WASHINGTON STATE
DEPARTMENT OF
ECOLOGY

Totten and Eld Inlets Clean Water Projects

Final Report

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WASHINGTON STATE
DEPARTMENT OF
ECOLOGY

Totten and Eld Inlets Clean Water Projects

Final Report

by
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Abstract

Ten years (1992-2002) of water-quality monitoring and analysis for fecal coliform bacteria (FC) levels and loading were completed in six sub-basins discharging to Totten and Eld inlets in Puget Sound in Washington State. The EPA-funded monitoring program goal was to determine the effectiveness of watershed-scale, nonpoint-source pollution management programs for improving water quality. The sub-basins are McLane and Perry in Eld Inlet, and Burns, Pierre, Schneider, and Kennedy in Totten Inlet. Study design was single-site, before/after for all streams except Schneider (test) and Kennedy (control) paired watershed analysis.

For the ten-year monitoring period, the FC trend was up significantly (α=0.05) at McLane, and down at all other streams, but significantly only at Pierre. The FC loading trend was up significantly at McLane, and up, but not significantly, at Schneider and Kennedy. The trend was down, but not significantly, at the other streams. Incorporating historical data back to 1983, the FC trend was up significantly at McLane, and down at all other streams, but significantly only at Perry.

Post pollution-control FC levels – both concentrations and loadings – have fluctuated considerably from year to year. In all cases where significant improvement occurred for at least one two-year averaged period, the average of the last monitoring period (2000-2002) is higher than the prior low value. All streams violated state water quality standards for FC at some time during the study after best management practices were implemented; Burns and Pierre violated the standards every year of the study.

A number of factors, including re-prioritization, reorganization, and staff turnover, as well as complex interagency relationships, reduced the agencies' abilities to meet original pollution-control goals, including improving land management and water quality. These factors also affected the ability to monitor land-use and land-management practices. Overall, there was an impaired ability to link water quality changes to land-management programs.

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Glossary

Animal unit	A unit of measurement for any animal feeding operation calculated by adding the following numbers: the number of slaughter and feeder cattle multiplied by 1.0, plus the number of mature dairy cattle multiplied by 1.4, plus the number of swine weighing over 25 kilograms (approximately 55 pounds) multiplied by 0.4, plus the number of sheep multiplied by 0.1, plus the number of horses multiplied by 2.0 (40 CFR Part 122, Appendix B). from: http://www.epa.gov/OWOW/NPS/MMGI/Chapter2/ch2-3.html
AU	Animal unit(s) (see definition above)
BMP	best management practice
CCWF	Centennial Clean Water Fund
cfu	colony-forming units (bacterial concentration count)
DOH	Department of Health, State of Washington
DQO	data quality objective
Ecology	Department of Ecology, State of Washington
EA Program	Environmental Assessment Program (Ecology); formerly EILS
EILS	Environmental Investigations and Laboratory Services Program (Ecology); now the EA Program
EPA	United States Environmental Protection Agency
FC	Fecal coliform bacteria. A group of bacteria used as an indicator of bacterial pollution affecting human water use.
FTE	full time equivalent (staffing level)
GIS	Geographic Information System
L	liter
MF	membrane filter
mg	milligram
mL	milliliter
MPN	most probable number
NMP	National Monitoring Program (under Clean Water Act section 319)
MRLC	Multi-Resolution Land Use Characteristics Consortium; a consortium of federal agencies; i.e., United States Geologic Survey, U.S. Environmental Protection Agency, National Oceanic and Atmospheric Administration, U.S. Forest Service, National Aeronautic and Space Administration, and Bureau of Land Management
NRCS	Natural Resources Conservation Service (formerly Soil Conservation Service), a division of the U.S. Department of Agriculture
NTU	Nephelometric Turbidity Unit. The degree of light scattered by a specific concentration of a formazin polymer
OSSS	on-site sewage system (septic system)
ROD	Record of Decision
SPI	Shellfish Protection Initiative
TCD	Thurston Conservation District
TCEHD	Thurston County Environmental Health Division
TMDL	Total Maximum Daily Load
TSS	total suspended solids
*u*S/cm	microsiemens/cm. A measure of electrical conductivity or specific conductance. A measure of the ability of a fluid to carry a charge. Related to the concentration of dissolved charged (ionic) particles. The u is actually a representation of the Greek letter μ (mu).
USDA	United States Department of Agriculture

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Executive Summary

This report is a product of the Washington State Department of Ecology's participation in the U.S. Environmental Protection Agency's Clean Water Act, Section 319, National Monitoring Program (NMP). This completes the reporting requirement for states that receive grants under the Clean Water Act, Section 319 (EPA, 1991). In March 1995, Ecology received EPA approval of the final Quality Assurance Project Plan for this monitoring project (Seiders, 1995). We started comprehensive monitoring for this effort in 1992.

The goal of the NMP is to measure the effectiveness of nonpoint-source pollution management programs at improving water quality. The goal of the Washington NMP project was to measure the effectiveness of watershed-scale, pollution-control programs at reducing bacterial contamination affecting shellfish growing areas in Totten and Eld inlets in South Puget Sound.

Totten and Eld inlets in South Puget Sound are exceptionally productive shellfish areas. Nonpoint source bacterial contamination is a significant pollution threat to these inlets (Seiders, 1999b). While forestry is a major land use in many of the inlets' drainage basins with respect to acreage, residential and agricultural development has been occurring along stream corridors and marine shorelines. Most of the agriculture is on rural-residential small farms, not full-time commercial operations. Anthropogenic sources of bacterial pollution include failing on-site sewage systems (OSSSs – or septic systems) and small-farm, livestock-keeping practices. Urban, suburban, and rural growth increases the amount of pollution threatening the water quality of these inlets. Freshwater quality standards are frequently violated. To restore and protect these inlets and streams, local and state governments combined their efforts with intent to reduce bacterial pollution from failing septic systems and livestock-keeping practices.

The NMP study area is a portion of the Totten and Eld shellfish protection area. The pollutant of concern is fecal coliform bacteria (FC), which is an indicator of human pathogenic potential. Pollutant concentration and loading are both of interest. Freshwater monitoring was carried out in six freshwater sub-basins discharging into these inlets. The sub-basins are McLane and Perry in Eld Inlet, and Burns, Pierre, Schneider, and Kennedy in Totten Inlet.

Pollution-control studies and efforts have been ongoing since 1983 in Eld Inlet and 1985 in Totten Inlet. Because of concerns over threatened shellfish areas, starting in 1993, targeted pollution-control efforts for these inlets were funded by state grants with partial matching local funds. The work was carried out by local agencies. Combined expenditure of state grants and matching local funds was roughly $1.9 million. Some conservation district work occurred prior to that, funded by the Washington Conservation Commission. Factoring this work in, total expenditures probably exceeded $2 million. Pollution-control efforts included land-management best management practices (BMPs) and OSSS surveys and remedial action.

Water quality monitoring was initiated by Ecology in late 1992, starting with a screening study to supplement earlier Thurston County water quality data, and to determine the minimum detectable change in FC needed, given the sampling frequency regimen. We continued weekly wet-season monitoring until 1995, when the NMP grant to Ecology started funding the monitoring and data analysis portions of this effort. Ecology continued to pay for laboratory costs.

Ten years of monitoring water quality were completed by Ecology in these watersheds. Parameters monitored included fecal coliform bacteria (FC), total suspended solids (TSS), turbidity, flow, temperature, and conductivity. Precipitation data were obtained from federal, local, and commercial agencies. Water quality monitoring designs used in this study were before/after paired watershed and single site (Grabow et al., 1998). Paired watershed design has the potential to tell how much water quality improvement may be attributed to pollution-control efforts in one watershed, compared to an adjacent watershed without controls. Schneider was the treated watershed, and Kennedy was the control.

Analysis was for changes in FC contamination. Effectiveness analysis for this project had previously been based on measured changes in FC concentrations. The final analysis added changes in FC loading. Other additions to monitoring and analysis since the project began were dry-season monitoring and a McLane tributary (Swift Creek); there was also limited paired *E.coli*-FC and FC-Enterococci sampling, and limited nutrient sampling.

FC levels improved at Perry and Schneider creeks, and remained lower than pre-BMP levels. FC levels remained close to or worse than pre-BMP levels at the other streams, except for a brief improvement at Burns. In all cases at the end of the study, FC levels were close to or worse than best achieved levels earlier in the study. Pollution-control efforts cannot be definitively linked to improvement at Perry, because a simple before/after monitoring design was used there; or at Schneider, because there were non-BMP land-use changes unique to Schneider that may have affected FC levels.

All streams, including Kennedy, violated state water quality standards for FC at some time during the study. All streams violated the standards during the 2001 dry season; all except Kennedy violated the standards during the 2000 dry season; all but Kennedy and Perry violated the standards during the 1999 dry season; and Burns and Pierre violated the standards during the wet seasons every year of the study and also during all four dry seasons measured at the end of the study.

The project Quality Assurance Project Plan (Seiders, 1995) and the 1996 Annual Report (Seiders and Cusimano, 1996) provide details on project design and characteristics. The 1997 Annual Report (Seiders, 1999b) provides details on pollution-control efforts through 1997. No farm data were submitted for the Totten area by Thurston Conservation District or Thurston County since that report, except for one farm that had elicited a neighbor's complaint to Thurston County. Some new data were received for the Eld grant area.

Achievement of original watershed pollution-control goals was delayed, and sustainability is in question. Washington's Department of Health recently put Lower Eld Inlet back on a list of threatened commercial shellfish growing areas (PSWQAT, 2003). Institutional structure and change appeared to have roles in reducing the ability of state and local agencies to meet these goals. Complete and accurate data on pollution-control efforts have been elusive, and completeness and accuracy of these data are in question. Tracking the installation and maintenance of agricultural nonpoint pollution controls has been hampered by lack of specific reporting requirements in grant agreements. With limited state resources, lack of adequate reporting requirements and accountability, and lack of statutory authority or political will to inspect directly, it is not possible to adequately monitor grant recipients and their progress. Rapid demographic change impairs the ability to track land-use and BMP implementation and monitoring, and may be masking the effects of BMPs. Ambiguous, conflicting, and dated land-use data also limits the ability to link land use to water quality. Overlapping BMP implementation and grants, and grant extensions, blurred the definitions of pre- and post-implementation periods, impairing the ability to link BMP or grant programs to water quality changes.

Conclusions

Freshwater FC count and loading results suggest that for Burns, Pierre, and McLane creeks, the degree of BMP installation and maintenance is inadequate, and/or that unfactored demographic change may be eroding what might otherwise be improved conditions. For Schneider and Perry creeks, where water quality improved, the ability to link the improvement to pollution-control programs is hampered by lack of a control in one case, by non-BMP land-use change in the other case, and by inadequate BMP data in both cases. If effectiveness is measured by significant lasting decreases in pollution, then the results allow the possibility of effectiveness in these two cases. In those cases where pollution decreased, it appears to be on the rise again, which suggests that nonpoint pollution-control programs need to be at least cyclical if not continuous.

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Background

Problem Statement

The nonpoint-source pollution problem of greatest concern in the Totten and Eld watersheds is bacterial contamination of highly productive shellfish growing areas. Two major concerns drive pollution-control efforts in these watersheds – restrictions on shellfish harvest from Eld Inlet and population increases and associated human activities in both watersheds which would likely result in increased bacterial contamination, leading to further restriction or prohibition of shellfish harvest.

The major sources of bacteria in the two watersheds were identified in the watershed management plans as failing on-site sewage systems and poor livestock-keeping practices. Saturated soil conditions in the wet season (November-April) reduce the ability of many on-site sewage systems (OSSSs) – also called septic systems – to adequately treat sewage effluent. Saturated soils during the wet season result in increased stormwater runoff, exacerbating water quality problems from livestock-keeping practices such as overgrazing pastures and poor maintenance of livestock holding areas. Direct livestock access to streams and poorly maintained near-shore OSSSs are year-round problems.

Background

Puget Sound is a highly productive shellfish growing area. While it is difficult to obtain consistent, accurate data on shellfish production (PCSGA, 1999), roughly half of Washington's shellfish production comes from Puget Sound. Data from 1993 and 1997 indicate Puget Sound harvest was about $34 million. Totten and Eld Inlets, located in southern Puget Sound (Figure 1), are highly productive shellfish rearing areas (Determan, 1993; Hofstad and Tipton, 1998). These inlets produce most of Washington's manila clams and also contribute to Puget Sound's pacific oyster production (Seiders, 1999b). Totten-Little Skookum and Eld inlets produced 7% of the state's shellfish in 1990, 9% in 1995, and 11% in 2000 (WDFW, 2003).

Nonpoint source bacterial contamination is a significant pollution threat to these inlets (Seiders, 1999b). While forestry is a major land-use in many of the basins with respect to acreage, residential and agricultural development has been occurring along stream corridors and marine shorelines (Table 1, Figure 2, and Figure 3). Most of the agriculture is on rural-residential small farms, not full-time commercial operations. The two watersheds each have over 100 of these small farms. The farms are typically less than 20 acres, and keep several large animals, such as horses, cows, and llamas; some have flocks of food birds (e.g. chickens, ducks, and turkeys). Anthropogenic sources of bacterial pollution include failing OSSSs and small-farm livestock-keeping practices (Hofstad, 1993; Seiders, 1999b). Freshwater quality standards for fecal coliform bacteria (FC) are frequently violated. Turbidity standards also appear to be violated.

Commercial shellfish harvest areas are monitored by the state's Department of Health (DOH) for bacterial contamination and sanitary conditions, in accordance with federal Food and Drug Administration guidelines. FC contamination is monitored by routine periodic sampling in the marine waters where shellfish are harvested. Sanitary surveys may include evaluating shoreline and upland areas for actual and potential pollution sources, examining hydrologic factors and their effects on water quality, and routine FC monitoring results from the shellfish growing waters (FDA, 1995). The DOH shellfish harvest area classification system is shown in Table 2.

Shellfish Harvest Restrictions

Contamination of shellfish harvest areas by fecal coliform bacteria led to restricted harvesting in more than 40% of Puget Sound's previously certified areas (Seiders and Cusimano, 1996). As of 2000, there was restriction of one kind or another on about 25% of Puget Sound's commercial shellfish harvest areas (PSWQAT, 2001a); much of the increase in total acreage available for direct harvest was achieved by the addition of previously unclassified areas (PSWQAT, 2001b). As of 2002, 23% of Puget Sound's commercial shellfish harvest areas were restricted (Melvin, 2002).

Totten Inlet is currently classified by DOH as *approved* for shellfish harvest, except for the southern-most portion which was reclassified from *conditionally approved* to *unclassified* in 2000, and a small portion at Burns Cove which was reclassified from *approved* to *unclassified* in 2002 partially based on results from this study (Figure 2 and Figure 3). The area is considered threatened by bacterial nonpoint-source pollution.

Most of Eld Inlet is classified as *approved*. 690 acres in the southern portion of Eld Inlet were downgraded to *conditionally approved* in 1983; the conditional classification required that the area be closed to shellfish harvesting for three days following a rainfall of 1.25 inches or more in the previous 24 hours. 450 acres of this area was reclassified in 1998 to *approved*; the southern-most 240 acre portion was changed to *unclassified*, and remains so at this time (Melvin, 2002). This could be viewed as a downgrade, but may not be an issue if no one wants to harvest commercially in the area regardless of sanitation. There have been no commercial shellfish harvest requests for the aforementioned *unclassified* areas in Totten and Eld inlets (Berbells, 2002). Eld Inlet is still considered threatened by bacterial nonpoint-source pollution sources.

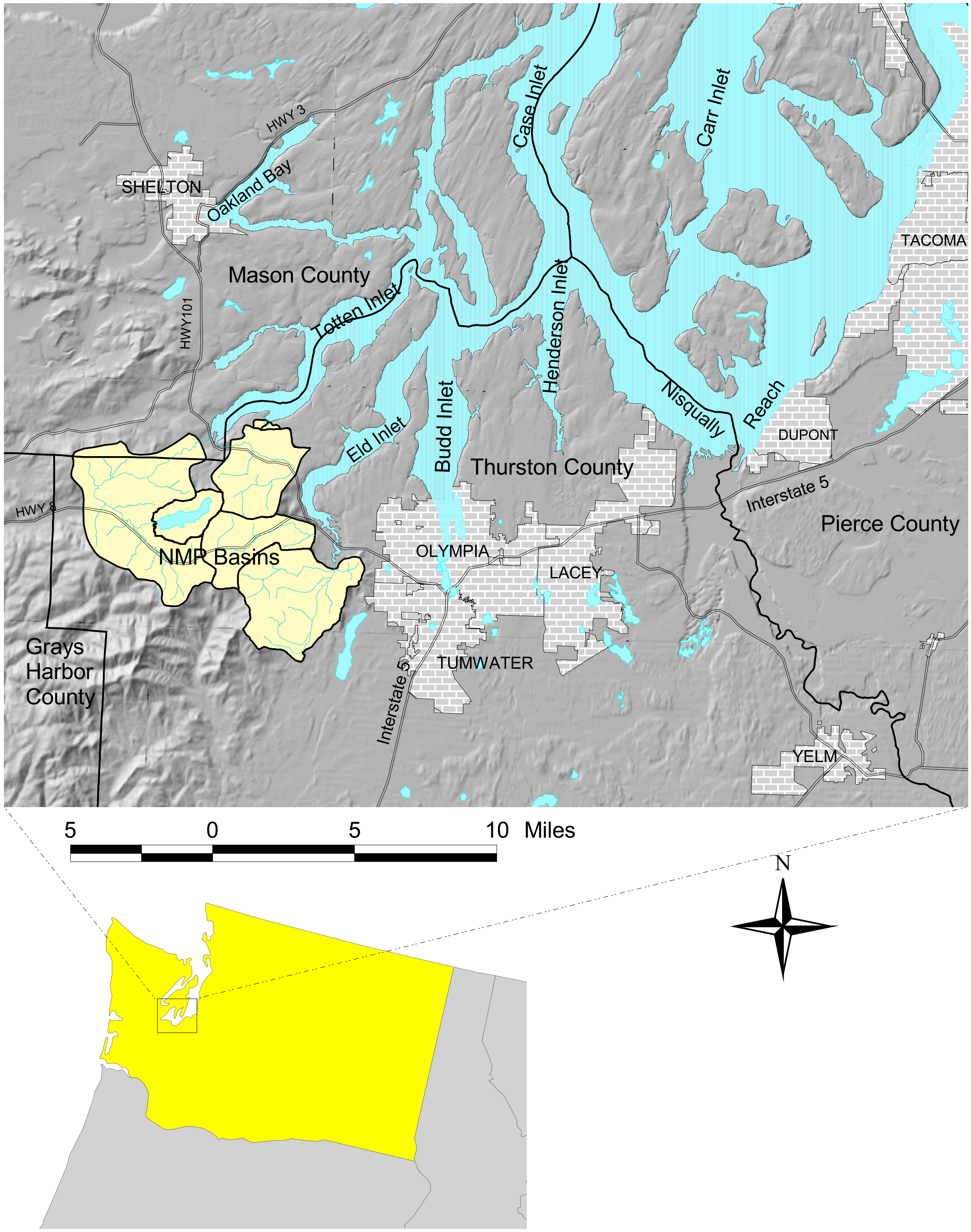

Figure 1. Location of study basins

Table 1. Land-use characteristics in the study basins

Assessor's Land-use Category *(% of area)*	Kennedy	Schneider	McLane	Perry	Burns	Pierre
residential	4%	8%	9%	3%	37%	34%
undeveloped residential	5%	15%	14%	11%	26%	35%
agriculture	0%	7%	4%	2%	36%	26%
forestry	84%	65%	71%	80%	0%	0%
commercial/public/other	5%	1%	1%	0%	0%	0%
roads	2%	3%	1%	4%	1%	5%
Total Acres	13,046	4,588	7,425	3,857	82	65
Potential Sources of FC Bacteria						
number of farm sites (est.)	3	26	43	8	3	2
wet season (Nov.-April) animal units (est.)	1	93	142	44	8	5
number of on-site sewage systems (est.)	21	118	295	57	13	9
% basin stream length through BMP sites	0%	28%	10%	6%	100%	53%
% basin stream length through other ag sites	1%	0%	8%	6%	0%	0%
% basin stream length through non-ag sites	99%	72%	82%	88%	0%	47%

Note: Land use areas based on Thurston County Assessor's 1995 tax designations, not true land cover.
Area data are from the Thurston County Assessor's data base through Thurston Geodata Center.
Number of farm sites, animal units, and on-site sewage systems data are from 1996 TCD and TCEHD data

Table 2. DOH shellfish harvest area classification system

Commercial

Approved (Open): Commercial harvest areas where evaluations of local pollution sources (sanitary surveys) and bacteriological water quality data show that fecal contamination and other harmful substances are not present in unsafe concentrations.

Conditionally Approved (Conditional): Commercial harvest areas that meet the criteria for an Approved area, but only during times of low or no rainfall.

Restricted: Commercial harvest areas where bacteriological water quality does not meet the standard for an approved classification, but a sanitary survey reveals sources of pollution that are not primarily from human sources.

Prohibited (Closed)*:* Commercial harvest areas where fecal contamination, pathogenic microorganisms, and other harmful substances might be present in unsafe concentrations.

Unclassified: Commercial harvest is not allowed. These are areas where there have been no requests for commercial shellfish harvest. They may be polluted or unpolluted; they are not tested for FC levels on a regular schedule as harvest areas are.

Recreational

The classification system is similar to the commercial classification. The notable exception is that ***Unclassified*** beaches are those where no formal assessment has been conducted. Only about 10% of recreational beaches have been classified, because high-use beaches located near potential harvest areas have top priority for classification.

Source: (DOH, 2002c)

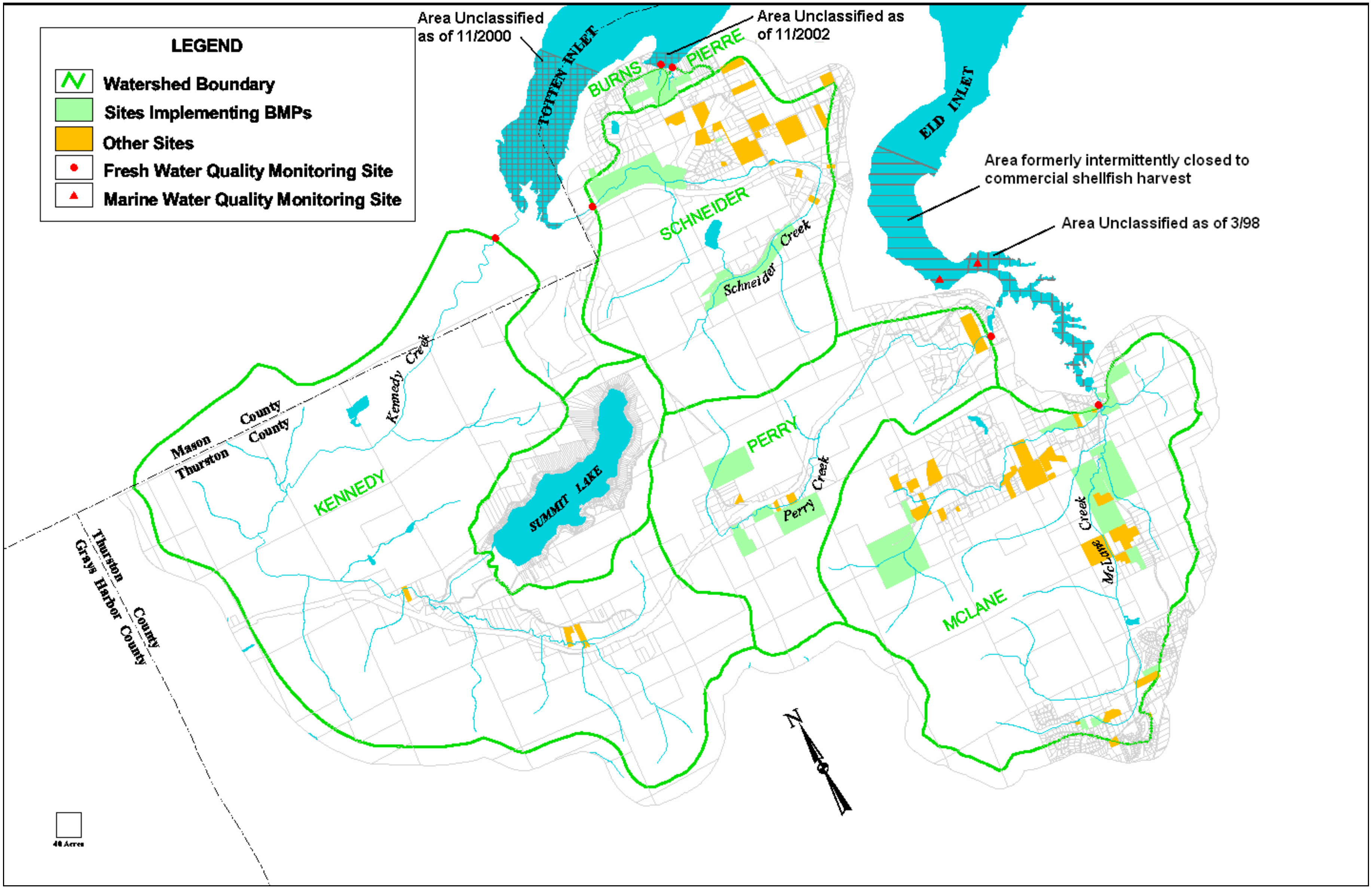

Figure 2. Land-use characteristics of study basins: Thurston County Assessor's 1995 Data

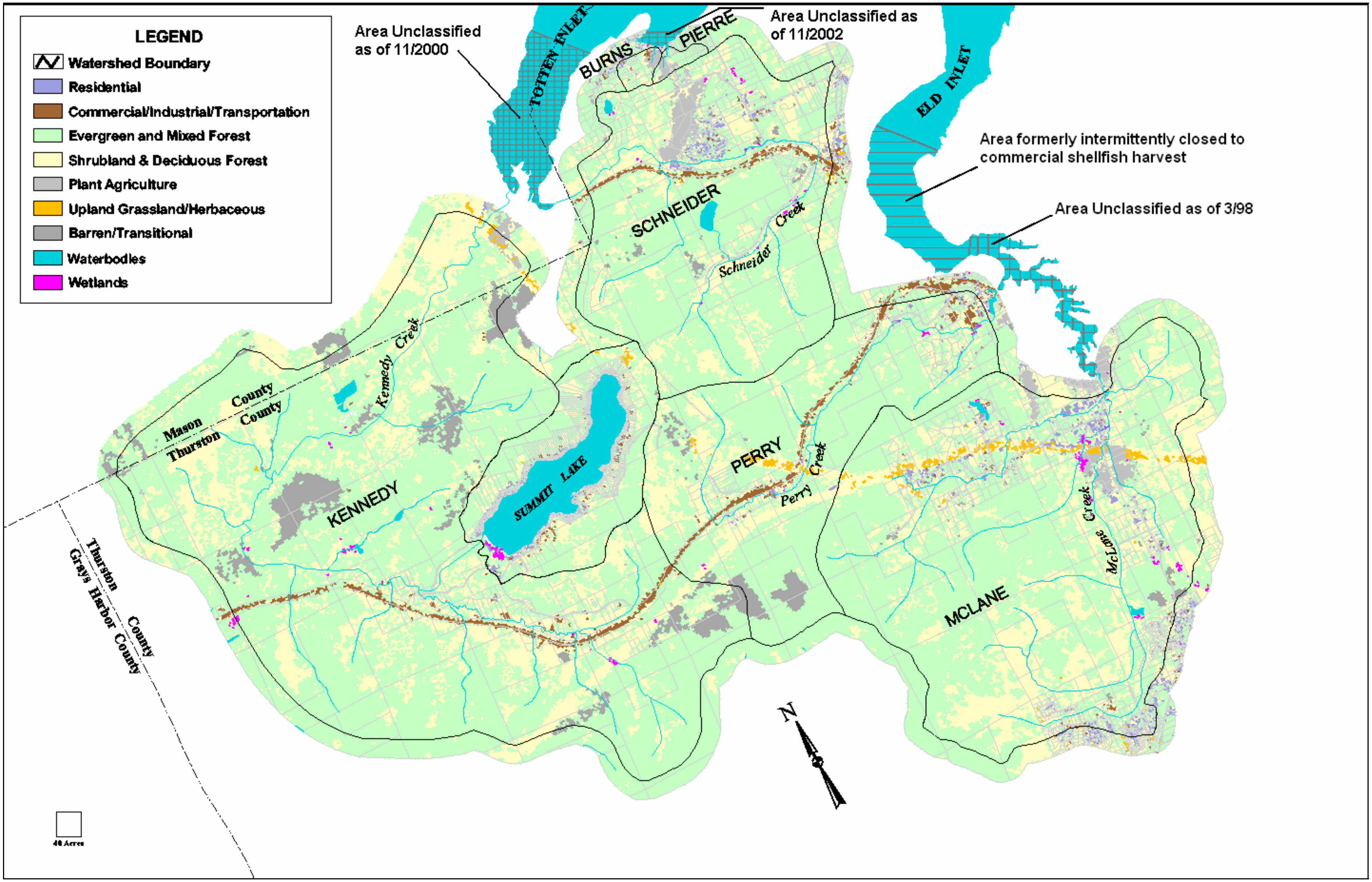

Figure 3. Land-use characteristics of study basins: 1992 MRLC NLCD data (USGS, 1992)
MRLC = Multi-Resolution Land Characteristics Consortium, NLCD = National Land Cover Data; see glossary for details

Pollution-control efforts

Pollution-control efforts in Puget Sound gained momentum in the mid to late 1980's after several shellfish growing areas were restricted or closed for shellfish harvesting. Closures resulted from high water-column fecal coliform bacteria concentrations and other sanitary conditions not meeting national health standards for shellfish rearing areas.

The creation of the Puget Sound Water Quality Authority, and funding mechanisms such as the Shellfish Protection Initiative and the Centennial Clean Water Fund enabled local governments to develop community-based watershed planning programs. The local planning efforts identified pollution problems and recommend management measures to control pollution within specific watersheds.

Farm management shellfish pollution-control efforts for these inlets were funded by land-owner assessments and state grants with partial matching local funds; this work was carried out by Thurston Conservation District. Grants were from the Shellfish Protection Initiative, the Centennial Clean Water Fund, and the Washington Conservation Commission. The Shellfish Protection Initiative grants also paid for on-site septic system inspections and dye-tracing; this work was carried out by Thurston County Environmental Health Division. Combined expenditure of state grants and matching funds within Totten and Eld inlets from 1993 was roughly $1.9 million. Some conservation district work occurred prior to that, funded by what was then a new assessment. Factoring this work in, total expenditures probably exceeded $2 million. An overview of the pollution-control grants and the National Monitoring Program (NMP) grant is shown in Figure 4. Pollution-control efforts included land-management best management practices (BMPs), and on-site sewage system (OSSS) surveys and remedial action.

Prior to the Centennial Clean Water Fund grant, Thurston County Environmental Health Division obtained three Clean Water Act Section 205(j) grants through the Washington State Department of Ecology. The grants were primarily for water quality studies, but there were elements of corrective actions, including referral of septic system failures, referral of animal-keeping and pasture-management problems to the U. S. Soil Conservation Service, and development of a recreational shellfish program (Hofstad 2003b).

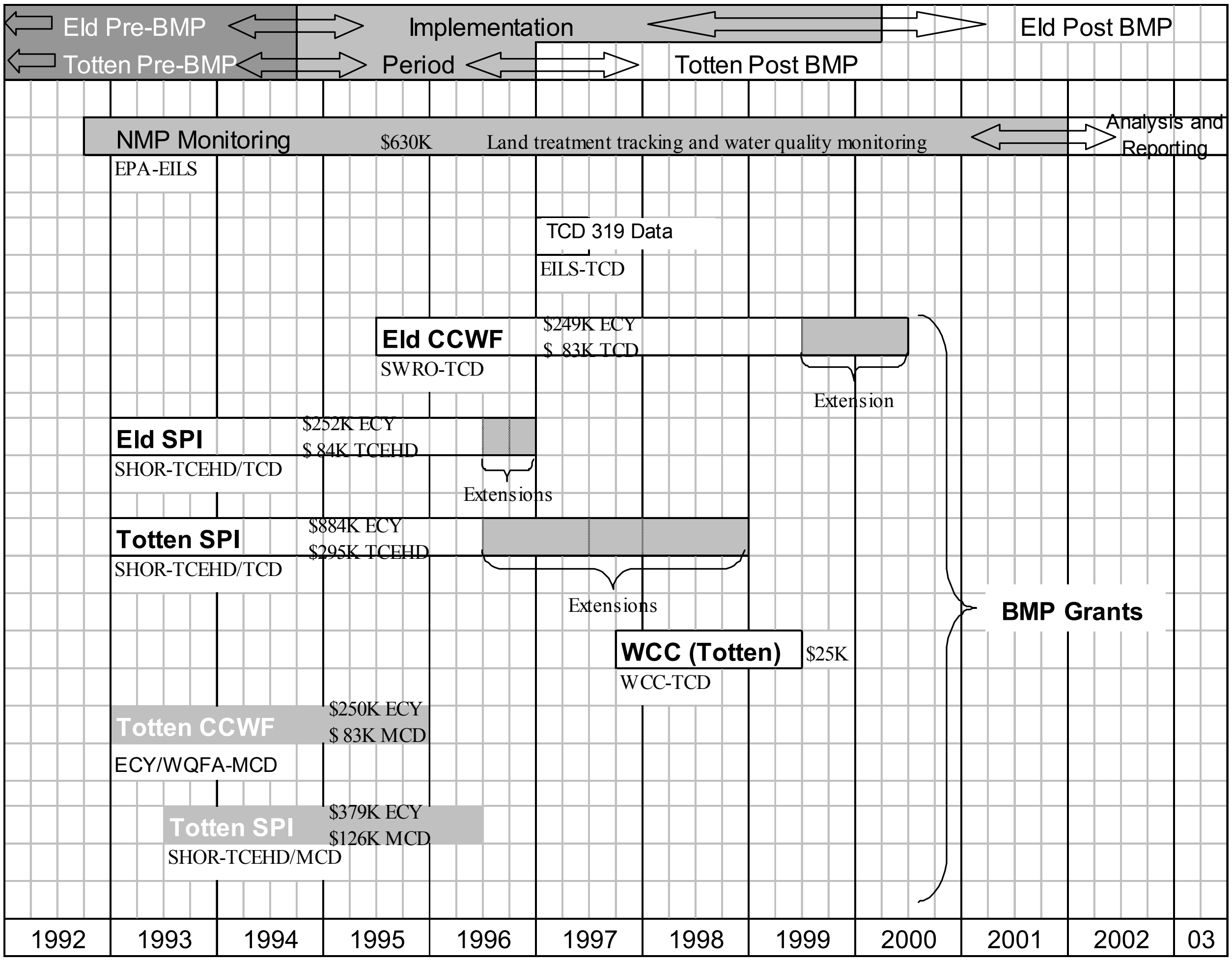

Figure 4. Grant funding timeline

		Grantor/grantee designation
EPA:	U.S. Environmental Protection Agency	grantor
ECY:	WA State Department of Ecology	grantee from EPA, grantor to TCEHD and TCD
WCC:	WA Conservation Commission	grantor
EILS:	Environmental Investigations and Laboratory Services; Now Environmental Assessment (EA) Program A division of the Department of Ecology	grantee
SHOR:	WA Ecology's Shorelands Program	grant initiator for ECY
SWRO:	WA Ecology's Southwest Regional Office	grant manager
TCEHD:	Thurston County Environmental Health Division	grantee from ECY, grantor to TCD
TCD:	Thurston Conservation District	grantee
MCD:	Mason Conservation District	grantee
CCWF:	WA Centennial Clean Water Fund	
SPI:	Shellfish Protection Initiative	

The bottom two timelines are for grants to Mason Conservation District for Totten Inlet. They are included here so the total shellfish protection effort for Totten Inlet can be seen; although any work resulting from these grants did not overlap the NMP sub-basin study areas. We do not have enough complete or accurate land-management data to tell how much of the money from these grants was spent within the NMP study area.

Demographic Change

Urban, suburban, and rural growth exacerbates the threat to water quality in these inlets. The rural nature of the area has made it an attractive place to live. Consequently, stream corridors and shorelines, particularly in northern Thurston County, have experienced considerable residential development in the past decade, and population pressures continue to increase. In 1990, Thurston County was ranked as the third fastest growing county in Washington with a population increase of nearly 30% since 1980 (Seiders and Cusimano, 1996). Between 1990 and 2002, population grew 16% within the Totten watershed and 24% within the Eld watershed (raw data from TRPC, 2002). One conservation district employee noted that property ownership turnover had been very high in the McLane sub-basin of the Eld Inlet watershed (Mead, 1999). Thurston County growth is projected at 51% from 2000 to 2020 (OFM, 2002).

National Monitoring Program in Relation to Totten and Eld Inlets

In 1992, the Department of Ecology initiated a monitoring program to evaluate the effectiveness of remedial land treatment practices on water quality. This monitoring effort was formalized in 1995 into an EPA Section 319 National Monitoring Program (NMP) project, funded by EPA. The NMP was established by EPA to evaluate water quality benefits from nonpoint-source pollution-control efforts nationwide. State or local nonpoint source-control projects were selected for long-term monitoring using EPA criteria specific to the NMP (EPA, 1991).

After reviewing nonpoint-source control projects in the Puget Sound and Chehalis River Basins, Ecology's Environmental Investigations and Laboratory Services Program (now Environmental Assessment Program) selected six sub-basins within the Totten-Little Skookum and Eld Inlet watersheds for this monitoring program. Substantial nonpoint source-control efforts were planned for the Totten-Little Skookum watershed between 1993 and 1996 through the state-sponsored Shellfish Protection Initiative. Basins within the adjacent Eld Inlet watershed would receive little source-control effort initially, but efforts were increased from 1996 to 1999.

The goal of the monitoring program was to monitor water quality over time to measure the effectiveness of pre-existing watershed-based, land-management programs. The question being asked is: How effective were the larger watershed pollution-control programs in reducing pollution in the six monitored sub-basins? Water quality monitoring was conducted from mid-November to mid-April on a weekly basis for at least 22 consecutive weeks each year. Fecal coliform bacteria was the pollutant of interest. Stream flow was measured and samples were also collected for suspended solids, turbidity, and conductivity; rainfall data were obtained from other agencies. Farm-plan BMP implementation was compiled from information provided by the Conservation districts. Ecology's NMP staff did not have control over any aspect of farm planning or BMP design, implementation, or monitoring.

Relationships of the agencies involved in pollution-control grants and monitoring efforts are shown in Figure 5.

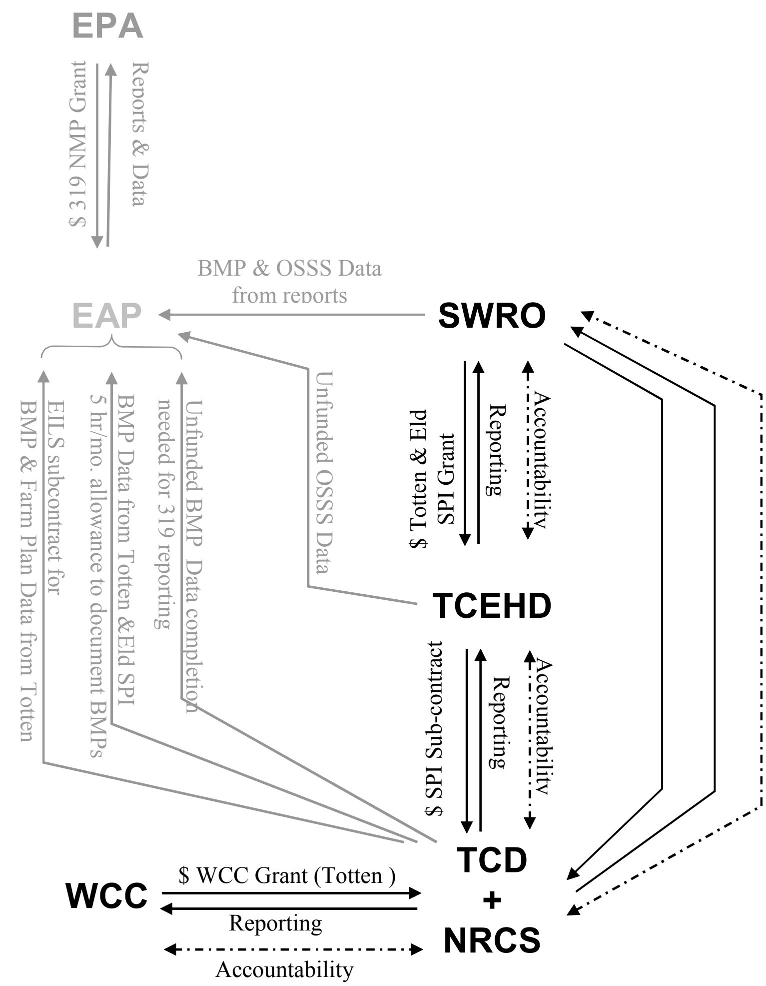

Figure 5. Agency and grant relationships

Gray images relate to monitoring; black to BMP work. Dashed lines associated with the word "Accountability" indicate weak points in tracking BMP implementation and performance.

EAP:	Environmental Assessment Program (a division of the Department of Ecology)
EPA:	U.S. Environmental Protection Agency
CCWF:	Centennial Clean Water Fund
NRCS:	National Resource Conservation Service
SPI:	Shellfish Protection Initiative
SWRO:	Southwest Regional Office (Department of Ecology)
TCD:	Thurston Conservation District
TCEHD:	Thurston County Environmental Health Division
WCC:	Washington Conservation Commission

Note that this is a snapshot in time; the full picture is more complex. Originally SPI grants were administered by the Ecology Shorelands Program Shellfish Protection Unit, which was dissolved under Ecology reprioritization and reorganization. The grants were transferred to the Water Quality Financial Assistance Program; grant managers were subsequently regionalized and became permit managers in addition to handling existing grant-management loads. Grant management has changed hands, as has water quality monitoring management. TCD staff turnover has been high. In March 1999, there were 19 employees including managers. Over the following year, five people who left where listed as managers at time of departure. By March 2000, seven original employees remained out of a total staff of fifteen. Of the eight new employees, there had been thirteen hires and five departures. (TCD, 2003).

Nonpoint-Source Pollution Management

Watershed action plans were completed for Eld and Totten inlets by the Eld Watershed Management Committee (1989) and the Totten-Little Skookum Watershed Management Committee (1989). The management plans were developed by local citizens, interested parties, and local and state government. The planning effort identified potential nonpoint sources of pollution and recommended management measures to prevent or mitigate pollution. The plans had goals and recommendations; timetables were general (e.g. short-term, long-term); costs, funding, and responsible agencies were identified; but other than reporting directives, there were no criteria or minimum elements that had to be met. Although public involvement and planning occurred subsequent to completing the management plans, until 1993 only limited resources were available to implement pollution controls.

Funding to implement pollution controls in Totten and Eld Inlet watersheds during the course of the NMP study came from Washington's Centennial Clean Water Fund (CCWF), the Washington Conservation Commission; and most of the funding came from the Ecology-funded Shellfish Protection Initiative (SPI). State and local groups developed the SPI in response to increased and persistent closures of shellfish harvest areas and threats to close additional areas. This program provided $3 million state-wide from State Referendum 39 funds for implementing management measures in targeted watersheds. These monies were a one-time source only.

The Totten-Little Skookum watershed received $1.3 million in grant funds as part of the SPI. Eld Inlet was not selected as an SPI project, but received $260,000 from the SPI program to augment ongoing source control efforts in specific areas. An additional $331,000 from the CCWF, awarded in 1994, targeted to farm planning and implementation activities in the Eld watershed from 1996 to 1999; this grant was later extended to mid-2000. Money for cost sharing or low interest loan contracts for site-specific management measures came from the SPI, the CCWF, the Farm Service Agency, the State Revolving Fund, and the U.S. Fish and Wildlife Service.

Implementing nonpoint-source pollution controls in Totten and Eld watersheds involved private citizens and local, state, and federal agencies including Thurston County Environmental Health Division (TCEHD), Thurston Conservation District (TCD), the Natural Resource Conservation Service, Washington Department of Health (DOH), Ecology, the Puget Sound Water Quality Authority, and EPA.

The major objective of managing nonpoint-source pollution in the study basins was to reduce the sources of pollution by repairing failing on-site sewage systems and implementing resource management plans (farm plans) on priority farm sites. Priority farm sites were those farms that potentially threatened the quality of receiving waters due to their physical location or known management problems such as animal access to a stream, large numbers of animals, and lack of adequate pollution controls. Generally, management measures involved surveying all potential sources of pollution in critical areas, estimating the water quality impact, and then planning and undertaking corrective actions.

In the study basins, TCD was the lead agency involved in prioritizing farm sites and developing farm plans. TCD conducted pollution-control education and outreach efforts, and developed farm plans with cooperating land owners. Farm plans addressed property resources and potential water quality impacts, and prescribed best management practices (BMPs) such as pasture and grazing management, livestock density reduction, animal waste management, stream fencing, and establishing stream buffer zones. Implementation of farm plans was voluntary in most cases. When the SPI grants were developed, there was intent to use state and local laws to encourage land owners to implement pollution controls.

These management strategies were typical of shellfish protection efforts occurring in Puget Sound as well as other coastal areas of Washington. Because bacterial contamination affects an important commercial and recreational industry, as well as a cultural identity, substantial efforts were expended to combat the problem. This document describes monitoring to evaluate the effectiveness of nonpoint pollution management programs in reducing fecal pollution in freshwater sub-basins within the Totten and Eld Inlet watersheds.

Water Quality Goals

The goal of the SPI was to reopen harvest-restricted growing areas and protect threatened, highly productive areas within a three-year time period; i.e., by 1996. SPI activities in Totten-Little Skookum were designed to protect the shellfish harvest classification in the inlet through nonpoint source controls. Success in achieving this goal would be determined by avoiding shellfish harvest restrictions in presently open areas (Totten Inlet) or the upgrade in shellfish harvest status of restricted areas (Eld Inlet) over three years. Shellfish harvest status is determined by DOH through a water quality monitoring program designed for human health risk assessment.

The NMP monitoring program required a more direct indicator of water quality improvement, and developed the quantitative water quality goals indicated in Table 3. The goals were set for five freshwater streams discharging into Totten and Eld inlets; they represented the estimated minimum detectable change in fecal coliform concentrations and were developed from the 1992-93 season monitoring results. This is the minimum change required before it is likely to be deemed statistically significant. The estimation technique is discussed in the Quality Assurance Project Plan (Seiders, 1995).

Table 3. Water quality median fecal coliform bacteria reduction goals

Stream	Reduce median FC concentrations by
Burns	63% (from 54 to 20 cfu/100 mL)
Pierre	69% (from 32 to 10 cfu/100 mL)
McLane	44% (from 39 to 22 cfu/100 mL)
Perry	60% (from 10 to 4 cfu/100 mL)
Schneider	50% (from 20 to 10 cfu/100 mL)

Originally Perry Creek did not have a median reduction goal. McLane was to be monitored in relation to Perry as a control. Loss of Perry as a control (residents wanted to implement BMPs) meant that Perry would need to be evaluated independently. A sixth stream, Kennedy Creek, was monitored as a paired control for Schneider Creek.

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Monitoring Methods

Site Selection

Ecology's Environmental Investigations and Laboratory Services (now named the Environmental Assessment Program) monitored multiple watersheds during the 1992-93 and 1993-94 wet seasons in order to evaluate the suitability of sites for long-term monitoring. The sites needed to be in an area where there was a nonpoint-source pollution problem that was being or would be addressed by watershed-based, pollution-control efforts. There had to be the potential to measure significant change in water quality, and to track land-use and farm-management changes. Six streams were selected. Physically these were three pairs; the members of each pair were adjacent, discharged close to the same point in an inlet, and had similar physiography and hydrogeology.

Site Location

Figure 6 shows the locations of the sampling sites. Geospatial data are shown in Figure 4.

Table 4. Sampling site locations

Creek	Station Description	County	WRIA	Latitude	Longitude
Burns	On the beach, just below Oyster Bay Rd.	Thurston	14	47.1064	123.0430
Pierre	About 80 M upstream from beach above Oyster Bay Rd.	Thurston	14	47.1051	123.0408
Kennedy	About 125 M upstream from the Old Pacific Highway bridge	Mason	14	47.0942	123.0921
Schneider	Below the house at the end of Pneumonia Gulch Rd.	Thurston	14	47.0923	123.0693
McLane	Under the bridge at Delphi Rd. (flow)	Thurston	13	47.0319	122.9898
McLane	About 100 M downstream from the bridge at Delphi Rd. (water quality)	Thurston	13	47.0323	122.9894
Perry	About 400 M up Perry Creek Rd., just below the foot bridge	Thurston	14	47.0491	123.0040
Swift	About 3 M above discharge into McLane Creek, just above bridge at Delphi	Thurston	13	47.0315	122.9898

Despite the fact that the Kennedy Creek sampling site was in Mason County, most of the Kennedy watershed is in Thurston County. Swift Creek is a major tributary to McLane; sampling started in the summer of 2000 because it was felt the data would be needed for a McLane total maximum daily load (TMDL) effort. Two sites are listed for McLane; one is for water quality samples, and the other is for flow.

Water Sampling and Flows

Sampling was conducted weekly. Starting in 1992, sampling occurred from early November to mid-April each year. Sampling was usually done on Tuesdays, but occasionally the schedule was pushed a day early or late for logistics reasons. A minimum of 22 sampling events occurred each wet season. Starting in the fall of 1998, weekly sampling was added five to six weeks earlier and later each season, and at a lower frequency during the summer. Pre-1992 fecal coliform (FC) data obtained from Thurston County Environmental Health Division were collected at a lower frequency, and the analysis method was most probable number (MPN).

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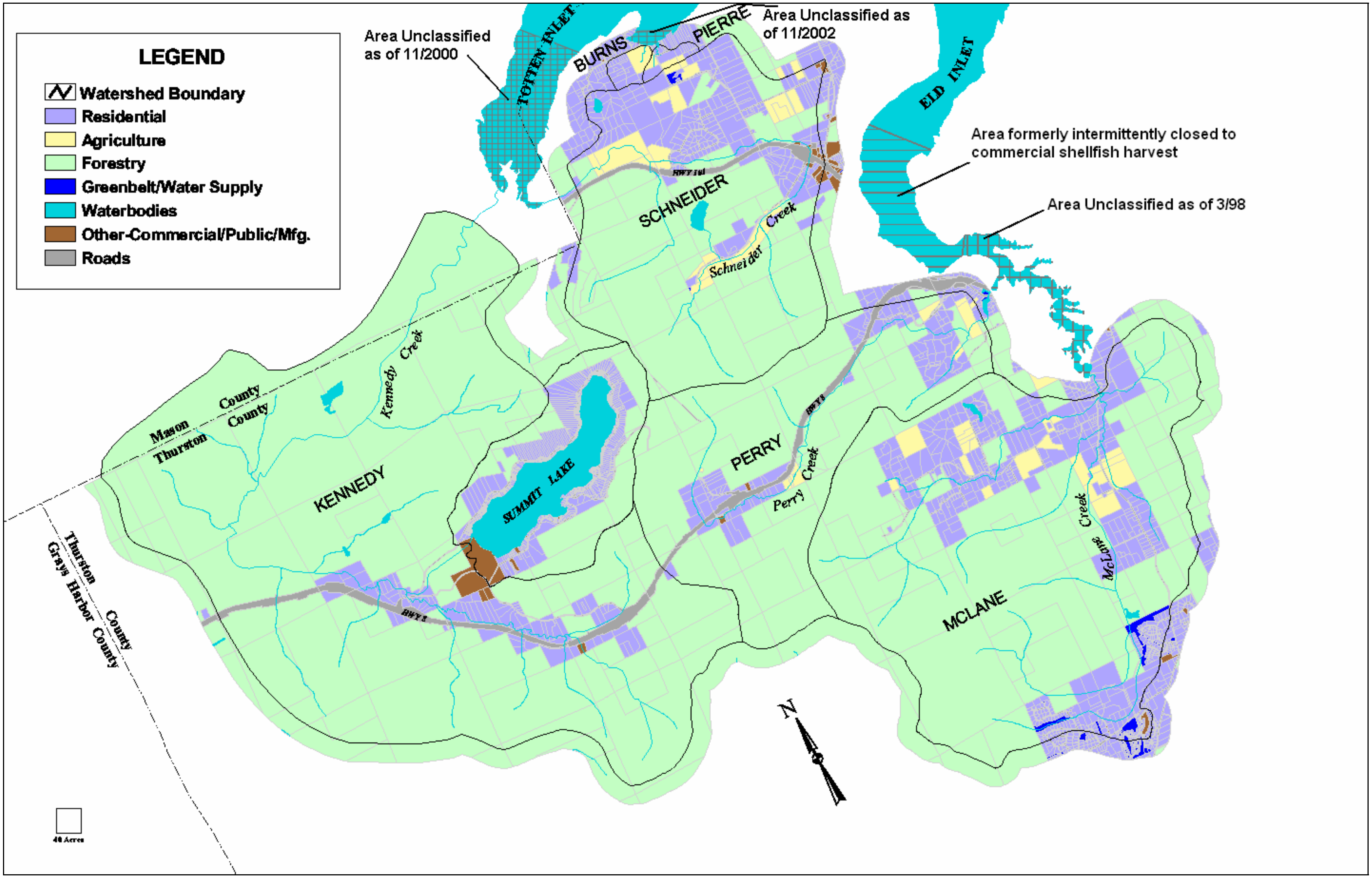

Figure 6. Farm sites in study basins: Assessor's 1995 data

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Sample collection

Monitoring was for fecal coliform (FC) bacteria, total suspended solids (TSS), turbidity, conductivity, temperature, stream water level (stage), and flow. Samples were collected for FC, TSS, turbidity, and conductivity. All were sub-surface grab-samples, except in a few cases at very low flow, when surface-grabs and/or composite samples were needed to obtain enough analyte; FC was never composited. All samples were taken to a field van and stored in ice for transportation to Ecology's Manchester Laboratory for analysis, except conductivity was measured in the van using a Beckman Solu-bridge Model RB-5 conductivity meter. Maximum holding time for bacteria was 30 hours until November 2000 when allowable holding time changed to 24 hours. Other holding times were 48 hours for turbidity, and seven days for TSS. Bacteria were cultured and counted using the membrane-filter method. Laboratory analytical methods are listed in Appendix A.

Field duplicate samples (two samples taken consecutively at the same location) were taken at one site each outing, resulting in duplicates for one out of each six regular samples. Usually, the field duplicate sample was split by Manchester Environmental Laboratory and two aliquots were analyzed as part of the laboratory's quality assurance protocols. A few exceptions occurred where samples other than the field duplicates were split at the laboratory.

Stream flow

Flow was measured by wading in-stream with a wading rod and a Marsh McBirney flow meter with a Hall-effect flow sensor. By and after fall 1998, all readings were done with model 2000, with rare exceptions. These exceptions and earlier readings were done with models 201 and 201D. At least 21 cross-sectional depth/width/flow measurements (20 segments) were considered desirable at each stream. At each point, flow was measured at 60% depth as measured from the surface, except when stream depth exceeded two feet and flow was judged to be laminar and unstratified. In cases where depth exceeded two feet, and at shallower depths when the flow appeared stratified, two readings would be taken at 20% and 80% depth, and averaged. In cases of extreme stratification, the 20/80 average would be averaged with a third reading at 60% depth. Integration time for readings could be as low as 20 seconds for very smooth steady flows, and as high as the average of two or more 30-second readings under unsteady conditions. Depth, width, and flow measurements were used to calculate overall stream flow in cubic feet per second, via the USGS method outlined by Cusimano (1993).

Stream stage

Stream stage was recorded whenever possible at each visit by reading fixed staff gauges; when direct flow measurement was not possible, rating curves were used to estimate flows. Sometimes inter-basin flow relationships had to be used. Unidata 1M depth capacitive probe and data-logger recording hydrographs were in place at all streams except Burns, to measure stage continuously (readings 30-minutes apart), except where equipment failed for unknown reasons, or flooding damaged equipment or otherwise resulted in unreliable readings. Burns did not get a stage recorder because there was no place to secure one that would not be damaged by salt water at high tide. It was assumed that Burns' continuous flow could be correlated with Pierre's, since the two sub-basins are right next to each other, and very small in size. However, it turned out that Pierre stream depth was frequently tidally influenced, so continuous stage could not be used to calculate continuous flow with the equipment used (Rantz, 2001). Thurston County's recording hydrograph on McLane Creek was used with inter-basin flow relationship curves to fill in continuous-flow data gaps when possible for the other streams.

Special sampling and flow considerations: Burns and McLane creeks

Two sites are listed for McLane because water quality samples needed to be taken downstream from the Swift Creek discharge area to allow adequate stream mixing. The downstream site was not suitable for measuring flows or establishment of a stream gauge or recording hydrograph, whereas the upstream site was suitable. Flow where measured was considered to be representative of downstream flow at the sampling point. At times, because of extremely high or low flow conditions, samples or flows had to be obtained up or downstream from the regular sampling sites at other streams; but, with the exception of Burns, the alternate sites were judged to be comparable to the regular sites. The Burns sites, while only about 30 feet apart from each other, were judged likely to differ because of high ground permeability (sand), and tidal marine influence. Periodic sampling at both up and downstream sites was used to establish a fecal coliform (FC) correction factor; and a Manning's roughness coefficient was established to maximize agreement between Manning's formula calculated flow and concurrently measured stream flow.

Rainfall

At the onset of this project, it was assumed that the Olympia Airport weather station would be representative of rainfall in the sub-basins, but this assumption was not tested. Rainfall daily average data for the Olympia Airport were obtained from NOAA (2002). Later, to test the assumption of representativeness, we compared Olympia Airport rainfall to rainfall at the Shelton Qirport (NOAA, 2002), and Green Cove and Summit Lake (Thurston County Storm and Surface Water Program, 1999). The last year of the study, we placed rain gauges at all NMP six sub-basins, as near as possible to the sampling sites, but as out in the open as possible to avoid rain-shadow effects from trees.

Additional Water Quality Sampling and Monitoring

Bacteria

In addition to FC, we sampled enterococci and *E. coli* in 1993 to "Evaluate applications of state and federal water quality criteria for fecal coliform, enterococcus, and *E. coli*" (Seiders, 1992). We sampled enterococci again from October 2000 through December 2001 because Ecology was considering changing its indicator for pathogenic potential from FC to enterococci, and wanted to run dual-sampling so there would be some basis for comparison later. However, Ecology later proposed *E. coli* as a substitute for FC, so enterococci sampling was discontinued. Laboratory analytical methods are listed in Appendix A. The data are available in Ecology's EIM data base, and are not published in this report, because they have no direct bearing on this NMP effort.

Nutrients and dissolved oxygen

Nutrient samples were collected monthly during NMP runs between October 1998 and September 1999 for Ecology's South Puget Sound Model Nutrient Study. Laboratory analytical methods are listed in Appendix A. Dissolved oxygen was measured monthly December through March of each wet season[1], except it was measured December through September during the 1998-1999 season. A YSI model 57 meter was used for direct in-stream measurement. This instrument was determined to have a precision of +/-1.0 mg/L by calibration against the azide-modified Winkler titration method (Sargeant, 2000). The nutrient and oxygen data are available in Ecology's EIM data base, and are not published in this report, because they have no direct bearing on this NMP effort.

Land use and land management

Data were collected by a variety of means through several sources. These included quarterly reports from Thurston Conservation District (TCD), interim and final reports from TCD and Thurston County Environmental Health Division (TCEHD), specific data requests from the NMP project manager to TCD and TCEHD, data base mining from the Thurston County Assessor's Office and Thurston GeoData Center, and use of GIS data available through Ecology's Information Services GIS team.

Land use classification is maintained by the Thurston County Assessor's office and is updated on an annual basis. Some of these data were obtained directly from the Assessor's Office, and some were obtained through Thurston GeoData Center. Type and extent of agricultural land use was to be updated by TCD on an annual basis. TCD quarterly and final reports on grant work completed were to include such things as manure management, stream buffers, and pasture management implemented. On-site sewage systems were to be surveyed by TCEHD once during the lifetime of the grant.

Some of the data came to the Ecology NMP project manager through Ecology's regional office, and some were conveyed directly. Data were to be obtained as scheduled in Appendix A. In practice, the schedule was not adhered to closely, at least in part because of the complexity of inter-agency relationships (Figure 5) combined with organizational and staff changes over time, and in part because of the lack of clear reporting requirements in the pollution-control grants.

[1] For Thurston County Environmental Health Division

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Water Quality Data Analysis Methods

General

Exploratory data analysis involved bar graphs, notched boxplots, and trend lines of data in order to get an overall picture of annual values, trends, and stream comparisons. Bar graphs were created using Excel® commercial software, and notched boxplots and trend lines were created using Systat® commercial software. The trend lines are simple regression trend lines of scatterplots of pollutant vs. date for defined periods of analyses.

Boxplot definitions differ among statistical software (Frigge et al., 1989). The Systat® method uses the Tukey (1977) definition as follows: The horizontal line or narrowest box width near the center of the box corresponds to the median of the distribution. The top and bottom edges of the box correspond to the 25th percentile (first quartile) and 75th percentile (third quartile) of the data. The interquartile range (IQR) is the distance between the third and first quartiles. Stars are used to mark observations beyond 1.5·IQR from either side of the box. These are considered to be minor outliers. Circles mark major outliers that have values beyond 3·IQR from either end of the box. The lines, or whiskers, drawn from the top and bottom of the box extend to the most outlying value within 1.5·IQR from the ends. The notches in the sides mark the confidence intervals for the median (McGill et al., 1978). In comparing two boxplots along the same scale, if the intervals around two medians do not overlap, the two population medians can be considered different with about 95% confidence.

How to deal with statistical outliers is an area of concern. If these are false values, they ought to be discarded; but if they are true, they need to be retained, or the data set will be biased. In all cases where high FC counts were accompanied by duplicate field samples and lab splits, the duplicates confirmed that the values were really high, so none of the high-count data were discarded whether or not duplicates were available to confirm the results. To be confident in all cases would require duplicate field sampling and lab splits for all regular samples.

Significance is also an area of concern. As noted by Helberg (1996), "Significance (in the statistical sense) is really as much a function of sample size and experimental design as it is a function of strength of relationship". High variability combined with low sampling frequency results in low statistical power. Low variability combined with high sampling frequency may result in excessive statistical power. Data from a screening study were used to determine the sampling frequency needed to register significant change (Seiders, 1995).

Fecal Coliform Bacteria

Analysis is focused on the pollutant of concern, FC bacteria. Estimated data (code-qualified J for laboratory and j for field measurements) were not culled for the analysis. Statistical tests are all performed using Systat® v.10 and Minitab® v.13 commercial software.

Methods for all streams

- Analysis is for the wet season between November 6 and April 19 of each year, except where otherwise noted.
- Fecal coliform data were expected to have lognormal distributions; high skewness within all groups except the calibration-period for Perry Creek indicated this was likely, so all data were $\log_{10}$ transformed for statistical analysis.
- All transformed data were evaluated for normality by evaluating skewness, normal probability plots, frequency histograms, and use of the Kolomogorov-Smirnov Lilliefors test for normality. Transformed data sets that failed the Lilliefors test or exhibited skewness > 1 were considered to have non-normal distributions.
- Autocorrelation was tested for using the Minitab® time series autocorrelation graphical evaluation macro.
- α=0.05 for all significance tests, except where otherwise noted.

Table 5. Calibration and BMP periods in study basins.

Basin	Calibration Period	Post-BMP period
Kennedy	1988-1993, 5 seasons	not fixed; variable analysis
Schneider	1988-1993, 5 seasons	not fixed; variable analysis
McLane	1983-1989, 5 seasons	not fixed; variable analysis
Perry	1983-1989, 5 seasons	not fixed; variable analysis
Burns	1988-1993, 5 seasons	not fixed; variable analysis
Pierre	1986-1990, 4 seasons	not fixed; variable analysis

Calibration periods are based on known water quality monitoring dates. However, these are not 'clean' pre-BMP periods. BMPs were being implemented before the grant programs went into effect, but there were not adequate historical water quality data at that time, so increased calibration-period monitoring overlapped early BMP work. Post-BMP periods could not be defined clearly because the level of temporal detail in the Record of Decision was calendar-year, there were no BMP audits, and in some cases, reported BMP work was reported as being implemented gradually, over a long period of time.

For these reasons, rather than analyzing change between pre- and post-BMP periods, significant change is determined between calibration periods and overlapping two-year, post-calibration periods.

Methods for before/after analysis

- Percent change is determined between average $\log_{10}$(FC) counts and loadings for calibration and post-calibration periods.
- Student's t-test is used for significance of change if the $\log_{10}$ data distributions were normal; otherwise the Mann Whitney U-test is used.

➢ Early pre-NMP fecal coliform data needed for the calibration period for McLane and Perry creeks were determined using the 'most probable number' (MPN) method, which does not give identical results to the membrane filter (MF) method used for all later analysis. In order to make the data as comparable as possible, data were combined from three Ecology studies where both MPN and MF methods were used on samples either drawn at the same time or split by the laboratory (Joy, 2000; Sargeant, 2001; Seiders et al., 2001). Outliers were removed, and in the case of one tidally influenced stream, only data with salinity=0 were used. The data were then combined in order to obtain a regression relationship (Figure 7). All MPN data for McLane and Perry from 1983-1984 were converted to best estimate of MF using this relationship.

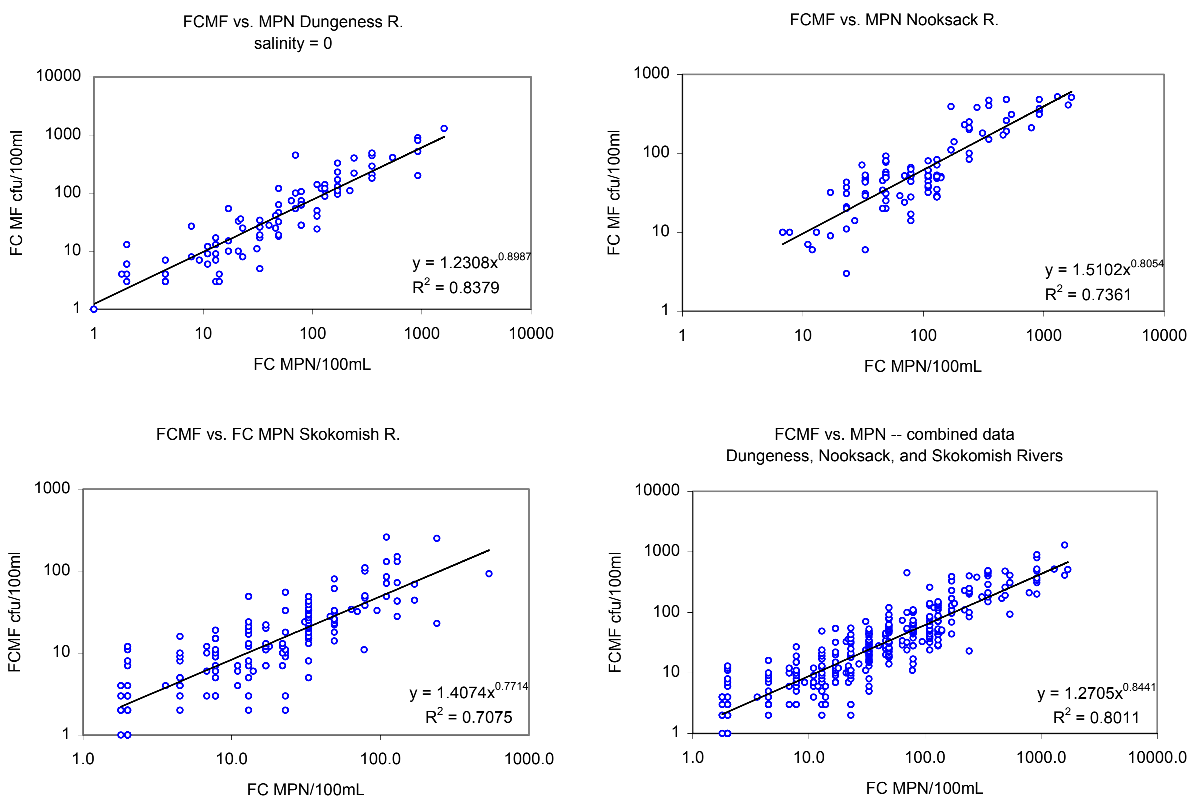

Figure 7. Fecal coliform membrane filter (FCMF) vs. most probable number (MPN)

At Burns Creek, samples had to periodically be drawn about 30 feet upstream at the under-road culvert discharge because of high tide. Because the regular sampling occurred on the beach, which was clearly subject to marine drainage as the tide went out, the two sites might not be comparable. Starting in 1999, sampling for fecal coliform was done frequently at both the original site and at the culvert discharge above. One curve could not be established that best represented the relationship between the two locations at both high and low concentrations. A linear relationship exists at high concentrations, but a power curve best represents the relationship at low concentrations (Figure 8).

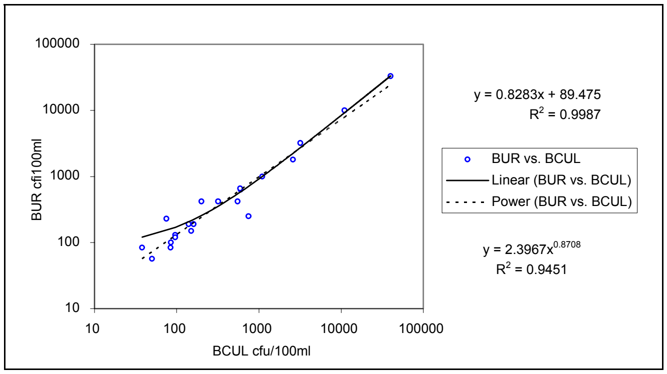

Figure 8. Fecal coliform at the regular Burns site and at the culvert discharge above

When samples were collected at the culvert, the linear relationship was used to adjust the fecal coliform values above 1000 cfu/100mL, and the power curve was used to adjust for values at and lower than 1000.

Method for paired watershed streams

Paired watershed method of analysis, described by Clausen and Spooner (1993) and Grabow et al. (1998), is used for measuring change at Schneider Creek, with Kennedy Creek as the control. The advantage of this method is that it factors out some non-BMP variables that can affect pollutant levels. Before/after design gives absolute percent change in pollutant levels; paired watershed design ideally gives percent change attributable to best management practices.

The paired watershed method "comprises two watersheds of similar location and land use (control and treatment) and two periods of study (calibration and treatment). Typically, one sampling station is positioned at the outlet of each watershed. During the calibration period (typically at least two years), land use at both control and treatment sites should remain the same. The goal is to establish a relationship between the watersheds. At the end of the calibration period, BMPs are implemented at the treatment site. The project then proceeds into the treatment period (usually at least two years). Again, the goal is to establish a relationship between control and treatment watersheds. The relationships are compared to see if a change has occurred due to BMP implementation" (Clausen and Spooner, 1993).

Originally we had two paired watershed sets – McLane/Perry and Schneider/Kennedy; but we lost the ability to use Perry as a control for McLane because residents in the Perry watershed wanted to implement BMPs. The Schneider/Kennedy setup differs from the classic paired watershed method described above, in that Kennedy was a relatively unpolluted stream during the rainy season, and Schneider was polluted. Instead of measuring percent change as a divergence (one stream getting cleaner than the other), we were measuring it as a convergence of pollution levels. The analytical mechanics of the paired watershed analysis are:

- Multiple regression is used for percent change and significance of change.
- The dependent variable is Schneider $\log_{10}$(FC).

- The independent variables are Kennedy $\log_{10}$(FC), Pre-Post (0-1), and interactive (Kennedy $\log_{10}$(FC)·Pre-Post).
- Plots of residuals against predicted values are examined for linearity, homogeneity of variance, and normality. These assumptions appear to be met in all cases.

Percent change is obtained from the regression coefficients, and significance is determined by regression p-values; significance is set at α=0.05. When percent change differs depending on pollutant concentration, the slopes of the regression lines differ. This is called a concentration-dependent or interactive effect. Regardless of whether there is a concentration-dependent effect or not, percent change is calculated as average percent change between the calibration period and each post-calibration period. When concentration-dependent effects are significant, they are retained as part of the regression equation. When they are not significant, they are removed, and the regression is run again. This lowers the p-value for the pre/post factor in the regression, increasing the significance of the percent change.

Flows

Rating curves were generated for flows compared to stream gauges, and for inter-basin flow relationships, using Excel® commercial software. When flows could not be measured directly as described in Methods, the rating curves were used to estimate the flows.

When the tide was in, flows could not be measured at Burns, which did not have a gauge. However, Burns does discharge through a round culvert. Starting in 1999, the stream width within the culvert was measured frequently when obtaining regular flow measurements. For paired data, Manning's equation was applied, adjusting Manning's n to yield the best relationship between measured flow and calculated flow.

Manning's Equation $$Q = \frac{1.486}{n} \cdot R^{2/3} S^{1/2} \cdot A$$

n = Manning's roughness coefficient; depends on stream
R = Hydraulic Radius (ft) = A/P_w
P_w = Wetted Perimeter (ft)
S = Channel Slope
A = cross-sectional area
Q = flow (cfs)

Manning's n was established to be 0.008, yielding a relationship of:

measured flow = 1.0006·calulated flow - 0.0001 $r^2 = 0.97$

Manning's equation was used to calculate flow on days when flow could not be measured directly because of tidal influence, or because of time or weather limitations.

Loading

Loading calculations were simple point-estimates:

$$\text{FC cfu/s} = \text{FC cfu/100mL} \cdot \text{flow ft}^3\text{/s} \cdot 28316.847\text{mL/ft}^3$$

Data Quality

Water Quality

Ecology's water quality data were reviewed for adherence to sample collection and analytical procedures, and data quality objectives (DQOs) (Appendix A). Puget Sound Protocols (Tetra Tech, 1986) for freshwater and general quality assurance/quality control procedures were followed for sample collection, identification, preservation, storage, and transport. Formal chain-of-custody procedures described in Ecology/EPA (1991) were followed to ensure sample security. Field instrument use followed manufacturers' instructions for maintenance, calibration, and operation.

Data quality objectives

Water quality data collected by Thurston County Environmental Health Division in the Totten basins from 1986 to 1992, and in the Eld basins between 1983 and 1992, were considered acceptable as discussed in the National Monitoring Program (NMP) QA Project Plan (Seiders, 1995). However, low sampling frequency brings into question representativeness, and lack of duplicates precludes precision estimation for these samples. Most of the water quality data collected by Ecology met DQOs for representativeness. DQOs for precision were met frequently for turbidity, but roughly half the cases were met for total suspended solids and less than half the cases were met for FC (Table 6). While individual measurements frequently met DQOs for accuracy, narrow estimates of true individual values cannot be made in cases where precision was low. The sampling and laboratory precision attained for FC is not likely to have improved without increasing the number of field duplicates and lab splits.

Laboratory-reported quality assurance

Through fall of 2000, holding times for all samples were met with one exception: FC samples from January 19, 1993 exceeded holding time by one day due to a winter storm preventing sample transport to the laboratory. In fall 2000, as a result of a mandate from EPA, the laboratory changed from a 30-hour holding time to 24 hours. Subsequently, more samples started exceeding holding times, but in no case was the original 30-hour holding time exceeded. FC counts were sometimes estimates because of spreader or background colonies, and sometimes because unexpected high counts exceeded the maximum 150 colony-forming units (cfu) per plate for accurate readings. In either of these situations, the reported value may be biased low; that is, the actual value is equal to or greater than the reported value. Relative percent differences (RPDs) were not always met; although this usually occurred when values were near the detection limit where RPDs are inherently high, so they are considered to be not meaningful. Raw data including qualifiers appear in Appendix B; a summary of data qualifier explanations appears in Appendix C; laboratory quality assurance and field notes appear in Appendix D.

Statistical quality assurance

The precision of FC, TSS, and turbidity field data was estimated from duplicate sample results. The term *estimated* is used instead of *determined* because replicate sampling was only done for a subset of the samples. Estimates of precision for field duplicate and lab split samples are presented in Table 6. Pooled variances and standard deviations are calculated from raw data using Microsoft Excel® commercial software. For all years and results, in three cases field duplicate precision was significantly[2] lower than lab split precision, and in eight cases, lab split precision was significantly lower than field duplicate precision. In 63% of these cases, there was no significant difference between field and lab duplicate variability. For turbidity and TSS, there was no significant difference between field and lab duplicates 80% of the time. For FC, 70% of the cases differed significantly; for three years field duplicate variability was higher, and for four years lab duplicate variability was higher. Pooled variances for all years combined are slightly higher for field duplicates than lab duplicates in the cases of all three parameters. This is consistent with the expectation that laboratory precision should be higher than field precision.

Comparison of results to original DQOs (Table 6, Appendix A) shows that DQOs were not met for any years for FC and TSS. FC and TSS DQOs were met more often for field duplicates than for lab duplicates. DQOs were met for turbidity field duplicates 50% of the years and lab duplicates 80% of the years. The results are consistent with the expectation that laboratory precision should be higher than field precision.

[2] F-test for differences in variability; α=0.05 (Zar, 1999)

Table 6. Data precision

		Pooled Standard Deviations						Percent of Duplicates Exceeding DQOs					
		FC		**TSS**		**Turbidity**		**FC**		**TSS**		**Turbidity**	
		Field Dup.	Lab Split	Field Dup.	Lab Split	Field Dup.	Lab Split	Field Dup.	Lab Split	Field Dup.	Lab Split	Field Dup.	Lab Split
Year 1	Sp	15	***36***	0.6	***4.3***	0.4	***5.8***	76.5	52.9	58.8	40.0	0.0	0.0
1992-93	n	18	18	18	16	18	16						
Year 2	Sp	38	46	10.6	12.3	10.0	10.6	78.3	58.3	65.2	58.3	4.3	0.0
1993-94	n	22	19	22	19	22	19						
Year 3	Sp	19	***73***	66.3	46.5	37.3	29.2	73.9	78.3	56.5	37.5	13.0	4.2
1994-95	n	18	23	18	24	18	24						
Year 4	Sp	15	15	15.8	23.6	9.1	***15.9***	65.2	60.9	39.1	43.5	4.3	4.3
1995-96	n	23	23	23	23	23	23						
Year 5	Sp	***20***	7	7.1	8.4	9.8	9.5	59.1	40.9	59.1	31.8	0.0	0.0
1996-97	n	22	22	22	22	22	22						
Year 6	Sp	6	***12***	8.2	***20.7***	12.7	14.8	43.5	59.1	65.2	47.8	4.3	0.0
1997-98	n	23	22	23	23	23	23						
Year 7	Sp	***23***	13	13.0	9.9	8.3	10.1	66.7	58.3	66.7	54.2	0.0	0.0
1998-99	n	24	24	24	24	24	22						
Year 8	Sp	18	***56***	16.9	11.7	14.0	9.8	53.8	54.2	50.0	45.5	0.0	0.0
1999-2000	n	26	24	24	22	25	24						
Year 9	Sp	15	15	15.7	13.3	13.2	11.8	58.3	54.2	41.7	21.7	8.3	0.0
2000-2001	n	24	24	24	23	24	23						
Year 10	Sp	***35***	21	11.3	12.6	7.5	8.4	58.3	56.5	37.5	13.6	0.0	0.0
2001-2002	n	23	23	24	22	24	23						
All Years	Sp	22	***36***	22.3	20.6	14.5	14.4	62.9	57.5	53.7	39.6	3.5	0.9
1992-2002	n	223	222	222	218	223	219						

Field Dup. = field duplicate (FD) and regular sample (RS)
Lab Split = lab split (LS); same thing as lab duplicate
Sp = pooled standard deviation (square root of pooled variance)
n = number of sample pairs
Outlines indicate the precision of the lab splits and field duplicates does not differ significantly at $\alpha = 0.05$
Bold italic indicates whether the field duplicate or lab split Sp is significantly higher at $\alpha = 0.05$

Table 7 shows means and variances of FC samples and the pooled variances for the laboratory split and field duplicate samples for each station for the entire 1992-2002 study period. The field duplicate and lab split variances do not differ from each other significantly.

Table 7. Quality assurance statistics for log_{10}(FC) data by station.

Station	Sample			Field Replicate		Lab Split		Lab Split Sp^2	Field Rep Sp^2
All Years	mean	n	S^2	n	Sp^2	n	Sp^2	/Field Rep Sp^2	/Sample S^2
Burns	2.286	269	0.526	53	0.431	49	0.440	102%	82%
Kennedy	0.861	297	0.392	34	0.313	34	0.290	93%	80%
McLane	1.691	297	0.323	64	0.501	64	0.469	94%	155%
Pierre	1.971	264	0.374	37	0.249	39	0.304	122%	67%
Perry	1.105	297	0.355	42	0.313	41	0.342	109%	88%
Schneider	1.308	297	0.436	71	0.440	66	0.458	104%	101%

Sample mean and n are for regular samples for all years
Lab Split and Field Replicate n = number of splits and replicates for all years
Sp = pooled standard deviation (= square root of pooled variance)
Sp^2 = pooled variance

The precision targets for FC specified in the QA Project Plan were not met. Factors contributing to this might include the nature of the sampled medium, longer holding times (30 and 24 hours versus 6 hours as specified in APHA (1992)), and smaller sample sizes than those used in studies described by APHA (1992).

Sample collection and analysis protocols were followed, so the only way to increase precision in all cases would be to increase the number of field duplicates and lab splits. This would also result in higher accuracy, as would reducing the occurrence of FC count estimates ('J' data-qualifier in Appendixes B and C).

Regardless of the failure to meet DQOs in many cases, we could not afford to eliminate the data, since sampling frequency was at or near the minimum required to detect significant change. J-qualified FC counts were retained for the same reason. In addition, J-qualified high-count FC data were already likely to be biased low, and removing those data would further low-bias the data sets.

Autocorrelation was assumed to be absent and seasonality was considered to not be a factor at the beginning of this study (Seiders, 1999b).

Water Flow

Periodically, severe weather and/or high stream flows made direct measurement of flows hazardous. In these cases direct stream-flow measurements were not taken, but stage was recorded if possible. Recording hydrographs were in place to measure stream stage, and in some cases could measure heights where staff gauges were flooded over. Flow-to-gauge and flow-to-stage rating curves had good correlation within the measured ranges; regression was at least $r^2>0.8$, and frequently $r^2>0.9$. Inter-basin relationships were not as good ($r^2>0.7$). Some stream hydrograph data over the last seven years have been lost as a result of equipment problems and/or extreme weather events when recording hydrographs were flooded over. Where needed, Thurston County McLane hydrograph flows are used to fill data gaps; when doing so, we used a rating curve of county flow vs. Ecology's flow to correct the data. Most of the stream-flow data are adequate; but the data are biased low at high flows when streams have reached and exceeded out-of-bank flood stage.

Extensive work was done on validating rating curves for all flows estimated by gauge-height. Linearity was not assumed; curves were picked from power, second and third-order polynomial, exponential, and linear types to maximize r^2 values. Most of the time a power curve was the best fit, especially when regressing lower flows.

Precipitation

At the beginning of the study, it was assumed that rainfall at the Olympia Airport was adequate to characterize rainfall at the NMP sample sites. In order to test this assumption, data from three nearby weather stations for November 17, 1993 through December 31, 1997 were compared to Olympia data. Notched boxplots with 95% confidence intervals were produced for the Olympia Airport (in Tumwater), Green Cove (on the west border of Olympia), the Shelton Airport (Sanderson Field), and Summit Lake (Figure 9). Only the median rainfall at the Shelton Airport differs significantly from the median at Olympia. The Summit Lake station is closer to and therefore more likely to be representative of the NMP sites than the Shelton Airport. On this basis, the original assumption of comparability cannot be ruled out.

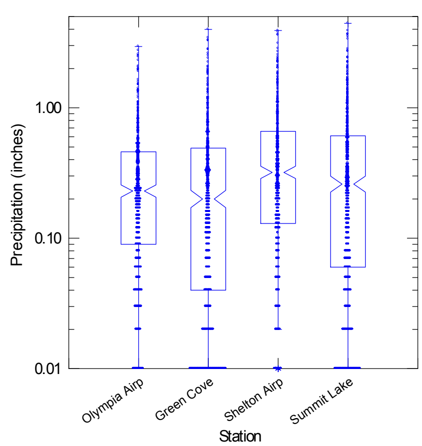

Figure 9. Notched boxplots of daily precipitation at the Olympia Airport and three adjacent weather stations

We also tested rainfall comparability between the NMP sties. During spring 2002, rain gauges were placed at all six sub-basins, as near as possible to the sampling sites, while being as out in the open as possible to avoid rain-shadow effects from trees. Thirteen readings were taken between March 27 and June 11, 2002.

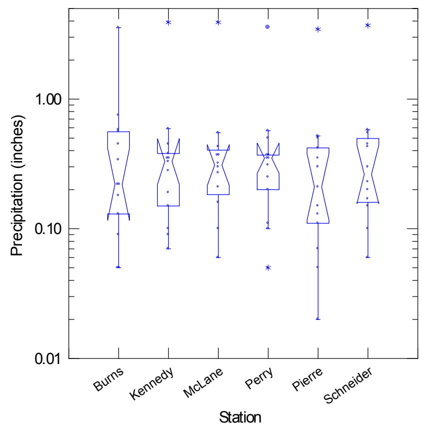

Figure 10. Cumulative precipitation at NMP sites between March 27 and June 11, 2002

All the 95% confidence intervals overlap, indicating no significant difference in rainfall between the median rainfall for the sites for this limited test. Total rainfall for this period was between 3.45 and 3.9 inches, depending on the station.

Pollution Control

On-site sewage system data

DQOs were thought to be adequate for OSSS work because Thurston County Environmental Health Division (TCEHD) maintained a data base of septic system surveys. Recent contact with TCEHD indicated that the surveys were conducted along the shoreline of Totten Inlet, but data did not go into the data base for any inland (freshwater) properties. Nevertheless, the county did deliver data for surveys of some OSSSs adjacent to freshwater streams, but that did not include all OSSSs within the NMP study area (Hofstad, 2002b). Most planned surveys were completed, but surveys were not planned for the entire NMP area. There were no surveys planned for Kennedy[3], McLane, or Perry sub-basins. Surveys were targeted for 33/118 of the OSSSs in Schneider sub-basin (28%), 1/13 in Burns (8%), and 2/9 in Pierre (22%). The data that were obtained are believed to be accurate.

Farm land-use data

Watershed-scale, land-use data are inconsistent, and deficient in accuracy and precision. Inaccuracy is reflected by inability to determine from the public record and farm inventories what some land is being used for at any given point in time (e.g. residential vs. agricultural).

[3] except for Summit Lake, which was not included in the NMP study area

Imprecision is reflected by inability to determine type and concentration of agricultural use (e.g. numbers and types of livestock per acre).

Figure 2 shows land use based on the County Assessor's Office; but designation does not allow for a detailed understanding of use, and does not always reflect actual land use. For example, a parcel listed as residential may have as much livestock as another listed as agricultural. Further, one agricultural parcel may have livestock, while another may be used for crop production only. Whatever the designation, it is for the entire parcel, while only a portion of the parcel may be used for the designated use. Multiple-use cannot be discerned from this data base.

Figure 3 shows land use as inferred from satellite imagery. These data are more detailed with regard to actual use coverage; but note that while plant agriculture and grassland are listed, there is no information about livestock presence. Land-use data from farm surveys have the potential to be the most detailed and accurate data, but these data are limited by resource limitations (time and personnel required to visit each farm), and by the nature of voluntary cooperation of land owners, which generally precludes the ability to evaluate non-cooperators' lands.

The nature and quality of farm planning and BMP implementation data are discussed in the context of the DQOs found in Appendix A and with respect to the data's accuracy, completeness, and representativeness. The quality of agricultural remedial actions data is poor. The complex nature of farm management, farm plans, BMP implementation, record keeping, and resource allocation at state and local governments make it difficult to obtain data of adequate quality. The possibility exists that during the course of this study, some of the reported work may not have been done (Sontag, 2000).

Quantification of the level of BMP planning and implementation in the study basins has been difficult. The original approach for the Totten and Eld Shellfish Protection Initiative (SPI)-funded grants was to review farm site inventories and Records of Decision (RODs) for each farm and then tally data on animals, BMP plans and their implementation, and related factors to develop basin-wide summaries of pollution sources and pollution controls.

Carrying out this approach was difficult because of inadequate record keeping and reporting practices. Information about the timing and characteristics of BMP implementation was recorded and/or reported in different formats, and information between formats frequently disagreed. Information from two reporting formats was examined in order to estimate the extent of disagreement in reporting pollution-control data. Formats examined were the reports required by grants (quarterly, annual, and final) and the ROD formats used by the Natural Resources Conservation Service (NRCS). BMP implementation characteristics such as the individual practice and its timing, location, and amount were compared. This comparison found that about 20-30% of the reported instances of BMP implementation agreed between the two formats. The remainder of the data (70-80%) did not agree (Seiders, 1996). To improve the quality of pollution-control data, Ecology contracted with Thurston Conservation District (TCD) to provide complete and accurate RODs for farms assisted under the SPI grants.

Little new BMP data from the Totten or Eld SPI efforts have become available since the last annual report (Seiders, 1999b). The Centennial Clean Water Fund, Eld Farmers for Clean Water final report was submitted by TCD in 2001, but most of the work was done outside the NMP area. Data were submitted in narrative form and via frequently inconsistent and incompletely filled out paper forms, making it very difficult to extract and consolidate data. There are some discrepancies between grantee reports and signed farm plans or records of decision.

Of 113 farms listed as priority farms in the entire Eld watershed grant area, 65 are listed as cooperators, and 32 chose to participate. There were 13 farms within the NMP area designated 'priority' as of August 1996. An earlier prioritization (May 1996) listed 15 farms. Out of these, three chose to cooperate. Of these three, for one farm there is no ROD or any other information regarding work done; the report states number of BMPs as "missing" and percent completion as "unknown". For another farm, one report summary states that 6/8, (75%) of the BMPs were completed, but the ROD and a different summary state that none were completed. The third farm completed 5/6 or 83% of its planned BMPs, although for one, more fencing was installed than planned for.

The data are not considered to be reliable for any kind of rigorous statistical analysis. Besides the deficiencies in installation data, nothing is known of the current status of maintenance or operation of any of the BMPs. Out of necessity, what BMP completion information exists is used to graphically show the relationships between percent BMP completion, grant periods, and water quality; but with the knowledge that there is some degree of uncertainty in BMP timing, and a high degree of uncertainty in percent BMP completion.

Parameters and reporting units

Measuring the amount of pollution controls installed in a basin is complicated by changes in NRCS conventions for naming BMPs. Some BMP names and codes are no longer used and/or have been replaced. For example, Prescribed Grazing is now used in place of Deferred Grazing, Pasture and Hayland Management, and Planned Grazing System. Occasionally, non-standard or localized BMP names are reported, such as winter confinement, restricted winter use, and buffer. The degree to which similarly named BMPs perform and benefit water quality has not been explored.

BMP planning and implementation data, which were reported in non-standard units, were converted to standard units using farm site information and assumptions (Table 8). These conversions allowed data to be compiled and summarized for each basin.

Table 8. BMPs reported with different units.

NRCS BMP #	BMP Description	Units Used for Reporting
412	Grassed Waterway	acres and feet
580	Streambank Protection	acres and feet
575	Livestock Crossing	feet and each
393	Filter Strip	acres and feet
382	Fencing	acres and feet
322	Channel Vegetation	acres and feet
313	Waste Storage Structure	structure and acres
558	Roof Runoff Management	system, feet, and acres

the standard reporting units are underlined

Values for animal units were estimated from various basin and farm site inventories performed by TCD between 1989 and 1996. The numbers and variety of animals were converted to a common term (animal units) based on animal weight. Table 9 lists animal types found and the animal units used in compiling these data. Error associated with these estimates is unknown, since animal types and numbers may change from year to year.

Table 9. Animal unit values.

Animal	Weight pounds	Animal Unit value
Mature Dairy Cow	1400	1.4
Breeding Stock Cattle	1000	1
Horse	1000	1
Mule	1000	1
Arabian Horse	900	0.9
Feeder Beef	875	0.875
Bull/Bull Calf	875	0.875
Pony	700	0.7
Donkey	600	0.6
Heifer/Heifer Calf	550	0.55
Foal or Calf	500	0.5
Sow and Litter	375	0.375
Boar	350	0.35
Gestating Sow	275	0.275
Llama	250	0.25
Calf	250	0.25
Finishing Pig	185	0.185
Miniature Donkey or Pig	150	0.15
Calf (0-2 months old)	150	0.15
Growing Pig	110	0.11
Sheep or Goat	100	0.1
pygmy Goat	50	0.05
Nursery Pig	50	0.05
Turkey - Breeding Stock	20	0.02
Turkey On Feed	15	0.015
Chicken	5	0.005
Layer	4	0.004
Pullet (>3 mo. old)	4	0.004
Broiler Chicken	2.2	0.0022
Pullet (<3mo. old)	2.2	0.0022

Source: (NRCS, 2003)

Animal data

Animal counts were obtained primarily from "windshield surveys" (farm drive-by's). Updates were infrequent. With the exception of one horse farm adjacent to Schneider Creek, where counts were done frequently, the data are not considered to be reliable for any kind of statistical analysis.

Spatial resolution

The location of best management practice (BMP) installation in relation to basin streams is important in evaluating their effect on water quality. BMP data are recorded and reported at two levels: (1) at the farm site and farm field, and (2) at the farm only. For example, a farm plan may indicate that fields numbered 1, 3, 5, and 7 are each planned for 2, 4, 6, and 8 acres of Prescribed Grazing. Another way this BMP effort might be recorded is simply as 20 acres of Prescribed Grazing on that farm; no field numbers are indicated. Assessment of the BMP effort in the first case would result in a tally of four instances of Prescribed Grazing applied for a total of 20 acres. In the second case, the assessment would result in a tally of a single instance of Prescribed Grazing for a total of 20 acres. While the total acreage reported is the same, the frequency or count of discrete BMP applications is different. Appendices A and B, and the data summaries presented below, contain a mixture of such reporting practices and likely result in an inaccurate number of BMPs planned and/or implemented. Consistent recording and reporting practices would greatly help the effort to accurately determine the extent of BMP implementation.

Temporal resolution

The timing of actual BMP implementation and maintenance is needed to link water quality to pollution controls. The common practice was to record the year of planned implementation as well as the year of actual implementation on the Record of Decision (ROD). Occasionally, the month and year of BMP actions is provided. There are instances where BMPs were installed, but the date was not recorded on the ROD. In order to complete these missing data for analysis purposes only, the dates and amounts designated in the "planned" column of the ROD were used as the dates and amounts of actual implementation of the corresponding BMP. The original data quality objective (DQO), to know the week of implementation, was not met. The current resolution (to the year of implementation) can be used but does not allow as thorough an analysis if resolution to the week or month were available.

Accuracy, representativeness, and completeness

BMP data may be accurate for the time they are installed or implemented. However, the accuracy of the data decreases over time because it is unknown if BMPs are properly operated and maintained after installation. Lack of knowledge about the long-term accuracy of BMPs exists, in part, because state and local efforts have focused on writing farm plans and implementing BMPs rather than on determining whether BMPs are adequately operated and maintained. No agency is tasked with determining whether BMPs installed through publicly-funded programs are properly operated or maintained after their initial installation. Likewise, OSSS data are only accurate for the time they are collected.

As with temporal resolution, there were some instances where BMPs were installed, but the amount of BMP implemented was not recorded on the ROD. In order to complete these missing data for analysis purposes only, the amounts designated in the "planned" column of the ROD were used as the dates and amount of actual implementation of the corresponding BMP; these are designated as *uncertain* BMPs.

A confounding factor in some cases is that some BMPs are not effective when first implemented, but become effective over time. For example, vegetative plantings become effective as they grow to cover a site; they are not effective when first put in. Some structures like stream crossings and fencing may also exhibit some lag, as they do not immediately remedy built-up manure along stream sides. When studying the effect of a single BMP type, it is possible to statistically evaluate gradual change over time; however, in this study, there was a diverse mix of BMP types, with a range of effectiveness immediacy.

The reported BMPs represent an uncertain level of pollution control in the study area because:

- OSSS surveys were not planned for in all NMP freshwater sub-basins
- post-survey status of OSSSs is not known; only the status of cooperators' farms is known except in some cases where enforcement actions occurred
- BMP data only represent pollution-control efforts where Thurston Conservation District (TCD) was involved in farm planning
- only NRCS-approved BMPs were included in farm plans
- animal counts were infrequent and incomplete
- it seems unlikely that many farms would have developed farm plans without TCD's involvement; whether any farms implemented BMPs in response to education and outreach efforts, but did not enter the farm planning process with TCD, is also unknown

Results

Monitoring Data

Raw data appear in Appendix B; data qualifier descriptions are in Appendix C. Analysis is focused on the pollutant of concern, fecal coliform (FC) bacteria. Data quality-coded as estimates were not culled for this analysis; all are code-qualified (J or j).

Exploratory data analysis

Bar graphs of geometric mean values (GMVs) for November to mid-April wet seasons indicate that the highest FC levels are found in Burns and Pierre, followed by McLane and Schneider, with Perry and Kennedy creeks having the lowest FC levels (Figure 11). Bar graphs of FC loading indicate that McLane has the highest FC loading, followed by Kennedy, Schneider, and Perry, with Burns and Pierre creeks having the lowest FC loading (Figure 12). The order of streams from lowest to highest FC counts is not the same as the order for FC loading. This is important to note both from TMDL and shellfish protection perspectives. Bar graphs are also provided for arithmetic mean FC levels (Figure 13) and loading (Figure 14). Geometric mean is useful because it is used for the water quality standard, but it is biased low for lognormal data; arithmetic mean is an unbiased estimator (Gilbert, 1987; Parkhurst, 1998).

Notched boxplots[4] for the entire period show high FC variability at all streams (Figure 15). High variability combined with low sampling frequency prior to NMP monitoring results in wide 95% confidence limits. A pattern that emerges in general is oscillation between periods of higher and lower GMV counts. Figure 16 shows boxplots for FC loading. Boxplots for total suspended solids (TSS), TSS loading, turbidity, flow, and conductivity are shown in Appendix E.

Scatterplots with trend lines and 95% confidence intervals (Figure 17) indicate that for the ten-year monitoring period, the wet-season FC trend was up significantly at McLane, up slightly but not significantly at Burns, Kennedy, and Perry, and down at the two other streams, but significantly only at Pierre. The FC loading trend (Figure 18) was upward significantly at McLane, and not significantly at Burns and Kennedy. The trend was downward, but not significantly, at the three other streams. Incorporating historical data back to 1983 or 1986 depending on stream, the FC trend was up significantly at McLane, up slightly but not significantly at Burns and Kennedy, down significantly at Perry, and down slightly but not significantly at Pierre and Schneider (Figure 19). During this extended time-frame, FC loading was up significantly at McLane and not significantly at Schneider and Kennedy; the loading trend was downward at the other streams, but not significantly (Figure 20).

Even where trend lines are significant, pollution levels – both concentrations and loadings – fluctuated considerably from year to year, and in all cases where significant improvement occurred for at least one two-year averaged period, the average of the 2000-2002 seasons was higher than the two-year low value.

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[4] See notched boxplot definition in the Methods section

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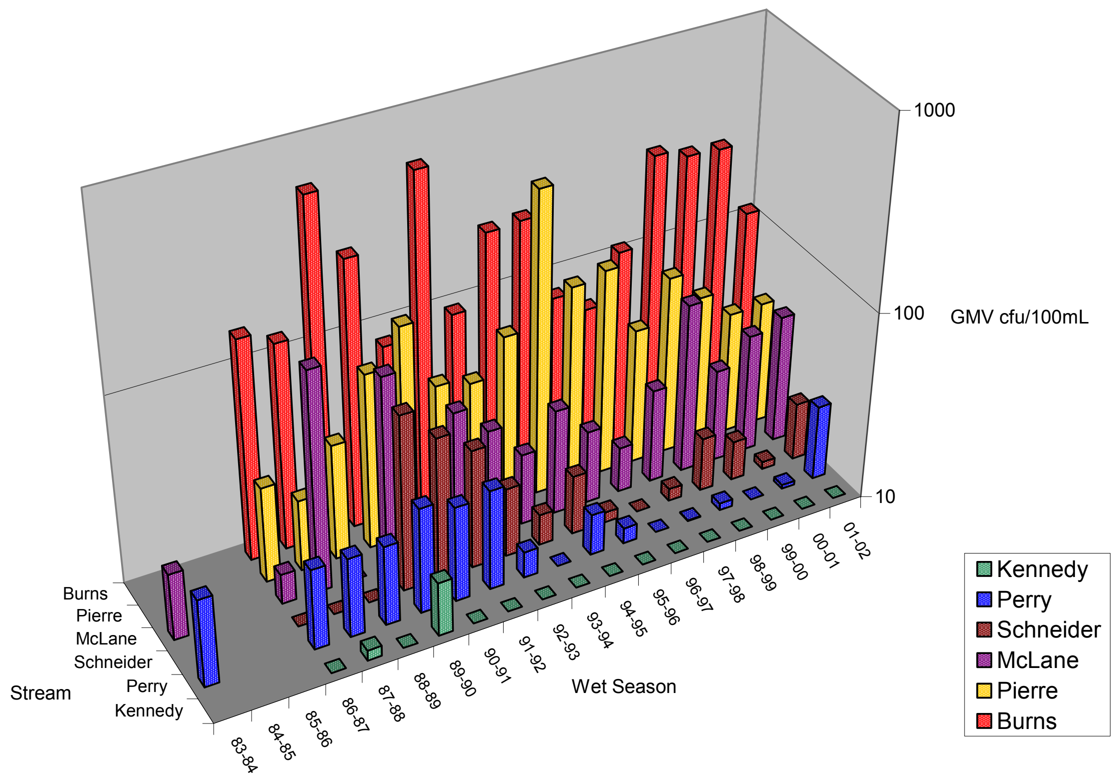

Figure 11. NMP wet-season (Nov-Apr) fecal coliform levels (GMV)

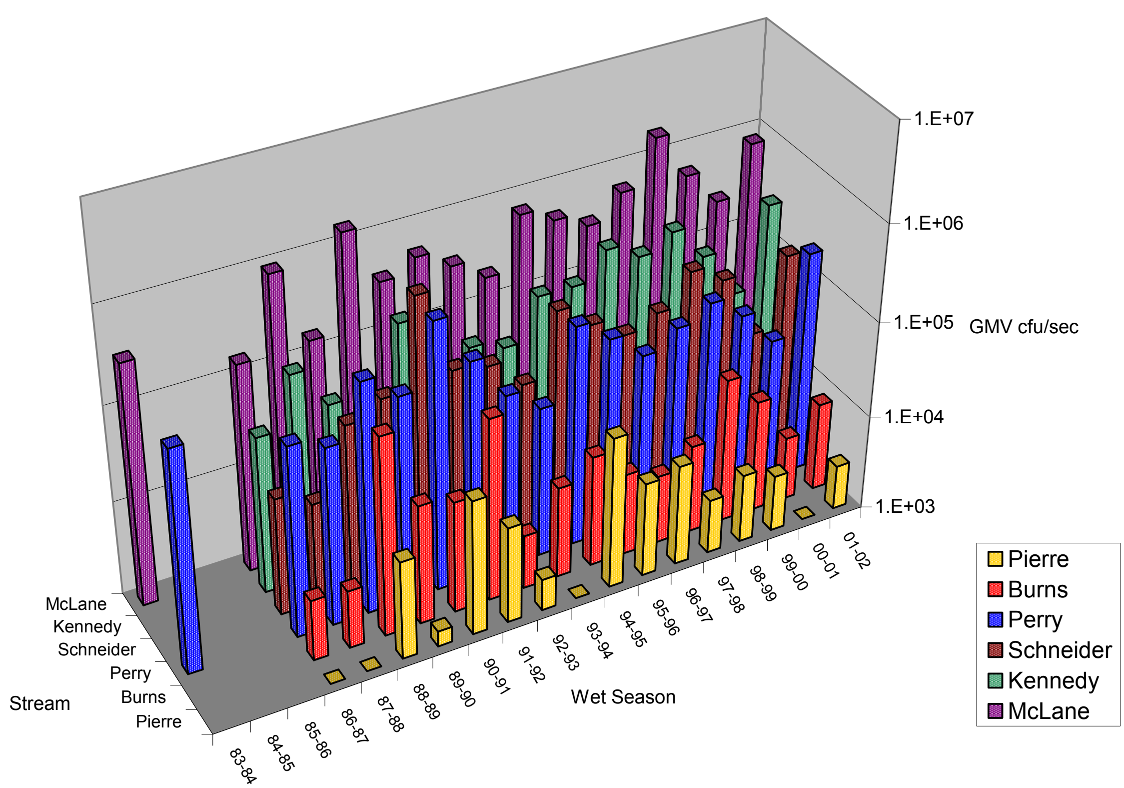

Figure 12. NMP wet-season (Nov-Apr) fecal coliform Loading (GMV)

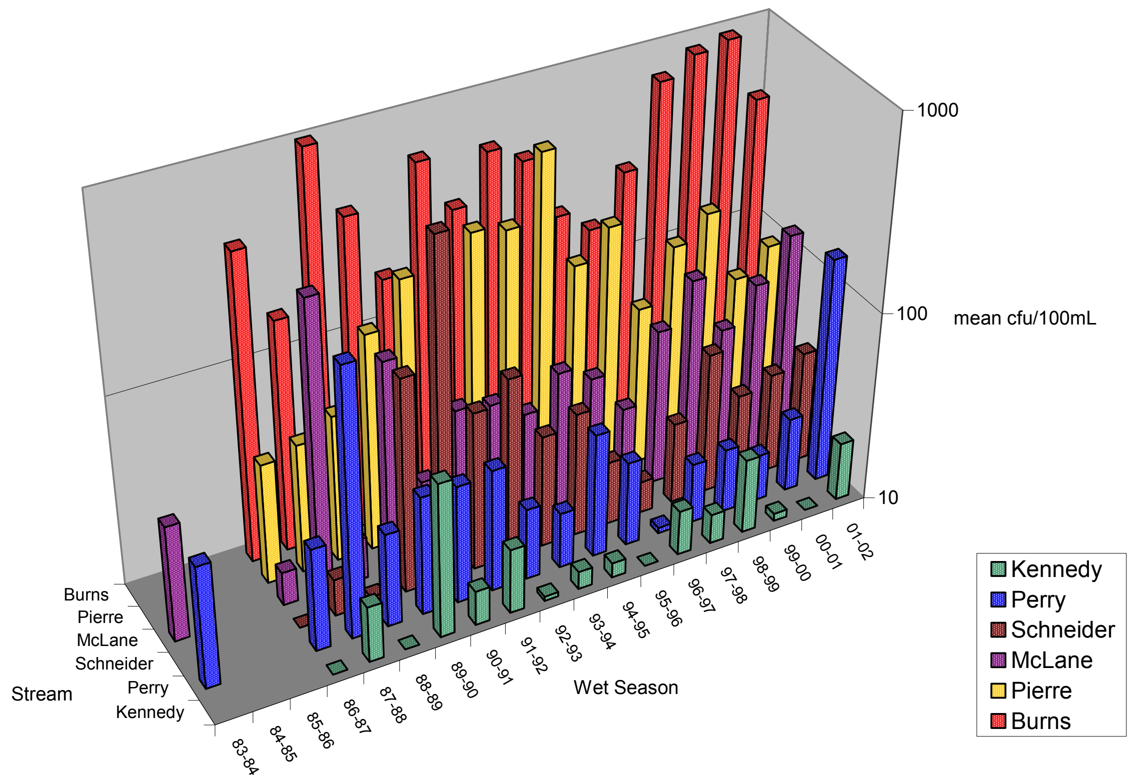

Figure 13. Arithmetic mean fecal coliform levels

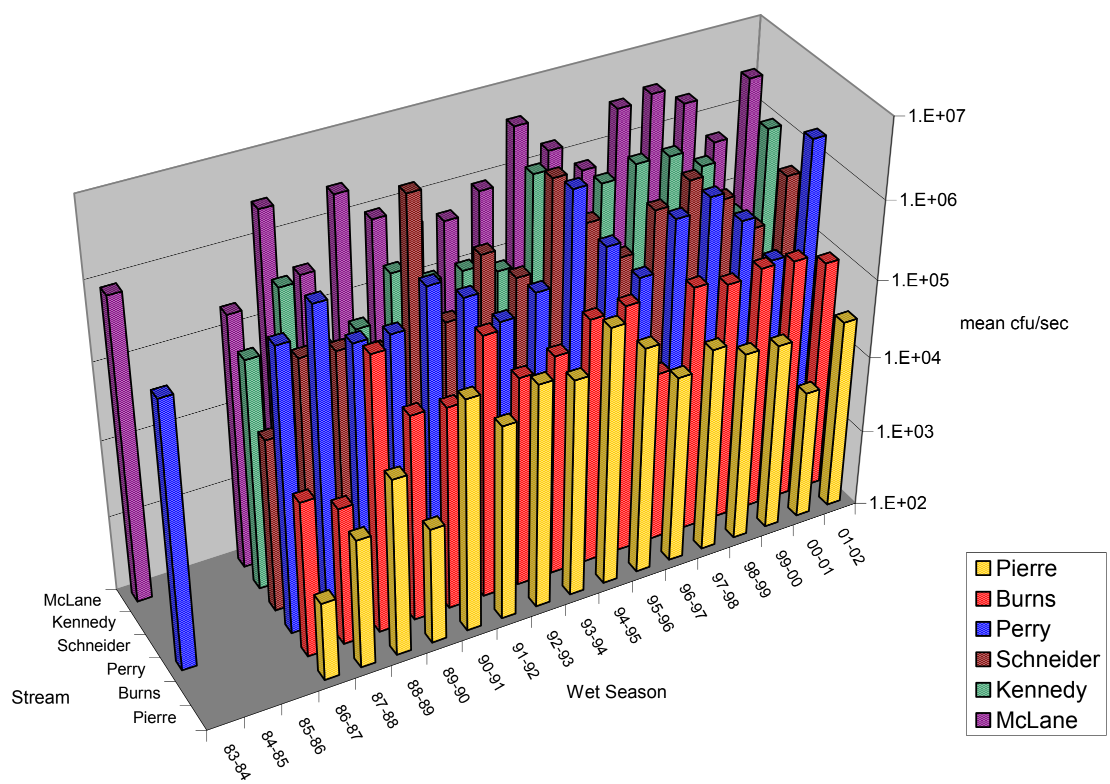

Figure 14. Arithmetic mean fecal coliform loading

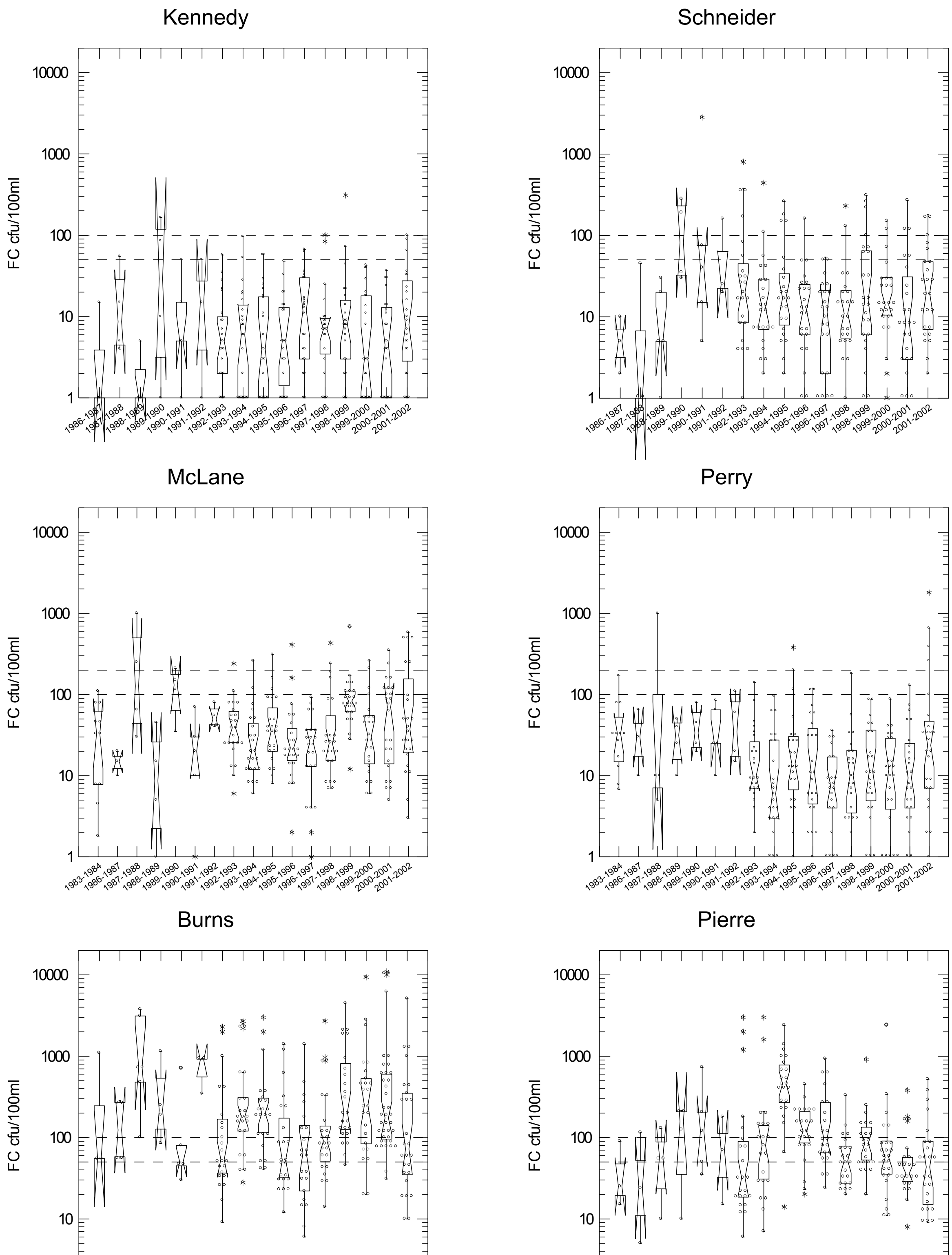

Figure 15. Fecal coliform notched boxplots
Dashed lines are part 1 and part 2 values of the water quality standard (Table 10).

Table 10. Washington water quality standards for fecal coliform bacteria

Class AA Standard
Part 1 - geometric mean value (GMV) shall not exceed 50 colonies/100mL
Part 2 - not more than 10% of the samples used for calculating the GMV shall exceed 100 colonies/100mL

Class A Standard
Part 1 - geometric mean value (GMV) shall not exceed 100 colonies/100mL
Part 2 - not more than 10% of the samples used for calculating the GMV shall exceed 200 colonies/100mL

The FC criteria do not address the number or timing of samples used to determine compliance or violations.

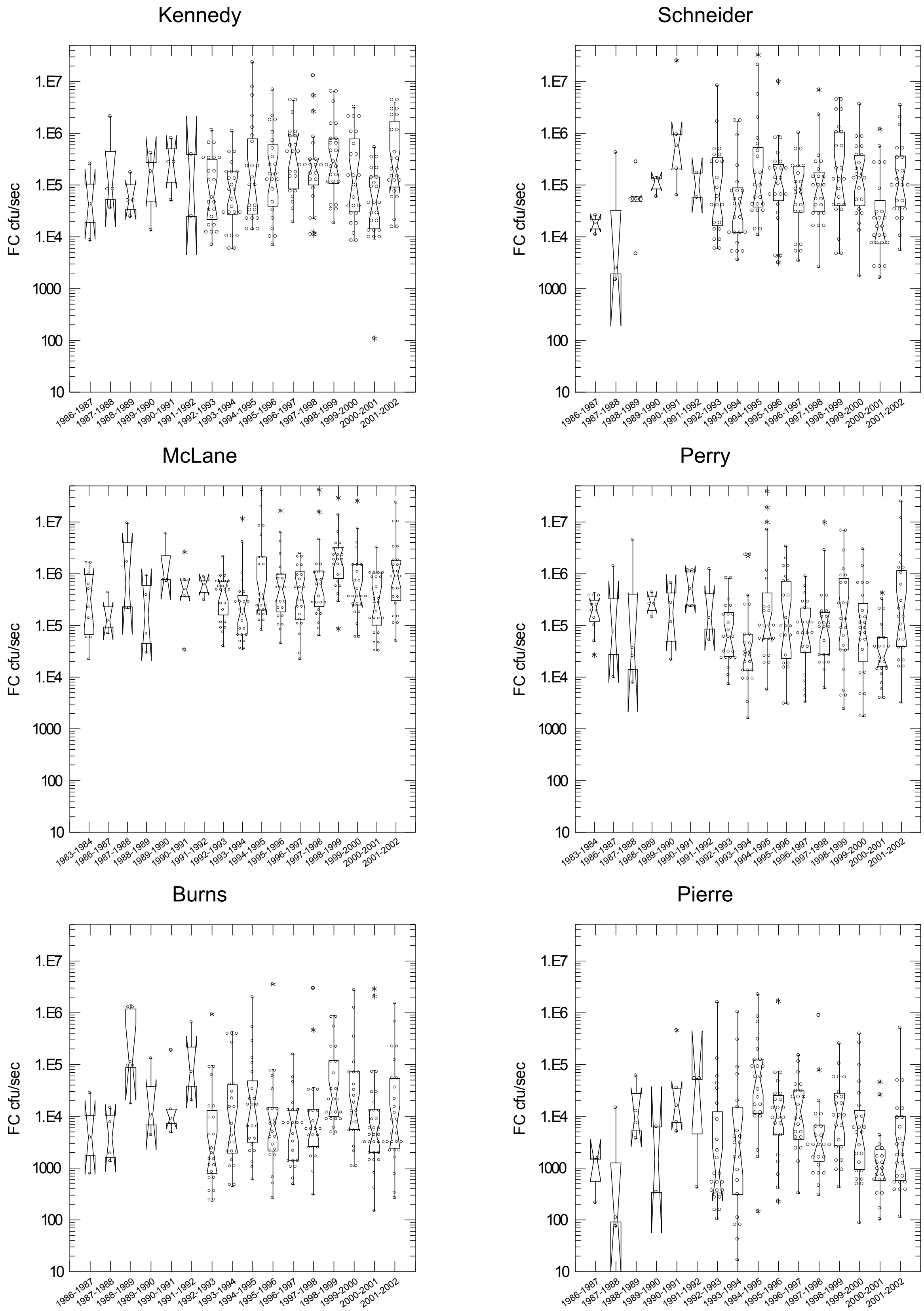

Figure 16. Fecal coliform loading notched boxplots

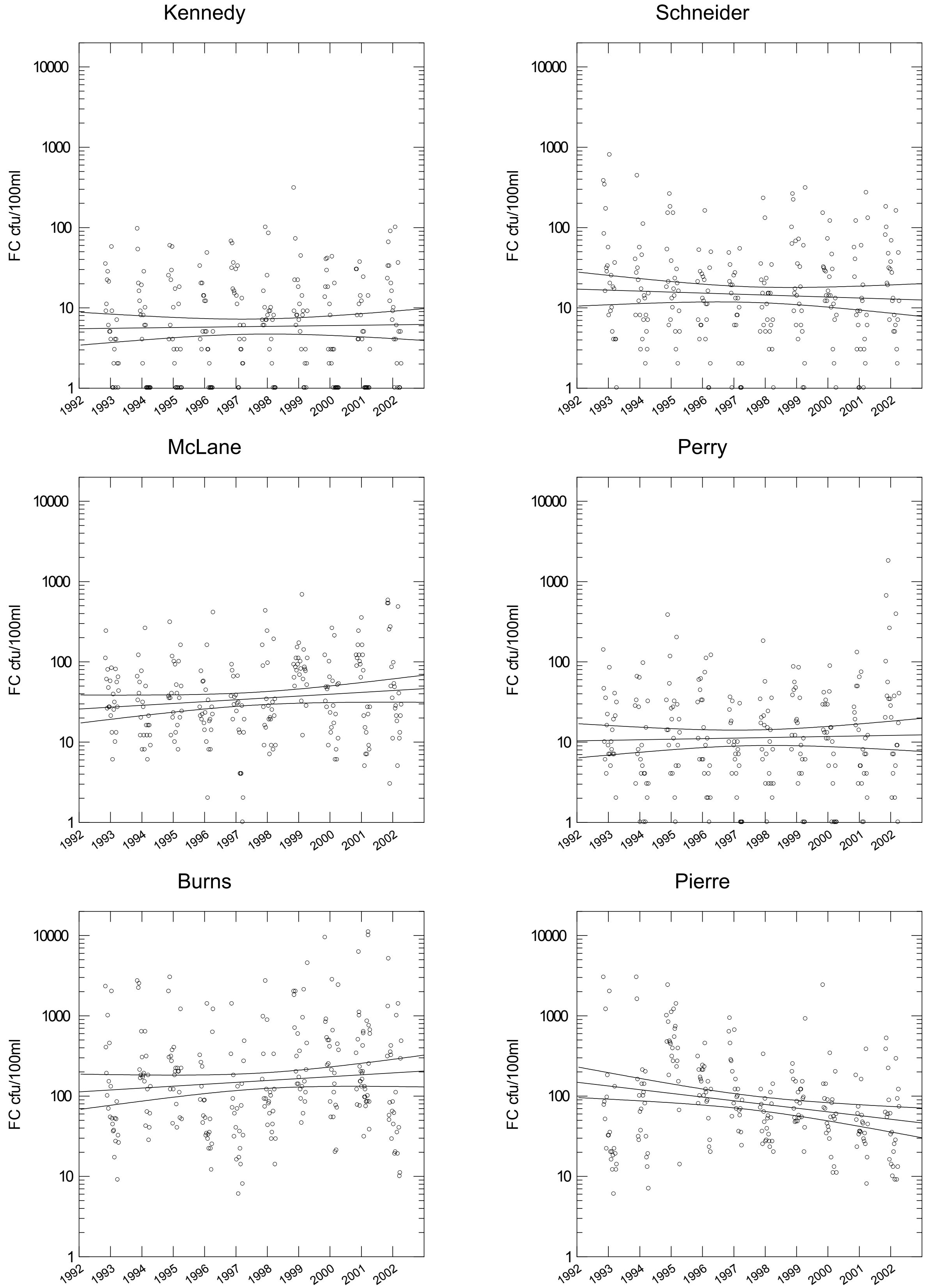

Figure 17. Fecal coliform trend line and 95% confidence interval 1992-2002

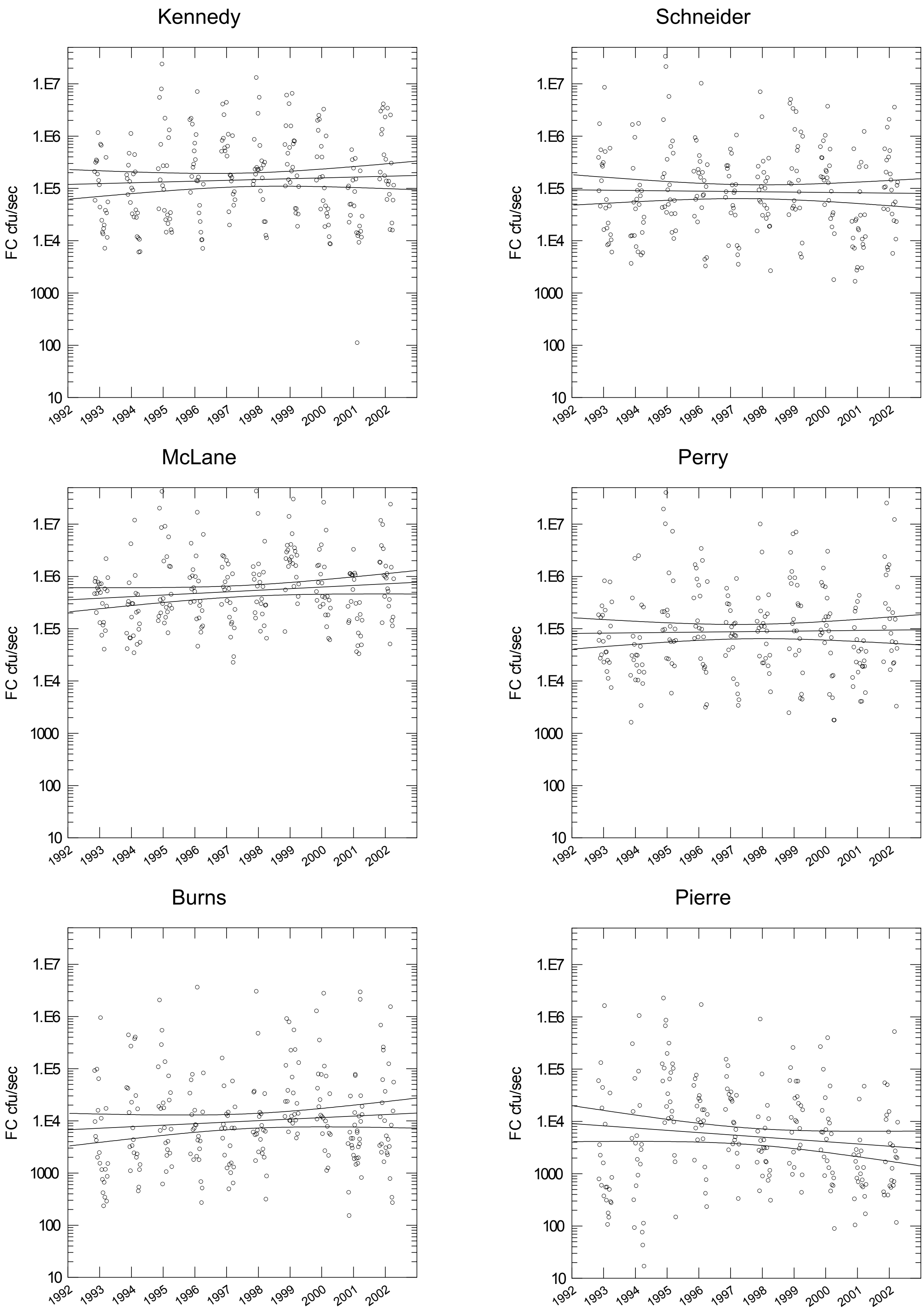

Figure 18. Fecal coliform loading trend line and 95% confidence interval 1992-2002

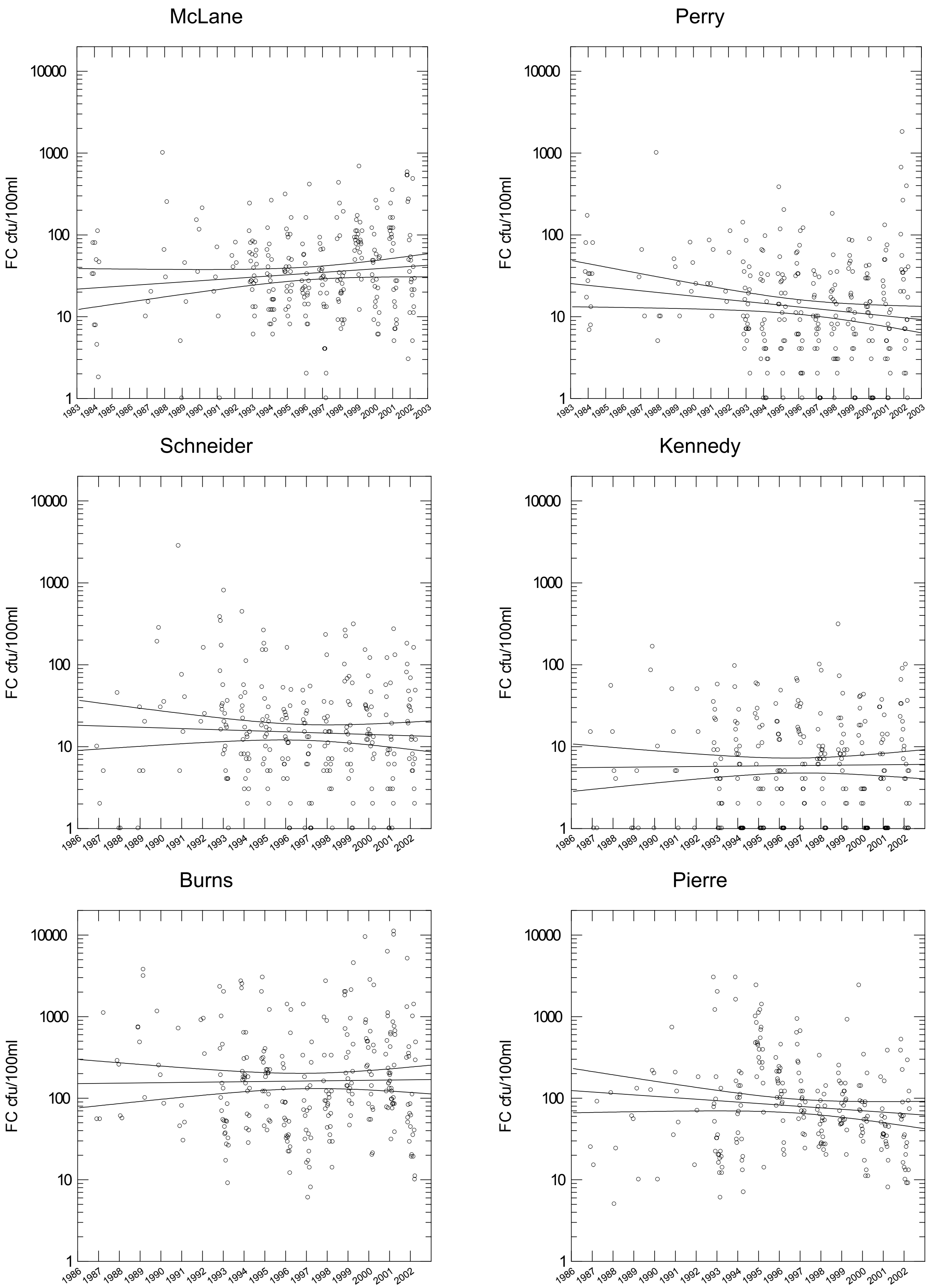

Figure 19. Fecal coliform trend line and 95% confidence interval 1983/1986-2002

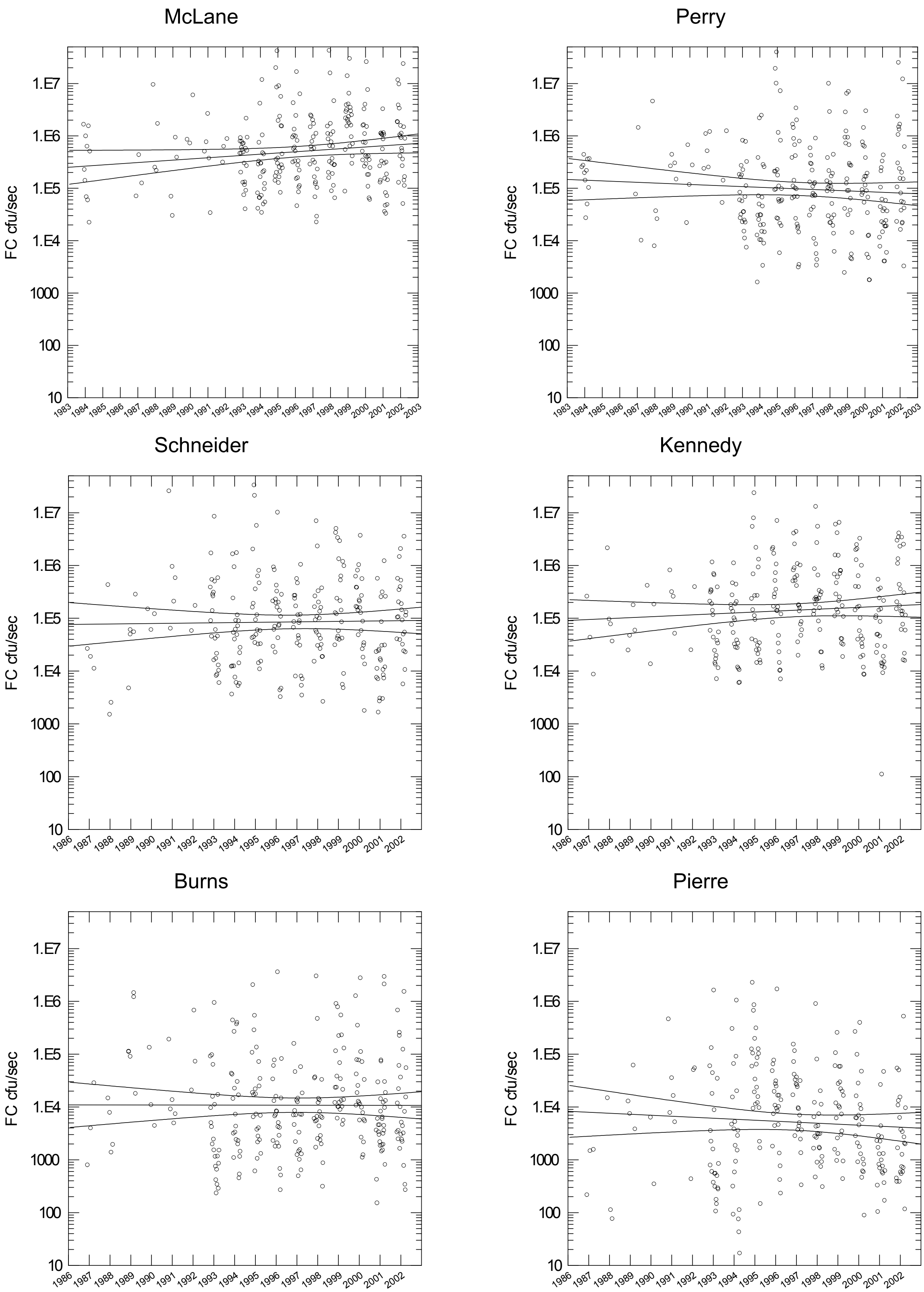

Figure 20. Fecal coliform loading trend line and 95% confidence interval 1983/1986-2002

Calibration period and post-BMP data analysis

Calibration and post-BMP periods for each basin are defined in Table 5. As noted there, the periods are not absolute; there is some blurring of the period definitions. The calibration period was when baseline water quality monitoring occurred. With the exception of Pierre, it was not strictly a 'pre-' period, because some BMPs were being installed at the time. Burns, Schneider, and Kennedy were the only streams where we were able to monitor during the calibration period, but sample size was marginal because there was only one year of data collection. In order to improve sample size and representativeness, earlier ambient data from TCEHD were combined with Ecology data. Only historical water quality data from TCEHD were used for the Pierre, McLane and Perry calibration periods.

Post-BMP periods could not be clearly defined for all sub-basins because some BMPs were being installed before the grants started, there was gradual BMP implementation during grants, and because of overlapping grants and grant extensions.

Year-to-year changes

The temporal relationships between grant-funding, BMP implementation, FC wet-season geometric mean values (GMVs) and percent change from year-to-year in Totten Inlet watersheds are shown in Figure 21; loading is shown in Figure 22. The same relationships for Eld Inlet watersheds are shown in Figure 23 and Figure 24. For these graphs, percent change for Schneider is calculated using simple post-calibration level as a percent of calibration-period level. No clear common pattern emerges linking grant funding, BMPs, and water quality for all streams. Significance of percent change is not evaluated here.

In the Totten Inlet watershed, Burns yearly FC count GMV fluctuated considerably, rising above the calibration period for two years, dropping below for three years, then rising above for three years, and dropping below for the last monitoring year. Pierre's worst FC levels were after the calibration period, from the beginning to mid-grant period. FC levels dropped after that, but at the end of the monitoring period were no lower than during the calibration period. There is an appearance that the watershed efforts may have resulted in an improvement after a substantial initial decline in water quality, but there is no net improvement. Schneider FC decreased to below the calibration-period level early during the watershed grant period and stayed below that level during the entire monitoring period.

The loading picture in the Totten Inlet watershed is not as good. Burns FC wet-season loading GMV fluctuated above and below the calibration-period level, ending up slightly higher at the end of the study than during the calibration period. Pierre loading decreased slightly below the calibration period one year, but was generally very high, and was higher at the end of the study than during the calibration period. Schneider loading also oscillated, but at the end of the study wound up slightly lower than the calibration period.

In Eld Inlet, the McLane FC count GMV level peaked immediately following the calibration period, then decreased gradually with some fluctuation over the course of BMP implementation, but rose above calibration-period levels the past five years. Perry FC count GMV also got worse following the calibration period, but then improved during the course of BMP implementation, until the last monitoring year, when the level rose back to the calibration-period level.

GMV loading for McLane followed a similar pattern to FC levels. Perry loading fluctuated more, rising above calibration-period loading about mid-way during BMP implementation, followed by six years below, and then rising again above the calibration-period level the last year of the study.

Of the five watersheds, only at Schneider did FC GMV counts decrease and then stay below the calibration period levels during the study, although Perry dropped and then stayed below the calibration-period level until the last year of monitoring. Schneider was the only stream where FC loading GMV was lower at the end of the study than during the calibration period.

Original median water quality goals met

Table 7 reiterates FC median goals presented in the Background section, and shows results over the past ten years. During this period the goal was met for two years for McLane and one year for Schneider. These were not pollution-control goals; rather, at the time they were set, they were considered to be necessary targets to establish significant change. These figures appear to be conservative; significant change was discernable more frequently than these median results suggest.

Table 11. Fecal coliform median goals and results, 1992-2002

	92-93	93-94	94-95	95-96	96-97	97-98	98-99	99-00	00-01	01-02	Target cfu/100ml
Burns	54	180	213	53	69	91	216	330	210	73	**20**
Kennedy	5	7	4	5	13	7	8	3	5	8	
McLane	39	**20**	35	**22**	26	25	83	30	70	38	**22**
Pierre	32	93	460	120	99	52	85	58	36	44	**10**
Perry	10	6	14	11	8	10	12	13	10	26	**4**
Schneider	20	13	18	11	12	11	16	14	**8**	20	**10**

Outlined bold values indicate the fecal coliform median goals were met.

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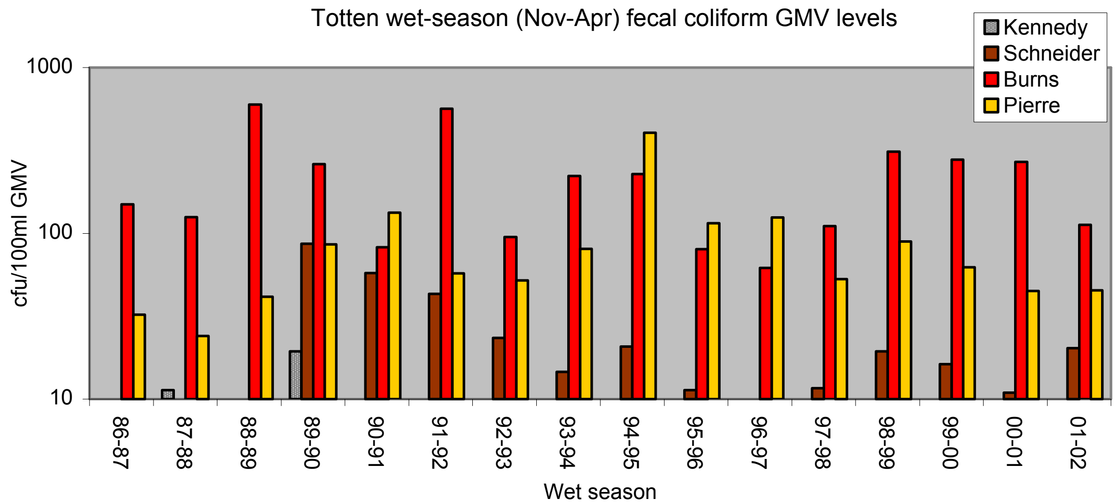

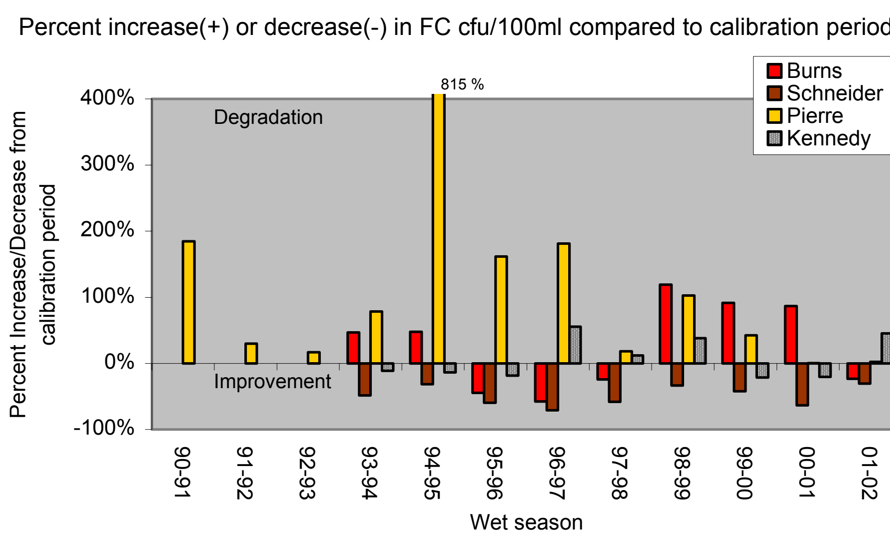

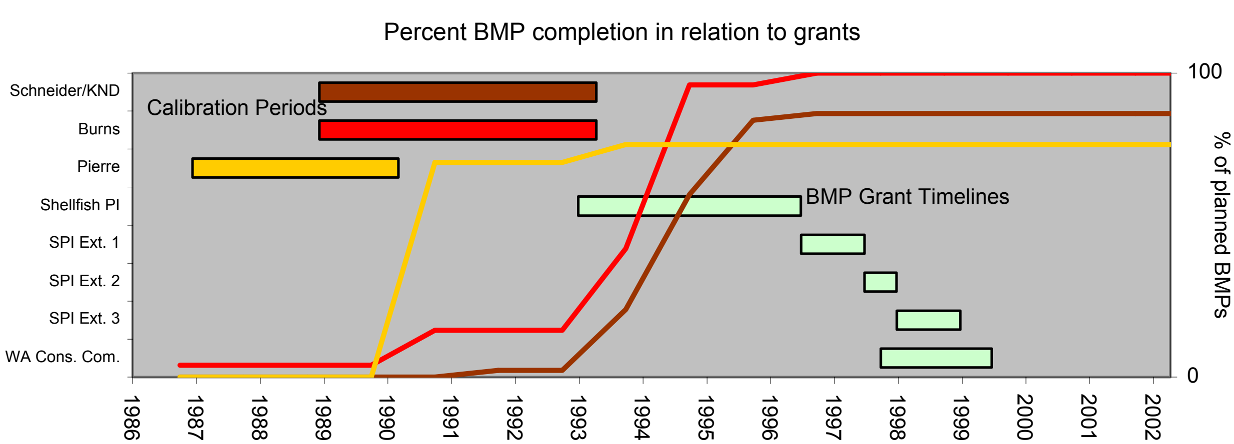

Figure 21. Totten wet-season (Nov-Apr) fecal coliform GMV levels with timelines
The % BMPs timelines are not precise

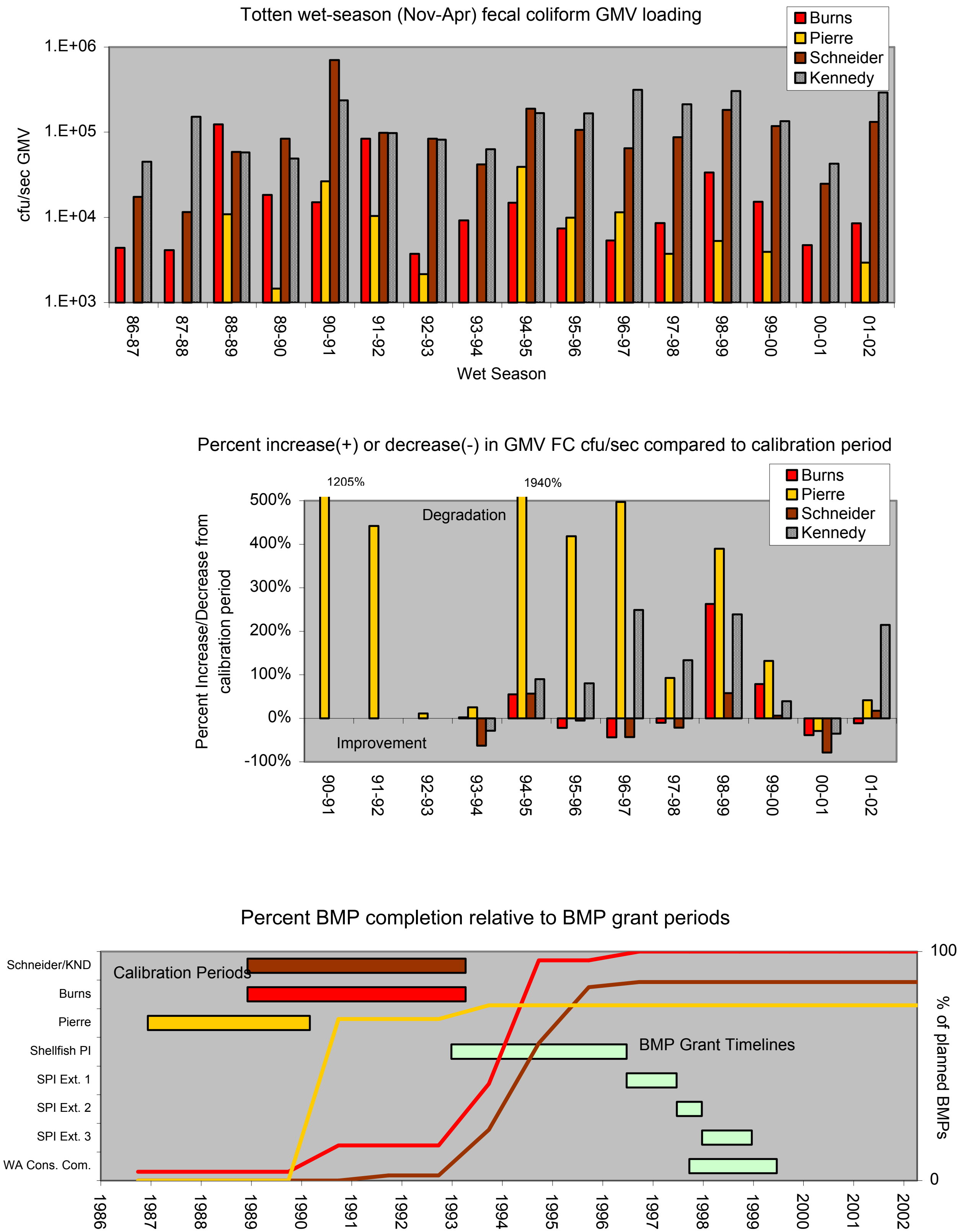

Figure 22. Totten wet-season (Nov-Apr) fecal coliform GMV loading with timelines
The % BMPs timelines are not precise

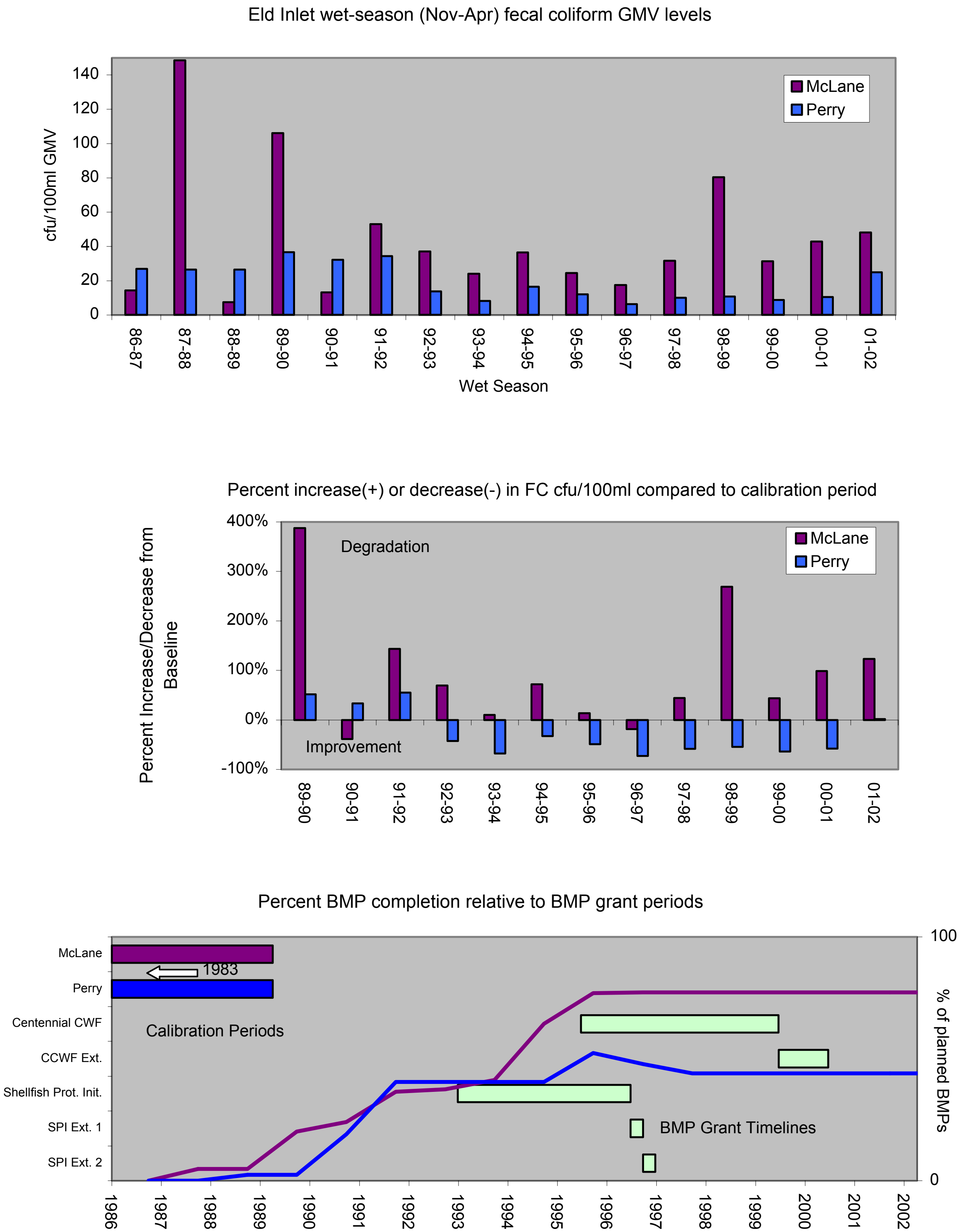

Figure 23. Eld wet-season (Nov-Apr) fecal coliform GMV levels with timelines
The % BMPs timelines are not precise

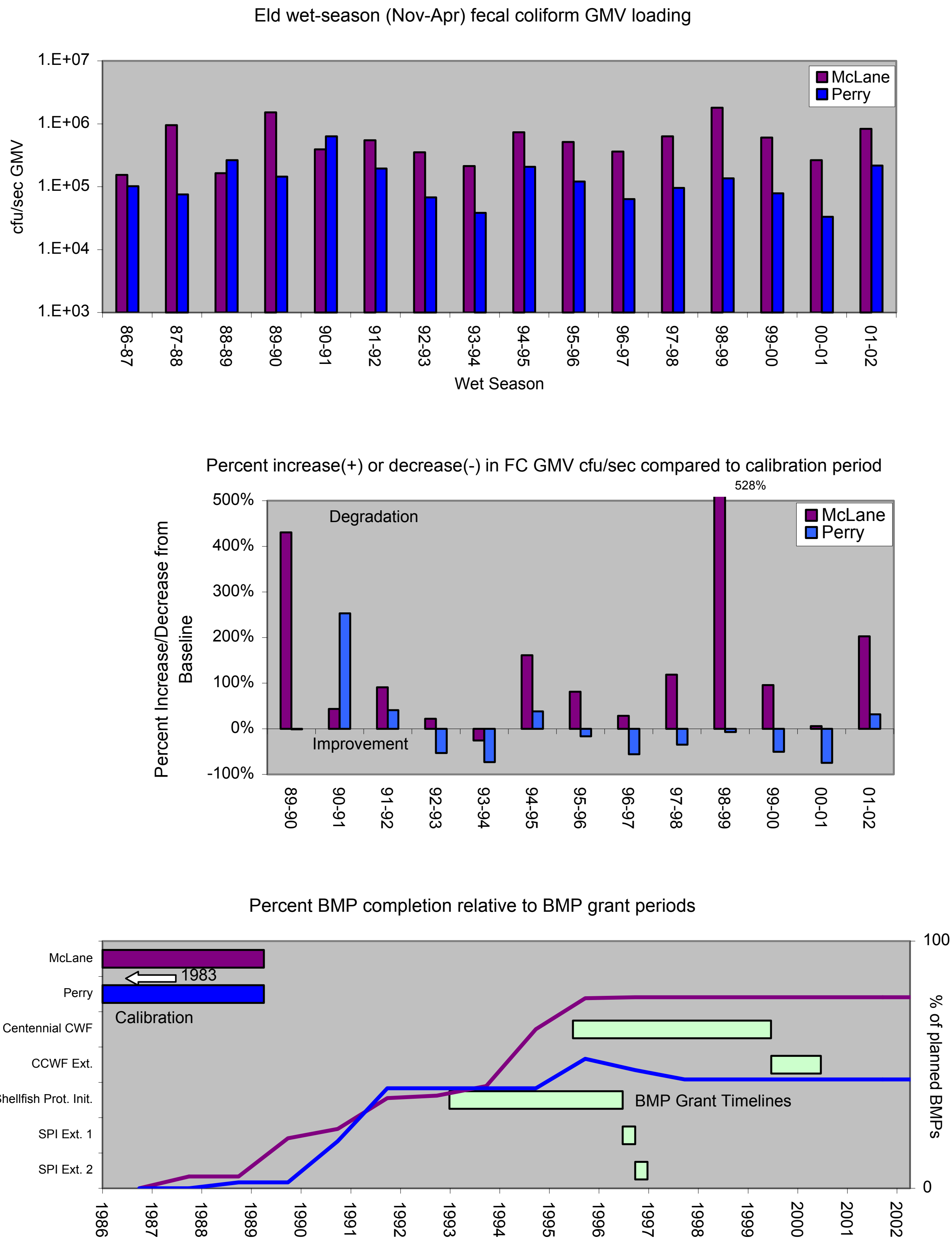

Figure 24. Eld wet-season (Nov-Apr) fecal coliform GMV loading with timelines
The % BMPs timelines are not precise

Significant change

There were no clean post-treatment periods to compare to calibration periods because BMPs were implemented over prolonged periods that did not coincide neatly with the pollution-control grants. As a result, percent change and its significance were determined using overlapping two-year post-calibration periods to keep the post-BMP period sample numbers fairly comparable to the calibration periods, and to have high enough sample numbers for adequate statistical power.

Before/after streams

The before/after method for determining significant change is described in the Water Quality Data Analysis Methods section of this report.

Paired watershed

The paired watershed method is described in the Water Quality Data Analysis Methods section. The treatment watershed is Schneider; the control is Kennedy. The graphical output of the paired watershed multiple regression appears in Figure 25, which shows regression lines for $\log_{10}$ transformed FC concentration data for Schneider vs. Kennedy over the course of the project. The solid line is the relationship between Schneider and Kennedy during the calibration period. The dashed line in each graph is the relationship between Schneider and Kennedy during a designated two-year period following the calibration period. Improvement is indicated by the dashed line dropping further below the solid line; degradation is indicated by the dashed line re-approaching or rising above the solid line.

Percent change is obtained from the calibration period and post-treatment period regression coefficients, and significance is obtained from regression p-values.

All streams

Some autocorrelation was evident in log transformations of some of the results and in some of the residuals of the paired watershed regressions. Interpretation is difficult because sampling was random, not regular periodic, for at least part of all the calibration periods. The post-calibration periods comprised two years, with fairly regular periodic sampling[5] broken up by a half-year of no sampling during the dry season. Autocorrelation was present during less than a third of the time blocks; when it was present, it was not very strong, and lags where autocorrelation was evident varied. It is possible that some percent change significances are inflated.

The results in Table 12 and Figure 26 are based on before/after significance tests and paired watershed regressions. These show percent change and statistical significance.

[5] Weekly sampling, although occasionally the sampling day of the week was changed, and sample times varied to some extent.

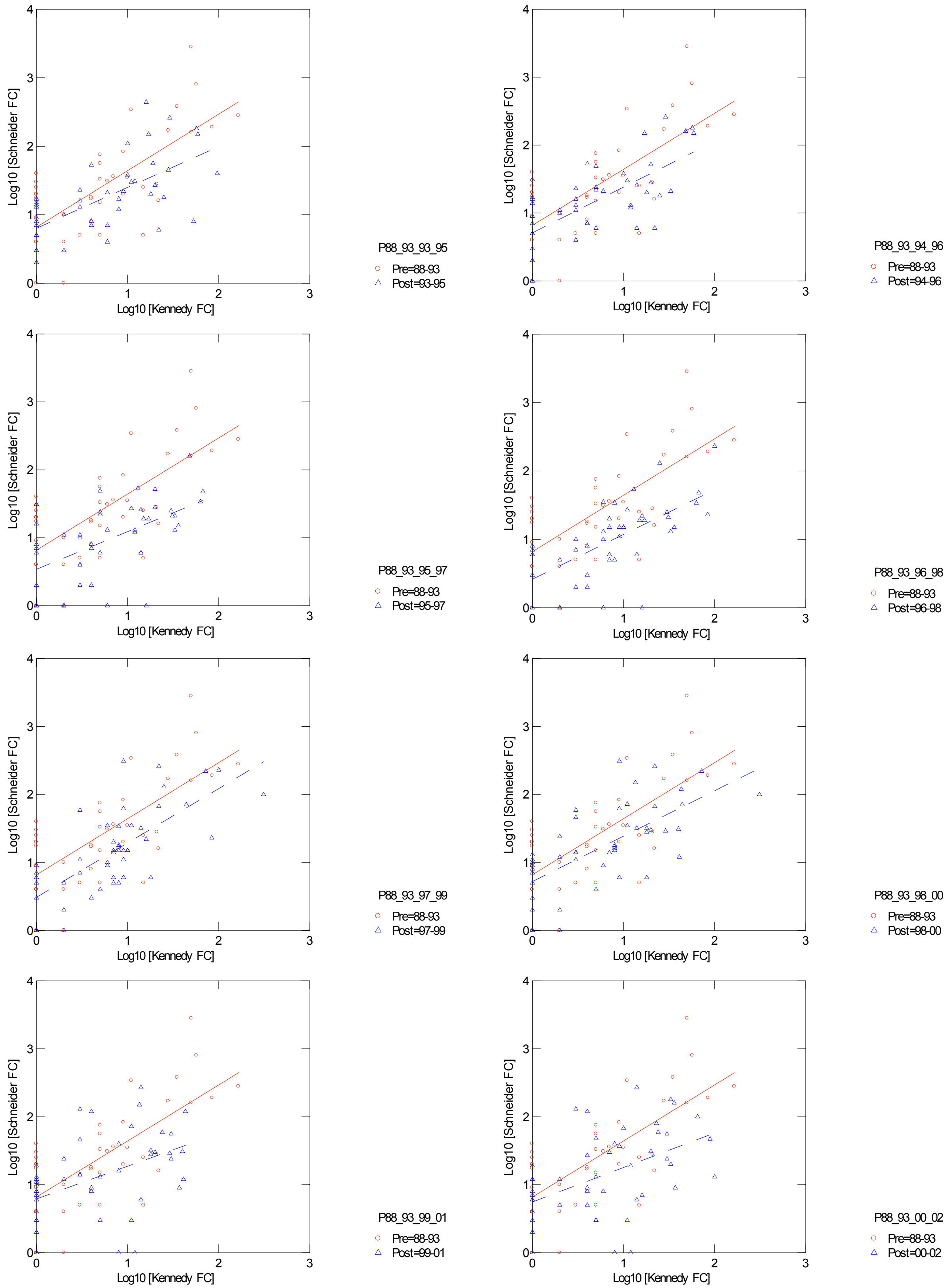

Figure 25. Paired watershed regressions of pre- and post-BMP $\log_{10}$(FC) data
Solid line = calibration period; dashed line = post- period. Schneider is the treated watershed.

Table 12. Fecal coliform count percent change and its significance

	Burns	McLane	Pierre	Perry	Schneider paired watershed	Schneider	Kennedy
Calibration period	88-93	83-89	86-90	83-89	88-93	88-93	88-93
Calibration period *n*	*39*	*22*	*14*	*23*	*39*	*39*	*39*
Post-period							
1987-1989							
1988-1990							
1989-1991		54%		41%			
1990-1992		13%	112%	43%			
1991-1993		79%	18%	-33%			
1992-1994		37%	43%	-57%			
1993-1995	47%	38%	**320%**	**-54%**	-35%	-40%	-12%
1994-1996	-9%	40%	**389%**	-42%	**-40%**	-47%	-16%
1995-1997	**-51%**	-3%	**171%**	**-63%**	**-68%**	**-65%**	12%
1996-1998	-43%	9%	81%	**-66%**	**-71%**	**-65%**	31%
1997-1999	30%	**133%**	55%	**-56%**	**-56%**	-47%	25%
1998-2000	**105%**	**130%**	69%	**-59%**	**-40%**	-38%	4%
1999-2001	**89%**	69%	21%	**-61%**	**-46%**	**-54%**	-21%
2000-2002	20%	**111%**	1%	-35%	**-52%**	**-50%**	7%

Bold underline indicates statistical significance at α=0.05
Blue text and (-) sign indicate pollution reduction
Red text and no sign indicate pollution increase

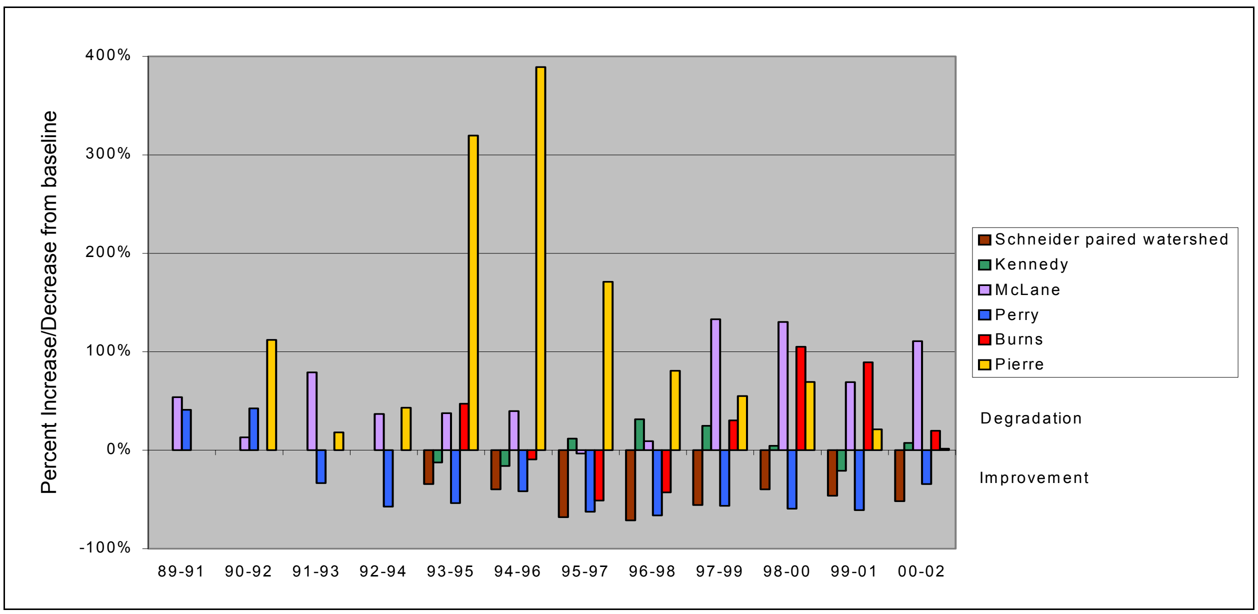

Figure 26. Percent change in fecal coliform cfu/100mL compared to calibration period, by 2-year blocks

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Figure 27 shows regression lines for log_{10} transformed FC loading data for Schneider vs. Kennedy. The solid line is the relationship between Schneider and Kennedy during the 1988-1993 calibration period. The dashed line in each graph is the relationship between Schneider and Kennedy during a designated two-year period following calibration period. Improvement is indicated by the dashed line dropping further below the solid line; degradation is indicated by the dashed line re-approaching or rising above the solid line.

Percent change is obtained from the calibration period and post-treatment period regression coefficients, and significance is obtained from regression p-values.

Schneider paired watershed FC results in Table 13 and Figure 28 are based on the results of these regressions. These show percent change and statistical significance.

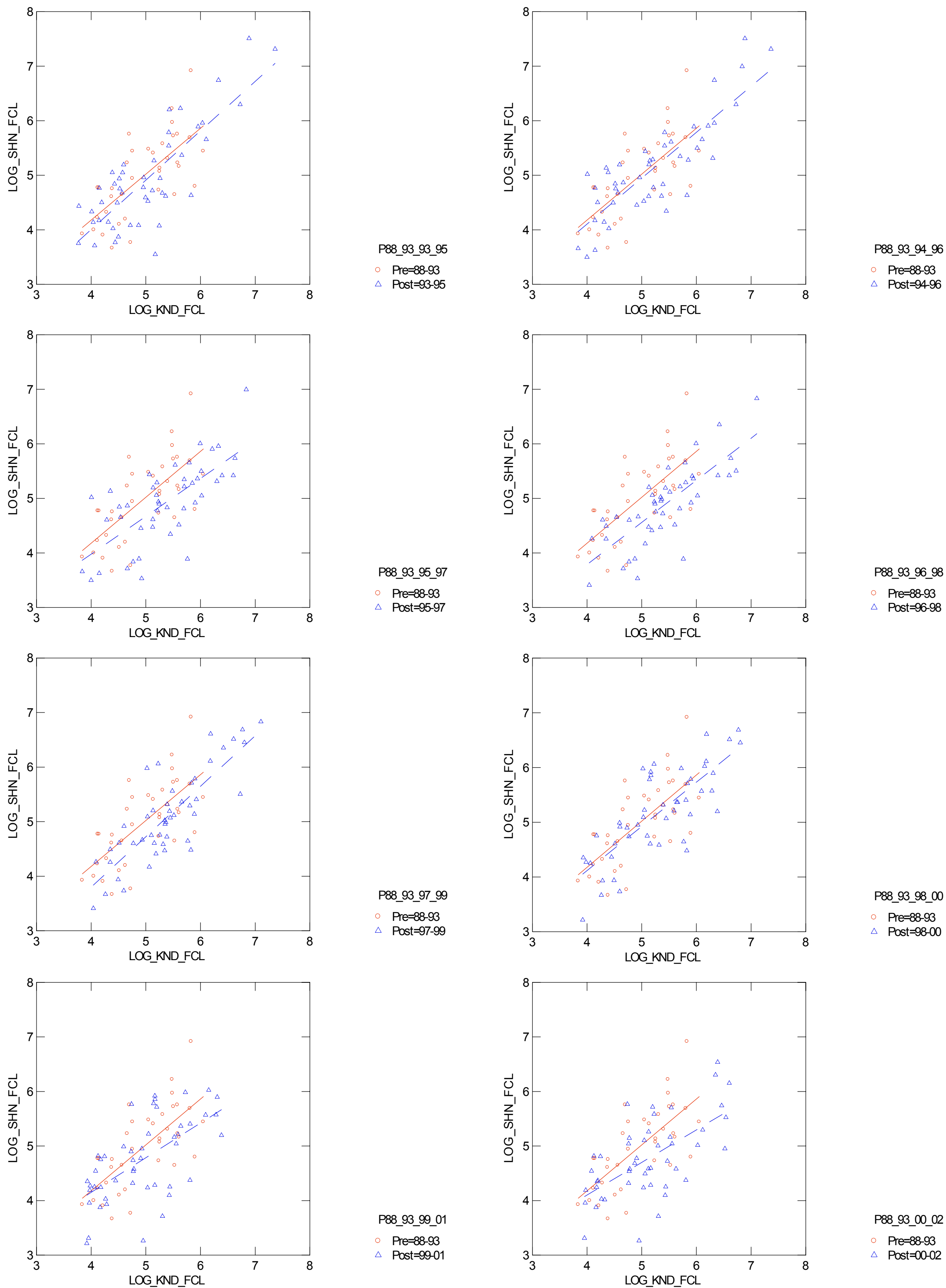

Figure 27. Paired watershed regressions of pre- and post-BMP $\log_{10}$(FC) loading data
Solid line = calibration period; dashed line = post- period. Schneider is the treated watershed.

Table 13. Fecal coliform loading percent change and its significance

	Burns	McLane	Pierre	Perry	Schneider paired watershed	Schneider	Kennedy
Calibration period	88-93	83-89	86-90	83-89	88-93	88-93	88-93
Calibration period *n*	*39*	*21*	*12*	*22*	*36*	*37*	*36*
Post-period							
1987-1989							
1988-1990							
1989-1991		134%		101%			
1990-1992		60%	**838%**	150%			
1991-1993		29%	33%	-47%			
1992-1994		-5%	71%	**-65%**			
1993-1995	26%	39%	439%	-39%	-22%	-24%	16%
1994-1996	9%	118%	**929%**	7%	-16%	22%	85%
1995-1997	-33%	53%	**456%**	-39%	-57%	-26%	**149%**
1996-1998	-28%	68%	**235%**	-46%	**-66%**	-33%	**184%**
1997-1999	83%	**275%**	207%	-22%	**-49%**	12%	**182%**
1998-2000	**157%**	**250%**	234%	-32%	-20%	30%	**117%**
1999-2001	4%	44%	33%	**-65%**	-40%	-50%	-5%
2000-2002	-21%	79%	2%	-43%	**-52%**	-48%	43%

Bold underline indicates statistical significance at α=0.05
Blue text and (-) sign indicate pollution reduction
Red text and no sign indicate pollution increase

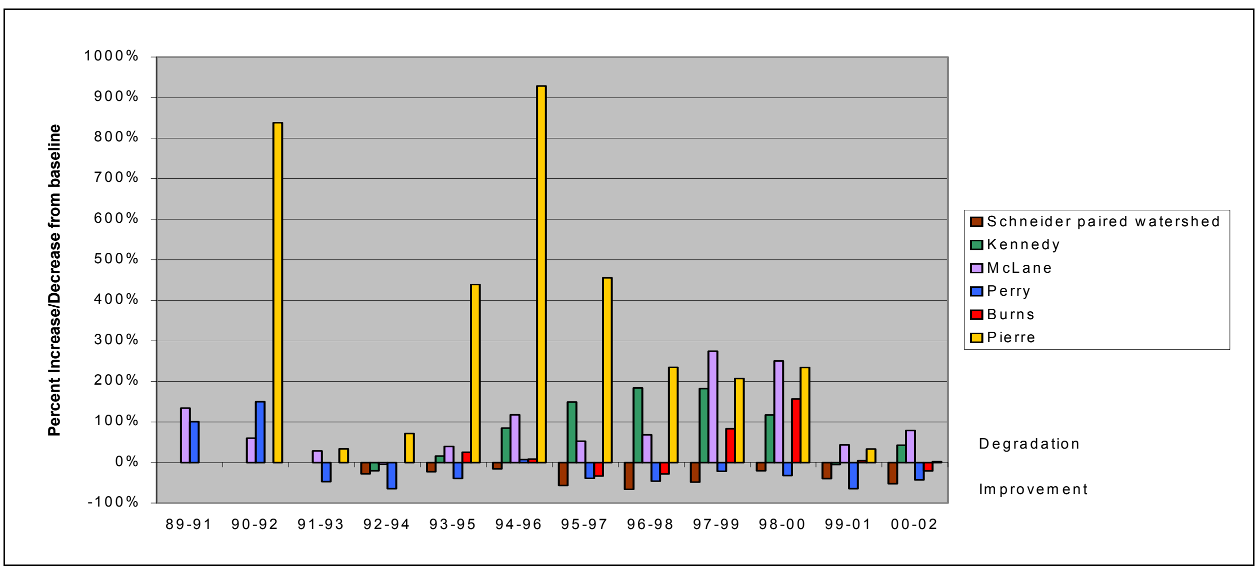

Figure 28. Percent change in fecal coliform loading cfu/sec compared to calibration period, by 2-year blocks

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Table 12 and Figure 26 show FC percent change at all streams including the paired watershed control (Kennedy). The measure is two-year block averages compared to the calibration period for each stream.

A significant 51% FC decrease at Burns was followed by a significant 105% increase, finally diminishing to a non-significant 20% increase the last two years (2000-2002) of the study. Pierre had consistently significantly elevated FC levels during the post-BMP period, peaking at a 389% increase in FC count during 1994-1996; but the 2000-2002 period is only 1% higher than the calibration period. McLane had a non-significant 3% reduction in FC during 1995-1997, but FC count increased after that, peaking at a significant 133% increase during 1997-1999. After a brief non-significant increase, Perry FC count decreased to a significant 66% during 1996-1998. This improvement held until 2000-2002, when the improvement was decreased to a 35% non-significant reduction. Schneider FC decreased, but not significantly, 35% during the first post-calibration period (1993-1995), then decreased further significantly to 71% from 1996-1998. Subsequent FC counts rose, but remained significantly below the calibration-period counts.

While Schneider FC decreased to below the calibration-period level early during the watershed grant period and stayed below that level during the entire grant period, some of the decrease may be attributed to changes in farm ownership resulting in a non-BMP-related farm management change. One farm, just upstream of the sample site, changed ownership after the original farm plan was developed. Fewer horses were observed at this farm since 1996 than in previous years; no horses were observed from late winter 1997 until fall of 2000. The historical data (Appendix B) show that FC levels increased about the same time (1990) that the original owners began keeping horses on the farm (Seiders, 1999b). We could not factor in number of horses because counts were not always certain; the range was zero to 40. By using a horses present/not-present factor in the paired watershed regression, horses are significant ($p=0.044$) for FC concentration and $p=0.033$ for FC loading during the 1995-1997 period, a period of significant reduction in loading for Schneider. The horses factor is also significant for FC loading during the 1999-2001 period.

Simple before/after analysis for Schneider shows a similar pattern, although the results are generally not as pronounced or significant as with the paired watershed analysis. Although Kennedy was the paired watershed control, results are shown for comparison to Schneider. As with all other streams, FC levels were higher at Kennedy during the last period (2000-2002) than during the prior minimum FC period (1999-2001).

Table 13 and Figure 28 show the same analysis for FC loading data. In general, percent improvement is smaller for FC loading than FC count, and improvement is significant less frequently for loading than for count. Lower incidence of significance is likely a result of higher variability with FC loading than with FC count. Degradation is generally more pronounced for FC loading than FC count, and degradation is significant more frequently for loading than for count. Increased frequency of degradation significance is likely a result of the severity of the degradation. Aside from these observations, FC loading patterns are similar to FC count patterns in that Burns and McLane were degraded most of the time, and Pierre was degraded during the entire study. Perry was improved most of the time, and Schneider was improved all of the time; although only a few of the improvements were significant.

Kennedy FC loading percent change is considerably more extreme than its FC count percent change. This is to be expected because during the wet season Kennedy typically has very low FC counts but very high flows compared to the other streams. High flow results in high loading, even at low concentrations; only McLane's loading is greater than Kennedy's because of McLane's higher FC counts (see Figure 12).

Late trends

In order to evaluate sustainability of FC changes, the last two-year monitoring period (2000-2002) was compared to the lowest achieved FC count and loading two-year periods, except for Pierre, where the lowest FC counts and loading occurred during the calibration period.

At Burns there was a significant 145% increase from the lowest period (1995-1997) to the 2000-2002 period. Pierre had consistently significantly elevated FC counts during the post-BMP period, although the degree of impairment appears to be diminishing over time. McLane FC counts were elevated all periods except 1995-97, after which the count rose, and ended at a significant 118%. The final Perry FC count was a 94% non-significant increase over the 1996-1998 period. While there were FC count improvement at Schneider after the calibration period, FC count for the 2000-2002 period was a significant 61% higher than the 1996-1998 period. Figure 29 shows the pre- and post-regression lines. These data are summarized in Table 14.

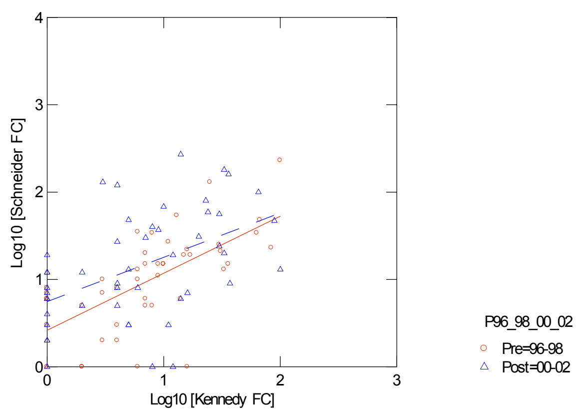

Figure 29. Paired watershed lowest achieved and most recent $\log_{10}$(FC) concentration regressions
Solid line = 1996-1998; dashed line = 2000-2002. Schneider is the treated watershed; Kennedy is the control.

Table 14. Increases in fecal coliform count from the lowest achieved count

	Burns	McLane	Pierre	Perry	Schneider paired watershed	Schneider	Kennedy
Minimum Period	95-97	95-97	86-90	96-98	96-98	95-97	96-98
Change to 2000-2002	**145%**	**118%**	1%	94%	**61%**	46%	36%

Bold underlined numbers indicate significance at α=0.05

As with FC count, final FC loading values were higher than lowest achieved values, but mostly by not as great a magnitude. At Burns there was a 18% non-significant increase from the lowest period (1995-1997) to the 2000-2002 period. At the same time, this represented a non-significant 21% decrease from the calibration period, and a more substantial decrease from the peak loading period (1998-2000), so this might be viewed as an improving trend, albeit a very short-term one. Pierre had consistently significantly elevated FC loading during the post-BMP period, peaking at nine times calibration period loading. The degree of impairment then decreased over time, and at the end of the study was indistinguishable from the calibration period. The decrease could be viewed as an improving trend from the worst point in time, but is no change from the calibration period. McLane FC loading ended at a significant 88% increase over the 1992-94 low period. The final Perry FC count was a 63% non-significant increase over the 1996-1998 period. While there were FC count improvement at Schneider after the calibration period, FC count for the 2000-2002 period was a significant 24% higher than the 1996-1998 period. Figure 30 shows the pre- and post-regression lines. These data are summarized in Table 15.

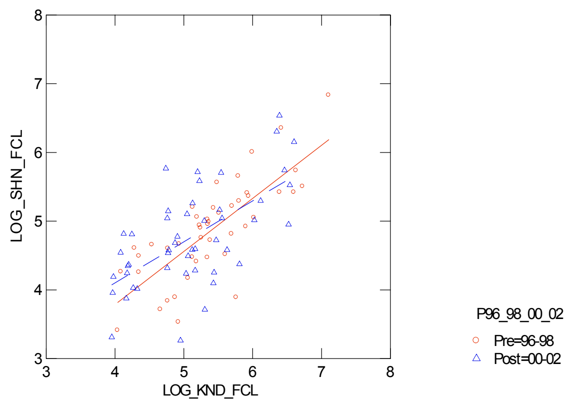

Figure 30. Paired watershed lowest achieved and most recent $\log_{10}$(FC) loading regressions
Solid line = 1996-1998; dashed line = 2000-2002.
Schneider is the treated watershed; Kennedy is the control.

Table 15. Increases in fecal coliform loading from the lowest achieved count

	Burns	McLane	Pierre	Perry	Schneider paired watershed	Schneider	Kennedy
Minimum Period	95-97	92-94	86-90	92-94	96-98	99-01	92-94
Change to 2000-2002	18%	**88%**	2%	63%	**24%**	5%	50%

Bold underlined numbers indicate significance at α=0.05

Water quality standard compliance

Fecal coliform bacteria

Table 16 compares the NMP wet-season fecal coliform (FC) data to Washington State water quality standards (Ecology, 1997). Kennedy met both parts of the fecal coliform standard all years. McLane and Perry met part 1 all years, but violated part 2 the last year of the study. Schneider met part 1 of the standard all years, but violated part 2 the first, third, seventh and ninth years. Pierre violated part 2 all years and part 1 the first eight years. Burns violated both parts of the standard all years.

Table 16. Comparison of fecal coliform data to water quality standard

		Geometric means for wet seasons (cfu/100 ml)									
	Class	92-93	93-94	94-95	95-96	96-97	97-98	98-99	99-00	00-01	01-02
Kennedy	AA	5	5	5	5	9	7	8	5	5	8
Schneider	AA	23	15	21	11	8	12	19	16	11	20
McLane	A	37	24	36	24	17	32	80	31	43	48
Perry	A	14	8	17	12	6	10	11	9	10	25
Pierre	AA	**52**	**81**	**400**	**110**	**120**	**53**	**89**	**62**	45	45
Burns	AA	**95**	**220**	**230**	**80**	**62**	**110**	**310**	**280**	**270**	**110**

		Percent of wet season samples exceeding WQ Standard Part 2									
	Class	92-93	93-94	94-95	95-96	96-97	97-98	98-99	99-00	00-01	01-02
Kennedy	AA	0	0	0	0	0	0	4	0	0	0
Schneider	AA	**17**	9	**17**	4	0	9	**13**	8	**13**	8
McLane	A	4	4	4	4	0	9	4	8	8	**25**
Perry	A	0	0	4	0	0	0	0	0	0	**17**
Pierre	AA	**22**	**50**	**91**	**57**	**45**	**17**	**39**	**21**	**14**	**17**
Burns	AA	**35**	**75**	**79**	**30**	**32**	**39**	**83**	**71**	**75**	**42**

Bold values indicate violations of FC water quality standard
Washington water quality standards are defined in Table 10

Meeting the freshwater quality standard does not necessarily mean that shellfish waters are protected. Because bacterial die-off and dilution may occur, violating the freshwater quality standard upstream does not necessarily result in violations of the marine standard in the receiving waters. The marine water quality standard values for shellfish harvest protection are lower than the freshwater standard values, and the marine standard is based on 30 consecutive samples spread out over several years. The most probable number (MPN) method is used for marine bacteria enumeration. The standard is as follows:

Part 1 - geometric mean value (GMV) shall not exceed 14 MPN/100mL
Part 2 – the 90^{th} percentile shall exceed 43 MPN/100mL

Looking at freshwater five-week moving geometric means for the same period, water quality standard violations occurred with higher frequency as indicated below. This view is used because five samples is the minimum required for 303(d) impaired water listing under the federal Clean Water Act. Table 17 summarizes seasons during which at least one five-week period resulted in a violation of part 1 or part 2 of the standards.

Table 17. Wet season 5-week moving geometric mean water quality standard violations

	Class	92-93	93-94	94-95	95-96	96-97	97-98	98-99	99-00	00-01	01-02
Kennedy	AA							X			
Schneider	AA	X	X	X	X		X	X	X	X	X
McLane	A	X	X	X	X		X	X	X	X	X
Perry	A			X							X
Burns	AA	X	X	X	X	X	X	X	X	X	X
Pierre	AA	X	X	X	X	X	X	X	X	X	X

Sampling was extended before and after the regular NMP sampling-window for the 1999 and later seasons. These dry seasons are from April 20 through November 5 of each year, except for 2002, when sampling ended June 11 (Table 18).

Table 18. Dry season water quality violations

	1999	2000	2001	2002	
Burns	**1800**	**1800**	**1300**	**130**	NMP Dry-season
Kennedy	9	17	26	6	fecal coliform count
McLane	**230**	**260**	**190**	52	geometric mean values
Pierre	**110**	**170**	**520**	**150**	
Perry	12	19	34	15	
Schneider	40	**110**	**110**	20	
Burns	**100**	**91**	**100**	**50**	NMP Dry-season
Kennedy	0	0	**18**	0	percent of samples exceeding
McLane	**35**	**53**	**44**	0	water quality standard part 2 for
Pierre	**67**	**44**	**73**	**63**	fecal coliform
Perry	6	0	**12**	0	
Schneider	**12**	**35**	**65**	0	
Burns	**X**	**X**	**X**	**X**	NMP Dry-season
Kennedy			**X**		violations of water quality standard
McLane	**X**	**X**	**X**		for fecal coliform; part 1 or part 2
Pierre	**X**	**X**	**X**	**X**	
Perry		**X**	**X**		
Schneider	**X**	**X**	**X**		
Burns	7	10	12	8	NMP Dry-season
Kennedy	17	16	17	8	number of samples
McLane	17	16	18	8	
Pierre	9	9	11	8	
Perry	17	16	17	8	
Schneider	17	16	17	8	

Bold = water quality violation

Turbidity

There were no upstream measurements for any of the NMP streams, so background turbidity could not be determined that way. If in lieu of upstream measurements, the 10th percentile value is accepted as background, then background would be from 1.04 to 9.12 NTU depending on stream, setting the water quality standard between 6.04 and 14.12 NTU (Table 19). On this basis, all streams violated the turbidity standards – Kennedy, Perry, and Schneider during some to many years of the study, and the other streams during all years of the study. All streams violated the water quality standard for turbidity during the last period – October 2001 through mid-June 2002.

There are no migratory salmonids at Burns or Pierre, so spawning activity is not a possibility for increasing turbidity there. Visual inspection of graphs of turbidity vs. part of wet year suggests spawning activity may be a factor at the other streams between early November and late December, but it is just as likely that increased erosion and runoff from storm events is the cause. It appears that all six streams should be listed for violating the state turbidity water quality standard.

Table 19. Turbidity water quality violations October 2001-June 2002

Stream	Maximum NTU 10th percentile[6]	NTU+5	Percent in violation	Number of violations
Burns	9.12	14.12	20.0	6
Kennedy	1.5	6.5	17.1	6
McLane	2	7	16.7	6
Perry	1.04	6.04	19.4	7
Pierre	8.04	13.04	22.6	7
Schneider	2.52	7.52	22.2	8

Total suspended solids

Total suspended solids (TSS) correlated fairly well with turbidity; $r^2 = 0.61$. There is no state water quality criterion for TSS.

[6] For five Oct.-Sept. wet-years 1997-2002; except 1997 when sampling started in November, and 2002 when sampling ended in June instead of September.

Precipitation

Olympia Airport water-year (October 1 – September 30) precipitation for 1986-2002 is shown in Figure 31 with a line indicating normal (30-year average) precipitation. NMP November–April wet-season precipitation is shown in Figure 32. NMP wet-season and wet-year precipitation were proportional for the period of the study. The relationship is shown in Figure 33.

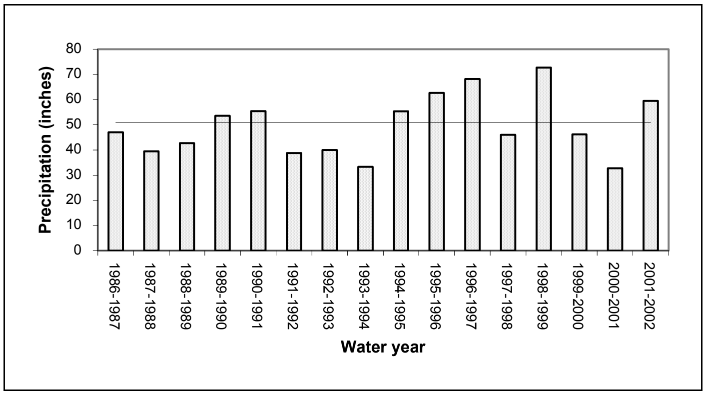

Figure 31. October 1- September 30 water-year precipitation
Horizontal line is normal precipitation

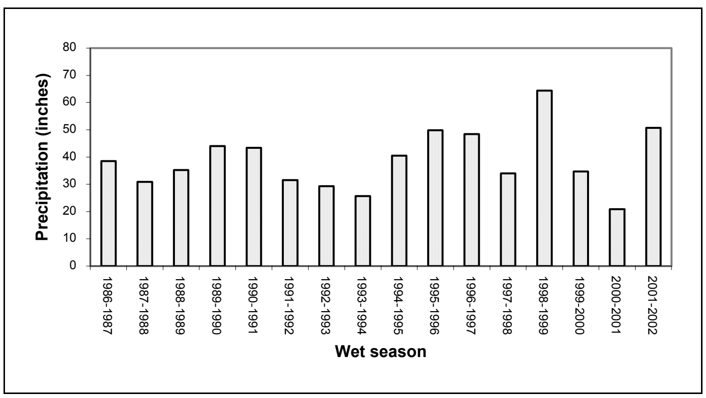

Figure 32. NMP November-April wet-season precipitation

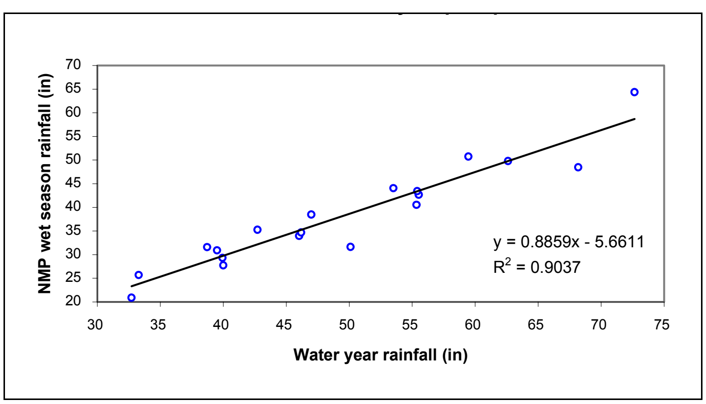

Figure 33. NMP wet season vs. water-year precipitation

Best Management Practices Data

Little new data has been submitted to Ecology reflecting any work that was done by the county or conservation district in the NMP sub-basins since 1996. Considerable work was reported for other areas of Eld Inlet, and some work was done in Totten Inlet, but not grant-related, and not formally reported. The new data were reported in the final report for the Centennial Clean Water Fund, Eld Farmers for Clean Water grant (TCD, 2000). Thurston County Environmental Health Division (TCEHD) had done some follow-up monitoring on Pierre Creek, and found runoff from a particular property was causing fecal pollution in the creek. Thurston Conservation District supplied technical support to the property owner. There was no follow up by TCEHD, and there were no further complaints brought to the attention of the district. For Eld Inlet, the number of priority farms changed from 15 priority farms (May 1996 list) to 13 (August 1996 list). We were not able to ascertain why the number of priority farms changed. Three cooperators were listed within the NMP area. Of these, data were available for two farms, but not the third.

Available BMP data from all grants were pooled into a single data base, with the knowledge that the data are incomplete, imprecise, and may be in error in some instances. We have no way of validating these data. Animal count data were pieced together from farm plans, farm surveys, and one windshield (drive-by) survey of our own. Like the BMP data, the animal data are incomplete, imprecise, and may be in error in some instances. OSSS survey data were pieced together from a variety of reports and communications. The OSSS data are from a very limited time span, and are not representative of the entire NMP study area; they were considered to be accurate at the time they were collected. As with the BMPs, the current status of operations and maintenance of OSSSs is not known.

With those caveats in mind, BMPs applications in the study basins are enumerated in Appendix Table F-1, and the amount of individual BMPs applied is enumerated in Appendix Table F-2. The data are summarized in Table 20, which makes some of the uncertainty about BMP completion apparent. Numbers of BMPs installed in the six sub-basins over time are shown graphically in Figure 34.

Table 20. Best management practices by type and sub-basin

Basin Characteristic	Burns	Kennedy	McLane	Pierre	Perry	Schneider	All basins
On-site sewage systems (as of 1997)							
Number of OSSS in basin (est.)	13	21(1)	295	9	57	118	513
Number of OSSS targeted for survey	1	0	0	2	0	33	36
Number of OSSS surveyed	1	0	0	2	0	12	15
Percent of targeted OSSS surveyed	100%	na	na	100%	na	36%	na
Farm plan development (through 2000)							
Number of farms in basin	3	3	43	2	8	26	85
Number of farm plans developed	3	0	17	2	5	5	32
Number of priority farms in basin (2)	3	2	27; 12; 12	2	7; 0; 3,2	17	58; 36; 39,38
Number of priority farms with farm plans (2)	3	0	14, 4, 1	2	3, na, 1	4	26, 13, 15
Percent of priority farms with farm plans (2)	100%	0%	52%, 33%, 8%	100%	43%, 33-50%	24%	45%, 25%, 38-39%
Farm plan signature (through 2000)							
Number of farm plans signed by TCD	2	na	8	1	3	4	18
Percent of farm plans signed by TCD	67%	na	47%	50%	60%	80%	56%
Number of farm plans signed by landowner	3	na	6	1	3	3	16
Percent of farm plans signed by landowner	100%	na	38%	50%	75%	60%	50%
Number of farm plans without signature	0	na	8	0	2	0	10
BMP and farm plan implementation (through 2000)							
Number of BMPs planned	26	0	110	17	50	45	248
Number of BMPs implemented	26	0	85	13	22	39	185
Total BMP units installed; e.g. feet, acres	3140	0	25599	57	1735	21063	51593
Total BMP units planned; e.g. feet, acres	3165	0	32558	62	17234	21367	74385
Uncertain BMP units installed (3)	0	0	1778	0	2736	0	0
Percent of numbers of BMPs implemented	100%	na	77%	76%	44%	87%	77%
Percent of BMP units installed	99%	na	79%	92%	10%	99%	69%
Percent of BMP units installed including uncertain BMPs	99%	na	84%	92%	26%	99%	69%
Number of farm plans with 100 percent BMP installation	3	na	8	0	2	4	16
Percent of farm plans with 100 percent BMP installation	1.0	na	0.5	0.0	0.4	0.8	0.5
Animal units and acreage (as of 1997)							
Wet season animal units (A.U.) in basin (est.)	7.6	1.0	142.0	5.0	44.3	93.0	292.9
Number of A.U. managed by farm plans (est.)	7.6	0.0	101.2	5.0	36.9	25.1	175.8
Percent of A.U managed by farm plans (est.)	100%	0%	71%	100%	83%	27%	60%
Number of acres identified as farms in basin	54	23	750	26	191	507	1550
Number of farm acres managed by farm plans	54	0	462	26	153	314	1007
Percent farm acres managed by farm plans	100%	0%	62%	100%	80%	62%	65%

(1) Excludes systems within the Summit Lake basin
(2) Based on farms identified as "priority" in various inventories by TCD as part of scoping for SPI & CCWF work.
Inventories as of 1989; 1993 (SPI); and 1996 (Eld CCWF)
For 1996 (Eld CCWF), two values are given; the priority list changed between 5/96 and 8/96.
(3) Uncertain designation is for BMPs that were checked off as installed, but no date was given for installation.

There is a high degree of uncertainty about the values in this table.

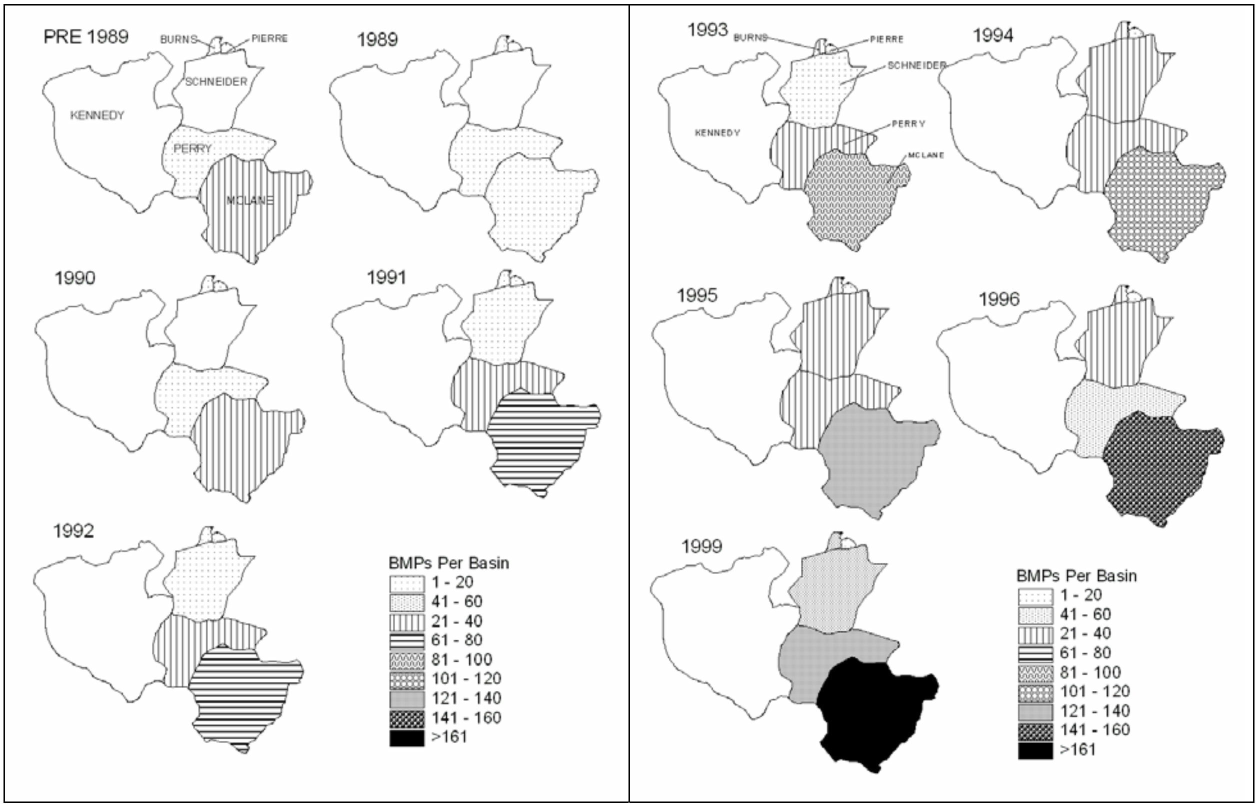

Figure 34. BMPs installed in NMP sub-basins by year

As noted above, animal counts were mostly done by drive-by "windshield" surveys, which were infrequent. Table 21 gives some idea of the variability in animal populations over time and by sub-basin.

Table 21. Animal units by sub-basin and date

	1989	1992-93	1996	1996-97	2002
Burns	9	8	7	8	11
Kennedy	10	--	--	1	5
McLane	112	90	--	142	47
Pierre	--	2	2	5	1
Perry	56	78	59.8	44	6
Schneider	--	35	56	93	70

OSSSs at Summit Lake in the Kennedy sub-basin were excluded from the NMP study. Although Summit Lake frequently violates drinking water standards for bacteria because of poorly functioning on-site sewage systems, from a non-drinking-water quality point of view, it is not regarded as a significant source of downstream bacteria levels for two reasons: 1) bacteria levels in the open-water area of the lake are typically low, from 1-5 cfu/100mL, and 2) significant bacteria die-off probably occurs during travel from Summit Lake to the mouth of Kennedy Creek (Seiders 1995).

OSSS surveys were not planned for the entire NMP area. Of the planned surveys, 3/3 (100%) were completed in the Burns and Pierre sub-basins, and 12/33 (36%) in the Schneider sub-basin

(Table 20). As noted previously, no information is available regarding the current status of on-site sewage systems (OSSSs) in the NMP area. Figure 35 shows properties with OSSSs and their distances relative to NMP streams. This was determined using the Thurston County Assessor's data base to establish parcels with residences, and GIS was used to establish parcel distance from freshwater streams.

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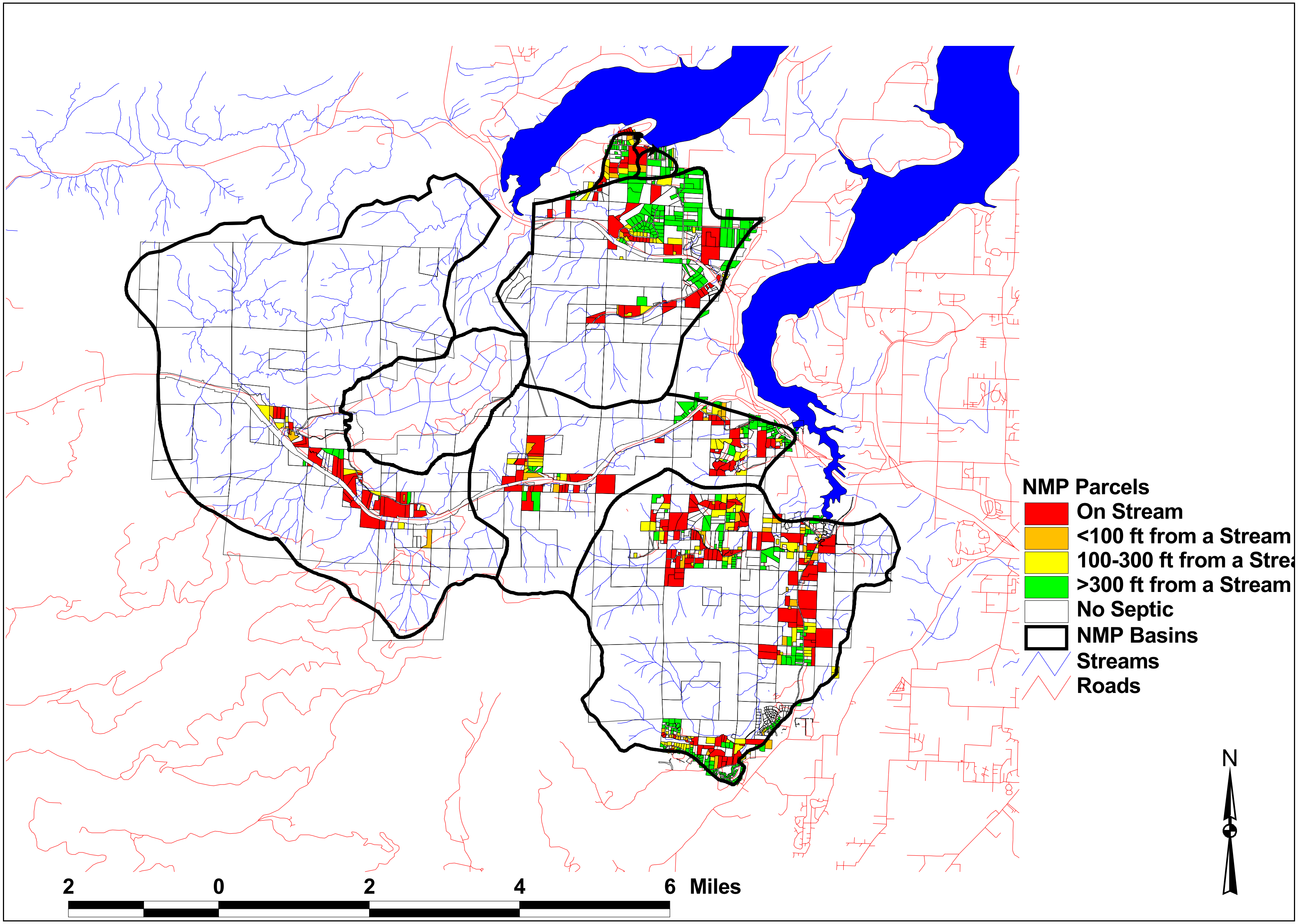

Figure 35. NMP Properties with septic systems; location relative to freshwater streams

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Discussion

General

Effectiveness analysis for this project had previously been based on measured changes in fecal coliform bacteria (FC) concentrations. The current analysis adds changes in FC loading (concentration multiplied by volumetric flow) to the analysis. The most definitive method to measure change is *paired watershed*, followed by *upstream/downstream*. The least definitive method is simple *before/after* analysis (Grabow et al., 1998). Paired watershed design yields the percent change that may be attributed to land treatment improvements in a treated watershed compared to a control. This factors out some seasonality and climatic events, but may be confounded by non-BMP, land-use or management changes in the treatment watershed, and any land use or management changes in the control watershed.

Interpreting Freshwater Results

Fecal coliform trends

There are several difficulties interpreting trends. One is the degree to which trends may be relied upon to predict behavior outside the measured range; another is that extreme events within the measured range can leverage the trend line. Short-term trends may be transient, yet long-term trends may mask potentially important current or new trends. The freshwater FC trend lines in Figures 15-18 cover the entire period under study; they do not represent exclusively post-BMP implementation conditions. The trends are described in the Results section, and are straightforward, except Pierre's trend is influenced by high leverage from very high FC counts and loading the first half of the study. Further, Pierre's FC two-year geometric mean value (GMV) count and loading never dropped below the calibration-period levels, and at last check were marginally above the calibration-period levels. Attributing this trend to grants or pollution-control efforts is further confounded because the high pollution levels occurred mostly after best management practices (BMP) implementation but before the Shellfish Protection Initiative (SPI) grants were issued.

For all streams, FC loading indicated smaller improvements or greater degradation than occurred with FC concentration as expressed in trend line slope. In some cases FC loading increased while FC concentration decreased. This is plausible for the following reasons: (1) during sustained rainfall, after the first flush of pollutant runoff to a stream, concentrations may decrease while flow and loading remain high, and (2) dilution may occur during increased flows when the pollutant source is direct and constant.

Fecal coliform percent change

Statistical analysis comparing wet-season FC concentrations and loadings before and after the BMP grant periods is described in detail in the Results section. FC levels improved at Burns and McLane, then got worse than the baseline levels; got worse at Pierre, then improved, but wound up the same as the baseline level; and improved at Perry and Schneider, but then degraded, although not back to the baseline levels. Loading followed similar patterns, although where there was improvement, the percent change was generally smaller than the percent change in the corresponding FC level, with the exception of Burns which wound up with a net improvement in FC, although not statistically significant. The ability to detect significant change is hampered somewhat by historically low sampling frequency, resulting in some pre-BMP data that are of questionable representativeness and high variability.

Even where trend lines are significant, pollution levels – both concentrations and loadings – have fluctuated considerably from year to year (Figure 15 and Figure 16). At all streams where FC concentration or loading decreased, it later rose – in some cases to near or higher than pre-BMP levels. In all cases where significant improvement occurred for at least one two-year averaged period, the average of the last two monitored seasons (2000-2002) was higher than the two-year low value. This current increase is significant for Burns, McLane, and Schneider FC counts, and McLane and Schneider FC loading (Figure 26 and Figure 28).

Continuous fecal coliform loading estimation

Continuous loading could not be calculated from the available data. While a number of storm events were captured each sampling year, the runoff profile for FC is not known for these streams. Runoff profiles would require very high frequency sampling during several rain events (Sorens and Nelson, 2001), which was beyond the design and capacity of this study. Sorens and Nelson state, "the unknown variability of the concentration between samples can lead to errors. Much or most of the load in a stream is transported during storms, and often the majority of the storm load is transported during the "first flush" or the rising limb of the hydrograph. This load is missed unless storms are intensively sampled".

These authors found that the smaller and flashier the stream, and higher the variability of the pollutants, the higher sampling frequency is needed in order to make accurate load estimates. They determined that the optimum sampling interval during storm events was between one and four hours, depending on pollutant, for a first-order stream; hourly sampling was required for total suspended solids. They did not test for FC, but we know from the NMP study that it is highly variable. Sorens and Nelson's (2001) findings agreed with those of Richards (1999), who demonstrated that accurate continuous loading estimates require focused high frequency sampling during rain events, when most runoff and erosion-induced loading occurs.

In an attempt to fill the between-sample FC data gaps, we tried to model continuous FC after Cohn et al. (1992), but the measured log(FC) vs. predicted log(FC) regression r^2 was 0.26, which is too weak of a relationship for modeling FC. Continuous stage recorders were in place at all streams except Burns. As noted in the Results section, continuous stage could not be calculated for Burns or Pierre because of tidal influence. Equipment failures resulted in gaps in the data, but most of the time gaps could be filled in by estimates calculated from inter-basin flow relationships. The most common cause for missing data was flooding over stage recorder probes, and when flows were too high to get into sites to read stream gauges. Unfortunately, these were the highest flow conditions, when loading was likely to be highest. Even when recording hydrograph probes and stream gauges were not flooded over, at high flows, it was unsafe to measure stream flows; so high flows calculated outside rating curves are estimates with high degrees of uncertainty. Sometimes probes were damaged by flooding, and sometimes data loggers failed for unknown reasons.

Between the inability to model between-sample FC concentrations and gaps in the continuous flow record, we were unable to calculate integrated total loading for each wet season; we were only able to report seasonal averages of point-estimates from each week's measurements.

Linking Water Quality Changes to BMPs and Grant Programs

Freshwater: National Monitoring Program

According to Spooner and Line (1993), "A consistent multi-year improving trend in water quality after implementation of BMPs provides evidence needed to attribute water quality improvements to land treatment". The other requirement is that there be enough complete and accurate land-use and land-treatment information to be able to rule out other possible causes for changes in pollution levels. A paired watershed or at least an upstream/downstream study is needed to be definitive. Four questions must be answered:

1. Has there been significant improvement?
2. Is the improvement continuing or at least holding?
3. Can improvement be linked to improvements in land treatment?
4. Are the land treatment changes and grant programs connected?

Conditions did not improve in Burns, Pierre, and McLane watersheds. Conditions worsened at times, then improved, but are currently no better or worse than during the calibration periods. For these streams, the answer to all four of the above questions is no, whether looking at FC concentration or FC loading.

For Schneider and Perry watersheds, the answer to the first question is yes. There were significant decreases in FC concentration and loading. For both streams, the answer to the second question is maybe. In both cases, FC concentration and loading were better during the post-calibration period than during the calibration period, but at the end of the study levels rose above best-achieved levels. FC loading followed a similar pattern, although the percent increases at the end of the study were smaller.

In Schneider's case, the answer to the third question is a qualified yes. Schneider was a paired watershed design, so seasonal and transient weather effects were factored out. The improvement in FC levels was significant, and it followed the implementation of BMPs. However, change in land use unrelated to BMPs at one farm also may have had a significant role in FC reduction at Schneider. The answer to question four appears to be yes for Schneider. The grant programs were closely aligned with BMP work, and continued past BMP installation; the grants are likely to have played a role in sustaining the improvements.

For Perry, the answer to question three is maybe. Because Perry was not a paired watershed design, we cannot rule out non-BMP factors having an effect on FC levels. However, the improvements do match the timing of BMPs. The answer to question four is partially because some of the BMP work started before the SPI grant was issued.

For Perry and Schneider, the increase in FC levels during the last two-year period of the study may be coincidental, or it may be because the grants ended two to three years prior, and conditions worsened without a pollution-control presence by state or local agencies. Only continued monitoring over time will tell. These results are summarized in Table 22.

Table 22. Linking water quality changes to BMPs and grant programs

	Burns	Pierre	McLane	Perry	Schneider
1. Has there been significant improvement?	No	No	No	Yes	Yes
2. Is the improvement continuing or at least holding?	n/a	n/a	n/a	Maybe	Maybe
3. Can improvement be linked to improvements in land treatment?	n/a	n/a	n/a	Maybe	Yes, qualified
4. Are the land treatment changes and grant programs connected?	Yes	Partially	Partially	Partially	Yes

Marine: Shellfish Protection Initiative and Centennial Clean Water Fund grants

The goals of the Shellfish Protection Initiative (SPI) were to restore the restricted shellfish harvest area in Eld Inlet to unrestricted (Washington State Department of Health *approved* classification), and to protect threatened shellfish areas in Totten Inlet. The goal of the Eld SPI to restore Eld to *approved* within three years was not achieved. Toward the end of the Eld SPI grant, the Eld Centennial Clean Water Fund (CCWF) grant was issued, and Eld was reclassified to *approved* in 1998, two years after the target date from the SPI grant.

Washington Department of Health (DOH) marine stations 159 and 160 (formerly 6 and 7 respectively) are at the southern end of the *approved* area in Eld Inlet. Station 159 is just below the north boundary of the *unclassified* area, and station 160 is in the *approved* area just to the north of the *unclassified* area. These stations are the two closest to the NMP discharge area, and do not represent all of Eld Inlet. This is the head of the inlet where flushing is weakest (PSWQAT, 2002). Long-term marine FC trends reported through 2000 were downward (improving) at station 160, and no trend at station 159. Marine FC levels near the NMP stream discharges are currently similar to those before the SPI (Figure 36). Note that DOH shellfish area classification is not based only on FC levels, but is also based on the potential for pollution determined by shoreline surveys.

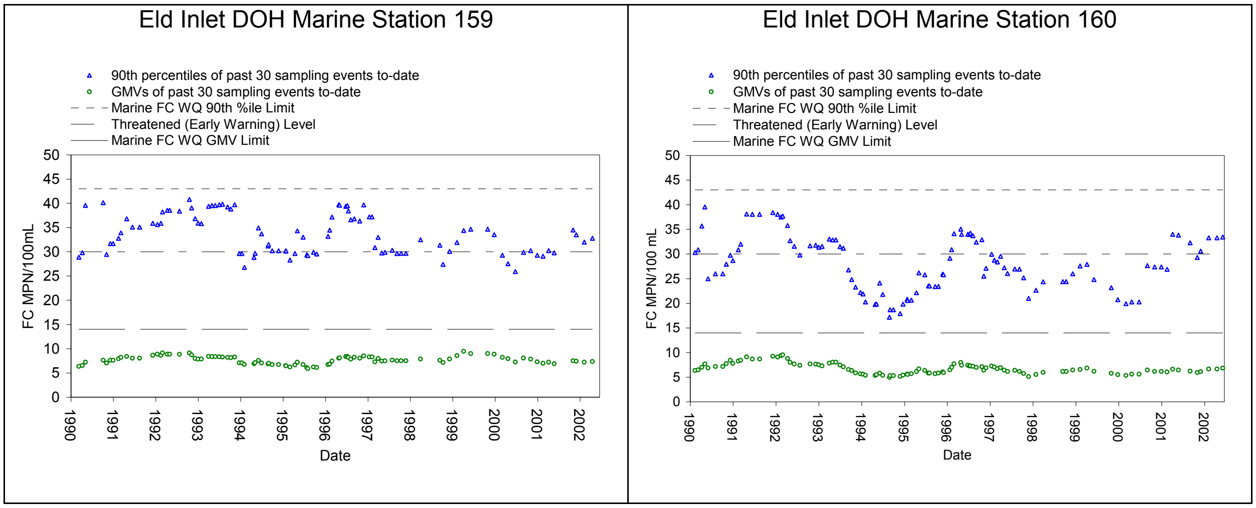

Figure 36. Eld Inlet marine fecal coliform levels near NMP stream discharges
Data are from DOH (2002a, 2003a)

The 30 MPN/100mL level is part of the DOH early warning report system which classifies an area as threatened with a downgrade if the 90th percentile at one or more stations equals or exceeds 30 MPN/100mL of water (Determan, 2003; PSWQAT, 2002). For both areas, decreases in both geometric mean and 90th percentile[7] FC levels occurred about midstream during each of the Eld SPI and CCWF grants and then rose again toward the end of each grant period. Levels at both stations have risen since the end of the CCWF grant (Figure 36). Threatened status for Eld Inlet was announced by the Puget Sound Water Quality Action Team in July, 2003 (PSWQAT, 2003). A DOH map of threatened sites indicates Eld was designated as threatened in April, 2003 (DOH, 2003b).

There are no DOH marine sampling stations within the unclassified area at the southern end of Totten Inlet, into which Kennedy and Schneider creeks discharge. Station 136 is near the Burns Point shoreline in the *approved* area just north of the Burns Cove *unclassified* boundary, and station 137 is in the *approved* area near the shoreline about midpoint between Burns Point and the *unclassified* boundary to the south. Both stations had improving (decreasing) FC trends during the period the Totten SPI grant was in effect. Levels at station 136 continued to decline for two years following the end of the grant in 1998 and have risen since 2000; levels at station 137 have been rising since the end of the SPI grant in 1998. Levels at both stations meet marine water quality standards (Figure 37).

[7] Data are $\log_{10}$ transformed; the base 90th percentile is the antilog of the sum of the mean of the transformed data and 1.28 times the standard deviation of the transformed data; and "The MPN values that signify the upper or lower range of sensitivity of the MPN tests in the 90th percentile calculation shall be increased or decreased by one significant number". (FDA, 2000)

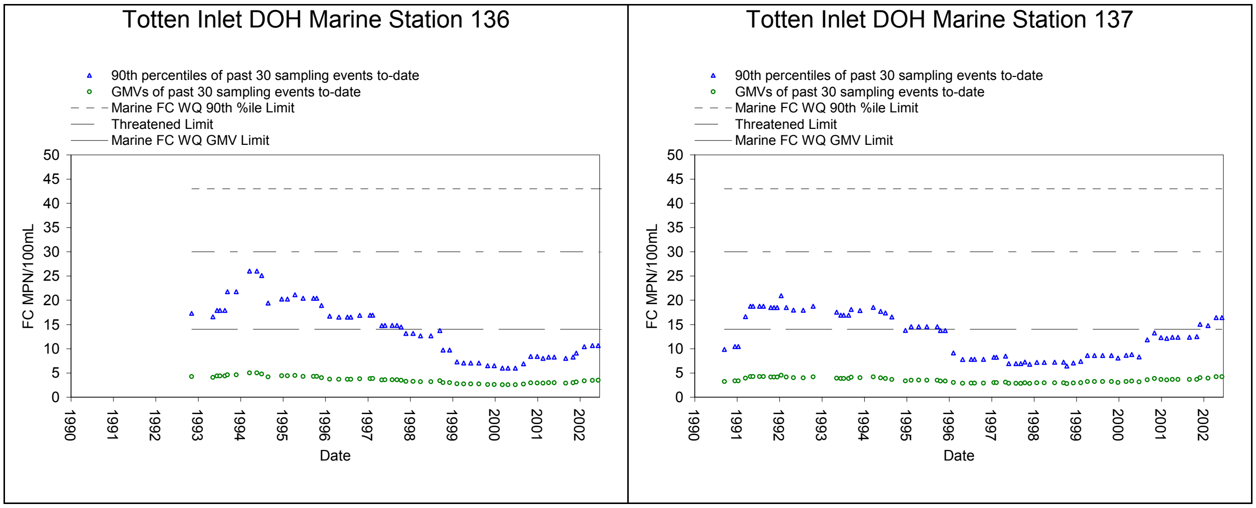

Figure 37. Totten Inlet marine fecal coliform levels near NMP stream discharges
Data are from DOH (2003)
Data were not available for station 136 prior to 1993

While there appears to be a connection between the grants and marine water quality, the scope of the NMP was to evaluate the effectiveness of the grants in improving freshwater quality in sub-basins discharging to these marine inlets.

Difficulties Linking Freshwater Quality Changes to Watershed-Level Pollution-Control Programs

When pollution-control goals are met in watersheds, we would like to be able to link that success to watershed-level, pollution-control programs. When goals are not met, we need to determine what was lacking in the programs. A program may be completely successful in task implementation; e.g. targeted number of farm plans completed or septic systems repaired. But completion of all tasks does not guarantee that water quality goals will be met. This can occur when the scope of pollution-control targets is incomplete, when participation by land owners is incomplete, and when there is limited or no follow-through to ensure the proper operation and maintenance of BMPs and septic systems over time. Incomplete pollution-control efforts and inadequate reporting on those efforts can both contribute to difficulty linking water quality changes to watershed-level, pollution-control programs.

Different goals for pollution-control grants and the monitoring program

The SPI and CCWF grant programs had different goals than the NMP. While these goals were complementary, not contradictory, the differences created difficulties linking water quality changes to remedial efforts. The SPI and CCWF goals were to restore and protect a beneficial use, shellfish production. The NMP goal was to measure the effectiveness of watershed-level, pollution-control efforts. It was designed to measure the amount and significance of improvement in the quality of freshwater discharging to the shellfish growing areas, and to try to link those changes to watershed pollution-control efforts.

Different criteria for grant completion and measuring effectiveness

In order to link water quality changes to pollution-control efforts, there was a need to quantify completion of grant tasks within the NMP study area. The Totten and Eld SPI grants were not designed with detailed documentation of pollution-control efforts as a priority. The Eld CCWF grant was written with requirements for documentation, but follow-through was lacking, delivered data required substantial sifting, and the data were incomplete.

Data on farm-plan implementation were difficult to obtain at times, and were often incomplete and sometimes inaccurate. Lack of institutional accountability requirements was evidenced by lack of specific reporting requirements. This resulted in difficulty collecting, compiling, and analyzing pollution-control data. The intent and meaning of grant language were interpreted differently by various parties over time, which created differences of opinion with regard to the degree to which farm plans and BMPs had been completed (Seiders, 1999a). Change in grant requirements without formal grant amendments also impaired the ability to measure grant success against original objectives, since original targets were changed without a historical record of the rationale for the change. The monitoring design measure was target number of farm plans signed and target amount of BMPs installed. Demographic change and lack of a program for continual monitoring of BMP maintenance, operations, or performance limited the ability to track land-use changes and BMP durability.

Synchronization between variables and monitoring

The ability to link water quality changes to BMP activities requires an experimental control situation with adequate water quality monitoring during distinct pre-BMP (calibration period), BMP implementation, and post-BMP periods. The experimental lines are blurred if some BMPs are already in progress during the calibration period, or if land use or ownership changes over time. Hydrogeologic differences between sub-basins and changes in precipitation from year to year further complicate the experimental design. Grants that overlap in time and grant extensions blur the definitions of pre- and post-BMP implementation periods. Even when significance can be demonstrated statistically, representativeness comes into question.

Baseline data

Pollution controls

For reasons discussed above, historical data on pollution controls were not complete or reliable.

Water quality

The ability to detect significant change in water quality may be hampered by inadequate historical ambient monitoring and by inability to support long enough pre- and post-BMP monitoring for statistically valid and meaningful analysis. Ambient bacteria sampling frequency is often too low to be useful for pre-BMP calibration needed to be able to detect significant change resulting from pollution-control efforts. Further, paired-watershed or at least upstream/downstream monitoring is needed to be able to attribute improvements in water quality to pollution-control efforts, and ambient monitoring design needs to factor this in. The NMP project encountered this problem. The pollution-control efforts were based on a known pollution-caused use impairment, but very limited freshwater sampling had been done by the time pollution-control efforts started. In 1983, McLane and Perry were sampled 11 times during November-April wet-season periods; then there was a two-year break with no sampling. After that, sampling frequency at what would become the NMP study streams was only three to five November-April wet-season samples per year. It wasn't until fall 1992, when the screening study commenced in preparation for the NMP, that the sampling frequency was increased to weekly sampling for the entire wet season. That only gave one year of monitoring before pollution-control grants were issued, and it followed some pollution-control efforts that had already begun in the watersheds before the grants were issued.

Factors Affecting the Ability to Meet Original Pollution-Control Goals

The ability to meet original pollution-control goals has been hampered by reliance on voluntary efforts over regulatory mandatory compliance. The backdrop is a conflict between private property rights and community environmental rights (Mrachek, 1995). Ability to meet goals has also been impaired by demographic change (Determan, 1993; Mead, 1999). Also presenting difficulties are complex inter-agency relationships (Figure 5), combined with organizational changes and staff turnover and reductions within state and local agencies. State budget prioritization of natural resource programs (OFM, 2003) present increasing limits to environmental agencies carrying out their mandated duties.

Unlike permitted activities covered by the Clean Water Act National Pollutant Discharge Elimination System (NPDES), rural residential small farm practices and on-site sewage systems (OSSSs) do not require permits at federal or state levels, so there is no regulatory inspection or enforcement mechanism at these levels to prevent pollution. This does not mean that pollution is legal; but it does mean that where local statute does not regulate farming or require OSSS inspections, the mechanisms to prevent pollution are limited to voluntary efforts by land owners, and willingness of local and state agencies to participate in enforcement actions when pollution does occur.

Voluntary participation and compliance

Expectations for measuring water quality improvement from nonpoint pollution-control projects may need to be reduced because desired levels of voluntary participation may not be reached. With both Totten and Eld SPI grants, and with the Eld CCWF grant, not all priority farms became involved in the farm planning process (Sagen, 1996; TCD, 1997; TCD, 2000). Forty-five percent of the SPI priority farms in the NMP study basins participated in developing farm plans, and 42% participated in OSSS surveys. For the Eld Farmers for Clean Water CCWF grant, 3 of 15 NMP-area priority farms, or 20%, are listed as cooperators. Of those, according to the record of decision, one farm did not complete any BMPs. Of the two remaining farms, one completed 83% of the BMPs it had planned, and there is no record of BMPs planned or completed for the other farm. That leaves participation at 13% of priority farms with 36% BMP completion at the participating farms.

There is a conflict between privacy or property rights and enforcement concerns, and the legitimate need to enforce against polluters. While enforcement is required in some cases to stop pollution, desire for privacy, or fear of enforcement or loss of property-rights, may keep some individuals from participating in watershed cleanup efforts. According to Thurston Conservation District (TCD, 2000), many potential cooperators backed away from the Eld Farmers CCWF grant when they found out that information about their farms could not be kept confidential, that it would eventually be released to Ecology, and that there was a referral process for enforcement by Thurston County Environmental Health Division.

On the other hand, in the NMP study area, enforcement efforts evidently played a role in motivating non-cooperating land owners to participate in pollution-control efforts prior to the SPI and associated grant programs. Of ten farm plans developed in Schneider, Burns, and Pierre basins, five of the sites developed farm plans solely through voluntary action. The remaining five sites were encouraged to develop farm plans through a referral process which proceeded from requests for cooperation towards formal enforcement of state water quality laws (Starry, 1990; Hofstad, 1993). This referral process involved the farm operators, TCEHD, TCD, and Ecology. After completion of the SPI grants, but under the Eld Farmers CCWF grant, one farm adjacent to Pierre Creek in Totten Inlet appears to have improved land management as a result of an enforcement advisory by the county (TCD, 2000), although the owner did not agree to a farm plan.

The choice of whether or not to participate in farm planning and pollution-control efforts was made by land owners. Without the potential of enforcement actions by government agencies, conservation districts were unable to implement corrective actions at polluting, non-cooperating farms. Field staff at Ecology's Southwest Regional Office have heard requests from several counties and conservation districts that Ecology increase its enforcement presence, because an increased Ecology presence boosts counties' and conservation districts' ability to achieve voluntary compliance (Hempleman, 2002b; Mead, 1999; Madsen, 2002). The regional office had only one non-dairy agricultural inspection and enforcement position, and funding for that position was eliminated as a result of state budget reductions (Cornett, 2003).

Because there is no longer funding for non-dairy agricultural inspection and enforcement, dairy pollution issues will be managed like other water quality complaints, that is, prioritized to determine the level of response. These concerns will be managed on a complaint response basis, and will be prioritized low unless there is a serious water quality issue, a TMDL issue, a shellfish bed impact, or another concern requiring a response. Responsibility for dairy inspections and enforcement is being transferred by legislative directive from Ecology to the Department of Agriculture in July 2003 (Cornett, 2003).

An important element of the SPI projects was an intensive sanitary survey program using dye testing to identify failing systems. Participation was mandatory, with administrative search warrants being issued when compliance was not agreed to (TCEHD, 1995). A State Supreme Court ruling, Seattle v. McCready (1994), stipulated the conditions that must be met to exercise administrative search warrants. Thurston County Sanitary Code did not meet these conditions for dye testing, and the program switched from mandatory to voluntary (TCEHD, 1996).

In 1995 the county amended its Sanitary Code to allow administrative search warrants to be continued for dye testing septic systems. However, there was uncertainty over whether the new code would stand a legal test. Rather than to cause undue stress to citizens and risk the threat of lawsuits against the county should the law fail, the county Board of Health directed staff to work with other counties and the state to pursue the issue of administrative search warrants through the state legislature (Hedges, 1996). The legislature addressed the issue in 1998 with state bill SSB 5636; this was followed up by modification of Revised Code of Washington 70.118.030. The Eld SPI grant closed in 1996, and the Totten SPI grant closed in 1998.

After inspections changed from mandatory to voluntary, participation in the program dropped in both Eld and Totten inlets (Hofstad et al. 1996; Hofstad & Tipton, 1998). Some homeowners did not respond to requests for consent, and some did not consent. Some who gave consent were initially hesitant to do so because without warrant authority, the county health department could not ensure that all houses identified within a survey area would be surveyed. Most of those who were initially hesitant felt it was unfair that those who gave consent risked the possibility of having their septic system defined as failing, while others could choose not to participate in the survey and avoid such risk (TCEHD, 1995).

Wolf (1995) noted that, "The question of an enforcement mechanism for an NPS[8] program is particularly intricate, given historic resistance to regulation among rural populations, the political influence of the agricultural sector, and the question of constitutionality of land-use controls". Over the course of the NMP effort in Ecology's Southwest Regional Office area, including Thurston County, there has been a decrease in ability to inspect and enforce. Limited state resources limit access to non-cooperators' property (Manning, 2000). Current budget reductions[9] raise the likelihood of even fewer resources being available for pollution prevention and remediation.

Demographic change

When land ownership changes, the investment made in education and farm planning efforts for a particular property may be lost. Unless the watershed-based, pollution-control efforts include follow-up with new owners, the original efforts are likely to become diluted. While physical BMP elements like fencing remain, these require proper operation and maintenance. For example, fencing is the physical element required for riparian protection and pasture management; but without proper management, the fencing itself does not automatically afford environmental protection. If fencing is not kept in good repair, or if the gates are not managed as intended, the fencing does not serve its intended function. New owners may not be aware of the management and maintenance needed to prevent pollution.

Population growth may be accompanied by land conversion and subdivision. For example, an 80-acre tract of forest may be logged and subdivided into 16 five-acre home properties, some of which are likely to become rural-residential small farms, and all of which will have OSSSs. As with one-to-one land-ownership changes, unless the watershed-based, pollution-control efforts

[8] Nonpoint Source
[9] Washington State budget reductions for the 2003-2005 biennium total $2.4 billion, which is 10.4% of the state general fund budget.

include follow-up with new land owners, the original watershed efforts are likely to become diluted. Furthermore, as the population increases, per-capita pollution must be decreased just to hold even on pollution loading. When population doubles, per-capita pollution must be cut in half for no change in loading. For the 24% population increase in the Eld watershed between 1990 and 2002, a 19% reduction in per-capita FC loading was required just to keep loading from increasing. Further reductions were needed for water quality improvement.

Institutional factors

Inter- and intra-agency grant, responsibility, and reporting relationships are complex, impairing both the assurance of BMP implementation and the ability to coordinate collection and transmittal of BMP information. State BMP grant money was issued to Thurston County; Thurston County Environmental Health Division (TCEHD) performed on-site septic system work directly, and sub-contracted to Thurston Conservation District (TCD) for land-use education and BMP work. TCD recorded BMPs and reported progress to TCEHD, which then reported directly to an Ecology regional office, and/or to Ecology's Environmental Assessment (EA) Program. In some cases TCD delivered information directly to the EA Program (Figure 5). Ecology's regional office grant managers are now also involved in permit-management and enforcement efforts, leaving less time for grant management.

Relationships and budgets

Institutional structure and change creates barriers to success of long-term BMP implementation or monitoring projects. Reorganizations and reprioritizations can shift funding to other program areas. State agency leadership and funding is periodically influenced by election results.
A large part of Ecology's funding is from the state legislature, which may affect the agency via targeted funding and budget cuts. Citizen initiatives limiting tax revenues and directing expenditures have similar effects. Two-year legislative, initiative, and budget cycles mean that reorganization and reprioritization may occur at this frequency. Federal funding (such as EPA 319 NMP grants) can provide some guarantee of long-term project commitment, but even that is subject to periodic renewal and commitment from EPA and Congress.

The share of state general fund money that went to environmental and recreational agencies during the 1989-1991 biennium was 2.64%; that shrank to 1.6% by the 1995-1997 biennium and remained the same through the 1999-2001 biennium (OFM, 2003). This was 61% of the 1989-1991 share. 2000 per capita spending on these programs was 91% of what it was in 1990 (OFM, 2003).

An example of budget cuts affecting the ability of environmental agencies getting their work done is loss of state library services. A budget cut of $2.7 million eliminates services which had been available exclusively to state employees and legislative staff and designed to support informed public policy. The specialized services that will no longer be available as of July 1, 2003 include: access to many databases and electronic journals; access to the netLibrary eBook collection; interlibrary borrowing except in the subject areas of Washington history, genealogy, and state and federal government; booking or reserving of training videos; direct mailing and hand delivery of materials to individuals' offices; an on-site legislative reference librarian;

professional journals and books purchased specifically for state government; and training to meet specific research needs of state government (WSL, 2003). Among these services are ones which have assisted environmental agencies in getting their jobs done.

At the conservation district level, which is where most of the hands-on, pollution-control work gets done, there is a lack of stable continuous funding. Prior to 1993, when TCD started getting money from a district property tax assessment, it had to rely exclusively on grant funding. Applying and making a case for grants is a time-consuming process, which takes time away from the substance work of conservation and pollution control. In addition, over the years TCD has found fewer grant monies available. In 2002, Thurston County commissioners voted to reallocate just over one quarter (28%) of TCD's assessment to county control. That means TCD will need to apply to the county for that money, apply elsewhere for funding, or potentially lose staff and reduce the amount of work they can do. While there is likely to be some effect on TCD operations, the money under county control is designated for shellfish protection efforts within the current shellfish protection districts (Henderson and Nisqually).

Goals and limitations

Conflicting goals within pollution-control agencies can reduce the likelihood of success of BMP programs, and hinder the ability to collect adequate data to measure change over time. For example, grant officers may be directed to prioritize their time to issue and close out grants; remaining time may be inadequate to make sure that grant tasks or water quality improvements are achieved. In this case, there are conflicts between grant programs and the ability of monitoring staff to provide information to support good water quality management decisions.

Limitations and conflicting mandates of participating agencies and programs, in conjunction with public concerns, create barriers to participation by land owners. Conservation districts are mandated to assist farmers, and are not regulatory or enforcement agents (Trefry, 1986 (ca.)). Conservation districts have no statutory mandate to refer non-cooperators, and grant conditions requiring referral may not be implemented. In addition, privacy is an issue for many land owners, yet public disclosure laws preclude conservation districts from guaranteeing confidentiality. Some land owners choose not to participate in pollution-control programs because of concerns over enforcement or privacy (TCD, 2000).

As noted in the *Voluntary participation and compliance* section, litigation can play a role in limiting pollution-control efforts. Another instance where this occurred was with attempted follow-through for a Totten/Little Skookum SPI grant task. The grant called for a feasibility study for requiring operations and maintenance permits for all septic systems in the watershed. The study was completed, but litigation over a water quality fee at the county level was a contributing factor to the county not fully developing an operations and maintenance program (Hofstad, 2003c).

Accountability

Reporting

Reporting needs and requirements differ within and among agencies, which complicates efforts to obtain meaningful information about pollution-control work. There is no Ecology requirement that grants contain BMP data reporting; neither data elements nor specific format are required (Ecology, 2000 (Revised); Stewart, 2000; James, 2002). That is not to say that Ecology grants never have data-reporting requirements; it is simply not an Ecology requirement. The Eld Centennial grant did contain requirements for data reporting. However, there was no standard data format or emphasis at the staff level to require the data to be provided. Ecology's Environmental Information Management (EIM) data base currently does not have fields for BMP data (Neumiller, 2003; Stewart, 2003).

TCD data recording format, content, and reporting has varied over time, and has been dependent on funding and granting-agency requirements. All SPI parties recognized this before the NMP effort began. They consciously decided to use reporting formats already in use, expecting the needed pollution-control information to be present. Ecology's requirements for grant compliance have differed from the Environmental Assessment Program's needs for analysis. Two reporting levels exist for grants: fiscal, which is required by law, and any other information required by the grant. Reporting on grant activities often entails dollars spent, but does not detail progress toward implementation goals.

Pollution-control data had to be pieced together from quarterly and final reports, farm plan records, and some personal communications. Some conservation district data came via the county to Ecology's regional office, and then to NMP staff; some came from the district to Ecology's regional office, then to NMP staff; and some were transmitted directly from the district to NMP staff. Likewise, some county data went to Ecology's regional office and then to NMP staff, and some were transmitted directly to NMP staff.

Accounting and work completion

Not all state grant-charged work was completed in the larger grant area (Sontag, 2000), and this may have resulted in some BMP work not being done in the smaller NMP study area. NMP staff attempted to reconcile differences between our assessment of grant project completion and TCD's assessment. TCD and a former Ecology SPI grant manager asserted that all work had been completed. NMP staff analyzing data provided by the district concluded that in relation to the original targets, less than 100% of the farm plans and BMPs had been completed (Seiders, 1999b). Several workers at TCD brought to the attention of the State Auditor that targeted grant monies were being spent on other projects. The State Auditor confirmed that "grants were being charged for work that was not performed", and that the TCD did not have "adequate internal controls over disbursements to sufficiently prevent or detect unallowable expenditures or misappropriation of public assets" (Sontag, 2000). Subsequent to that, TCD has undergone a complete change of management, and the current staff has been very cooperative and helpful with Ecology, although it has been hampered by past record-keeping practices.

Coordination

Coordination among and within agencies takes considerable effort; yet agencies have not invested in the levels of coordination needed to assure that watershed plans and grants are implemented as intended. For example, there has been no Watershed Action Plan lead for Eld Inlet for ten years, since Thurston County quit funding the position, and the Totten-Little Skookum Action Plan group disbanded in 1989, although some aspects of the plan have been implemented since then.

Case in point: evolution of the Shellfish Protection Initiative as a nonpoint pollution-control effort

The history of the nonpoint pollution-control efforts in Totten and Eld watersheds illustrates some of the factors discussed above, and provides insight into the response and durability of institutional programs designed to address nonpoint pollution. One indicator of a successful nonpoint pollution program is its durability over years and decades. The history of the Shellfish Protection Initiative (SPI) is recounted here because of its role in managing nonpoint pollution in the Totten and Eld watersheds.

The SPI grant effort came about due to frustration with efforts that were failing to prevent shellfish harvest restrictions and closures in Washington. In the early 1980s, Ecology helped establish an interagency Shellfish Advisory Committee. Members of the Advisory Committee helped Ecology identify needs and solutions to the continuing decline in water quality of shellfish harvest areas. In 1984, Ecology published its Shellfish Protection Strategy. Heightened concerns of the shellfish industry in 1990 led Ecology to find funds to act on controlling nonpoint pollution. The Shellfish Advisory Committee identified barriers to success of past and current programs and tried to design a program that would succeed at controlling nonpoint pollution. The resultant SPI was designed to get pollution controls implemented. Grant monies would be awarded to applicants from areas where watershed planning and public outreach had already occurred. Approximately three million dollars from the state Referendum 39 account were to finance five SPI projects over a three to five year period. The SPI projects were selected in the summer of 1992; about $1.1 million was allocated to Thurston County and $0.4 million to Mason County. None of the Mason County work was targeted at the NMP study area.

The grant application and interview process made clear that this was an assertive program. Ecology and the state Department of Health (DOH) would shepherd the projects towards their objectives. The application process provided substantial information about the water quality problems, the sources of water pollution, and the abilities and readiness of local governments to focus on prioritized pollutant sources through regulatory and voluntary mechanisms. For the SPI projects, Ecology increased its grant oversight activities, required quarterly roundtable meetings to bring project participants together, required quarterly reports that addressed specific topics and progress, and offered technical and enforcement assistance to grant recipients. The SPI was expected to be the most assertive and able program to succeed in getting nonpoint pollution controls implemented where they were most needed to protect water quality.

Early in 1992, Ecology was narrowing its search for a nonpoint pollution-control implementation project for long-term monitoring within the context of the National Monitoring Program (NMP). The goal of the monitoring project was to evaluate the effectiveness of such programs. From about a dozen potential watershed projects, comments were solicited from local and state government staff who would be involved with nonpoint pollution-control projects. The NMP was explained as a separate project focused on evaluating the effectiveness of a nonpoint pollution-control project. The NMP was characterized as dovetailing with a selected watershed project. The NMP would monitor water quality and the implementation of pollution controls over a 6-10 year period. The Totten and Eld SPI projects best fit EPA's project selection criteria and were proposed for Washington's NMP project. EPA conditionally approved the NMP proposal in the spring of 1993 and gave final approval in March 1995. Approval assured a long-term funding commitment by EPA for NMP monitoring activities.

The SPI grants were managed by Ecology staff from the Shorelands and Coastal Zone Management Program's Shellfish Protection Unit. The Unit staff focused on protecting and restoring shellfish harvest areas around the state by coordinating nonpoint pollution remedial efforts among various local and state governments. A two-phase grant application and interview process occurred from March to July 1992. Finalists were selected in July 1992 and grant contracts were developed during the remainder of the year. The Totten/Little Skookum inlets SPI grant contract was signed in December 1992, as was the Eld Inlet SPI grant. Both SPI grants were between Ecology and TCEHD. TCEHD then subcontracted with TCD to perform the agricultural remedial tasks of the grant. Although minor differences in wording exist between the Ecology SPI grant and TCD's subcontract, the intent of the agricultural tasks did not change.

As the SPI projects gained momentum and local governments progressed with their pollution-control programs, changes within Ecology led to a re-alignment of agency priorities and staff responsibilities. These changes were driven by reductions in staff, changes in upper-level management, and reorganization. In the summer of 1993, the Shellfish Protection Unit was disbanded. Staff were either cut or reassigned to positions at Ecology headquarters or regional offices. An unofficial Shellfish Protection Team, made up of former Shellfish Protection Unit members who remained at Ecology headquarters, survived until March 1994.

By January 1995, Ecology's ongoing shellfish protection efforts were further reduced as staff were reassigned and given work duties unrelated to shellfish protection. Ecology had planned to select a manager for the SPI grants but this never occurred (Pivirotto, 1995). Ecology's role was reduced to disbursing payments to grant recipients. Grants were turned over to Ecology's Southwest Regional Office, which had just absorbed staff from a merger of the Water Quality Financial Assistance Program with the Water Quality Program. Under this reorganization, workload increased for some staff and/or time allotted for grant management decreased. There was also a time-consuming learning curve as some took on financial roles they had no prior experience with. The last SPI roundtable meeting for the Totten and Eld SPI projects occurred in July 1995. Ecology technical support and strong oversight of the SPI projects came to an end. Other SPI participants also experienced changes in management and staffing since the SPI grants were signed.

In 1993 Thurston Conservation District (TCD) was able to expand programs and staff after receiving a monetary assessment. By 1995 the staff at TCD was at 16; however, staffing numbers shrank back to 10 in 2002. These numbers are for all TCD staff, including support staff (management and reception); only part of the staff was responsible for surface-water-quality project work, in addition to other work. Also, the relationship between TCD and the Natural Resources Conservation Service (NRCS) suffered when TCD and the NRCS relocated in 1998, resulting in an end of co-housing. NRCS workload and reorganization have resulted in less support for TCD since 1993. Around 2000, the Washington Conservation Commission began receiving money from the legislature for engineering services, which enabled the conservation districts to hire an engineer to share. This had enabled TCD to complete more projects without waiting for NRCS engineering staff. This resulted in shorter project turnaround times. More engineering money came through for the 2003-04 biennium; however, it is unclear how secure funding will be in future years. TCD will subcontract engineering jobs as they no longer have the engineer in-house. In 2000, TCD reorganized, dropping several management positions. This fostered communication and teamwork, but workload has been spread among remaining staff, which has resulted in a much heavier workload for remaining staff (Whalen, 2002). TCEHD appeared to have remained more stable (Seiders, 1999b), but it shrank from a peak of 6.9 surface water full-time employees (FTEs) in 1996 to 2.4 in 2002. The 2003 budget calls for a reduction to 2.3 FTEs (Hofstad, 2003a).

Some of the pollution-control efforts in the Totten and Eld watersheds include Ecology-administered grants with a variety of objectives. For the NMP effort, the original objectives of these projects were interpreted as milestones for measuring progress and evaluating the effectiveness of the pollution-control program. The distinction between grant objectives and grant requirements is important because each is evaluated differently. Responsibility for compliance with grant requirements falls under Ecology grant management, not the NMP project. Project objectives are developed by grant applicants; Ecology then funds projects that appear to have a good chance to achieve their objectives. Ecology does not penalize grant recipients for not achieving the goals of the grant, as long as a good faith effort is made. While the grant objectives of the Totten SPI were not fully achieved, the grant recipients met the requirements of the grant and performed admirably under the circumstances (Pivirotto, 1998).

This grant-management approach played a role in the varied expectations of the Totten and Eld SPI-funded projects and the Eld CCWF project. Grant language was interpreted differently by different project participants over time; this likely evolved from changes in and reduced communication among participating staff. Changes in grant objectives and mechanisms to achieve those objectives became better known during discussions in the summer of 1998. For example, grant-required enforcement mechanisms that were designed to encourage non-cooperating land owners to improve their farm management practices were discontinued in these projects. Project objectives evolved over time. Therefore, achievement of the original objectives was not a high priority.

Dichotomies

There is a conflict that limits conclusions that can be drawn from this study: study independence vs. need for the data on an ongoing basis for environmental protection. We cannot answer the question, "How successful is a BMP program likely to be in the absence of a water quality monitoring program?" The presence of monitoring activities may have an effect on the degree of participation and effort by land owners and other agencies. Making water quality monitoring results available on a periodic or ongoing basis introduces informational feedback that is not present in BMP programs that lack monitoring. We cannot assume where BMPs are implemented, and environmental improvement occurs, it would have occurred to the same degree without monitoring. This suggests that monitoring may be a necessary component of any BMP program. In any event, monitoring is required to determine the effectiveness of BMP programs.

Measuring water quality in a representative and accurate manner often requires the cooperation of land owners. Ecology staff had to make assurances that NMP water quality monitoring results would not result in enforcement actions in order to get community agreement for the project. Yet there is a community responsibility to report health hazards. NMP water quality data were periodically delivered to the county health department; and in 2000, Ecology instituted a practice of routinely reporting fecal coliform levels at or above 200 cfu/100mL to the county and Ecology's regional office.

Because these measurements were for whole watershed sub-basins, they could not be used to pinpoint the source of the pollution, so they could not result directly in enforcement. In theory, there might be follow-up by the county or the regional office to identify the source of pollution and to get land-owner cooperation for pollution reduction. This could have two side-effects. One could be an effect on the outcome of the monitoring program, as discussed above. The other could be objections to the monitoring program itself.

Follow-through on these water quality impairment reports did not occur because of lack of funding. Starting May 2000, Ecology's NMP staff started notifying Thurston County and Ecology's Southwest Regional Office whenever FC counts reached 200 cfu/100mL or higher. The county did no follow-up source-identification work because they had no funding for it, and no land owners were contacted following the high FC count notifications (Hofstad, 2002a). Ecology's Southwest Regional Office did no follow-up due to limited investigative and enforcement capacity (Hempleman, 2003b).

Historical Review of Incomplete Participation in Pollution-control Programs

Implementing pollution controls and evaluating their effectiveness requires a substantial investment by individuals and institutions alike. In Wisconsin, Wolf (1995) examined the institutional difficulties in determining levels of success of the state's water quality program. Areas reviewed included water quality (before and after BMP implementation), participation in pollution-control programs, and the effectiveness of institutional coordination. Wolf concluded that an inadequate level of participation in voluntary programs was the main reason for little or no measurable improvements in water quality.

In Washington, previous attempts to evaluate the effectiveness of pollution-control efforts have also been hindered by inadequate participation in voluntary programs or lack of information about the extent of participation that did occur.

Dickes and Merrill (1990) assessed the effectiveness of dairy farm BMP implementation on water quality in the Johnson Creek watershed in northwest Washington. Water quality remained poor after 80% of planned BMPs were implemented on 45 dairy farms. Improper management techniques and/or the influence of non-participating farms were suggested as reasons for continued pollution of watershed streams.

Bachert (1993) evaluated the status of farm planning for 675 dairies in northwest Washington, and found that 50% had farm plans while 37% did not. The remaining 13% of the farms were not contacted. Of the farms with plans, about 39% of the plans were fully implemented, 46% were partially implemented, and the remaining 15% had no implementation. Bachert also reported on dairy farmers' reasons for and for not implementing and maintaining BMPs. The primary reason given for implementing BMPs was regulations requiring waste management. The next most cited reason was special funding allowing increased available cost-share money and increased activity by conservation agencies. High cost was listed as the primary reason for not implementing BMPs. The next reason, changing farm leases, was not generally applicable to rural-residential home farms.

Bachert's finding concerning cost-share was shared by Hempleman (2003a), who observed that providing cost-share for BMPs as well as OSSSs increases the rate of compliance, usually significantly.

Determan (1993) described efforts to clean up contaminated shellfish beds in Puget Sound and reported on factors affecting the integrity of farm plans. Ongoing changes in land use and farm management presented challenges in developing and tracking farm plan implementation. Determan found that no agency tracked such changes or monitored the level of farm plan implementation. Constraints to progress included land-owner resistance, staffing and funding difficulties at conservation districts, and time needed to "sell" and implement farm plans.

Dickes and Patterson (1994) found that bacterial water quality had declined in the Burley and Minter creek watersheds after 10 years of rural, nonpoint pollution-control implementation. A large percent of acreage had been treated with BMPs in these watersheds which drain to productive shellfish harvest areas. Reasons for the continued decline in water quality included population increases, changes in the locations and magnitudes of contaminant sources, and failure to focus efforts on priority areas. More information about the nature, location, and timing of pollution controls may have given a clearer picture as to why 10 years of nonpoint control efforts did not result in expected water quality improvements.

Western Washington University (1996) recently completed four years of a five-year study to document changes in water quality as dairy waste pollution controls are installed in the Kamm Creek basin. The Natural Resources Conservation Service is working with about 25 dairy farms in this USDA Water Quality Special Project area. Improvements in water quality have not yet been seen. Vandersypen (1997) reported that land use and BMP data of sufficient detail were not available at the time to assess BMP effectiveness in terms of water quality. As in the Johnson Creek and Burley-Minter Creek studies, lack of information about the nature, location, and timing of pollution controls limited the ability to measure the success of nonpoint pollution-control efforts.

Lack of information about nonpoint pollution controls is a recurring theme and limiting factor in Washington's efforts to measure the effects of nonpoint pollution programs on water quality. While this Totten and Eld Inlet Clean Water Projects study has produced data on pollution controls that were planned, there are large data gaps with regard to implementation. The current situation is the same as Determan found in 1993: there is currently no agency responsible for tracking the durability of rural nonpoint pollution controls installed through publicly-funded programs. This results in no measure of whether agricultural BMPs are properly used and/or maintained during their life expectancy. Without this information, it is not possible to definitively evaluate the effectiveness of these pollution-control efforts.

Outlook for Shellfish

The outlook for shellfish is clouded. Totten and Eld inlets remain threatened by bacterial pollution. Analysis of post- vs. pre-BMP periods indicates FC loading, which is the primary measure of concern for shellfish, has not improved at Burns, Pierre, or McLane. Loading decreased significantly during several post-BMP years at both Perry and Schneider, but the decrease was not significant at Perry for the last two-year period (2000-2002). Factors other than BMPs cannot be ruled out as affecting the results at Perry, and a non-BMP related land-use change at Schneider appears to be responsible for some of the improvement there.

One goal of the Shellfish Protection Initiative (SPI) was to upgrade Eld Inlet from *conditional* harvest to *approved* within three years; the SPI grants were issued in 1993. In Eld Inlet, marine water FC levels did generally go down (DOH, 1998; DOH, 2000). Most of Eld Inlet that had been classified *conditional* for shellfish harvest was reclassified *approved* in 1998, two years behind the 1996 target. DOH cites OSSS work and livestock BMP installations as responsible for improvements. However, a substantial portion of this improvement is likely from OSSS work done when there was a grant-funded intensive septic system inspection program in effect, with possible enforcement. This program is no longer mandatory for homeowners. The southern-most reach of Eld Inlet was reclassified from *conditional* to *unclassified*, which means that portion is now off-limits to commercial shellfish harvest. At the two Eld Inlet DOH marine monitoring stations nearest to NMP discharges, FC levels rose from lows around 1995 to near historical high values by 1996-97 for both stations: 1999-2000 for one station, and 2001-2002 for the other station. Both DOH Eld marine stations closest to the NMP Eld freshwater streams have been at or exceeded the DOH *threatened* level for prolonged periods at times from 1990 to and including 2002 (Figure 36).

The southern-most portion of Totten Inlet was changed from *approved* to *unclassified* around November 2000, in part because of difficulty getting a boat in to sample this shallow area. Recently DOH changed a small portion of Burns Cove in Totten Inlet from *approved* to *unclassified* based on the NMP sampling information from Burns and Pierre creeks in association with data gathered during a DOH watershed evaluation. According to DOH, there have been no requests for commercial shellfish harvest in this or the southern *unclassified* area. DOH will conduct a watershed evaluation of Eld Inlet in the near future, and will use the NMP Eld data in that effort as well (Berbells, 2002).

In Puget Sound, despite the restoration of thousands of acres of shellfish beds, shellfish from 25% of the commercial growing areas still are not safe to eat (PSWQAT, 2001a). For sound and coastal harvest areas combined, 47,051 acres of shellfish harvest area were downgraded between 1981 and 2002, while only 18,294 acres were upgraded. On the other hand, of these totals, 10,754 acres were upgraded between 1996 and 2002, while 2,091 acres were downgraded (DOH, 2002b). Whether the current improvements represent a trend or an anomaly remains to be seen.

Are the BMP Programs Effective?

The intent of this study is not to determine whether or to what degree particular BMPs are effective; its purpose is to measure the effectiveness of BMP programs on watershed scales. While sub-basin, pollution-control goals were not met, the situation would probably be worse if those BMPs were not in place. Also, demographic change (increase in population and animals) may be overwhelming the original control efforts. Where pollution did not decrease to desired levels, part of the reason is likely to have been project incompletion and non-participation. Another cause may be improper or inadequate BMP operations and maintenance. Pollution has increased the past one or two wet seasons, but it is unclear if this is a trend or an anomaly. The time-frame for substantial environmental data collection for any one project is inadequate to answer long-term environmental performance questions.

The findings of this study are consistent with the State of Washington Joint Legislative Audit and Review Committee report on funding for environmental projects (JLARC, 2001). The report draws a distinction between distributing money and investing in improvements for environmental quality. Information is required for investing, but since environmental programs in Washington are generally lacking needed information, the programs are primarily distributing money rather than investing it. The report concludes that "Environmental investments are intended to produce a return of quality improvements in water, land, or species resources. Without measurable returns, it is impossible to determine if investments have been effective". The Washington NMP study showed mixed results. Some water quality improved and some got worse. Even where improvement occurred, subsequent quality has taken a downturn or its future is in question.

The JLARC report also concluded that, "Solid data is missing for monitoring environmental quality, learning from past projects, and coordinating investments across programs. While some steps have been taken towards developing meaningful environmental performance measures and coordinating projects, these efforts are only in their infancy". In the case of the NMP effort, we do have good environmental quality data from late 1992, but ambient data used for much of the calibration period, as well as pollution-control and land-use data, are deficient. Where environmental improvement did occur, we cannot adequately answer the question of whether the improvement was due to the pollution-control programs.

Recommendations

1. Ecology must substantially increase ambient monitoring in coverage and frequency, if it wants to measure change at any given time against the historical record. Sampling frequency needs to be great enough to establish baseline conditions for comparison at later dates. Project water quality monitoring should commence as far in advance of any planned best management practices (BMP) work as possible, and should continue for a minimum of two years after BMP completion. Ambient and project baseline monitoring for contaminants should be conducted year-round until such point it can be demonstrated on a case-by-case basis that seasonality and climatic variability have insignificant effects on contaminant level or loading measurements, or until the critical periods are well defined.

2. Sample replication should be increased from the current Ecology practice of 10% replication. Precision can be inferred but not determined for any sample that is not collected at least in duplicate. This is especially important for samples of known high variability like bacteria, for which both field and lab split sample replication should be increased. The number of laboratory dilutions should be increased to reduce the incidence of counts that are "at or above the reported value". Statistical power analysis should be undertaken in all cases to determine the minimum sampling frequency required for meaningful results.

3. Seasonal climatic patterns and weather events need to be factored out when determining effectiveness of watershed pollution-control efforts. Paired watershed and upstream/downstream monitoring can do this if all assumptions are met, but the real world often differs from the ideal condition. Analytical methods should be applied to account for seasonal climatic and transient weather factors.

4. Upstream/downstream monitoring should be included with all monitoring projects, even paired watershed studies. Lack of ability to restrict BMP installation in control watersheds is good for environmental protection goals, but can cause loss of usefulness of a stream as a control. The upstream/downstream method maintains an internal control for isolating the effects of BMP implementation.

5. Stream flows should be measured synoptically with pollutant sampling whenever possible in order to have the ability to estimate loading and covariate effects.

6. States should engage in concerted efforts to obtain and consolidate statewide demographic and land-use data with both geo-spatial and ownership information. The data need to be updated annually, and the historical data should be as accessible as current data, so changes can be measured over time.

7. Counties need on-site sewage (septic) system (OSSS) operations and maintenance programs that track all systems. Requirements should include periodic leakage

inspection, repair when leakage is present, solids buildup inspection, pumping when indicated by inspection, and reporting.

8. Nonpoint-source pollution grants and loans for agriculture and OSSSs need to have unambiguous language with regard to performance expectations and measures, as well as data collection, storage, and reporting requirements.
   - Land-use and management practices, livestock populations, and measurements of pollution-control installations and operations and maintenance need to be documented and reported for all projects.
   - If state environmental agencies want to know whether pollution-control grants are resulting in water quality improvements, they need to fund water quality monitoring staff for this purpose.
   - Some form of BMP data-reporting standardization is needed, including a requirement for electronic data submittal with electronic signature, and a quality assurance process.
   - When grant language calls for farm prioritization, it also needs to call for stating the rationale for each farm's priority ranking. As priority lists change, the changes need to be documented, stating why each prioritization changed, so that the evolution of the lists can be understood later.
   - Changes in any grant requirements need to be documented as grant amendments with explanatory text.

9. If nonpoint-source granting agencies or their governing bodies want to promote the effective expenditure of public funds in issuing nonpoint agricultural and OSSS grants, they need to evaluate grant programs in the contexts of accountability, documentation, and effectiveness. This is consistent with the Joint Legislative Audit and Review Committee report (JLARC, 2001) on distributing vs. investing money. Following are recommendations for better accountability:
   - For multi-agency and/or multi-level projects, agencies need to establish project managers to coordinate efforts and keep projects on track for the lives of the projects, including preliminary and follow-up work.
   - Agencies need to have low grant-to-grant-manager ratios to allow grant managers more time to visit projects and thoroughly review all reports to ensure all grant tasks have been completed.
   - Agencies need to hold grantees accountable for grant performance, including but not limited to completion of farm plans and BMPs, record-keeping, and data delivery. Ideally grant managers should have workloads that allow this level of oversight. If agencies cannot afford this level of oversight, at least random audits of satisfaction of grant requirements should be considered.
   - Agencies should consider implementing performance-based payments on grants, where the extent to which the original intent of the grant has been satisfied would determine the portion of grant funds disbursed.

- ➢ Any grant money disbursed by an agency that results in increased property value for a land owner needs to be conditioned on written agreement by the beneficiary land owner to allow access to the property by all grantors for the life of the property improvement; i.e., if a state agency grants money to a county which then sub-grants to a land owner, both the state and county should have access to inspect the property. Life spans of improvements should be clearly defined in policy and grant language. If feasible, these agreements should be written into easements in land titles, so transfer of property will not negate the public's investment in water quality and the means to ensure protections.

10. The downside of the above element is that some land owners may be reluctant to participate in pollution-control efforts, if they feel that privacy is threatened, chance of enforcement action is increased, or that they will be liable for cleanup while non-participators may not be. Environmental agencies need to engage in open dialogue about this conflict between accountability and participation. Policies should be developed addressing this issue, so that expectations of all parties will be clear when promoting participation in pollution-control programs.

11. Nonpoint pollution efforts need stable long-term funding bases.

    - ➢ In the face of constantly changing land use and ownership, farm management planning and on-site oversight are dynamic and interactive processes. The conservation districts and/or counties need to visit and revisit these properties. Cleanup efforts in any given watershed need to be continuous or at least revisited with some regularity.
    - ➢ A critical aspect is incentives. Providing cost-share money for BMPs and OSSSs increases the rate of compliance.

12. Ecology should consider encouraging the state, local agencies, or land trusts to purchase riparian properties in cases where watershed cleanup efforts have failed to be achieved or failed to be lasting.

13. Environmental agencies should review their programs for conflicting mandates and implementations.

14. All six streams in this National Monitoring Program study should be included on the federal Clean Water Act section 303(d) list as not meeting water quality standards for fecal coliform bacteria and turbidity; and total maximum daily load (TMDL) studies should be developed for these parameters. The six streams are currently listed for pH, but five of these streams have low ionic strength, so the listings may be in error. We recommend that only Burns Creek remain listed for pH.

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Appendix A

Analytical Methods and Data Quality Objectives

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Field Measurements

Parameter Code	Parameter	Method	Lower Reporting Limit	Target Precision	Bias
v	Velocity	Hall-effect Current Meter: Marsh McBirney models 2000, 201, 201D	0 ft./sec	±0.05 f/s	NA
T deg C	Temperature degrees Celsius	Alcohol Thermometer: Range 0-50 deg. C	0 deg. C	±0.2̃ C	NA
DO	Dissolved Oxygen	Field DO Meter: YSI Model 57	0 mg/L	±1.0 mg/L	NA
COND	Conductivity	Field Meter/Conductivity Bridge: Beckman Solu-Bridge model BR-5	1 μS/cm	±20 μS/cm	NA

General Chemistry

Parameter Code	Parameter	Method	Lower Reporting Limit	Target Precision	Bias
DOC	Dissolved organic carbon	EPA 415.1	1.0 mg/L		NA
EC	*Escherichia coli*	MUG	1cfu/100ml		low at > 150 cfu
ENTMF	Enterococci membrane filter	EPA 1600	1cfu/100ml		low at > 150 cfu
FCMF	Fecal coliform membrane filter	SM 16-909C	1cfu/100ml		low at > 150 cfu
NH_3	Ammonia nitrogen	EPA 350.1	0.01 mg/L		NA
NO_2 NO_3	Nitrate + nitrite nitrogen	EPA 353.2	0.01 mg/L		NA
PO_4	Orthophosphate	EPA 365.3	0.01 mg/L		NA
TOC	Total organic carbon	EPA 415.1	1.0 mg/L		NA
TPN	Total persulfate nitrogen	SM 4500 NO3-F Modified	0.01mg/L		NA
TSS	Total suspended solids	EPA 160.2; SM-17 2540C	1.0 mg/L	s = ±5.2 @ 15 mg/L s = ±24 @ 242 mg/L s = ±13 @ 1707 mg/L or %RSD =< -7.2791Ln(x) + 53.062 (x = replicate mean)	NA
TURB	Turbidity	EPA 180.1	0.1 NTU	s = ±0.6 @ 26NTU s = ±4.7 @ 180NTU	NA

Method Abbreviations

EPA: US Environmental Protection Agency

MUG: (4-Methyl-Umbelliferyl-β-D Glucuronide) a two-step membrane-filtration method for detection of total coliforms and *Escherichia coli*

SM: Standard Methods

Land-Use and Management

Management Measures Parameter	Unit of Measure	Method of Collection	Collection Frequency	Temporal Accuracy
inventory on-site sewage system	each	door to door survey and county records	once during project life	month
repair on-site sewage system	each	surveys and repair orders	when repair completed	week
farm inventory	each	survey	when completed	week
pasture/grazing management	acres and # of animals	farm plan & review	annually	week
stream fencing	feet	farm plan & review	annually	week
stream buffer	feet	farm plan & review	annually	week
gutters/downspouts	rainwater diverted	farm plan & review	annually	week
manure management	# of animals, systems, acres	farm plan & review	annually	week
forest harvest	acres	forest practices applications	annually	week

Land-Use Parameter	Unit of Measure	Method of Collection	Collection Frequency	Temporal Accuracy
agriculture	acre	farm inventory, tax assessments	annually	year
pasture	acre	farm inventory, revisits	annually	year
other	acre	farm inventory, revisits	annually	year
residential	acre	tax assessments	annually	year
suburban	acre	tax assessments	annually	year
urban	acre	tax assessments	annually	year
rural	acre	tax assessments	annually	year
forestry	acre	tax assessments	annually	year
undeveloped	acre	tax assessments	annually	year
commercial	acre	tax assessments	annually	year
industrial	acre	tax assessments	annually	year
other	acre	tax assessments	annually	year

Appendix B

Water Quality Data from Totten and Eld Inlet Study Basins

See Data Appendixes (Appendix B, C, and D) supplement
Ecology Publication 03-03-011

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Appendix C

Explanatory Notes for Water Quality Data

See Data Appendixes (Appendix B, C, and D) supplement
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Appendix D

Water Quality Data Results
Quality Assurance Notes

See Data Appendixes (Appendix B, C, and D) supplement
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Appendix E

Water Quality Graphs

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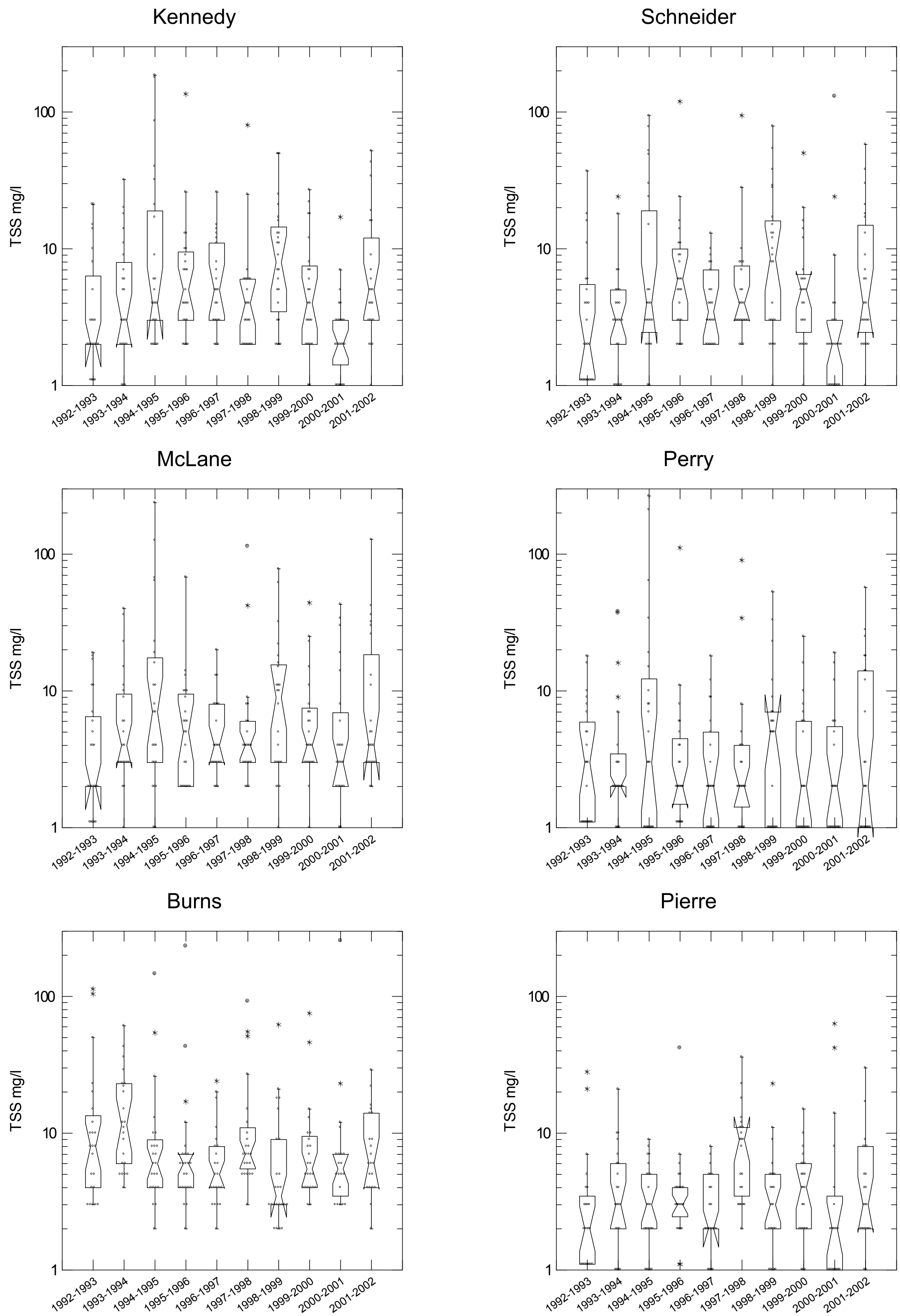

Figure E-1. Total suspended solids notched box plots

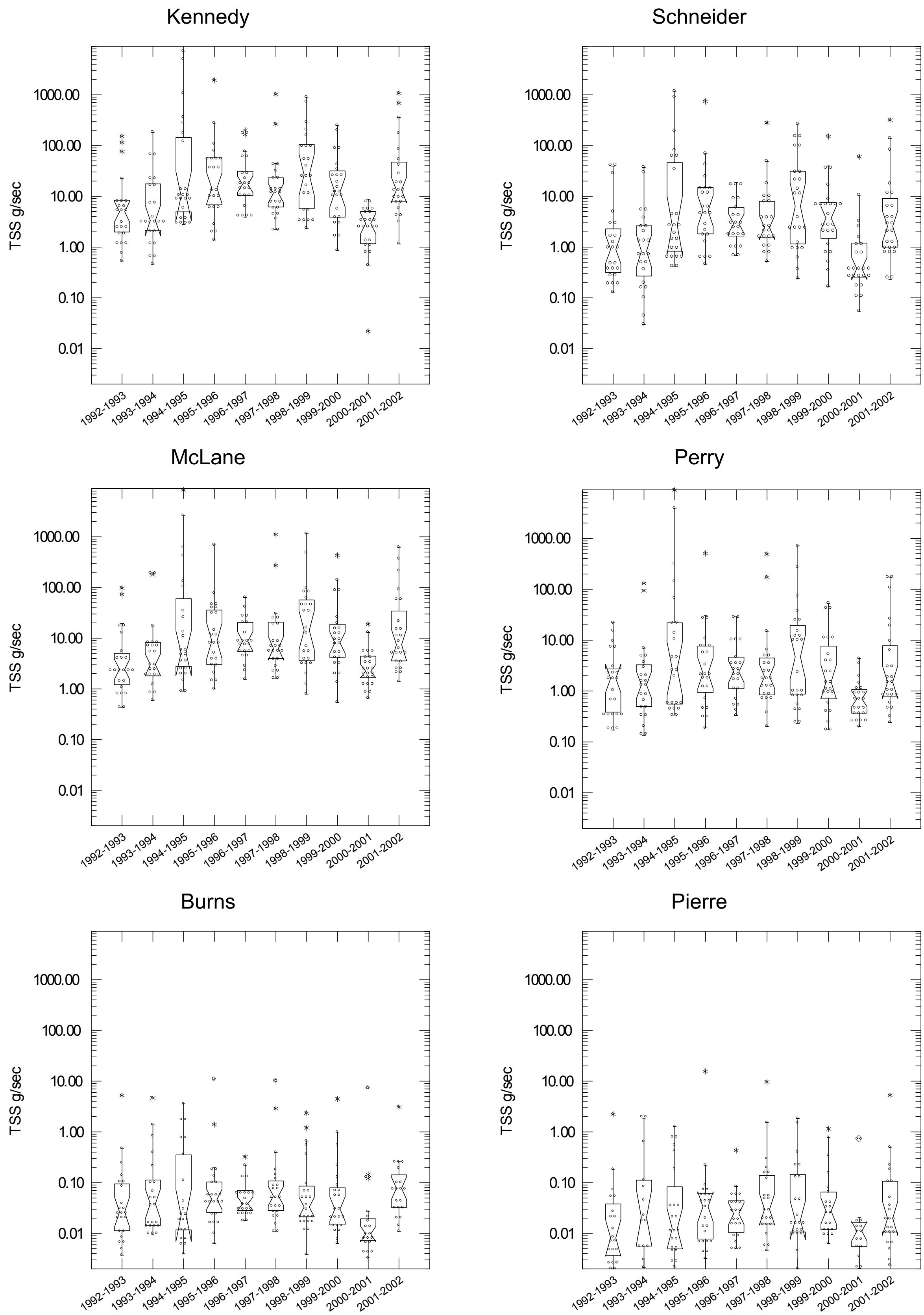

Figure E-2. Total suspended solids loading notched box plots

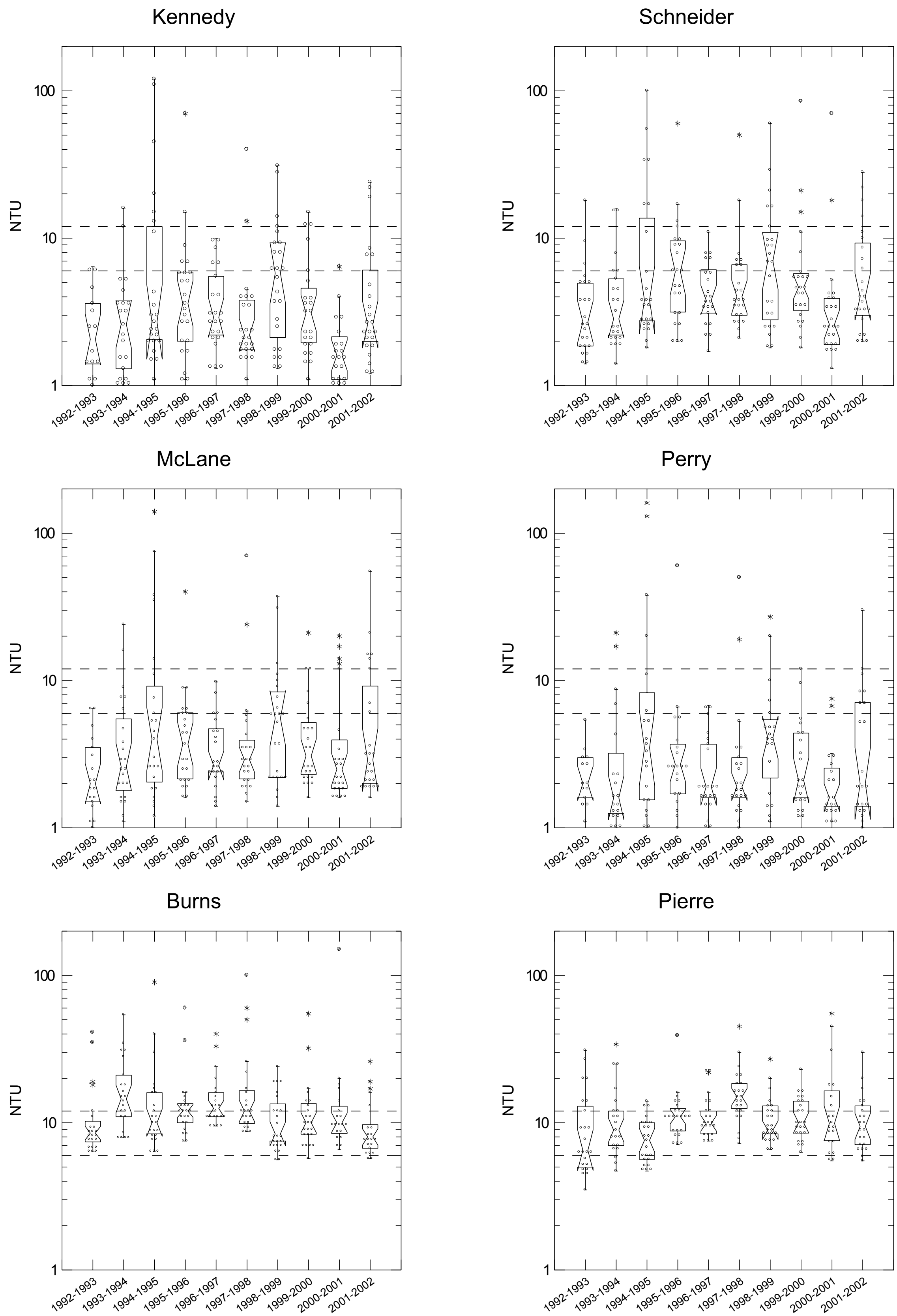

Figure E-3. Turbidity notched box plots

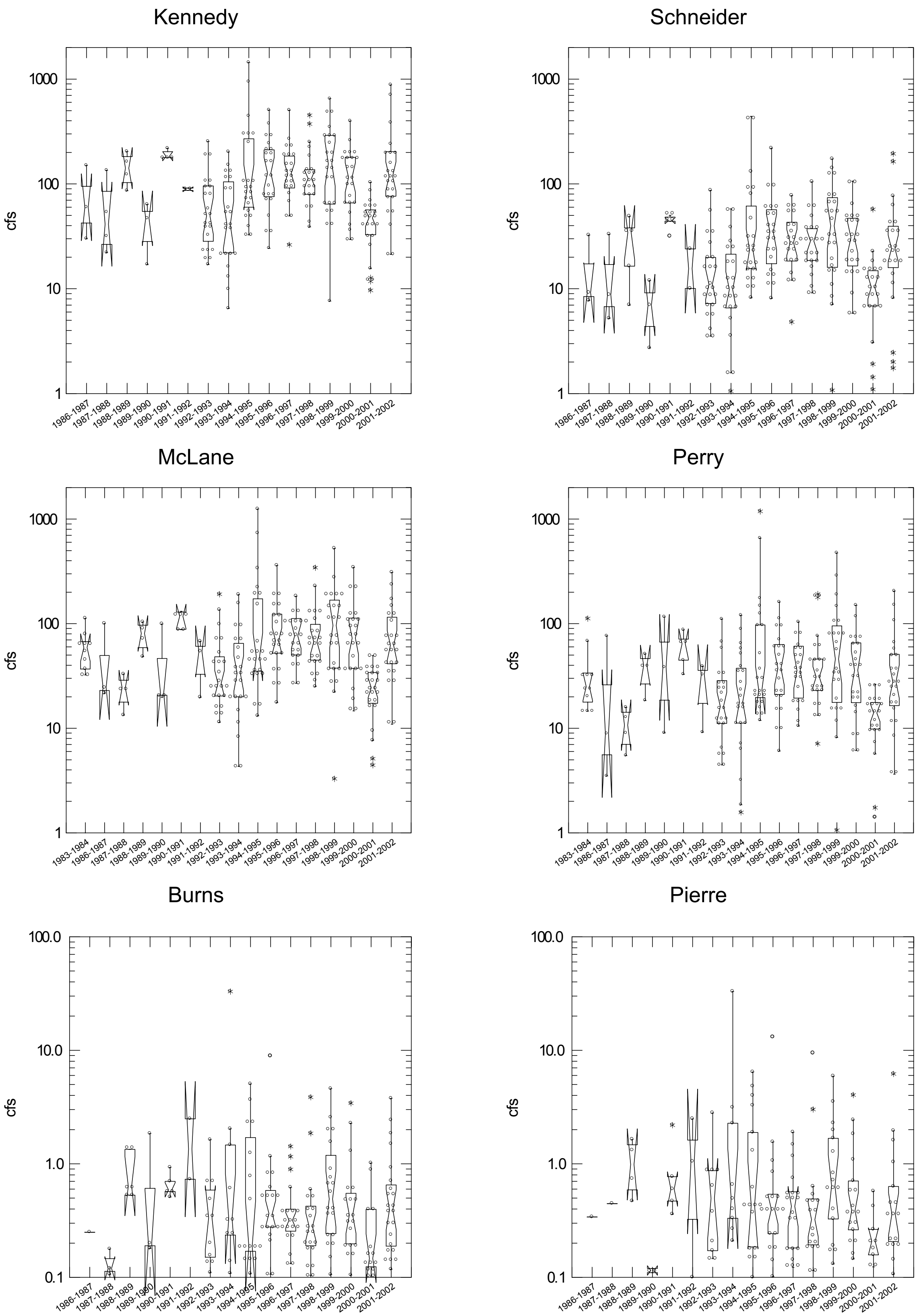

Figure E-4. Flows in cubic feet per second

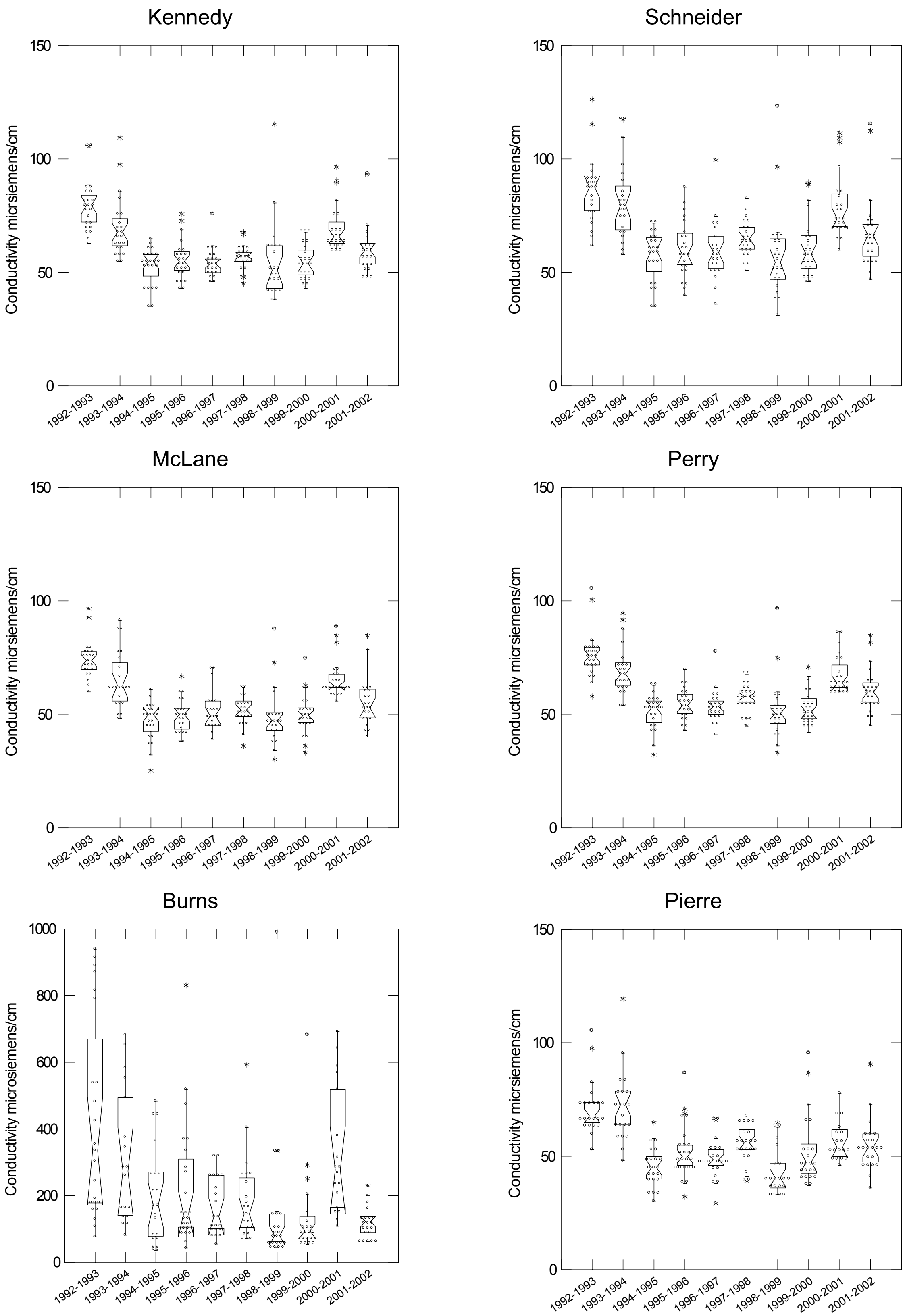

Figure E-5. Conductivity notched box plots

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Appendix F

Best Management Practices Applied in Study Basins

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Appendix F. Best Management Practices Applied in Study Basins

Table F-1. Number of farms where individual BMPs were applied in study basins

BMP#	BMP Description	Burns	Kennedy	McLane	Perry	Pierre	Schneider	Total
322	Channel Vegetation	0	0	1	0	0	0	1
342	Critical Area Planting	0	0	0	0	0	1	1
344	Crop Residue Use	1	0	0	0	0	0	1
352	Deferred Grazing (1)	3	0	3	0	1	0	7
382	Fencing	3	0	13	6	1	6	29
393	Filter Strip	1	0	10	2	2	4	19
395	Fish Stream Improvement	0	0	5	1	0	4	10
654	Forest Harvest Trails	0	0	0	0	0	1	1
490	Forest Site Preparation	0	0	0	0	0	1	1
666	Forest Stand Improvement	0	0	0	0	0	1	1
412	Grassed Waterway	0	0	1	0	1	0	2
561	Heavy Use Area Protection	0	0	2	0	0	0	2
430	Irrigation Pipeline	0	0	1	0	0	0	1
575	Livestock Crossing (2)	0	0	1	0	0	0	1
472	Livestock Exclusion	1	0	8	2	2	4	17
590	Nutrient Mgmt	3	0	2	0	1	2	8
510	Pasture & Hayland Mgmt (3)	0	0	7	0	0	2	9
512	Pasture & Hayland Planting	2	0	0	1	1	1	5
516	Pipeline	1	0	1	1	0	0	3
556	Planned Grazing System (1)	1	0	1	0	0	0	2
528	Prescribed Grazing	3	0	3	0	2	2	10
530	Proper Woodland Grazing	0	0	0	0	0	0	0
558	Roof Runoff Mgmt	2	0	5	2	1	1	11
570	Runoff Mgmt System	0	0	0	0	0	0	0
575	Stock Trails and Walkways	0	0	0	0	0	1	1
580	Streambank Protection	0	0	1	1	0	1	3
612	Tree/Shrub Establishment	1	0	0	0	0	0	1
660	Tree/Shrub Pruning	0	0	0	0	0	1	1
614	Trough	1	0	9	6	0	0	16
620	Underground Outlet	0	0	0	0	0	0	0
312	Waste Mgmt System	0	0	0	0	0	0	0
313	Waste Storage Structure	1	0	3	0	1	1	6
633	Waste Utilization (4)	0	0	4	0	0	3	7
645	Wildlife Upland Habitat Mgmt	2	0	3	0	0	2	7
644	Wildlife Wetland Habitat Mgmt	0	0	1	0	0	0	1
	Total BMPs Installed	26	0	85	22	13	39	185

Notes: (1) Prescribed Grazing (#528) now used.
(2) Streambank Protection (#580) or Stream Channel Stabilization (#584) now used.
(3) Prescribed Grazing (#528) now used unless hayland.
(4) Nutrient Management (#590) now used.

This is an enumeration of farms where particular BMPs were installed, not an enumeration of total number of times particular BMPs were installed. For example, if fencing was installed at a particular farm, the count for fencing would be 1, even if several fields were fenced.

There is a high degree of uncertainty about the values in this table.

Appendix F. Best Management Practices Applied in Study Basins

Table F-2. Amount of individual BMPs applied in study basins

BMP#	BMP Description	Units	Burns	Kennedy	McLane	Perry	Pierre	Schneider	Total
322	Channel Vegetation	acres	0	0	2	0	0	0	2
342	Critical Area Planting	acres	0	0	0	0	0	2	2
344	Crop Residue Use	acres	23	0	0	0	0	0	23
352	Deferred Grazing (1)	acres	13	0	41	0	6	0	60
382	Fencing	feet	2,000	0	14,732	2,727	50	10,072	29,581
393	Filter Strip	acres	1	0	14	4	2	33	53
395	Fish Stream Improvement	feet	0	0	5,470	220	0	6,200	11,890
654	Forest Harvest Trails	acres	0	0	0	0	0	427	427
490	Forest Site Preparation	acres	0	0	0	0	0	427	427
666	Forest Stand Improvement	acres	0	0	0	0	0	427	427
412	Grassed Waterway	acres	0	0	0	0	6	0	6
561	Heavy Use Area Protection	acres	0	0	3	0	0	0	3
430	Irrigation Pipeline	feet	0	0	200	0	0	0	200
575	Livestock Crossing (2)	each	0	0	1	0	0	0	1
472	Livestock Exclusion	acres	15	0	59	7	5	79	165
590	Nutrient Mgmt	acres	36	0	42	0	6	111	195
510	Pasture & Hayland Mgmt (3)	acres	0	0	104	0	0	127	231
512	Pasture & Hayland Planting	acres	4	0	0	5	6	1	16
516	Pipeline	feet	890	0	400	1,802	0	0	3,092
556	Planned Grazing System (1)	acres	23	0	28	0	0	0	51
528	Prescribed Grazing	acres	28	0	21	0	9	111	169
558	Roof Runoff Mgmt	system	2	0	4	2	1	1	10
570	Runoff Mgmt System	system	0	0	1	0	0	0	1
575	Stock Trails and Walkways	feet	0	0	0	0	0	30	30
580	Streambank Protection	feet	0	0	2,500	300	0	2,000	4,800
612	Tree/Shrub Establishment	acres	15	0	0	0	0	0	15
660	Tree/Shrub Pruning	acres	0	0	0	0	0	427	427
614	Trough	each	1	0	17	6	0	0	24
620	Underground Outlet	feet	0	0	0	0	0	0	0
312	Waste Mgmt System	system	0	0	0	0	0	0	0
313	Waste Storage Structure	structure	1	0	3	0	1	1	6
633	Waste Utilization (4)	acres	0	0	58	0	0	111	169
645	Wildlife Upland Habitat Mgmt	acres	51	0	207	0	0	610	868
644	Wildlife Wetland Habitat Mgmt	acres	0	0	5	0	0	0	5

Notes: (1) Prescribed Grazing (#528) now used.
(2) Streambank Protection (#580) or Stream Channel Stabilization (#584) now used.
(3) Prescribed Grazing (#528) now used unless hayland.
(4) Nutrient Management (#590) now used.

There is a high degree of uncertainty about the values in this table.