Pollution Identification and Correction
A Public Health Approach to Low Dissolved Oxygen in Hood Canal

Leslie Banigan, R.S., and Melinda J. Fohn
Kitsap County Health District

ABSTRACT

Hood Canal in Puget Sound has a history of low dissolved oxygen and anecdotal information suggests periodic fish kills dating back to the early 1900s. Recent oxygen levels are the lowest in recorded history, resulting in fish kills in 2002, 2003 and 2006 and prompting concerns about long-term health of the canal.

A Preliminary Assessment and Corrective Action Plan (PACA) theorized nutrient contamination as a source of the dissolved oxygen problem because excess nutrients stimulate algal growth, which uses oxygen as it breaks down (Puget Sound Action Team May 2004). Mathematical estimates were used to identify nitrogen from onsite sewage systems (OSS) as the major anthropogenic source to Hood Canal.

The Kitsap County Health District (Health District) conducted a fecal coliform Pollution Identification and Correction (PIC) project in 2005 to: protect public health by correcting failing OSS; assess the relationship between FC and nitrate+nitrite nitrogen in fresh water drainages, and determine net nutrient reductions after correcting failing OSS.

Twelve failing OSS were identified and corrected in the southern nine miles of shoreline comprising 340 residences (4% failure rate). No statistical correlation between FC and nitrate+nitrite nitrogen was found. Shoreline discharges from failing OSS showed elevated nutrients, which were reduced after correction. Shoreline flows demonstrated statistically significant nutrient reductions compared to controls after correction of failing OSS.

INTRODUCTION AND BACKGROUND

Kitsap County is located in the west Puget Sound area of Washington State. County leaders created a Surface and Stormwater Management (KCSSWM) Program in 1993 to address nonpoint source pollution and water quality. For more information about the program, please refer to the case study by Puget Sound Action Team, Kitsap County Surface and Stormwater Management Program, April 2005, Publication No. PSAT 05-06.

Successful clean water programs require political support, stable funding and proactive public education. They must be applied fairly to encourage voluntary participation. The Health District's Water Quality program is funded by the KCSSWM stormwater utility. The Water Quality Program's mission is to "protect the public from waterborne illness and other water quality related hazards". Water Quality's fecal PIC program developed standard procedures, effective public outreach, enforcement capability, and consistent follow-up. Project areas are determined by a Priority List mechanism based on long-term water quality monitoring to identify and rank polluted areas for clean up. Work is conducted pursuant to established and approved PIC Protocols and utilizes proactive public outreach to prevent future water pollution (Kitsap County Health

District 2003). The program can utilize enforcement capability through Kitsap County's OSS and solid waste regulations (Bremerton-Kitsap County Board of Health 1998; Kitsap County Board of Health 2004). Non-participating properties are assessed during wet weather conditions to determine whether they are discharging fecal pollution.

The PIC program has voluntary participation ranging from 82% to 100%. High participation is encouraged through communicating a documented water quality problem, treating owners and residents with respect, and making participation convenient by providing evening and weekend meeting times.

Hood Canal is located in west Puget Sound, Washington. Jefferson County is on the west shore of upper Hood Canal, Mason County borders lower Hood Canal, and Kitsap County is on the east shore of upper Hood Canal. Hypoxic conditions in Hood Canal have become more widespread resulting in fish kills in 2002, 2003 and 2006. The area of low dissolved oxygen is getting larger, spreading northwards, and lasting longer. (http://www.hoodcanal.washington.edu. 2007). Recreational and commercial fisheries are closed for bottom fish until conditions improve. The causes of low dissolved oxygen are not known at this time but are under investigation by the Hood Canal Dissolved Oxygen Program.

Failing OSS are a public health threat. They also discharge organic material that uses dissolved oxygen as it breaks down. The Health District's approach is to protect the public by finding and fixing OSS that are failing to the Hood Canal shoreline and educating shoreline property owners and residents to prevent future fecal pollution.

The PACA theorized that excess nitrogen is causing the low dissolved oxygen problem (Puget Sound Action Team 2004). In response, the Health District initiated preliminary nutrient studies to determine the relationship between fecal coliform and nutrients, and whether correcting failing OSS nets reduction of nutrients to the shoreline.

PIC project work targets the upper Hood Canal watershed from the Hood Canal bridge south to the Kitsap-Mason county line. All work was conducted pursuant to the Health District's PIC Protocols and funding match was provided by the KCSSWM stormwater utility.

The project is being performed in two phases: 2005, which is complete; and 2006-2008, which is in progress. Project work in 2005 was funded through early action activities coordinated by the Puget Sound Action Team and the United States Environmental Protection Agency as specified in the approved quality assurance project plan. (Kitsap County Health District January 24, 2005). Project work was reported in the Health District's Upper Hood Canal Restoration Project Final Report (Kitsap County Health District 2006). Washington state Department of Ecology's Centennial Clean Water Fund is providing grant funding for work conducted from 2006 through 2008 pursuant to the approved quality assurance project plan (Kitsap County Health District 2006).

Project components include shoreline evaluation, parcel evaluations in areas with elevated fecal coliform, and a pilot nutrient project.

SHORELINE EVALUTION METHODS

Field safety and field equipment are crucial to successful shoreline evaluation. The Health District's PIC Protocols provide detailed guidance and an equipment list. Field staff must work within the sampling protocols and laboratory schedule and know local property access and consent policies in order to effectively use data collected. The Health District prepares a fact sheet detailing the documented problem and contact information for distribution during the project.

The shoreline evaluation involves collecting shoreline discharges pursuant to sampling protocols. All discharges from curtain drains, bulkhead drains, drainage culverts, overland flows, and significant beach flows that appear to originate from the near shore property are sampled for fecal coliform during low tide. Samples are collected at low tide to target the discharge of freshwater versus residual marine water.

Field staff assess whether a representative flow can be measured, record a detailed description and GPS coordinates for the site, and take a digital photo. Discharges with fecal coliform concentrations of 200 FC / 100ml or more are confirmed by collecting a second sample. Those sites where confirmation sample results are 200 FC / 100ml or more are considered fecal hotspots. Hotspots are investigated and parcel investigations are conducted beginning with parcels immediately adjacent to the discharge.

PARCEL EVALUATION METHODS

Parcels are evaluated for fecal sources and to provide information to prevent premature onsite sewage system failures and animal waste violations. Field staff prepare for parcel evaluation by researching assessor tax records and onsite sewage permit records. Records are reviewed and pertinent information is recorded on a survey form. OSS permit records are attached to the survey form with an extra copy for the property owner or resident.

Property owners or residents are contacted and an informational interview is conducted to gather information about water use habits. Field staff request access and consent to field inspect OSS and other potential fecal sources. Permission to collect water samples and to conduct dye tests is requested as necessary. Dye testing is conducted to determine if a hydraulic connection exists 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 and 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.

Non-participating parcels are evaluated during wet weather conditions to determine whether the property may have a fecal pollution source.

PILOT NUTRIENT STUDY METHODS

Fecal Coliform and Nitrate+nitrite Nitrogen Correlation Study

A fecal coliform and nitrate+nitrite nitrogen correlation study was conducted by collecting paired samples from the most densely developed portion of Kitsap's Hood Canal shoreline. Density was calculated by identifying properties in the field and by geographic information system imagery of plat overlays. A total of 55 drainages were sampled each on January 30, 31; March 2; and April 13, 2005 for three separate sampling events. Three sites were omitted from the March and April events due to lack of flow, and one site was lost due to a landslide.

The three sampling events were categorized according to the total rainfall depth for one week prior to the sample date. 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, was categorized as "moderate" as 0.67 inches of rain fell in the previous week and the third event, April 13, was considered "heavy" as 1.18 inches of rain fell in the previous week.

Where possible, flow data was collected by the bucket and stopwatch method three times and averaged. Those that were not collectable were estimated pursuant to the quality assurance project plan. (Kitsap County Health District 2005).

Before and After Fecal Source Correction Investigation

A "Before" and "After" fecal source correction investigation was conducted on discharges with elevated FC caused by confirmed failing onsite sewage systems and non-impacted, similar control sites nearby. Sampling was performed during wet season dry conditions occurring from February to April 2005, 2006 and 2007. Water samples were collected three times before and three times after the onsite failure was corrected and analyzed for FC, ammonia, nitrate+nitrite nitrogen, and ortho-phosphorus. Peer review of the 2005 project report resulted in measuring Salinity in 2007. Flow was measured through the bucket and stopwatch method or visual estimation.

SHORELINE AND PARCEL EVALUATION RESULTS

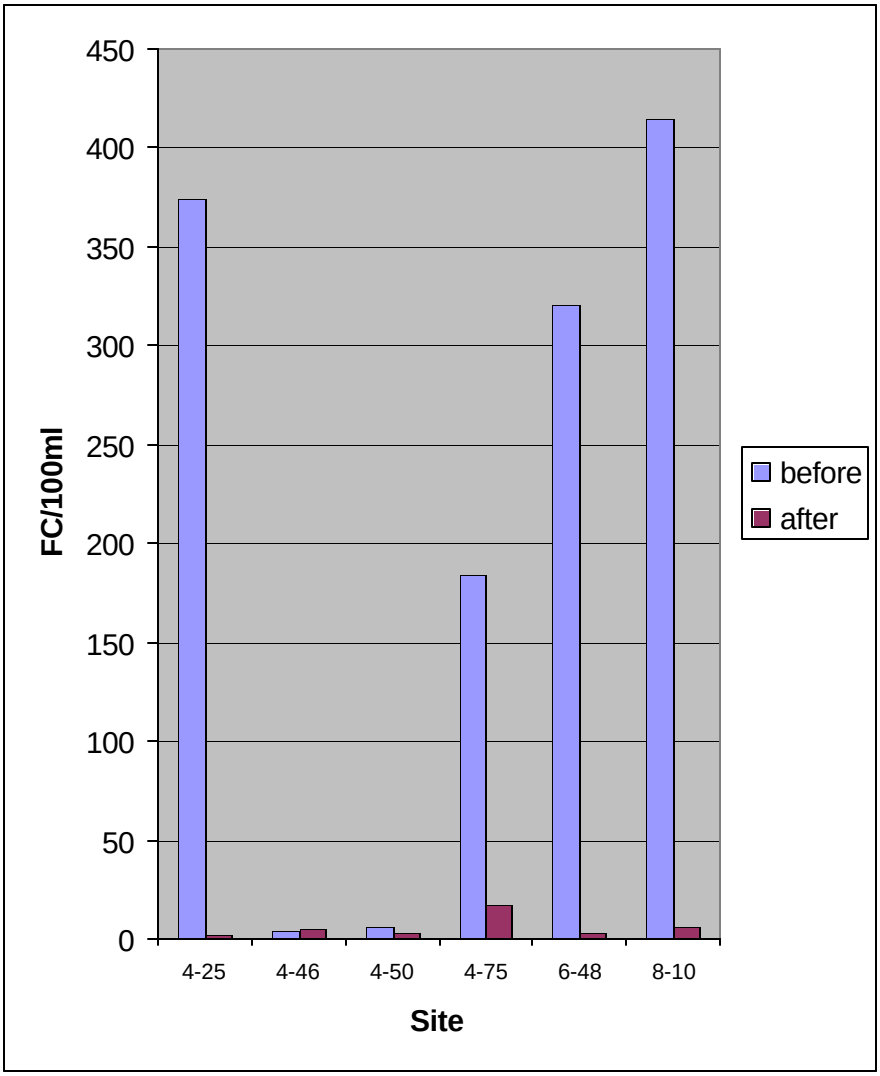
Seventeen miles of developed Hood Canal shoreline were targeted for evaluation. To date, the Health District has conducted wet weather shoreline evaluation of all 17 miles. Approximately 4 miles of undeveloped shoreline in the project area were not surveyed. Staff is scheduled to conduct dry weather shoreline evaluation of the 17 miles of developed shoreline in Summer 2007.

In 2005, staff found twelve failing OSS in the southern eight miles of developed shoreline comprising 340 homes. This failure rate of less than 4% is on the low end of the range of Health District project results since 1996, where failure rates ranged from 4% to 15%. Since January 2007, staff found ten failing OSS in the northern nine miles. Two hotspots are under investigation at this time.

PILOT NUTRIENT DISCHARGE STUDY RESULTS

Figure 1 illustrates large FC reductions after correcting failing OSS in four of the six study drainages. Site 4-45 and 4-50 were greywater discharges with low fecal concentrations. Site 6-48 was a greywater discharge with a high fecal concentration.

Figure 1. Comparison of FC Before and After OSS Correction



Fecal Coliform and Nitrate+nitrite Nitrogen Correlation Study

No correlation was found between FC and nitrate+nitrite nitrogen. 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 (Kitsap County Health District 2006).

Before and After Fecal Source Correction Investigation

Household waste enters the septic tank in the form of ammonia, where it is converted to nitrate+nitrite nitrogen. It is unclear how much of the nitrate+nitrite nitrogen is denitrified or taken up by plants in a drainfield with conforming setbacks to surface and

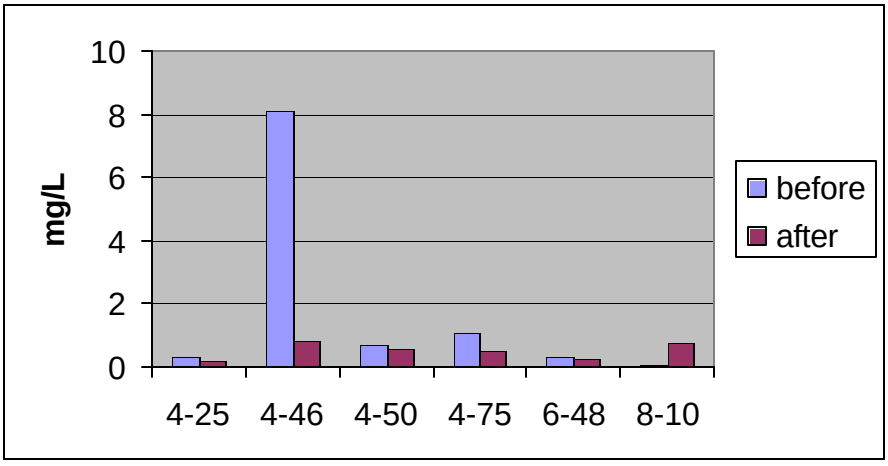
ground water and hardpan. Ortho-phosphorus is the biologically available form of phosphorus, a nutrient common in the environment from soils and from human laundry products and sewage effluent. The presence of elevated ammonia nitrogen and ortho-phosphorus can be indicative of incomplete OSS treatment.

Shoreline discharges from failing onsite systems showed elevated nutrients and nutrients were reduced after correction. Discharge samples from six of the confirmed failing OSS were collected for special study events. 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. Control sites were located not more than four properties from the impact site and were similar discharges, such as curtain drains or bulkhead drains. Samples were analyzed for nitrate+nitrite nitrogen, ammonia nitrogen and ortho-phosphorus.

Shoreline discharges from failing OSS demonstrated statistically significant reductions as compared to control discharges. Four of the six study sites showed statistically significant reductions in nitrate+nitrite nitrogen (**Figure 2)** (Sites 4-25, 4-46, 4-50, and 4-75). Elevated nitrate+nitrite nitrogen before correction was most likely due to incomplete treatment of septic tank effluent in the drainfield. Five of the six sites replaced the OSS and one removed a well overflow from the drainfield area (Site 4-75). One site showed a statistically significant increase in nitrate+nitrite nitrogen due to extensive land clearing upgradient of the drainage (Site 8-10).

Site 4-46 was a greywater discharge into a bulkhead drain. Site 4-75 had a broken tile drainage line from a well overflow located between the tank and the drainfield, allowing well water to flow through the drainfield and into a drain at the beach.

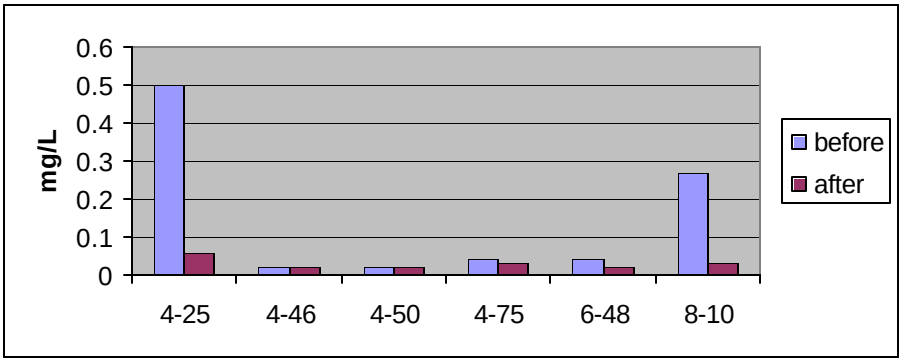
Figure 2. Nitrate+nitrite Before and After OSS Correction



Site 8-10 showed statistically significant reduction in ortho-phosphorus (**Figure 3)** and ammonia (**Figure 4)**. The OSS was located in the shoreline bulkhead and sewage effluent received only partial treatment in the tank before discharging to the shoreline. The site was a direct discharge due to 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's 750-gallon capacity is undersized for the four

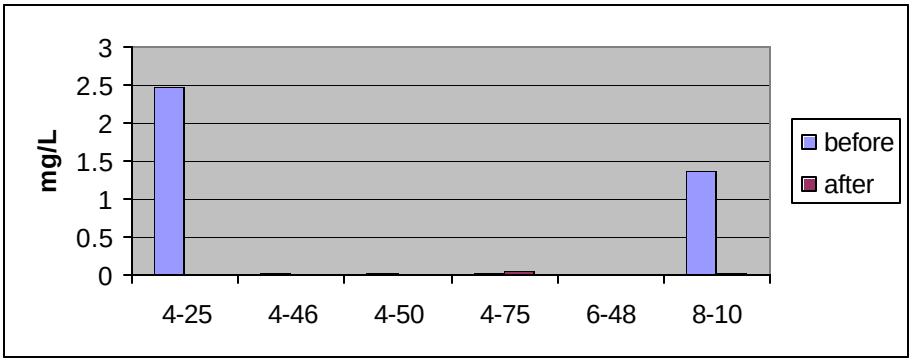
bedrooms served, which results in incomplete nitrification of the sewage effluent. Site 4-25 was also a direct discharge to the shoreline due to close proximity of the system to the marine water.

Figure 3. Ortho-phosphorus Before and After OSS Correction



Sites 4-46, 4-50, and 6-48 exhibited low ammonia concentrations because they were greywater discharges. Site 4-75 had low ammonia concentrations because the septic tank was converting the ammonia to nitrate+nitrite nitrogen, which was carried to the shoreline by the well overflow running through the drainfield.

Figure 4. Ammonia Before and After OSS Correction



CONCLUSIONS

The Health District has conducted wet weather shoreline evaluation of all 17 miles of developed Hood Canal shoreline (excluding Bangor Submarine Base). In 2005, staff found twelve failing OSS in the southern eight miles of developed shoreline comprising 340 homes. This failure rate of less than 4% is on the low end of the range of Health District project results since 1996, where failure rates ranged from 4% to 15%. Since January 2007, staff found ten failing OSS in the northern nine miles. Two hotspots are under investigation at this time.

No correlation was found between FC and nitrate+nitrite nitrogen. Results ranged from 0.01 to 9.80 mg/L nitrate+nitrite nitrogen and did not increase during rain conditions

Shoreline discharges from failing OSS showed elevated nutrients. Failing OSS contribute nitrogen to shoreline discharges in the form of nitrate+nitrite or ammonia nitrogen and is dependent upon the mechanism of the failing OSS.

Shoreline discharges from failing OSS demonstrated statistically significant reductions of nutrients as compared to control discharges. Shoreline discharges from four of the six study sites showed statistically significant reductions in nitrate+nitrite nitrogen following OSS repair. One site showed a statistically significant increase in nitrate+nitrite nitrogen due to extensive land clearing upgradient of the drainage (site 8-10). One site showed statistically significant reduction in ortho-phosphorus and ammonia.

The Health District's approach to Hood Canal's low dissolved oxygen problem is to protect both public and environmental health by finding and fixing OSS that are failing to the shoreline and proactively educating owners and residents. Nutrient studies did not demonstrate a relationship between FC and nutrients. Correcting failing OSS nets reduction of nutrients to the shoreline.

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