PRELIMINARY ASSESSMENT OF LOWER HOOD CANAL STREAMS: 2004 STUDY

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ABSTRACT

Development of the Watershed Planning Act (RCW 90-82) required that Water Resource Inventory Areas (WRIAs) develop a watershed plan. During development of the WRIA 16 watershed plan, baseline water quality data for many of the streams was found lacking; particularly for streams along Lower Hood Canal. The purpose of this study was to provide baseline data for small streams draining to the Canal and help identify potential problem areas for future watershed management efforts. During this effort, fourteen streams along the North and South Shore of Lower Hood Canal were monitored. These streams represented only about 30% of the landmass that contributes runoff to this part of the canal. These streams included Big Bend, Alderbrook, Unnamed, Shady Beach, Twanoh, Twanoh Falls, Mulberg, Happy Hollow, Holyoke, and Deveraux on the South Shore and the Tahuya River, Mission, Shoofly, and Stimson Creeks on the North Shore. Three streams sampled exceeded fecal coliform standards during dry season monitoring (Big Bend, Mulberg, and Deveraux Creeks). High temperatures were measured in all of the North Shore streams on at least one occasion during dry season monitoring, however only the Tahuya River represented a water quality standard exceedance. Nutrient concentrations were generally low and resulted in low yields when compared to small to large size rivers in Puget Sound. Minor exceptions to this were observed in Alderbrook and Unnamed Creeks. Alderbrook Creek measured higher than average nitrogen loads. Summer unit runoff in Unnamed Creek was notably higher in the dry season than wet, which led to high nutrient yields. No strong recommendations could be derived from this data for watershed planning purposes. There are a few streams that had elevated fecal coliform bacteria levels, but even in these cases the concentrations are low in comparison to most impacted streams and may be more indicative of the low water year than of problems. No problems were at a level to justify major investigative efforts.

INTRODUCTION

In 1998, the Watershed Planning Act (RCW 90-82) was developed requiring that Water Resource Inventory Areas (WRIAs) develop a watershed plan. One of the data gaps identified during development of the watershed plan for WRIA 16 was baseline water quality data for many of the smaller streams in the WRIA. Other than some bacteria data, there was almost no data on the streams along Lower Hood Canal. This, in addition to fecal bacteria contamination concerns in Hood Canal that have resulted in shellfish area closures made this a high priority for watershed-based monitoring. Furthermore, in recent years, the frequency of fish kills believed to be associated with low dissolved oxygen has increased within the canal. This has drawn statewide as well as national attention to the area (Stiffler, L., 2004; Dodge, J, 2004 and 2005). A primary concern has been that anthropogenic sources of nutrients and other pollutants may be contributing to the problems identified in Hood Canal (Fagergren, et al, 2004). Therefore, information about surface water runoff characteristics is key for watershed planning in the Hood Canal area.

The purpose of this study was to provide baseline data for small streams draining to the Canal and help identify potential problem areas for future watershed management efforts. Initially, the study focused on the South Shore of Lower Hood Canal (WRIA 16). The monitoring effort was expanded to include some streams on the North Shore of the Canal. Mason and Kitsap Counties provided funding for this study through watershed planning grants from the Washington State Department of Ecology for WRIA's 14 (South Shore), 16 (South Shore) and 15 (North Shore).

The primary objectives of this study were to; characterize runoff from streams entering Lower Hood Canal, assess potential land use impacts to selected drainages, and make recommendations where appropriate for more intensive investigative studies. Due to budget constraints, an optimized approach was taken developing the monitoring plan. Monitoring was scheduled to focus on the periods of greatest concern; the wet weather season when the greatest variability in flow and pollutant concentrations can be expected, and mid to late summer when seasonal residents have returned to the area and stream flows are the lowest. This approach resulted in a reduction in the total number of sampling events. Analytical parameters measured were selected to identify impacts that are typically associated with streams in developing areas.

STUDY AREA DESCRIPTION

Hood Canal is an "L-shaped" fjord located on the western side of the Puget Sound Basin (Figure 1). The Canal is approximately 60 miles in length, and the last 15 miles forms the bottom of the "L" that bends to the east at the mouth of the Skokomish River (Fagergren et al., 2004). Topography in the shorter, east-west directing arm, often referred to as Lower Hood Canal, consists of gently sloping forested hills. Soils in the area are generally diverse and representative of steep well-drained areas (USDA, 1951). On average, Lower Hood Canal receives approximately 60 inches of rain annually, with a gradient of higher to lower precipitation from west to east (Golder, 2003).

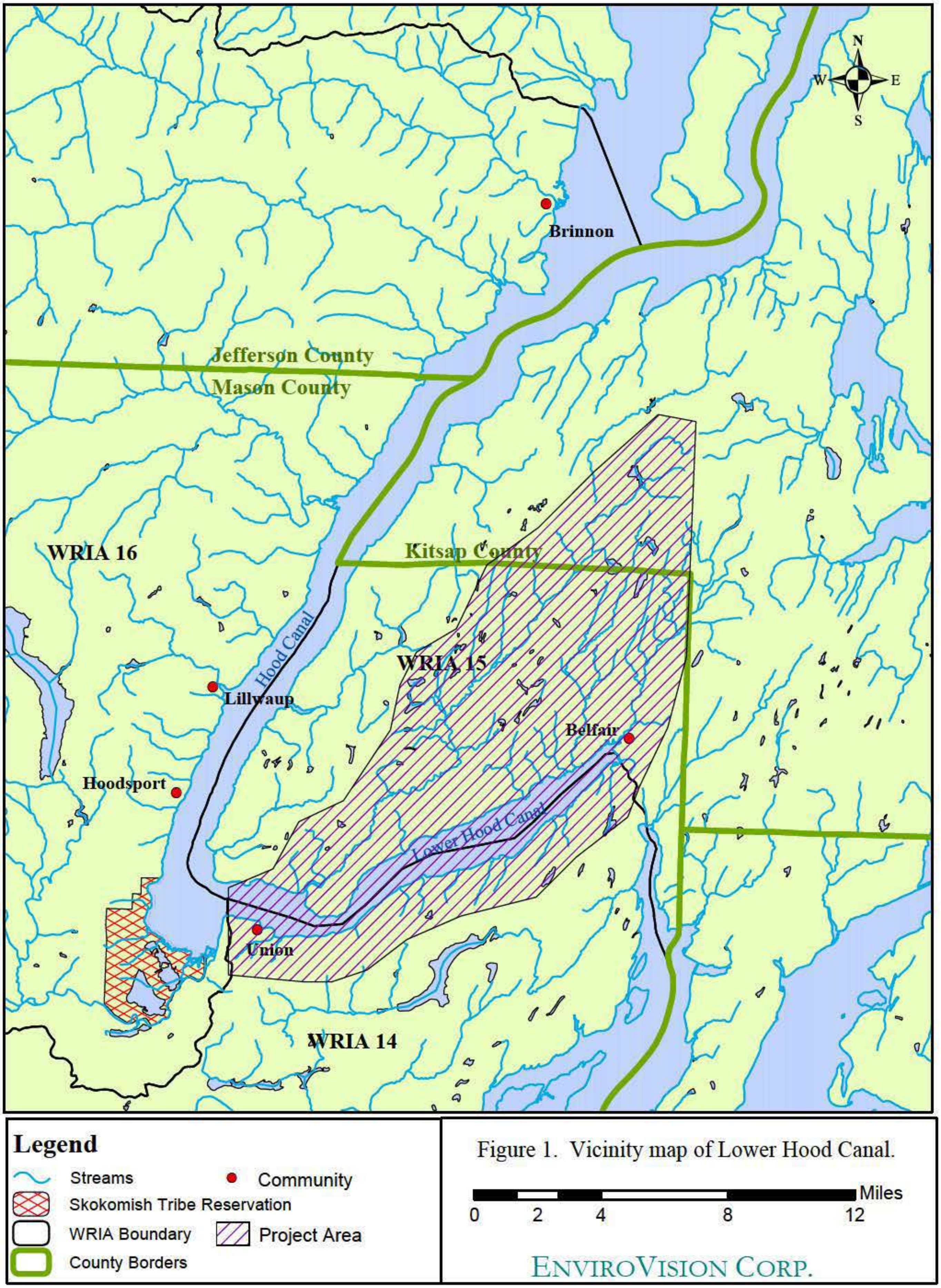


Figure 1. Vicinity map of Lower Hood Canal.

Lower Hood Canal consists of two major shorelines and is situated in two Water Resource Inventory Areas (WRIAs) (Figure 1). In this study, the "South Shore" refers to the area between the Skokomish River and Belfair. This area officially falls within the jurisdictional boundaries of WRIA 14, however, WRIA 16, which covers the western shores of the canal, had included the South Shore within their planning efforts to allow more efficient planning for the Hood Canal area. The "North Shore" refers to the area that extends from Belfair west to the Tahuya River at Sisters Point. This area lies within WRIA 15.

Development, primarily single-family residential homes and small commercial establishments, generally occurs in close proximity to main highways that line the canal. However, the majority of the area is heavily forested. There are two major state parks and one state forest located within the study area (Belfair State Park, Twanoh State Park and the Tahuya State Forest).

The South Shore drainage is comprised of eleven identified streams (WSCC, 2003) and many seeps and other small drainages. The total drainage area of the South Shore (between Union and Belfair) is approximately 29 mi^2. Ten streams, representing 9 mi^2 of this shore were monitored during this effort. These streams included Big Bend, Alderbrook, Unnamed, Shady Beach, Twanoh, Twanoh Falls, Mulberg, Happy Hollow, Holyoke, and Deveraux (Figure 2). This is roughly 31% of the total drainage to this shoreline. Most of the subbasins are small; all are less than 2 mi^2 (Table 1). Deveraux Creek has the largest watershed (1.9 mi^2), while several of the monitored streams have watersheds that are less than 0.1 mi^2.

Table 1. Land use/land cover for Lower Hood Canal Drainages.

DRAINAGE NAME	DRAINAGE AREA (mi^2)	RURAL DEVELOPMENT(1)	URBAN DEVELOPMENT(2)	COMMERCIAL DEVELOPMENT(3)	RANGELAND(4)	FORESTLAND(5)	OTHER (6)
South Shore							
Big Bend Creek	0.94	0.1%	21.4%	-	7.7%	70.5%	0.3%
Alderbrook Creek	0.26	-	-	14.1%	4.0%	77.1%	4.8%
Unnamed Creek	0.08	-	-	-	20.9%	77.4%	1.6%
Shady Beach Creek	0.41	-	-	-	24.3%	75.4%	0.3%
Twanoh Creek	0.67	-	-	-	1.1%	97.6%	1.3%
Twanoh Falls Creek	1.27	-	-	2.7%	10.9%	84.7%	1.6%
Mulberg Creek	0.73	-	-	11.4%	18.9%	67.3%	2.4%
Happy Hollow Creek	1.06	-	-	-	25.4%	72.6%	2.1%
Holyoke Creek	1.27	-	4.4%	11.8%	11.8%	71.6%	0.4%
Deveraux Creek	1.93	0.9%	1.0%	8.9%	23.9%	55.8%	9.5%
North Shore							
Mission Creek	13.46	0.1%	1.7%	0.6%	16.1%	79.9%	4.3%
Stimson Creek	2.17	-	-	-	13.4%	86.2%	0.4%
Shoofly Creek	0.91	-	-	-	8.9%	90.4%	0.6%
Tahuya River	45.20	-	1.1%	2.9%	16.4%	78.5%	5.0%

Based on 1999 satellite imagery. (Source: Mason and Kitsap Counties, 2000)

(1) Rural Development – Large, lot low density development
(2) Urban Development – Medium density residential (2-5 units per acre), High density residential (multifamily, >5 units per acre)
(3) Commercial Development – Retail, office, and industrial lands
(4) Rangeland – Open grassland and shrub/brush land
(5) Forestland – Deciduous, coniferous and mixed forest areas
(6) Other - Includes beaches, water and rocky areas.

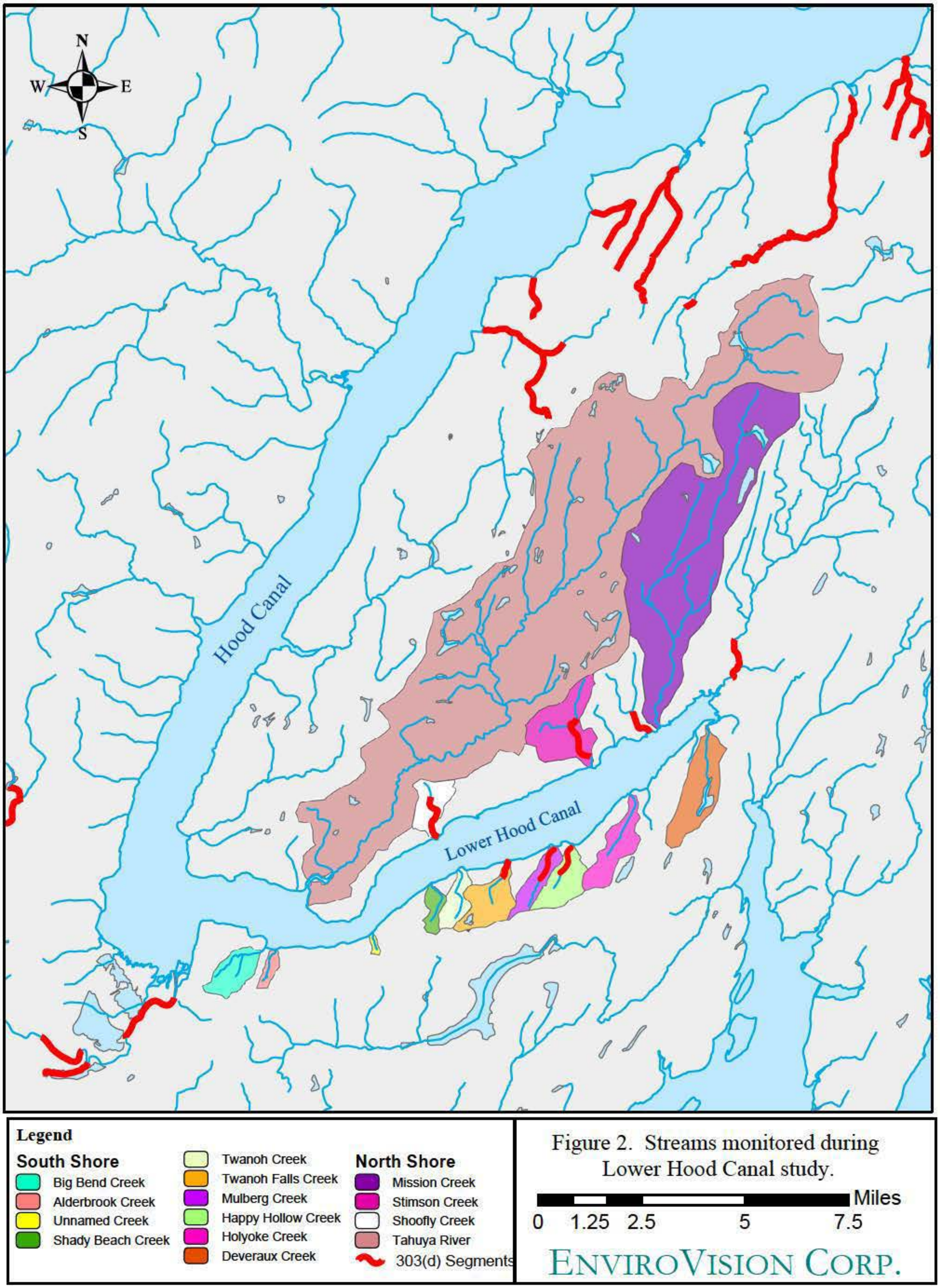


Figure 2. Streams monitored during Lower Hood Canal study.

Most of the land (75%) is classified as forest, rangeland accounts for the second highest land use category (15%). Development associated with the "built" environment (i.e., that denoted as rural, urban and commercial) ranges from 0% to 22% between subbasins, and averages less than 8% (Table 1). Only five of the fourteen streams monitored had estimated built environment of greater than 10% including Big Bend, Alderbrook, Mulberg, Holyoke and Deveraux. Impervious area estimates were calculated for these five streams. Three of the five streams (Big Bend, Alderbrook and Holyoke) were estimated to have total impervious areas greater than 10%. According to recent research on Puget Sound lowland streams, it is during the initial phases of development, as impervious area is reaching the 10% range, that the most rapid changes occur to the physical and biological stream environment (May et al, 1997).

The North Shore includes at least seven major (>0.25 mi^2) drainage areas or subbasins. These subbasins represent about 100 mi^2 of contributing landmass and included; Union River, Mission Creek, Little Mission Creek, Stimson Creek, Little Shoofly Creek, Shoofly Creek, and the Tahuya River. Four of these subbasins (Tahuya River, Mission, Shoofly, and Stimson Creeks) were monitored during this effort, representing 62 mi^2; approximately 62% of the drainage area from this shore (Figure 2). By far the largest North Shore subbasin is the Tahuya River, which is 45 mi^2 in size and accounts for nearly half of the contributing area. Almost 85 % of the land cover in these subbasins is classified as forestland, with less than 3 % developed (Table 1). Most of the development is associated with Belfair and the narrow strip of shoreline along North Shore Road.

METHODS

SITE SELECTION

An initial reconnaissance survey of the South Shore was conducted on September 17, 2003. Notable seeps, culverts, streams and drainage channels that directly entered Hood Canal were identified and Global Positioning System (GPS) points were collected for each. Preliminary notes were taken on land use and development in the vicinity of each drainage. This survey provided background information for the site selection process.

Based on the reconnaissance survey, a list of ten streams along the South Shore of the Canal were selected and recommended to the Planning Unit and Technical Committee Initially the goals in site selection were to try to capture 80% of the land mass draining to the study area and to represent both developed and undeveloped drainages for comparison. The Technical Committee reviewed the list of streams and then visited the sites. Minor modifications and were made to give higher priority to 303(d) listings and salmon bearing streams. These streams included Big Bend Creek, Alderbrook Creek, Unnamed Creek, Shady Beach Creek, Twanoh Creek, Twanoh Falls Creek, Mulberg Creek, Happy Hollow Creek, Holyoke Creek and Deveraux Creek (Figure 2). These streams represent only about 30 percent of the land mass but do provide an accurate representation of the variation in development conditions along the Canal.

The WRIA 16 Planning Unit on behalf of WRIA 15 also selected three streams for monitoring on the North Shore of Hood Canal. These included the Tahuya River, Stimson Creek, and

Shoofly Creek. After the first monitoring date, Mission Creek was added to the sample sites on the North Shore (Figure 2).

Specific sample collection locations for each stream were selected based on desired qualifications including U-shaped channel or culvert, little to no undercutting of streambanks, and limited presence of vegetative growth in channel (Table 2). Selected sampling sites were also located above saltwater influence and downstream of development. Many of the sites were located upstream of Highway 106 and therefore did not include runoff from the highway or the few homes located on the downstream side of the highway.

Table 2. Sample locations and descriptions for streams along Lower Hood Canal[(1)].

General Name	Latitude	Longitude	Location Description
Big Bend Creek[(2)]	47.3481567	123.0747493	Upstream of the mouth, accessed through picnic Site #1.
Alderbrook Creek[(2)]	47.3479280	123.0682144	Near the mouth at the pedestrian bridge.
Unnamed Creek	47.3553552	123.0169366	South side of SR 106 across from address 9741 SR 106.
Shady Beach Creek	47.3729380	122.9877056	South of SR 106, culvert opening at approximately Road Mile 11.5.
Twanoh Creek[(2)]	47.3783508	122.9738788	At the mouth, below the pedestrian bridge in the beachside portion of Twanoh State Park.
Twanoh Falls Creek[(2)]	47.3814287	122.9490942	South of SR 106, at 1st house on Creekside Drive
Mulberg (Unnamed) Creek[(2)(3)]	47.3872002	122.9250608	South of SR 106, the mouth of culvert under highway, downstream of concrete fish pond.
Happy Hollow Creek[(2)]	47.3879229	122.9159413	South side of SR 106, approximately 50 feet upstream of culvert.
Holyoke Creek[(2)]	47.4051508	122.8852912	Upstream of saltwater influence, accessed through second upstream property
Deveraux Creek[(2)]	47.4298333	122. 8482583	South of SR 106, culvert entrance across from 19601 SR 106.
Mission Creek	47.4315925	122.8748775	Upstream of saltwater influence in Belfair State Park.
Stimson Creek	47.4159924	122.9078618	Private bridge, 5081 North Shore Road
Shoofly Creek	47.3897426	122.9863637	Mouth, 9371 North Shore Road
Tahuya River	47.3783396	123.0335029	Upstream of saltwater influence, approximately one mile from mouth on eastern branch.

(1) Locations and descriptions are for site sampled throughout majority of monitoring. Adjustments to sites made in early samplings are not included.

(2) Since many small streams have multiple names, general names have been obtained from the Salmon and Steelhead Habitat Limiting Factors Analysis for WRIAs 14 North and 15 West (WSCC, 2003).

(3) Mulberg Creek has been described in the Salmon and Steelhead Habitat Limiting Factors Analysis and on the 303(d) List as Unnamed Creek.

A couple of modifications were made to sample collection locations during the project. During the second monitoring event, the site at Holyoke Creek was moved approximately 200 feet upstream at the request of the property owner. Due to culvert maintenance that occurred between the 2nd and 3rd sample dates, the Twanoh Falls site was also moved slightly upstream (approximately 40-50 feet). The table below lists the latitude/longitude of each site and describes specific sample locations (Table 2).

LAND USE ANALYSIS

A literature review and database search was conducted for water quality information for streams along the South and North Shores of Lower Hood Canal. Stream names and locations from several sources were also reviewed for consistency and accuracy. Clipped and mosaicked United States Geological Survey (USGS) 7.5 minute topographical maps of the South and North Shores of lower Hood Canal were downloaded into ESRI® ArcGIS® 8.3 Geographic Information System (GIS). The differentially corrected positions of the GPS points taken at the monitoring sites were plotted on the georeferenced topographical maps and compared against stream locations on: topographical maps, aerial photographs, State of Washington Department of Natural Resources (WDNR) hydrography layer, and maps from Salmon and Steelhead Habitat Limiting Factors Analysis in the project area (Table 3) (WSCC, 2003).

Subbasins associated with the monitoring sites were delineated and digitized at a scale of 1:24,000. The boundaries of the subbasins were digitized along drainage divides (ridges) on the georeferenced topographical maps, with the terminus of the subbasin at the point where the stream entered Hood Canal. This method is similar to that used by WDNR to delineate Watershed Administrative Units (WAUs), which are a subset of Water Resource Inventory Areas (WRIAs). Many of the WAUs in the project area were digitized at a scale too coarse to discern the boundaries of the selected subbasins and there was a need for further refinement. Once the boundaries of the subbasins were delineated, they were compared against boundaries of the WAUs already established in the project area and against hydrography and aerial photography, to check accuracy.

A land use/land cover and impervious surface database for the project area was provided by Mason and Kitsap Counties. The database classifications were based on satellite imagery (LandSat 7 TM) from July 1999 (Mason and Kitsap Counties, 2000). The imagery was classified with the purpose of rapidly building a database to be used for fisheries and watershed management in Hood Canal (Mason and Kitsap Counties, 2000). Using ESRI® ArcGIS® 8.3, land use/land cover and impervious surface themes were intersected with the digitized subbasins (polygons) to generate land use/land cover and impervious surface characteristics for each subbasin (Table 1). Table 3 summarizes data sources used to conduct the GIS analysis.

Table 3. GIS databases used to characterize Lower Hood Canal subbasins.

Database	Date	Scale	Source
Land Use/Land Cover and Impervious Surface Mapping	December 2000	1:24,000	Mason and Kitsap Counties
Washington Orthophotos (DOQs)	June 1990	1 meter resolution	University of Washington
Georeferenced USGS Topographical Maps	1985	1:24,000	University of Washington
Hydrography	July 2003	1:24,000	WDNR
Watershed Administrative Units	May 2000	1:24,000	WDNR

MONITORING STRATEGY

A monitoring strategy, which included five monitoring events during the wet weather season and four during late summer, was developed to focus efforts on the period of highest variability in flow and pollutant concentrations (wet weather) and the period when seasonal residents had returned to the area. (Note: Because the North Shore sites were added later in the season (February), only four wet weather events were monitored.) Monitoring of the fourteen selected streams was done over a two-day period, the South Shore sites on the first day and the North Shore sites on the second day. By keeping the monitoring days together, similarity in weather and climatic conditions was maintained and data between the two shorelines could be compared more easily. This was considered especially important during the wet weather season when runoff conditions can change rapidly.

Wet season monitoring was defined as the period between January and early April 2004. Generally, wet weather monitoring was scheduled to occur at two to three week intervals. However, in an effort to target rain events, the specific sampling days (within those weeks) were selected based on rain and runoff potential. Unfortunately, the 2004 wet season was unusually dry and the rain events monitored were relatively small.

Dry season monitoring was defined by the return of seasonal residents. Therefore, the monitoring schedule was set to occur every three weeks between early July and the beginning of September. Specific sampling days were purposely set to occur just after the major 4th of July and Labor Day holidays.

SAMPLING METHODS

Stream velocity was measured with a Swoffer Meter at each of the drainages, except Mission Creek and Tahuya River. Stream name, total width, depth, and velocity measurements were recorded for each stream and later converted to a flow measurement. Measurements were taken following standard methods described in the Lower Hood Canal Water Quality QAPP (Appendix A). For Mission Creek and the Tahuya River, water level was recorded from existing upstream gauges on the Tahuya River, Little Tahuya River and Mission Creek. Water level data recorded during the monitoring was provided to the Hood Canal Salmon Enhancement Group (HCSEG) who supplied the level to flow conversion results (Rose, R. Pers. Comm.). These results were based on rating curve data developed by HCSEG.

At each stream, samples were collected for total suspended solids (TSS), biochemical oxygen demand (BOD), total phosphorus (TP), nitrates+nitrites (N+N), and fecal coliform bacteria (FC) using methods described in the QAPP (Appendix A). All samples were stored in an iced cooler and delivered to the laboratory within 24 hours.

Field measurements of temperature, salinity and specific conductance were also taken at each site. Each measurement was recorded on data sheets, as was site location, date and time. A one-time measurement of pH measurements was made during the last monitoring event. Changes in adjacent land use, construction activities and comments from property owners were documented in field notes from each visit..

DATA MANAGEMENT AND QUALITY ASSURANCE

Quality Control (QC) samples were collected for both field and laboratory activities. Field replicates were taken at a minimum frequency of 10 percent of samples or at least once per sample day. Replicates were not identified when sent to the laboratory and were used to represent variation in the samples. The following field quality control procedures were applied:

- Field replicates were used to make "accept" or "reject" decisions and to assess variation. Replicates within 10 percent of the original were accepted without reservation. Replicates above 10 percent of their original were rejected.
- Laboratory duplicates were accepted if duplicates were within 20 percent relative percent difference (RPD) of their twin. For those greater than 20 percent, concentrations less than five times the detection limit were accepted. Duplicates greater than this were rejected.
- Field QC checks included verification that equipment was properly calibrated and accurate records were kept during all site visits.
- The conductivity probe was calibrated prior to each sample day. Also, laboratory analysis was run on 10 percent or one per sample day to verify calibration.

Quality Assurance and Quality Control (QA/QC) checks were performed on all laboratory data. This included checking detection limits, duplicate, matrix spike and blank samples against criteria, as well as checking against blind field replicates. No data was rejected as a result of this evaluation.

All field and laboratory data was entered into Microsoft® Excel spreadsheets for each drainage basin. Mean values were calculated for wet and dry season monitoring for all parameters; geometric mean values were determined for bacteria results. For results below detection, half the detection value was used for calculating the mean value. The standard method for fecal coliform measurements is to use a greater than sign for colonies counted above 80. Therefore, those results are considered an estimate. In instances where results were greater than 80, the estimated value was used in geometric mean calculations.

Pollutant loads for nutrients, fecal coliform bacteria and total suspended solids were calculated by multiplying instantaneous flow rates and concentrations of each pollutant and converting to tons per year. Since concentrations and flows fluctuate widely over a given day and month, depending on rainfall, loading calculations do not reflect loading rates for days not sampled. Even though these calculated daily load rates might not actually reflect true daily mean values, these may reflect large changes and trends. Total pollutant yields were calculated by adjusting the calculated loads by drainage area.

RESULTS

COMPARISON TO WATER QUALITY STANDARDS

Water quality standards have been set to protect aquatic life and other beneficial uses of these streams. In Washington State new standards have been proposed are in the process of being revised and finalized. Many of the changes to the standards have been driven by the need to better reflect salmon protection needs. In the currently proposed standards, all streams in this study area have been designated in the State's water quality standards as Salmon and Trout Spawning, Non-Core Rearing and Migration as well as Primary Contact Recreation (Appendix B). However, recent review of the proposed water quality standards by EPA has resulted in their recommendation to adjust the designation for the Tahuya River to Salmon and Trout Spawning, Core Rearing and Migration due to chum salmon and steelhead spawning grounds (EPA, 2005). This potential change in proposed classification affects which temperature standard is applied to the stream.

The Washington State Department of Ecology (Ecology) creates a list of waters that do not, or are not expected to meet the State surface-water quality standards. This report is referred to as the "List of Impaired and Threatened Waterbodies", or the "303(d) list". The most recent listings of freshwater bodies in Lower Hood Canal include segments of Happy Hollow, Twanoh, Twanoh Falls, Mulberg (listed as Unnamed on the 303(d) List), Stimson, and Shoofly Creeks (Ecology, 1998; Ecology, 2004a). Happy Hollow, Twanoh, Mulberg, Stimson, and Shoofly Creeks were listed due to fecal coliform (FC) bacteria problems, while Twanoh Falls and Mulberg Creeks were listed for pH (Ecology, 1998; Ecology, 2004a).

When surface-waters are categorized as "polluted" a clean up plan (often in the form of a total maximum daily load (TMDL) analysis) is required to identify methods for controlling pollution and monitoring the effectiveness of these controls. At this time, there are no control plans developed for these streams (Ecology, 2004b; Hempleman C., Pers. Comm.). However, during the fiscal 2006-year, a restoration and monitoring study will be conducted for Mission Creek (Garland, D., Pers. Comm.). This study will determine if Mission Creek will receive priority on the next TMDL project list for the region (Garland, D., Pers. Comm.). Currently one year of FC bacteria data for Mission Creek has been collected in a preliminary assessment for the proposed

TMDL (Garland, D., Pers. Comm.). The Union River, which is in the project area but not part of this study, has a TMDL for fecal coliform.

For fecal coliform bacteria, the standard for streams is based on primary contact requirements. Therefore, fecal coliform organism levels must not exceed a geometric mean value of 100/100mL, with no more than 10% of the samples collected exceeding 200/100 mL (Ecology, 2003). A geometric mean value was determined for each season during the monitoring period as recommended in the standards (Ecology, 2003). However, the geometric mean value is comprised of less than the preferred number of five or more samples. All exceedances of the standard occurred during summer season monitoring where the sample size was four.

Fecal coliform standards were exceeded in three of the fourteen streams sampled; all during dry season monitoring. These streams included Big Bend, Mulberg, and Deveraux Creeks. Fecal coliform results for Big Bend and Mulberg Creeks were consistently high over the summer months. Results for Deveraux Creek are not necessarily indicative of a water quality problem. The very low stream flows made collection of an uncontaminated sample difficult and the stagnant conditions were not reflective of streamflow.

Although FC results were higher in some streams during the dry season monitoring, wet season fecal coliform results for all streams remained consistently very low (<25/100mL). When the geometric mean is calculated for the entire monitoring period (wet and dry season), no one stream had results above the water quality standards.

The temperature standard for all but the Tahuya River is the highest 7-day average of the daily maximum temperature should not exceed 17.5ºC. (This is based on Salmon and Trout Spawning, Non-Core Rearing and Migration criteria.) Since temperature measurements were not collected on a daily basis, the results for this study are not directly comparable. None of the streams under the Non-Core designation were above the standard. However, Mission, Shoofly, and Stimson Creeks had temperatures above 17.0ºC on at least one occasion, which indicates temperatures may exceed the standard on occasion. There is little development in these drainages and riparian zones appear to be well shaded (WSCC, 2003), and few water withdrawals were identified (Golder, 2003) that could increase stream temperatures. So the usual causes for temperature increases do not appear to apply.

The Tahuya River, however, did exceed the 16.0ºC temperature standard set within the Salmon and Trout Spawning, Core Rearing and Migration criteria. Much of the Tahuya River drains commercial and private forestlands (Kitsap PUD, 1997). This may contribute to the higher temperatures recorded in that drainage as well as high temperatures observed in Lake Tahuya (Kitsap County, 2002).

HYDROLOGIC ASSESSMENT

Since the subbasins are similar in terms of geology, topography, climate and even land use, differences in hydrologic pattern can be used to imply differences in groundwater influence. Unit runoff values (the volume of water contributed per square mile of drainage area (cfs/mi^2)) were calculated for each of the subbasins as a means of examining differences. The unit runoff calculation is a method of adjusting the flow volume to compensate for drainage size that allows direct comparisons between subbasins of different sizes. Large differences in unit runoff, especially during summer base flow conditions, would reflect either human caused changes to the water regime (i.e., out of basin water transfers, or surface water withdrawals and/or supplementation by groundwater) or differences in groundwater input.

Table 4 provides a summary of flow and unit runoff data for these subbasins as well as an estimate from nearby large subbasins that also drain to Hood Canal. An important limitation of this study and these comparisons is that the unit runoff estimates were derived from a maximum of nine instantaneous flow measurements made over one year (four during peak dry weather and five during wet weather), rather from long term gauging records. The average shown in Table 4 represents an average of those nine values and does not reflect an actual annual average. The most critical information may be the dry weather results since these reflect baseflow conditions. The summer of 2004 was unusually hot and dry and therefore the calculated unit runoffs likely reflect close to worse case conditions. On the other hand, the winter wet weather season was also particularly dry and therefore these do not reflect average or worse case winter period unit runoffs.

As shown in the Table, the larger river basins on the west side of the canal (Skokomish, Hamma Hamma and Duckabush) had high unit runoffs compared to most of the streams monitored during this effort. Possibly a function of the different geology and topography on the west side of the Canal, but the differences may also be related to the period of record and data sets used. It is also interesting to note that the North Shore streams were fairly similar in terms of unit runoff and generally appeared to be low when compared to the South Shore streams. The South Shore streams exhibited a wide variation in unit runoff; from 0.33 to 7.89 cfs/mi2. Although much more flow data would be required to improve confidence in these relationships, since all these flows were collected within one day of each other, the comparisons between the study streams may be valid.

Figures 3 and 4 display the summer period and winter period unit runoff for each Subbasin, respectively. As shown in Figure 3, the average summer period unit runoff was approximately 2 cfs/mi^2. Only three subbasins (Alderbrook, Unnamed Creek, and Twanoh Creeks) exhibited unit runoffs that were notably greater than this. The higher unit runoff indicates these basins may be more influenced by groundwater inputs. The Unnamed Creek had a substantially higher summer time yield than all the others, more than twice as high as the next highest subbasin (Alderbrook Creek). Water temperature in this stream was also very low, lending further evidence of groundwater influence.

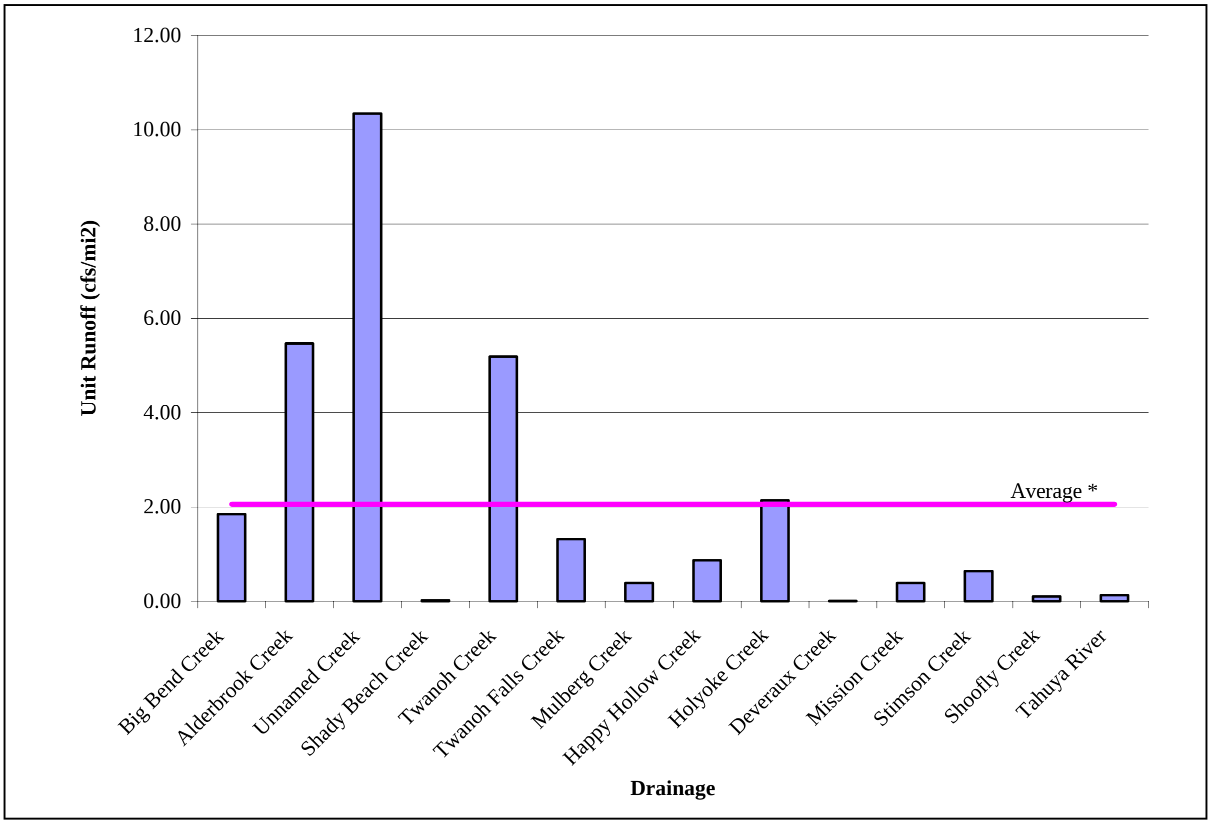
Table 4. Unit Runoff for drainages along the shorelines of Hood Canal.

	Flow Range (cfs)	Drainage Area (mi^2)	Unit Runoff Winter (cfs/mi^2)	Unit Runoff Summer (cfs/mi^2)	Unit Runoff Average (cfs/mi^2)
South Shore					
Big Bend Creek	1.31 - 7.30	0.94	5.74	1.85	3.79
Alderbrook Creek	0.76 - 3.06	0.26	7.97	5.47	6.72
Unnamed Creek	0.30 - 1.19	0.08	5.43	10.34	7.89
Shady Beach Creek	0.00 - 0.58	0.41	0.45	0.02	0.23
Twanoh Creek	2.85 - 4.69	0.67	5.47	5.19	5.33
Twanoh Falls Creek	1.22 - 5.03	1.27	2.48	1.32	1.90
Mulberg Creek	0.05 - 0.69	0.73	0.28	0.39	0.33
Happy Hollow Creek	0.61 - 5.83	1.06	2.94	0.87	1.91
Holyoke Creek	2.51 - 7.87	1.27	3.21	2.14	2.68
Deveraux Creek	0.00 - 7.11	1.93	1.51	0.01	0.76
North Shore					
Mission Creek(2)	4.00 - 33.41	13.08	2.23	0.38	1.31
Stimson Creek	1.15 - 9.67	2.17	2.89	0.64	1.76
Shoofly Creek	0.03 - 2.29	0.91	2.23	0.10	1.16
Tahuya River(2)	3.90 - 99.14	34.28	2.83	0.13	1.48
Other Hood Canal Streams					
Skokomish River	1223	227			5.39
Hamma Hamma River(1)	364	51.3			7.10
Dosewalips River(1)	297	116			2.56
Duckabush River	420	66.5			6.32

(1) Drainage basin size and unit runoff calculated from Golder, 2003, Table 5-1.
(2) Flow determined from water level measurements obtained at existing gauge sites and converted to flow by the Hood Canal Salmon Enhancement Group (Rose, R. Pers. Comm.)

If the Unnamed Creek were removed from the calculation of average summer unit runoff (due to its anomalous results) the average summer period unit runoff would be half; approximately 1 cfs/mi^2. Even with this modification there are a number of drainages that exhibited summer water yields that were substantially lower than average. Shady Beach, Deveraux, Shoofly and Tahuya were especially low; Deveraux and Shady Beach were dry or nearly dry much of the summer. These streams would appear to be less influenced by groundwater. Two of the four streams that flowed all summer did exhibit temperature exceedance problems (Shoofly and Tahuya).

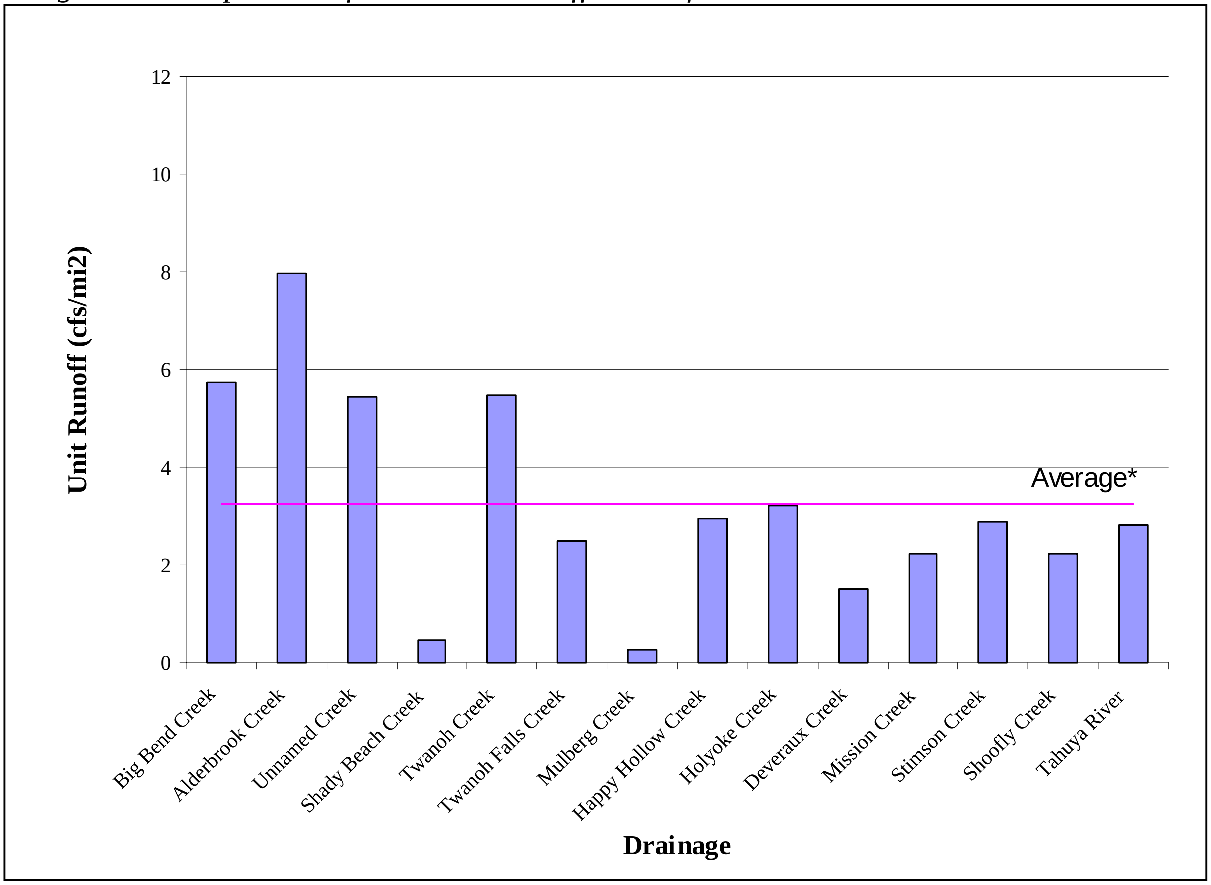
Figure 3. Comparison of summer unit runoff values for drainages on Hood Canal.



* Average of summer unit runoff for all sites sampled.

As shown in Figure 4, winter water yields were generally higher and exhibited less overall variation in yield than summer period observations. A comparison of summer and winter yields is also informative. In Mulberg and Twanoh Creeks, there was little difference between wet and dry season unit runoff. Twanoh Creek has a much higher than average yield during both seasons. This stream has a small drainage area and must have a large steady groundwater contribution. While the Mulberg Creek subbasin is about the same drainage size as Twanoh, it yields about 15 times less water than Twanoh. This indicates that both have a steady groundwater input that mask the surface runoff influence. It is possible that during more typical (wetter) conditions surface runoff would exhibit more influence; that is true for all the subbasins.

Figure 4. Comparison of winter unit runoff values for Hood Canal streams.



* Average of wet season unit runoff for all sites sampled.

The most notable anomaly with comparison of wet and dry season yields is associated with Unnamed Creek. In this case there is a visibly and measurably higher discharge during summer, which results in unit yields that are approximately twice as high in summer as in winter. (The water is also consistently cold, averaging below 10ºC during the summer.) The most likely explanation for a higher summer water yield would be that groundwater withdrawals (i.e., a well) are high and that the withdrawn groundwater is being directly discharged to the stream. A common example of this would be a fish hatchery that might use well water as a water source but after flowing through the hatchery, the water is discharged to a nearby stream. There are no hatcheries in this area. There is some development within this subbasin, and since many of the area homes are seasonal, this was considered as an explanation for the seasonal difference in water yield. That is, the water from these homes would be supplied from a well (groundwater) and returned to the stream via septic field discharge and overland flow from landscape watering and etc. However, this is apparently not the case. According to a local resident (Adams, A. Pers. Comm.), the handful of homes in this subbasin rely on the stream for their water source. If this is true, it should result in decreased summer stream flows and water yields; not increased. The WRIA 16 technical assessment (Golder, 2003) indicates there may be two small groundwater rights in this subbasin and a few small surface water rights.

Evaluation of Pollutant Contributions

Pollutant loads and yields for TP, N+N and TSS were calculated to enhance comparison between subbasins. Calculation of pollutant loads (total pollutant contribution in tons per year) is useful in understanding the total amount of pollutant that is entering another system such as Hood Canal from a stream and for determining which streams are the largest contributors. If streams are already considered polluted (i.e. on the 303(d) list), these comparisons can be important for determining where the most benefit may be gained from clean up efforts. Pollutant yield (tons per mile square per year) calculations are similar to the "unit runoff" calculation for stream flow; they provide a method of normalizing the pollutant loading data to account for differences in drainage area size. Yield calculations are more useful for comparing between different drainage sizes. Load and yield data for nutrients and total suspended solids are summarized in Table 5.

Table 5. Load and yield calculation for each subbasin.

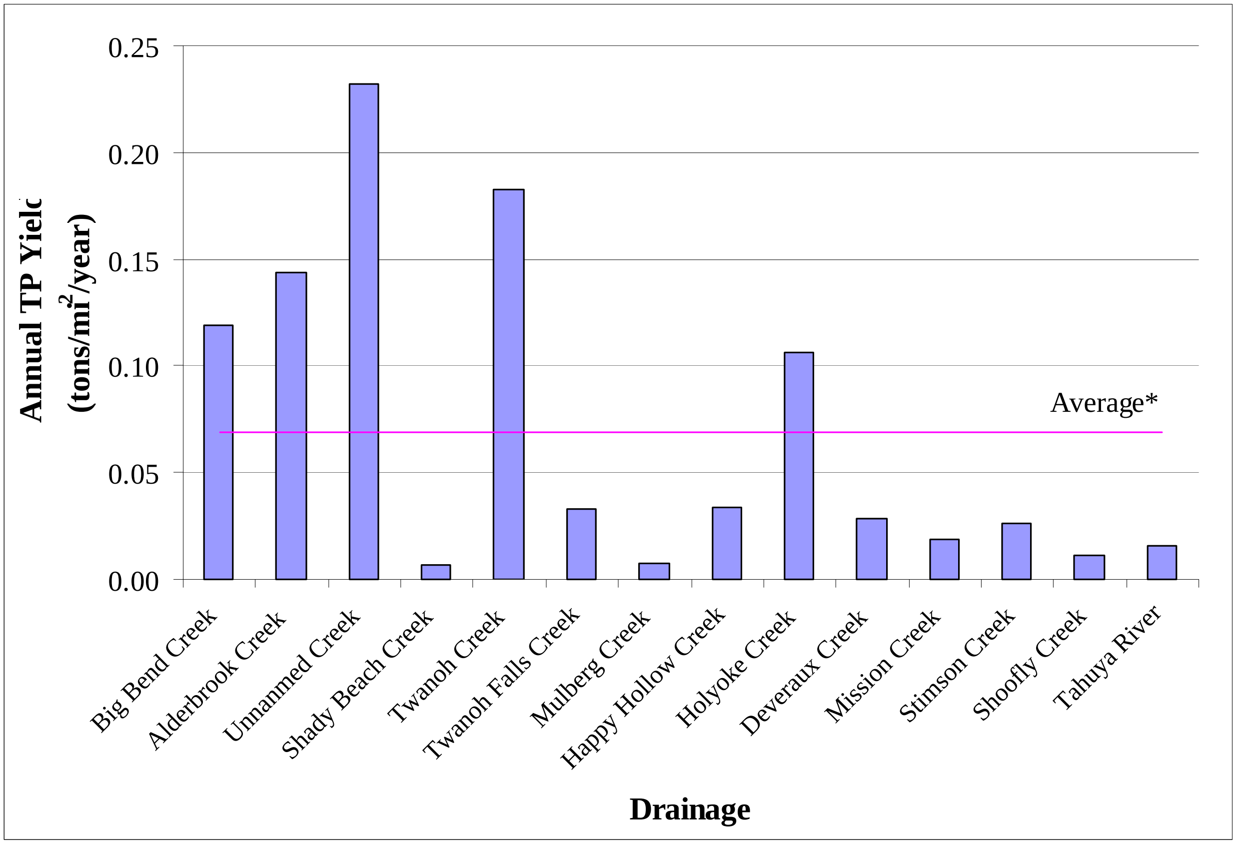
	Drainage (mi^2)	Total Phosphorus		Nitrate+ Nitrite		Total Suspended Solids	
		Load	Yield	Load	Yield	Load	Yield
South Shore							
Big Bend Creek	0.94	0.112	0.119	0.544	0.576	7.33	7.76
Alderbrook Creek	0.26	0.037	0.144	0.406	1.578	1.01	3.92
Unnamed Creek	0.08	0.019	0.232	0.018	0.222	0.69	8.40
Shady Beach Creek	0.41	0.003	0.007	0.001	0.002	0.57	1.39
Twanoh Creek	0.67	0.123	0.182	0.129	0.192	1.36	2.03
Twanoh Falls Creek	1.27	0.042	0.033	0.415	0.326	1.18	0.92
Mulberg Creek	0.73	0.006	0.008	0.132	0.180	0.76	1.03
Happy Hollow Creek	1.06	0.036	0.034	0.563	0.529	2.18	2.05
Holyoke Creek	1.27	0.135	0.106	0.698	0.552	3.87	3.05
Deveraux Creek	1.93	0.055	0.028	0.400	0.207	14.16	7.34
South Shore Average	**0.86**	**0.057**	**0.089**	**0.331**	**0.436**	**3.31**	**3.79**
South Shore Totals	**8.63**	**0.567**	**0.893**	**3.306**	**4.363**	**33.10**	**37.90**
North Shore							
Mission Creek	13.08	0.240	0.018	3.557	0.272	11.26	0.86
Stimson Creek	2.17	0.057	0.026	0.372	0.172	4.82	2.22
Shoofly Creek	0.91	0.010	0.011	0.147	0.162	0.93	1.02
Tahuya River	34.28	0.531	0.015	2.741	0.080	188.31	5.49
North Shore Average	**12.61**	**0.210**	**0.018**	**1.704**	**0.171**	**51.33**	**2.40**
North Shore Total	**50.44**	**0.838**	**0.071**	**6.818**	**0.686**	**205.31**	**9.60**

Load = tons/year, Yield = tons/mi^2/year

Total phosphorus (TP) loads were generally low in all of the subbasins. The total TP load from the South Shore sites was 0.57 tons/yr; the total estimated TP load from the North Shore sites was 0.84 tons/yr (Table 5). The Tahuya River had by far the highest load, a function of its much greater size.

The average TP yield was 0.089 tons/yr from the South Shore sites and 0.018 tons/yr from the North Shore sites. (South Shore yield estimates were notably higher for both nutrients and TSS results even though unit runoff values were far lower for the South Shore streams, so in general this seems to be the more important shoreline in terms of pollutant contributions.) Those streams where the TP yield was notably higher included; Alderbrook, Unnamed , and Twanoh Creeks (Figure 5). To evaluate the extent to which differences in TP yield could be explained by differences in unit runoff; a regression analysis was done (Figure 6). The results indicate that 90% of the variability between subbasins could be attributed to differences in unit runoff. This, in combination with the low concentrations measured, is evidence that these are background concentrations of phosphorus and represent the amount naturally supplied by movement of water through soils and over the surface of the watershed.

Figure 5. Total phosphorus yields for streams on Lower Hood Canal.



* Average based on TP yields for all sites sampled.

Figure 6. Regression analysis of total phosphorus yield and unit runoff.

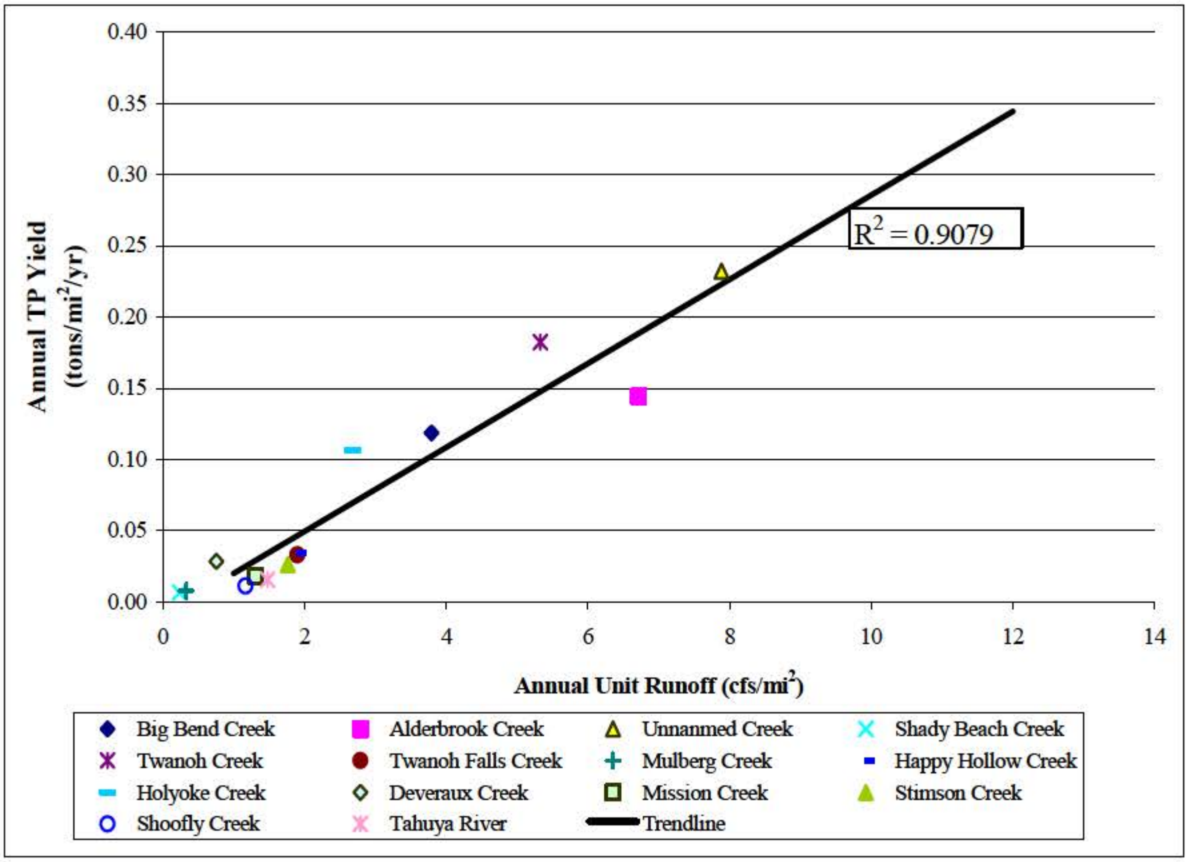


Table 6 summarizes some of the total phosphorus loads and yields identified for other Puget Sound streams (Embrey and Inkpen, 1998). Total phosphorus yields were generally low in all of the streams as compared to other Puget Sound streams and rivers. In comparison to three other Hood Canal rivers (Skokomish, Hamma Hamma, and Dosewallips Rivers), most (nine) of the streams yielded about half the TP levels. Yields for Unnamed Creek and Twanoh Creek were notably higher than the other streams and were comparable to large streams (Table 6, Figure 5). Unnamed Creek had the highest calculated yield; a function of the high unit runoff measured in this stream.

Table 6. Total phosphorus and total inorganic nitrogen loads and yields for Puget Sound streams. (Source: Embrey and Inkpen, 1998; Golder, 2003).

	DRAINAGE	TOTAL PHOSPHORUS		TOTAL INORGANIC NITROGEN	
	(mi^2)	Load	Yield	Load	Yield
Skokomish River	227	60	0.3	170	0.7
Hamma Hamma River	51.3	10	0.2	45	0.9
Dosewallips River	116	6	0.06	47	0.5
Puyallup River	948	340	0.4	950	1.0
Nisqually River	517	48	0.09	340	0.6
Dungeness River	66.5	7	0.05	52	0.3

Load = tons/year, Yield = tons/mi^2/year

Nitrate+nitrite loads were much higher relative to total phosphorus loads. Several streams had values of over 0.400 tons/yr. (Table 5). The highest loads were estimated for the Tahuya River and Mission Creek, which would be expected given that they are by far the largest sized drainages. The total N+N load from the South Shore sites was 3.306 tons/yr; the total N+N load from the North Shore sites was 6.818 tons/yr.

Figure 7 compares the yield for N+N results for each subbasin. Generally, N+N yields were not as variable between streams as TP yields. Alderbrook had by far the highest yield; almost three times higher than Big Bend Creek the second highest and more than ten times higher than the average yield measured. N+N yields could not be directly compared to USGS results since those results were based on total inorganic nitrogen of which N+N is only a subset.

Figure 8 displays results from regression analysis of N+N yields and unit runoff. As shown, the relationship is fairly weak; only 28% of the differences can be explained by differences in unit runoff. The weakness is driven by results from Twanoh and Unnamed Creeks, due to their unusually high unit runoffs, and by Alderbrooks high concentrations. The resort located near the base of this stream and especially the golf course associated with the resort are possible sources of this nitrogen. Use of nitrogen rich fertilizers is a common practice on golf courses for maintaining the dark green turf.

If the average study area yield value for TP (0.069) and N+N (0.361) is applied to the entire landmass that contributes to the lower arm of Hood Canal (129 mi^2), the total annual contribution would be 8.90 tons for TP and 46.57 tons for N+N.

Figure 7. Nitrate+nitrite yields for Lower Hood Canal streams.

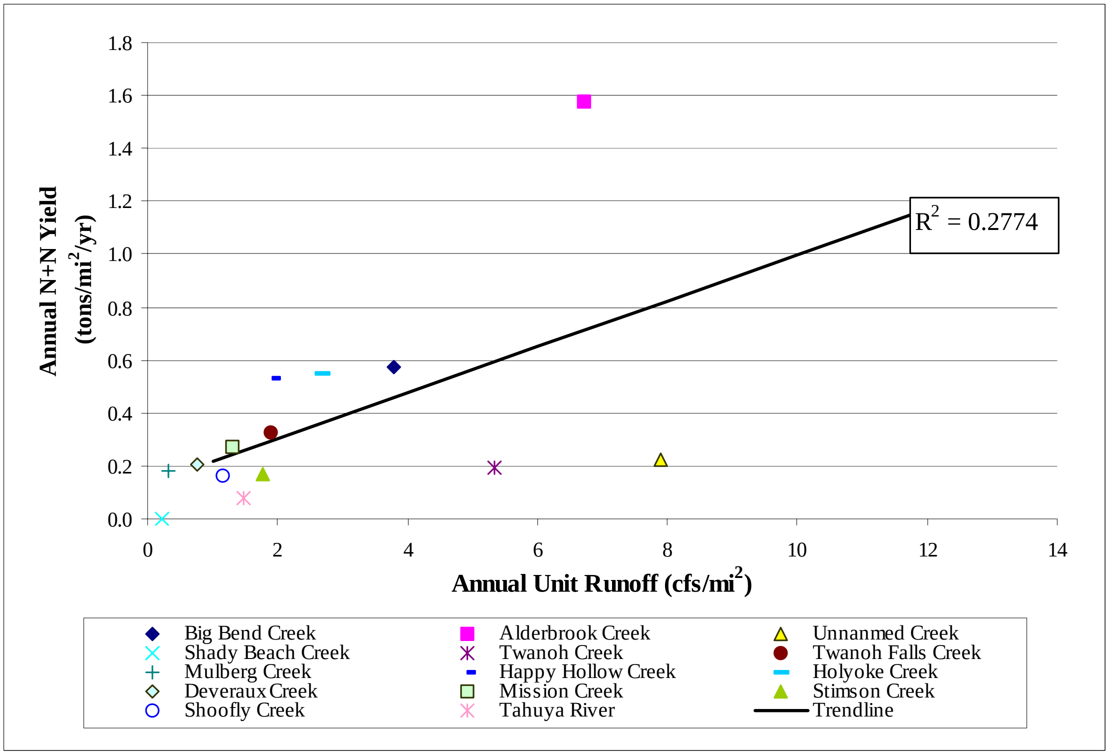
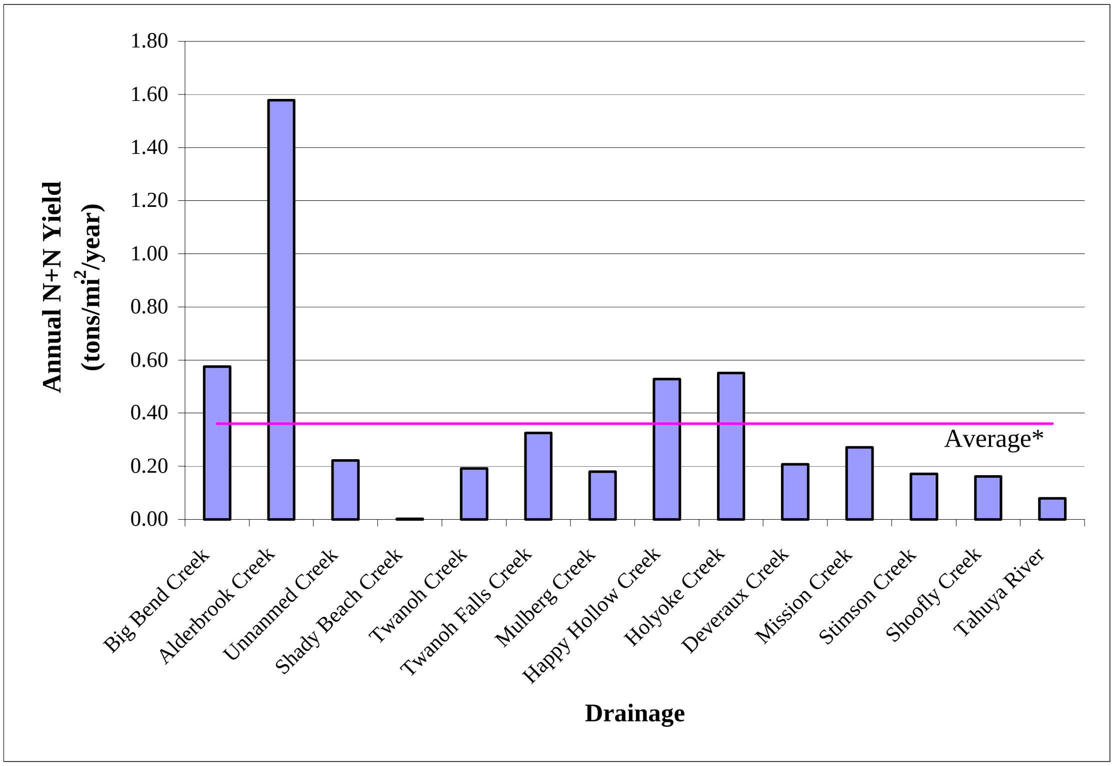


Figure 8. Regression analysis of nitrate+nitrite yield and unit runoff.

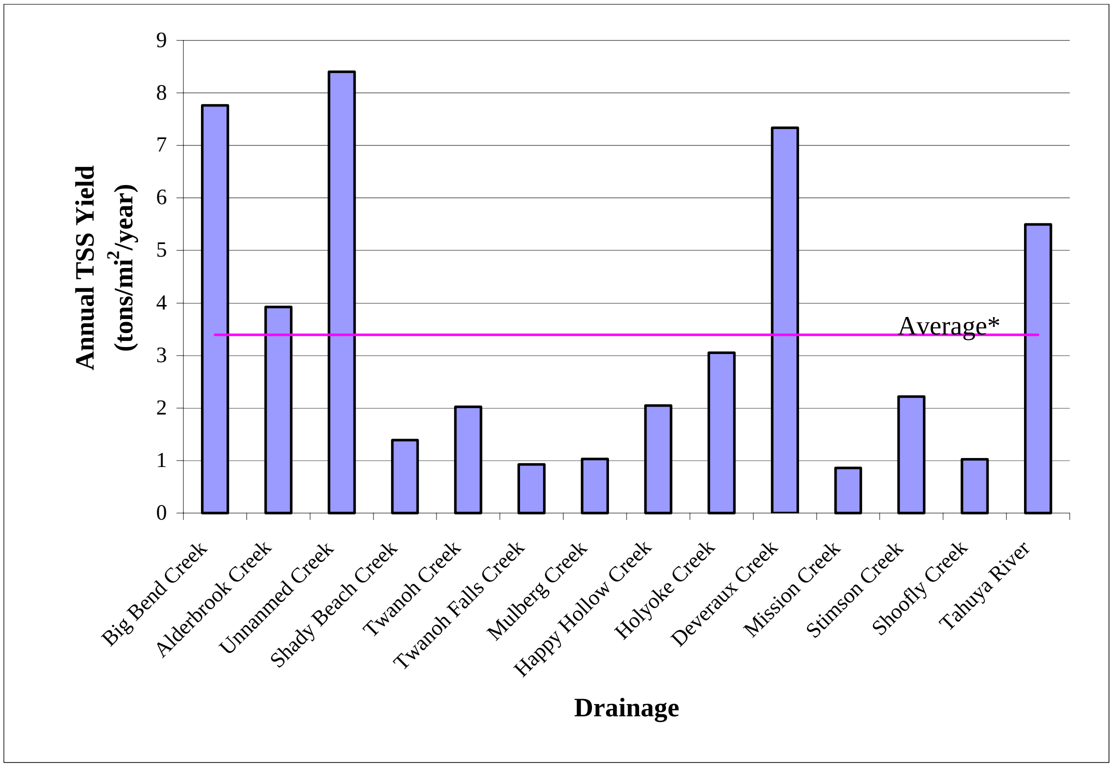


* Average based on N+N yields for all sites sampled.

TSS loads exhibited more variation between subbasins than the nutrient values did (Table 5). The total TSS load for South Shore streams was 33 tons/yr, while for the North Shore it was 205 tons/yr. The high North Shore load was driven by the Tahuya River, which is not only the largest drainage but also the one with consistently highest TSS concentrations.

High variability in results was also observed for TSS yield calculations (Figure 9). The average yield measured was 3.39 tons/mi^2/yr. Streams with TSS yields notably higher than this included; Unnamed Creek, Big Bend Creek, Deveraux Creek and the Tahuya River (Figure 9). As described previously, unusually high unit runoff drives the high yield values for all parameters on Unnamed Creek.

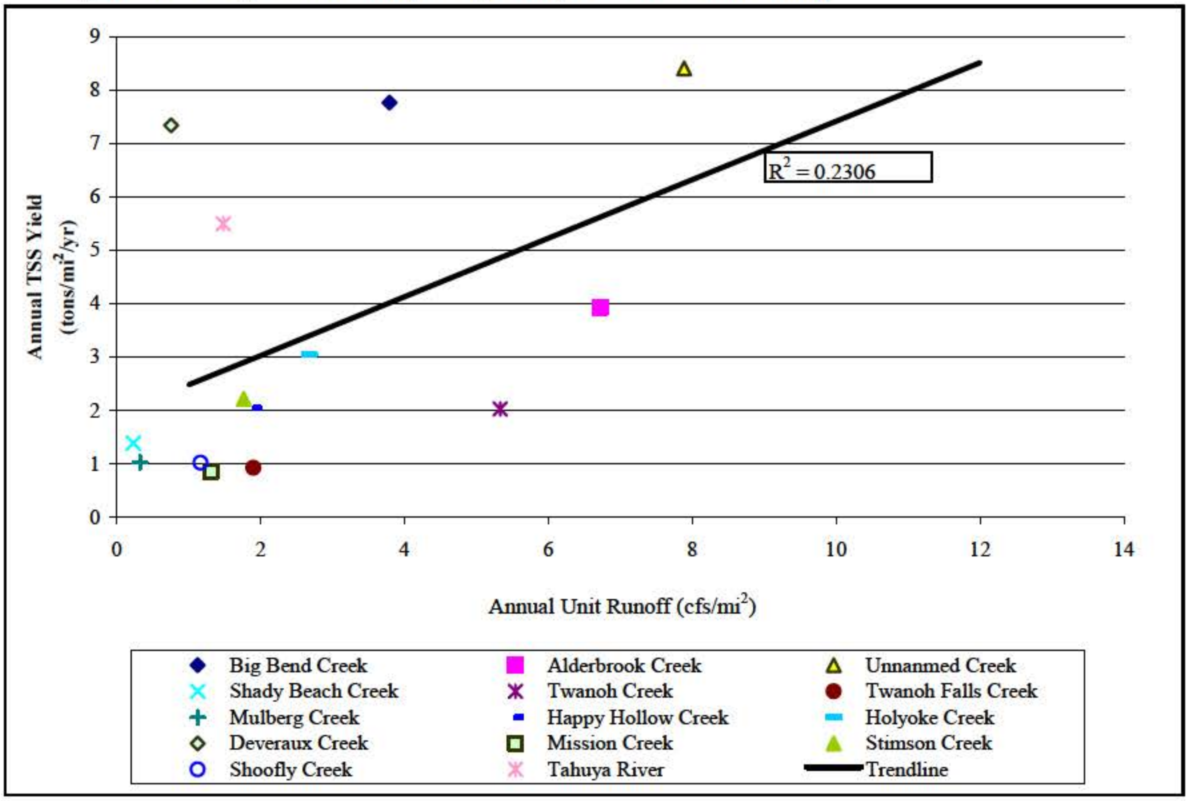
Figure 9. TSS yields for Lower Hood Canal streams.



* Average based on TSS yields for all sites.

No strong correlation was found between TSS and unit runoff (Figure 10), thus differences in pollutant yield cannot be directly attributed to differences in runoff. Consequently the differences in yield may be evidence of different watershed conditions. For example, the higher yields in the Tahuya River could be directly associated with commercial forestry practices in the drainage. There was a large variation in TSS concentrations in Deveraux Creek throughout the monitoring period. Deveraux Creek's higher yield during summer could be explained by the presence of iron precipitate in the water and low runoff. This stream also has a lake at its headwaters, which could also influence stream chemistry. For example, high summer period TSS concentrations could be a reflection of increased algae in the lake and outflow.

Figure 10. Regression analysis of TSS yields and unit runoff.



RESULTS BY SUBBASINS

The following sections describe the physical characteristics and water quality monitoring results for each subbasin. Existing data from the Washington State Department of Ecology (Ecology) Section 303(d) List (Ecology, 2004a), Salmon and Steelhead Limiting Factors Analysis (WSCC, 2003), refugia reports (May and Peterson, 2003; CTC, 2003) and other technical reports are described. Land use information obtained from GIS analysis is also provided along with descriptions of habitat, stream corridor and channel elements observed during monitoring are also included. Figure 2 displays the drainage areas associated with these subbasins. Summary data tables are provided for individual subbasins, the entire data set is contained in Appendix C.

Big Bend Creek

The mouth of Big Bend Creek is located approximately two miles east of the Skokomish River mouth at approximate Road Mile 6. Union is located where it discharges to Lower Hood Canal. The drainage area is 0.94 mi^2. Approximately 21.5% of Big Bend's drainage area is urban development, while the majority of the basin is mixed forestland (70.5%). Although the creek runs through heavily developed areas, much of the riparian corridor has remained intact.

The riparian corridor consists of mixed mature coniferous and deciduous forest with dense underbrush. The stream channel is comprised of cobble and gravel with large woody debris, logjams and other small debris throughout. According to the Limiting Factors Analysis (LFA), road densities in this subbasin are high at 6.1 miles per square mile (WSCC, 2003). The LFA describes a fish barrier located at RM 0.7 and the loss of floodplain habitat in the lower reaches (WSCC, 2003).

Water quality results for Big Bend Creek are summarized in Table 7. No water quality standard exceedances occurred during wet season monitoring. However, all (four of four) FC bacteria (FC) samples exceeded water quality standards during dry season monitoring. Although the concentrations were not particularly high when compared to urban streams, the consistency in exceedances indicates on ongoing problem. The maximum temperature measured was 13.4 ºC well below the State standard of 17.5ºC.

Table 7. Summary of monitoring results for Big Bend Creek.

	TSS (mg/L)	**FC**[(1)] (#/100 mL)	**TP** (mg/L)	**N+N** (mg/L)	**Temp** (ºC)	**Flow** (cfs)	**Unit Runoff** (cfs/mi^2)
Wet Season	1.93 (0.63 - 2.60)	5 (<2 - 22)	0.029 (0.024 - 0.031)	0.175 (0.142 - 0.210)	6.6 (2.4 - 9.6)	5.42 (3.67 - 7.30)	5.74
Dry Season	2.28 (1.40 - 3.00)	136 (112 - 290)	0.036 (0.031 - 0.039)	0.137 (0.125 - 0.157)	12.5 (11.6 - 13.4)	1.74 (1.31 - 2.46)	1.85

(1) Mean calculated as geometric mean value.

Nutrient concentrations (TP & N+N) were within a moderate to moderately high range when compared to the other streams monitored in this study. There was no notable difference between wet and dry season results for nutrient parameters. This stream had a close to average dry season unit runoff, but due to the moderately high nutrient concentrations the yields of both N+N and TP were fairly high when compared to the rest of the data set.

Alderbrook Creek

Alderbrook Creek enters Hood Canal approximately 1.5 miles east of Union. This stream is approximately 0.7 miles in length (WSCC, 2003) and has a drainage area of 0.26 mi^2. Although Alderbrook Creek subbasin primarily consists of mixed forestland (77%), there is a fair amount of commercial development (14.1%) located near the mouth. The subbasin has high road densities of 10.3 miles per square mile of drainage (WSCC, 2003).

The lower portion (below SR 106) of Alderbrook Creek was modified and restored during the recent renovation of the Alderbrook Resort and Spa. The renovation has improved fish passage with fish ladders and orchestrated pools and riffles. However, it has also created a loss in floodplain habitat in this stream (WSCC, 2003). Upstream of the resort, riparian conditions are rated good (WSCC, 2003). The stream has a gravel cobble substrate and the amount of large woody debris is rated as fair to good in the upper reaches (WSCC, 2003).

There were no exceedances of water quality standards for this stream (Table 8). FC bacteria concentrations were quite low. TSS concentrations were low and nutrient concentrations were generally low to moderate and did not vary widely. There was little measured seasonal variation in these parameters.

This stream had the highest N+N yield of all the streams monitored, more than ten times higher than the average. However, this was combined with a high unit runoff that remained high even during summer, evidence of high groundwater influence. This observation implies that some of the increase in N+N yield can be explained simply by water supply. However, there is a golf course in the lower reaches of this stream and these are often important contributing sources of nitrogen.

Table 8. Summary of sampling results for Alderbrook Creek.

	TSS (mg/L)	**FC[1]** (#/100 mL)	**TP** (mg/L)	**N+N** (mg/L)	**Temp** (°C)	**Flow** (cfs)	**Unit Runoff** (cfs/mi^2)
Wet Season	0.38 (<0.50 - 0.63)	2 (<2 - 8)	0.019 (0.014 - 0.023)	0.229 (0.209 - 0.271)	7.3 (4.7 - 8.9)	2.05 (1.31 - 3.06)	7.97
Dry Season	0.82 (0.63 - 1.00)	5 (<2 - 28)	0.025 (0.024 - 0.025)	0.253 (0.242 - 0.269)	11.6 (10.6 - 12.3)	1.41 (0.76 - 2.07)	5.47

(1) Mean calculated as geometric mean value.

Unnamed Creek

Unnamed Creek is located approximately three miles east of Union. This subbasin has the smallest drainage area of those monitored (0.08 mi^2) and is relatively undeveloped. The drainage is comprised primarily of forestland (77%) and rangeland (21%) (Table 1). This stream was not included in the LFA report; therefore information on road densities and other characteristics is not available. A limited survey indicated that the riparian corridor consists of a mixed deciduous and coniferous forest. The channel substrate near the sample site consists of cobble and gravel.

There were no measured exceedances of water quality standards (Table 9) in this stream. FC bacteria concentrations were consistently low. Water temperatures remained cool during summer; in fact there was little difference between winter and summer measurements. The most interesting aspect of the results for this stream was the high flow measured (given the size of the drainage) and the fact that flow actually increased during summer; the unit runoff value doubled in the summer. Clearly there is a strong groundwater influence, however it is not clear why groundwater input would increase during summer. Nutrient and TSS concentrations remained constant between seasons. TP concentrations were moderate, while N+N concentrations were quite low.

Table 9. Summary of results for Unnamed Creek during monitoring.

	TSS (mg/L)	**FC[1]** (#/100 mL)	**TP** (mg/L)	**N+N** (mg/L)	**Temp** (°C)	**Flow** (cfs)	**Unit Runoff** (cfs/mi^2)
Wet Season	1.15 (<0.50 - 2.90)	1 (<2 - 2)	0.031 (0.027 - 0.038)	0.012 (0.010 - 0.014)	7.7 (5.9 - 8.7)	0.45 (0.30 - 0.62)	5.43
Dry Season	1.03 (0.083 - 1.20)	3 (<2 - 12)	0.029 (0.027 - 0.031)	0.046 (0.010 - 0.129)	9.8 (9.5 - 10.2)	0.85 (0.62 -1.19)	10.34

(1) Mean calculated as geometric mean value.

Shady Beach Creek

The mouth of the Shady Beach Creek is located approximately five miles east of Union. This stream drains approximately 0.41 mi^2. The stream consists of a steep, deeply incised channel approximately one to two feet in width. Large woody debris in the lower reaches near the SR-106 crossing creates pools and a "step-like" nature to the channel.

The Shady Beach Creek is considered undeveloped. Approximately 99% of this drainage is rangeland or mixed forestland. As with many of the streams along Hood Canal, the upper reaches are relatively undeveloped, and development is concentrated near the mouth and along the Hood Canal shoreline. This stream was not included in the LFA report; therefore information on road densities and other characteristics is not available.

Table 10 summarizes results for the Shady Beach Creek. There were no excursions above water quality standards for any of the parameters sampled. FC bacteria were quite low. The maximum temperature measured was 14.3^oC. Although this is a high temperature relative to the most of the other streams monitored, it is likely a natural function of the size of this stream and the very low flows. Evidence of iron precipitate (reddish-brown floc) was observed during all dry season events. Iron precipitate is typically formed when groundwater comes into contact with oxygenated stream water; evidence of groundwater input. However, the stream was nearly dry during summer, so the volume of groundwater supplied is apparently minimal. TSS and TP concentrations increased substantially during dry season monitoring. However, this was probably a function of the low water and the iron precipitate, that may have skewed both TP and TSS values.

Table 10. Summary of sample results for Shady Beach Creek.

	TSS (mg/L)	**FC** [1] (#/100 mL)	**TP** (mg/L)	**N+N** (mg/L)	**Temp** (^oC)	**Flow** (cfs)	**Unit Runoff** (cfs/mi^2)
Wet Season	<0.50 (<0.50)	2 (<2 – 16)	0.007 (0.003 – 0.010)	0.008 (0.004 – 0.012)	7.0 (4.0 – 8.8)	0.18 (0.02 – 0.58)	0.45
Dry Season	6.13 (1.20 – 17.00)	13 (<2 – 34)	0.051 (0.007 – 0.134)	0.009 (<0.010 – 0.014)	14.3 (13.0 – 15.0)	0.01 (0.00 – 0.02)	0.02

(1) Mean calculated as geometric mean value.

Twanoh Creek

Twanoh Creek discharges to Hood Canal at Twanoh State Park, the sample site was located just upstream of the mouth within the Park. The stream is approximately 1.5 miles long (WSCC, 2003) and drains approximately 0.7 mi^2. The drainage is relatively undeveloped; 99% of the drainage consists of mixed forest and rangeland (Table 1). According to the LFA, there are approximately 4.1 mi^2 of roads in the Twanoh Creek drainage (WSCC, 2003).

The LFA describes the stream channel as dominated by riffles and glides with poor pool frequency (WSCC, 2003). Floodplain conditions are considered poor in the lower reaches of Twanoh Creek due to bank armoring and there is little to no off-channel habitat (WSCC, 2003). The substrate is dominated by gravel and cobble. Embeddedness in the lower reaches (up to 0.25 miles) was rated as low and there was no information for upstream reaches (WSCC, 2003).

There are few large woody debris in the lower reaches but relatively abundant upstream (WSCC, 2003). There are no known fish passage barriers in this stream (WSCC, 2003).

Fifty percent of the FC bacteria results exceeded the 100/100mL standard during the dry season. However, concentrations were not particularly high and the resultant mean value (GMV) was within the standard. This stream is included on the 303(d) list due to FC bacteria problems, although these data do not support that listing, they do indicate that it may be borderline. Water temperature was quite low and well within the standard. TSS, TP, and N+N concentrations were all low and exhibited little between season variation (Table 11). Flow varied little between seasons and combined with the cool temperatures, indicate a steady influence from groundwater.

Table 11. Summary of sampling results for Twanoh Creek.

	TSS (mg/L)	**FC**(1) (#/100 mL)	**TP** (mg/L)	**N+N** (mg/L)	**Temp** (°C)	**Flow** (cfs)	**Unit Runoff** (cfs/mi^2)
Wet Season	<0.50 (<0.50)	2 (<2-4)	0.033 (0.028-0.036)	0.043 (0.029-0.062)	7.6 (5.9-9.0)	3.69 (2.85-4.69)	5.47
Dry Season	0.39 (<0.50 - 0.50)	92 (62 - 124)	0.037 (0.035 - 0.039)	0.031 (0.025 - 0.041)	10.3 (9.9-10.7)	3.49 (3.01-3.77)	5.19

(1) Mean calculated as geometric mean value.

Twanoh Falls Creek

Twanoh Falls Creek is located 0.5 miles east of Twanoh Creek. The creek enters Hood Canal within the gates of a private beach at Forest Beach. This stream is approximately 1.7 miles long and has nearly two miles of tributaries. Its drainage area has been estimated at 1.27 mi^2. Approximately 95% of the drainage is mixed forest and rangeland, while 3% is considered commercial development (Table 1). Along the lower reaches there is dense residential development (WSCC, 2003). In the Twanoh Falls Creek drainage, there are 5.4 miles of road per square mile of drainage area (WSCC, 2003).

The channel substrate consists of gravel, cobble and sediment. The lower 100 meters has been channelized and the banks armored. This has reduced floodplain connectivity and habitat (WSCC, 2003). Sediment build-up at the SR 106 culvert is due to the lack of transport capabilities (low gradient and low flow) in the lower reaches. There are several large pools at a frequency of 30-50% in the channel (WSCC, 2003). There is one partial fish barrier in the lower reaches of Twanoh Falls Creek (~RM 0.25) (WSCC, 2003).

There were no excursions above state water quality standards for either FC bacteria or temperature in this stream. Temperature remained cool all summer even though there is no evidence of substantial groundwater influence. This stream is included in the most recent 303(d) list due to FC bacteria problems. This limited data set does not support that listing. This stream is also list for pH exceedances; the one time measurement of pH in this stream was within standards but clearly it is not representative of conditions. TSS and TP concentrations were low throughout monitoring, while N+N was moderate. Nitrate+nitrite sample results decreased by 50% between wet and dry seasons (Table 12). Summer period unit runoff was just below the average for the stream. Overall, pollutant yields were low to average in comparison to other streams.

Table 12. Summary of monitoring results for Twanoh Falls Creek.

	TSS (mg/L)	**FC**[(1)] (#/100 mL)	**TP** (mg/L)	**N+N** (mg/L)	**Temp** (^oC)	**Flow** (cfs)	**Unit Runoff** (cfs/mi^2)
Wet Season	<0.50 (<0.50 - 0.50)	2 (<2 - 12)	0.014 (0.011 - 0.019)	0.232 (0.169 - 0.273)	7.5 (5.1 - 9.3)	3.16 (1.73 - 5.03)	2.48
Dry Season	0.50 (0.50)	26 (4 - 64)	0.022 (0.021 - 0.023)	0.120 (0.104 - 0.142)	11.0 (10.3 - 11.6)	1.68 (1.22 - 1.98)	1.32

(1) Mean calculated as geometric mean value.

Mulberg Creek

Mulberg Creek enters Hood Canal approximately two miles east of Twanoh State Park. (This stream is labeled Unnamed Creek in many documents including the Limiting Factors Analysis and Ecology's 303(d) Lists. However in this document, it is referred to as Mulberg Creek.) Mulberg Creek is approximately 1.5 miles long with 0.4 miles of tributaries (WSCC, 2003). Its drainage area has been estimated at 0.72 mi^2.

When compared to other stream along the south shore, the Mulberg Creek drainage is relatively developed with 11% commercial development. Approximately 86% of the drainage is mixed forest and rangeland. Road densities were estimated at 2.9 miles per square mile (WSCC, 2003). At the mouth, the floodplain is highly restricted by residential development and streambank armoring.

Slightly upstream of SR 106, there is an abandoned concrete trout pond that restricts channel movement, fish passage and sediment transport. Upstream of the trout pond, the stream channel consists of cobble and gravel substrate, dense thicket riparian vegetation, and frequent woody debris. There was no information in the LFA that described riparian conditions for this stream.

Table 13 summarizes water quality monitoring results for Mulberg Creek. Three of four dry season FC bacteria concentrations exceeded 100/100mL, resulting in a GMV that exceeded State standards. This stream is included in the most recent 303(d) list due to FC bacteria problems. This limited data set supports that listing. The maximum temperature measured was below the State standard, a somewhat surprising result given the low flow and apparent lack of groundwater influence. This stream is also listed for pH exceedances; the one time measurement of pH in this stream was within standards, but clearly it is not representative of conditions. TSS results were high during both seasons as were N+N results. TP concentrations were moderate. Flow was low and varied little between seasons. This corresponded to a very low unit runoff that resulted in low load and yield estimates for all parameters.

Table 13. Summary of monitoring results for Mulberg Creek.

	TSS (mg/L)	**FC**[(1)] (#/100 mL)	**TP** (mg/L)	**N+N** (mg/L)	**Temp** (^oC)	**Flow** (cfs)	**Unit Runoff** (cfs/mi^2)
Wet Season	3.66 (2.10-6.80)	3 (<2-24)	0.025 (0.022-0.028)	0.564 (0.530-0.598)	7.6 (4.2-9.9)	0.20 (0.06-0.55)	0.28
Dry Season	2.75 (1.50 - 5.30)	126 (30 - 310)	0.022 (0.017 - 0.034)	0.554 (0.495 - 0.645)	13.2 (12.1-14.3)	0.28 (0.05-0.69)	0.39

(1) Mean calculated as geometric mean value.

Happy Hollow Creek

Happy Hollow Creek is located approximately five miles west of the SR 106 and SR 3 junction and is adjacent to Happy Hollow Road. The stream has a gradient of approximately two to four percent and is 0.8 miles in length. This drainage area is slightly more than 1 mi^2. Approximately 98% of the Happy Hollow Creek drainage is undeveloped (Table 1). Road densities in this drainage are rated good at 0.7 miles per square mile (WSCC, 2003). There is a gas station and convenience store adjacent to the stream near its mouth. Runoff from the parking area flows directly into the stream via a corrugated pipe.

The riparian condition of Happy Hollow is considered good (WSCC, 2003). The overstory consists of mixed deciduous and coniferous trees with an understory of dense ferns, ivy, and small shrubs. The channel substrate is gravel and hardpan clay with steep banks on either side. There are approximately 0.3 to 0.5 pieces of large woody debris per meter of channel length (WSCC, 2003). There are no known fish passage barriers in this stream (WSCC, 2003).

FC bacteria results were above state water quality standards on only one of four samples during dry season monitoring, resulting in a GMV that is well within State standards. Maximum measured temperature was a cool 10.8ºC (Table 14). TSS concentrations were consistently low during both seasons. TP and N+N concentrations were both fairly low during the wet season but increased during the dry season. Summer period unit runoff was low; approximately half of the average calculated for these streams. This and the low to moderate pollutant concentrations resulted in low pollutant yields from this stream.

Table 14. Summary of water quality results for Happy Hollow Creek.

	TSS (mg/L)	**FC**[(1)] (#/100 mL)	**TP** (mg/L)	**N+N** (mg/L)	**Temp** (^oC)	**Flow** (cfs)	**Unit Runoff** (cfs/mi^2)
Wet Season	0.73 (<0.50-1.50)	3 (<2-8)	0.012 (0.007-0.017)	0.182 (0.085-0.278)	7.1 (3.9-9.7)	3.13 (1.77-5.83)	2.94
Dry Season	1.48 (0.50 - 2.80)	73 (46 - 160)	0.025 (0.021 - 0.026)	0.387 (0.376 - 0.398)	10.8 (10.2-11.4)	0.93 (0.61-1.24)	0.87

(1) Mean calculated as geometric mean value.

Holyoke Creek

Holyoke Creek enters Hood Canal approximately three miles west of the junction of SR 106 and SR 3. This stream is approximately 2.4 miles long with two miles of tributaries and has a drainage area of 1.27 mi^2. This drainage is fairly developed when compared to other study site streams. There is an estimated, 4% residential development, 12% commercial development, and 84% mixed forest and rangeland. Road densities are high at 4.8 miles per square mile (WSCC, 2003).

Channel condition in the lower reach of Holyoke Creek is influenced by tidal activity. Sediment content in the lower mile of the stream is high, and there is little gravel or cobble in the streambed. Large woody debris is frequent in the channel at approximately 0.4 to 0.6 pieces per meter (WSCC, 2003). Pool frequency is rated fair with pools covering roughly 30 to 50 percent of the stream surface area (WSCC, 2003).

There were no excursions above State water quality standards for temperature or FC bacteria in this stream. TSS, TP, and N+N concentrations were generally within the moderate range when compared to other study streams (Table 15). The summer period unit runoff was close to the average estimated for the study streams. This, in combination with the moderately high pollutant concentrations resulted in moderately high pollutant yields.

Table 15. Summary of water quality results for Holyoke Creek.

	TSS (mg/L)	**FC[(1)]** (#/100 mL)	**TP** (mg/L)	**N+N** (mg/L)	**Temp** (^oC)	**Flow** (cfs)	**Unit Runoff** (cfs/mi^2)
Wet Season	1.45 (<0.50-4.50)	3 (<2-10)	0.031 (0.025-0.036)	0.237 (0.157-0.278)	7.4 (4.6-10.4)	4.07 (2.63-7.87)	3.21
Dry Season	0.89 (0.50 - 1.20)	35 (18 - 68)	0.050 (0.049 - 0.051)	0.186 (0.172 - 0.207)	10.5 (10.2-11.1)	2.71 (2.51-3.07)	2.14

(1) Mean calculated as geometric mean value.

Deveraux Creek

The mouth of Deveraux Creek is located approximately 0.5 miles west of the SR 106 and SR 3 junction along SR 106. The headwaters of the stream originate at Lake Deveraux approximately three miles upstream (WSCC, 2003). The stream has a drainage area of nearly two mi^2 and a gradient of two to four percent.

An estimated 11% of the drainage is residentially or commercially developed (Table 1). Much of this development is along the shorelines of Lake Deveraux. Road density is considered high at 5.8 miles per square mile (WSCC, 2003). Development in the Deveraux drainage basin has created fish passage barriers and stream constrictions (WSCC, 2003).

At the sample site along SR 106, the stream has a channel width of 1.5 to 2.0 feet and an average depth of 0.75 feet. The substrate at this location consists of a few rocks and cobbles. In the vicinity of the sample site and just upstream, blackberry and grasses dominate the riparian vegetation and there are few trees. The vegetation downstream changes to dense forest and salt marsh near the mouth (WSCC, 2003).

No pre-existing water quality data was identified for this stream. However, there have been concerns about bacteria problems near the mouth (Lincoln, K. Pers. Comm.). The primary basis for this concern has been related to shellfish bed closures in Lynch Cove (Bennett-Cummings, P. Pers. Comm.).

There was little flow in the stream even in July and the stream was dry for most of the summer; which is, according to the adjacent property owner, apparently a common condition. TSS and TP concentrations were high in the two dry season samples (Table 16); however, iron precipitate was evident on both days and likely affected these results. FC bacteria concentrations were quite high in the two dry season samples; the State standard was exceeded for this period. All dry season sample results are suspect due to the low flow and difficulty in obtaining a "clean" sample. The flow data indicates outflow from the lake is the primary source of flows. Therefore the water quality results likely reflect lake conditions. One curious aspect of the data was the high N+N concentrations measured during winter; the concentration was second only to Mulberg Creek. This does not appear to be a function of septic influence since FC bacteria are low, and it outside what might be expected for discharge from the lake since the lake TP concentrations were low during winter.

It is not surprising, given the lack of flow in the summer that the unit runoff was low. The flows were also quite low during early wet season monitoring. This can be common in streams that originate as outflow from a lake since the timing and volume of discharge is related to lake levels.

Table 16. Summary of sampling results for Deveraux Creek.

	TSS (mg/L)	**FC(1)** (#/100 mL)	**TP** (mg/L)	**N+N** (mg/L)	**Temp** (°C)	**Flow** (cfs)	**Unit Runoff** (cfs/mi²)
Wet Season	3.43 (0.63-9.10)	4 (2-8)	0.015 (0.009-0.023)	0.429 (0.322-0.660)	6.6 (2.8-10.3)	2.91 (0.73-7.11)	1.51
Dry Season(2)	16.50 (6.0 - 27.00)	476 (426 - 532)	0.062 (0.032 - 0.092)	0.134 (0.031 - 0.237)	14.4 (14.1-14.4)	0.01 (0.01-0.01)	0.01

(1) Geometric means were determined.
(2) During two sample events there was no water in the stream channel, n = 2.

Mission Creek

Mission Creek flows into Hood Canal approximately three miles west of the town of Belfair on the North Shore. The mainstem and its six tributaries include approximately 20 miles of stream channel and represent a drainage basin that is approximately 13.5 mi^2 (WSCC, 2003; Barnes, et al., 1995). Mission Creek's headwaters stem from wetlands north of Mission Lake and emerge as outflow from the lake.

The stream has little development; approximately 2.5% of the drainage is comprised of residential and commercial development (Table 1). The majority of this is in the lower 1.5 miles. The remainder of the drainage (96%) is forest and rangeland, including a large portion of Washington Department of Natural Resources (WDNR) land and privately managed forests. Road densities in the drainage were estimated at 4.0 miles per square mile (WSCC 2003).

Mission Creek is dominated by gravel substrate. The LFA describes Mission Creek as having optimal fines (<10%). The percentage of Large Woody Debris (LWD) (30-40%) and LWD quantity were rated good (WSCC, 2003). However, the recruitment potential for LWD was only rated fair due to lack of large trees in the riparian zone (WSCC, 2003). Floodplain conditions were rated fair. One fish passage barrier is located at the outflow of Mission Lake (WSCC, 2003).

Table 17 summarizes water quality data for Mission Creek. Although there was one occasion when FC bacteria exceeded 100/100mL, the water quality standard was not violated (i.e. the GMV was less than 100). Temperature was above standard on one occasion. Nutrient and TSS concentrations were low to moderate throughout sampling, which in combination with the low unit runoff resulted in low pollutant yields from this stream.

Table 17. Water quality results summary for Mission Creek.

	TSS (mg/L)	**FC**[(1)] (#/100 mL)	**TP** (mg/L)	**N+N** (mg/L)	**Temp** (^{o}C)	**Flow** (cfs)	**Unit Runoff** (cfs/mi^2)
Wet Season	0.73 (<0.50-1.3)	8 (2-40)	0.011 (0.007-0.015)	0.200 (0.175-0.224)	8.1 (7.7-9.0)	29 (27.03-33.41)	2.23
Dry Season	0.63 (0.50 - 0.83)	88 (56 - 292)	0.018 (0.015 - 0.020)	0.227 (0.185 - 0.267)	14.6 (12.4-17.2)	5.03 (4.00-6.30)	0.38

(1) Mean calculated as geometric mean value.

Stimson Creek

Stimson Creek enters Hood Canal approximately six miles west of Belfair on the North Shore. The stream is about 5.3 miles long (WSCC, 2003) and has a drainage area of 2.2 mi^2. Stimson Creek's headwaters stem from the several small wetlands along Elfendahl Pass Road.

The stream is relatively undeveloped; approximately 99% of the drainage is forest and rangeland (Table 1). The majority of development is located along the Hood Canal shoreline downstream of Highway 300. Along this lower reach (below RM 0.25), the east bank has been armored and the stream channelized. Road densities are elevated in the drainage at roughly 4.2 miles per square mile (WSCC, 2003).

The LFA for Stimson Creek describes good levels of fines, fair to good large woody debris abundance and good pool quality (WSCC, 2003). The channel substrate at the sample site consisted of a cobble and gravel base. Only a few fish passage barriers were identified in this stream (WSCC, 2003).

FC bacteria met water quality standards at this site, although there was one excursion above 100/100mL (Table 18) This stream is included in the most recent 303(d) list due to FC bacteria problems (Ecology, 2004a). This limited data set does not support that listing. Temperature did not exceed standards. Nutrients and TSS concentrations were relatively low throughout the monitoring. The unit runoff was low, which in combination with the low concentrations resulted in below average pollutant yields for this stream.

Table 18. Summary of monitoring results for Stimson Creek.

	TSS (mg/L)	**FC(1)** (#/100 mL)	**TP** (mg/L)	**N+N** (mg/L)	**Temp** (^oC)	**Flow** (cfs)	**Unit Runoff** (cfs/mi^2)
Wet Season	1.21 (<0.50 - 2.5)	29 (2 - 120)	0.011 (0.005 - 0.014)	0.099 (0.087 - 0.125)	8.2 (7.6 - 8.8)	6 (4.68 - 9.67)	2.89
Dry Season	1.38 (1.00 - 1.70)	19 (12 - 28)	0.020 (0.018 - 0.034)	0.101 (0.091 - 0.115)	14.2 (12.4 - 16.9)	1.39 (1.15 - 1.94)	0.64

(1) Mean calculated as geometric mean value.

Shoofly Creek

Shoofly Creek enters Hood Canal approximately twelve miles west of Belfair on the North Shore. It is approximately 1.5 miles long (WSCC, 2003), with a drainage size of slightly less than one square mile. Development in this drainage consists primarily of forest and rangeland (99%) (Table 1). Road densities are considered to be high at 4.4 miles per square mile (WSCC, 2003).

As with the other streams, residential development is concentrated near the mouth. The channel has been filled and the area developed for residential properties below North Shore Road (WSCC, 2003). The stream is also dredged in this area to maintain flow capacity and therefore, floodplain connectivity and habitat has been lost (WSCC, 2003). There are no known fish passage barriers in this stream (WSCC, 2003).

The substrate consists of gravel and fine material. The Limiting Factors Analysis describes high sediment content in Shoofly Creek and fair streambank stability throughout the entire channel (WSCC, 2003). According to the LFA, flow in this stream is largely dependent on groundwater (WSCC, 2003).

All FC bacteria concentrations were well below 100/100mL (Table 19). This stream is included in the most recent 303(d) list due to FC bacteria problems. This limited data set does not support that listing. Temperature neared standard exceedance on two occasions indicting that there is a potential for problem conditions in this stream. However, flow was negligible during dry season monitoring and is the primary influence on temperature. Nutrients and TSS concentrations were generally very low. The dry season unit runoff for this stream was the lowest measured, if intermittent streams are not considered. This, in combination with the high temperatures measured, indicates that there is not a strong influence by groundwater in terms of the volume of water contributed to the stream.

Table 19. Summary of monitoring results for Shoofly Creek.

	TSS (mg/L)	**FC(1)** (#/100 mL)	**TP** (mg/L)	**N+N** (mg/L)	**Temp** (^oC)	**Flow** (cfs)	**Unit Runoff** (cfs/mi^2)
Wet Season	0.25 (<0.50)	3 (<2 - 6)	0.007 (0.003 - 0.011)	0.148 (0.109 - 0.200)	8.5 (8.0 - 9.2)	2 (1.66 - 2.29)	2.23
Dry Season	0.90 (<0.50 - 1.30)	49 (28 - 76)	0.012 (0.006 - 0.017)	0.138 (0.130 - 0.143)	15.6 (13.4 - 17.3)	0.10 (0.03 - 0.23)	0.10

(1) Mean calculated as geometric mean value.

Tahuya River

The Tahuya River is the largest River on the Kitsap Peninsula (WSCC, 2003). The river has a drainage area of a more than 45 mi^2 and is approximately 21 miles long. An additional 65 miles of tributaries feed into the river (WSCC, 2003). Land use is primarily forest and rangeland (85%) with 4% urban and commercial development (Table 1). There are approximately 4.5 miles of road per square mile of drainage area, which is considered a high density (WSCC, 2003).

The Tahuya River has sandy and gravelly substrate through much of its channel. Fine sediment enters the streams through recreational vehicle crossing and trails (WSCC, 2003). However, percent fines were rated fair to good throughout the drainage (WSCC, 2003). Numerous complete and partial fish barriers are found throughout the Tahuya River channel (WSCC, 2003).

Frequent instances of high temperatures (>16ºC) have been measured during summer months (WSCC, 2003 and Kitsap County, 2002). There have also been exceedances of dissolved oxygen and turbidity standards (Kitsap County, 2002). Conversely FC bacteria concentrations have not exceeded State standards; there was only one excursion above 100/100mL during monitoring performed between 1996 and 2002 by Kitsap County (Kitsap County, 2002). None were measured during this study.

Due to the size of this river, the large estuary and difficulties in estimating flows, the sample site was located approximately three miles upstream from the shoreline of Hood Canal. Flow data was collected by the Hood Canal Salmon Enhancement Group at their gauge site located approximately eleven miles upstream of the mouth at the Tahuya Belfair Road Bridge. Load and yield data was corrected to reflect the difference.

Table 20 summarizes results for the Tahuya River from this monitoring effort. As shown, all FC bacteria concentrations were low, while temperature exceeded standards on two of four dry season samplings. This supports previous findings and indicates that the duration of high temperature conditions may be long. Nutrient levels in this stream were consistently low, while TSS was within a moderate range when compared to other streams monitored.

There was a wide range in flows resulting in one of the lowest dry season unit runoff estimates and yet a close to average wet season unit runoff. This indicates that this drainage is driven by surface runoff and has little groundwater influence. This condition, if not natural, can sometimes be attributed to forest practices and removal of tree cover.

Table 20. Summary of monitoring results for the Tahuya River.

	TSS (mg/L)	**FC**(1) (#/100 mL)	**TP** (mg/L)	**N+N** (mg/L)	**Temp** (°C)	**Flow**(2) (cfs)	**Unit Runoff** (cfs/mi^2)
Wet Season	4.4 (3.9 - 5.3)	5 (<2 - 8)	0.011 (0.006 - 0.013)	0.085 (0.071 - 0.094)	8.7 (6.9 - 9.9)	97.04 (94.93 - 99.14)	2.83
Dry Season	3.23 (1.30 - 4.60)	23 (10 - 36)	0.011 (0.006 - 0.017)	0.026 (0.021 - 0.036)	15.4 (13.4-17.3)	4.33 (3.90 - 4.81)	0.13

(1) Mean calculated as geometric mean value.
(2) Flow measurements from the Little Tahuya River and Tahuya River were combined to reflect discharge at sample site downstream of flow gauges. (Source: Hood Canal Salmon Enhancement Group)

DISCUSSION AND CONCLUSIONS

During this effort, fourteen streams along the north and south shore of the lower arm of Hood Canal were monitored. These streams represented only about 30% of the land mass that contributes runoff to this part of the canal. However, together they did encompass the range of subbasin sizes, land use and developed conditions that exist in the Canal.

There are two important limitations to this study that need to be considered when discussing results. First, all of the results are influenced by the abnormally dry weather experienced in 2004. Evidence of the year's low precipitation is demonstrated by annual mean flows provided in the USGS report for the Tahuya River. Mean annual flows for the Tahuya River for 1971-2004 were 152 cfs (USGS, 2004) and in this study, the Tahuya River average flow was 51 cfs. None of the monitoring events include a period of high rainfall and saturated watershed conditions. Pollutant load and yield values during the wet season especially, will likely increase during a more typical year. On the other hand, these data are a good reflection of background conditions; the pollutant concentrations (with a few exceptions) may largely reflect the amount naturally supplied by movement of water through soils and over the surface of the watershed. This certainly appears to be true for TP since the yield correlated so well with unit runoff values ($R^2 = 0.9079$).

The second critical limitation is the number of sampling events and the use of these nine events to estimate annual variation and loads. By monitoring during both wet and dry season it was expected that the annual variation would be captured; which as described above was not likely the case.

It is also important to understand that with the exception of Alderbrook, Twanoh, Mission, Stimson, and Shoofly Creeks, samples were collected upstream of Highway 106 or North Shore Road. Discharges through bulkheads, septic systems, yard runoff and etc associated with the strip of land between the highway and marine water are not accounted for, for the majority of streams.

Nutrient concentrations were generally low and resulted in low yields when compared to small to large size rivers in Puget Sound. In a recent water quality assessment of streams in the Puget Sound Basin TP yields ranged from 0.05 to 0.4 tons/mi^2 (Embrey and Inkpen, 1998). However, it was noted in the study that nutrient yields from Olympic mountain streams on the west side of Puget Sound were much lower than those reported for the east side of the Sound. Yields in other Hood Canal rivers such as the Skokomish, Hamma Hamma, Duckabush, Dosewallips and Dewatto Rivers ranged in 0.06 to 0.3 tons/mi^2 for total phosphorus (Embrey and Inkpen, 1998). The range estimated for streams in this study was even lower than for the Hood Canal rivers assessed by the USGS, (i.e., 0.008 to 0.232 tons/mi^2 for TP), the majority of streams were below 0.06 tons/mi^2.

If the average study area yield value for TP (0.069) and N+N (0.361) is applied to the entire landmass that contributes to the lower arm of Hood Canal (129 mi^2), the total annual contribution would be 8.90 tons for TP and 46.57 tons for N+N. A recent USGS report estimated that streams draining to Hood Canal contributed 421±162 tons of nitrogen to the Canal each year (USGS, 2004). These estimates can not be directly compared because results from this study reflect only a fraction of the nitrogen (nitrate+nitrite) and covers only two of the four shores that contribute nutrients. However, they do appear to be within the same ballpark, especially given the coarse nature of all of the estimates.

In terms of watershed planning and possible recommendations for more intensive investigative efforts, there are no strong recommendations that can be derived from this data. There are a few streams that have elevated FC bacteria levels, but even in these cases the concentrations are low in comparison to most impacted streams. None were at a level to justify major investigative efforts. However, bacteria concentrations could be expected to be more influenced by the low water year. Additional monitoring planned for 2005 may be useful for making this determination.

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APPENDIX A

Lower Hood Canal Water Quality Monitoring
Quality Assurance Project Plan

HOOD CANAL
WATER QUALITY MONITORING
QUALITY ASSURANCE PROJECT PLAN

The following plan describes specific procedures and methods that will be followed when implementing Hood Canal Water Quality monitoring. These protocols were developed to help insure consistency in data collection and reporting.

1.0 PROBLEM AND BACKGROUND INFORMATION

1.1 PROBLEM

Dissolved oxygen, fecal coliform bacteria and even pH exceedances have been documented in the lower Hood Canal area. The primary objective of this project is to identify and quantify drainage sources to the lower Hood Canal, as well as provide an evaluation/comparison of pollutant loads from contributing sources.

The Water Resource Inventory Areas (WRIA) 15 and 16 Technical Committees have contracted EnviroVision to monitor several streams and drainages along the South and North Shores of Hood Canal. The intent of this monitoring project is to provide baseline data for an area that has very little water quality background information. The dataset developed can be combined with existing monitoring efforts by others (e.g. Mason County, Skokomish Tribe, Washington State Department of Health (DOH), Hood Canal Salmon Enhancement Group (HCSEG)) to increase knowledge within the project area.

1.2 MONITORING RATIONAL

The monitoring strategy which includes five monitoring events during the wet weather season and four during late summer was developed to focus efforts on the period of highest variability in flow and pollutant concentrations (wet weather) and the period when seasonal residents have returned.

In this case, the wet weather period has been defined as January through March 2004. The five wet weather events are generally scheduled to occur at two to three week intervals. Since the purpose is to capture the typical range of conditions that occur during the wet weather period and because stream quality is highly reactive to weather conditions, there is no need to strictly adhere to this schedule. Monitoring three days in a row might be reasonable if those three days encapsulated a period before, during, and after a rain event. The selection of specific sampling dates will be made by the field team. For example, if rain events do not occur during the first few monitoring events, the field team may decide to delay or move up a sampling day in order to capture a predicted event in order to insure there is some representation of these conditions in the data set.

Ten sites were selected along the south shore of Hood Canal based on group discussions with the WRIA 16 Technical Committee as well as aerial photographs and land use. Our goal during the selection process was to capture nearly 80% of the drainage in the south shore area and to develop a representation of developed and undeveloped drainages for comparison. Four sites have also been selected for monitoring on the North Shore of Hood Canal. Preliminary selections include the Tahuya River, Stimson Creek, Shoofly Creek and Mission Creek. Attempts will be made to schedule north and south shore sampling events to coincide with each other. Each sampling station is located just upstream of saltwater influence but may fall within tidal fluctuations. Specific descriptions of the stations have been included in the table below, however each station will be referred by general name throughout the monitoring process (Table 1).

Table 1. Site names, descriptions and locations for water quality sampling on the South Shore of Hood Canal. (At the time of the QAPP development, exact sample locations for the North Shore sites had not been determined.)

General Name	Latitude	Longitude	Location Description
Big Bend Creek(1)	47°20'52.79"N	123°04'26.00"W	At the mouth on the south side of SR 106 in the state ROW, access through campground
Alderbrook Creek(1)	47°20'52.56"N	123°04'05.66"W	Near the mouth at the pedestrian bridge. Access to the creek is through the development construction.
Unnamed Drainage	47°21’19.45”N	123°01’01.18”W	South side of SR 106 across from address 9741 SR 106
Shady Beach Drainage	47°22'22.73"N	122°59'15.90"W	On the south side of SR 106 at the entrance to the culvert under the highway.
Twanoh Creek(1)	47°22'41.94"N	122°58'25.58"W	At the mouth below the pedestrian bridge in the beachside park.
Twanoh Falls Creek(1)	47°22'54.66"N	122°56'54.61"W	North of SR 106 upstream of gated private beach.
Unnamed (Mulberg) Creek(1)	47°23'13.94"N	122°55'30.13"W	At the mouth in the State ROW on the south side of SR 106
Happy Hollow Creek(1)	47°23'17.22"N	122°54'57.23"W	South side of SR 106 Just upstream of culvert.
Holyoke Creek(1)	47°24'22.05"N	122°53'09.89"W	Upstream of the saltwater influence just after first bend in stream, access through property, using stairs and platform on embankment.
Deveraux Creek(1)	47°25'47.42"N	122°50'53.73"W	Upstream from mouth, access through private property at 19601 State Route 106.

(1) Since many small streams have multiple names, general names have been obtained from the Salmon and Steelhead Habitat Limiting Factors Analysis for WRIAs 14 North and 15 West, Washington State Conservation Commission, June 2003.

2.0 OVERVIEW OF PROJECT QUALITY OBJECTIVES

The following elements define the data quality objectives for the surface water quality monitoring and specify the methods used to evaluate them. Further detail on the use of these methods to evaluate the precision, bias is provided in Section 4.0, Quality Control Procedures.

- **Precision** is a measurement of the scatter in data due to random error and is stated in terms of percent relative standard deviation (RSD). Major sources of random error are the sampling and analytical procedures. The total precision of results can be estimated from the results of replicate samples. For laboratory analysis, precision will be assessed using laboratory duplicates. To assess precision in the field, water quality field replicates will be collected for at least 10 percent of the samples submitted for analysis.

- **Bias** is a measure of the difference between the result for a parameter and the true value due to systematic errors**.** Potential sources of bias include; (1) sample collection, (2) physical or chemical instability of samples, (3) interference effects, (4) inability to measure all forms of a determinant, (5) calibration of the measurement system, and (6) contamination.

  Previous studies pertaining to the sources of bias due to sampling have led to the recommended procedures currently in use. Thus, careful adherence to standard procedures for collection, preservation, transportation, and storage of samples will reduce or eliminate most sources of bias. Bias affecting laboratory measurement procedures will be assessed by the use of matrix spike recovery, method blanks, and check samples in accordance with the laboratory Quality Assurance (QA) Plan. Analysis of split samples will provide an estimate of overall sampling bias including variation in concentration due to sample heterogeneity. Matrix spikes are used to detect interference effects due to the sample matrix. An estimate of bias due to calibration is calculated from the difference between the check standard results and the true concentration.

- **Detection Limits** for the parameters to be analyzed for this project represent the measurement quality objectives.

- **Representativeness** is achieved by selecting sampling locations, methods, and times so that the data describe the site conditions that the project seeks to evaluate. The sampling design was developed to ensure the data are representative. Samples will be taken at the same location and at nearly the same time during the monitoring period. Samples will be collected systematically through entire monitoring period. Additionally, representativeness of the data is assured through definition of stream locations and qualifying conditions.

- **Comparability** will be maintained by ensuring usage of standard operating procedures when collecting and handling samples. Various reporting methods such as unit measures will be consistent between samplings and all sampling methods will be consistent with the standard procedures outlined in this report. Careful planning of fieldwork and methods will maximize the amount of accurate and comparable data. Designing each monitoring "tier" so that it can be accomplished in one field day or that up and down stream stations are monitored somewhat simultaneously also enhances comparability.

3.0 SCHEDULE

The monitoring schedule will be as follows:

- Wet season monitoring will occur five times between January and April 2004 (four times for North Shore locations). During each event, flow, temperature, specific conductivity, and salinity data will be collected. Grab samples for total phosphorus (TP), nitrates and nitrites, total suspended solids (TSS), fecal coliform bacteria (FC bacteria) and biochemical oxygen demand (BOD) will also be collected at each station.

- Four late Spring/early Summer monitoring events will occur between July and September 2004. The same parameters for the wet season monitoring will be sampled.

- Sampling sites will be located upstream from saltwater influences and will be identified with flagging tape so that the same site is sampled each time.

4.0 DATA MEASUREMENT AND ACQUISITION

4.1 FIELD PREPARATION

The following field preparation practices provide the setting to develop quality data collection:

- Calibrate all field meters as per manufacturers specifications.

- Bottles will be collected, organized and labeled for sample collection including labeling of blind and replicate sample bottles.

- Equipment will be checked for damage and wear and tear.

- A random quality assurance (QA) site will be selected prior to each field day. Replicate/QA samples will be labeled and sent as "blind" replicates to the lab for analysis.

4.2 FIELD PROCEDURES

During a field day, the major priority is thorough documentation. The following are some sample collection ground rules that will be adhered to.

- Prior to sampling at each stream site, field staff will record the approximate temperature, weather, time, and date as well as provide a summary of weather conditions in the previous days. In addition, observations with respect to adjacent land use and flow conditions within the stream should be recorded.

- All sampling will be consistent. Field staff will maintain the same sampling method, collection location and equipment for each station. If a change is necessary, it will be documented.

- Documentation of equipment used, problems incurred, batch sizes, calibration results, etc, will be recorded so that a permanent record is maintained.

Water Chemistry

Field Meters (temperature, conductivity, and salinity)
An YSI 30 water quality probe will be held upstream from the entry point in stream for at least two minutes until measurements stabilize. Parameter measurements will be recorded on data sheets, as will be site location, date and time. If temperature, specific conductivity, or salinity results indicate that water quality standards are not met (e.g. temperature readings above 12°C), additional measurements will be taken along the stream cross-section to evaluate the consistency and reliability of the result and determine its extent.

Grab Samples: (Nutrients, TSS, fecal coliform bacteria, and BOD)
The analytical laboratory (Aquatic Research, Inc.) will provide sterile bottles and testing facilities. Samples will be collected by entering the water downstream of the sample site. Each sample bottle, except bacteria, will be rinsed three times prior to sample collection and contamination minimized. Samples are collected by facing upstream, turning the bottle upside down and plunging it vertically through the water surface and then facing the bottle into the flow and slowly moving the bottle up and out of the water. Sample bottles will be labeled with sample number, date, time, sample type (i.e. nutrients, bacteria, etc) and location and logged onto a data sheet. Samples should be stored in an iced cooler until delivered to the laboratory within 48 hours for analysis.

Samples that Require Special Care: (Bacteria)
Bacteria samples must be collected to minimize potential for contamination. Care will be taken to not touch the inside, edge or cap of the sterilized bottle when collecting the sample. Also, because bacteria collect on the surface film of the water, the method of sampling described above, which requires the bottle to be plunged quickly through the surface film, is very important.

Flow Monitoring

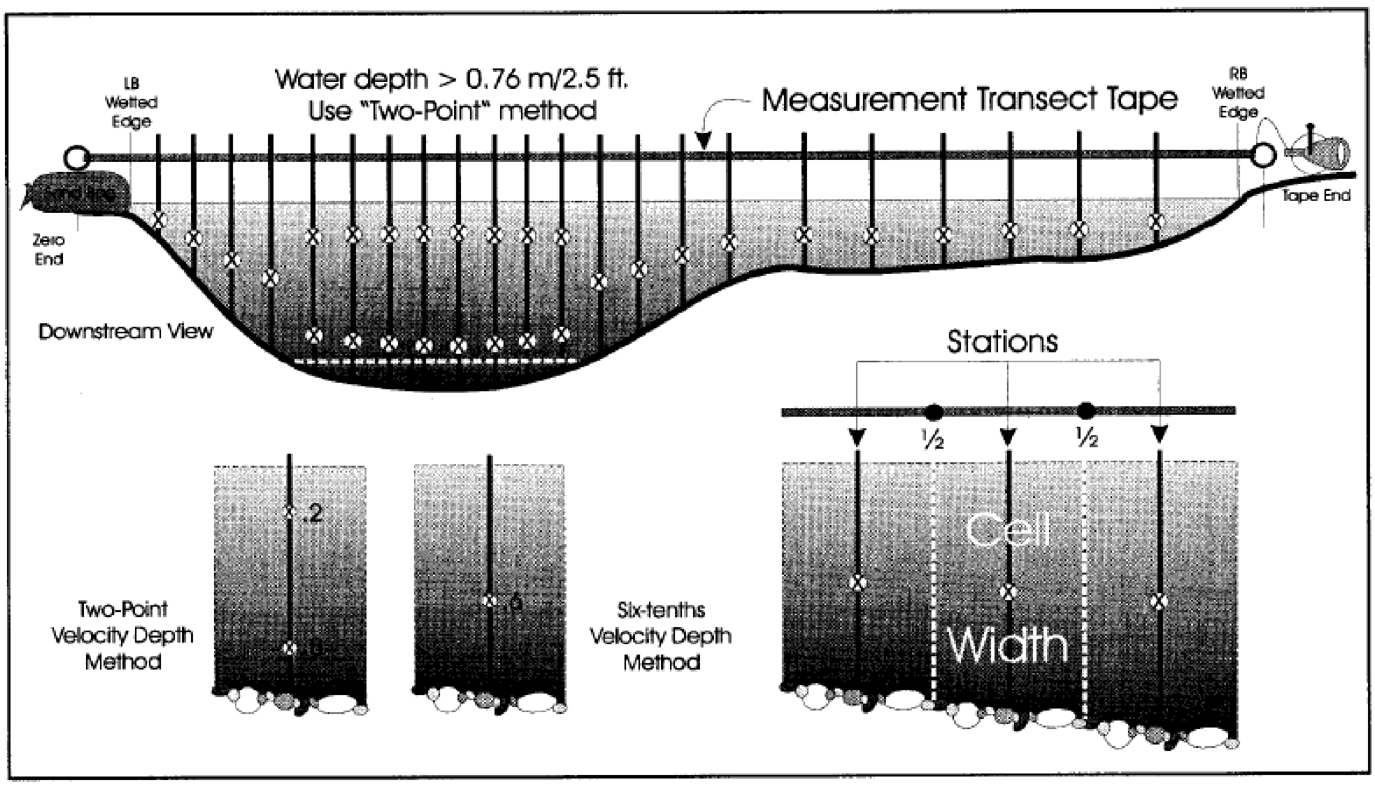
The most common procedure for measuring discharge is based on “velocity-area” calculations. Because velocity and depth can vary greatly across a stream, accuracy in flow measurement is achieved by measuring the mean velocity at many incremental distances over the cross-section of the stream (Figure 1). The standard is to measure flow at 20 places in the cross section. (Done by dividing the total stream width by 20 and using the result as the measurement interval). Velocity varies vertically at each point in the stream. Stream hydrologists have determined that in a stream segment that is less than 2.5 feet deep, the best estimate of average velocity occurs at 60 percent of the total depth. If a segment is greater than 2.5 feet deep, a velocity measurement should be taken at 20 and 80 percent depths and the average of these two values used to represent average velocity at that location.

Flow measurements for this project will be determined using a Swoffer Meter. Measurements will be taken at twenty locations where streams measure ten feet or more in width following standard methods provided in the TFW Manual. Streams measuring less than ten feet in width will have flow measurements taken at approximately half-foot intervals or a minimum of 2-4 measurements. Two velocity measurements will be taken at the 20 and 80 percent depths in streams where the depth is greater than 2.5 feet.

Station number, stream name, and total stream width will be recorded for each flow monitoring station. Total water depth and depth of velocity measurement should be recorded as well as the velocity measured at each depth.

More detailed references for stream flow monitoring can be found in TFW Monitoring Program Method Manual for Wadeable Stream Discharge Measurement (1999).

Figure 1: Cross section of stream showing tape position, depth and velocity measurement stations, and cell width boundaries. (TFW, 1999)



4.3 LABORATORY PROCEDURES

Analytical parameters and methods, detection limits and units, preservation methods, and holding times for samples collected during monitoring are summarized in Table 2. Aquatic Research, Inc. will take the lead on laboratory analysis and internal QA checks.

TABLE 2. Parameters and analytical methods.

Parameter	Method	Matrix/Type	Detection Limit	Holding Time
Total Suspended Solids	EPA 160.2	Water/Grab	0.05 mg/L	7 days
Phosphorous (total)	EPA 365.1	Water/Grab	0.002 mg/L	28 days
Nitrate-Nitrite	EPA 353.2	Water/Grab	0.01 mg/L	28 days
Fecal coliform	SM189222D	Water/Grab	2/100 mL	48 hours
Biochemical oxygen Demand (5-day)	EPA 405.1	Water/Composite	2 mg/L	48 hours

5.0 QUALITY CONTROL PROCEDURES

Quality control samples will be collected for both and field and laboratory activities. Field quality control samples will include the collection of field replicate samples. Field replicates will be collected at a minimum frequency of 10 percent of the samples. Laboratory quality control samples will include laboratory blanks, laboratory duplicates, matrix spikes, and laboratory control samples. These will be analyzed with a minimum frequency of 5 percent for each analytical parameter batch. The following field and laboratory quality control procedures apply to the entire data set for a given parameter measured during a specific laboratory "batch" are summarized as follows:

- **Field Replicates:** Field replicates are collected to represent field variation. These results are not used to make decisions to "accept" or "reject" data, however the data will be examined to assess variation and look for possible problems. Replicates will not be identified when submitted to the laboratory. Replicate results will be reported separately in the database, but the average of the two results will be used for data evaluation.

- **Laboratory Blanks:** The quality control objective for the laboratory blank is for a concentration less than the specified detection limit. If the blank concentration is greater than the field samples, the values will be rejected or re-analysis will be requested, unless the field samples are below the non-detectable limit. The laboratory QA Officer will review laboratory procedures and decide if samples should be re-analyzed if blank contamination is noted.

- **Laboratory Duplicates:** Laboratory duplicates are one sample that has been split into two containers. If both sample results are below laboratory detection limits, no evaluation of duplicates is required. If duplicates are within 20 percent relative percent difference (RPD) of their twin they are acceptable. For duplicate RPD values that are greater than 20 percent:

  - Since RPD criteria may be misleading at low concentrations, all data that exceed the 20 percent RPD value will be assessed to determine whether the concentration measured was within 5 times the Detection Limit. If this is the case, the data will be accepted without reservation.

  - RPD values that do not meet the above criteria but are less than 35% RPD will be considered for inclusion as an "estimated" value if all other lab QA for that parameter (i.e., blanks, detection limits, and matrix spikes) are acceptable.

  - Parameters with RPDs of greater than 35% will be considered for rejection.

- **Matrix Spikes:** The quality control (QC) objective for matrix spike percent recovery varies with the analytical method. For samples that show matrix spike recoveries outside the QC criteria, the sample results may be assigned data qualifiers or the sample may be re-analyzed. The laboratory QA Officer will be responsible for making initial determinations, but will include the information with the submitted data.

- **Quality Control Requirements**:

  - *Field QC Checks* - Data quality will be addressed with consistent performance of valid procedures documented in this plan. Sampling locations will be clearly established and proper calibration and maintenance of instruments, handling of samples and accurate recording of data will be applied. Data quality can be further checked with replicate sampling and adherence to standard procedures.

  - *Laboratory QC Checks* - The laboratory will maintain their own standard procedures and will follow according to laboratory certification regulation.

  - *Data Analysis QC Checks* – All QA checks for data will be completed before the data is entered into the database.

- **Field Meter Calibration:**

  - Field personnel will routinely inspect equipment for damage and perform routine preventative maintenance and cleaning of field equipment based on manufacturers recommendations.

  - Conductivity/Salinity Probes: These will be calibrated against a known standard at the beginning and end of the field day. The measured conductivity will be within 10% of the theoretical value.

6.0 DATA MANAGEMENT PROCEDURES

Field staff will fill out chain of custody forms with date, time, sample and location. Copies will be retained for the project files following submittal of samples. The laboratory will send water quality data directly to the designated Task Manager with a narrative of QA/QC results and discussions of any discrepancies. Established databases of water quality data will be spot-checked (recommend 10% cross-checking by a different person) for erroneous data entry. Laboratory water quality reports and case narratives will be included as an appendix in the reports.

Ecology's Environmental Information Management (EIM) system will be used for information management and will allow for future access, sharing and manipulation of the data. Using the EIM protocol and format has at least two advantages: first, utilizing an existing well-established database saves resources and second, if Ecology does begin to accept and manage all water quality data, the data entry and format will already be consistent. A third advantage is that Ecology staff are typically available for technical support.

The EIM essentially consists of three data submittal forms that describe the study, location, and result data. Data from field measurements and laboratory results will be entered into EIM spreadsheets, as they are collected throughout the project.

Consistent implementation of the data management system is critical when it comes to data sharing and eventual analysis. For this reason, EnviroVision Corp. will act as data steward for information gathered during monitoring. As steward, EnviroVision will maintain the main data set; including checking data formatting and general QA/QC, as well as act as the liaison with Ecology's EIM manager.

7.0 REFERENCES

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APPENDIX B

Summary of State Water Quality Standards

APPENDIX B. WATER QUALITY STANDARDS

Water quality standards have been set to protect aquatic life and other beneficial uses of these streams. In Washington State new standards have been proposed are in the process of being revised and finalized. Many of the changes have been driven by the need to better reflect salmon protection needs. In the currently proposed standards, all streams in this study area have been designated in the State's water quality standards as Salmon and Trout Spawning, Non-Core Rearing and Migration as well as Primary Contact Recreation. However, recent review of the proposed water quality standards by EPA has resulted in their recommendation to adjust the designation for the Tahuya River to Salmon and Trout Spawning, Core Rearing and Migration due to chum salmon and steelhead spawning grounds (EPA, 2005). As will be described below, this change affects which temperature standard is applied to the stream.

Washington State Department of Ecology creates a list of waters that do not, or are not expected to meet the state surface-water quality standards. This report is referred to as the "List of Impaired and Threatened Waterbodies", or the "303(d) list". The most recent listings in Lower Hood Canal include segments of Happy Hollow, Twanoh, Twanoh Falls, Mulberg (listed as Unnamed), Stimson, and Shoofly Creeks (Ecology, 1998; Ecology, 2004). Happy Hollow, Twanoh, Mulberg, Stimson and Shoofly Creeks were listed due to fecal coliform (FC) bacteria problems, while Twanoh Falls and Mulberg Creeks were listed for pH (Ecology, 1998; Ecology, 2004).

The following table summarizes state water quality standards for this project.

Table 1. Summary of water quality standards.

CATEGORY		TEMPERATURE	BACTERIA (1)	PH
Anadromous Salmon & Trout	Spawning, Core Rearing, & Migration	Highest 7-DADMax 16°C, with human induced impacts ≤0.3°C	**Extraordinary Primary Contact -** Fecal Coliform organism levels must not exceed a geometric mean value of 50/100mL, with no more than 10% of samples above 100/100 mL	6.5 to 8.5, human induced variation <0.2
	Spawning, Noncore Rearing, & Migration	Highest 7-DADMax 17.5°C, with human induced impacts ≤0.3°C	**Primary Contact** - Fecal Coliform organism levels must not exceed a geometric mean value of 100/100mL, with no more than 10% of samples above 200/100 mL	6.5 to 8.5, human induced variation <0.2
	Rearing & Migration Only	Highest 7-DADMax 17.5°C, with human induced impacts ≤0.3°C	**Secondary Contact** – Enterococci levels must not exceed a geometric mean of 200/100mL, with no more than 10% of samples above 400/100 mL	6.5 to 8.5, human induced variation <0.2

(1) Bacteria standards are based on recreational use criteria described in the WAC. Primary Contact means activities where there will be direct contact with water including swimming and submergence. Secondary Contact activities are those where there would be limited contact with the water, such as wading or fishing.

APPENDIX C

Water Quality Monitoring Data for
Streams in Lower Hood Canal

BIG BEND CREEK DATA

Wet Season

Date	BOD	TSS		FC		TP		N+N		Specific Conductance	Temp.	Salinity	pH	Flow
	(mg/L)	(mg/L)	(tons/yr)	(#/100mL)	(#/yr)	(mg/L)	(tons/yr)	(mg/L)	(tons/yr)	(uS)	(°C)	(ppt)		(cfs)
1/5/2004	<2.00	0.63	2.35	6	2.0E+10	0.030	0.112	0.210	0.783	83.1/81.1	2.4	0.0	NS	3.79
1/20/2004	<2.00	2.60	17.68	16	9.9E+10	0.031	0.211	0.184	1.252	70.8/69.3	7.3	0.0	NS	6.91
2/4/2004	<2.00	1.40	10.06	2	1.3E+10	0.024	0.172	0.194	1.394	67.6	7.0	0.0	NS	7.30
3/4/2004	<2.00	2.50	9.03	22	7.2E+10	0.030	0.108	0.142	0.513	81.2	6.9	0.0	NS	3.67
3/30/2004	<2.00	2.50	13.31	1	4.8E+09	0.030	0.160	0.145	0.772	82.4	9.6	0.0	NS	5.41
GeoMean				5	2.5E+10									5.20
Mean	<2.00	1.93	10.49			0.03	0.16	0.175	0.943		6.6	0.0		5.42
Range	(<2.00)	(0.63-2.60)		(<2-22)		(0.024-0.031)		(0.142-0.210)			(2.4-9.6)			(3.67-7.30)

NS = Not Sampled

Dry Season

Date	BOD	TSS		FC		TP		N+N		Specific Conductance	Temp.	Salinity	pH	Flow
	(mg/L)	(mg/L)	(tons/yr)	(#/100mL)	(#/yr)	(mg/L)	(tons/yr)	(mg/L)	(tons/yr)	(uS)	(°C)	(ppt)		(cfs)
7/8/04	<2.00	3.00	4.58	166	2.3E+11	0.037	0.056	0.157	0.240	99.7	11.6	0.0	NS	1.55
7/28/04	<2.00	2.70	4.39	64	9.4E+10	0.039	0.063	0.136	0.221	107.5	13.4	0.1	NS	1.65
8/19/04	<2.00	1.40	3.39	290	6.4E+11	0.035	0.085	0.125	0.303	109.8	13.2	0.1	NS	2.46
9/7/04	<2.00	2.00	2.58	112	1.3E+11	0.031	0.040	0.129	0.166	102.2	11.6	0.0	7.17	1.31
GeoMean				136	2.1E+11									
Mean	<2.00	2.28	3.73			0.036	0.061	0.137	0.232		12.5	0.1		1.74
Range	(<2.00)	(1.40 - 3.00)		(112 - 290)		(0.031 - 0.039)		(0.125 - 0.157)			(11.6-13.4)			(1.31-2.46)

NS = Not Sampled

ALDERBROOK CREEK DATA

Wet Season

Date	BOD	TSS		FC		TP		N+N		Specific Conductance	Temp.	Salinity	pH	Flow
	(mg/L)	(mg/L)	(tons/yr)	(#/100mL)	(#/yr)	(mg/L)	(tons/yr)	(mg/L)	(tons/yr)	(uS)	(^{o}C)	(ppt)		(cfs)
1/5/2004	<2.00	<0.50	0.39	2	2.8E+09	0.019	0.030	0.271	0.421	127/122.0	4.7	0.1	NS	1.58
1/20/2004	<2.00	<0.50	0.75	8	2.2E+10	0.017	0.051	0.229	0.690	103/101.8	7.8	0.0	NS	3.06
2/4/2004	<2.00	<0.50	0.53	<2	1.9E+09	0.016	0.034	0.209	0.446	98.4	7.7	0.0	NS	2.17
3/4/2004	<2.00	0.63	0.81	2	2.3E+09	0.023	0.030	0.211	0.272	120.8	7.4	0.1	NS	1.31
3/30/2004	<2.00	0.50	1.05	<2	1.9E+09	0.021	0.044	0.227	0.478	117.9	8.9	0.1	NS	2.14
GeoMean				3	3.5E+09									
Mean	<2.00	0.38	0.71			0.019	0.038	0.229	0.462		7.3	0.06		2.05
Range	(<2.00)	(<0.50-0.63)		(<2-8)		(0.014-0.023)		(0.209-0.271)			(4.7-8.9)			(1.31-3.06)

NS = Not Sampled

Dry Season

Date	BOD	TSS		FC		TP		N+N		Specific Conductance	Temp.	Salinity	pH	Flow
	(mg/L)	(mg/L)	(tons/yr)	(#/100mL)	(#/yr)	(mg/L)	(tons/yr)	(mg/L)	(tons/yr)	(uS)	(^{o}C)	(ppt)		(cfs)
7/8/04	<2.00	0.83	1.15	<2	1.3E+09	0.024	0.033	0.269	0.373	138.6	10.6	0.1	NS	1.41
7/28/04	<2.00	0.83	0.62	28	1.9E+10	0.025	0.019	0.254	0.190	139.2	12.3	0.1	NS	0.76
8/19/04	<2.00	0.63	1.28	2	3.7E+09	0.025	0.051	0.242	0.493	139.7	12.3	0.1	NS	2.07
9/8/04	<2.00	1.00	1.37	14	1.7E+10	0.025	0.034	0.245	0.335	140.0	11.3	0.1	7.60	1.39
GeoMean				9	6.3E+09									
Mean	<2.00	0.82	1.11			0.025	0.034	0.253	0.348		11.6	0.1		1.41
Range	(<2.00)	(0.63 - 1.00)		<2 - 28)		(0.024 - 0.025)		(0.242 - 0.269)			(10.6-12.3)			(0.76-2.07)

NS = Not Sampled

UNNAMED CREEK DATA

Wet Season

Date	BOD	TSS		FC		TP		N+N		Specific Conductance	Temp.	Salinity	pH	Flow
	(mg/L)	(mg/L)	(tons/yr)	(#/100mL)	(#/yr)	(mg/L)	(tons/yr)	(mg/L)	(tons/yr)	(uS)	(^{o}C)	(ppt)		(cfs)
1/5/2004	<2.00	2.90	1.00	2	6.3E+08	0.038	0.013	0.013	0.004	84.6/82.2	5.9	0.0	NS	0.35
1/20/2004	<2.00	0.75	0.36	<2	4.4E+08	0.028	0.014	0.014	0.007	80.5/79.4	8.3	0.0	NS	0.49
2/4/2004	<2.00	<0.50	0.09	<2	3.4E+08	0.027	0.010	0.011	0.004	77.6	8.0	0.0	NS	0.38
3/4/2004	<2.00	1.00	0.30	<2	2.7E+08	0.031	0.009	0.012	0.004	81.3	7.7	0.0	NS	0.30
3/31/2004	<2.00	0.87	0.53	<2	5.5E+08	0.033	0.020	0.010	0.006	80.9	8.7	0.0	NS	0.62
GeoMean				2	4.2E+08									
Mean	<2.00	1.38	0.46			0.031	0.013	0.012	0.005		7.7			0.45
Range	<2.00	(<0.50-2.90)		(<2-2)		(0.027-0.038)		(0.010-0.014)			(5.9-8.7)			(0.30-0.62)

NS = Not Sampled

Dry Season

Date	BOD	TSS		FC		TP		N+N		Specific Conductance	Temp.	Salinity	pH	Flow
	(mg/L)	(mg/L)	(tons/yr)	(#/100mL)	(#/yr)	(mg/L)	(tons/yr)	(mg/L)	(tons/yr)	(uS)	(^{o}C)	(ppt)		(cfs)
7/8/04	<2.00	1.20	0.73	<2	5.5E+08	0.028	0.017	0.031	0.019	83.5	9.5	0.0	NS	0.62
7/28/04	<2.00	1.00	0.91	10	8.2E+09	0.027	0.024	0.013	0.012	82.6	10.2	0.0	NS	0.92
8/19/04	<2.00	1.10	1.29	<2	1.1E+09	0.030	0.035	0.010	0.012	83.5	9.9	0.0	NS	1.19
9/7/04	<2.00	0.83	0.56	12	7.3E+09	0.031	0.021	0.129	0.086	83.2	9.5	0.0	7.3	0.68
GeoMean				3	2.4E+09									
Mean	<2.00	1.03	0.87			0.029	0.024	0.046	0.032		9.8	0.0		0.85
Range	(<2.00)	(0.083 - 1.20)		(<2 - 12)		(0.027 - 0.031)		(0.010 - 0.129)			(9.5-10.2)			(0.62-1.19)

NS = Not Sampled

SHADY BEACH CREEK DATA

Wet Season

Date	BOD	TSS		FC		TP		N+N		Specific Conductance	Temp.	Salinity	pH	Flow
	(mg/L)	(mg/L)	(tons/yr)	(#/100mL)	(#/yr)	(mg/L)	(tons/yr)	(mg/L)	(tons/yr)	(uS)	(^{o}C)	(ppt)		(cfs)
1/5/2004	<2.00	<0.50	0.01	2	7.1E+07	0.003	0.000	0.011	0.000	62.5/62.0	4.0	0.0	NS	0.04
1/20/2004	<2.00	<0.50	0.06	<2	2.2E+08	0.006	0.001	0.012	0.003	56.2/55.9	7.7	0.0	NS	0.25
2/4/2004	<2.00	<0.50	0.14	2	1.0E+09	0.007	0.004	0.008	0.005	34.2	7.5	0.0	NS	0.58
3/4/2004	<2.00	<0.50	0.01	16	4.3E+08	0.010	0.000	<0.010	0.000	68.7	7.0	0.0	NS	0.03
3/31/2004	<2.00	<0.50	0.00	<2	1.8E+07	0.007	0.000	0.004	0.000	76.5	8.8	0.0	NS	0.02
GeoMean				2	1.7E+08									
Mean	<2.00	<0.50	0.045			0.007	0.001	0.008	0.002		7.0			0.18
Range	(<2.00)	(<0.50)		(<2-16)		(0.003-0.010)		(0.004-0.012)			(4.0-8.8)			(0.02-0.58)

NS = Not Sampled

Dry Season

Date	BOD	TSS		FC		TP		N+N		Specific Conductance	Temp.	Salinity	pH	Flow
	(mg/L)	(mg/L)	(tons/yr)	(#/100mL)	(#/yr)	(mg/L)	(tons/yr)	(mg/L)	(tons/yr)	(uS)	(^{o}C)	(ppt)		(cfs)
7/8/04	<2.00	2.30	0.00	34	0.0E+00	0.040	0.000	<0.010	0.000	115.6	13.0	0.1	NS	0.00
7/28/04	<2.00	17.00	0.17	34	3.0E+08	0.134	0.001	0.012	0.000	119.0	14.5	0.1	NS	0.01
8/19/04	<2.00	4.00	0.00	<2	0.0E+00	0.022	0.000	<0.010	0.000	114.0	15.0	0.1	NS	0.00
9/7/04	<2.00	1.20	0.02	26	4.6E+08	0.007	0.000	0.014	0.000	105.6	14.6	0.1	6.8	0.02
GeoMean				13										
Mean	<2.00	6.13	0.05			0.051	0.000	0.009	0.000		14.3	0.1		0.01
Range	(<2.00)	(1.20 - 17.00)		(<2 - 34)		(0.007 - 0.134)		(<0.010 - 0.014)			(13.0-15.0)			(0.00-0.02)

NS = Not Sampled

TWANOH CREEK DATA

Wet Season

Date	BOD	TSS		FC		TP		N+N		Specific Conductance	Temp.	Salinity	pH	Flow
	(mg/L)	(mg/L)	(tons/yr)	(#/100mL)	(#/yr)	(mg/L)	(tons/yr)	(mg/L)	(tons/yr)	(uS)	(^{o}C)	(ppt)		(cfs)
1/5/2004	<2.00	<0.50	0.70	2	5.1E+09	0.034	0.095	0.062	0.174	81.30	5.9	0.0	NS	2.85
1/20/2004	<2.00	<0.50	0.80	<2	2.9E+09	0.032	0.102	0.047	0.150	74.70	8.0	0.0	NS	3.24
2/4/2004	<2.00	<0.50	1.15	4	1.7E+10	0.028	0.129	0.043	0.199	68.7	7.7	0.0	NS	4.69
3/4/2004	<2.00	<0.50	1.00	4	1.4E+10	0.036	0.144	0.033	0.132	79.2	7.6	0.0	NS	4.05
3/31/2004	<2.00	<0.50	0.89	<2	3.2E+09	0.036	0.128	0.029	0.103	80.7	9.0	0.0	NS	3.60
GeoMean				2	6.5E+09									
Mean	<2.00	<0.50	0.907			0.033	0.120	0.043	0.151		7.6			3.69
Range	(<2.00)	(<0.50)		(<2-4)		(0.028-0.036)		(0.029-0.062)			(5.9-9.0)			(2.85-4.69)

NS = Not Sampled

Dry Season

Date	BOD	TSS		FC		TP		N+N		Specific Conductance.	Temp.	Salinity	pH	Flow
	(mg/L)	(mg/L)	(tons/yr)	(#/100mL)	(#/yr)	(mg/L)	(tons/yr)	(mg/L)	(tons/yr)	(uS)	(^{o}C)	(ppt)		(cfs)
7/8/04	<2.00	<0.50	0.93	78	2.6E+11	0.036	0.134	0.041	0.152	83.5	9.9	0.0	NS	3.77
7/28/04	<2.00	0.50	1.82	120	4.0E+11	0.039	0.142	0.025	0.091	83.2	10.7	0.0	NS	3.69
8/19/04	<2.00	0.50	1.48	62	1.7E+11	0.038	0.113	0.026	0.077	83.8	10.6	0.0	NS	3.01
9/7/04	2.12	0.17	0.59	124	3.9E+11	0.035	0.121	0.032	0.110	59.8	10.0	0.0	7.4	3.50
GeoMean				92	2.9E+11									
Mean	<2.00	0.39	1.20			0.037	0.127	0.031	0.108		10.3	0.0		3.49
Range	(<2.00 - 2.12)	(<0.50 - 0.50)		(62 - 124)		(0.035 - 0.039)		(0.025 - 0.041)			(9.9-10.7)			(3.01-3.77)

NS = Not Sampled

TWANOH FALLS CREEK DATA

Wet Season

Date	BOD	TSS		FC		TP		N+N		Specific Conductance	Temp.	Salinity	pH	Flow
	(mg/L)	(mg/L)	(tons/yr)	(#/100mL)	(#/yr)	(mg/L)	(tons/yr)	(mg/L)	(tons/yr)	(uS)	(^{o}C)	(ppt)		(cfs)
1/5/2004	<2.00	<0.50	0.61	<2	2.2E+09	0.011	0.027	0.273	0.698	76.0/74.5	5.1	0.0	NS	2.46
1/20/2004	<2.00	<0.50	0.91	<2	3.3E+09	0.011	0.040	0.271	1.045	63.3/62.5	7.8	0.0	NS	3.71
2/4/2004	<2.00	0.50	2.48	<2	4.5E+09	0.011	0.054	0.255	1.333	57.3	7.4	0.0	NS	5.03
3/4/2004	<2.00	<0.50	0.43	2	3.1E+09	0.019	0.032	0.194	0.349	74.0	7.7	0.0	NS	1.73
3/31/2004	<2.00	<0.50	0.70	12	3.1E+10	0.016	0.045	0.169	0.502	76.8	9.3	0.0	NS	2.86
GeoMean				2	5.0E+09									
Mean	<2.00	<0.50	1.02			0.014	0.040	0.232	0.785		7.5			3.16
Range	(<2.00)	(<0.50-0.50)		(<2-12)		(0.011-0.019)		(0.169-0.273)			(5.1-9.3)			(1.73-5.03)

NS = Not Sampled

Dry Season

Date	BOD	TSS		FC		TP		N+N		Specific Conductance	Temp.	Salinity	pH	Flow
	(mg/L)	(mg/L)	(tons/yr)	(#/100mL)	(#/yr)	(mg/L)	(tons/yr)	(mg/L)	(tons/yr)	(uS)	(^{o}C)	(ppt)		(cfs)
7/8/04	<2.00	0.50	0.97	58	1.0E+11	0.022	0.043	0.142	0.277	88.5	10.3	0.0	NS	1.98
7/28/04	<2.00	0.50	0.60	32	3.5E+10	0.023	0.028	0.122	0.147	88.7	11.6	0.0	NS	1.22
8/19/04	<2.00	0.50	0.77	4	5.6E+09	0.023	0.036	0.104	0.161	89.8	11.5	0.0	NS	1.57
9/7/04	<2.00	0.50	0.95	64	1.1E+11	0.021	0.040	0.111	0.211	87.2	10.6	0.0	6.66	1.93
GeoMean				26	3.9E+10									
Mean	<2.00	0.50	0.82			0.022	0.036	0.120	0.199		11.0	0.0		1.68
Range	(<2.00)	(0.50)		(4 - 64)		(0.021 - 0.023)		(0.104 - 0.142)			(10.3-11.6)			(1.22-1.98)

NS = Not Sampled

MULBERG CREEK DATA

Wet Season

Date	BOD	TSS		FC		TP		N+N		Specific Conductance	Temp.	Salinity	pH	Flow
	(mg/L)	(mg/L)	(tons/yr)	(#/100mL)	(#/yr)	(mg/L)	(tons/yr)	(mg/L)	(tons/yr)	(uS)	(°C)	(ppt)		(cfs)
1/5/2004	<2.00	6.80	0.87	2	2.3E+08	0.028	0.004	0.598	0.077	144.0/136.7	4.2	0.1	NS	0.13
1/20/2004	<2.00	4.60	2.49	<2	4.9E+08	0.025	0.014	0.530	0.287	161/157.3	8.2	0.1	NS	0.55
2/4/2004	<2.00	2.10	0.35	<2	1.5E+08	0.022	0.004	0.543	0.091	100.2	7.7	0.1	NS	0.17
3/4/2004	<2.00	2.50	0.25	24	2.1E+09	0.028	0.003	0.595	0.059	135.6	7.8	0.1	NS	0.10
3/31/2004	<2.00	2.30	0.14	4	2.1E+08	0.024	0.001	0.553	0.033	132.4	9.9	0.1	NS	0.06
GeoMean				3	3.8E+08									
Mean	<2.00	3.66	0.82			0.025	0.005	0.564	0.109		7.6			0.20
Range	(<2.00)	(2.10-6.80)		(<2-24)		(0.022-0.028)		(0.530-0.598)			(4.2-9.9)			(0.06-0.55)

NS = Not Sampled

Dry Season

Date	BOD	TSS		FC		TP		N+N		Specific Conductance	Temp.	Salinity	pH	Flow
	(mg/L)	(mg/L)	(tons/yr)	(#/100mL)	(#/yr)	(mg/L)	(tons/yr)	(mg/L)	(tons/yr)	(uS)	(°C)	(ppt)		(cfs)
7/8/04	<2.00	5.30	1.67	310	8.9E+10	0.016	0.005	0.495	0.156	129.9	12.2	0.0	NS	0.32
7/28/04	<2.00	1.50	1.02	102	6.3E+10	0.034	0.023	0.645	0.438	131.0	14.0	0.1	NS	0.69
8/19/04	<2.00	2.70	0.13	30	1.3E+09	0.022	0.001	0.532	0.026	126.4	14.3	0.1	NS	0.05
9/7/04	<2.00	1.50	0.10	266	1.7E+10	0.017	0.001	0.544	0.037	130.9	12.1	0.1	7.2	0.07
GeoMean				126	1.9E+10									
Mean	<2.00	2.75	0.73			0.022	0.008	0.554	0.164		13.2	0.1		0.28
Range	(<2.00)	(1.50 - 5.30)		(30 - 310)		(0.017 - 0.034)		(0.495 - 0.645)			(12.1-14.3)			(0.05-0.69)

NS = Not Sampled

HAPPY HOLLOW CREEK DATA

Wet Season

Date	BOD	TSS		FC		TP		N+N		Specific Conductance	Temp.	Salinity	pH	Flow
	(mg/L)	(mg/L)	(tons/yr)	(#/100mL)	(#/yr)	(mg/L)	(tons/yr)	(mg/L)	(tons/yr)	(uS)	(^{o}C)	(ppt)		(cfs)
1/5/2004	<2.00	<0.50	0.44	6	9.5E+09	0.011	0.019	0.278	0.484	65.5/62.1	3.9	0.0	NS	1.77
1/20/2004	<2.00	0.50	1.64	8	2.4E+10	0.007	0.023	0.136	0.447	46.6/42.8	7.6	0.0	NS	3.34
2/4/2004	<2.00	1.50	8.61	4	2.1E+10	0.009	0.052	0.085	0.488	39.7	6.9	0.0	NS	5.83
3/4/2004	<2.00	0.63	1.60	2	4.6E+09	0.017	0.043	0.193	0.490	60.5	7.5	0.0	NS	2.58
3/31/2004	<2.00	0.75	1.59	<2	1.9E+09	0.015	0.032	0.216	0.457	66.5	9.7	0.0	NS	2.15
GeoMean				3	8.4E+09									
Mean	<2.00	0.73	2.77			0.012	0.034	0.182	0.473		7.1			3.13
Range	(<2.00)	(<0.50-1.50)		(<2-8)		(0.007-0.017)		(0.085-0.278)			(3.9-9.7)			(1.77-5.83)

NS = Not Sampled

Dry Season

Date	BOD	TSS		FC		TP		N+N		Specific Conductance	Temp.	Salinity	pH	Flow
	(mg/L)	(mg/L)	(tons/yr)	(#/100mL)	(#/yr)	(mg/L)	(tons/yr)	(mg/L)	(tons/yr)	(uS)	(^{o}C)	(ppt)		(cfs)
7/8/04	<2.00	2.80	1.68	76	4.1E+10	0.026	0.016	0.376	0.226	103.2	10.2	0.0	NS	0.61
7/28/04	<2.00	1.00	1.02	46	4.3E+10	0.026	0.027	0.398	0.407	103.7	11.4	0.1	NS	1.04
8/19/04	<2.00	1.60	1.29	52	3.8E+10	0.026	0.021	0.390	0.315	103.9	11.1	0.1	NS	0.82
9/7/04	<2.00	0.50	0.61	160	1.8E+11	0.021	0.026	0.385	0.470	104.4	10.5	0.1	7.12	1.24
GeoMean				73	5.9E+10									
Mean	<2.00	1.48	1.15			0.025	0.022	0.387	0.354		10.8	0.1		0.93
Range	(<2.00)	(0.50 - 2.80)		(46 - 160)		(0.021 - 0.026)		(0.376 - 0.398)			(10.2-11.4)			(0.61-1.24)

NS = Not Sampled

HOLYOKE CREEK DATA

Wet Season

Date	BOD	TSS		FC		TP		N+N		Specific Conductance	Temp.	Salinity	pH	Flow
	(mg/L)	(mg/L)	(tons/yr)	(#/100mL)	(#/yr)	(mg/L)	(tons/yr)	(mg/L)	(tons/yr)	(uS)	(^{o}C)	(ppt)		(cfs)
1/5/2004	<2.00	2.00	5.83	4	1.1E+10	0.036	0.105	0.278	0.810	88.9/87.6	4.6	0.0	NS	2.96
1/20/2004	<2.00	<0.50	0.91	10	3.3E+10	0.025	0.091	0.271	0.982	64.7/64.0	7.4	0.0	NS	3.68
2/4/2004	<2.00	4.50	34.86	6	4.2E+10	0.025	0.194	0.265	2.053	34.4	6.7	0.0	NS	7.87
3/4/2004	<2.00	<0.50	0.79	<2	2.9E+09	0.035	0.111	0.213	0.673	82.0	7.9	0.0	NS	3.21
3/31/2004	<2.00	<0.50	0.65	<2	2.4E+09	0.036	0.093	0.157	0.406	82.9	10.4	0.0	NS	2.63
GeoMean				3	1.0E+10									
Mean	<2.00	1.45	8.61			0.031	0.119	0.237	0.985		7.4			4.07
Range	(<2.00)	(<0.50-4.50)		(<2-10)		(0.025-0.036)		(0.157-0.278)			(4.6-10.4)			(2.63-7.87)

NS = Not Sampled

Dry Season

Date	BOD	TSS		FC		TP		N+N		Specific Conductance	Temp.	Salinity	pH	Flow
	(mg/L)	(mg/L)	(tons/yr)	(#/100mL)	(#/yr)	(mg/L)	(tons/yr)	(mg/L)	(tons/yr)	(uS)	(^{o}C)	(ppt)		(cfs)
7/8/04	<2.00	1.20	3.63	68	1.9E+11	0.049	0.148	0.207	0.626	111.5	10.4	0.1	NS	3.07
7/28/04	<2.00	0.50	1.32	34	8.1E+10	0.051	0.135	0.191	0.504	109.3	10.2	0.1	NS	2.68
8/19/04	<2.00	0.87	2.19	18	4.1E+10	0.051	0.129	0.172	0.433	108.8	11.1	0.1	NS	2.56
9/7/04	<2.00	1.00	2.47	38	8.5E+10	0.050	0.124	0.175	0.432	109.1	10.2	0.1	7.29	2.51
GeoMean				35	8.5E+10									
Mean	<2.00	0.89	2.40			0.050	0.134	0.186	0.499		10.5	0.1		2.71
Range	(<2.00)	(0.50 - 1.20)		(18 - 68)		(0.049 - 0.051)		(0.172 - 0.207)			(10.2-11.1)			(2.51-3.07)

NS = Not Sampled

DEVERAUX CREEK DATA

Wet Season

Date	BOD	TSS		FC		TP		N+N		Specific Conductance	Temp.	Salinity	pH	Flow
	(mg/L)	(mg/L)	(tons/yr)	(#/100mL)	(#/yr)	(mg/L)	(tons/yr)	(mg/L)	(tons/yr)	(uS)	(^{o}C)	(ppt)		(cfs)
1/5/2004	<2.00	0.63	0.45	2	1.3E+09	0.009	0.006	0.660	0.474	70.9/70.4	2.8	0.0	NS	0.73
1/20/2004	<2.00	3.00	11.04	6	2.0E+10	0.012	0.044	0.389	1.432	42.9/42.9	6.6	0.0	NS	3.74
2/4/2004	<2.00	9.10	63.69	2	1.3E+10	0.023	0.161	0.322	2.254	37.4	6.1	0.0	NS	7.11
3/4/2004	<2.00	2.30	4.84	8	1.5E+10	0.018	0.038	0.357	0.752	49.5	7.1	0.0	NS	2.14
3/31/2004	<2.00	2.10	1.67	4	2.9E+09	0.014	0.011	0.419	0.334	62.1	10.3	0.0	NS	0.81
GeoMean				4	6.8E+09									
Mean	<2.00	3.43	16.34			0.015	0.052	0.429	1.049		6.6			2.91
Range	(<2.00)	(0.63-9.10)		(2-8)		(0.009-0.023)		(0.322-0.660)			(2.8-10.3)			(0.73-7.11)

NS = Not Sampled

Dry Season

Date	BOD	TSS		FC		TP		N+N		Specific Conductance	Temp.	Salinity	pH	Flow
	(mg/L)	(mg/L)	(tons/yr)	(#/100mL)	(#/yr)	(mg/L)	(tons/yr)	(mg/L)	(tons/yr)	(uS)	(^{o}C)	(ppt)		(cfs)
7/8/04	<2.00	27.00	0.27	532	4.8E+09	0.092	0.001	0.237	0.002	108.4	14.1	0.1	NS	0.01
7/28/04	NW	NW	NW	NW	NW	NW	NW	NW	NW	NW	NW	NW	NW	NW
8/19/04	NW	NW	NW	NW	NW	NW	NW	NW	NW	NW	NW	NW	NW	NW
9/7/04	<2.00	6.00	0.06	426	3.8E+09	0.032	0.000	0.031	0.000	123.0	14.6	0.1	6.09	0.01
GeoMean				476	4.3E+09									
Mean	<2.00	16.50	0.16			0.062	0.001	0.134	0.001		14.4	0.1		0.01
Range	(<2.00)	(6.0 - 27.00)		(426 - 532)		(0.032 - 0.092)		(0.031 - 0.237)			(14.1-14.4)			(0.01-0.01)

NS = Not Sampled
NW = No Water, Stream was dry.

MISSION CREEK DATA

Wet Season

Date	BOD	TSS		FC		TP		N+N		Specific Conductance	Temp.	Salinity	pH	Flow
	(mg/L)	(mg/L)	(tons/yr)	(#/100mL)	(#/yr)	(mg/L)	(tons/yr)	(mg/L)	(tons/yr)	(uS)	(oC)	(ppt)		(cfs)
3/4/04	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	
3/10/04	<2.00	0.63	20.72	2	6.0E+10	0.007	0.230	0.224	7.367	55.4	7.7	0.0	NS	33.41
3/24/04	<2.00	1.30	34.59	40	9.7E+11	0.015	0.399	0.202	5.375	64.5	9.0	0.0	NS	27.03
3/31/04	<2.00	0.25	6.65	6	1.4E+11	0.012	0.319	0.175	4.656	57.2	7.7	0.0	NS	27.03
GeoMean				8	3.9E+11									
Mean	<2.00	0.73	20.65			0.011	0.316	0.200	5.799		8.1			29.16
Range	(<2.00)	(<0.50-1.3)		(2-40)		(0.007-0.015)		(0.175-0.224)			(7.7-9.0)			(27.03-33.41)

NS = Not Sampled

Dry Season

Date	BOD	TSS		FC		TP		N+N		Specific Conductance	Temp.	Salinity	pH	Flow
	(mg/L)	(mg/L)	(tons/yr)	(#/100mL)	(#/yr)	(mg/L)	(tons/yr)	(mg/L)	(tons/yr)	(uS)	(oC)	(ppt)		(cfs)
7/8/04	<2.00	0.67	4.15	292	1.6E+12	0.018	0.112	0.244	1.513	101.2	14.0	0.0	NS	6.3
7/27/04	<2.00	0.50	2.41	56	2.5E+11	0.020	0.096	0.267	1.288	82.4	17.2	0.0	NS	4.9
8/17/04	<2.00	0.50	1.97	58	2.1E+11	0.017	0.067	0.211	0.831	81.5	14.8	0.0	NS	4
9/7/04	<2.00	0.83	4.00	64	2.8E+11	0.015	0.072	0.185	0.892	85.9	12.4	0.0	6.90	4.9
GeoMean				88	5.9E+11									
Mean	<2.00	0.63	3.13			0.018	0.087	0.227	1.131		14.6	0.0		5.03
Range	(<2.00)	(0.50 - 0.83)		(56 - 292)		(0.015 - 0.020)		(0.185 - 0.267)			(12.4-17.2)			(4.00-6.30)

NS = Not Sampled

STIMSON CREEK DATA

Wet Season

Date	BOD	TSS		FC		TP		N+N		Specific Conductance	Temp.	Salinity	pH	Flow
	(mg/L)	(mg/L)	(tons/yr)	(#/100mL)	(#/yr)	(mg/L)	(tons/yr)	(mg/L)	(tons/yr)	(uS)	(oC)	(ppt)		(cfs)
3/4/04	<2.00	0.50	2.74	2	1.0E+10	0.014	0.077	0.087	0.476	59.7	8.0	0.0	NS	5.61
3/10/04	<2.00	0.63	5.94	120	1.0E+12	0.005	0.047	0.125	1.179	56.0	8.5	0.0	NS	9.67
3/24/04	<2.00	2.50	11.41	52	2.2E+11	0.012	0.055	0.093	0.424	64.1	8.8	0.0	NS	4.68
3/31/04	<2.00	<0.50	1.24	56	2.6E+11	0.012	0.060	0.091	0.453	64.7	7.6	0.0	NS	5.10
GeoMean				29	1.6E+11									
Mean	<2.00	1.21	5.33			0.011	0.060	0.099	0.633		8.2			6.27
Range	(<2.00)	(<0.50-2.5)		(2 - 120)		(0.005-0.014)		(0.087-0.125)			(7.6-8.8)			(4.68-9.67)

NS = Not Sampled

Dry Season

Date	BOD	TSS		FC		TP		N+N		Specific Conductance	Temp.	Salinity	pH	Flow
	(mg/L)	(mg/L)	(tons/yr)	(#/100mL)	(#/yr)	(mg/L)	(tons/yr)	(mg/L)	(tons/yr)	(uS)	(oC)	(ppt)		(cfs)
7/8/04	<2.00	1.30	2.48	16	2.8E+10	0.018	0.034	0.096	0.183	87.6	13.2	0.0	NS	1.94
7/27/04	<2.00	1.70	2.13	12	1.4E+10	0.023	0.029	0.115	0.144	89.3	16.9	0.0	NS	1.27
8/17/04	<2.00	1.50	1.70	24	2.5E+10	0.020	0.023	0.101	0.114	90.3	14.4	0.0	NS	1.15
9/7/04	<2.00	1.00	1.16	28	3.0E+10	0.018	0.021	0.091	0.106	91.4	12.4	0.0	7.32	1.18
GeoMean				19	2.3E+10							0.0		
Arith Mean	<2.00	1.38	1.87			0.020	0.027	0.101	0.137		14.2	0.0		1.39
Range	<2.00	(1.00 - 1.70)		(12 - 28)		(0.018 - 0.034)		(0.091 - 0.115)			(12.4-16.9)			(1.15-1.94)

NS = Not Sampled

SHOOFLY CREEK DATA

Wet Season

Date	BOD	TSS		FC		TP		N+N		Specific Conductance.	Temp.	Salinity	pH	Flow
	(mg/L)	(mg/L)	(tons/yr)	(#/100mL)	(#/yr)	(mg/L)	(tons/yr)	(mg/L)	(tons/yr)	(uS)	(oC)	(ppt)		(cfs)
3/4/04	<2.00	<0.50	0.41	6	8.9E+09	0.011	0.018	0.131	0.214	55.8	8.0	0.0	NS	1.66
3/10/04	<2.00	<0.50	0.56	<2	2.0E+09	0.003	0.007	0.200	0.451	55.9	9.2	0.0	NS	2.29
3/24/04	<2.00	<0.50	0.56	<2	2.0E+09	0.007	0.016	0.109	0.246	57.7	8.8	0.0	NS	2.29
3/31/04	<2.00	<0.50	0.46	2	3.3E+09	0.008	0.015	0.152	0.278	59.3	8.0	0.0	NS	1.86
Geomean				3	3.3E+09									
Mean	<2.00	<0.50	0.26			0.007	0.014	0.148	0.297		8.5			2.03
Range	(<2.00)	(<0.50)		(<2-6)		(0.003-0.011)		(0.109-0.200)			(8.0-9.2)			(1.66-2.29)

NS = Not Sampled

Dry Season

Date	BOD	TSS		FC		TP		N+N		Specific Conductance.	Temp.	Salinity	pH	Flow
	(mg/L)	(mg/L)	(tons/yr)	(#/100mL)	(#/yr)	(mg/L)	(tons/yr)	(mg/L)	(tons/yr)	(uS)	(oC)	(ppt)		(cfs)
7/8/04	<2.00	0.50	0.11	76	1.6E+10	0.011	0.002	0.130	0.029	72.9	13.7	0.0	NS	0.23
7/27/04	<2.00	1.30	0.04	28	7.5E+08	0.016	0.000	0.143	0.004	74.8	18.6	0.0	NS	0.03
8/17/04	<2.00	<0.50	0.01	56	3.0E+09	0.011	0.001	0.136	0.008	76.1	16.0	0.0	NS	0.06
9/7/04	<2.00	<0.50	0.01	48	2.6E+09	0.011	0.001	0.141	0.008	77.0	14.2	0.0	7.43	0.06
GeoMean				49	3.1E+09							0.0		
Mean	<2.00	0.90	0.05			0.012	0.001	0.138	0.013		15.6	0.0		0.10
Range	(<2.00)	(<0.50 - 1.30)		(28 - 76)		(0.011 - 0.016)		(0.130 - 0.143)			(13.7 - 18.6)			(0.03 - 0.23)

NS = Not Sampled

TAHUYA RIVER DATA

Wet Season

Date	BOD	TSS		FC		TP		N+N		Specific Conductance	Temp.	Salinity	pH	Flow[1]
	(mg/L)	(mg/L)	(tons/yr)	(#/100mL)	(#/yr)	(mg/L)	(tons/yr)	(mg/L)	(tons/yr)	(uS)	(oC)	(ppt)		(cfs)
3/4/04	<2.00	5.3	506.2	8	6.9E+11	0.013	1.242	0.090	8.596	49.5	6.9	0.0	NS	97.04
3/10/04	<2.00	4.1	391.6	<2	8.7E+10	0.006	0.573	0.094	8.979	47.8	9.9	0.0	NS	97.04
3/24/04	<2.00	4.3	410.7	6	5.2E+11	0.013	1.242	0.071	6.782	54.5	9.1	0.0	NS	97.04
3/31/04	<2.00	3.9	372.5	2	1.7E+11	0.011	1.051	0.085	8.119	49.9	8.8	0.0	NS	97.04
GeoMean				5	2.7E+11									
Mean	<2.00	4.4	420.3			0.011	1.027	0.085	8.119		8.7			97.04
Range	(<2.00)	(3.9-5.3)		(<2-8)		(0.006-0.013)		(0.071-0.094)			(6.9-9.9)			(94.93-99.14)

NS = Not Sampled
(1) Flow measurements for March 2004 were averaged (n = 2).

Dry Season

Date	BOD	TSS		FC		TP		N+N		Specific Conductance	Temp.	Salinity	pH	Flow
	(mg/L)	(mg/L)	(tons/yr)	(#/100mL)	(#/yr)	(mg/L)	(tons/yr)	(mg/L)	(tons/yr)	(uS)	(oC)	(ppt)		(cfs)
7/8/04	<2.00	3.00	14.19	30	1.3E+11	0.006	0.028	0.036	0.170	114.60	14.2	0.1	NS	4.81
7/27/04	<2.00	1.30	5.13	28	1.0E+11	0.008	0.032	0.021	0.083	121.80	17.3	0.1	NS	4.01
8/19/04	<2.00	4.60	17.66	10	3.5E+10	0.017	0.065	0.021	0.081	84.10	16.7	0.0	NS	3.90
9/7/04	<2.00	4.00	18.15	36	1.5E+11	0.012	0.054	0.026	0.118	74.80	13.4	0.6	6.31	4.61
GeoMean				23	9.0E+10									
Mean	<2.00	3.23	13.78			0.011	0.045	0.026	0.113		15.4	0.2		4.33
Range	(<2.00)	(1.30 - 4.60)		(10 - 36)		(0.006 - 0.017)		(0.021 - 0.036)			(13.4-17.3)			(3.90 - 4.81)

NS = Not Sampled