WASHINGTON STATE
DEPARTMENT OF
ECOLOGY

Union River Fecal Coliform Total Maximum Daily Load Study

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Union River Fecal Coliform Total Maximum Daily Load Study

by
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Abstract

A Total Maximum Daily Load (TMDL) was initiated for the Union River for fecal coliform bacteria. Dry season concentrations higher than those in the wet season suggest that there is a continuous, steady component to the pollution loading. Since concentrations are relatively high during the wet season and flows are dramatically higher, there is also a storm-related component to the loading. Pollution sources in the basin are exclusively nonpoint. The predominant sources are likely agriculture, on-site disposal (septic) systems, and post-development activities attributable to urban development (e.g., domesticated animals). Fecal coliform loading capacity is established and load allocations are recommended.

Acknowledgments

This study would not have been possible without the help of many people.

- Jim Zimny, Craig Swanson, and the other staff at the Bremerton Kitsap County Health District for coordination with their study of the upper Union River basin and assistance throughout the project.

- Norm Glenn for his comments on the initial draft of the report.

- Michelle Ideker for formatting and editing the report.

Introduction

The Union River is a largely rural stream that is listed under Section 303(d) of the federal Clean Water Act as not meeting water quality standards for fecal coliform bacteria below the intake from the City of Bremerton domestic water supply reservoir. The Union River originates about three miles west of the Bremerton Reservoir. The main stream and its four major tributaries, Bear Creek, Hazel Creek, East Fork, and Northeast Fork, combine to make up over 13 miles of stream corridor. In addition, there are several smaller tributaries that contribute to the river's flow. The Union River flows southwest into Mason County where it discharges into Lower Hood Canal at Belfair (BKCHD, 2001). The Union River drainage supports Chinook, Chum, Coho, Steelhead, and Cutthroat Trout (CTC, 2000).

Section 303(d) of the Clean Water Act mandates that Washington State establish Total Maximum Daily Loads (TMDLs) for surface waters that do not meet standards after application of technology-based pollution controls. The U.S. Environmental Protection Agency (EPA) has established regulations (40 CFR 130) and developed guidance (EPA, 1991) for establishing TMDLs.

Under the Clean Water Act, every state has its own water quality standards designed to protect, restore, and preserve water quality. Water quality standards consist of designated uses, such as cold water biota and drinking water supply, and associated numeric criteria, needed to achieve those uses. When a lake, river, or stream fails to meet the designated water quality standards after application of required technology-based controls, the Clean Water Act requires that the state place the water body on a list of "impaired" water bodies and to prepare an analysis called a Total Maximum Daily Load (TMDL).

The goal of a TMDL is to ensure the impaired water will attain water quality standards. A TMDL includes a written, quantitative assessment of water quality problems and of the pollutant sources that cause the problems. The TMDL determines the amount of a given pollutant, which can be discharged to the water body and still meet standards, called the loading capacity, and allocates that load among the various sources. If the pollutant comes from a discrete source (point source) such as an industrial facility's discharge pipe, that facility's share of the loading capacity is called a wasteload allocation. If it comes from a diffuse source (nonpoint source) such as a farm, that facility's share is called a load allocation.

The TMDL must also consider seasonal variations and include a margin of safety that takes into account any lack of knowledge about the causes of the water quality problem or its loading capacity. The sum of the individual allocations and the margin of safety must be equal to or less than the loading capacity.

The Washington State Department of Ecology (Ecology) is establishing a TMDL for the Union River and Bear Creek for fecal coliform (FC) bacteria. This TMDL will address impairments to swimming due to high fecal coliform levels.

Project Objectives

The primary objective of this study is to evaluate and recommend a TMDL strategy, including load allocations for fecal coliform bacteria sources on the Union River, to meet state water quality standards and to protect the beneficial use of swimming in the Union River and Bear Creek (a tributary).

The study objectives will be accomplished by conducting water quality sampling in the Union River and Bear Creek. These data will be used to estimate the existing fecal coliform loads and concentrations along the length of the river. The analysis of the data will determine the loading capacity of fecal coliform needed to meet water quality standards, and load allocations will be recommended.

Geographic Setting

The study area is the Union River located on the southern Kitsap Peninsula, southeast of the Olympic National Park near Belfair, Washington. The river and its tributaries drain approximately 23 square miles (14,500 acres) and flows into Lynch Cove, which is the furthest extent of Hood Canal. The largest tributaries to the river are the East Fork, Northeast Fork, Bear Creek, and Hazel Creek.

The headwaters of the Union River begin several miles west of Bremerton at a 1500 elevation. Although the river gradients are high at the headwaters, the river is mostly a broad river valley with stream gradients near three percent. Basin soils are made up of a highly erodible mix of glacial outwash silt, sand, and gravel. Because of the low stream gradient in the lower river basin, the river has only minor erosion problems. Most eroded material is deposited near the river mouth as alluvial floodplain and mudflat sediments.

Casad Dam, located above McKenna Falls (a natural fish barrier), impounds the headwaters of the Union River. The reservoir created by the dam provides 65% of the drinking water for the City of Bremerton. The city maintains very strict water quality controls at the reservoir because it is one of the few unfiltered systems in the country. No public access is allowed to the watershed above the reservoir and the access roads are gated and patrolled. The only activity that the city allows in the 3,000 acre watershed is forestry (Cahall, 2001).

The Union River basin is located in a largely rural setting with few prominent urban areas or major point sources. Belfair, an unincorporated city located near the mouth, is the largest urban area in the basin. The most common land uses in the basin include forestry and small agricultural or livestock operations. Other land uses include a City of Bremerton domestic water supply reservoir, a county landfill, an airport, and several sand and gravel operations. Managed forests and the restricted access area for the water supply reservoir dominate the upper basin.

The lower Union River contains salmon habitat for small runs of chum, chinook, coho, cutthroat, and steelhead. Figure 1 is a map of the study area, which also indicates the locations of the previous Union River sample sites.

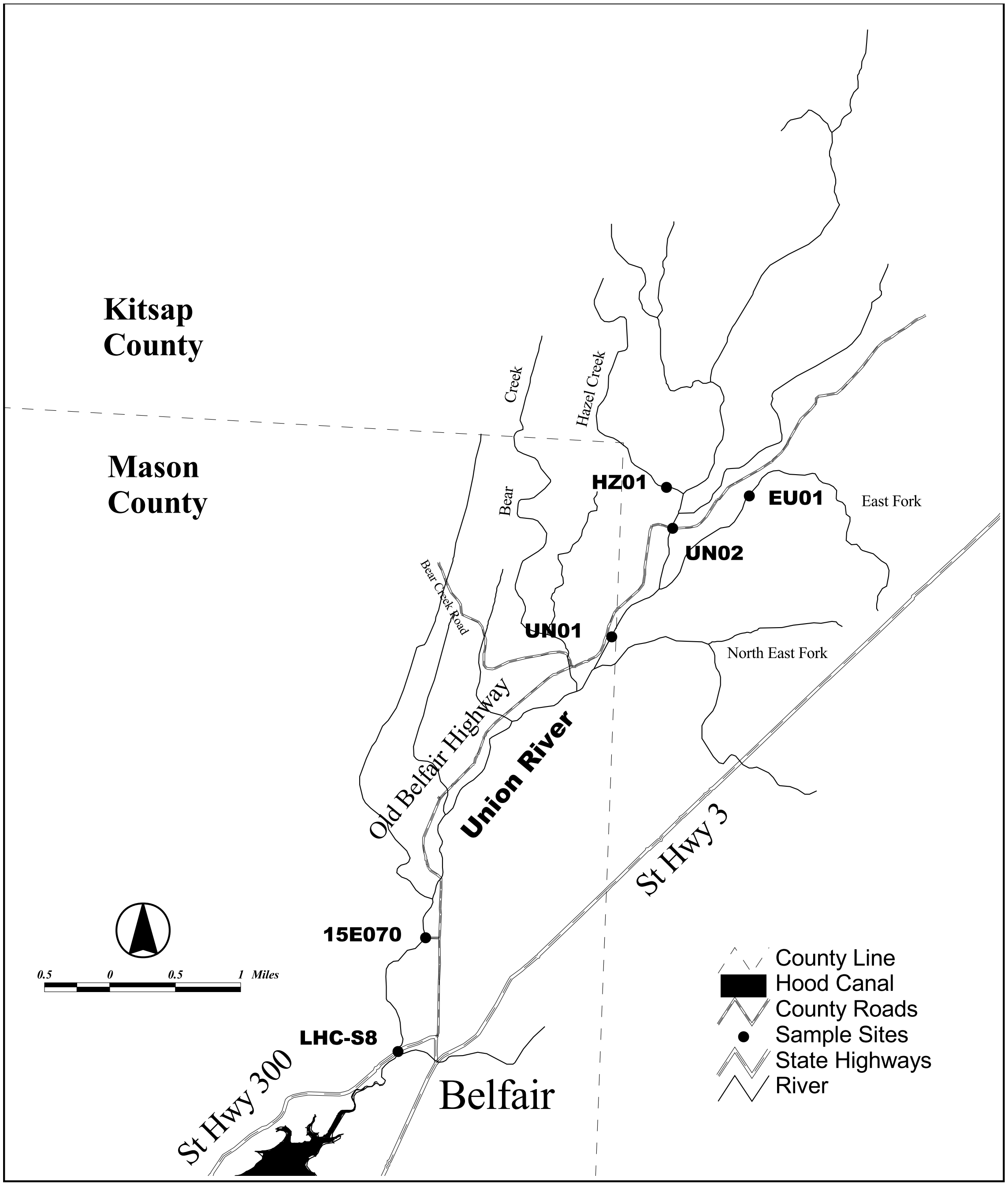

Figure 1. Previous Union River water quality monitoring stations (also see Table 1).

Applicable Water Quality Standards

Within the state of Washington, water quality standards are published pursuant to Chapter 90.48 of the Revised Code of Washington (RCW). Authority to adopt rules, regulations, and standards as are necessary to protect the environment is vested with the Department of Ecology. Under the federal Clean Water Act, the EPA Regional Administrator must approve the water quality standards adopted by the State (Section 303(c)(3)). Through adoption of these water quality standards, Washington has designated certain characteristic uses to be protected and the criteria necessary to protect these uses [Washington Administrative Code (WAC), Chapter 173-201A]. These standards were last adopted in November 1997.

This TMDL is designed to address impairments of characteristic uses caused by fecal coliform levels above state standards. The characteristic uses designated for protection in Union River are as follows:

"Characteristic uses. Characteristic uses shall include, but not be limited to, the following:
(i) Water supply (domestic, industrial, agricultural).
(ii) Stock watering.
(iii) Fish and shellfish:
Salmonid migration, rearing, spawning, and harvesting.
Other fish migration, rearing, spawning, and harvesting.
Clam, oyster and mussel rearing, spawning, and harvesting
Crustaceans and other shellfish (crabs, shrimp, crayfish, scallops, etc.) rearing, spawning, and harvesting.
(iv) Wildlife habitat.
(v) Recreation (primary contact recreation, sport fishing, boating, and aesthetic enjoyment).
(vi) Commerce and navigation."

[WAC 173-201A-030(1)(b)]

The TMDL applies to waters of the Union River Basin. These waters are designated as Class AA. The water quality standards describe criteria for fecal coliform. Different criteria apply to fresh and marine water.

For Class AA freshwaters:

> *"Freshwater – fecal coliform levels shall both not exceed a geometric mean value of 50 colonies/100 mL and not have more than 10 percent of all samples obtained for calculating the geometric mean value exceeding 100 colonies/100 mL."*

[WAC 173-201A-030(1)(c)(i)(A)]

The water quality standards describe the averaging periods in the calculation of the geometric mean for the fecal coliform criteria:

> *"In determining compliance with the fecal coliform criteria in WAC 173-201A-030, averaging of data collected beyond a thirty-day period,… shall not be permitted when such averaging would skew the data set as to mask noncompliance periods."*

[WAC 173-201A-060(3)]

Historical Study Review

Ecology's Environmental Assessment Program – Environmental Monitoring and Trends Section has collected data from one freshwater station on the Union River and one marine station in Lynch Cove near the mouth of the Union River. The freshwater station is located north of Belfair at river mile 1.7. The freshwater station was monitored once a month from October 1997 through September 1998. The marine station was monitored once a month from December 1990 through September 1996.

The Bremerton-Kitsap County Health District (BKCHD) also collected data from several stations located in the upper Union River basin. These data span the period from March 1996 to December 1998.

Further, the Mason County Water Quality Program, under a Shellfish Project, collected Union River data at the Highway 300 bridge. These data were collected on a sporadic basis from August 1990 to August 1991. Table 1 shows the names, station codes, and locations of all previous Union River monitoring stations. Sample station locations are shown in Figure 1.

Table 1. Historical fecal coliform monitoring in the Union River watershed.

Agency	**Station**	**River Mile**	**Latitude**	**Longitude**	**Period of Record**
Mason County	LHC-S8	0.5	47°27' 07"	122° 49' 57"	8/90 – 8/91
Dept. of Ecology	15E070	1.7	47°27' 53"	122° 49' 46"	10/97 - 9/98
Kitsap County	UN01	4.8	47°30' 44"	122° 47' 22"	10/97 – 12/98
Kitsap County	UN02	6.0	47°30' 44"	122° 47' 22"	3/96 – 12/98
Kitsap County	EU01	tributary	47°30' 52"	122° 47' 20"	3/96 – 7/97
Kitsap County	HZ01	tributary	47°30' 57"	122° 47' 46"	3/96 – 7/97

Historical data summaries from LHC-S8, 15E070, UN01, and UN02 are plotted in Figure 2. The existing data indicate that each station has violated the state water quality Class AA standard of 50 fecal coliform colonies/100mL. The existing data also indicate a pattern of increasing fecal coliform concentrations as you go downstream and some occasionally high concentrations at all stations. The river was originally listed because of some excursions above the fecal coliform criteria at station LHC-S8 (at Highway 300) that occurred during a 1990-91 Mason County Shellfish Protection Project study. As a result of past fecal coliform measurements that show that water quality criteria for bacteria in the Union River have been exceeded. The river has been included on the current Section 303(d) list for Washington State.

It is important to also note that the City of Bremerton collects fecal coliform bacteria water samples above the study area at least five days per week at their McKenna Falls Intake Structure in compliance with the Safe Drinking Water Act/Surface Water Treatment Rule. Because this is an unfiltered water source for the city, 90% of the samples taken during the previous six months must be less than 20 fecal coliform colonies/100ml. Since the city has consistently found fecal coliform concentrations below this allowed amount (Cahall, 2001), the data was not included in this review.

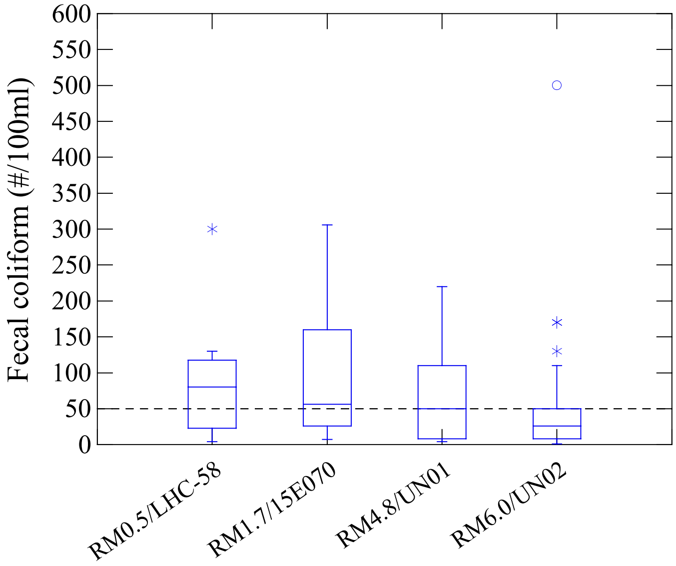

Figure 2. Fecal coliform concentration vs. river mile/sampling station in the Union River[1].

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[1] Each box represents the interquartile range or the 50% of the data between the 25th and 75th percentiles, the line in the box is the median, the end of the whiskers are the minimum and maximum data point within 1.5 times the interquartile range, an”*” is an outlier between 1.5 and 3 times the interquartile range, and an “o” is an outlier greater than 3 times the interquartile range.

Description of Pollution Sources

There are no point source discharges permitted under the National Pollutant Discharge Elimination System program (NPDES) to the Union River. Other potential fecal coliform nonpoint sources within the Union River watershed include:

- Commercial and residential septic systems.
  Septic systems can be a source of pollutants to the river if they are sub-standard, failing, or located adjacent to a waterbody. Sewage from failing residential on-site sewage systems, inadequate community wastewater treatment systems and sewage spills from sewage collection systems are all potential sources of bacteria, excess nutrients and other contaminants.

- Urban and semi-urban stormwater run-off.
  Insufficient stormwater control and treatment can cause excessive sedimentation and erosion, increased stream temperatures, decreased dissolved oxygen levels, and introduction of bacteria, toxic chemicals, metals and other contaminants.

- City of Bremerton biosolid - land application program.
  Bremerton land applies biosolids from their STP to about 470 acres in the upper Union River watershed.

- Small scale farming or commercial horticultural activities.
  Small scale farming and commercial horticulture typically involve fertilizers, pesticides, and animal wastes. In addition to use of pesticides and fertilizers, agricultural practices can impact water resources in other ways. Runoff from feedlots and manure piles, common in many agricultural areas, can be significant sources of nitrogen and phosphorus pollution to surface and groundwaters. Bacterial pollution from farms has been implicated in many shellfish bed closures around the country.

- Wildlife.
  Wildlife may contribute nutrients, particulate organic material, and pathogens to surface waters, occasionally in significant amounts. Terrestrial wildlife rarely contributes significant nutrients to surface waterbodies. However, pet wastes deposited on curbs and paved surfaces may enter surface waters as runoff during storm events and contribute significantly to excessive nutrient pollution as well as shellfish bed bacterial contamination (Horner, 1994).

Study Methods

The project's objectives were met through a combination of water quality monitoring, flow monitoring, load analysis, transport analysis, and evaluation of fecal coliform distributions within the Union River under various scenarios of flow and seasonal conditions.

Monitoring

Water quality data were collected at approximately monthly intervals between January and December 1999 at the five lower Union River basin stations (Table 2 and Figure 3). Appendix A contains the study results.

Flow gaging stations were also established at UR2Tmbr, UR3River, UR4Arch, and UR5Bear to help establish study flow curves and collect flow data for loading analysis.

Table 2. Project sampling stations.

Station ID	Location	Agency
UR1Hy300	Union River Mile 0.4 At the Highway 300 Bridge Lat: 47°27′08″, Long: 122°50′02″	Ecology
UR2Tmbr	Union River Mile 1.3 At Timberline Drive Lat: 47°27′53″, Long: 122°49′47″	Ecology
UR3River	Union River Mile 1.8 At the Old Belfair Highway Bridge Lat: 47°28′17″, Long: 122°49′39″	Ecology
UR4Arch	Union River Mile 4.5 At KCB Archery Range Lat: 47°29′47″, Long: 122°48′07″	Ecology
UR5Bear	Bear Creek River Mile 0.5 At the Bear Creek Road Bridge Lat: 47°29′47″, Long: 122°48′28″	Ecology

Project Organization

Individuals with responsibility for the supervision or implementation of the project are employees or volunteers in the Environmental Assessment Program (EA) of the Washington State Department of Ecology, P.O. Box 47600, Olympia, WA 98504-7600, (360) 407-6000, except as noted:

- *William Ward.* Project lead and principal investigator responsible for overall project management, preparation of Quality Assurance Project Plan (QAPP), project supervision, completion of field sampling events, analysis of project data, and preparation of draft and final reports.

- *William Ehinger.* Unit Supervisor responsible for project oversight, analysis of project data, development of water quality models, and review of the QAPP and final report.

- *Steve Butkus.* Responsible for analysis of project data, development of water quality models, and assistance with draft and final reports.

- *Brad Hopkins, Dale Clark, and Chris Evans.* Responsible for installation and maintenance of flow gaging stations, and development of flow rating curves.

- *Stuart Magoon and the Manchester Environmental Laboratory staff.* Responsible for the laboratory analysis. In addition, appropriate laboratory staff were also responsible for coordinating analysis requests, scheduling sample processing, conducting appropriate analyses, and entering results into the Laboratory Information Management System (LIMS) and sending hard copy of results to the project lead.

- *Cliff Kirchmer.* Responsible for review of project QAPP.

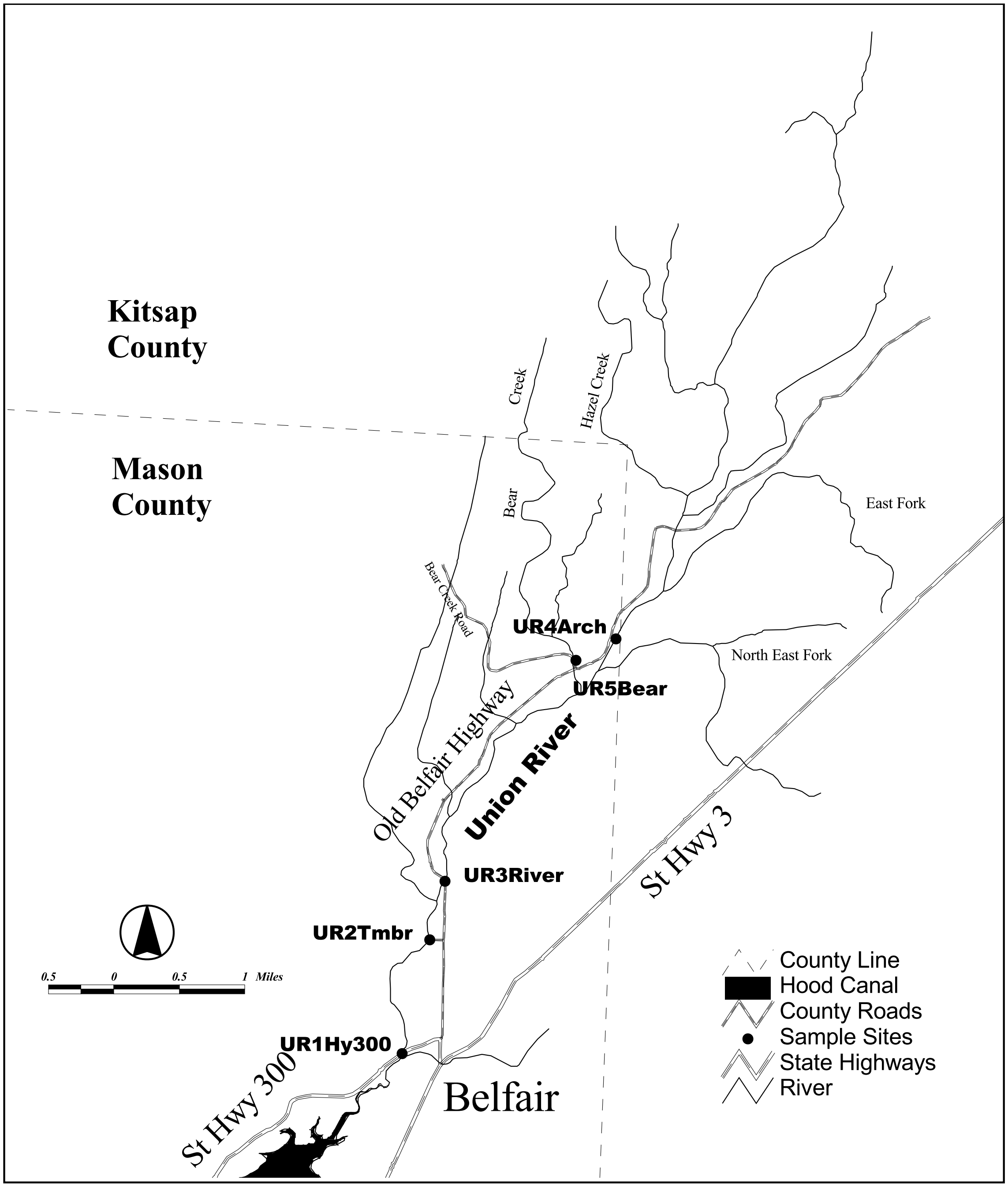

Figure 3. Union River water quality monitoring stations.

Data Quality Objectives and Analytical Procedures

Analytical methods and the detection or precision limits for field measurements and lab analyses of conventional and biological parameters are listed in Table 3. The laboratory's data quality objectives and quality control procedures are documented in the Manchester Environmental Laboratory Lab Users Manual (MEL, 1994). Data generated from laboratory analyses of the water samples collected for this study all met the MEL quality assurance requirements and were considered acceptable for use.

Table 3. Summary of field and laboratory methods.

Parameter	Abbr.	Accuracy	Method[a]
Field Measurements			
Velocity		± 0.05	Current meter
Dissolved Oxygen	DO	± 0.1 mg/L	Winkler Titration
pH		± 0.1 su	Field meter (Electrode)
Conductivity	Cond	± 1 µmhos/cm	Field meter (Electrode)
Temperature	Temp	± 0.1 °C	Field meter (Thermistor)
General Chemistry			
Ammonia	NH_3	0.01 mg/L	EPA 350.1
Nitrate-Nitrite	NO_3+NO_2	0.01 mg/L	EPA 353.2
Total Phosphorus	TP	0.01 mg/L	EPA 365.3
Orthophosphate	OP	0.01 mg/L	EPA 365.3
Total Persulfate Nitrogen	TPN	0.01 mg/L	SM 18 #4500 NO_3-F
Turbidity	Turb	0.1 NTU	EPA 180.1
Total Suspended Solids	TSS	1 mg/L	EPA 160.2
Fecal coliform MPN	FC	3 MPN/100mL	SM18 MPN[1] 9221C
Escherichia coli MPN	E. coli	3 MPN/100mL	SM18 MPN[1] 9221F

[a] SM = Standard methods for the examination of water and wastewater. Eighteenth edition (1992). American Public Health Association, American Water Works Association, and Water Environment Federation. Washington, D.C.

[1] Most Probable Number

Sampling and Quality Control Procedures

The monthly sampling and field measurement procedures used during this study followed the river and stream sampling protocols for the Environmental Monitoring and Trends Section described by Hallock, et al., (1998), and Ehinger (1995), unless otherwise noted. All surface water samples were collected in pre-cleaned containers supplied by Manchester Environmental Laboratory (MEL) and described by MEL (1994).

Water samples for specific conductivity, pH, dissolved oxygen, turbidity, total suspended solids (TSS), and nutrients were collected by lowering a stainless steel sampling bucket with two 1000mL bottles (located in attached bottle holders) just below the water surface.

Fecal coliform and E. *coli* "samples" were collected in an autoclaved bottle that was lowered just below the water surface in a flow-orienting sampler.

Samples obtained for later analysis at MEL were labeled with the date, sample site, the chemical analyses requested, and placed in coolers containing ice as soon as possible. All samples were transported to the laboratory the day they were taken. Laboratory analysis of bacterial samples began within 24 hours after sampling.

The nutrient sample for Ammonia, Nitrate-Nitrite, Total Persulfate Nitrogen, and Total Phosphorus analysis at MEL was poured from one of the 1000mL samples into a clear Nalgene bottle containing an acid preservative. A portion of the remaining 1000mL sample was then filtered through a 0.45 µm membrane filter into an amber Nalgene bottle for the Ortho-Phosphate analysis at MEL.

Dissolved oxygen "samples" were fixed immediately, and later titrated (modified Winkler titration; APHA, 1998) within 24 hours of collection.

Water temperature was measured in situ with a thermistor. River stage height “reference point” (RP) measurements were taken at each station from the bridge markers established by the Stream Hydrology Unit. Field measurements for specific conductivity and pH were made with portable Orion and Beckman meters. All field meters were calibrated in accordance with the manufacturers’ instructions.

Fecal coliform and E. coli determinations were performed by the MEL using a U.S. Food and Drug Administration (FDA) modification of the MPN method using A-1 media with MUG added (personal communication with Nancy Jensen, Manchester Environmental Laboratory). Lab quality control procedures followed standard operating procedures described in MEL (1994).

Quality Assurance

The QA program for the stream sampling protocols used by the Environmental Monitoring and Trends Section typically consists of three parts: (1) adherence to a procedure manual for sample/data collection and periodic evaluation of sampling personnel, (2) instrument calibration methods, and schedules, and (3) the collection of field quality control (QC) samples.

The only exceptions to the QA program were that no Field Blanks or Duplicates (splits) were collected to minimize costs. These QA samples were already considered to be verifiable through the annual evaluation of the ongoing ambient stream-monitoring program that has the same field sampling protocols used in the study. The QA of the 1999 ambient river and stream monitoring program indicated that the program results were within acceptable ranges as determined by Hallock et al. (2001).

The precision of the sampling was determined using the statistic of relative error (Reckhow, et al. 1986). The relative error, also known as the standard error of the coefficient of variation, presents variation as a percentage of the mean. The relative error was calculated from the results of the replicate samples taken over the study period (Table 4). The relative error of the replicate samples was found to be 184%. In similar studies of fecal coliform, Seiders (2001) and Joy (2000) found much lower values of precision from replicate samples, at 19% and 28% respectively.

Fecal coliform bacteria in stream tend to be more inherently variable than other water quality indicators. This is because bacterial populations have a patchy distribution in the environment and are intermittently discharged to streams. Coots (1994) found that the precision of replicate samples for fecal coliform increase as the concentrations decrease. The high relative error for fecal coliform replicates from this study likely result from the relatively low fecal coliform concentrations found in the samples. The fecal coliform concentrations measured in the studies of Seiders (2001) and Joy (2000) were much higher than found in this study, resulting in lower precision of replicate samples.

Table 4. Precision of Ecology fecal coliform concentrations on Union River.

Sampling Date	Station	Fecal Coliform (cfu/100mL)	
		Sample	Replicate
30 March 1999	UR4Arch	17	22
18 May 1999	UR3River	49	170
24 August 1999	UR2Tmbr	240	350
28 September 1999	UR1Hy300	49	49
26 October 1999	UR3River	33	79
14 December 1999	UR5Bear	8	23

Modeling Approach

The general approach for determining the loading capacity for fecal coliform has three parts to the analysis. First, a multivariate regression model is constructed that estimates fecal coliform levels from other variables such as season and flow. Second, fecal coliform levels are estimated from available flow data. The empirical model is used to increase sample size and to provide information on prediction uncertainty for defining a margin of safety. Third, a cumulative frequency distribution is constructed using the estimated values and the statistical rollback method (Ott, 1995) applied to determine the loading capacity and load reductions needed to meet water quality standards.

Relationships between fecal coliform, flow, and season of data collected in the Union River and Bear Creek was investigated with multivariate regression techniques. Fecal coliform concentration was modeled using the following equation:

$$\text{Log } 10[\text{Fecal coliform}] = \text{constant} + \text{log10}(\text{flow}) + \text{log10}(\text{flow})\text{\^{}}2 + \sin(2*\pi*t) + \cos(2*\pi*t) + \sin(4*\pi*t) + \cos(4*\pi*t)$$

The data were log10-transformed to stabilze the variance. Linear and quadratic flow terms were included to capture linear and curvilinear relantionships between flow and concentration. Seasonal functions (sin cos) were used to account for seasonality on an annual cycle (2*pi*t) and semiannual ((4*pi*t) cycles (where t= time in years). When a seasonal term was significant ($P<0.05$), both terms with that cycle were included (Helsel and Hirsch 1992). When the quadratic flow term was significant, both flow terms were included in the model. While this can inflate the estimates of standard error of the coefficients, it has no effect on model predictions. A smearing correction (Duan, 1983) was used to correct for bias in the predictions when converting from log space to normal space.

The empirical models derived were all found to be significant. A squared logarithmic space for flow was found to best represent each of the three models derived for four stations where flow data were available: UR2Tmbr, UR3River, UR4Arch, and UR5Bear. The bias corrected models were used for predicting the 1999 daily fecal coliform concentrations from flow and seasonality for these four stations. For those dates that flow data were not collected, the fecal coliform concentration measured for that same month was used. No flow data were collected near the mouth of the Union River at station UR1HY300, since the location is tidally influenced. For this location, the 12 monthly fecal coliform measurements were used for the analysis.

Loading Capacity Analysis

Identification of the loading capacity is an important step in developing TMDLs. The loading capacity provides a reference for calculating the amount of pollutant reduction needed to bring a water into compliance with water quality standards. By definition, a TMDL is the sum of the allocations. An allocation is defined as the portion of a receiving water's loading capacity that is assigned to a particular source. EPA defines the loading capacity as "the greatest amount of loading that a water can receive without violating water quality standards."

To determine the loading capacity requires more than just reducing the geometric mean since both criteria of the standard need to be met. The load must be reduced such that the entire distribution of values meets both criteria. One way to determine the reduction needed is with the statistical approach of rollback (Ott, 1995).

The statistical rollback method involves determining the (log) distribution statistics and calculating the 90th percentile based on the mean, standard deviation, and Z-score. The distribution is adjusted such that both the geometric mean does not exceed the part criterion of 50 cfu/100mL and no more than 10 percent of the values exceed the second part criterion of 100 cfu/100mL. The geometric mean is then determined from the adjusted distribution. If the adjusted geometric mean is less than the first part criterion of 50 cfu/100mL, then the adjusted distribution meets the standard and represents the loading capacity in the receiving water. If the adjusted geometric mean is greater than the first part criterion of 50 cfu/100mL, the distribution is adjusted further until the criterion is met and represents the loading capacity.

From the distribution of the measured and estimated fecal coliform values, different percent reductions are needed at each location to meet the standard (Tables 5 to 9).

At all stations, the 10th percentile fecal coliform criterion will need to be lower than the value specified in the standards in order to meet the geometric mean. This is based on the assumption that the distribution of fecal coliform will remain the same after the load reductions and the larger of the two criteria reductions will be needed to meet the standard overall.

Calculating the geometric mean using a period of data over 30-days is not appropriate since the result does mask noncompliance. The water quality standards confine the period for calculating the geometric mean to 30-days, only if longer averaging periods show compliance. The fecal coliform concentrations (both measured and estimated from the empirical model) verify that the water quality standard is not being met at all the stations during at least one month of the year. For example, the fecal coliform data collected at UR4Arch meets the criteria on an annual basis, but the standards are not met during the summer months.

Table 5. Load reductions needed to meet fecal coliform standards at Union River mile 0.4 (UR1Hwy300).

Date	Load Reduction Needed (%)	Geometric Mean Needed (cfu/100mL)	10% of Samples Cannot be Over(cfu/100mL)
1999 (all months)	8%	44	100

Table 6. Load reductions needed to meet fecal coliform standards at Union River mile 1.3 (UR2Tmbr).

Date	Load Reduction Needed (%)	Geometric Mean Needed (cfu/100mL)	10% of Samples Cannot be Over (cfu/100mL)
January	0	50	100
February	0	50	100
March	0	50	100
April	0	50	100
May	17%	50	70
June	29%	50	63
July	36%	50	55
August	38%	50	54
September	30%	50	66
October	0	50	100
November	10%	50	50
December	0	50	100
Annual	9%	50	100

Table 7. Load reductions needed to meet fecal coliform standards at Union River mile 1.8 (UR3River).

Date	Load Reduction Needed (%)	Geometric Mean Needed (cfu/100mL)	10% of Samples Cannot be Over (cfu/100mL)
January	0	50	100
February	0	50	100
March	0	50	100
April	0	50	100
May	3%	50	65
June	17%	50	60
July	22%	50	51
August	21%	50	53
September	17%	50	55
October	13%	50	53
November	10%	50	57
December	4%	50	62
Annual	8%	46	100

Table 8. Load reductions needed to meet fecal coliform standards at Union River mile 4.5 (UR4Arch).

Date	Load Reduction Needed (%)	Geometric Mean Needed (cfu/100mL)	10% of Samples Cannot be Over (cfu/100mL)
January	0	50	100
February	0	50	100
March	0	50	100
April	0	50	100
May	3%	50	70
June	17%	50	57
July	17%	50	57
August	7%	50	62
September	0	50	100
October	0	50	100
November	3%	50	64
December	5%	50	65
Annual	0	50	100

Table 9. Load reductions needed to meet fecal coliform standards at Bear Creek (UR5Bear).

Date	Load Reduction Needed (%)	Geometric Mean Needed (cfu/100mL)	10% of Samples Cannot be Over (cfu/100mL)
January	0	50	100
February	0	50	100
March	0	50	100
April	0	50	100
May	0	50	100
June	12%	50	62
July	7%	50	75
August	0	50	100
September	0	50	100
October	0	50	100
November	0	50	100
December	0	50	100
Annual	0	50	100

The federal statute requires that a margin of safety be identified to account for uncertainty when establishing a TMDL. The margin of safety can be explicit in the form of an allocation, or implicit in the use of conservative assumptions in the analysis. One approach to setting a margin of safety is to set allocations based on conditions during the most critical period. In the analysis of the data above, the summer months are the critical period where fecal coliform standards are not being met. The management measures used for abating the fecal coliform pollution sources are not applied seasonally, but put into place for year-round treatment. Setting the loading capacity based on the most critical month will be protective of the other months of the year when standards are currently met. Using the critical period will serve as the inherent margin of safety for this TMDL. Federal regulations allow TMDLs to be express in terms of "other appropriate measures" (40 CFR 130.2(i)). Although a fecal coliform TMDL can be presented as a load (cfu/day), the resulting numbers are of little value from a management perspective. For fecal coliform, it is more appropriate to represent the loading capacity as distribution concentrations and load reductions. Defining the loading capacity in these surrogate terms will allow monitoring data to be used to verify effectiveness of meeting the TMDL goals. Table 10 presents the load allocations for each station and Table 11 presents the surrogate measures for the TMDL. The loads from the station UR1HY300 could not be calculated since no flow data was collected. However, the fecal coliform data was sufficient to establish the TMDL surrogate measures.

Table 10. Loading capacity for fecal coliform in the Union River and Bear Creek.

Station	**Reach**	**Load Reduction Needed (%)**	**Fecal Coliform Loading Capacity (cfu/day)**
UR1HY300	Mouth to RM 1.3	8%	--
UR2Tmbr	RM 1.3 to RM 1.8	38%	4.8×10^{17}
UR3River	RM 1.8 to RM 4.5	22%	1.9×10^{12}
UR4Arch	RM 4.5 to Headwaters	17%	1.7×10^{12}
UR5Bear	Bear Creek	12%	1.4×10^{12}

Table 11. TMDL surrogate measures in the Union River and Bear Creek.

Station	**Reach**	**Geometric Mean (cfu/100mL)**	**10% of Samples Cannot be Over (cfu/100mL)**
UR1HY300	Mouth to RM 1.3	44	100
UR2Tmbr	RM 1.3 to RM 1.8	50	54
UR3River	RM 1.8 to RM 4.5	50	51
UR4Arch	RM 4.5 to Headwaters	50	57
UR5Bear	Bear Creek	50	62

Load Allocations

Available information on the relative contributions from the various nonpoint sources contributing to exceedance of the fecal coliform standards in the Union River did not allow development of load allocations by source type. The most probable sources of contamination are agricultural and livestock practices, septic tank failures, and runoff from highways and commercial businesses. Available analytical tools do not exist that allow a determination of the expected percent reduction of fecal coliform loads from specific pollution control activities that could possibly be applied. Load allocations were developed as percent reductions within each segment of the river and its tributaries and are listed in Table 10. Table lists the geometric means and the 90th percentiles estimated from the monitoring data for each site. Table 11 also lists the geometric means and 90th percentiles required to meet the standard at each site for both parts of the criteria. The percent reductions required by each part of the criteria were compared, and the most restrictive criterion was used to establish the recommended target level or load allocation (Table 10). The statistical method used to set the targets is discussed in Ott (1995). These site-specific allocations will be used to monitor the success of source control management measures taken in each subbasin.

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Appendix A

1999 Union River Laboratory and Field Measurements

Appendix A. 1999 Union River Laboratory and Field Measurements

Date	Station ID	Time (Hour)	Temp (°C)	DO (mg/L)	DO % Sat'n	pH (S.U.)	Cond (umhos /cm)	TPN (mg/L)	NH3 (mg/L)	NO2-NO3 (mg/L)	TP (mg/L)	OP (mg/L)	FC (#/100 mL)	E. coli (#/100 mL)	TSS (mg/L)	Turb. (NTU)	Baro. Press. (In. Hg)
1/26/1999	UR1HY300	9:35	5.1	11.0	86.4	6.5	57	0.500	0.010 U	0.369 J	0.018	0.019	49	49	12	4.1	30.05
1/26/1999	UR2TMBR	12:20	5.2	11.2	88.2	6.8	45	-	-	-	-	-	13	13	8	3.0	30.15
1/26/1999	UR3RIVER	12:00	5.1	11.4	89.6	6.9	44	-	-	-	-	-	27	27	9	3.0	30.10
1/26/1999	UR4ARCH	11:00	4.5	11.5	89.3	6.8	42	0.559	0.010 U	0.421 J	0.010 U	0.009	33	33	13	2.2	30.00
1/26/1999	UR5BEAR	11:30	5.5	11.8	94.0	7.0	32	0.297	0.010 U	0.221 J	0.010 U	0.014	4.5	4.5	3	0.9	29.99
2/23/1999	UR1HY300	9:15	4.7	11.9	92.5	6.9	39	0.393 J	0.015 J	0.275	0.039	0.006	23	23	60	14.0	29.98
2/23/1999	UR2TMBR	10:00	4.7	11.7	91.0	6.7	38	-	-	-	-	-	23	23	55	12.0	29.92
2/23/1999	UR3RIVER	10:30	4.7	11.8	91.8	6.9	38	-	-	-	-	-	33	33	50	13.0	29.90
2/23/1999	UR4ARCH	11:45	5.1	11.7	92.2	6.9	28	0.370 J	0.010 U	0.265	0.015	0.005	33	33	13	4.7	29.79
2/23/1999	UR5BEAR	11:10	4.6	12.1	94.2	7.0	39	0.304 J	0.010 U	0.212	0.016	0.006	2	2	8	2.9	29.82
3/30/1999	UR1HY300	9:40	5.3	11.1	87.6	6.8	81	0.507	0.016	0.365	0.047	0.024	49	23	5	2.6	30.87
3/30/1999	UR2TMBR	10:20	5.4	11.3	89.5	7.0	80	-	-	-	-	-	22	22	4	2.5	30.88
3/30/1999	UR3RIVER	10:40	5.4	11.5	91.1	7.1	78	-	-	-	-	-	22	22	5	2.3	30.88
3/30/1999	UR4ARCH	11:05	5.3	11.5	91.1	7.1	79	0.649	0.010 U	0.482	0.037	0.017	17	17	4	3.4	30.88
3/30/1999	*UR4ARCH*	11:10	5.3	11.4	90.3	7.1	79	0.633	0.010 U	0.489	0.035	0.016	22	22	3	2.2	30.88
3/30/1999	UR5BEAR	11:50	6.1	11.6	93.9	7.3	58	0.402	0.010 U	0.269	0.039	0.022	4.5	4.5	1	0.9	30.88
4/27/1999	UR1HY300	9:35	7.1	10.7	88.4	7.3	100	0.382	0.030	0.229	0.028	0.013	33	33	3	1.3	30.27
4/27/1999	UR2TMBR	10:20	7.1	11.3	93.4	7.4	105	-	-	-	-	-	49	22	2	0.9	30.25
4/27/1999	UR3RIVER	10:40	7.1	11.5	95.1	7.5	96	-	-	-	-	-	49	33	2	0.8	30.25
4/27/1999	UR4ARCH	11:20	7.1	10.9	90.4	7.4	105	0.581	0.027	0.468	0.021	0.007	23	23	2	1.2	30.14
4/27/1999	UR5BEAR	11:40	7.1	11.6	96.2	7.6	74	0.372	0.021	0.288	0.026	0.012	1.8 U	1.8 U	4	1.1	30.09
5/18/1999	UR1HY300	10:15	8.3	10.9	92.7	7.5	100	0.430	0.025	0.283	0.043	0.011	110	110	4	1.9	30.07
5/18/1999	UR2TMBR	9:50	8.2	11.8	100.2	7.3	100	-	-	-	-	-	110	70	4	1.5	30.06
5/18/1999	UR3RIVER	10:30	8.3	11.1	94.6	7.5	102	-	-	-	-	-	49	33	5	1.7	30.05
5/18/1999	*UR3RIVER*	10:30	8.3	11.1	94.6	7.4	100	-	-	-	-	-	170	110	4	1.7	30.05
5/18/1999	UR4ARCH	11:10	8.6	10.4	89.5	7.4	100	0.599	0.027	0.387	0.035	0.007	79	79	3	2.1	29.98
5/18/1999	UR5BEAR	11:40	8.1	11.3	96.1	7.8	70	0.330	0.017	0.269	0.040	0.013	110	110	1	0.8	29.98
6/29/1999	UR1HY300	9:00	9.1	10.2	88.5	7.0	102	0.383	0.018	0.332	0.044	0.018	33	33	4	1.3	30.09
6/29/1999	UR2TMBR	9:40	9.1	10.2	88.5	7.3	103	-	-	-	-	-	79	49	4	1.2	30.08
6/29/1999	UR3RIVER	10:20	9.2	10.4	90.5	7.5	100	-	-	-	-	-	110	110	4	1.5	30.06
6/29/1999	UR4ARCH	11:20	9.7	10.0	88.3	7.6	102	0.508	0.014	0.420	0.035	0.010	79	79	6	3.1	29.95
6/29/1999	UR5BEAR	10:35	8.8	11.0	95.1	7.7	70	0.302	0.010 U	0.277	0.040	0.016	33	33	2	0.5	29.94
7/27/1999	UR1HY300	9:50	9.9	9.9	87.5	7.6	111	0.390	0.021	0.269	0.051	0.019	49	49	3	1.8	29.92
7/27/1999	UR2TMBR	10:15	10.3	9.8	87.5	7.5	115	-	-	-	-	-	460	460	3	1.9	29.85
7/27/1999	UR3RIVER	10:35	10.3	10.0	89.4	7.5	108	-	-	-	-	-	170	170	3	1.4	29.80
7/27/1999	UR4ARCH	11:20	11.0	9.7	88.3	7.5	105	0.526	0.028	0.412	0.038	0.011	70	70	2	1.6	29.65
7/27/1999	UR5BEAR	11:50	10.0	10.5	93.5	7.7	81	0.292	0.017	0.265	0.044	0.016	33	33	1	0.7	29.60
8/24/1999	UR1HY300	9:00	10.1	9.6	85.3	6.9	106	0.358	0.010 U	0.270	0.050	0.023	170	170	5	1.0	29.94
8/24/1999	UR2TMBR	9:50	10.4	9.8	87.7	7.4	104	-	-	-	-	-	240	130	12	1.2	29.92
8/24/1999	*UR2TMBR*	10:00	10.4	10.0	89.5	7.5	104	-	-	-	-	-	350	350	4	1.1	29.92
8/24/1999	UR3RIVER	10:20	10.6	9.9	89.1	7.4	102	-	-	-	-	-	170	170	2	1.0	29.88
8/24/1999	UR4ARCH	11:30	11.7	9.7	89.8	7.5	106	0.445	0.010 U	0.354	0.042	0.013	79	79	2	1.5	29.75
8/24/1999	UR5BEAR	10:40	10.0	10.7	95.2	7.7	77	0.274	0.010 U	0.256	0.043	0.018	17	17	2	0.6	29.81
9/28/1999	UR1HY300	9:10	6.6	10.5	85.7	7.7	105	0.331	0.040	0.265	0.050	0.018	49	49	2	1.0	30.28
9/28/1999	*UR1HY300*	9:30	6.6	10.6	86.5	7.2	105	0.320	0.035	0.264	0.050	0.018	49	49	2	1.3	30.28
9/28/1999	UR2TMBR	10:05	7.0	10.5	86.6	7.4	106	-	-	-	-	-	23	23	1	1.0	30.24
9/28/1999	UR3RIVER	10:25	6.8	10.8	88.7	7.5	104	-	-	-	-	-	70	70	2	0.9	30.15
9/28/1999	UR4ARCH	11:20	6.9	10.8	89.1	7.5	106	0.482	0.036	0.377	0.038	0.008	31	31	2	1.5	30.05
9/28/1999	UR5BEAR	11:40	7.2	11.4	94.8	7.6	80	0.250	0.031	0.219	0.040	0.014	1.8 U	1.8 U	1 U	0.5 U	30.04
10/26/1999	UR1HY300	9:25	7.1	10.3	85.1	6.8	102	0.298	0.010 U	0.233	0.060	0.016	17	17	1	1.1	30.24
10/26/1999	UR2TMBR	10:25	7.2	10.4	86.2	7.4	104	-	-	-	-	-	17	17	1	0.8	30.20
10/26/1999	UR3RIVER	10:40	7.3	10.6	88.1	7.5	106	-	-	-	-	-	33	33	1 U	0.8	30.14
10/26/1999	*UR3RIVER*	10:55	7.2	10.7	88.7	7.4	105	-	-	-	-	-	79	79	2	0.7	30.14
10/26/1999	UR4ARCH	11:20	7.3	10.5	87.5	7.5	104	0.394	0.010 U	0.298	0.046	0.008	33	33	2	0.9	30.09
10/26/1999	UR5BEAR	12:10	7.3	11.2	93.4	7.6	76	0.199	0.010 U	0.177	0.054	0.012	4.5	4.5	1 U	0.5 U	30.05
11/30/1999	UR1HY300	9:10	6.7	10.3	84.2	7.1	80	0.493	0.013	0.342	0.040	0.014	160	110	5	2.2	30.00
11/30/1999	UR2TMBR	10:05	6.6	10.5	85.7	7.3	78	-	-	-	-	-	79	79	3	1.8	30.00
11/30/1999	UR3RIVER	10:25	6.6	10.6	86.6	7.4	75	-	-	-	-	-	110	110	3	1.7	29.99
11/30/1999	UR4ARCH	11:20	6.6	10.3	84.3	7.3	80	0.616	0.010 U	0.467	0.031	0.007	33	33	2	1.3	29.84
11/30/1999	UR5BEAR	10:45	6.4	11.3	92.1	7.5	50	0.398	0.010 U	0.330	0.024	0.006	4	4	1	0.7	29.86
12/14/1999	UR1HY300	9:35	8.7	10.8	92.8	-	51	0.451	0.011	0.346	0.033	0.013	170	170	9	4.3	-
12/14/1999	UR2TMBR	13:05	7.4	11.0	91.6	-	45	-	-	-	-	-	46	46	12	4.2	-
12/14/1999	UR3RIVER	12:45	7.3	11.1	92.3	-	48	-	-	-	-	-	49	49	11	4.8	-
12/14/1999	UR4ARCH	11:10	7.0	10.9	90.2	-	48	0.531	0.010 U	0.400	0.025	0.008	130	130	8	3.0	-
12/14/1999	UR5BEAR	12:10	7.3	11.6	96.7	-	30	0.323	0.010 U	0.266	0.022	0.007	7.8	7.8	3	1.6	-
12/14/1999	*UR5BEAR*	12:25	7.3	11.6	96.7	-	30	-	-	-	-	-	23	7.8	19	1.9	-

Station ID = Replicate sample for that survey.
- = No analysis for that parameter.
J = The analyte was positively identified; the numerical result is an estimate.
U = The analyte was not detected at or above the detection limit.