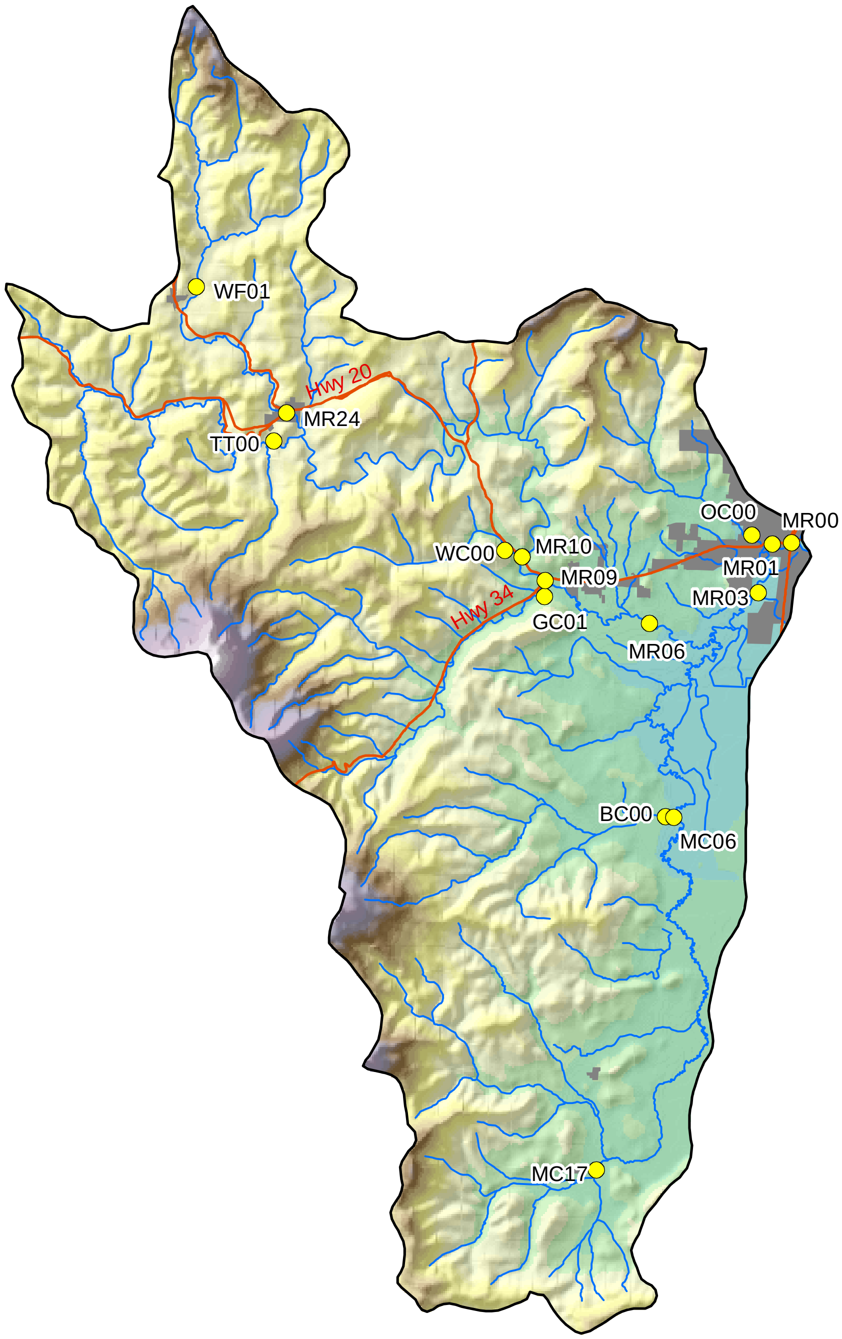
Marys River Watershed

Phase I Water Quality Monitoring



Marys River Watershed Council

and

E & S Environmental Chemistry, Inc.

MARYS RIVER WATERSHED

PHASE I WATER QUALITY MONITORING

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TABLE OF CONTENTS

SUMMARY AND CONCLUSIONS

During the Phase I Water Quality Study, 13 sites in the Marys River basin were sampled for a variety of water quality constituents monthly from August 2001 through July 2002. In addition, five sites were sampled for bacteria 5 times in 30 days according to Oregon Department of Environmental Quality methods for water quality standards compliance. Temperature data were recorded at 40 minute intervals at 13 sites in the basin between July and October 2001. Aquatic macroinvertebrates were collected and analyzed from 13 sites in the fall of 2001 and spring of 2002 in cooperation with the advanced biology classes of Philomath High School.

The purpose of the Phase I study was to obtain basic water quality data from throughout the Marys River basin in order to describe the basic water quality condition of the basin and to obtain data on which to base future plans for long-term water quality monitoring and restoration. Sampling sites were chosen to represent the full range of conditions in the basin. Some sites were at points draining high gradient, forested headwaters areas, some were in mid-basin areas draining mixed use areas, some in areas of intense agricultural activity, and others in mainstem reaches passing through developed urban areas.

The results of the Phase I study indicate that overall water quality in the Marys River basin is fair to good. Although the lower regions of the basin were too warm for cold water fish, streams draining the upper reaches appear to have water quality, primarily temperature and dissolved oxygen, sufficient to support resident trout species. Nutrient concentrations were generally low, especially nitrogen, and while there is evidence that some nutrients are reaching the streams from upland sources, the condition is not widespread in the basin. Sites sampled on Muddy Creek, however, had high concentrations of nitrogen and phosphorus in relation to other sites in the basin.

Coliform bacteria were present throughout the basin. However, based on the current *E. coli* standard, severe problems sufficient to adversely affect beneficial uses (water contact recreation) apear to be limited to one or two locations or subbasins. Fecal coliform bacteria, however, were very high throughout the watershed with respect to the former standard of 200 organisms/100 mL and the current standard for marine waters of 43 organisms/100 mL. The difference between the results for fecal coliform and *E. coli* could not be explained. Additional sampling and laboratory investigation may be necessary to resolve the discrepancy between fecal coliform and *E. coli*.

Results of bacteria sampling suggest the presence of a source of bacterial contamination in the West Fork Marys River. Upper Muddy Creek also may be subject to a source of bacterial contamination. It had the highest and most frequent high values for fecal coliform bacteria of any site sampled. Oak Creek also had high counts for bacteria, both fecal coliform and *E. coli*. Oak Creek was the only site that did not meet the *E. coli* water quality standard during the 30-day sampling.

Measured turbidity values were generally low. Chronic turbidity does not appear to be a problem. However, results from storm sampling and other studies suggest that episodic high turbidity is associated with periods of heavy rainfall and high runoff .

Three of the sites sampled during the Phase I study appear to be adversely affected with respect to water quality. Upper Muddy Creek and lower Muddy Creek show evidence of nutrient inputs from agricultural activity and effects of a possible source of bacterial contamination. Lower Muddy Creek had depressed dissolved oxygen levels suggesting a high organic load to the stream. This could be the result of increased productivity caused by nutrient inputs to the stream. Oak Creek is adversely affected by bacterial content in excess of the Oregon Department of Environmental Quality water quality standards.

INTRODUCTION

Background

The Marys River enters the Willamette River at Corvallis. Its 310 sq mi watershed drains the Coast Range on the west side of the Willamette Valley in the vicinity of Marys Peak (Figure 1). Included in the watershed are the urban areas of Philomath and Corvallis. The several tributaries and the mainstem flow through forested, agricultural, and urban lands, and are influenced by both urban and rural activities (Figure 2). Available data show that some of the tributaries and portions of the mainstem do not meet current water quality standards for water temperature or bacterial contamination. As a consequence, the Marys River, from Greasy Creek to the mouth, has been included on the list of water quality impaired water bodies (303d list) by the Oregon Department of Environmental Quality (ODEQ).

ODEQ has collected water quality data at one site near the mouth of the Marys River as part of its ongoing ambient water quality monitoring program. Prior to the Phase I study, little water quality information was available from within the watershed. While the ODEQ data are useful to indicate the general water quality condition of the basin as a whole, they are not sufficient to determine what particular area or activity within the watershed might be contributing to the observed water quality problems. Nor are the data sufficient to develop plans for restoration activity within the watershed. In order to more closely identify areas of potential adverse effect on water quality, and to adequately plan and prioritize restoration activity, more data were necessary. The Phase I Water Quality Monitoring Study was intended to be the first step to obtain the necessary information.

Other Studies

Several recent studies have examined existing data or collected data relating directly or indirectly to water quality in the Marys River watershed.

Pearcy (1999) conducted a temperature study at 42 sites in the Marys River watershed during the summers of 1998 and 1999. They found that most tributaries had temperatures that were suitable for cutthroat trout (defined as 69° F or less), but the Marys River downstream of its confluence with the Tum Tum river, and the lower reaches of some tributaries were excessively warm. Using a mathematical model (SSTEMP) they were able to accurately predict

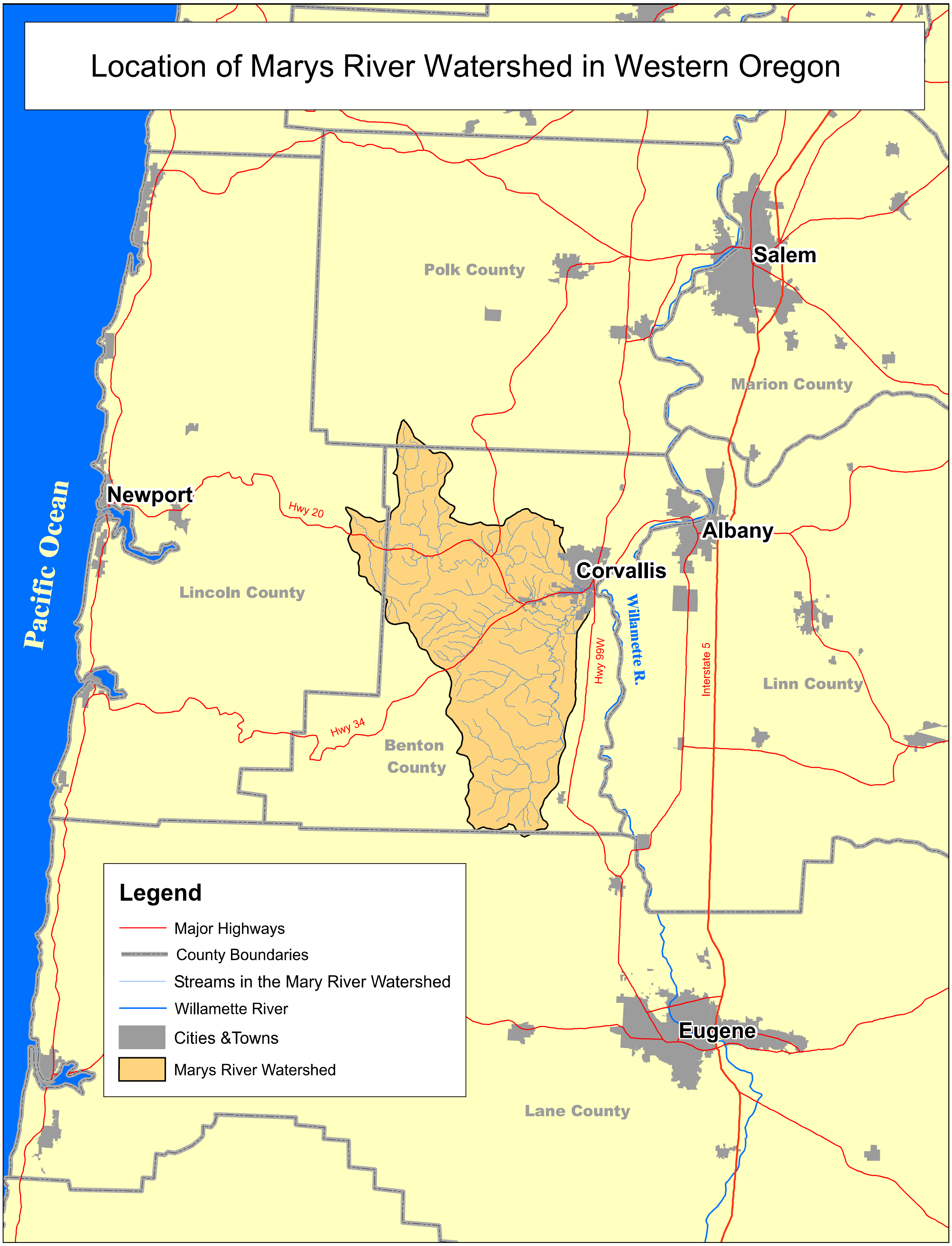

Figure 1. Map showing the location of the Marys River basin within Oregon.

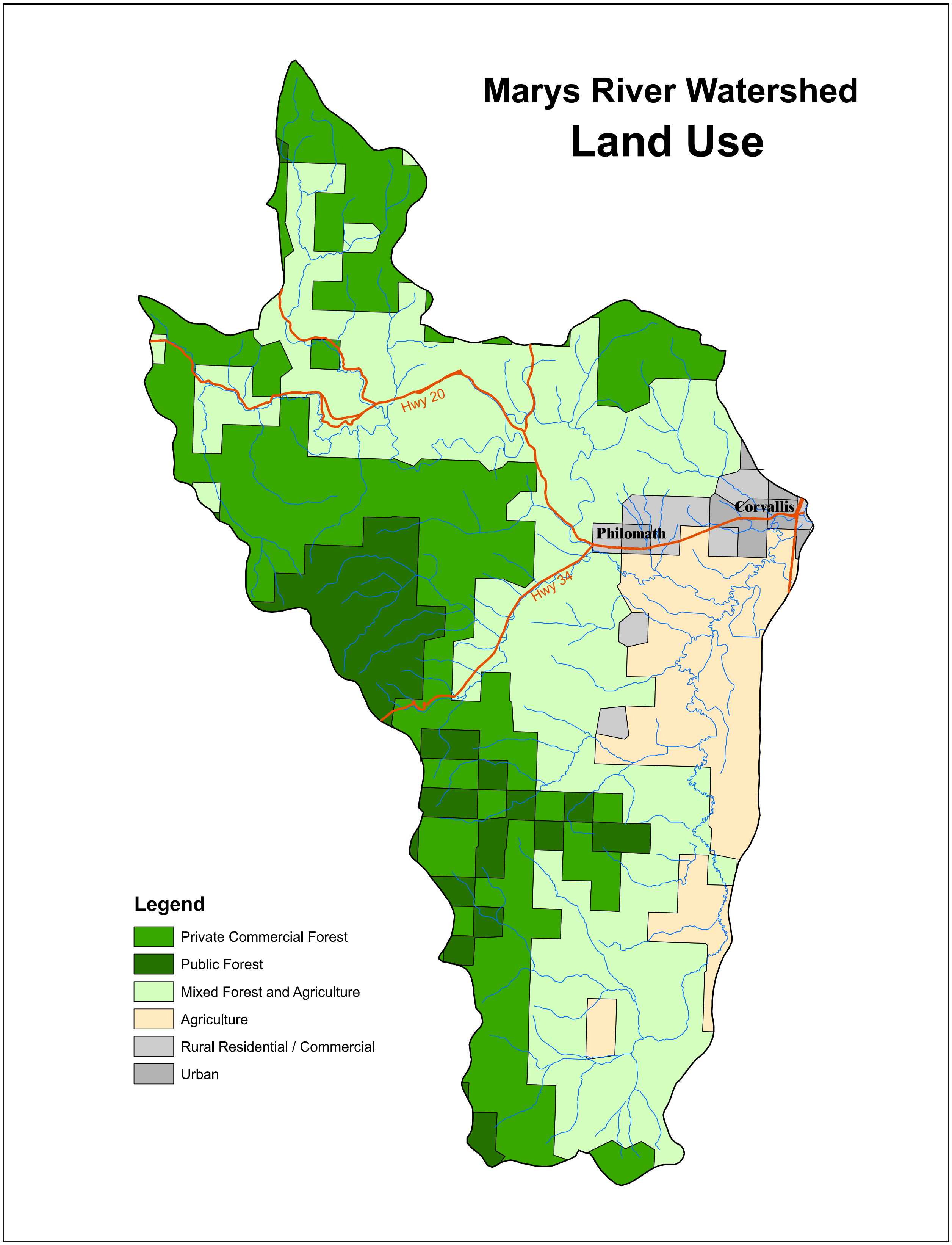

Figure 2. Map showing land use in the Marys River Watershed (Source: Ecosystems Northwest 1999).

water temperatures in a portion of the Marys River based on weather and hydrology. They determined that increased shading could effectively reduce water temperature in some portions of the river.

The Marys River Preliminary Assessment (Ecosystems Northwest 1999) reviewed existing data collected by the City of Corvallis, the City of Philomath, and ODEQ. Existing data showed bacterial contamination in Oak Creek and, to a lesser extent, in Squaw Creek, Lower Marys River, and the tributaries to Muddy Creek. Point sources, such as the Philomath waste water treatment plant, did not appear to be important sources of bacteria, but runoff from livestock operations may be a contributing factor. Fecal coliform bacteria were found in the absence of anthropogenic sources. Stream temperatures in much of the Marys River exceeded the current water quality standard for salmonid rearing of 64° F (17.8° C), but temperatures above 64° F may occur naturally. The lack of systematic long-term water quality data hampered the assessment of water quality in the basin. The authors recommended that the Watershed Council develop a long-term program to monitor water quality and quantity throughout the basin.

Glassmann (2000) conducted a study of turbidity and sediment mineralogy in the Marys River basin during 1998 to 2000. He found that the Marys River experiences high turbidity during periods of high stream discharge during the winter. The source of the turbidity and suspended sediment came mainly from deep erosional processes in the basaltic landscapes in the middle portion of the watershed. The high wintertime turbidity appeared to be largely of natural origin, although it may have been augmented by the effects of various management activities that expose deeper soil layers. Extremely high turbidity and sediment loads resulted from several man-made causes such as culvert washout on forest roads. Lack of adequate data made it difficult to determine the “background” level of turbidity in the Marys River.

An evaluation of water quality in Muddy Creek (Hulse et al. 1997) measured discharge, total suspended sediment, total phosphorus, and nitrate in Muddy Creek during two winter rainfall events. Conclusions of this work were that water quality in Muddy Creek was fair to good and that livestock operations or fertilizer applications were not widespread problems affecting surface water quality in Muddy Creek.

The ODEQ collects data on the Marys River near the mouth as part of an ongoing ambient water quality monitoring program. In their water quality index report (Cude 1996) they conclude that water quality in the Marys River is generally poor during fall, winter, and spring, and fair during the summer because of high concentrations of fecal coliform bacteria, total phosphorus, total solids, biochemical oxygen demand, and nitrate. These conditions were attributed to the presence of untreated human or animal waste, nutrients, and other organic materials in the water as a result of runoff and erosion during high flows. The report noted that the severity and frequency of adverse water quality impacts from the Philomath waste water treatment plant decreased between 1986 and 1995, and that water quality improved significantly during this period.

Oregon State University formed a study team to investigate the management of University lands along Oak Creek. Their report (Gregory et al. 2000) recommended several actions that the University should take with regard to Oak Creek. The actions include continuous monitoring at selected sites and regular synoptic monitoring of the riparian network, developing guidelines for environmentally sound manure application, removal of buildings within the riparian area whenever possible, eliminating water withdrawal from Oak Creek, removal of all dams and barriers to fish movement, and mapping of storm drains to eliminate potential hazardous waste discharges to Oak Creek.

As part of the NAWQA water monitoring program, the USGS has prepared a report detailing water quality in the Willamette River Basin for 1991 through 1995 that provides a regional context for Marys River water quality (Wenz et al. 1998).

Purpose

The purpose of the Phase I monitoring study was to obtain water quality data from key locations within the Marys River basin. The data gathered will be used to guide development of future long-term water quality monitoring plans, and to begin to develop and prioritize restoration activities within the basin. Additional specific objectives included the following:

- Determine the general water quality characteristics of various stream segments;
- Identify tributaries that are acceptable for spawning and rearing of native cold water fish species;
- Identify tributaries or stream segments that contribute to water quality degradation; and
- Identify stream segments that may be unfit for water contact recreation.

Monitoring Sites

Monitoring sites were chosen to provide information on the greatest area of the watershed within the confines of limited resources. In order to accomplish this, sites were located at the mouths of major tributaries, and on the mainstem at sites upstream and downstream of areas that might potentially contribute to water quality problems. Ultimately, fifteen sites were sampled, seven on the Marys River mainstem, two on Muddy Creek, and one each near the mouths of Oak Creek, Beaver Creek, Greasy Creek, Woods Creek, Tum Tum River, and the West Fork Marys River. The tributary sample sites encompassed water draining approximately 54 percent of the total watershed area not including sites on lower Muddy Creek and mainstem Marys River. The details of the location and characteristics of the sites are provided in Figure 3 and Table 1.

Table 1. Phase I sample sites in the Marys River basin.

Site ID[1]	Description	Latitude	Longitude
BC00	Beaver Creek at Tyee Winery Bridge	44.45664	123.32305
GC01	Greasy Creek at Grange Hall Bridge	44.53397	123.38746
MC06	Muddy Creek at Greenberry Rd Bridge	44.45657	123.31883
MC17	Muddy Creek at Alpine Bridge	44.32914	123.35129
MR00	Highway 99 Bridge over Marys River	44.55644	123.26460
MR01	Marys River Avery Park Bridge	44.55563	123.27423
MR03	Marys River at Thom Whittier's	44.53813	123.28017
MR06	Marys River at Bellfountain Rd Bridge	44.52572	123.33444
MR09	Marys River at Highway 34 Bridge	44.53988	123.38734
MR10	Marys River at Highway 20 Bridge (Lumber Yard)	44.54810	123.39937
MR24	Marys River at Blodgett	44.59662	123.52033
OC00	Oak Creek near mouth	44.55881	123.28438
TT00	Tum Tum River near mouth	44.58617	123.52604
WC00	Woods Creek near mouth	44.54810	123.39937
WF01	West Fork Marys River at Long Rd Bridge	44.64047	123.56772

[1] Site IDs consist of a two-letter code for the stream, and a two-digit code for the approximate river mile above the mouth. Thus, MR06 is on the Marys River about 6 mi above the mouth.

The sites chosen represent different geomorphic regions of the basin:

- Forested headwaters area

    WF01, MR24, TT00

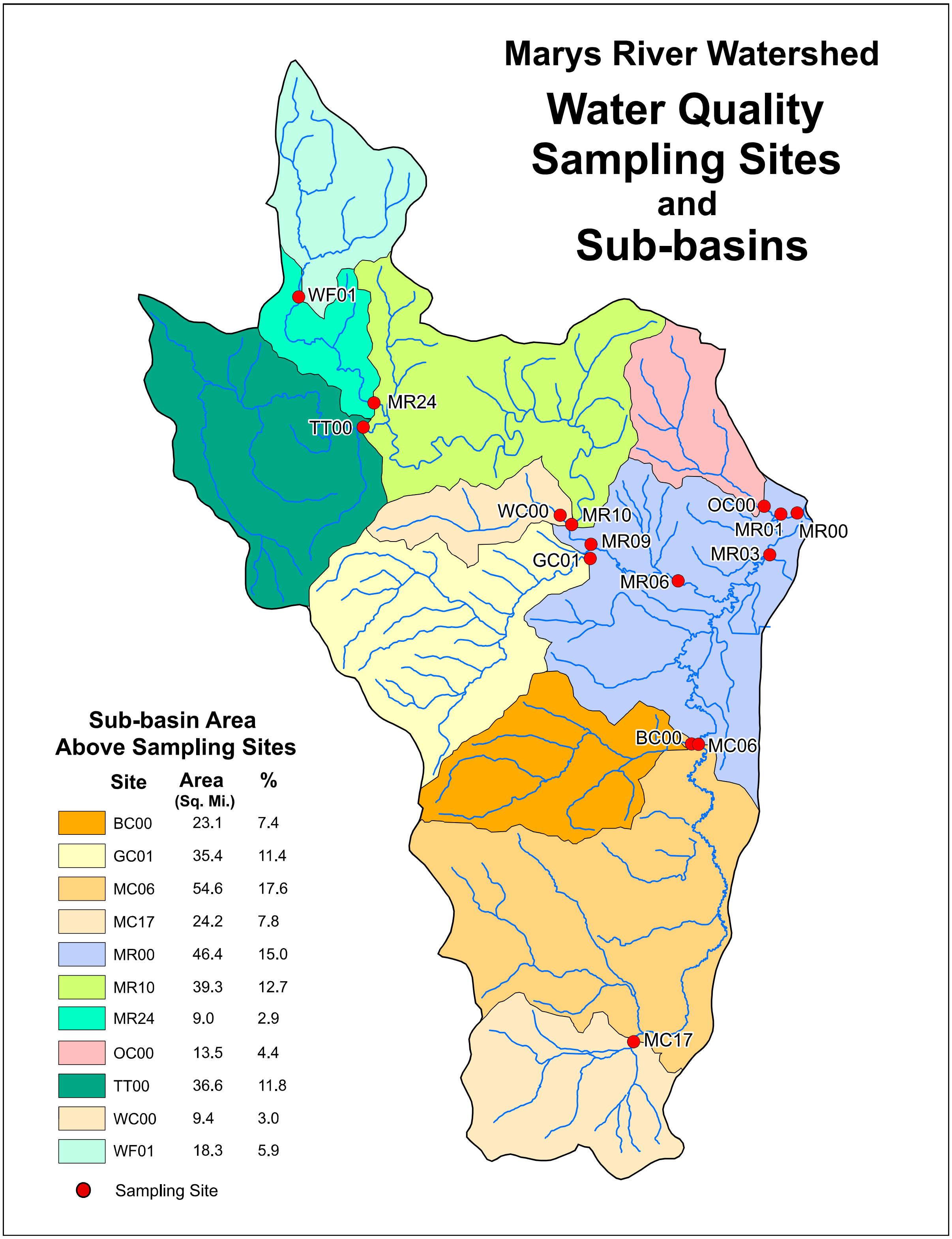

Figure 3. Phase I sample sites in the Marys River basin.

- Mid-basin mixed use area

  WC00, GC01, BC00, MR10, MR09, MC17
- Muddy Creek agricultural area

  MC06
- Oak Creek

  OC00
- Main stem subject to urban influence

  MR06, MR03, MR01, MR00

Constituents

Constituents to be measured were chosen to provide basic information about the water quality conditions in the streams, as well as information about specific water quality concerns. To that end the following constituents were measured:

For general water quality conditions,

- Water temperature
- Dissolved oxygen concentration and percent saturation
- pH
- Specific conductance
- Turbidity
- Aquatic macroinvertebrates (in cooperation with Philomath High School)

For specific water quality concerns,

- Fecal coliform bacteria
- *Escherichia coli* bacteria
- Nitrate nitrogen
- Total Kjeldahl nitrogen
- Total phosphorus

Water Temperature

Cool water is necessary for the survival and success of native trout and a variety of other aquatic life. Excessively warm temperature can adversely affect the survival and growth of many native species. Although there is some debate about which temperature criteria are appropriate for lowland streams and rivers, current Oregon water quality standards, applied to nearly all Oregon streams, are designed to protect salmonids. Temperature was included in this study because portions of the Marys River have been determined to exceed the existing salmonid rearing criterion.

Dissolved Oxygen

Aquatic organisms need oxygen to survive. Oxygen from the air dissolves in water in inverse proportion to the water temperature. Warmer water contains less dissolved oxygen at saturated conditions. Organisms adapted to cool water are usually also adapted to relatively high dissolved oxygen conditions. If the dissolved oxygen is too low, the growth and survival of these organisms is jeopardized. Dissolved oxygen can be reduced by bacterial respiration if discharges or overland runoff containing high concentration of organic material enters the stream. High concentration of nitrogen and phosphorus can also lead to conditions with low oxygen. Dissolved oxygen was included in this study because it is an important determinant of stream health.

pH

pH is a measure of the acidity of water. The chemical form and availability of nutrients, as well as the toxicity of pollutants, can be strongly influenced by pH. Pollutants can contribute to changes in pH as can the growth of aquatic plants through photosynthesis. Excessively high or low pH can create conditions directly toxic to aquatic organisms, or indirectly toxic by influencing the availability and toxicity of metals, ammonia, or other potentially toxic ions. pH was included in this study because it is an important indicator of potential water quality problems.

Specific conductance

Specific conductance is a measure of the ability of water to conduct an electric current. It is an indirect measure of the amount of dissolved substances in the water. At relatively high levels, dissolved substances adversely affect the use of water for beneficial uses such as drinking or stock watering, and can become directly toxic to aquatic organisms. At the lower levels found in the Marys River, changes in specific conductance can indicate the presence of polluted discharge or overland runoff entering a stream. Specific conductance was included in this study as an indicator of possible contamination.

Aquatic macroinvertebrates

Aquatic organisms living in the stream can be a better indicator of stream health than chemical measurements of water quality. Many invertebrate organisms live in the stream for months or years, do not move far relative to the stream length, and so are affected for a long time by the conditions in the stream. Aquatic organisms thus integrate the conditions over a longer period while chemical measurements are typically taken at a single instant in time. Certain organisms are particularly sensitive to impaired water quality, and others are tolerant of polluted conditions. An estimate of water quality conditions can be developed by collecting samples of the small aquatic organisms living in the stream bottom, identifying what organisms are present and abundant, and comparing those to the species present at particular reference sites. Aquatic macroinvertebrates were included in this study as an indicator of water quality conditions.

Bacteria

Bacteria occur naturally in all bodies of water. Certain types of bacteria, however, can indicate the presence of contamination by animal or human wastes. Contact with or ingestion of certain bacteria, viruses, protozoa, and other microbes can cause skin and respiratory ailments, gastroenteritis, and other illnesses. By controlling the presence of indicator bacteria, it is assumed that other harmful bacteria are also being controlled. Two forms of bacteria are commonly used as indicator species, fecal coliform bacteria and *Escherichia coli*. The current ODEQ water quality standard for ambient water is based on *E. coli*. Bacteria were included in this study because portions of the Marys River have been included in the 303d list of water quality impaired water bodies for bacteria in non-summer months.

Nitrogen

Nitrogen contamination of groundwater is a major concern, especially in regions where agricultural fertilizers are applied. When ingested by humans, high concentrations of nitrate can be converted to nitrite and lead to methemoglobinemia (blue baby syndrome) which can be fatal to infants. Nitrate is soluble and moves quickly through soils. Although there are natural sources of nitrate in water (rainfall, decay of plant material, bacterial nitrogen fixation, and animal manure), the presence of high levels of nitrate in stream water can indicate potential contamination. Nitrogen is also a primary algal nutrient. High levels of nitrogen can lead to excessive growth of algae and aquatic plants which can become a nuisance and also adversely affect water quality. Total Kjeldahl nitrogen is a measure of the total amount of organically-bound nitrogen. After decomposition it can be converted to nitrate. Nitrate was included in this study as an indicator of potential stream contamination.

Phosphorus

Phosphorus occurs in rocks and other mineral deposits, but it also enters surface water as partially treated or untreated sewage, runoff from agricultural sites, and runoff from fertilized lawns. Phosphorus is a key element necessary for the growth of plants, and if present in excess in aquatic systems can lead to eutrophication – the overproduction of algae. This overproduction can lead to a variety of problems ranging from low dissolved oxygen, excessively high pH, decrease in diversity, poor food supply, and perhaps toxic algal blooms. Phosphorus was included in this study as an indicator of possible water quality problems.

Turbidity

Turbidity is a measure of the clarity of the water. High turbidity is associated with high suspended solids, and can be an indicator of erosion related to land use in the watershed. At high levels of turbidity the ability of salmonids to see their prey is impaired. High sediment loads can bury gravel areas necessary for salmonid spawning and invertebrate habitat. Phosphorus is also closely associated with fine soil particles, so high turbidity can be an indicator of high phosphorus loading to the stream. Turbidity was included in this study as an indicator of possible adverse water quality effects from land management activities.

Sampling Design

Four different sampling schemes were used during the Phase I study. Most constituents were sampled monthly at thirteen sites throughout the watershed in order to provide a general overview of water quality conditions in the basin. Incorporated into the monthly sampling were specific samples during the low flow period in summer and during a rainfall event near the beginning of the winter rainy period. In addition to the regular monthly samples, bacteria samples were collected five times in a 30-day period in summer 2001 to correspond with the sampling regime used by ODEQ for water quality standards compliance. Compliance monitoring samples were clustered in areas of known problems (Oak Creek) and areas where most summertime water contact recreation occurs (lower Marys River).

Temperature was recorded during the monthly sampling visits, but was also recorded using automated data loggers (Onset Optic Stowaways) at 40-minute intervals at 13 sites between mid July and October, 2001. The calibration of the data loggers was verified prior to installation. At one site (MR01) temperature was recorded until early November. Data from the automated data loggers form the basis for conclusions about temperature in the basin.

Aquatic macroinvertebrate sampling was conducted in cooperation with Philomath High School. Students in the advanced field biology class collected samples from 13 sites during fall 2001 and spring 2002. The students analyzed the samples. A check set of samples was provided to a professional lab for verification and validation of the students' work. Table 2 presents the distribution of various sampling methods among the 15 selected sites.

Table 2. Locations sampled during the Phase I study.

Site ID	Site Name	Monthly	30-day Bacteria	Temperature	Invertebrates
MR00	Highway 99		✓		
MR01	Avery Park	✓	✓	✓	✓
MR03	Whittier	✓	✓	✓	✓
MR06	Bellfountain	✓	✓	✓	✓
MR09	Highway 34		✓		
MR10	Lumber	✓		✓	✓
MR24	Blodgett	✓		✓	✓
MC06	Greenberry	✓		✓	✓
MC17	Alpine	✓		✓	✓
WF01	West Fork	✓		✓	✓
TT00	Tum Tum	✓		✓	✓
WC01	Woods Creek	✓		✓	✓
GC01	Greasy Creek	✓		✓	✓
BC01	Tyee	✓		✓	✓
OC01	Oak Creek	✓	✓	✓	✓

[1] Sites MR00 and MR09 were only sampled during July and August 2001 and were not included in the monthly water quality sampling.

METHODS

Sampling

Sampling methods followed the Oregon Salmon Plan (OWEB 1999) protocols. Water samples were collected directly from the stream into clean bottles. When access to the stream was not possible due to high water or other factors, samples were collected using a clean bucket from a bridge crossing and dispensed into clean bottles. Samples were kept on ice and delivered to the laboratory for analysis the same day they were collected. Replicate samples for quality assurance were collected with every sample batch.

Bacteria samples were collected into clean sterile bottles supplied by the laboratory according to instructions provided by the lab. Samples were kept on ice and returned to the lab for processing within six hours of the time they were collected.

Field measurements for dissolved oxygen, pH, specific conductance, and temperature were made with a YSI 600 Multiparameter datasonde and Model 610DM data logger. Prior to each use the instrument was calibrated according to the manufacturers instructions.

Laboratory

Water and bacteria samples were analyzed according to standard methods by Pacific Analytical Laboratory of Corvallis, Ore. Methods and reporting limits are presented in Table 3.

For nitrate and TKN, most results were below the method reporting limit. For some of those analyses the laboratory was able to provide estimated values. Because these estimated values are lower than the reporting limit, they cannot be considered analytically valid, but, in the absence of other data, they can provide some insight into the water quality conditions in the basin.

Table 3. Analytical methods used during the Phase I study.

Constituent	Method	Reporting Limit	Units
Fecal coliform	SM 9223B	<1	MPN index/100 mL
E. coli	SM 9223B	<1	MPN index/100 mL
Nitrate nitrogen	SM 4500-NO3-D	1.0	mg/L
TKN	SM4500-Norg-B	0.5	mg/L
Total phosphorus	SM 4500-P-B5D	0.01	mg/L
Turbidity	SM 2130B	0.1	NTU

RESULTS

Temperature

Water temperature was measured at 40-minute intervals from July 12, 2001 through October 8, 2001 at 13 sites. At one site, MR01, temperature monitoring continued until November 2, 2001. The minimum water temperature was 9.9° C measured in West Fork Marys River (WF01) on September 29th, the maximum temperature of 25.6° C was measured in the Marys River at site MR10 on August 12th. Descriptive statistics for the temperature data are provided in Appendix Table A-10. As can be seen in the summary box plot (Figure 4)[1], there is a clear trend in temperature. In general, sites in the upper regions of the watershed, or draining forested areas, had cooler temperatures than sites lower in the watershed or draining agricultural areas. The sites can be grouped into three sets based on their temperature characteristics:

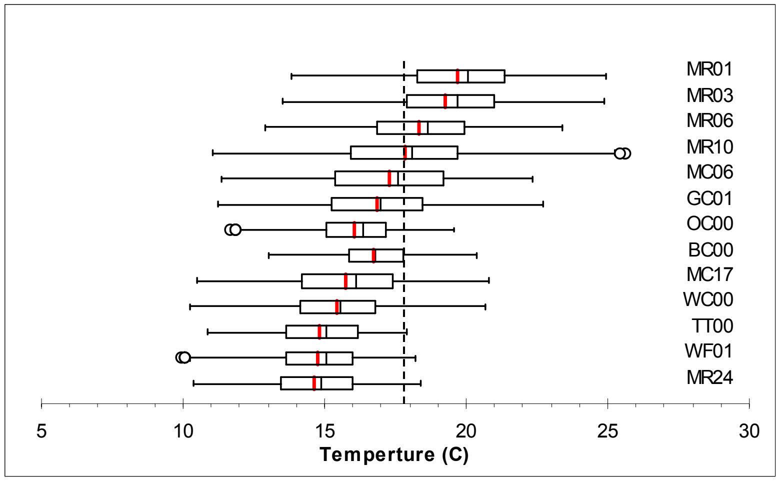

Figure 4. Distribution of temperature values measured at 40-minute intervals at various locations in the Marys River basin July to October, 2001. The dashed line marks the water quality standard maximum temperature for salmonid rearing.

- Sites MR24, WF01, and TT00 were the coolest and showed the smallest response to ambient air temperature. These sites are all high in the watershed, have relatively steep gradient, and drain largely forested areas.

- Sites MR01, MR03, MR06, MR10, MC06, and GC01 were the warmest, and showed the greatest response to ambient air temperature. These sites are all low in the watershed, have low gradient, drain largely agricultural or urban areas, or have relatively small flows during the summer.

- Sites OC00, BC00, MC17, and WC00 were intermediate in temperature and response, and are also located in an intermediate position in the watershed, or drain mixed-use areas.

[1] Box plots represent the data distribution. The ends of the box represent the 25th and 75th percentiles. The heavy line through the box is the mean, the lighter line the median. The "whiskers" extend to the furthest data point within 1.5 times the interquartile distance from the ends of the box. Circles represent statistical outliers.

Figure 5 shows the 7-day running average daily maximum temperature for the sites monitored. The 7-day running mean is the basis for the ODEQ water quality standard. Several patterns are evident in addition to the overall warming as water travels downstream. Temperatures at all sites show several congruent increases and decreases in temperature throughout the summer. These general changes in temperature are a response to ambient air temperatures as illustrated in Figure 6. In addition all sites exhibit a general cooling trend from July to October, and the difference in temperature between sites becomes smaller and tends to converge. Water temperature differences between sites are likely to be small during the winter.

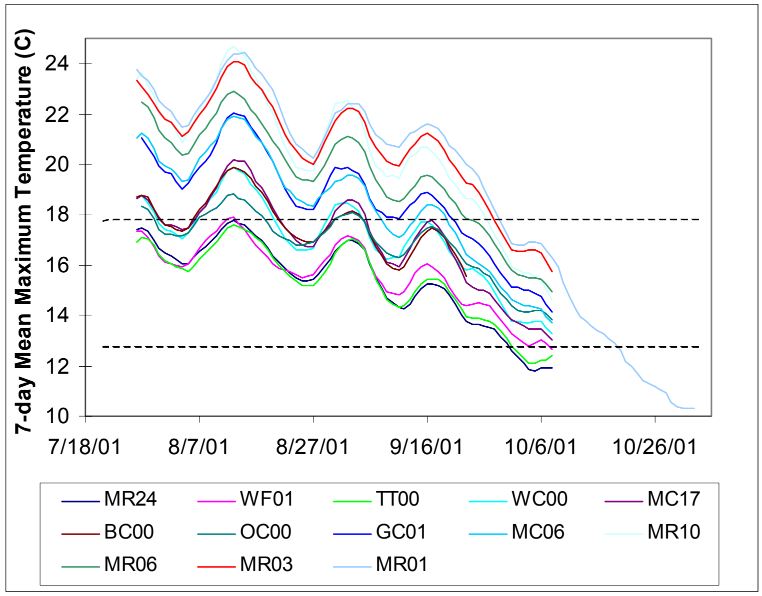

Figure 5. 7-day running mean of maximum daily water temperature measured at various locations in the Marys River basin. The horizontal lines mark the ODEQ water quality standard for salmonid rearing and spawning.

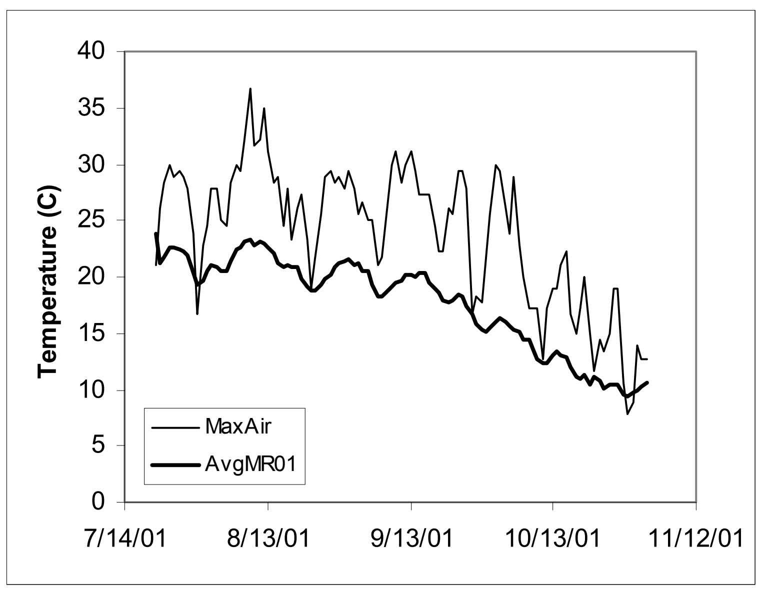

Figure 6. Maximum air temperature at Corvallis and mean daily water temperature in the Marys River near the mouth.

There was a warming trend evident in both Muddy Creek and Marys River, the only streams with multiple sites. Based on comparison of seasonal median temperatures at each site, the trend was 0.13° C per river mile for Muddy Creek, and 0.22° C per river mile on the Marys River below RM 24. Similar calculation using the warmest day, August 12th, gave slightly higher warming rates; 0.16° C per mile for Muddy Creek and 0.28° C per mile for Marys

River (Figure 7). These values are similar to values observed by Andrus and Pearcy (Pearcy 1999). The warming observed is not, however, strictly linear. Superimposed on the general downstream warming trend are localized variations, most likely the result of input from cold groundwater. For example, on the day of warmest temperature at site MR01 (8/12/01), the overall warming rate in the Marys River was 0.28º C per mile, but site MR10 had the warmest temperature (25.6º C) and the furthest upstream site (WF01) was warmer (18.1º C) than the next site downstream (MR24, 17.89º C).

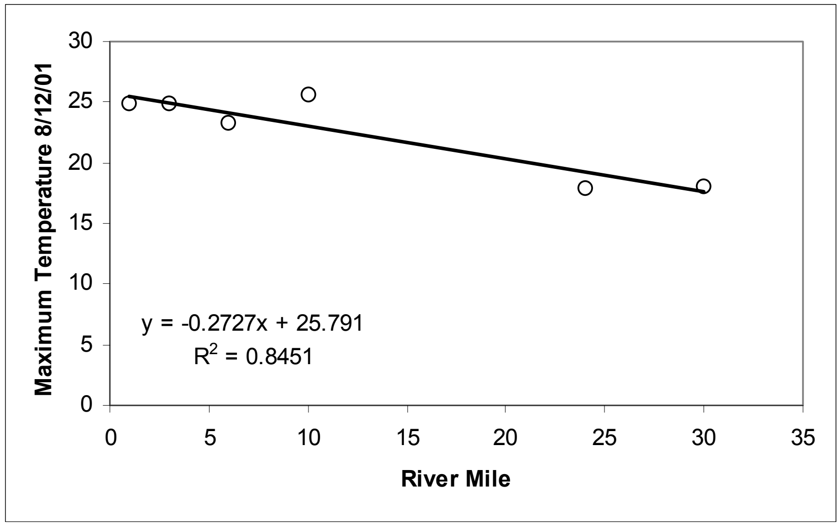

Figure 7. Graph of daily maximum temperature on August 12, 2001 against river mile in Marys River. The slope of the regression line shows a warming trend of 0.28° C per mile.

At only three of the sites (MR24, WF01, TT00) was the 7-day average maximum temperature (7-day average) always less than the current water quality standard for salmonid rearing of 17.8º C (64º F). The 7-day average at all the other sites exceeded the water quality standard for at least several days during the summer. At the six warmest sites, the 7-day average was above the standard for most of the summer.

Bacteria

Bacteria were sampled under two regimes; monthly at 13 sites to obtain a general picture of conditions in the watershed, and 5 times in 30 days during July and August, 2001 at six sites, to correspond with ODEQ methodology for determining water quality standards compliance. The results of bacteria compliance monitoring are presented in Table 4.

The water quality standard for *E. coli* requires that the log mean of five or more samples taken within 30 days be less than 126 organisms/100 mL with a single sample maximum not to exceed 406 organisms per 100 mL. Only the site at the mouth of Oak Creek exceeded the standard. At Oak Creek, both the log mean and the single sample maximum exceeded the standard.

Table 4. Results of bacteria (*E coli*) compliance monitoring in Marys River during July and August 2001. The results are based on five samples collected with in a 30-day period.		
Site	**Log Mean (n =5) No./100mL**	**Single Sample Maximum No./100mL**
MR00	28.81	46
MR01	39.09	80
MR03	55.01	140
MR06	88.73	180
MR09	46.25	76
OC01	155.9	2400

Both *E. coli* and fecal coliform bacteria were sampled during the monthly monitoring. Descriptive statistics for bacteria data are presented in Appendix Table A-1 and A-3. Fecal coliform results were highly variable, with sample results spanning nearly the complete range of the test (< 1 to > 2400 organisms/100 mL) on nearly every sampling occasion. Site MC17 had the highest number of fecal coliform samples exceeding 2000 organisms/100 mL (58 percent), followed by OC01 (43 percent), WC00 (41 percent) GC01 (38 percent) and WF01 (37 percent). No other site had more than 25 percent of samples with fecal coliform >2000 organisms/100 mL. Samples collected in February, March, and April were notable for their relatively low numbers of fecal coliforms (Figure 8). However, measured values at virtually all sites and sample occasions were very high compared with the former health standard (200 organisms/100 mL). Appendix Map A-1 shows the distribution of mean values for fecal coliform.

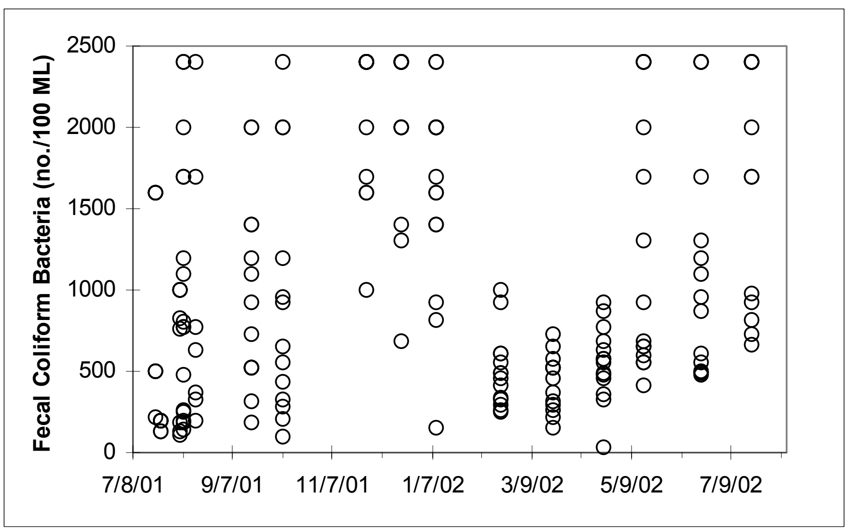

Figure 8. Fecal coliform bacteria measured at various sites in the Marys River basin in 2001 and 2002.

Also notable in the fecal coliform results were the relatively low numbers of fecal coliform bacteria found in the Marys River. With the exception site MR06, median values of fecal coliform for the Marys River sites were all well below 1000 organisms/100 mL, with most below 500. Site MR06 in contrast had a median value of 1500 organisms/100 mL (Figure 9). This suggests that there could be a source of bacterial contamination between site MR10 and site MR06, a reach of the river that encompasses the urban area of Philomath, and the Philomath Wastewater Treatment Plant outfall.

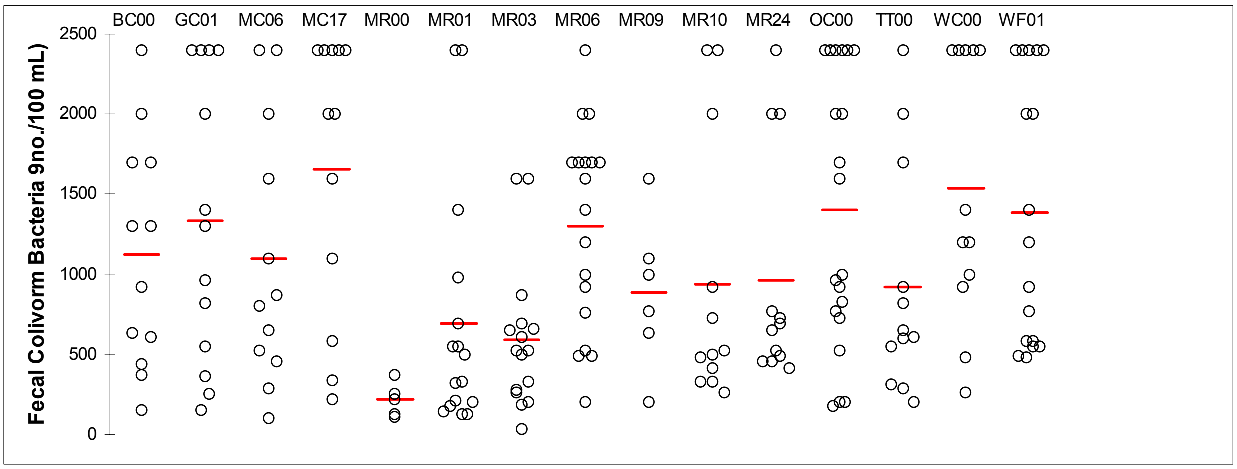

Figure 9. Distribution of fecal coliform bacteria values measures at various sites in the Marys River basin August through July 2001-2001. The horizontal lines mark the mean value for each site.

The results for *E. coli* are similar to those for fecal coliform only in that values are relatively low during the late winter months (December through March). Other than that, the results differ substantially. *E. coli* were much less variable, and less abundant that fecal coliform (Figure 10). The results show a seasonal pattern, with relatively low values during the summer (July and August) and late winter, and increasing values in fall (September to November) and spring (April to June). Although these results are for only one

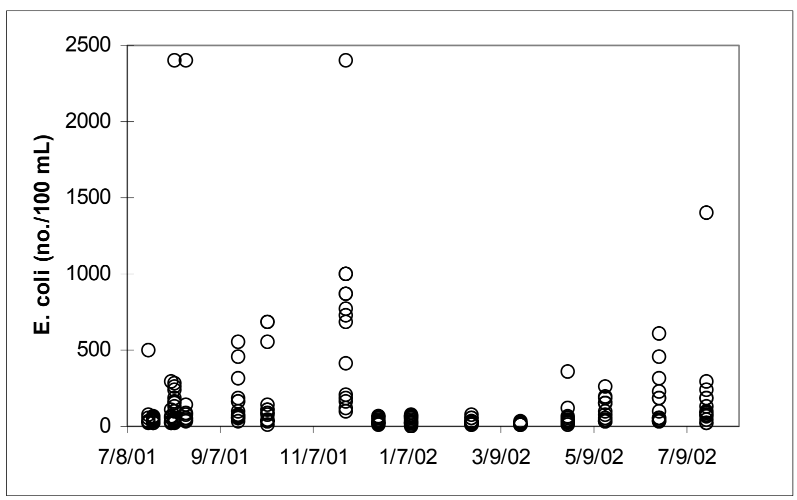

Figure 10. Values measured for *E. coli* bacteria at various sites in the Marys River basin during 2001-2002.

year, and may be expected to vary considerably from year-to-year, the pattern is roughly similar to that seen in the monthly sampling conducted by the City of Corvallis near the mouth of Oak Creek (Figure 11) and probably reflects flushing of bacteria into the stream system during rainy periods. *E. coli* concentrations were less variable between sites than were fecal coliform, with most median values falling in the range of 30 to 60 organisms/100 mL (Figure 12). There are no evident trends associated with river mile, or location of the site within the watershed. Site MR00 was the exception, with a median value of 150 organisms/100 mL, but this site was sampled only during July and August so is not comparable to sites which were sampled for the whole year. The differences between sites on the Marys River in the vicinity of Philomath seen in the fecal coliform results are not apparent in the *E. coli* results. Site MC17 had the highest mean *E. coli* value. Site MC 17 also had a large number of particularly high values for fecal coliforms.

Appendix Map A-2 shows the distribution of mean *E. coli* values throughout the basin.

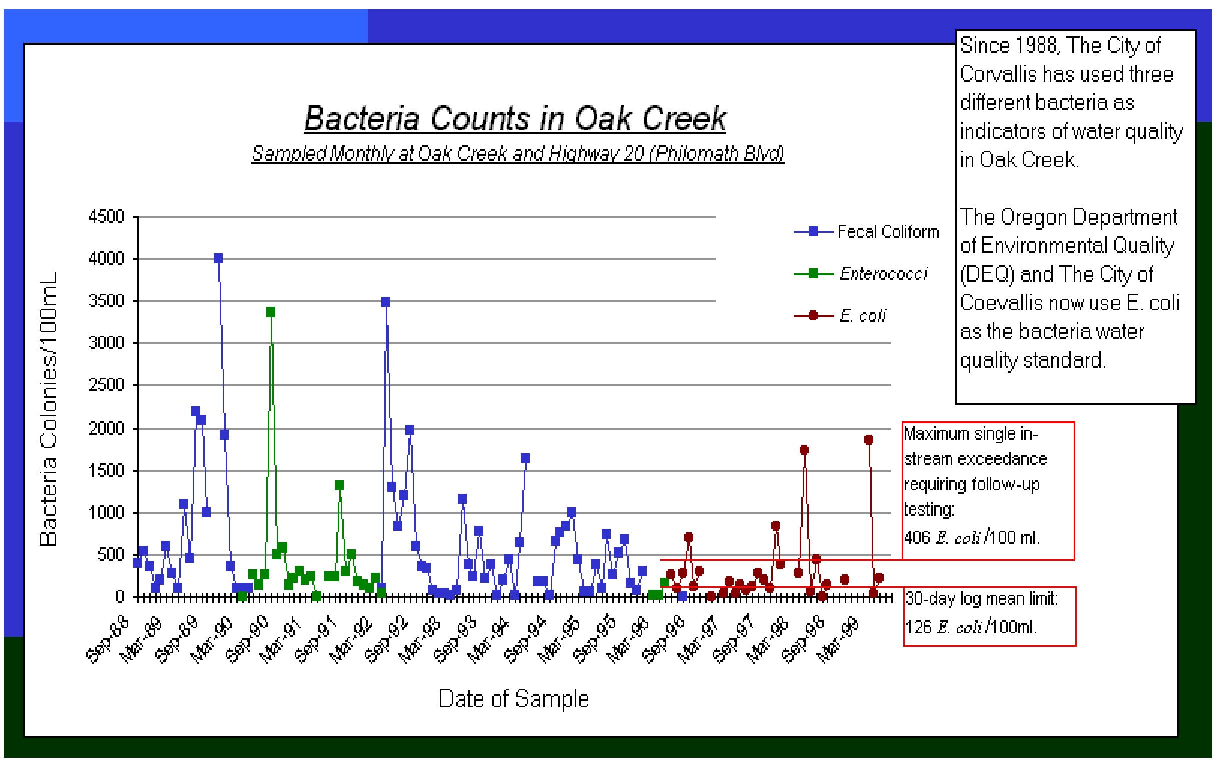

Figure 11. Bacteria counts from Oak Creek. (Source: URL www.orst.edu/dept/oakcreek/files/banner3.html)

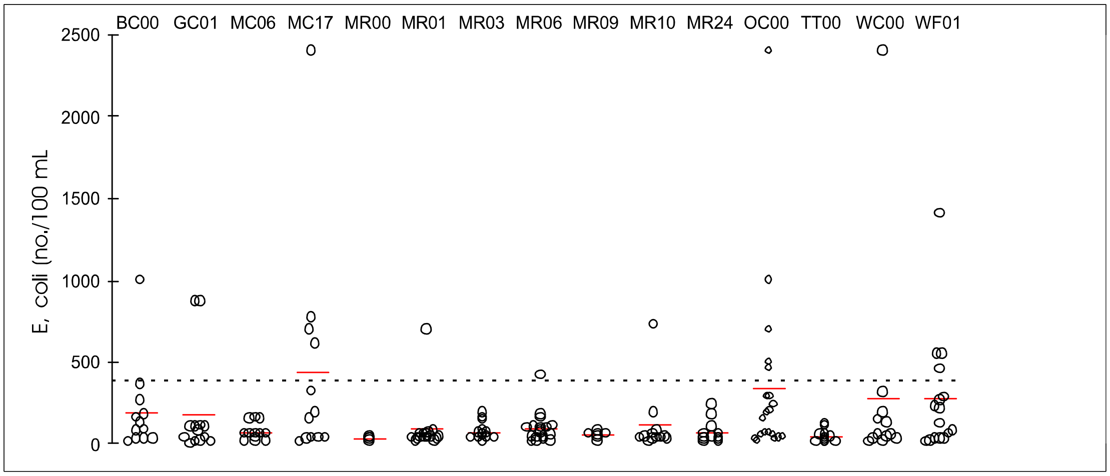

Figure 12. Values of *E. coli* bacteria measured at various sites in the Marys River basin August through July 2001-2002. The horizontal lines mark the mean of values at each site. Dashed line shows the single-sample water quality standard.

Turbidity

Turbidity was measured monthly at 13 sites. The values observed ranged from a low of 0.39 NTU at site GC01 on July 22, 2002 to a high of 55.5 NTU measured at site OC00 on November 28, 2001. This range most likely does not represent the full extent of variation in turbidity values. Even though the samples were collected during a variety of flow conditions, individual monthly samples are unlikely to catch the peak of turbidity (Glassmann 2000), which generally occurs during very high discharge. Mean turbidity for the period of sampling ranged from 2.9 NTU at site MR24 to 14.7 NTU at site MC17. The lowest average turbidity values were recorded at sites MR24, WF01 and TT00, sites draining forest areas relatively high in the watershed. The highest average turbidity values were found at sites MC17 and OC00 (Figure 13). Summary statistics for turbidity data are provided in Appendix Table A-9.

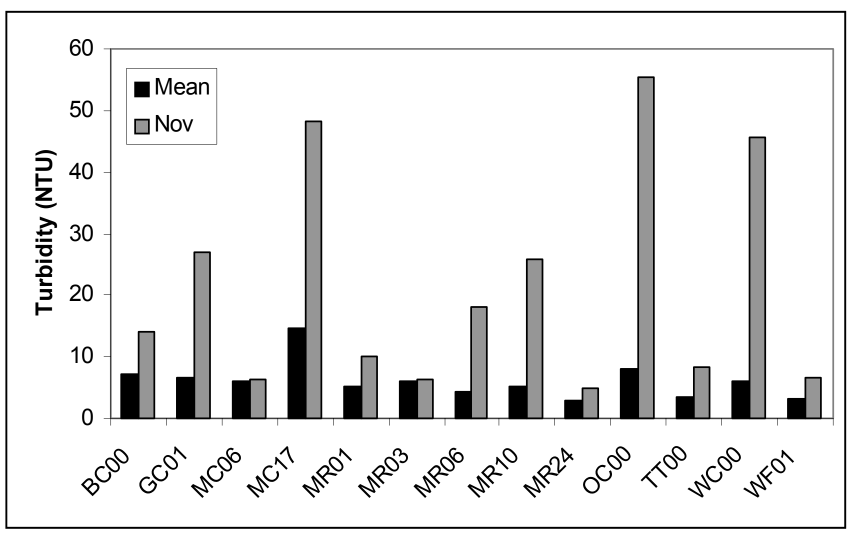

Figure 13. Turbidity values measured at various sites in the Marys River basin August through July 2001-2002. Black bars are the mean values at each site, grey bars are values measured during a precipitation event in November 2001.

In general turbidity values measured in Marys River and its tributaries were less than 10 NTU, with some notable exceptions (Figure 14). In November, all sites exhibited elevated turbidity values. The November sample date (11/28) corresponded to the first heavy and sustained precipitation event of the fall. Although discharge measurements are not available, it is probable that the heavy rain on the day of sampling and during the days preceding resulted in substantial increase in flow. Relatively high turbidity values at site MC17 in March and May, and at site MR03 in March also correspond to days of higher precipitation than the preceding few days. In March and May, the absolute amount of precipitation was relatively small (0.09 and 0.32 in respectively) and appears not to have affected turbidity throughout the entire watershed.

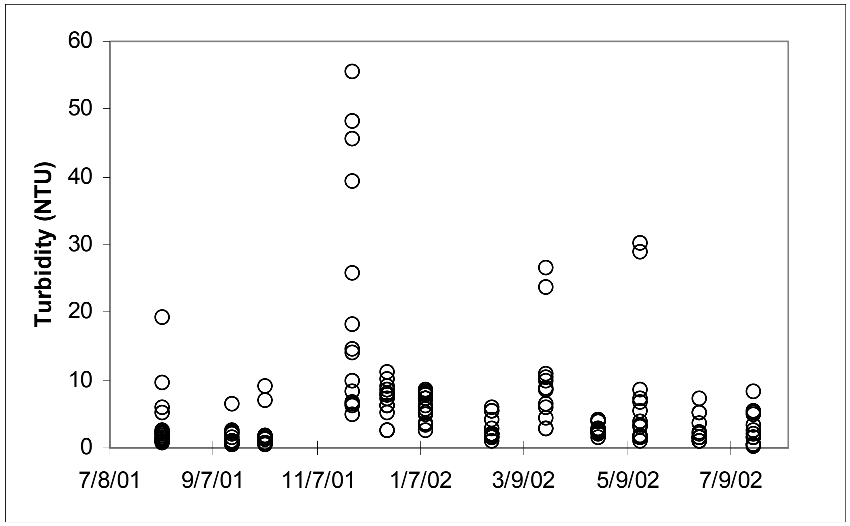

Figure 14. Turbidity values measured at various sites in the Marys River basin during 2001-2002.

The pattern of turbidity values recorded during a precipitation event on November 28th provide some insight into erosion patterns in the watershed. High turbidity at site WC00, GC01, and OC00 reflect the erodible nature of the landscape in these watersheds (Glassmann 2000). The increase in turbidity between site MR03 and MR01 reflects the input of high turbidity from Oak Creek (OC00). In contrast to findings of Glassmann, however, turbidity did not increase monotonically along the length of Marys River, but rather decreased between site MR10 and site MR03. Appendix Map A-3 shows the distribution of turbidity values in the watershed for November 28th.

Specific Conductance

Specific conductance was measured monthly at 13 sites. The observed values ranged from a minimum of 16 µS/cm at site MR06 on March 22nd to a maximum of 274 µS/cm at site OC00 on July 22nd. Specific conductance showed a seasonal pattern (Figure 15) with lower values in the winter when flows were high, increasing through the summer when flows decreased. Specific conductance also had a spatial pattern. Downstream sites generally had higher specific conductance than did sites further upstream (Figure 16). Summary statistics for specific conductance are provided in Appendix Table A-6.

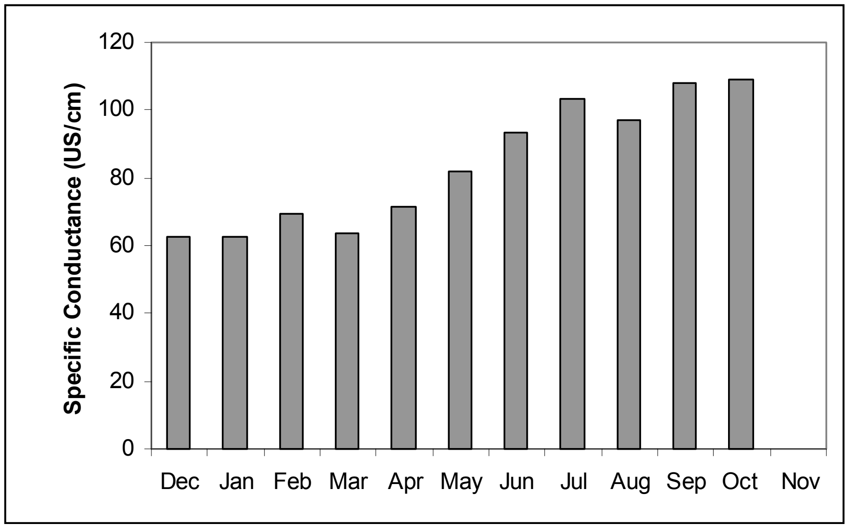

Figure 15. Specific conductance measured at various sites in the Marys River basin during 2001-2002. Bars represent the mean value for all sites by month.

Oak Creek was notable because its specific conductance was markedly higher than that of any other site measured (Figure 16). This may indicate a source of contamination on Oak Creek, however data collected by Oregon State University students (Harding 2002) from 1994 to 1997 at sites upstream from the University campus suggest that the higher values may occur naturally (Figure 17). It is not clear if the OSU data are recorded as ambient conductivity or specific conductance (adjusted to 25° C). In any case, values measured during the Phase I study bracket those measured by OSU. Appendix map A-4 shows the distribution of mean specific conductance through the watershed.

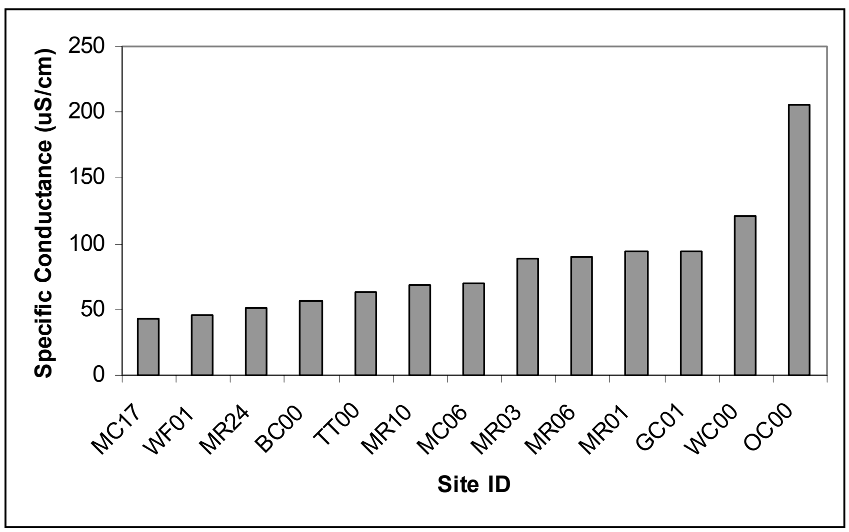

Figure 16. Specific conductance values measured at various sites in the Marys River basin during August through July 2001-2002. Bars represent the mean of all samples at each site.

Dissolved Oxygen

Dissolved oxygen was measured monthly at 13 sites. The lowest value, 2.63 mg/L, was measured at site MC06 on September 17, 2001; the highest dissolved oxygen value,16.6 mg/L,

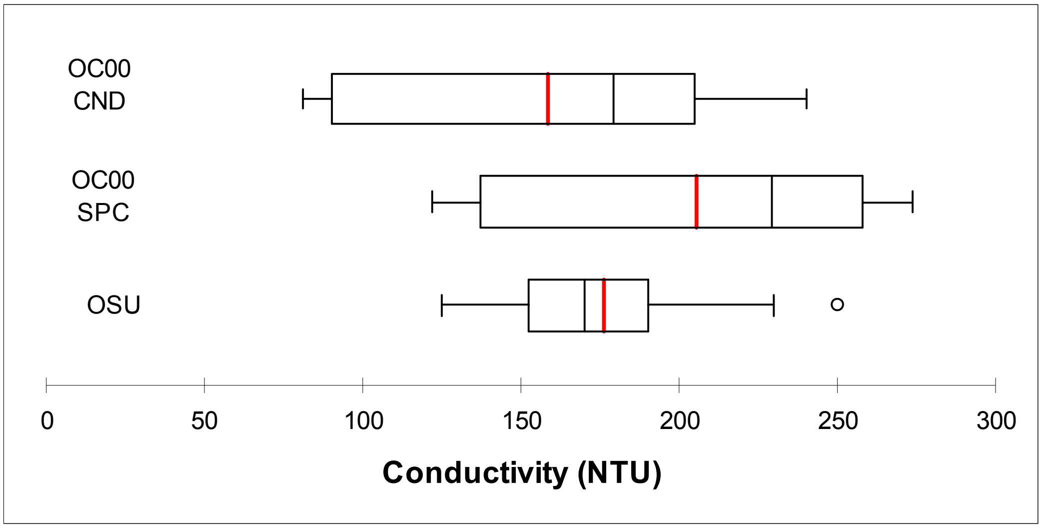

Figure 17. Conductivity values measured in Oak Creek near the mouth. OC00 denotes samples measured during the Phase I study in 2001-2002, OSU denotes samples measured by Oregon State University in 1994-1998. SPC denotes samples corrected for temperature differences. The heavy vertical line in the box represents the mean, the lighter line the median.

was recorded at site MR10 on the same date. Summary statistics for dissolved oxygen are provided in Appendix Table A-2.

A seasonal pattern was observed with dissolved oxygen values generally higher in the winter than in the summer. This is to be expected because of the increased solubility of oxygen in water at low temperature. The minimum measured value at most sites equaled or exceeded the minimum water quality criterion (8 mg/L)for salmonid rearing (Figure 18). The exceptions were sites MR24, OC00, TT00, and MC06. Site MC06, on Muddy Creek, was notable for its especially low values of dissolved oxygen. The distribution of dissolved oxygen values was similar at most sites with two exceptions; site MC06 had noticeably lower dissolved oxygen than the other sites, and

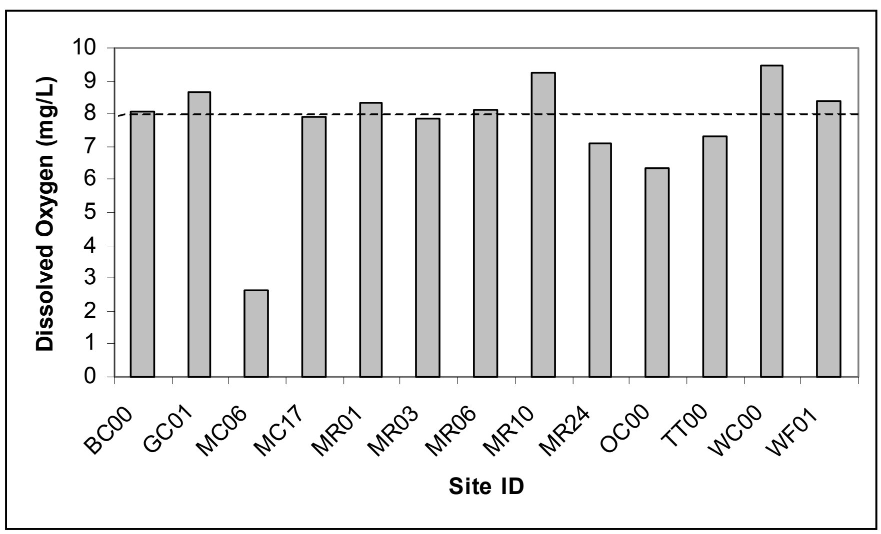

Figure 18. Dissolved oxygen values measured at various sites in the Marys River basin during August through July 2001-2002. Bars represent the minimum value measured at each site during the Phase I study.

site MR10, while not extremely different, tended to have higher values than other sites (Figure 19). Appendix map A-5 shows the spatial distribution of minimum dissolved oxygen values.

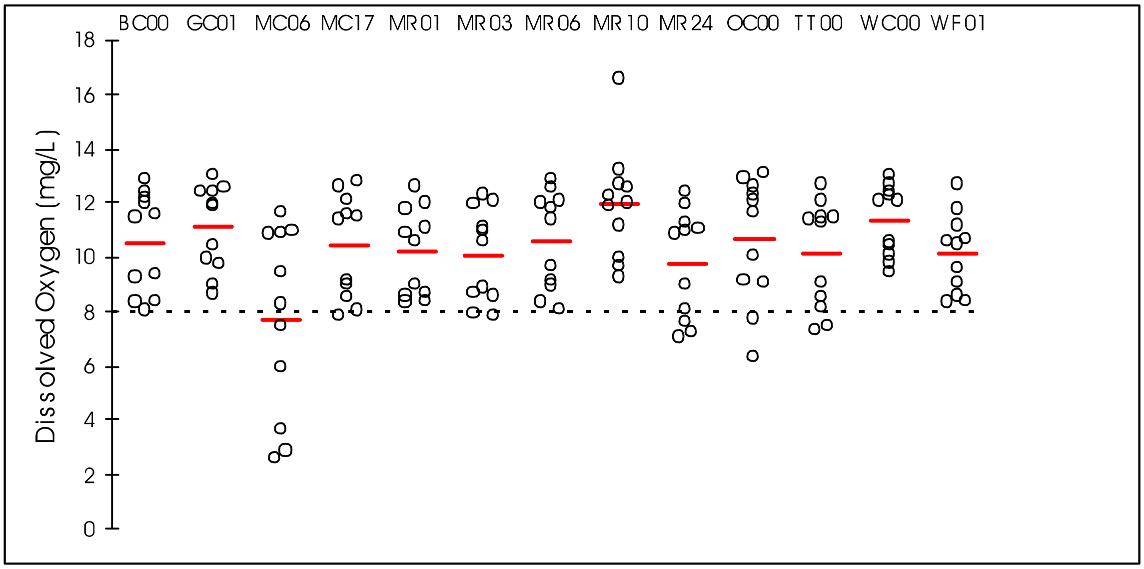

Figure 19. Values of dissolved oxygen measured at various sites in the Marys River basin August through July 2001-2002. The horizontal lines mark the mean of values at each site. The dashed line shows the water quality standard for salmonid rearing.

pH

During the Phase I study, pH was measured monthly at 13 sites, plus five times in July and August 2001 at two additional sites. The minium value, 6.36, was recorded at site MR24 on October 8, 2001. The maximum value was 8.05 recorded at site MR10 on July 22, 2002. With only four isolated exceptions, all pH values measured during the Phase I study fell within the current water quality standard range of 6.5 to 8.5. There was little difference in pH among the sites (Figure 20). No strong seasonal pattern is evident in the data, but there appears to be a shift in pH between January and February. Measurements taken in February through July average approximately 0.5 pH units higher than measurements taken in August through January (Figure 21). This is apparently the result of replacing the pH electrode on the multi parameter instrument used to measure pH, which significantly reduced the response time of the instrument. Summary statistics for pH are provided in Appendix Table A-5.

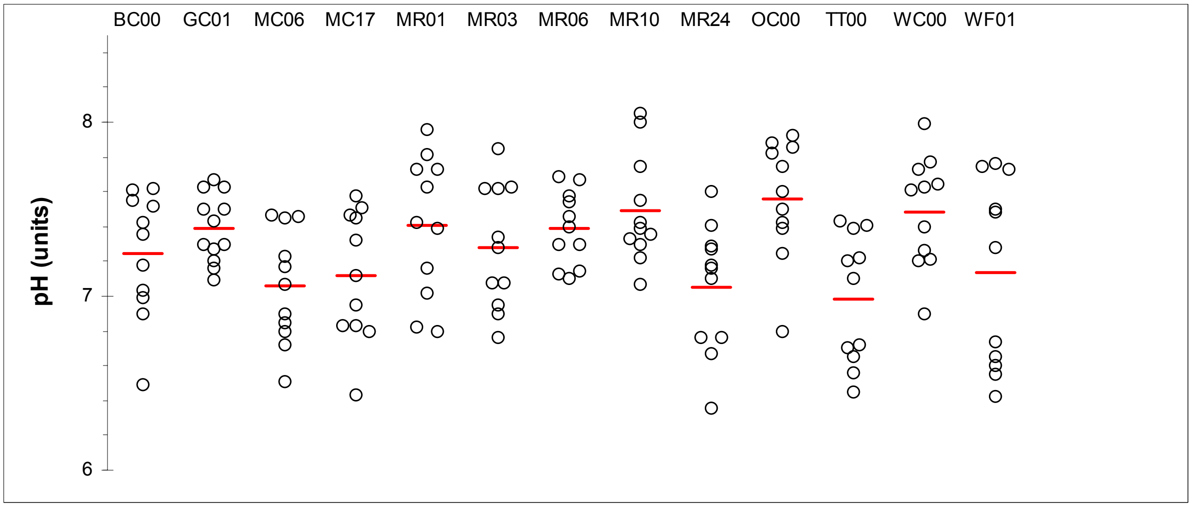

Figure 20. Values of pH measured at various sites in the Marys River basin August through July 2001-2002. The horizontal lines mark the mean of values at each site.

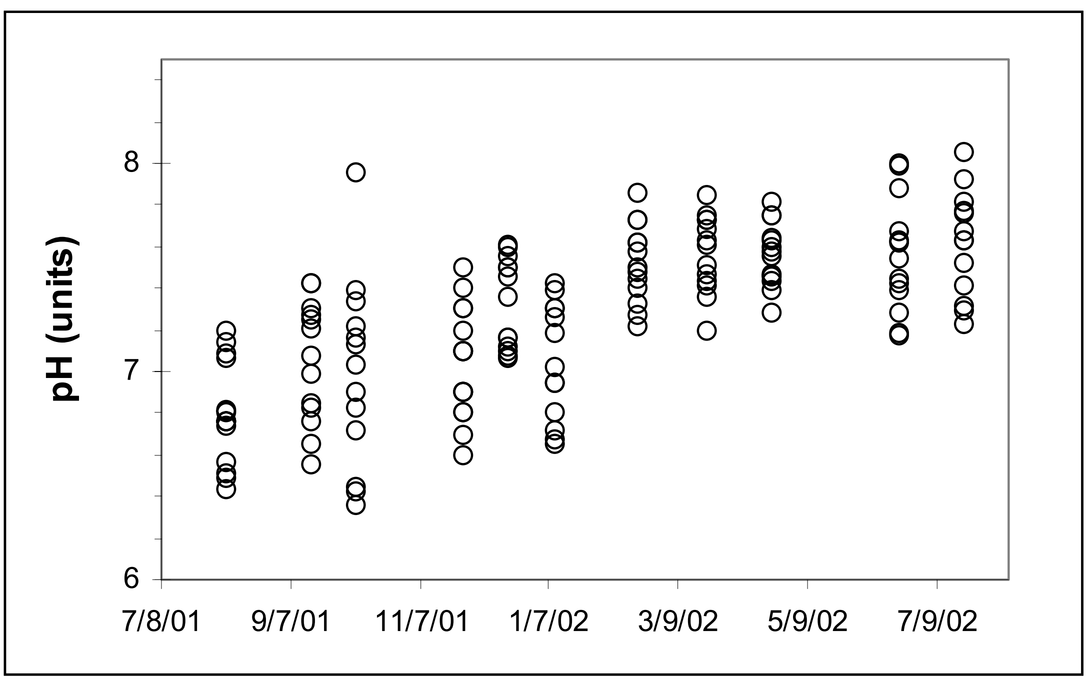

Figure 21. Values of pH measured at various sites in the Marys River basin in 2001-2002.

Nutrients

Nitrogen

Nitrate-nitrogen (NO_3) was measured monthly at 13 sites. Most values were below the analytical method reporting limit of 1.0 mg/L NO_3 as nitrogen, although in some instances it was possible to estimate values between 0.5 and 1.0 mg/L. The highest value recorded was 5.5 mg/L at site MC06 on November 28, 2001 (Figure 22) . Nitrate was most commonly present at concentrations above the reporting limit during November and December. This is not unusual. Nitrate can increase in the soil during dry months and, when the rainy season starts, be exported to the streams rapidly because it is readily soluble. In addition, biological demand for nitrogen in the watershed soils and streams is highest during the growing season, in spring and summer.

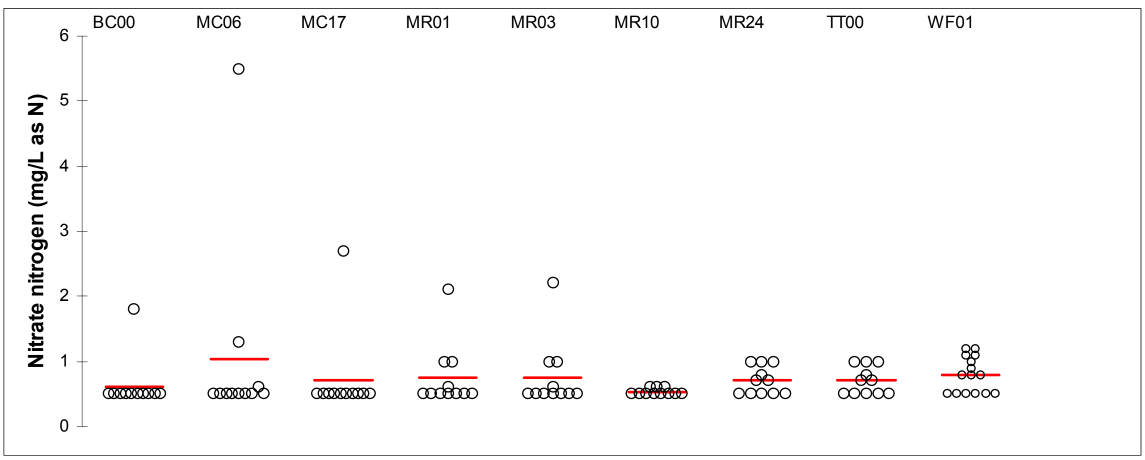

Figure 22. Values of nitrate nitrogen measured at various sites in the Marys River basin August through July 2001-2002. The horizontal lines mark the mean of values at each site. Sites GC01, MR06, WC00, and OC00 are not represented on the graph because they had no measured or estimated values greater than the anaytical method reporting limit.

Measurable nitrate appears more frequently at some sites than at others (Table 5). The sites with the most values above the method detection limit were in the upper reaches of the watershed, whereas the sites with the highest measured values were on Muddy Creek or on Marys River below the confluence with Muddy Creek.

Results for total Kjeldahl nitrogen (TKN) are similar to those for nitrate nitrogen. Most samples had values less than the analytical method reporting limit of 0.5 mg/L. The major exception was during the rainfall event sampled in November 2001 when values for all sites were greater than the reporting limit, with a maximum value of 3.0 mg/L recorded at sites MR03

Table 5. The number of positive detections of nitrate at various sites in the Marys River basin during the Phase I study.

Site	Number of Hits[1]	**Maximum value** (mg/L)
BC00	1	1.8
MC17	1	2.7
MC06	3	5.5
MR10	3	0.7
MR03	4	2.2
MR01	4	2.1
WF01	6	1.2
TT00	6	1.0
MR24	6	1.0

[1]Number of measured values >1.0 or estimated values >0.5

and MR01. No site had TKN present above the method reporting limit on more than two occasions.

Summary statistics for nitrate and TKN are presented in Appendix Tables A-4 and A-7. Appendix Map A-6 shows spatial distribution of maximum NO_3 values.

Total Phosphorus

Total phosphorous was measured monthly at 13 sites. As with nitrate and TKN, many values were below the method reporting limit of 0.05 mg/L P. The highest value of 1.0 mg/L was recorded at site WC00 on November 28, 2001, although no other value exceeded 0.33 mg/L. Total phosphorus was most commonly detected at sites BC00, GC01, OC00, and WF01, with the highest value among them 0.33 mg/L at OC00 in November. Site MC06 had the highest average total phosphate concentration (Figure 23). Summary statistics for total phosphorus are provided in Appendix Table A-8. Appendix map A-7 shows the spatial distribution of mean total phosphorus values.

Aquatic Macroinvertebrates

[Data on aquatic macroinvertebrates were not available in time for inclusion in the final report, and will be dealt with in a separate technical memorandum.]

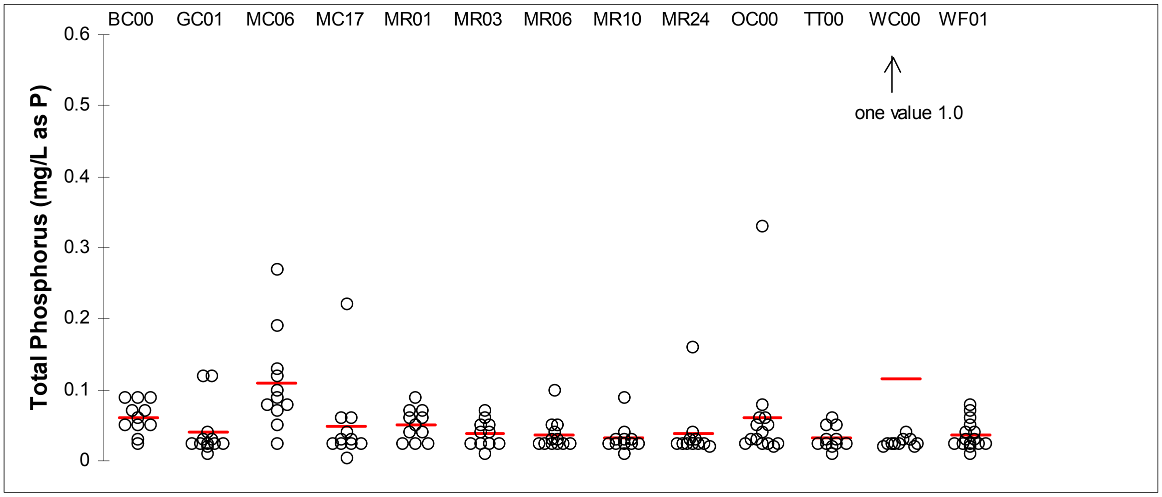

Figure 23. Values of total phosphorus measured at various sites in the Marys River basin August through July 2001-2002. The horizontal lines mark the mean of values at each site.

DISCUSSION

Water Quality

With the data collected during the Phase I study, it is possible to make a first approximation evaluation of water quality in the Marys River basin, and to identify some stream reaches or subbasins in which water problems may warrant further investigation.

The Oregon Watershed Assessment Manual (WPN 1999) includes water quality indicators and evaluation criteria, based on ODEQ water quality standards, that can be used to assess the level of water quality impairment. It is appropriate to use evaluation criteria for salmonid fish as the most sensitive species because cutthroat trout are present in the upland portions of the Marys River basin during the summer, and may be present throughout the basin during the winter (Table 6).

For purposes of this discussion, fewer than 15 percent of samples exceeding the criteria will be taken to indicate no impairment, 15 to 50 percent exceeding indicates moderate impairment, and more than 50 percent exceeding indicates impaired water quality that would adversely affect beneficial uses.

The Marys River is listed as water quality impaired for temperature because it does not meet ODEQ water quality standards based on periodic measurements made at the Highway 99 bridge (site MC00). Based on the data collected during the Phase I study, it would appear that several subwatersheds in the upper portion of the basin do meet the water quality standard for salmonid rearing of 17.8º C (Table 7). The Phase I study did not include daily temperature measurements during the winter, so it is inappropriate to estimate the level of impairment for salmonid spawning.

Table 6. Water quality evaluation indicators (WPN 1999).

Water Quality Attribute	Evaluation Criteria
Temperature Salmonid spawning Salmonid rearing	 Daily maximum = 55° F (12.8° C) (7-day moving average) Daily maximum = 64° F (17.8° C) (7-day moving average)
Dissolved oxygen Salmonid spawning Salmonid rearing	 11.0 mg/L 8.0 mg/L
pH	Not less than 6.5 or greater than 8.5
Nutrients Total phosphorus Nitrate nitrogen	 0.05 mg/L 0.30 mg/L
Turbidity	50 NTU maximum
Bacteria (water contact recreation)	126 *E. coli*/100 mL (30-day geometric mean, n≥ 5) 406 *E. coli*/100 mL (Single sample maximum)

Table 7. Level of impairment for temperature at Phase I sites in Marys River.

Site	Percent Exceeding 17.8° C	Level of Impairment
MR24	0	None
TT00	0	None
WF01	3	None
OC00	27	Moderate
WC00	32	Moderate
MC17	35	Moderate
BC00	42	Moderate
MC06	69	Impaired
GC01	75	Impaired
MR06	82	Impaired
MR10	85	Impaired
MR03	88	Impaired
MR01	88	Impaired

The Marys River is also listed as water quality impaired for bacteria, based on samples collected near the mouth. During the Phase I 30-day sampling, only one of the 5 sites sampled exceeded either of the *E. coli* bacteria evaluation criteria. At the mouth of Oak Creek, site OC00, five samples collected during July and August 2001 exceeded a geometric mean of 126 *E. coli*/100 mL, and two of the five exceeded the single sample maximum of 406 organisms/100 mL.

During the monthly sampling of Phase I study, all of the sites sampled during the entire year, with the exception of MR06, had at least one sample that exceeded the single sample criterion. Most sites had only one value greater than 406 *E. coli*/100 mL, but sites MC17, OC00, and WF01 had numerous values above 406 organisms/100 mL. These results suggest that the Marys River as a whole is not seriously impaired with respect to *E. coli* bacteria, but that some sites may be at risk for bacterial contamination. In contrast, the fecal coliform bacteria data suggested widespread contamination throughout the period of study.

Ten percent of the samples analyzed during the Phase I study had dissolved oxygen less than 8.0 mg/L, and one-third of those were from one site, MC06. This suggests that the Marys River is not seriously impaired for salmonid rearing with respect to dissolved oxygen. Fifty-three percent of the samples measured had dissolved oxygen less than 11 mg/L. This suggest moderate impairment for salmonid spawning, however, this standard is applied only during the spawning season (Feb-May) when most dissolved oxygen values in the watershed were greater than 11.0 mg/L (Figure 24).

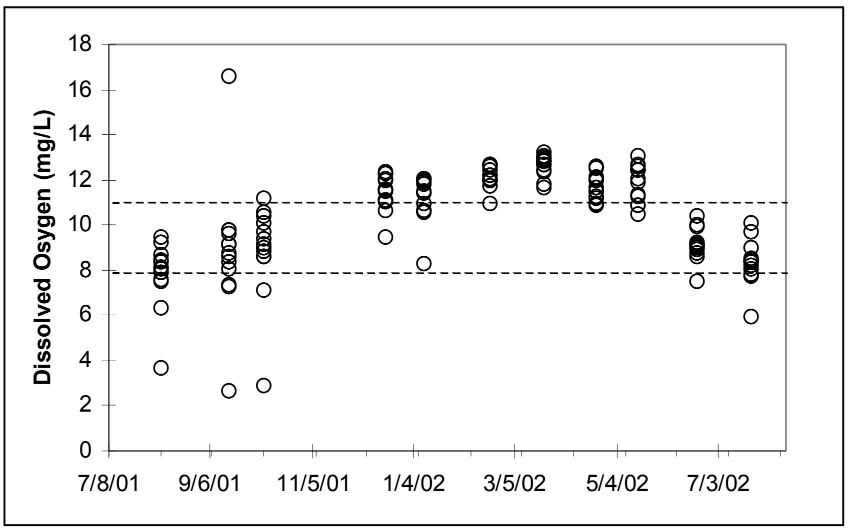

Figure 24. Values of dissolved oxygen measured at various sites in the Marys River basin in 2001-2002. The horizontal lines represent the ODEQ water quality standard for salmonid spawing (11 mg/L) and salmonid rearing (8 mg/L).

Only 4 of the 195 readings measured during the Phase I study at all sites were below the pH evaluation criterion of 6.5, and none were above 8.5. The Marys River is not impaired with respect to pH.

The analytical method reporting limit of 0.5 mg/L for nitrate-nitrogen was greater than the evaluation criterion of 0.3 mg/L, so direct assessment of water quality condition for nitrate is not appropriate. That nearly all of the samples measured had values less than the method reporting limit suggests, however, that nitrate is not a serious problem within the watershed. Several high values obtained during the early winter precipitation runoff indicate that nitrate is reaching the streams, and suggest that further investigation into possible sources might be warranted.

Of the total phosphorus measurements taken during the Phase I study, 34 percent were greater than the evaluation criterion of 0.05 mg/L. Of these, nearly half (46 percent) were from Muddy Creek sites (MC06 and MC17) and the Marys River below the confluence with Muddy Creek (sites MR03 and MR01). Sites higher in the watershed, with the exception of WF01, had few samples with total phosphorus greater than 0.05 mg/L. This suggests the possibility of anthropogenic inputs of phosphorus to the streams, especially in Muddy Creek and the lower reaches of Marys River. However, investigations in other Willamette basin streams draining the Coast Range have found that the background phosphorus concentration in groundwater entering streams can be as great as 0.14 mg/L (McCarthy 1996).

One turbidity value measured during the Phase I study exceeded the evaluation criterion of 55 NTU. However, other studies (Glassmann 2000) have measured values considerably higher than this. High turbidity is associated with high flow events, and only one large precipitation event was sampled during the Phase I study. These results suggest that chronic turbidity problems are not present in the Marys River basin, but episodic problems may exist associated with heavy precipitation and runoff events.

The results of the Phase I study suggest that water quality in the Marys River is fair to good. Summer temperatures in the middle and lower reaches are clearly not amenable to trout or salmon, but tributaries higher in the basin appear cool enough to support salmonids. *E. coli* bacteria problems appear to be localized and not a particular problem in the mainstem Marys River. However, fecal coliform bacteria concentrations were high throughout the watershed and throughout the monitoring period. Dissolved oxygen appears to be adequate for aquatic life during all seasons. Nutrient concentrations suggest that some sources of nitrogen and phosphorus may exist in the watershed, particularly on Muddy Creek.

Sites

A second objective of the Phase I study was to identify places in the Marys River basin that might deserve greater attention either for continued monitoring or as sites with need or potential for effective restoration. The data collected during the Phase I study permit the identification of several such sites.

Upper Basin Sites

West Fork Marys River (WF01), Tum Tum River (TT00), and upper Marys River (MR24) drain the upper, mostly forested reaches of the watershed. The streams have relatively high gradient, and more shading than much of the rest of the basin. These three sites are similar in that they all had low minimum pH values, frequent occurrence of lower than average pH, and frequent occurrence of detectable or estimated nitrate. Tum Tum River and upper Marys River also had minimum and mean dissolved oxygen values lower than most of the other sites. West Fork Marys River had a large number of fecal coliform values at or above the maximum limit of the analytical method, a higher mean fecal coliform abundance, and especially high and frequent values for *E. coli*.

The low pH and relatively high nitrate values in these three subbasins are probably natural consequences of their geographic position. They are rainwater dominated streams, especially during the winter. The natural pH of rainwater can be as low as 5.7, and coastal streams in Oregon frequently have pH approaching 6.0 during the winter months. The consistent presence of nitrate in these streams could be the result of nitrogen fixation by bacteria associated with alder trees.

Harder to explain is the relatively low dissolved oxygen. Although the absolute values of dissolved oxygen are not low enough to cause undue concern, in these cooler streams one would expect dissolved oxygen to be somewhat higher than elsewhere in the basin. The data suggest that there is some mechanism removing oxygen from the stream; perhaps areas of contact with quantities of organic matter, such as wetlands. Alternatively, input of cooler groundwater with low dissolved oxygen may be exerting an influence.

The frequency and abundance of fecal coliform bacteria and *E. coli* in the West Fork Marys River suggests a source of contamination by human or animal waste upstream of the site. It is possible that the bacteria are of natural origin from wildlife, but further investigation is warranted.

Mid-basin Sites

Sites that represent drainage from the mid-basin include Marys River above Philomath (MR10), Woods Creek (WC00), Greasy Creek (GC01) and Beaver Creek (BC00). They drain primarily the eastern side of Marys Peak and originate in a geologic region of weathered basalt. Greasy Creek, Woods Creek, and Marys River above Philomath are all among the sites with the highest maximum turbidity of the sites sampled. Beaver Creek, Greasy Creek, and Woods Creek also had higher mean values, and more frequent extreme values of fecal coliform bacteria than most of the other sites. Site MR10 was notable in this group in that it did not have notably high fecal coliforms, possibly a function of dilution from other tributaries.

The high turbidity noted in these sites is probably a function of the geology of their basins, but it may be exacerbated by land use or management activity such as road building and/or bank erosion. Although it is not clear that management activities are the cause of high turbidity in these basins, attention paid to reducing management effects could have greater benefits in these areas prone to contributing sediment to the streams.

The relatively high fecal coliform may indicate sources of contamination, but it is possible that natural sources could exist. There are other bacterial species, such as *Klebsiella* sp., which live in the soil and are also detected by the fecal coliform test. Investigations to verify the presence or absence of potential sources of bacterial contamination in these basins could lead to effective restoration activities.

Muddy Creek

The two sites on Muddy Creek, although they are in the same subbasin, are different in character. The upper Muddy Creek site (MC17) drains a higher gradient, forested, headwaters area, perhaps more similar to the mid-basin sites, while the lower Muddy Creek site (MC06) reflects the passage of the stream through a low gradient agricultural area. Site MC17 had especially low minimum pH values, and frequent lower than average pH values relative to the other sites – similar to the upper basin sites – and notably high maximum and mean turbidity values – similar to the mid-basin sites. Site MC17 also had the highest mean fecal coliform values and the greatest frequency of extreme fecal coliform values of all the sites.

Site MC06 also had fecal coliform values higher than most other sites, but MC06 was notable among all the sites for its very low minimum dissolved oxygen values and low mean dissolved oxygen. Another distinguishing characteristic, which MC06 shared with the upstream site (MC17) was the high concentration of nutrients, both nitrate-nitrogen and total phosphorus, present in relation to the other sites.

Muddy Creek drains approximately 42 percent of the total area of the Marys River basin and can account for 40 percent of the flow during high-flow periods in the winter (Ecosystems Northwest 1999). Muddy Creek has a strong influence on the water quality at Marys River sites below the confluence at about river mile 5. Much of the contact recreation in the Marys River occurs below the mouth of Muddy Creek. The possibility of bacterial contamination in Muddy Creek is a concern for water-based recreation. It seems evident from the high nutrient values in Muddy Creek that management activity in the subbasin is having an effect on water quality. In addition, the very low dissolved oxygen values at site MC06 suggest a high load of organic material. Efforts to locate and alleviate the factors influencing Muddy Creek could provide significant water quality benefits.

Oak Creek

Oak Creek is unique among the sites sampled during the Phase I study because of its relatively high specific conductance, which appears to be of natural origin. Oak Creek flows through the agricultural areas of the Oregon State University campus which may account for the high abundance and frequent occurrence of fecal coliform bacteria and *E. coli*. Oak Creek was the only site that did not meet the ODEQ water quality standard for bacteria during the 30-day test. Oak Creek also had high values of maximum turbidity and maximum total phosphorus, perhaps a consequence of erosion during high runoff.

Oregon State University has formed a task force to recommend monitoring and management activities for the watershed.

Marys River Mainstem

Three sites represented the Marys River mainstem during the Phase I monitoring study; site MR01 at the Avery Park Bridge, site MR03 at a private residence (T. Whittier), and MR06 at Bellfountain Road. These sites tend to reflect upstream influences. So, for example, sites MR01 and MR03, but not MR06, had high maximum nitrate-nitrogen, a result of the influence of Muddy Creek which enters between MR06 and MR03. All three sites had warm temperatures (mean > 17.8 C), a consequence of their position low in the basin.

Notably, site MR06 had consistently higher fecal coliform than did site MR10 upstream. This suggest a potential source of fecal coliform in the Philomath urban area. This condition was not, however, present in the *E. coli* data.

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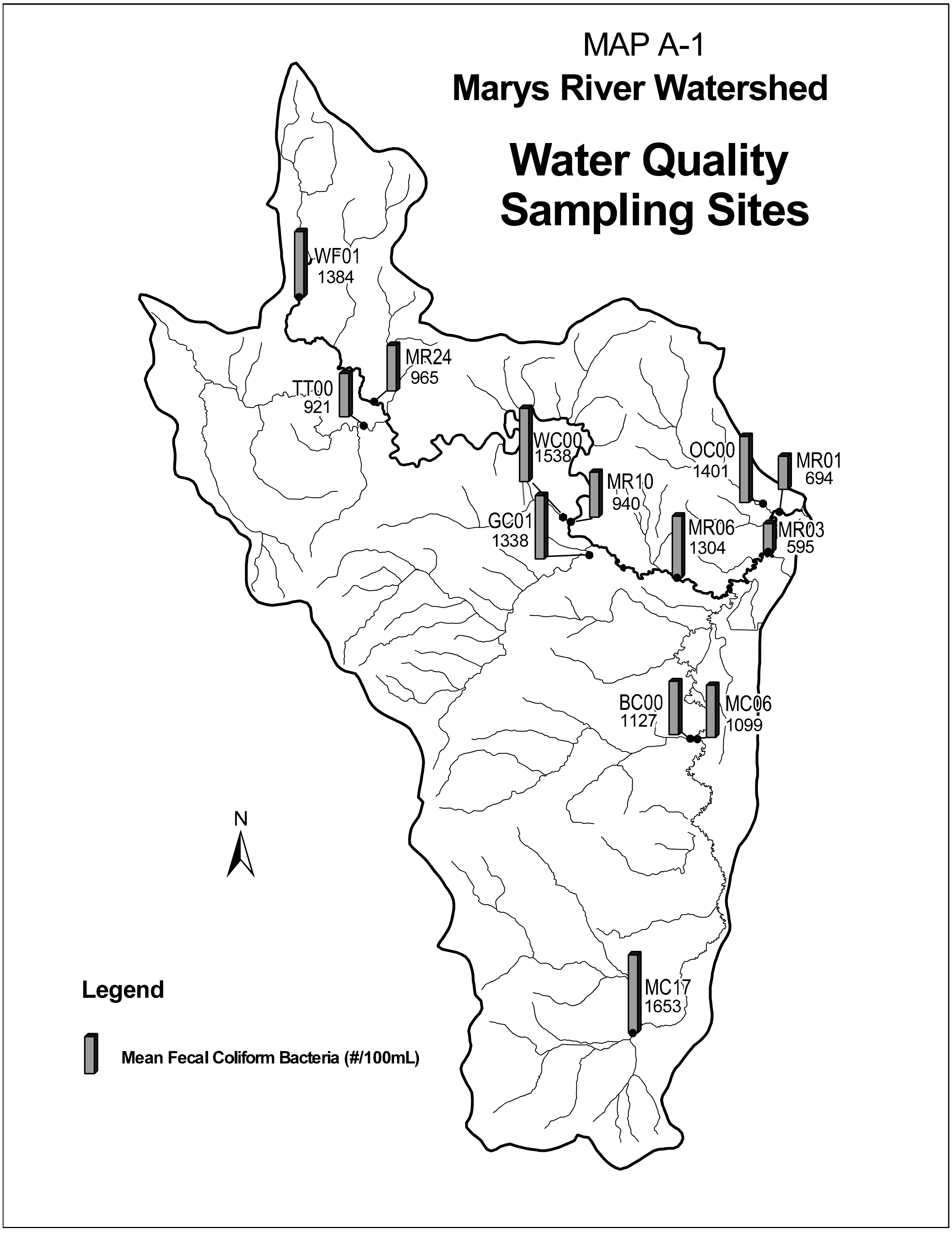
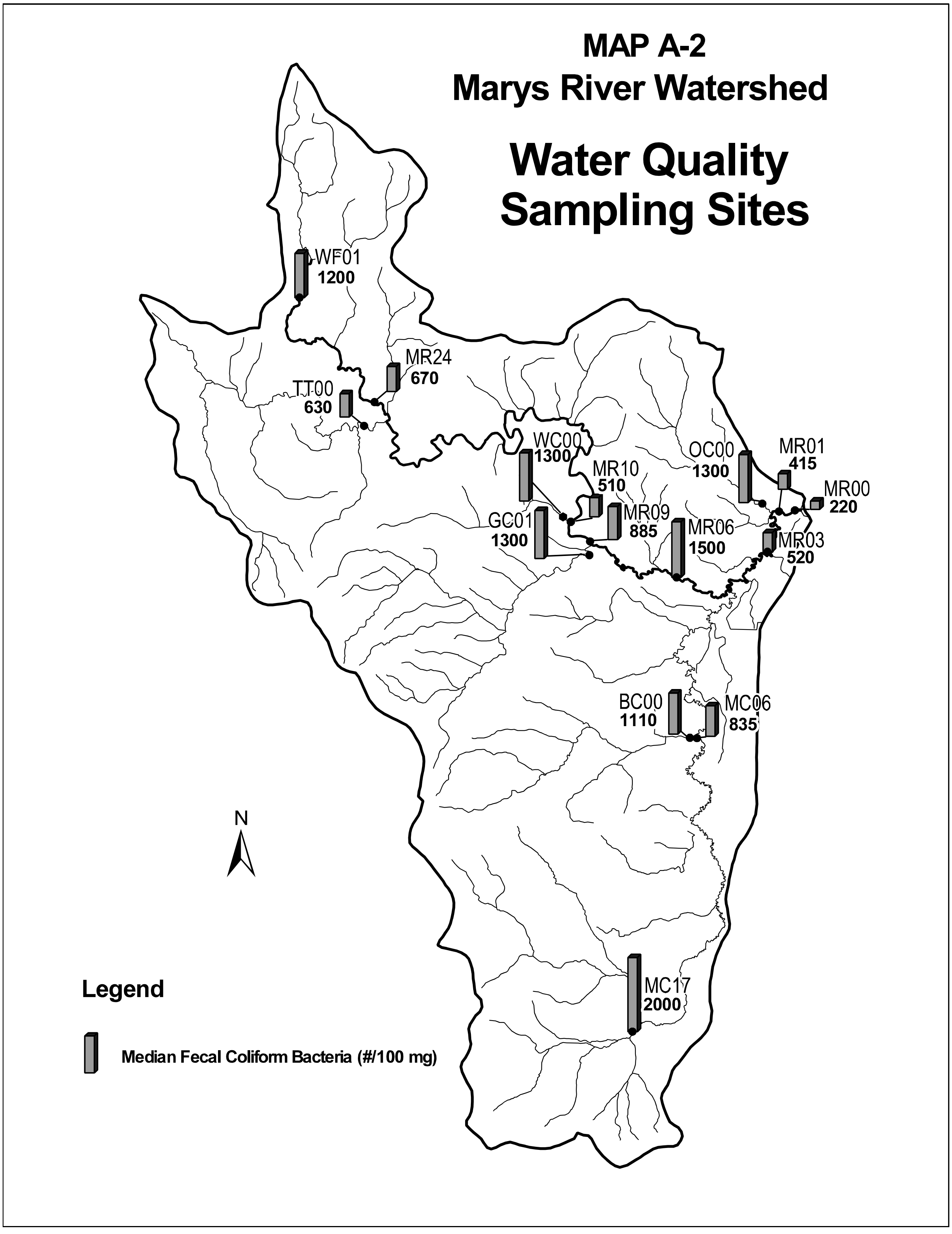
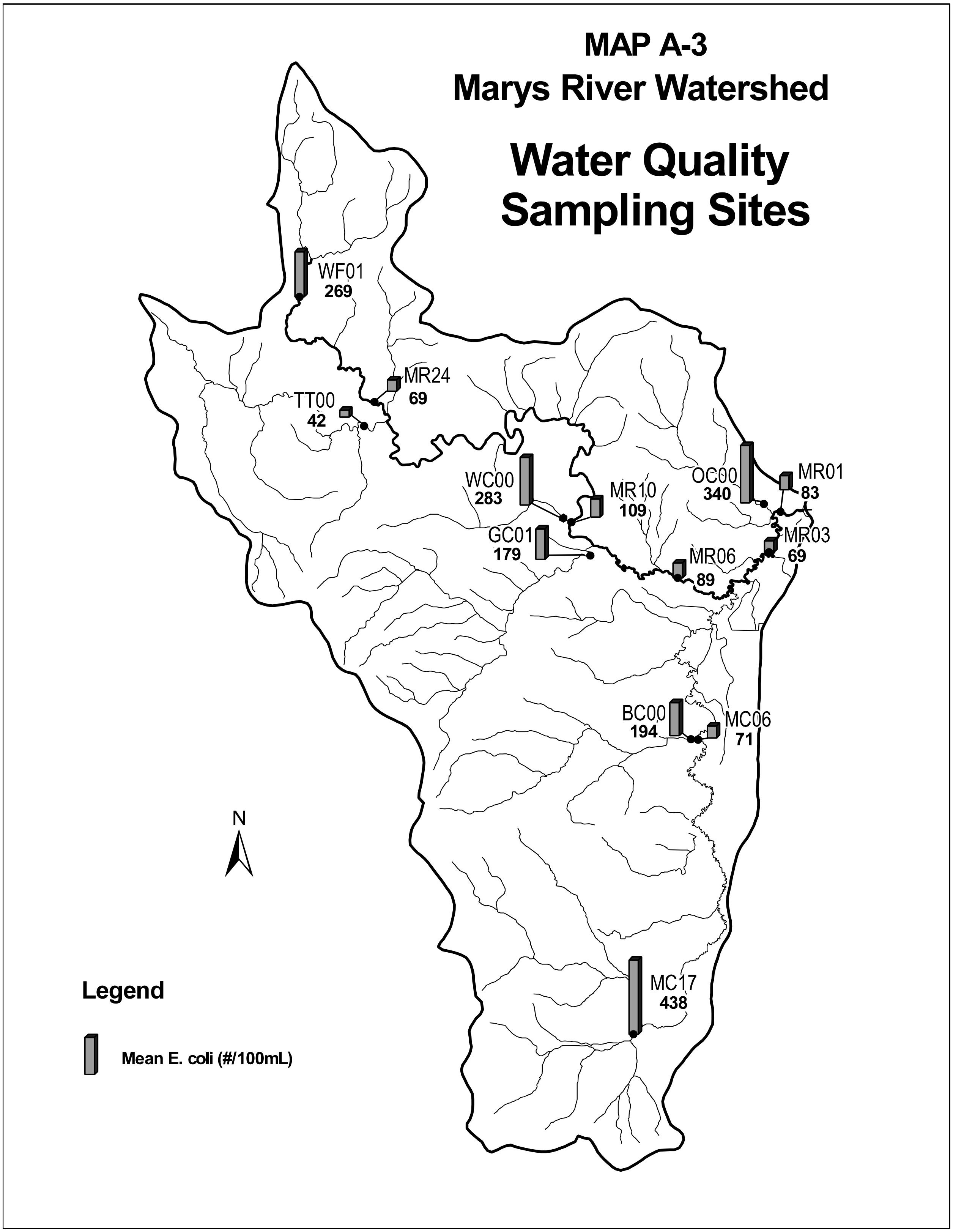
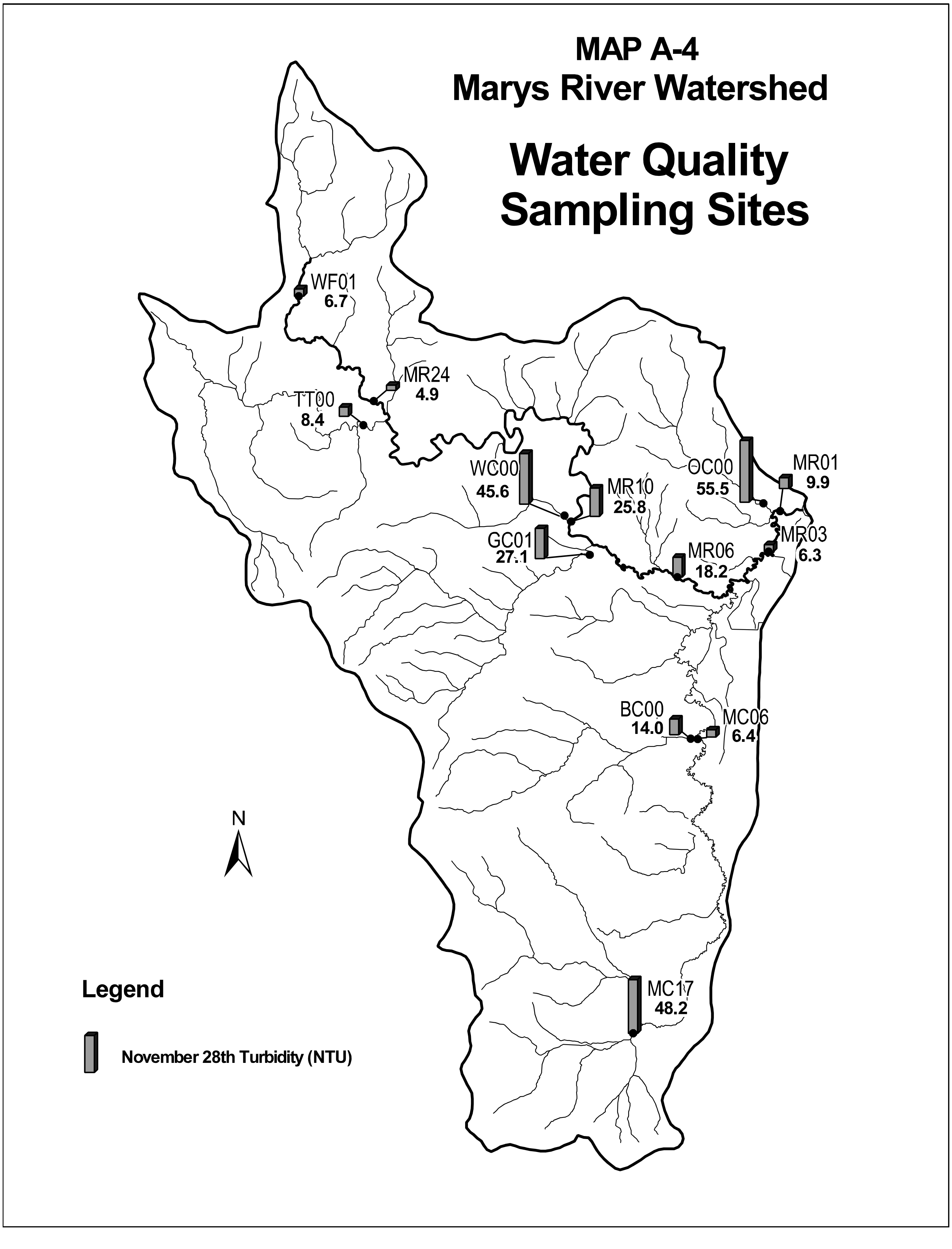
APPENDIX 1

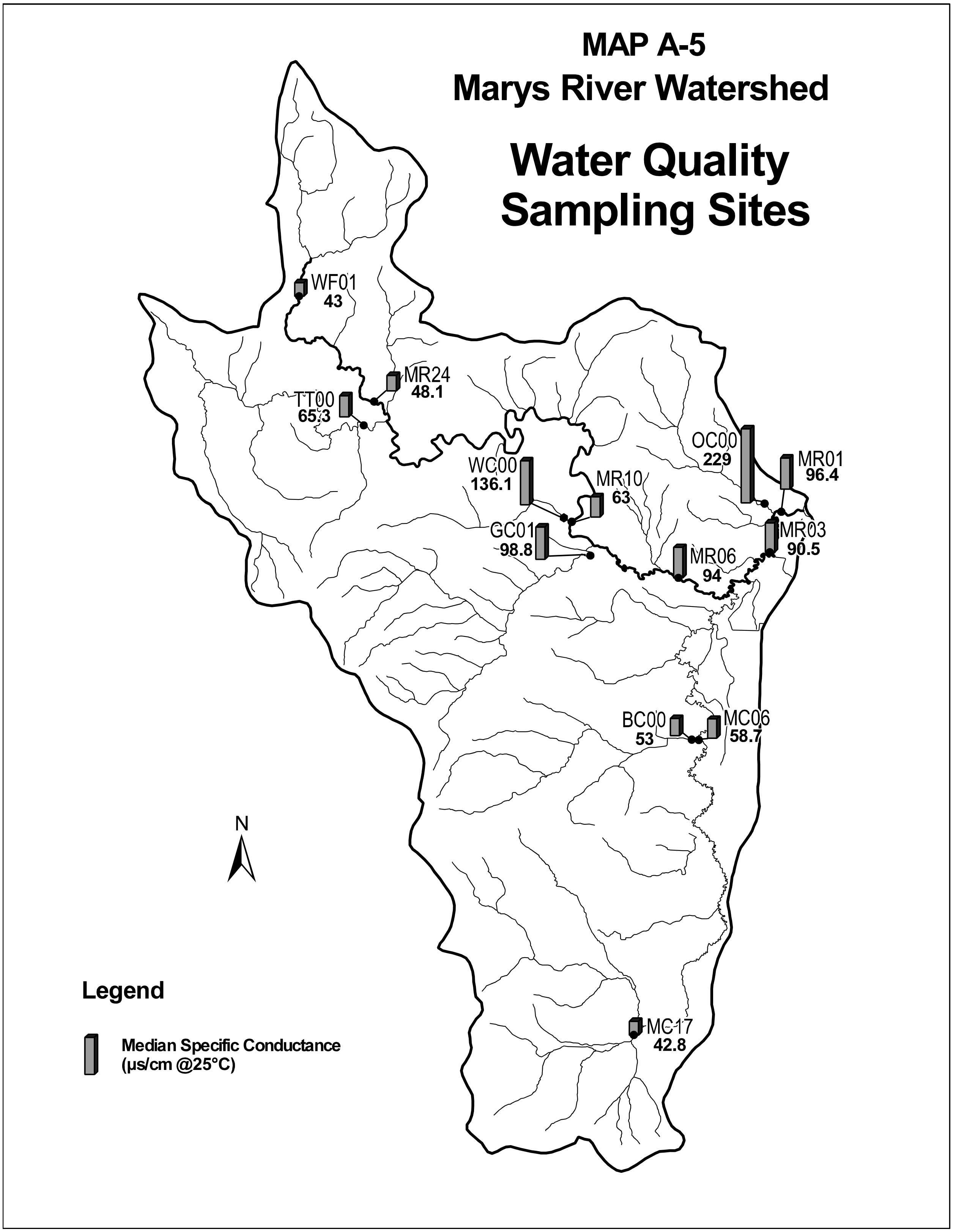
MAPS

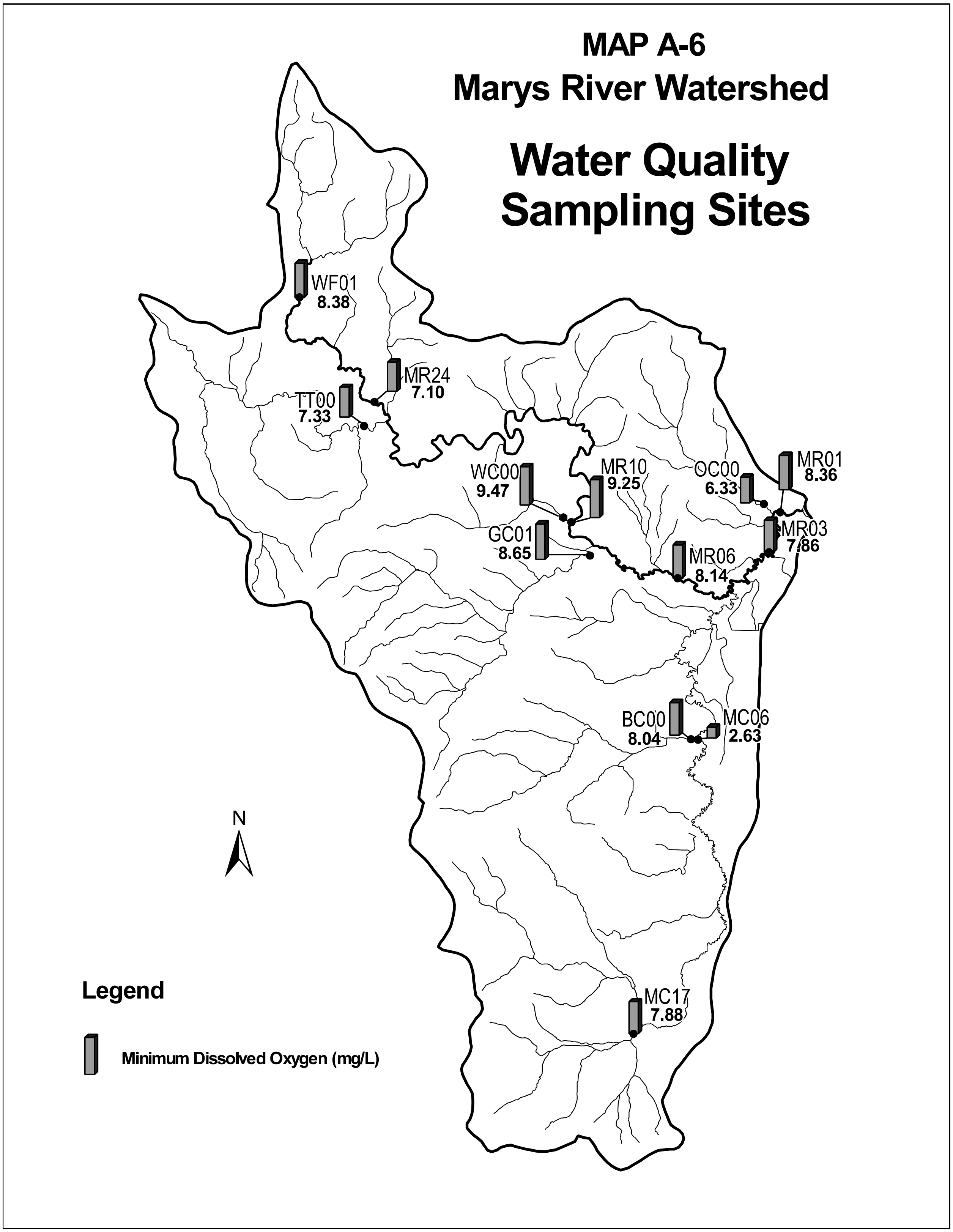

MAP A-1
Marys River Watershed
Water Quality
Sampling Sites
WF01
1384
MR24
965
TT00
921
WC00
1538
OC00
1401
MR01
694
MR10
940
GC01
1338
MR06
1304
MR03
595
BC00
1127
MC06
1099
N
MC17
1653
Legend
Mean Fecal Coliform Bacteria (#/100mL)

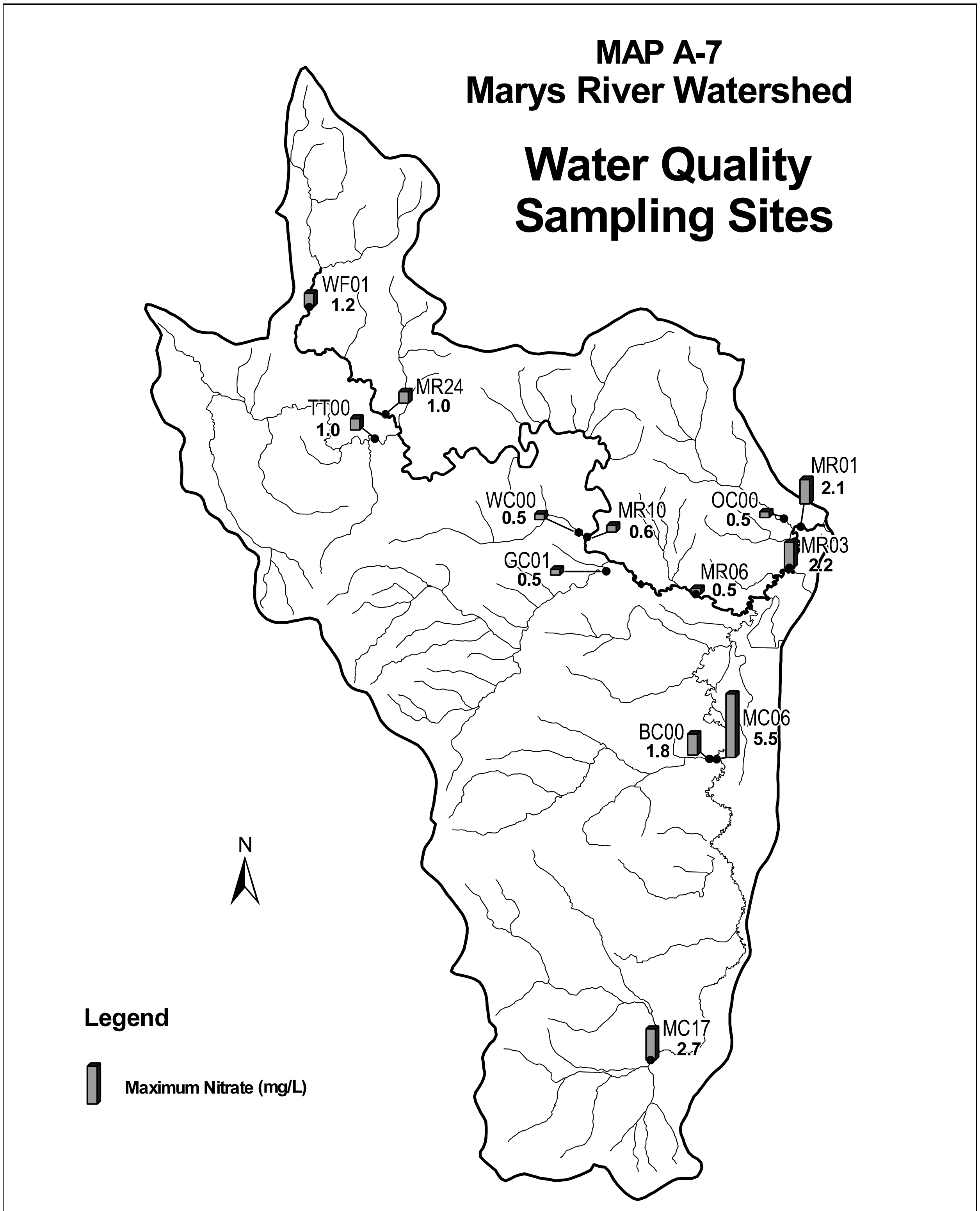

MAP A-2
Marys River Watershed
Water Quality
Sampling Sites
WF01
1200
MR24
670
TT00
630
WC00
1300
MR10
510
GC01
1300
MR09
885
MR06
1500
OC00
1300
MR01
415
MR00
220
MR03
520
BC00
1110
MC06
835
MC17
2000
N
Legend
Median Fecal Coliform Bacteria (#/100 mg)


MAP A-3
Marys River Watershed
Water Quality
Sampling Sites
WF01
269
MR24
69
TT00
42
WC00
283
MR10
109
OC00
340
MR01
83
GC01
179
MR06
89
MR03
69
BC00
194
MC06
71
N
MC17
438
Legend
Mean E. coli (#/100mL)

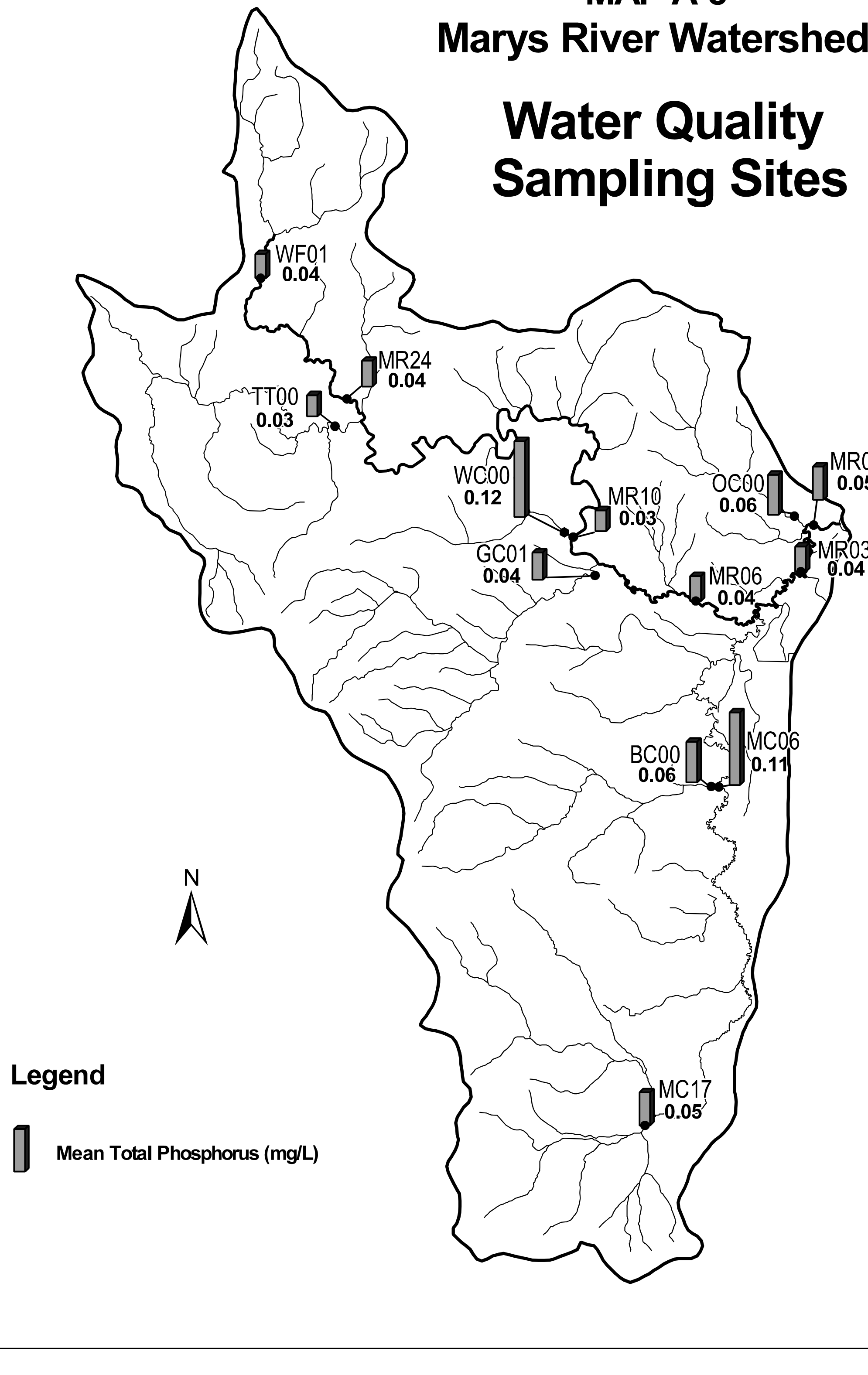

MAP A-4
Marys River Watershed
Water Quality
Sampling Sites
WF01
6.7
MR24
4.9
TT00
8.4
WC00
45.6
MR10
25.8
OC00
55.5
MR01
9.9
GC01
27.1
MR06
18.2
MR03
6.3
BC00
14.0
MC06
6.4
N
MC17
48.2
Legend
November 28th Turbidity (NTU)


MAP A-5
Marys River Watershed
Water Quality
Sampling Sites
WF01
43
MR24
48.1
TT00
65.3
OC00
229
MR01
96.4
WC00
136.1
MR10
63
GC01
98.8
MR03
90.5
MR06
94
BC00
53
MC06
58.7
N
Legend
Median Specific Conductance
(µs/cm @25°C)
MC17
42.8


MAP A-6
Marys River Watershed
Water Quality
Sampling Sites
WF01
8.38
MR24
7.10
TT00
7.33
WC00
9.47
MR10
9.25
OC00
6.33
MR01
8.36
GC01
8.65
MR06
8.14
MR03
7.86
BC00
8.04
MC06
2.63
N
MC17
7.88
Legend
Minimum Dissolved Oxygen (mg/L)


MAP A-7
Marys River Watershed
Water Quality
Sampling Sites
WF01
1.2
MR24
1.0
TT00
1.0
MR01
2.1
WC00
0.5
MR10
0.6
OC00
0.5
MR03
2.2
GC01
0.5
MR06
0.5
MC06
5.5
BC00
1.8
N
Legend
MC17
2.7
Maximum Nitrate (mg/L)

MAP A-8
Marys River Watershed
Water Quality Sampling Sites



APPENDIX 2

QUANTITATIVE DATA DESCRIPTION

Appendix Table A-1. Quantitative data description
Fecal Coliform Bacteria

No missing values

COLI

	BC00	GC01	MC06	MC17	MR00	MR01	MR03	MR06	MR09	MR10	MR24	OC00	TT00	WC00	WF01
No of values used	12	13	12	12	5	16	16	18	6	12	12	20	12	12	17
No of values ignored	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
No of min. val.	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
% of min. val.	8.33	7.69	8.33	8.33	20.00	6.25	6.25	5.56	16.67	8.33	8.33	5.00	8.33	8.33	5.88
Minimum	150.00	150.00	100.00	220.00	110.00	129.80	35.00	200.50	200.50	260.00	410.00	180.00	200.00	260.00	480.00
1st quartile	525.00	455.00	490.00	840.00	119.90	190.00	270.00	760.00	630.00	370.00	475.00	750.00	430.00	960.00	565.00
Median	1110.00	1300.00	835.00	2000.00	220.00	415.00	520.00	1500.00	885.00	510.00	670.00	1300.00	630.00	1300.00	1200.00
3rd quartile	1700.00	2400.00	1800.00	2400.00	310.00	835.00	675.00	1700.00	1100.00	1460.00	1385.00	2400.00	1310.00	2400.00	2400.00
Maximum	2400.00	2400.00	2400.00	2400.00	370.00	2400.00	1600.00	2400.00	1600.00	2400.00	2400.00	2400.00	2400.00	2400.00	2400.00
Range	2250.00	2250.00	2300.00	2180.00	260.00	2270.20	1565.00	2199.50	1399.50	2140.00	1990.00	2220.00	2200.00	2140.00	1920.00
Total	13520.00	17390.00	13190.00	19840.00	1079.80	11109.80	9515.50	23480.50	5300.50	11280.00	11580.00	28011.00	11050.00	18460.00	23520.00
Mean	1126.67	1337.69	1099.17	1653.33	215.96	694.36	594.72	1304.47	883.42	940.00	965.00	1400.55	920.83	1538.33	1383.53
Geometric mean	875.36	973.56	794.88	1304.66	196.18	433.50	436.58	1108.76	745.15	687.80	783.48	1060.27	702.65	1274.86	1138.51
Harmonic mean	612.64	613.96	492.80	867.79	178.30	298.14	251.34	860.20	576.50	541.95	673.26	685.66	541.81	961.48	932.76
Kurtosis (Pearson)	-1.42	-1.77	-1.40	-1.50	-1.74	0.50	0.37	-1.28	-1.37	-1.02	-0.88	-1.68	-0.77	-1.72	-1.86
Skewness (Pearson)	0.26	0.06	0.50	-0.57	0.33	1.38	1.13	-0.18	0.07	0.92	1.00	-0.04	0.90	-0.08	0.18
Kurtosis	-1.04	-1.73	-1.01	-1.19	-0.14	1.86	1.66	-1.01	0.59	-0.29	-0.02	-1.63	0.19	-1.61	-1.89
Skewness	0.34	0.07	0.65	-0.75	0.68	1.68	1.38	-0.22	0.12	1.21	1.31	-0.05	1.17	-0.11	0.22
CV (standard deviation/mean)	0.64	0.67	0.74	0.52	0.48	1.08	0.76	0.48	0.54	0.88	0.75	0.61	0.78	0.53	0.60
Sample variance	471322.22	733740.83	598957.64	689022.22	8710.89	527401.22	190461.19	375285.57	186241.70	625033.33	475958.33	687254.72	472574.31	615563.89	638058.13
Estimated variance	514169.70	794885.90	653408.33	751660.61	10888.61	562561.30	203158.60	397361.19	223490.04	681854.55	519227.27	723426.02	515535.61	671524.24	677936.76
Sample standard deviation	686.53	856.59	773.92	830.07	93.33	726.22	436.42	612.61	431.56	790.59	689.90	829.01	687.44	784.58	798.79
Estimated standard deviation	717.06	891.56	808.34	866.98	104.35	750.04	450.73	630.37	472.75	825.74	720.57	850.54	718.01	819.47	823.37
Mean absolute deviation	606.67	765.21	667.36	737.78	76.85	550.32	314.62	539.48	349.92	663.33	584.17	769.45	556.25	718.06	744.91
Standard deviation of the mean	207.00	247.28	233.35	250.28	46.67	187.51	112.68	148.58	193.00	238.37	208.01	190.19	207.27	236.56	199.70

Appendix Table A-2. Quantitative data description
Dissolved Oxygen concentration

No missing values

DOCON

	BC00	GC01	MC06	MC17	MR01	MR03	MR06	MR10	MR24	OC00	TT00	WC00	WF01
No of values used	11	11	11	11	11	11	11	11	11	11	11	11	11
No of values ignored	0	0	0	0	0	0	0	0	0	0	0	0	0
No of min. val.	1	1	1	1	1	1	1	1	1	1	1	1	1
% of min. val.	9.091	9.091	9.091	9.091	9.091	9.091	9.091	9.091	9.091	9.091	9.091	9.091	9.091
Minimum	8.040	8.650	2.630	7.880	8.360	7.860	8.140	9.250	7.100	6.330	7.330	9.470	8.380
1st quartile	8.410	9.760	3.660	8.540	8.610	8.580	8.940	10.020	7.610	9.120	8.190	10.110	8.600
Median	11.470	11.900	8.270	11.410	10.620	10.590	11.380	12.000	10.860	11.680	11.300	12.090	10.470
3rd quartile	12.210	12.450	10.900	12.170	11.800	11.940	12.070	12.700	11.280	12.660	11.490	12.420	11.190
Maximum	12.860	13.070	11.680	12.820	12.640	12.330	12.870	16.620	12.430	13.090	12.700	13.030	12.680
Range	4.820	4.420	9.050	4.940	4.280	4.470	4.730	7.370	5.330	6.760	5.370	3.560	4.300
Total	116.070	122.240	84.760	114.840	112.250	110.990	117.030	131.380	107.650	117.170	111.120	124.950	111.610
Mean	10.552	11.113	7.705	10.440	10.205	10.090	10.639	11.944	9.786	10.652	10.102	11.359	10.146
Geometric mean	10.398	11.006	6.813	10.277	10.090	9.954	10.498	11.795	9.595	10.397	9.917	11.291	10.056
Harmonic mean	10.242	10.896	5.823	10.112	9.976	9.818	10.355	11.655	9.399	10.114	9.728	11.222	9.966
Kurtosis (Pearson)	-1.899	-1.730	-1.667	-1.886	-1.812	-1.845	-1.855	0.073	-1.821	-1.319	-1.825	-1.838	-1.382
Skewness (Pearson)	-0.157	-0.268	-0.330	-0.116	0.102	-0.032	-0.166	0.723	-0.161	-0.515	-0.189	-0.172	0.208
Kurtosis	-1.946	-1.605	-1.478	-1.920	-1.771	-1.837	-1.858	2.031	-1.790	-0.776	-1.797	-1.823	-0.904
Skewness	-0.211	-0.360	-0.444	-0.155	0.137	-0.043	-0.224	0.972	-0.216	-0.693	-0.254	-0.231	0.279
CV (standard deviation/mean)	0.176	0.143	0.447	0.183	0.158	0.171	0.168	0.170	0.203	0.216	0.196	0.114	0.141
Sample variance	3.145	2.282	10.767	3.306	2.352	2.701	2.905	3.746	3.597	4.825	3.568	1.515	1.859
Estimated variance	3.460	2.510	11.844	3.637	2.587	2.971	3.195	4.120	3.956	5.307	3.925	1.667	2.045
Sample standard deviation	1.774	1.511	3.281	1.818	1.533	1.643	1.704	1.935	1.896	2.197	1.889	1.231	1.363
Estimated standard deviation	1.860	1.584	3.441	1.907	1.608	1.724	1.787	2.030	1.989	2.304	1.981	1.291	1.430
Mean absolute deviation	1.693	1.413	2.889	1.733	1.431	1.540	1.616	1.400	1.780	1.973	1.793	1.172	1.188
Standard deviation of the mean	0.561	0.478	1.038	0.575	0.485	0.520	0.539	0.612	0.600	0.695	0.597	0.389	0.431

Appendix Table A-3. Quantitative data description
E. coli bacteria

No missing values

E COLI

	BC00	GC01	MC06	MC17	MR00	MR01	MR03	MR06	MR09	MR10	MR24	OC00	TT00	WC00	WF01
No of values used	12	13	12	12	5	16	16	18	6	12	12	20	12	12	16
No of values ignored	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
No of min. val.	1	1	2	1	1	1	1	1	1	1	1	1	1	1	1
% of min. val.	8.33	7.69	16.67	8.33	20.00	6.25	6.25	5.56	16.67	8.33	8.33	5.00	8.33	8.33	6.25
Minimum	10.00	4.00	16.00	6.30	18.00	15.00	6.20	10.00	17.00	12.00	7.40	17.00	6.00	10.00	12.00
1st quartile	26.00	12.90	28.50	32.50	20.10	30.50	34.50	32.00	41.00	28.50	25.00	47.65	13.00	25.50	26.00
Median	107.00	78.00	59.00	170.00	30.00	39.50	51.50	71.00	56.05	38.50	41.00	167.50	30.50	50.00	165.00
3rd quartile	220.00	105.00	106.50	650.00	41.00	60.00	78.50	99.00	59.00	68.00	80.50	375.00	52.00	165.00	370.00
Maximum	1000.00	870.00	160.00	2400.00	46.00	690.00	190.00	410.00	76.00	730.00	240.00	2400.00	120.00	2400.00	1400.00
Range	990.00	866.00	144.00	2393.70	28.00	675.00	183.80	400.00	59.00	718.00	232.60	2383.00	114.00	2390.00	1388.00
Total	2332.00	2328.10	849.00	5259.30	152.20	1325.40	1100.60	1609.90	305.10	1303.00	827.40	6793.70	501.00	3390.00	4298.00
Mean	194.33	179.08	70.75	438.28	30.44	82.84	68.79	89.44	50.85	108.58	68.95	339.69	41.75	282.50	268.63
Geometric mean	91.22	53.12	53.21	135.39	28.81	46.02	52.68	59.73	46.25	50.98	44.29	141.34	28.29	73.42	117.34
Harmonic mean	43.86	18.86	39.09	38.42	27.26	36.67	35.86	39.26	40.24	35.47	28.68	69.66	19.19	35.05	50.60
Kurtosis (Pearson)	3.19	0.87	-1.22	2.90	-1.85	9.07	-0.03	4.95	-1.22	4.60	0.33	7.05	-0.44	5.19	3.59
Skewness (Pearson)	2.01	1.64	0.67	1.93	0.21	3.21	1.11	2.20	-0.47	2.42	1.31	2.66	1.00	2.56	1.96
Kurtosis	7.67	3.01	-0.66	7.12	-0.83	15.53	1.03	8.38	1.22	10.33	2.26	10.99	0.80	11.45	6.80
Skewness	2.63	2.10	0.88	2.52	0.44	3.92	1.35	2.62	-0.84	3.17	1.72	3.12	1.31	3.36	2.39
CV (standard deviation/mean)	1.42	1.73	0.75	1.55	0.37	1.97	0.75	1.04	0.39	1.85	1.04	1.62	0.91	2.38	1.32
Sample variance	69440.72	88259.91	2573.02	421749.25	99.17	24882.15	2485.67	8200.43	335.55	37116.74	4683.79	286591.15	1320.19	414977.92	118162.73
Estimated variance	75753.52	95614.90	2806.93	460090.09	123.97	26540.96	2651.38	8682.81	402.66	40490.99	5109.59	301674.90	1440.20	452703.18	126040.25
Sample standard deviation	263.52	297.09	50.73	649.42	9.96	157.74	49.86	90.56	18.32	192.66	68.44	535.34	36.33	644.19	343.75
Estimated standard deviation	275.23	309.22	52.98	678.30	11.13	162.91	51.49	93.18	20.07	201.22	71.48	549.25	37.95	672.83	355.02
Mean absolute deviation	172.83	212.59	41.29	452.82	8.45	75.90	38.16	57.61	14.57	117.14	52.19	335.16	28.54	357.50	237.11
Standard deviation of the mean	79.45	85.76	15.29	195.81	4.98	40.73	12.87	21.96	8.19	58.09	20.63	122.82	10.96	194.23	88.76

Appendix Table A-4. Quantitative data description
Nitrate nitrogen

No missing values

NO3

	BC00	GC01	MC06	MC17	MR01	MR03	MR06	MR10	MR24	OC00	TT00	WC00	WF01
No of values used	11.00	12.00	11.00	11.00	11.00	11.00	12.00	11.00	11.00	14.00	11.00	11.00	15.00
No of values ignored	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
No of min. val.	10.00	12.00	8.00	10.00	7.00	7.00	12.00	8.00	5.00	14.00	5.00	11.00	6.00
% of min. val.	90.91	100.00	72.73	90.91	63.64	63.64	100.00	72.73	45.45	100.00	45.45	100.00	40.00
Minimum	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
1st quartile	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Median	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.70	0.50	0.70	0.50	0.80
3rd quartile	0.50	0.50	0.55	0.50	0.80	0.80	0.50	0.55	1.00	0.50	1.00	0.50	1.10
Maximum	1.80	0.50	5.50	2.70	2.10	2.20	0.50	0.60	1.00	0.50	1.00	0.50	1.20
Range	1.30	0.00	5.00	2.20	1.60	1.70	0.00	0.10	0.50	0.00	0.50	0.00	0.70
Total	6.80	6.00	11.40	7.70	8.20	8.30	6.00	5.80	7.70	7.00	7.70	5.50	11.90
Mean	0.62	0.50	1.04	0.70	0.75	0.75	0.50	0.53	0.70	0.50	0.70	0.50	0.79
Geometric mean	0.56	0.50	0.69	0.58	0.66	0.66	0.50	0.53	0.67	0.50	0.67	0.50	0.75
Harmonic mean	0.54	0.50	0.59	0.54	0.61	0.61	0.50	0.52	0.64	0.50	0.64	0.50	0.70
Kurtosis (Pearson)	4.52		4.15	4.52	2.33	2.54		-1.31	-1.72		-1.72		-1.69
Skewness (Pearson)	2.47		2.36	2.47	1.86	1.91		0.88	0.36		0.36		0.16
Kurtosis	11.00		10.25	11.00	6.59	7.01		-0.76	-1.59		-1.59		-1.61
Skewness	3.32		3.18	3.32	2.50	2.57		1.19	0.49		0.49		0.19
CV (standard deviation/mean)	0.63	0.00	1.45	0.95	0.66	0.69	0.00	0.09	0.31	0.00	0.31	0.00	0.35
Sample variance	0.14	0.00	2.04	0.40	0.22	0.24	0.00	0.00	0.04	0.00	0.04	0.00	0.07
Estimated variance	0.15	0.00	2.25	0.44	0.24	0.27	0.00	0.00	0.05	0.00	0.05	0.00	0.08
Sample standard deviation	0.37	0.00	1.43	0.63	0.47	0.49	0.00	0.04	0.21	0.00	0.21	0.00	0.27
Estimated standard deviation	0.39	0.00	1.50	0.66	0.49	0.52	0.00	0.05	0.22	0.00	0.22	0.00	0.28
Mean absolute deviation	0.21	0.00	0.86	0.36	0.34	0.35	0.00	0.04	0.18	0.00	0.18	0.00	0.23
Standard deviation of the mean	0.12	0.00	0.45	0.20	0.15	0.16	0.00	0.01	0.07	0.00	0.07	0.00	0.07

Appendix Table A-5. Quantitative data description
pH

No missing values

PH

	BC00	GC01	MC06	MC17	MR01	MR03	MR06	MR10	MR24	OC00	TT00	WC00	WF01
No of values used	11	12	11	11	11	11	11	11	11	11	11	11	11
No of values ignored	0	0	0	0	0	0	0	0	0	0	0	0	0
No of min. val.	1	1	1	1	1	1	1	1	1	1	1	1	1
% of min. val.	9.09	8.33	9.09	9.09	9.09	9.09	9.09	9.09	9.09	9.09	9.09	9.09	9.09
Minimum	6.49	7.09	6.51	6.43	6.80	6.76	7.10	7.07	6.36	6.80	6.45	6.90	6.42
1st quartile	6.99	7.24	6.80	6.83	7.02	6.95	7.14	7.30	6.76	7.39	6.65	7.21	6.60
Median	7.36	7.37	7.07	7.12	7.42	7.28	7.40	7.39	7.16	7.60	7.10	7.61	7.28
3rd quartile	7.55	7.57	7.45	7.47	7.73	7.62	7.58	7.75	7.29	7.86	7.39	7.73	7.73
Maximum	7.62	7.67	7.47	7.58	7.96	7.85	7.69	8.05	7.60	7.92	7.43	7.99	7.76
Range	1.13	0.58	0.96	1.15	1.16	1.09	0.59	0.98	1.24	1.12	0.98	1.09	1.34
Total	79.67	88.68	77.63	78.29	81.47	80.11	81.31	82.44	77.56	83.19	76.83	82.34	78.46
Mean	7.24	7.39	7.06	7.12	7.41	7.28	7.39	7.49	7.05	7.56	6.98	7.49	7.13
Geometric mean	7.23	7.39	7.05	7.11	7.40	7.27	7.39	7.49	7.04	7.56	6.98	7.48	7.11
Harmonic mean	7.23	7.39	7.04	7.10	7.39	7.27	7.39	7.48	7.03	7.55	6.97	7.47	7.10
Kurtosis (Pearson)	-0.84	-1.60	-1.51	-1.42	-1.58	-1.59	-1.65	-1.08	-1.14	-0.34	-1.85	-1.15	-1.95
Skewness (Pearson)	-0.65	0.03	-0.08	-0.27	-0.25	0.10	-0.02	0.60	-0.35	-0.82	-0.09	-0.23	-0.05
Kurtosis	0.18	-1.38	-1.17	-0.97	-1.31	-1.33	-1.44	-0.30	-0.42	1.20	-1.86	-0.44	-2.04
Skewness	-0.88	0.04	-0.10	-0.37	-0.33	0.13	-0.03	0.80	-0.48	-1.11	-0.12	-0.31	-0.07
CV (standard deviation/mean)	0.05	0.03	0.05	0.05	0.05	0.05	0.03	0.04	0.05	0.04	0.05	0.04	0.08
Sample variance	0.12	0.04	0.10	0.13	0.15	0.12	0.04	0.09	0.12	0.10	0.13	0.09	0.27
Estimated variance	0.13	0.04	0.11	0.14	0.17	0.13	0.05	0.10	0.14	0.12	0.14	0.10	0.29
Sample standard deviation	0.34	0.19	0.31	0.36	0.39	0.34	0.21	0.30	0.35	0.32	0.36	0.30	0.52
Estimated standard deviation	0.36	0.20	0.33	0.38	0.41	0.36	0.22	0.31	0.37	0.34	0.37	0.32	0.54
Mean absolute deviation	0.30	0.17	0.27	0.32	0.33	0.30	0.18	0.25	0.30	0.26	0.34	0.27	0.49
Standard deviation of the mean	0.11	0.06	0.10	0.11	0.12	0.11	0.06	0.09	0.11	0.10	0.11	0.10	0.16

Appendix Table A-6. Quantitative data description
Specific Conductance

No missing values

SPC

	BC00	GC01	MC06	MC17	MR01	MR03	MR06	MR10	MR24	OC00	TT00	WC00	WF01
No of values used	11	11	11	11	11	11	11	11	11	11	11	11	11
No of values ignored	0	0	0	0	0	0	0	0	0	0	0	0	0
No of min. val.	1	1	1	1	1	1	1	1	1	1	1	1	1
% of min. val.	9.091	9.091	9.091	9.091	9.091	9.091	9.091	9.091	9.091	9.091	9.091	9.091	9.091
Minimum	30.600	69.000	49.000	35.000	64.000	62.000	16.000	18.200	41.000	122.000	51.000	67.000	34.000
1st quartile	46.000	73.000	55.000	38.000	66.000	65.000	67.000	58.000	42.000	137.000	52.000	93.000	42.000
Median	53.000	98.800	58.700	42.800	96.400	90.500	94.000	63.000	48.100	229.000	65.300	136.100	43.000
3rd quartile	72.000	116.000	94.000	50.000	121.000	110.000	108.000	84.500	60.000	258.000	75.000	147.000	49.500
Maximum	74.000	118.000	110.000	56.000	135.000	120.000	115.000	100.000	68.000	274.000	76.000	150.000	54.000
Range	43.400	49.000	61.000	21.000	71.000	58.000	99.000	81.800	27.000	152.000	25.000	83.000	20.000
Total	623.600	1038.800	774.700	479.800	1038.400	969.500	920.900	761.200	561.100	2259.800	694.300	1327.100	498.800
Mean	56.691	94.436	70.427	43.618	94.400	88.136	83.718	69.200	51.009	205.436	63.118	120.645	45.345
Geometric mean	54.848	92.489	67.554	43.133	91.063	85.697	75.899	64.117	50.112	197.067	62.358	116.951	44.987
Harmonic mean	52.861	90.533	65.112	42.663	87.858	83.326	61.924	56.310	49.275	188.267	61.605	112.895	44.617
Kurtosis (Pearson)	-1.477	-1.922	-1.311	-1.429	-1.687	-1.742	0.146	-0.277	-1.568	-1.800	-1.919	-1.544	-0.961
Skewness (Pearson)	-0.192	-0.080	0.717	0.329	0.199	0.146	-0.966	-0.608	0.468	-0.291	0.026	-0.407	-0.165
Kurtosis	-1.096	-1.992	-0.761	-0.998	-1.518	-1.629	2.178	1.325	-1.279	-1.747	-1.987	-1.230	-0.055
Skewness	-0.258	-0.107	0.963	0.442	0.268	0.196	-1.299	-0.818	0.629	-0.392	0.035	-0.547	-0.222
CV (standard deviation/mean)	0.256	0.210	0.318	0.158	0.280	0.247	0.342	0.332	0.202	0.285	0.162	0.245	0.130
Sample variance	191.537	357.359	456.517	43.349	632.909	429.550	745.449	479.564	96.310	3112.413	95.285	794.512	31.448
Estimated variance	210.691	393.095	502.168	47.684	696.200	472.505	819.994	527.520	105.941	3423.655	104.814	873.963	34.593
Sample standard deviation	13.840	18.904	21.366	6.584	25.158	20.726	27.303	21.899	9.814	55.789	9.761	28.187	5.608
Estimated standard deviation	14.515	19.827	22.409	6.905	26.386	21.737	28.636	22.968	10.293	58.512	10.238	29.563	5.882
Mean absolute deviation	12.645	17.851	18.962	5.802	22.364	18.669	21.926	17.636	8.721	51.488	9.198	26.405	4.740
Standard deviation of the mean	4.376	5.978	6.757	2.082	7.956	6.554	8.634	6.925	3.103	17.642	3.087	8.914	1.773

Appendix Table A-7. Quantitative data description
Total Kjeldahl Nitrogen

No missing values

TKN

	BC00	GC01	MC06	MC17	MR01	MR03	MR06	MR10	MR24	OC00	TT00	WC00	WF01
No of values used	12	12	11	11	11	11	12	11	11	14	11	11	15
No of values ignored	0	0	0	0	0	0	0	0	0	0	0	0	0
No of min. val.	6	1	1	1	1	1	1	1	4	1	1	1	7
% of min. val.	50.000	8.333	9.091	9.091	9.091	9.091	8.333	9.091	36.364	7.143	9.091	9.091	46.667
Minimum	0.200	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.200	0.100	0.100	0.100	0.200
1st quartile	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200
Median	0.225	0.250	0.250	0.250	0.250	0.250	0.225	0.250	0.250	0.250	0.250	0.250	0.250
3rd quartile	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500
Maximum	1.100	1.500	1.200	1.800	3.000	3.000	1.400	1.800	1.000	2.700	1.100	2.200	1.900
Range	0.900	1.400	1.100	1.700	2.900	2.900	1.300	1.700	0.800	2.600	1.000	2.100	1.700
Total	4.300	5.800	4.500	4.700	5.900	5.900	4.500	5.900	4.200	7.050	4.000	5.100	6.050
Mean	0.358	0.483	0.409	0.427	0.536	0.536	0.375	0.536	0.382	0.504	0.364	0.464	0.403
Geometric mean	0.301	0.343	0.327	0.307	0.321	0.321	0.290	0.366	0.330	0.342	0.293	0.312	0.310
Harmonic mean	0.267	0.264	0.265	0.247	0.248	0.248	0.241	0.273	0.293	0.270	0.245	0.247	0.270
Kurtosis (Pearson)	2.048	0.066	1.000	3.270	4.094	4.094	3.103	0.141	0.941	6.028	1.300	3.698	6.452
Skewness (Pearson)	1.708	1.305	1.333	2.088	2.337	2.337	1.982	1.311	1.344	2.631	1.478	2.217	2.680
Kurtosis	5.512	1.764	3.900	8.477	10.139	10.139	7.508	2.168	3.781	11.627	4.506	9.340	11.812
Skewness	2.236	1.709	1.792	2.807	3.142	3.142	2.595	1.762	1.807	3.305	1.987	2.981	3.313
CV (standard deviation/mean)	0.745	0.977	0.759	1.117	1.546	1.546	0.937	1.028	0.637	1.302	0.778	1.280	1.076
Sample variance	0.065	0.204	0.088	0.207	0.625	0.625	0.113	0.276	0.054	0.399	0.073	0.320	0.176
Estimated variance	0.071	0.223	0.096	0.228	0.688	0.688	0.123	0.304	0.059	0.430	0.080	0.352	0.188
Sample standard deviation	0.256	0.452	0.296	0.455	0.791	0.791	0.336	0.526	0.232	0.632	0.270	0.566	0.419
Estimated standard deviation	0.267	0.472	0.310	0.477	0.829	0.829	0.351	0.551	0.243	0.656	0.283	0.593	0.434
Mean absolute deviation	0.194	0.331	0.228	0.289	0.448	0.448	0.233	0.387	0.180	0.342	0.208	0.336	0.251
Standard deviation of the mean	0.077	0.136	0.094	0.144	0.250	0.250	0.101	0.166	0.073	0.175	0.085	0.179	0.112

Appendix Table A-8. Quantitative data description
Total Phosphorus

No missing values

TP

	BC00	GC01	MC06	MC17	MR01	MR03	MR06	MR10	MR24	OC00	TT00	WC00	WF01
No of values used	11	12	11	11	11	11	12	11	11	14	11	11	15
No of values ignored	0	0	0	0	0	0	0	0	0	0	0	0	0
No of min. val.	1	1	1	1	3	1	6	1	1	1	1	2	1
% of min. val.	9.09	8.33	9.09	9.09	27.27	9.09	50.00	9.09	9.09	7.14	9.09	18.18	6.67
Minimum	0.03	0.01	0.03	0.01	0.03	0.01	0.03	0.01	0.02	0.02	0.01	0.02	0.01
1st quartile	0.05	0.03	0.07	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Median	0.06	0.03	0.09	0.03	0.05	0.04	0.03	0.03	0.03	0.04	0.03	0.03	0.03
3rd quartile	0.09	0.04	0.13	0.06	0.07	0.05	0.05	0.03	0.03	0.06	0.04	0.03	0.05
Maximum	0.09	0.12	0.27	0.22	0.09	0.07	0.10	0.09	0.16	0.33	0.06	1.00	0.08
Range	0.07	0.11	0.25	0.22	0.07	0.06	0.08	0.08	0.14	0.31	0.05	0.98	0.07
Total	0.68	0.50	1.21	0.55	0.56	0.42	0.45	0.36	0.43	0.85	0.35	1.27	0.56
Mean	0.06	0.04	0.11	0.05	0.05	0.04	0.04	0.03	0.04	0.06	0.03	0.12	0.04
Geometric mean	0.06	0.03	0.09	0.03	0.05	0.03	0.03	0.03	0.03	0.04	0.03	0.04	0.03
Harmonic mean	0.05	0.03	0.08	0.02	0.04	0.03	0.03	0.03	0.03	0.04	0.03	0.03	0.03
Kurtosis (Pearson)	-1.45	0.33	0.15	3.48	-1.32	-1.26	2.60	2.95	4.29	6.42	-1.04	4.52	-0.56
Skewness (Pearson)	-0.09	1.45	1.04	2.15	0.24	0.22	1.87	1.92	2.40	2.73	0.56	2.47	0.82
Kurtosis	-1.04	2.27	2.19	8.91	-0.78	-0.65	6.56	7.83	10.53	12.29	-0.22	10.99	0.26
Skewness	-0.12	1.90	1.40	2.89	0.32	0.30	2.45	2.58	3.22	3.43	0.76	3.31	1.02
CV (standard deviation/mean)	0.38	0.91	0.63	1.19	0.43	0.47	0.58	0.63	1.03	1.31	0.47	2.55	0.54
Sample variance	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.08	0.00
Estimated variance	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.09	0.00
Sample standard deviation	0.02	0.04	0.07	0.06	0.02	0.02	0.02	0.02	0.04	0.08	0.01	0.28	0.02
Estimated standard deviation	0.02	0.04	0.07	0.06	0.02	0.02	0.02	0.02	0.04	0.08	0.02	0.29	0.02
Mean absolute deviation	0.02	0.03	0.05	0.03	0.02	0.01	0.02	0.01	0.02	0.04	0.01	0.16	0.02
Standard deviation of the mean	0.01	0.01	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.02	0.00	0.09	0.01

Appendix Table A-9. Quantitative data description
Turbidity

No missing values

TURB

	BC00	GC01	MC06	MC17	MR01	MR03	MR06	MR10	MR24	OC00	TT00	WC00	WF01
No of values used	12	13	12	13	12	12	13	12	13	12	12	12	16
No of values ignored	0	0	0	0	0	0	0	0	0	0	0	0	0
No of min. val.	1	1	1	1	1	1	1	1	1	1	1	1	1
% of min. val.	8.33	7.69	8.33	7.69	8.33	8.33	7.69	8.33	7.69	8.33	8.33	8.33	6.25
Minimum	1.51	0.39	2.26	2.96	0.70	0.78	0.59	0.43	1.51	0.53	1.12	0.52	1.04
1st quartile	3.27	0.86	5.31	5.73	2.34	1.71	1.02	1.01	1.63	1.21	1.48	1.19	2.16
Median	6.22	2.64	6.21	7.92	4.15	5.32	1.68	1.85	2.66	2.32	2.01	1.66	2.68
3rd quartile	10.14	7.87	7.81	27.77	8.56	6.82	7.22	7.62	4.61	8.56	6.16	3.47	3.21
Maximum	19.25	39.50	8.65	48.20	9.97	23.77	18.20	25.80	5.09	55.50	8.36	45.60	6.72
Range	17.74	39.11	6.39	45.24	9.27	22.99	17.61	25.37	3.58	54.97	7.24	45.08	5.68
Total	87.84	86.12	73.20	190.80	62.16	71.15	54.58	62.82	37.95	97.30	42.11	72.80	48.55
Mean	7.32	6.62	6.10	14.68	5.18	5.93	4.20	5.24	2.92	8.11	3.51	6.07	3.03
Geometric mean	5.58	2.70	5.65	10.10	4.03	3.95	2.44	2.47	2.63	3.23	2.65	2.33	2.74
Harmonic mean	4.10	1.38	5.07	7.57	2.85	2.61	1.64	1.39	2.39	1.83	2.13	1.45	2.50
Kurtosis (Pearson)	-0.40	3.77	-0.96	-0.16	-1.61	3.03	1.69	2.23	-1.52	4.68	-1.37	4.94	0.99
Skewness (Pearson)	0.83	2.15	-0.51	1.11	0.30	1.90	1.61	1.77	0.54	2.42	0.73	2.50	1.42
Kurtosis	0.88	8.21	-0.18	1.16	-1.41	7.37	4.49	5.86	-1.27	10.49	-0.96	10.98	2.66
Skewness	1.08	2.76	-0.67	1.42	0.40	2.49	2.06	2.32	0.70	3.17	0.95	3.28	1.73
CV (standard deviation/mean)	0.73	1.62	0.35	0.96	0.65	1.04	1.20	1.40	0.48	1.89	0.81	2.09	0.52
Sample variance	26.20	106.85	4.19	182.30	10.40	34.62	23.56	49.38	1.83	214.74	7.33	146.91	2.29
Estimated variance	28.58	115.75	4.58	197.49	11.34	37.76	25.52	53.87	1.99	234.27	7.99	160.26	2.44
Sample standard deviation	5.12	10.34	2.05	13.50	3.22	5.88	4.85	7.03	1.35	14.65	2.71	12.12	1.51
Estimated standard deviation	5.35	10.76	2.14	14.05	3.37	6.15	5.05	7.34	1.41	15.31	2.83	12.66	1.56
Mean absolute deviation	4.04	6.88	1.64	11.57	2.90	3.66	3.77	5.19	1.18	8.41	2.47	7.08	1.07
Standard deviation of the mean	1.54	2.98	0.62	3.90	0.97	1.77	1.40	2.12	0.39	4.42	0.82	3.65	0.39

Appendix Table A-10. Quantitative data description
Temperature

TEMP

	MR24	WF01	TT00	WC00	MC17	BC00	OC00	GC01	MC06	MR10	MR06	MR03	MR01
No of values used	2854.00	2853.00	2854.00	2852.00	2844.00	2292.00	2815.00	2816.00	2844.00	2853.00	2808.00	2838.00	2850.00
No of values ignored	4.00	5.00	4.00	6.00	14.00	566.00	43.00	42.00	14.00	5.00	50.00	20.00	8.00
No of min. val.	8.00	1.00	25.00	2.00	4.00	3.00	3.00	5.00	4.00	3.00	3.00	7.00	4.00
% of min. val.	0.28	0.04	0.88	0.07	0.14	0.13	0.11	0.18	0.14	0.11	0.11	0.25	0.14
Minimum	10.38	9.93	10.85	10.27	10.52	13.03	11.68	11.22	11.33	11.02	12.93	13.49	13.81
1st quartile	13.48	13.65	13.64	14.14	14.22	15.84	15.09	15.26	15.37	15.94	16.85	17.91	18.25
Median	14.87	15.05	15.04	15.56	16.12	16.79	16.36	16.99	17.60	18.08	18.62	19.69	20.04
3rd quartile	15.98	16.00	16.16	16.82	17.39	17.75	17.16	18.44	19.22	19.71	19.92	20.99	21.34
Maximum	18.37	18.23	17.91	20.69	20.78	20.34	19.58	22.70	22.33	25.59	23.40	24.88	24.91
Range	7.99	8.30	7.06	10.42	10.26	7.31	7.90	11.48	11.00	14.57	10.47	11.39	11.10
Total	41701.38	42110.25	42300.16	43955.07	44711.41	38319.03	45178.02	47428.02	49067.84	50951.83	51507.66	54738.59	56153.13
Mean	14.61	14.76	14.82	15.41	15.72	16.72	16.05	16.84	17.25	17.86	18.34	19.29	19.70
Geometric mean	14.49	14.65	14.71	15.28	15.56	16.66	15.96	16.67	17.06	17.61	18.19	19.14	19.54
Harmonic mean	14.36	14.53	14.59	15.14	15.39	16.59	15.88	16.49	16.87	17.35	18.04	18.97	19.38
Kurtosis (Pearson)	-0.67	-0.40	-0.69	-0.31	-0.63	-0.31	-0.22	-0.44	-0.77	-0.33	-0.50	-0.41	-0.49
Skewness (Pearson)	-0.41	-0.51	-0.46	-0.26	-0.31	-0.06	-0.61	-0.12	-0.26	-0.14	-0.23	-0.43	-0.45
Kurtosis	-0.67	-0.40	-0.69	-0.31	-0.63	-0.31	-0.21	-0.44	-0.77	-0.33	-0.50	-0.41	-0.49
Skewness	-0.41	-0.51	-0.46	-0.26	-0.31	-0.06	-0.61	-0.12	-0.26	-0.14	-0.23	-0.43	-0.45
CV (standard deviation/mean)	0.13	0.12	0.12	0.13	0.14	0.09	0.10	0.14	0.15	0.16	0.13	0.12	0.12
Sample variance	3.39	3.08	3.19	3.98	4.78	2.09	2.56	5.62	6.27	8.40	5.27	5.59	5.91
Estimated variance	3.39	3.08	3.19	3.99	4.79	2.09	2.57	5.63	6.27	8.40	5.27	5.60	5.91
Sample standard deviation	1.84	1.75	1.79	2.00	2.19	1.44	1.60	2.37	2.50	2.90	2.29	2.37	2.43
Estimated standard deviation	1.84	1.75	1.79	2.00	2.19	1.44	1.60	2.37	2.50	2.90	2.30	2.37	2.43
Mean absolute deviation	1.51	1.43	1.46	1.60	1.80	1.16	1.28	1.91	2.09	2.31	1.85	1.90	1.97
Standard deviation of the mean	0.03	0.03	0.03	0.04	0.04	0.03	0.03	0.04	0.05	0.05	0.04	0.04	0.05