REMEDIATION OF AGRICULTURAL CONTRIBUTIONS OF FECAL COLIFORM BACTERIA, SEDIMENT, AND HEAT IN THE TILLAMOOK BASIN

FINAL REPORT AND CONCLUSIONS OF THE BEAVER CREEK PROJECT

E&S Environmental Restoration, Inc.

September 2002

REMEDIATION OF AGRICULTURAL CONTRIBUTIONS OF FECAL COLIFORM BACTERIA, SEDIMENT, AND HEAT IN THE TILLAMOOK BASIN: FINAL REPORT AND CONCLUSIONS OF THE BEAVER CREEK PROJECT

Timothy J. Sullivan[1]
Mark Wustenberg[2]
Kai U. Snyder[3]
James Moore[4]
Deian Moore[3]
Erin Gilbert[3]
Eric Mallery[5]

Report to:

Tillamook County Performance Partnership
Oregon Watershed Enhancement Board
Oregon Department of Environmental Quality
U.S. Environmental Protection Agency

September 2002

Submitted by:

E&S Environmental Restoration, Inc.
P.O. Box 84
Corvallis, OR 97339

---

[1] E&S Environmental Restoration, Inc., P.O. Box 84, Corvallis, OR 97339

[2] Kilchis Dairy Herd Services, P.O. Box 327, Bay City, OR 97107

[3] E&S Environmental Chemistry, Inc., P.O. Box 609, Corvallis, OR 97339

[4] Dept. Bioengineering, Oregon State University, Corvallis, OR 97331

[5] Oregon Streamside Services, 11880 Hwy 101S, Tillamook, OR 97141

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ACKNOWLEDGMENTS

This research was supported by grants from the Tillamook Bay National Estuary Project, Oregon Watershed Enhancement Board, Oregon Department of Environmental Quality, and U.S. Environmental Protection Agency. This report has not been subjected to official agency review and no agency endorsement is implied.

Administrative assistance was provided by Steve Nelson, Roxanna Hinzman, Rich Felley, Bruce Apple, Tom Shafer, Yvonne Vallette, and Claudine Rehn.

We are very grateful to the landowners, the Johnston and Hofmann families, for their willingness to permit this research to be conducted on their farms, and for their cooperation throughout this effort.

Field assistance was provided by Greg McGrath, Dave Peterson, Joe Bischoff, Benn Eilers, Kellie Vaché, Bob Rees, and Shawn Allen.

Assistance in site selection was provided by Shawn Reiersgaard, Bruce Apple, Bob Pedersen, Rich Felley, and Dale Buck.

Native plants were donated by Kurt Heckeroth of the U.S. Bureau of Land Management. Fencing materials were donated by the Tillamook County Creamery Association. Planting assistance was provided by volunteers from the Tillamook Bay Watershed Council.

ABSTRACT

The Beaver Creek Demonstration Project was conducted over a four-year period in a tributary subwatershed to the Tillamook River watershed. The goal was to demonstrate and quantify effective remediation of high water temperature, fecal coliform bacteria (FCB), and sediment load contributions to stream water in a way that did not diminish the productivity of adjacent farms. This was accomplished by streamside fencing, water diversion, riparian planting, enhancement of small wetlands, changes in manure management practices, and water quality monitoring in both the treatment and a reference (control) subwatershed before and after implementation of these actions.

The results of water quality monitoring efforts prior to conducting the on-the-ground work illustrated substantial contamination of runoff with bacteria as the streams pass through the agricultural portion of the study area. Results also showed substantial bacterial contamination in one tributary upstream of agricultural land use. The data collected during the first two years of monitoring provided a good baseline against which to measure improvements associated with subsequent restoration efforts.

As a consequence of the restoration actions enacted, the contribution of FCB from agricultural land to the stream was reduced dramatically, especially in Year 4 in comparison with the pre-treatment period (Years 1 and 2). Total suspended solids (TSS) concentrations also decreased and there was some indication of decreasing peak streamwater temperature. Conclusions for FCB include the following. The median FCB concentration at the downstream treatment watershed site (BEA-FRZ) decreased by 76% from pre-treatment to post-treatment periods, and the percentage of storm samples exceeding the 200 cfu/100 ml standard decreased by 45%. The improvement for Year 4, as compared with the overall pre-treatment period, ranged from 45% reduction in median FCB concentration during fall to 63% and 88% reductions during winter and spring, respectively. During Year 4, water exiting the treatment watershed below the farms had, on average, lower FCB concentration than water entering the farms from the forest in one of the tributary streams.

Clearly, fencing, riparian planting, hydrological modifications, and manure-spreading setbacks have helped to improve water quality in the Beaver Creek watershed. This project has quantified achievable reductions in the contributions of bacteria and sediment in agricultural areas over the short-term. Quantification of long-term reductions would require continued monitoring. Such improvements are expected to reduce bacterial contamination of the river and

bay, reduce stream bank erosion and erosion from agricultural fields, reduce sediment transport from uplands to the lower river and the bay, reduce stream temperatures, improve the integrity of aquatic biological communities in streams draining agricultural lands, and improve salmonid habitat quality in the upper and lower watershed.

1.0 INTRODUCTION

1.1 BACKGROUND

Tillamook Bay and its watershed have a long history of water quality problems (Blair and Michener 1962, Jackson and Glendening 1982, Musselman 1986, Oregon Department of Environmental Quality 1994) and of programs to address those problems. In the early 1980's, the Oregon Department of Environmental Quality (ODEQ) received a federal grant under section 208 of the Clean Water Act, which created the Rural Clean Water Program (RCWP), to identify bacterial sources to the bay and to develop a fecal coliform bacteria (FCB) management plan for the watershed. The Agricultural Stabilization and Conservation Service received federal funding through the RCWP to provide cost sharing for farmers to adopt better management practices and to construct the facilities to do so. Despite progress in these efforts to restore water quality, both fresh and saline waters in the Tillamook Basin often fail to meet water quality standards.

Through the RCWP during the 1980's, major bacterial sources were identified and various measures taken to decrease bacterial pollution. The RCWP provided over $6 million in cost-share money to improve manure management facilities on dairy farms. Many wastewater treatment plants and septic systems were also upgraded during that time period. Although these efforts resulted in improved management practices in the region (Arnold et al. 1989, Dorsey-Kramer 1996), bacterial contamination still causes water quality violations in Tillamook area rivers and streams, and elevated levels in Tillamook Bay during and after rainstorm events (Sullivan et al. 1998a,b).

Water quality bacteria standards for recreational contact and shellfish growing waters differ; but standards in both fresh water and the bay have long been violated in the Tillamook watershed (Jackson and Glendening 1982). The bacteria standard for recreational contact (formerly fecal coliform bacteria [FCB], currently *E. coli*) applies to both fresh and saline waters and is intended to protect people in contact with water such as swimmers. The shellfish standard (FCB) is much more stringent, as it is designed to protect people from pathogens which might be consumed with raw shellfish.

Bacterial problems often close harvesting in Tillamook Bay, which has been one of Oregon's leading producers of shellfish, particularly oysters. Oregon has adopted the water quality standards for bacterial and other pathogens in estuarine water set by the federal Food and Drug Administration (FDA) for interstate commerce (U.S. Dept. of Health and Human Services

1995). Bacterial concentrations in the bay have historically been high during the wet seasons of the year: fall, winter, and early spring. Due to the bay's unpredictable water quality and many point and nonpoint sources of bacteria and viruses, oyster culture is allowed only in specified areas of the bay, and harvesting is allowed only under certain conditions, as identified in the shellfish management plan for Tillamook Bay (Oregon Department of Agriculture 1991).

Section 303(d) of the federal Clean Water Act requires the Oregon DEQ to list water quality impaired water bodies for the entire state. A water body is "water quality impaired" when it violates the State's water quality standards, either numeric or narrative. In the Tillamook Bay area, only bacteria and water temperature have been sufficiently documented as a basis for listing water bodies. Fecal coliform and *E. coli* levels commonly exceed the former and current recreational contact standards, respectively, in the streams and rivers, and FCB levels exceed both the recreational standard and the shellfish harvest standard in the bay. Freshwater values occasionally exceed 12,000 cfu/100 ml and estuarine values occasionally exceed 1,600 cfu/100 ml in the watershed.

E&S Environmental Restoration, Inc. initiated the Beaver Creek Remediation Project in 1998, in association with the Tillamook Bay National Estuary Project. The Beaver Creek Project is a demonstration effort aimed at documenting and quantifying improved water quality for an entire subbasin of the Tillamook River subsequent to performance of a range of on-the-ground actions.

1.2 GOALS AND OBJECTIVES

Dairy farmers in the Tillamook Basin (and elsewhere) feel threatened by the prospect of additional nonpoint source (NPS) pollution regulatory actions and remain unconvinced that management activities on their individual farms make any appreciable difference for water quality in the Basin. Many are skeptical that land use (especially riparian management) impacts water and habitat quality issues related to sediment flux, temperature, and aquatic biota. What is needed is a clear and unambiguous demonstration of improvement subsequent to remediation on neighboring farms. Such a demonstration must remove only minor amounts of farmland from productivity, be simple and inexpensive to implement, enhance rather than detract from the aesthetic qualities and economics of the farm, and yield measurable improvements in water quality. Several methods are available with which to remediate NPS pollution contributions to river waters from dairy farming and other agricultural activities. Chief among these are constructed or enhanced wetlands, fenced riparian areas, and altered hydrology to route surface water away from areas of concentrated animal use. It is not known, however, how large wetland or riparian filters need to be in order to optimize removal efficiencies for bacteria, sediment, or nutrients. Optimal design features such as buffer widths, hydrologic retention, and plant species mixes are poorly known. These issues are important because farmers are rightfully reluctant to remove large portions of their farms from productivity in the hopes of improving water quality. What is needed is better information regarding the extent to which effective filtration can be provided with minimal loss of productive land.

The ultimate goal of the ongoing effort is to demonstrate and quantify effective remediation of high water temperature, FCB, and sediment load contributions to river waters from an agricultural subbasin of the Tillamook River in a way that does not diminish the productivity of adjacent farms. This is being accomplished by a combination of streamside fencing, water diversion, riparian planting, enhancement of multiple small wetlands, changes in manure management practices, and water quality monitoring before and after implementation of these remediation efforts. Primary objectives are to:

- improve water quality in a subbasin of one of the rivers that flows into Tillamook Bay;
- improve aquatic habitat quality by reducing sediment transport and water temperature and reducing the load of bacteria that is transported to the lower river and oyster beds in the bay;
- quantify the effectiveness of these measures by monitoring FCB, water temperature, turbidity, and TSS; and
- demonstrate the environmental benefits that can be achieved through implementing cost-effective management practices and remediation efforts.

The project specifically addresses each of the priority problem areas of the Tillamook Basin initially identified by the Tillamook Bay National Estuary Project (TBNEP 1999): fecal bacterial contamination, sedimentation, and salmonid habitat degradation. Specific improvements, and associated uncertainty, are being quantified and will be communicated to local stakeholders.

2.0 METHODS

2.1 SITE SELECTION AND LANDOWNER COOPERATION

Considerable effort was devoted to selection of an appropriate subbasin in which to conduct the remediation project as well as an appropriate reference (control) watershed. This was done in conjunction with local agency representatives and other knowledgeable stakeholders. Input was provided to the project team from representatives of the Tillamook County Creamery Association (TCCA), TBNEP, Oregon State University Extension Service, Oregon Department of Agriculture, Natural Resources Conservation Service, and Tillamook Soil and Water Conservation District. Several candidate subbasins were selected and contacts with landowners were initiated.

Two subbasins were selected from among the candidates, and more extensive discussions with landowners and farm managers were conducted. It was determined that either subbasin (Upper Tillamook River mainstem or Beaver Creek, a tributary to the Tillamook River) would be appropriate for the proposed remediation, with the other serving as the reference (control) subbasin. It soon became apparent that landowner cooperation was most likely to occur in the Beaver Creek subbasin, and farm visits to the three upper farms in this subbasin revealed excellent potential for remediation work. Subsequently, a protracted period of discussions and farm visits by members of the project team was required to convince landowners and their family members on two of the farms of the benefits of participating in this project. In December, 1998, the second farm owner agreed in principle to participate. In anticipation of this agreement, some pre-treatment water quality monitoring had been initiated in September, 1998. The third owner declined the invitation to participate.

The farms selected for remediation are two of the three uppermost farms in the Beaver Creek watershed. Three major tributary streams contribute flow from the forest to the pasturelands on these farms, Bear Creek to the north and the north and south forks of Beaver Creek (Figure 1). Remediation work has focused on the uppermost and lowest of the three farms in the upper watershed, and we are quantifying the extent to which water quality has improved as a consequence. Although it would have been desirable to conduct work on all of the farms in the upper watershed, we believe that our work on two of three farms is probably more representative of what might occur basin-wide. If water quality can be substantially improved subsequent to

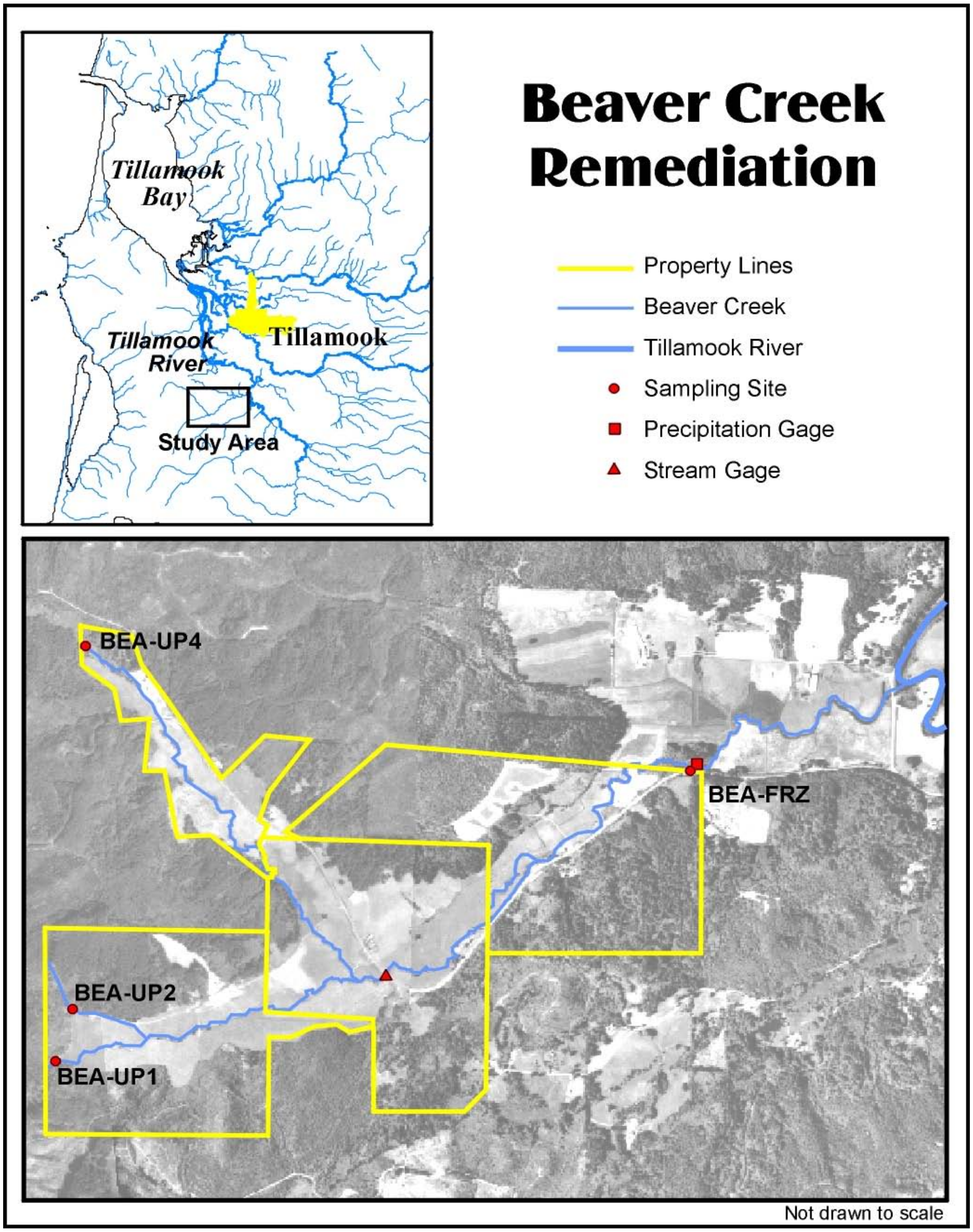


Figure 1. Sample site locations in the remediation project area. Three sampling sites are situated at the forest/agriculture interface of the three primary tributaries to Beaver Creek. The fourth site is located just downstream of the farms targeted for remediation work. The locations of property boundaries and the sites for monitoring precipitation and streamflow are also shown. Work was done for the project on the upper farm (which includes the two upstream parcels) and the lower farm, which terminates at site BEA-FRZ.

on-the-ground efforts on two of the farms, this improvement likely represents an achievable target for remediation throughout the Tillamook Basin.

The uppermost dairy is comprised of approximately 100 milking age Holstein cows and about the same number of heifers (6 months to calving). Cows and heifers are pastured from approximately April through October, with some variability depending on rainfall and grass growth. Animals are fully confined during the winter months.

During the summer, approximately 40 to 45% of the milking cow dry matter ration requirements are supplied from pasture under an intensive rotational grazing scheme. Heifers take a majority of their nutrient needs from pasture during this time as well. Early in the spring, during the period of rapid grass growth, some pasture areas are left ungrazed and are harvested as hay for use during the winter.

The lower farm property is rented by a neighboring dairy and used for heifers. Approximately 50 heifers from 6 to 22 months of age are kept there year-round. The heifers have access to pasture 12 months of the year with minimal additional supplementation from April to November. From approximately November through March, their diet is fully supplemented with hay and grain and does not rely on significant pasture consumption.

The land between the two treatment areas, that did not participate in the study, is used for beef cattle. The owner keeps approximately 25 head of beef cattle, which essentially have access to the pasture area 12 months of the year with minimal control over grazing behavior. During the spring, summer, and fall, pasture supplies essentially all of their dry matter needs. During the winter, they receive minimal additional supplementation with hay and freechoice protein/mineral supplement.

Work that we have done on the participating farms (and fencing work completed just prior to initiation of this project) has helped to improve farm management. Suspected benefits include the following:

1. Participating and down-stream farmers have a cleaner source of water. This may reduce the frequency of disease problems in the herds.

2. Exclusion of animals from muddy riparian areas reduces the time required to clean animals for milking and may improve the quality of the milk.

3. The fencing constructed along the riparian corridors of the lowest farm make it easier and less expensive to utilize compartmentalized grazing rotation. This allows for more sophisticated management and consequent increased efficiency of operation.

4. Bank erosion, and consequent loss of farmland, will be reduced.

The farmers have given up some land from productivity to create riparian buffer zones, but this should be compensated by the increases in efficiency, outlined above. Many of the kinds of changes included in this program might soon be required of the farmers by regulatory agencies.

2.2 PRE-TREATMENT SITE DESCRIPTION AND ASSESSMENT OF PROBLEM AREAS

During the year prior to initiation of this project, much of the streamside area on the uppermost farm was fenced by the landowner. Very small buffer strips (~ 1-2 m) were provided between fence and top of streambank. Much of the streamside area of the middle farm (not participating in this project) was also fenced during that period. Very little fencing had been done in the past on the lower farm; most riparian areas on the lower farm were readily accessible to livestock. Some riparian and wetland areas on the middle and upper farm were also accessible to livestock.

Many areas of streambank erosion were present in the study area; especially on the lower and middle farms. Many of these erosion-prone areas were frequented by livestock during part of the year.

Riparian areas on the lower farm were heavily vegetated with blackberry in many areas. Blackberry thickets were sufficiently dense and extensive as to preclude planting a diversity of native plants (including trees) throughout large portions of the riparian zone. In addition, these thickets obstructed fence line locations in some places.

There were two areas, one on the upper farm and one on the lower farm, where runoff patterns contributed surface runoff during periods of heavy precipitation that flowed directly from areas heavily utilized by livestock into adjacent streams or open drainage ditches. In both cases, these source areas were adjacent to the respective barns on those farms.

There were also many areas on all three farms where the surface contours of the land allowed direct overland flow to enter streams from pasture areas during periods of heavy rainfall. These were generally locations where the pastures sloped abruptly to the edge of the streambank.

Thus, there were many potential source areas for bacteria and sediment contributions to Beaver Creek and its tributary streams. In addition, there was a general lack of trees throughout the riparian zones on all three farms and only a limited amount of shading of the streams was provided by existing riparian vegetation.

Although soils were saturated throughout much of the rainy season in many places, areas of wetland vegetation were scattered. Existing wetlands were grazed by livestock and wetland function appeared to be diminished. An extensive riparian wetland and former stream channel system on the lower farm had been partially isolated from streamflow by prior ditching.

2.3 APPROACH

There are four farms along Beaver Creek, three of which are above the area of tidal influence, and are within the area of this project. The upper farm is split into two tracts of land in the southwest (including sites BEA-UP1 and BEA-UP2) and the northwest (including site BEA-UP4) portions of the agricultural land that occurs within the watershed (Figure 1). The north and south forks of Beaver Creek (southwest) and Bear Creek (northwest) drain forested uplands prior to entering agricultural land on the upper farm. Bear Creek joins Beaver Creek on the middle farm just above the stream gage that was installed for this project. The precipitation gage and the main stream sampling site (BEA-FRZ) are located just below the property boundary of the lower farm (at the lower end of the project). Downstream from site BEA-FRZ is a fourth farm occupied by a combination of pasture lands and estuarine wetlands adjacent to the confluence of Beaver Creek and the Tillamook River.

Surface waters have been monitored above and below the remediation subbasin (Figure 1) and in the reference (control) subbasin. The experimental and reference watersheds are located in close proximity (5 km) and are similar in size, land use, and physiography (Table 1).

Table 1. Characteristics of the experimental and reference watersheds.

	Experimental	Reference
Area (km^2)	10.4	10.0
Elevation (m)		
Minimum	4	42
Mean	59	128
Maximum	186	407
Land Use (%)		
Agriculture	9.0	7.3
Forest	88.8	91.9
Wetland	1.1	0.0
Rural Residential	0.2	0.8
Annual Precipitation (cm)	216	229

Monitoring includes measurement of rainfall intensity, stream discharge, and sampling of five to ten storms per year. Both parameter concentrations and loads have been calculated and results have been expressed as discharge-weighted storm-median concentrations or storm loads. Storm results were classified by storm type (based on rainfall intensity, maximum discharge, season, and antecedent hydrological conditions) for year-to-year comparisons.

The environmental restoration approach has involved the fencing of riparian areas, altering hydrological runoff to minimize bacterial input, and enhancing several small wetlands in runoff-contributing agricultural areas. Riparian and wetland areas were planted with native species. Enhanced wetland systems were designed to filter stream flow, especially during high-flow periods.

Our initial proposal called for extensive wetland construction and enhancement, especially on the middle and lower farms. The proposed wetlands were designed to improve filtration of runoff in order to minimize downstream bacterial and sediment loads. This issue of wetland construction and enhancement proved to be the most contentious for landowners. The owner of the middle farm declined to participate in the project at all, and the owners of the upper and lower farms each decided not to grant permission for us to conduct some or all of the intended wetland work on their farms.

In this project, we wish to quantify specific improvements (and the uncertainty associated with those improvements) in water quality within the treatment watershed. We have measured changes in stream temperature, storm-driven bacteria concentrations and loads, and sediment fluxes in response to focused remediation efforts. Monitoring has been conducted for four years, two years of pre-treatment and two years of post-treatment.

During the four-year period of study, there have been gaps in the data record for some variables, attributable to equipment malfunction, battery failure, or loss or burial of tributary stream temperature monitors during high discharge. In addition, stream sampling was initiated prior to installation of stream discharge and precipitation monitoring equipment. Data gaps caused by these problems were generally of short duration and were filled using measurements from alternate sites and empirical relationships. Details on these approaches to filling data gaps are provided in Appendix A.

Continuous stream stage was measured at the Beaver Creek Bridge in the middle of the study area using a pressure transducer, starting in December of 1998 and continuing to the present (Figure 1). Discharge was calculated using a rating curve derived from the stage/discharge relationship. Stage measurements were collected every 15 or 30 minutes using a Solinst Levelogger pressure transducer installed in a stilling well. These data were corrected with corresponding barometric pressure values, measured at a nearby site using a Hobo pressure logger. Stream discharge was measured in the field at a representative range of stage heights by measuring water velocity and water height at 1 to 2 foot intervals across the stream on a transect perpendicular to flow. Discharge (velocity times the cross-sectional area of water) was calculated at each transect interval and then summed to obtain a final value. Water velocity was measured at 40 percent of the water height using a Marsh McBurney Flow Meter. Stage was recorded in the field at the time of discharge measurement using a staff gage attached to the bridge.

Discharge at the primary treatment watershed sampling site (BEA-FRZ) was estimated from discharge at the gaging station by accounting for differences in drainage area, assuming that discharge changed in direct proportion to the change in drainage area. Discharge at the reference watershed sampling site (TIL-YEL) was estimated by accounting for differences in both drainage area and precipitation. The latter correction was based on the PRISM model (Daly et al. 1994), which estimated a 6% difference in precipitation between the reference and treatment watersheds (Table 1). Discharge estimates at the two primary sampling sites were 11% and 13% higher, respectively, than the measured discharge at the gaging station. Measured rainfall at Tillamook was used to fill the data gap in the Beaver Creek precipitation record (Figure 2).

Paired samples were collected from the primary monitoring sites in each of the treatment and reference watersheds, generally within less than one hour of each other. Water quality monitoring was conducted during 15 storms prior to and 15 storms subsequent to implementation of on-the-ground work. Samples were also collected at the forest/agriculture interface on each of the three upper tributary streams. Upper sites were not sampled on all sampling occasions during the storms, but data from the upper sites were collected to correspond with 65% of the samples collected at the site below the farms.

Monitoring included temperature, turbidity, TSS on a less frequent basis (87 samples), and FCB. TSS was estimated for all sampling occasions from turbidity measurements and observed turbidity/TSS relationships. The realized improvements in stream temperature and the concentrations and loadings of FCB and TSS were quantified. Comparisons were based on differences between treatment and reference watersheds and differences between the upper tributary sites and the primary site below the farms.

Temperature monitors were placed at each of the monitoring sites and data were collected during the period May to October of each year. Temperature data were successfully collected throughout the period of record at sites BEA-FRZ, TIL-YEL, and BEA-UP1. There were gaps in the temperature data for two of the upper tributary sites of Beaver Creek during the months of May and June in 1999 and 2001. These data gaps were caused by loss of the monitor or by equipment failure, and were generally of about five weeks in duration. Data gaps for these tributary sites were filled with values estimated from the South Fork of Beaver Creek tributary site using regression equations for each month separately (Appendix A). Data gaps were more extensive for the upper tributary sites in 2000, especially at site BEA-UP2, due to loss or burial of temperature monitors. Data for the discharge-weighted average temperature of the upper tributary sites are therefore not presented for the summer of 2000.

For turbidity and TSS, the success of the restoration was measured as differences between the pre- and post-treatment periods and as change in the difference (plus or minus) between the reference and the treatment subbasins. This was a straightforward paired-catchment analysis. For bacteria, we wished to quantify improvement in both bacterial concentrations and loads. This was done using several approaches, in anticipation of a high degree of temporal variability. These included analyzing for trends within designated storm types, flow-weighted storm median concentrations, and total storm loads.

Water quality entering farmland from the forest was estimated from the average of the constituent concentrations at the three upper sites, weighted (before calculating the average) by the stream discharge for each tributary. The latter was estimated from measured discharge for the watershed at the gaging station and the relative contributing area of each subwatershed. The estimated flow-weighted average constituent concentration in the tributary streams for each sample occasion was subtracted from the respective measured concentration at the BEA-FRZ site to estimate the concentration of bacteria, sediment, or heat in streamwater that was contributed by the farms.

E&S Environmental Restoration, Inc. is coordinating the effort. Other participants include E&S Environmental Chemistry, Inc., Oregon State University, Kilchis Dairy Herd Services, Tillamook County Creamery Association, Oregon Streamside Services, and Rees Enterprises. Riparian planting has been accomplished with the aid of volunteers from the local watershed council. Collaborating agencies include the Tillamook County Performance Partnership, Oregon Department of Environmental Quality, OSU Extension Service, Natural Resources Conservation

Service, U.S. Environmental Protection Agency, Oregon Department of Agriculture, Tillamook County Creamery Association, and Tillamook Soil and Water Conservation District.

At a minimum, we anticipated at the outset of this project a 25% reduction in FCB within two years and a 50% reduction within four years in the remediated subbasin. Reductions in sediment and temperature were expected to be less dramatic, but clearly measurable. These expectations were modified downward by our failure to obtain landowner participation on the middle farm and also landowner reluctance on the other two farms to allow some of the proposed wetland enhancement work.

2.3.1 On-the-Ground Activities

A preliminary plan was formulated for the remediation actions. It included completing the riparian fencing along all of the stream and ditch areas and rerouting some of the streamflow into a former stream channel on the lower farm. The stream location had previously been changed by ditching, and some of the old channel areas provide greater opportunity for removal of sediment and bacteria from the discharge. A series of small wetlands was identified for enhancement through minor excavation and/or placement of sandbags, planting with native vegetation, and fencing.

Ground work completed during the summer of 2000 focused largely on three key issues:

- diverting the surface water away from areas frequented by animals,
- providing additional filtration to aid in the removal of fecal bacteria and sediment from runoff, and
- excluding the animals from the riparian and wetland areas.

The type of work conducted in each of these areas is outlined below.

Using the preliminary restoration plan as a base, specific sites were identified for remediation. At these sites, small wetland areas were enhanced to aid in filtration of stormflow runoff from pastureland before it enters permanent stream channels and also to contain runoff, allowing infiltration and retention of both sediment and bacteria. Wetlands and riparian areas were fenced and planted with a mixture of native wetland vegetation (Table 2). Streamside areas on the lower farm were fenced to allow development of riparian vegetation buffers and to reduce bank erosion, enhance stream shading, and provide a biological filter for stormflow runoff. In addition, damaged areas of fencing on the upper farm, mainly in areas that had experienced recent stream erosion, were repaired. In these areas, new sections of fenceline were installed. New Zealand high tension electric fence was used, which has proven superior for use in flood-prone areas. Livestock watering troughs and piping were installed in three locations on the lower farm. Runoff flowpaths from pasture to streams and ditches were modified where necessary to increase detention time and contact with soils and vegetation.

Table 2. Native species planted.

Quantity	Scientific Name	Common Name
1000	*Carex deweyana*	dewey sedge
2500	*Carex obnupta*	slough sedge
1000	*Cornus stolonifera*	red osier dogwood
600	*Scirpus microcarpus*	small fruited bulrush
120	*Acer circinatum*	vine maple
300	*Polystichum munitum*	sword fern
300	*Glyceria elata*	tall mannagrass
100	*Scirpus acutus*	hard stem bulrush
100	*Scirpus tabernaenontani*	soft stem bulrush
260	*Thuja plicata*	western red cedar
25	*Fraxinus latifolia*	Oregon ash
550	*Picea sitchensis*	sitka spruce
20	*Acer macrophyllum*	big leaf maple
5	*Oemleria cerasiformis*	Indian plum
20	*Sambucus racemosa*	red elderberry
10	*Physocarpus capitatus*	Pacific ninebark

Newly-fenced riparian areas were replanted with a mixture of grasses in eroded areas and native shrubs and trees. Species were selected to maximize bank stabilization, shading, and development of future streamside coarse woody debris.

A series of small wetlands was enhanced on the lower farm along a former stream channel. Soils are Hebo (HbA) series hydric soils. This area represents an old stream channel that has been partially bypassed by ditching. The vegetation was characterized by blackberry and a few hydrophytic species (e.g., *Eleocharis*). The old channel was reconnected by a pipe and the wetlands restored through minor excavation, increased ponding, and fencing, and they were replanted with native wetland and riparian plant species. The wetlands are small (approximately

6-12 feet wide and 40 to 100 feet long each) and are connected by the old stream channel. The wetland series was connected to the stream through an 8 inch pipe used to divert water into the wetlands. The pipe was fitted with a shut-off control valve and a fish screen. Excavated material was used to contour the wetlands in order to increase ponding.

2.3.1.1 Hydrologic Modifications

Three water diversion systems were installed, two of which were designed to reroute runoff water in areas frequented by cows. The first diversion was installed on the upper farm adjacent to the barn. An open ditch carried runoff and groundwater that originated on the hillslope behind the barn, and the ditch continued for about 450 ft before entering the main stream channel of Beaver Creek. The area around this ditch was heavily utilized by dairy cows and was judged to be the likely largest single bacteria source area on the upper farm. During rainstorms, the soil in that area often became saturated for prolonged periods and provided extensive areas for direct runoff contributions to the ditch and stream system. The existing runoff pattern thus carried water directly through the portion of the farm that experienced the greatest amount of animal traffic. We determined that the best way to isolate the water from the animals was to install a buried pipe to carry the runoff from behind the barn to the point where the ditch joined the stream. The new pipe (12″ corrugated PVC) and an overflow outlet were installed in September, 2000, and the existing ditch was filled in. This activity added a small amount of land into production.

The second diversion was installed on the lower farm to accomplish essentially the same purpose. In this case, surface runoff during rainstorms flowed directly downhill from the barn to Beaver Creek. The amount of water was much less than was the case on the upper farm, however, because there was no stream or groundwater source in the area around the barn on the lower farm. In this latter case, the problem was restricted to surface runoff from rainfall that could not infiltrate the compacted soils around the barn. A perforated 4″ PVC pipe was buried in coarse gravel that was hauled to the site and the pipe was installed parallel to the stream near the top of the streambank. This pipe was structured to intercept surface runoff that was moving from the barn towards the stream. The runoff, which contains only rather small volumes of (highly contaminated) water was rerouted to the adjacent pasture. Thus, this water will now infiltrate the soil of the pasture prior to moving laterally to enter the stream channel. This movement through soil will aid in the removal of fecal bacteria from the runoff.

The third diversion that we installed was intended to improve water filtration capabilities by diverting a portion of the water in Beaver Creek, which had earlier been ditched near the property line, back into the old stream channel that meandered through the pasture. This old stream channel provided more opportunity to enhance wetland function than the existing (and previously ditched) stream channel. An 8” pipe was installed to connect Beaver Creek to the old stream channel, and a shut-off valve was installed to conform with permit requirements and to allow experimental regulation of water flow through the old stream channel. A culvert was also installed to carry surface runoff from the pasture of the adjacent farm into the top of the old stream channel, and a one-way valve was installed on the culvert to prevent water from flowing from the old stream channel back up to the pasture on the adjacent farm.

Connection of the channel did not occur until after all of the excavation was completed, so as to minimize sediment loading to surface waters. Water withdrawals only occur during the period of November 1 to May 1 because of stream dewatering concerns. The water control device was screened to prohibit fish passage.

The streamside and ditchside areas on both of the farms were surveyed to determine the location of all areas where surface runoff might flow directly from the pasture into the stream or ditch during periods of heavy rainfall. The ground in all such areas was recontoured, by hand shovel work, to construct a shallow trench and adjacent berm, running parallel to the water course. The objective was to force future surface runoff from the pasture to infiltrate soil and pasture vegetation prior to entering the water course. This will help to remove fecal bacteria from the water before it contaminates the stream.

Two undersized culverts were replaced on the upper farm during September, 2001. At both locations, high stream flows would occasionally exceed the capacity of the culverts and cause the stream to overflow its banks and move across adjacent pastureland.

2.3.1.2 Wetland Enhancement

A series of small wetland areas was enhanced along the length of the old stream channel, which rejoins Beaver Creek further downstream, near the barn on the lower farm. Minor excavation was done on the top wetland area. In addition, six small dams were installed at appropriate locations to create ponded areas. The dams were constructed of sand bags, stacked about 2 ft high, extending across the stream channel.

Similarly, a series of three small ponded areas was created and fenced along the ditch line that runs along the northern edge of the pasture on the lower farm. These ponded areas were also planted with native wetland vegetation, which enhances bacterial and sediment removal from the runoff water.

2.3.1.3 Fencing

In order to exclude animals from the riparian and wetland areas, a New Zealand high tensile fence was installed along all water courses on the lower farm during the summer of 2000. Approximately 2.4 mi of fencing was installed, along with 750 ft of buried waterline that supplies three watering troughs. Additional fencing was installed on the upper farm in areas where the previously-installed fence had been damaged by bank erosion. Approximately 550 ft of new fencing was installed on the upper farm in December, 2000. Riparian buffer widths differ among the three farms. On the upper farm, fencing installed by the landowner prior to initiation of the project provided for fenced riparian buffers generally about 1 to 2 m in width. Fenced riparian areas on the middle farm have riparian buffers about 2 to 3 m in width. Fencing installed on the lower farm for this project provided riparian buffers that are generally about 3 to 4 m wide in most places, but considerably wider in some areas.

2.3.1.4 Blackberry Removal and Planting Efforts

Prior to initiation of this project, many of the streamside areas of the lower farm were inundated with blackberry, primarily non-native Himalayan blackberry. Much of this blackberry was hand-cleared to make room for fence construction and to allow for subsequent riparian planting with shade trees and with a greater diversity of native riparian and wetland plant species.

We began the planting efforts during early March, 2000, on the upper farm. The balance of the planting (Table 2) was completed in March, 2001. Most of the trees and shrubs that we planted were tubed to minimize animal damage.

2.3.1.5 Maintenance

Some maintenance was required during the first few years for the newly planted trees and shrubs. Grasses were cleared away from the new plants on one occasion during each spring or summer period after planting. Some fence maintenance will be required to trim riparian vegetation and/or repair fencing as needed. These activities will largely be conducted by the landowners.

2.3.2 Water Monitoring

Sampling sites were selected at the three forest/agriculture interface locations (both upper forks of Beaver Creek and Bear Creek) and on Beaver Creek just below the lower portion of the lower farm (Figure 1). A precipitation gage was installed at the downstream site. A staff gage and pressure transducer were installed at the bridge crossing below the confluence of Bear and Beaver Creeks to measure discharge. A sampling site was also selected for the reference (untreated) watershed at the Yellow Fir Road crossing of the upper Tillamook River, 1.2 miles north of Highway 101 on Yellow Fir Road.

Streamwater samples were routinely analyzed for turbidity and FCB. Duplicate and deionized water blank samples were submitted as routine samples to the laboratory as checks on analytical quality. *In situ* measurements were collected for temperature using tidbit continuous temperature monitors. A subset of samples was analyzed for TSS by gravimetric 103C analysis.

The extent to which water quality has improved in Beaver Creek as a consequence of the restoration work and the change in manure management varies according to the statistic selected for measurement. Because bacterial measurements periodically exhibit a limited number of extremely high values, quantification on the basis of mean values is problematic; high outliers exert too much influence on the mean statistic. We therefore selected the median and quartile (25^{th} and 75^{th} percentile) statistics to indicate patterns of change. For many analyses, median and quartile values are presented for the monitoring period, either before or after implementation of on-the-ground actions or for individual storm events. For many other analyses, within-storm parameter values were weighted by discharge prior to calculating the median and quartile statistics. This was done by calculating the median measured value of the instantaneous FCB load (FCB concentration x discharge) and dividing it by the median discharge during the sampling period.

2.3.3 Description of Laboratories and QA/QC

Samples were stored on ice in coolers after collection and transported to the Kilchis Analytical Laboratory and Oregon State University Department of Soil Science for analysis. The Kilchis Analytical Laboratory is located in Bay City, Oregon and provides bacterial analysis laboratory services. The laboratory is directed by Dr. Mark Wustenberg and Judy Wustenberg and is certified for FCB presence/absence determinations for drinking water. The laboratory staff work closely with the local dairy industry and have been involved in educational efforts concerning herd management and implementation of Best Management Practices.

Sample aliquots for TSS were measured at the Central Analytical Laboratory at Oregon State University in Corvallis, an analytical service laboratory which serves the university community and governmental agencies. It supports the university in its research and extension missions in agriculture and related environmental issues, concentrated in the area of soil, plant tissue, and water analysis.

Quality of the analysis is maintained by a QA/QC program which may vary depending on the needs of the research. Minimum requirements for the laboratory include:

- Maintaining instrument log books including identification of samples run, calibration information, instrumentation settings, maintenance performed, and other observations which may affect the quality of the results.
- Calibration of instruments is performed with each set of samples analyzed with no more than 35 samples between recalibrations.
- An independent check standard or check sample is run with each calibration.
- A minimum of two blanks, one duplicate, and one spiked sample are analyzed with each sample set.

Chain of custody of samples was maintained by a log-in system that assigns a number unique to the sample set and sample. This number is marked on each sample and a preprinted label is applied to the log sheet when the sample enters the laboratory. This number is used for any subsequent analysis identification. All sample logs and data are kept on a computer system which is backed up daily by the network administrator and weekly by a computer specialist. Hard copies are also kept to ensure no loss of data or chain of custody.

The overall quality assurance objectives for the project were to implement quality control-requirements for laboratory analysis that would provide data that could be used to achieve the program objectives, and to follow procedures that would provide data of known quality in terms of precision, accuracy, completeness, representativeness, and comparability.

About 10% of the samples analyzed were allocated to QA/QC, and these included field duplicates and blanks. QA/QC samples were used to quantify sampling and analytical variability.

All plasticware and aliquot bottles for measurement of TSS were Nalgene® high density polyethylene. Bacteria samples were collected into new sterile bottles or sterilized sample bottles (using an autoclave).

Samples were collected from near mid-stream in mid-water column. Two samples were collected on each sample occasion, one for bacteria and one for other constituents. The sampling crew attached a label at the time of sample collection. This label contained a three-letter code to identify the stream, then a three-letter or number code to identify the sampling location, followed by a two-number code to identify sample number. As an example, TIL-YEL-02 would be a sample from the Tillamook River collected at Yellow Fir Road and this would be the second sample collected at this site during this storm.

On the E&S chain of custody record form, there is information to determine sample name, date, time of day, test requested, and comments. When the samples were delivered to the bacteria laboratory, a second chain of custody form was started for use in the lab. On this was noted the name of who collected the samples and the date and time the samples were delivered to the laboratory. The person who received the samples signed them in and recorded the date and time. This form also identified the project name and contained the sample date and number.

The bacteria laboratory also utilized a worksheet which showed who collected, analyzed, and counted the plates and the three dates for these activities. On the worksheet, there was a sample number, identifying number, volume of sample water filtered, plate count, and calculated cfu/100 ml. Information from these worksheets was transferred to a results form. This showed the sample identification and the resulting plate count. This form was reviewed and the reviewer signature was noted. The calculations were reviewed a second time after the form was received by E&S from the laboratory.

Within the laboratory, the equipment is maintained and monitored to public health certification standards. FCB concentrations were determined using the membrane filter technique described in Standard Methods for the Examination of Water and Wastewater.

Laboratory blank samples were made for each analysis requiring sample preparation. These samples indicate control of contamination during sample preparation. The laboratory blank was made from reagent grade water and was prepared in the same manner as the samples. A single laboratory blank was generated for each sample preparation batch. For samples not requiring preparation, a laboratory blank was used to monitor background changes in measurement systems. These were made from reagent grade water and treated in an identical fashion to samples prepared for these tests. Results of laboratory blank analyses indicated that sample contamination did not occur.

Sample Custody and Documentation Procedures

Sample bottles were labeled with indelible ink. Sample identification included the year, month, day and station code. A field log book was kept in which station codes, date and time of sampling, and all field data were recorded. Notes on any unusual conditions at the sample sites or any circumstances that my have caused deviation from normal procedures were also recorded in the field book.

Document control procedures included the following:

- records were clear, comprehensive, and written in indelible ink;
- corrections to data sheets and logbooks were made by drawing a single line through the error and initialing and dating the correction;
- before release of data, records were cross-checked for consistency between sample tags, custody records, bench sheets, personal and instrument logs, and other relevant data; and
- documents were archived in the project records.

Data were reported as hard copy delivered by the laboratory to E&S. Field data were examined for internal consistency and reported. Data were entered into a computer database in a format compatible with Excel for Windows.

Prior to data analysis and interpretation, all data entered into the database were validated by evaluation of blanks, duplicate samples, checks for time series anomalies, and outlier analysis.

3.0 RESULTS

3.1 PRECIPITATION AND HYDROLOGY

Daily precipitation amounts recorded for Beaver Creek are shown in Figure 2 for the period of study to date, using a water year starting September 1 of each year. Precipitation patterns were generally similar from year to year, except during the drought year (2001) and were typical of Oregon coastal locations. Most of the precipitation occurred during the months October through April, with the wettest periods generally in November, December, and January.

Observed patterns of discharge in Beaver Creek were similar to observed patterns in precipitation. Figure 3 shows the discharge estimates for the four years of monitoring and indicates the 30 storms that were monitored during this study. A few monitored storms were not as large as forecasted and provided less than 3 cm of precipitation. Small storms were most commonly monitored during the spring season. About half of the monitored storms contributed more than 6 cm and five storms more than 11 cm of precipitation (Table 3).

Total Beaver Creek storm discharge varied among the monitored storms from less than 100 million liters during three storms to over a billion liters during five storms. Estimated storm discharge was similar between the treatment and reference watersheds (Table 3).

Both the precipitation and Beaver Creek discharge illustrate the magnitude of the drought that occurred during the 2001 water year. There were no significant storm events during the 2000-2001 fall to spring period. Cumulative discharge during the October 1 to March 20 period (4×10^9 L) was only 24% of the average discharge over the same period during the other three years of study (Figure 3). There were only two storms that proved to be of any magnitude at all. One occurred on Christmas day when sampling and laboratory staff were unavailable. The second occurred, and was sampled, in mid-March. Even those storms were small in comparison with fall or winter storms during previous years and during the subsequent year (Figure 3).

Discharge patterns were modified by on-the-ground work at several locations for this project. The two culverts installed on the upper farm will prevent stream overflow from crossing pastureland and then re-entering the stream. A new 60" culvert was installed at the driveway intersection with Beaver Creek. The existing 48" culvert was moved to an upper access road

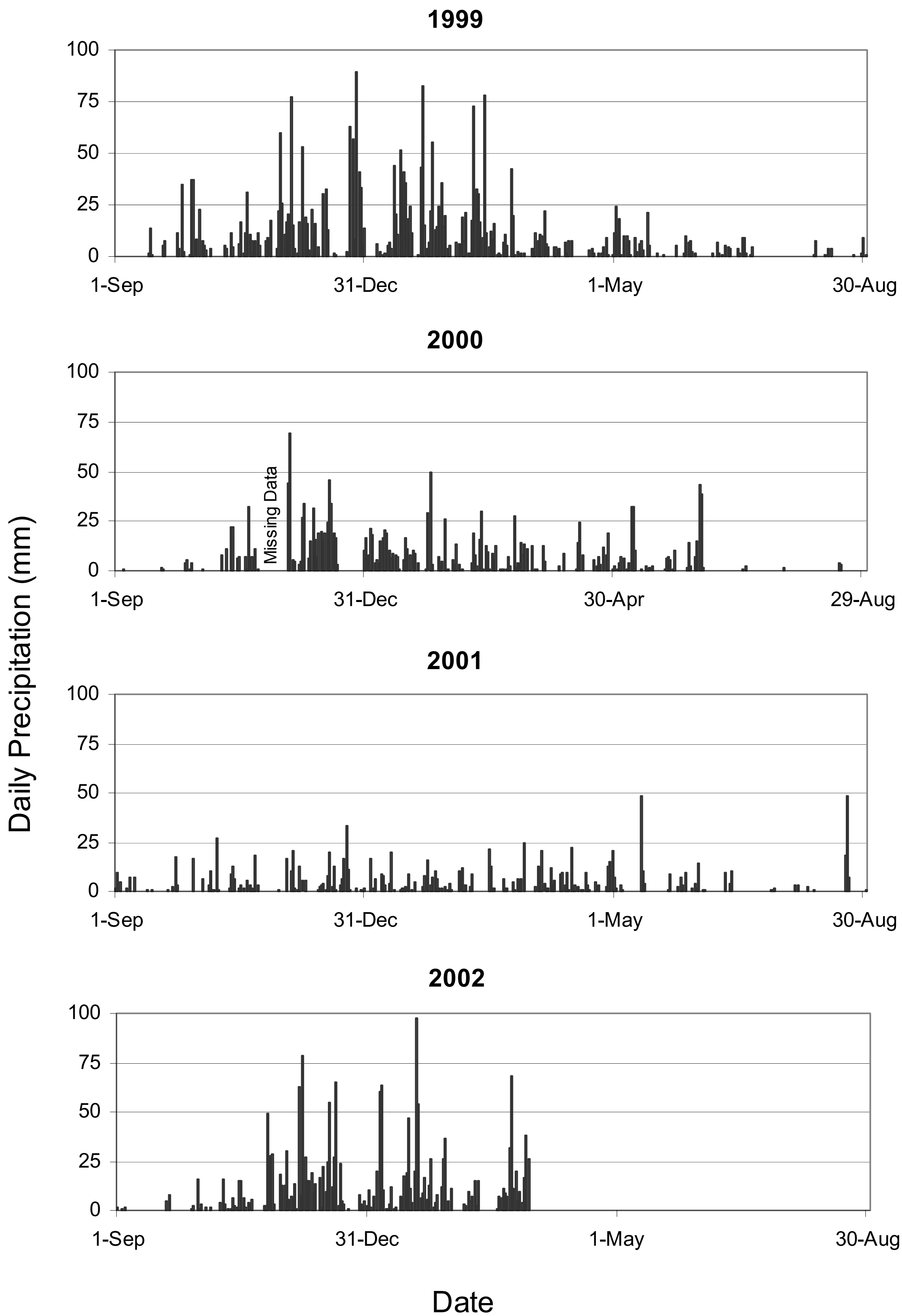


Figure 2. Daily precipitation in the Beaver Creek watershed.

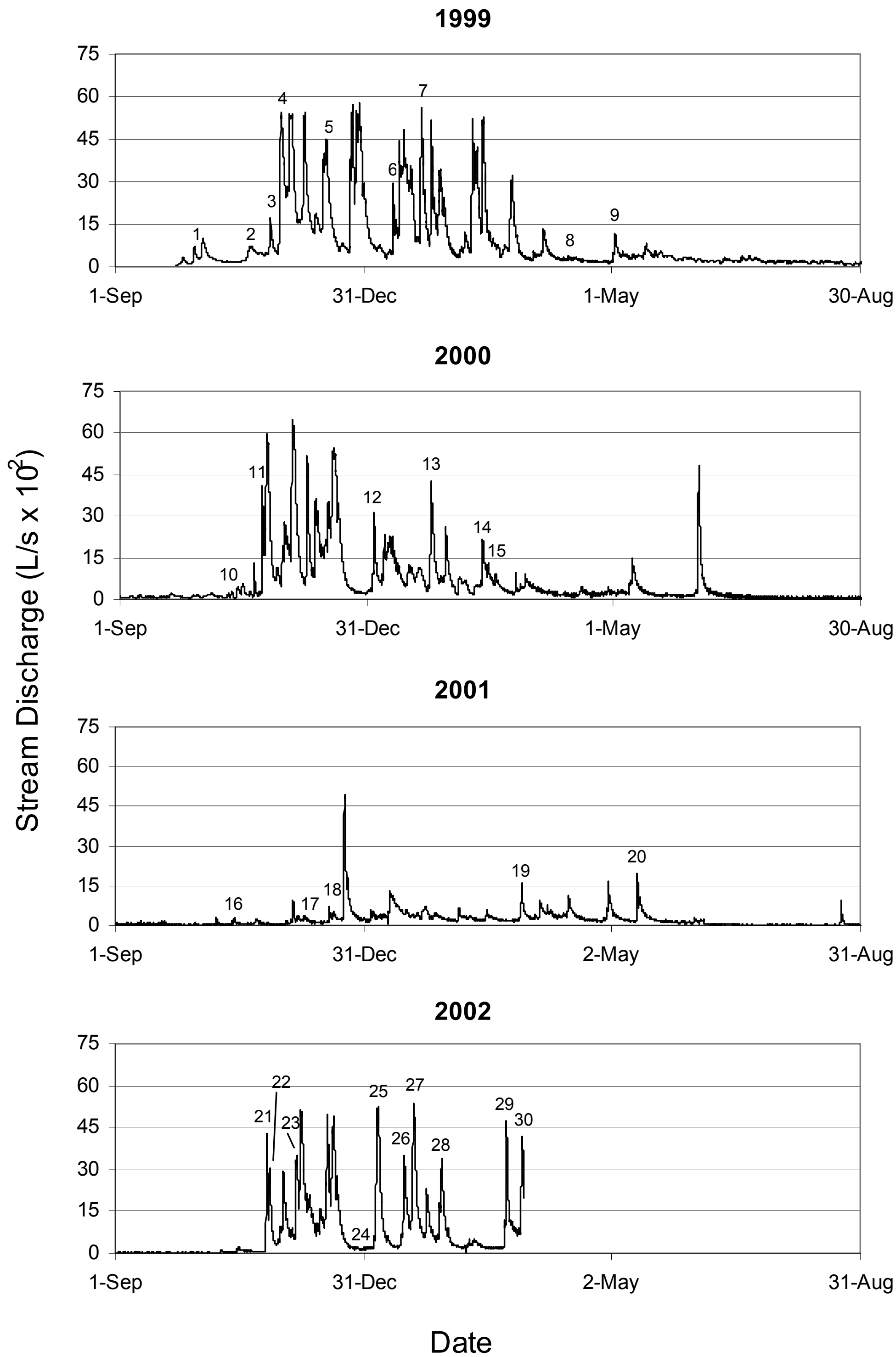


Figure 3. Estimated discharge of Beaver Creek throughout the period of study. Each of the monitored storms is indicated with a number which corresponds with storm numbers presented in the tables.

Table 3. Selected major characteristics of storms sampled at the downstream Beaver Creek and reference watershed sites during four years of study.

Storm #	Date Storm Began	Season	Total Storm Discharge (L x 10^6)		Total Storm Precip. (cm)	Number of Samples (n)	Discharge-weighted Storm Median FCB (cfu/100 ml)		Unweighted Storm Median FCB (cfu/100 ml)	
			BEA-FRZ	TIL-YEL			BEA-FRZ	TIL-YEL	BEA-FRZ	TIL-YEL
Pretreatment										
1	10/8/1998	Fall	121	123	7.5	4	3876	5000	3140	3370
2	11/5/1998	Fall	322	328	5.9	5	431	249	450	230
3	11/12/1998	Fall	352	358	3.4	8	259	366	240	270
4	11/20/1998	Fall	1,270	1,293	11.7	5	771	715	760	740
5	12/11/1998	Winter	1,431	1,457	7.5	6	373	162	345	196
6	1/12/1999	Winter	249	254	5.0	6	655	192	650	92
7	1/27/1999	Winter	1,097	1,117	14.4	5	969	639	710	410
8	4/7/1999	Spring	139	142	2.3	5	25	210	24	240
9	5/1/1999	Spring	231	236	5.5	6	1631	2926	1895	1830
10	10/27/1999	Fall	83	84	4.4	7	2200	5060	2300	4300
11	11/8/1999	Fall	368	375	no data	6	2112	413	1010	355
12	1/3/2000	Winter	383	390	4.5	6	372	549	368	575
13	1/31/2000	Winter	692	704	7.8	7	88	282	100	310
14	2/24/2000	Spring	357	364	4.6	8	306	274	197	240
15	2/28/2000	Spring	279	284	2.3	5	23	272	27	270
Post-Treatment										
16	10/27/2000	Fall	37	37	2.7	8	2935	2674	2350	1740
17	11/28/2000	Fall	106	108	2.4	5	86	130	92	170
18	12/14/2000	Winter	151	154	3.6	8	166	210	170	205
19	3/15/2001	Spring	242	246	2.8	9	63	440	62	430
20	5/14/2001	Spring	254	259	6.4	6	4629	702	4318	675
21	11/13/2001	Fall	379	386	7.7	6	1521	2056	2200	2800
22	11/15/2001	Fall	336	342	3.2	4	955	1565	825	1415
23	11/27/2001	Fall	499	508	7.1	8	463	744	545	845
24	12/31/2001	Winter	56	57	1.9	6	47	199	48	196
25	1/7/2002	Winter	1,244	1,267	14.9	6	84	322	84	320
26	1/19/2002	Winter	621	632	7.1	8	46	193	58	254
27	1/24/2002	Winter	1,034	1,053	17.1	6	26	109	26	108
28	2/6/2002	Winter	663	675	6.8	9	37	155	45	162
29	3/10/2002	Spring	594	605	11.0	8	36	770	65	680
30	3/18/2002	Spring	571	581	6.5	6	17	237	20	340

crossing with the north fork of Beaver Creek, where the existing undersized side-by-side pair of culverts had deteriorated. Runoff patterns were altered in the vicinity of the principal animal holding facilities on both the upper and lower farms in order to minimize direct fecal contamination of runoff from areas of concentrated animal use. A portion of Beaver Creek flow was diverted through the old stream channel, and associated enhanced wetlands on the lower farm.

Hydrological modifications within the treatment watershed have been successful, based on visual inspection, in routing runoff water away from areas of concentrated animal activity. In addition, recontouring of streambank areas appears to have resulted in increased filtration of direct surface runoff by soils prior to entering open water courses.

3.2 FECAL COLIFORM BACTERIA

The Beaver Creek site immediately downstream of the project area is called BEA-FRZ. The reference watershed monitoring site at the Yellow Fir Rd crossing of the Tillamook River is called TIL-YEL. FCB concentrations at both sites frequently exceeded 2,000 cfu/100 ml during storm events during the pre-treatment period, occasionally exceeding 6,000 cfu/100 ml (Figure 4). About one-fourth of the samples collected from each of those sites during the pre-treatment period had FCB > 1,000 cfu/100 ml (Figure 4).

FCB loads and flow-weighted storm average concentrations were calculated from measured FCB concentrations and estimated discharge. FCB loads were considerably lower in the 2000-2001 sampling season at both BEA-FRZ and TIL-YEL, due to drought conditions, than either previously or subsequently (Figure 5). The FCB load was also considerably lower during the drought year at the upper tributary site BEA-UP4, less so for the other two upper tributary sites (Figure 5).

The discharge-weighted storm-median FCB concentration in the reference watershed (site TIL-YEL) was similar between the pre-treatment and post-treatment periods of study (Table 4). Median values were 405 and 360 cfu/100 ml and the pre- and post-treatment interquartile ranges were also similar: 25th percentile, 136 and 140 cfu/100 ml; 75th percentile, 863 and 880 cfu/ml). Discharge-weighted mean values were nearly identical (407 and 408 cfu/100 ml, respectively). In contrast, the median discharge-weighted storm-median FCB concentration in the treatment watershed (site BEA-FRZ) was 385 cfu/100 ml during the pre-treatment period (interquartile range, 100-1,003), but decreased by 76% to 92 cfu/100 ml during the post-treatment period

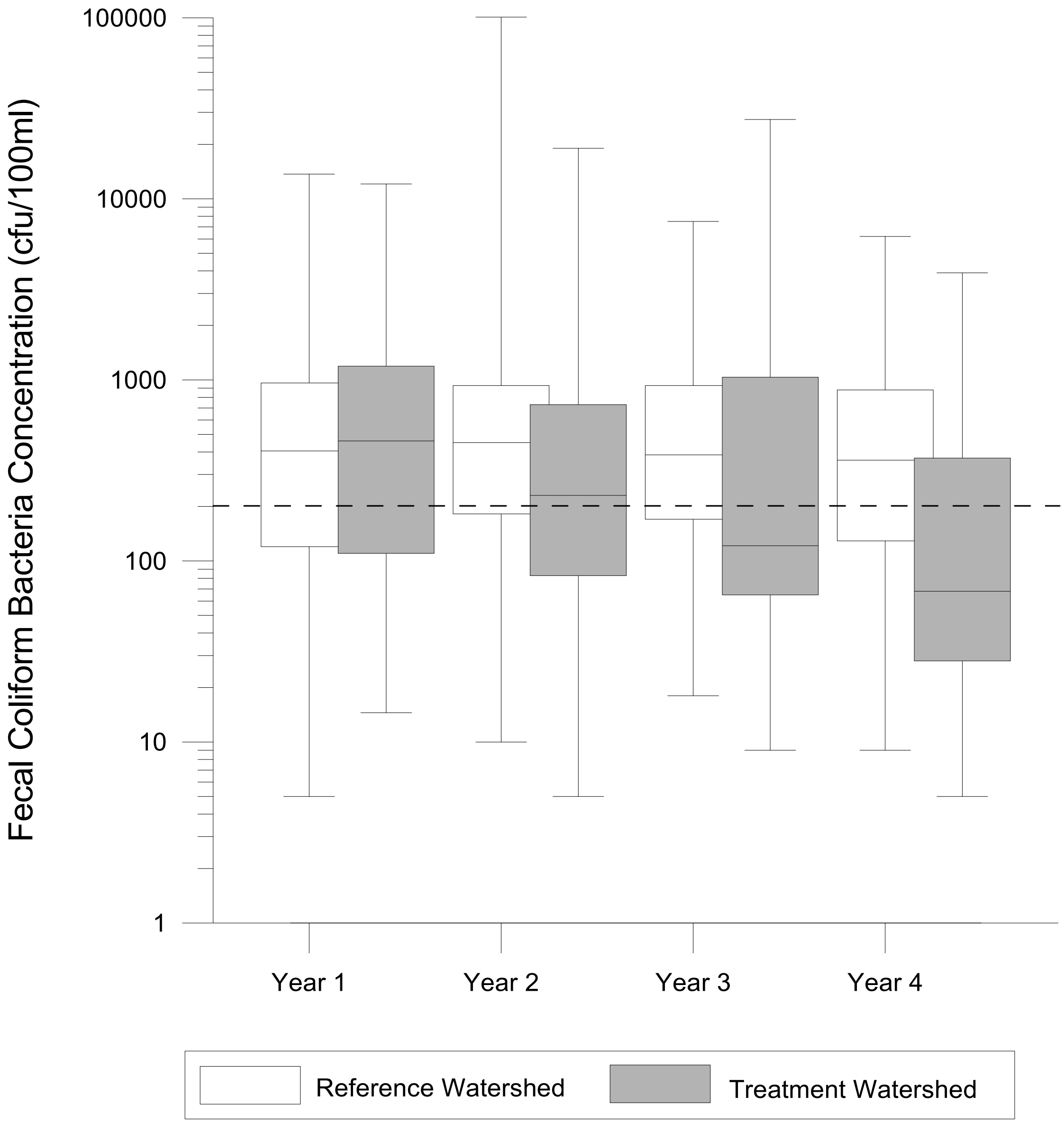


Figure 4. Box and whisker plots of the fecal coliform bacteria concentrations downstream of the remediation project area on Beaver Creek (site BEA-FRZ), downstream of the reference (control) watershed on the upper Tillamook River at the Yellow Fir Road bridge crossing (TIL-YEL), and at the forest/agriculture interface on the three tributary streams to Beaver Creek: the two upper Beaver Creek tributaries (BEA-UP1 and BEA-UP2) and Bear Creek (BEA-UP4). A dotted reference line is provided to indicate FCB concentration = 200 cfu/100 ml, a common FCB freshwater standard. The box delimits the middle 50% of the values; the line through the box indicates the median value.

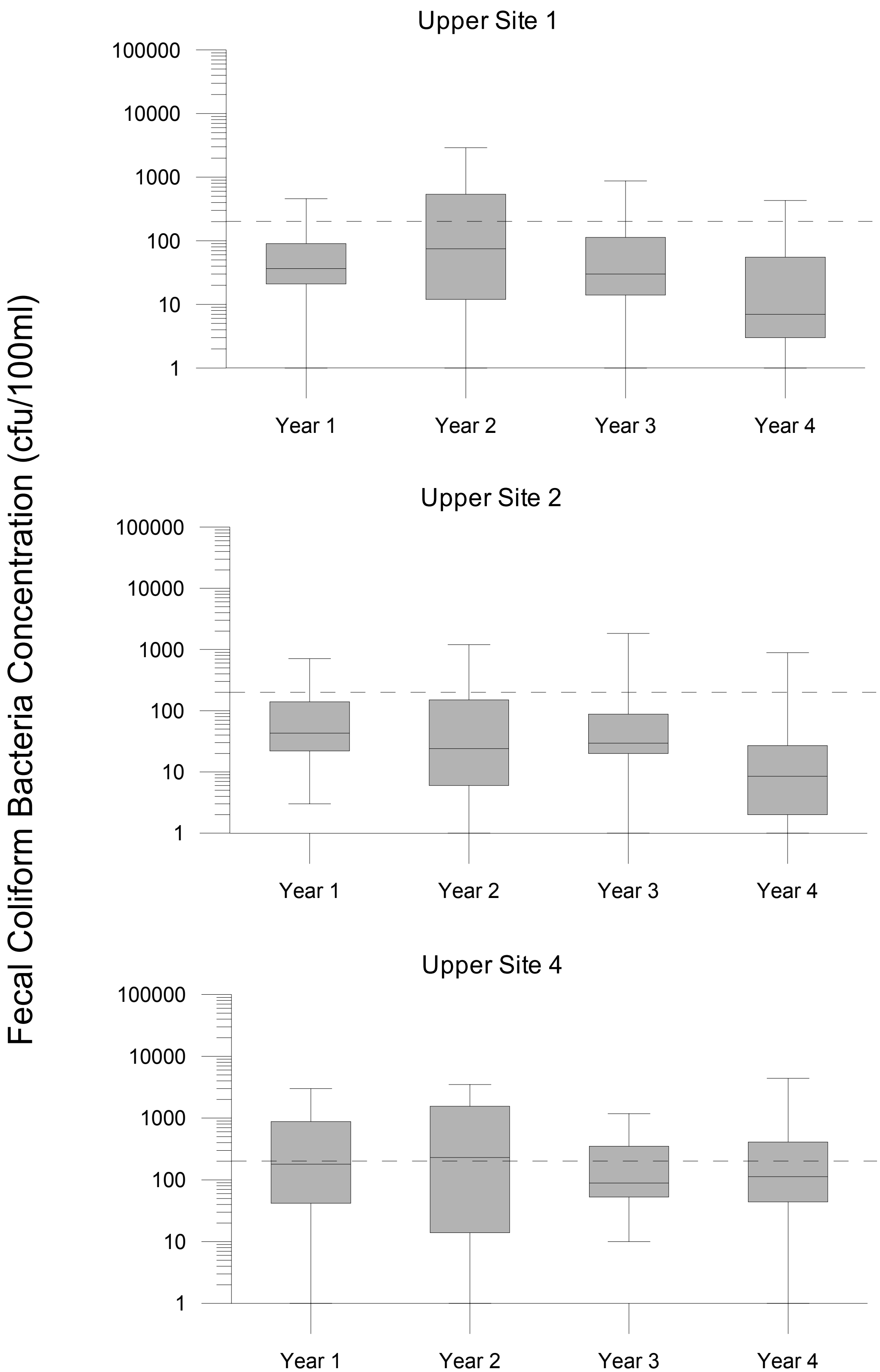


Figure 4. Continued.

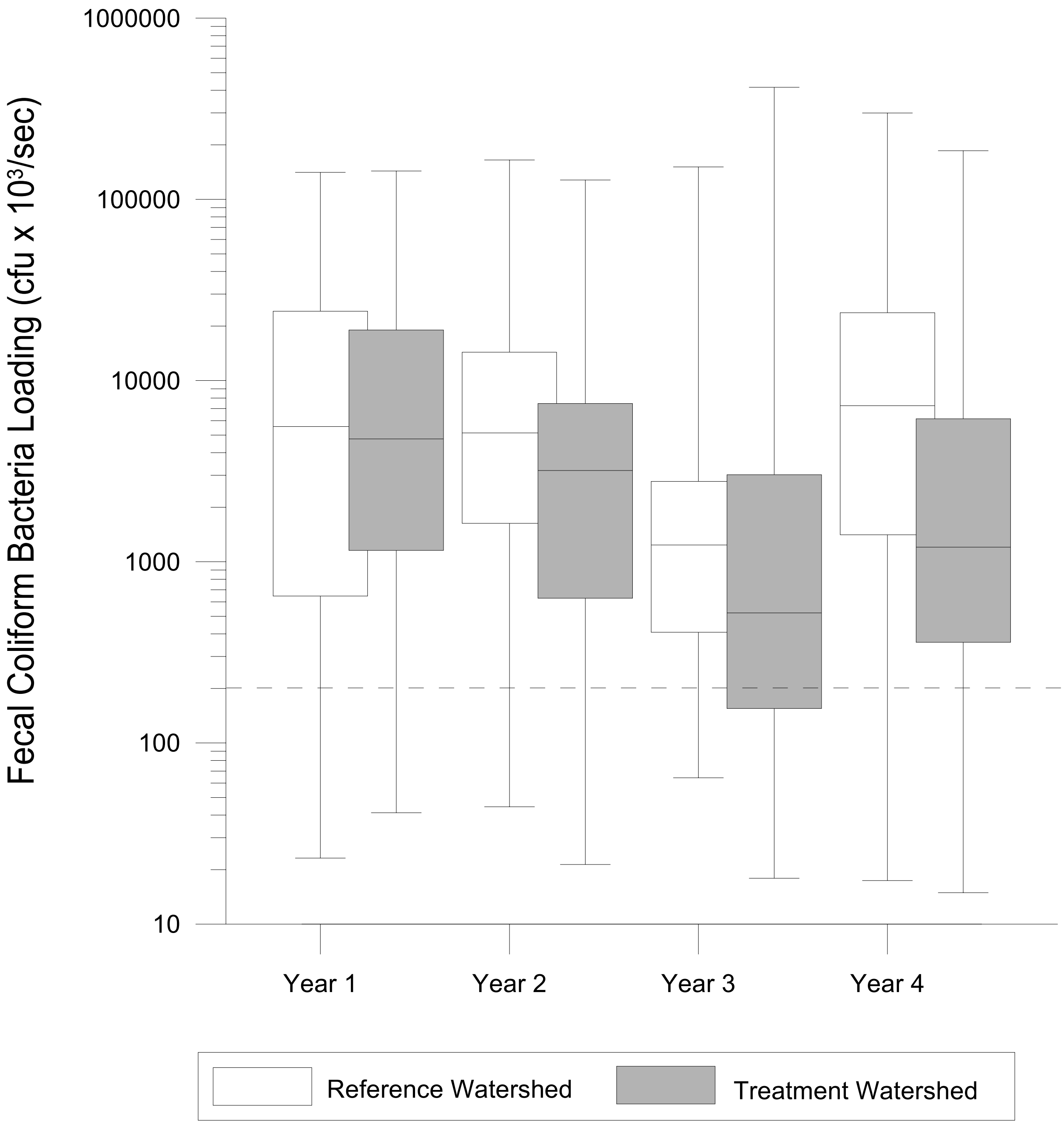


Figure 5. Box and whisker plots of FCB loading at sites BEA-FRZ and TIL-YEL (first panel) and at the three forest/agriculture interface tributary sites (panels 2 through 4). A reference line is provided to indicate an FCB loading of 200 cfu/sec for ease of comparison among sites.

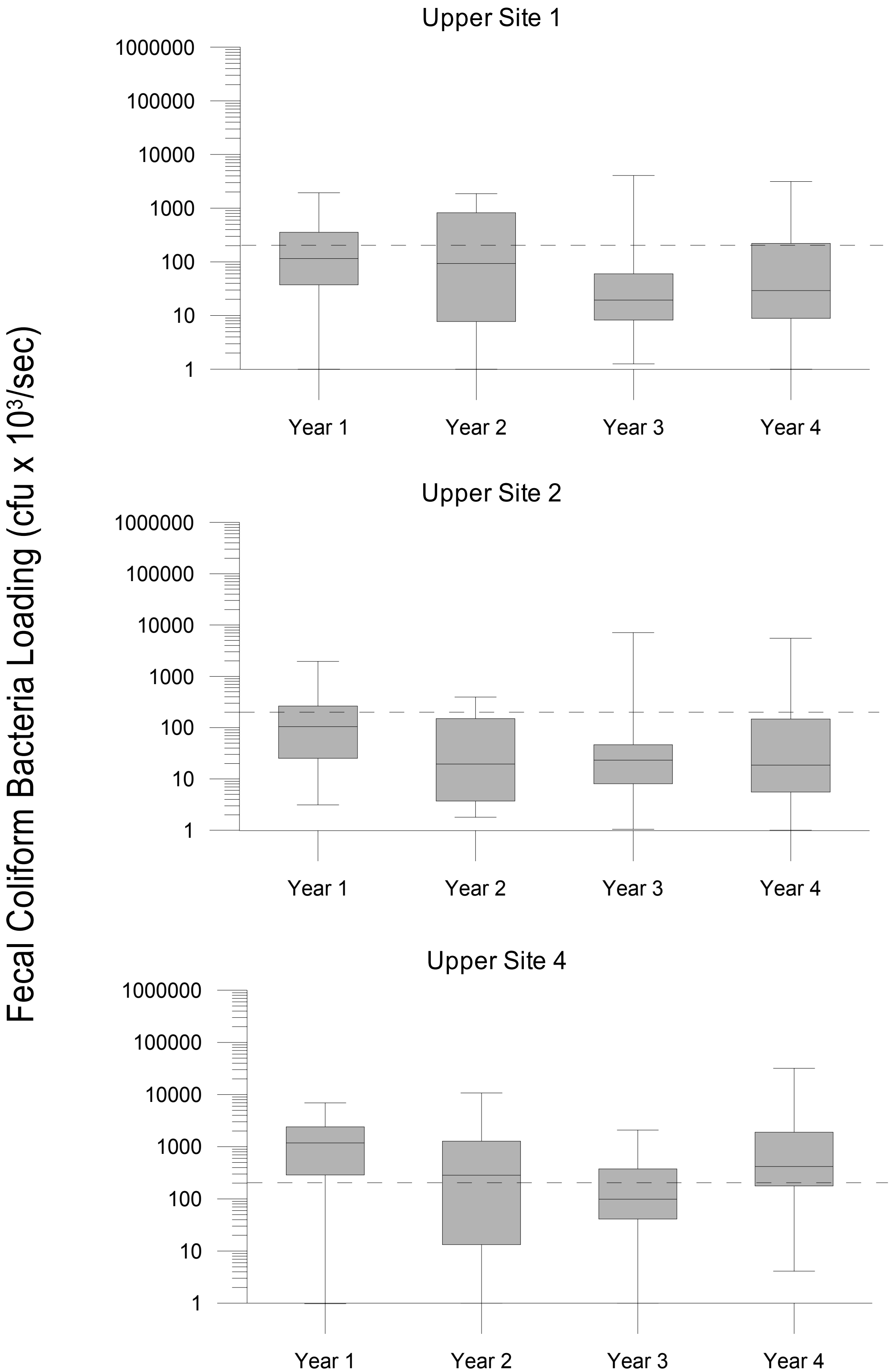


Figure 5. Continued.

Table 4. Fecal coliform bacteria storm measurements throughout the period of study for BEA-FRZ and TIL-YEL (paired data samples).						
	BEA-FRZ			**TIL-YEL**		
FCB Data Criterion	Year 1 + 2	Year 3 +4	Year 4	Year 1 + 2	Year 3 +4	Year 4
Number of Samples	96	109	71	96	109	71
Median	385	92	68	405	360	360
25th Quartile	100	43	29	136	140	135
75th Quartile	1003	500	320	863	880	855
Percent > 200 cfu/100ml	65	36	34	70	64	62
Percent > 1000 CFU/100ml	25	17	11	22	21	21

(interquartile range, 43-500). Similarly, the discharge-weighted mean FCB concentration at site BEA-FRZ decreased by 78% from pre- to post-treatment period. The decrease in FCB concentration, as compared with pre-treatment conditions, was more pronounced in Year 4 than in Year 3 at the BEA-FRZ site, but not at TIL-YEL. The median discharge-weighted FCB concentration during Year 4 was 82% lower than during the pre-treatment period (Table 4).

The ratio of the discharge-weighted storm-median FCB concentration at the two primary sampling sites (treatment divided by reference watershed) showed considerable variability during the two years of pre-treatment data, with 53% of the monitored storms having discharge-weighted storm-median FCB concentration higher at the reference watershed and 47% of the monitored storms higher at the treatment watershed (median ratio 0.78; Table 5, Figure 6). The variability in this ratio decreased substantially during the post-treatment two-year period,

Table 5. Discharge-weighted storm median FCB concentration (cfu/100ml) at the primary sampling site in each of the reference and treatment watersheds during four years of study.									
	Treatment Site (BEA-FRZ)			**Reference Site (TIL-YEL)**			**Ratio (BEA-FRZ ÷ TIL-YEL)**		
Storm Year	Median	25th Percentile	75th Percentile	Median	25th Percentile	75th Percentile	Median	25th Percentile	75th Percentile
1	655	373	969	366	210	715	1.08	0.71	1.73
2	339	143	372	347	276	515	0.56	0.34	1.01
Total Pre-Treatment Period	**431**	**282**	**1300**	**366**	**261**	**677**	**0.78**	**0.50**	**1.62**
3	166	86	2935	440	210	702	0.79	0.66	1.10
4	47	37	368	280	195	764	0.24	0.24	0.52
Total Post-Treatment Period	**84**	**42**	**709**	**322**	**196**	**757**	**00.26**	**0.24**	**0.70**

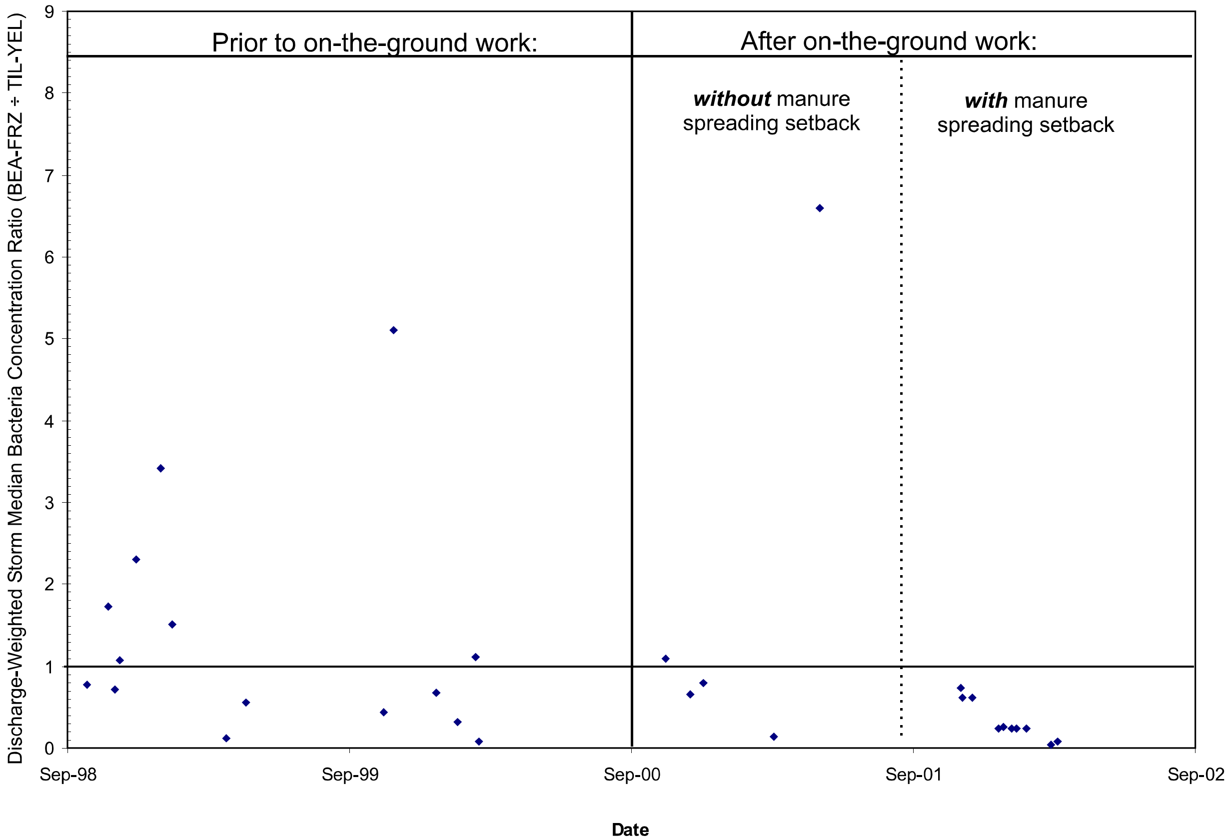


Figure 6. Within-storm ratio of fecal coliform bacteria concentration expressed as the ratio of the discharge-weighted median concentration at Beaver Creek divided by the discharge-weighted median concentration at the reference watershed. Data are provided for 15 storms sampled prior to conducting on-the-ground work (mostly conducted during the period June to September 2000) and 15 storms sampled subsequent to conducting on-the-ground work. A manure management change was implemented in September, 2001, after which manure was not spread within 25 ft of fence lines.

especially during Year 4. During the post-treatment period, the median ratio was 0.26 (Table 5). During Year 4, all 10 of the monitored storms exhibited ratios less than 1.0, and the ratios decreased steadily throughout the year, to values near 0.1 in spring.

Throughout the study, storms often showed lower bacteria concentrations in the treatment watershed (Figure 4). The major differences between the pre-treatment and post-treatment periods was the dramatic decline in the frequency of storms that showed higher bacteria concentrations in the treatment watershed, from 40% during the pre-treatment period to 20% during the post-treatment period. During Year 4, none of the monitored storms showed higher discharge-weighted storm average bacteria concentration in the treatment watershed.

FCB measurements at site BEA-FRZ in the treatment watershed were substantially lower during the post-treatment period (Year 3 + 4) than during the pre-treatment period (Year 1 + 2). The median value decreased by about 75% and both the 25th and 75th percentiles decreased by more than half (Table 4). In addition, the percent of samples exceeding the health standard of 200 cfu/100 ml decreased by about half from pre-treatment to post-treatment period. Furthermore, reductions in FCB concentrations during Year 4, after implementation of an 8 m manure spreading setback from riparian fence lines, were substantially lower than concentrations averaged over the entire post-treatment period (Table 4). During Year 4, the median FCB at BEA-FRZ was only 18% of the pre-treatment median, and each of the quartiles was reduced by more than two-thirds. In contrast, comparable data for the reference watershed, at site TIL-YEL, showed very consistent patterns from pre-treatment to post-treatment (Table 4).

Improvements in water quality were not uniform across seasons. During the pre-treatment period, the seasonal median FCB concentration was higher in the treatment watershed than in the reference watershed during fall (Table 6). During winter, the median FCB concentration was similar between the two watersheds. During spring, the pre-treatment median concentration was lower in the treatment watershed. During all three seasons, the median FCB concentration was dramatically reduced in Year 4, as compared with the pre-treatment period. The improvement in median FCB concentration obtained for Year 4 in the treatment watershed was much larger, however, for spring samples (88% reduction) than for winter samples (63% reduction) and fall samples (45% reduction; Table 6).

Table 6. Ratio between watersheds of seasonal median FCB concentrations, expressed as the seasonal median concentration in the treatment watershed (site BEA-FRZ) divided by the seasonal median concentration in the reference watershed (TIL-YEL).

Season	Ratio of Median FCB Concentration in the Treatment and Reference Watersheds		
	Pre-treatment (n)	Year 4 (n)	Pre-treatment ÷ Year 4*
Fall	1.24 (32)	0.68 (10)	0.55
Winter	0.99 (38)	0.37 (47)	0.37
Spring	0.61 (25)	0.07 (14)	0.12

* The pre-treatment ratio divided by the Year 4 ratio quantifies the extent to which median ratio values improved from the pre-treatment period to the final year of monitoring. For example, spring data suggested an 88% improvement in Year 4 compared with pre-treatment data.

FCB measurements have also been collected at each of the upstream Beaver Creek tributaries, near the point where they exit forest land and enter agricultural land. These sites are labeled BEA-UP1, BEA-UP2, and BEA-UP4. FCB concentrations were often > 200 cfu/100 ml at these forest/agriculture interface sites, especially during fall storms, when concentrations > 1,000 cfu/100 ml were commonly encountered. FCB concentrations were especially high at the forest/agriculture interface on Bear Creek (site BEA-UP4), which is situated immediately downstream of extensive beaver activity. The source of the high FCB at this site is not known but is believed to be beavers and/or perhaps other wildlife in the upper, forested watershed.

FCB concentrations at the BEA-UP4 site were consistently higher than concentrations in the other two tributary streams (Table 7). In fact, the median measured FCB concentration at site BEA-UP4 was higher than 100 cfu/100 ml during every year except the drought year (Year 3). In addition, the median FCB concentration at site BEA-UP4 was higher than the median FCB concentration at the site below the treatment area (BEA-FRZ) during Year 4 of the study. In other words, on average, the water exiting the farms during Year 4 (after treatment) had a lower concentration of bacteria than the water entering the farms from the forest in one of the three tributaries. Bacteria concentrations in the BEA-UP4 tributary were diluted, however, by the lower concentrations in the other two tributary streams.

During the first two years of pre-treatment monitoring, prior to conducting most of the on-the-ground work in the Beaver Creek watershed, there was substantial variability in the value of the within-storm ratio of bacterial concentration at the two primary monitoring sites, with storm median values approximately equally distributed above and below 1.0 (Figure 6). Most of the on-the-ground work was conducted during the period June through September, 2000. Since that time, most storms have shown values below 1.0. In September, 2001, a manure management change was implemented by the farmers who own the top farm in the treatment watershed (and also spread manure on the middle farm). Under the new policy, manure spreading now does not occur within about 25 ft of the fence line. (Previously the landowners spread manure right up to the fence line, which is generally less than about 3-6 ft from the streams on the top farm.) Since adopting this new manure management policy, median storm ratio results have been between about 0.1 and 0.8, suggesting more than a 50% reduction, on average, in bacteria concentration compared with pre-treatment conditions. In addition, pre-treatment data and data collected after most of the on-the-ground work was completed in September, 2000, generally suggest a gradual

Table 7. Fecal coliform bacteria storm measurements throughout the period of study for the three forest/agriculture interface sites along the tributary streams to Beaver Creek.

FCB Data Criterion	BEA-UP1					BEA-UP2					BEA-UP4				
	Yr 1	Yr 2	Yr 3	Yr 4	Total	Yr 1	Yr 2	Yr 3	Yr 4	Total	Yr 1	Yr 2	Yr 3	Yr 4	Total
Number of Samples	38	21	25	58	142	38	21	26	58	143	33	21	25	58	137
Median	37	75	30	7	30	43	24	30	9	24	180	230	89	113	143
25th Quartile	21	12	14	3	7	23	6	20	2	8	42	14	53	44	41
75th Quartile	88	400	97	52	78	136	130	87	27	89	710	1370	320	405	520
Percent > 200 cfu/100 ml	16%	38%	12%	7%	15%	13%	14%	12%	5%	10%	42%	52%	36%	38%	41%
Percent > 100 cfu/100 ml	24%	43%	24%	12%	22%	29%	29%	23%	14%	22%	64%	57%	44%	50%	53%

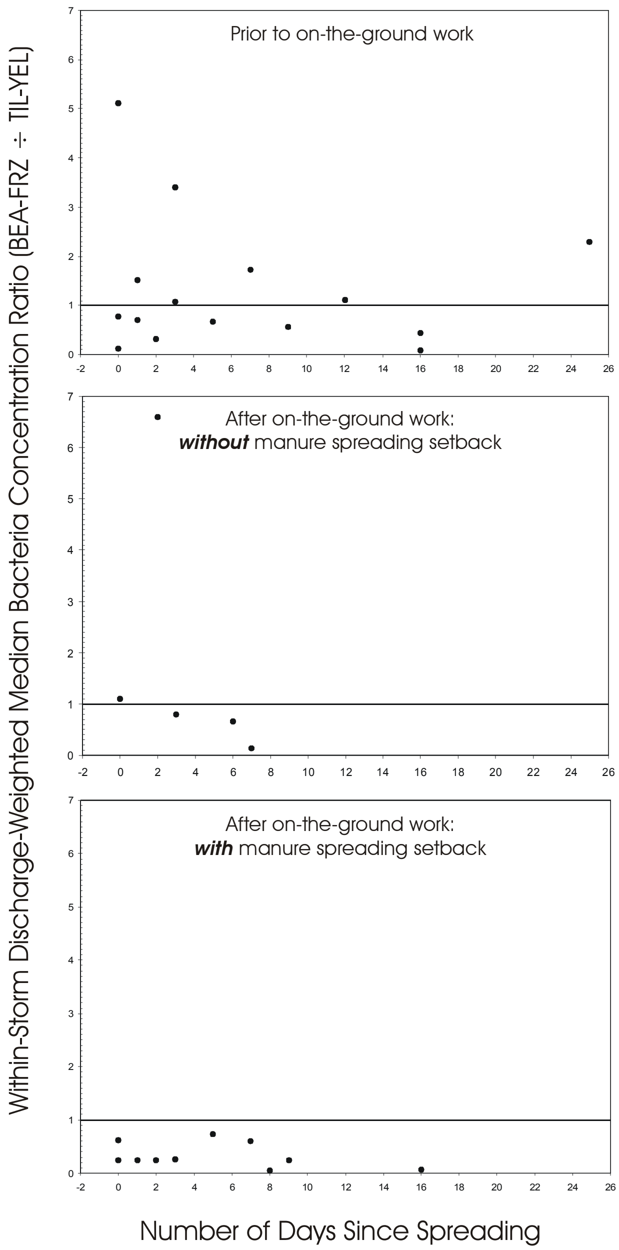
decrease in the ratio of discharge-weighted bacteria concentrations as a function of the number of days in advance of the storm at which the most recent manure spreading occurred (Figure 7). Such a relationship was less evident for post-spreading setback data (Figure 7, bottom panel).

The within-storm geometric mean of the FCB concentration was calculated at the downstream sampling site in each of the watersheds, because this is the statistic upon which the FCB health standard is commonly based. In the reference watershed, 73% of sampled storms exhibited a geometric mean FCB concentration > 200 cfu/100 ml during the pre-treatment period, compared with 60% during the post-treatment period. Similarly, 60% of the sampled storms in the treatment watershed showed geometric mean FCB concentration > 200 cfu/100 ml during the pre-treatment period. However, that percentage was reduced approximately in half for the post-treatment period (Table 8). Similarly, only 40% of sampled post-treatment storms and 30% of the sampled Year 4 storms had a geometric mean FCB concentration > 100 cfu/100 ml, compared with 80% during the pre-treatment period. In the reference watershed, the percent of sampled storms showing geometric mean FCB concentrations > 100 cfu/100 ml was very similar between the pre- and post-treatment periods (~ 90%; Table 8).

The three sampled Year 4 storms that showed geometric mean FCB concentrations > 200 cfu/100 ml at site BEA-FRZ were the first three sampled storms of that year. If the estimated bacterial contributions from the upper tributary sites (forested land use) were subtracted from the BEA-FRZ data, the storm geometric mean FCB concentration was reduced to well under the 200 cfu/100 ml standard (67 cfu/100 ml) during one of those three storms.

Table 8. Percent of sampled storms that exhibited geometric mean FCB concentration greater than 200 or 100 cfu/100 ml.

	Geometric Mean FCB > 200 cfu/100 ml		Geometric Mean FCB > 100 cfu/100 ml	
Time Period	BEA-FRZ	TIL-YEL	BEA-FRZ	TIL-YEL
Pre-treatment	60	73	80	93
Post-treatment	33	60	40	93
Year 4	30	60	30	90



Treatment site higher than reference site half of time, lower half of time; generally declining trend with timing of manure spreading.

Treatment site higher than reference site when storm was preceded by manure spreading within 2 days; treatment site lower when preceded by manure spreading within 3 or more days; ratio generally decreases with number of days since spreading.

Treatment site consistently 20 to 90% below reference site, irrespective of how recently manure was spread.

Figure 7. Relationship between the discharge-weighted median within-storm value for fecal coliform bacteria concentration at Beaver Creek divided by concentration at the reference watershed versus number of days in advance of the storm at which manure was spread on either the upper or middle Beaver Creek farm. Pre-treatment data (through 9/00) are shown in the top panel. Post-treatment storms prior to implementing manure spreading setback are shown in the middle panel (Year 3), and storms subsequent to implementing spreading setback (Year 4) are shown in the bottom panel.

Storms that were sampled and analyzed for FCB within the treatment and reference watersheds were classified according to both the amount of rainfall that occurred during the storm and the cumulative rainfall that occurred during the 7-day period preceding the storm. Storms of varying size and varying antecedent wetness exhibited high discharge-weighted median storm FCB concentration at both of the primary monitoring sites: BEA-FRZ and TIL-YEL (Figure 8). The observed patterns were very consistent in indicating, however, that high FCB concentrations at both sites were associated with either relatively dry conditions during the 7-day period preceding the storm (≤ 4 cm cumulative precipitation) or large storm size (> 6 cm precipitation). For example, during the fall season, four storms at BEA-FRZ and five storms at TIL-YEL showed discharge-weighted median FCB concentration > 1000 cfu/100 ml. In all cases except one of the TIL-YEL storm data sets, those high FCB values were associated with relatively dry antecedent conditions (6 points) and/or large storm size (4 points).

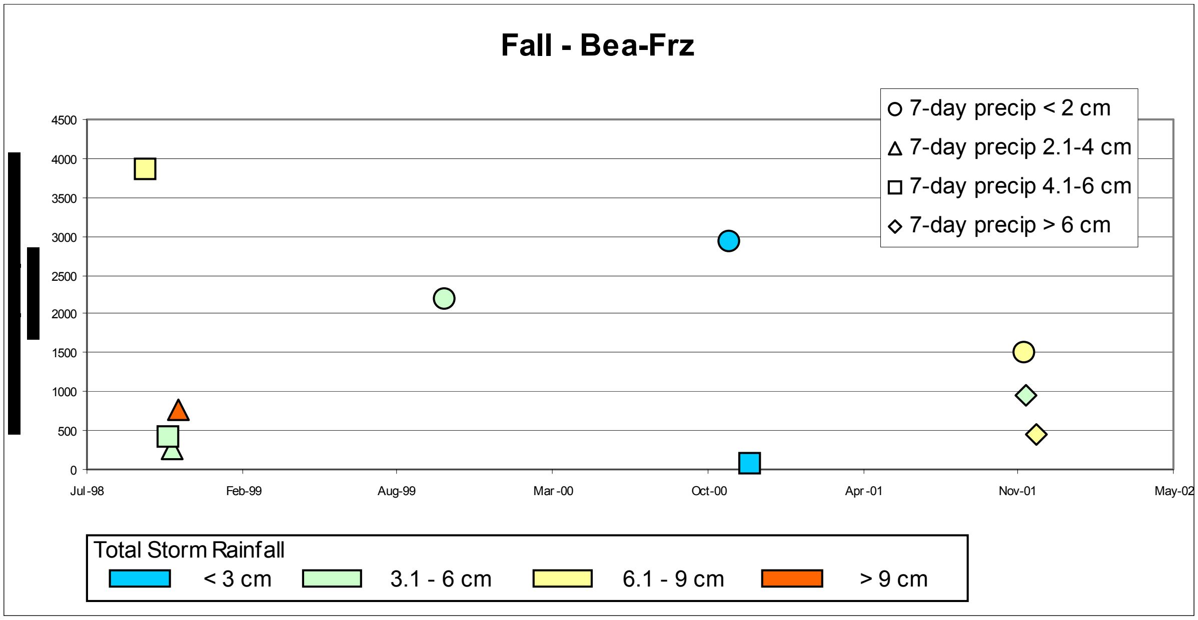
During winter, somewhat lower FCB values than those commonly observed during fall can be considered high; for example, none of the winter storms showed discharge-weighted median FCB concentration > 1000 cfu/100 ml. However, four winter storms at BEA-FRZ and five winter storms at TIL-YEL showed FCB concentration > 200 cfu/100 ml. All of those storms were associated with relatively dry antecedent conditions (6 points) and/or large storm size (5 points). Similarly, all three spring storms at BEA-FRZ and all four spring storms at TIL-YEL that showed FCB > 300 cfu/100 ml were preceded by relatively dry conditions (6 points) and/or were relatively large in size (3 points).

These analyses were also conducted using a 14-day antecedent wetness criterion, rather than the 7-day value discussed above. Results were identical.

3.3 TURBIDITY AND TOTAL SUSPENDED SOLIDS

Turbidity was measured on most sampling occasions. The results of those measurements are shown for the primary sites (BEA-FRZ and TIL-YEL) in Figure 9. Turbidity increased dramatically with storm events, regardless of the size of the storm, and also regardless of season.

During the pre-treatment period, 43% of the measured paired turbidity values (n=75) showed higher turbidity at the treatment site (BEA-FRZ) than at the reference site (TIL-YEL). That percentage was reduced in half to 22% in Year 4 (n=69).



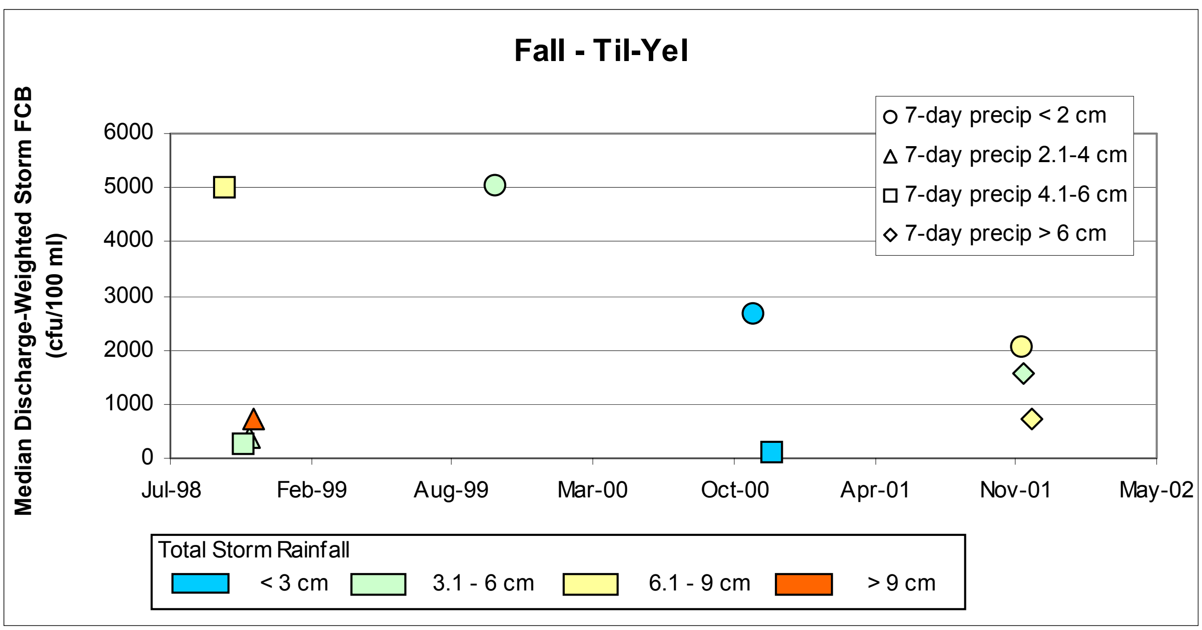
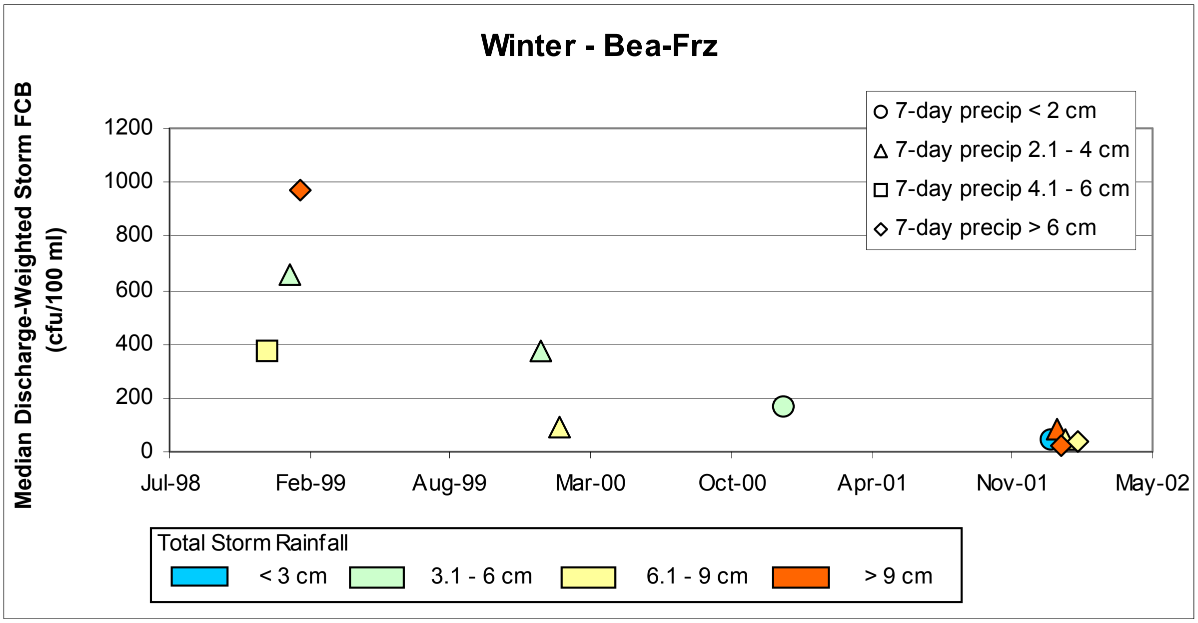


Figure 8. Discharge-weighted storm median FCB concentrations measured throughout the period of study at sites BEA-FRZ and TIL-YEL. Results are presented by season and storms are classified according to storm size and antecedent wetness.



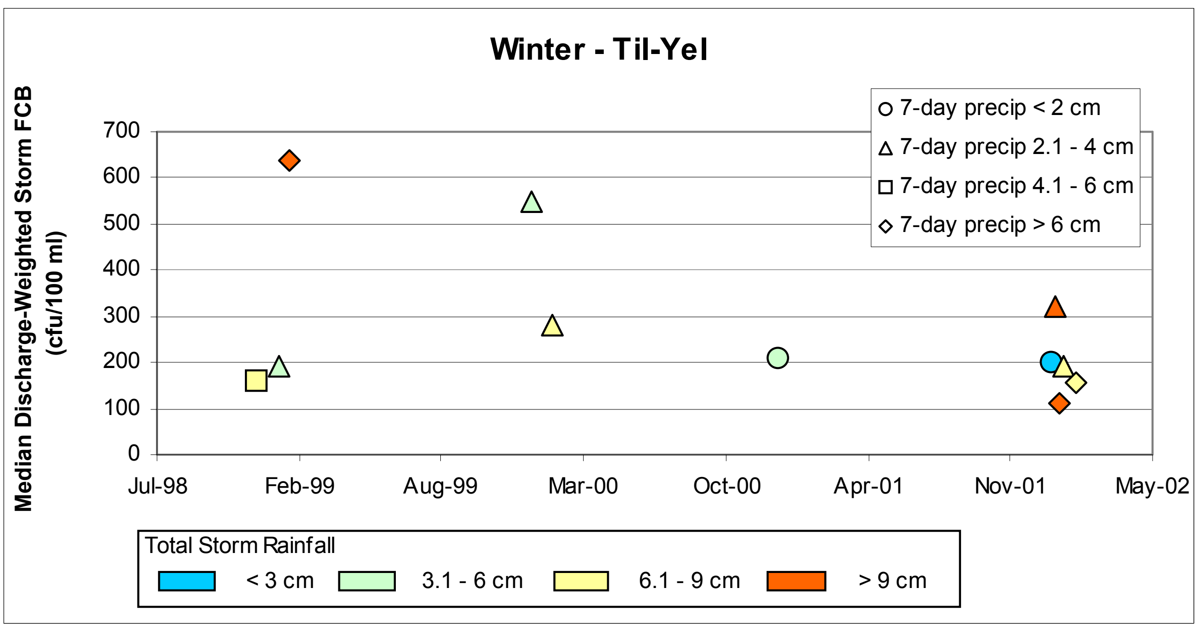
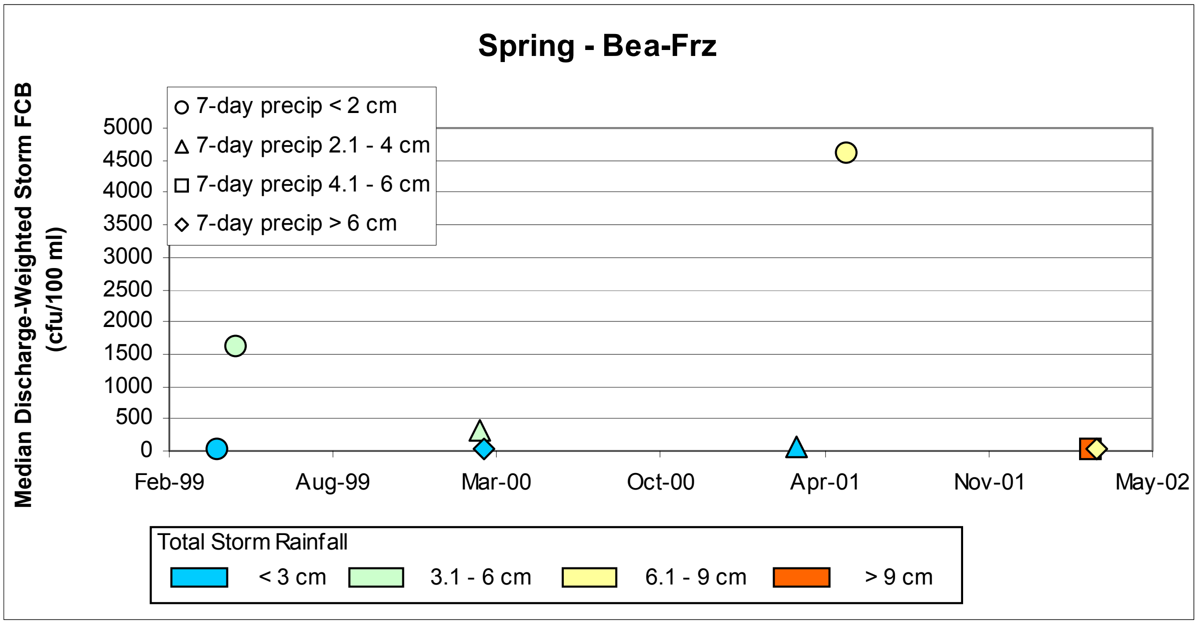


Figure 8. Continued.



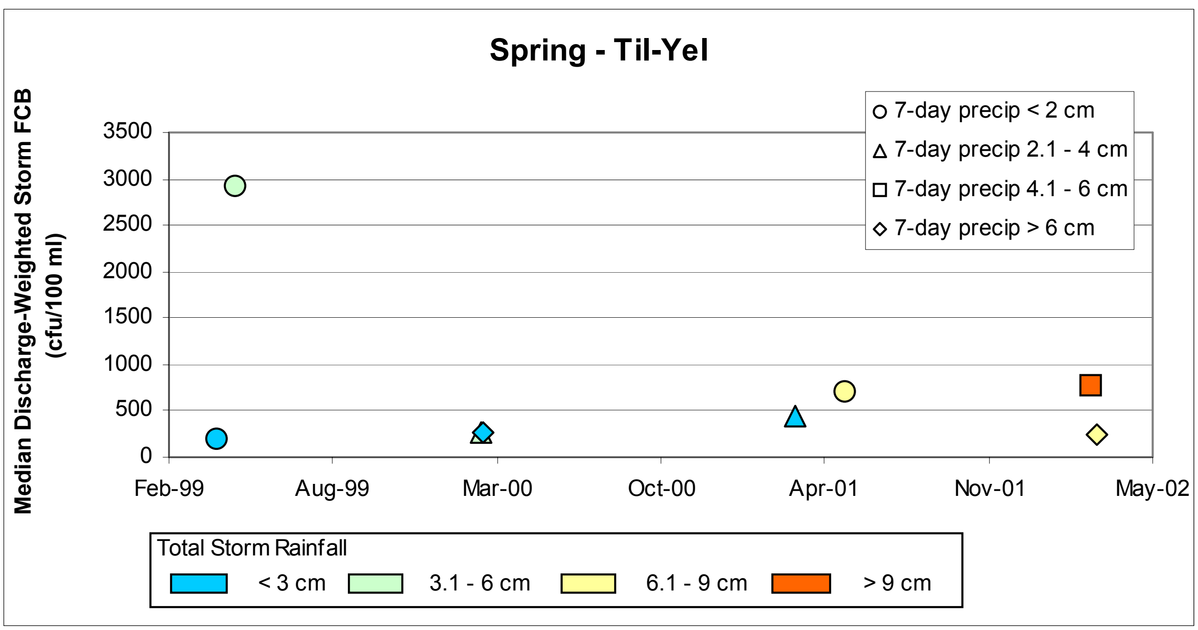


Figure 8. Continued.

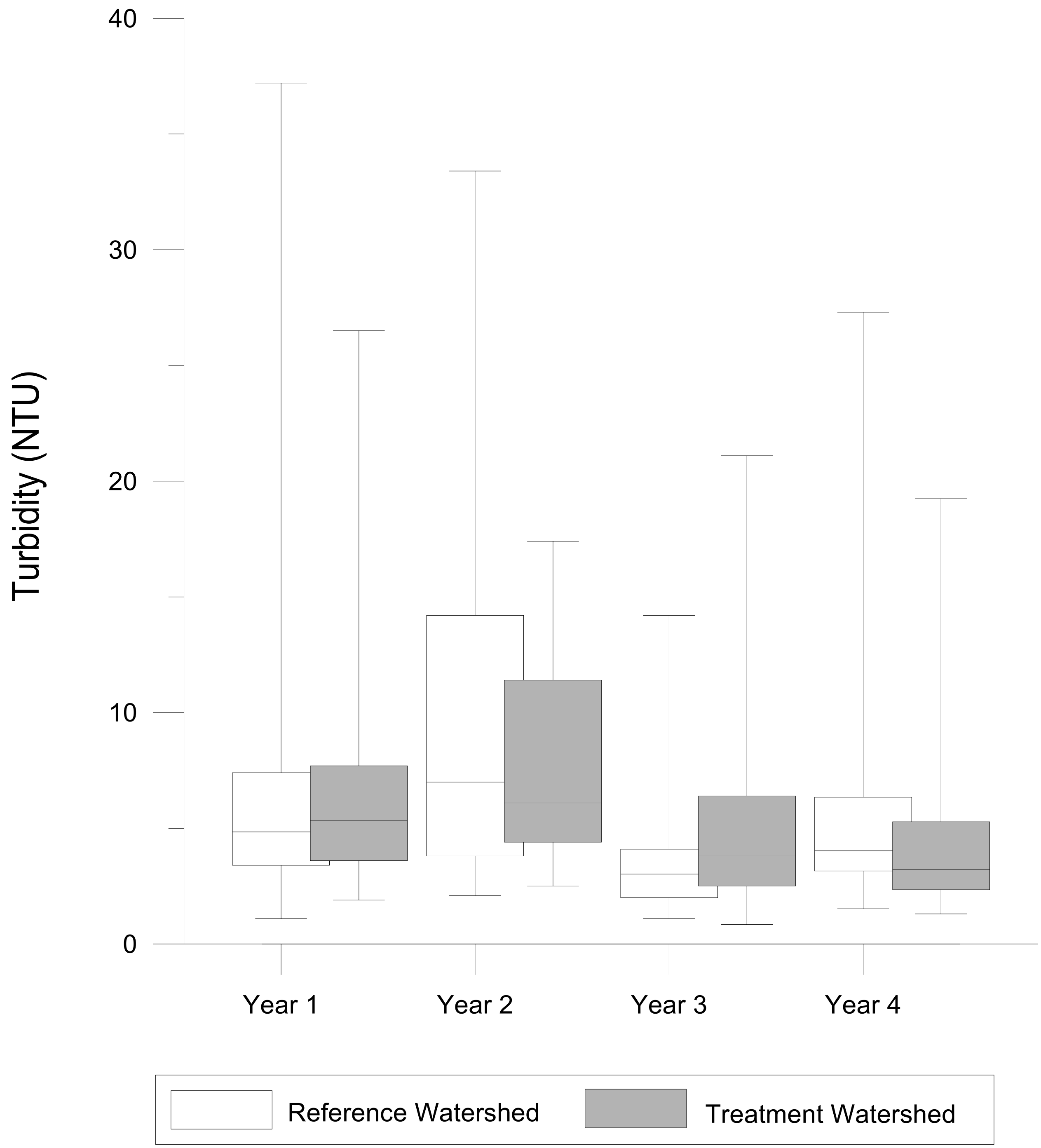


Figure 9. Box and whisker plot showing measured turbidity values at sites BEA-FRZ (treatment watershed) and TIL-YEL (reference watershed) during each of four years of study.

The median turbidity measured in the treatment watershed decreased by 41% from the pre-treatment period to Year 4. During the same period, the median turbidity measured in the reference watershed decreased by 25% (Table 9). The 75th percentile value for turbidity also decreased from the pre-treatment period to Year 4 in both watersheds, by 39% in the reference watershed and by 45% in the treatment watershed.

A turbidity screening criterion of 50 NTU was recommended by WPN (1999) to protect against adverse impacts on salmonids associated with inability to see prey items. None of the turbidity values measured at site BEA-FRZ or TIL-YEL exceeded that evaluation criterion. Median values were consistently less than 6 NTU and 75th percentile values were less than about 10 NTU (Table 9).

Table 9. Turbidity storm measurements for BEA-FRZ and TIL-YEL (paired data samples).

	BEA-FRZ			TIL-YEL		
FCB Data Criterion	Year 1 + 2	Year 3 +4	Year 4	Year 1 + 2	Year 3 +4	Year 4
Number of Samples	72	106	69	71	106	69
Median	5.4	3.4	3.2	5.3	3.7	4.0
25th Quartile	4.0	2.4	2.3	3.6	2.7	3.2
75th Quartile	9.1	5.4	5.2	10.2	5.9	6.3

Turbidity values were substantially lower in both the treatment and reference watersheds during Year 3 as compared with the pre-treatment period (Figure 9). This was likely due in large part to the low precipitation and discharge experienced during the Year 3 drought. During Year 4, turbidity values increased in the reference watershed, but continued to decline in the treatment watershed (Figure 9).

TSS was measured less frequently, only on 12% of the sampling occasions. Measured TSS values were closely correlated with measured turbidity, and we therefore used the turbidity measurements to estimate TSS for all sampling occasions using the equation shown in Figure 10.

Estimated median TSS values decreased from the pretreatment period to Year 4 by 29% in the reference watershed, but by 49% in the treatment watershed (Table 10). During Year 4, half of the TSS point estimates at sites BEA-FRZ ranged from 5 to 13 mg/L, whereas half of the estimates at TIL-YEL ranged from 7 to 17 mg/L.

Table 10. Estimated TSS storm measurements (mg/L) for BEA-FRZ and TIL-YEL (paired data samples).						
FCB Data Criterion	**BEA-FRZ**			**TIL-YEL**		
	Year 1 + 2	Year 3 + 4	Year 4	Year 1 + 2	Year 3 + 4	Year 4
Number of Samples	72	106	69	72	106	69
Median	14.0	7.9	7.2	13.7	8.7	9.7
25th Quartile	9.6	4.8	4.6	8.3	5.6	7.1
75th Quartile	26.0	14.1	13.4	29.9	15.5	16.9

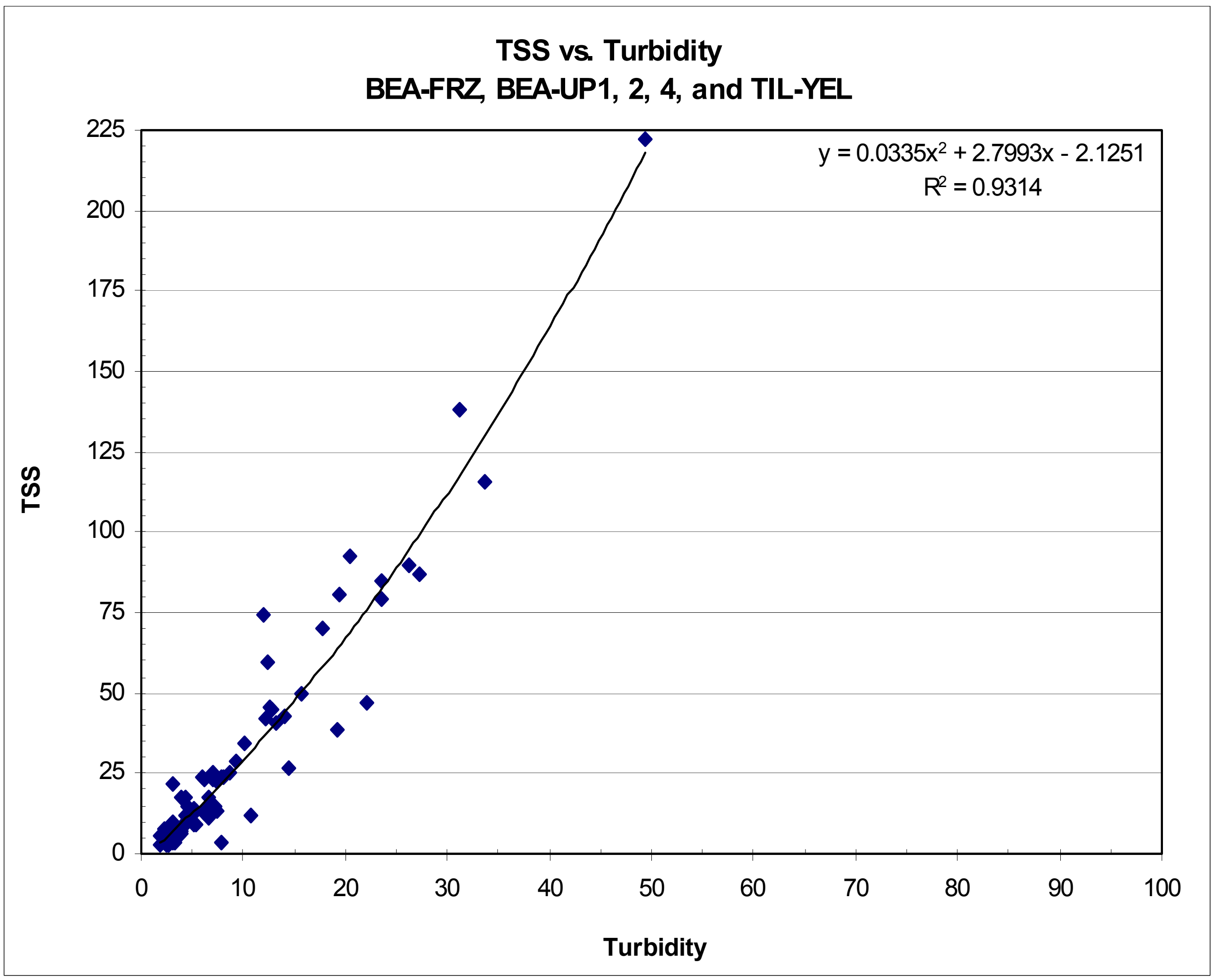


Figure 10. Relationship between measured values of TSS and turbidity for all samples for which both parameters were measured (n = 87). Samples analyzed for both turbidity and TSS were distributed as follows: TIL-YEL, 28; BEA-FRZ, 22; BEA-UP1, 13; BEA-UP2, 15; BEA-UP4, 9.

3.4 TEMPERATURE

Temperature data were collected at the five remediation monitoring sites and at site TIL-YEL using calibrated tidbit temperature loggers. Stream temperatures increased from the forest/agriculture interface to the BEA-FRZ site during the pre-treatment period, suggesting that stream warming occurs as a result of a lack of shade in the agricultural portions of the watershed.

Water temperature at the primary monitoring site in Beaver Creek is shown for the spring to mid-fall seasons of 1999, 2000, and 2001 in Figure 11. During the two years of pre-treatment data (1999 and 2000), water temperature (reported as the 7-day average maximum) in Beaver Creek exceeded the water quality standard of 12.8°C (salmonid spawning) throughout the entire monitoring periods, and also exceeded the 17.8°C salmonid rearing standard for extended periods during summer months. In 2001, however, after implementation of on-the-ground actions, stream temperatures at BEA-FRZ frequently reached, but seldom exceeded, the less stringent temperature criterion.

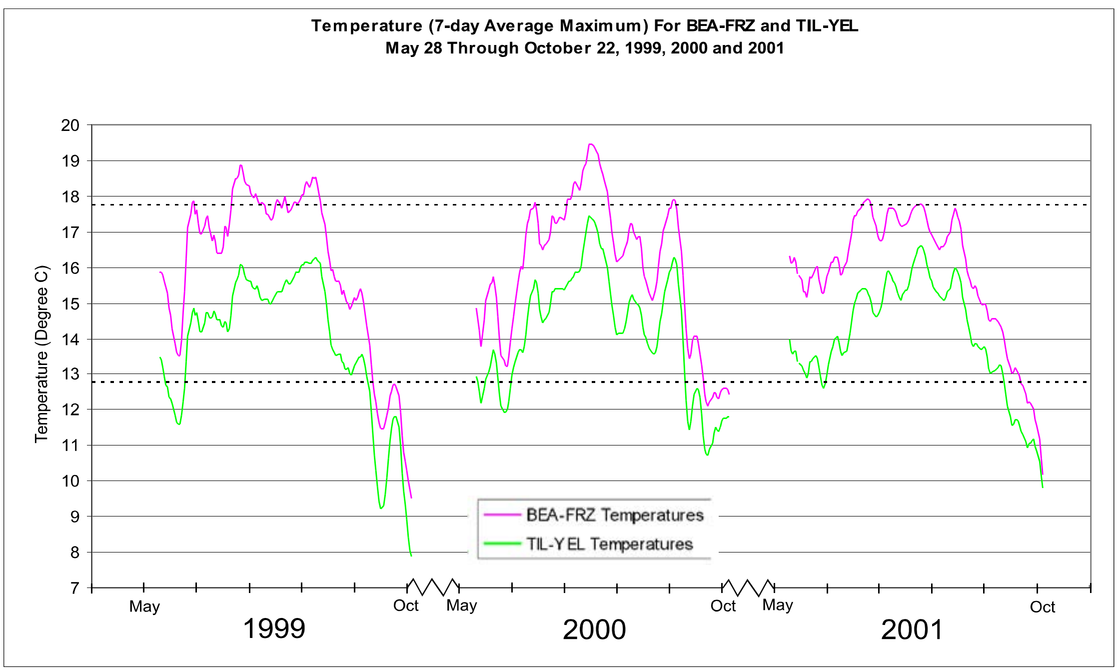


Figure 11. Seven-day average maximum stream temperature of Beaver Creek and the Upper Tillamook River at the primary monitoring sites (BEA-FRZ and TIL-YEL) during the May to October period of 1999, 2000, and 2001. Dotted reference lines are provided to indicate the standards for salmonid spawning (12.8°C) and rearing (17.8°C).

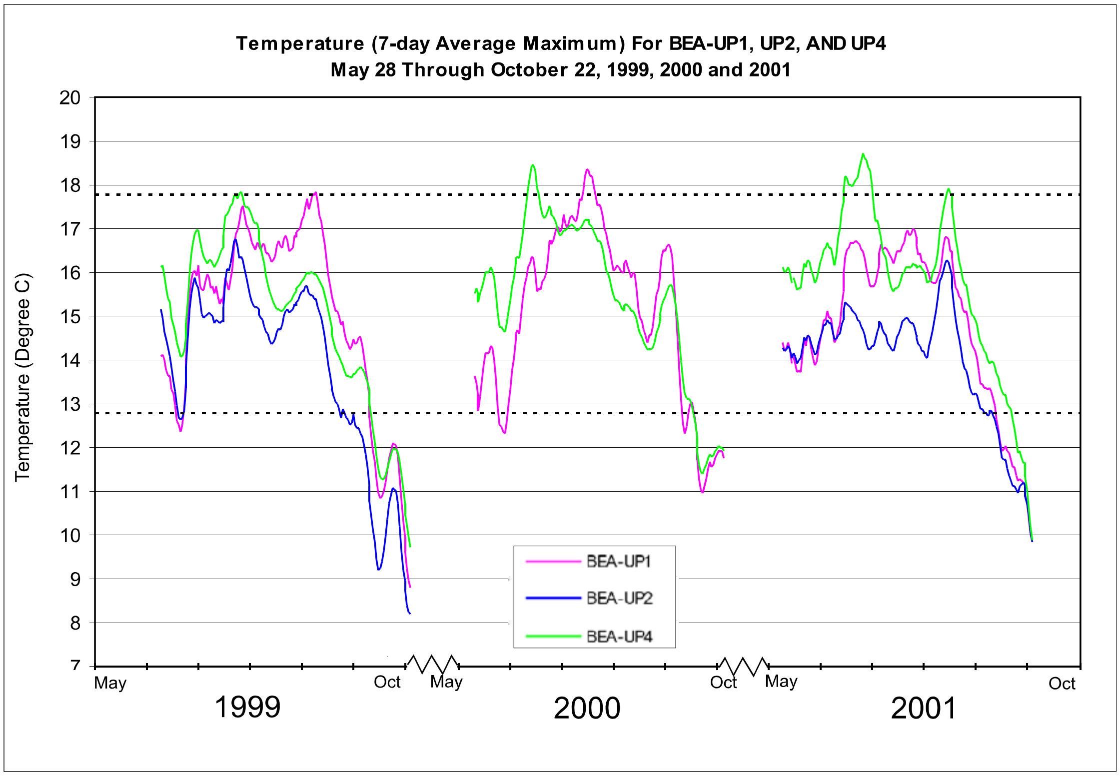


Figure 12. Seven-day average maximum stream temperature of the three upper tributary streams that flow into Beaver Creek during the May to October period of 1999, 2000, and 2001. Dotted reference lines are provided to indicate the standards for salmonid spawning (12.8°C) and rearing (17.8°C).

Temperature data at the three upper tributary sites are shown in Figure 12. Stream temperature at two of the upper sites (BEA-UP1 and BEA-UP2) often reached, and occasionally exceeded, the 17.8°C temperature standard during all three years. Data were not available for 2000 at site UP4 due to loss of the temperature monitor.

The stream temperature differences between the treatment and control watersheds are shown in Figure 13 for each of the three years of temperature to date. During the pretreatment period (1999 and 2000), the temperature at site BEA-FRZ in Beaver Creek was generally about 1° to 3°C warmer than at site TIL-YEL in the reference watershed. These differences were more pronounced (2° to 3°C) during the first half, and less pronounced (1° to 2°C) during the second half, of the temperature monitoring period, May to October (Figure 13). There is some indication of an improvement (smaller difference) in temperature in the treatment watershed during the second half of the monitoring period in 2001. If such improvement in temperature

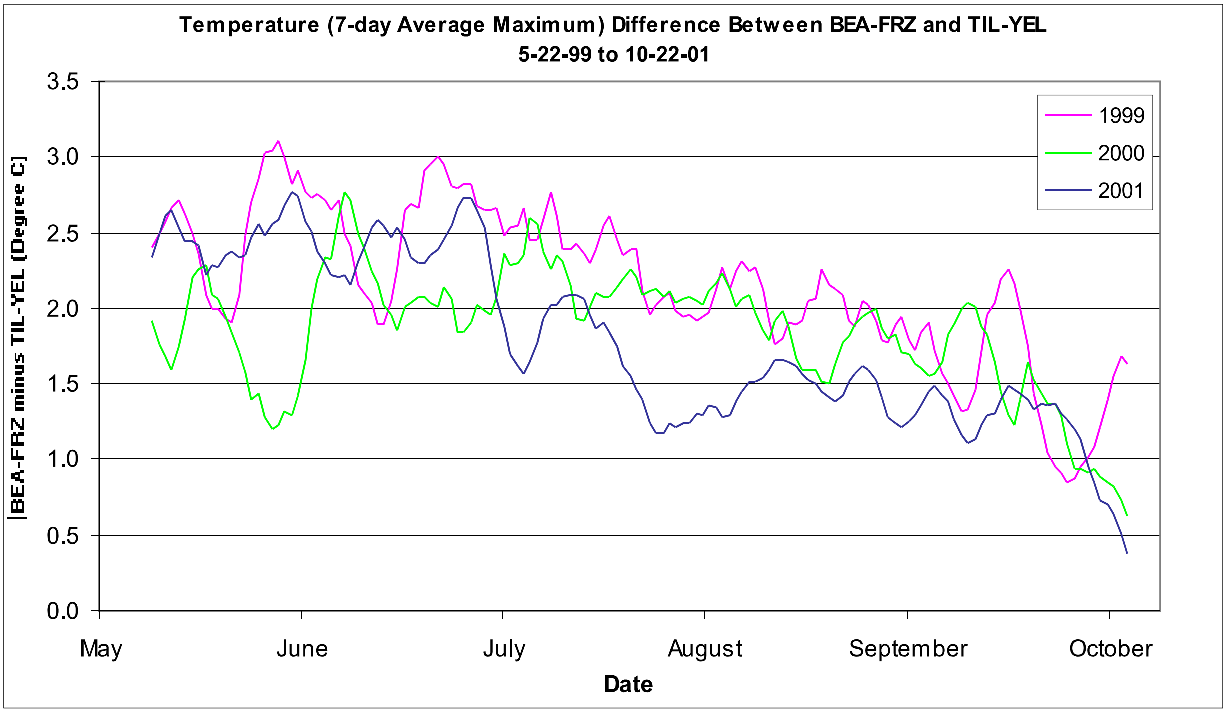


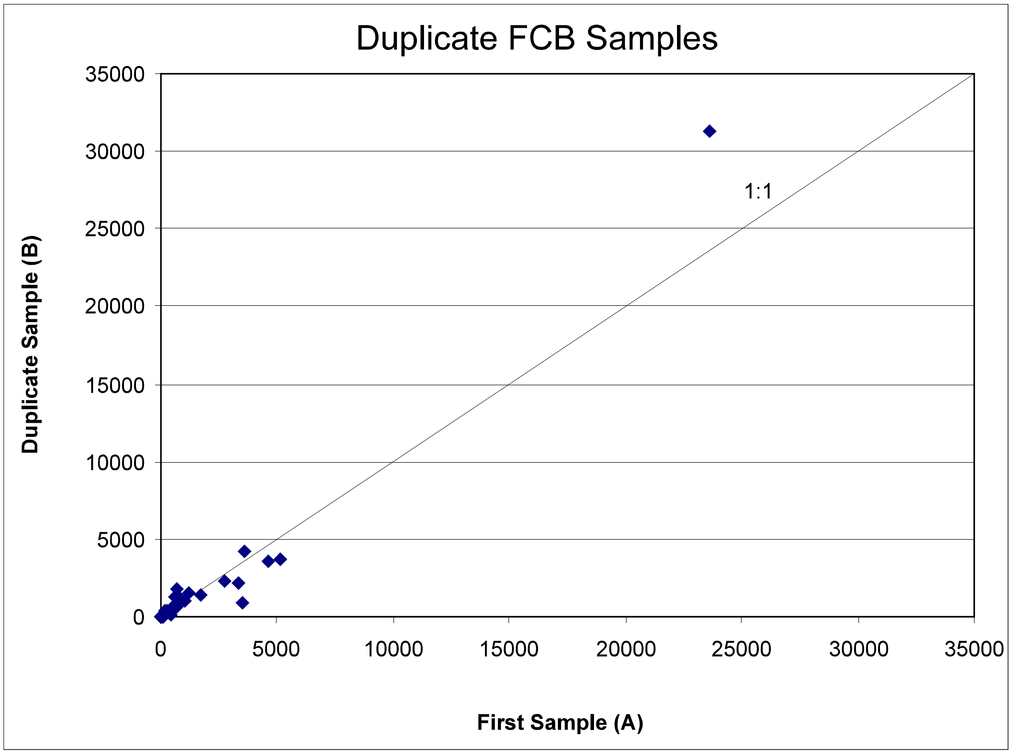
Figure 13. Temperature difference between the reference and treatment streams during the three summer seasons monitored to date.

has occurred, it is likely due to growth of tall grass adjacent to the stream. Planted shrubs and trees are not yet large enough to provide shading.

3.5. QUALITY ASSURANCE

Results of replicate analyses for FCB and turbidity are shown in Figures 14 and 15. The values of the relative error and absolute error were calculated for each of the replicate pairs of FCB and turbidity measurements. For FCB replicate pairs (n=57), the median absolute error (concentration difference between Sample A and Sample B) was 22 cfu/100 ml. Twenty eight percent of the replicate pairs had an absolute error greater than 100 cfu/100 ml. The relative error (RE) was expressed as:

$$RE = \frac{|C_1 - C_2|}{(C_1 + C_2)/2} x100$$



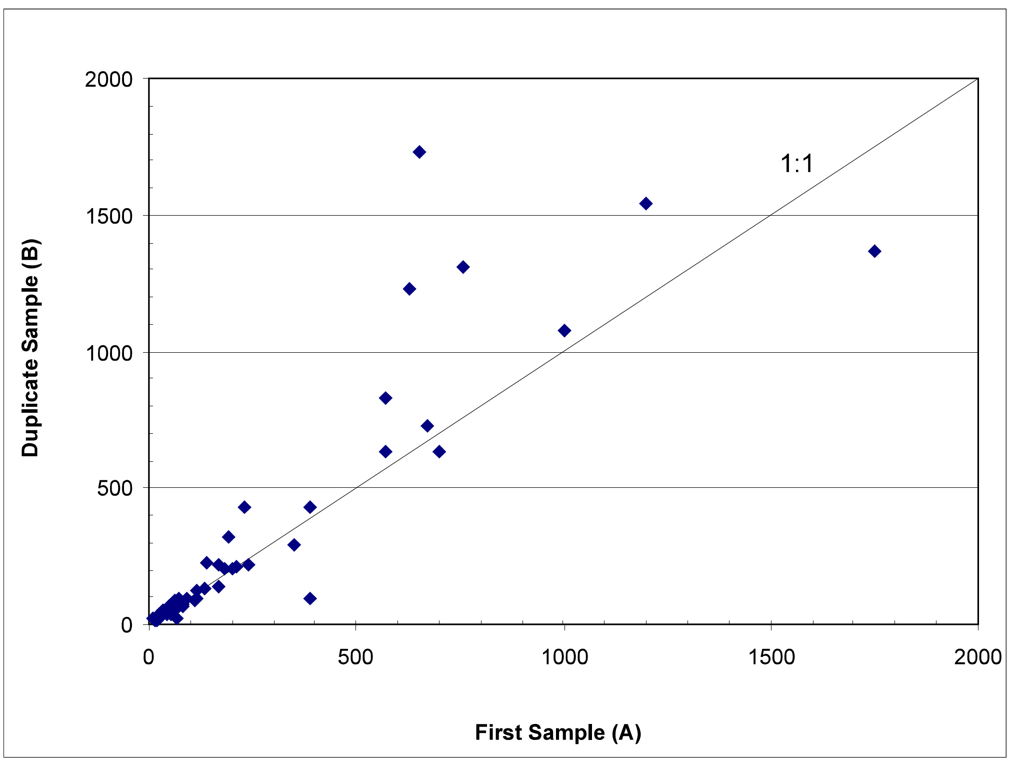


Figure 14. Results of replicate analyses of FCB for stream samples from the treatment and reference watersheds. Units on both axes are cfu/100 ml. Results of all replicate analyses are shown in the top panel and for only those analyses having values less than 2000 cfu/100 ml in the bottom panel.

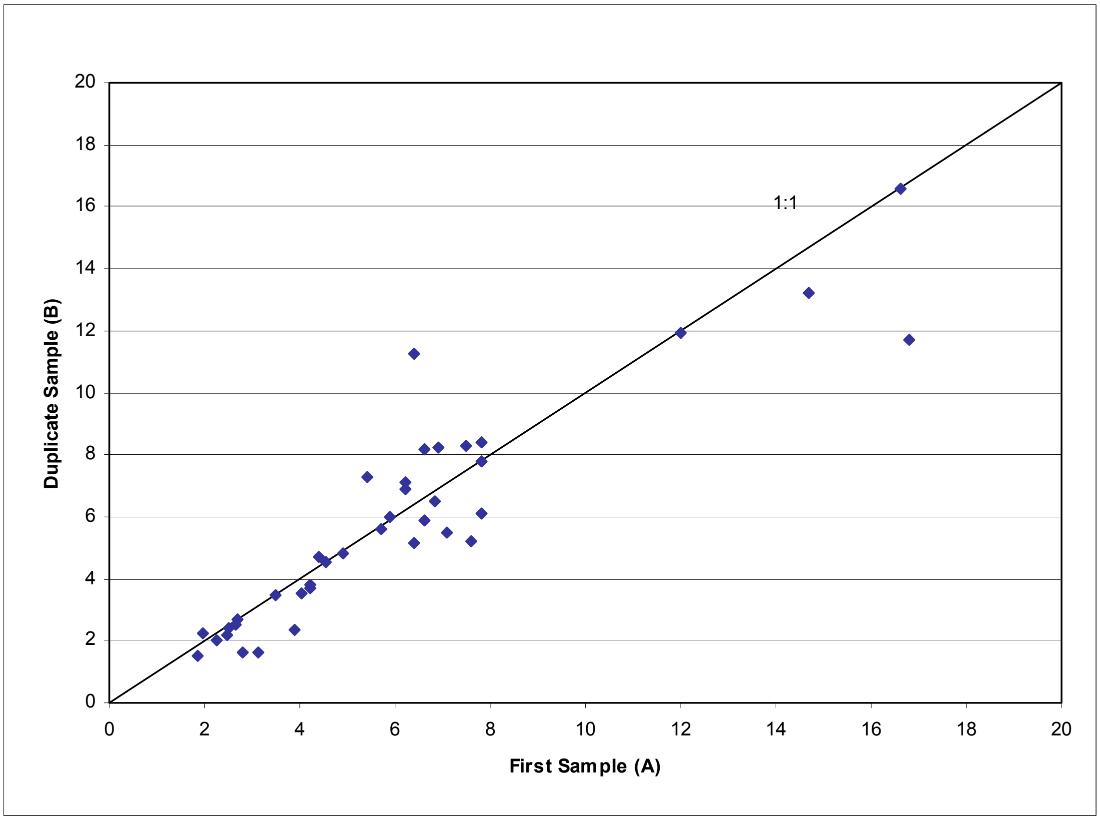


Figure 15. Results of replicate analyses of turbidity for stream samples from the treatment and reference watersheds.

where: C_1 = concentration of Sample A

C_2 = concentration of Sample B

The median relative error (MRE) was 24%. Eighteen percent of the replicate pairs had RE greater than 50%, and 7% of the replicate pairs had RE greater than 75%.

For replicate turbidity measurements (n=38), the median absolute error was 0.5 NTU and the MRE was 11%. Only 8% of the duplicate pairs had either an absolute error greater than 2.0 NTU or a RE greater than 50%.

3.6 VEGETATION

Some planting was completed on the upper farm during the spring of 2000, and more extensive planting on both the upper and lower farms was completed during spring, 2001. Progress of vegetation development in the riparian zone will be tracked via periodic photodocumentation. Some shading is now provided for the stream by growth of grass along the streambanks. Shrubs and trees planted within the fenced riparian areas have not yet grown sufficiently to provide additional stream shading.

3.7 CONTRIBUTION TO WATER QUALITY FROM AGRICULTURAL LAND USE

Water quality was monitored in each of the three tributary streams that flow from the forested portions of the Beaver Creek watershed to the agricultural land of the upper farm. This forested land above the tributary sampling sites represents 68% of the watershed, as defined by the location of the primary sampling site (BEA-FRZ). The remainder includes pasture land (~10%) and forest that drains into the system below the three tributary streams (~22%).

Water quality data (FCB, turbidity) were collected from the three tributary streams on the majority of the sampling occasions. Stream temperature was successfully monitored at all sites throughout the summer seasons in Years 1 and 3; Year 4 temperature data collection is in progress.

The contributions of FCB, sediment, and heat from the lower 32% of the watershed, below the forest/agriculture interface on the three tributary streams, were estimated for sampling occasions and periods for which data were successfully collected. For FCB and TSS, this included 65 and 73%, respectively, of the sampling occasions, and for temperature, it included the summer seasons of 1999 and 2001. In each case, the contribution of FCB, TSS, or heat from the upper tributary stream subwatersheds was subtracted from the analogous parameter value at site BEA-FRZ. Tributary values were weighted by contributing area, and therefore by presumed discharge, for the calculation.

We estimated the concentrations of FCB contributed to Beaver Creek from the agricultural portion of the watershed by subtracting contributions from the forested tributaries. This was done for all sampling occasions for which samples were collected at site BEA-FRZ plus each of the three forest/agriculture interface tributary sites. During the two years of pre-treatment data collection, 57% of the samples (n=31) exhibited FCB concentrations that could be attributed to agricultural land use above the health threshold of 200 cfu/100 ml. That percentage decreased to 42% in Year 3 (n=24) and 23% in Year 4 (n=56). Most (77%) of the high FCB concentrations during Year 4 were recorded during early season storms (prior to December 1).

During the pre-treatment year 1999, the estimated increase in the 7-day average daily maximum temperature of Beaver Creek from the forest/agriculture interface to site BEA-FRZ ranged from about 1° C during May and October to about 2° C in July and August (Figure 16). The estimated increase in stream temperature from top to bottom of the pasture lands was generally similar for 2001, suggesting little or no improvement to date in the stream temperature rise associated with change in land use along Beaver Creek from forest to agriculture. More data will be required to evaluate if, and to what extent, the remediation efforts may have contributed to decreased water temperature in Beaver Creek. Further improvement is anticipated as the trees and shrubs that were planted in the riparian areas continue to grow.

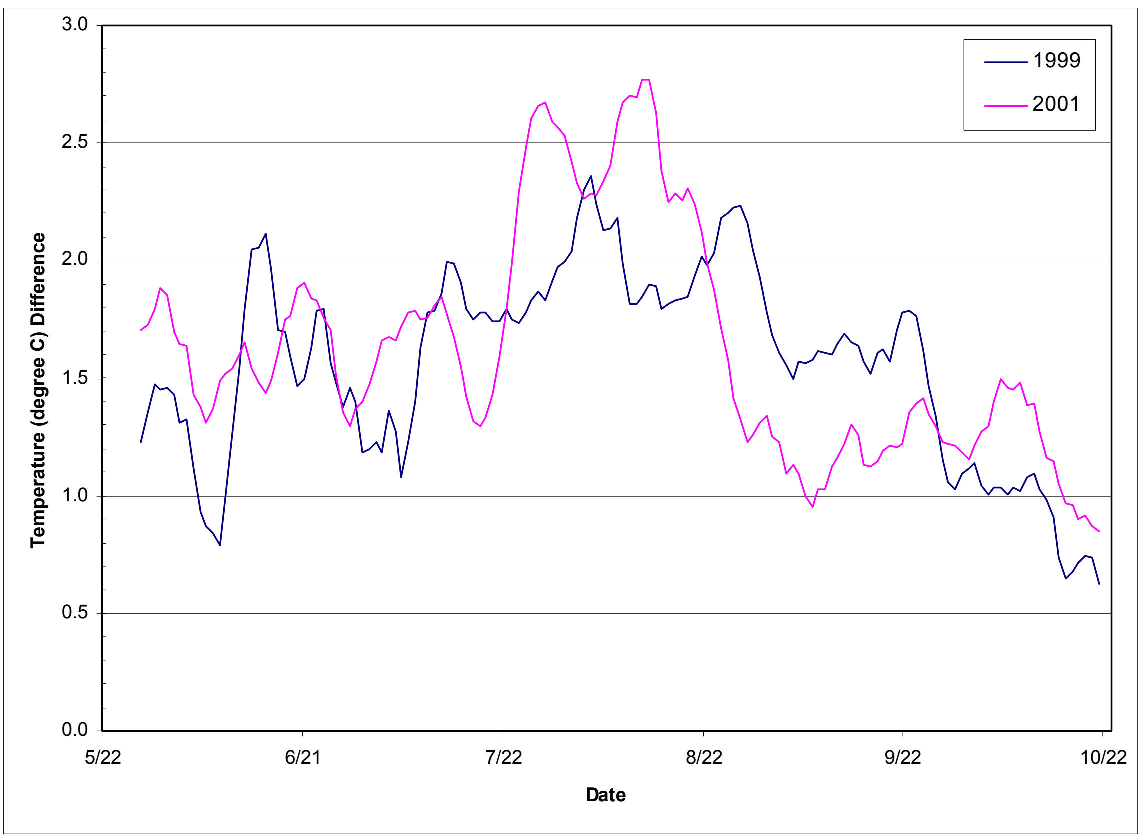


Figure 16. Estimated rise in the 7-day average stream temperature of Beaver Creek during 1999 and 2001 from the forest/agriculture interface of the three tributary streams (discharge-weighted average temperature) to site BEA-FRZ below the farms.

3.8 LANDOWNER RECEPTION

At the onset of this project, we seriously underestimated the amount of time required for landowner interaction. The project was significantly delayed from the beginning by the difficulty of locating a suitable subbasin where we would have good opportunity for remediation and where there was any possibility of landowner willingness to participate. Even on the farms that did agree to participate, landowners were, for the most part, very reluctant to allow on-the-ground work to be conducted on their farms. In addition, the landowners, in some cases, changed their minds about planned actions as the scheduled date for an action was approached. Landowners remain very concerned about the loss of productive land to allow for riparian buffer zones and about the perceived likelihood that regulatory agencies will unfairly enforce more restrictive regulations, especially with regard to wetlands and riparian buffer zone widths.

In addition, landowners were initially unconvinced that the management of their farms was detrimental to the stream environment or the water quality in any way. Many seemed to feel that they have been unfairly blamed for water quality problems caused elsewhere in the watershed.

A great deal of effort has been expended in this project to work constructively with the participating landowners and to address all of their concerns about the work on their land. The end result, so far, has been that we have been able to do less on-the-ground work than was initially planned. However, we have fostered positive, constructive working relationships with the participating landowners that may prove to be especially helpful as the Tillamook County Estuary Partnership expands its efforts to improve water quality on other properties throughout the Tillamook Basin.

4.0 CONCLUSIONS

The results of water quality monitoring efforts conducted prior to conducting the on-the-ground work illustrated substantial contamination of runoff with bacteria as the streams pass through the agricultural portion of the study area. Results also showed substantial bacterial contamination in one tributary upstream of agricultural land use, presumably from wildlife. The data collected during the first two years of monitoring provided a good baseline against which to measure improvements associated with subsequent restoration efforts.

Conclusions include the following:

- During the pre-treatment period, about one-fourth of the stream samples at both of the primary monitoring sites (BEA-FRZ and TIL-YEL) had FCB > 1,000 cfu/100 ml. That percentage decreased to 11% at BEA-FRZ in Year 4, but remained similar at TIL-YEL. Such high FCB concentrations at BEA-FRZ during Year 4 were generally confined to the fall season.

- The median FCB concentration at site BEA-FRZ decreased by 76% from pre-treatment to post-treatment periods, and the percentage of storm samples exceeding the health standard of 200 cfu/100 ml decreased by 45%.

- The discharge-weighted, storm-median and storm-mean FCB concentrations in the treatment watershed decreased by 76% to 78% from pre-treatment to post-treatment periods, but stayed at similar levels in the reference watershed.

- Water quality improvements at site BEA-FRZ from the pre-treatment to post-treatment period were not uniform across seasons. The improvement for Year 4, as compared with the overall pre-treatment period, ranged from 45% reduction in median FCB concentration during fall to 63% and 88% reductions during winter and spring, respectively.

- Monitored storms frequently showed lower FCB concentrations in the treatment watershed than in the reference watershed throughout the study. However, the frequency at which storms showed higher concentrations in the treatment watershed decreased dramatically after completion of on-the-ground restoration work, and decreased to zero by Year 4 of the study.

- FCB concentrations were often high at the forest/agriculture interface on Bear Creek (site BEA-UP4), presumably due to wildlife contributions of bacteria. The median FCB concentration at site BEA-UP4 was higher than 100 cfu/100 ml during every year of study except the drought year (Year 3) and 41% of the samples collected during the study exceeded the 200 cfu/100 ml standard.

- During Year 4 of the study, water exiting the treatment watershed below the farms had, on average, lower FCB concentration than water entering the farms from the forest in the Bear Creek tributary stream.

- During Year 4 of the study, the within-storm geometric mean of the FCB concentration only exceeded 200 cfu/100 ml during the three storms sampled during fall, and for one of those storms the exceedence of the 200 cfu/100 ml standard could be attributed to bacteria originating in the forested portion of the watershed. Only 30% of the sampled Year 4 storms (all during fall) had geometric mean FCB > 100 cfu/100 ml at BEA-FRZ, compared with 80% during the pre-treatment period and ~90% throughout the study at TIL-Yel.

- Monitoring data collected to date for turbidity, TSS, and stream temperature suggest some reductions during the post-treatment period. Such reductions are small, however, compared with observed variability. A longer period of record would be required to quantify improvements for these parameters.

Clearly, fencing, riparian planting, hydrological modifications, and manure-spreading setbacks have helped to improve water quality in the Beaver Creek watershed. This project has quantified achievable reductions in the contributions of bacteria and sediment in agricultural areas over the short-term. Quantification of long-term reductions would require continued monitoring. Such improvements are expected to reduce bacterial contamination of the river and bay, reduce stream bank erosion and erosion from agricultural fields, reduce sediment transport from uplands to the lower river and the bay, reduce stream temperatures, improve the integrity of aquatic biological communities in streams draining agricultural lands, and improve salmonid habitat quality in the upper and lower watershed. Most importantly, some of these improvements have been measured and quantified in the short-term. Further documentation of the extent of improvement for each critical parameter would help state agencies to refine estimates of achievable improvements (i.e., Senate Bill 1010, TMDL process, 303d listings, etc.) and should be communicated to the agricultural community in the Tillamook Basin.

The rainy season of 2000-2001 was exceptionally dry. There were no large storms, and the rivers and streams were at or near baseflow conditions for most of the fall, winter, and spring. This unusual weather had a large impact on hydrology and on bacterial and sediment fluxes. Such variation is one reason why additional years of monitoring data would be required to fully quantify improvements that may occur as a consequence of the actions taken within this project.

Water quality conditions have continued to improve since implementation of on-the-ground actions. FCB concentrations and turbidity levels were lower during Year 4 than they were during Year 3. In addition, the ratio of FCB concentrations in the treatment watershed compared to the reference watershed decreased throughout Year 4. At the end of the monitoring period, storm-median discharge-weighted FCB concentrations in Beaver Creek were only about 10% of the concentrations measured in the reference watershed, and the FCB standard (200 cfu/100 ml) was seldom exceeded. It is not clear to what extent water quality in Beaver Creek will continue to improve as riparian vegetation develops. Thus far, however, results look very promising.

5.0 LITERATURE CITED

Arnold, J.G., J.R. Williams, A.D. Nicks, and N.B. Sammons. 1989. SWRRB, A basin scale simulation model for soil and water resources management. Texas A&M Press, College Station, TX.

Blair, T. and K. Michener. 1962. Sanitary survey of Tillamook Bay and sanitary significance of the fecal coliform organism in shellfish growing area waters. Internal report, Oregon State Board of Health, Portland, OR.

Dorsey-Kramer, J., N.S. Urquhart, J.R. Miner, and J.A. Moore. 1996. Tillamook Bay tributaries water quality improves after BMP installation. Tech. Pap. No. 10,942. Oregon Agric. Exp. Sta., Corvallis, OR.

Jackson, J. and E. Glendening. 1982. Tillamook Bay bacteria study fecal source summary report. Oregon Department of Environmental Quality, Portland, OR.

Musselman, J. 1986. Sanitary survey of shellfish waters. Tillamook Bay, Oregon, Dec. 1986. U.S. Dept. of Health and Human Services, Public Health Service, Food and Drug Administration, Shellfish Sanitation Branch.

Oregon Department of Agriculture. 1991. Tillamook management plan for commercial shellfish harvesting. Oregon Dept. of Agriculture, Food Safety Div., Salem, OR.

Oregon Department of Environmental Quality. 1994. Oregon's 1994 Water Quality Status Assessment Report: 305(b). Oregon Department of Environmental Quality, Portland, OR.

Sullivan, T.J., J. M. Bischoff, K.B. Vaché, M. Wustenberg, and J. Moore. 1998a. Water quality monitoring in the Tillamook Watershed. Results of a one-year periodic monitoring and storm sampling program. Report to Tillamook Bay National Estuary Project. E&S Environmental Chemistry, Inc.

Sullivan, T.J., J.M. Bischoff, and K.B. Vaché. 1998b. Results of storm sampling in the Tillamook Bay Watershed. Report to Tillamook Bay National Estuary Project. E&S Environmental Chemistry, Inc.

Tillamook Bay National Estuary Project. 1999. Tillamook Bay Comprehensive Conservation and Management Plan. TBNEP, Garibaldi, Oregon.

Watershed Professionals Network (WPN). 1999. Oregon Watershed Assessment Manual. June 1999. Prepared for the Governor's Watershed Enhancement Board, Salem, OR.

Appendix A

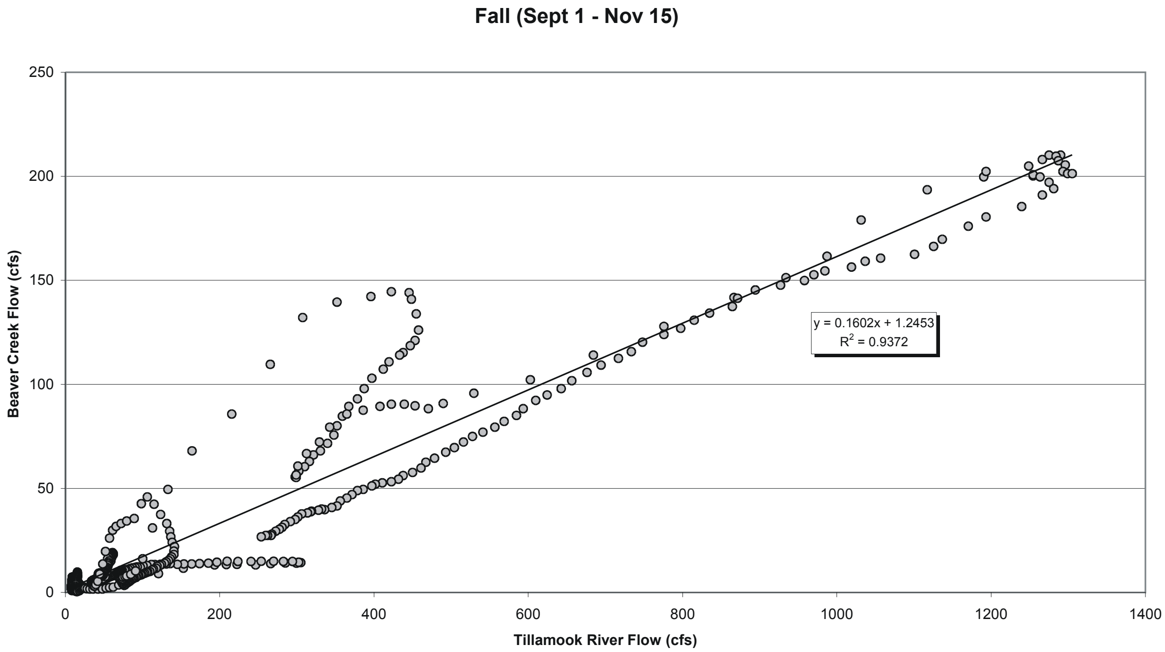
Methods to Fill Data Gaps

Minor data gaps occurred in the databases generated for stream stage, discharge, precipitation, and stream temperature in two of the upper tributary streams. Approaches used to fill those data gaps are described below.

Stream Stage and Discharge

Due to a lag time between the start of water sampling (10/8/98) and the instrumentation of Beaver Creek to collect precipitation and flow measurements (12/16/98), there were gaps in the discharge and precipitation records. In order to estimate a flow record for Beaver Creek for this time, a relationship was developed between the discharge records of Beaver Creek and the Tillamook River, using a 22-month period of overlap from 12/16/98 to 10/1/00. The drought water year of 2001 was not included in this relationship, as it was not representative of hydrologic conditions present during the times without flow data for Beaver Creek. Using this period of overlap, Beaver Creek discharge was regressed against Tillamook River discharge, and separate trend line equations were calculated for annual time intervals defined as fall (September 1 to November 15) and winter (November 16 to February 15; Figure A-1). The winter relationship was fit with two trend lines, the first being fit to the entire data set (but used predictively only for Tillamook River flows of less than 2,000 cfs), and the second being fit only to Tillamook River flows greater than 2,000 cfs. These equations were then used to estimate Beaver Creek discharge values for the time period of 10/1/98 to 12/16/98.

Due to periods of time in the record with missing or suspect barometric pressure data, a technique was developed to correct stage height values without using a barometric pressure measurement. Eleven field observations of stage height were plotted against corresponding pressure transducer values, uncorrected for barometric pressure. These points were fitted with a trend line to create a simple linear equation to explain the difference between the actual stage (measured in the field) and the stage recorded by pressure transducer (Figure A-2). This equation was then used to correct stage height in the absence of barometric pressure data. The final record of discharge for Beaver Creek was calculated primarily from stage data that were corrected using barometric pressure, with a small percentage of discharge calculated using stage obtained by this second method.



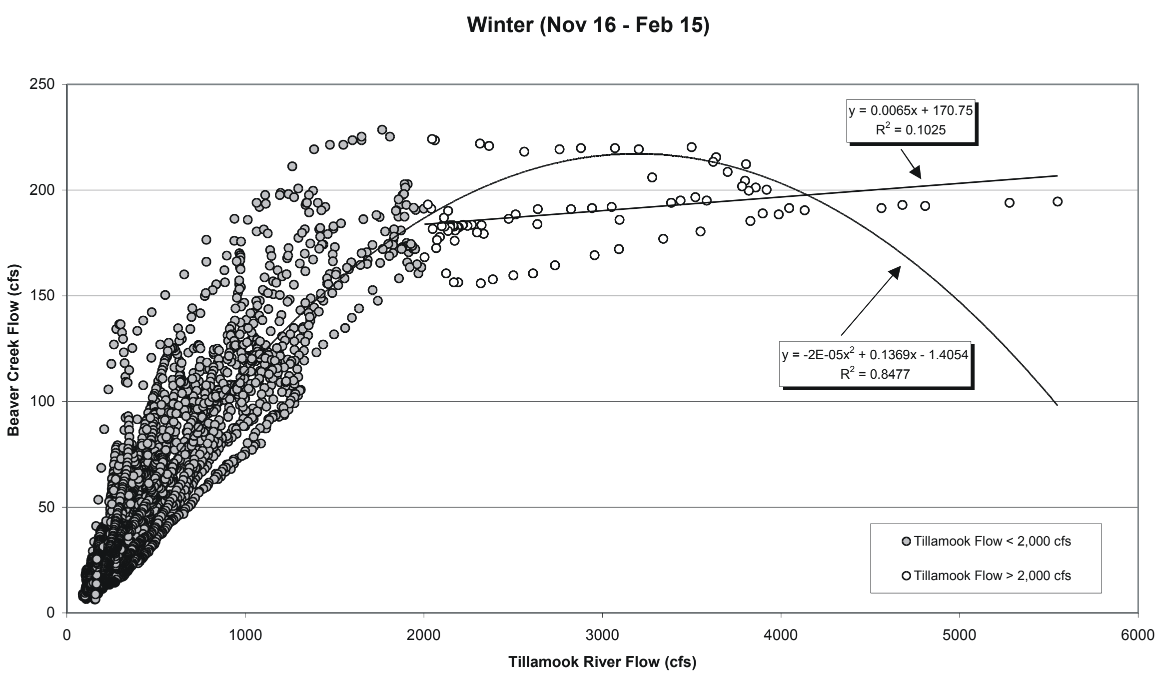


Figure A-1. Relationships for fall and winter between discharge in Beaver Creek and discharge in the Tillamook River at the Oregon Water Resources Department gaging station.

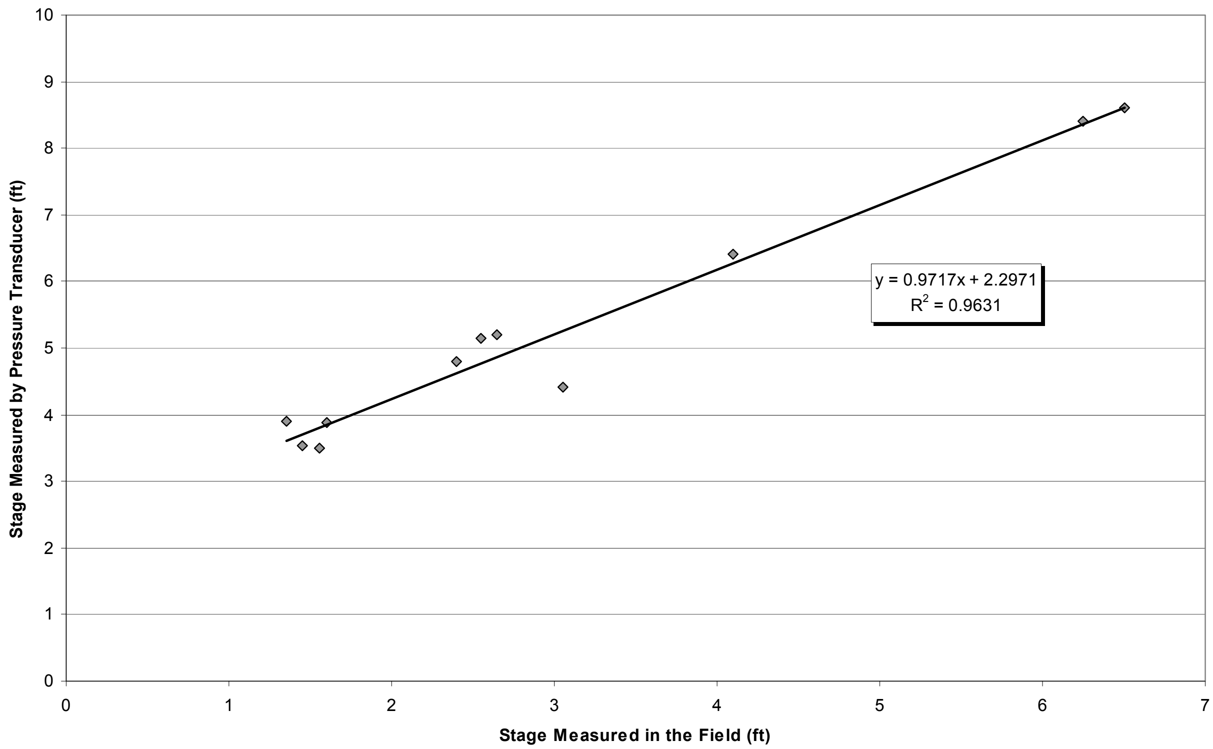


Figure A-2. Relationship between Beaver Creek stage measured by pressure transducer, uncorrected for barometric pressure, and stage measured in the field using a staff gage.

Rainfall

Missing rainfall values during the period September 1, 1998 to December 16, 1998 (prior to instrumentation of the Beaver Creek watershed) were estimated using precipitation data collected at Tillamook. Two years of overlapping data (1999 and 2000) covering the period September 1 - December 16 were used to develop a predictive relationship (Figure A-3).

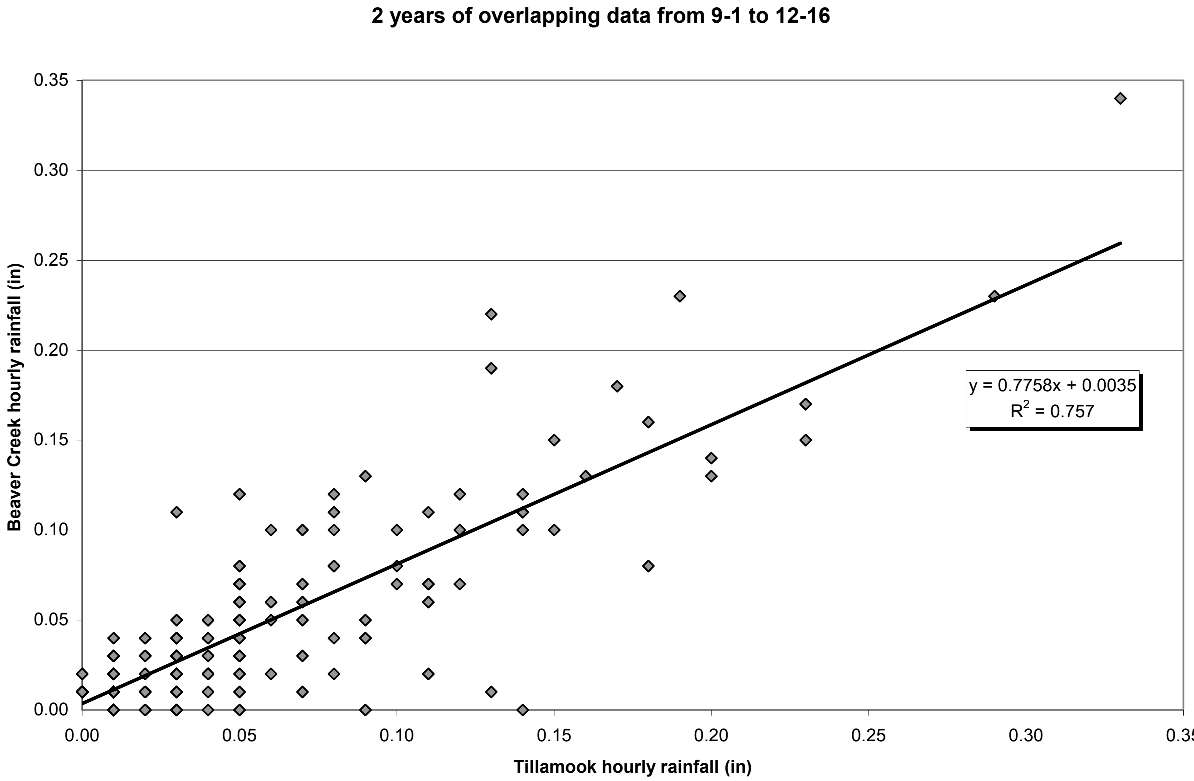


Figure A-3. Measured rainfall at site BEA-FRZ compared with measured rainfall in Tillamook for the period of overlap from September 1 to December 16. This relationship was used to estimate precipitation at Beaver Creek during that time period when data for Beaver Creek were not available.

Stream Temperature

Stream temperature values were missing for some May and June periods at two of the upper tributary stream sites: BEA-UP2 and BEA-UP4. Regression equations between simultaneous upper tributary stream temperature measurements were established by month, and generally showed consistent patterns in temperature between site BEA-UP1 and each of the two sites for which there were missing values, with r^2 values ranging from 0.4 to 0.8 (Figure A-4). These regression relationships were used to fill data gaps in May and June of 1999 and 2001 at sites BEA-UP2 and BEA-UP4.

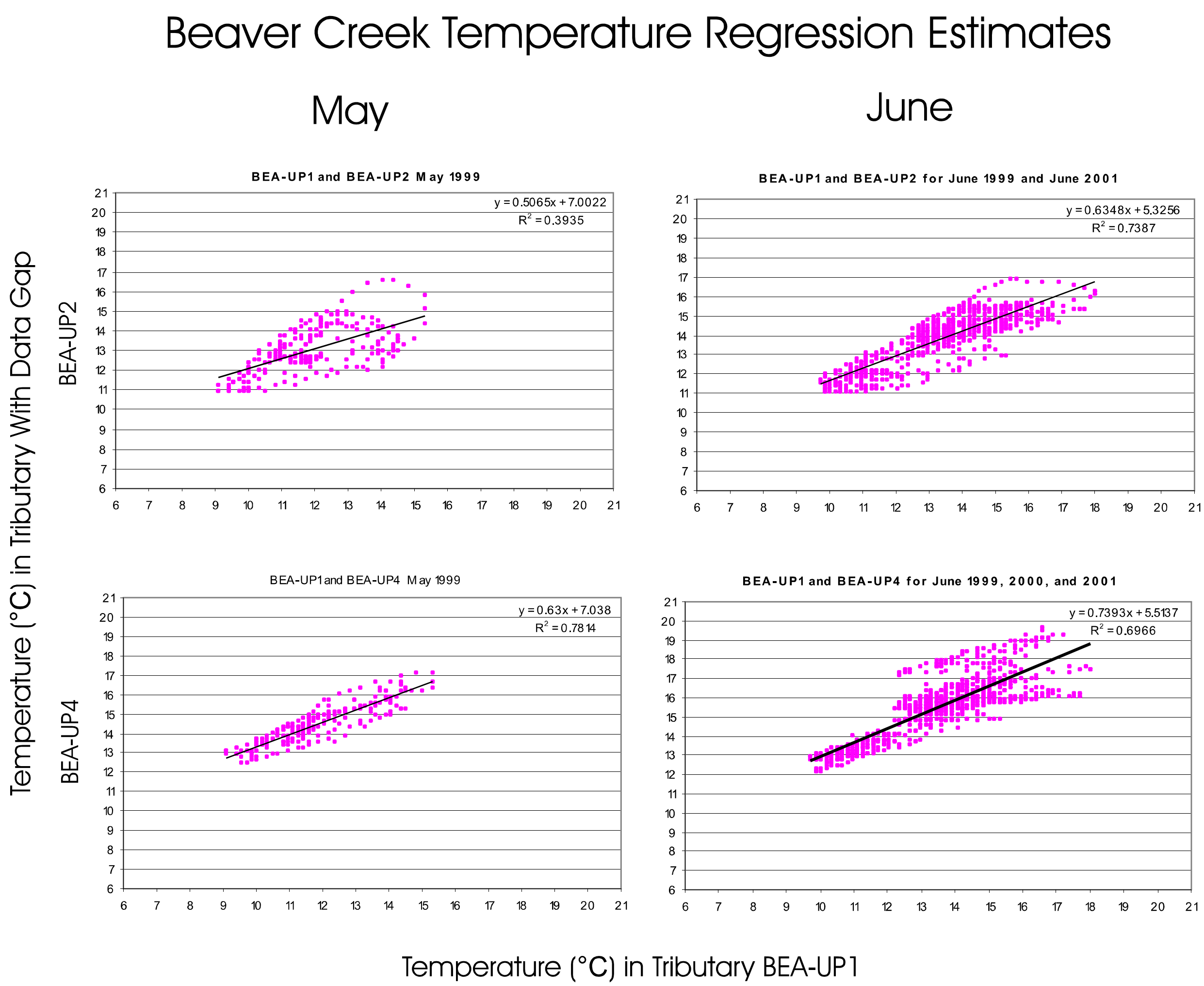


Figure A-4. Relationships between temperature measured in the South Fork of Beaver Creek tributary site compared with the other two upper tributary sites during the months of May and June. These relationships were used to fill temperature data gaps for the North Fork of Beaver Creek and for Bear Creek in 1999 and 2001.