	wildlife					21.57
A315	L27361-38	2/25/2003	1030	Base	winter	102879	avian	wildlife					21.57
A315	L27361-38	2/25/2003	1030	Base	winter	102881	avian	wildlife					21.57
A315	L27361-38	2/25/2003	1030	Base	winter	102880	raccoon	wildlife					21.57
A315	L27361-39	2/25/2003	1033	Base	winter	102882	avian	wildlife					21.57
A315	L27361-40	2/25/2003	1036	Base	winter	101673	avian	wildlife					21.57
A315	L27033-18	3/9/2003	1149	Storm	winter	101679	deer/elk	wildlife					23.67
A315	L27033-18	3/9/2003	1149	Storm	winter	101680	canine	canine/feline					23.67
A315	L27033-19	3/9/2003	1151	Storm	winter	101682	canine	canine/feline					23.67
A315	L27033-19	3/9/2003	1151	Storm	winter	101683	canine	canine/feline					23.67
A315	L27033-20	3/9/2003	1153	Storm	winter	101684	canine	canine/feline					24.04
A315	L27033-20	3/9/2003	1153	Storm	winter	101685	canine	canine/feline					24.04
A315	L27271-16	4/9/2003	819	Storm	winter	102927	rodent/beaver	wildlife	2500				25.9
A315	L27271-19	4/9/2003	831	Storm	winter	102884	avian	wildlife					26.67
A315	L27271-19	4/9/2003	831	Storm	winter	102885	canine	canine/feline					26.67
A315	L27271-20	4/9/2003	835	Storm	winter	101718	bovine	livestock					26.67
A315	L27826-36	4/28/2003	1231	Base	winter	101742	rodent/beaver	wildlife					18.63

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A315	L27826-38	4/28/2003	1237	Base	winter	101759	raccoon	wildlife					18.63
A315	L27826-39	4/28/2003	1240	Base	winter	101760	rodent/beaver	wildlife					18.32
A315	L27826-39	4/28/2003	1240	Base	winter	101761	canine	canine/feline					18.32
A315	L27783-38	6/2/2003	912	Storm	summer	101779	deer/elk	wildlife					4.08
A315	L28447-37	6/9/2003	1004	Base	summer	101805	canine	canine/feline					3.39
A315	L28447-38	6/9/2003	1006	Base	summer	101806	canine	canine/feline					3.39
A315	L28018-16	10/6/2003	2350	Storm	summer	83447	avian	wildlife	4000	E			0.5
A315	L28018-16	10/6/2003	2350	Storm	summer	83449	raccoon	wildlife	4000	E			0.5
A315	L28018-16	10/6/2003	2350	Storm	summer	83448	rodent/beaver	wildlife	4000	E			0.5
A315	L28018-17	10/6/2003	2353	Storm	summer	83452	avian	wildlife					0.5
A315	L28018-17	10/6/2003	2353	Storm	summer	83451	waterfowl	wildlife					0.5
A315	L28018-17	10/6/2003	2353	Storm	summer	83450	canine	canine/feline					0.5
A315	L28018-18	10/6/2003	2356	Storm	summer	83453	avian	wildlife					0.5
A315	L28018-18	10/6/2003	2356	Storm	summer	83454	avian	wildlife					0.5
A315	L28018-18	10/6/2003	2356	Storm	summer	83455	waterfowl	wildlife					0.5
A315	L28018-19	10/6/2003	2359	Storm	summer	83456	avian	wildlife					0.5
A315	L28018-19	10/6/2003	2359	Storm	summer	83457	avian	wildlife					0.5
A315	L28018-19	10/6/2003	2359	Storm	summer	83458	deer/elk	wildlife					0.5
A315	L28018-20	10/7/2003	2	Storm	summer	83459	avian	wildlife					0.5
A315	L28018-20	10/7/2003	2	Storm	summer	83460	avian	wildlife					0.5
A315	L28018-20	10/7/2003	2	Storm	summer	83461	deer/elk	wildlife					0.5
A315	L27770-16	10/17/2003	858	Storm	summer	84997	avian	wildlife					17.41
A315	L27770-16	10/17/2003	858	Storm	summer	84998	deer/elk	wildlife					17.41
A315	L27770-16	10/17/2003	858	Storm	summer	84999	canine	canine/feline					17.41
A315	L27770-17	10/17/2003	900	Storm	summer	85000	avian	wildlife					17.41
A315	L27770-17	10/17/2003	900	Storm	summer	85003	avian	wildlife					17.41
A315	L27770-17	10/17/2003	900	Storm	summer	85002	rodent/beaver	wildlife					17.41
A315	L27770-17	10/17/2003	900	Storm	summer	85001	canine	canine/feline					17.41
A315	L27770-18	10/17/2003	902	Storm	summer	85004	avian	wildlife					17.41
A315	L27770-18	10/17/2003	902	Storm	summer	85006	avian	wildlife					17.41
A315	L27770-18	10/17/2003	902	Storm	summer	85005	feline	canine/feline					17.41
A315	L27770-19	10/17/2003	904	Storm	summer	85009	avian	wildlife					17.41
A315	L27770-19	10/17/2003	904	Storm	summer	85008	rodent/beaver	wildlife					17.41

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A315	L27770-19	10/17/2003	904	Storm	summer	85007	horse	livestock					17.41
A315	L27770-20	10/17/2003	906	Storm	summer	85012	avian	wildlife					17.41
A315	L27770-20	10/17/2003	906	Storm	summer	85010	rodent/beaver	wildlife					17.41
A315	L27770-20	10/17/2003	906	Storm	summer	85011	rodent/beaver	wildlife					17.41
A315	L30144-16	11/18/2003	1325	Storm	winter	86016	deer/elk	wildlife					36.06
A315	L30144-16	11/18/2003	1325	Storm	winter	86017	canine	canine/feline					36.06
A315	L30144-17	11/18/2003	1327	Storm	winter	86018	avian	wildlife					36.06
A315	L30144-17	11/18/2003	1327	Storm	winter	86019	avian	wildlife					36.06
A315	L30144-17	11/18/2003	1327	Storm	winter	86020	human	human					36.06
A315	L30144-18	11/18/2003	1329	Storm	winter	86021	avian	wildlife					36.06
A315	L30144-18	11/18/2003	1329	Storm	winter	86022	avian	wildlife					36.06
A315	L30144-18	11/18/2003	1329	Storm	winter	86023	avian	wildlife					36.06
A315	L30144-19	11/18/2003	1331	Storm	winter	86026	rodent/beaver	wildlife					36.06
A315	L30144-19	11/18/2003	1331	Storm	winter	86024	canine	canine/feline					36.06
A315	L30144-19	11/18/2003	1331	Storm	winter	86025	canine	canine/feline					36.06
A315	L30144-20	11/18/2003	1333	Storm	winter	86027	rodent/beaver	wildlife					36.06
A315	L30144-20	11/18/2003	1333	Storm	winter	86028	rodent/beaver	wildlife					36.06
A315	L29825-36	3/16/2004	1235	Base	winter	90465	avian	wildlife	17				13.01
A315	L29825-36	3/16/2004	1235	Base	winter	90464	rodent/beaver	wildlife	17				13.01
A315	L29825-36	3/16/2004	1235	Base	winter	90466	canine	canine/feline	17				13.01
A315	L29825-37	3/16/2004	1238	Base	winter	90469	avian	wildlife					13.27
A315	L29825-37	3/16/2004	1238	Base	winter	90467	raccoon	wildlife					13.27
A315	L29825-37	3/16/2004	1238	Base	winter	90468	rodent/beaver	wildlife					13.27
A315	L29825-38	3/16/2004	1241	Base	winter	90471	rodent/beaver	wildlife					13.27
A315	L29825-38	3/16/2004	1241	Base	winter	90470	waterfowl	wildlife					13.27
A315	L29825-38	3/16/2004	1241	Base	winter	90472	waterfowl	wildlife					13.27
A315	L29825-39	3/16/2004	1244	Base	winter	90473	deer/elk	wildlife					13.27
A315	L29825-39	3/16/2004	1244	Base	winter	90474	deer/elk	wildlife					13.27
A315	L29825-39	3/16/2004	1244	Base	winter	90475	rodent/beaver	wildlife					13.27
A315	L29825-40	3/16/2004	1247	Base	winter	90478	avian	wildlife					13.27
A315	L29825-40	3/16/2004	1247	Base	winter	90476	rodent/beaver	wildlife					13.27
A315	L29825-40	3/16/2004	1247	Base	winter	90477	canine	canine/feline					13.27
A315	L29940-16	3/25/2004	1258	Storm	winter	90774	rodent/beaver	wildlife	600				27.45

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A315	L29940-16	3/25/2004	1258	Storm	winter	90775	rodent/beaver	wildlife	600				27.45
A315	L29940-17	3/25/2004	1300	Storm	winter	90778	opossum	wildlife					27.45
A315	L29940-17	3/25/2004	1300	Storm	winter	90776	rodent/beaver	wildlife					27.45
A315	L29940-17	3/25/2004	1300	Storm	winter	90777	rodent/beaver	wildlife					27.45
A315	L29940-18	3/25/2004	1302	Storm	winter	90779	avian	wildlife					27.45
A315	L29940-18	3/25/2004	1302	Storm	winter	90781	avian	wildlife					27.45
A315	L29940-18	3/25/2004	1302	Storm	winter	90782	avian	wildlife					27.45
A315	L29940-18	3/25/2004	1302	Storm	winter	90783	avian	wildlife					27.45
A315	L29940-18	3/25/2004	1302	Storm	winter	90780	rodent/beaver	wildlife					27.45
A315	L29940-19	3/25/2004	1304	Storm	winter	90785	avian	wildlife					27.45
A315	L29940-19	3/25/2004	1304	Storm	winter	90786	avian	wildlife					27.45
A315	L29940-19	3/25/2004	1304	Storm	winter	90784	rodent/beaver	wildlife					27.45
A315	L29940-20	3/25/2004	1306	Storm	winter	90787	avian	wildlife					27.45
A315	L29940-20	3/25/2004	1306	Storm	winter	90788	avian	wildlife					27.45
A315	L29940-20	3/25/2004	1306	Storm	winter	90789	canine	canine/feline					27.45
A315	L31629-16	5/26/2004	931	Storm	winter	93722	waterfowl	wildlife	550				3.17
A315	L31629-16	5/26/2004	931	Storm	winter	93724	waterfowl	wildlife	550				3.17
A315	L31629-16	5/26/2004	931	Storm	winter	93723	canine	canine/feline	550				3.17
A315	L31629-17	5/26/2004	933	Storm	winter	93725	rodent/beaver	wildlife					3.17
A315	L31629-17	5/26/2004	933	Storm	winter	93726	rodent/beaver	wildlife					3.17
A315	L31629-17	5/26/2004	933	Storm	winter	93727	rodent/beaver	wildlife					3.17
A315	L31629-18	5/26/2004	935	Storm	winter	93730	avian	wildlife					3.17
A315	L31629-18	5/26/2004	935	Storm	winter	93728	rodent/beaver	wildlife					3.17
A315	L31629-18	5/26/2004	935	Storm	winter	93729	waterfowl	wildlife					3.17
A315	L31629-19	5/26/2004	937	Storm	winter	93733	avian	wildlife					3.17
A315	L31629-19	5/26/2004	937	Storm	winter	93732	waterfowl	wildlife					3.17
A315	L31629-19	5/26/2004	937	Storm	winter	93731	horse	livestock					3.17
A315	L31629-20	5/26/2004	939	Storm	winter	93734	canine	canine/feline					3.28
A315	L31629-20	5/26/2004	939	Storm	winter	93735	canine	canine/feline					3.28
A315	L31629-20	5/26/2004	939	Storm	winter	93736	canine	canine/feline					3.28
A317	L23007-15	2/13/2002	1400	Base	winter	103524	avian	wildlife	43		43		32.29
A317	L23007-15	2/13/2002	1400	Base	winter	103525	avian	wildlife	43		43		32.29
A317	L23007-15	2/13/2002	1400	Base	winter	103526	avian	wildlife	43		43		32.29

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A317	L23007-15	2/13/2002	1400	Base	winter	103527	avian	wildlife	43		43		32.29
A317	L23474-5	3/25/2002	1203	Base	winter	103553	raccoon	wildlife	55		65		36.38
A317	L23474-5	3/25/2002	1203	Base	winter	103554	waterfowl	wildlife	55		65		36.38
A317	L23474-5	3/25/2002	1203	Base	winter	103556	unknown	unknown	55		65		36.38
A317	L23474-5	3/25/2002	1203	Base	winter	103555	canine	canine/feline	55		65		36.38
A317	L23947-5	4/24/2002	1044	Base	winter	103586	avian	wildlife	41		51		24.84
A317	L23947-5	4/24/2002	1044	Base	winter	103584	raccoon	wildlife	41		51		24.84
A317	L23947-5	4/24/2002	1044	Base	winter	103585	raccoon	wildlife	42		51		24.84
A317	L23947-5	4/24/2002	1044	Base	winter	103583	waterfowl	wildlife	42		51		24.84
A317	L24477-5	6/12/2002	1145	Base	summer	103612	avian	wildlife	60		76		15.42
A317	L24477-5	6/12/2002	1145	Base	summer	103611	raccoon	wildlife	60		76		15.42
A317	L24477-5	6/12/2002	1145	Base	summer	103613	rodent/beaver	wildlife	60		76		15.42
A317	L24477-5	6/12/2002	1145	Base	summer	103614	canine	canine/feline	60		76		15.42
A317	L25056-1	8/6/2002	1109	Base	summer	103633	avian	wildlife	190		470		13.29
A317	L25056-1	8/6/2002	1109	Base	summer	103634	avian	wildlife	190		470		13.29
A317	L25056-1	8/6/2002	1109	Base	summer	103635	avian	wildlife	190		470		13.29
A317	L25935-6	10/22/2002	1103	Base	summer	103666	avian	wildlife	59		68		9.17
A317	L25935-6	10/22/2002	1103	Base	summer	103667	avian	wildlife	59		68		9.17
A317	L25935-6	10/22/2002	1103	Base	summer	103664	raccoon	wildlife	59		68		9.17
A317	L25935-6	10/22/2002	1103	Base	summer	103665	rodent/beaver	wildlife	59		68		9.17
A317	L26568-6	12/3/2002	1048	Base	winter	103713	avian	wildlife	70		62		9.17
A317	L26568-6	12/3/2002	1048	Base	winter	103715	raccoon	wildlife	70		62		9.17
A317	L26568-6	12/3/2002	1048	Base	winter	103716	raccoon	wildlife	70		62		9.17
A317	L26568-6	12/3/2002	1048	Base	winter	103714	rodent/beaver	wildlife	70		62		9.17
A317	L26887-22	1/22/2003	1113	Storm	winter	101593	avian	wildlife					82.83
A317	L26887-24	1/22/2003	1119	Storm	winter	101594	feline	canine/feline					82.83
A317	L27037-21	2/13/2003	1011	Base	winter	104093	avian	wildlife	45				18.87
A317	L27037-21	2/13/2003	1011	Base	winter	104100	avian	wildlife	45				18.87
A317	L27037-21	2/13/2003	1011	Base	winter	104094	rodent/beaver	wildlife	45				18.87
A317	L27037-21	2/13/2003	1011	Base	winter	104092	unknown	unknown	45				18.87
A317	L27037-21	2/13/2003	1011	Base	winter	104095	unknown	unknown	45				18.87
A317	L27037-21	2/13/2003	1011	Base	winter	104099	unknown	unknown	45				18.87
A317	L27037-21	2/13/2003	1011	Base	winter	104096	canine	canine/feline	45				18.87

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A317	L27037-21	2/13/2003	1011	Base	winter	104098	feline	canine/feline	45				18.87
A317	L27037-21	2/13/2003	1011	Base	winter	104101	feline	canine/feline	45				18.87
A317	L27037-22	2/13/2003	1014	Base	winter	104065	rodent/beaver	wildlife					18.87
A317	L27037-22	2/13/2003	1014	Base	winter	104064	waterfowl	wildlife					18.87
A317	L27037-22	2/13/2003	1014	Base	winter	104066	waterfowl	wildlife					18.87
A317	L27037-22	2/13/2003	1014	Base	winter	104060	unknown	unknown					18.87
A317	L27037-22	2/13/2003	1014	Base	winter	104062	unknown	unknown					18.87
A317	L27037-22	2/13/2003	1014	Base	winter	104063	unknown	unknown					18.87
A317	L27037-22	2/13/2003	1014	Base	winter	104068	unknown	unknown					18.87
A317	L27037-22	2/13/2003	1014	Base	winter	104067	canine	canine/feline					18.87
A317	L27037-25	2/13/2003	1023	Base	winter	101625	avian	wildlife					18.87
A317	L27037-25	2/13/2003	1023	Base	winter	104070	avian	wildlife					18.87
A317	L27037-25	2/13/2003	1023	Base	winter	104071	opossum	wildlife					18.87
A317	L27037-25	2/13/2003	1023	Base	winter	104069	rodent/beaver	wildlife					18.87
A317	L27037-25	2/13/2003	1023	Base	winter	102900	unknown	unknown					18.87
A317	L27037-25	2/13/2003	1023	Base	winter	104072	canine	canine/feline					18.87
A317	L27361-26	2/25/2003	1106	Base	winter	101630	avian	wildlife	39				21.72
A317	L27361-26	2/25/2003	1106	Base	winter	101631	rodent/beaver	wildlife	39				21.72
A317	L27361-27	2/25/2003	1109	Base	winter	102878	avian	wildlife					21.72
A317	L27361-27	2/25/2003	1109	Base	winter	102916	canine	canine/feline					21.72
A317	L27361-28	2/25/2003	1112	Base	winter	101666	avian	wildlife					21.72
A317	L27361-28	2/25/2003	1112	Base	winter	102917	avian	wildlife					21.72
A317	L27271-11	4/9/2003	743	Storm	winter	102926	rodent/beaver	wildlife	310				91.47
A317	L27271-13	4/9/2003	749	Storm	winter	101711	canine	canine/feline					91.47
A317	L27271-14	4/9/2003	752	Storm	winter	101712	unknown	unknown					91.47
A317	L27271-15	4/9/2003	755	Storm	winter	101714	rodent/beaver	wildlife					99.25
A317	L27271-15	4/9/2003	755	Storm	winter	101713	unknown	unknown					99.25
A317	L27826-26	4/29/2003	1012	Base	winter	101749	avian	wildlife	76				14.35
A317	L27826-27	4/29/2003	1015	Base	winter	101750	raccoon	wildlife					14.35
A317	L27826-27	4/29/2003	1015	Base	winter	102932	canine	canine/feline					14.35
A317	L27826-28	4/29/2003	1018	Base	winter	101752	avian	wildlife					14.35
A317	L27826-28	4/29/2003	1018	Base	winter	101751	rodent/beaver	wildlife					14.35
A317	L27826-29	4/29/2003	1021	Base	winter	101827	avian	wildlife					14.35

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A317	L27826-29	4/29/2003	1021	Base	winter	102933	avian	wildlife					14.35
A317	L27826-29	4/29/2003	1021	Base	winter	101753	canine	canine/feline					14.35
A317	L27826-29	4/29/2003	1021	Base	winter	102934	canine	canine/feline					14.35
A317	L27826-30	4/29/2003	1024	Base	winter	101754	avian	wildlife					14.35
A317	L28447-26	6/9/2003	1050	Base	summer	101794	avian	wildlife	150				5.51
A317	L28447-27	6/9/2003	1053	Base	summer	101795	avian	wildlife					5.51
A317	L28447-28	6/9/2003	1056	Base	summer	101796	avian	wildlife					5.51
A317	L28447-29	6/9/2003	1059	Base	summer	102941	rodent/beaver	wildlife					5.51
A317	L28447-29	6/9/2003	1059	Base	summer	102940	canine	canine/feline					5.51
A317	L28447-30	6/9/2003	1102	Base	summer	101798	raccoon	wildlife					5.51
A317	L29246-26	8/27/2003	1026	Base	summer	82339	deer/elk	wildlife	170				4.41
A317	L29246-26	8/27/2003	1026	Base	summer	82338	raccoon	wildlife	170				4.41
A317	L29246-26	8/27/2003	1026	Base	summer	82337	feline	canine/feline	170				4.41
A317	L29246-27	8/27/2003	1029	Base	summer	82342	raccoon	wildlife					4.41
A317	L29246-27	8/27/2003	1029	Base	summer	82343	rodent/beaver	wildlife					4.41
A317	L29246-27	8/27/2003	1029	Base	summer	82341	canine	canine/feline					4.41
A317	L29246-27	8/27/2003	1029	Base	summer	82340	squirrel	wildlife					4.41
A317	L29246-28	8/27/2003	1031	Base	summer	82344	avian	wildlife					4.41
A317	L29246-28	8/27/2003	1031	Base	summer	82345	canine	canine/feline					4.41
A317	L29246-29	8/27/2003	1034	Base	summer	82346	canine	canine/feline					4.41
A317	L29246-29	8/27/2003	1034	Base	summer	82347	canine	canine/feline					4.41
A317	L29246-30	8/27/2003	1037	Base	summer	82348	avian	wildlife					4.41
A317	L29246-30	8/27/2003	1037	Base	summer	82349	raccoon	wildlife					4.41
A317	L29246-30	8/27/2003	1037	Base	summer	82350	canine	canine/feline					4.41
A317	L28018-11	10/7/2003	36	Storm	summer	83431	avian	wildlife	2500	E			4.28
A317	L28018-11	10/7/2003	36	Storm	summer	83432	avian	wildlife	2500	E			4.28
A317	L28018-11	10/7/2003	36	Storm	summer	83433	deer/elk	wildlife	2500	E			4.28
A317	L28018-12	10/7/2003	38	Storm	summer	83435	avian	wildlife					4.28
A317	L28018-12	10/7/2003	38	Storm	summer	83436	avian	wildlife					4.28
A317	L28018-12	10/7/2003	38	Storm	summer	83434	canine	canine/feline					4.28
A317	L28018-13	10/7/2003	40	Storm	summer	83439	avian	wildlife					4.28
A317	L28018-13	10/7/2003	40	Storm	summer	83438	deer/elk	wildlife					4.28
A317	L28018-13	10/7/2003	40	Storm	summer	83437	rodent/beaver	wildlife					4.28

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A317	L28018-14	10/7/2003	42	Storm	summer	83440	avian	wildlife					4.28
A317	L28018-14	10/7/2003	42	Storm	summer	83441	avian	wildlife					4.28
A317	L28018-14	10/7/2003	42	Storm	summer	83443	raccoon	wildlife					4.28
A317	L28018-14	10/7/2003	42	Storm	summer	83442	rodent/beaver	wildlife					4.28
A317	L28018-15	10/7/2003	44	Storm	summer	83444	raccoon	wildlife					4.28
A317	L28018-15	10/7/2003	44	Storm	summer	83445	rodent/beaver	wildlife					4.28
A317	L28018-15	10/7/2003	44	Storm	summer	83446	rodent/beaver	wildlife					4.28
A317	L27770-11	10/18/2003	1000	Storm	summer	84930	avian	wildlife	180				38.29
A317	L27770-11	10/18/2003	1000	Storm	summer	84932	rodent/beaver	wildlife	180				38.29
A317	L27770-11	10/18/2003	1000	Storm	summer	84931	waterfowl	wildlife	180				38.29
A317	L27770-12	10/18/2003	1003	Storm	summer	84933	avian	wildlife					38.29
A317	L27770-12	10/18/2003	1003	Storm	summer	84934	avian	wildlife					38.29
A317	L27770-12	10/18/2003	1003	Storm	summer	84935	rodent/beaver	wildlife					38.29
A317	L27770-13	10/18/2003	1006	Storm	summer	84938	avian	wildlife					38.29
A317	L27770-13	10/18/2003	1006	Storm	summer	84936	rodent/beaver	wildlife					38.29
A317	L27770-13	10/18/2003	1006	Storm	summer	84937	unknown	unknown					38.29
A317	L27770-14	10/18/2003	1009	Storm	summer	84939	avian	wildlife					37.83
A317	L27770-14	10/18/2003	1009	Storm	summer	84941	avian	wildlife					37.83
A317	L27770-14	10/18/2003	1009	Storm	summer	84940	raccoon	wildlife					37.83
A317	L27770-14	10/18/2003	1009	Storm	summer	84942	canine	canine/feline					37.83
A317	L27770-15	10/18/2003	1012	Storm	summer	84994	avian	wildlife					37.83
A317	L27770-15	10/18/2003	1012	Storm	summer	84995	avian	wildlife					37.83
A317	L27770-15	10/18/2003	1012	Storm	summer	84996	deer/elk	wildlife					37.83
A317	L27770-15	10/18/2003	1012	Storm	summer	84993	canine	canine/feline					37.83
A317	L30144-11	11/19/2003	1027	Storm	winter	86002	avian	wildlife	1900				189.3
A317	L30144-11	11/19/2003	1027	Storm	winter	86003	rodent/beaver	wildlife	1900				189.3
A317	L30144-11	11/19/2003	1027	Storm	winter	86000	waterfowl	wildlife	1900				189.3
A317	L30144-11	11/19/2003	1027	Storm	winter	86001	waterfowl	wildlife					189.3
A317	L30144-12	11/19/2003	1029	Storm	winter	86004	avian	wildlife					189.3
A317	L30144-12	11/19/2003	1029	Storm	winter	86005	avian	wildlife					189.3
A317	L30144-12	11/19/2003	1029	Storm	winter	86006	unknown	unknown					189.3
A317	L30144-13	11/19/2003	1031	Storm	winter	86007	avian	wildlife					189.3
A317	L30144-13	11/19/2003	1031	Storm	winter	86008	canine	canine/feline					189.3

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A317	L30144-13	11/19/2003	1031	Storm	winter	86009	canine	canine/feline					189.3
A317	L30144-14	11/19/2003	1033	Storm	winter	86010	rodent/beaver	wildlife					189.3
A317	L30144-14	11/19/2003	1033	Storm	winter	86011	rodent/beaver	wildlife					189.3
A317	L30144-14	11/19/2003	1033	Storm	winter	86012	rodent/beaver	wildlife					189.3
A317	L30144-15	11/19/2003	1035	Storm	winter	86013	rodent/beaver	wildlife					189.3
A317	L30144-15	11/19/2003	1035	Storm	winter	86014	rodent/beaver	wildlife					189.3
A317	L30144-15	11/19/2003	1035	Storm	winter	86015	rodent/beaver	wildlife					189.3
A317	L29825-26	3/16/2004	1322	Base	winter	90432	avian	wildlife	180				18.27
A317	L29825-26	3/16/2004	1322	Base	winter	90434	avian	wildlife	180				18.27
A317	L29825-26	3/16/2004	1322	Base	winter	90433	raccoon	wildlife	180				18.27
A317	L29825-27	3/16/2004	1325	Base	winter	90437	raccoon	wildlife					18.27
A317	L29825-27	3/16/2004	1325	Base	winter	90436	rodent/beaver	wildlife					18.27
A317	L29825-27	3/16/2004	1325	Base	winter	90435	canine	canine/feline					18.27
A317	L29825-28	3/16/2004	1328	Base	winter	90439	avian	wildlife					18.27
A317	L29825-28	3/16/2004	1328	Base	winter	90440	avian	wildlife					18.27
A317	L29825-28	3/16/2004	1328	Base	winter	90441	rodent/beaver	wildlife					18.27
A317	L29825-28	3/16/2004	1328	Base	winter	90438	canine	canine/feline					18.27
A317	L29825-29	3/16/2004	1331	Base	winter	90443	avian	wildlife					18.27
A317	L29825-29	3/16/2004	1331	Base	winter	90442	avian	wildlife					18.27
A317	L29825-29	3/16/2004	1331	Base	winter	90444	rodent/beaver	wildlife					18.27
A317	L29825-30	3/16/2004	1334	Base	winter	90447	avian	wildlife					18.27
A317	L29825-30	3/16/2004	1334	Base	winter	90445	waterfowl	wildlife					18.27
A317	L29825-30	3/16/2004	1334	Base	winter	90446	canine	canine/feline					18.27
A317	L29940-11	3/25/2004	1222	Storm	winter	90760	avian	wildlife	640				44.41
A317	L29940-11	3/25/2004	1222	Storm	winter	90758	canine	canine/feline	640				44.41
A317	L29940-11	3/25/2004	1222	Storm	winter	90759	canine	canine/feline	640				44.41
A317	L29940-11	3/25/2004	1222	Storm	winter	90761	canine	canine/feline	640				44.41
A317	L29940-12	3/25/2004	1125	Storm	winter	90763	avian	wildlife					45.85
A317	L29940-12	3/25/2004	1125	Storm	winter	90764	avian	wildlife					45.85
A317	L29940-12	3/25/2004	1125	Storm	winter	90762	deer/elk	wildlife					45.85
A317	L29940-13	3/25/2004	1128	Storm	winter	90765	avian	wildlife					45.85
A317	L29940-13	3/25/2004	1128	Storm	winter	90766	avian	wildlife					45.85
A317	L29940-13	3/25/2004	1128	Storm	winter	90767	avian	wildlife					45.85

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A317	L29940-14	3/25/2004	1131	Storm	winter	90768	waterfowl	wildlife					45.85
A317	L29940-14	3/25/2004	1131	Storm	winter	90769	canine	canine/feline					45.85
A317	L29940-14	3/25/2004	1131	Storm	winter	90770	canine	canine/feline					45.85
A317	L29940-15	3/25/2004	1134	Storm	winter	90771	avian	wildlife					45.85
A317	L29940-15	3/25/2004	1134	Storm	winter	90772	rodent/beaver	wildlife					45.85
A317	L29940-15	3/25/2004	1134	Storm	winter	90773	rodent/beaver	wildlife					45.85
A317	L31629-11	5/26/2004	853	Storm	winter	93715	raccoon	wildlife	650				
A317	L31629-11	5/26/2004	853	Storm	winter	93714	rodent/beaver	wildlife	650				
A317	L31629-11	5/26/2004	853	Storm	winter	93713	canine	canine/feline	650				
A317	L31629-12	5/26/2004	855	Storm	winter	93716	raccoon	wildlife					
A317	L31629-12	5/26/2004	855	Storm	winter	93717	canine	canine/feline					
A317	L31629-13	5/26/2004	857	Storm	winter	93718	avian	wildlife					
A317	L31629-13	5/26/2004	857	Storm	winter	93719	rodent/beaver	wildlife					
A317	L31629-15	5/26/2004	901	Storm	winter	93720	rodent/beaver	wildlife					
A317	L31629-15	5/26/2004	901	Storm	winter	93721	rodent/beaver	wildlife					
A307	L23007-1	2/13/2002	1711	Base	winter	103494	canine	canine/feline	230		410		1.45
A307	L23007-1	2/13/2002	1711	Base	winter	103495	canine	canine/feline	230		410		1.45
A307	L23007-1	2/13/2002	1711	Base	winter	103496	canine	canine/feline	230		410		1.45
A307	L23007-1	2/13/2002	1711	Base	winter	103497	canine	canine/feline	230		410		1.45
A307	L23007-2	2/13/2002	111	Base	winter	103499	avian	wildlife	160		92		1.55
A307	L23007-2	2/13/2002	111	Base	winter	103502	coyote	wildlife	160		92		1.55
A307	L23007-2	2/13/2002	111	Base	winter	103498	raccoon	wildlife	160		92		1.55
A307	L23007-2	2/13/2002	111	Base	winter	103501	raccoon	wildlife	160		92		1.55
A307	L23007-2	2/13/2002	111	Base	winter	103500	rodent/beaver	wildlife	160		92		1.55
A307	L23007-3	2/13/2002	911	Base	winter	103504	unknown	unknown	120		90		1.45
A307	L23007-3	2/13/2002	911	Base	winter	103506	canine	canine/feline	120		90		1.45
A307	L23007-3	2/13/2002	911	Base	winter	103503	human	human	120		90		1.45
A307	L23007-3	2/13/2002	911	Base	winter	103505	human	human	120		90		1.45
A307	L23473-1,2,3	3/25/2002		Base	winter	103539	avian	wildlife					
A307	L23473-1,2,3	3/25/2002		Base	winter	103528	avian	wildlife					
A307	L23473-1,2,3	3/25/2002		Base	winter	103537	avian	wildlife					
A307	L23473-1,2,3	3/25/2002		Base	winter	103529	raccoon	wildlife					
A307	L23473-1,2,3	3/25/2002		Base	winter	103531	raccoon	wildlife					

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A307	L23473-1,2,3	3/25/2002		Base	winter	103532	rodent/beaver	wildlife					
A307	L23473-1,2,3	3/25/2002		Base	winter	103534	rodent/beaver	wildlife					
A307	L23473-1,2,3	3/25/2002		Base	winter	103535	rodent/beaver	wildlife					
A307	L23473-1,2,3	3/25/2002		Base	winter	103536	rodent/beaver	wildlife					
A307	L23473-1,2,3	3/25/2002		Base	winter	103530	canine	canine/feline					
A307	L23473-1,2,3	3/25/2002		Base	winter	103533	canine	canine/feline					
A307	L23473-1,2,3	3/25/2002		Base	winter	103538	feline	canine/feline					
A307	L23945-1	4/24/2002	1212	Base	winter	103561	rodent/beaver	wildlife	52	H	56		1.25
A307	L23945-1	4/24/2002	1212	Base	winter	103560	waterfowl	wildlife	52	H	56		1.25
A307	L23945-1	4/24/2002	1212	Base	winter	103563	waterfowl	wildlife	52	H	56		1.25
A307	L23945-1	4/24/2002	1212	Base	winter	103562	canine	canine/feline	52	H	56		1.25
A307	L23945-2	4/24/2002	2012	Base	winter	103565	avian	wildlife	50		51		1.25
A307	L23945-2	4/24/2002	2012	Base	winter	103564	raccoon	wildlife	50		51		1.25
A307	L23945-2	4/24/2002	2012	Base	winter	103567	rodent/beaver	wildlife	50		51		1.25
A307	L23945-2	4/24/2002	2012	Base	winter	103566	canine	canine/feline	50		51		1.25
A307	L23945-3	4/25/2002	412	Base	winter	103568	raccoon	wildlife	60		50		1.25
A307	L23945-3	4/25/2002	412	Base	winter	103569	rodent/beaver	wildlife	60		50		1.25
A307	L23945-3	4/25/2002	412	Base	winter	103570	canine	canine/feline	60		50		1.25
A307	L23945-3	4/25/2002	412	Base	winter	103571	canine	canine/feline	60		50		1.25
A307	L24476-1	6/12/2002	1500	Base	summer	103587	avian	wildlife	94		110		0.84
A307	L24476-1	6/12/2002	1500	Base	summer	103588	avian	wildlife	94		110		0.84
A307	L24476-1	6/12/2002	1500	Base	summer	103590	avian	wildlife	94		110		0.84
A307	L24476-1	6/12/2002	1500	Base	summer	103589	canine	canine/feline	94		110		0.84
A307	L24476-2	6/12/2002	2300	Base	summer	103593	avian	wildlife	860		2100		0.84
A307	L24476-2	6/12/2002	2300	Base	summer	103591	canine	canine/feline	860		2100		0.84
A307	L24476-2	6/12/2002	2300	Base	summer	103592	canine	canine/feline	861		2100		0.84
A307	L24476-2	6/12/2002	2300	Base	summer	103594	canine	canine/feline	861		2100		0.84
A307	L24476-3	6/13/2002	700	Base	summer	103595	canine	canine/feline	740		920		0.84
A307	L24476-3	6/13/2002	700	Base	summer	103596	canine	canine/feline	740		920		0.84
A307	L24476-3	6/13/2002	700	Base	summer	103597	canine	canine/feline	740		920		0.84
A307	L25055-4	8/6/2002	1400	Base	summer	103625	avian	wildlife	169		140		0.92
A307	L25055-4	8/6/2002	1400	Base	summer	103626	avian	wildlife	169		140		0.92
A307	L25055-4	8/6/2002	1400	Base	summer	103627	avian	wildlife	170		140		0.92

Table A-1. Project database for the Green-Duwamish watershed Microbial Source Tracking Study

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A307	L25055-4	8/6/2002	1400	Base	summer	103624	horse	livestock	170		140		0.92
A307	L25055-5	8/6/2002	2200	Base	summer	103628	avian	wildlife	240		350		0.84
A307	L25055-5	8/6/2002	2200	Base	summer	103629	canine	canine/feline	240		350		0.84
A307	L25055-6	8/6/2002	600	Base	summer	103631	avian	wildlife	170		280		1
A307	L25055-6	8/6/2002	600	Base	summer	103632	avian	wildlife	170		280		1
A307	L25055-6	8/6/2002	600	Base	summer	103630	waterfowl	wildlife	170		280		1
A307	L25934-1	10/22/2002	1500	Base	summer	103668	rodent/beaver	wildlife	41		65		0.77
A307	L25934-1	10/22/2002	1500	Base	summer	103669	rodent/beaver	wildlife	41		65		0.77
A307	L25934-1	10/22/2002	1500	Base	summer	103670	feline	canine/feline	41		65		0.77
A307	L25934-2	10/22/2002	2300	Base	summer	103672	opossum	wildlife	41		52		0.77
A307	L25934-2	10/22/2002	2300	Base	summer	103671	rodent/beaver	wildlife	41		52		0.77
A307	L25934-2	10/22/2002	2300	Base	summer	103673	rodent/beaver	wildlife	41		52		0.77
A307	L25934-3	10/23/2002	700	Base	summer	103675	avian	wildlife	60		110		0.77
A307	L25934-3	10/23/2002	700	Base	summer	103674	rodent/beaver	wildlife	60		110		0.77
A307	L25934-3	10/23/2002	700	Base	summer	103676	rodent/beaver	wildlife	60		110		0.77
A307	L26567-1	12/3/2002	1500	Base	winter	103694	raccoon	wildlife	51		54		0.77
A307	L26567-1	12/3/2002	1500	Base	winter	103693	rodent/beaver	wildlife	51		54		0.77
A307	L26567-1	12/3/2002	1500	Base	winter	103695	rodent/beaver	wildlife	51		54		0.77
A307	L26567-2	12/3/2002	2300	Base	winter	103698	avian	wildlife	41		39		0.77
A307	L26567-2	12/3/2002	2300	Base	winter	103697	avian	wildlife	41		39		0.77
A307	L26567-2	12/3/2002	2300	Base	winter	103696	feline	canine/feline	41		39		0.77
A307	L26567-3	12/4/2002	700	Storm	winter	103699	avian	wildlife	86		160		0.64
A307	L26567-3	12/4/2002	700	Storm	winter	103700	avian	wildlife	86		160		0.64
A307	L26567-3	12/4/2002	700	Storm	winter	103701	avian	wildlife	86		160		0.64
A307	L26567-3	12/4/2002	700	Storm	winter	103702	rodent/beaver	wildlife	86		160		0.64
A307	L26887-5	1/23/2003	845	Storm	winter	101589	unknown	unknown					3.82
A307	L27037-1	2/12/2003	1351	Base	winter	102899	avian	wildlife	23				1.07
A307	L27037-1	2/12/2003	1351	Base	winter	104082	avian	wildlife	23				1.07
A307	L27037-1	2/12/2003	1351	Base	winter	104083	avian	wildlife	23				1.07
A307	L27037-1	2/12/2003	1351	Base	winter	104085	avian	wildlife	23				1.07
A307	L27037-1	2/12/2003	1351	Base	winter	104088	avian	wildlife	23				1.07
A307	L27037-1	2/12/2003	1351	Base	winter	101612	raccoon	wildlife	23				1.07
A307	L27037-1	2/12/2003	1351	Base	winter	104086	raccoon	wildlife	23				1.07

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A307	L27037-1	2/12/2003	1351	Base	winter	104084	rodent/beaver	wildlife	23				1.07
A307	L27037-1	2/12/2003	1351	Base	winter	104087	waterfowl	wildlife	23				1.07
A307	L27037-2	2/12/2003	1353	Base	winter	101613	rodent/beaver	wildlife					1.07
A307	L27037-3	2/12/2003	1355	Base	winter	104058	rodent/beaver	wildlife					1.07
A307	L27037-3	2/12/2003	1355	Base	winter	104057	unknown	unknown					1.07
A307	L27037-5	2/12/2003	1359	Base	winter	101614	avian	wildlife					1.07
A307	L27361-1	2/25/2003	1224	Base	winter	104142	avian	wildlife	130				1.14
A307	L27361-1	2/25/2003	1224	Base	winter	102909	raccoon	wildlife	130				1.14
A307	L27361-1	2/25/2003	1224	Base	winter	101626	rodent/beaver	wildlife	130				1.14
A307	L27361-1	2/25/2003	1224	Base	winter	104139	feline	canine/feline	130				1.14
A307	L27361-1	2/25/2003	1224	Base	winter	104137	bovine	livestock	130				1.14
A307	L27361-1	2/25/2003	1224	Base	winter	104138	bovine	livestock	130				1.14
A307	L27361-2	2/25/2003	1227	Base	winter	101635	avian	wildlife					1.14
A307	L27361-2	2/25/2003	1227	Base	winter	101826	muskrat	wildlife					1.14
A307	L27361-3	2/25/2003	1230	Base	winter	101637	avian	wildlife					1.14
A307	L27361-3	2/25/2003	1230	Base	winter	102914	avian	wildlife					1.14
A307	L27361-4	2/25/2003	1233	Base	winter	101638	avian	wildlife					1.14
A307	L27361-4	2/25/2003	1233	Base	winter	101639	avian	wildlife					1.14
A307	L27361-4	2/25/2003	1233	Base	winter	102907	unknown	unknown					1.14
A307	L27361-5	2/25/2003	1236	Base	winter	101640	avian	wildlife					1.14
A307	L27361-5	2/25/2003	1236	Base	winter	101641	avian	wildlife					1.14
A307	L27361-5	2/25/2003	1236	Base	winter	102908	avian	wildlife					1.14
A307	L27361-5	2/25/2003	1236	Base	winter	101642	waterfowl	wildlife					1.14
A307	L27271-1	4/9/2003	701	Storm	winter	102925	canine	canine/feline	77				4.87
A307	L27271-1	4/9/2003	701	Storm	winter	102924	unknown	unknown	77				4.87
A307	L27271-2	4/9/2003	704	Storm	winter	101705	rodent/beaver	wildlife					4.87
A307	L27271-3	4/9/2003	707	Storm	winter	101706	raccoon	wildlife					4.87
A307	L27271-3	4/9/2003	707	Storm	winter	101707	raccoon	wildlife					4.87
A307	L27271-4	4/9/2003	710	Storm	winter	101708	avian	wildlife					5.42
A307	L27826-1	4/28/2003	1336	Base	winter	101814	raccoon	wildlife					0.94
A307	L27826-1	4/28/2003	1336	Base	winter	101733	canine	canine/feline					0.94
A307	L27826-2	4/28/2003	1340	Base	winter	101815	unknown	unknown					0.94
A307	L27826-4	4/28/2003	1348	Base	winter	101817	rodent/beaver	wildlife					0.94

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A307	L27826-4	4/28/2003	1348	Base	winter	101816	canine	canine/feline					0.94
A307	L27826-5	4/28/2003	1352	Base	winter	101735	avian	wildlife					0.94
A307	L27826-5	4/28/2003	1352	Base	winter	101734	canine	canine/feline					0.94
A307	L27783-2	6/2/2003	1119	Base	summer	102888	unknown	unknown					0.76
A307	L27783-3	6/2/2003	1121	Base	summer	101822	raccoon	wildlife					0.76
A307	L27783-3	6/2/2003	1121	Base	summer	101820	rodent/beaver	wildlife					0.76
A307	L27783-5	6/2/2003	1127	Base	summer	101767	raccoon	wildlife					0.76
A307	L28447-2	6/9/2003	1132	Base	summer	102891	canine	canine/feline					0.7
A307	L28447-3	6/9/2003	1134	Base	summer	101825	raccoon	wildlife					0.7
A307	L28447-3	6/9/2003	1134	Base	summer	102936	unknown	unknown					0.7
A307	L28447-4	6/9/2003	1136	Base	summer	102892	waterfowl	wildlife					0.7
A307	L28447-5	6/9/2003	1138	Base	summer	102893	waterfowl	wildlife					0.7
A307	L29246-1	8/26/2003	1302	Base	summer	82273	avian	wildlife					0.7
A307	L29246-1	8/26/2003	1302	Base	summer	82272	raccoon	wildlife					0.7
A307	L29246-1	8/26/2003	1302	Base	summer	82274	rodent/beaver	wildlife					0.7
A307	L29246-2	8/26/2003	1304	Base	summer	82275	waterfowl	wildlife					0.7
A307	L29246-2	8/26/2003	1304	Base	summer	82276	canine	canine/feline					0.7
A307	L29246-2	8/26/2003	1304	Base	summer	82277	feline	canine/feline					0.7
A307	L29246-3	8/26/2003	1306	Base	summer	82280	avian	wildlife					0.7
A307	L29246-3	8/26/2003	1306	Base	summer	82281	avian	wildlife					0.7
A307	L29246-3	8/26/2003	1306	Base	summer	82278	deer/elk	wildlife					0.7
A307	L29246-3	8/26/2003	1306	Base	summer	82279	raccoon	wildlife					0.7
A307	L29246-4	8/26/2003	1308	Base	summer	82284	waterfowl	wildlife					0.7
A307	L29246-4	8/26/2003	1308	Base	summer	82282	canine	canine/feline					0.7
A307	L29246-4	8/26/2003	1308	Base	summer	82283	unknown	unknown					0.7
A307	L29246-5	8/26/2003	1310	Base	summer	82287	avian	wildlife					0.7
A307	L29246-5	8/26/2003	1310	Base	summer	82285	rodent/beaver	wildlife					0.7
A307	L29246-5	8/26/2003	1310	Base	summer	82286	squirrel	wildlife					0.7
A307	L28018-1	10/7/2003	145	Storm	summer	83404	rodent/beaver	wildlife	460				1.63
A307	L28018-2	10/7/2003	147	Storm	summer	83405	canine	canine/feline					1.63
A307	L28018-2	10/7/2003	147	Storm	summer	83406	canine	canine/feline					1.63
A307	L28018-2	10/7/2003	147	Storm	summer	83407	canine	canine/feline					1.63
A307	L28018-3	10/7/2003	149	Storm	summer	83408	opossum	wildlife					1.63

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A307	L28018-3	10/7/2003	149	Storm	summer	83409	rodent/beaver	wildlife					1.63
A307	L28018-3	10/7/2003	149	Storm	summer	83410	rodent/beaver	wildlife					1.63
A307	L28018-4	10/7/2003	151	Storm	summer	83411	avian	wildlife					1.63
A307	L28018-4	10/7/2003	151	Storm	summer	83413	avian	wildlife					1.63
A307	L28018-4	10/7/2003	151	Storm	summer	83412	canine	canine/feline					1.63
A307	L28018-5	10/7/2003	153	Storm	summer	83414	canine	canine/feline					1.63
A307	L28018-5	10/7/2003	153	Storm	summer	83415	canine	canine/feline					1.63
A307	L27770-1	10/17/2003	941	Storm	summer	84902	avian	wildlife					2.09
A307	L27770-1	10/17/2003	941	Storm	summer	84900	rodent/beaver	wildlife					2.09
A307	L27770-1	10/17/2003	941	Storm	summer	84903	rodent/beaver	wildlife					2.09
A307	L27770-1	10/17/2003	941	Storm	summer	84901	canine	canine/feline					2.09
A307	L27770-1	10/17/2003	941	Storm	summer	84899	feline	canine/feline					2.09
A307	L27770-2	10/17/2003	943	Storm	summer	84904	avian	wildlife					2.09
A307	L27770-2	10/17/2003	943	Storm	summer	84905	rodent/beaver	wildlife					2.09
A307	L27770-3	10/17/2003	945	Storm	summer	84906	raccoon	wildlife					2.09
A307	L27770-3	10/17/2003	945	Storm	summer	84908	raccoon	wildlife					2.09
A307	L27770-3	10/17/2003	945	Storm	summer	84907	squirrel	wildlife					2.09
A307	L27770-4	10/17/2003	947	Storm	summer	84909	avian	wildlife					2.09
A307	L27770-4	10/17/2003	947	Storm	summer	84910	avian	wildlife					2.09
A307	L27770-4	10/17/2003	947	Storm	summer	84911	human	human					2.09
A307	L27770-5	10/17/2003	949	Storm	summer	84913	deer/elk	wildlife					2.09
A307	L27770-5	10/17/2003	949	Storm	summer	84912	rodent/beaver	wildlife					2.09
A307	L27770-5	10/17/2003	949	Storm	summer	84914	canine	canine/feline					2.09
A307	L30144-1	11/18/2003	1453	Storm	winter	85971	avian	wildlife	2500				3.38
A307	L30144-1	11/18/2003	1453	Storm	winter	85973	raccoon	wildlife	2500				3.38
A307	L30144-1	11/18/2003	1453	Storm	winter	85972	waterfowl	wildlife	2500				3.38
A307	L30144-2	11/18/2003	1455	Storm	winter	85975	raccoon	wildlife					3.27
A307	L30144-2	11/18/2003	1455	Storm	winter	85976	raccoon	wildlife					3.27
A307	L30144-2	11/18/2003	1455	Storm	winter	85974	waterfowl	wildlife					3.27
A307	L30144-3	11/18/2003	1457	Storm	winter	85978	avian	wildlife					3.27
A307	L30144-3	11/18/2003	1457	Storm	winter	85977	rodent/beaver	wildlife					3.27
A307	L30144-3	11/18/2003	1457	Storm	winter	85979	unknown	unknown					3.27
A307	L30144-4	11/18/2003	1459	Storm	winter	85980	avian	wildlife					3.27

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A307	L30144-4	11/18/2003	1459	Storm	winter	85981	avian	wildlife					3.27
A307	L30144-4	11/18/2003	1459	Storm	winter	85982	unknown	unknown					3.27
A307	L30144-4	11/18/2003	1459	Storm	winter	85983	unknown	unknown					3.27
A307	L30144-5	11/18/2003	1501	Storm	winter	85985	coyote	wildlife					3.27
A307	L30144-5	11/18/2003	1501	Storm	winter	85986	canine	canine/feline					3.27
A307	L30144-5	11/18/2003	1501	Storm	winter	85984	human	human					3.27
A307	L29825-1	3/16/2004	1422	Base	winter	90377	rodent/beaver	wildlife	49				1.05
A307	L29825-1	3/16/2004	1422	Base	winter	90378	rodent/beaver	wildlife	49				1.05
A307	L29825-1	3/16/2004	1422	Base	winter	90376	canine	canine/feline	49				1.05
A307	L29825-2	3/16/2004	1424	Base	winter	90379	avian	wildlife					0.99
A307	L29825-2	3/16/2004	1424	Base	winter	90380	avian	wildlife					0.99
A307	L29825-2	3/16/2004	1424	Base	winter	90495	avian	wildlife					0.99
A307	L29825-2	3/16/2004	1424	Base	winter	90496	avian	wildlife					0.99
A307	L29825-2	3/16/2004	1424	Base	winter	90381	rodent/beaver	wildlife					0.99
A307	L29825-2	3/16/2004	1424	Base	winter	90382	canine	canine/feline					0.99
A307	L29825-2	3/16/2004	1424	Base	winter	90494	human	human					0.99
A307	L29825-3	3/16/2004	1426	Base	winter	90383	raccoon	wildlife					0.99
A307	L29825-3	3/16/2004	1426	Base	winter	90384	raccoon	wildlife					0.99
A307	L29825-3	3/16/2004	1426	Base	winter	90385	raccoon	wildlife					0.99
A307	L29825-4	3/16/2004	1428	Base	winter	90388	avian	wildlife					0.99
A307	L29825-4	3/16/2004	1428	Base	winter	90387	canine	canine/feline					0.99
A307	L29825-4	3/16/2004	1428	Base	winter	90386	human	human					0.99
A307	L29825-5	3/16/2004	1430	Base	winter	90389	avian	wildlife					0.99
A307	L29825-5	3/16/2004	1430	Base	winter	90391	rodent/beaver	wildlife					0.99
A307	L29825-5	3/16/2004	1430	Base	winter	90390	canine	canine/feline					0.99
A307	L29940-1	3/25/2004	1111	Storm	winter	90729	rodent/beaver	wildlife	410				1.11
A307	L29940-1	3/25/2004	1111	Storm	winter	90727	unknown	unknown	410				1.11
A307	L29940-1	3/25/2004	1111	Storm	winter	90728	unknown	unknown	410				1.11
A307	L29940-2	3/25/2004	1113	Storm	winter	90730	unknown	unknown					1.11
A307	L29940-3	3/25/2004	1115	Storm	winter	90734	raccoon	wildlife					1.11
A307	L29940-3	3/25/2004	1115	Storm	winter	90733	unknown	unknown					1.11
A307	L29940-4	3/25/2004	1117	Storm	winter	90736	unknown	unknown					1.11
A307	L29940-4	3/25/2004	1117	Storm	winter	90738	unknown	unknown					1.11

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A307	L29940-5	3/25/2004	1119	Storm	winter	90740	avian	wildlife					1.11
A307	L29940-5	3/25/2004	1119	Storm	winter	90741	avian	wildlife					1.11
A307	L29940-5	3/25/2004	1119	Storm	winter	90739	opossum	wildlife					1.11
A307	L29940-5	3/25/2004	1119	Storm	winter	90742	unknown	unknown					1.11
A307	L31629-1	5/26/2004	741	Storm	winter	93684	avian	wildlife	6600				0.93
A307	L31629-1	5/26/2004	741	Storm	winter	93685	rodent/beaver	wildlife	6600				0.93
A307	L31629-1	5/26/2004	741	Storm	winter	93686	canine	canine/feline	6600				0.93
A307	L31629-2	5/26/2004	743	Storm	winter	93687	avian	wildlife					0.93
A307	L31629-2	5/26/2004	743	Storm	winter	93688	avian	wildlife					0.93
A307	L31629-2	5/26/2004	743	Storm	winter	93689	canine	canine/feline					0.93
A307	L31629-3	5/26/2004	745	Storm	winter	93691	waterfowl	wildlife					0.93
A307	L31629-3	5/26/2004	745	Storm	winter	93690	canine	canine/feline					0.93
A307	L31629-3	5/26/2004	745	Storm	winter	93692	unknown	unknown					0.93
A307	L31629-4	5/26/2004	747	Storm	winter	93693	avian	wildlife					0.93
A307	L31629-4	5/26/2004	747	Storm	winter	93694	unknown	unknown					0.93
A307	L31629-5	5/26/2004	749	Storm	winter	93697	avian	wildlife					0.93
A307	L31629-5	5/26/2004	749	Storm	winter	93695	rodent/beaver	wildlife					0.93
A307	L31629-5	5/26/2004	749	Storm	winter	93696	rodent/beaver	wildlife					0.93

H indicates that one or more sample handling requirements were not met in terms of sample collection, holding time, storage conditions, or sample preservation.
C indicates confluent growth; the value reported can be used as an indicator of relative abundance not as an accurate count of the associated organism.
E indicates estimate of number of microorganisms, rather than actual count.

APPENDIX B

Statistical Results

Table B-1. Mann-Whitney U test results for hydrologic and seasonal comparisons of bacteria data collected for the Green--Duwamish MST study.

Bacteria	Comparison	U[a]	p-value[b]
E. coli	All sites base versus storm	1211	**0.0000**
	E319 base versus storm	14.0	**0.0177**
	B319 base versus storm	1.0	**0.0421**
	D319 base versus storm	4.0	**0.0446**
	A310 base versus storm	3.5	**0.0013**
	O322 base versus storm	3.0	**0.0026**
	A320 base versus storm	4.0	0.1441
	A315 base versus storm	0.0	**0.0044**
	A317 base versus storm	1.5	**0.0010**
	A307 base versus storm	24.0	**0.0186**
	All sites summer versus winter	1996	**0.0096**
	E319 summer versus winter	31.5	0.6652
	B319 summer versus winter	5.0	0.3836
	D319 summer versus winter	5.0	0.0890
	A310 summer versus winter	20.0	**0.0029**
	O322 summer versus winter	25.5	0.4507
	A320 summer versus winter	15.0	0.3173
	A315 summer versus winter	8.0	0.3083
	A317 summer versus winter	32.5	0.4218
	A307 summer versus winter	64.5	0.2211
Fecal coliform[c]	All sites summer versus winter	329	**0.0004**
	E319 summer versus winter	5.0	0.5426
	B319 summer versus winter	NA	NA
	D319 summer versus winter	NA	NA
	A310 summer versus winter	6.0	0.6547
	O322 summer versus winter	2.0	0.1573
	A320 summer versus winter	6.0	0.6547
	A315 summer versus winter	2.0	0.3545
	A317 summer versus winter	0.0	**0.0339**
	A307 summer versus winter	20.5	**0.0275**

[a] Computed test statistic from Mann Whitney U-test.

[b] Values in **bold** indicate significant differences exist at $\alpha = 0.05$.

[c] Insufficient fecal coliform data were collected during storm flow to conduct the hydrologic comparison.

NA = Data not available (samples not collected).

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NA = Data not available (samples not collected).

Table B2. Spatial comparison of bacteria data collected for the Green MST.

		Site[b]				
Bacteria	p-value[a]	Low Mean Rank				High Mean Rank
E. coli						
River stations	**0.00741**	E319	B319	A310	D319	
Stream stations	**0.00802**	A320	0322	A307	A317	A315
Fecal coliform						
River stations	**0.00143**	E319	A310			
Stream stations	**0.02047**	A320	0322	A317	A307	A315

[a] Values in **bold** indicate significant differences exist between sites based on a Kruskal-Wallis ANOVA (α=0.05).

[b] Monitoring stations connected by a single unbroken line are not significantly different based on a nonparametric multiple range test.

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