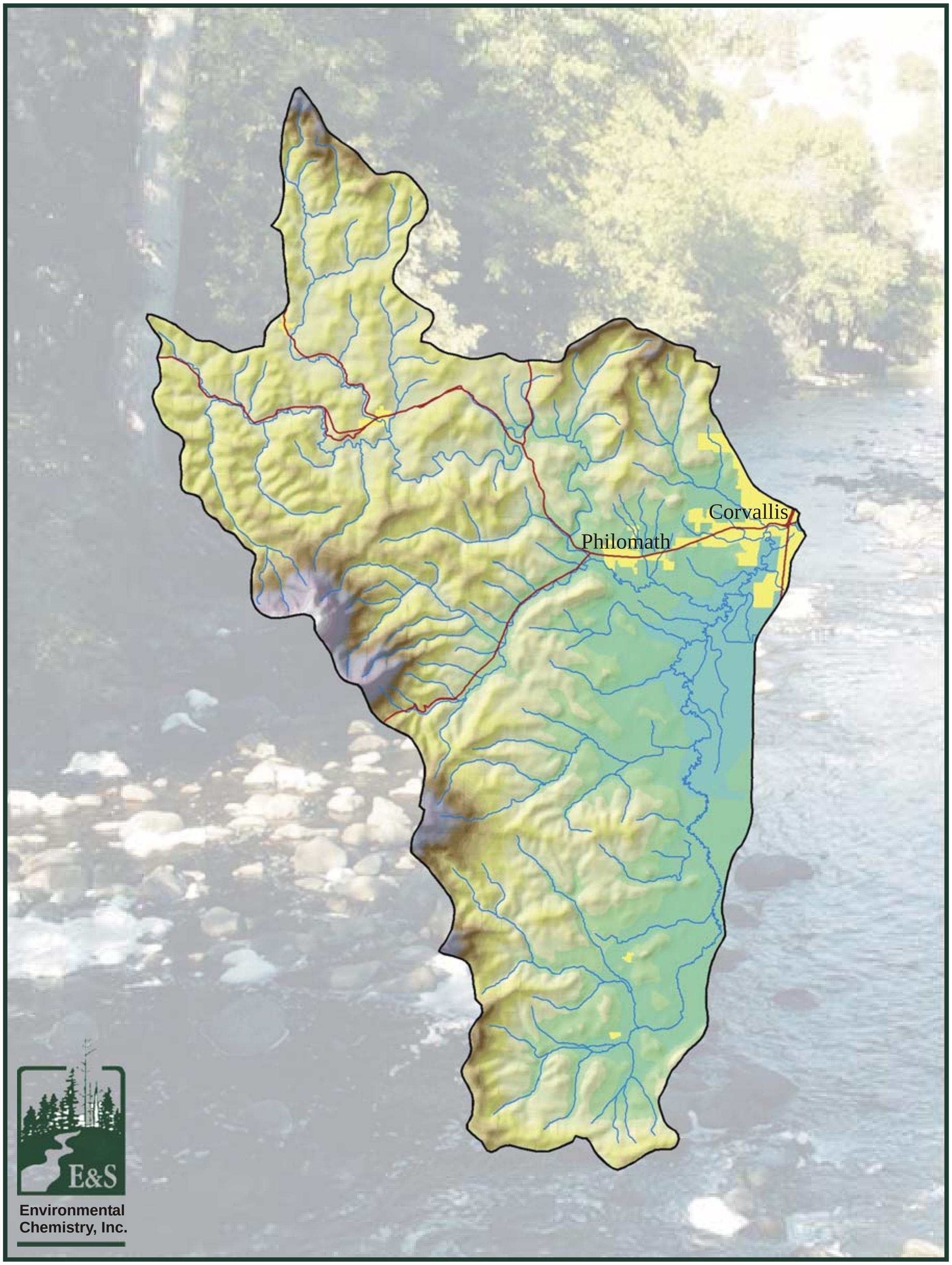
Marys River Watershed

Phase II Water Quality Monitoring



Final Report
July, 2005

E&S Environmental Chemistry, Inc.
and
Marys River Watershed Council

MARYS RIVER WATERSHED

PHASE II WATER QUALITY MONITORING

FINAL REPORT

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Summary

As a result of work during the Phase I Study, three sites were identified that appeared to be adversely affected with respect to water quality. Upper Muddy Creek and lower Muddy Creek showed evidence of possible 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. In the 2001 study, *E. coli* numbers in August were higher downstream of Philomath than upstream, suggesting a possible source of bacterial contamination in the central Philomath area.

In response to these results, the Marys River Watershed Council developed a second phase sampling program to gain a clearer understanding of the potential causes of the observed results, and to help develop restoration activities to remedy any identified problems. The Phase II study was directed toward the Marys River and Muddy Creek. Conditions on Oak Creek are being addressed by Oregon State University.

Phosphorus concentrations in Muddy Creek are comparable to those found in other streams and rivers in the vicinity. PO4 concentrations in Muddy Creek compare favorably with EPA nutrient criteria recommended for streams in the Willamette Valley, but are relatively high compared to proposed nutrient criteria for lakes and reservoirs. Judging by the lakes criteria, phosphorus concentration in Muddy Creek is relatively high and might be expected to contribute to excessive growth of aquatic plants, both algae and rooted vegetation.

There is a statistically significant increase in phosphorus concentration from upstream to downstream in Muddy Creek. The increase is quite regular, suggesting that the source of phosphorus is most likely the result of non-point source runoff. The available data are not sufficient to determine if the source is the result of management activity, or natural geologic processes.

Dissolved oxygen is low in Muddy Creek with median values typically near 50 percent saturation and minimum values as low as 6 percent saturation. Starr Creek was the exception with a median concentration of greater than 80 percent saturation and minimum of 59 percent. This suggests that a there is a substantial source of oxygen demand present in Muddy Creek. Although there are no water quality standards or guidance values for ambient BOD, waters with

BOD5 levels greater than 10 mg/L can be considered polluted and values less than 4 relatively clean.

The results of BOD analysis for Muddy Creek samples during Phase 2 suggest that ambient levels can be high enough to be considered polluted. High levels of BOD could be responsible for the low dissolved oxygen concentrations observed in Muddy Creek. The available data have not identified a localized source for organic matter load to Muddy Creek..

In contrast to Muddy Creek, dissolved oxygen concentration in the Marys River indicates relatively good conditions. Median dissolved oxygen values were in the range of 80 to 90 percent saturation with maximums near 100 percent and minimums greater than 70 percent; values that do not suggest excessive organic load.

Temperature in the areas sampled in Muddy Creek and the Marys River exceeds the current water quality standard for salmon and trout rearing and migration and for salmon migration corridors. Low flow and slow velocity during the summer, especially in Muddy Creek, contribute to the warming of the stream. The relative absence of streamside vegetation capable of providing shade for the stream may also be a contributing factor.

Sampling for bacteria in the Marys River during low flow conditions for the Phase 2 monitoring program have confirmed the relatively low summertime levels of *E. coli* in the river. All samples collected to date have been within the water quality standard for water contact recreation. Low flow sampling did not confirm the suspicion that the waste water treatment facility was a source of bacterial contamination to the Marys River. Much of the *E. coli* in the Marys River at Philomath appeared to originate upstream of Highway 34. Although there was no statistically significant difference in E coli numbers among the sites sampled at low flow on the Marys River between Highway 34 and Bellfountain Road, a number of higher values at site MR3 may suggest a potential contribution in the reach above Fern Road.

Bacteria counts were much higher for samples collected during rain events than during low flow. Counts are high at the most upstream site, Highway 34, indicating that much of the bacterial content in the river is coming from upstream sources. There is no statistically significant difference in *E. Coli* abundance among the sites sampled on the Marys River during rain events, although some higher values at the site MR4 and MR5 suggest there may be some contribution of *E. coli* below Fern Road.

Water quality sampling on Muddy Creek and the Marys River during the Phase 2 monitoring project has not confirmed the presence of any particular point source contributing to high phosphorus concentration, low dissolved oxygen, or high bacteria counts. The conclusion from the Phase 1 and Phase 2 studies is that diffuse sources are the most important factor influencing the constituents considered. In the absence of identified point sources, restoration actions might most effectively be addressed toward investigation of current land use practices in the watershed, and developing and encouraging the use of management methods that will reduce, to the extent possible, loading to the streams of organic matter and phosphorus.
Changes in phosphorus and dissolved oxygen in Muddy Creek above and below McFadden marsh, while not statistically significant, may suggest an opportunity for relatively greater improvement in this reach than at other sites sampled. Increased summertime flow could have a beneficial effect on the water quality constituents measured during Phases 1 and 2 of the Marys River water quality study.

Sustained monitoring is a necessary component to any water quality improvement plan. Many of the improvement measures put into practice may take years to effect an observable improvement in water quality, and it may require many measures implemented across much of the watershed to produce measurable change. Without sustained monitoring it will be difficult to measure the effect of any improvement activity. A modest program of monthly sampling for selected constituents at a few sites augmented by annual or biennial short-term detailed sampling for one or more constituents, if sustained for the long term, could be an effective program. Sites to be considered could include:

- The Marys River at Highway 34
- The Marys River at Bellfountain Road
- The Marys River at Avery Park
- Muddy Creek at Greenberry Road
- Muddy Creek at McFarland Road near Alpine
- Muddy Creek near the confluence with the Marys River (access to this site would require arrangement with local property owners).

Constituents to measure could include temperature, dissolved oxygen, phosphorus, bacteria (*E. coli*), specific conductance, turbidity, and chlorophyll *a*.

Description of the Project

The Marys River Phase II water quality monitoring project was an extension of the Phase I study conducted in 2001 and 2002. It was intended to gather more detailed information for selected constituents (bacteria, dissolved oxygen, and phosphorus) on reaches of Muddy Creek and the Marys River that were identified as potential problem areas during the Phase I study.

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.

Other Studies

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

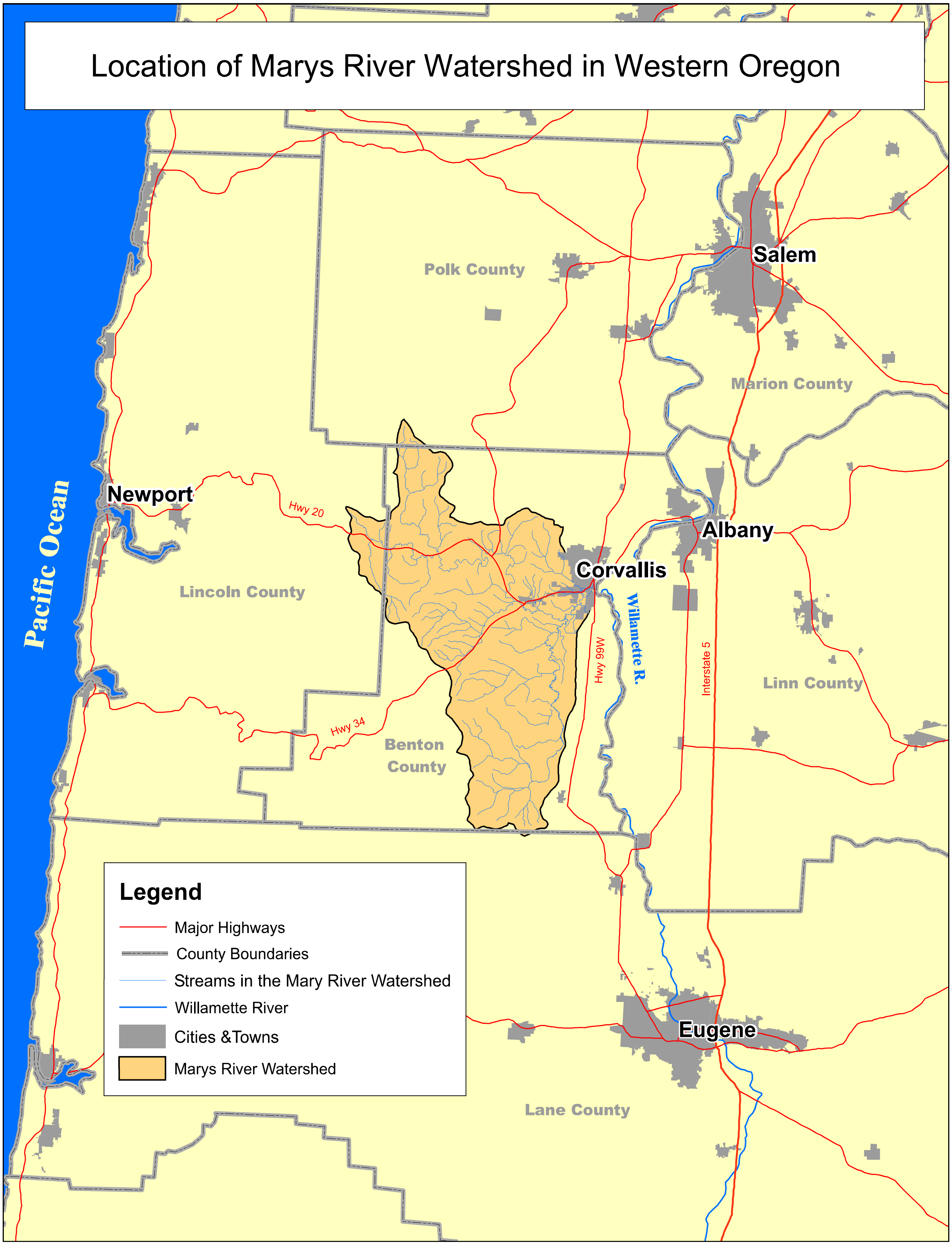

Figure 1. Map showing the location of the Marys River basin within Oregon.

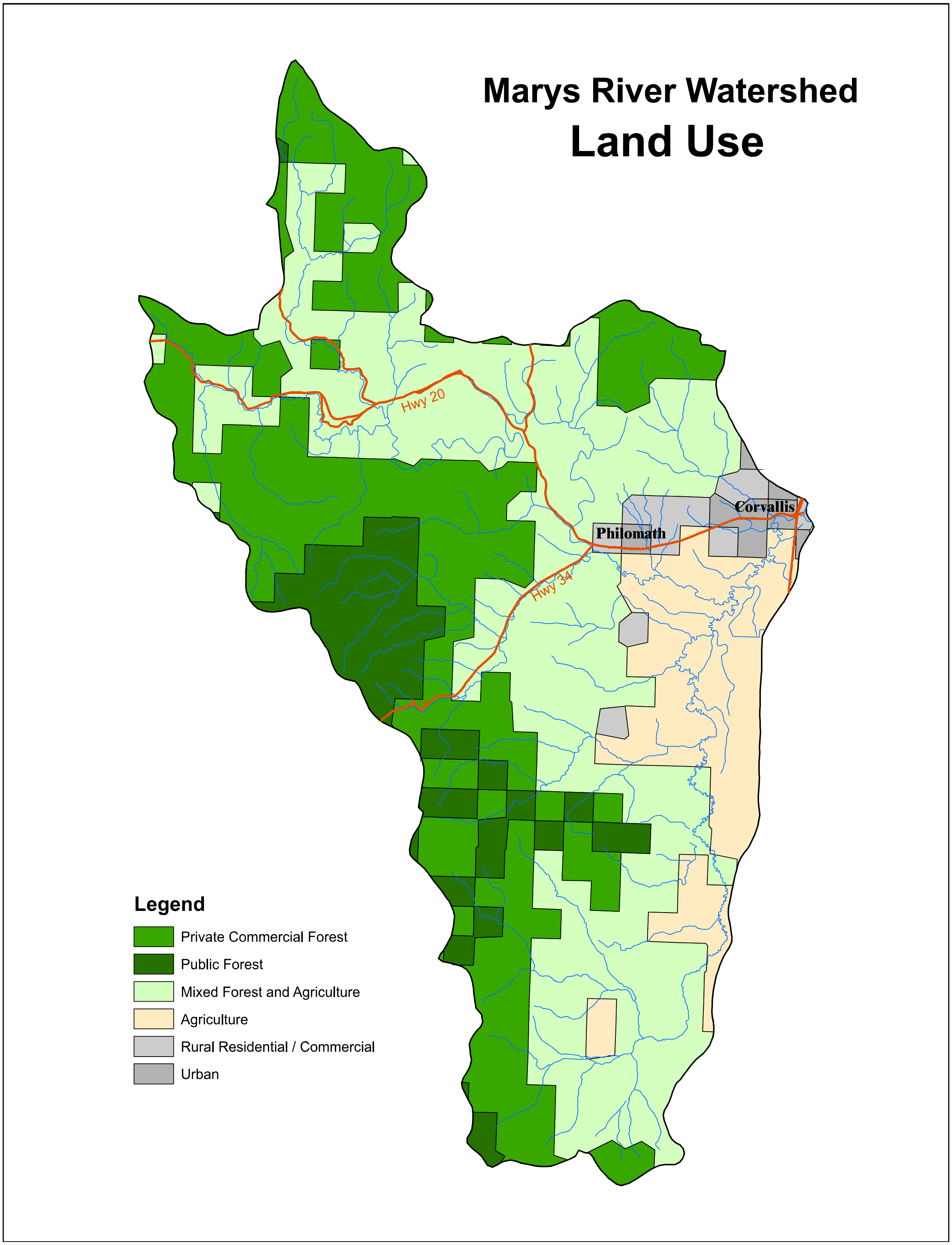

Figure 2. Map showing land use in the Marys River Watershed (Source: Ecosystems Northwest 1999).

Pearcy (1999) conducted a temperature study at 42 sites in the Marys River watershed during the summers of 1998 and 1999. He found that most tributaries had temperatures that were suitable for cutthroat trout (defined as 69º 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) he was able to accurately predict water temperatures in a portion of the Marys River based on weather and hydrology. He 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 could 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 (Wentz et al. 1998).

Prior to 2001 most water quality data from the Marys River catchment had been collected near the mouth. Based on that information the river was considered “water quality limited” because of elevated temperatures, excessively high concentrations of *E. coli* bacteria during the winter, low dissolved oxygen concentrations, and excessive flow allocation. On the current (2002) list of water quality limited waterbodies (“303d list”) the Marys river is included for temperature (summer), fecal coliform (winter, spring, fall), and dissolved oxygen (October 1 - May 31). Muddy Creek, a major tributary of the Marys River is included for temperature (summer).

During the Phase I Water Quality Study (Raymond et al. 2002), 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. Sampling sites were chosen to represent the full range of conditions in the basin.

The results of the Phase I study indicated that overall water quality in the Marys River basin was fair to good. Streams in lower regions of the basin were too warm for cold water fish, but streams draining the upper reaches appeared 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 was evidence that some nutrients were reaching the streams from upland sources, the condition was 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, but severe problems sufficient to adversely affect beneficial uses (water contact recreation) appeared 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.

Results of bacteria sampling suggested 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 did not appear to be a problem. However, results from storm sampling and other studies suggested that episodic high turbidity was associated with periods of heavy rainfall and high runoff .

Three of the sites sampled during the Phase I study appeared to be adversely affected with respect to water quality. Upper Muddy Creek and lower Muddy Creek showed 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 have been the result of increased productivity caused by nutrient inputs to the stream. Oak Creek was adversely affected by bacterial content in excess of the Oregon Department of Environmental Quality water quality standards.

In response to these results, the Marys River Watershed Council developed a second phase sampling program to gain a clearer understanding of the potential causes of the observed results, and to help develop restoration activities to remedy any identified problems. The current study is directed toward the Marys River and Muddy Creek. Conditions on Oak Creek are being addressed by Oregon State University.

Phase 2 Materials and Methods

Proposed Sampling Plan

Marys River

In the 2001 study, *E. coli* numbers in August were higher downstream of Philomath than upstream, suggesting a possible source of bacterial contamination in the central Philomath area. Possible sources could include the Philomath waste water treatment plant discharge, failing on-site septic systems, leaks in the sanitary sewer system, storm water discharge, or runoff from residential areas.

Samples were to be collected from the river during low flow (June, July or August) at ten sites on alternate days for ten days (five sample sets). Samples would be analyzed for the presence and abundance of *E. coli* bacteria in accordance with current Oregon water quality standards. Additional samples were to be collected at the same ten sites at eight-hour intervals during a 48 to 72 hour period during each of two rainstorms during the late fall and early winter.

Muddy Creek

Samples taken during 2001 suggested that potential sources of excess oxygen demand and phosphorus existed on Muddy Creek. The proposed sampling plan was intended to locate these potential sources.

Samples were to be collected on two occasions from multiple sites in the catchment to be analyzed for 5-day biochemical oxygen demand (BOD_5). On two consecutive days in June dissolved oxygen would be measured at one-to-four hour intervals at 5 - 10 locations in Muddy Creek and tributaries. On two consecutive days in July, August, and September dissolved oxygen would be measured at the same sites twice per day in the early morning and late afternoon. One sample to be analyzed for phosphorus would be collected at each site on each day dissolved oxygen was measured.

Modifications to Proposed Plan

Limited access to private property resulted in the selection of only seven sample locations on Muddy Creek and six locations on the Marys River rather than the proposed ten locations. Delays in funding to start the project resulted in no samples collected during June. The initial sampling during a late fall rainstorm was completed successfully, but a significant dry period during January and February prevented sampling during a mid-winter rainstorm. The first significant rain in March was sampled instead. The final sampling schedule included:

Muddy Creek

- Seven sample locations
- BOD at all sites twice (July 15 and 16)
- Dissolved oxygen and temperature at all sites every 4 hours for two consecutive days (8:00 AM, Noon, 4:00 PM, 8:00 PM) (July 17 and 18).
- Dissolved oxygen and temperature morning and afternoon; two consecutive days in August and September (August 14 and 15; September 18 and 19).

Phosphorus was collected at all sites once per day on July 17 and 18, August 14 and 15, and September 18 and 19.

Marys River

- Six sample locations
- Dissolved oxygen temperature, and bacteria two days in July (July 2 and 20).
- Dissolved oxygen, temperature, and bacteria: every other day for 10 days (August 9 - 22).
- Bacteria: every 8 hours, 2-3 days during two storms. (October 8-9, and March 27-28).

Sample Sites

Marys River

The Marys River is a low gradient meandering stream with a fine-grained channel bed. This study sampled the portion of Marys River that flows between Highway 34 and Bellfountain Road. This reach includes the confluence of Marys River with Newton Creek and Greasy Creek. Newton Creek is a very small tributary that flows through the city of Philomath, some agriculture, and rural residential land use prior to entering the Marys River. Greasy Creek is a higher gradient cobble and gravel streambed with rural residential and forestry land uses. The land uses in this portion of the Marys River include rural residential, farming, and industrial, as well as the city water intake and the wastewater treatment plant (WWTP).

The study reach was selected based on findings from the Water Quality Phase I project which identified the study reach as a potential source of *E. coli* bacteria. Sites were positioned along the reach to capture water quality above and below points of interest (e.g. above and below the City of Philomath wastewater treatment plant discharge, above and below Greasy and Newton Creeks) Sample sites are described in Table 1. Figure 3 illustrates the sample locations.

Muddy Creek

Muddy Creek is a low gradient, low velocity, meandering stream, with a fine-grained channel bed. It is a main tributary to the Marys River comprising roughly 48% of the watershed area. This study sampled the portion of the creek that flows between Dawson and Greenberry roads. Land use includes agriculture and the Finley Wildlife Refuge. Sites were selected to determine relative inputs from the wildlife refuge and a dairy operation. Muddy Creek sample locations are described in Table 2. Figure 4 illustrates the sample locations.

Table 1. Phase II water quality sample locations on Marys River.

Site ID	Latitude	Longitude	Site Name	Description	Representation
MR1	44.54033	123.38757	Highway 34	Sampled at Miller Timber Services near small wooden pump house just upstream from bridge over highway 34.	Upstream of potential bacteria sources
MR2	44.53780	123.37630	Intake	Sample at access point near the white water tank and intake pump for city of Philomath.	Downstream of confluence with Greasy Creek, upstream of Gathering Together Farms
MR3	44.53112	123.37208	Fern Rd.	Gathering Together Farm just upstream from Fern Road.	Downstream of city water intake, rural residential and organic farm.
MR3	44.52945	123.36867	Fern Rd	Moved our sample to under the bridge at Fern Road for winter sampling.	Same as above.
MR4	44.52713	123.34895	WWTP	Access via rural residential road (Les and Bobs).	Upstream of waste water treatment discharge and downstream of rural residential
MR5	44.52905	123.34442	Newton	Sample above confluence with Newton. During second winter storm could not cross Newton safely, so downstream of Newton-but likely not below the mixing zone with Newton and Mary.	City of Philomath and rural residential. During summer this was upstream of Newton and downstream of City Discharge. During second winter storm, it was mostly representative of Newton Creek.
MR6	44.52563	123.33462	Bellfountain	Sample at bridge that crosses Marys River at Bellfountain Road.	Downstream of Newton, rural residential.

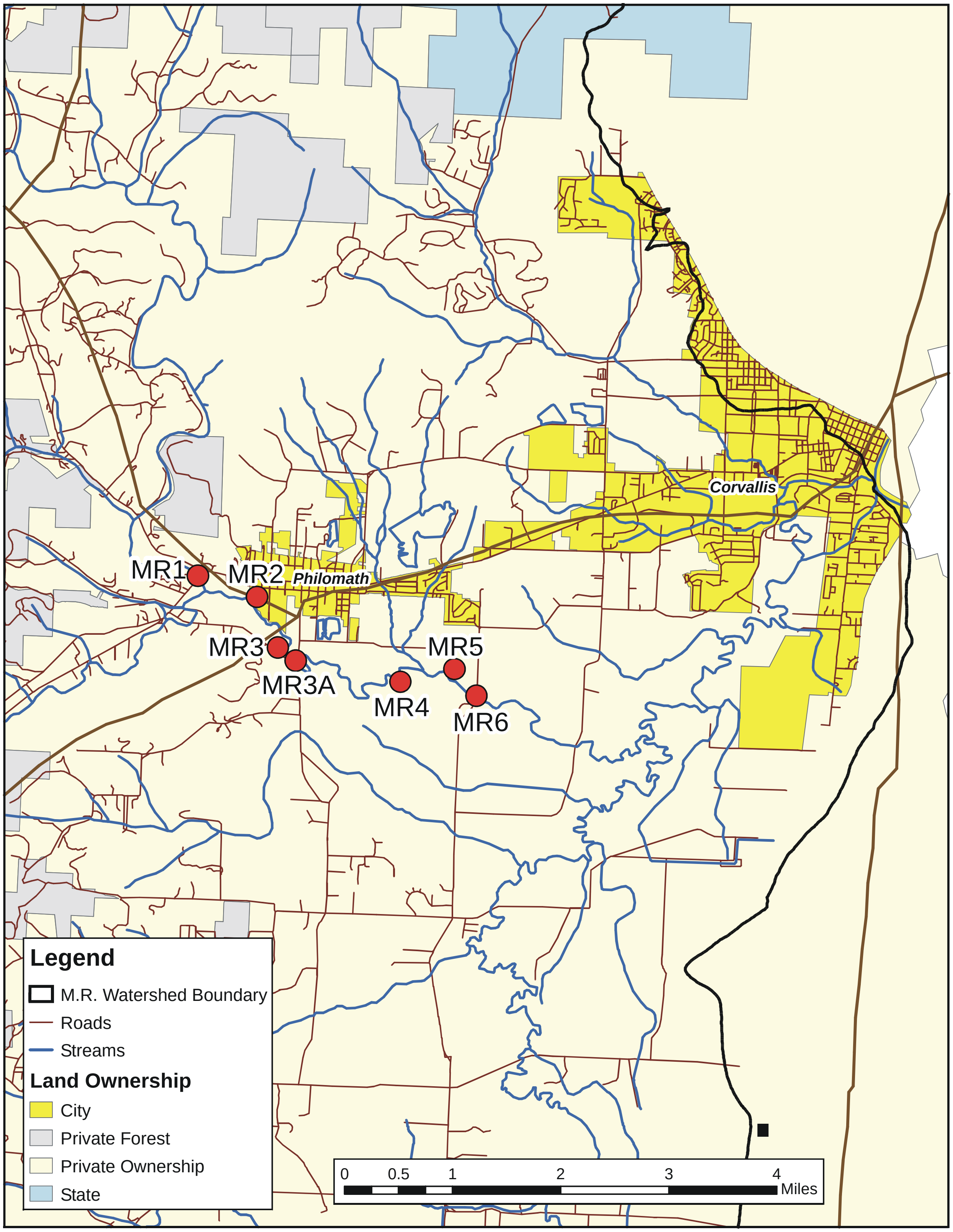

Figure 3. Sample site locations on the Marys River for Phase 2 water quality monitoring.

Table 2. Phase II water quality sample sites on Muddy Creek.

Site ID	Latitude	Longitude	Site Name	Description	Representation
MU1	44.35919	123.31956	Dawson Road	Main stem Muddy Creek. Water is backed up from a beaver pond.	Upstream of potential phosphorus inputs. Appears to be a huge beaver pond. Agriculture/farming land use.
MU2	44.37861	123.30331	McFarland West	Tiny tributary to Muddy Creek. Sample on McFarland Road at northeast side 2nd bridge west of Highway 99.	"Tributary" to Muddy-very low gradient, barely flows even in winter.
MC3	44.37703	123.29922	McFarland East	Main stem Muddy Creek. On McFarland Rd. Just past first bridge west of Highway 99 where river runs along McFarland Road for a short distance.	Rural residential, farming. Main stem Muddy border the south (upstream) end of the marsh.
MU4	44.38967	123.30153	Bruce	Main stem Muddy Creek on Bruce Road at the second bridge west of 99. Sample on Southwest side of bridge. This portion of the Muddy is just west of the McFadden Marsh Viewing area (first bridge).	This site is the first one near the McFadden Marsh (Adjacent). Main stem Muddy, wooded (hardwoods) riparian area.
MU5	44.42056	123.30958	Finley	Main stem Muddy Creek. On Finley Refuge Road at the first bridge west of Highway 99.	Downstream of McFadden Marsh. Wooded (hardwoods) riparian area. The refuge manages a pasture just upstream from this portion of the Muddy. Two or three ponds in the pasture.
MU6	44.45694	123.33733	Starr Creek	Tributary to Muddy Creek. High gradient, cobble stream. On Bellfountain Road, just north of junction with Greenberry.	Drains agriculture/farming Relatively high gradient tributary to Muddy. This site is close to Phase I site BC00 (Beaver Creek).
MU7	44.4565	123.31786	Greenberry	Main stem Muddy Creek. Sample at bridge on Greenberry Road, on the south east side of bridge.	Main stem Muddy, wooded riparian area. Dairy operation is upstream. (Dairy may have ceased operation.)

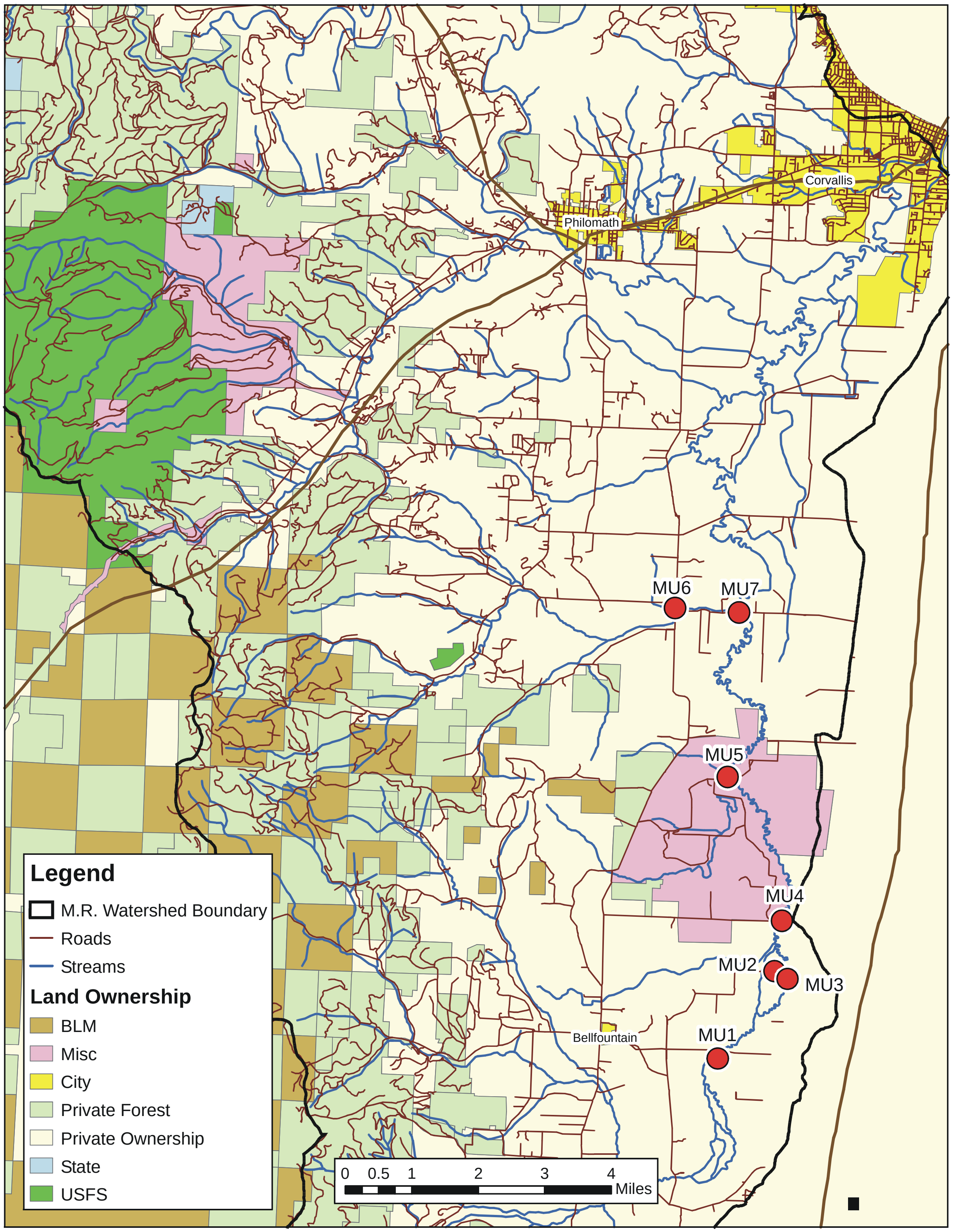

Figure 4. Sample site locations on Muddy Creek for Phase 2 water quality monitoring.

Comparison to Phase I Sites

Several sites chosen for Phase II are comparable or equivalent to sites sampled for the Phase I study. The equivalent sites are listed in Table 3.

Table 3. Comparison of Phase I and Phase II sample sites on the Marys River and Muddy Creek.

Phase I Site Description	Phase I Site ID	Phase II Site ID	Phase II Site Description
Muddy Creek at Greenberry Rd Bridge	MC06	MU7	Muddy Creek at Greenberry Rd.
Beaver Creek at Tyee Winery Bridge	BC00	MU6	Starr Creek at Bellfountain Rd.
		MU5	Dawson Road
		MU4	McFarland west
		MU3	McFarland east
		MU2	Bruce Road
		MU1	Finley Refuge Road
Muddy Creek at Alpine Bridge	MC17		
Highway 99 Bridge over Marys River	MR00		
Marys River Avery Park Bridge	MR01		
Marys River at Thom Whittier's	MR03		
Marys River at Bellfountain Rd Bridge	MR06	MR6	Marys River at Bellfountain Rd.
		MR5	Newton Creek
		MR4	WWTP
		MR3	Fern Rd
		MR2	Intake
Marys River at Highway 34 Bridge	MR09	MR1	Marys River at Highway 34
Marys River at Highway 20 Bridge	MR10		
Marys River at Blodgett	MR24		

Sample Collection and Analysis

Sampling methods followed the Oregon Salmon Plan protocols (OWEB 1999). Water samples were collected for analysis for bacteria (*E. coli*), biochemical oxygen demand (BOD), and orthophosphate phosphorus (PO4). Orthophosphate was chosen rather than total phosphorus because in-kind donation of analytical costs provided significant cost savings. Results from Phase I indicated that orthophosphate was highly correlated with total phosphorus.

Bacteria samples were collected (according to instructions provided by the lab) into clean sterile bottles supplied by the laboratory. Samples were kept on ice and returned to the lab for processing within six hours of the time they were collected. Samples for chemical analysis were collected into clean bottles supplied by the laboratory after rinsing with sample. Samples were kept on ice until delivery to the laboratory. Replicate samples for quality assurance were collected with every sample batch.

Samples for BOD were analyzed by CH2M Hill Applied Sciences Laboratory, 2300 NW Walnut Blvd. Corvallis, Ore. Bacteriological samples were analyzed by Pacific Analytical Laboratory, 529 NW 5th St., Corvallis, Ore. Orthophosphate phosphorus samples were analyzed by E&S Environmental Chemistry, 2161 NW Fillmore Av., Corvallis, Ore. Analytical methods and reporting limits are provided in Table 4.

Table 4. Analytical methods for Marys River Phase II water quality sampling.

Constituent	Method	Reporting Limit
Biochemical oxygen demand	EPA 405.1	2 mg/L
E. coli	SM 9223 B MPN[1]	Minimum: 1 MPN index/100 mL Maximum: 2400 MPN index/100 mL
Orthophosphate phosphorus	Hach 8048[2]	0.01 mg/L as P

[1] Standard Methods for the Examination of Water and Wastes

[2] This method for the Model 2400 spectrophotometer is equivalent to EPA 365.2.

Field measurements for dissolved oxygen, and temperature were made with a YSI Model 85 dissolved oxygen and conductivity meter. Prior to each use the instrument was calibrated according to the manufacturers instructions.

Results

Discharge

The winter of 2004-2005 was unusual because of the extreme lack of precipitation during the winter. Based on rainfall records for Salem, Ore., this was the second driest November through February on record (Table 5). The lack of rainfall resulted in unusually low flows in the Marys River (Figure 5). The low discharge and lack of rainfall events caused the sampling program for Phase II to be modified from the original plan.

Table 5. Five years with lowest winter rainfall as recorded at Salem, Ore.

Water Year	Oct	Nov	Dec	Jan	Feb	March	Oct-Mar
1977	1.51	1.13	1.26	0.88	2.83	3.33	10.94
2005	*3.30*	*2.14*	*3.89*	*1.46*	*0.60*	*4.15*	*15.54*
2001	2.40	2.53	3.62	1.81	1.22	2.82	14.40
1960	1.53	2.06	3.97	4.41	5.41	6.99	24.37
1979	0.37	4.50	2.64	2.84	7.19	2.17	19.71
1971-2000 Average	3.03	6.39	6.46	5.84	5.09	4.17	30.98

Source: Oregon Climate Service 2005

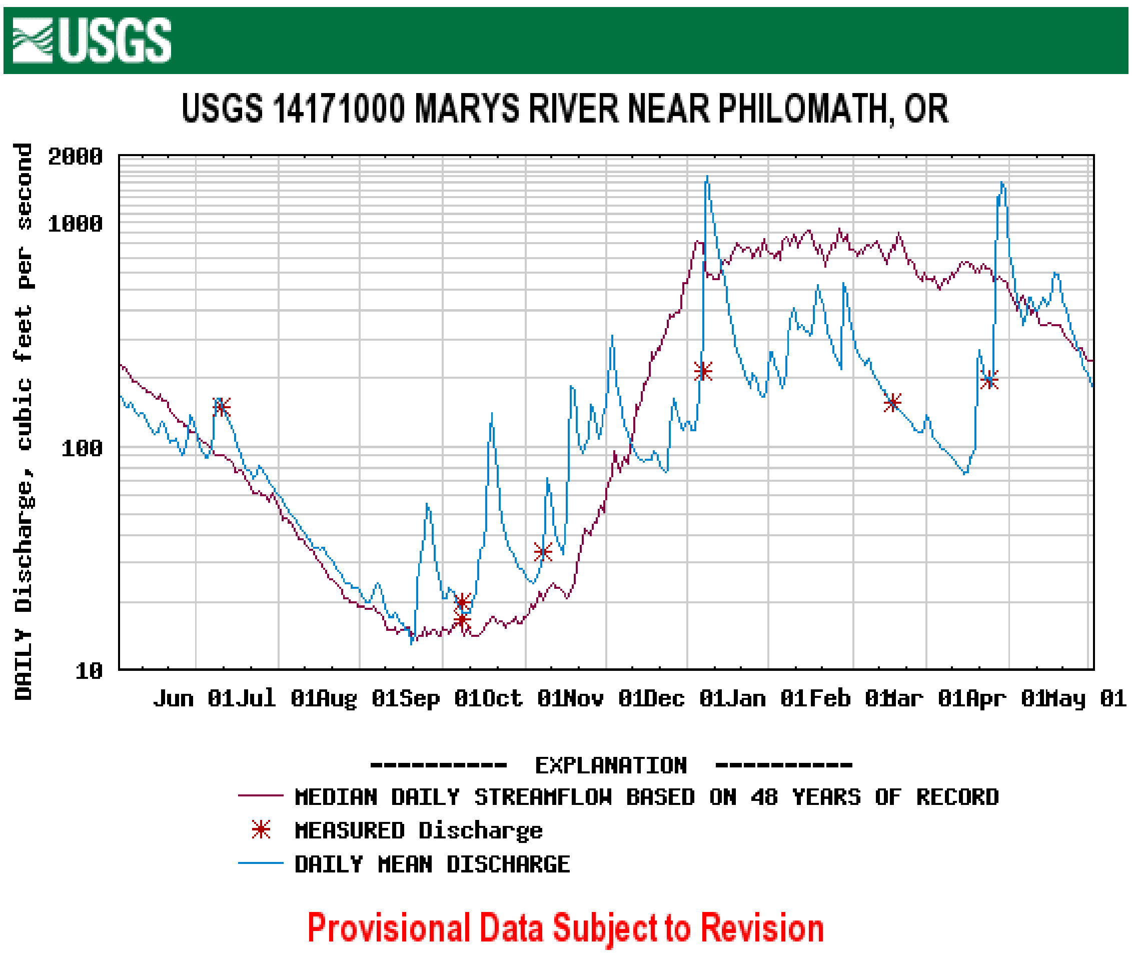

Figure 5. Winter 2004-2005 discharge in the Marys River. (Source USGS NWIS web page http://waterdata.usgs.gov/or/nwis/dv?format=gif&period=365&site_no=14171000. Acessed on May 1, 2005.)

Muddy Creek

Biochemical Oxygen Demand

Biochemical oxygen demand was measured on samples collected on two consecutive days in July. The results are provided in Table 6. The cause of the difference in BOD measured on two consecutive days is not explained. It could be the result of episodic input of organic matter to the stream or possibly to differences in technique between different volunteer field workers.

Table 6. Results of BOD analysis on samples from Muddy Creek.

Site ID	Site Name	BOD results	
		July 15, 2004	July 16, 2004
MU1	Dawson Bridge	7	<2
MU2	McFarland West	6	3
MU3	McFarland East	<2	<2
MU4	Bruce Road	<2	<2
MU5	Finley	7	<2
MU6	Starr Creek	6	<2
MU7	Greenberry	7	<2

Temperature and Dissolved Oxygen

The results from all sites for temperature and dissolved oxygen in July through September during the Phase II monitoring activity for Muddy Creek showed that:

- Average temperature for all sites on Muddy Creek was 19.9º C and ranged from 17.0-20.9º C.
- Maximum temperature ranged from 19.9º C to 26.0º C.
- Minimum temperature ranged from 11.8-14.2º C.
- Average dissolved oxygen concentration at all sites was 4.6 mg/l and ranged from 4.4-7.6 mg/l
- Maximum dissolved oxygen at all sites ranged between 6.1 - 10.4 mg/l.
- Minimum dissolved oxygen at all sites ranged from 0.6 - 5.6 mg/l.

More detailed results of temperature measurements taken in Muddy Creek are provided in Table 7 and Figure 6[3]. In the aggregate, temperatures along the reach of Muddy Creek sampled during Phase II do not differ greatly. Starr Creek (MU6) is cooler than Muddy Creek. Figure 7 presents the temperature measurements plotted against time of day. A regression line illustrates the trend of temperature increase through the day.

Table 7. Temperature values measured in Muddy Creek in July, August, and September 2004.

	MU1	MU2	MU3	MU4	MU5	MU6	MU7
No. of values used	18	18	18	18	18	17	17
Minimum	14.1	13.8	14.2	14.1	13.9	11.8	14.2
Median	21.5	20.4	21.6	21.2	22.2	17.9	21.0
Maximum	26.0	24.6	22.9	25.1	23.7	19.9	23.7
Mean	20.91	19.95	20.28	20.46	20.62	17.01	20.28
Sample standard deviation	3.63	2.81	3.03	3.40	3.19	2.55	3.18

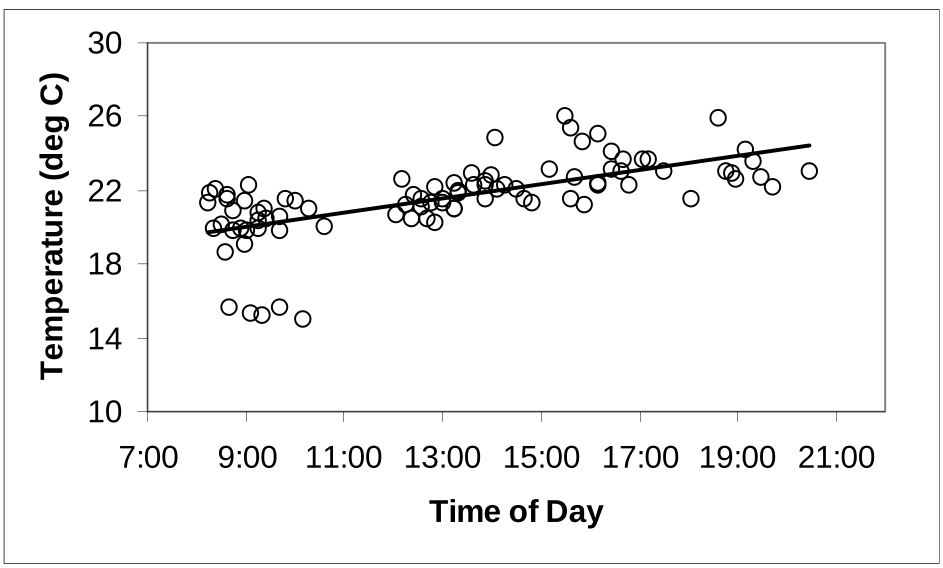

Figure 6. Temperature vs. time of day for temperature data collected on Muddy Creek during Phase 2 water quality monitoring, 2004-2005.

[3]Many of the figures in this report are presented as box plots. A box plot shows the distribution and magnitude of the data. The box extends from the 25th to 75th percentile, and encloses 50 percent of the data. The line through the box locates the median, or middle value. The whiskers extend to the largest or smallest data point that is not an outlier. Outliers (asterisks) are beyond 1.5x the interquartile distance. Extreme outliers (open circles) are beyond 3x the interquartile distance.

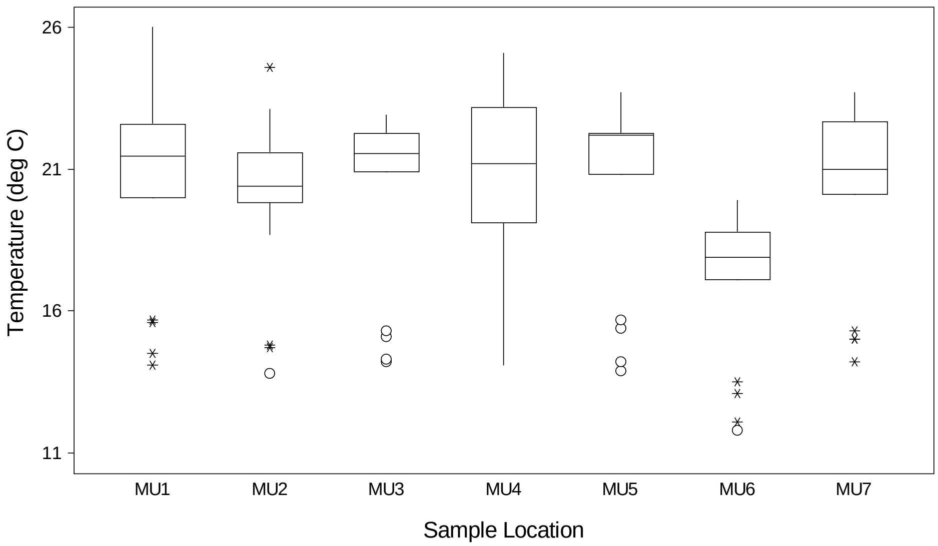

Figure 7. Box plot illustrating temperature data collected during Phase 2 water quality monitoring on Muddy Creek. MU1 = Dawson Road, MU2 = McFarland West, MC3 = McFarland East, MU4 = Bruce Road, MU5 = Finley, MU6 = Starr Creek, MU7 = Greenberry Road.

Dissolved oxygen concentration data are summarized in Table 8 and illustrated in Figure 8. Dissolved oxygen concentration in Muddy Creek is low with average percent saturation for Phase II measurements ranging from 40 percent at McFarland west (MU3) to 59 percent at Bruce, near McFadden marsh (MU4). Dissolved oxygen concentration is higher in Starr Creek (78 percent) than in Muddy Creek. Dissolved oxygen concentration decreases between site MU4 and MU5, a reach that crosses most of the Finley Wildlife Refuge. Dissolved oxygen at tributary site MU2 (McFarland east) is especially low. Dissolved oxygen concentration tends to increase through out the day (Figure 9).

Phosphorus

A summary of results for orthophosphate phosphorus is provided in Table 9, and illustrated in Figure 10. Orthophosphate concentration ranged from 0.01 to 0.06 mg/L with an overall average value of 0.03 mg/L. An increasing trend of phosphorus concentration is evident along Muddy Creek, with a marked increase between site MU4 and MU5. Site MU7, at Greenberry Road had significantly higher phosphorus concentration than the other Muddy Creek sites.

Table 8. Dissolved oxygen concentration (mg/L) measured in Muddy Creek

	MU1	MU2	MU3	MU4	MU5	MU6	MU7
No of values used	18	18	18	18	18	17	17
Minimum	2.7	0.6	1.5	2.2	1.4	5.3	3.2
Median	4.3	1.8	4.1	5.8	4.2	7.4	4.5
Maximum	6.2	10.4	6.1	7.2	8.2	9.1	6.4
Mean	4.35	2.58	3.52	5.37	4.00	7.42	4.62
Sample standard deviation	1.21	2.36	1.43	1.41	1.70	1.14	0.90

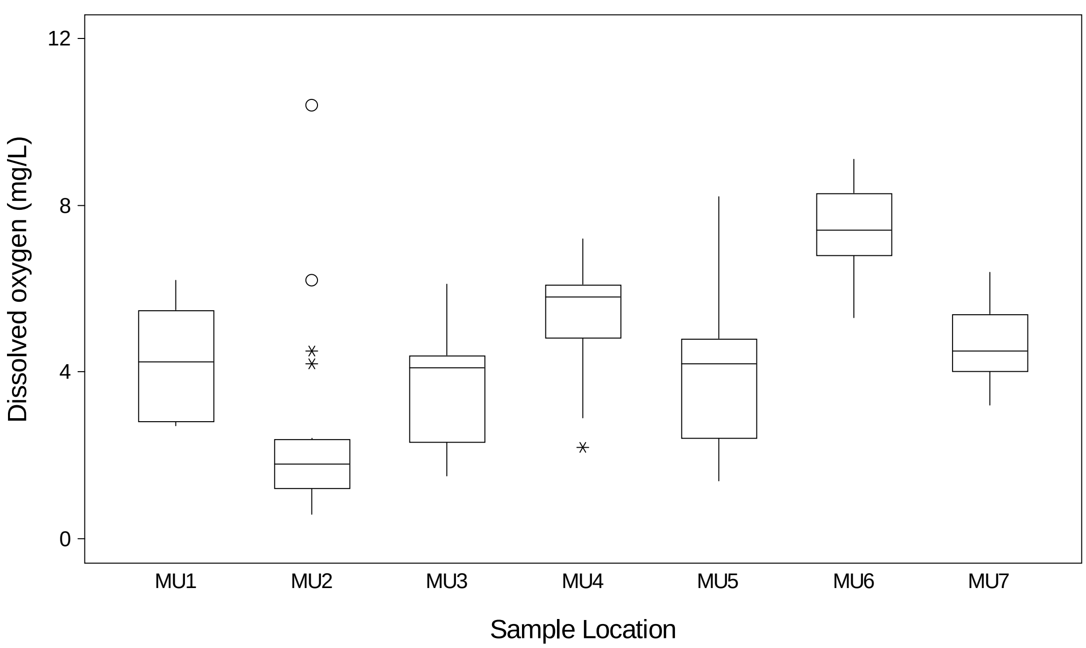

Figure 8. Box plot illustrating dissolved oxygen data collected during Phase 2 water quality monitoring on Muddy Creek. MU1 = Dawson Road, MU2 = McFarland West, MC3 = McFarland East, MU4 = Bruce Road, MU5 = Finley, MU6 = Starr Creek, MU7 = Greenberry Road.

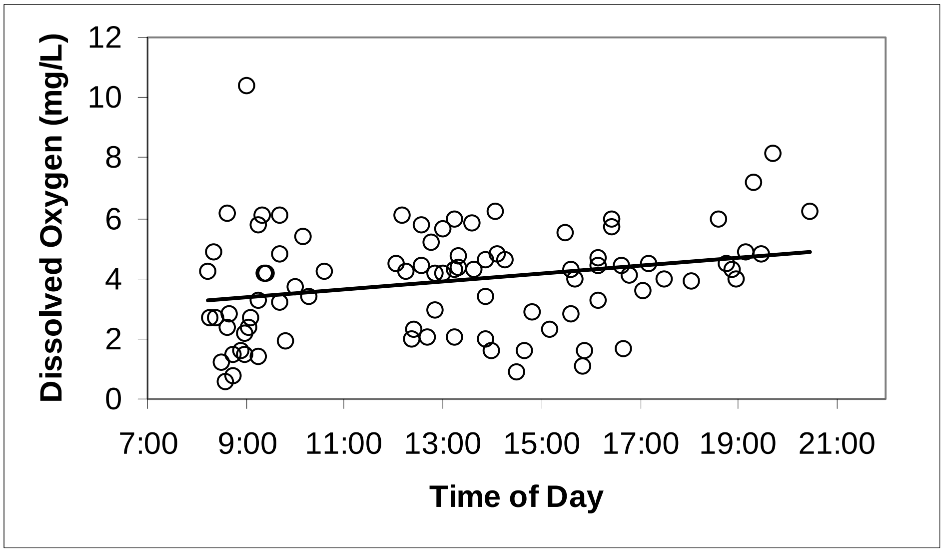

Figure 9. Dissolved oxygen concentration vs. time of day for data collected during Phase 2 water quality monitoring, 2004-2005.

Table 9. Orthophosphate concentration (mg/L as P) measured in Muddy Creek

	MU1	MU2	MU3	MU4	MU5	MU6	MU7
No of values used	7	6	7	7	7	7	13
Minimum	0.010	0.010	0.020	0.010	0.020	0.020	0.030
Median	0.020	0.025	0.030	0.030	0.030	0.030	0.040
Maximum	0.030	0.040	0.030	0.040	0.040	0.050	0.060
Mean	0.020	0.025	0.026	0.026	0.033	0.033	0.040
Sample standard deviation	0.005	0.010	0.005	0.009	0.007	0.010	0.010

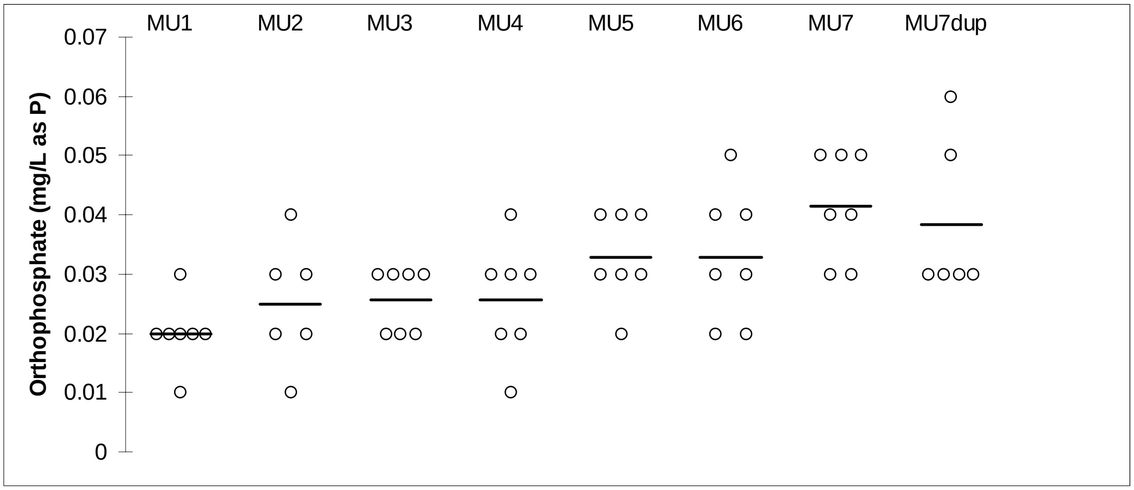

Figure 10. Scattergram showing phosphorus data collected in Muddy Creek during July - October, 2004..

Marys River

Temperature and Dissolved Oxygen

The overall averages for dissolved oxygen and temperature measured at all sites in the Marys River in July and August showed that

- The average temperature was 22.3^o C and ranged from 18.3 to 24.1^o C.
- The average dissolved oxygen concentration was 7.6 mg/L and ranged from 6.2 to 9.2 mg/L.
- The average oxygen saturation was 86.7 percent and ranged from 71 to 106 percent.

More detailed summaries for temperature and dissolved oxygen are provided in Table 10, and illustrated in Figures 11 and 12. Although there is no statistically significant difference in temperature between the Marys River sites, a trend in temperature appears to be present. The river cools between Highway 34 (MR1) and the site below Greasy Creek (MR2). The river then tends to warm up as the water travels downstream. Dissolved oxygen, likewise, shows no statistically significant difference between the sites, but a possible trend appears in the data. Median dissolved oxygen values downstream of the waste water treatment plan discharge (MR5 and MR6) are slightly lower than at upstream stations, and the preponderance of low dissolved oxygen values increases downstream.

Table 10. Temperature and dissolved oxygen measured in the Marys River in July and August, 2004.

Site	Name	Statistic	Dissolved Oxygen (mg/L)	Dissolved Oxygen (%)	Temperature (deg C)
MR1	Highway 34	N	8	8	8
		Mean	7.87	90.1	22.3
		SD	0.76	8.47	1.34
		Minimum	6.9	79.0	19.3
		Median	7.7	90.4	22.7
		Maximum	9.2	106.0	23.6
MR2	Intake	N	8	8	8
		Mean	7.76	87.2	21.6
		SD	0.69	6.91	1.53
		Minimum	6.8	78.4	18.4
		Median	7.6	85.5	22.0
		Maximum	8.8	100.0	22.9
MR3	Fern Rd.	N	8	8	8
		Mean	7.65	86.5	21.7
		SD	0.78	9.29	1.75
		Minimum	6.6	74.0	18.3
		Median	7.9	87.0	21.9
		Maximum	8.6	97.0	23.6
MR4	WWTP	N	8	8	8
		Mean	7.37	85.2	22.3
		SD	0.72	8.48	1.50
		Minimum	6.2	71.9	19.0
		Median	7.75	87.9	22.8
		Maximum	8.1	97.0	23.7
MR5	Newton	N	8	8	8
		Mean	7.31	85.9	22.6
		SD	0.53	6.71	1.37
		Minimum	6.7	77.6	19.5
		Median	7.2	85.0	23.2
		Maximum	8.1	97.5	23.6
MR6	Bellfountain	N	9	9	9
		Mean	7.36	85.3	22.9
		SD	0.71	10.46	1.26
		Minimum	6.5	72.0	19.9
		Median	7.1	82.3	23.3
		Maximum	8.5	103.0	24.1

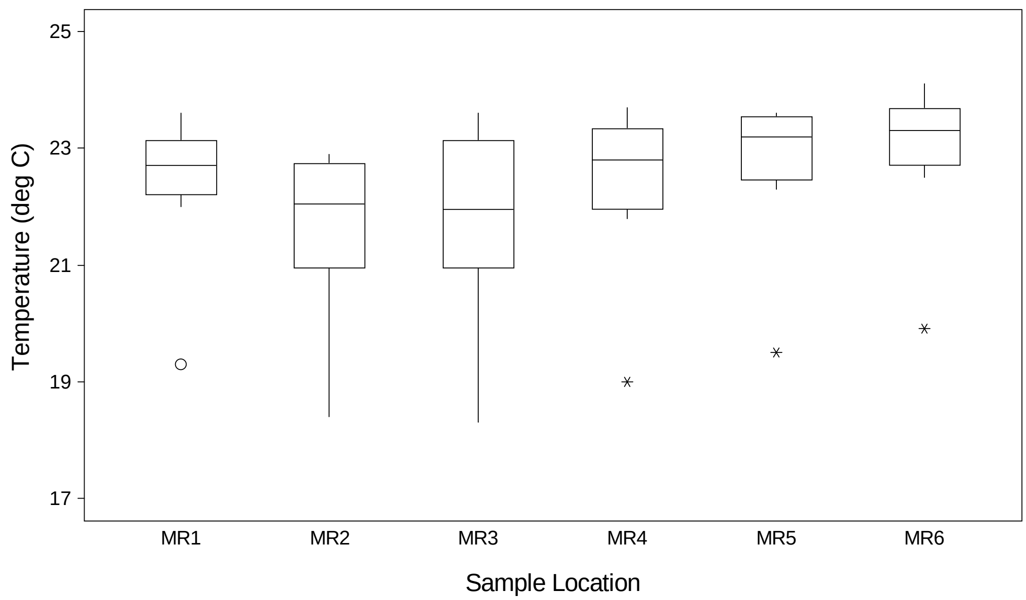

Figure 11. Box plot illustrating temperature data collected during Phase 2 water quality monitoring on Marys River July - September 2004. MR1 = Highway 34, MR2 = above city water intake, MR3 = Marys River near Fern Road, MR4 = above WWTP discharge, MR5 = near mouth of Newton Creek, MR6 = Marys River at Bellfountain Road.

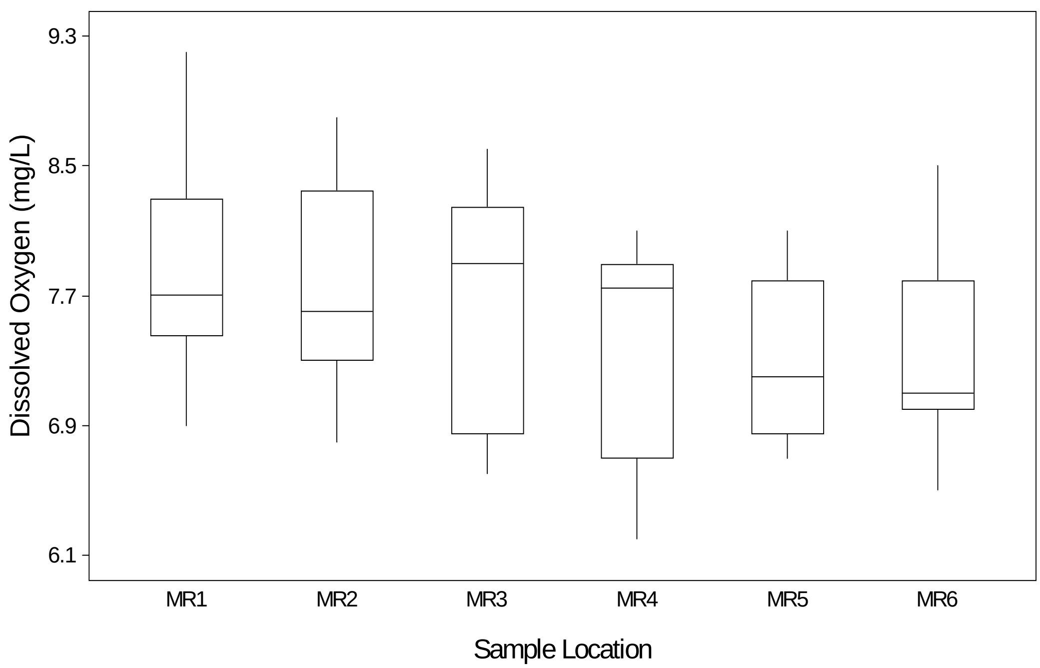

Figure 12. Box plot illustrating dissolved oxygen data collected during Phase 2 water quality monitoring on Marys River July - September 2004. MR1 = Highway 34, MR2 = above city water intake, MR3 = Marys River near Fern Road, MR4 = above WWTP discharge, MR5 = near mouth of Newton Creek, MR6 = Marys River at Bellfountain Road.

Bacteria

Bacterial abundance in the river is influenced by the flow regime. Samples for bacteria (*E. coli)* analysis were collected under two different regimes during Phase 2; summertime low flow, and winter time rainfall runoff events (Figure 13). Summary statistics for all samples under each flow regime are provided in Table 11. Summary plots of bacteria results by site are provided in Figures 14 and 15.

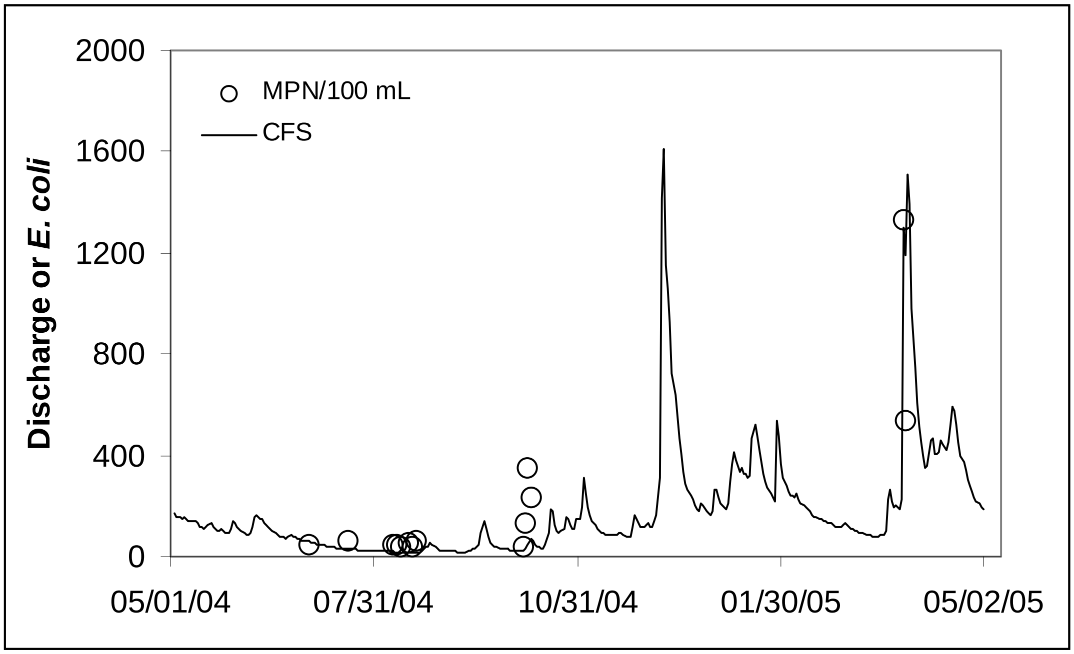

Figure 13. Average *E. Coli* abundance for all sites on a given day and discharge vs. date.

Table 11. *E. coli* abundance (MPN/100 mL) measured in Marys River in 2004 to 2005.

Statistic	Low Flow	High Flow
N	56	90
Mean	49.53	541.9
Std. Deviation	23.20	640.7
Minimum	16	17
Median	44	245
Maximum	141	>2400
Geometric Mean	45.24	165.8

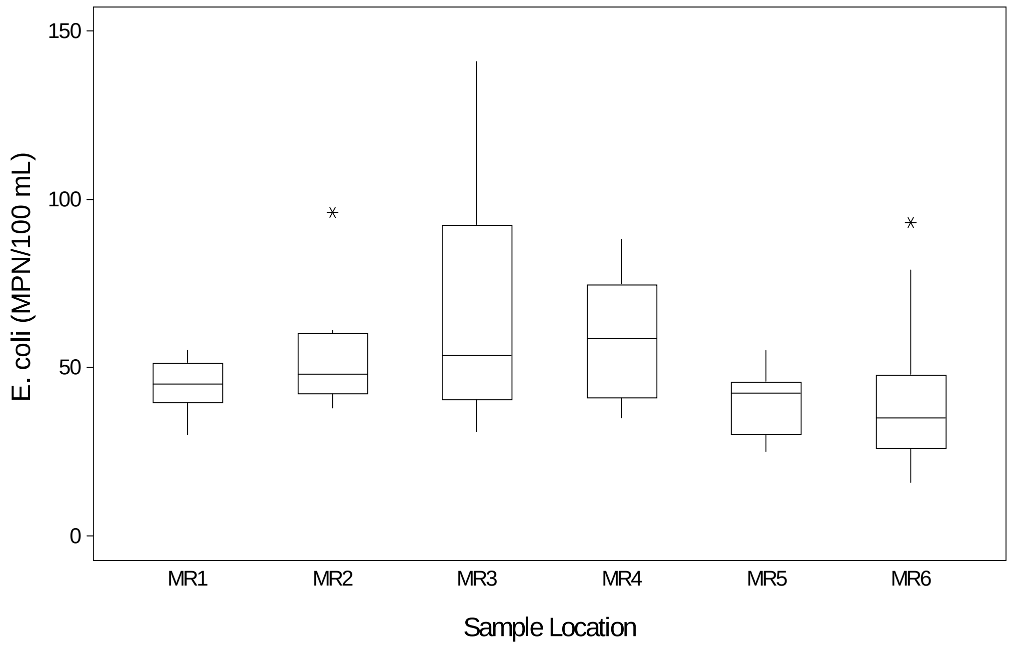

Figure 14. Box plot illustrating bacteria data collected at low flow during Phase 2 water quality monitoring on Marys River July - September 2004. MR1 = Highway 34, MR2 = above city water intake, MR3 = Marys River near Fern Road, MR4 = above WWTP discharge, MR5 = near mouth of Newton Creek, MR6 = Marys River at Bellfountain Road.

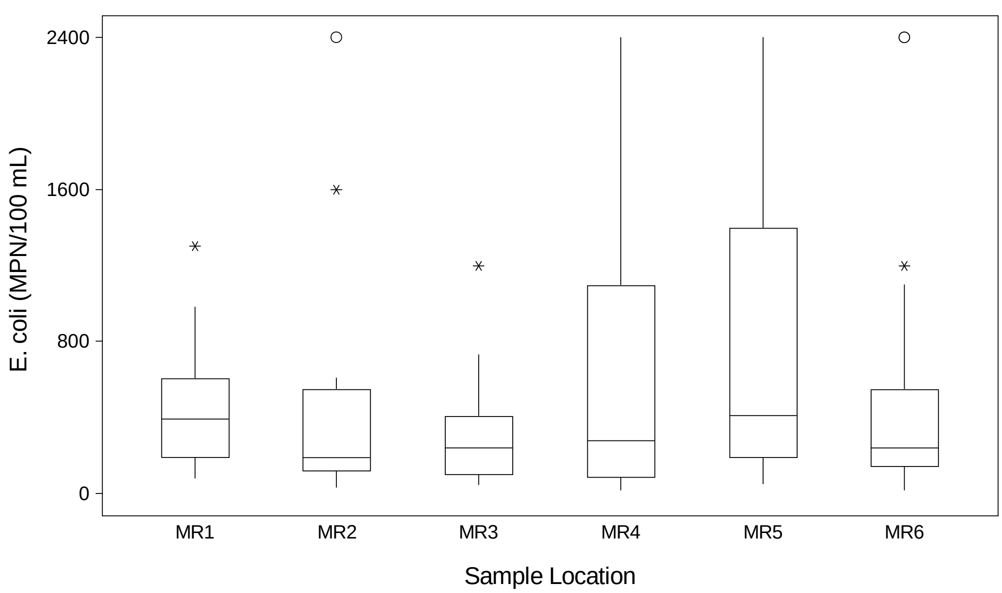

Figure 15. Box plot illustrating bacteria data collected during rainfall events for Phase 2 water quality monitoring on Marys River July - September 2004. MR1 = Highway 34, MR2 = above city water intake, MR3 = Marys River near Fern Road, MR4 = above WWTP discharge, MR5 = near mouth of Newton Creek, MR6 = Marys River at Bellfountain Road.

There is significantly more *E. Coli* found in the Marys River near Philomath during high flow than during low flow (Figure 16). There are no statistically significant differences in *E. Coli* abundance between sites at either low flow or high flow conditions. Examination of the box plots, however, suggests that some differences may occur. Under low flow conditions sites MR3 (Fern Road) and MR4 (above the WWTP discharge) appear to experience a greater number of relatively high *E. Coli* counts. None of the sites exceed the water quality standard for water contact recreation at low flow (Geometric mean < 126 MPN/100 mL, no single value > 406 MPN/100 mL). At high flow associated with rainfall events, all sites exceed the water quality standard for water contact recreation (Figure 17). Sites MR4 and MR5 also appear to experience a greater number of high values.

Comparison of Phase I and Phase II Data

Data were collected at two sites on Muddy Creek and two sites on the Marys River during both Phase 1 and Phase 2 sampling programs. The data from these four sites are summarized in Table 12, and illustrated in Figure 18. Phase 2 average temperatures are somewhat higher and average dissolved oxygen somewhat lower than Phase 1 for comparable sites. This is most likely because Phase 2 sampling was concentrated in the summer, while Phase 1 sampling occurred throughout the year. Phase 2 measurements of orthophosphate phosphorus would be expected to be somewhat lower than Phase 1 measurements of total phosphorus, and this is indeed the case, but there is no significant difference between the phosphorus measurements of Phase 1 and Phase 2. .

Data comparisons for *E. coli* were limited to the low flow months because discharge has such a large effect on bacteria numbers. There is no significant difference between the Phase 1 and Phase 2 *E. coli* counts.

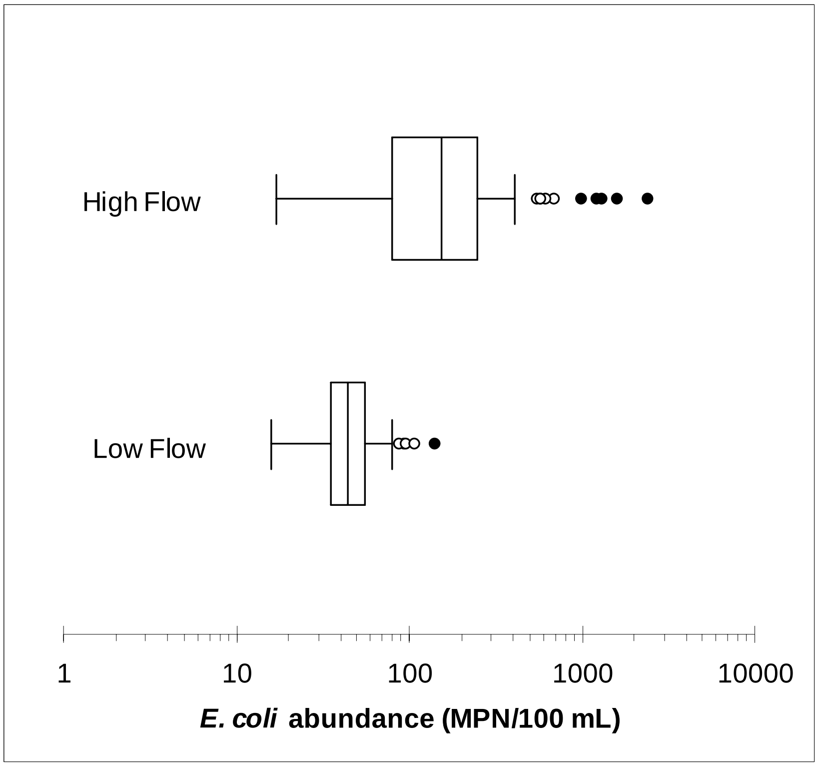

Figure 16. Box plot illustrating the difference in *E. Coli* abundance in the Marys River near Philomath between low flow and high flow.

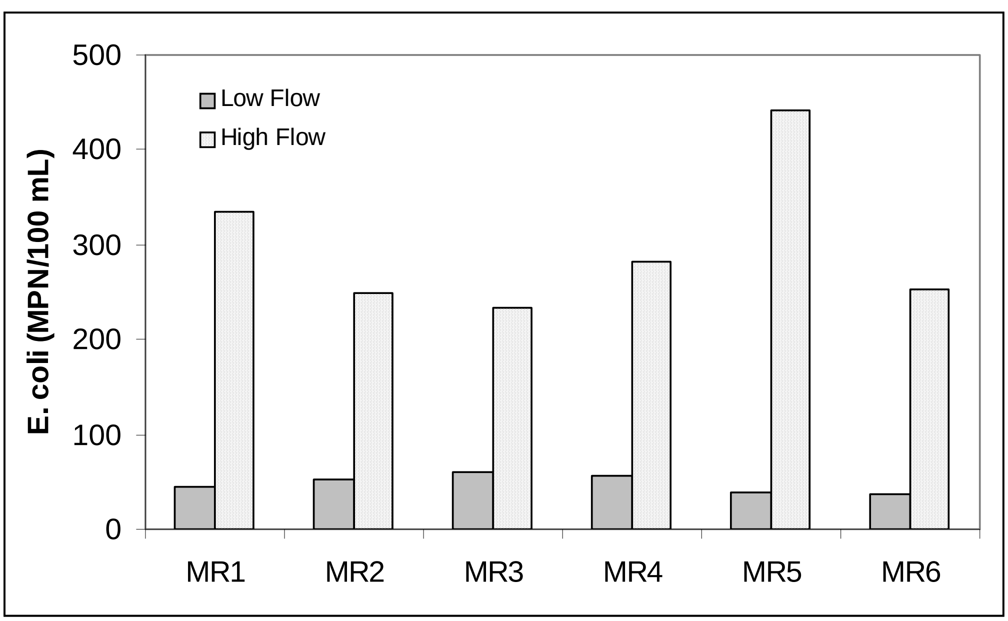

Figure 17. Comparison of geometric means of *E. Coli* abundance at low flow and high flow in the Marys River.

Table 12. Comparison of Phase I and Phase II water quality data.

Parameter	Starr Creek (Beaver Creek)		Muddy Creek at Greenberry Rd.		Marys River at Bellfountain Rd.		Marys River at Highway 34	
	Phase 1 BC00	Phase 2 MU6	Phase1 MC06	Phase 2 MU7	Phase 1 R06	Phase 2 MR6	Phase 1 MR09	Phase 2 MR1
***E. Coli* (MPN/100 mL)**								
N	12		12		18	16	6	8
Mean	194.33		40.75		89.44	40.50	50.85	44.62
Std Dev.	275.23		52.98		93.18	20.76	20.07	8.41
Minimum	10		16		10	16	17	30
Median	107		59		71	35	56.05	45
Maximum	1000		160		410	93	76	55
Dissolved Oxygen (mg/L)								
N	11	17	11	17	11	9		8
Mean	10.55	7.42	7.70	4.62	10.64	7.37		7.87
Std Dev.	1.86	1.18	3.44	0.93	1.79	0.71		0.77
Minimum	8.04	5.3	2.63	3.2	8.14	6.5		6.9
Median	11.47	7.4	8.27	4.5	11.38	7.1		7.7
Maximum	12.86	9.1	11.68	6.4	12.87	8.5		9.2
Temperature (deg C)								
N	11	17	11	17	11	9		8
Mean	12.02	17.01	13.29	20.28	13.265	22.9		22.37
Std Dev.	4.24	2.63	4.87	3.28	5.56	1.26		1.34
Minimum	4.37	11.8	6.69	14.2	7.34	19.9		19.3
Median	11.90	17.9	12.43	21.0	12.90	23.3		22.7
Maximum	18.16	19.9	20.18	23.7	21.77	24.1		23.6
Phosphorus (mg/L as P)[1]								
N	11	7	11	13	12			
Mean	0.061	.033	0.109	0.040	0.037			
Std Dev.	0.023	0.01	0.069	0.011	0.022			
Minimum	0.025	0.02	0.025	0.03	0.025			
Median	0.060	0.03	0.090	0.035	0.027			
Maximum	0.090	0.05	0.270	0.06	0.100			

[1]Phase 1 reported total phosphorus, Phase 2 reported orthophosphate phosphorus.

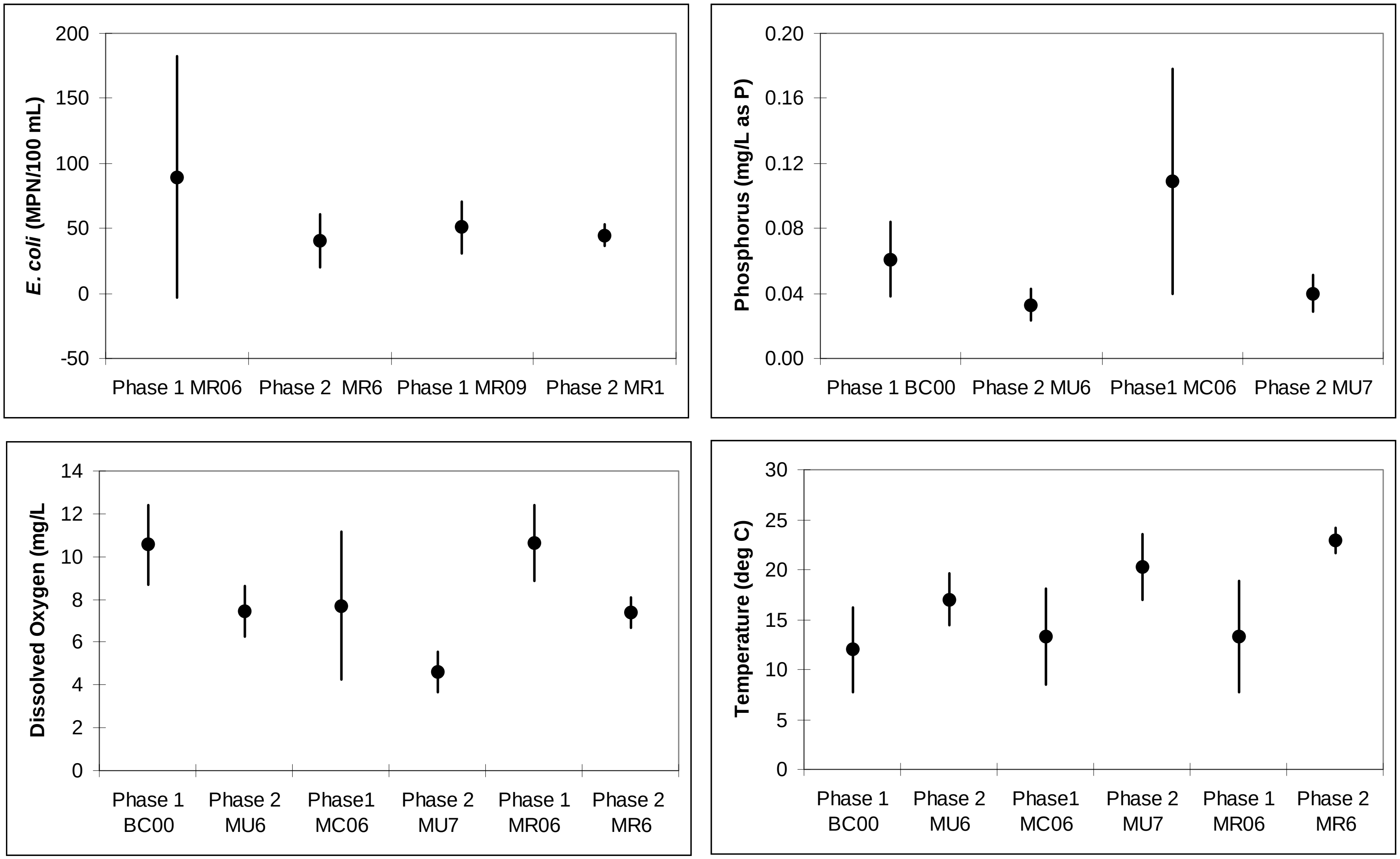

Figure 18. Comparison of Phase 1 (2001-2002) and Phase 2 (2004-2005) data for comparable sites (mean ± 1 std. dev.) MR06 and MR6 = Marys River at Bellfountain Road, MR09 and MR1 = Marys River at Highway 34, BC00 and MU6 = Starr Creek (Beaver eek) near Greenberry Road, MC06 and MU7 = Muddy Creek at Greenberry Road,

Discussion

Phosphorus

Phosphorus concentrations in Muddy Creek are comparable to those found in other streams and rivers in the vicinity (Table 13). PO4 in Muddy Creek compares favorably with EPA nutrient criteria recommended for the Willamette Valley (0.047 mg/L total phosphorus, EPA 2001). Although this study measured orthophosphate phosphorus, comparison with the results of Phase I suggest that the values are similar to those for total phosphorus. During the summer, especially, Muddy Creek is very slow moving and tends to resemble a series of small ponds, rather than a flowing stream. It might therefore be more appropriate to compare phosphorus concentrations to nutrient criteria for lakes and reservoirs. Such criteria for the Willamette Valley are still under development, but criteria have been developed for the Coast Range (0.007 mg/L) and the Puget Lowlands (0.022 mg/L) (EPA 2000). Judging by these criteria, phosphorus concentration in Muddy Creek is relatively high and might be expected to contribute to excessive growth of aquatic plants, both algae and rooted vegetation.

There is a statistically significant increase in phosphorus concentration from upstream to downstream in Muddy Creek (Figure 19). The increase is quite regular, suggesting that the source of phosphorus is dispersed, rather than from a particular location, that is, it is most likely the result of non-point source runoff. The available data are not sufficient to determine if the source is the result of management activity, or natural geologic processes.

Dissolved Oxygen and Temperature

Dissolved oxygen is low in Muddy Creek with median values typically near 50 percent saturation and minimum values as low as 6 percent saturation. Starr Creek was the exception with a median concentration of greater than 80 percent saturation and minimum of 59 percent. The phosphorus concentrations in Muddy Creek are sufficient to support high rates of plant productivity that could lead to large daily swings in dissolved oxygen concentration. This might account for the low values recorded. However, the data do not show the high afternoon concentrations of dissolved oxygen that might be expected as a result of photosynthetic oxygen production. This suggests that a there is a substantial source of oxygen demand present in Muddy Creek. Although there are no water quality standards or guidance values for ambient BOD, waters with BOD5 levels greater than 10 mg/L can be considered polluted and values

Table 13 Phosphorus values from sites near Philomath.

Location	N	Average Total Phosphorus (mg/L)
Long Tom River at Stow Pit Road (Monroe)[1]	61	0.09
Marys River at US 99 (Corvallis)[1]	42	0.09
Willamette River at Corvallis Water Intake [1]	1	0.04
Willamette River at Old Hwy 34 B [1]	113	0.07
Willamette River at Pope and Talbot Outfall [1]	2	1.35
Marys River Phase 1(all sites)[2]	56	0.04
Muddy Creek near Corvallis [1]	1	0.13
Muddy Creek Phase 1 (all sites)[1]	22	0.08
Muddy Creek Phase 2 (all sites) (PO4-P)[2]	54	0.03

[1]EPA: http://oaspub.epa.gov/pls/nutdb/reports.control

[2]Marys River Watershed Council

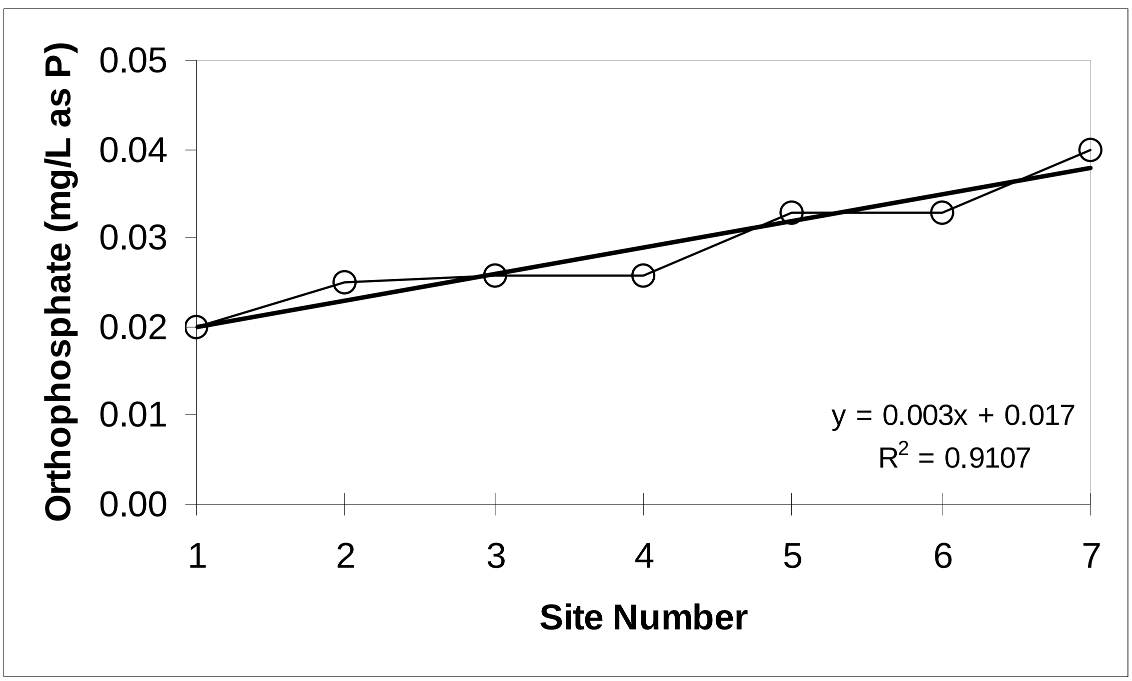

Figure 19. Average PO4 concentration vs site order upstream to downstream (right to left). The heavy line represents the linear regression of phosphorus versus site.

less than 4 mg/L reasonably clean (McNeeley et al. 1979). BOD effluent limitations for discharge of treated wastewater to tributaries of the Willamette River during low flow conditions are set at 5 mg/L (OAR 340-041-0345).

The results of BOD analysis for Muddy Creek samples during Phase 2 appear to be highly variable, but suggest that ambient levels can be high enough to be considered polluted (average for all sites for July 15 = 5.3 mg/L). High levels of BOD could be responsible for the low dissolved oxygen concentrations observed in Muddy Creek. There is no suggestion in the limited available data that suggest a localized source for organic matter load to Muddy Creek..

In contrast to Muddy Creek, dissolved oxygen concentration in the Marys River indicates relatively good conditions. Median dissolved oxygen values were in the range of 80 to 90 percent saturation with maximums near 100 percent and minimums greater than 70 percent; values that do not suggest excessive organic load.

Temperature in the areas sampled in Muddy Creek and the Marys River exceeds the current water quality standard for salmon and trout rearing and migration (18^{o} C) and for salmon migration corridor (20^{o} C) (OAR 340-041-0028). Low flow and slow velocity during the summer, especially in Muddy Creek, contribute to the warming of the stream. The relative absence of streamside vegetation capable of providing shade for the stream may also be a contributing factor.

Bacteria

Sampling for bacteria in the Marys River during low flow conditions for the Phase 2 monitoring program confirmed the relatively low summertime levels of *E. coli* in the river. All samples collected to date have been within the water quality standard for water contact recreation (geometric mean < 126 organisms/100 mL, maximum < 406 organisms /100 mL, OAR 340-041-0009). Low flow sampling did not confirm the suspicion that the waste water treatment facility was a source of bacterial contamination to the Marys River. Much of the *E. coli* in the Marys River at Philomath appeared to originate upstream of Highway 34. Although there was no statistically significant difference in *E. coli* numbers among the sites sampled at low flow on the Marys River between Highway 34 and Bellfountain Road, a number of higher values at site MR3 may suggest a potential contribution in the reach above Fern Road.

Bacteria counts were much higher for samples collected during rain events than during low flow. Counts are high at the most upstream site, Highway 34, indicating that much of the bacterial content in the river is coming from upstream sources. There is no statistically significant difference in *E. Coli* abundance among the sites sampled on the Marys River during rain events, although some higher values at the site MR4 and MR5 suggest there may be some contribution of *E. coli* below Fern Road.

Studies using DNA profiles suggest that nearly all *E. coli* found in surface water comes from wild or domestic animals (geese, gulls, deer, cattle, and swine), rather than humans (Boekhoff et al. 2004, Williamson et al. 2004), that more *E. coli* comes from fresh fecal material than from aged material (Vinten et al. 2004), and that there is little regrowth of *E. coli* in the environment (Kinzelman et al. 2004). Studies in Manitoba (Williamson et al 2004) and Wisconsin (Kinzelman et al. 2004) indicate that *E. coli* can be released to ambient water from *E. coli* present in the soil at waters edge during turbulent conditions of changing water level.

Recommendations

Water quality sampling on Muddy Creek and the Marys River during the Phase 2 monitoring project has not confirmed the presence of any particular point source contributing to high phosphorus concentration, low dissolved oxygen, or high bacteria counts. The general conclusion from the Phase 1 and Phase 2 studies is that diffuse sources are the most important factor influencing the constituents considered. In the absence of identified point sources, restoration actions might most effectively be addressed toward investigation of current land use practices in the watershed, and developing and encouraging the use of management methods that will reduce, to the extent possible, loading to the streams of organic matter and phosphorus. Changes in phosphorus and dissolved oxygen in Muddy Creek above and below McFadden marsh, while not statistically significant, may suggest an opportunity for relatively greater improvement in this reach than at other sites sampled.

Increased summertime flow could have a beneficial effect on the water quality constituents measured during Phases 1 and 2 of the Marys River water quality study. Current flow conditions in the Marys River, measured at Philomath, are listed below (ODA 2002):

C	Average Winter Flow	1121 cfs
C	Average Summer Flow	50 cfs
C	Minimum Annual Flow	4 cfs
C	Maximum Annual Flow	13,600 cfs
C	Average Flow	467 cfs

Current appropriations on the Marys River include 142 cfs for consumptive use and 11 cfs in-stream appropriation for fish and wildlife. Increasing flow in the streams to the extent possible will have a beneficial effect on water quality.

Sustained monitoring is a necessary component to any water quality improvement plan. Many of the improvement measures put into practice may take years to effect an observable improvement in water quality, and it may require many measures implemented across much of the watershed to produce measurable change. Without sustained monitoring in will be difficult to measure the effect of any improvement activity. A modest program of monthly sampling for selected constituents at a few sites augmented by annual or biennial short-term detailed sampling for one or more constituents, if sustained for the long term, could be an effective program. Sites to be considered could include:

- C The Marys River at Highway 34
- C The Marys River at Bellfountain Road
- C The Marys River at Avery Park
- C Muddy Creek at Greenberry Road
- C Muddy Creek at McFarland Road near Alpine
- C Muddy Creek near the confluence with the Marys River (access to this site would require arrangement with local property owners).

Constituents to measure could include temperature, dissolved oxygen, phosphorus, bacteria (*E. coli*), specific conductance, turbidity, and chlorophyll *a*.

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APPENDICES

Appendix 1 - Volunteer Support and Landowner Cooperation

The volunteer and landowner support for this project was exemplary. In total, members of the Marys River Watershed Council and community volunteered 73.5 hours of their time to collect data on the Marys and Muddy Rivers (Table A1). Also, children accompanied their parents for a total of 18 hours of data collection, which provided educational opportunities regarding water quality, riparian and wetland habitat, and stream flow processes. The success of this project is due in large part to the time donated by these volunteers for data collection and the access granted to the river by landowners. This project was particularly taxing on volunteers given the sample protocol that often called for data collection at all times of day and night, multiple days in a row, and sometimes during inclement weather. Landowners were also important in this respect because they allowed us to walk across their property at strange hours of the day and night.

Table A1. Summary of volunteer hours by adults and children and landowner support.

Project	Volunteers Or Landowner	Activity	Total Hours
Marys & Muddy	Blain Hoy Ken Krawse Barry Reeves Sue Helback Greg Alpert	Collected temperature and dissolved oxygen on Marys and Muddy. Also collected BOD and phosphorus samples on the Muddy and bacteria samples on the Marys	73.5
Marys & Muddy	Arielle Alpert Sabrina Simpson Bethany Llewellyn Barry Reeves' Daughter Olivia Helback	Accompanied parents on data collection activities and learned about water quality, stream flow, and habitat on the Marys and Muddy rivers.	21
Marys	Miller Timber Services City of Philomath (Beau Vencill) Merv and Carol Moldowan Laura Pavelek Gathering Together Farm	Provided access Mr. Vencill also spent an afternoon to help locate sites.	NA

Expenditures

In-kind Contributions

E&S Environmental Chemistry Inc. provided a YSI Model 85 dissolved oxygen/conductivity meter for 24 days at $25/day ($600)

E&S Environmental Chemistry Inc. provided laboratory analysis for 54 phosphorus samples at $17 per sample ($918).

Appendix 2 - Data

Quantitative data description
E. Coli (MPN/100 mL)

	MR1	MR2	MR3	MR4	MR5	MR6	MU1	MU2	MU3	MU4	MU5	MU6	MU7
No. of values used	45	45	45	45	45	68	63	61	62	64	63	60	60
No. of values ignored	0	0	0	0	0	0	0	1	0	0	0	0	0
No. of min. val.	1	1	1	1	1	1	1	1	3	1	1	2	2
% of min. val.	2.2	2.2	2.2	2.2	2.2	1.5	1.6	1.6	4.8	1.6	1.6	3.3	3.3
Minimum	6.9	6.8	6.6	6.2	6.7	6.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1st quartile	22.5	21.7	21.7	22.0	22.8	23.2	4.2	1.8	2.9	5.7	3.7	7.1	4.3
Median	52.0	60.0	64.0	59.0	48.0	59.0	20.0	14.0	16.0	17.2	15.7	15.3	17.7
3rd quartile	130.0	100.0	103.5	90.5	118.8	140.0	32.0	21.4	22.8	36.0	23.7	67.3	41.5
Maximum	1300	2400	1200	2400	2400	2400	76	70	60	85	94	93	72
Range	1293	2393	1193	2394	2393	2394	76	70	60	85	94	93	72
Sum	7269	7882	6044	9900	12113	14044	1346	842	1155	1537	1259	1760	1293
Mean	161.5	175.2	134.3	220.0	269.2	206.5	21.4	13.8	18.6	24.0	20.0	29.3	21.5
Geometric mean	58.5	54.6	54.7	56.9	60.8	63.2	7.2	5.0	6.3	7.9	7.0	9.3	7.8
Harmonic mean	26.3	25.7	25.6	24.6	24.7	28.2	0.2	0.2	0.2	0.2	0.3	0.2	0.3
Kurtosis (Pearson)	6.3	16.5	10.1	8.8	6.3	14.7	-0.1	3.8	-0.5	-0.6	1.4	-1.0	-0.8
Skewness (Pearson)	2.5	4.0	3.0	3.0	2.7	3.7	0.9	1.6	0.8	0.9	1.3	0.9	0.7
Kurtosis	7.7	19.7	12.2	10.6	7.7	16.5	0.1	4.5	-0.3	-0.4	1.8	-0.9	-0.7
Skewness	2.7	4.3	3.2	3.2	2.9	3.9	1.0	1.6	0.9	1.0	1.3	0.9	0.8
CV (std deviation/mean)	1.7	2.4	1.7	2.2	2.2	2.2	1.0	1.0	1.0	1.0	1.0	1.1	0.9
Sample variance	72161	176674	48799	227623	328779	196873	423	181	315	605	400	1010	408
Estimated variance	73801	180689	49908	232797	336251	199812	430	184	321	614	406	1027	415
Sample std deviation	268.6	420.3	220.9	477.1	573.4	443.7	20.6	13.4	17.8	24.6	20.0	31.8	20.2
Estimated std deviation	271.7	425.1	223.4	482.5	579.9	447.0	20.7	13.5	17.9	24.8	20.2	32.0	20.4
Mean absolute deviation	177.5	204.8	137.2	285.3	356.7	244.7	16.4	10.4	14.2	19.9	15.4	27.9	16.8
Median abs deviation	40.7	38.5	42.2	36.3	39.0	36.4	15.5	9.5	11.8	12.0	11.4	8.5	13.6
Standard-error	40.5	63.4	33.3	71.9	86.4	54.2	2.6	1.7	2.3	3.1	2.5	4.1	2.6
Lower bound Mean CI	79.9	47.5	67.2	75.0	95.0	98.3	16.1	10.3	14.1	17.8	14.9	21.1	16.3
Upper bound Mean CI	243.1	302.9	201.4	364.9	443.4	314.7	26.6	17.3	23.2	30.2	25.1	37.6	26.8

Note: The standard deviation and confidence interval of the mean are valid only if the sample results from simple random sampling

Quantitative data description
Dissolved Oxygen concentration (mg/L)

	MR1	MR2	MR3	MR4	MR5	MR6	MU1	MU2	MU3	MU4	MU5	MU6
No. of values used	8	8	8	8	8	9	18	18	18	18	18	17
No. of values ignored	0	0	0	0	0	0	0	0	0	0	0	0
No. of min. val.	1	1	1	1	1	1	3	1	2	1	1	1
% of min. val.	12.5	12.5	12.5	12.5	12.5	11.1	16.7	5.6	11.1	5.6	5.6	5.9
Minimum	6.9	6.8	6.6	6.2	6.7	6.5	2.7	0.6	1.5	2.2	1.4	5.3
1st quartile	7.4	7.3	6.9	6.7	6.9	6.8	2.8	1.2	2.3	4.9	2.4	6.8
Median	7.7	7.6	7.9	7.8	7.2	7.1	4.3	1.8	4.1	5.8	4.2	7.4
3rd quartile	8.3	8.3	8.2	7.9	7.8	7.8	5.5	2.4	4.4	6.1	4.8	8.4
Maximum	9.2	8.8	8.6	8.1	8.1	8.5	6.2	10.4	6.1	7.2	8.2	9.1
Range	2.3	2.0	2.0	1.9	1.4	2.0	3.5	9.8	4.6	5.0	6.8	3.8
Sum	62.9	62.0	61.1	59.0	58.6	66.3	78.4	46.5	63.4	96.6	72.1	126.1
Mean	7.9	7.7	7.6	7.4	7.3	7.4	4.4	2.6	3.5	5.4	4.0	7.4
Geometric mean	7.8	7.7	7.6	7.3	7.3	7.3	4.2	1.9	3.2	5.1	3.6	7.3
Harmonic mean	7.8	7.7	7.6	7.3	7.3	7.3	4.0	1.6	2.8	4.8	3.2	7.2
Kurtosis (Pearson)	-1.2	-1.5	-1.8	-1.7	-1.8	-1.4	-1.4	3.4	-1.4	-0.6	-0.3	-1.1
Skewness (Pearson)	0.5	0.3	-0.3	-0.5	0.2	0.5	0.0	2.0	0.0	-0.9	0.4	-0.3
Kurtosis	0.0	-0.9	-1.7	-1.3	-1.7	-0.7	-1.2	6.0	-1.3	0.1	0.4	-0.7
Skewness	0.8	0.4	-0.4	-0.8	0.3	0.7	0.0	2.3	-0.1	-1.1	0.5	-0.4
CV (standard deviation/mean)	0.1	0.1	0.1	0.1	0.1	0.1	0.3	0.9	0.4	0.3	0.4	0.2
Sample variance	0.5	0.4	0.5	0.5	0.2	0.4	1.5	5.5	2.1	2.0	2.9	1.3
Estimated variance	0.6	0.5	0.6	0.5	0.3	0.5	1.6	5.9	2.2	2.1	3.1	1.4
Sample standard deviation	0.7	0.7	0.7	0.7	0.5	0.7	1.2	2.4	1.4	1.4	1.7	1.1
Estimated standard deviation	0.8	0.7	0.8	0.7	0.5	0.7	1.2	2.4	1.5	1.5	1.7	1.2
Mean absolute deviation	0.6	0.6	0.7	0.6	0.4	0.6	1.0	1.7	1.3	1.1	1.4	0.9
Median absolute deviation	0.3	0.5	0.5	0.3	0.5	0.4	1.4	0.6	1.2	0.4	1.1	0.7
Standard-error	0.3	0.2	0.3	0.3	0.2	0.2	0.3	0.6	0.3	0.3	0.4	0.3
Lower bound Mean CI	7.2	7.2	7.0	6.8	6.9	6.8	3.7	1.4	2.8	4.6	3.1	6.8
Upper bound Mean CI	8.5	8.3	8.3	8.0	7.8	7.9	5.0	3.8	4.3	6.1	4.9	8.0

Note: The standard deviation and confidence interval of the mean are valid only if the sample results from simple random sampling

Quantitative data description
PO4-P (mg/L)

	MU1	MU2	MU3	MU4	MU5	MU6	MU7	MU7dup
No. of values used	7	6	7	7	7	7	7	6
No. of values ignored	0	0	0	0	0	0	0	0
No. of min. val.	1	1	3	1	1	2	2	4
% of min. val.	14.286	16.667	42.857	14.286	14.286	28.571	28.571	66.667
Minimum	0.010	0.010	0.020	0.010	0.020	0.020	0.030	0.030
1st quartile	0.020	0.020	0.020	0.020	0.030	0.020	0.030	0.030
Median	0.020	0.025	0.030	0.030	0.030	0.030	0.040	0.030
3rd quartile	0.020	0.030	0.030	0.030	0.040	0.040	0.050	0.050
Maximum	0.030	0.040	0.030	0.040	0.040	0.050	0.050	0.060
Range	0.020	0.030	0.010	0.030	0.020	0.030	0.020	0.030
Sum	0.140	0.150	0.180	0.180	0.230	0.230	0.290	0.230
Mean	0.020	0.025	0.026	0.026	0.033	0.033	0.041	0.038
Geometric mean	0.019	0.023	0.025	0.024	0.032	0.031	0.041	0.037
Harmonic mean	0.018	0.021	0.025	0.022	0.031	0.030	0.040	0.035
Kurtosis (Pearson)	-0.429	-1.571	-2.204	-1.334	-1.454	-1.636	-1.903	-1.621
Skewness (Pearson)	0.000	0.000	-0.229	-0.169	-0.364	0.152	-0.216	0.670
Kurtosis	3.000	-0.248	-2.800	0.042	-0.350	-0.944	-1.817	-0.459
Skewness	0.000	0.000	-0.374	-0.277	-0.595	0.249	-0.353	1.207
CV (standard deviation/mean)	0.289	0.420	0.208	0.380	0.230	0.339	0.217	0.347
Sample variance	2.86E-05	9.17E-05	2.45E-05	8.16E-05	4.90E-05	1.06E-04	6.94E-05	1.47E-04
Estimated variance	3.33E-05	1.10E-04	2.86E-05	9.52E-05	5.71E-05	1.24E-04	8.10E-05	1.77E-04
Sample standard deviation	0.005	0.010	0.005	0.009	0.007	0.010	0.008	0.012
Estimated standard deviation	0.006	0.010	0.005	0.010	0.008	0.011	0.009	0.013
Mean absolute deviation	0.003	0.008	0.005	0.008	0.006	0.009	0.007	0.011
Median absolute deviation	0.000	0.005	0.000	0.010	0.010	0.010	0.010	0.000
Standard-error	0.002	0.004	0.002	0.004	0.003	0.004	0.003	0.005
Lower bound Mean CI	0.015	0.014	0.021	0.017	0.026	0.023	0.033	0.024
Upper bound Mean CI	0.025	0.036	0.031	0.035	0.040	0.043	0.050	0.052

Note: The standard deviation and confidence interval of the mean are valid only if the sample results from simple random sampling

Quantitative data description
Water Temperature (ºC)

	MR1	MR2	MR3	MR4	MR5	MR6	MU1	MU2	MU3	MU4	MU5	MU6	MU7
No. of values used	8	8	8	8	8	9	18	18	18	18	18	17	17
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.	12.5	12.5	12.5	12.5	12.5	11.1	5.6	5.6	5.6	5.6	5.6	5.9	5.9
Minimum	19.3	18.4	18.3	19.0	19.5	19.9	14.1	13.8	14.2	14.1	13.9	11.8	14.2
1st quartile	22.2	21.0	21.0	22.0	22.5	22.6	20.0	19.8	20.9	19.1	20.8	15.3	17.7
Median	22.7	22.1	22.0	22.8	23.2	23.3	21.5	20.4	21.6	21.2	22.2	17.9	21.0
3rd quartile	23.2	22.8	23.2	23.4	23.6	23.8	22.6	21.6	22.3	23.2	22.3	18.8	22.7
Maximum	23.6	22.9	23.6	23.7	23.6	24.1	26.0	24.6	22.9	25.1	23.7	19.9	23.7
Range	4.3	4.5	5.3	4.7	4.1	4.2	11.9	10.8	8.7	11.0	9.8	8.1	9.5
Sum	179.0	172.8	174.0	178.9	181.5	206.7	376.4	359.1	365.1	368.2	371.1	289.2	344.8
Mean	22.4	21.6	21.8	22.4	22.7	23.0	20.9	20.0	20.3	20.5	20.6	17.0	20.3
Geometric mean	22.3	21.5	21.7	22.3	22.6	22.9	20.6	19.7	20.0	20.1	20.3	16.8	20.0
Harmonic mean	22.3	21.5	21.6	22.3	22.6	22.9	20.2	19.5	19.7	19.8	20.0	16.6	19.7
Kurtosis (Pearson)	0.6	-0.4	-0.8	0.3	0.7	1.0	-0.9	-0.2	-0.5	-1.1	-0.5	-0.7	-1.0
Skewness (Pearson)	-1.4	-1.0	-0.7	-1.2	-1.4	-1.5	-0.5	-0.8	-1.1	-0.6	-1.1	-1.0	-0.8
Kurtosis	4.9	2.1	1.2	4.0	5.2	5.0	-0.5	0.6	0.1	-0.7	0.2	-0.1	-0.5
Skewness	-2.1	-1.5	-1.1	-1.9	-2.2	-2.1	-0.6	-1.0	-1.4	-0.7	-1.4	-1.2	-1.0
CV (standard deviation/mean)	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.1	0.2	0.2	0.2	0.2	0.2
Sample variance	1.6	2.1	2.7	2.0	1.7	1.4	13.2	7.9	9.2	11.5	10.2	6.5	10.1
Estimated variance	1.8	2.4	3.1	2.3	1.9	1.6	14.0	8.4	9.7	12.2	10.8	6.9	10.7
Sample standard deviation	1.3	1.4	1.6	1.4	1.3	1.2	3.6	2.8	3.0	3.4	3.2	2.6	3.2
Estimated standard deviation	1.3	1.5	1.8	1.5	1.4	1.3	3.7	2.9	3.1	3.5	3.3	2.6	3.3
Mean absolute deviation	0.9	1.1	1.3	1.0	0.9	0.8	2.8	2.0	2.5	2.8	2.6	2.1	2.6
Median absolute deviation	0.5	0.7	1.2	0.6	0.4	0.5	1.3	1.0	0.7	2.1	0.8	0.9	1.7
Standard-error	0.5	0.5	0.6	0.5	0.5	0.4	0.9	0.7	0.7	0.8	0.8	0.6	0.8
Lower bound Mean CI	21.3	20.3	20.3	21.1	21.5	22.0	19.1	18.5	18.7	18.7	19.0	15.7	18.6
Upper bound Mean CI	23.5	22.9	23.2	23.6	23.8	23.9	22.8	21.4	21.8	22.2	22.3	18.4	22.0

Note: The standard deviation and confidence interval of the mean are valid only if the sample results from simple random sampling