EDMONDS WATER QUALITY MONITORING PROJECT

PRELIMINARY REPORT

October 2015 to May 2016

EDMONDS -WOODWAY HIGH SCHOOL
STUDENTS SAVING SALMON

EDMONDS STREAM TEAM

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EXECUTIVE SUMMARY

Edmonds-Woodway High School students in the Students Saving Salmon club volunteered to collect monthly water quality measurements starting at the beginning of the 2015/2016 school year from several streams that flow through or near the downtown area of Edmonds. This citizen science project, called the Edmonds Stream Team, was initiated because water quality data from Edmonds streams and the Marsh is lacking and there are concerns about the health of our streams and how stream water quality including stormwater may be affecting aquatic organisms and salmon.

Students monitored and collected data on upstream and downstream sites in Willow Creek, Shell Creek, Shellabarger Creek, and the Edmonds Marsh for water quality parameters that are important for aquatic organism survival. Water samples were also collected seasonally for lab analysis for dissolved metals, petroleum-derived compounds, and fecal coliform bacteria. Macroinvertebrate sampling and identification occurred at upper Shell Creek assisted by staff from Sound Salmon Solutions.

A total of 16 sites were designated for monitoring (see map in Appendix 1) to ensure a representative sample of each stream and the Marsh. Sites were monitored by four Stream Teams, with two to four students each, during the first two weeks of each month from October 2015 to May 2016. Students used a YSI Professional Plus instrument to collect measurements for water temperature, dissolved oxygen, oxygen saturation, pH, conductivity, specific conductance, total dissolved solids, salinity and nitrates. Monitoring site data including air temperature, water depth, stream width, clarity, vegetation, bottom substrate were also collected. All data were recorded on a standardized data sheet and then entered into a Google Drive database. Quality control measures included filed monitoring protocols, repeat samples and review/editing of database entries. The database is available for public access at: https://docs.google.com/spreadsheets/d/1KeA6zoxVKimg0semyQJVqPJVemSBh74R-yON3BAe1_Y/edit#gid=1161067171

This preliminary report summarizes the results for the first eight months (October 2015 to May 2016) of this project. The primary water parameters - water temperature, pH, and dissolved oxygen - were collected at each site each month and the recorded measurements were evaluated against the Washington State Water Quality Criteria for freshwater aquatic life (see Washington Administrative Code 173-201A-030).

Average water temperatures in the three creeks ranged from 51.0°F in the fall to 49.1°F in the winter to 53.8°F in the spring. These temperatures are below the maximum temperature requirement of 60.8°F for salmon in the Washington Administrative Code. Summer temperatures will be assessed when collected.

Dissolved oxygen levels in the three creeks ranged from a low of 9.3 mg/L to a high of 12.5 mg/L which are well above the 1-day minimum requirement of 8.0 mg/L in the Washington Administrative Code for salmonid spawning, rearing and migration.

Higher dissolved oxygen levels are more critical in Shell Creek than the other two creeks because salmon do spawn in the lower reaches of the Shell Creek. Salmon eggs in the gravel in the winter in Shell Creek require higher dissolved oxygen levels than specified in the Wash. Admin. Code to grow and hatch. The dissolved oxygen levels measured in lower Shell Creek were 11.0 mg/L in November, 11.4 mg/L in December, 11.2 mg/L in January and 12.1 mg/L in February. Thus, the measured dissolved oxygen levels in lower Shell Creek were within the optimum levels necessary for chum salmon eggs. Overall, lower

Shell Creek averaged 11.0 mg/L dissolved oxygen for all months (October to May) while upper Shell Creek averaged 9.6 mg/L over all months.

The pH level in the three creeks generally stayed constant through the eight months averaging pH 7.7 except for a December decline in all streams down to an average pH 7.2 probably caused by heavy rainfall since rain tends to be more acidic (pH 5.6) than stream water. All of the observed pH levels in the creeks were within the pH 6.5 to 8.5 range in the Washington Administrative Code that is suitable for salmon. Heavy rainfall in December also resulted in reduced conductivity readings at all sites since rainwater contains less ions (thus lower conductivity) than stream water.

Nitrate levels in all three creeks were low averaging 1.3 mg/L for six months (October to March) with a high of 2.3 mg/L in February (which was also the month with highest average nitrate levels at 2.0 mg/L).

The main water body flowing through the Edmonds Marsh (from Shellabarger inlet at the Hwy 104 culverts to the Marsh outlet) had dissolved oxygen averaging 9.4 mg/L that exceeded minimal requirements for all months with a high of 11.3 mg/L in April and low of 7.9 mg/L in October. However, dissolved oxygen measured on the northern edge of the Marsh along Harbor Square was too low (averaging 1.8 mg/L) for salmon survival in all months except March when it increased to 7.1 mg/L.

Water temperature at all sites in the Marsh exhibited the expected trend of decreasing temperatures in the fall (average 54.2°F from October to early December) with winter lows (average 47.6°F for January to early March) and increases into spring (average 58.5°F from April to May). There was an unexpected high water temperature reading of 68.5°F at the Marsh outlet on May 10th, which was confirmed with a replicate sample. The high reading was very different from the May water temperatures of the Shellabarger inlet which was 57.7°F and the lower Willow Creek incoming flow which was 56.1°F. The high reading in May may be an artifact of monitoring the Marsh outlet at the end of a very low tide cycle when most of the Marsh waters had drained down to very low levels.

The edges of the Edmonds Marsh along Harbor Square were more acidic (average pH 6.61) than the main flow through the Marsh from the Shellabarger inlet at the Hwy 104 culverts to the Marsh outlet (average pH 7.31) in all months. One site along Harbor Square in January had a measured pH of 6.47 and that was the only Marsh site that wasn’t within the WA Water Quality Standard of between pH 6.5 and pH 8.5.

Salinity measurements at the Marsh outlet (which is representative of the main body of the Marsh) from December to early March (averaging 0.14 ppt) reflect the low salinity of the incoming freshwater from the Shellabarger inlet and lower Willow Creek (both having average salinity of 0.11 ppt for all months). But, when the tide gate is secured open (from mid-March to mid-October), the salinity measurements were significantly greater in the Marsh with 9.76 ppt salinity in October, 6.8 ppt in April and 3.2 ppt in May. The ecological functions and environmental benefits of this estuarine wetland would be enhanced by keeping the tidegate secured open year-round and moving forward with the Willow Creek Daylighting project to open a tidal channel to Puget Sound that will allow full and uninhibited tidal exchange in the Edmonds Marsh.

Water samples for fecal coliform bacteria analysis were collected from 14 monitoring sites in February and 11 sites in April. The lower Shellabarger Creek, the Shellabarger Marsh, the Shellabarger inlet to the Edmonds Marsh, and the Edmonds Marsh outlet sites all had counts of fecal coliform bacteria exceeding 100 colonies/100 mL in one or both months sampled. In contrast, the upper and lower Willow and Shell

Creek sites had an average fecal coliform count of 29 colonies in Shell Creek and 10 colonies in Willow Creek. Although there are no Washington Water Quality Standards for fecal coliform for freshwater aquatic life, the high levels observed may exceed the Washington criteria for water contact recreation (i.e., levels must not exceed a geometric mean value of 100 colonies/100 mL in areas used by swimmers), thus indicating a potential water quality problem (even though these waters are not used by swimmers). Further, and likely more intense, sampling for fecal coliform is needed to better understand the elevated fecal coliform levels in Shellabarger.

Water samples for dissolved metals were collected in the fall (October 2015), winter (January 2016) and spring (April 2016) from lower creek sites and the Edmonds Marsh. All sites had very low levels of arsenic, cadmium, chromium, cooper, iron, lead, and zinc detected in the samples. Mercury was not detected at any of the sites. Iron (which was analyzed only in the winter samples) and zinc had higher levels detected than the other metals, but the levels were below the Washington standards.

Water samples for petroleum-derived compounds were collected in the fall (October 2015), winter (January 2016) and spring (April 2016) from lower creek sites and the Edmonds Marsh. Total petroleum hydrocarbons (TPH) were detected at all sites sampled in all three seasons (fall, winter and spring). For those sites sampled in all three seasons, they each had all three types of petroleum hydrocarbons - diesel, oil, and volatile range - detected in at least one of the season samples except the lower Willow Creek site which had no volatile range TPH detected in any sample. Lab analyses for polycyclic aromatic hydrocarbons (PAH) were limited to five samples from the Marsh outlet in all three seasons (fall, winter, spring) and at lower Willow Creek and the eastern Marsh edge in the fall due to the cost of the lab analysis. None of the 18 types of PAH analyzed for were detected at levels greater than 0.016 µg/L.

Stream biomonitoring using the presence of benthic (bottom dwelling) macroinvertebrates as a biotic indicators of stream health and water quality was conducted in upper Shell Creek in early May. Macroinvertebrates (i.e., insect larvae, crustaceans (amphipods, isopods) and mollusks (snails) that are visible to the naked eye) were collected and identified . Since some benthic macroinvertebrates cannot survive in polluted water while others can survive or even thrive in polluted water, the presence/absence of the different macroinvertebrates was used as a relative indicator of water quality. About 15 different macroinvertebrates, with varying pollutant tolerance, were found in the Shell Creek sample resulting in an index rating of ‘good’ water quality.

The first eight months of the project has demonstrated that a citizen science project utilizing volunteer high school students can be successful in collecting high quality scientific data while providing students hands-on experience in conducting field science. The current water quality monitoring project should continue is so annual trends can be evaluated and baseline information established. Having a long term data series will allow for future comparisons to potential environmental or pollutant driven perturbations and potential effects of climate change.

The water quality of Shell Creek, which has a wild spawning run of chum salmon, needs to be kept optimal for salmon. Other creeks, such as Shellabarger Creek, although impacted by development and piped channels, also needs to have good water quality not only for potential salmon use in remaining usable salmon habitat, but to ensure the watershed contributes to good water quality in downstream areas such as the Marsh and Puget Sound. Actions that may be taken in Edmonds to maintain or improve water quality and habitat conditions are provided in the recommendations section of this report.

INTRODUCTION

This preliminary report summarizes the results from the first eight months of a citizen science project, called the Edmonds Stream Team, conducted by Edmonds -Woodway High School (EWHS) students in the Students Saving Salmon club. Students volunteered to conduct monthly water quality monitoring in several Edmonds streams and the Edmonds Marsh to determine the condition of these waters and whether the quality of water may be affecting aquatic life and salmon.

The City of Edmonds has several creeks draining into Puget Sound that may support salmon, but unfortunately there is little baseline data on water quality in these streams nor information on whether stormwater and other runoff may be affecting the ability of these streams to support salmon. There was one instance of a die-off of juvenile coho salmon in May of 2004 at the Willow Creek Hatchery that was attributed to potential stormwater pollutants in Willow Creek after a rainstorm, but no water quality data was available to evaluate it (Seattle Times, May 26, 2004). To address the lack of water quality data, the Edmonds Stream Team, a citizen science project with volunteer high school students from the EWHS Students Saving Salmon club, was implemented.

In December of 2014, local community members knowledgeable in salmon and environmental issues partnered with EWHS science teachers, the City of Edmonds Public Works Department, EarthCorps, and Sound Salmon Solutions to design and implement a student program to determine the condition of the Edmonds Marsh and several Edmonds streams that flow through or near downtown Edmonds. This citizen science project, called the Edmonds Stream Team, was designed to train and support EWHS students in the collection of high quality scientific information on water quality and assist the students in using the resulting data to engage in community efforts to address water quality, stormwater and wildlife habitat issues in Edmonds.

EWHS students in the Students Saving Salmon club formed volunteer stream teams that have participated in the Edmonds Stream Team since the beginning of the 2015/2016 school year. The Students Saving Salmon club was formed in 2014 by EWHS students concerned about their environment, especially salmon and their habitat. To achieve their goal of fostering and reestablishing salmon runs in Edmonds, students in the club wanted to learn more about Edmonds watersheds and conservation/restoration efforts so they could encourage measures that will make the local environment better for people and salmon. The City of Edmonds’ ongoing restoration work in the Edmonds Marsh to improve salmon access and provide juvenile salmon rearing habitat (called the "Willow Creek Daylighting Project”) by constructing an open daylighted tidal channel (Shannon and Wilson, Inc. 2013) motivated students to become involved in community efforts to restore salmon. The Students Saving Salmon club objectives are to participate in city government processes and community habitat enhancement efforts; develop educational materials and news articles; and, participate in projects, such as the Edmonds Stream Team citizen science project, to collect and disseminate scientific information on the environment.

Stream monitoring programs are essential for assessing current conditions and tracking changes in water quality over time to identify potential problems and/or determine if community actions have been successful. Unfortunately, city and state staff and funding resources are limited, and stream monitoring in urban areas such as Edmonds cannot be implemented without volunteer support. Thus, the Edmonds Stream Team citizen science project was designed to provide important baseline information to city and state government agencies to assist in environmental assessments and decision-making. The Edmonds Stream team not only collected data on basic water parameters, but also conducted bacterial monitoring for fecal coliform, biomonitoring using macroinvertebrates, and sampling water for dissolved metals and petroleum- derived compounds. This citizen science project also provides a great opportunity for high school students to become involved in field science and gain greater understanding of environmental issues.

When a stream falls outside healthy levels, it can have devastating effects on the organisms inhabiting that stream. The influx of stormwater and other environmental conditions can change the health of streams. High influxes of nitrates from nitrogen fertilizers can lead to algal blooms; once the algae dies off, it depletes the stream of oxygen, preventing fish from surviving there. Temperatures elevated above the levels that can support salmon will cause salmon to leave in search of cooler waters. Good water quality is essential to maintaining the presence of salmon in streams. Salmon transfer nutrients obtained in the ocean (marine derived nutrients) up rivers; when salmon die in a stream, they serve as a fertilizer for nearby plants and enrich both forest and stream ecosystems. Maintaining the health of the waters of rivers, streams, and the Puget Sound is also important to our economy. The commercial, recreational and tribal salmon fishing groups are a major economic asset to the Puget Sound region, and their continuation and the recovery of salmon are reliant on the quality of the Puget Sound's fresh and marine waters.

Stormwater runoff is one of the largest pollutants of streams and the Puget Sound. When people use lawn fertilizer, wash their car on impervious surfaces, have car leaks, or fail to pick up after their dog, they introduce contaminants to the environment. When it rains, these contaminants are washed into streams and the Puget Sound, where they may prove toxic for many organisms and can have devastating effects on river and ocean ecosystems. Recent studies have documented unexpected mortality of pre-spawn adult coho salmon as they enter streams in Puget Sound. Although stormwater is considered the likely cause of mortality, the specific toxins in the stormwater that may be responsible have not been identified (Scholz et al. 2011, Spromberg 2015). Streamside habitat is also a critical factor for stream quality; when trees grow alongside a stream, they secure the banks and prevent excess sediments in the stream and provide shade that helps keep streams cool and oxygenated for the aquatic insect larvae which comprise the diet of salmon. Nonetheless, water temperature, pH, dissolved oxygen, conductivity, and nutrients are among the basic characteristics of stream water that can be used to determine the quality of the stream and assess changes that may occur due to stormwater influx and environmental conditions.

BACKGROUND

Edmonds Watersheds and Creeks

Watersheds in the City of Edmonds are made up of small creeks or underground pipes that drain directly to Puget Sound or to the east into Lake Ballinger (which flows to Lake Washington and then to Puget Sound). Many creeks in Edmonds flow in a combination of open stream channels and underground pipes. The underground pipes collect flows from storm drains located along paved streets and parking lots and connect them to streams or large pipes that flow directly to Puget Sound. In some Edmonds watersheds, flows are in underground pipes most of the way to Puget Sound. Edmonds also has several wetlands that provide wildlife habitat including the Edmonds Marsh, Good Hope Pond, Shell Creek Marsh, and wetlands adjacent to the creeks. A map showing the Edmonds Watersheds and Creeks is provided in Appendix A.

All Edmonds creeks are designated as Type F (streams that contain fish habitat) in the Edmonds City Development Code (EDCD) in section 23.90.010. None of the Edmonds creeks are designated as "shorelines of the state" because they do not meet the 20 cubic-foot-per-second annual flow threshold for classification as a water of the state (Sea Run Consultants et al. 2007). The EDCD 23.90.010 lists the following creeks as those which anadromous fish species (fish born in freshwater that migrate to the ocean to grow into adults, and then return to spawn in freshwater streams) are known to occur: Willow Creek, Shellabarger Creek, Shell Creek, Hindley Creek, Perrinville Creek, and Lunds Gulch Creek.

Since the Edmonds Marsh is currently the focus of a major City of Edmonds restoration project, called the “Willow Creek Daylighting” project, the Edmonds Stream Team citizen science project was designed to focus on the Edmonds Marsh and the two creeks (Willow and Shellabarger) that flow into the Marsh so that pre-restoration project baseline data are collected. By including Shell Creek, which currently has spawning salmon return each year, the project covers water quality for the downtown area of Edmonds.

Edmonds Marsh

The Edmonds Marsh, located on the west side of Highway 104 south of downtown Edmonds, receives drainage from Shellabarger Creek Basin (378 acres), the Willow Creek Basin (393 acres), and another 61 acres from local areas (i.e., Harbor Square, adjacent Highway 104 storm drains, and the old UnoCal site) that drain into the Marsh (Herrera Environmental Consultants Inc. and City of Edmonds 2010). The Edmonds Marsh drains to Puget Sound through a channelized portion of Willow Creek at the southwest end of the Marsh. The channel passes through two large culverts under the railroad tracks into an open basin and then into a 48 inch pipe that passes through a tide gate and extends1,275 feet before draining into the lower intertidal area of Marina Beach (Sea-Run Consulting et al. 2007). The tide gate functions to prevent tidal saltwater intrusion into the Marsh from mid-October through mid-March to avoid flooding potential when high tides coincide with heavy rainfall; during the spring and summer months the tide gate is opened so that the Marsh is tidally influenced. The 23 acre Edmonds Marsh is a City of Edmonds Park managed by the Parks, Recreation and Cultural Services Department.

Willow Creek

Willow Creek flows through a largely residential area draining a 393-acre basin area of which 183 acres are in Edmonds and the remaining acreage in Woodway (Herrera Environmental Consultants Inc. and City of Edmonds 2010). Willow Creek starts in Edmonds and flows through Woodway before draining into the Edmonds Marsh on the west side of SR 104 just north of Pine Street (adjacent to the Willow Creek Hatchery).

Willow Creek is reported to contain coho salmon, cutthroat trout, and, historically, chum salmon (CH2M HILL 2004). Juvenile salmon were observed in Willow Creek in 2016, but these may have been releases from the Willow Creek Hatchery. The current 1,275 foot entrance pipe to Willow Creek/Marsh from Puget Sound (in subtidal area) likely precludes most adult salmon passage into the Marsh and creeks.

Shellabarger Creek

Shellabarger Creek drains a 378-acre basin area (called the “Edmonds Bowl”) and flows into the Shellabarger Marsh (a name we have coined for the marsh located within several private properties on the east side of Highway 104) which then drains into the Edmonds Marsh through two large culverts under Highway 104. The Shellabarger Creek corridor is heavily developed. The stream passes through culverts in many locations and most of the open reaches are located in landscaped residential areas (Herrera Environmental Consultants Inc. and City of Edmonds 2010).

Information on fish use of Shellabarger Creek is limited as WDFW has not conducted fish surveys in the creek. Resident cutthroat are likely present, and the creek is accessible to anadromous fish that use Edmonds Marsh (Sea-Run Consulting et al. 2007). Similar to Willow Creek though, the current 1,275 pipe outlet to Puget Sound likely precludes adult salmon from entering the Marsh and thus upstream to Shellabarger Creek. However, there was a possible adult salmon occurrence in the upper middle fork of Shellabarger Creek in the fall of 2014 based on the description of a fish observed upstream of culvert on 7th Avenue; it was either a coho salmon or a large cutthroat trout (My Edmonds News article; February 14, 2015).

Shell Creek

The Shell Creek basin comprises a drainage area of 821 acres, which includes the 178-acre Hindley Creek subbasin (Herrera Environmental Consultants Inc. and City of Edmonds 2010). Hindley Creek empties into Shell Creek west of Brookmere Drive just north of Caspers Street. Both Shell Creek and Hindley Creek have diversion structures that convey high flows directly into Puget Sound via a pipe system. The Shell Creek diversion structure and a fish ladder are located on Daley Street east of 7th Avenue. The Hindley Creek bypass begins at 9th Avenue N and Hindley Lane, where it enters the same pipe used for the Shell Creek bypass. Shell Creek flows through several undeveloped areas including Yost Park at the upper end of the creek and an open area on private property at the terminal end of the creek just east of the railroad tracks. The Shell Creek Marsh is located just north of Shell Creek at its terminal area east of the tracks.

Adult chum salmon were observed in lower Shell Creek in November 2015. Lower Shell Creek residents have reported seeing adult salmon in Shell Creek each year from late October to early December. WDFW has not conducted any recent fish surveys in the Shell Creek, but their biologists counted six chum salmon carcasses in the lower reach of Shell Creek during a November 2002 survey. Other biologists reported both coho and chum salmon spawning in lower Shell Creek in 2000 and 2001 (Sea-Run Consulting et al. 2007).

Water Quality Parameters

The Edmonds Stream Team collected data on water temperature, pH, dissolved oxygen, dissolved oxygen saturation, conductivity, specific conductance, total dissolved solids, salinity and nitrates. A description of each parameter and why it is important to aquatic organisms follows.

Water Temperature

Water temperature is a standard water parameter collected because it is the most critical factor influencing biological and chemical conditions in water. The solubility of oxygen, other gases and some compounds change with water temperature thus changing their effects on aquatic organisms. Colder water holds more oxygen and as water temperature increases, the capacity of water to hold dissolved oxygen becomes lower. If water is too warm, it will not hold enough oxygen for aquatic organisms to survive. Increasing water temperature not only increases the solubility of toxic compounds such as heavy metals, but it can also influence an organism's tolerance limits. For example, aquatic organism mortality rates for zinc are significantly higher at temperatures above 25°C (77°F) than at temperatures below 20°C (68°F). Water temperature also affects the metabolic rates and biological activity of aquatic organisms and influences their chosen habitats as well as behavioral choices, such as moving to warmer or cooler water after feeding (Kemker 2014).

Water temperature can be affected by many environmental conditions such as sunlight/solar radiation, heat transfer from the atmosphere, stream habitat, and turbidity. Shallow and surface waters are more easily influenced by these factors than deep water. Man-made influences on water temperature include runoff, riparian habitat alterations (e.g., building structures, removing/altering vegetation), large wood removal, thermal pollution, and impoundments.

Salmon require a supply of cold and clean water for optimal survival success. While water temperature requirements vary depending on salmonid species and life stage, generally salmonids require stream temperatures less than 17.8°C (64°F) for successful migration and rearing and less than 15.6°C (60°F) for spawning. Studies vary on optimum and preferred temperatures; a study on coho and Chinook by Stein et al. (1972) reports optimal growth for juvenile salmon in freshwater occurs in water temperatures of 9° to 13° C (48.2° to 55.4°F). Stream water temperatures above 17.8°C (64°F) cause additional stress and reduce survival while long term exposure to water temperatures higher than 24°C (75°F) are fatal to salmonids (Kerwin 2001).

Dissolved Oxygen

Dissolved Oxygen (DO) is a very important parameter in assessing water quality because of its influence on the organisms living within a body of water. DO is the amount of oxygen that is dissolved in water at a given temperature. Oxygen concentrations are much higher in air (about 21%) than in water (>1 %). This difference in concentration causes oxygen molecules in the air to dissolve into the water. More oxygen dissolves more quickly through aeration caused by wind (creating waves), rapids, waterfalls, ground water discharge or other forms of running water. Dissolved oxygen also enters water through plant photosynthesis.

There are many different factors that affect the amount of dissolved oxygen in water, the main one being temperature. Cold water can hold more oxygen than warm water. Warmer water becomes "saturated" more easily with oxygen, but it actually holds less oxygen. For example, if water becomes too warm in the summer months, the dissolved oxygen levels may become suboptimal for fish even if the water is 100% saturated with oxygen. Rivers and streams tend to stay near or slightly above 100 percent air saturation due to relatively large surface areas, aeration from rapids, and groundwater discharge. While groundwater usually has low DO levels, groundwater-fed streams can hold more oxygen due to the influx of colder water and the mixing it causes. Also, as the salinity of water increases, its ability to dissolve oxygen decreases; so saltwater holds less oxygen than freshwater.

Dissolved oxygen is necessary for many forms of aquatic life including fish, invertebrates, bacteria and plants. These organisms use oxygen in respiration, similar to organisms on land. The amount of dissolved oxygen needed varies from creature to creature. While some bottom feeders, crabs, oysters and worms can survive on low levels of DO (1-6 mg/L), most fish need higher levels of 4-15 mg/L (Kemker 2014).

The mean dissolved oxygen level necessary for adult salmonids is 6.5 mg/L, and the minimum is 4 mg/L. The Washington Administrative Code sets a 1-day minimum requirement of 8.0 mg/L for salmonid spawning, rearing and migration. Salmon generally attempt to avoid areas where dissolved oxygen is less than 5 mg/L and will begin to die if exposed to dissolved oxygen levels less than 3 mg/L for more than a few days. For salmon eggs, dissolved oxygen levels below 11 mg/L will delay their hatching, and below 8 mg/L will impair their growth and lower their survival rates. When dissolved oxygen falls below 6 mg/L, the majority of salmon eggs will die (Carter 2005).

pH

The pH of a stream determines the solubility of nutrients and chemicals in the water thus affecting the aquatic organism in the water. pH is the measure of the hydrogen ion concentration in water with 7 being neutral. Solutions with a pH above 7.0 are considered basic or alkaline, and solutions with a pH below 7.0 are considered acidic. Acidic water (low pH) dissolves nutrients and chemicals at a greater rate thereby making them more available for uptake by plants and animals, while a high pH can make nutrients insoluble and therefore unavailable to plants and animals. However, a very low pH (very acidic) can dissolve heavy metals, and make pollutants bio-available.

There are many factors that can affect pH in water, both natural and man-made. Most natural changes occur due to interactions with surrounding rock (particularly carbonate forms) and other materials. The pH of water can be affected by rain which is slightly acidic (pH of 5.6) because rainfall naturally interacts with carbon dioxide molecules in the atmosphere creating carbonic acid in the raindrops, thus lowering the rain's pH value (note: a pH level of 5.6, though acidic, is not considered acid rain which is below pH 5.0). Carbon dioxide concentrations can also affect pH; although carbon dioxide exists in water in a dissolved state (like oxygen), it can also react with water to form carbonic acid and reduce pH. Pine or fir needles can also decrease the pH of soil, and any water that runs over it, as they decompose.

A pH range between 6.0 and 9.0 is suitable for many fish, though salmon do best in waters with pH levels between 6.5 and 8.5.

Conductivity, Total Dissolved Solids, Salinity

Monitoring conductivity, total dissolved solids, and salinity provides insights into the amounts of inorganic and organic substances in water. Conductivity is a measure of water's ability to pass an electrical current. This ability is directly related to the concentration of ions in the water. These conductive ions come from dissolved salts and inorganic materials such as alkalis, chlorides, sulfides and carbonate compounds. The more ions that are present, the higher the conductivity of water. Likewise, the fewer ions that are in the water, the less conductive it is. Distilled or deionized water has a very low (if not negligible) conductivity value. Sea water, on the other hand, has very high conductivity.

Total dissolved solids (TDS) is similar to conductivity measurements but it is the total amount of all inorganic and organic substances smaller than two micrometers (i.e., dissolved) in water including minerals, salts, metals, cations or anions. TDS concentrations are equal to the sum of positively charged ions (cations) and negatively charged ions (anions) in the water. Sources for TDS include agricultural run-off, urban run-off, industrial wastewater, sewage, and natural sources such as leaves, silt, plankton, and rocks.

Salinity is a measure of the amount of salts in the water. Because dissolved sodium ions increase salinity as well as conductivity, the two measures are related. The salts in sea water are primarily sodium chloride, but can include smaller amounts of magnesium sulfate, potassium nitrate, and sodium bicarbonate which all dissolve into ions. Seawater typically has a salinity of about 35 parts per thousand (ppt) although lower values are typical near shore especially where rivers enter the ocean.

Conductivity and TDS are affected by the presence of inorganic compounds which are influenced by the geology and size of the area through which water flows. As rock and soil erode, minerals dissolve and they increase TDS, thus also increasing conductivity. Human impacts can influence conductivity and TDS through industrial and wastewater discharges, road runoff (particularly melting salts) and agricultural runoff. Rain is normally low in conductivity and can lower the conductivity of a water body during heavy rainfall. Significant changes in conductivity can indicate a discharge or some other form of pollution that can affect salmon and other aquatic organisms.

Nutrients

Nutrients are elements required for the growth of organisms. Nitrogen, phosphorus, and carbon are the three most important nutrients for aquatic plants. For this study, only nitrates (a form of nitrogen combined with oxygen) were monitored because that is the only nutrient that the electronic meter available to the project could measure.

Although nitrogen compounds are essential for plant and animal life, high levels can cause detrimental effects. High levels of nutrients in a body of water may cause plant life and algae to flourish causing blooms that can choke out other organisms. These large plant populations caused by excess nutrients may eventually deplete available dissolved oxygen (a process called eutrophication). These excess nutrients may come from runoff from fertilized farmlands and lawns, sewage, detergents, animal wastes, and leaking septic systems. Nitrates and ammonia are the most common forms of nitrogen and the most useable by aquatic plants, but significant amounts of nitrogen can be present in other forms.

Concentrations of nitrates are usually expressed as nitrate-nitrogen (NO_3-N) and not as nitrate (NO_3). A nitrate-nitrogen measurement in water of less than 1.0 mg/L is considered to be excellent; between 1.1-3 mg/L is considered to be good; between 3.1-5 mg/L is fair; and greater than 5 mg/L is considered to be poor.

Dissolved Metals and Petroleum Compounds

Dissolved metals and petroleum-derived compounds are some of the more common contaminants in water that can be toxic or adversely affect aquatic organisms at higher levels, although some may be toxic at low levels or long exposure. Many of the metals are naturally occurring in the terrestrial and aquatic environments in trace amounts and only become of concern at higher levels. Petroleum-derived compound enter the air, water and soil from numerable sources. Unfortunately, lab costs to detect metals or petroleum-derived products are expensive.

Heavy metals such as zinc, iron, and copper are naturally occurring substances in the Earth's crust. Some metals are needed by humans in trace amounts to maintain optimum body function, while others such as mercury, arsenic, and cadmium can be harmful. All metals can be toxic if levels are too high. Exposure to high levels of zinc for example over long periods of time may cause adverse health effects in humans. Most metals stay bound to the solid particles in the ground, but can become suspended or dissolve in water dependent on a number of conditions such as water hardness and pH levels. Dissolved metals occur in different forms and some may be more toxic than others. The different metals also have varying degrees of natural occurrence. Iron for example, has high abundance within the earth’s crust, and it commonly occurs in all freshwater environments and often reaches significantly higher concentrations in water and sediments than other trace metals (Vuori 1995).

Total Petroleum Hydrocarbons (TPH) is a term used to describe a broad family of several hundred chemical compounds that originally come from crude oil. In this sense, TPH is really a mixture of chemicals. They are called hydrocarbons because almost all of them are made entirely from hydrogen and carbon. Crude oils can vary in how much of each chemical they contain, and so can the petroleum products that are made from crude oils. Because modern society uses so many petroleum-based products (for example, gasoline, kerosene, fuel oil, mineral oil, and asphalt), contamination of the environment by them is potentially widespread. Contamination caused by petroleum products will contain a variety of these hydrocarbons. Because there are so many, it is not usually practical to measure each one individually. Therefore, it is useful to measure the total amount of all hydrocarbons found together in a particular sample (i.e., total petroleum hydrocarbons). TPD is measured in three ranges – gasoline, diesel and oil – but the tests are not specifically for gasoline, diesel fuel, or oil, but rather are tests for petroleum hydrocarbons that are in the "range" of those found in gasoline, diesel fuel or oil. The effects of exposure to TPH depend on many factors including the types of chemical compounds in the TPH, how long the exposure lasts, and the amount of the chemicals contacted. Very little is known about the toxicity of many TPH compounds (Todd et al. 1999).

Polycyclic aromatic hydrocarbons (PAH) originate from petroleum and combustion products. The major sources of PAH in the environment are municipalities and industries that generate large quantities of PAHs, such as aluminum smelting, creosote, and oil refining. Atmospheric emissions from incineration and automobile emissions are other major sources of PAHs. PAHs are also introduced into marine systems through accidental spills of fuel oil, crude oil, and other petroleum products. PAHs are very toxic to invertebrates and fish and their occurrence has only increased in the aquatic environment over time (Johnson et al. 2008).

Fecal Coliform Bacteria

Bacterial monitoring is another method of assessing water quality using indicator bacteria such as fecal coliform to determine the potential presence of pathogens that may be harmful to humans. Fecal coliform are a sub-group of coliform bacteria that are commonly found in the environment (e.g., in soil or vegetation). Fecal coliform live in the digestive tracks of warm-blooded animals (humans, dogs, cats, birds, other mammals, etc.), and are excreted in the feces. Although most fecal coliform bacteria are not harmful, some are pathogenic. The presence of fecal coliform in aquatic environments may indicate that the water has been contaminated with the fecal material through direct discharge from mammals and birds, from agricultural and storm runoff, and from human sewage. High levels of fecal coliform bacteria is an indicator that other pathogens may also be present. Recent advances in the use of indicator bacteria have shown that Escherichia coli (E. coli) and Enterococci (in saltwater) bacteria (which are sub-groups of the fecal coliform bacteria) are more reliable for predicting the presence of disease-causing organisms and are now recommended for use in bacterial monitoring programs by the EPA.

Macroinvertebrates

Stream biomonitoring is another method of assessing water quality using the presence of benthic (bottom dwelling) macroinvertebrates as an indicator of the potential level of pollutants in a stream. Benthic macroinvertebrates are aquatic insect larvae, crustaceans (amphipods, isopods) and mollusks (snails) that are visible to the naked eye. Some benthic macroinvertebrates cannot survive in polluted water while others can survive or even thrive in polluted water. Thus, the occurrence of different species/genera of macroinvertebrates (each have differing pollutant tolerance) in a water sample can be used as a relative indicator of water quality. Further, since benthic macroinvertebrates spend most of their aquatic occurrence in the same general stream location, they may better reflect longer term stream conditions than water sampling measurements which only reflect the condition of the stream at the moment that the sample was taken.

METHODS

This citizen science project was designed for high school student involvement. Students were trained in field data collection protocols including use and maintenance of electronic instruments, field data collection protocols, and database management.

Monitoring Locations and Schedule

Monitoring sites were selected to provide representative locations for upper and lower reaches of Shellabarger, Willow and Shell Creeks and various locations including incoming/outgoing flow sites in the Edmonds Marsh. Selection criteria included easy and safe access to creek sites and property owner permission. Shellabarger Creek has three geographically separated forks in the upper creek area and only the middle and southern forks could be monitored. Shellabarger Creek monitoring included the Shellabarger Marsh where it flows under Highway 104 into the Edmonds Marsh. The Marsh was a challenge to establish sites since only the edges of the Marsh were easily accessible and the western and southern edges were not accessible (Burlington Northern Railroad property and old UnoCal site). Fortunately, the City allowed access to the fenced Marsh outlet basin (west of railroad tracks) in the Marina parking lot which was an ideal location to sample outgoing water from the main body of the Marsh. A map showing the location of each monitoring site is provided in Appendix B.

A sampling plan was developed that called for monitoring designated sites at least once-a-month. The Students Saving Salmon club formed four teams of two to four students with each team responsible for monitoring four sites each in Willow Creek, Shell Creek, Shellabarger Creek, and Edmonds Marsh respectively on one day each month. This ensured that the upper and lower portion of each creek and the incoming/outgoing sites at the Marsh were monitored on the same day. Each team selected a date, based on team member availability, for monitoring so that all 16 sites were monitored in the first two weeks of each month. Monitoring occurred in the afternoon (after school) regardless of weather except for two days when monitoring occurred on Saturday morning due to conflicting student weekday activities.

Monitoring Equipment

A rugged, high quality handheld multiparameter instrument, a YSI Professional Plus (YSI ProPlus), was used by students to collect water quality data. The YSI ProPlus is equipped with a 4 meter (12 foot) cable (to allow monitoring off low bridges) with an attached Quatro probe that holds four user replaceable sensors for temperature/conductivity, dissolved oxygen, pH and nitrate measurements. The instrument was calibrated by the project leader each month just prior to that month’s monitoring.

Water Quality Parameters Monitored

There are many parameters that can be monitored to assess a stream’s condition or trends in water quality. The Edmonds Stream Team chose to emulate the Washington State Department of Ecology’s ambient water quality monitoring program (Von Prause 2014) which collects monthly data in rivers and streams throughout Washington. We were however limited on available equipment and laboratory access to collect all of the State’s standard parameters monthly. We did collect dissolved oxygen, pH, temperature, conductivity, and nitrates each month, but did not have the additional capacity to collect ammonia, total phosphorus, total nitrogen, turbidity, fecal coliform and total suspended solids data as the State does at all stations each month. The specifics of each parameter collected by the Edmonds Stream Team is as follows.

Water temperature was recorded to the nearest tenth degree (0.1) Fahrenheit (°F) and also reported (converted) in Celsius (°C) in the database. Measured temperatures were evaluated against Washington’s Water Quality Standards (WAC 173-201A-210) which sets aquatic life standards (7 day average of daily maximum temperatures) at 63.5°F (17.5°C) for salmonid spawning, rearing and migration and at 60.8°F (16.0°C) for core summer salmonid habitat.

pH was reported to the nearest hundredth (0.01) on pH scale of 0 to 14. Measured pH values were evaluated against Washington's Water Quality Standards (WAC 173-201A-210) which sets all aquatic life pH criteria to be within a range of 6.5 to 8.5.

Dissolved oxygen levels were recorded to the nearest tenth (0.1) mg/L of oxygen at each monitored site. Measured dissolved oxygen levels (mg/L) were evaluated against Washington's Water Quality Standards (WAC 173-201A-210) which sets a lowest 1-day minimum at 8.0 mg/L for salmonid spawning, rearing and migration; and, 6.5 mg/L for salmon rearing and migration only.

Conductivity was recorded to the nearest tenth microSiemens per centimeter (µS/cm). Total dissolved solids (TDS) were recorded in grams per liter (g/L). Salinity was recorded in parts per thousand (ppt). There are no Washington Water Quality Standards for these parameters.

Conductivity measurements were also reported as 'specific conductance' which is the conductivity measurement corrected to 25°C (77°F). Since water temperature affects conductivity measurements, reporting conductivity at a standardized temperature (25°C / 77°F) allows the data to be easily compared and provides a standardized method of reporting conductivity.

To monitor nutrients, a nitrate sensor on the YSI ProPlus instrument was used. Phosphorus was not monitored. Nitrate concentration expressed as nitrate-nitrogen (NO_3-N) was recorded in mg/L. The nitrate sensor began failing during the April monitoring period so the data in this report for nitrates is limited to the October to March timeframe.

Data Collection, Management and Quality Control

In addition to water parameter measurements, basic data (e.g., depth/width of stream, vegetation, bottom substrate, air temperature, water flow, water clarity, past precipitation, etc.) were recorded on the 'Water Quality Data Sheet' (see Appendix 3) for each site monitored. The water quality data were later entered into a 'Edmonds Water Quality Database' spreadsheet that is maintained in Google Drive (so it is easily accessible online for student data entry as well as public access).

Quality control and assurance measures involved adherence to monitoring protocols, data review, routine instrument calibration, replicate measurements, and separate measurements by the project leader to validate results. The Project Leader accompanied students on all collections to ensure adherence to monitoring protocols. Water quality measurements for all sites (including replicates) were reviewed each month to ensure any data abnormalities were evaluated and replicate measurements taken as necessary. Data rows in the database were protected (so they could not be altered except by the database manager) after data entry had been reviewed.

Backups of the database were made routinely. Questionable or potentially erroneous data were flagged in the database.

Lab analysis for dissolved metals and petroleum compounds

The sampling plan called for water samples to be collected and delivered to an accredited water analysis laboratory for petroleum-derived compounds and dissolved metals testing four times per year (once each season - winter, spring, summer, fall) and during storm events in spring and/or fall at the lower creek sites and the Marsh. Stormwater samples were to be 'first flush' samples collected during a rainstorm with a forecast of 0.25 inches or greater after three days of no rain. The number of sites, frequency of collection and number of pollutants analyzed was restricted due to costs of laboratory analysis and availability of grant funds to conduct the laboratory analyses. Samples were collected in sterile bottles provided by the Lab. Although three seasonal samples were collected, the stormwater samples unfortunately were not collected primarily due to inadequate dry spells before heavy rains occurred and logistical limitations due to a 24 hour sample delivery time to the lab which was closed on weekends.

Thirteen water samples collected in sterile bottles provided by the Lab in the fall (October 2015), winter (January 2016) and spring (April 2016) from lower Shell, Shellabarger and Willow Creeks and the Edmonds Marsh were delivered to the ALS Environmental Laboratory in Everett for analysis. The samples were analyzed for arsenic (As), cadmium (Cd), chromium (Cr), cooper (Cu), iron (Fe), lead (Pb), mercury (Hg), and zinc (Zn) and levels detected were reported in micrograms per liter (µg/L). The fall samples did not include Pb and Hg analysis, and only the spring samples included Fe analysis. All samples were analyzed for BTEX (benzene, toluene, ethylbenzene, and xylenes) and TPH (total petroleum hydrocarbons). A limited number of samples were analyzed for PAH (polycyclic aromatic hydrocarbons) due to the high cost of the analysis. The Edmonds Marsh outlet was the only site sampled for PAH in all three seasons.

Lab analysis for fecal coliform bacteria

Students collected periodic water samples that were analyzed for fecal coliform (E. coli) at the Edmonds Wastewater Treatment Plant, and for coliform bacteria and E. coli at North Seattle Community College.

The North Seattle Community College (NSCC) microbiology lab analyzed water samples from eight monitoring sites in their November 16, 2015 class and fifteen sites in their February 16, 2016 class. The water samples were analyzed during laboratory exercises for coliform bacteria using the 'multiple tube fermentation' process. Three EWHS participated in the coliform bacteria sessions at both classes.

One of the EWHS students (Rondi Nordal) independently conducted follow-up analyses at both NSCC classes to confirm the presence of E. coli in the Edmonds Marsh outlet samples. The process involved a series of tests starting with the multiple tube fermentation technique, in which a growth solution (also called a broth) is used to grow bacteria from the water sample. As each test is conducted, more information is gathered about the type of bacteria or mixture of bacteria that is in the water. The first step is to determine if any bacteria are present using a growth medium. If there is any substantial growth, based on the lab protocol, a sample of the broth is then transferred to another medium (with a different solution) to further identify it. This process continues until a point where the species can be determined according to a list of characteristics typical of lab specimens (the limitation of this is that 'wild' strains may not adhere to the typical characteristics of a lab sample and may make it more difficult to determine the species). Nonetheless, it was concluded in both labs that E. coli was present in the Edmonds Marsh outlet sample.

In January 2016, the City of Edmonds agreed to analyze water samples for fecal coliform several times a year. Eleven students were trained on water sampling for fecal coliform and attended a demonstration on the lab processes for detection of fecal coliform. Water samples were then collected by students in sterile Whirl-Pack bags from fourteen monitoring sites in February 2016 (winter sample) and eleven monitoring sites in April 2016 (spring sample). Each water sample was stored on ice during field collection and delivered to the Lab within 2 hours of collection. The spring samples included replicate samples from two sites collected on adjacent days before/during/after rain events. The Lab processed each sample using the Membrane Filter Procedure (mFC/Rosalic Acid Broth).

There are no Washington Water Quality Standards for fecal coliform for freshwater aquatic life. However, there are criteria in the Washington Administrative Code (173-201A-260) for water contact recreation which sets a 'primary contact recreation' criteria that fecal coliform organism levels must not exceed a geometric mean value of 100 colonies/100 mL, with not more than 10 percent of all samples (or any single sample when less than ten sample points exist) obtained for calculating the geometric mean value exceeding 200 colonies /100 mL. A 'secondary contact recreation' criteria is the same except the 100 colonies value is set at 200 colonies and the not more than ten percent for the 200 colonies value is set at 400 colonies.

Collecting and identifying macroinvertebrates

Sound Salmon Solutions conducted macroinvertebrate identification training with EWHS IB Science classes. Macroinvertebrate water samples were collected by students using D shaped kick nets at the upper Shell Creek monitoring site in Yost Park on May 2nd and 3rd. The water samples were examined in the IB classes on May 4th and 5th. The macroinvertebrates identified were classified into three groups based on their pollution tolerance. Group 1 macroinvertebrates, consisting of caddisfly larvae, mayfly nymphs, stonefly nymphs are intolerant of pollution; Group 2 macroinvertebrates, consisting of scud, cranefly larvae, are partially tolerant of pollution; and, Group 3 macroinvertebrates, consisting of aquatic worm, blackfly larvae, midge larvae are tolerant of pollution.

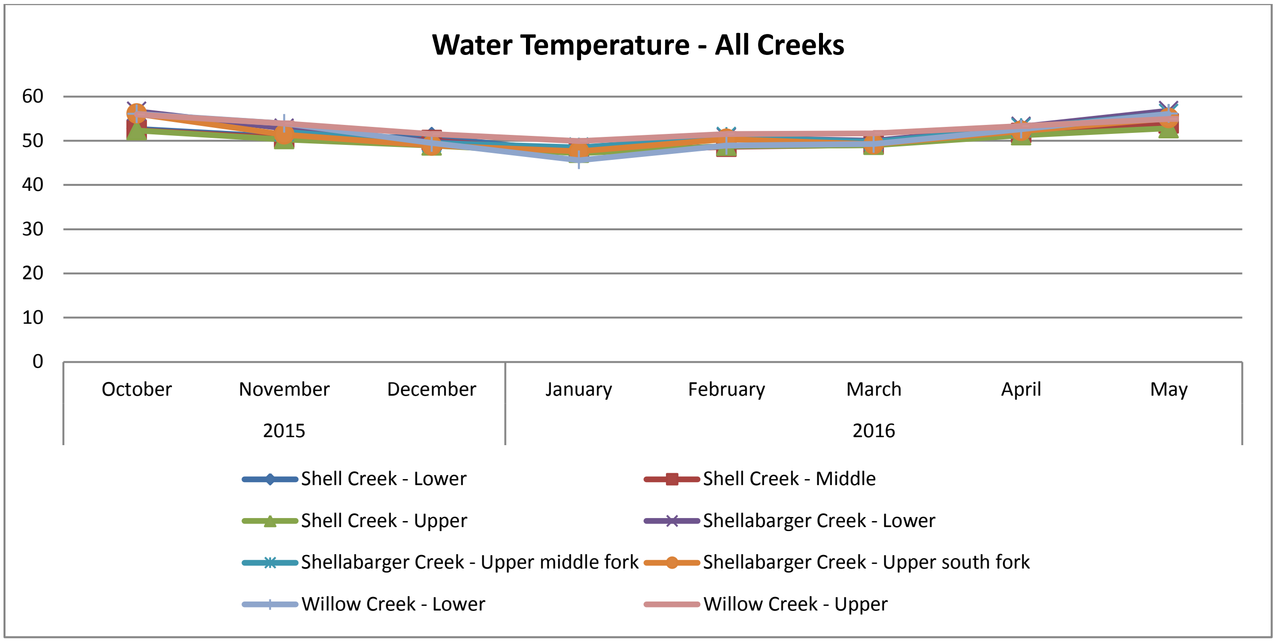
RESULTS

This preliminary report provides results for the first eight months (October through May) of this project on monthly water quality trends, bacteria (fecal coliform) monitoring in February and April, biomonitoring (macroinvertebrate sampling) in May, and seasonal lab results on dissolved metal and petroleum-derived compounds.

Water quality trends

The water temperature, dissolved oxygen and pH trends observed were as expected with water temperatures changing with season and dissolved oxygen levels fluctuating with water temperature (i.e., higher dissolved oxygen levels with colder waters). The specific results for each parameter are below.

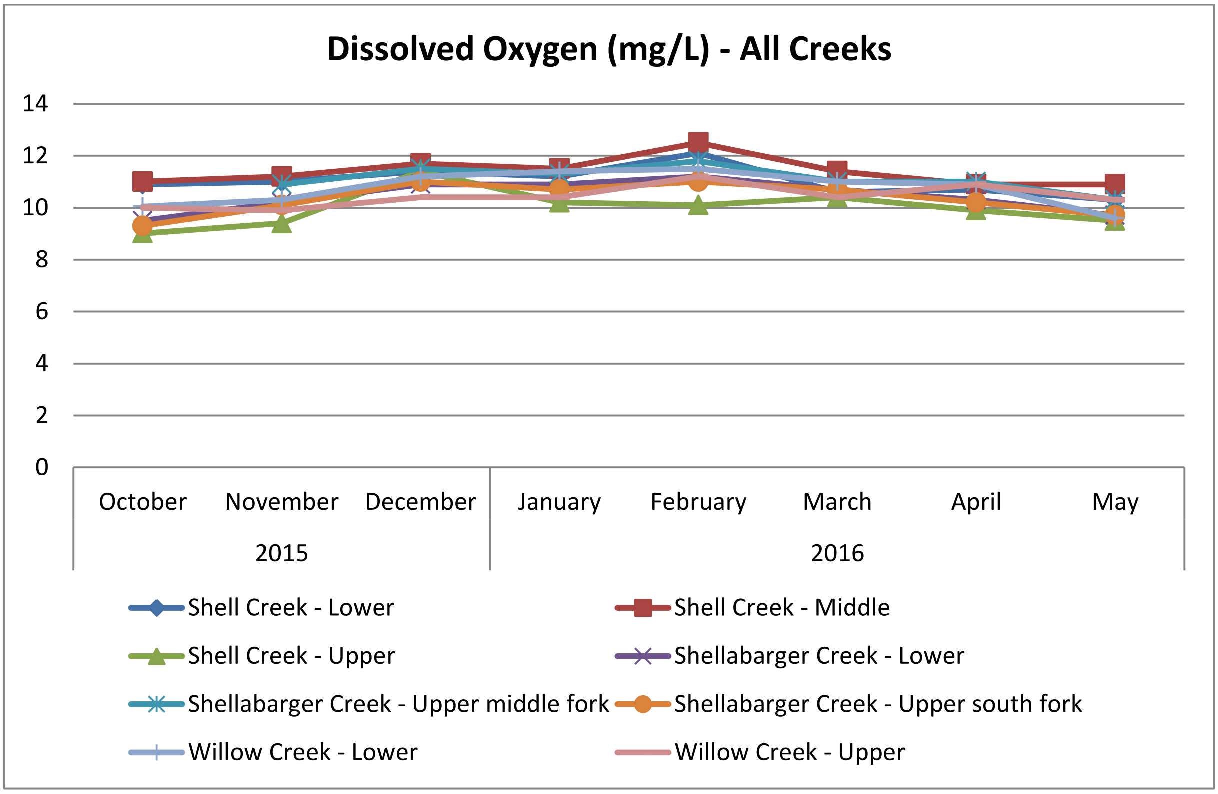
Water Temperature



Water temperature in the three creeks exhibited the expected trend of decreasing temperatures in the fall (average 51.0°F from October to early December) with winter lows (average 49.1°F for January to early March) and increases into spring (average 53.8°F from April to May). The overall average temperature in all creeks (for all eight months) was 51.6°F ranging from a high of 56.8°F in May in lower Shellabarger Creek to a low of 45.6°F in January in lower Willow Creek. The Marsh temperatures are presented separately below in the Marsh results. Note that the eight months monitored to date do not include the summer months of potentially higher water temperatures.

All of the observed water temperatures in the three creeks from October 2015 to May 2016 were below the 60.8°F threshold for 'core summer salmonid habitat' set forth in the Washington Water Quality Standards (WAC 173-201A-210).

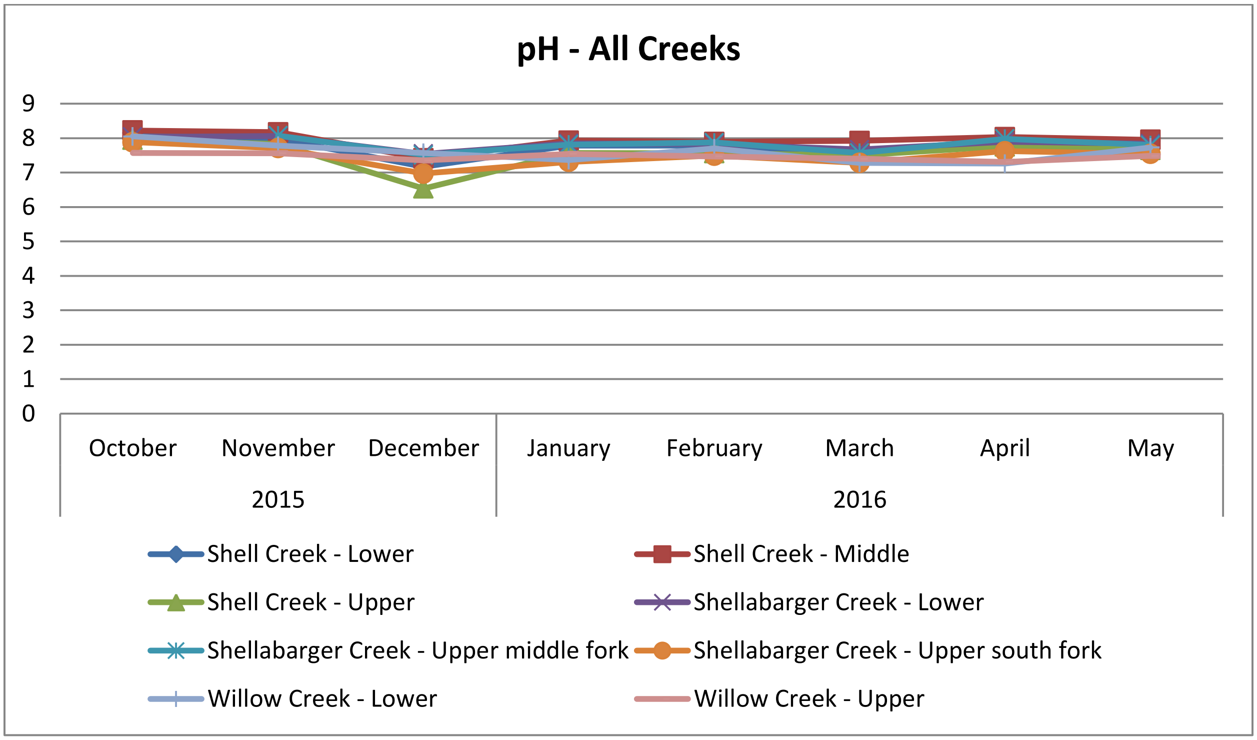
Dissolved Oxygen



Dissolved oxygen in the three Creeks generally had an opposite trend of water temperature. Since colder water holds more dissolved oxygen than warmer water, the trend observed was increasing dissolved oxygen in the fall (average 10.8 mg/L from October to early December) with winter highs (average 11.1 mg/L from January to early March) and decreasing into spring (average 10.3 mg/L from April to May). The overall average dissolved oxygen level in all creeks (for all eight months) was 10.5 mg/L ranging from a high of 12.5 mg/L in February in middle Shell Creek to a low of 9.3 mg/L in October in the upper south fork of Shellabarger Creek. The Marsh dissolved oxygen levels varied by site and are presented separately below in the Marsh results.

All of the observed dissolved oxygen levels in the three creeks from October 2015 to May 2016 were above the 1-day minimum of 8.0 mg/L for salmonid spawning, rearing and migration set forth in the Washington Water Quality Standards (WAC 173-201A-210). However, growing salmon eggs in stream gravel do best in dissolved oxygen levels of 11 mg/L. Since salmon currently are known to only spawn in one of the three creeks studied (Shell Creek), the desired 11 mg/L dissolved oxygen level is assessed below in the Shell Creek results.

pH



The pH in all three Creeks generally stayed constant in each creek averaging pH 7.71 (for all eight months) except for a decline down to an average pH 7.26 that occurred in December during a period of rainstorms and a smaller decline down to an average pH 7.52 in March again during a period of greater rain. Rain is more acidic than stream water and heavy rains likely caused the reduced pH levels. The average pH was highest in middle Shell Creek with a pH 7.94 and lowest in upper Willow Creek with a pH 7.46. The highest pH measured in a creek was pH 8.22 in middle Shell Creek in October. The lowest pH measured in a creek was pH 6.97 in upper south fork of Shellabarger Creek in December. The Marsh pH measurements varied by site and are presented separately below in the Marsh results. All of the observed pH levels in the Creeks were within the pH 6.5 to 8.5 range that is suitable for salmon and within the Washington Water Quality Standards for aquatic life.

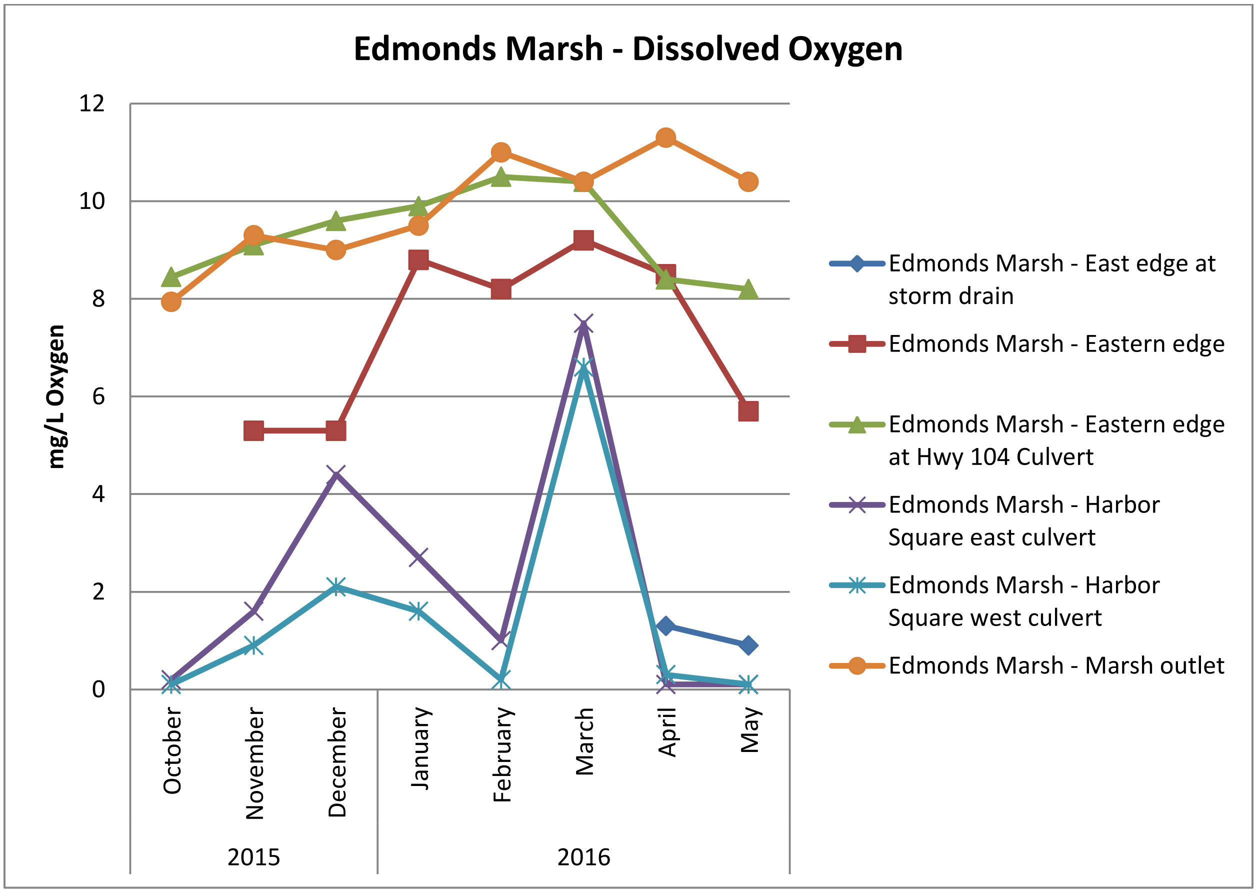
Conductivity

Conductivity measurements in all three creeks averaged 246.2 µS/cm ranging from an average high of 308.4 µS/cm in upper Shell Creek in February and a low of 81.1 µS/cm in upper Shell Creek in December. Conductivity readings in the creeks averaged between 243 and 285 µS/cm in all months except for December and March when they dropped down to an average 135.6 µS/cm in December and 205.8 µS/cm in March. Both December and March were periods of high rainfall which would be expected to lower creek conductivity measurements since rainwater is generally low in ions (thus low in conductivity). The conductivity measurements in the Marsh were affected by the tidegate with high conductivity levels recorded during saltwater intrusion. In October, while the tidegate was still secured open, the conductivity measured at the Marsh outlet basin was 11,439.5 μS/cm. Such high conductivity readings in the Marsh are not unexpected since saltwater has much more dissolved ions and solids than freshwater.

Nitrates

Nitrate levels in all three creeks were low averaging 1.3 mg/L for six months (October to March). Since the nitrate sensor began to fail in April, the nitrate data collected in April and May are considered invalid. The average nitrate level was highest in the upper middle fork of Shellabarger Creek with 1.6 mg/L nitrates and lowest in lower Shell Creek with 1.2 mg/L nitrates. The highest nitrates level measured in a creek was 2.3 mg/L in upper Shell Creek in February (which was also the month with highest average nitrate levels at 2.0 mg/L). The lowest nitrates level measured in a creek was also in upper Shell Creek with 0.3 mg/L measured in December. The Edmonds Marsh also had very low nitrate levels averaging 1.7 mg/L nitrates at all sites. The highest nitrate measurement of 6.2 mg/L in the Edmonds Marsh was at the Marsh outlet basin in October when the tide gate was open allowing saltwater to enter the Marsh. These low levels of nitrates do not rise to a level of concern for excess nutrients in any of the streams or Marsh during the October to May timeframe.

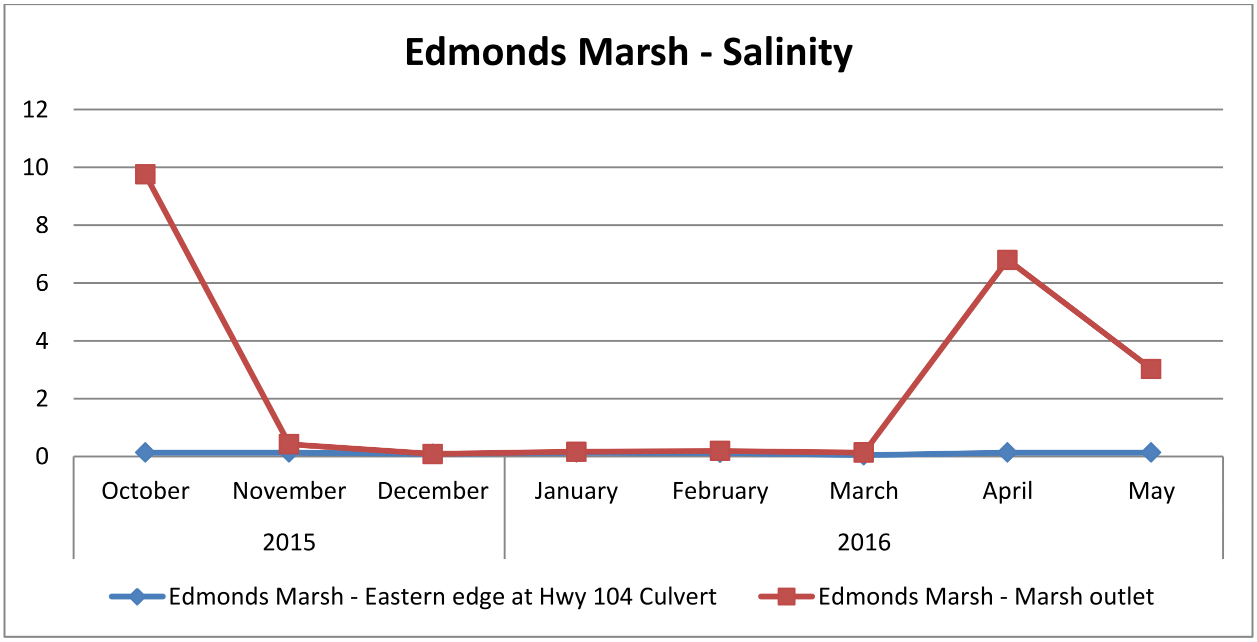
Edmonds Marsh



Edmonds Marsh - Dissolved Oxygen. The main flow through the Edmonds Marsh (from Shellabarger inlet at the Hwy 104 culverts to the Marsh outlet) had dissolved oxygen averaging 9.4 mg/L that exceeded minimal requirements for all months with a high of 11.3 mg/L in April and low of 7.9 mg/L in October. However, dissolved oxygen measured on the northern edge of the Marsh along Harbor Square was too low (averaging 1.8 mg/L) for salmon survival in all months except March when it increased to 7.1 mg/L. The northern edge of the Marsh had standing water with decaying matter substrate in most months with apparently little to no water circulation with the water in the main body of the Marsh. The eastern edge of the Marsh also had standing water, but appeared to have some circulation with the Shellabarger inflow resulting in dissolved oxygen levels averaging 8.7 mg/L from January to April, but only averaging 5.5 mg/L in November, December and May. Another eastern edge Marsh site opposite a Highway 104 drain was only monitored in April and May and had dissolved oxygen levels of 1.3 and 0.9 mg/L, which are well below salmon requirements. Resident cutthroat trout and any salmon present in the Marsh would likely avoid the edges of the Marsh due to the low dissolved oxygen levels.

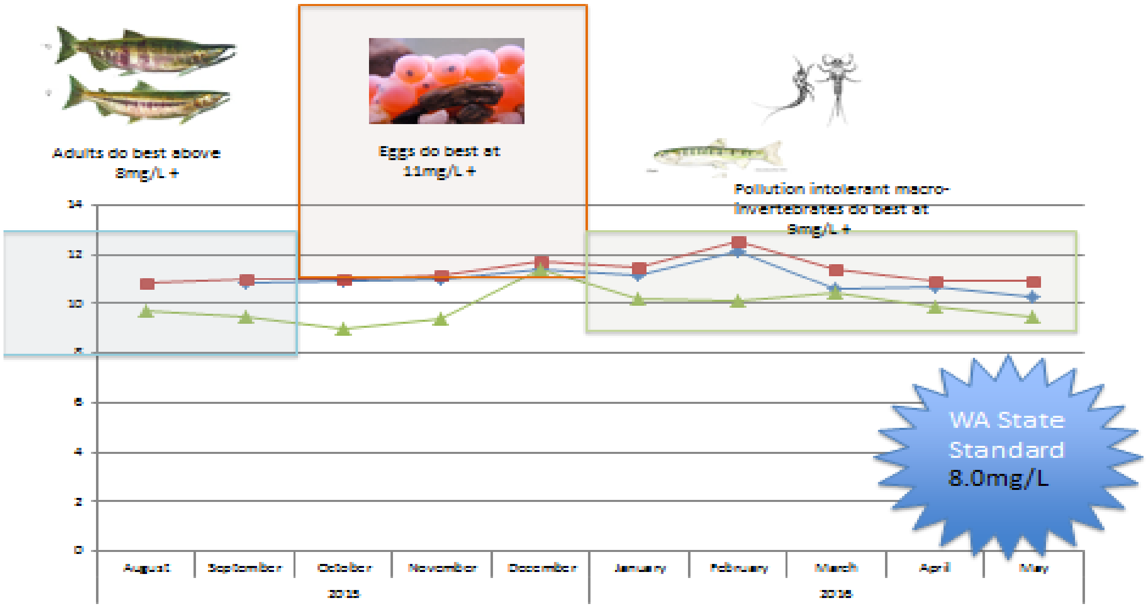
Edmonds Marsh - Water Temperature. Water temperature at all sites in the Marsh exhibited the expected trend of decreasing temperatures in the fall (average 54.2°F from October to early December) with winter lows (average 47.6°F for January to early March) and increases into spring (average 58.5°F from April to May). The lowest temperature recorded was 44.2°F in January on the north edge of the Marsh at Harbor Square and the highest temperature was 68.5°F in May at the Marsh outlet. The 68.5°F reading on May 10th, which was confirmed with a replicate sample, is very different from the May water temperatures of the Shellabarger inlet which was 57.7°F and the lower Willow Creek incoming flow which was 56.1°F. The high reading may be an artifact of the spring/summer monitoring protocol for the Marsh outlet which calls for monitoring during low tide to avoid sampling incoming saltwater from Puget Sound. The May temperature reading was taken when the Marsh was at its lowest level and thus likely influenced by ambient air and soil temperatures. Besides this one higher temperature, there were only two other temperature recordings (61.9°F in May and 61.0°F in October on north edge of Marsh) that exceeded the 60.8°F core summer salmonid habitat criteria in Washington's Water Quality Standards. These data do not include summer measurements which will need to be evaluated against the standards.

Edmonds marsh – pH. The edges of the Edmonds Marsh along Harbor Square were more acidic (average pH 6.61) than the main flow through the Marsh from the Shellabarger inlet at the Hwy 104 culverts to the Marsh outlet (average pH 7.31) in all months. One site along Harbor Square in January had a measured pH of 6.47 and that was the only Marsh site that wasn't within the Washington Water Quality Standard of between pH 6.5 and pH 8.5 for salmon.



Edmonds Marsh – Salinity. The salinity of the water in the Marsh is affected by a tidegate located downstream of the Marsh outlet. The tidegate functions to prevent saltwater intrusion into the Marsh from mid-October to mid-March (to prevent flooding during periods of coinciding high rainfall and high tides). In mid-March, the tidegate is secured in an open position to allow full tidal exchange of saltwater through the spring/summer months. The salinity measurements at the Marsh outlet (which is representative of the main body of the Marsh) from December to early March (averaging 0.14 ppt) reflect the low salinity of the incoming freshwater from the Shellabarger inlet and lower Willow Creek (both having average salinity of 0.11 ppt for all months). But, when the tide gate is secured open, the salinity measurements were significantly greater in the Marsh with 9.76 ppt salinity in October, 6.8 ppt in April and 3.2 ppt in May. The Marsh outlet salinity measurements during months when the tide gate is secured open are affected by when in the tidal cycle the measurements are taken. The spring/summer monitoring protocol for the Marsh outlet calls for monitoring during low tide to avoid sampling incoming saltwater from Puget Sound, and thus results in lower salinity readings (due to mixing with freshwater) than would be observed during incoming tidal saltwater (since saltwater has a salinity of about 35 ppt). The November salinity measurement at the Marsh outlet (after the tide gate was ‘closed’ on October 27th) was 0.42 ppt salinity, and the higher level may reflect residual salinity in the Marsh sediments. The northern edge of the Marsh (along Harbor Square) had an average salinity of 0.30 ppt over all months with declines in salinity in December to 0.14 ppt and March to 0.05 ppt salinity during periods of higher rainfall which likely diluted the water. The influx of tidal water when the tidegate was secured open did not alter the average salinity readings along the northern edge of the Marsh indicating the tide waters do not reach this area. The Edmonds Marsh would likely be a better environment for aquatic organisms if the tidegate was secured open year-round because the saltwater/freshwater interface in a marsh is known to be one of the most productive environments for aquatic organisms.

Shell Creek



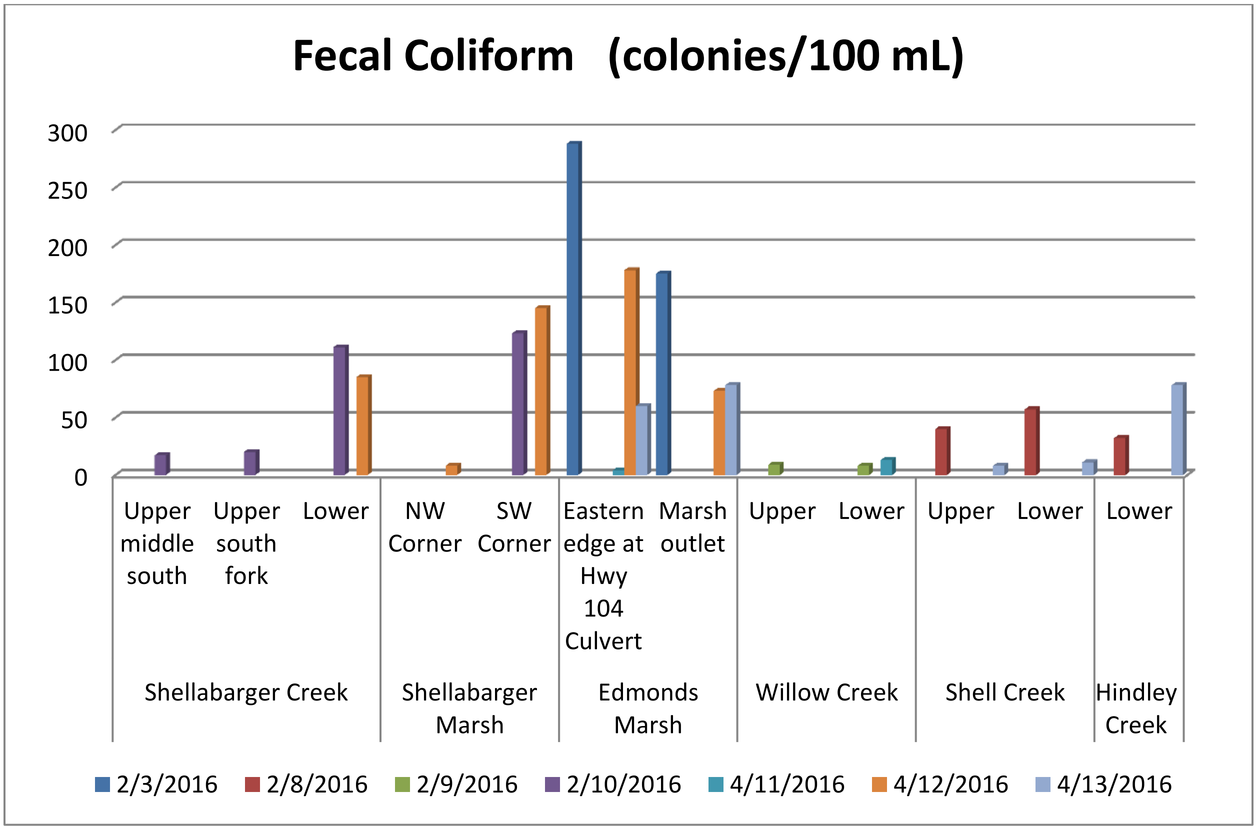
Shell Creek dissolved oxygen (DO) levels are more critical in Shell Creek than the other two creeks because chum salmon spawn in the lower reach of the Shell Creek and salmon eggs are in the gravel in the winter. Salmon eggs require higher dissolved oxygen levels to grow and hatch, and the DO levels for each month that eggs may be in the gravel were evaluated. The dissolved oxygen levels measured in lower Shell Creek were 11.0 mg/L in November, 11.4 mg/L in December, 11.2 mg/L in January and 12.1 mg/L in February. Thus, the measured dissolved oxygen levels in lower Shell Creek were within the optimum levels necessary for chum salmon eggs. Overall, the lower Shell Creek averaged 11.0 mg/L for all months (October to May) while upper Shell Creek averaged 9.6 mg/L DO over all months. The lower DO levels at the upper end of Shell Creek probably reflects groundwater (which has lower DO) entering the creek. The average level of dissolved oxygen of 10.4 mg/L throughout the creek (upper, middle and lower) in all months monitored exceeds the requirements in the Washington Water Quality Standards.

Shell Creek – Water Temperature. Shell Creek water temperatures did not fluctuate much from the upper to lower reaches of the creek averaging only a 0.5 degree difference. The greatest difference was 2.5 degrees in May. Shell Creek followed the expected trend of decreasing water temperature into the winter (from average 50.2°F in fall to 48.4°F) and then increasing into spring (average 52.9°F). Temperatures were compared to chum salmon life history requirements, and found to be within acceptable limits.

Willow Creek and Shellabarger Creek

The general water quality conditions of both creeks are presented above in the overview of all three creeks. Since both Willow and Shellabarger Creeks flow into the Edmonds Marsh, their respective conditions and relative contribution to the water quality of the Marsh were compared. The average pH of Willow Creek was more acidic than Shellabarger Creek (pH 7.56 vs 7.72) while the ‘body’ of the Marsh (as measured at the Marsh outlet basin and the Shellabarger Marsh inlet) was closer to neutral with an average pH of 7.4. In both Willow and Shellabarger Creeks, the pH tended to increase slightly from the upper reaches to the lower creek. The average dissolved oxygen level for all months was the same for both creeks (10.5 mg/L) while the Marsh outlet had a lower average of 9.5 mg/L. Shellabarger Creek flows into the Shellabarger Marsh before its water enters the Marsh, and the Shellabarger Marsh had a lower average dissolved oxygen level than the creek (DO of 9.1 mg/L vs 10.3 mg/L at lower creek). The upper middle fork of Shellabarger was unique in that its average dissolved oxygen level of 11.1 mg/L was higher than DO at the lower end of the creek (10.3 mg/L). In all other creeks/forks of creeks, the upper reaches usually have a lower DO levels than the lower reaches of the creek. The average water temperature over all months was slightly lower in Shellabarger Creek (51.9°F) than Willow Creek (52.4°F) and the Marsh outlet averaged a bit higher than both creeks (55.8°F).

Fecal Coliform Bacteria

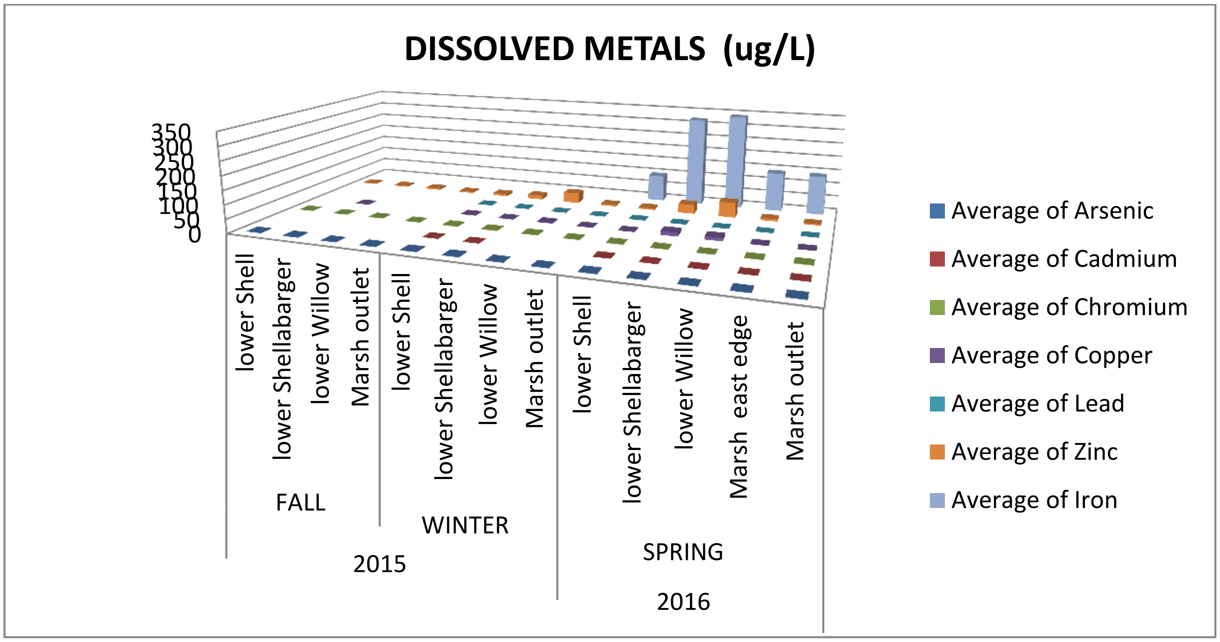


Counts of fecal coliform bacteria colonies cultured from water samples collected in February and April showed some sites had much higher levels of fecal coliform bacteria than others. The lower Shellabarger Creek, the Shellabarger Marsh, the Shellabarger inlet to the Edmonds Marsh, and the Edmonds Marsh outlet sites all had counts of fecal coliform bacteria exceeding 100 colonies/100 mL in one or both months sampled. In contrast, the upper and lower Willow and Shell Creek sites had an average fecal coliform count of 29 colonies in Shell Creek and 10 colonies in Willow Creek. Sites along the north periphery of the Marsh (along Harbor Square) also had very low bacteria counts (less than 10 colonies). There are no Washington Water Quality Standards for fecal coliform for freshwater aquatic life. However, if we use the Washington criteria for water contact recreation (i.e., levels must not exceed a geometric mean value of 100 colonies/100 mL) as an indicator of a potential bacteria problem, then the elevated Shellabarger bacteria counts in contrast to the other creeks may be a concern.

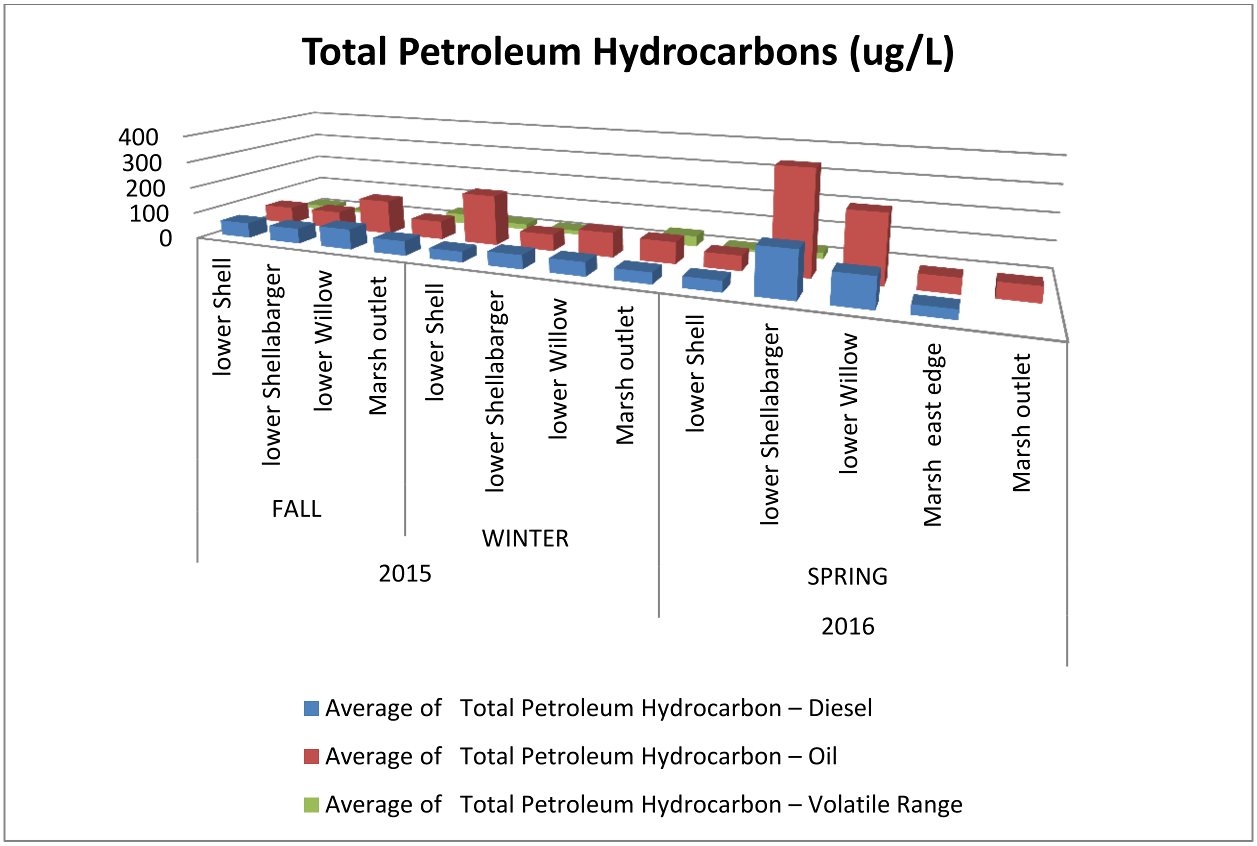
The upper Shellabarger Creek was sampled on February 10th and had 17 colonies in the upper middle fork and 20 colonies in the upper south fork while the lower Shellabarger Creek sample had 111 colonies counted on the same day. This suggests the source of the elevated fecal coliform levels are downstream of the upper Shellabarger Creek areas. Since the waters downstream of lower Shellabarger Creek (i.e., the Marsh inlet and outlet) also had elevated fecal coliform counts, it suggests Shellabarger Creek is the source of fecal coliform bacteria in the Marsh. This is further evidenced by the February 3rd sample collected at the Shellabarger inlet to the Marsh having 288 colonies while the Marsh outlet sample (which was collected within an hour of the inlet sample) had 175 colonies likely indicating dilution with the lower fecal bacteria waters from Willow Creek.

In April, consecutive day water samples were collected over three days at the Shellabarger inlet to the Marsh. The first sample was taken on April 11, which was a dry day with the last rainfall six days prior. The second sample was taken on April 12 during a rain event that had accumulated about 0.05 inches of rain up to the time of sampling (rain amounts were obtained from the Weather Underground website). The third sample was taken on April 13th which was a dry day that followed a total accumulation of 0.09 inches of rain on the previous day. The fecal coliform counts for the samples were 4 colonies on April 11th, 178 colonies on April 12th, and 60 colonies on April 13th. These data show the influence of rainfall on the fecal coliform counts and suggest the need for further consecutive day sampling at each of the sites to better understand the source of the elevated fecal coliform counts.

Dissolved Metals and Petroleum Compounds



All sites had very low levels of the dissolved metals (As, Cd, Cr, Cu, Fe, Pb, Zn) that were tested for. Mercury was not detected at any of the sites. As shown in the graph, iron (which was analyzed only in the winter samples) and zinc had higher levels detected than the other metals which were essentially at trace amounts. However, both iron and zinc levels detected were well below the Washington Water Quality Standards of 124 µg/L for zinc and 1000 µg/L. The highest zinc level detected was 54 µg/L in the April sample from lower Willow Creek. The highest iron level detected was 340 µg/L also in the April sample from lower Willow Creek. These and additional dissolved metal data collections planned will be reviewed further along with any standards during preparation of an annual report. Data collected to date will serve as baseline seasonal data on dissolved metals in Edmonds streams as they were collected on a seasonal basis and not targeted on storm events. Water samples collected in the future during storm events can then be compared to these baseline data to assess stormwater contribution to dissolved metals in the creeks and Marsh.



Total petroleum hydrocarbons (TPH) were detected at all sites sampled in all three seasons (fall, winter and spring). Sites sampled in all three seasons had each of the three ranges of petroleum hydrocarbons - diesel, oil, and volatile range - detected in at least one of the season samples except the lower Willow Creek site which had no volatile range TPH detected in any sample. The Marsh outlet site only had oil range TPH detected in the spring season. The east edge of the Marsh (along Highway 104) was sampled only in the spring season and had oil and diesel range TPH detected, but not volatile range TPH. Higher levels of diesel and oil range TPH were observed in the spring in lower Willow and lower Shellabarger Creeks. These TPH data and any standards that apply will be reviewed further during the preparation of an annual report. The data collected to date will serve as baseline seasonal data for Edmonds streams since they were collected on a seasonal basis and not targeted on storm events. Future samples taken during storm events can be compared to these baseline data to assess stormwater contribution to TPH in the creeks and Marsh.

POLYCYCLIC AROMATIC HYDROCARBONS (PAH)

Polycyclic Aromatic Hydrocarbons	lower Willow 10/21/15	Marsh outlet 10/25/15	Marsh outlet 1/16/16	Marsh outlet 4/12/16	Marsh east edge 4/13/16
1-Methylnaphthalene (µg/L)	ND	ND	**0.0027**	**0.0015**	**0.0012**
2-Methylnaphthalene (µg/L)	ND	ND	**0.0027**	ND	ND
Acenaphthene (µg/L)	ND	ND	**0.0039**	**0.0049**	ND
Acenaphthylene (µg/L)	ND	ND	ND	ND	ND
Anthracene (µg/L)	ND	ND	**0.0063**	ND	**0.0038**
Benzo[A]Anthracene (µg/L)	**0.0078**	ND	**0.0057**	**0.0071**	**0.0064**
Benzo(A)Pyrene (µg/L)	ND	ND	**0.0072**	**0.014**	**0.012**
Benzo(B)Fluoranthene (µg/L)	ND	ND	ND	**0.013**	**0.0099**
Benzo(G,H,I)Perylene (µg/L)	ND	ND	ND	ND	ND
Benzo(K)Fluoranthene (µg/L)	ND	ND	ND	**0.015**	**0.012**
Chrysene (µg/L)	**0.0075**	ND	ND	**0.0021**	**0.0060**
Dibenzo(A,H)Anthracene (µg/L)	ND	ND	ND	ND	**0.0057**
Fluoranthene (µg/L)	**0.0041**	**0.011**	**0.0041**	**0.0034**	**0.0025**
Fluorene (µg/L)	ND	**0.0096**	**0.0021**	**0.0027**	**0.0022**
Indeno(1,2,3-Cd)Pyrene (µg/L)	ND	ND	ND	**0.012**	**0.0098**
Naphthalene (µg/L)	**0.0024**	**0.0034**	**0.0089**	**0.0035**	**0.0030**
Phenanthrene (µg/L)	ND	**0.010**	**0.0053**	**0.0051**	**0.0035**
Pyrene (µg/L)	**0.016**	**0.014**	**0.0062**	**0.0095**	**0.0044**
Total Suspended Solids (mg/L)	ND	**10**	ND	ND	ND
Hardness (CaCO3), mg/L	**98**	**790**	**98**	**1300**	**110**

ND = Not detected

Lab analyses for PAH were limited to a few samples due to the cost of the lab analysis. The five water samples analyzed for PAH were collected at the Marsh outlet in all three seasons (fall, winter, spring), at lower Willow Creek in the fall, and at a site on the east edge of the Marsh in the spring. None of the 18 types of PAH analyzed for were detected at levels greater than 0.016 µg/L. The spring season samples had the greatest number of types of PAH detected. These PAH data and any standards that apply will be reviewed further during preparation of an annual report. These data will serve as baseline seasonal data for the Edmonds Marsh since they were collected on a seasonal basis and not targeted on storm events. Future samples taken during storm events can be compared to these baseline data to assess stormwater contribution to PAH in the creeks and Marsh.

Macroinvertebrates

Students scanned the water samples collected at upper Shell Creek and identified the macroinvertebrates in the samples using a dichotomous key. The identified macroinvertebrates were then assigned to their respective pollution tolerance groups as shown in the following table.

Type of Macroinvertebrate	Group 1: Intolerant of Pollution	Group 2: Partially Tolerant of Pollution	Group 3: Tolerant of Pollution
aquatic snail	x		
aquatic worm			x
blackfly larvae			x
caddisfly larvae	x		
cranefly larvae		x	
mayfly nymph	x		
midge larvae			x
scud		x	
stonefly larvae	x		

The number of different types of macroinvertebrates in each group were summed and multiplied by a weighting factor (3 for Group 1, 2 for Group 2, and 1 for Group 3). The sum of the all the weighted values was then divided by the total number of macroinvertebrate types resulting in an index. The index value was compared to a quality ranking of 2.7+ being excellent; 2.0 to 2.6 being good; 1.6 to 1.9 being fair, and 0 to 1.5 being poor. Resulting student index scores ranged from 2.0 to 2.2 with the majority at 2.1 which falls in the 'good' quality ranking.

Community Outreach

EWHS Students Saving Salmon members made several community presentations on the water quality project and the importance of healthy habitat and water quality for salmon and aquatic organisms. On October 13, 2015, four students gave a presentation to the Edmonds City Council about Students Saving Salmon and the planned water quality monitoring project. Students committed and the Council agreed to receive semi-annual reporting of the water quality results. Students also participated in and gave the same presentations at a October 28, 2015 Town Hall meeting in Edmonds. On March 11, 2016, students gave a presentation on initial water quality results at a Pilchuck Audubon meeting in Everett, WA. Several students also provided public testimony at a March 15, 2016 public hearing on the Edmonds City Council's proposed critical area regulations. On May 7, 2016, Students Saving Salmon had a table at the annual Edmonds Watershed Fun Fair where students explained the project to the public and answered questions about stormwater. Local newspaper articles written by the students or about the students appeared in My Edmonds News (2/14/15, 10/14/15, 11/01/15, 11/11/15, 11/19/15, 12/16/15, 01/18/16, 03/16/16), the Edmonds Beacon (10/22/15, 11/12/15, 01/14/16, 03/31/16), and the Everett Herald (11/23/15, 02/12/16, 03/16/16).

Ten EWHS students participated in an introductory survey for spawning salmon in lower Shell Creek in November 2015 and met with local residents to discuss salmon occurrence. Although several chum salmon spawners were present, no spawning or obvious redds (i.e., gravel containing salmon eggs) were observed.

DISCUSSION

Water quality monitoring to date has not indicated any potentially serious water quality problems in the three creeks monitored. The main body of the Edmonds Marsh does not appear to have water quality problems though the Marsh would function better ecologically if saltwater intrusion occurred year-round. The edges of the Marsh had lower water quality, especially dissolved oxygen, likely due to the lack of water circulation. The ‘Willow Creek Daylighting Project’ which will allow year-round tidal saltwater intrusion into the Marsh may improve water circulation on the edges of the Marsh.

The current water quality monitoring project should continue as is so that annual trends can be evaluated and baseline information is established. Having a long term data series will allow for future comparisons to potential environmental or pollutant driven perturbations and potential effects of climate change. Collection of water samples for dissolved metal and petroleum-derived compounds analyses during storm events should be pursued contingent on grant funds to cover the expensive costs of lab analysis.

Seasonal monitoring of all sites for fecal coliform should continue (as long as City agrees to analyze the samples), but with more intense sampling, perhaps 3-5 day consecutive samples, for the lower Shellabarger and Marsh sites. Although bacterial DNA testing is expensive, it may be beneficial to determine the source of the fecal coliform bacteria in the higher count samples (i.e., is it from dogs, birds, people, or other warm blooded animals).

Several additional water parameters, such as turbidity and phosphorus levels, need to be collected by the project to make it more comparable to the state’s ambient water quality monitoring program. The project is pursuing purchase of an electronic field photometer so that these additional important water parameters can be routinely collected as well as water hardness, alkalinity, and some dissolved metal levels. With the purchase of the photometer, we will be able to collect all of the standard parameters currently collected by the Washington Dept. of Ecology’s program (which has been a project goal since inception). The photometer also can also be used to measure nitrates and dissolved oxygen and serve to periodically validate the measurements from the YSI Professional Plus instrument thus further ensuring quality data collection.

The sites selected for monitoring appear to be adequate for assessing the health of each creek and Marsh. But, the project will be pursuing additional sites if sufficient numbers of students volunteer in the coming year. An additional site in the upper north fork of Shellabarger Creek (near Maple Street and 7th/8th avenues) and middle Shellabarger (at 5th Avenue) would provide more complete coverage of the entire Shellabarger drainage and allow us to better pin-point any water quality problems that may arise. Also, an additional site in middle Willow Creek (in Woodway) and possibly additional upper areas of Shell Creek may be beneficial. It would also be useful to sample the south edge of the Marsh along the old UnoCal property, but the WA Dept. of Ecology (who is overseeing cleanup of site) has advised they would not allow us access. The lower area of Shell Creek, just before it passes under the railroad tracks, would be an ideal area for conducting chum salmon spawning surveys and we will continue to seek the property owner's permission to access that area.

The project has demonstrated that a citizen science project utilizing volunteer high school students can be successful in collecting good quality scientific data and providing students hands-on experience in conducting field science. The four student Stream Teams stayed intact through the entire school year with at least one student present at each monitoring site every month. In spite of their ongoing array of extra-curricular high school activities and involvement in sports, band and family activities, the students upheld their initial commitment to fully participate in the water quality monitoring project. Students adhered to the field sampling protocols in spite of adverse weather in the winter and ensured quality data was collected throughout the school year. From the students' perspective, the project has provided them valuable experience that they can use as they pursue college education and careers in environmental sciences.

RECOMMENDATIONS

We recommend that the City Council continue to support this citizen science project utilizing high school students. It not only provides needed baseline data on the condition of several Edmonds streams and the Marsh, but also provides students with training and practical field experience in the use of actual data to address environmental issues. This is especially important to those students who want to pursue an environmental science career.

The water quality of Shell Creek needs to be kept optimal for salmon in order to support the naturally occurring spawning run of chum salmon. Other creeks, such as Shellabarger Creek, that are impacted by development and piped channels, also need to have good water quality not only for potential salmon use in remaining usable salmon habitat, but to ensure the watershed contributes to good water quality in downstream areas such as the Edmonds Marsh and Puget Sound. We urge the City to move rapidly to complete the 'Willow Creek Daylighting' project as that will improve the ecological functions of the Marsh by allowing unrestricted daily tidal exchange of saltwater and salmon access.

There are a number of actions that can be taken in Edmonds to ensure good water quality. Improvements can still be made to enhance the survival of aquatic organisms and foster recovery of salmon. The following is a list of some actions that the community can take to maintain or improve water quality and habitat conditions for salmon.

- Eliminate use of chemical fertilizers; use organic fertilizers sparingly
- Eliminate use of pesticides near streams and reduce/eliminate use where they can enter streams
- Clean up after pets (i.e., pick-up dog poop)
- Eliminate detergents and contaminants going into storm drains - wash cars at a carwash or on lawn
- Fix auto oil leaks and avoid fluid leaks/spills
- Encourage the State to pursue treatment of highway runoff
- Encourage better management of stormwater
- Pursue methods of eliminating roadway contaminants such as advanced technology street sweepers
- Install more rain gardens
- Require low impact development (LID) and green building along streams and wetlands
- Encourage use of permeable pavement/concrete for parking lots and driveways
- Improve/enhance stream/wetland habitat
    - Remove invasive plant species
    - Provide large, densely vegetated (with native shrubs and trees) streamside areas
    - Remove obstacles to salmon passage (e.g., Shell Creek passage barrier near 7th and Glen St.)
    - Avoid construction of structures or impervious pavement near streams and wetlands
    - Pursue funding sources for conservation easements or streamside property acquisitions
    - Improve regulatory regimes to better protect/preserve streamside and wetland habitat.

ACKNOWLEDGMENTS

Thanks to all of the EWHS students who volunteered to participate in the field monitoring program, through good weather and rainstorms: Arisbeth Acosta, Sergel Amar, Mrad Amar, Lindsey Barnes, Autumn Beeghley, Katharina Brinschwitz, Pavi Chance, Joe Cooper, Fatima Fatty, Andie Foster, Luis Guerrero, Justin Heckt, Sam Kleven, Emily McLaughlin Sta. Maria, Rondi Nordal, YeJi Oh and Afua Tiwaa. We also thank the adult volunteers who accompanied the project leader in the field: Valerie Stewart, Peggy Foreman, Nancy Scordino, Geoff Bennett and Dave Millette. Sound Salmon Solutions, Edmonds Salmon Chapter of Trout Unlimited, Puget SoundKeeper Alliance, and Edmonds City Council member Neil Tibbot also joined us in our field monitoring.

We thank the City of Edmonds, especially the Public Works Department and Mike Cawrse, for their support and assistance in designing and implementing the project, providing access to the Marsh outlet basin, assisting in contacting Edmonds residents to gain access to their property for water monitoring, and for analyzing our water samples for fecal coliform bacteria. Special thanks to Jeanne McKenzie at the Lab for analyzing the water samples and conducting demonstrations for the students (and accommodating our sometimes late delivery of water samples with a smile!).

We appreciate the encouragement from the Edmonds City Council, especially Diane Buckshnis, and Mayor Earling for funding support for operational expenses. The funding has allowed us to purchase critically needed calibration fluids, outreach materials, field supplies and a new photometer that will allow collection of additional water parameters that otherwise can't be measured.

The project would not have been possible without Hubbard Foundation grant funds that were used by the Edmonds School District to purchase the professional multiparameter water quality instrument. Special thanks to Dave Millette, Geoff Bennett and school district administration staff for helping secure the grant and purchase the water quality meter from YSI.

Grant funds from the National Fish and Wildlife Foundation and Google.org were used to pay the costs for dissolved metals and petroleum-derived compound analyses at an accredited laboratory (ALS Environmental Laboratory in Everett, WA). We thank EarthCorps, especially Keeley O'Connell and Pipo Bui, for sponsoring and administering these grants for us.

We thank Rosalind (Rosie) Billharz, microbiology instructor at North Seattle Community College, for having our water samples tested by college student for coliform bacteria and allowing EWHS students to participate. We also thank Kelley Govan, with Sound Salmon Solutions, for training students on macroinvertebrates.

Special thanks to all the Edmonds property owners, especially Jenny Anttila, Ruth Blaikie, Lynn Lawrence, Edmonds Park Apartments, Willow Creek Condominiums and Edmonds City Parks Department, for allowing students on their property to access the stream monitoring sites. Ruth Blaikie also provided local knowledge perspectives on salmon occurrence in lower Shell Creek to students.

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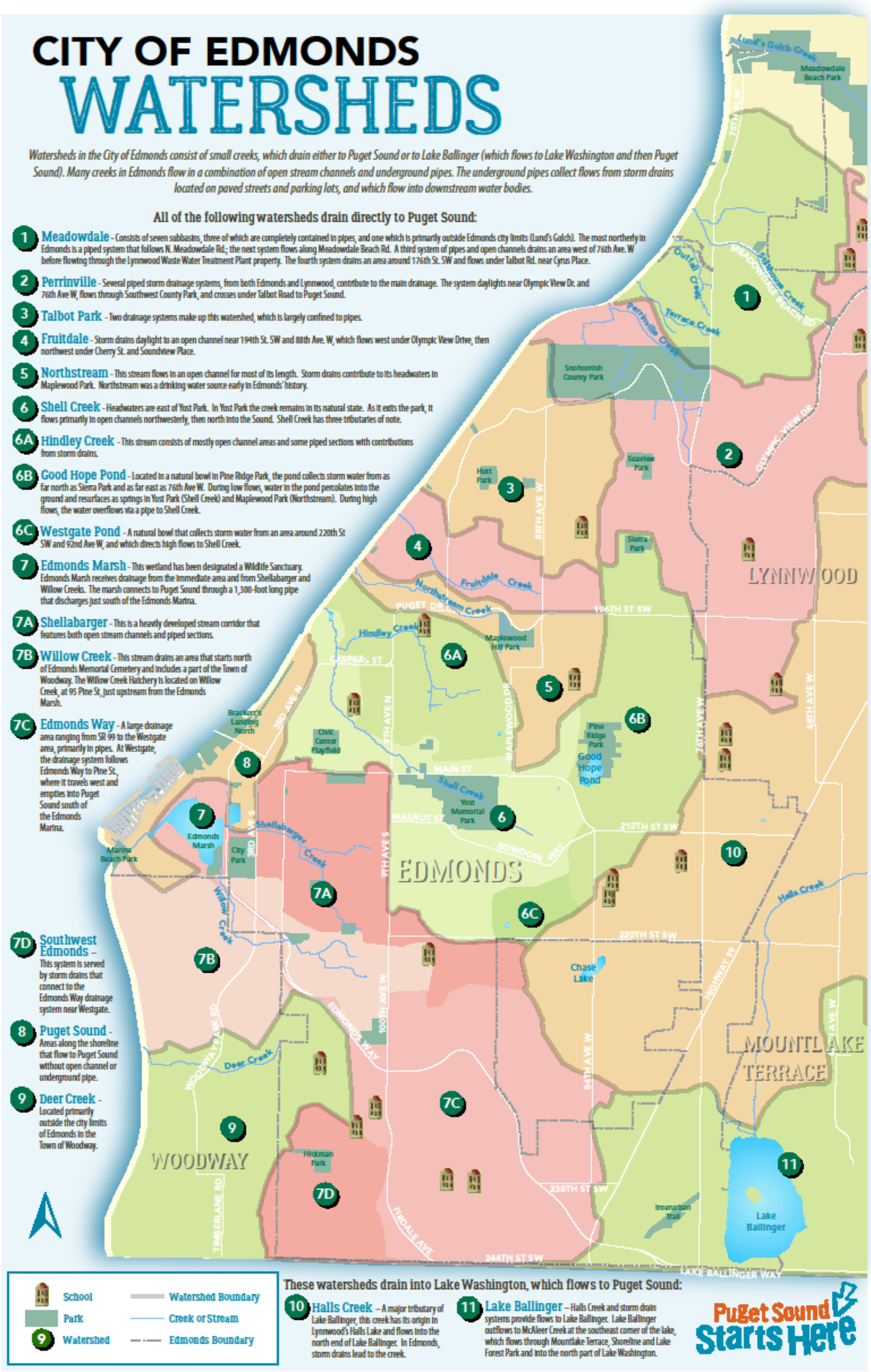
APPENDIX 1. CITY OF EDMONDS WATERSHEDS



CITY OF EDMONDS WATERSHEDS

Watersheds in the City of Edmonds consist of small creeks, which drain either to Puget Sound or to Lake Ballinger (which flows to Lake Washington and then Puget Sound). Many creeks in Edmonds flow in a combination of open stream channels and underground pipes. The underground pipes collect flows from storm drains located on paved streets and parking lots, and which flow into downstream water bodies.

All of the following watersheds drain directly to Puget Sound:

1 **Meadowdale** - Consists of seven subbasins, three of which are completely contained in pipes, and one which is primarily outside Edmonds city limits (Lund's Gulch). The most northerly in Edmonds is a piped system that follows N. Meadowdale Rd.; the next system flows along Meadowdale Beach Rd. A third system of pipes and open channels drains an area west of 76th Ave. W before flowing through the Lynnwood Waste Water Treatment Plant property. The fourth system drains an area around 176th St. SW and flows under Talbot Rd. near Cyrus Place.

2 **Perrinville** - Several piped storm drainage systems, from both Edmonds and Lynnwood, contribute to the main drainage. The system daylights near Olympic View Dr. and 76th Ave W, flows through Southwest County Park, and crosses under Talbot Road to Puget Sound.

3 **Talbot Park** - Two drainage systems make up this watershed, which is largely confined to pipes.

4 **Fruitdale** - Storm drains daylight to an open channel near 194th St. SW and 88th Ave. W, which flows west under Olympic View Drive, then northwest under Cherry St. and Soundview Place.

5 **Northstream** - This stream flows in an open channel for most of its length. Storm drains contribute to its headwaters in Maplewood Park. Northstream was a drinking water source early in Edmonds' history.

6 **Shell Creek** - Headwaters are east of Yost Park. In Yost Park the creek remains in its natural state. As it exits the park, it flows primarily in open channels northwesterly, then north into the Sound. Shell Creek has three tributaries of note.

6A **Hindley Creek** - This stream consists of mostly open channel areas and some piped sections with contributions from storm drains.

6B **Good Hope Pond** - Located in a natural bowl in Pine Ridge Park, the pond collects storm water from as far north as Sierra Park and as far east as 76th Ave W. During low flows, water in the pond percolates into the ground and resurfaces as springs in Yost Park (Shell Creek) and Maplewood Park (Northstream). During high flows, the water overflows via a pipe to Shell Creek.

6C **Westgate Pond** - A natural bowl that collects storm water from an area around 220th St SW and 92nd Ave W, and which directs high flows to Shell Creek.

7 **Edmonds Marsh** - This wetland has been designated a Wildlife Sanctuary. Edmonds Marsh receives drainage from the immediate area and from Shellabarger and Willow Creeks. The marsh connects to Puget Sound through a 1,300-foot long pipe that discharges just south of the Edmonds Marina.

7A **Shellabarger** - This is a heavily developed stream corridor that features both open stream channels and piped sections.

7B **Willow Creek** - This stream drains an area that starts north of Edmonds Memorial Cemetery and includes a part of the Town of Woodway. The Willow Creek Hatchery is located on Willow Creek, at 95 Pine St, just upstream from the Edmonds Marsh.

7C **Edmonds Way** - A large drainage area ranging from SR 99 to the Westgate area, primarily in pipes. At Westgate, the drainage system follows Edmonds Way to Pine St, where it travels west and empties into Puget Sound south of the Edmonds Marina.

7D **Southwest Edmonds** – This system is served by storm drains that connect to the Edmonds Way drainage system near Westgate.

8 **Puget Sound** - Areas along the shoreline that flow to Puget Sound without open channel or underground pipe.

9 **Deer Creek** - Located primarily outside the city limits of Edmonds in the Town of Woodway.

These watersheds drain into Lake Washington, which flows to Puget Sound:

10 **Halls Creek** – A major tributary of Lake Ballinger, this creek has its origin in Lynnwood's Halls Lake and flows into the north end of Lake Ballinger. In Edmonds, storm drains lead to the creek.

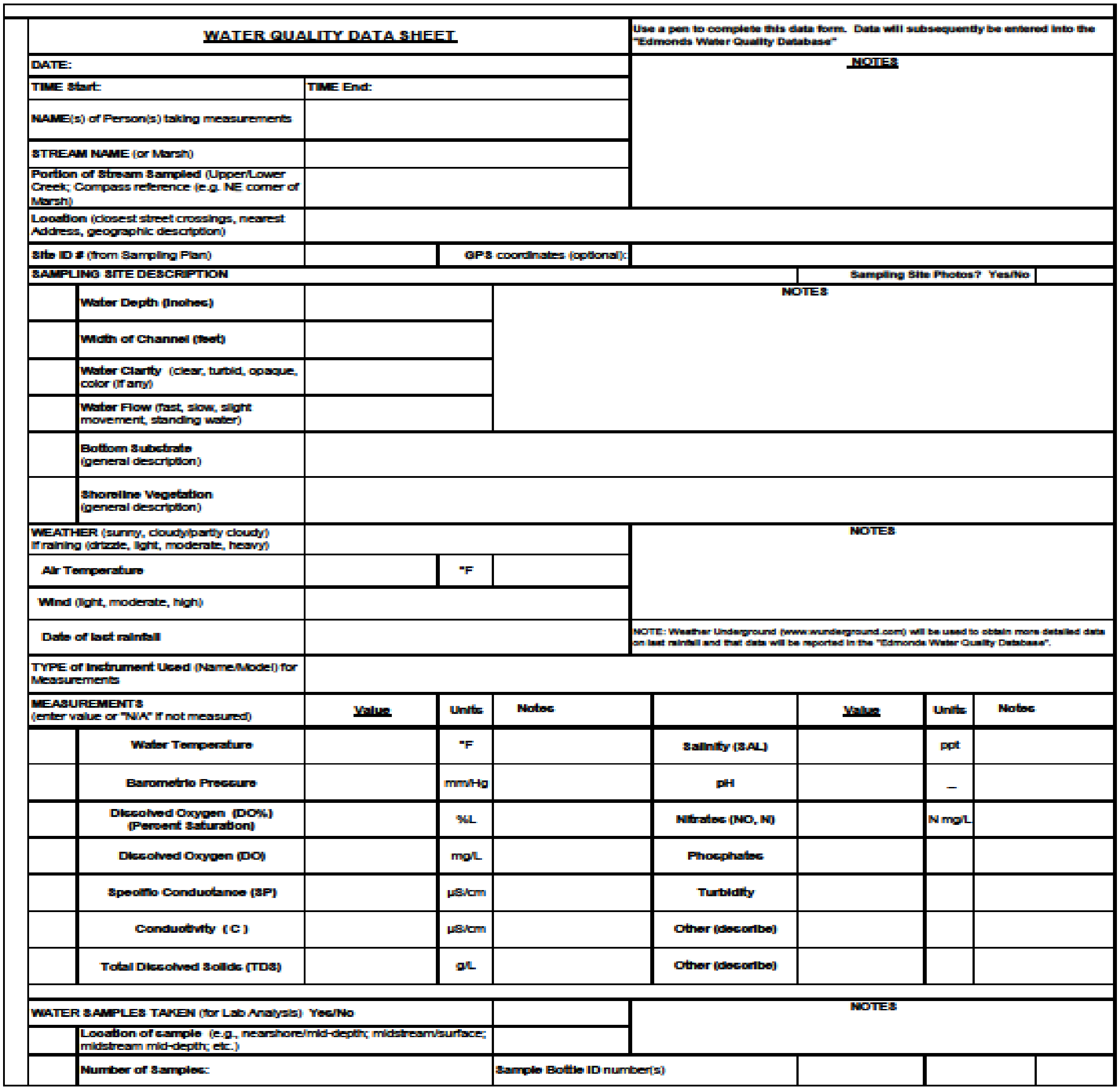
11 **Lake Ballinger** – Halls Creek and storm drain systems provide flows to Lake Ballinger. Lake Ballinger outflows to McAleer Creek at the southeast corner of the lake, which flows through Mountlake Terrace, Shoreline and Lake Forest Park and into the north part of Lake Washington.

APPENDIX 2. MONITORING SITES

SAMPLING SITES

A.1	Willow Creek, upper (6th Ave S and Elm Place)
B.1	Willow Creek, lower (Willow Creek Hatchery (Pine St and Hwy 104))
C.1	Shellabarger Creek, upper south fork (7th Ave S and Fir St)
D.1	Shellabarger Creek, upper middle fork (7th Ave S between Spruce and Hemlock St)
E.1	Shellabarger Creek, upper north fork (8th Ave and Maple St)
F.1	Shellabarger Creek, lower (3rd Ave S and Kelso Ct)
G.1	Shell Creek, upper (Yost Park, trail off Main St and Olympic Ave)
H.1	Shell Creek, middle (7th Ave S and Glen St)
H.2	Shell Creek, middle/lower (Caspers Street and 7th Ave)
I.1	Shell Creek, lower (beach side (west) of railroad tracks)
I.2	Shell Creek, lower (Brookmere Drive)
J.1	Shellabarger Marsh (at culvert on east side of Hwy 104)
K.1	Edmonds Marsh, eastern edge (at culvert on west side of Hwy 104)
K.2	Edmonds Marsh, eastern edge (Hwy 104 just north of pedestrian crossing)
L.1	Edmonds Marsh, northern edge (eastern culvert off Harbor Square parking lot)
L.2	Edmonds Marsh, northern edge (western culvert off Harbor Square parking lot)
N.1	Edmonds Marsh, western outfall basin (small fenced basin at Marina parking lot)
P.1	Hindley Creek, lower (off Brookmere Drive)
P.2	Hindley Creek, middle (8th Ave N and Hindley Lane)

APPENDIX 3. WATER QUALITY DATA SHEET



WATER QUALITY DATA SHEET

Use a pen to complete this data form. Data will subsequently be entered into the "Edmonds Water Quality Database"

DATE:

TIME Start:

TIME End:

NAME(s) of Person(s) taking measurements

STREAM NAME (or Marsh)

Portion of Stream Sampled (Upper/Lower Creek; Compass reference (e.g. NE corner of Marsh)

Location (closest street crossings, nearest Address, geographic description)

Site ID # (from Sampling Plan)

GPS coordinates (optional):

NOTES

SAMPLING SITE DESCRIPTION

Sampling Site Photos? Yes/No

Water Depth (Inches)

Width of Channel (feet)

Water Clarity (clear, turbid, opaque, color (if any)

Water Flow (fast, slow, slight movement, standing water)

Bottom Substrate (general description)

Shoreline Vegetation (general description)

NOTES

WEATHER (sunny, cloudy/partly cloudy) If raining (drizzle, light, moderate, heavy)

Air Temperature °F

Wind (light, moderate, high)

Date of last rainfall

NOTES

NOTE: Weather Underground (www.wunderground.com) will be used to obtain more detailed data on last rainfall and that data will be reported in the "Edmonds Water Quality Database".

TYPE of Instrument Used (Name/Model) for Measurements

MEASUREMENTS (enter value or "N/A" if not measured)	**Value**	**Units**	**Notes**		**Value**	**Units**	**Notes**
Water Temperature		°F		**Salinity (SAL)**		ppt	
Barometric Pressure		mm/Hg		**pH**		_	
Dissolved Oxygen (DO%) (Percent Saturation)		%L		**Nitrates (NO, N)**		N mg/L	
Dissolved Oxygen (DO)		mg/L		**Phosphates**			
Specific Conductance (SP)		µS/cm		**Turbidity**			
Conductivity (C)		µS/cm		**Other (describe)**			
Total Dissolved Solids (TDS)		g/L		**Other (describe)**			

WATER SAMPLES TAKEN (for Lab Analysis) **Yes/No**

Location of sample (e.g., nearshore/mid-depth; midstream/surface; midstream mid-depth; etc.)

NOTES

Number of Samples:

Sample Bottle ID number(s)