WASHINGTON STATE
DEPARTMENT OF
ECOLOGY

Watershed Briefing Paper for the Nooksack Water Resource Inventory Area

May 1995
Publication No. 95-321

Printed on Recycled Paper

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Abstract

This report summarizes the water quality studies conducted by the Environmental Investigations and Laboratory Services Program at the Washington State Department of Ecology in Water Resource Inventory Area 1, the Nooksack. Ambient monitoring and intensive surveys have documented chronic violations of fecal coliform bacteria and dissolved oxygen in the lowland fresh water bodies, as well as elevated levels of nutrients, turbidity, and suspended solids. Violations of fecal coliform bacteria and dissolved oxygen standards have also been recorded in Bellingham Bay. Sediments from Whatcom Creek, an urban stream, have measurable concentrations of pentachlorophenol and caused significant mortality in a bioassay at one out of two sites. Potentially harmful levels of cadmium were identified in Dakota Creek. Nitrogen and pesticide loading to the surficial outwash aquifers are major concerns.

Recommendations are made to expand the ambient monitoring program, and to conduct additional biological assessment studies, intensive surveys, and Class II inspections. Additional ground water studies and aquifer characterization are also recommended.

Executive Summary

Purpose and Basin Characterization

This briefing paper summarizes water quality studies conducted by the Environmental Investigations and Laboratory Services Program (EILS) of the Washington State Department of Ecology (Ecology) in Water Resource Inventory Area (WRIA) 1, the Nooksack.

The Nooksack River drains the majority of WRIA 1, flowing into Bellingham Bay. Other significant streams and their receiving waters include California and Dakota creeks (Drayton Harbor), Lummi River (Lummi Bay), Whatcom Creek (Bellingham Bay), and the Sumas and Chilliwack rivers (Fraser River in Canada).

Major production of ground water in the study area is from sandy and gravelly glacial outwash deposits and valley alluvium found in the Whatcom Basin, and along valley floors of the Nooksack River and its three major forks. The principal aquifer in the Nooksack Watershed is the Sumas Aquifer. The shallow outwash aquifers readily interact with surface water.

The Ecology 1994 303(d) list of impaired waters includes 33 waterbodies within the Nooksack WRIA. The water quality problems documented on this list can be summarized into the following general categories:

- Water quality standard violations for fecal coliform, dissolved oxygen, pH, temperature, and ammonia in the western lowlands, generally associated with agricultural practices, particularly dairies;
- Fine sediment and temperature problems in the eastern highlands, associated with timber harvesting; and
- Mercury and pentachlorophenol contamination in urban-industrial areas.

EILS Data and Reports

EILS has conducted a considerable amount of water quality work in the Nooksack WRIA during the past ten years. The ambient monitoring program has collected water quality data at 5 river sites, 3 lake sites, 8 marine water sites, and 2 marine sediment chemistry and invertebrate sites. Two total maximum daily load (TMDL) studies have been conducted, and numerous intensive surveys have been completed, including Class II inspections of wastewater treatment plants and ground water studies.

Issues

Ambient monitoring has documented chronic violations of water quality standards for fecal coliform bacteria in the lower mainstem (near Brennan), and on several major tributaries (Silver Creek, Sumas River, and Whatcom Creek). Dissolved oxygen standards are frequently violated on Silver Creek and the Sumas River. Nutrient levels on these two tributaries are among the highest recorded in the Puget Sound basin. Nutrients, turbidity, and total suspended solids in the lower mainstem (near Brennan) are all in the upper range of those found in the Puget Sound Basin.

Bellingham Bay exhibits persistent stratification, and may be susceptible to excessive phytoplankton growth and eutrophication with additional nutrient inputs. Fecal contamination may be of some concern in the bay, as may episodic hypoxia in the deeper waters. The presence or absence of harmful algae is poorly documented.

EILS studies in the Fishtrap, Bertrand, Dakota, and Johnson Creek watersheds have documented widespread water quality degradation due to inadequate agricultural and dairy waste management practices. The parameters identified in these studies that exceed water quality standards are fecal coliform, dissolved oxygen, ammonia, and pH.

Potentially harmful levels of cadmium were identified in Dakota Creek.

Sediments from Whatcom Creek, an urban stream, have measurable concentrations of pentachlorophenol and caused significant mortality in a bioassay at one out of two sites. This stream receives runoff from streets in the center of Bellingham as well as a wood treating facility.

Nitrogen and pesticide loading to the surficial outwash aquifers are major concerns. Sources of nitrogen include land application of dairy wastes, dairy waste storage pond leakage, commercial fertilizer applications, and on-site septic systems. Nitrogen ground water contamination has been documented from both lagoon leakage and manure land application. To date, based on limited data, pesticides that exceeded drinking water standards are due primarily to the use of now-canceled or restricted-use pesticides such as EDB and 1,2-dichloropropane. Nitrate and pesticide contamination have been identified in Canadian ground water that is hydraulically connected to the Sumas Aquifer in the Nooksack Basin. The contaminant loading crossing the border southward from Canada in unknown.

High chloride concentrations in ground water may be a problem near Puget Sound. These arise from two sources: 1) residual chloride from connate water and 2) saltwater intrusion.

Recommendations

Five additional freshwater ambient monitoring stations are suggested for consideration. Biological assessment studies are recommended for areas impacted by forest practices and agriculture.

Lake monitoring in WRIA 1 has been fairly minimal, and should be increased in agricultural areas and in areas vulnerable to or experiencing rapid development.

Additional monitoring in Bellingham Bay is warranted for fecal contamination, dissolved oxygen, nutrients, and phytoplankton species and abundance.

Alternatives to traditional EILS TMDL studies are suggested for many of the 303(d)-listed water bodies to address nonpoint pollution problems.

Intensive surveys are recommended to further identify and reduce toxic contaminants in Dakota and Whatcom creeks. Two industrial wastewater treatment plants are recommended for follow-up investigations based on Class II inspections. Other facilities that have not received an EILS Class II inspection within the last five years are identified.

The impact of land application of dairy wastes on the quality of the Sumas Aquifer needs to be defined. In addition, baseline ground water quality surveys should be conducted for selected portions of the Sumas Aquifer. Priority sites for ground water surveys should be new dairy locations or dairy expansions, agricultural areas where pesticide use is high, urban growth areas, and municipal and industrial wastewater application areas.

The surficial aquifers should be characterized throughout the watershed. Ground water data for the watershed should be collected, compiled, and entered into a common Ecology database.

Acknowledgements

This report represents the work of many EILS investigators. The report sections were written by the following authors:

Introductory sections - Karol Erickson
Ambient freshwater - Brad Hopkins
Ambient marine water - Jan Newton
Ambient sediment - Roberto J. Llansó
Biological assessment - Rob Plotnikoff
Basin characterization and conventional parameters - Emmanuel Nocon
Toxics - Art Johnson
Compliance - Steve Golding
Ground water - Denis Erickson (EILS) and Dave Garland (Water Quality Program)
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Karol Erickson compiled and edited the sections. Barbara Tovrea provided invaluable word processing support with assistance from Kim Douglas, Kelly Carruth, and Joan LeTourneau.

Introduction

Purpose

This briefing paper summarizes water quality studies conducted by the Environmental Investigations and Laboratory Services Program (EILS) of the Washington State Department of Ecology (Ecology) in Water Resource Inventory Area (WRIA) 1, the Nooksack. The report focuses on the most recent ten years of data and reports; however older information is included if it was considered to be important.

Basin Description

The Nooksack WRIA is located on the northern end of Puget Sound, in the extreme northwestern part of the state. The study area covers nearly all of Whatcom County and a small piece of northern Skagit County (Figure 1). The study area is bordered by the Strait of Georgia to the west, Canada to the north, the Cascade Range to the east, and the Skagit Basin to the south.

Land elevations vary from sea level in the west to over 10,000 feet at Mount Baker to the east. The eastern portions of the study area are characterized by high topographic relief with steep mountain peaks and deep river valleys. The western portions of the study area generally consist of lowlands with defined plateau uplands.

The climate in the study area is maritime, characterized by wet, mild winters and dry, cool summers. The recorded mean annual precipitation at Bellingham (elevation 50 ft.) and Mount Baker (elevation 10,775 ft.) is 32 inches and 109 inches, respectively. Seventy-five percent of the year's precipitation falls between the months of October and March.

Vegetation also varies by elevation. Douglas fir, western hemlock, and western red cedar dominate the eastern forest lands. The western lowlands are a highly developed agricultural area. Much of the land is planted to hay, pasture, and other forage crops to support the dairy industry.

Land use and land cover can be generalized into three categories: 1) forest and cleared areas in the eastern half of the study area, 2) agricultural lands dominating the western half, and 3) urban/industrial areas along the I-5 corridor, the west coast, and other population centers.

County jurisdiction within the study area consist of Whatcom (94%) and Skagit (6%) counties with an estimated area population of 140,500. There are seven incorporated cities, all located within the western half of the study area, and all located within

Whatcom County: Bellingham (pop. 55,480), Blaine (pop. 2,860), Everson (pop. 1,685), Ferndale (pop. 6,420), Lynden (pop. 6,480), Nooksack (pop. 675), and Sumas (pop. 839). Unincorporated areas have an estimated population of 66,000.

Mount Baker National Forest and the North Cascade National Park cover most of the eastern half of the basin. The Lummi Indian reservation surrounds Lummi Bay.

Hydrology

Surface Water Characterization

The study area is comprised of several watersheds of which the Nooksack River is the largest, representing 62% of the WRIA (777 sq. mi. within the U.S. and 49 sq. mi. in Canada). The Nooksack River heads as three separate rivers in the Cascades; the North (288 sq. mi.), Middle (101 sq. mi.), and South (182 sq. mi.) forks. The three forks flow through mountainous terrain, joining east of Deming in the center of the Nooksack Basin and continuing westward 35 miles through rolling lowlands to Bellingham Bay. Four major streams (drainage area greater than 10 square miles) drain directly into the mainstem Nooksack River between the mouth and the confluence with the south fork (SF): Ten Mile, Bertrand, Fishtrap, and Anderson creeks.

The Sumas (52 sq. mi.) and Chilliwack (170 sq. mi.) rivers head between the Nooksack River Basin and the Canadian border, and drain approximately 222 square miles of WRIA 1 until flowing northward into Canada and to the Fraser River in British Columbia. Dakota Creek (28 sq. mi.) and California Creek (23 sq. mi.) flow directly into Drayton Harbor, just south of the Canadian border. Terrell Creek (17 sq. mi.) flows into Birch Bay, and the Lummi River flows into Lummi Bay.

Streamflow regimes vary by elevation. Glacier-fed streams have high flows early each summer, a well-sustained flow during late summer and early fall, and a low-water period during the winter (e.g., NF Nooksack). Entirely lowland streams have high winter flows and low summer/fall flows (e.g., Fishtrap Creek). Streams draining both high and lowlands have two low-flow periods, one in the winter and one in later summer and early fall (e.g., SF Nooksack near Wickersham).

Hydrogeologic Characterization

Geologic framework controls the occurrence and movement of ground water, and the geology in the Nooksack Watershed is diverse. The Whatcom Basin, the west portion of the watershed, is characterized by glacial and alluvial sediments up to 600 feet thick overlying sedimentary bedrock. The Eastern Upland, the central, east, and south portions of the watershed, consists of sedimentary, metamorphic, and igneous bedrock (Shumway *et al.*, 1960).

Major production of ground water is from sandy and gravelly glacial outwash deposits and valley alluvium found in the Whatcom basin, and along valley floors of the Nooksack River and its three major forks. The metamorphic and igneous rocks transmit water poorly and are not considered significant for this briefing paper. Most of the hydrogeologic work done in the WRIA, has occurred within the Whatcom basin portion of the WRIA.

The principal aquifer in the Nooksack WRIA is the Sumas Aquifer. The Sumas Aquifer underlies the flat glacial outwash plain known as the Lynden Terrace (Shumway *et al.*, 1960). The aquifer is situated north of the city of Lynden between Bertrand Creek on the west and the city of Sumas on the east.

The Sumas Aquifer consists mostly of sand and gravel outwash deposits with some alluvial deposits associated with modern rivers and streams. Typically, the aquifer is shallow and unconfined. The thickness usually ranges from 40 to 80 feet. The aquifer is recharged by infiltrated precipitation and irrigation. The aquifer is susceptible to contamination from land uses due to its physical characteristics.

The Sumas Aquifer is hydraulically connected to the Abbotsford Aquifer across the Canadian border to the north. The Abbotsford-Sumas Aquifer is the largest unconfined aquifer in the region. It is an important source of water for municipal, domestic, and agricultural use on both sides of the border. The Abbotsford-Sumas Aquifer also serves as an important source of summer streamflows for surface water drainage tributary to the Fraser, Sumas, and Nooksack rivers in Canada and the United States. An estimated 625,000 cubic feet per day of ground water flows south across the U.S./Canadian border into Whatcom County.

In addition to the Sumas Aquifer, Cox and Kahle (1993) identified three other hydrogeologic units in the area: the Everson-Vashon unit, the Vashon Aquifer, and the bedrock aquifers.

The Everson-Vashon unit consists mostly of glaciomarine drift, unsorted clay, and sandy silt, with thin and discontinuous layers of sand and till. In general, the unit transmits water poorly relative to the outwash deposits, and acts as an aquitard that separates the Sumas Aquifer from deeper aquifers. However, in places, hydraulic connection between deeper aquifers may be substantial. The typical thickness ranges from 100 to 200 feet.

The Vashon Aquifer, which consists of poorly sorted till and gravel deposits, crops out in the eastern margin of the Whatcom Basin. The aquifer underlies the Everson-Vashon unit but is discontinuous and limited in extent. The thickness is unknown but is probably less than 200 feet.

The bedrock aquifers consist of sedimentary rocks of the Huntingdon and Chuckanut Formations. Ground water moves through bedrock aquifers primarily along fractures. The bedrock aquifers, although locally important, are not considered as significant as the shallow outwash aquifers.

Surface Water/Ground Water Interaction

The shallow outwash aquifers readily interact with surface water. Conceptually, on a regional scale, ground water is recharged by infiltrated surface water in the foothills and uplands. In the lowlands ground water discharges to surface water. Ground water contributions to surface water are expected to vary spatially and temporally. Two major factors affecting the degree of interaction are: 1) hydrologic properties of aquifer and stream-bottom sediments, and 2) the thickness of the aquifer interacting with the stream. High production wells drafting water from the river valley aquifers are particularly a concern because of the limited lateral extent of the aquifers.

Studies have been done in the basin to quantify ground water/surface water interaction, especially in response to water appropriations. Culhane and Gibbons (1993; 1994) used an analytical ground water model to try to identify a critical distance, beyond which a pumping well would not draw significant amounts of water from Johnson Creek. Erickson and Norton (1990) estimated the ground water contribution to Bertrand Creek to range from 0.5 to 5 cubic feet second/mile.

Water Quality Standards

Water Quality Classifications

The following water bodies have been given specific water quality classifications in Chapter 173-201A of the Washington Administrative Code (WAC):

Waterbody Name	Waterbody Segment Location/Description	Class
Nooksack River	From mouth to Maple Creek (river mi. 49.7)	A
	From Maple Creek (river mi. 49.7) to headwaters	AA
	South fork, from mouth to Skookum Creek (river mi. 14.3)	A
	South fork, from Skookum Creek (river mi. 14.3) to headwaters	AA
	Middle fork	AA
Sumas River	From Canadian border (river mi. 12) to headwaters (river mi. 23)	A
Drayton Harbor	South of entrance	A (marine)
North Puget Sound	West of longitude 122°39' W, except as otherwise noted	AA (marine)
Bellingham Bay	East of longitude 122°39' W	A (marine)

AA = extraordinary
A = excellent

The remaining waterbodies are classified according to the general classifications given in WAC 173-201A-120 as follows: Class AA waters consist of surface waters lying within national parks, national forests and/or wilderness areas; all feeder streams to lakes; and all tributaries to Class AA waters. Lake Class consists of all lakes, reservoirs with a mean detention time of greater than 15 days, and reservoirs established on preexisting lakes. All other water bodies are classified as Class A.

Ecology adopted Water Quality Standards for Ground Waters of the State of Washington, Chapter 173-200 WAC, in December 1990. These standards essentially apply a drinking water classification to all ground water in Washington State unless available data indicate otherwise. The standards apply a policy of antidegradation to all ground waters of the state.

Water Quality-Limited Waterbodies

Surface Water

The Ecology 1994 303(d) list (Appendix A) includes 33 waterbodies within the Nooksack WRIA. The water quality problems documented on this list can be summarized into the following general categories:

- Water quality standard violations for fecal coliform, dissolved oxygen, pH, temperature, and ammonia in the western lowlands, generally associated with agricultural practices, particularly dairies. Waterbodies in this category consist of Drayton Harbor, Lummi Bay and Hale Passage, Dakota Creek, Nooksack River, Tenmile Creek, Kamm Slough (and tributaries), Silver Creek, Bertrand Creek (and tributaries), Fishtrap Creek (and tributaries), Sumas River, Johnson Creek, Pangborn Creek, and Squaw Creek.

- Fine sediment and temperature problems in the eastern highlands, associated with timber harvesting. Waterbodies in this category consist of the South and Middle Forks and the mainstem Nooksack River, and Anderson, Racehorse, Boulder, Cornell, Gallop, Howard, and Canyon Lake Creeks.

- Mercury and pentachlorophenol contamination in urban-industrial areas. Waterbodies in this category consist of the inner Bellingham Bay and Whatcom Waterway (listed for mercury) and Whatcom Creek (listed for pentachlorophenol).

Ground Water

If water quality limited designations were available for aquifers, the Sumas Aquifer would have to be considered a prime contender in Washington State. Severe nitrate contamination has been documented in numerous locations in the aquifer and conditions are expected to worsen with increased growth and agricultural intensity, and expansion of dairy herd sizes.

EILS' Data and Reports

Ambient Monitoring

River and Stream Water Chemistry

The Washington State Department of Ecology's (Ecology) Ambient Monitoring Section (AMS) collects monthly water quality information at many locations across the state. Parameters routinely monitored include nutrients, dissolved oxygen, temperature, pH, conductivity, fecal coliform, total suspended solids, and turbidity. In some cases, low level metals have also been sampled.

Recent annual summaries of water quality information can be found in Hopkins (1993), Hopkins (1994), Hallock and Hopkins (1994), and Hallock and Ehinger (1995). The following section discusses water quality and corresponding violations of Washington State Water Quality Standards (WSWQS) at specific stations in WRIA 1 (Figure 1). For convenience, Table 1 lists the violations of water quality standards observed over the last seven years.

Nooksack River @ Brennan 01A050 - The ambient core station at RM 3.4 has been monitored monthly since WY 1978. Water quality at this station is generally good/fair. Elevated fecal coliform bacteria levels are the major water quality concern. Twenty-eight percent of the fecal coliform bacterial levels measured over the last seven years violated Class "A" WSWQS (no more than 10% > 200 organisms per 100 mL). Nutrient, turbidity, and total suspended solids levels are within the upper range of those found in the Puget Sound Basin. The elevated total suspended solids and turbidity may, in part, be attributed to glacial melt. Samples for low level metals (As, Cr, Cu, Cd, Pb, Ni, Zn, and Hg) were collected in May and September, 1994. Concentrations were all at or near the method detection limit (Hallock and Ehinger, 1995). Long-term trend work on ambient data from WY 1979-1991 showed flow adjusted conductivity levels increasing by < 1 percent per year and turbidity levels decreasing by < 2 percent per year (Hopkins, 1993). The remaining parameters showed no statistically significant trends. Summary graphics of recent water quality results and 12 year trends are presented in Hopkins (1993).

Nooksack River @ North Cedarville 01A120 - The ambient station at RM 30.8 was monitored monthly from WY 1978 through WY 1991, and again in WY 1993. This station was added to the long-term Ambient Network in WY 1995. Water quality at this station is good with only occasional water quality violations. Fecal coliform levels were measured over the WSWQS only twice within the last five years (see Table 1 and footnote). Nitrate + nitrite, turbidity, and total suspended solids levels were in the median range of those found in the Puget Sound Basin. Total phosphorus levels, however, are in the upper range of those found in the Puget Sound Basin. Hopkins (1994) provides six year averages of water quality data at this location.

Silver Creek @ Brennan 01B050 - The ambient station at RM 2.5 was monitored monthly during WY 1992 and WY 1993. Water quality at this station is poor with many water quality violations recorded during the two years of monitoring (see Table 1). This station appears to have chronic fecal coliform problems and depressed dissolved oxygen levels. Nutrients are in the upper range of those found in the Puget Sound Basin. Samples for low level metals (As, Cr, Cu, Cd, Pb, Ni, Zn, and Hg) were collected in May and September, 1994. Concentrations were all at or near the method detection limit (Hopkins 1995). Raw data for the two years of sampling are in Hopkins (1994), Hopkins (1995) and Hallock and Hopkins (1994).

Sumas River near Huntingdon B.C. 01D070 - The ambient station at RM 11.9 was monitored monthly from WY 1978 to WY 1992. Water quality at this station is poor with many violations in two of the four WSWQS evaluated. Eighty-three percent of the fecal coliform bacteria levels measured over the last five years that the station was monitored were above the Class "A" WSWQS (see Table 1). Dissolved oxygen standards were also violated twenty-four percent of the time during the same period. Nutrient levels are among the highest seen in Washington State. Hopkins (1994) provides six year averages of water quality data at this location.

Whatcom Creek @ Bellingham 01E050 - The ambient station at RM 0.25 was monitored monthly during WY 1994 only. Water quality at this station is fair/poor with water quality violations recorded for fecal coliform bacteria and temperature (see Table 1). Nutrient, turbidity, and total suspended solids levels are in the median range of those found in the Puget Sound Basin. Hallock (1995) provides the raw data for WY 1994.

Thirty fresh water locations within the Nooksack WRIA are listed in Ecology's 1994 303(d) list (Appendix A). Table 2 lists the three AMS stations included in the 1994 303(d) list and the parameter(s) that violate Washington State water quality standards. Twenty-three of the remaining twenty-seven stations are on sloughs, ditches, or streams that are smaller than the ambient program normally samples. With respect to the four remaining reaches, they are located on three rivers AMS could monitor. These three rivers are the south fork and middle fork of the Nooksack, and the mainstem Nooksack above the confluence with the middle fork.

River and Stream Biological Assessment

The Nooksack River watershed is one of Washington State's northernmost streams surveyed in our biological monitoring program. A single tributary site (Hedrick Creek) was monitored for benthic macroinvertebrate condition and for surface water characterization. Information acquired for the Hedrick Creek stream site was part of the Timber, Fish, and Wildlife Ecoregion Bioassessment Pilot Project (Plotnikoff, 1992). This project focused on characterizing regional reference stream conditions.

The upper portion of the Nooksack River watershed contains stream channels that can be eroded easily during periods of naturally occurring floods or when forest practices have exposed sensitive stream channel segments to the force of a flood. This condition was illustrated at our study reach on Hedrick Creek where the stream channel underwent some change due to winter flooding events.

Benthic macroinvertebrate community diversity was considerably higher during the summer than in other seasons. The unpredictability of stream channel movement had its greatest potential during fall, winter, and spring seasons. Also, the greatest number of taxa intolerant to stream disturbances were present during the summer season. The Hedrick Creek macroinvertebrate community condition was considered moderate among all Cascade reference sites surveyed.

Lakes

Data are available for only three lakes in WRIA 1: Emerald (Toad), Whatcom, and Wiser. Ecology staff collect total phosphorus, total nitrogen, and chlorophyll *a* twice annually at each lake, and volunteers monitor water clarity twice weekly during the algal growing season. The water quality information generated by this program is primarily used to evaluate the trophic state of the lake.

Emerald Lake (from Rector, 1995b) - Emerald Lake was monitored in 1993 and 1994 and had good to fair water clarity. In May, the lake had a high concentration of total phosphorus and a high density of algae, but in August both total phosphorus concentrations and algal densities were only moderately high. The lake also had low oxygen concentrations at the lake bottom, and it appeared that internal loading of phosphorus from the sediment may have occurred. As a result, the lake was described as meso-eutrophic in 1993.

Lake Whatcom (from Rector, 1991) - In 1991, Lake Whatcom was monitored mid-channel (straight out from the Sudden Valley Development). This basin had good water clarity in 1991 with Secchi depths ranging from 16 to 21 feet. Total phosphorus levels were very low and total nitrogen levels moderately high. Based on this 1991 information, the main basin of Lake Whatcom was described as oligotrophic. But the shallow, northwest basin which drains directly to Whatcom Creek was not sampled. That basin has much worse water quality than the main basin where Ecology sampled (Rector and Matthews, 1987).

Wiser Lake (from Rector, 1995b) - Wiser Lake was monitored in 1993 and 1994, and had poor water clarity, high nutrient concentrations, and high densities of algae and aquatic plants. These qualities all indicate Wiser Lake was eutrophic.

Marine Water Quality

Station coordinates and the data record for all stations sampled in Bellingham Bay are listed in Table 3. In 1989, the Ambient Monitoring Section's (AMS) marine water column sampling program, reflecting coordination with the Puget Sound Ambient Monitoring Program, shifted their sampling focus from near-shore stations to those which were more representative of open-estuary conditions. Under the current implementation plan (Janzen, 1992), AMS monitoring in Bellingham Bay is at Station BLL009 only. This station is presently sampled monthly throughout the year. This report is a brief summary of the temperature, salinity, density, fecal coliform bacteria, secchi depth, dissolved oxygen, and nutrient data from Bellingham Bay stations.

In comparison with the main basin of Puget Sound, as characterized by Station PSB003, Bellingham Bay Station BLL009 shows higher seasonal variation in both its surface temperature and salinity (Figure 2). This is due to the influence of the Nooksack River (affecting both the salinity and temperature), the stronger density stratification (resulting in less mixing), and the shallower bathymetry of Bellingham Bay.

Bellingham Bay exhibits a stratified density structure, as is typical of many estuaries within Puget Sound. Freshwater input, primarily from the Nooksack River, does not readily mix with the marine waters of the bay, but rather overlies the saltier, denser water. Mixing is positively correlated to the amount of wind or tidal forcing, and negatively correlated with the intensity of the water density differences. Density differences are due to both salinity (runoff and precipitation) and temperature (solar radiation). Because these factors are quite variable in Puget Sound, the degree of stratification and its seasonal pattern also varies substantially for different areas of Puget Sound. On a stratification classification scheme of: persistent, seasonal, episodic, or weak, Bellingham Bay is classified as persistently stratified, that is, it shows stratification (delta sigma-t >2; see Newton *et al.*, 1994 for explanation) over the entire wateryear.

Estuaries with persistent stratification are particularly most sensitive to nutrient or contaminant inputs. Bellingham Bay has shown high fecal coliform counts (>14 organisms/100 mL) at all of the monitoring stations except BLL010 near Eliza Island (Figure 3). Severely high counts were recorded in the mid 1970's at Stations BLL002, 003, and 004. None of these stations have been monitored since WY 1977. Data from BLL009, where monitoring has been continuous from Wateryear 1978 through 1994, shows neither an improving nor declining trend. Fecal contamination is therefore of concern in Bellingham Bay.

Significant riverine input will contribute sedimentary load to the estuary. As indicated by Secchi depth, light penetrates less deeply in Bellingham Bay than in the main basin of Puget Sound (Figure 4). This is due to a higher prevalence of suspended particles (both sedimentary and biogenic) that attenuate light. No change (trend) was found for secchi depths at station BLL009 between 1978 and 1984. Regression analysis yielded a slope not significantly different than zero.

Historic data indicates that low dissolved oxygen has been a significant problem in parts of Bellingham Bay. At stations BLL002, 003, and 004 (sampled only in the mid-1970's), D.O. concentrations below 5 mg/L were recorded frequently.

Conditions at BLL002 were particularly severe, with D.O. concentrations < 2 mg/L in 12 of 28 months sampled, and anoxic (D.O. = 0.0) in five months sampled. Three different stations sampled in the early and mid-1980's (BLL006, 008, and 009) also violated water quality standards, particularly in deep waters. The one station currently sampled (BLL009) has shown only occasional excursions near 6 mg/L since sampling began there in 1978, and no violations since WY 1989. Consequently, the only recent ambient monitoring data available do not suggest D.O. problems exist in Bellingham Bay, but these data may be unrepresentative. Since low D.O. concentrations can be quite localized, the present extent, duration, or severity of low D.O. in other areas of Bellingham Bay is not known.

Bellingham Bay has extended periods when nitrogenous nutrients are below detection levels and thus, potentially limiting to phytoplankton growth. This is typical of persistently stratified estuaries but in contrast to the Puget Sound main basin (Figure 5) where such occurrences are seldom and brief. This difference has important implications for nutrient loading. If additional nutrients are added to the bay, this would support phytoplankton in excess of the natural population. Such eutrophication typically leads to water quality problems. We do not have adequate data to address the status of nutrient loading and phytoplankton response in Bellingham Bay. Based on its physical characteristics, the bay would be sensitive to significant loading.

In addition to nutrient concentrations, the relative abundance of the various nutrients, such as NO_3^-, NH_4^+, PO_4^{-3}, and trace elements, such as Si, Fe, Mn, can determine which phytoplankton species will succeed. The occurrence of harmful or toxic phytoplankton may be linked to the presence or relative abundance of certain nutrients, although other causes may also exist. The presence of harmful algal blooms in Bellingham Bay is poorly documented. To some extent, this indicates a lack of outbreaks, but it also indicates a lack of monitoring. Paralytic shellfish poison (PSP) -producing phytoplankton species are annually found near Portage Spit (Lummi Reservation), causing seasonal bed closures (M. McCallam, DOH, pers. comm.).

We do not have any data to evaluate whether organic or heavy metal contaminants are a problem in the water column of Bellingham Bay.

Marine Sediment Quality

Ecology's Ambient Monitoring Section has collected sediment chemistry and benthic invertebrate data from two stations located in Bellingham Bay. These stations have been monitored for metals, multiple organic compounds, total sulfides, organic carbon, and sediment grain size. In addition, benthic invertebrates have been sampled at these stations to characterize community structure.

Station 4 is located west of Chuckanut Bay, two miles southwest of Post Point and South Bellingham. Station 4 has been sampled annually since 1989. Station 203R is located one mile southwest of the city of Bellingham, near a dredge disposal site. This station was sampled in 1991, and again in 1994.

These stations have similar sediment characteristics. Sediments are comprised of 90-95 percent silt plus clay and about two percent total organic carbon. Sulfides are moderately high at Station 4 with a maximum estimated concentration of 500 mg S/kg detected in April 1992. However, sulfide concentrations at Station 203R were undetected in 1991 (we have no data for 1994).

All 47 metals and organic parameters with Washington State Sediment Quality Standard Chemical Criteria were well below standards (if detected) at both stations. Metals with highest concentrations in sediments of Bellingham Bay were arsenic (Station 4, 6.1-19.1 ppm; Station 203R, 15.2-18 ppm), chromium (Station 4, 47.8-60.7 ppm; Station 203R, 76.6-95.2 ppm), copper (Station 203R, 48.6-58.6 ppm) and zinc (Station 4, 87.8-95.7 ppm; Station 203R, 96.9-108 ppm). Only chromium in Station 203R had concentrations larger than the range exhibited by sediments at ambient monitoring locations throughout Puget Sound. When detected, hydrocarbon concentrations were near the analytical detection limits. Resin acids and guaiacols were also monitored and frequently detected at Station 4 from 1989 through 1993, although concentrations were low (near analytical detection limits). Other studies (Tetra Tech, 1991; Battelle, 1986; PTI, 1989b; and Cubbage 1991, 1993a, b), conducted in nearshore and contaminated areas, have reported mercury and rarely copper levels above Sediment Quality Standards in Bellingham Bay.

Benthic abundance and species richness at the Marine Sediment Monitoring stations in Bellingham Bay were similar to those exhibited at other ambient locations in Puget Sound of similar sediment characteristics. Mean total abundance ranged from 201.4 to 472.0 organisms per 0.1 m^2 at Station 4, and from 259.0 to 726.0 organisms per 0.1 m^2 at Station 203R (1989-1993, N=5; 1994, N=3). The number of species ranged from 55 to 85 at Station 4, and was 83 at Station 203R in 1991 (data for 1994 not available). Polychaetous annelids and molluscs comprised the largest portion of the population at Station 4, followed by crustaceans. At this station, annelids accounted for 8-57 percent of the total number of organisms, and molluscs (mostly bivalves) accounted for 17-63 percent. Polychaetous annelids were more abundant at Station 203R, accounting for 62-65 percent of the total number of organisms at this station. Molluscs accounted for 1-6 percent. The relatively larger contribution of bivalves to Station 4 was due primarily to two small clams, *Axinopsida serricata* and *Acila castrensis*. Brittle stars (*Amphiodia urtica*) were also abundant at Station 4, ranking numerically as the top dominant species in some years. In contrast, Station 203R was numerically dominated by cirratullid polychaetes (*Aphelochaeta* spp.). Brittle stars (*A. urtica*) were also present at Station 203R but with lower abundance.

While analysis of spatial and temporal patterns in abundance and species richness of macrobenthos in Puget Sound is still in progress, it is possible to point out some relationships between sediment quality and community structure in Bellingham Bay. High sulfide concentrations may contribute to the observed large percentage of the bivalves *A. serricata* and *A. castrensis* at Station 4. Thyasirid bivalves, to which *A. serricata* belongs, are hardy species generally inhabiting sediments with reduced oxygen concentrations or elevated concentrations of hydrogen sulfide. The nuculid *A. castrensis* may possibly indicate similar sediment conditions, although this relationship has not yet been evaluated in our Marine Sediment Monitoring Program. Likewise, we have not yet evaluated the relationship between *A. urtica* and sediment type. It is possible that sulfide concentrations at Station 4 are a result of episodic, low, near bottom dissolved oxygen concentrations which might occur partly in response to the discharge plume of the Nooksack River, presumably through sedimentation or water column density stratification. Station 203R, being shallower, may be affected to a lesser extent (if at all) by low dissolved oxygen concentrations. On the other hand, the dominant species at this station, *Aphelochaeta* spp., are associated in Puget Sound with stations located near sources of pollution (e.g., Commencement Bay), where chemical contamination has been detected. However, the relationships between *Aphelochaeta* and disturbance from chemical contamination (e.g., the relatively higher concentrations of metals at Station 203R near the city of Bellingham) remain to be investigated.

TMDLs

A "total maximum daily load" (TMDL) study was conducted on the Fishtrap Creek watershed for fecal coliform (Erickson, 1995). Load allocations for fecal coliform were established to meet the Class A water quality standard of 100 organisms/100 mL. These allocations require from 57 to 96 percent reductions in bacteria loading to the creek. Figure 6 shows the geometric mean of fecal coliform levels at each site compared to the state water quality criterion of 100 organisms/100 mL. Recommendations include accelerating the dairy waste permitting program in the basin and more extensive development of farm waste management systems. The study establishes the TMDL for fecal coliform, with the assumption that control measures installed for fecal coliform will also correct violations of dissolved oxygen and ammonia.

Based on a survey of the Sumas River, Cusimano (1992) recommended waste load allocations for the Sumas wastewater treatment plant (WTP) and load allocations for nonpoint sources for ammonia, biochemical oxygen demand, total residual chlorine (TRC), and fecal coliform. The study found high levels of fecal coliform (exceeding the standard) and nitrogen above the treatment plant, likely due to agricultural nonpoint sources. Modeling of the WTP discharge predicted water quality violations for TRC and dissolved oxygen during critical conditions.

Intensive Surveys

Freshwater

Erickson (1994) conducted a literature review of surface water quality studies related to dairy waste practices. The review contains summaries of 48 documents statewide, and each document's conclusions regarding water quality degradation or beneficial use impairment due to dairy waste. Impacted areas in the Nooksack WRIA included Fishtrap, Bertrand, Kamm, Tenmile, Johnson, Dakota, California, and Silver Creek watersheds; the Sumas and Nooksack rivers, and Drayton Harbor. The most common water quality impacts were higher fecal coliform levels and lower dissolved oxygen levels. The most common beneficial use impairment was fish habitat degradation.

A water quality screening of Fishtrap, Bertrand and Dakota Creek watersheds (Dickes, 1992a) found similar results and conclusions as in Erickson (1995) study above. This report indicated that violations of water quality criteria for fecal coliform, dissolved oxygen, and ammonia occurred in areas with concentrated agriculture, primarily commercial dairy operations. Figures 7 and 8 show sites with violations of state water quality criteria.

Monitoring was performed in the Johnson Creek Watershed (Dickes and Merrill, 1990) to assess water quality as related to Class A standards, and to compare conditions to a 1980/81 pre-Best Management Practice (BMP) study. The study found water quality in Johnson Creek Watershed to be impaired and in violation of Class A standards for fecal coliform, dissolved oxygen, and pH. Fecal coliform, nitrate, and total phosphorus concentrations increased significantly between the pre- and post-BMP implementation studies, but turbidity decreased. According to this study, it appears that manure continues to reach creeks in the watershed regardless of the BMPs. This may possibly be due to improper management techniques and/or non-participating farms. The study concludes that BMPs, as implemented to date, have not improved water quality in Johnson Creek Watershed, however, without BMPs the resource could have shown significant deterioration after ten years.

A follow-up water quality survey of Johnson Creek Watershed conducted by Dickes (1992b) found continued violations of Class A standards for fecal coliform bacteria and dissolved oxygen. None of the monitoring locations in this survey yielded data which fully met Class A standards. The report indicated that impacts from dairy wastes would explain the elevated fecal coliform and depressed oxygen documented in the study, however, effects from other livestock farms and failing septic systems could be other possible sources.

An investigation of recurrent fish kills at Maritime Heritage Fish Hatchery (MHFH) in Bellingham was conducted (Ostergaard, 1992) to follow up on earlier investigations (Kendra and Willms, 1990; Kendra, 1989). According to this most recent study, MHFH was plagued with recurrent fish kills every fall until 1990. The kills coincided with the first heavy runoff after a storm (first flush) and appeared to affect only coho salmon. Fall fish kills did not occur at MHFH in 1990 or 1991, although spring kills did occur in both of these years. Spring fish kills at MHFH began occurring in 1989. Hatchery water is supplied by Whatcom Creek, an urban stream which drains downtown Bellingham. Since mortality typically coincides with first-flush storm events, reports suggests that toxicants in runoff to Whatcom Creek may be responsible. Kendra isolated zinc, lead, and copper as the most toxic contaminants in both stormwater and hatchery ponds. Conventional and priority pollutant scans of hatchery water taken during kill episodes showed that copper, lead, and zinc were the only substances detected above federal toxicity criteria (Figure 9). Metals concentrations were below LC_{50} values, possibly due to late sampling during storm events. However, additive or synergistic metals toxicity could not be discounted. Histopathological examination of moribund coho revealed no evidence of infection or disease, but a proliferation of chloride cells in gill tissue may have been induced by metals contamination.

A water quality investigation (Kendra, 1986b) conducted in 1986 detected elevated levels of cadmium in surface waters and sediment of Dakota Creek. Although limited data were generated from this investigation, analytical results suggest that cadmium in Dakota Creek waters (detected at 12.1 μg/L) may have exceeded EPA standards for chronic saltwater concentration (9.3 μg/L) and/or freshwater standards for acute (1.8 μg/L) and chronic (0.66 μg/L) concentrations. The land use in the Dakota Creek basin is largely devoted to dairy production and the source of cadmium was not discovered during this investigation.

Surface water pesticide samples are limited to Fishtrap Creek. Seven herbicides and pentachlorophenol were detected in one or more of five water samples collected during 1992-93 (Davis, 1993; Davis and Johnson, 1994). Atrazine and bromacil were detected in every sample, but these and all other compounds were at trace levels of 1.5 ppb or less.

Fish samples from the Nooksack River, Fishtrap Creek, Lake Samish, and Claypit Pond show low to non-detectable levels of bioaccumulative pollutants (Cubbage, 1989; Davis, 1993; Johnson and Norton, 1990). Priority pollutants were not elevated in sediment samples from two sites in Lake Samish (Johnson and Norton, 1990). Sediment bioassays near the mouth of Whatcom Creek in 1993 showed some toxicity, possibly due to phenol and/or pentachlorophenol (Cubbage, 1994). High concentrations of chromium have been detected in the sediments of 11 acre Claypit Pond, downstream of a municipal incinerator (Cubbage, 1989).

Marine

An investigation conducted on Blaine industrial sector wastewater discharge to Drayton Harbor (Kendra, 1986a) documented untreated discharges of excessive organics, solids, and grease loads contributed by local seafood processors. The illegal discharges were attributed to overloads at the Blaine wastewater treatment plant, during which time city officials diverted the untreated processing waste stream to the mouth of Drayton Harbor. The raw waste stream from the industrial sector was high in turbidity, solids, oil and grease, biological oxygen demand, ammonia, and fecal coliform. It was recommended that simple screening and oil separation may provide sufficient pretreatment to prevent municipal plant overloads.

A substantial amount of data has been collected on chemical contaminants in marine sediments and biota, primarily by other groups at Ecology or other agencies. The primary contaminant of concern has been mercury from the old Georgia-Pacific chlor-alkali plant that began operation in 1964 (PTI, 1991a). As noted below, the level of mercury contamination in Bellingham Bay has decreased over the years.

Metals, organochlorines, and aromatic hydrocarbons in Dungeness crabs and littleneck clams collected from Bellingham Bay were analyzed in 1990 (Cubbage, 1991). Results showed mercury levels (< 0.1 - 0.16 ppm) were low and had declined compared to concentrations measured in shellfish and other organisms during the last 20 years (Nelson *et al.*, 1974; Roesijadi *et al.*, 1981; NOAA, 1987; CH_2M Hill, 1984). Other contaminants were not detected at significant concentrations. These findings are consistent with recent monitoring done by PSAMP on chemical contaminants in English sole and little neck clams at several sites between Bellingham Bay and Birch Bay (Department of Health, 1992-93; Department of Fish & Wildlife, 1989-92). A 1991 EPA study of dioxins and furans in crabs from 11 areas in Puget Sound found the lowest muscle tissue concentrations in samples from Bellingham Bay (PTI, 1991a).

Metals were analyzed in bottom sediments collected from five sites in eastern Bellingham Bay in 1993 (Cubbage, 1993a). Concentrations were low except for two sites where mercury was above marine sediment standards. A priority pollutant scan of sediments at a Bellingham Bay shipyard and marina in 1993 showed several contaminants above criteria at the shipyard including lead, copper, zinc, arsenic, phenol, and PCBs (Cubbage, 1993b). Tributyltin also exceeded an interim Puget Sound Dredge Disposal Analysis screening level for sediment disposal. Only phenol was found above criteria in the marina sediments. This survey also obtained data on chemical contaminants in Bellingham storm drain sediments.

A Class II inspection of the Intalco aluminum plant found very high concentrations of PAHs and PCBs in sediments near the process wastewater outfall (Heffner, 1989).

A 1989 EPA-sponsored review of data from 66 stations in Bellingham Bay identified a few stations as problem areas, chiefly due to elevated concentrations of mercury and/or depressed benthic invertebrate communities: mouth of Whatcom Creek (five stations); near Georgia-Pacific outfall (two stations); near Post Point WWTP outfall (five stations); and off Fairhaven shoreline (one station) (PTI, 1989a). Historical data show mercury concentrations in sediments have declined over a broad area of Bellingham Bay (Battelle, 1986; Bothner *et al.*, 1980).

EPA ranked the potential for toxics-related problems in non-urban bays of the watershed as follows: Medium - Cherry Point, Drayton Harbor, Point Roberts, Samish Bay; Low - Birch Bay, Boundary Bay, Semiahmoo Bay, Lummi Bay (Tetra Tech, 1988). NOAA conducted field investigations of petroleum contamination in the Strait of Juan de Fuca and Northern Puget Sound in the late 1970's that included Cherry Point (NOAA, 1981).

Compliance

There are currently 51 dischargers in the Nooksack WRIA that have permits under the National Pollutant Discharge Elimination System (NPDES) and State Waste Discharge Permit Program (WAC 173-216). These include:

NPDES Major Permits - 4 Industrial, 1 Municipal
NPDES Minor Permits - 12 Industrial, 12 Municipal
State Discharge to Publicly Owned Treatment Works (POTW) Permits - 19 Industrial
State Discharge to Ground Permits - 3 Industrial

The following summarizes information from five industrial and three municipal discharge facilities that have had EILS Class II inspections during the last ten years. It is important to note that Class II inspections more than five years old may not be representative of the facility today.

Inspections at industrial discharge facilities indicate general compliance with permit requirements, with some exceptions. A 1989 inspection at the British Petroleum Oil Refinery found mercury and cyanide at concentrations above various freshwater and saltwater water quality criteria (Hallinan, 1990). Acute bioassay toxicity was observed in the fathead minnow, and chronic effects were noted in Pacific oysters and sea urchins. Sediments surrounding the outfall were contaminated with various PAHs, dibenzofuran, and a PCB. All were below proposed State sediment quality standards.

Data from the ARCO Refinery at Cherry Point indicate compliance with daily maximum and daily average NPDES permit limits. However, amphipod and echinoderm larvae mortality was observed in the edge of dilution zone sediment, and echinoderm larvae mortality was observed in background sediments (Heffner and Serdar, 1993).

The Georgia-Pacific Corporation pulp and paper mill in Bellingham was inspected in 1993 (Golding, 1994). Copper was found at a concentration over four times EPA acute marine water quality criteria. Total mercury was within the daily limit but higher than the monthly average limit. *Ceriodaphnia dubia* and Pacific oyster demonstrated chronic toxicity in the mill effluent. Mercury was found in concentrations up to 74% above marine sediment quality criteria.

Intalco is a large primary aluminum smelter near Ferndale, with two outfalls discharging into the Strait of Georgia (Heffner, 1989). A 1988 inspection found both discharges met permit effluent limits. However, very high concentrations of PAHs and PCBs were found in the sediments near the process wastewater outfall.

The Bellingham Frozen Foods wastewater treatment facility includes an aerated storage lagoon and spray fields for the land application of wastewater. Data indicate organophosphate and carbamate pesticides were in the wastewater in 1993, however, the permit does not require monitoring for these pesticides (Stasch, 1994).

Inspections for municipal dischargers conducted during the past eight years include the Bellingham Post Point Pollution Control Plant (Reif, 1988), the Ferndale Wastewater Treatment Plant (Ruiz, 1989), and the town of Sumas Wastewater Treatment Plan (Glenn, 1992b). The data indicated problems in two plants: Post Point plant, with three effluent bioassays (rainbow trout, oyster larvae, and Microtox) showing varying degrees of toxicity; and Ferndale, with very high ammonia, and concentrations of copper, lead, mercury and nickel which exceeded current acute and/or chronic marine criteria.

Ground Water

EILS Ground Water Studies

Following is a brief summary of the limited EILS ground water studies conducted in the Nooksack WRIA. Although the data are not extensive, they indicate ground water quality has been degraded by inadequate waste management and pesticide application practices from some dairy, potato, and berry farms.

In 1989 twenty-seven wells near Bertrand Creek, located about 3 miles west of Lynden, were tested for 46 pesticides and nitrite+nitrate-N. Twenty-one of these wells were used for domestic purposes. The area was chosen for study because of known ethylene dibromide (EDB) contamination in ground water (DSHS, 1985; Black and Veatch, 1986). At least one pesticide was detected in 12 of the wells (Erickson and Norton, 1990). Concentrations exceeded proposed Maximum Contaminant Levels for 1,2-dichloropropane in five wells, for ethylene dibromide in one well, and for dibromochloropropane in one well. Nitrite+nitrate-N was detected in 26 of the wells with a mean concentration of 6.7 mg/L. The MCL of 10 mg/L was exceeded in seven of the wells. Figures 10, 11, and 12 show relative locations and concentrations for EDB, 1,2-dichloropropane, and nitrate found in Nooksack area ground water.

There have been four studies conducted to quantify the impacts on ground water from dairy farms. Two of the studies found elevated concentrations of ammonia-N, nitrite+nitrate-N, total dissolved solids, phosphate-P, total organic carbon, chemical oxygen demand, chloride and fecal coliform (Erickson, 1992; 1994). A third study

(Erickson, 1991) found ground water with similar contamination, with the exception of fecal coliform. In each case leaking dairy waste storage lagoons or ponds were believed to be the source of contamination. The fourth study was conducted by Garland and Erickson (1994) on land application of cow manure. The data showed no statistically significant differences in the analytes sampled in domestic wells near a lagoon system.

A water-level monitoring study was conducted at Bellingham Frozen Foods in 1993 (Erickson, 1994b). Land application of vegetable processing wastewater is subject to State Waste Discharge Permit requirements. One requirement of the permit is that land application of wastewater is not allowed when the unsaturated zone (the interval between the ground surface and the water table) is less than three feet. The results of this study showed that water levels were within three feet of the surface in three wells by late October and in the fourth well by December 1.

A study of ground water quality at the old Roeder landfill, a site adjacent to Bellingham Bay, is soon to be completed (Cubbage, in progress). Preliminary data are being analyzed by the client and verification sampling is scheduled for May 1995.

Permitted Discharges to Ground

Bellingham Frozen Foods, Ferry Brothers and Ocean Star Seafood are permitted to discharge to ground. Ground water monitoring is required at Bellingham Frozen Foods. Also, a large development in the Kendall Creek Valley, which is served by Whatcom County Water District #13, uses a community on-site drainfield for wastewater disposal. The effect of these discharges on ground water quality is unknown. Ground water flow and quality data are needed to characterize potential impacts of the drainfield.

Trans-Border Ground Water Flow

The quality of ground water flow crossing the border from Canada is unknown. Nitrate and pesticide contamination have been identified in ground water north of the border (Liebscher *et al.*, 1992). Ground water contamination originating from Canada will require coordination with the Abbotsford-Sumas Aquifer Task Force, or equivalent, to address contamination issues.

High Chloride Concentrations

High chloride concentrations in ground water originate from two sources: 1) residual chloride from connate water and 2) saltwater intrusion.

Saline ground water was found in a well with an intake at approximately 300 feet above sea level near the town of Glacier on the Mt. Baker Highway. Another saline flowing artesian well near Lake Fazon polluted the lake for many years until the well was properly capped. Saline ground water also has been found at the Recomp site (formerly Thermal Reduction incinerator) and at the Bellingham Frozen Foods (now Dean Foods) food processing wastewater sprayfield near the mouth of the Nooksack River.

Other Data and Reports

Other major water quality monitoring efforts in the Nooksack WRIA have been conducted by USGS, Whatcom Conservation District, Whatcom County, Western Washington University, and the Lummi Tribe. The USGS is considering the Nooksack River watershed for possible inclusion in its National Water Quality Assessment Program (NAWQA).

Various lake monitoring programs have also been under taken in WRIA 1, however, their status is unknown (Rector, 1995a).

Additional sources of ground water information are listed in Appendix B.

Summary of Issues

Ambient Monitoring

Ambient monitoring has documented chronic violations of water quality standards for fecal coliform bacteria in the lower mainstem (near Brennan), and on several major tributaries (Silver Creek, Sumas River, and Whatcom Creek). Dissolved oxygen standards are frequently violated on Silver Creek and the Sumas River. Nutrient levels on these two tributaries are among the highest recorded in the Puget Sound basin. Nutrients, turbidity, and total suspended solids in the lower mainstem (near Brennan) are all in the upper range of those found in the Puget Sound Basin.

Bellingham Bay exhibits persistent stratification, and may be susceptible to excessive phytoplankton growth and eutrophication with additional nutrient inputs. Fecal contamination may be of some concern in the bay, as may episodic hypoxia in the deeper waters. The presence or absence of harmful algae is poorly documented.

Intensive Surveys

EILS studies in the Fishtrap, Bertrand, Dakota, and Johnson creek watersheds have documented widespread water quality degradation due to inadequate agricultural and dairy waste management practices. The parameters identified in these studies that exceed water quality standards are fecal coliform, dissolved oxygen, ammonia, and pH. A TMDL has been recommended for Fishtrap Creek.

Potentially harmful levels of cadmium were identified in Dakota Creek.

Sediments from Whatcom Creek, an urban stream, have measurable concentrations of pentachlorophenol and caused significant mortality in a bioassay at one out of two sites. This stream receives runoff from streets in the center of Bellingham, as well as a wood treating facility.

Compliance

Industrial major dischargers that have not received EILS Class II inspections during the past five years are: Tosco Northwest Company and Intalco-Ferndale. The Tenaska Cogeneration Plant, a minor discharger, has not received an EILS Class II inspection.

Past inspections point to problems which may warrant further investigation. These include:

- Effluent toxicity in the Tosco (British Petroleum) discharge.
- Mercury in sediments near the Georgia-Pacific outfall exceeding Marine Sediment Quality Standards criteria.
- Very high concentrations of PAHs and PCBs found near the Intalco outfall.

Ground Water

Nitrogen and pesticide loading to the surficial outwash aquifers are major concerns. Sources of nitrogen include land application of dairy wastes, dairy waste storage pond leakage, commercial fertilizer applications and on-site septic systems. Nitrogen ground water contamination has been documented from both lagoon leakage (Erickson, 1991, 1992, and 1994a) and manure land application (Garland and Erickson, 1994). To date, based on limited data, pesticides that exceeded drinking water standards are due primarily to the use of now-canceled or restricted-use pesticides such as EDB and 1,2-dichloropropane.

A lot of ground water information exists; however, the raw data are not readily usable. Data exist in various formats (usually paper) requiring time-consuming compilation.

Needs and Recommendations

Ambient Monitoring

River and Stream Water Chemistry

The following are locations within the Nooksack WRIA that should be considered for future ambient freshwater basin stations. These locations are listed in their order of priority.

1) **Sumas River near Huntingdon B.C.:** Rationale - Historical information shows this station has poor water quality. This station has been inactive since WY 1992.

2) **Upper Sumas River near Nooksack:** Rationale - Background information for #1.

3) **SF of the Nooksack River:** Rationale - No information.

4) **MF of the Nooksack River:** Rationale - No information.

5) **Nooksack River above the MF:** Rationale - No information.

Low level metals monitoring should be continued on the Nooksack River at Brennan. Rationale - This station was initially considered for listing on the 1994 303(d) list for lead and cadmium. Additional metals information, especially the dissolved fraction, would be useful.

River and Stream Biological Assessment

The Nooksack River watershed has two major land use influences that could degrade stream condition: agriculture and forest practices. The lower watershed land use consists mainly of agricultural practices. Conversely, the upper watershed land use is dominated by forest practice activity. Stream degradation from either of these land uses can have dramatic effects on the physical instream habitat and consequently on the biota.

Most of the tributary streams in the lower watershed have been channelized or physically altered. These impacts are easy to detect using benthic macroinvertebrate information. Several streams are likely candidates for biological monitoring: Tenmile Creek, Kamm Creek, Bertrand Creek, and Deer Creek. Two of the streams have had some biological descriptions completed from earlier studies. The forested, upper watershed region of the Nooksack River has several examples of degraded and reference site conditions. Forest practice effects on stream biota can be evaluated by surveying paired sites in the South Fork Nooksack River and North Fork Nooksack River. Thompson Creek is a tributary on the North Fork Nooksack River that was recommended as a reference site. Cornell Creek and West Cornell Creek are visually degraded sites that have been altered by excessive sediment transport during recent floods. The South Fork Nooksack River is easily accessible by highway and will likely contain many more streams that have been degraded by human activity. Some mainstem river sites that are wadable can be surveyed. Direct comparisons between mainstem sites on the 3 forks and lower river can be used to determine the source of impact: natural physical variation of the stream channel, or human alteration of the stream environment.

Lake monitoring in WRIA 1 has been fairly minimal, and should be increased particularly in areas vulnerable to or experiencing rapid development. Lakes located in agricultural areas may also be susceptible to eutrophication impacts, and additional monitoring may be warranted there.

Additional monitoring in Bellingham Bay is warranted for fecal contamination, deep water dissolved oxygen, nutrient concentrations, and phytoplankton species and abundance.

TMDLs

The 303(d) list for the Nooksack WRIA is dominated by nonpoint source pollutants. All of these waterbodies could be considered candidates for TMDL studies; however, EILS' traditional TMDL studies may not be the most appropriate mechanism for addressing these water quality problems. In many cases, planning, assessment, and control activities by local watershed action teams may be sufficient to qualify for a TMDL. In these instances, the work performed by local groups should be packaged as a TMDL and submitted to EPA for approval.

In other areas, formation of a watershed action team and development of a watershed plan may be the most appropriate and successful approach to solving water quality problems. EILS may contribute technical assistance, and perhaps limited monitoring, in these cases.

In areas where sources of water quality problems are not well understood, a TMDL study may be appropriate.

In forested areas with sediment and temperature problems, watershed analysis conducted pursuant to Chapter 222-22 WAC may be the most appropriate approach.

Intensive Surveys

Further studies should be conducted on Dakota Creek to determine the source and extent of cadmium contamination in the watershed. If survey results demonstrate that cadmium levels in the creek are of major concern, sampling commercially grown oysters in Drayton Harbor will be necessary, because shellfish can accumulate cadmium in their tissue to concentrations potentially harmful to humans.

The Nooksack WRIA would benefit from a better understanding of bacterial transport from upper watershed areas to shellfish beds. This would allow more focused source control in land areas directly contributing to shellfish contamination.

Monitoring should be conducted for currently used pesticides in streams draining major agricultural areas.

Technical assistance should be provided to permitted facilities emphasizing source control and pollution prevention to reduce discharges of contaminants into Whatcom Creek.

Compliance

Class II inspections are needed for the following facilities:

Industrial: Tosco, Georgia-Pacific, and Intalco.

Municipal: The Bellingham Post Point WWTP, the only municipal major discharger in the watershed, has not received an EILS Class II inspection during the past five years. Of the seven municipal minor dischargers in the watershed, only Sumas has received an EILS Class II inspection during the past five years. Birch Bay, Blaine, Everson, Ferndale, Lynden, and Whatcom County PUD#1 have not.

Ground Water

The impact of the land application of dairy wastes on the quality of the Sumas Aquifer needs to be defined. Ground water quality should be monitored and waste application tracked for selected areas. The study should be conducted in conjunction with current ongoing studies by the WSU Cooperative Extension, Whatcom County Conservation District, and U.S. Soil Conservation Service on wastewater application practices for optimal crop yield and soil conditions.

Baseline ground water quality surveys should be conducted for selected portions of the Sumas Aquifer. Priority sites for ground water surveys should be new dairy locations or dairy expansions, agricultural areas where pesticide use is high, urban growth areas, and municipal and industrial wastewater application areas. This information will help characterize ground water quality and will help identify water quality changes associated with land use.

The surficial aquifers should be characterized throughout the watershed. Characterization should include lateral and vertical boundaries, lithology, spatial distribution of hydrologic properties, depths to ground water, flow directions, and estimates of ground water/surface water interaction.

Effects of waste discharges on ground water quality should be defined at the following facilities:

- Ferry Brothers
- Ocean Star Seafood
- Kendall Creek On-site Wastewater Disposal

Ground water data for the watershed should be collected, compiled, and entered into a common Ecology database.

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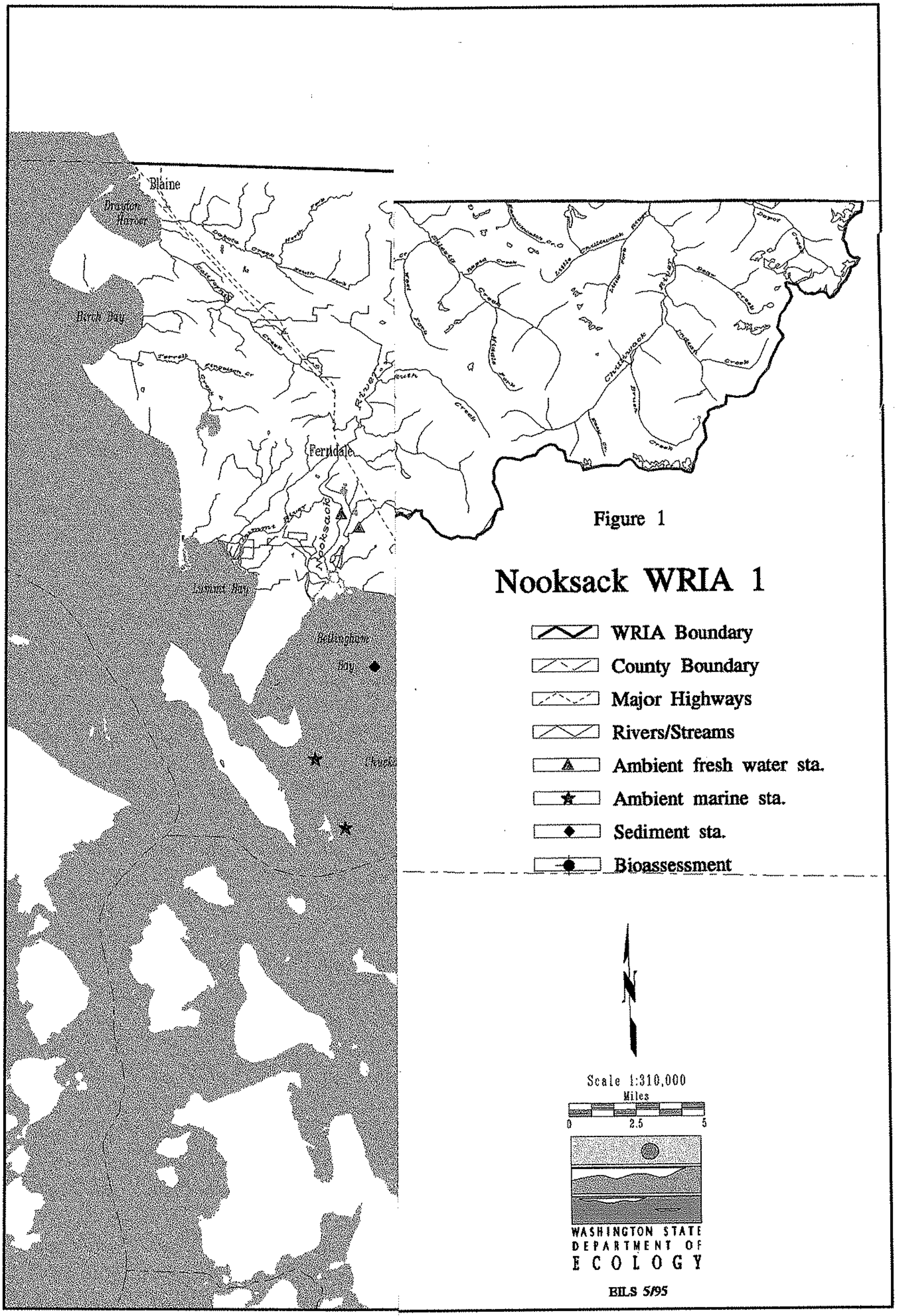

Figure 1

Nooksack WRIA 1

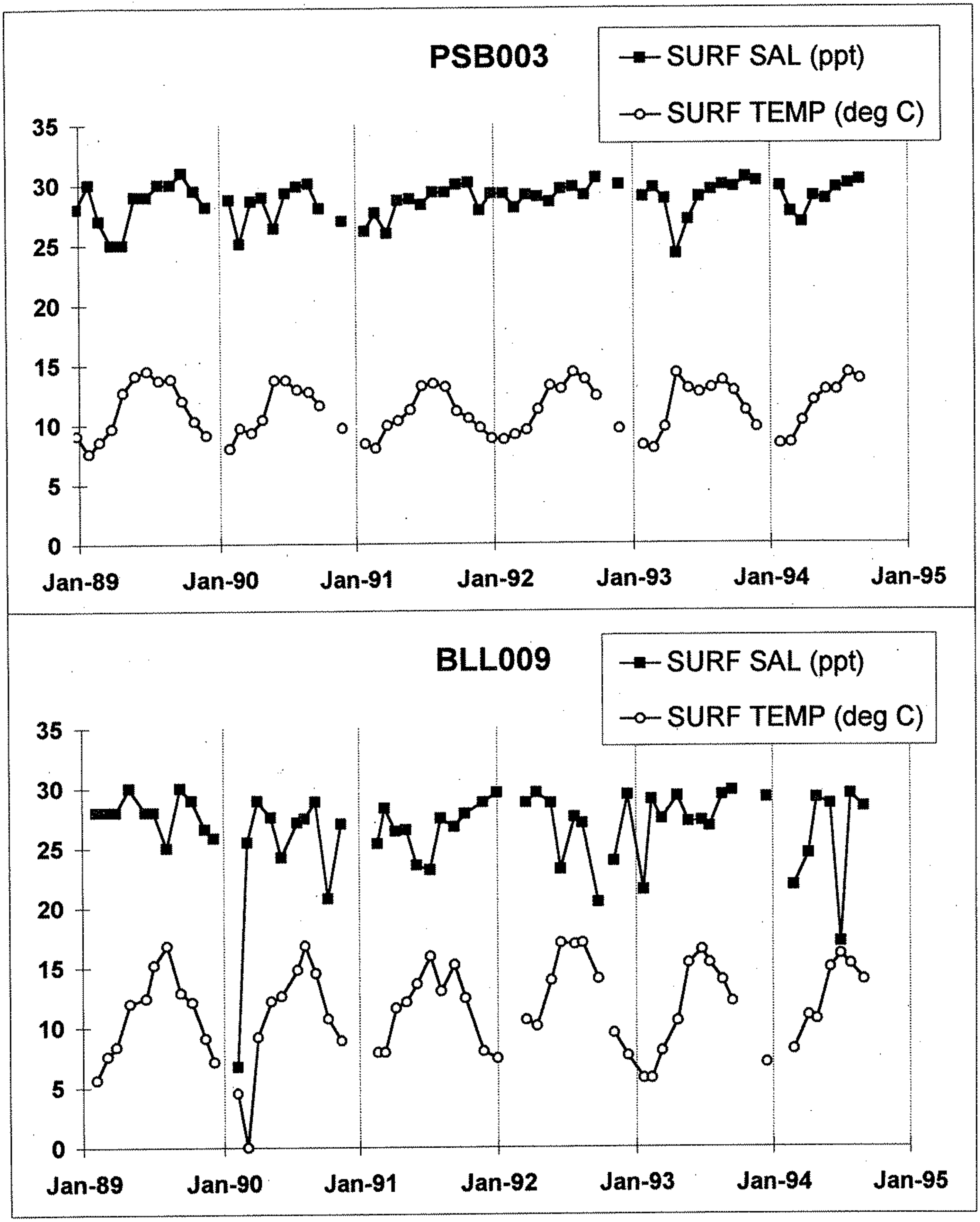

Figure 2. Sea surface salinity (ppt) and temperature (deg C) for the Puget Sound main basin (PSB003) and Bellingham Bay (BLL009).

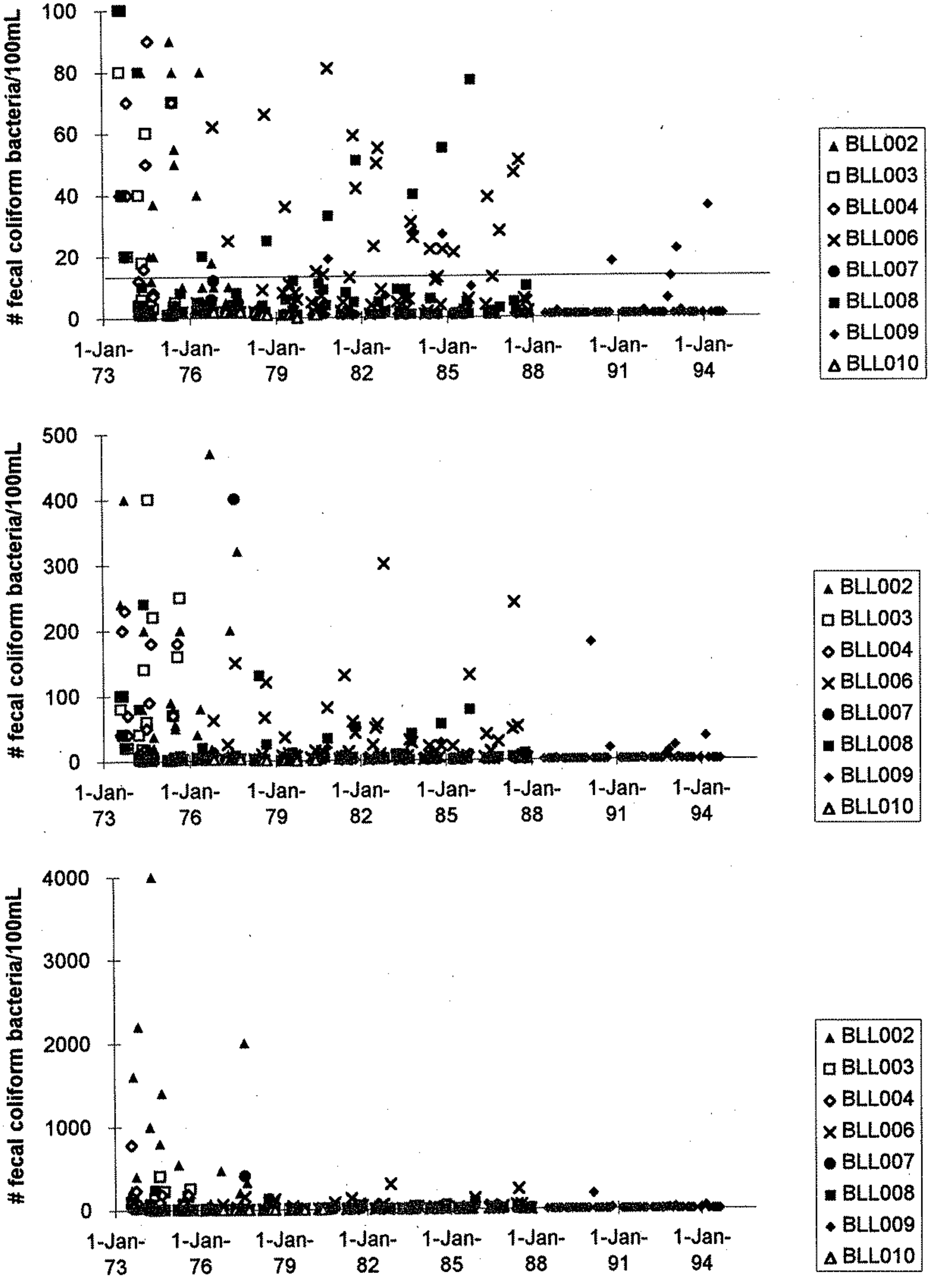

Figure 3. Fecal coliform counts for Bellingham Bay stations. Only BLL009 has data after 1989. Data are plotted versus different coordinates to show magnitude of excursion. Water quality standard is 14 organisms/mL, represented by line on top graph.

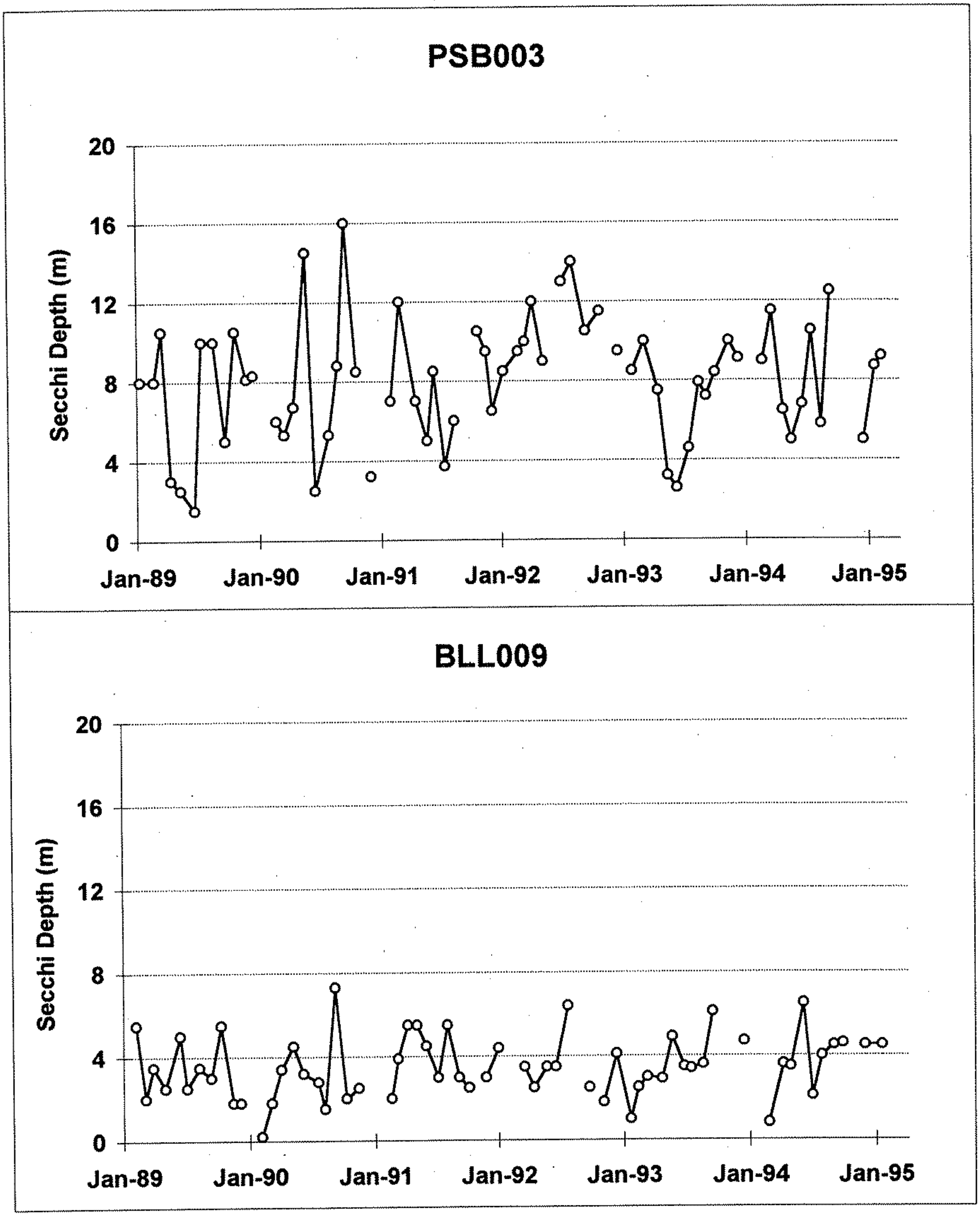

Figure 4. Secchi readings (m) for the Puget Sound main basin (PSB003) and Bellingham Bay (BLL009).

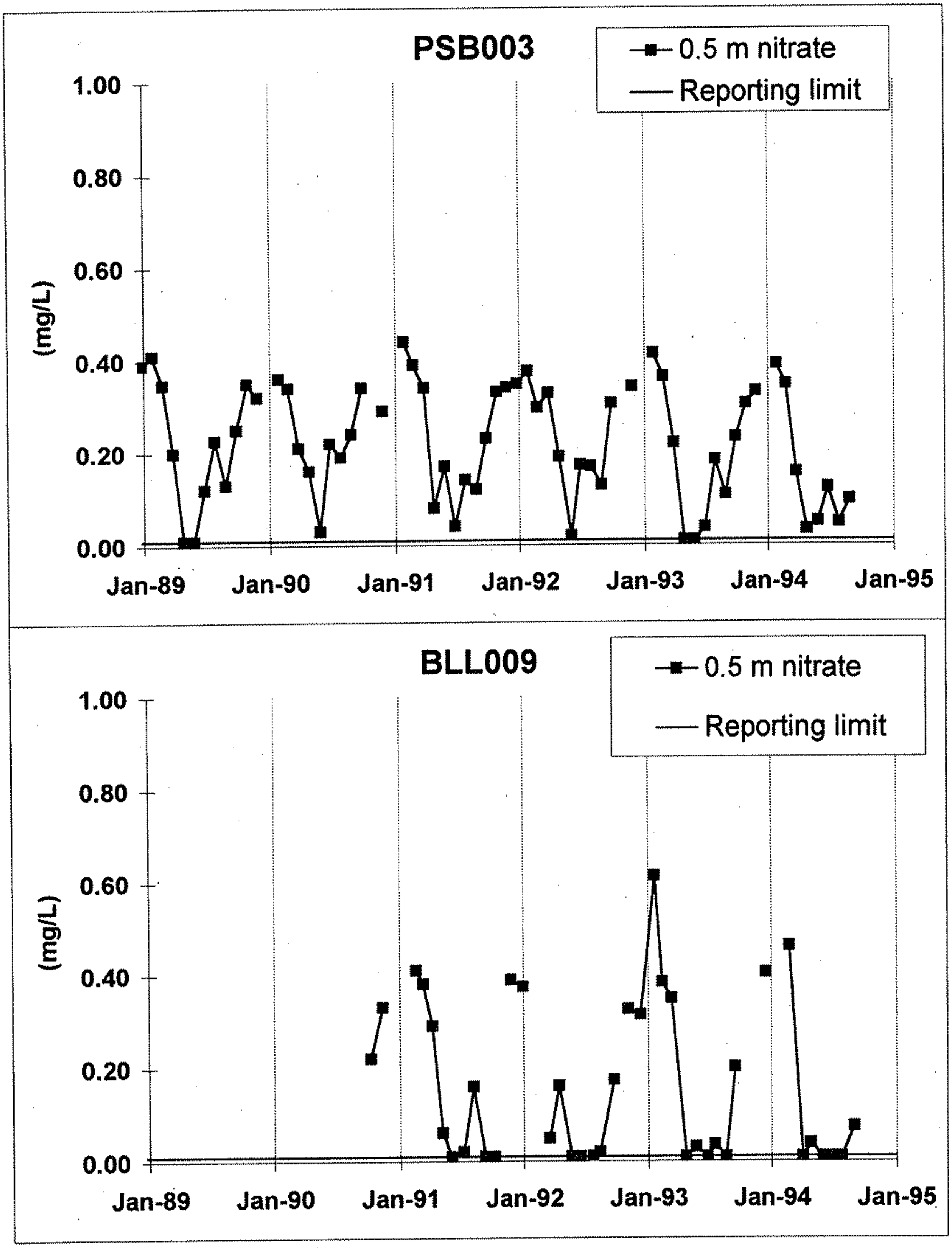

Figure 5. Nitrate concentrations (mg/L) for the Puget Sound main basin (PSB003) and Bellingham Bay (BLL009).

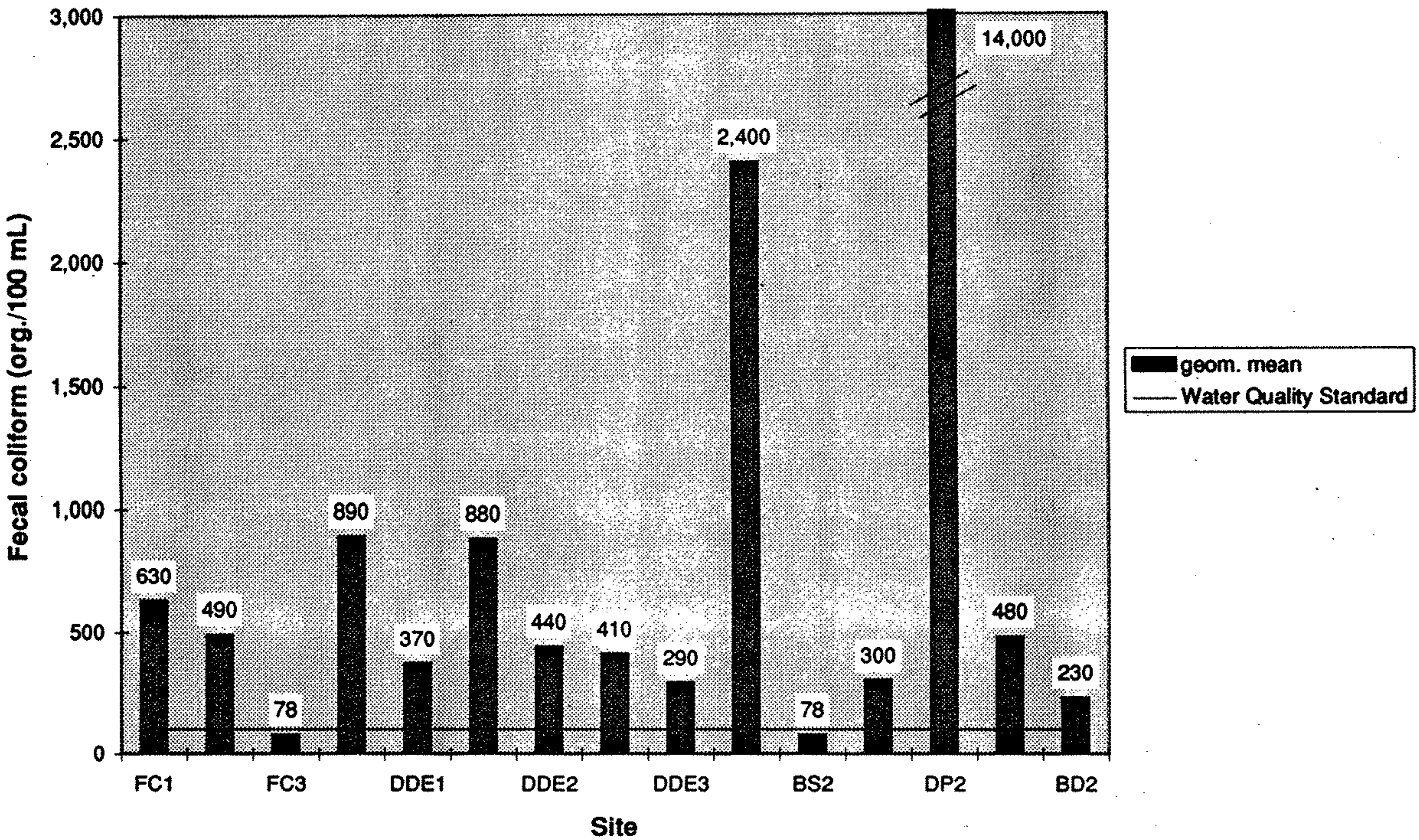

Figure 6. Fecal coliform geometric mean values at each site within the Fishtrap Creek TMDL study area.

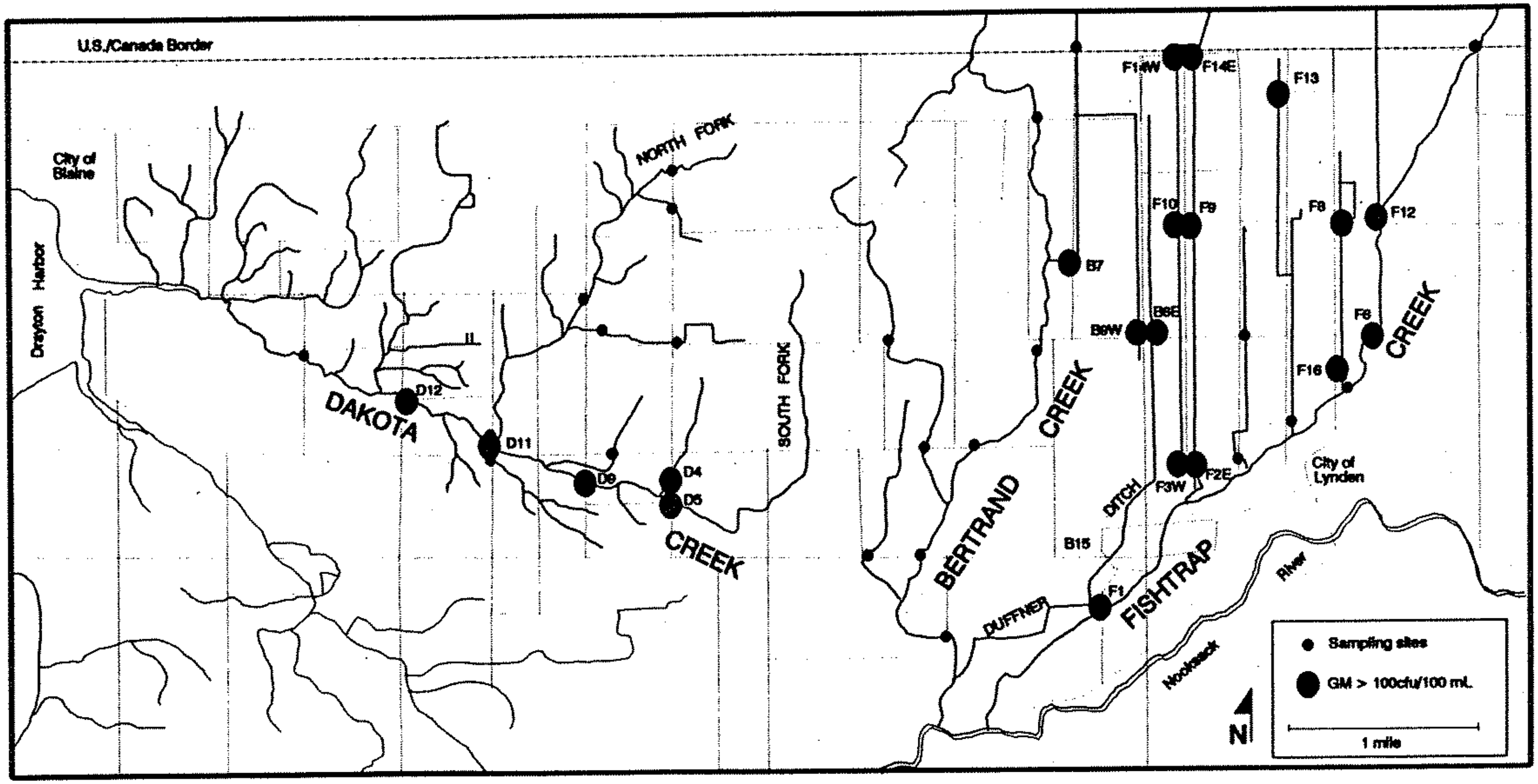

Figure 7. Water quality sampling sites for fecal coliform bacteria on Dakota, Bertrand, and Fishtrap Creeks, February-March 1992. The large markers identify sites where the geometric mean (GM) for the study period was greater than 100 cfu/100 mL.

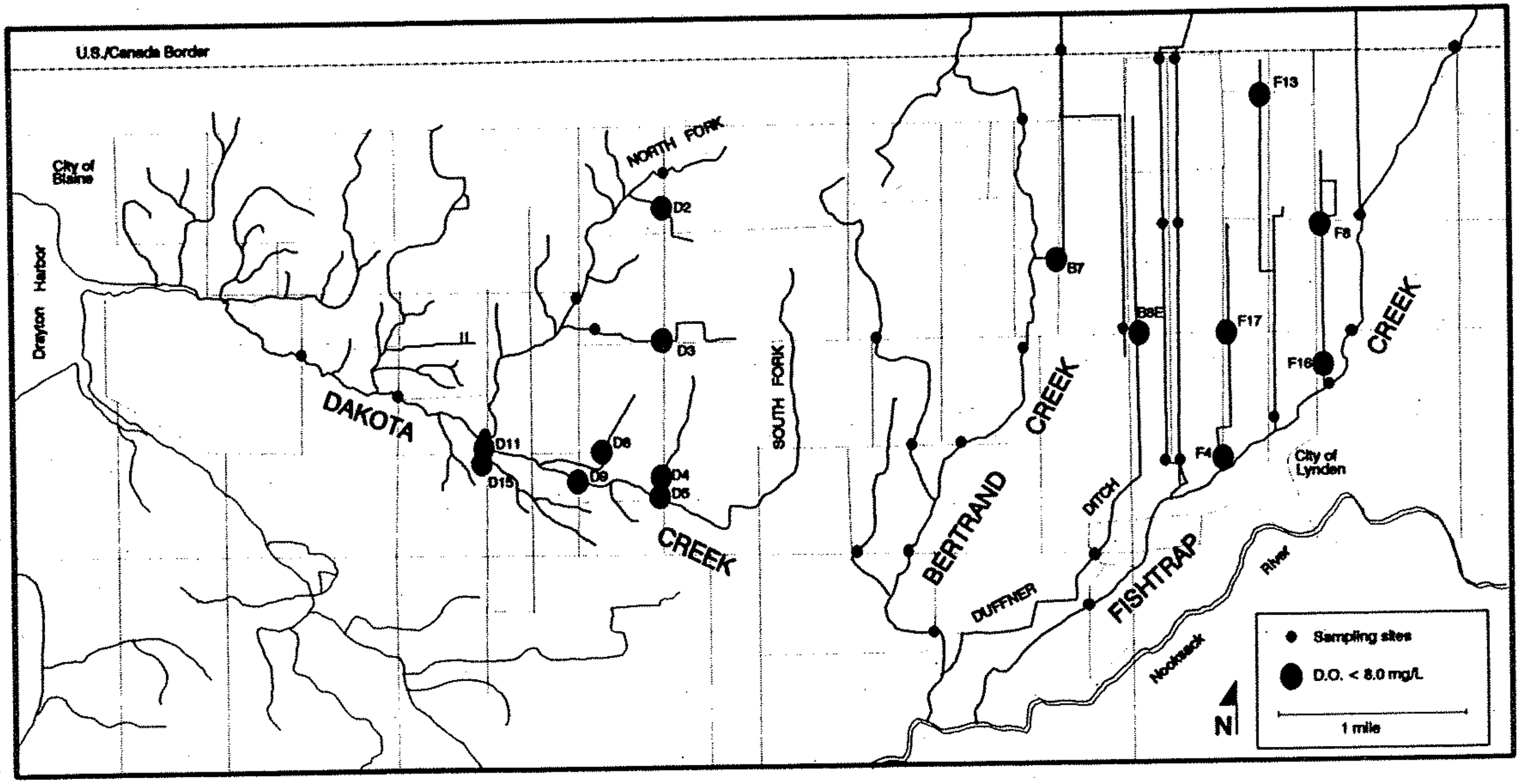

Figure 8. Water quality sampling sites for dissolved oxygen (D.O.) on Dakota, Bertrand, and Fishtrap Creeks, February-March 1992. Large markers identify sites where there was at least one violation of the Class A criterion for D.O.

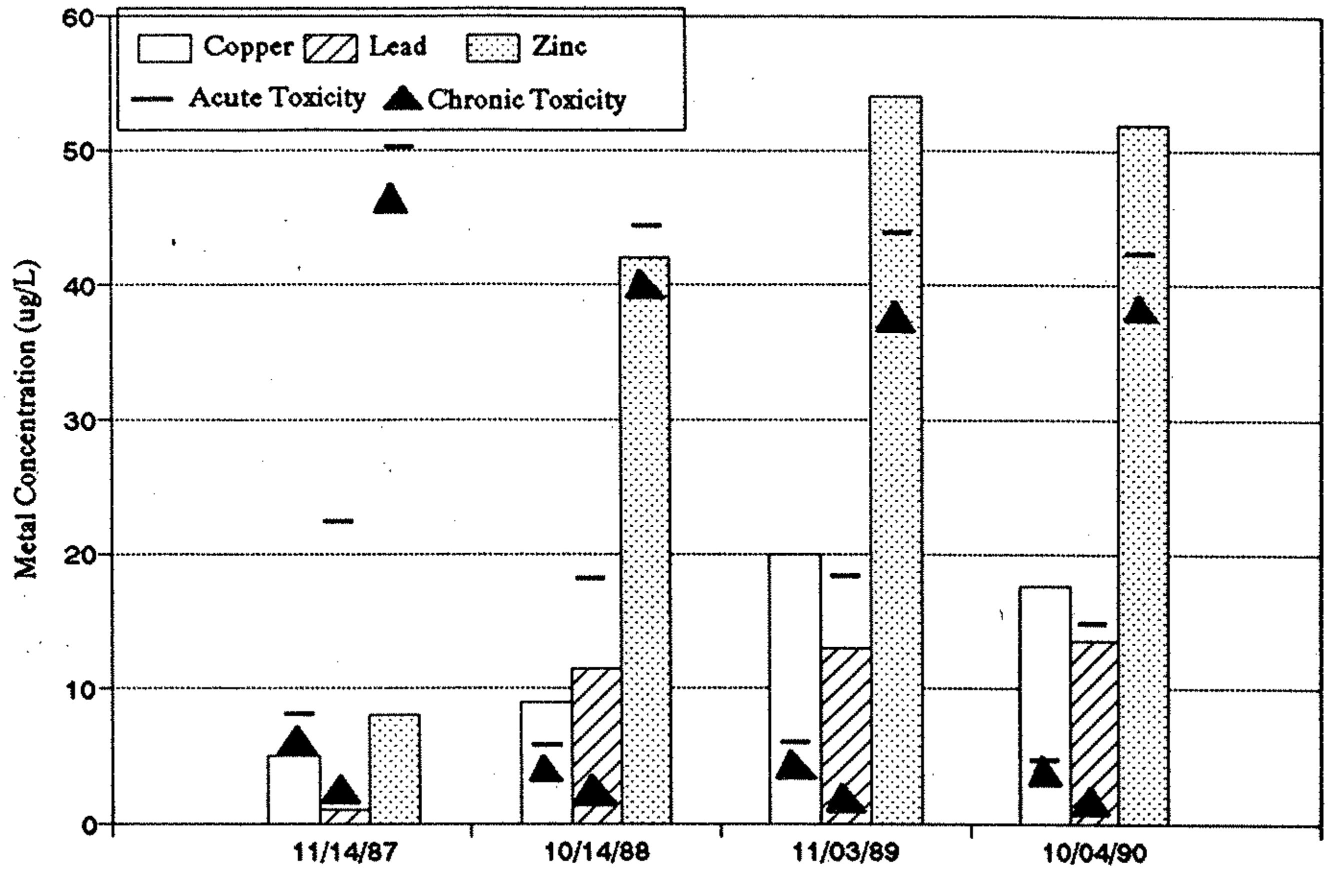

Figure 9. Total copper, lead, and zinc measured during fish kills and/or storm events at MHFH, 1987-1990. Acute and chronic toxicity criteria (based on total recoverable metals) are shown for reference.

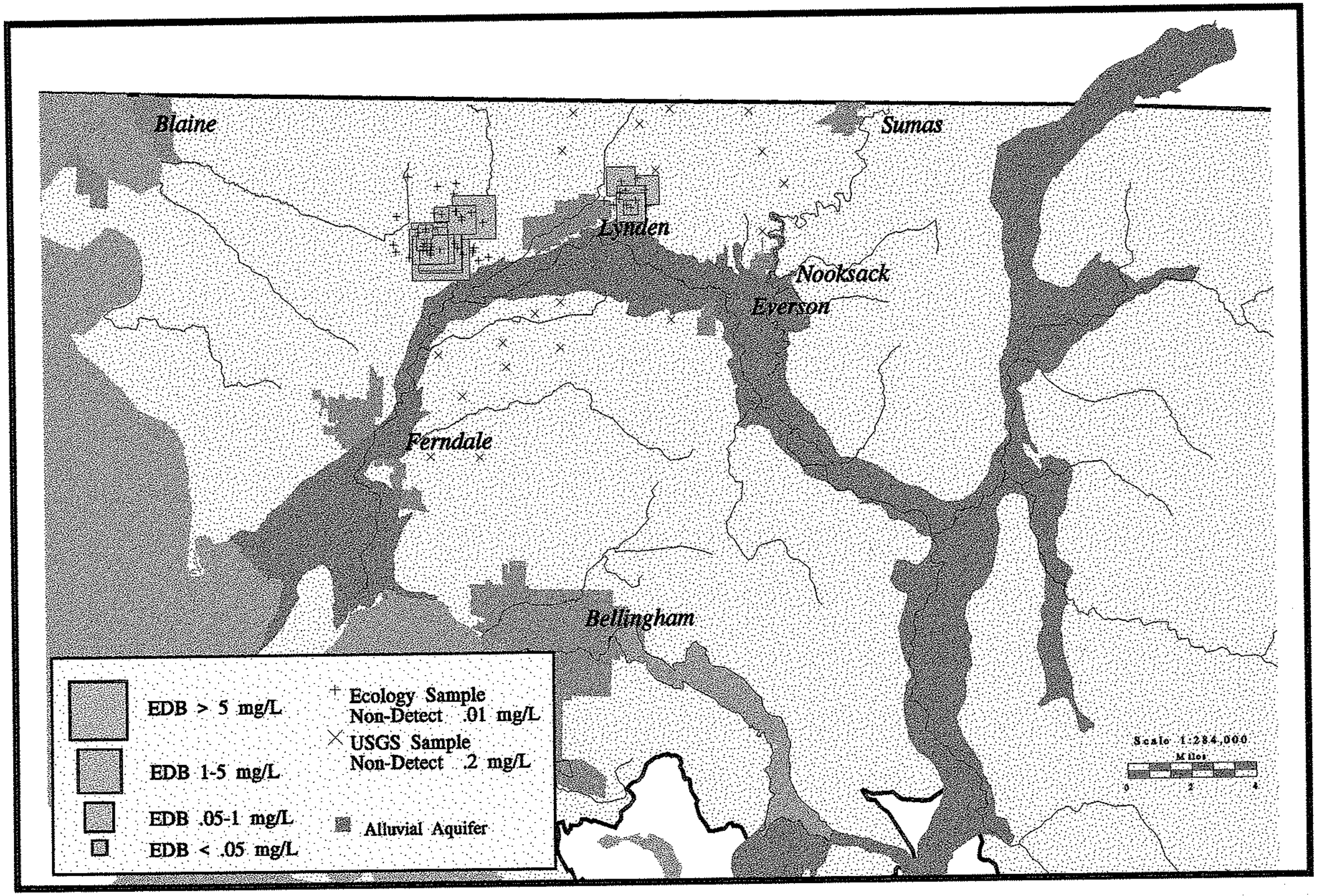

Figure 10. Ethylene dibromide in selected Whatcom County ground water monitoring wells, 1986-1989.

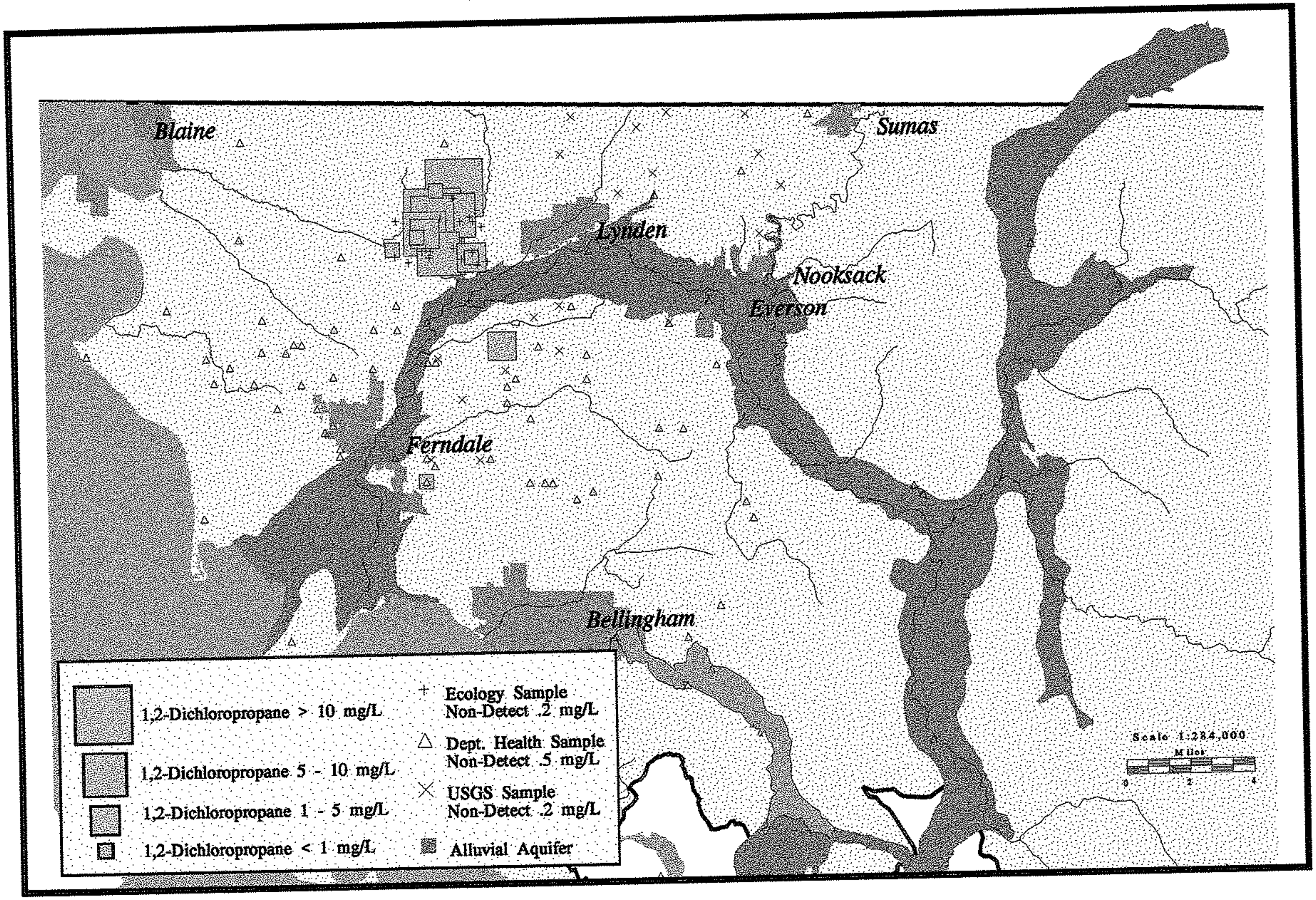

Figure 11. 1,2-Dicloropropane in selected Whatcom County ground water monitoring wells, 1986-1989.

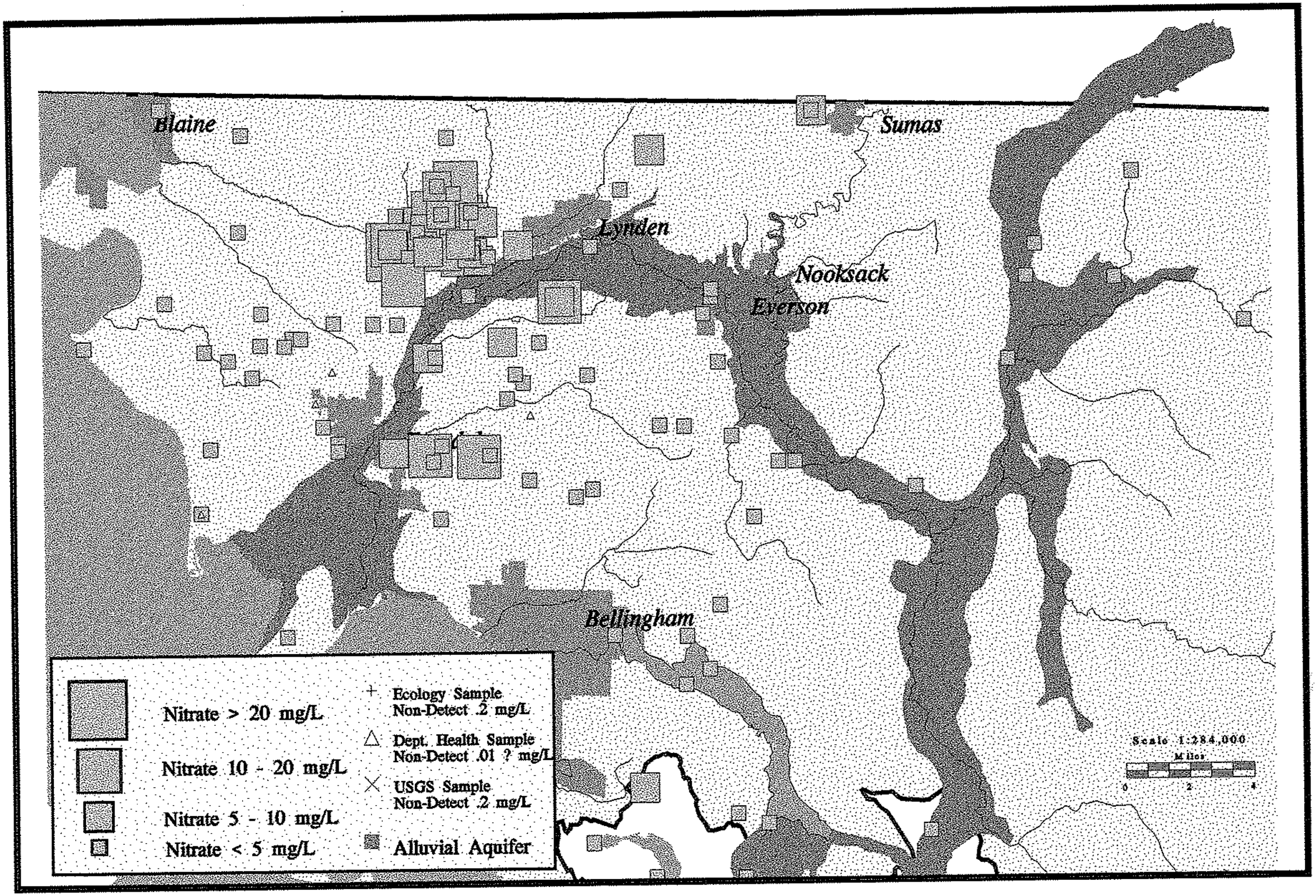

Figure 12. Nitrite+Nitrate-N in selected Whatcom County ground water monitoring wells, 1988-1992.

Table 1. Water quality standard violations for temperature, pH, dissolved oxygen, and fecal coliform bacteria recorded from WY 1988 to WY 1994 for Ecology's ambient monitoring location in the Nooksack WRIA.

Station Location	Parameter	Total Samples	Number of Violations	Percent Violations
Nooksack R @ Brennan	FC**	79	22	28
(Class "A")	pH	76	0	0
	D.O.	82	0	0
	Temp	82	0	0
Nooksack R @ N. Cedarville	FC	58	2	3
(Class "A")	pH	56	0	0
	D.O.	60	0	0
	Temp	60	0	0
Silver Ck. nr Brennan	FC	21	8	38
(Class "A")	pH	23	0	0
	D.O.	23	13	57
	Temp	23	1	4
Sumas R. nr Huntingdon B.C.	FC	54	45	83
(Class "A")	pH	55	0	0
	D.O.	59	14	24
	Temp	59	0	0
Whatcom Ck. @ Bellingham	FC	12	5	42
(Class "A")	pH	10	0	0
	D.O.	12	0	0
	Temp	12	2	17

** Fecal Coliform Bacteria standards are not violated unless the "Percent Violations" column is greater than 10 percent.

Table 2. Locations within the Nooksack WRIA that are listed in the 1994 Section 303(d) of the Federal Clean Water Act based on Ecology's ambient monitoring data.

Station Location	Parameter(s) that Violates Standard
Nooksack River at Brennan	Fecal Coliform Bacteria
Silver Creek near Brennan	Dissolved Oxygen Fecal Coliform Bacteria
Sumas River near Huntingdon B.C.	Dissolved Oxygen Fecal Coliform Bacteria

Table 3. Marine water column data available from the Ambient Monitoring Section. An "X" denotes monthly data, although parameters sampled, methods, and sampling design has varied to some extent. Continuous profiles and winter data were not obtained until WY 1989.

Station Number	Station Name	Latitude (deg min N)	Longitude (deg min W)	WY: 73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95
Bellingham Bay																										
BLL002	Std Oil Dock	48 45.1	122 29.2	X	X	X	X	X																		
BLL003	S. Whatcom WW	48 44.7	122 29.6	X	X	X																				
BLL004	Yacht Harbor	48 45.2	122 30.4	X	X	X																				
BLL006	Nun Buoy 4	48 44.1	122 30.1				X	X	X	X	X	X	X	X	X	X	X	X	X							
BLL007	Cannery Shipyard	48 43.4	122 30.8				X	X																		
BLL008	Post Point	48 42.8	122 31.8	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X							
BLL009	Pt. Frances	48 41.2	122 35.9						X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
BLL010	Eliza Island	48 38.3	122 34.7					X	X	X	X															

Appendices

Appendix A. 1994 Section 303(d) List submitted to EPA.

WATERBODY SEGMENT NUMBER	WATERBODY NAME	PARAMETERS EXCEEDING STANDARDS	BASIS FOR LISTING
WA-01-0020	DRAYTON HARBOR	Fecal Coliform	Department of Health Prohibited Commercial Shellfish Area based on water quality surveys.
WA-01-0050	BELLINGHAM BAY (INNER) AND WHATCOM WATERWAY	Mercury	Station clusters of potential concern based on exceedance of cleanup screening levels in sediment.
WA-01-0070	LUMMI BAY AND HALE PASSAGE	Fecal Coliform	DSHS Report: Cleland, 1985.
WA-01-1002	DAKOTA CREEK	Dissolved Oxygen	Ecology Report: Dickes, B. 1992.
		Fecal Coliform	Ecology Report: Dickes, B. 1992.
WA-01-1010	NOOKSACK RIVER	Fecal Coliform	19 excursions beyond criteria at Ecology ambient monitoring station 01A050 between 1/1/90 and 1/1/92
WA-01-1012	TENMILE CREEK	Ammonia-N	Whatcom County Conservation District, 1990.
		Dissolved Oxygen	Whatcom County Conservation District, 1990.
		Temperature	Whatcom County Conservation District, 1990.
		Fecal Coliform	Whatcom County Conservation District, 1990.
WA-01-1015	KAMM SLOUGH	Dissolved Oxygen	Tetra Tech, 1989 = 6 excursions beyond criteria at RM 0.6, and 1 excursion beyond criteria at RM 4.0 between 10/88 and 9/89
		pH	Tetra Tech, 1989 = 5 excursions beyond criteria at RM 0.6, 4 excursions at RM 3.1, 4 excursions at RM 4.0, and 5 excursions at RM 4.5 between 10/88 and 9/89.
		Fecal Coliform	Tetra Tech, 1989 = 6 excursions beyond criteria at RM 0.6, 8 excursions at RM 3.1, 7 excursions at RM 4.0, and 1 excursion at RM 4.5 (geom. mean with sample size of 1) between 10/88 and 9/89.
WA-01-1016	MORMON DITCH	Dissolved oxygen	Tetra Tech, 1989 = 10 excursions beyond criteria at RM 0.5 between 11/88 and 9/89.
		pH	Tetra Tech, 1989 = 8 excursions beyond criteria at RM 0.5 between 11/88 and 9/89.
		Fecal Coliform	Tetra Tech, 1989 = 7 excursions beyond criteria (geom. mean with sample size of 1) at RM 0.5 between 11/88 and 9/89.

WATERBODY SEGMENT NUMBER	WATERBODY NAME	PARAMETERS EXCEEDING STANDARDS	BASIS FOR LISTING
WA-01-1030	NOOKSACK RIVER, S.F.	Fine Sediment	The following references document habitat alterations: Schuett-Hames, 1988b. = mean value of 11.7% from 1982-1987; CES, 1993. = 0% in surface sediment samples, 34% in subsurface samples; The following references document impairment of characteristic uses: Doughty, 1987. = documented decline in Chinook stock; SASSI, 1993.= Chinook stock listed as critical; The following references document antropogenic contribution of sediment: Benda, 1993. CES, 1993. Gowen, 1989. PEAK NW, 1986a. PEAK NW, 1986b.
WA-01-1040	NOOKSACK RIVER, S.F.	Fine Sediment	The following references document habitat alterations: Schuett-Hames, 1984a = 10.7% in 1982; Schuett-Hames, 1988b = mean value of 11.7% from 1982-1987; CES, 1993 = 0% in surface sediment samples, 34% in subsurface sediment samples; The following references document impairment of characteristic uses: Doughty, 1987. = documented decline in Chinook stock; SASSI, 1993.= Chinook stock listed as critical; The following references document antropogenic contribution of sediment: Benda, 1993. CES, 1993. Gowen, 1989. PEAK NW, 1986a. PEAK NW, 1986b.
		Temperature	Data submitted by Dan Neff of the Lummi Tribe show 29 excursions beyond criteria between 7/28/92 and 8/30/92.
WA-01-1060	NOOKSACK RIVER, M.F.	Temperature	Data submitted by Dan Neff of the Lummi Tribe show 8 excursions beyond criteria between 7/30/92 and 9/4/92.

WATERBODY SEGMENT NUMBER	WATERBODY NAME	PARAMETERS EXCEEDING STANDARDS	BASIS FOR LISTING
WA-01-1080	NOOKSACK RIVER	Fine Sediment	The following references document habitat alterations: Schuett-Hames, 1984a. = 14% in 1983. Schuett-Hames, 1988b. = 14% in 1983. The following references document impairment of characteristic uses: Doughty, 1987. = documented decline in Chinook stock; SASSI, 1993. = Chinook stock listed as critical; The following references document antropogenic contribution of sediment: Benda, 1993. Gowen, 1989. PEAK NW, 1986a. PEAK NW, 1986b.
WA-01-1101	SILVER CREEK	Dissolved Oxygen	Multiple excursions at Ecology ambient monitoring station 01B050 between 10/91 and 9/92.
		Fecal Coliform	Multiple excursions (geom. mean with a sample size of 1) at Ecology ambient monitoring station 01B050 between 10/91 and 9/92.
WA-01-1110	BERTRAND CREEK	Dissolved Oxygen	Ecology Report: Dickes, 1992. Contributing pollution sources are in Canada.
		Fecal Coliform	Ecology Report: Dickes, 1992. Contributing pollution sources are in Canada.
WA-01-1111	DUFFNER DITCH	Dissolved Oxygen	Ecology Report: Dickes, 1992.
		Temperature	Ecology Report: Dickes, 1992.
WA-01-1115	FISHTRAP CREEK	Fecal Coliform	Ecology Report: Dickes, 1992 = excursions beyond criteria at 5 locations during 2/92 and 3/92.
WA-01-1116	DOUBLE DITCH DRAIN	Fecal Coliform	Ecology Report: Dickes, 1992 = excursions beyond criteria at 6 locations during 2/92 and 3/92.
WA-01-1117	BENSON ROAD DITCH	Dissolved Oxygen	Ecology Report: Dickes, 1992 = 3 excursions beyond criteria at E. Badger Road and Benson Road between 2/5/92 and 3/11/92.
WA-01-1118	DEPOT ROAD DITCH	Dissolved Oxygen	Ecology Report: Dickes, 1992 = 2 excursions beyond criteria at Vissner Road and Depot Road on 3/4/92 and 3/11/92.
		Fecal Coliform	Ecology Report: Dickes, 1992 = excursions beyond criteria at Vissner Road and Depot Road during 2/92 and 3/92.
WA-01-1119	BENDER ROAD DITCH	Dissolved Oxygen	Ecology Report: Dickes, 1992 = 2 excursions beyond criteria at Panghorn Road and Bender Road on 2/5/92 and 3/4/92.

WATERBODY SEGMENT NUMBER	WATERBODY NAME	PARAMETERS EXCEEDING STANDARDS	BASIS FOR LISTING
		Fecal Coliform	Ecology Report: Dickes, 1992 = excursions beyond criteria at 2 locations during 2/92 and 3/92.
WA-01-1120	ANDERSON CREEK	Fine Sediment	The following references document habitat alterations: Schuett-Hames, 1984a. = 29.1% in 1983. Schuett-Hames, 1988b. = mean value of 20.4% between 1983-1985; The following references document impairment of characteristic uses: Doughty, 1987. = documented decline in Chinook stock; The following references document antropogenic contribution of sediment: Benda, 1993. Gowen, 1989. PEAK NW, 1986a. PEAK NW, 1986b.
WA-01-1145	RACEHORSE CREEK	Fine Sediment	The following references document habitat alterations: Schuett-Hames, 1984a. = 19.7% in 1983. Schuett-Hames, 1988b. = 17.8% in 1985. The following references document impairment of characteristic uses: Schuett-Hames, 1987. = documented decline in Chinook stock; Doughty, 1987.= documented decline in Chinook stock; The following references document antropogenic contribution of sediment: Benda, 1993. Gowen, 1989. PEAK NW, 1986a. PEAK NW, 1986b.
		Temperature	Data submitted by Dan Neff of the Lummi Tribe show 32 excursions beyond criteria between 7/24/92 and 9/4/92.
WA-01-1155	BOULDER CREEK	Temperature	Neff, 1993b. = 5 excursions beyond criteria between 7/30/93 and 8/30/93.
WA-01-1170	CORNELL CREEK	Temperature	Data submitted by Dan Neff of the Lummi Tribe show 32 excursions beyond criteria between 7/30/92 and 8/30/92.
WA-01-1175	GALLOP CREEK	Temperature	Data submitted by Dan Neff of the Lummi Tribe show 26 excursions beyond criteria between 7/30/92 and 8/30/92.

WATERBODY SEGMENT NUMBER	WATERBODY NAME	PARAMETERS EXCEEDING STANDARDS	BASIS FOR LISTING
WA-01-1290	HOWARD CREEK	Fine Sediment	The following references document habitat alterations: Schuett-Hames, 1988b. = mean value of 15.24% in 1984; The following references document impairment of characteristic uses: Doughty, 1987. = documented decline in Chinook stock; The following references document antropogenic contribution of sediment: Benda, 1993. Gowen, 1989. PEAK NW, 1986a. PEAK NW, 1986b.
WA-01-1310	CANYON LAKE CREEK	Temperature	Data submitted by Dan Neff of the Lummi Tribe show 31 excursions beyond criteria between 7/27/92 and 9/4/92.
WA-01-2010	**SUMAS RIVER**	**Dissolved Oxygen**	Ecology Report: Cusimano, 1992.; 9 excursions beyond criteria at Ecology ambient monitoring station 01D070 between 1/1/90 and 1/1/92; The likely cause of these excursions is an impoundment in Canada. Stratification behind the impoundment causes oxygen depletion. Remedies to the problem may not be available. Ecology's Water Quality Program Policy on TMDLs adopted 8/93 specifies that EPA is expected to conduct all interstate TMDLs according to the federal Clean Water Act.
		Fecal Coliform	Ecology Report: Cusimano, 1992.; 28 excursions beyond criteria at Ecology ambient monitoring station 01D070 between 1/1/90 and 1/1/92.
WA-01-2020	JOHNSON CREEK	Dissolved Oxygen	Ecology Report: Dickes, 1992. Ecology Report: Dickes and Merrill, 1990.
		Fecal Coliform	Ecology Report: Dickes, 1992. Ecology Report: Dickes and Merrill, 1990.
WA-01-2030	SUMAS CREEK	Fecal Coliform	Ecology Report: Dickes and Merrill, 1990.
WA-01-2040	PANGBORN CREEK	Dissolved Oxygen	Ecology Report: Dickes and Merrill, 1990.
		pH	Ecology Report: Dickes and Merrill, 1990.
		Fecal Coliform	Ecology Report: Dickes and Merrill, 1990.
WA-01-2050	SQUAW CREEK	Fecal Coliform	Ecology Report: Dickes and Merrill, 1990.
		Dissolved Oxygen	Ecology Report: Dickes and Merrill, 1990.
		pH	Ecology Report: Dickes and Merrill, 1990.
WA-01-3110	WHATCOM CREEK	Pentachlorophenol	Ecology Report: Kendra, 1988.
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