# Comparative Water Quality of Cozine, Gooseneck and Mill Creeks

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December 9, 2013
ENVS 385 Research Methods
Linfield College

**INTRODUCTION**

Water is an essential compound to the survival of all living organisms. Without it, life as we know it would not be able to flourish. Yet, it is not just water that is needed, but clean water free of pollution. Harmful pollutants caused by human sources such as fertilizer and/or chemical spills can become introduced into aquatic environments through runoff and underground seeps. Pollutants can be harmful to humans, animals, and aquatic life in the affected waters (Cunningham and Cunningham 2010). Water quality varied greatly over the past century in the United States, and national concern developed about dirty water. The concerns raised by the public led to the Water Pollution Control Act (WPCA) in 1948. The WPCA put the responsibility for water clean up in the hands of state and local agencies. The result limited the efficacy of the federal government in improving water quality across the nation. In 1972, the WPCA was changed into the Clean Water Act (CWA), which is still in effect today. The CWA had a new goal of restoring and maintaining water quality to federal standards enforced by the individual states. The main emphasis of the CWA was to require permits for point sources of pollution and to give responsibility to citizens to not pollute (EPA 2012c). The CWA reduced the amount of pollution entering our water from municipal and industrial sources while also facilitating the clean up of many affected waterways (Andreen 2004). Point pollution therefore was handled under the act, and many sources were eliminated and controlled. Now many of our pollution problems come from non-point sources, causing the need for more work to be done to ensure that water quality remains high (EPA 2012c).

Low water quality can affect the ecosystem surrounding a water source. Water quality as a whole is a measure of suitability for living organisms based on physical, chemical and biological attributes (USGS 2012a). Aquatic organisms have very specific needs, and fluctuations in water quality adversely affect the organisms' living conditions. Polluted waterways often have elevated and above average levels of nutrients. The added nutrients will often decrease the oxygen available in the water, cause algal blooms, and alter the pH and temperature, all of which can cause the death of sensitive species (Mueller and Helsel 2009). Often the nutrients come from non-point pollution sources such as the runoff from agriculture that contains animal waste or fertilizers. Water quality is based on standards that the CWA puts forth to ensure water is suitable for marine life and human uses, including consumption. To determine if these standards are met, measurements are taken by various organizations and presented by the states to the Environmental Protection Agency (DEQ 2012).

The environmental research methods class of fall 2013 analyzed the water quality of three creeks in the Yamhill watershed: Cozine, Gooseneck and Mill Creeks. Our research builds on data collected by previous years' classes (Colahan et al. 2011; Weinbender and Crane 2011; Bailey et al. 2012). The goals of the project were to gain a better understanding of water quality at each site, see how the sites differ and determine causes for any differences, and examine changes in water quality over time. Because Cozine is surrounded by an urban environment, whereas both Gooseneck and Mill are in a rural setting, we hypothesized that Cozine would have the lowest overall water quality. The Greater Yamhill Watershed Council did restoration projects in Gooseneck Creek (Waterways Consulting 2013), so we also hypothesized that the water quality should be improving over time in Gooseneck and Mill.

The Oregon Department of Environmental Quality (ODEQ) made previous assessments of water quality in its 2010 Integrated Report Assessment Database. They used a ranking system of 5 categories to indicate the degree of water quality. Waters with poor quality require the calculation of the total maximum daily load (TMDL), which is the maximum amount of a pollutant that can be present in the body of water while still allowing it to meet standards. A TMDL is an important step towards reducing the level of a pollutant in a particular water body so standards can be met. Category 1 meets the DEQ water quality standards for all parameters of water quality measured. Category 2 meets some of these standards. Category 3 means that the data available is not sufficient to determine the status of the water body. This could mean that enough data has simply not been attained, or that it is suspected that a certain standard is not being met, but the pollutant causing the problem is not known. Category 4 signifies that the water quality of the water body is limited, or not meeting standards, but that a TMDL is not needed, either because there already is one or more of the standards not being met on account of a non-pollutant factor such as low flow rate. Category 5 does not meet water quality standards to the extent that a TMDL is needed (ODEQ 2010).

Waters tested by the DEQ can be placed in several categories at the same time, based on different factors. For example, a stream could meet standards for most parameters measured, and be classified as category 2. However, the same stream could have a fecal contamination problem and be classified as category 5 with regards to fecal contaminants. In 1998, Cozine Creek was assessed and determined to not have an official DEQ water body status due to insufficient data. The database noted however, that fecal coliform contamination was present. Gooseneck Creek has been tested for biological criteria as well, and due to an unknown pollutant factor, has been placed in category 3. Gooseneck was classified to be a category 4 with respect to flow, but a TMDL was not needed because flow is not considered a pollutant. The Gooseneck Creek data was collected between 1998 and 2004. The DEQ has conducted the most testing on Mill Creek. Sampling from different areas along Mill Creek from 2003 and 2004 revealed an unknown pollutant impairing biological systems, warranting a classification of category 3. Other places along the creek, however, were listed as category 2, which meets the DEQ standards for biological criteria. The creek was tested in 1998 for dissolved oxygen (DO), pH, temperature, and fecal coliforms and met the DEQ standards. It was noted that this was an improvement in Mill Creek from the 1980s, when testing showed standards were not met for some of the proposed parameters. Similar to Gooseneck Creek, Mill Creek was listed as category 4 for flow modification (ODEQ 2010).

All of the sites we sampled are located in the Yamhill Watershed within the Willamette Valley of Oregon. Kalapuya Indians, who originally inhabited the area, altered the ecosystem by selectively burning forests to mold the land to their purposes (Bower et al. 1999). The region is made up mainly of natural forest and grassland, which has led to it widely being used for farming and ranching. Cozine Creek is the exception, running through the heart of McMinnville, Oregon. Due to the urban environment the water quality of the creek has been negatively impacted. In 2009 it was determined to have *E. Coli* contamination. The source of the pollution, a sewer pipe discharging in the creek, was repaired. Since then, the *E. Coli* counts have dropped. It is normal to see trash on the banks and in the creek. Invasive species such as thistles (*Cirsium spp.*), English ivy (*Hedera helix*), and Himalayan blackberry (*Rubus armenicus)* dominate the riparian vegetation (ODA 2012). The riparian vegetation influences the organic matter that is deposited into streams and can change the amount of sunlight that is able to penetrate through to the stream, which in turn affects temperature. Urban streams tend to have higher rates of erosion of both the bed and banks, fewer pieces of large woody debris, and more simplified morphology, due to urban development, all of which can have negative effects on stream health (McBride and Booth 2005). Restoration of urban creeks is challenging because urbanization affects a stream so immensely that small-scale projects do not often lead to major improvements in water quality (Booth 2005).

Mill and Gooseneck Creeks are located in Polk County in a sparsely populated, rural area of private land ownership. Gooseneck joins Mill just downstream from our Gooseneck Creek surveying sites (DEQ 2006). In the late 1800s and early 1900s, humans altered Gooseneck and

Mill Creeks to facilitate logging. Dikes and dams were built along Mill Creek; these have since been removed although remnants remain. A trench was dug from Mill Creek to the town of Sheridan to transport logs to the lumber mill there (Bower et al. 1999). Gooseneck Creek was straightened so logs could be floated down it. This led to increased flow rates that decimated the bottom of the creek so that only the underlying bedrock remained. This resulted in a lowered water table in the area. Gooseneck became the site of a restoration project conducted by the Greater Yamhill Watershed Council in 2009. Restoration efforts reopened a blocked side channel, (originally used to capture logs) in order to allow water runoff. Log weirs were constructed to slow the flow and create pools and riffles that would allow gravel to accumulate on the bottom of the creek and restore the original habitat (Waterways Consulting 2009). Gooseneck has multiple weirs and side channels creating pools that attract various organisms. Not all of the weirs survived heavy flow in the winter from 2012-2013, and those that have broken apart have been rendered useless. There is thick vegetation consisting mainly of bushes, thick grasses, deciduous trees and some conifers along the banks of both Gooseneck and Mill Creeks (Bower et. al. 1999). Today, the land surrounding Mill and Gooseneck Creeks is mostly agricultural. Within the whole of the Mill Creek Watershed, which includes Mill and Gooseneck creeks, there are ten Concentrated Animal Feeding Operations (CAFOs), eight of which are dairies with herds from 100 to 5,000 cows. These CAFOs constitute much of the land use surrounding Mill Creek and can be sources of fecal contaminants and nutrients (DEQ 2006). Testing the combination of these three sites will allow us to compare urban vs. rural effects on water quality.

**Water Quality Variables**

There are many different ways to determine how clean water is. Some common parameters for testing water quality include chemical, physical, and biological analyses (Resh and Unzicker 1975). We tested various aquatic indicators of water quality at Cozine, Gooseneck, and Mill creeks. We tested pH, DO, flow rate, temperature, depth, turbidity, Biochemical Oxygen Demand (BOD), macroinvertebrates, and levels of bacteria.

One measure used to determine overall quality of water is pH. Many biological life forms can’t survive if the conditions are too acidic or basic. pH ranges from 0 to 14, with 7 being neutral. Natural waterways typically range between 6.5-8.5. Added pollutants can change the pH, which in turn causes the levels of nutrients and metals to vary. This can lead to toxic conditions for organisms living in the water (USGS 2012b).

Temperature is another important factor in determining the water quality. Most aquatic life can only survive within a small range of temperatures. Depending on location and the type of organisms present, bodies of water can be classified and the ideal temperature range determined (WA DoE 2012). Temperature is directly related to flow rate and amount of shade. Changing these can raise the temperature, adversely affecting entire ecosystems. We also measured flow rate to determine the overall quality of water because flow affects the temperature of the water.

Dissolved oxygen (DO) is another important measurement to take into account when examining water quality. It is the amount of oxygen available to aquatic organisms. Flow can affect DO because water flowing over rocks and logs becomes aerated. Stagnant waters have lower levels of DO because they are typically warmer than faster moving water (Michigan DEQ 2012). Some animals, like trout, are able to thrive in areas where there are higher levels of oxygen in the water, so high DO indicates high water quality (Earth Force 2010a). Pools or slow waters are parts of the stream where the structure of the streambed and habitat create a spot where flow is slower and depth is deeper. Riffles are areas of the stream or river where water is more turbulent and running over rocks; they tend to be in the straighter parts of the stream (EPA 2012d). The wide array of habitat is necessary for high diversity in stream flora and fauna because of increased niches and available resources. Pools, for example, can help create a cooler temperature and slower moving water system for young fish to rest as they travel upstream (Palmer 1993). Slow and fast moving waters can be a defining feature of the stream and give insights into how the physical and biological factors play a role in the health of the stream.

Biochemical oxygen demand (BOD) is another factor we measured to examine water quality. BOD reflects the oxygen demand of the microorganisms and organic debris suspended in the water, as well as oxidants that chemically react to remove dissolved oxygen from the water. BOD is important because a high BOD combined with a low DO level can lead to depleted oxygen levels. BOD most often directly relates to runoff, detritus, sewage overflow, water treatment plant outflow, failing septic systems, feedlots, and food processing plants (EPA 2012c).

Turbidity is another important water quality parameter. Turbidity measures the amount of suspended particles in the water that block the passage of light to the benthic layer of the stream. These particles can include sediment, plankton, algae, and other materials. Higher turbidity results in higher water temperatures because particles in the water absorb the heat of solar energy. Because warmer water holds less DO than cold water, higher turbidity results in lower DO. Sources of turbidity include urban runoff, erosion, excessive algal growth and waste discharge. The consequences of high turbidity for aquatic life includes clogging fish gills, which lowers their immunity to disease, smothers fish and macroinvertebrate eggs, and reduces the fecundity of fish (EPA 2012e).

High levels of nutrients such as nitrate, ammonia and phosphorus can lead to depletions of DO and increased bacterial growth. Sources of ammonia are mostly natural such as animal waste, whereas sources of nitrates are mostly human caused such as fertilizer runoff, failing septic systems, and animal manure runoff (SEPA 2013). In excess, ammonia and nitrates can cause eutrophication in bodies of water, stimulating an over production of algal growth, thus increasing BOD. Phosphates come from animal, human and industrial waste that washes into waterways. Phosphate in excess can also cause eutrophication (Earth Force 2010c). Because of this, we tested the levels of these compounds in the water. Although naturally occurring, high levels of these nutrients can disrupt the balance of an aquatic ecosystem (Michigan DEQ 2012).

Sampling bacteria is another good parameter that indicates water quality. Many different types of bacteria are found in water, the majority of which are natural and good for the ecosystem. However, some can be harmful and must be monitored to keep our waters safe (CDC 2012). *E.coli* is a key indicator of fecal coliforms in water systems. *E.coli* lives in the intestinal tracts of vertebrates. It is released into the environment with fecal material and can cause harmful health impacts on organisms in aquatic ecosystems, including humans who participate in recreational activities. Fecal coliforms enter the waterways from run off, sewage seepage, and direct deposits from animals. They can also be washed into waterways from land during rainfall (EPA 2008). *E.coli* and coliform sampling is crucial to monitor fecal matter in waterways (Ishii and Sadowsky 2008), because while fecal coliforms themselves do not necessarily cause disease, they are good indicators of other disease causing bacteria in streams (EPA 2008).

Along with chemical factors, macroinvertebrates are biological indicators of water quality. They can provide insight about water quality over time because they must be able to survive and reproduce their environment. Having a variety of different aquatic species is indicative of high water quality and low levels of pollution (Lindbo and Renfro 2003). Because varying species have varying tolerances to levels of pollution, we used a rating system called the Pollution Tolerance Index (PTI) to categorize those we found at the various test sites.

Macroinvertebrates are acutely affected by the amount of dissolved oxygen in water. Those that indicate healthy, good quality water are found in areas of high dissolved oxygen, and those that indicate poor quality water are found in areas of low dissolved oxygen (Myslinski and

Ginsburg 1977). Macroinvertebrates production is linked to the stream environment and has been shown to be positively correlated with nitrates and alkalinity (Krueger and Waters 1983). Macroinvertebrates help with decomposition of organic material in the streambed, whereas the level of nitrates and the alkalinity affect the rate of decomposition. A stream's physical and chemical characteristics are linked together, and macroinvertebrates are a way to look into these stream qualities.

## METHODS

### Site Selection and Description

Two creek locations were randomly selected by the 2011 spring ENVS 385 class at Cozine and Gooseneck Creeks. That class chose the area where the Gooseneck sample sites would be to study the impact of a restoration completed by the Greater Yamhill Watershed Council. The Cozine sites were chosen because they were adjacent to the Linfield College campus. In addition, Cozine is an urban stream and would allow comparison between a rural stream and an urban one. At each stream location, three sample sites were randomly chosen (Colahan et al. 2011). The fall 2012 ENVS 385 class added sites at Mill Creek for comparison to Gooseneck Creek. Again, individual sample locations were randomly selected. Each class took GPS readings at each site and placed flagging to ease locating sites in the future (Bailey et al. 2012). Our class (Fall 2013) used the same sample sites at each stream. We took GPS readings (Table 1).

Table 1: GPS Coordinates for Each Site Location (Fall 2013)

| Site | Latitude | Longitude |
|---|---|---|
| Mill 1 | N 45.03385 | W 123.42480 |
| Mill 2 | N 45.03366 | W 123.42520 |
| Mill 3 | N 45.03310 | W 123.42564 |
| Gooseneck 1 | N 45.03108 | W 123.43077 |
| Gooseneck 2 | N 45.03054 | W 123.43047 |
| Gooseneck 3 | N 45.02998 | W 123.43034 |
| Cozine 1 | N 45.20309 | W 123.19790 |
| Cozine 2 | N 45.20295 | W 123.19790 |
| Cozine 3 | N 45.20288 | W 123.19790 |

Samples at Mill Creek were taken on September 11 and October 9, 2013. Site 1 was characterized by slow moving water and pools that narrowed in width after an upstream riffle. The depth in this part of the creek was 20 to 30 cm deep, with some shallower areas on the rock beds and deeper depressions in the streambed. The stream bottom was mostly large cobbles and rocks with some gravel. Site 2 exhibited fast moving water, or a riffle, that was shallow and wide. This part of the stream was wider as the water from the upstream riffle spread over a flatter landscape. In dry seasons, the water level is usually not high and can result in a split stream. This portion of the stream was much shallower than sites 1 and 3, with most of our measured depths being less than 15cm. Site 3 also had fast moving water and as it was the riffle upstream from site 2. This part of the stream had a stronger flow and was much narrower than the rest of the stream. Mill Creek was shaded by a riparian buffer of mostly Red Alder (*Alnus rubra*) and willows (S*alix spp.*) but also contained shrubs and herbaceous plants. Figure 1 shows the approximate site locations at Mill Creek.


*Figure 1: Aerial View of Mill Creek. (Bailey, 2012)*

Gooseneck Creek samples were collected on September 18 and October 9, 2013. Site 1, was a pool just past an old restoration weir that had been washed out. This pool was well shaded from the eroded bank and several large trees. The stream was only about 3m wide and the depth was 20 to 30 cm. Although there was some gravel in the stream, most of the streambed consisted of bedrock. Site 2 was characterized by slow moving water that was located after a weir. There was a small plunge pool below where the weir had been placed, then it became shallower again. Our samples were taken in or just downstream from the plunge pool. The bed consisted of some large boulders and cobbles on the carbonate bedrock. An overgrown side channel that floods during high water began on the eastern bank of the stream just above site 2. This side channel would have emptied out at site 1. Site 3 was characterized by slow moving water and was located right after a weir that was still intact. It consisted of a wide spreading pool that concentrated into a single riffle immediately downstream. Most of the stream bottom consisted of bedrock, although there was gravel on the side of the streambed. The Gooseneck Creek site was surrounded by similar species as Mill Creek, including Red Alder (*Alnus rubra)* and Willow *(Salix spp.).* Figure 2 shows the approximate site location of each site.

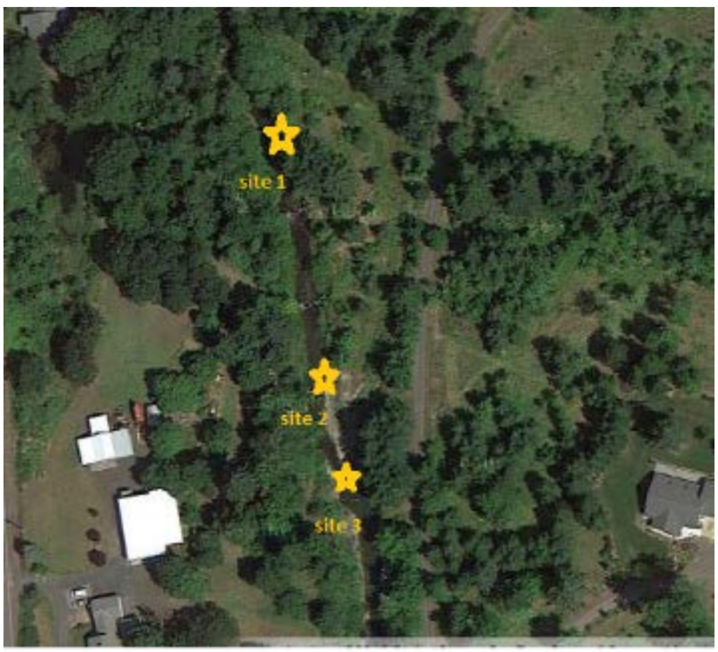


*Figure 2: Aerial View of Gooseneck Creek. (Bailey, 2012)*

We collected data at Cozine Creek on September 18th and October 23rd. Site 1 was characterized by slow moving water that included logs partially blocking the stream flow. The sediment was fine and composed of silt and clay. Site 2 was a pool at a slight bend in the stream. The sediment at site 2 consisted of large rocks and gravel intermixed with the muddy sediment. Site 3 was fast moving water located between a foot bridge over the creek and the bridge where Highway 99W crosses the stream. There was a pile of woody debris and fallen trees at the downstream end of the site that created a deeper riffle. The depth varied depending on the location of the stream but ranged between 40 and 85 cm. The stream was surround by young

Oregon Ash (*Fraxinus latifolia*) and White Oak (*Quercus garryana*). In addition, Cozine creek is surrounded by dense thickets of Himalayan blackberry (*Rubus armeniacus)* and other non-native species. The stream is impacted by urbanization and runoff from the surrounding environment and trash is commonly found in the creek and on the shore. Figure 3 shows the approximate locations the three sites.


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*Figure 3: Aerial View of Cozine Creek. (Bailey, 2012)*

**Water Quality Sampling Methods**

At each site we collected two water samples. One was collected using a sterile Nalgene bottle and immediately placed in a cooler with ice. The second was collected in a BOD bottle, ensuring no air bubbles were in the bottle. The BOD samples were wrapped in foil and placed in the cooler. Both bottles were returned to Linfield's College's Environmental Science Lab. The sterile samples were stored in the freezer until the water could be analyzed. The BOD samples were stored in a dark cabinet at room temperature for 5 days. We collected the water samples before other measurements in order to obtain the cleanest possible sample. We then measured pH, DO, temperature, and flow rate at each site, taking triplicate measurements of each parameter. In addition, macroinvertebrate sampling was done three times at each site.

**pH**

At each site pH was measured using a Hannah Instruments pH meter (model number: H198128). The probe was submerged under the water and the measurement was recorded after the pH reading became stable.

**Dissolved Oxygen (DO) and Temperature**

DO and temperature were measured at each site using a Hanna Instruments DO meter (model number: HI9146). The DO meter was calibrated to both 0% and 100% oxygen before leaving the laboratory to improve accuracy. The probe was placed in the stream. After the reading stabilized, temperature was recorded in degrees C; DO was recorded in both parts per million and as percent.

**Biochemical Oxygen Demand**

The BOD bottles were placed in a dark cabinet in the lab for five days. On the fifth day, DO measurements were taken in triplicate from each water sample using the DO meter. We calculated BOD by subtracting the five-day DO from the original DO (EPA 2012a).

**Flow Rate**

Rate of water flow was measured using a Geopack flow meter (model MFP51). The meter was submerged with the propeller facing oncoming water and held still. When the average flow over 6 seconds became stable, the reading was recorded.

**Turbidity, Chemical Tests, and Coliform Bacteria**

For these measurements, the previously collected, frozen water samples were thawed, and the water used to measure turbidity, nitrate, ammonia, phosphate and coliform bacteria.

**Turbidity**

Turbidity was measured with a Hannah Instruments Turbidity meter (model number: HI93703). Each sample was shaken before the water was poured into a cuvette. The cuvette was placed into the turbidity meter reading chamber and ftu (formazin turbidity units) were measured. Turbidity was measured three times from each sample.

**Nitrate Nitrogen**

We used a LaMotte Nitrate Nitrogen water test kit (model number 3354) to determine the level of nitrate nitrogen in each sample of water as per the directions in the LaMotte test kit (LaMotte 2012c). Each water sample was tested in triplicated.

**Ammonia-Nitrogen**

Each water sample was tested for ammonia-nitrogen using a LaMotte Ammonia-Nitrogen water test kit (model number 5864), using the directions provided with the kit (LaMotte 2012a). Each sample was analyzed in triplicate.

**Phosphorus**

We used a LaMotte Low Range Phosphorus water test kit (model PAL, code: 3121-01) to determine the level of phosphorus in each water sample according to the directions (LaMotte 2012b). Each sample was analyzed in triplicate.

**Coliform Bacterial Sampling**

Each thawed water sample was also used to assess the level of coliform bacteria (*E.coli* and other coliform bacteria). Using Easy Gel Kits as per directions, we pipetted 2 mL of water from the Cozine sample for September 18, 2013 and 5 mL of water from all other samples. Three plates were made from each water sample. The plates were placed in an incubator at 35°C for 48 hours. After that time, plates were removed and the colonies were counted. Colonies appearing dark blue or purple were counted as *E. coli*. Colonies that appeared pink were counted as other coliform bacteria (Micrology 2008).

**Macroinvertebrate Sampling**

Macroinvertebrates were not sampled until the October collection dates. Macroinvertebrates were collected from each sample site at three random locations determined by using a grid system. We used two D nets to collect organisms in a square foot area from the bottom of the creek. One net was placed along the bottom facing upstream in order to catch any organisms floating down with the current. The other was placed upstream facing the other and scraped along the bottom to loosen the organisms on rocks or in sediment. This process was repeated several times at each square foot. Rocks and large sediment were hand brushed to remove organisms that might be clinging to them. The nets were then emptied into tubs and all living organisms were collected and placed in jars with 95% isopropyl alcohol.

Preserved organisms were classified in the lab using dissecting microscopes. Macroinvertebrates were identified to the lowest taxa possible using stream macroinvertebrate field guides (Edwards 2008; Stroud Water Research Center 2013). We then calculated the pollution tolerance index (PTI) for each site. This was done by grouping the organisms into categories based on the Chesapeake Bay Water Initiative (Mitchell and Strapp 1997). Organisms in Group I that are very pollution intolerant (e.g., stoneflies and mayflies) received a score of three in the rating system. Group II organisms can live in a wide variety of conditions (e.g., craneflies and scuds) and received two points. Group III organisms can tolerate high levels of pollution (e.g., worms and snails) and received one point (Mitchell and Strapp 1997).

After species were identified, each species was grouped into an abundance category. Samples from each site were lumped together to examine abundance of species at each location. Species with numbers between one and ten were ranked as rare, species with numbers greater than 10 were considered common, and species with numbers greater than 100 were marked as dominant. The abundance category was then multiplied by an index value determined by the pollution tolerance group number for the species. The numbers were totaled, giving our PTI index number. That could be used to determine the quality of the stream. If the sum of the abundance index fell below 20 the stream was rated as poor, between 20 and 40 the stream was fair, and greater than 40 was a good quality stream (Mitchell and Strapp 1997).

### Statistical Analysis

We used the statistical analysis program SPSS to analyze the data. We used a one-way ANOVA with a Tukey post-hoc test to test for significant differences in each water quality variable among the sites using October data. We used a two-tailed paired t-test to test for significant differences between fall 2011 and October 2013, fall 2012 and October 2013, and September 2013 and October 2013. In using one-way ANOVAs, we assumed the observations were independent and not related to one another, the dependent variables were normally distributed, and variances were equal across groups. For the two-tailed paired t-tests, we assumed the dependent variables were normally distributed and the independent variables were dichotomous and had paired groups (Urdan 2010)

## RESULTS

DO was significantly lower at Cozine Creek than the other to creeks (Table 2). BOD was significantly higher at Cozine and Gooseneck than Mill Creek. Cozine had significantly higher temperature, turbidity, phosphate and ammonia than the other creeks. Flow was significantly higher at Mill than Cozine or Gooseneck.

Table 2: Mean (standard deviation) of water quality variables at Cozine, Mill, and Gooseneck Creeks in October 2013, as well as the probability from the ANOVA . Different letters denote significant differences among creeks as per Tukey Post Hoc test. Significant variables are highlighted.

| Parameter | Cozine | Mill | Gooseneck | probability |
|---|---|---|---|---|
| **DO(%)** | 58.5(6.5) a | 90.1(1.7) b | 96.7 (2.8) c | <0.0001 |
| **Phosphate (ppm)** | 0.04 (0.05) a | 0.00 (0) b | 0.00 (0) b | 0.006 |
| **Nitrates (ppm)** | 0.11 (0.22) | 0.0 (0.0) | 0.0 (0.0) | 0.123 |
| **Ammonia (ppm)** | 0.23 (0.08) a | 0.04 (0.03) b | 0.10 (0.06) b | 0.00 |
| **Turbidity** | 5.95 (2.37) a | 1.12 (0.23) b | 2.43 (0.57) b | 0.00 |
| **pH** | 6.3 (0.5) | 6.7 (0.3) | 6.5 (0.6) | 0.249 |
| **Flow** | 0.7 (1.0) a | 53.9 (35) b | 12.3 (1.7) a | 0.00 |
| **Temperature** | 11.5 (1.4) a | 7.2 (1.3) b | 8.2 (1.0) b | 0.00 |
| **BOD** | 9.8 (6.0) a | 1.1 (4.2) b | 11.3 (6.3) a | 0.001 |

We compared water quality measurements taken in September 2013 to those collected in October 2013. At Cozine Creek, we found that temperature and phosphates were significantly higher in September, whereas DO and nitrates were significantly higher in October (Table 3). At Gooseneck Creek, pH, temperature, and turbidity were significantly higher in September, and flow and DO were significantly higher in October. At Mill Creek, temperature, BOD, turbidity and ammonia were significantly higher in September, and flow was significantly higher in October.

Table 3: Mean (standard deviation) for water quality variables in September 2013 and October 2013 at Gooseneck, Mill, and Cozine Creeks. Probability is from two-tailed, paired t-test analyses. Significant variables are highlighted.

| **Parameter** | **Site Location** | **September 2013** | **October 2013** | **probability** |
|---|---|---|---|---|
| **pH** | Cozine | 6.3 (0.5) | 6.3 (0.5) | 0.6085 |
| | Gooseneck | 7.2 (0.2) | 6.5 (0.6) | 0.0167 |
| | Mill | 6.7 (1.2) | 6.7 (0.3) | 0.2548 |
| **Flow** | Cozine | 0.4 (0.9) | 0.7 (0.3) | 0.6811 |
| | Gooseneck | 1.1 (1.1) | 12.2 (1.7) | <0.0001 |
| | Mill | 17.3 (14.4) | 53.9 (34.7) | 0.0009 |
| **Temp C** | Cozine | 13.4 (0.7) | 11.5 (1.4) | 0.0085 |
| | Gooseneck | 21.9 (1.9) | 8.2 (1.0) | <0.0001 |
| | Mill | 15.8 (2.1) | 7.2 (1.3) | <0.0001 |
| **DO (%)** | Cozine | 43.5 (8.6) | 58.5 (6.5) | 0.0002 |
| | Gooseneck | 93.3 (1.6) | 96.7 (2.8) | 0.0343 |
| | Mill | 91.8 (3.8) | 90.1 (1.7) | 0.2993 |
| **BOD (%)** | Cozine | 16.0 (14.0) | 9.8 (6.0) | 0.3406 |
| | Gooseneck | -0.1 (35.2) | 11.3 (6.3) | 0.3012 |
| | Mill | 29.9 (5.8) | 1.1 (4.2) | <0.0001 |
| **Turbidity (ftu)** | Cozine | 9.1 (5.6) | 5.9 (2.4) | 0.1576 |
| | Gooseneck | 4.7 (1.6) | 2.4 (0.6) | 0.0034 |
| | Mill | 3.7 (0.6) | 1.1 (0.2) | 0.0034 |
| **Nitrate (ppm)** | Cozine | 0.0 (0) | 0.1 (0.2) | 0.169 |
| | Gooseneck | 0.0 (0) | 0.0 (0) | - |
| | Mill | 0.0 (0) | 0.0 (0) | - |
| **Phosphates (ppm)** | Cozine | 0.1 (0.1) | 0.0 (0) | 0.0353 |
| | Gooseneck | 0.0 (0) | 0.0 (0) | - |
| | Mill | 0.0 (0) | 0.0 (0) | - |
| **Ammonia (ppm)** | Cozine | 0.1 (0) | 0.2 (0.1) | 0.0049 |
| | Gooseneck | 0.3 (0.3) | 0.1 (0.1) | 0.2618 |
| | Mill | 0.1 (0.1) | 0.0 (0.0) | 0.0432 |

At Cozine Creek, DO, flow, BOD, temperature, phosphates and pH were significantly higher in 2011 than in 2012 or 2013 (Table 4). Nitrates were significantly higher in 2013 than 2011 or 2012. At Gooseneck Creek, temperature was significantly lower in 2013 than 2011 or 2012. pH was significantly higher in 2012, flow was significantly higher in 2013, and BOD was significantly higher in 2011. At Mill Creek, BOD and temperature was significantly lower in 2013, and flow was significantly higher in 2013.

Table 4: Mean (standard deviation) for water quality variables comparing Fall 2011 to Fall 2013 and Fall 2012 to Fall 2013 at Gooseneck, Mill, and Cozine Creeks. Probability is from two-tailed, paired t-test analyses; with each pair of years having a posted p-value. Significant variables are highlighted.

| **Parameter** | **Site** | **Fall 2011** | **Fall 2012** | **Fall 2013** | **Probability (2011 vs 2013)** | **Probability (2012 vs 2013)** |
|---|---|---|---|---|---|---|
| **DO %** | Cozine | 69.3 (2.9) | 58.2 (1.0) | 58.5 (6.5) | 0.001 | 0.912 |
| | Gooseneck | 97 (1.2) | 89.42 (4.72) | 96.7 (2.8) | 0.750 | 0.808 |
| | Mill | NA | 90.22 (3.76) | 90.1 (1.70) | NA | 0.590 |
| **Temp C** | Cozine | 12.3 (0.1) | 9.6 (0.35) | 11.5 (1.4) | 0.091 | 0.027 |
| | Gooseneck | 12.2 (0.2) | 12.3 (0.71) | 8.2 (1) | 0.000 | 0.000 |
| | Mill | NA | 8.24 (0.58) | 7.19 (1.34) | NA | 0.005 |
| **pH** | Cozine | 6.8 (0.2) | 6.49 (0.26) | 6.3 (0.5) | 0.001 | 0.036 |
| | Gooseneck | 6.6 (0.4) | 7.12 (0.24) | 6.5 (0.6) | 0.807 | 0.001 |
| | Mill | NA | 6.53 (0.32) | 5.19 (2.95) | NA | 0.182 |
| **Flow (cm/s)** | Cozine | 44.9 (73.6) | 10.5 (8.6) | 0.7 (1.0) | 0.108 | 0.01 |
| | Gooseneck | 5.4 (2.7) | 10.0 (0.0) | 12.3 (1.7) | 0.000 | 0.003 |
| | Mill | NA | 16.11 (10.09) | 53.89 (34.97) | NA | 0.002 |
| **BOD %** | Cozine | 22.1 (7.6) | 3.7 (3.8) | 9.8 (6.0) | 0.001 | 0.078 |
| | Gooseneck | 32.9 (2.7) | 4.1 (7.83) | 11.3 (6.3) | 0.000 | 0.135 |
| | Mill | NA | 10.58 (6.42) | 0.91 (4.22) | NA | 0.012 |
| **Phosphate (ppm)** | Cozine | 0.2 (0.0) | 0.0 (0.0) | 0.0 (0.1) | 0.000 | 0.035 |
| | Gooseneck | 0.0 (0.0) | 0.0 (0.0) | 0.0 (0.0) | - | - |
| | Mill | NA | 0.0 (0.0) | 0.0 (0.0) | NA | - |
| **Nitrate (ppm)** | Cozine | 0.0 (0.0) | 0.0 (0.0) | 0.1 (0.2) | 0.170 | 0.169 |
| | Gooseneck | 0.5 (0) | 0.0 (0.0) | 0.0 (0.0) | - | - |
| | Mill | NA | 0.0 (0.0) | 0.0 (0.0) | NA | - |

There were significantly more coliform bacteria in Cozine Creek than in Gooseneck or Mill Creeks in both September and October in 2013 (Table 5).

Table 5: Mean (standard deviation) of the number of coliform bacteria in October 2013 at Cozine, Mill, and Gooseneck Creeks, as well as the probability from the ANOVA. Different letters denote significant differences among creeks as per a Tukey Post Hoc test. Significant variable are highlighted.

| | ***E. coli*** **(colonies per 100mL) Sept 2013** | **Other coliforms (colonies per 100 mL) Sept 2013** | ***E. coli*** **(colonies per 100mL) Oct 2013** | **Other coliforms (colonies per 100 mL) Oct 2013** |
|---|---|---|---|---|
| **Cozine** | 44.4 (68.2) | 138.9 (92.8) a | 17.8 (27.3) | 55.6 (37.1) a |
| **Gooseneck** | 26.7 (28.3) | 8.9 (14.5) b | 26.7 (28.3) | 8.9 (14.5) b |
| **Mill** | 4.4 (2.9) | 0.0 (0) b | 4.4 (8.8) | 0.0 (0) b |
| **Probablity** | 0.1626 | <0.0001 | 0.1466 | <0.0001 |

There were significantly more *E. coli* in Cozine Creek in 2012 than in 2013 (Table 6), but there were significantly more *E. coli* in Gooseneck Creek in 2013 than in 2012 and 2011. There were significantly more other coliforms at Cozine Creek in 2013 than 2011. There were also significantly more other coliforms at Mill Creek in 2012 than 2013.

Table 6: Mean, (standard deviation) and p value for results of paired t-tests for bacterial counts from 2011 to 2013 and 2012 to 2013. Significant differences are highlighted.

| | Cozine | | Gooseneck | | Mill | |
|---|---|---|---|---|---|---|
| | ***E.coli*** **(colonies per 100mL)** | **Other coliforms (colonies per 100mL)** | ***E.coli*** **(colonies per 100mL)** | **Other coliforms (colonies per 100mL)** | ***E.coli*** **(colonies per 100mL)** | **Other coliforms (colonies per 100mL)** |
| **Fall 2011** | 22.2 (27.3) | 0.0 (0) | 24.4 (29.6) | 13.3 (26.5) | NA | NA |
| **Fall 2012** | 61.1 (33.9) | 93.3 (48.1) | 2.2 (6.5) | 5.6 (11.5) | 2.2 (6.5) | 8.9 (14.1) |
| **Fall 2013** | 17.8 (27.3) | 55.6 (37.1) | 26.7 (28.3) | 8.8 (14.5) | 4.4 (8.8) | 0.0 (0) |
| **Probability (2011 vs. 2013)** | 0.772 | 0.002 | 0.049 | 0.178 | NA | NA |
| **Probability (2012 vs. 2013)** | 0.073 | 0.237 | 0.038 | 0.282 | 0.594 | 0.023 |

There were significantly more other coliforms in Cozine Creek in October than in September 2013 (Table 7). But there were significantly more *E. coli* and other coliforms in Mill Creek in September than in October 2013.

Table 7: Mean, (standard deviation) and p value for results of paired t-tests for bacterial counts comparing September 2013 to October 2013.

| | **Cozine** | | **Gooseneck** | | **Mill** | |
|---|---|---|---|---|---|---|
| | **E.coli (colonies per 100mL)** | **Other coliforms (colonies per 100mL)** | **E.coli (colonies per 100mL)** | **Other coliforms (colonies per 100mL)** | **E.coli (colonies per 100mL)** | **Other coliforms (colonies per 100mL)** |
| **Sept 2013** | 11.1 (22.0) | 0.0 (0) | 26.7 (28.3) | 8.9 (14.5) | 38.9 (33.3) | 22.2 (26.4) |
| **Oct 2013** | 17.8 (27.3) | 55.6 (37.1) | 26.7 (28.3) | 8.9 (14.5) | 4.4 (8.8) | 0.0 (0) |
| **probability** | 0.638 | 0.002 | -- | -- | 0.022 | 0.035 |

Mill Creek had the greatest number of species of macroinvertebrates, but the results were not significantly different among the sites (Table 8).

Table 8 The number of macroinvertebrate organisms collected at each of the three creeks, as well as total number of species and total number of organisms per creek.

| | **Cozine** | **Gooseneck** | **Mill** |
|---|---|---|---|
| **Mayflies** | 2 | 48 | 20 |
| **Stoneflies** | 4 | 67 | 111 |
| **Netspinners** | 0 | 2 | 19 |
| **Scuds** | 47 | 1 | 4 |
| **Dragonflies** | 5 | 0 | 0 |
| **Craneflies** | 0 | 1 | 6 |
| **Alderflies** | 0 | 0 | 3 |
| **Worms** | 36 | 3 | 4 |
| **Snails** | 20 | 27 | 1 |
| **Mites** | 5 | 5 | 2 |
| **Midges** | 16 | 3 | 1 |
| **Total # Species** | 13 | 14 | 17 |
| **Total** | **135** | **157** | **171** |

Gooseneck and Mill Creeks had higher numbers of pollution sensitive species (Table 9) than Cozine Creek, but all three creeks had similar numbers of wide spread and pollution tolerant species.

Table 9. The number species in each of the three Pollution Tolerance Index group at each Creek.

| Site | Group I - Pollution Sensitive | Group II - Wide Spread | Group III – Pollution Tolerant |
|---|---|---|---|
| **Cozine** | 4 | 2 | 4 |
| **Gooseneck** | 9 | 2 | 4 |
| **Mill** | 9 | 3 | 4 |

Mill and Gooseneck Creeks had higher PTI levels than did Cozine Creek (Table 10), although the results were not significantly different among the sites (p=0.565)). Based on the average PIT, Mill and Gooseneck Creeks were rated fair, whereas Cozine Creek was rated poor.

Table 10. Pollution Tolerance Index (PTI) values per site, with mean and standard deviation per stream.

| Site | PTI per site | Average PTI | Standard Deviation | Average Stream Quality |
|---|---|---|---|---|
| **Cozine 1** | 28.1 | 19.7 | 7.7 | Poor |
| **Cozine 2** | 18.1 | | | |
| **Cozine 3** | 13 | | | |
| **Gooseneck 1** | 23 | 29.2 | 11.4 | Fair |
| **Gooseneck 2** | 22.3 | | | |
| **Gooseneck 3** | 42.4 | | | |
| **Mill 1** | 15 | 30.1 | 16.8 | Fair |
| **Mill 2** | 27 | | | |
| **Mill 3** | 48.2 | | | |

**DISCUSSION**

Based on the water quality parameters we tested this fall, Gooseneck and Mill creeks appear to have better water quality than Cozine Creek. In particular, DO, temperature, phosphates, nitrates and coliform bacterial data suggest that our original hypothesis was correct. We hypothesized that Cozine Creek's water quality would have remained about the same as last year, which we did not find to be true. It seems to have slightly deteriorated in quality as shown by temperature, flow, BOD, and coliform bacterial data. Our other hypothesis was that Gooseneck and Mill creeks would have improved in water quality since last year. We also found this hypothesis was not supported by our data, instead water quality seems to have remained the same.

When looking at the trends in each creek over the last three years, water quality in Cozine Creek appears to have declined or remained the same since 2011 as shown by flow, temperature, pH, DO and phosphate data. Gooseneck and Mill Creeks have remained about the same in water quality. However, it is important to note that our data represents a collection of points in time, making it difficult to draw firm conclusions.

Although we collected samples in September and October 2013,we only used the October data for statistical analysis unless otherwise noted. Air temperature seems to have had an effect on water temperature at each creek because days with lower air temperature had lower water temperature. On October 9, the average air temperature was 9°C, and water temperature at Mill was 7.2°C. On October 16, the average air temperature was 11°C, and the average water temperature at Gooseneck was 8.2°C. Lastly, on October 23, the average air temperature was 13°C, and the average water temperature at Cozine was 11.5C (Wunderground 2013). This shows a positive correlation between air temperature and water temperature.

Temperature, flow, BOD, nutrient content, and bacteria are all factors that either influence or are influenced by DO levels within a stream (MDNR 2013). Typically, DO is lower when temperature is higher and flow is lower (EPA 2012a). The temperature at Cozine Creek was higher and flow was lower than at the other two creeks. This could partially explain why DO at Cozine was lower than Gooseneck or Mill. However, Cozine Creek also had the highest concentrations of nutrients (phosphates, nitrates and ammonia), as well as the highest level of coliform bacteria. Increased bacteria and nutrients in a stream usually result in higher BOD. When BOD is high, DO is usually low (EPA 2012a). Although Cozine Creek did not have the highest BOD, it was still relatively high. Cozine Creek also had the highest turbidity, which could possibly be explained by the high numbers of bacteria in the stream.

Temperatures were higher at Gooseneck than at Mill Creek, but lower than temperatures at Cozine Creek. The flow at Gooseneck was higher than Cozine but less than at Mill. However, DO was higher at Gooseneck than at the other creeks. BOD was higher at Cozine and Gooseneck Creeks. This may be due to higher levels of nutrients, which frequently leads to algal blooms and bacterial growth. This can cause high demand for oxygen and low DO in streams (USGS 2012a). The moderate levels of turbidity in Gooseneck Creek may be related to bacteria (EPA 2012e).

Temperatures were lowest and flow was highest at Mill Creek, which, along with Gooseneck had higher levels of DO than Cozine Creek. Turbidity and BOD were low at Mill, which may relate to the absence of nutrients and low bacterial levels in the creek (EPA 2012e).

The chemical and bacterial water quality findings correlate fairly well with our macroinvertebrate data. Measurement such as DO and bacterial levels represent the quality of water on the date the samples were taken. Macroinvertebrates show water quality over a long time as the water must maintain a certain quality long enough to support pollution sensitive organisms (Lindbo and Renfro 2003). The PTI rating we used ranked Cozine Creek as poor and Mill and Gooseneck creeks as fair (Mitchell and Stapp 1997). Most of the specimens sampled from Cozine Creek were categorized as pollution tolerant; whereas Mill and Gooseneck had greater numbers of pollution sensitive species. These findings are consistent with other studies; pollution intolerant species cannot thrive in urban environments with increased exposure to human interactions (Lear 2009). Stream environment and macroinvertebrates are a way to assess potential fish habitat and how well fish species could survive. This is because many species of pollution intolerant macroinvertebrates, such as mayflies, are some of the primary sources of food for fish (SciOly 2013).

When we compared the data we collected this fall to the data collected by the previous two year’s data, we see that Cozine Creek has consistently had poor water quality whereas Gooseneck (in 2011 and 2012) and Mill (in 2012) had fair water quality. This correlates with the macroinvertebrate findings. At this point, though, it is hard to demonstrate any real trends in water quality based on the chemical or bacterial measurements. It is hard to compare the DO data as we used three different DO meters over the 3 years, sometimes using two in one season. In addition, because our creek data was collected at points in time, it cannot capture the whole picture. We found many variables fluctuated from year to year, which may reflect nothing more than changes in weather.

Of note is the fact that this was the first year two collections were made, one in September and one in October. We compared the data from the two months to examine the differences. Temperature and turbidity tended to be higher in September, whereas flow and DO tended to be higher in October. Nutrient and bacterial levels varied by site. The week before the September sampling, there were 1.22 inches of rain. The week before the October sampling, there were only 0.5 inches of rain (Wunderground 2013). However, our stream depth data revealed that depths at all creeks were greater in October than in September. This may have been due to the reduced temperature that would reduce evaporation, as well as an overall accumulation of water.

The increased flow and decreased temperature may be the reason for an increase in DO observed at Cozine and Gooseneck Creeks as well as the decrease in BOD at Cozine and Mill Creeks due to the relationship between temperature and oxygen (Steichen et al 1979). It was interesting that turbidity decreased at all sites between September and October, because precipitation events often increase turbidity in streams by increasing nearby soil erosion due to runoff (Heinzel 1967).

pH only changed at Gooseneck when it decreased from September to October. The higher pH in September at this creek may be due to the fact that the creek bed is highly eroded down to carbonate bedrock (Bailey et al. 2012). Cozine Creek had increased *E.coli* and other coliform bacteria from September to October. Streams often have higher bacterial contamination on wet weather days or after large storm events, which may account for the increase in these numbers between September and October (Parks and VanBriesen 2009; Paul and Meyer 2001). Gooseneck Creek bacterial levels stayed the same, while Mill Creek levels decreased.

Overall, our data support our hypothesis that Cozine Creek has lower water quality than either Gooseneck or Mill Creeks. This is very likely due to its urban location, which contributes to higher nutrient and bacterial levels. Gooseneck and Mill, although located in agricultural areas, appear to be more buffered from the larger impacts of that land use, and have fair water quality. The data collected by our class are consistent with the findings of the 2011 and 2012 classes, suggesting that the streams are not improving.

**Limitations**

Like all studies, there are several limitations to this study. One limitation that became apparent when comparing our data to previous years is that three different DO meters have been used in the past three years. This presents a possible problem when comparing DO and BOD as we are unsure of the consistency among the meters.

Another major limitation is the impact of weather on stream water quality. The data we collected in September occurred after a major rain storm that was followed by a relative dry period. Another rain fall event occurred before we made our second collections in October. IN addition, the temperature had fallen significantly between the times of the collection. Although we attempted to account for this in our comparison the two sets of data, there may be some results that are not consistent due to this weather. We could only get weather data for McMinnville, which may not be accurate for Gooseneck and Mill Creeks.

A third limitation relates to identifying macroinvertebrates. All members of the class counted different jars. We each had different levels of knowledge about macroinvertebrates, so there may be inconsistencies and mistakes made in counting and identification. Two of the draw samples from Cozine Creek were brought into the lab, where we separated macroinvertebrates from the sediment under controlled conditions; all the others were completed in the field. This could have led to discrepancies in some of the Cozine data. In addition, the best time to sample macroinvertebrates in summer, which is the peak of larval abundance. By sampling in fall, we are not finding all the potential macroinvertebrate larvae that would be present several months earlier.

Finally, there is always the possibility of errors made recording or measuring data. Equipment may have been used improperly, or data may have ben written down incorrectly. Most of the equipment we used took a while to stabilize, so students may not always have waited for the most accurate reading. While we did our best to avoid these problems, there is always a chance that they occurred.

**Recommendations for Future Classes**

There are several recommendations we would suggest to future. First, adding a site upstream (preferably near the headwaters) of Cozine Creek would be beneficial in determining more about the quality of the headwaters and how it changes with urbanization. Adding headwater sites on Mill and Gooseneck would also be good. It might also be beneficial to use two urban streams to balance our two rural streams (Mill and Gooseneck). It would also be good to track the weather at our sites for a week before we sample the streams; that might be helpful in analyzing our findings. In the future, we should also test to see if nutrient levels are different in the lab than the field. We don't know how freezing the samples impacts the nutrient content although we do not believe it does. Also, for the best year to year comparisons, it would be important to use the same equipment every year.

**Acknowledgements**

We would like to thank Tom Rupers for allowing us to sample the sections of Gooseneck and Mill Creeks that run through his property. We would also like to thank the Greater Yamhill Watershed Council for their help in finding the site at Gooseneck Creek, as well as getting the class of Spring 2011 started on this project. We also would like to thank Barbara Van Ness for helping us in lab and the field.

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