KITSAP COUNTY HEALTH DISTRICT WATER QUALITY ANALYSIS OF HOOD CANAL SHORELINE DISCHARGES PART 1

1. INTRODUCTION AND BACKGROUND

1.1 Current Dissolved Oxygen Conditions in Hood Canal

Aquatic life needs dissolved oxygen in order to breathe. Southern Hood Canal has a history of low dissolved oxygen levels, which have caused periodic fish kills. Confirmed records of fish kills date back to the early 1960s and anecdotal records exist for the 1920s. Recent oxygen levels are among the lowest in recorded history, prompting increasing concerns about the long-term health of the canal.

In June and October of 2003, low-oxygen conditions killed thousands of juvenile perch and left numerous fishes, sea cucumbers and other marine life suffocating and dying. In winter, oxygen levels generally rebound with an exchange of water from the ocean. Monitoring performed by the Washington State Department of Ecology and the Hood Canal Salmon Enhancement Group show that hypoxic conditions may persist year-round in the southern portion, and the monitoring station in the north (Bangor) shows that hypoxia may be spreading north with conditions of biological stress for up to six months of the year (http://www.prism.washington.edu/hcdop/index.html 2005).

Hood Canal is a water body that is believed to be highly sensitive to eutrophication (i.e., it is "nitrogen limited" or very sensitive to the addition of nutrients, primarily nitrogen), in large part due to features inherent to the canal such as low flushing rates and frequent stratification (Newton, J., http://www.hoodcanal.washington.edu/aboutHC/scienceprimer.jsp?perPage=1&startIndex=0&View=&keyword=EDUPPT). When "excess" nutrients are added or discharged to the water, they cause algae blooms, which in turn consume oxygen from the water as they die and decompose.

There are both natural and anthropogenic (i.e., human-related) sources of nitrogen that are believed to be affecting Hood Canal's oxygen levels. Are human-related sources of nitrogen in the Hood Canal watershed worsening the low dissolved oxygen problems? And if so, what are the sources and levels of the human nitrogen contributions?

The Puget Sound Action Team (PSAT) and the Hood Canal Coordinating Council (HCCC) estimated the nitrogen contribution of human-related sources in the Preliminary Assessment and Corrective Action Plan (PACA) (PSAT and HCCC, Version 1, May 6, 2004 publication #PSAT04-06). The PACA theorizes that human sewage from onsite sewage systems (OSS) is the major source of nitrogen in Hood Canal, contributing between 39 and 241 tons annually. However, this was based on census data for the watershed, estimated values of wastewater generated by residents in the three-county area, and selected literature values of treatment efficiency for conventional OSS; it was not tied to empirical data. Several uncertainty factors related to the contribution of nitrogen are stated in the PACA, including: nitrogen contribution of failing OSS, impact of concentrated shoreline homes, the amount of nitrogen from upland homes compared to shoreline homes, and plant or stream biota uptake of nitrogen in soils or shallow groundwater aquifers.

The Hood Canal Dissolved Oxygen Program's Integrated Assessment and Modeling Study currently has an investigation in progress to coordinate marine and fresh water monitoring efforts, evaluate nutrient loading estimates and Hood Canal flushing rates, evaluate climate and ocean effects on the dissolved oxygen problems, better understand biota sensitivities, and to develop corrective actions.

This project was the Kitsap County Health District's initial study and investigation to ascertain OSS nutrient fate and transport to Hood Canal from about one half of the Kitsap County shoreline affecting Hood Canal.

1.2 Nutrients and Onsite Sewage Systems

State OSS treatment standard requirements, for both development applications and to review and approve OSS treatment technologies, include biological oxygen demand (BOD), carbonaceous oxygen demand (COD), total suspended solids (TSS), and fecal coliform bacteria (FC). Properly designed, sited, installed, and maintained *conventional* OSS (i.e., standard gravity systems consisting of a septic tank and drainfield) are highly effective (>90%) at removing and reducing pathogens, TSS, and BOD (USEPA, 2002).

Nitrate nitrogen can be a ground and surface water contaminant that causes a public health. It is a public health concern if present in drinking water above 10 mg/L, where it can cause methemoglobinemia (i.e., "blue baby syndrome"), although its occurrence is rare. Washington state has used minimum lot size requirements since 1974 to address this public health concern with required setbacks of onsite sewage system (OSS) drainfields to wells.

Nitrogen is a nutrient, which at high levels in marine waters promotes algae growth, and eutrophication. Excess algae growth consumes oxygen when algae dies and decomposes. Wastewater from toilets delivers about 75% of the nitrogen source to the OSS in the form of inorganic ammonia-nitrogen and organic nitrogen. Other nitrogen sources include food wastes and laundry water.

OSS design and installation is based on the fate and transport of wastewater pollutants through soil. The soil and the biomat that forms at the drainfield's interface with the soil are critical in treating pathogens and nutrients. A significant portion of nutrient treatment occurs in the drainfield soil. Anaerobic conditions in the septic tank convert most of the nitrogen in raw sewage to ammonia. When the septic tank effluent is sent to the drainfield, aerobic conditions at the soil interface converts the ammonia to nitrite and then nitrate; this process is called nitrification (USEPA, 2002).

The PACA nitrogen calculations for Hood Canal were based on the assumption that conventional OSS remove little of the nitrogen in septic tank effluent, approximately 30-70%. However, there are studies that demonstrate nitrate decreases as the effluent migrates through the soil. Microbial denitrification occurs in the soil and dilution can also occur. Drainfields are typically installed in the upper two feet of soil, and the vegetative cover above and near the drainfield will utilize much of the nitrogen (Salvato, 2003 and Viraraghavan and Warnock, 1976).

Many uncertainty factors are apparent regarding fate and transport of nutrients in Hood Canal and nationwide. The nitrogen removal efficiency is highly variable dependent on many factors including: OSS treatment type, design, installation, location, operation and maintenance, waste strength, water use, source water chemistry, disposal soil characteristics, surrounding vegetation (or lack thereof); and groundwater and surface water conditions including proximity to these waters.

Previously reported studies of OSS nutrient transport have been performed in the Pacific Northwest. These studies found nitrogen concentrations in down gradient groundwater samples similar, or reduced, and highly effective nitrogen removal rates by OSS. They stress that attenuation processes occurring during groundwater transport within the unsaturated soil horizon are responsible for high nitrogen removal rates.

A study by Patmont, Pelletier, Welch, Banton, and Ebbesmeyer in Lake Chelan showed two of seven test sites had nitrogen removal rates of 100 +/- 3% and two had 99 +/- 3% removal. The overall removal rates of nitrogen by OSS averaged 89 +/- 7%. Nitrogen removal was not correlated with depth to water, but appeared to be somewhat correlated with local hydraulic conductivity. The study notes that less permeable soils appear to better remove nitrogen, possibly due to greater residence time within the shallow vegetative root zone and associated plant uptake (Patmont, 1989). Hart Crowser cited nitrogen uptake by plants in shallow groundwater systems in Black Diamond, Washington, “owing to the general deficiency of this plant nutrient in regional soil systems” (Gessel, et.al., 1969; Harper-Owes, 1985). At the study sites on Lake Sawyer overall average nitrogen attenuation was 78.6 +/- 10.7%. Some sample sites showed 100% removal (Hart Crowser, 1990).

Recently passed Washington state regulation Chapter 246-272A WAC requires jurisdictions to develop plans by July 2007 to address local environmental concerns like nutrient pollution and low dissolved oxygen. The regulations include an effluent quality based nutrient standard and a framework for testing and certifying OSS treatment products for nutrient reduction.

Technologies have been readily available, and widely used, to reduce nitrogen in wastewater at municipal wastewater treatment plants for more than 30 years. Nitrogen reducing technologies are expensive and require constant maintenance and oversight, and have been limited to municipal treatment plants where the costs are spread out among many customers, and a public or private entity is commissioned to provide the constant oversight required. These technologies are being translated for individual and small community OSS use. Up to this point, their effectiveness and installation and maintenance costs have generally not proven to be a substantial improvement above properly sited conventional OSS (USEPA, 2002 and University of California, Davis, 2002)

Many questions remain. What are the nutrient impacts from OSS of properly functioning OSS and of failing OSS? And does repairing a failing OSS result in reduced nutrient impacts? Can anthropogenic source reduction favorably impact the low dissolved oxygen problem in Hood

Canal? If so, what technology is available? Are there existing OSS technologies or design and installation factors that are effective in reducing nutrients?

1.3 Onsite Sewage System Regulations in Kitsap County

Kitsap County adopted local OSS regulations by ordinance in1961 (Bremerton-Kitsap County Department of Health, Rules and Regulations for Construction and Installation of Individual Sewage Disposal Systems, Kitsap County Ordinance No. 27-1961). The first state OSS regulations were adopted in 1974. OSS regulations have been revised or amended at the state and county levels multiple times since then, with each set of regulations generally more stringent then the ones they replaced (1978, 1980, 1982, 1985, 1989, 1995, 1996, 1998, and most recently in 2005). Kitsap County was one of the first counties in Washington to adopt operation and maintenance requirements for new and existing OSS in 1995; alternative (or advanced treatment) OSS are required to have an annual maintenance contract with a certified maintenance specialist, while standard gravity OSS are required to have their septic tank inspected, and pumped if necessary, every three years.

There are an estimated 60,000 OSS in Kitsap County that serve both residential and commercial development (more than 95% residential and less than 5% commercial). The majority of these OSS were permitted through the Kitsap County Health District, which means that they were designed and installed to meet the applicable regulations in effect at the time of development or repair.

Nearly 100% of OSS installed (new or repair) prior to 1961 up to the early 1990's were standard gravity OSS with at least 1 foot of vertical separation (the distance between the bottom of the drainfield and the highest seasonal water table or restrictive soil layer). From the early 1990's until the adoption of the new State OSS Regulations in 1995, standard gravity OSS were allowed with at least 2 feet of vertical separation, and pressure distribution OSS were required for sites with only 1 to 2 feet of vertical separation, provided that the standard horizontal setbacks to items like wells and surface waters were met. From 1995 to present, alternative OSS meeting Treatment Standard 2 (effluent discharge quality prior to the drainfield distribution system of 10 mg/ml TSS, 10 mg/ml BOD, and 800 FC/100ml) have been required for sites with 1 to 2 feet of vertical separation, pressure distribution for 2-3 feet vertical separation, and standard gravity OSS for sites with at least 3 feet of vertical separation when all of the standard horizontal separation requirements have been met.

Approximately 20% or less of OSS installed since 1995 have qualified for a Class B Vertical Separation Waiver, which allows standard gravity OSS for sites with 18 inches or greater vertical separation, or pressure distribution OSS for sites with 12 to 18 inches vertical separation, provided that special criteria including increased horizontal separations to surface waters and wells could be met.

The current 100-foot horizontal separation requirement between OSS drainfields and wells or surface waters has been in effect since 1974. Between 1961 and 1974, a 50-foot horizontal separation was required between drainfields and wells or surface waters. Class B waivers increase the minimum horizontal separations to 150 feet for surface waters and 200 feet for individual wells.

1.4 Other Onsite Sewage Considerations for Kitsap County

Water quality monitoring performed by the Kitsap County Health District (KCHD) and Washington State Department of Health (WSDOH) in the project area have determined marine and stream monitoring stations to be relatively good for water quality in terms of FC contamination. The Washington State Department of Health (WSDOH) has classified the shellfish beds as approved for the entire shoreline in the project area, with the exception of small closure zones in Holly, Kinman Creek, Jump-Off Joe Creek and Lofall (WSDOH, 2005).

KCHD marine water quality monitoring performed 1995-2004 shows that all eight nearshore marine monitoring stations in the project area meet the State Water Quality Standard for FC. Additionally, five of six stream mouth water quality monitoring stations meet the State Water Quality Standards for FC. Although Seabeck Creek recently failed the FC standard (Part 2), it has met the FC standard six of the past nine years, and is exhibiting an improving trend (KCHD, 2005).

Based on this FC information, there has been no evidence to suggest that failing OSS or systems providing inadequate bacterial treatment are prevalent or a problem in the Kitsap County portion of Hood Canal. In fact, the Hood Canal 2005 project shows a very low failure rate of 3% (eleven failures out of the 340 residences) in the project area.

General soil conditions are recognized as good for OSS treatment due to the presence of fine sands and silts, but possibly limited for hydraulic movement or “disposal” due to silts and the widespread presence of a “hardpan” layer at 24 to 60 inches of soil depth (USEPA, 2002 and USDA, 1980).

Because of these soil conditions and the siting and design requirements of state and local OSS regulations, OSS drainfields in Kitsap County are predominantly installed in the upper 12 inches of soil in order to maximize vertical separation, and are well within the vegetation root zone. Additionally, except in the cases of repairs or OSS installed prior to 1974, OSS drainfields are predominantly located at least 75 feet from surface waters, and most often greater than 100 feet (the required horizontal setback as of 1974).

2. PROJECT DESCRIPTION AND GOALS

The relationship between OSS and the discharge of fecal coliform (FC) bacteria are well understood. A failing, inadequate OSS will discharge untreated wastewater containing high levels of fecal bacteria. However, the relationship between a properly working OSS, operating under existing Federal, State and Local regulations, which does not meet the criteria for “failure” and the nutrients discharged to adjacent surface waters is poorly understood. This relationship is further complicated by the high variability in drainfield site conditions, OSS type, OSS use and the surrounding geology and hydrology. This project serves as a baseline for data collection of shoreline discharges for the purposes of identifying sources of FC pollution and, to a limited degree, the nutrient concentrations of shoreline discharges to Hood Canal. The relationship between nutrients and FC pollution will be explored on a shoreline with both properly working OSS and failing OSS.

This project has four distinct goals:

- Reduce FC pollution into Hood Canal along Kitsap County's shoreline from a variety of sources including failing OSS and inadequate animal waste management, from Warrenville south to the county line.
- Provide water quality data to determine if there is a correlation between FC levels and nutrients in freshwater discharges to the marine shoreline.
- Provide water quality data to determine if correction of FC sources also nets reductions in nutrients.
- Educate residents of the Upper Hood Canal watershed about the low dissolved oxygen problem and actions they can take to reduce bacterial and nutrient impacts to Hood Canal.

This project is designed to reduce oxygen demand and nutrient contamination to Hood Canal in the Upper Hood Canal watershed. The specific objectives of the shoreline survey are to:

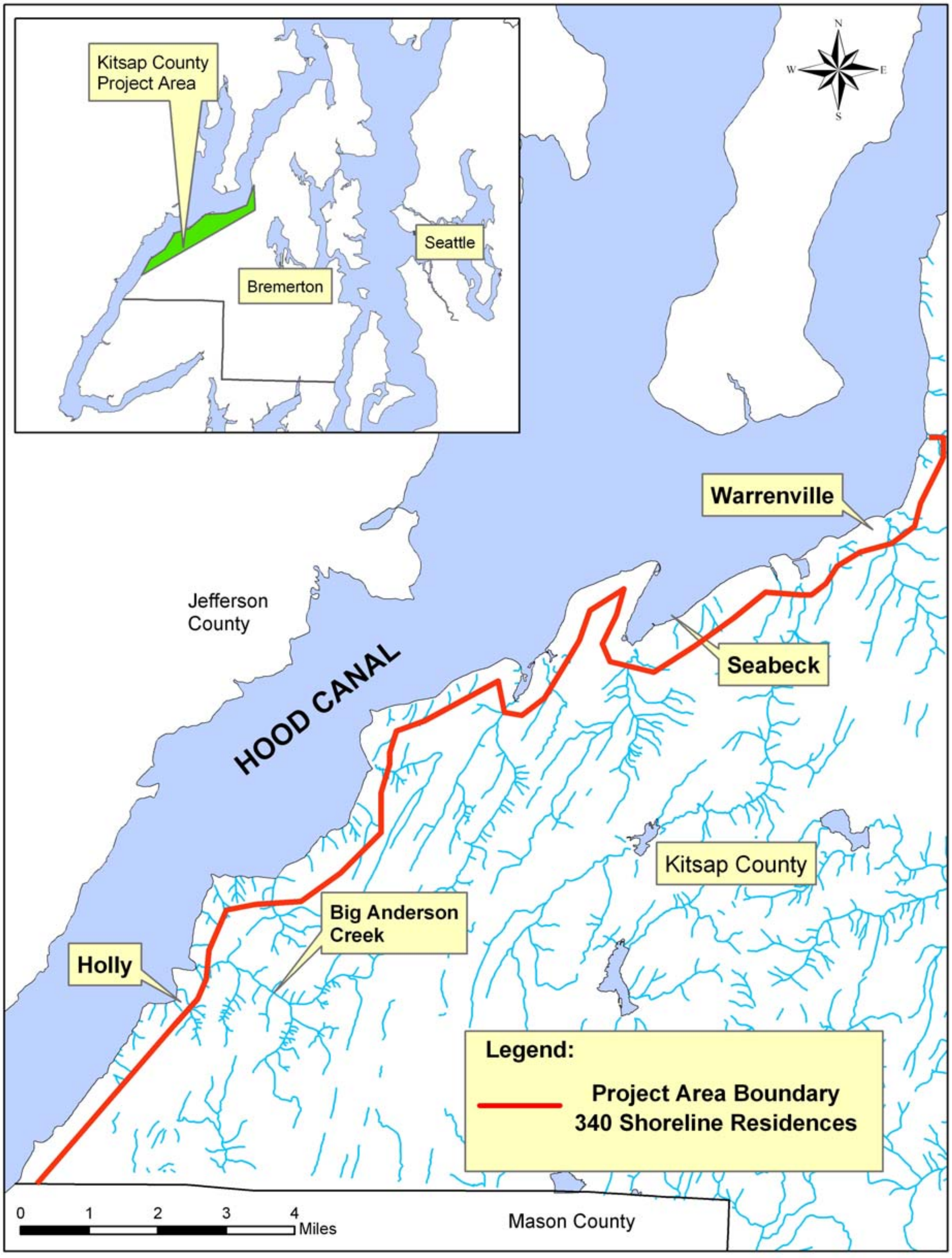
- Reduce oxygen demand and nutrient contamination from Big Anderson Creek and the Hood Canal shoreline from Warrenville south to the Kitsap County line by identifying and correcting FC pollution sources;
- Measure FC and nutrient concentrations of freshwater discharges to the marine shoreline; and
- Determine FC and nutrient concentrations of freshwater discharges for FC pollution sources before and after FC source correction.

This report will present preliminary results for shoreline water quality samples collected during 2005. It should be noted that this was a small, limited scope project that attempts a first step to investigate the theoretical estimation contained in the PACA concerning OSS nutrient impacts to Hood Canal. The findings of this project may be used as a baseline and platform for additional investigations aimed at characterizing and quantifying nutrient discharges to Hood Canal from OSS or other human sources as measured in shoreline discharges. This report does not include OSS post-correction monitoring for nutrients and fecal bacteria from failing OSS. A final report including post-correction monitoring will be completed in 2006.

3. PROJECT AREA DESCRIPTION

The northern boundary of the project area is Ioka Way in Silverdale, north of Seabeck, and the southern boundary is the Kitsap-Mason county border, south of Holly. Figure 1 shows the project area.

Figure 1. Kitsap County Health District Hood Canal Project Area



4. PROJECT DESIGN AND METHODS

The “Hood Canal Shoreline Survey Quality Assurance Project Plan” ([KCHD January 24, 2005, QAPP) was approved by the PSAT and the US Environmental Protection Agency. Data was collected and analyzed according to the QAPP. Shoreline sample collection and property survey methods are further described in the “Manual of Protocol: Fecal Coliform Bacteria Pollution Identification and Correction” KCHD, Version Nine, November 2003 *(PIC Protocols*).

4.1. Project Area Details

The shoreline survey was divided into nine (9) segments. The segments, locations, segment shoreline length in miles, number of residences and density expressed as residences per 0.1 mile are shown in Table 1. Figures 2, 3, and 4 show the locations of the segments. The total shoreline sampled was 9.0 miles with 340 shoreline residences. Segments 3, 4, 5, and 8 were the most densely developed shorelines with between 4.8 and 6.4 residences per 0.1 mile.

Approximately 4 miles of undeveloped shoreline in the project area were not surveyed. Shorelines with no residences were not surveyed because the goal of the project was to sample for FC and nutrient impacts from shoreline residences. Due to the limited funding of this project developed areas upland of undeveloped shorelines may impact shoreline these areas were considered a lesser priority and were not included in this study. Evaluation of shoreline discharges monitors the potential influence of OSS treatment, natural attenuation by soils and plants, and lot sizes. Additionally, the prevalence of hardpan observed at 24-60” depth in the project area may indicate that groundwater is discharged at the near shore environment, rather than through the surface well below the low tide region.

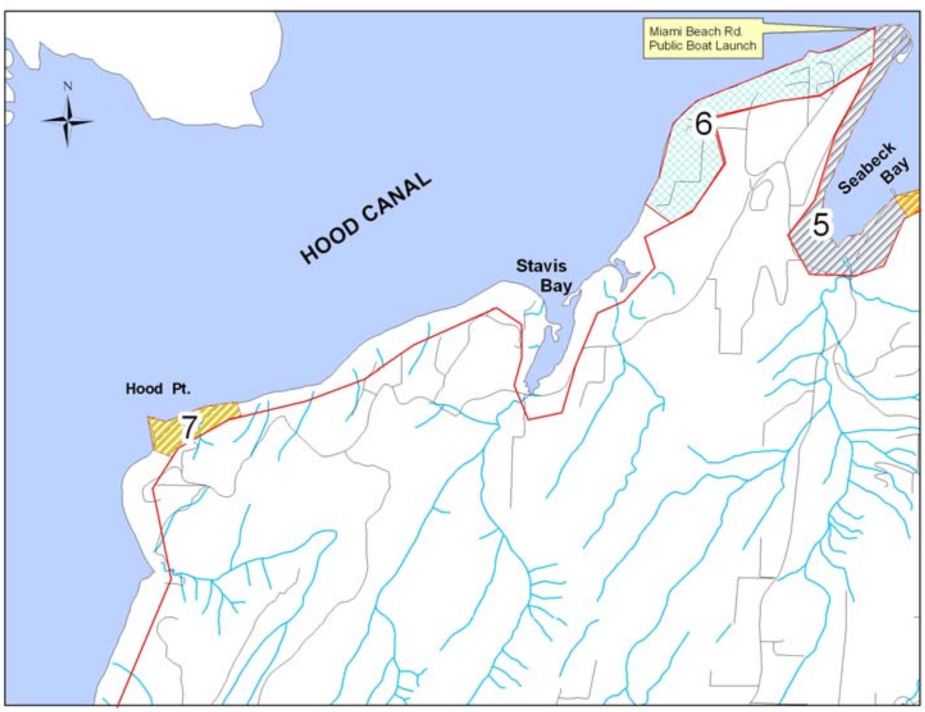
Table 1. Kitsap Hood Canal Shoreline Survey Areas

Segment	Starting Point	Finishing Point	Length of Shoreline (Miles)	Number of Residences	Residences Per 0.1 Mile
1	Ioka Drive	Little Anderson Creek	1.0	21	2.1
2	Little Anderson Creek	Big Beef Creek	1.5	37	3.1
3	Big Beef Creek	Little Beef Creek	0.4	22	5.5
4	Little Beef Creek	Seabeck Marina	1.6	102	6.4
5	Seabeck Marina	Misery Point Boat Ramp	1.2	63	5.3
6	Misery Point Boat Ramp	Sunset Lane	1.5	26	1.7
7	Stavis Bay	Hood Point Road	0.6	14	2.3
8	Big Anderson Creek	Holly Road	1.0	48	4.8
9	Forest Springs Road	Forest Springs Road	0.2	7	3.5
Totals			**9.0**	**340**	**3.8**

Figure 2. Kitsap Hood Canal Shoreline Survey Segments 1 through 6

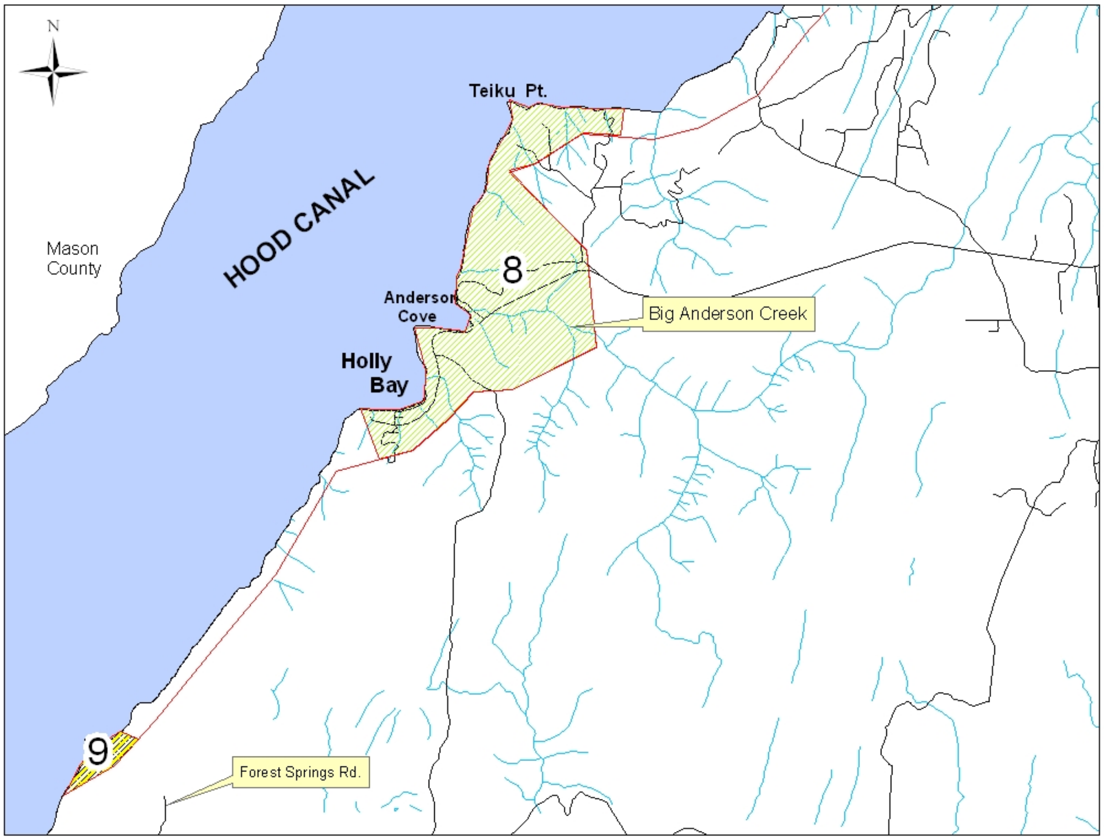
Shaded areas denote developed shoreline areas, which were surveyed

Figure 3. Kitsap Hood Canal Shoreline Segments 5 through 7



Shaded areas denote developed shoreline areas, which were surveyed

Figure 4. Hood Canal Shoreline Segments 8 and 9



Shaded areas denote developed shoreline areas, which were surveyed

4.2. Shoreline Sampling

FC bacteria are an indicator of human and animal waste and at elevated levels are indicative of significant contamination. FC contamination of surface waters increases the risk of disease from water contact or consuming shellfish. All discharges from curtain drains, bulkhead drains, drainage culverts, overland flows, and significant beach flows that appeared to originate from the nearshore property were sampled for FC during low tide in each shoreline segment. Samples were collected at low tide in order to target the discharge of freshwater versus the drainage of residual marine water.

Nitrogen undergoes transformations within and below the subsurface soil absorption trenches in the drainfield. These transformations include adsorption of ammonia in the soil, volatilization of ammonia in alkaline soils (common in the Hood Canal region), conversion of ammonia to nitrate nitrogen, and biological uptake of both ammonia and nitrate nitrogen by plants, and conversion of nitrate nitrogen to nitrogenous nitrogen. Studies of nitrogen immediately beneath the drainfield trenches demonstrate that most of the ammonia nitrogen is converted to nitrate and nitrite nitrogen due to the aerobic environment (UC Davis, 2002). Therefore, nitrate nitrogen, and the less abundant form, nitrite nitrogen, were selected as the nutrients for analysis in shoreline discharges.

Shoreline discharges with high FC levels and suspected failing OSS were sampled for nitrate +nitrite nitrogen, ammonia nitrogen and ortho-phosphorus. Ortho-phosphorus is the biologically available form of phosphorus, a nutrient common in the environment from soils and from human laundry products and sewage effluent. It is transported less readily from the OSS drainfield through alkaline soils due to adsorption to soil particles (Patmont, 1983). The presence of elevated ammonia nitrogen and ortho-phosphorus can be indicative of incomplete OSS treatment.

Segments 3 and 4 were calculated to be the most densely developed shorelines in the project area. Therefore, this area was selected for sampling of FC, nitrate+nitrite nitrogen and flow. Every shoreline discharge encountered in the shoreline survey of the areas shown in Figure 9 was sampled. This area had shoreline of high, medium and low bank. Flow data was collected by the bucket and stopwatch method when possible. The lowest measured flows were 0.01 gallons per minute. If the flow was determined to be very low then a flow rate of 0.1 gallons per minute was assigned for the purpose of determining loading calculations. This assignment is ten orders of magnitude higher than the lowest measured flows and produces an overestimation of the loading calculations. Three sampling events were conducted of the same 55 discharge sites in the areas indicated in Figure 9.

The nutrient composition of discharges from failing OSS is unknown. These “impact” sites, FC contaminated discharge sites from confirmed failing OSS, were sampled for the more complete suite of nutrients along with FC: nitrate+nitrite nitrogen, ammonia nitrogen and ortho-phosphorus. Corresponding low FC drainages nearby (control sites) were sampled for each impact site at the same time. Sampling was performed during wet season dry weather events occurring from February to April 2005. The control and impact sites will be sampled in February to April 2006 after FC source correction efforts are performed. These drainages have been sampled from one to three events and preliminary data representing before FC source correction conditions will be presented in this report.

4.3. Property Surveys

High FC drainages may be indicative of failing OSS and were investigated. Using established methods described in the *PIC Protocols*, property owners adjacent and sometimes upland of the high FC drainage were contacted. OSS dye testing is conducted to rule out a hydraulic connection between the OSS and high FC discharge. Activated charcoal packets are placed in the location of the high FC or greywater discharge. One week later these background charcoal packets are replaced. Dye is introduced to the OSS. If dye appears in the discharge or analysis reveals that dye is present in the charcoal packet, the OSS is determined to be failing.

A total of 50 properties were targeted for OSS surveys in the project area along with one public complaint and one repair plan. Besides investigating fifteen properties associated with high FC drainages, thirty five additional properties were contacted for OSS surveys. From 1999 to 2004 the Washington State Department of Health performed shoreline surveys of the study area in order to classify the area for commercial shellfish harvesting (WSDOH, 2005). Their survey resulted in a shellfish closure zone near 532 Allen King Rd W. in Holly and identified eighteen properties as “potential FC sources of concern”. Properties located in the Big Anderson Creek drainage were also surveyed due to 2003 declines in water quality at the mouth of the creek. Several properties requested OSS surveys during neighborhood workshops or were the result of a citizen sewage complaint or repair plan filed with the Health District.

5. RESULTS AND DISCUSSION

5.1. Identifying High FC Drainages of Kitsap Hood Canal Shoreline Discharges

5.1.1. FC Sampling of Shoreline Discharges

Shoreline discharge samples were collected on six different days between January 30, 2005 and February 14, 2005. Usually, two staff teams collected samples on each day. Detailed field notes, photographs and global positioning systems waypoints were collected in support of samples. On several occasions interviews and discussions were also made with shoreline property owners.

Surface water quality standards are established by the Washington Department of Ecology (Ecology) in Chapter 173-201A of the Washington Administrative Code (WAC). Freshwater in the Hood Canal Watershed is designated as “Extraordinary Primary”. Part 1 of the standard states that FC concentrations shall not exceed an average concentration of 50 FC/100 milliliters and Part 2 of the standard states that not more than 10% of samples shall exceed 100 FC/100 ml. The action level of discharges to the shoreline according to the *PIC Protocols* is twice the Part 2 FC standard. Therefore, the action level is 200 FC/100 ml of sample.

A total of 228 identified drainages were sampled. Eleven (11) discharges from shoreline segments 1 through 9 were above the 200 FC/100 ml action level. Table 2 summarizes the results. Segment 2 had by far the least discharges for each mile of shoreline with only four. Segment 2 is characterized by high banks with most water diverted north to Little Anderson Creek and south to Big Beef Creek. Alternatively, Segment 4 had a large number of drainages with 53 per mile.

Table 2. Kitsap Hood Canal Project Area Shoreline FC Discharge Results

Segment	Drainages per Mile[1]	Number of Drainages Sampled	Drainages greater than 200 cfu/100ml
1	26	26	0
2	4	6	0
3	23	9	0
4	53	84	6
5	17	20	2
6	25	37	1
7	23	14	0
8	26	26	2
9	30	6	0
Total		**228**	**11**

[1]Calculated per mile for comparison purposes.

Two greywater failures were identified during the shoreline survey by observing laundry discharges. Both greywater discharges were low for FC, 27 and 30 FC /100ml, and are not included in the drainages with high FC. However, they are included in the total count for failing OSS for the project. Both have been corrected by the property owners.

5.1.2. Confirmation FC Sampling of Shoreline Discharges

Confirmation samples were collected from the eleven drainages greater than 200 FC/100ml . The drainages were prioritized according to the *PIC protocols* using the geometric mean of the two samples. Nine of the eleven drainages were classified as High Priority with a geometric mean greater than 500 FC/100ml. Two drainages were classified as Low Priority with a geometric mean of less than 200 FC/100ml. Table 3 summarizes the results.

Table 3. Kitsap Hood Canal Project Area Confirmation Sampling of High FC Drainages

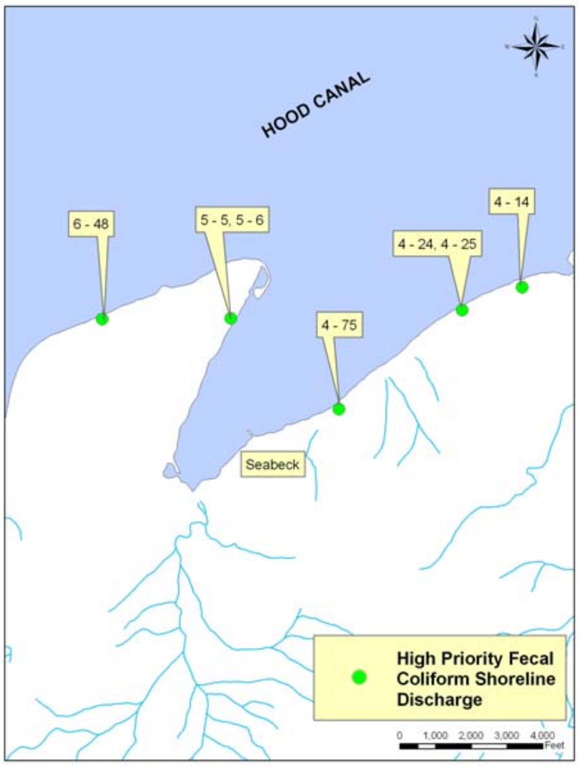
Drainage Identification	Event 1 FC/100ml	Event 2 FC/100ml	Geometric Mean FC/100ml
4-14	>1600	>1600	1600
4-24	>1600	240	620
4-25	>1600	900	1200
4-26	>1600	23	192
4-75	>1600	900	1200
4-78	>1600	13	35
5-5	1600	1600	1600
5-6	>1600	1600	1600
6-48	>1600	900	1200
8-10	>1600	50	504
8-11	1600	280	501

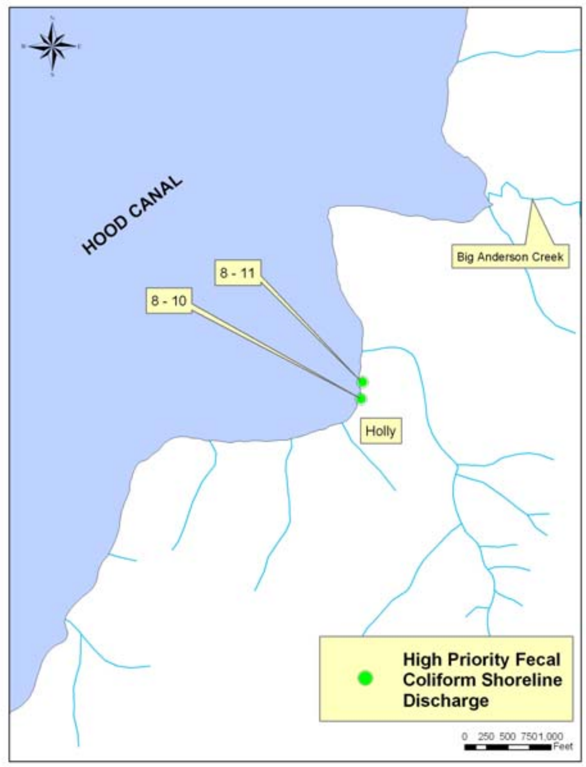
Shaded cells denote high priority drainages

The first number of the drainage nomenclature is the segment and the second number is the site number. Sites were numbered consecutively from north to south in the segment.

The nine High Priority drainages were investigated for pollution source identification and correction according to the *PIC Protocols*. Their locations are shown in Figures 5 and 6. As of September 2005 eight of the nine high priority drainages have been confirmed to be failing OSS through positive dye tests. A total of six failing OSS were identified, with two repaired and four in the repair process. The remaining drainage (8-11) resulted in negative dye tests of two OSS and will be resampled and reviewed during the winter of 2005-2006.

Figures 5 and 6. Locations of High Priority FC Drainages





5.2. FC and Nutrient Sampling of a Subset of Kitsap Hood Canal Shoreline Discharges

5.2.1. Description of the Sampling Events

Segment 3 and a portion of Segment 4 were identified to be the shorelines in the project area with the highest concentration of homes and smallest lot sizes. This determination was made by calculating the density as shown in Table 1. Density was determined by identifying properties in the field, and by geographic informations system imagery of plat overlays. Example shoreline aerial photos of a section of Segment 3 and Segment 4 are shown in Figures 7 and 8, respectively (Courtesy of Ecology, http://www.ecy.wa.gov/programs/sea/sma/atlas_home.html).

Segments 3 and 4 are located south of Big Beef Creek and north of the Seabeck Marina. Figure 9 shows the areas sampled for FC and nitrate + nitrite nitrogen. The study areas are not connected due to access issues. During non-rain events, the shoreline sample points were flowing indicating the discharges were likely representative of shallow groundwater.

Figure 7. Segment 3 Shoreline, South of Big Beef Creek

Photo courtesy of Ecology

Figure 8. Segment 4 Shoreline, North of Seabeck Marina

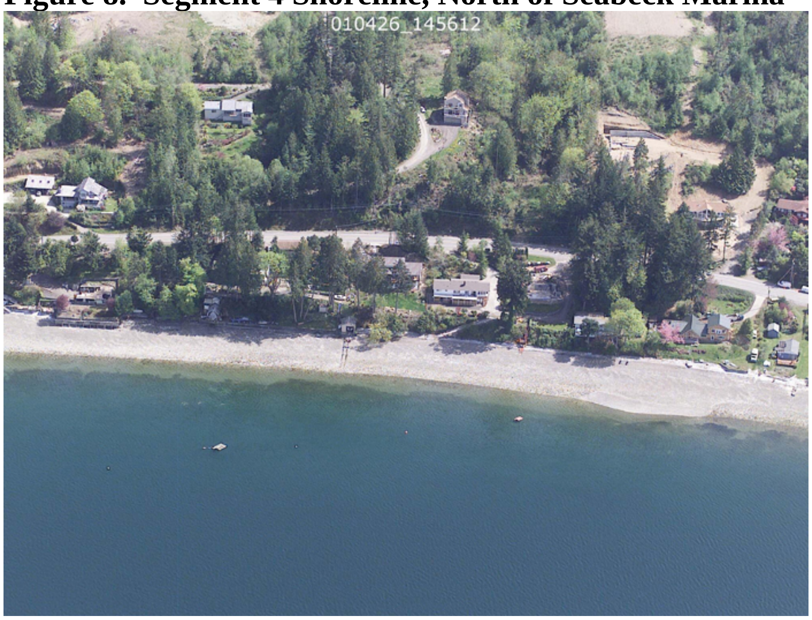
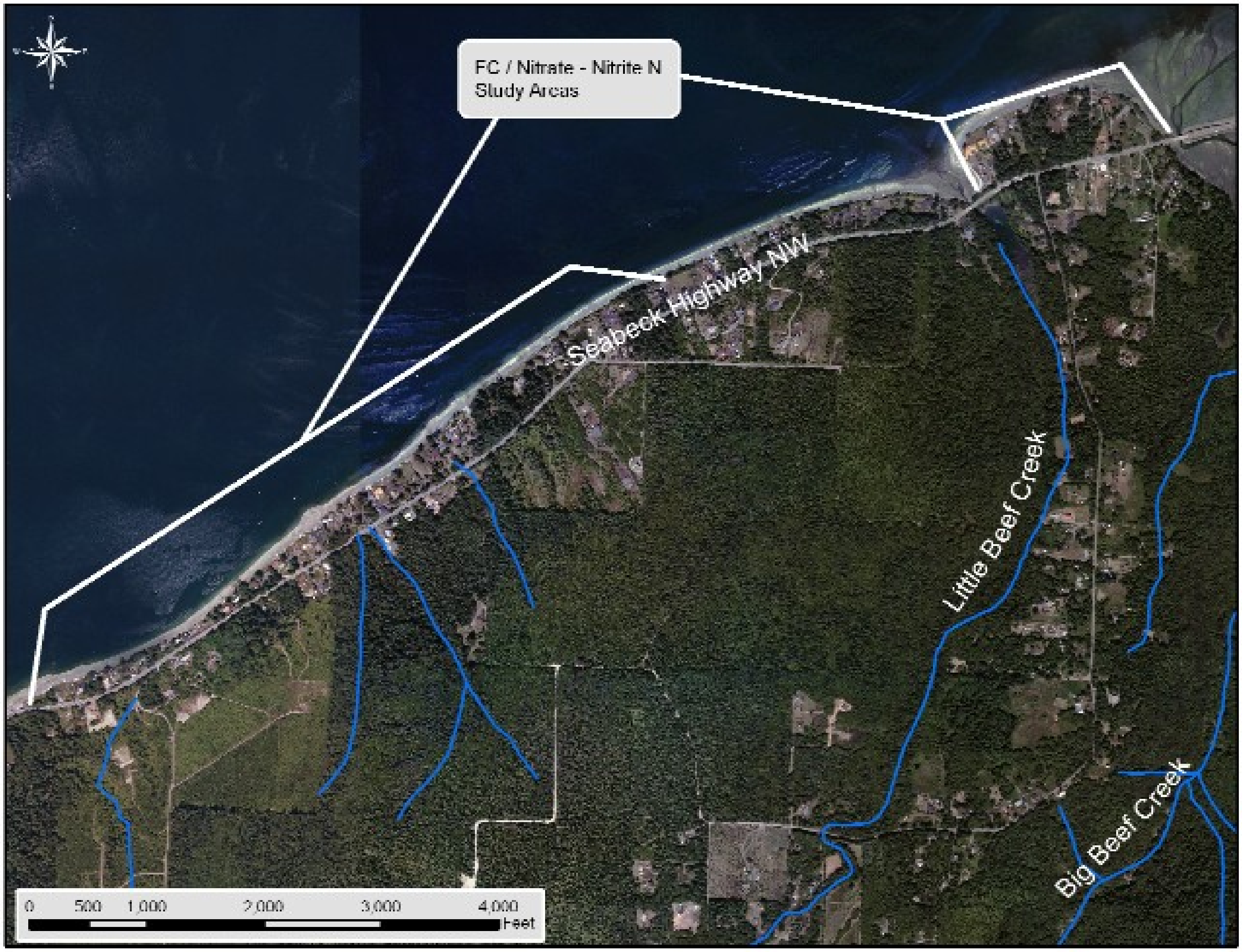


Photo courtesy of Ecology

Figure 9. Kitsap Hood Canal Shoreline Sampled for FC and Nitrate+Nitrite Nitrogen



Shoreline surveys are performed during low tides in order to access a long stretch of beach during the daylight hours for collecting samples. The time of year in which these surveys were performed provided limited daylight low tide windows for sampling. Therefore, due to the limited timeline (late January through late April) shoreline sampling was performed under a variety of weather conditions: dry, moderate and heavy rainfall events. Rainfall events were targeted in coordination with low-tide sequences in order to target surface and groundwater discharges.

Table 4. Rainfall Depth Prior to Sampling Event from KPUD Station 40, Seabeck, WA

Sampling Date	24 hour previous rain total (inches)	48 hour previous rain total (inches)	72 hour previous rain total (inches)	1 week previous rain total (inches)	Category of Event
January 30, 2005*	0.00	0.00	0.17	0.22	Dry
January 31, 2005*	0.00	0.17	0.17	0.22	Dry
March 2, 2005	0.07	0.67	0.67	0.67	Moderate
April 13, 2005	0.07	0.47	0.61	1.18	Heavy

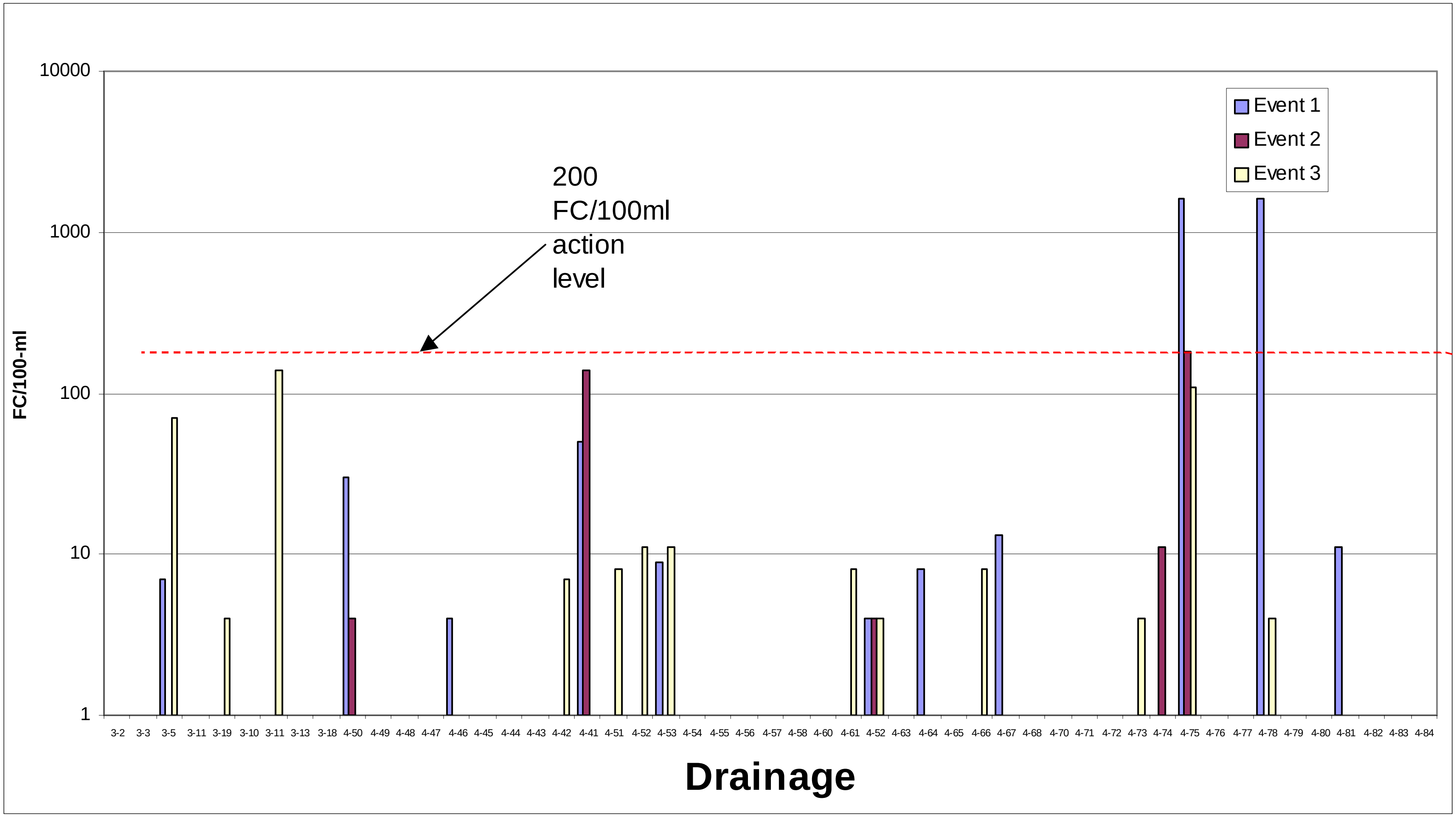
*January 30 and 31 are combined for one sampling event
Rainfall data provided by Kitsap Public Utility District #1 (KPUD)

A total of 55 drainages were sampled each on January 30, 31; March 2; and April 13, 2005 for a total of three separate sampling events. The three sampling events were categorized according to the total rainfall depth for one week prior to the sample date as summarized in Table 4. The first event conducted January 30 and 31 was categorized as "dry" since only 0.22 inches of rain fell in the previous week. The second event, March 2, 0.67 inches of rain fell in the previous week and was categorized as "moderate". The third event, April 13, 1.18 inches of rain fell in the previous week and was categorized as "heavy". These categories are referred to in the presentations of results.

5.2.2. Kitsap Hood Canal Shoreline Special Study Area FC and Nutrient Results

Fifty-five sites were sampled for the first event January 30 and 31, 2005. However, three sites were omitted from the March and April events due to lack of flow, and one site was lost due to a landslide after the first sampling event. Therefore, data for 51 discharge sites are presented. Figure 10 shows the FC results for the 51 sites (Note: the graph utilizes a logarithmic scale).

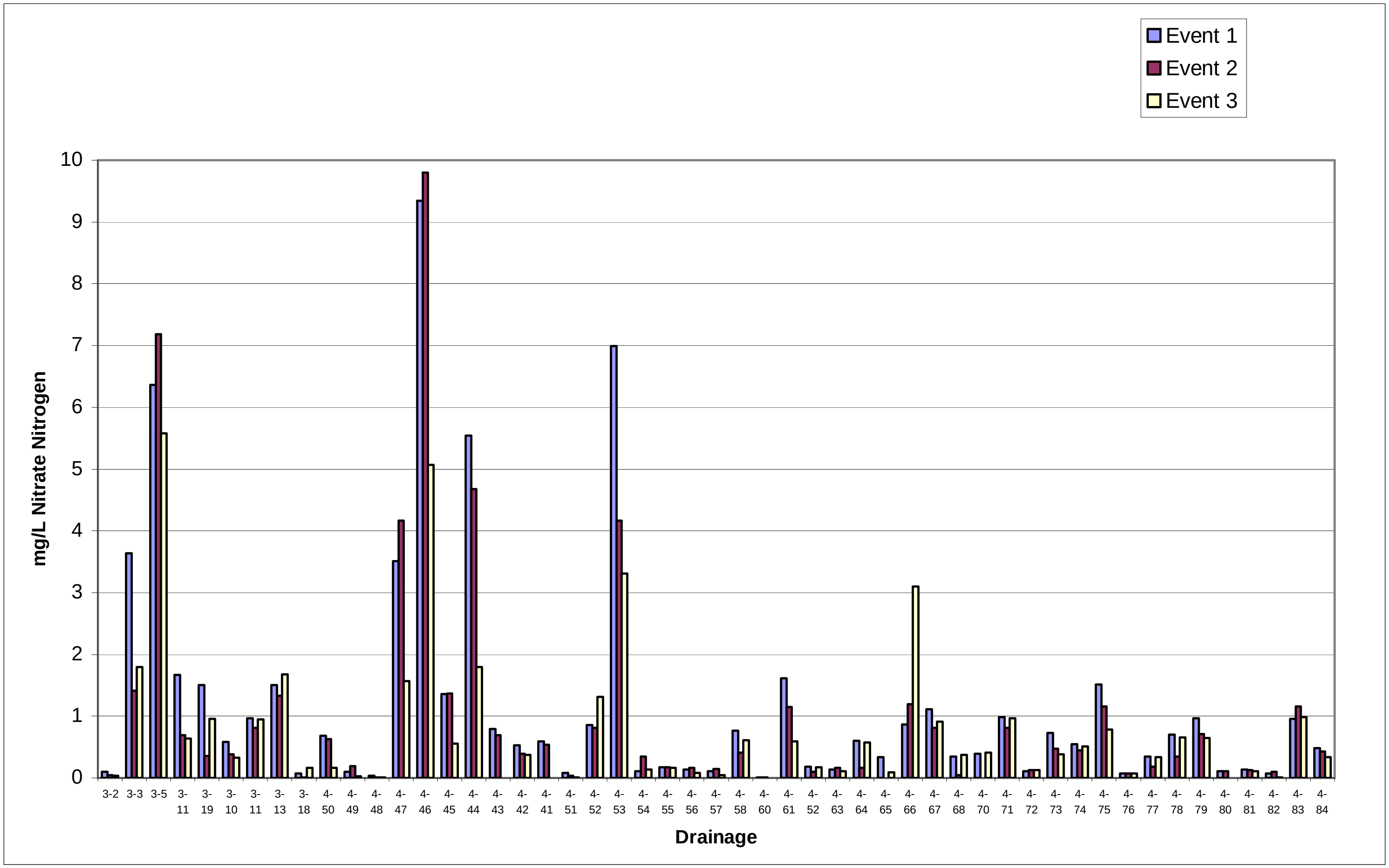
Figure 10. FC Concentrations in Upper Hood Canal Shoreline Discharges



All sites with a result of less than 2 FC/100ml, the detection limit of the test, are shown as a value of 1 FC/100ml. This section of shoreline had relatively few FC discharges greater than the 200 FC/100ml action level, which was typical of the entire project area. Only one site, 4-75, had FC levels consistently greater than the action level. This site was later proven to be an OSS failure through a positive dye test. Site 4-78 had one FC result greater than the action level. No failing OSS were identified at this drainage and the high result was most likely related to pet waste, as pet waste was observed on site. The homeowner was notified that fecal pollution was found in the shoreline discharge and advised of Kitsap's solid waste regulations for animal waste

Figure 11 shows the complete results for the nitrate+nitrite nitrogen concentrations for the shoreline discharges for the three sampling events.

Figure 11. Nitrate+Nitrite Nitrogen Concentrations in Kitsap Hood Canal Shoreline Discharges



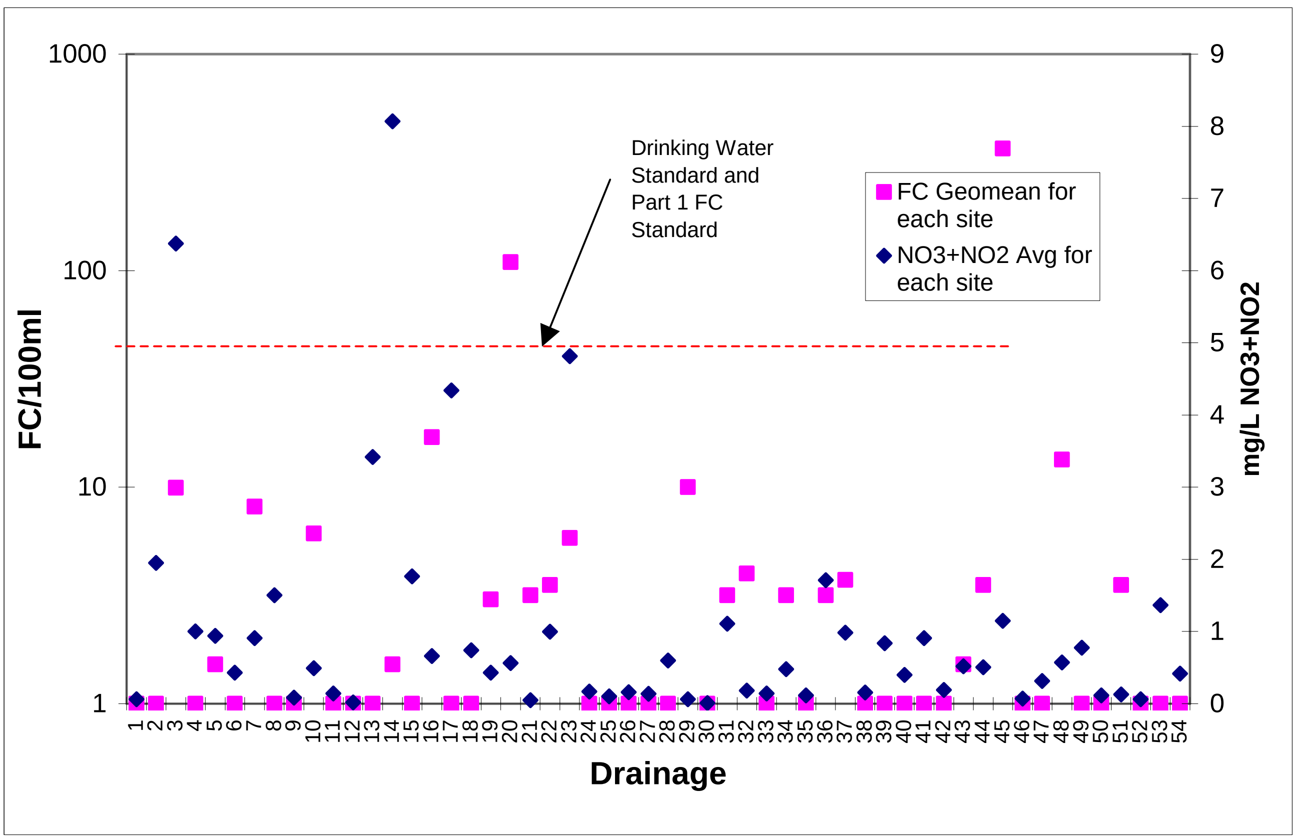
Results ranged from 0.01 to 9.80 mg/L nitrate+nitrite nitrogen. Sites with high concentrations and low concentrations were similar for each sampling event showing little variability.

No relevant dataset was found for comparison of the nitrate +nitrite nitrogen concentrations in this study. Hood Canal stream samples for nitrogen concentrations were collected by the Hood Canal Dissolved Oxygen Program freshwater sampling program during the same sampling time period of January through April 2005 (.http://www.prism.washington.edu/hcdop/index.html, 2005). The average concentration of nitrate +nitrite nitrogen in Hood Canal streams is relatively low at 0.25 mg/L. These larger streams represent flows influenced by larger basin areas. The optimum comparable data would be shoreline discharges from an undeveloped shoreline area.

5.2.3. FC and Nitrate+Nitrite Nitrogen Correlation

The geometric mean of FC concentrations and the arithmetic mean of the nitrate+nitrite concentrations are plotted in Figure 12. Statistically there was no correlation between FC and nitrate +nitrite nitrogen in shoreline discharges in the sampled areas in Hood Canal. In other words, FC bacteria concentrations do not rise or fall in relation with nitrate +nitrite nitrogen. Statistical analysis is shown in Appendix A

Figure 12. FC and Nitrate+Nitrite Concentrations in Kitsap Hood Canal Shoreline Discharges



5.2.4. Analysis of Nitrate+Nitrite Nitrogen Concentrations Between Sampling Events

Shoreline samples of nitrate+nitrite nitrogen were collected under three different rainfall conditions as discussed in section 5.2.1. Samples were collected when there was little rainfall (January 30 and 31, 2005), within 24 hours of a moderate rainfall event (March 2, 2005) and during a heavy rainfall event (April 13, 2005). It is important that samples taken at each site under different weather conditions are paired, so that the variation that exists is largely due to the effects of the rain and time, rather than location. Analysis is based on the difference between nitrogen concentrations at each location. The difference between concentrations at each sampling location was found by subtracting the concentration of the wetter event from the concentration of the drier event. Positive differences indicate that the concentration of the drier sampling period was higher than pf the wetter sampling period. Negative differences indicate the concentration was higher during the wetter period.

The box plot in Figure 13 shows similar distributions of the difference in nitrate+nitrite nitrogen concentrations between rain events. Of interest is whether the mean difference for each weather event is significantly different from zero. A difference of zero would suggest that rain has no effect on the nitrate+nitrite nitrogen concentration. A difference greater than zero would suggest the rain dilutes the nitrogen concentration.

The mean difference between the dry event and the moderate rain event is 0.16 mg/l (sd = 0.57). This is significantly different from zero ($p = 0.049$). The mean difference between the dry event and the heavy rain event is 0.40 mg/l (sd = 1.00). This is also significantly different from zero ($p = 0.009$). The mean difference between moderate rain events and heavy rain events is 0.24 mg/l (sd = 0.95). This is not significantly different from zero ($p = 0.100$).

Figure 13. Comparison of the Difference in Nitrate Concentration Between Dry-Moderate Rainfall, Dry-Heavy Rainfall and Moderate-Heavy Rainfall

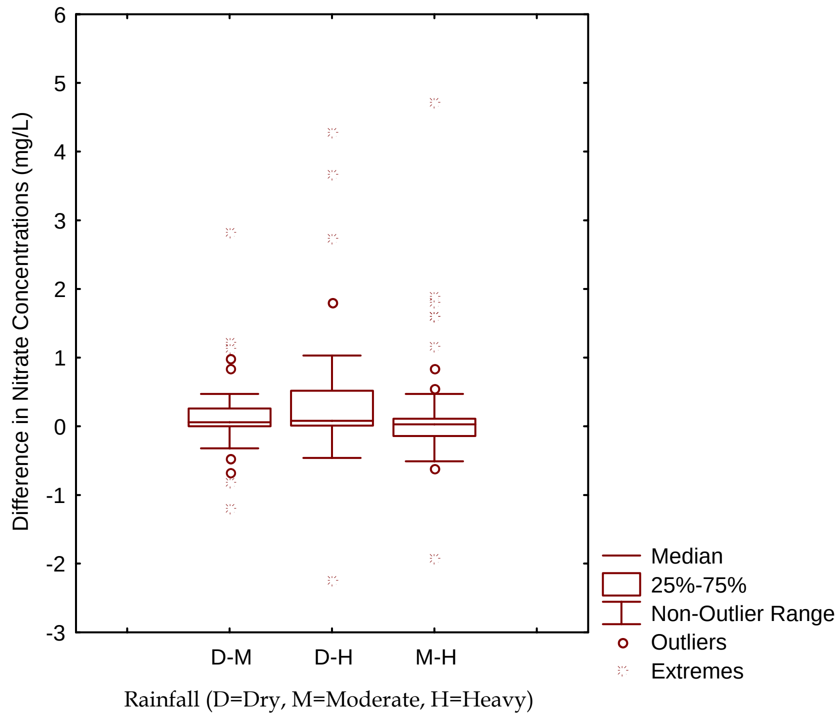


Figure 14. Nitrate+Nitrite Nitrogen Concentrations Distribution

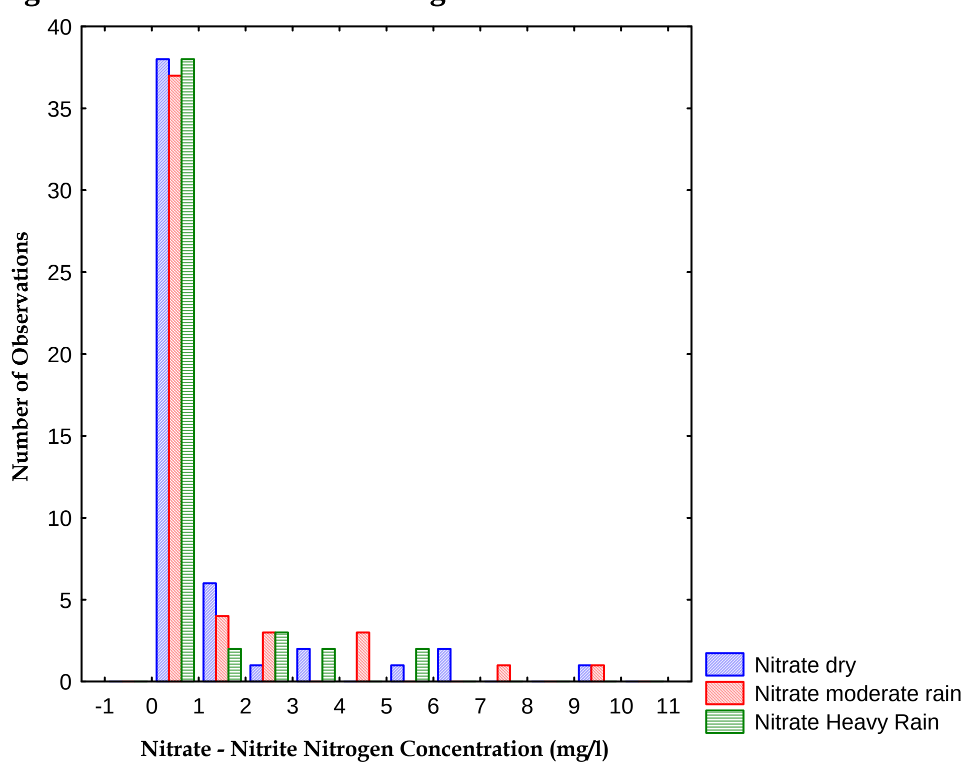
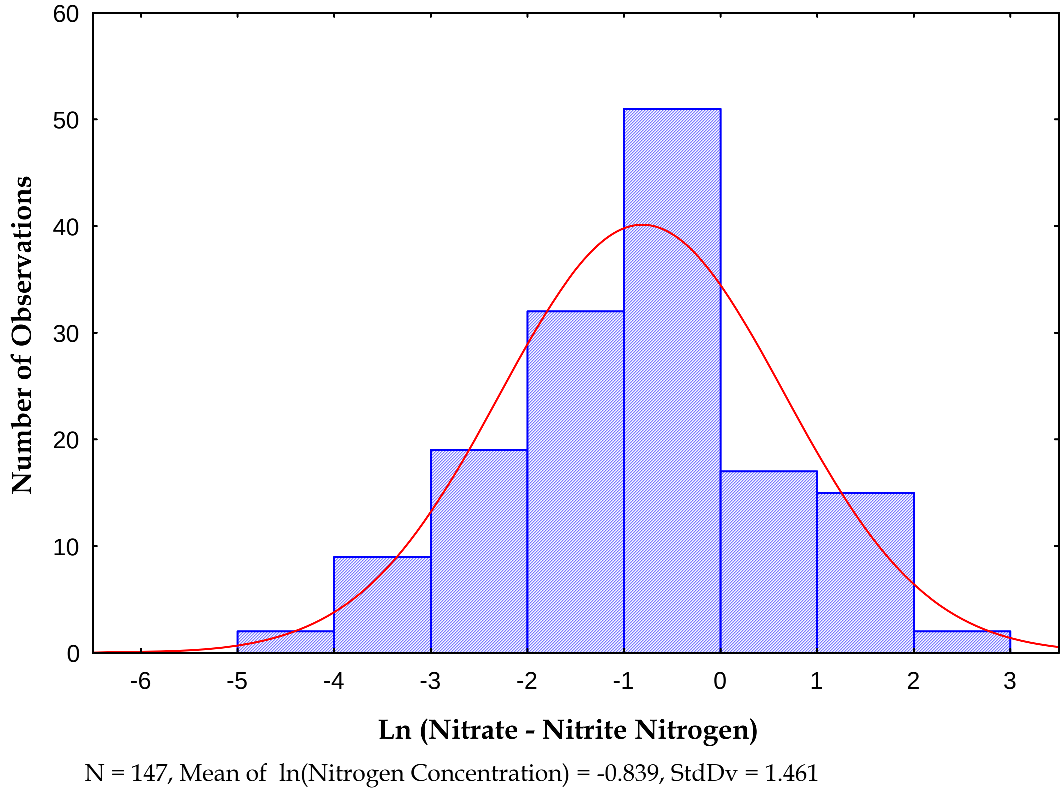


Figure 15. Distribution of the Logarithm of the Nitrate+Nitrite Nitrogen Concentrations

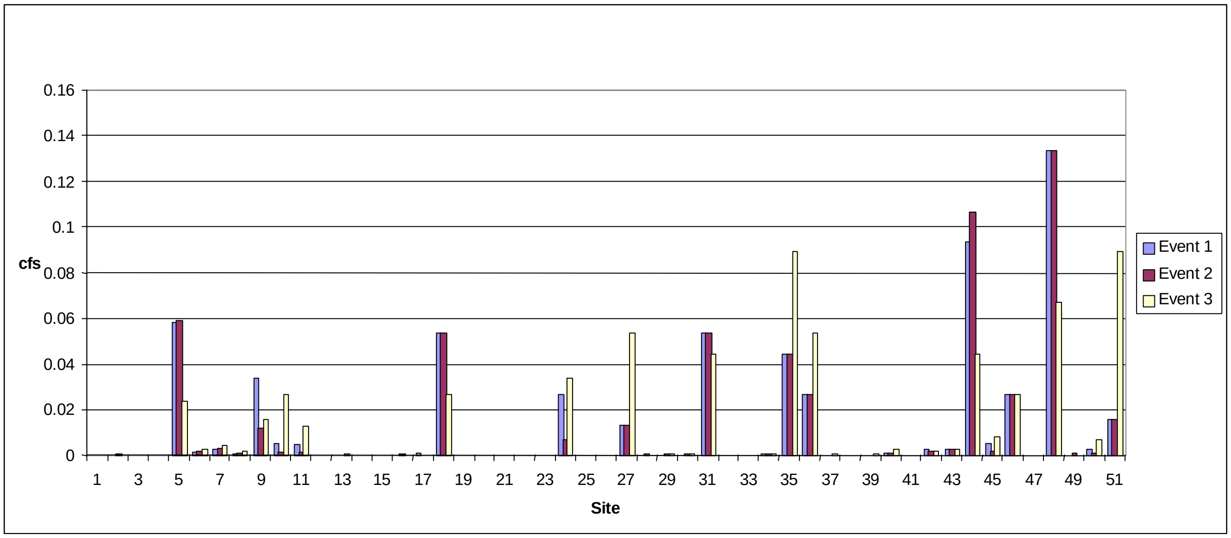


The distributions of data was similar between sampling events (Figure 14). This distribution is log normal meaning that the distribution of the logarithms of the data are approximately normal, as shown in Figure 15. The spread of the data between events shows that rain does influence the concentration. Moderate rain causes a reduction in the concentration of less than 0.2 mg/l and heavy rain causes a reduction of about 0.40 mg/l. Nonetheless, the distributions of the concentrations under all conditions are very similar. Therefore, the nitrate+nitrite nitrogen concentration remains similar at a discharge in relation to other discharge sites regardless of rain. Nitrate+nitrite nitrogen in shoreline discharges is constant and does not get flushed by rain, but is actually diluted.

5.2.5. Nitrate+Nitrite Nitrogen Loading of Shoreline Discharges into Hood Canal

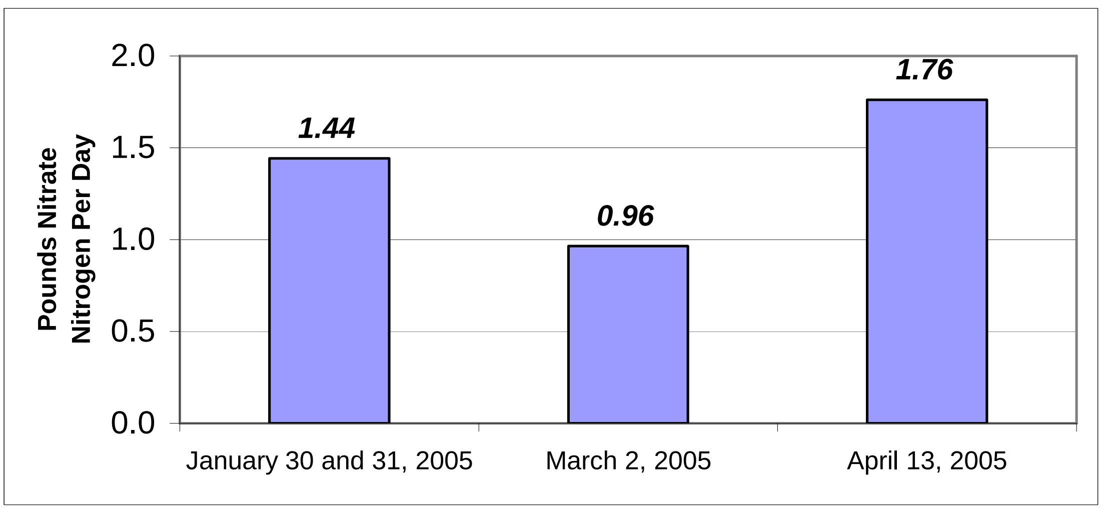
Flows were measured using the bucket and stopwatch method at 25 sites. The remaining 26 sites were determined to be very low flow and assigned a flow value of 0.1 gallon per minute because the flows were unable to be measured using the bucket and stopwatch method. Measured flows ranged from 0.01 to 60 gallons per minute. Flows were converted to cubic feet per second for graphing purposes. Figure 16 shows the range of discharge rates sampled for FC and nitrate+nitrite nitrogen. In most cases, the third event resulted in larger flows due to increased surface and groundwater flows. However, the wide variability of flows between each event at a site may be due to uncontrollable factors such as the inaccuracy of using the bucket and stopwatch method for flows from beach and bulkhead drainages, the time of sampling following the rainfall event, or the intensity and duration of the rainfall event.

Figure 16. Flow Rates of Hood Canal FC and Nitrate+Nitrite Nitrogen Discharge Sites



The flow rate and nitrate+nitrite nitrogen results were used to calculate the estimated pounds of nitrogen discharged for a 24 hour time period into Hood Canal during these three sampling events. Although the flow rate and concentration was measured at a discrete event, the assumption was made that both variables would remain constant over the 24 hour period. Figure 17 shows that a total of 0.96 to 1.76 pounds of nitrate+nitrite nitrogen were cumulatively discharged per event to Hood Canal from approximately 2 miles of shoreline flows from a densely developed area. Calculations are shown in Appendix B.

Figure 17. Estimated Total Pounds Nitrate+Nitrite Nitrogen Per Day



Nitrogen is a natural component of regional groundwater systems. Determining the contribution of human sources distinct from natural sources is difficult. In this study the nitrogen sources in shoreline flows can be of natural environmental or human origin. This water quality analysis did not differentiate between natural or human sources of nitrogen, only the total concentration of nitrogen in the flow.

In order to verify the estimate presented in the PACA these data were extrapolated to express the annual load of nitrate+nitrite nitrogen discharged to Hood Canal on a per mile of shoreline basis.

The PACA estimates the contribution of nitrogen from human sewage only into Hood Canal is 39-241 tons annually. Hood Canal possesses approximately 180 miles of shoreline (PACA, May, 2005) comprising of both developed and undeveloped areas. Therefore, the PACA estimate would translate to 0.22-1.34 tons of nitrogen per mile of shoreline.

Using the data collected from the Seabeck shoreline, the total pounds of nitrate nitrogen discharged on an annual basis was estimated at 642 pounds for two miles of developed shoreline sampled. This translates to 0.16 tons of nitrate nitrogen per mile of shoreline discharge measured. This is a high estimate because the shoreline area sampled is the most densely developed in the project area and the flows were over estimated. This measured estimate of both natural and human nitrogen sources is well below the PACA estimate for human sewage only. The measured nitrogen load accounts for a range from 12% to 74% of the estimates provided in the PACA.

These data, the correlating estimates, and the apparent adequate nitrogen removal capabilities of OSS in local studies demonstrates that the PACA is a preliminary assessment and is not representative of the actual OSS nitrogen contribution to Hood Canal and overestimates the relative nutrients impacts from OSS. Future studies should focus on site-specific nitrogen contributions of both natural regional groundwater systems and human sources.

5.3. Special Study of FC and Nutrient Concentrations in FC Contaminated Drainages

Nine FC contaminated drainages with FC discharges greater than the action level of 200 FC/100ml were identified in the project area, as discussed in Section 5.2. The nine FC contaminated drainages are located on seven shoreline properties. These drainages were investigated to determine sources of FC contamination.

The properties are spread throughout the project area, with three in segment 4, one each in segments 5 and 6, and two in segment 8. The locations are shown in Figures 5 and 6. Six of the properties have been confirmed to have failing OSS. The drainage identification and status of failure determination is shown in Table 5.

Table 5. Status of FC Contaminated Drainages

Drainage Identification	FC Geometric Mean FC/100ml	Dye Test Result	OSS Failure?
4-14	1600	Positive	Yes
4-24	620	Positive	Yes
4-25	1200	Same property as 4-24	
4-75	1200	Positive	Yes
5-5	1600	Positive	Yes
5-6	1600	Same property as 5-5	
6-48	1200	Positive	Yes
8-10	504	Positive	Yes
8-11	501	Negative	No

Discharge samples from three of the confirmed failing OSS were collected for two or three special study additional events following identification as high FC drainages. These sites are referred to as “impact” sites. Drainages adjacent to the “impact” sites with low FC concentrations were selected as “control” drainages for comparison to the high FC drainages. These control sites were located not more than a distance of four properties from the impact site. The control site selected was a similar drain type, such as bulkhead, curtain or beach drain. Samples were analyzed for nitrate+nitrite nitrogen, ammonia nitrogen and ortho-phosphorus. Figures 18, 19 and 20 summarize the nutrient concentrations at these sites. Figures are shown with the same scale on the Y-axis to more easily compare the three sites.

Figure 18. Nutrient Concentrations in Discharges from Site HC4-75 Failing OSS #1 and Control Site

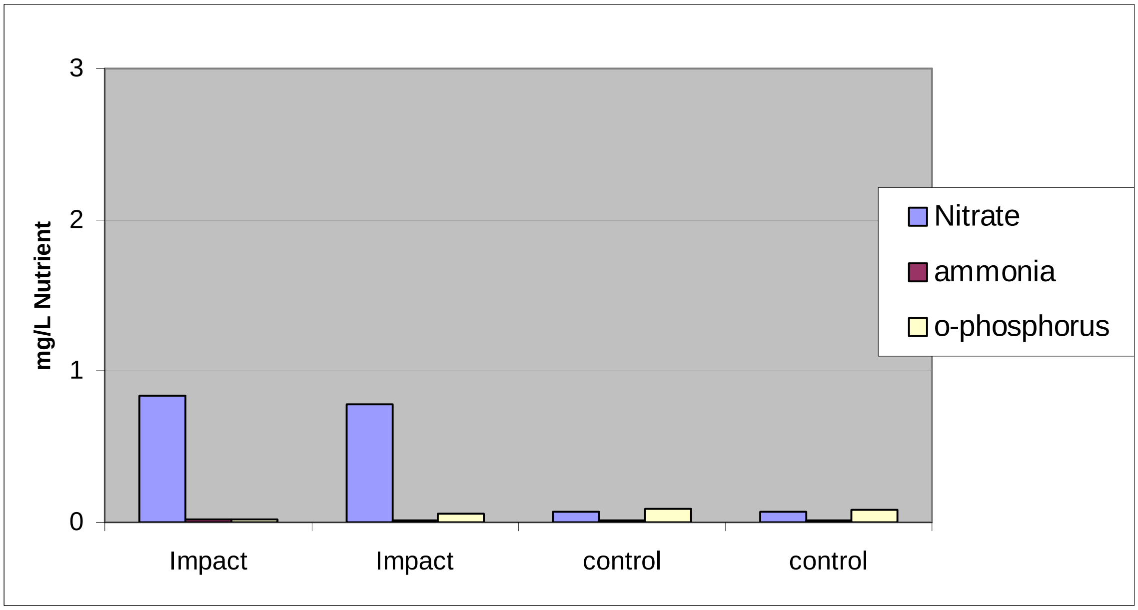


Figure 19. Nutrient Concentrations in Discharges from Site 5-5 Failing OSS #2 and Control Site

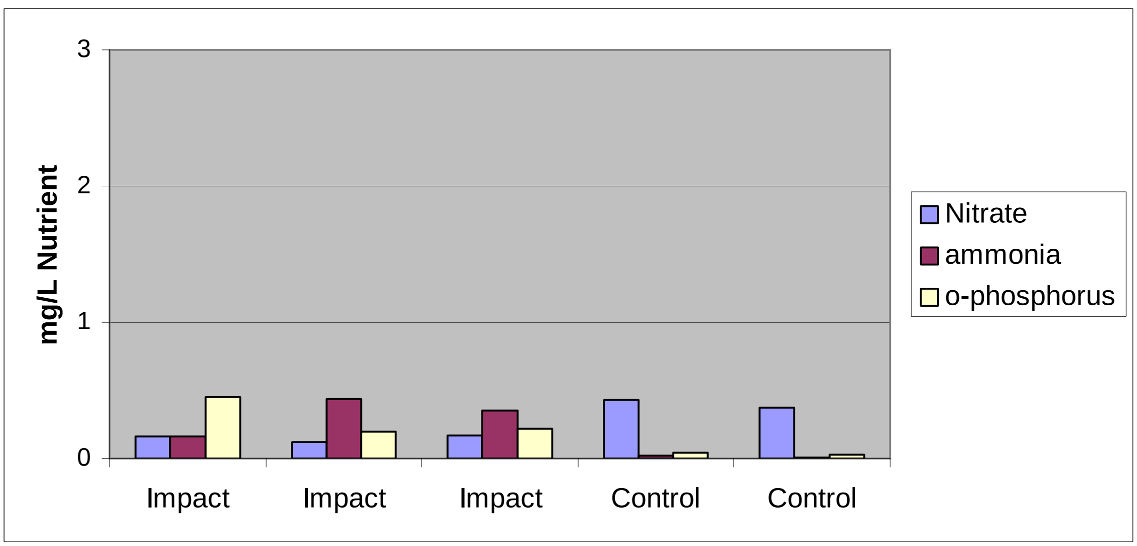
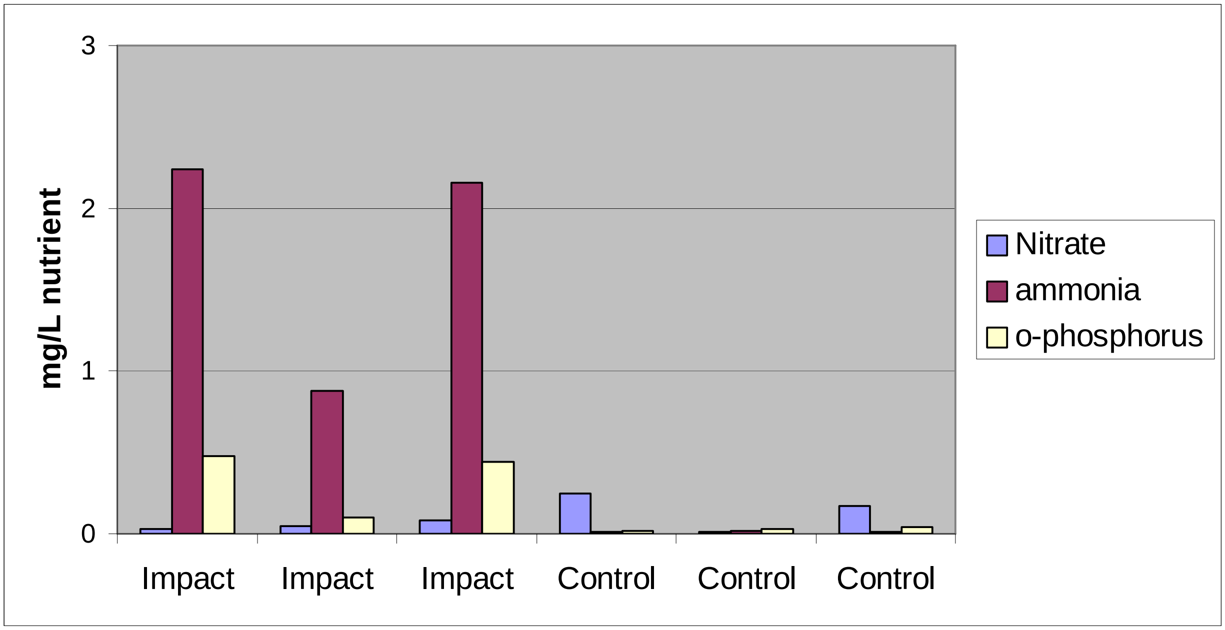


Figure 20. Nutrient Concentrations in Discharges from Site 8-10 Failing OSS #3 and Control



Results show that the nutrient levels of each failing OSS demonstrate unique patterns of nutrient concentrations. Site 4-75 failing OSS #1 shows only elevated nitrate nitrogen, where as sites 5-5 failing OSS #2 and 8-10 failing OSS #3 show elevated ammonia nitrogen and ortho-phosphorus in the impact discharges. A properly functioning OSS is effective at nitrification, which is the conversion of ammonia to nitrate-nitrogen.

The existing OSS records, OSS repair surveys and Health District Inspector survey records were reviewed. Analysis of these records in relation to the nutrients results are discussed below.

No records were found for the OSS serving site 4-75 failing OSS #1. Kitsap County's Assessor Tax system (ATS) shows the two bedroom house was built in 1936. Investigation resulted in discovery of a broken tile drainage line from a well overflow. The broken line was located between the tank and the drainfield and allowed the well water to flow through the drainfield and into a drain at the beach. Nitrate+nitrite nitrogen and fecal coliform bacteria were found in the discharge, which is consistent with the well water flushing through the drainfield. Ammonia was not found at the beach, which is consistent with the tank inspection finding no sign of groundwater intrusion into the tank.

No records were found for the OSS serving site HC5-5 failing OSS #2. ATS lists the residence as a one bedroom house built in 1950. The repair plan lists the home as a two bedroom and includes an alteration to a three-bedroom home. Three adults and two children live in the house and the failing OSS was located within 50' of Hood Canal. The drainfield repair survey for the site notes that the drainfield is very old/plugged and the drainfield is too close to the shoreline bulkhead. The elevated ammonia levels found at the shoreline indicate incomplete nitrification of the sewage effluent, which may be due to the size of the tank or proximity to the shoreline. The elevated orthophosphate levels may be the result of a drainfield undersized for the load, perhaps in combination with vertical and horizontal separation (undisturbed native soil setbacks to surface waters) inadequate for full treatment.

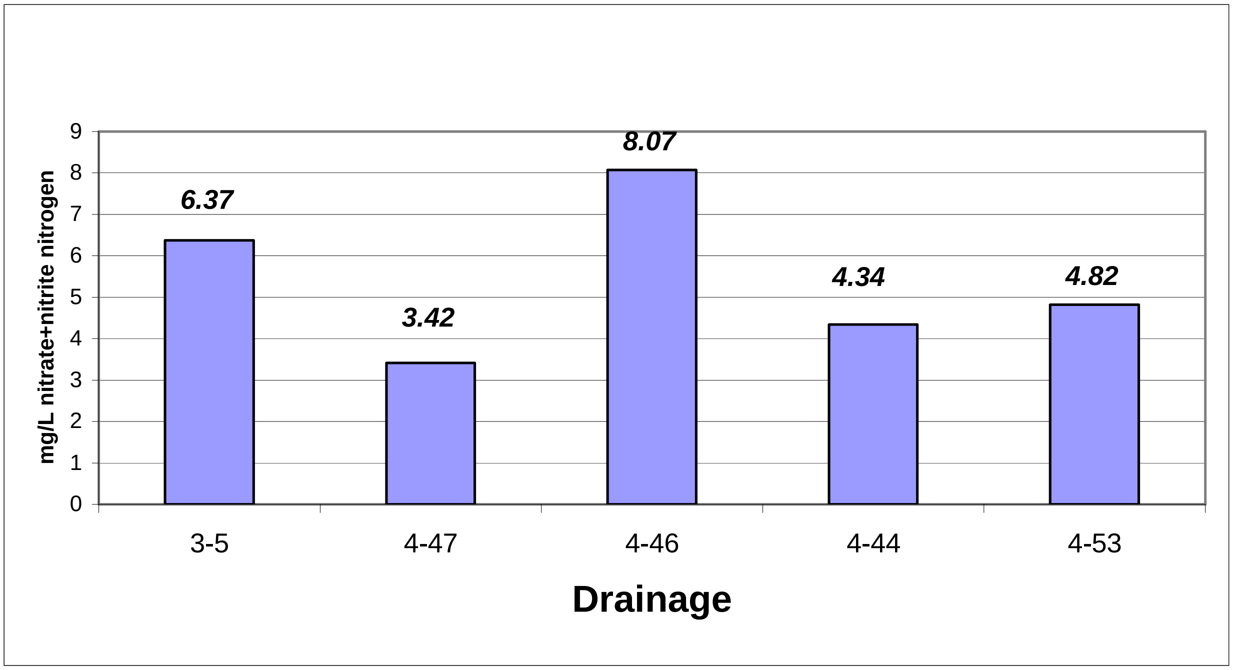
No installation records were found for the OSS serving site 8-10 failing OSS #3. A 1979 accepted Building Site Application notes “Existing sewage disposal system for 3 bedroom home. Prior to occupancy of new residence, sewage disposal system must be upgraded to 4 bedroom system.” ATS lists the residence as a four bedroom house built in 1981. The existing tank is approximately 50’ from Hood Canal and the drainfield is within 20’ of Hood Canal. This failure is considered a direct discharge due to the close proximity of the system to the marine water. This is consistent with nutrient sample results with very high ammonia levels and high ortho-phosphate levels. The septic tank 750 gallon capacity is undersized for the four bedrooms served, which results in incomplete nitrification of the sewage effluent. Vertical and horizontal separations are much less on this site than site HC5-5 failing OSS #2, which is likely the reason that ammonia levels are so much higher in the shoreline discharge. Like Site HC5-5 failing OSS #2, elevated ortho-phosphorus levels may be the result of an undersized drainfield in combination with very close proximity to Hood Canal.

As shown in Section 5.2.3 no correlation was found between FC and nitrate+nitrite nitrogen in shoreline discharges as discussed in Section 5.1. These were areas of few FC contaminated drainages. The correlation of FC to nutrients of drainages from confirmed failing OSS was next explored. Data from the impact sites and control sites were pooled separately and a correlation between FC and ammonia nitrogen, FC and nitrate+nitrite nitrogen, and FC and ortho-phosphorus was investigated. No correlation was found between FC and nitrate+nitrite nitrogen or FC and ortho-phosphorus in all datasets. A significant correlation exists between FC and ammonia ($p=0.001$) when both impact and control data is pooled. However, no correlation exists when analyzing impact data only ($p=0.09$) or the control data ($p=0.85$). This mixed result, particularly the lack of correlation for the impact only data, raises questions about the correlation for the combined data. Additional data from impact sites may either strengthen or weaken the correlation.

5.4. FC and Nutrient Concentrations in Nitrogen Contaminated Drainages

Some drainages sampled in Section 5.2.2, sampling segments 3 and 4, were found to have high arithmetic mean nitrate + nitrite nitrogen levels. In order to determine which drainages to investigate further the 90th percentile nitrate+nitrite concentration of the dataset was determined. The 90th percentile is 2.95 mg/L. Those five sites in the upper 10% of the values were visited. All five sites had low FC geometric mean concentrations of less than 10 FC/100ml. The sites and their corresponding nitrate+nitrite nitrogen values are shown in Figure 21.

Figure 21. Nitrate+Nitrite Nitrogen Arithmetic Mean of Three Sampling Events of the 90th Percentile Drainages



Four (3-5, 4-44, 4-46,and 4-47) of the five sites were sampled for ammonia-nitrogen and ortho-phosphorus. All sites sampled showed concentrations of these nutrients similar to control sites used for failing OSS (data not shown). No significant levels of ammonia nitrogen or ortho-phosphorus were detected. Property surveys were performed according to standard *PIC protocols* of the four properties with elevated nitrate+nitrite nitrogen levels in shoreline discharges. Results of property surveys are summarized in Table 6.

Table 6. Summary of Property Surveys of Elevated Nitrate+Nitrite Nitrogen Properties

Drainage	OSS Type and Condition	OSS Age (Years)	OSS Location	Bulkhead/Bank
3-5	Gravity, Used one week per year, no signs of failure	35	Between house and bulkhead	High bank with bulkhead
4-44	Gravity, no signs of failure	40	Between house and bulkhead	High bank with bulkhead
4-46 and 4-47	Gravity, Greywater discharge and failing OSS, repaired May 2005*	Original OSS 40	Between house and bulkhead. New system is aerobic treatment unit with subsurface drip irrigation upslope of the house and bulkhead.	High bank with bulkhead
4-53	Aerobic treatment unit to gravity distribution, no signs of failure	6	Between house and bulkhead, meets shoreline setbacks	High bank with bulkhead

*Nutrient samples were collected prior to repair of the failing OSS but during the greywater failure. The OSS failed after the greywater repair and prior to drainage sampling.

These four properties have varying characteristics in their OSS. Three OSS are older systems (35, 40 and 40 years of age respectively) located between the home and the bulkhead. One is a newer system meeting current OSS regulations for treatment standards and site setbacks from marine waters. “High Bank” was used to describe a bank greater than fifteen feet that had a 60 to 80 degree slope. All four sites were high bank with a bulkhead structure at the base. At all sites the nitrogen-rich flows originated from the property in the form of bulkhead drains, bulkhead surface flows or yard drains. These flows are perennial in the winter and, based on field inspection, are not connected to roadway runoff or a regional stormwater system. However, it was discovered during follow-up site visits with property owners that each site had yard waste piles. One property, 4-53, admitted to using lawn fertilizer frequently. At this time the exact source of the elevated nitrate+nitrite nitrogen source is unknown.

6. SUMMARY

During the project period of January 2005 to September 2005 the Kitsap County Health District completed the following in the Upper Hood Canal Watershed project area:

Shoreline FC Sampling

- Sampled 228 distinct shoreline freshwater discharges; 11 (5%) discharges had high FC (>200FC/100ml), nine were confirmed to be "high priority" drainages;
- Confirmed eight of the nine "high priority" drainages, or 4% of the total drainages, to be failing OSS located on six properties;
- OSS dye testing did not confirm the remaining "high priority" drainage; it will be reinvestigated in winter 2005-2006.

Shoreline Nutrient Sampling

- Sampled 51 discharges, or 22% of the total drainages, located in the Big Beef and Seabeck area for three events for FC and nitrate+nitrite nitrogen; no correlation between FC and nitrate+nitrite nitrogen was found in all three sampling events;
- Calculated the total loading of nitrate+nitrite nitrogen from the 51 discharge sites to be a maximum of 1.76 pounds per day;
- Estimated and extrapolated both natural and human nitrogen sources in shoreline discharges from 2 miles of developed shoreline. Nitrogen loading appears to be less than the PACA estimate for human sewage only;
- Concentrations of nitrate+nitrite nitrogen were significantly reduced during moderate and heavy rainfall events compared to a dry weather sampling event;
- Shoreline discharges from three selected failing OSS had elevated nitrate+nitrite nitrogen, ammonia nitrogen or ortho-phosphorus compared to shoreline discharges from properly working OSS; but no consistent correlation existed between FC and nitrate+nitrite nitrogen; FC and ammonia; or FC and ortho-phosphorus;
- Inspected four properties with elevated nitrate+nitrite nitrogen discharges, low FC and properly functioning OSS; all sites were located on high bank with bulkhead structures and had yard waste or excess fertilizer use; however, the source of the high nitrate+nitrite nitrogen was not specifically identified.

Property Surveys

- Visually inspected approximately 9 miles of developed shorelines comprising of 340 homes;
- Selected 50 properties for OSS surveys based upon high FC drainage results, or listed by WSDOH as "potential pollution sources", or located in the Big Anderson Creek drainage, or requested by property owners, or a result of a citizen sewage complaint; 96% of the properties have been reviewed; and
- Identified a project total of twelve (12) failing OSS during the project period of January 2005 to December 2005; eight OSS have been repaired, and the remaining four are in the OSS repair process.

7. CONCLUSIONS

The fate and transport of nitrogen in the Hood Canal Watershed is unknown. However, some estimates consider human sewage from OSS to be the major human-caused source of nitrogen, contributing between 39 and 241 tons annually (PACA, 2004). Estimates were based upon several assumptions such as the nitrogen from all OSS in the watershed are discharged to Hood Canal via streams, groundwater, and shorelines and that uptake by plants or bacterial denitrification had no impact on nitrogen removal.

The PACA nitrogen calculations for Hood Canal were based on the assumption that conventional OSS remove little of the nitrogen in septic tank effluent. However, there are a number of studies that demonstrate nitrate decreases as the effluent migrates through the soil. Drainfields are typically installed in the upper two feet of soil, and the vegetative cover above and near the drainfield will utilize much of the nitrogen. (Salvato, 2003 and Viraraghavan and Warnock, 1976). A study by Patmont, Pelletier, Welch, Banton, and Ebbesmeyer in Lake Chelan showed test sites had nitrogen removal averaging 89 +/- 3% removal, with four of seven sites reaching 99% removal (Patmont, 1989). Hart Crowser also cited nitrogen uptake by plants in shallow groundwater systems in the Northwest, "owing to the general deficiency of this plant nutrient in regional soil systems" (Gessel, et.al., 1969; Harper-Owes, 1985).

Based on past experience with OSS sanitary surveys and extensive local knowledge of the areas geology, there is a high level of confidence that shoreline discharges are representative of OSS treatment efficiencies. Shoreline discharge sampling demonstrated that the project area has few FC contaminated drainages confirming marine water quality monitoring data. Only 5% of the shoreline discharges were contaminated for FC. Additionally, the failing OSS rate was very low in the project area. In other KCHD project areas with documented marine or stream FC water quality problems the failing OSS rate varies from 8-30%. The failing OSS rate is only 3.5% in the Hood Canal project area.

Nitrogen is a natural component of regional groundwater systems. Determining the contribution of human sources distinct from natural sources is difficult. In this study the nitrogen sources in shoreline flows can be of natural environmental or human origin. This water quality analysis did not differentiate between natural or human sources of nitrogen, only the total concentration of nitrogen in the flow.

High FC concentrations in shoreline discharges is a strong indicator of failing OSS or inadequate animal waste management. In addition, it is well documented that properly operating OSS converts ammonia to nitrate nitrogen with some removal of nitrogen in the process. Nitrate+nitrite nitrogen levels were very low and did not increase during rain conditions. However, shoreline discharge nitrate+nitrite nitrogen concentrations did not correlate with FC concentrations. Additionally, failing OSS may contribute nitrogen in the form of nitrate+nitrite or ammonia nitrogen dependent upon the mechanism of the failing OSS. Finally, these regional preliminary data show very low nitrate+nitrite nitrogen levels, which appears to confirm studies that indicate significant nitrogen reduction in properly functioning OSS.

The data presented in this report represents a small, limited scope project that attempts a first step to investigate the theoretical estimation contained in the PACA concerning OSS nutrient impacts to Hood Canal. The findings of this project may be used as a baseline and platform for additional investigations aimed at characterizing and quantifying nutrient discharges to Hood Canal from OSS or other human sources as measured in shoreline discharges.

These data, the correlating estimates, and the apparent adequate nitrogen removal capabilities of

OSS in local studies demonstrates that the PACA is a preliminary assessment and is not representative of the actual OSS nitrogen contribution to Hood Canal and overestimates the relative nutrients impacts from OSS. Future studies should focus on site-specific nitrogen contributions of both natural regional groundwater systems and human sources

8. RECOMMENDATIONS

The Kitsap County Health District recommends the following investigations to explore the contribution of OSS nitrogen to Hood Canal:

- Determine the source of nitrate+nitrite nitrogen on properties with elevated concentrations as compared to control properties.
- Determine the nitrate+nitrite nitrogen concentrations of shoreline discharges from undeveloped Kitsap shorelines for comparison of shoreline discharges in this study.
- Determine the nitrate+nitrite nitrogen concentrations in shallow groundwater sampling upslope and down slope of properly working OSS in the Hood Canal watershed on shorelines and upland areas.
- Survey properties regarding yard waste and fertilizer use and correlate with nitrate+nitrite nitrogen water quality sampling.
- Perform site analysis of the nitrate+nitrite nitrogen study area; site analysis would include a review of OSS records, lot sizes, amount of native vegetation, setbacks from drainfield and components to shoreline, soil characteristics, and age of OSS; relate these characteristics with the nitrate+nitrite nitrogen results.

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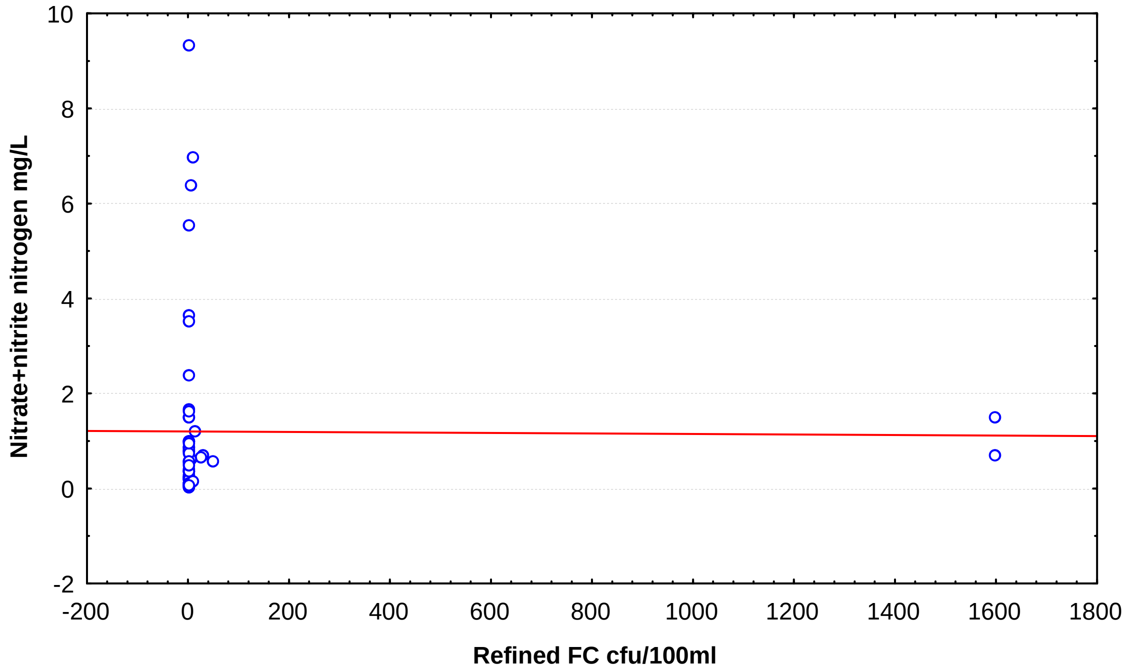
APPENDIX A

Hood Canal Project, a comparison of Fecal Coliform and Nitrate + Nitrite nitrogen By Pete Kaslik, Math Handyman, LLC

The objective of the first part of this study was to determine if there was a correlation between Fecal Coliform concentrations and Nitrate + Nitrite nitrogen. A correlation would suggest that by monitoring Fecal Coliform and correcting problems that contribute to high FC levels, a corresponding decrease in Nitrate + Nitrite nitrogen might be achieved.

The original data had values listed as <2. This is generally termed censored data. Because we do not know the value of each datum, a value of 1 was used in place of <2. The value from segment 4, site 59 was listed as <20. I considered this to be a typing error and replaced that value with a 1 as well. A value of 1600 was used for the data listed as >1600. A scatter plot of the data is shown below.

Hood Canal
Fecal Coliform and Nitrate + nitrite nitrogen
January 2005



Refined FC cfu/100mlNitrate+nitrite nitrogen mg/L: $r^2 = 0.0001$; $r = -0.0089$, $p = 0.9491$

As is evident in this graph, there is no correlation between Fecal Coliform concentrations and Nitrate + nitrite nitrogen concentrations. Both high and low nutrient values exist when there are very low FC levels and low values of nutrients exist when there are high values of FC.

The remainder of the study was based on the assumption that there would be a correlation between the two variables so that evidence could be gathered to determine if a reduction in FC resulted in a reduction in the nutrient levels. Without a correlation, that portion of the study is unlikely to provide any useful results. I suggest collaboration with all involved parties to decide on the next appropriate step to solving the problem of low oxygen in the Hood Canal.

APPENDIX B
Nitrogen Calculations for Hood Canal Shoreline Discharge

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	*Nitrogen and flow calculations*													
2	11-Jul-05									1 gallon equals 0.1336806 cubic feet				
3										1 gallon per minute equals 0.002228 cfs				
4			Nitrate/Nitrite mg/L			gpm			cfs					
5	**Segment**	**Drainage**	**Event 1**	**Event 2**	**Event 3**	**Flow1**	**Flow2**	**Flow3**	**Flow1**	**Flow2**	**Flow3**	**pounds nitrate/nitrate per day**		
6	3	2	0.10	0.05	0.04	0.1	0.1	0.1	0.000223	0.000223	0.000223	0.00012048	6.024E-05	4.81919E-05
7	3	3	3.64	2.41	2.80	0.132	0.132	0.132	0.000294	0.000294	0.000294	0.005788816	0.00383271	0.004452936
8	3	5	6.36	7.18	5.58	0.1	0.1	0.1	0.000223	0.000223	0.000223	0.007662519	0.00865045	0.006722776
9	3	11	1.67	0.69	0.64	0.1	0.1	0.1	0.000223	0.000223	0.000223	0.002012014	0.00083131	0.000771071
10	3	19	1.50	0.36	0.96	26.400	26.400	10.600	0.058819	0.058819	0.023617	0.477100243	0.11450406	0.122600305
11	3	20	0.58	0.38	0.33	0.892	0.892	1.067	0.001987	0.001987	0.002377	0.006233146	0.00408379	0.004240891
12	3	22	0.97	0.81	0.95	0.698	1.430	2.000	0.001554	0.003186	0.004456	0.008153314	0.01395518	0.022891173
13	3	23	1.50	1.33	1.68	1.280	0.400	0.857	0.002852	0.000891	0.001909	0.023132133	0.00640953	0.017339461
14	3	28	0.07	0.02	0.16	0.255	5.433	7.200	0.000569	0.012105	0.016042	0.000215338	0.00130921	0.01387928
15	4	50	0.68	0.63	0.16	15.000	0.600	12.000	0.03342	0.001337	0.026736	0.122889456	0.00455414	0.023132133
16	4	49	0.10	0.29	0.03	2.438	0.600	5.800	0.005432	0.001337	0.012922	0.002937299	0.00209635	0.00209635
17	4	48	0.04	0.02	0.02	2.201	2.201	2.201	0.004905	0.004905	0.004905	0.001060865	0.00053043	0.000530433
18	4	47	3.51	4.17	2.57	0.085	0.085	0.320	0.000189	0.000189	0.000713	0.003594517	0.00427041	0.009908264
19	4	46	9.34	9.80	5.07	0.088	0.088	0.088	0.000196	0.000196	0.000196	0.009902481	0.01039018	0.005375329
20	4	45	2.36	2.37	0.56	0.1	0.1	0.1	0.000223	0.000223	0.000223	0.002843325	0.00285537	0.000674687
21	4	46D	0.66	NS	NS	0.1	0.1	0.1	0.000223	0.000223	0.000223	0.000795167	#VALUE!	#VALUE!
22	4	44	5.54	4.68	2.80	0.189	0.189	0.189	0.000421	0.000421	0.000421	0.012614964	0.01065668	0.006375794
23	4	43	0.79	0.69	NS	0.094	0.094	0.094	0.000209	0.000209	0.000209	0.000894683	0.00078143	#VALUE!
24	4	42	0.53	0.39	0.37	12.000	24.000	12.000	0.026736	0.053472	0.026736	0.076625191	0.11276915	0.053493058
25	4	41	0.59	0.54	NS	0.022	0.022	0.022	4.9E-05	4.9E-05	4.9E-05	0.000156383	0.00014313	#VALUE!
26	4	51	0.08	0.04	0.02	0.1	0.1	0.1	0.000223	0.000223	0.000223	9.63839E-05	4.8192E-05	2.4096E-05
27	4	52	0.86	0.81	1.32	0.1	0.1	0.1	0.000223	0.000223	0.000223	0.001036127	0.00097589	0.001590334
28	4	53	6.99	4.17	3.31	0.1	0.1	0.1	0.000223	0.000223	0.000223	0.008421542	0.00502401	0.003987883
29	4	54	0.22	0.35	0.24	0.1	0.1	0.1	0.000223	0.000223	0.000223	0.000265056	0.00042168	0.000289152
30	4	55	0.27	0.17	0.16	3.000	3.000	15.033	0.006684	0.006684	0.033494	0.009758869	0.00614447	0.028979422
31	4	56	0.24	0.16	0.08	12.000	12.000	12.000	0.026736	0.026736	0.026736	0.034698199	0.02313213	0.011566066
32	4	57	0.21	0.15	0.05	0.1	0.1	0.1	0.000223	0.000223	0.000223	0.000253008	0.00018072	6.02399E-05
33	4	58	0.77	0.41	0.62	6.000	6.000	24.000	0.013368	0.013368	0.053472	0.055661695	0.02963805	0.179274031
34	4	59	0.06	NS	NS	0.1	0.1	0.1	0.000223	0.000223	0.000223	7.22879E-05	#VALUE!	#VALUE!
35	4	60	0.01	0.01	NS	0.262	0.262	0.262	0.000584	0.000584	0.000584	3.15657E-05	3.1566E-05	#VALUE!
36	4	61	1.62	1.15	0.59	0.200	0.200	0.240	0.000446	0.000446	0.000535	0.003903547	0.00277104	0.001705995
37	4	62	0.18	0.20	0.17	0.180	0.180	0.120	0.000401	0.000401	0.000267	0.000390355	0.00043373	0.000245779
38	4	63	0.24	0.26	0.22	24.000	24.000	20.000	0.053472	0.053472	0.04456	0.069396399	0.07517943	0.053011138
39	4	64	0.60	0.26	0.57	24.000	24.000	24.000	0.053472	0.053472	0.053472	0.173490997	0.07517943	0.164816448
40	4	65	0.34	NS	0.09	0.1	0.1	0.1	0.000223	0.000223	0.000223	0.000409632	#VALUE!	0.000108432
41	4	66	0.87	1.19	3.10	0.183	0.183	0.153	0.000408	0.000408	0.000342	0.001921654	0.00262847	0.005726809
42	4	67	1.22	0.81	0.92	1.000	1.000	40.000	0.002228	0.002228	0.08912	0.014698543	0.00975887	0.443365882
43	4	68	0.35	0.05	0.37	0.863	0.863	24.000	0.001924	0.001924	0.053472	0.0036405	0.00052007	0.106986115
44	4	69	0.84	NS	NS	12.000	12.000	12.000	0.026736	0.026736	0.026736	0.121443698	#VALUE!	#VALUE!
45	4	70	0.39	NS	0.41	0.120	0.120	0.120	0.000267	0.000267	0.000267	0.000563846	#VALUE!	0.000592761
46	4	71	0.98	0.81	0.97	0.1	0.1	0.1	0.000223	0.000223	0.000223	0.001180703	0.00097589	0.001168655
47	4	72	0.21	0.23	0.13	0.057	0.057	0.201	0.000127	0.000127	0.000447	0.000144214	0.00015795	0.000314292
48	4	73	0.73	0.47	0.38	0.470	0.470	1.020	0.001047	0.001047	0.002273	0.004133664	0.0026614	0.004669799
49	4	74	0.55	0.45	0.51	0.355	0.355	0.355	0.000792	0.000792	0.000792	0.002354578	0.00192647	0.002183336
50	4	75	1.51	1.16	0.78	0.880	0.880	0.880	0.001961	0.001961	0.001961	0.016009364	0.01229858	0.008269738
51	4	76	0.07	0.07	0.07	1.200	1.050	1.080	0.002674	0.002339	0.002406	0.001012031	0.00088553	0.000910828
52	4	77	0.35	0.28	0.34	1.000	48.000	20.000	0.002228	0.106944	0.04456	0.004216795	0.16192493	0.081926304
53	4	78	0.70	0.35	0.66	0.837	0.837	3.600	0.001864	0.001864	0.008021	0.007056104	0.00352805	0.028626015
54	4	79	0.97	0.71	0.65	2.400	12.000	12.000	0.005347	0.026736	0.026736	0.028047711	0.10264884	0.09397429
55	4	80	0.12	0.11	NS	0.1	0.1	0.1	0.000223	0.000223	0.000223	0.000144576	0.00013253	#VALUE!
56	4	81	0.14	0.13	0.12	60.000	60.000	30.000	0.13368	0.13368	0.06684	0.101203082	0.09397429	0.043372749
57	4	82	0.07	0.10	0.02	0.380	0.380	0.380	0.000847	0.000847	0.000847	0.000320476	0.00045782	9.15647E-05
58	4	83	0.96	2.16	0.98	0.427	0.427	3.000	0.000951	0.000951	0.006684	0.004934855	0.01110342	0.035421079
59	4	84	0.48	0.43	0.34	1.064	7.200	40.000	0.002371	0.016042	0.08912	0.006153147	0.03730056	0.163852609
60	NS=No sample collected							**Nitrate/nitrite nitrogen**			**Total**	**1.441797536**	**#VALUE!**	**#VALUE!**
61	No flow, used next flow point if possible. If none for all three events, used 0.1 since very low flow.													
62	non-detect for nitrogen, inserted 0.01 (detect limit)											***January 30 and 31***	***March 2***	***April 13***
63											**Values**	**1.44**	**0.96**	**1.76**
64	***Sample formula***													
65			Nitrate/Nitrite mg/L			gpm								
66			**Event 1**	**Event 2**	**Event 3**	**Flow1**	**Flow2**	**Flow3**						
67	**3**	**2**	**0.10**	**0.05**	**0.04**	**0.1**	**0.1**	**0.1**	cfs Flow 1	**=F65*0.002228**				
68									cfs Flow 2	**=G65*0.002228**				
69									cfs Flow 3	**=H65*0.002228**				
70									pounds nitrogen per day event 1	**=I65*86400*C65*28.32*0.00000221**				
71									pounds nitrogen per day event 2	**=J65*86400*D65*28.32*0.00000221**				
72									pounds nitrogen per day event 3	**=K65*86400*E65*28.32*0.00000221**				