# Mileta Creek Nitrogen Source Tracking Study

**February 2012**

http://your.kingcounty.gov/dnrp/library/2012/kcr2309.pdf

King County

Department of Natural Resources and Parks
Water and Land Resources Division
**Science and Technical Support Section**
King Street Center, KSC-NR-0600
201 South Jackson Street, Suite 600
Seattle, WA 98104
206-296-6519 TTY Relay: 711
www.kingcounty.gov/environment/wlr/science-section.aspx

This page left intentionally blank.

# Mileta Creek Nitrogen Source Tracking Study

## Prepared for:

U.S. EPA West Coast Estuaries Initiative Grant
Quartermaster Harbor Nitrogen Management Study

## Submitted by:

Curtis DeGasperi and Eric Ferguson
Science and Technical Support Section
King County Water & Land Resources Division
Department of Natural Resources & Parks

King County

This page left intentionally blank.

# Acknowledgements

Thanks especially to the field support provided by Dan Smith, King County Science and Technical Support Section.

# Citation

King County. 2012. Mileta Creek Nitrogen Source Tracking Study. Prepared by Curtis DeGasperi and Eric Ferguson, Water and Land Resources Division. Seattle, Washington.

This page left intentionally blank.

# Table of Contents



# Figures

# Tables

# EXECUTIVE SUMMARY

This report is part of the Quartermaster Harbor Nitrogen Management Study funded in part by a West Coast Estuaries Initiative grant from Region 10 of the U.S. Environmental Protection Agency. Quartermaster Harbor is a shallow estuarine embayment on Vashon-Maury Island in Puget Sound that experiences low dissolved oxygen concentrations during late summer/fall that fall below the applicable state water quality standard. The likely cause of these low oxygen levels is the growth and subsequent die-off of phytoplankton that consume dissolved oxygen in the water column and sediments as they decompose and settle to the bottom.

The Mileta Creek Nitrogen Source Tracking Study was conducted to identify locations on Mileta Creek where nitrate nitrogen[1] concentrations become elevated in winter. The study was conducted on November 17, 2010 at 16 locations in the drainage area representing Mileta Creek and associated smaller tributaries. Mileta Creek is a relatively small tributary to Quartermaster Harbor and it is the only tributary routinely monitored on the Maury portion of Vashon-Maury Island.

The source tracking study eliminated two potential sources (the golf course and the abandoned chicken barns) as the cause of elevated nitrate concentrations observed in Mileta Creek each winter. The actual source remains unknown, but has been isolated to the reaches upstream of the mainstem of Mileta Creek.

Potential sources include human activities (historic or current) in the upland reaches of Mileta Creek or nitrate derived from nitrogen fixing plants such as red alder. The timing and shape of the nitrate peak in Mileta Creek is similar to that observed in Shingle Mill, Judd, and Fisher creeks – particularly Fisher Creek, but the peak concentration is of significantly greater magnitude. Studies in other Pacific Northwest streams and rivers have noted this phenomenon of a pulse of nitrate input associated with the beginning of winter rains that finally saturate surface soils that remained relatively dry during the summer.

Although nitrogen fixing plants such as red alder may be a significant source of nitrate nitrogen in this basin, there does not appear to be an obvious relationship between the distribution of deciduous and mixed forest and longitudinal patterns in nitrate loading. Reaches over which gains in nitrate were apparent did traverse land classified as deciduous forest which likely included red alder. However, deciduous forest cover was also identified upstream of the sampling stations on a tributary just to the south of Mileta Creek which had consistently low nitrate concentrations and loading.

Forest clearing, especially clearing of red alder stands, is another potential source of nitrate to Mileta Creek, although review of digital orthophotos of the basin going back as far as 1998 do not indicate the clearing of any large tracts of land in the headwaters of Mileta Creek.

[1] Measured as nitrate plus nitrite nitrogen. Nitrite nitrogen concentrations are typically very low in well oxygenated ambient waters (Hem 1985) and are typically very near or below the analytical detection limit when specific measurements of nitrite nitrogen are made.

Another potential source of nitrogen suggested during a project presentation to the Vashon-Maury Island community in October 2011 was excreta from a historic heron rookery located in the basin. However, the rookery was last occupied in 1996 or 1997 and the location of the rookery appears to have been downstream of the location where the highest nitrate concentrations were observed in this study.

Further attempts to isolate the source(s) of elevated winter nitrate concentrations in Mileta Creek should include a more rapid way to identify the timing of peak nitrate concentrations so that the synoptic sampling effort can best capture the basinwide distribution of peak nitrate concentrations. Focus should be on the longitudinal variation of nitrate in the two forks of Mileta Creek upstream from the mainstem. A broad-scale effort to identify other small creeks with similarly elevated nitrate concentrations through synoptic sampling might also help to determine if elevated nitrate concentrations are isolated to Mileta Creek or are more widespread and associated with a particular combination of land cover and surface soil or subsurface geologic characteristics. More detailed classification of forest stand character beyond separation of evergreen, deciduous, and mixed forest to a quantification of red alder density would provide a means of more directly relating the amount of red alder to observed nitrate concentrations and loads in streams across a forest disturbance gradient.

# 1.0. INTRODUCTION

King County was awarded a West Coast Estuaries Initiative (WEI) grant by Region 10 of the U.S. Environmental Protection Agency (EPA) to conduct the Quartermaster Harbor Nitrogen Management Study. The goal of this study is to support the protection and restoration of Quartermaster Harbor–a high value, coastal aquatic resource on Vashon-Maury Island (VMI) in Puget Sound. Partners working with King County on this grant-funded study include the University of Washington–Tacoma (UWT) and the Washington Department of Ecology (Ecology). The WEI grant will also support the enhancement of aquatic resource protection programs in an area threatened by growth pressures. This report describes the Mileta Creek Nitrogen Source Tracking Study planned as part of the Quartermaster Harbor Nitrogen Management Study (King County 2009a).

## 1.1 Project Overview

Dissolved oxygen levels below Washington State marine water quality standards have been observed in Quartermaster Harbor over the last five years of monthly monitoring by King County (Figure 1). Dissolved oxygen is essential for fish and other marine life - when levels fall below critical thresholds, marine life can become stressed, die or if possible be forced to escape to more oxygenated waters. Low dissolved oxygen levels, combined with the high habitat value of Quartermaster Harbor and the occurrence of nitrate nitrogen in VMI groundwater and streams, in combination with ongoing population growth, make this project a high priority for King County. Quartermaster Harbor has many similarities with South Puget Sound embayments which do not meet state dissolved oxygen standards established for the protection of aquatic life (Albertson et al. 2002).

Quartermaster Harbor was one of 19 areas of Puget Sound judged to be relatively sensitive to anthropogenic nutrient inputs (Rensel Associates and PTI 1991). Excess nutrients, nitrogen compounds in particular, can lead to excessive phytoplankton and algae growth which can deplete oxygen concentrations when the algae die and are decomposed by bacteria in the water column and sediments (Figure 2). Nitrogen and phosphorus are essential nutrients for marine plants and phytoplankton. Although phosphorus compounds are important for phytoplankton growth, nitrogen is generally considered to be the limiting nutrient in marine waters of Puget Sound (Rensel Associates and PTI 1991).

The interactions between nitrate, algal biomass, and dissolved oxygen in Inner Quartermaster Harbor are illustrated in Figure 3. Algal biomass generally peaks during spring and summer, which coincides with a reduction of nitrate concentrations to below the limit of laboratory detection as a result of algal uptake and growth. The minimum oxygen concentrations observed in late summer and fall are associated with the final decline in the summer peaks in algal biomass. These data provide additional evidence that phytoplankton growth in the harbor is limited by nitrogen and that additional inputs of nitrogen to the harbor have the potential to fuel additional growth of algae and additional losses of oxygen when the algae die and are decomposed in the water column and sediments.

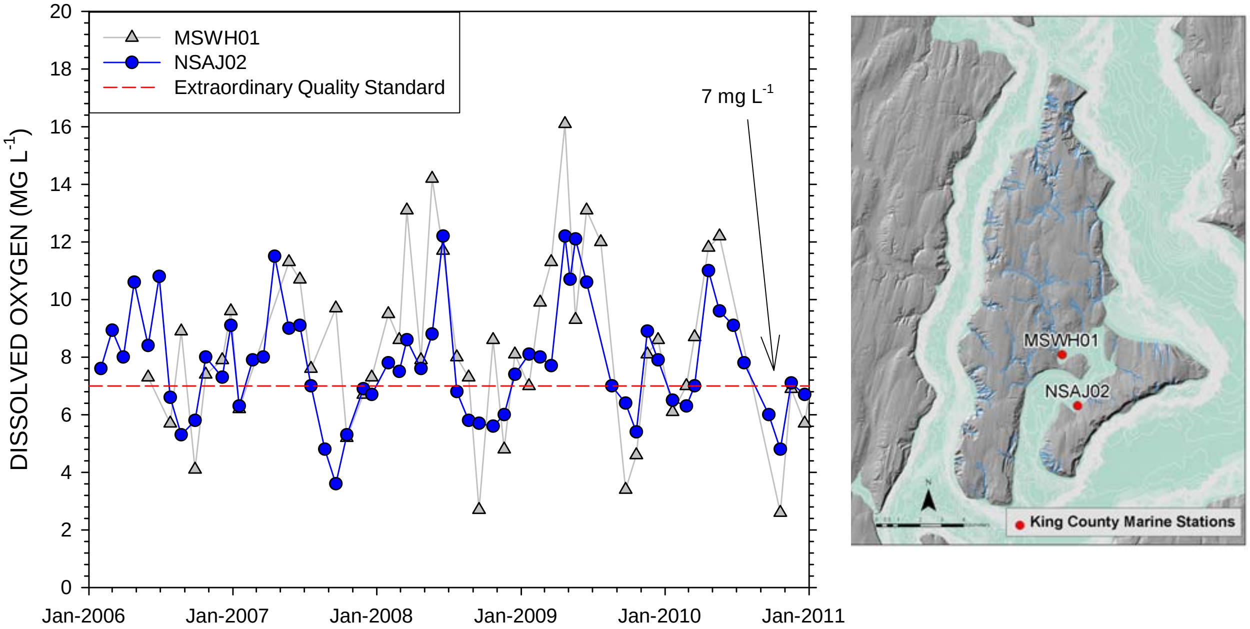


**Figure 1. Monthly dissolved oxygen concentrations measured in bottom waters of Quartermaster Harbor by King County.**

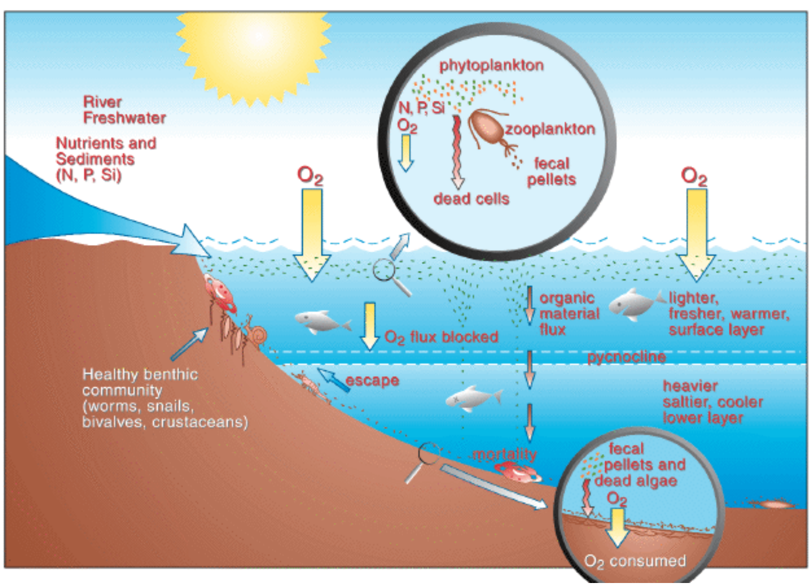


**Figure 2. Conceptual diagram of marine nutrient-oxygen dynamics (Source: Downing JA, et al. Gulf of Mexico hypoxia: land and sea interactions.**

*Note: Task force report no. 134. Ames, IA: Council for Agricultural Science and Technology, 1999 (http://www.ehponline.org/docs/2000/108-3/focusfig2B.GIF )*

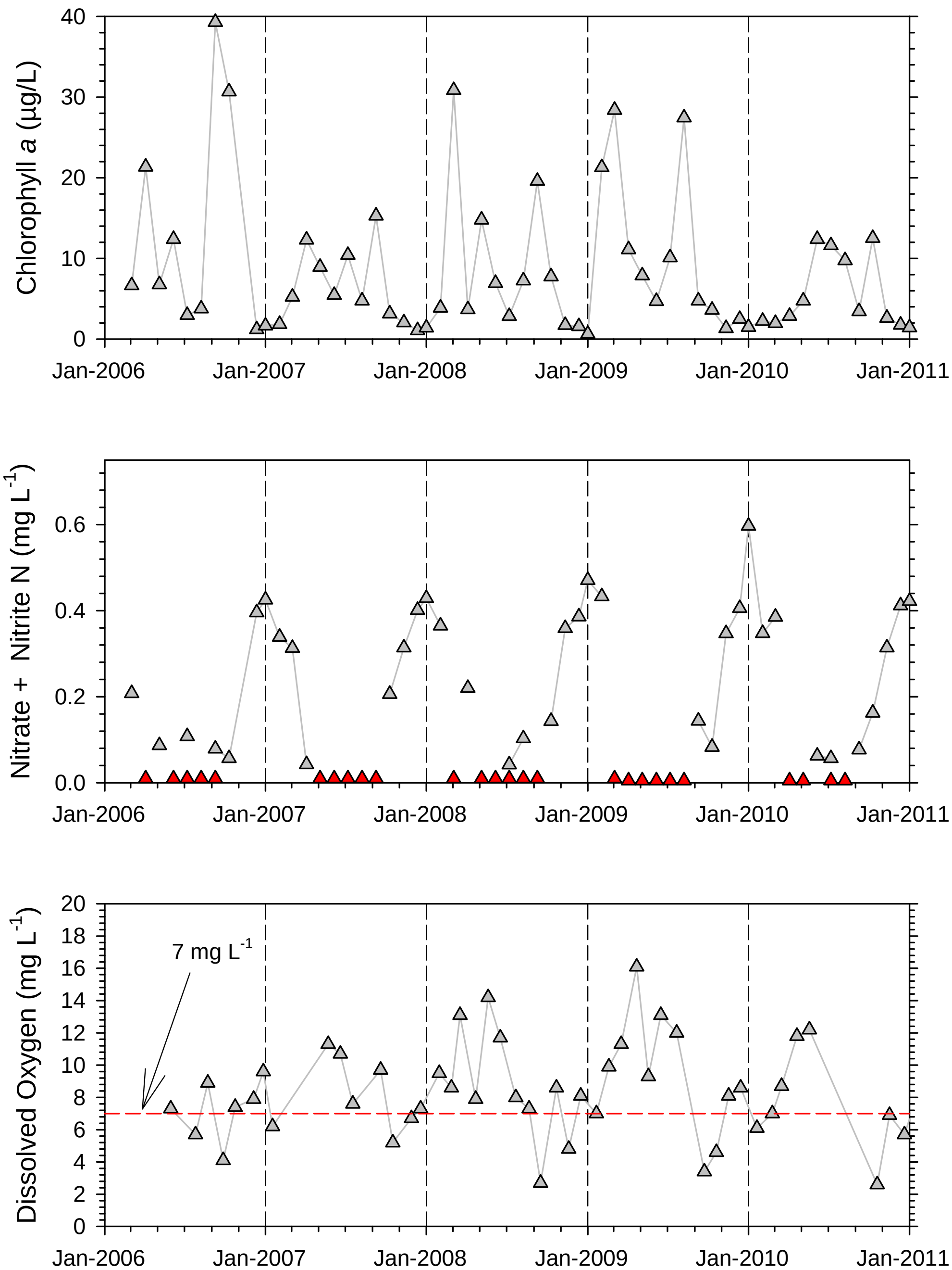


**Figure 3. Monthly concentrations of surface water algal biomass (based on measurements of chlorophyll *a*), surface concentrations of nitrate nitrogen, and bottom water dissolved oxygen concentrations at Stations MSWH01 in Inner Quartermaster Harbor.**

*Note: Red triangles in the center panel represent nitrate concentrations that were below the laboratory detection limit of 0.02 mg/L. The state standard for dissolved oxygen is shown as a dashed red line in the bottom panel.*

## 1.2 Study Area

Quartermaster Harbor is a shallow, protected embayment that comprises approximately 12.1 $km^2$ (3,000 acres) of water surface area in an inner and outer harbor and receives runoff from about 40 percent of Vashon-Maury Island (Figure 4). Inner Quartermaster Harbor is especially sheltered and Judd Creek, located in the northwestern portion of the inner harbor, is the largest freshwater input. Inner Quartermaster Harbor is shallow, with greatest depths of about 5 to 6 meters and very little tidal flushing. Outer Quartermaster Harbor water depths range from about 11 to 46 meters with more rapid tidal flushing. The subtidal sediments are generally dominated by silt and clay, although some shallow areas, especially in the outer harbor, are dominated by sand (University of Washington 1976, Long et al. 2002, King County 2009b, University of Washington Tacoma, unpublished data).

Mileta Creek is the largest tributary on Maury Island that drains to the channel between the Inner and Outer Harbor (see Figure 4). Preliminary geographic information system (GIS) analysis of recent high resolution digital elevation model (DEM) data and subsequent field investigation indicates that the Mileta Creek basin delineated by King County GIS staff is actually comprised of four separate drainages (Figure 5).

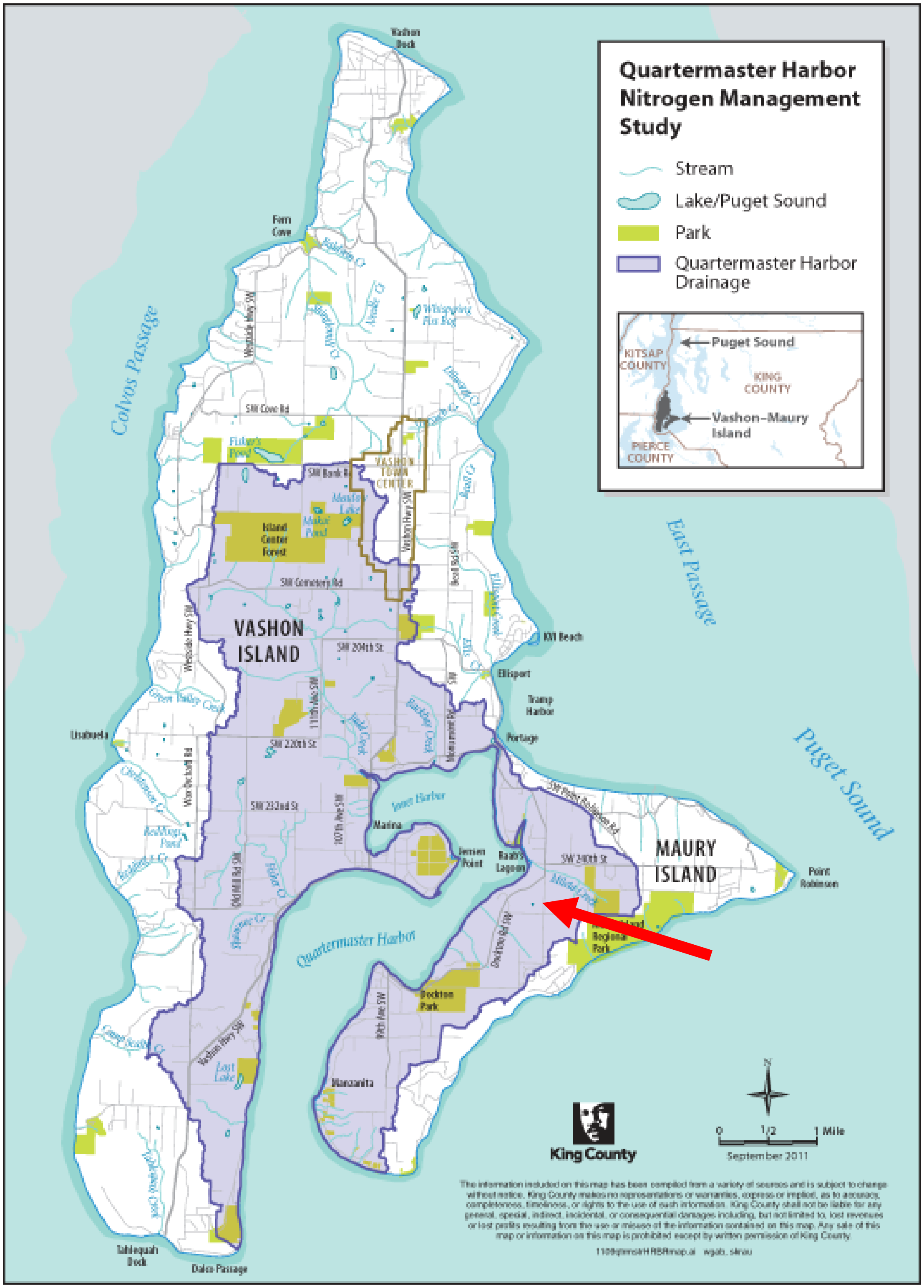


**Figure 4.** **Map of Vashon-Maury Island highlighting the drainage area to Quartermaster Harbor.**

*Note: Red arrow indicates location of Mileta Creek.*

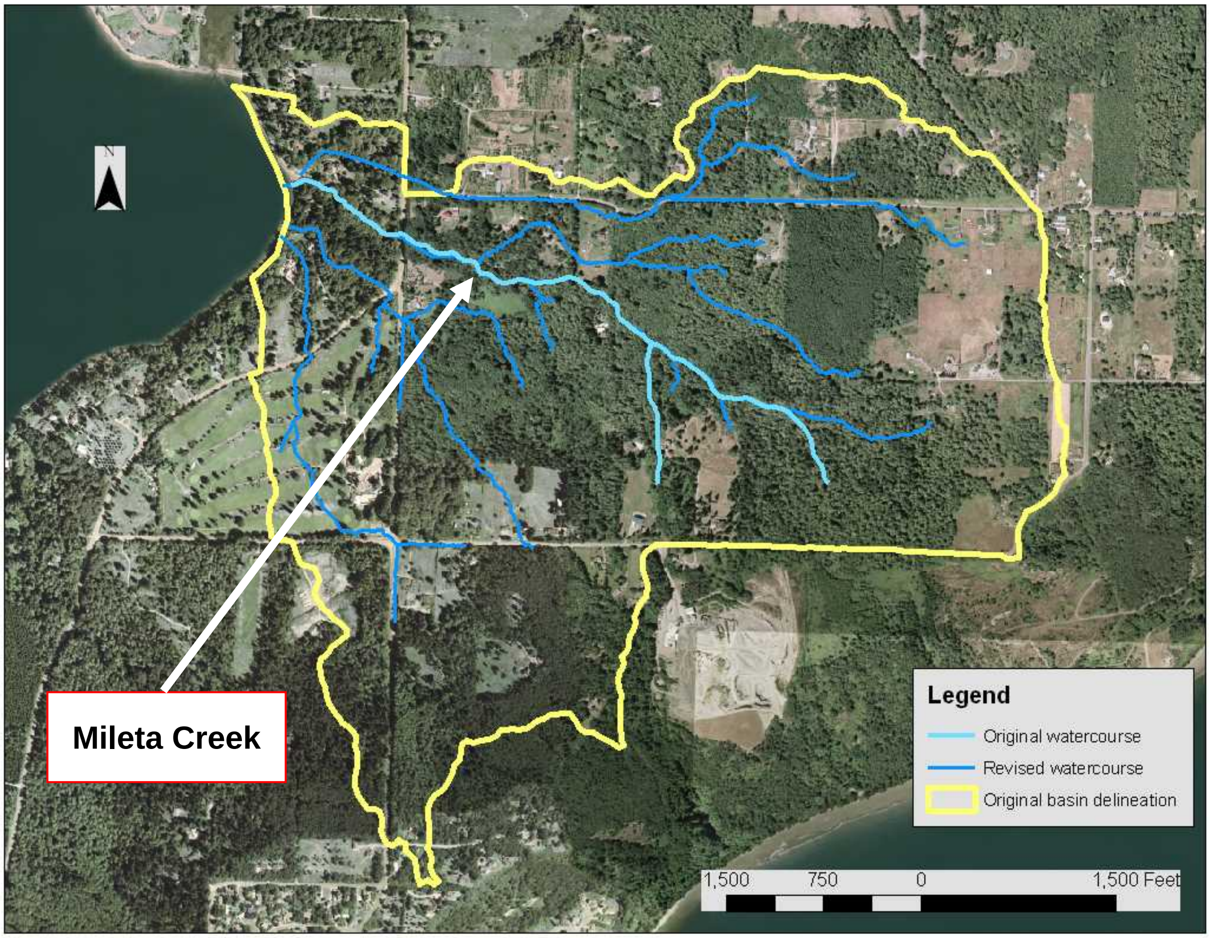


**Figure 5. Mileta Creek drainage basin as delineated by King County and the original and revised stream watercourses.**

*Note: The original GIS watercourse layer indicated only one stream (i.e., Mileta Creek). However, there appear to be at least four distinct streams draining the Mileta Creek basin delineated by King County.*

## 1.3 Background

Elevated nitrate concentrations of over 4 mg/L have been observed during winter months in Mileta Creek since routine monthly water quality monitoring began in late 2006 (Figure 6). Although nitrate concentrations typically increase in rural King County streams during the winter, concentrations above 4 mg/L have been observed routinely in only one other King County creek – Newaukum Creek – a tributary to the Green River which drains a basin dominated by agricultural land uses (King County, 2005; King County, 2007). However, elevated nitrate concentrations in Newaukum Creek coincide with elevated concentrations of ammonium nitrogen and soluble reactive phosphorus (SRP), while concentrations of ammonium and SRP in Mileta Creek remain low. The cause of the elevated winter nitrate concentrations in

Mileta Creek is unknown. Three other creeks on Vashon-Maury Island have been monitored over the same period of time and although concentrations of nitrate in these streams peak at the same time as Mileta Creek the concentrations are generally much lower, typically peaking near 2 mg/L or less during winter (see Figure 6).

It is also worth noting that the peak nitrate concentrations in Mileta Creek (and the smaller peaks in the other monitored creeks) typically occur after the minimum oxygen concentrations are observed in Quartermaster Harbor (see Figure 1).

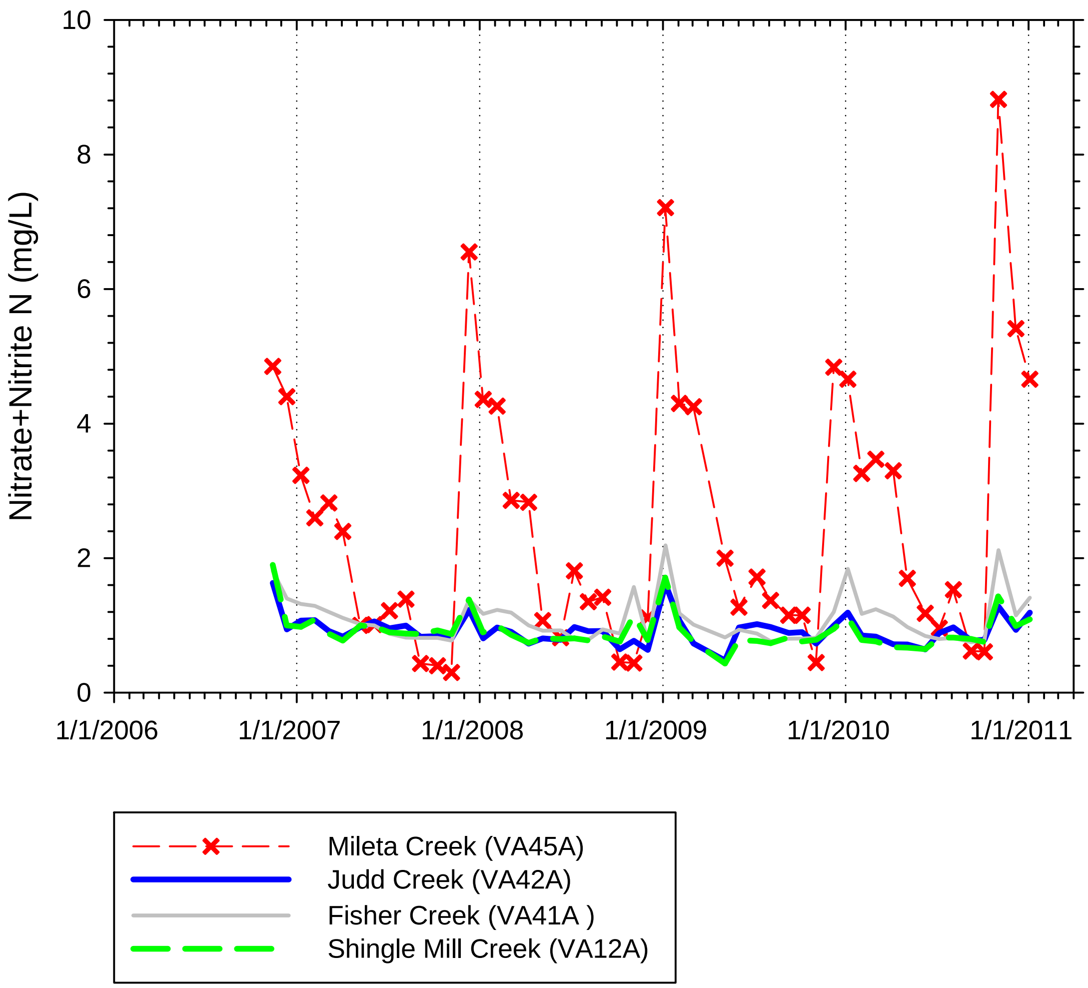


**Figure 6. Nitrate+Nitrite nitrogen concentrations measured in routine monthly water quality samples from four Vashon-Maury Island Creeks collected from November 2006 to January 2011.**

## 1.4 Study Goal

As part of a preliminary estimate of nutrient loading to Quartermaster Harbor, a recommendation was made to conduct a nitrogen source tracking study on Mileta Creek (King County, 2010a).

The purpose of this study was to determine if the source of elevated nitrate nitrogen to Mileta Creek could be identified or if the location where it enters the stream could be located more precisely. Samples along the stream reach would help identify the location along the stream where elevated levels of nitrogen are entering the waterway. This information will be incorporated into the overall study identifying nitrogen loading sources and potential management strategies of those sources.

## 1.5 Organization of Report

The report is organized into an introduction (this section), a section briefly describing the methods employed during the study (Methods), and a section summarizing the study results (Results).

A summary of the results and conclusions are provided in the Summary and Conclusions section. That section also provides some suggestions for additional studies that might help further isolate the source of nitrate in Mileta Creek.

# 2.0. METHODS

Details of the study design are provided in the Mileta Creek Nitrogen Source Tracking Quality Assurance Project Plan (King County 2010b). A general description of the study methods follows.

Samples along the stream reach of Mileta Creek and associated small tributaries within the delineated Mileta Creek drainage basin were taken at 16 locations on November 17, 2010 to help identify areas within the basin where elevated levels of nitrogen were entering the waterway. Some modifications were made to the originally proposed sampling locations as the result of efforts to secure access permission to private land and physical accessibility to the stream as determined by preliminary field reconnaissance work.

Since the timing of the initial increase in nitrate concentrations appears to vary during the fall/early winter period (see Figure 6), a threshold was used to determine when sampling as part of the source tracking study would occur. Source tracking sampling would be initiated within two weeks of when the routine monthly sample result for the nitrate concentration at the long term Mileta Creek sampling site (VA45A) exceeded 4 mg/L. Routine stream sampling on November 2, 2010 indicated a nitrate concentration of 8.82 mg/L – sampling commenced on the 17th of November, one day beyond the 2 week window designated in the QAPP

Sampling included field measurements of specific conductance, dissolved oxygen, temperature and pH and collection of samples for laboratory analysis of three forms of nitrogen – nitrate plus nitrite (identified as nitrate in the remainder of this report for convenience[2]); ammonium and total nitrogen. Stream flow was measured at 14 of the 16 sites. The two sites where flow was not measured were near the outlet of Mileta Creek and very near the location where the routine stream gauging location (36A) was co-located with another water quality sampling station (VA45R) and there were no significant inflows over this reach so additional flow measurements were not necessary.

Flow was measured so that the flux of nitrate nitrogen could be calculated to evaluate longitudinal patterns in nitrate loading and identify potential nitrate sources (or sinks) between sampling stations. Nitrate loading was calculated by multiplying the measured flow in cfs by the concentration measured in mg/L and multiplying the result by the conversion factor 2.45 to provide the final result of this calculation in units of kg N day$^{-1}$.

Station locations are shown in Figure 7 and coordinates for each sampling site are summarized in Table 1. Since the names of the tributaries besides Mileta Creek were not known, they have been designated as the North Tributary (tributary to the north of Mileta Creek), South Tributary (tributary just to the south of Mileta Creek), and the Southernmost Tributary (tributary farthest south within the currently delineated Mileta Creek basin) for discussion of results in this report (see Figure 7). The two main forks in Mileta Creek upstream of VA45B were also further designated as the North and South forks, respectively.

---

[2] Measured as nitrate plus nitrite nitrogen. Nitrite nitrogen concentrations are typically very low in well oxygenated ambient waters (Hem 1985) and are typically very near or below the analytical detection limit when specific measurements of nitrite nitrogen are made.


**Figure 7. Map showing locations of source tracking study sampling locations.**

*Note: White arrow indicates long term routine stream water quality monitoring location VA45A on Mileta Creek.*

**Table 1. Mileta Creek Nitrogen Source Tracking Study sampling station coordinates.**

| Station ID | Coordinates [a] (Easting/Northing) | |
|---|---|---|
| VA45A [b] | 1245477 | 145767 |
| VA45B | 1246118 | 145574 |
| VA45C | 1246143 | 145534 |
| VA45D | 1245497 | 146275 |
| VA45E | 1248911 | 144362 |
| VA45G | 1246159 | 145574 |
| VA45H | 1248349 | 145727 |
| VA45I | 1248715 | 144807 |
| VA45J | 125398 | 145229 |
| VA45K | 1246392 | 146060 |
| VA45L | 124743 | 145946 |
| VA45M | 1249386 | 145957 |
| VA45O | 1245388 | 145405 |
| VA45P | 1244838 | 144816 |
| VA45Q | 1245454 | 145222 |
| VA45R [c] | 1245664 | 145711 |

[a] *Coordinates are in Washington State Plane Feet North (HARN 1984)*

[b] *Long term Mileta Creek water quality monitoring location.*

[c] *King County stream gauging station 36A.*

# 3.0. RESULTS

Field sampling at the 16 source tracking stations was conducted between 9:35 AM and 12:45 PM local time on November 17, 2010. The study results are provided in Table 2.

**Table 2. Field and laboratory sampling results from the Mileta Creek Nitrogen Source Tracking Study conducted on November 17, 2010.**

| LOCATOR | Flow | NH4-N | NO32-N | TN | DO | SC | pH | T |
|---|---|---|---|---|---|---|---|---|
| | cfs | | mg/L | | | µS/cm | | °C |
| **Tributary north of Mileta** | | | | | | | | |
| VA45M | 0.045 | <0.005 | 0.439 | 0.909 | 7.4 | 70 | 7.27 | 9.1 |
| VA45L | 0.075 | 0.0064 | 2.45 | 3.64 | 7.4 | 110 | 6.85 | 9.1 |
| VA45K | 0.070 | 0.005 | 2.04 | 2.85 | 7.6 | 111 | 7.02 | 9.1 |
| VA45D | 0.101 | <0.005 | 1.57 | 2.76 | 7.8 | 105 | 7.33 | 9.3 |
| **Mileta Creek** | | | | | | | | |
| *North Fork* | | | | | | | | |
| VA45I | 0.063 | <0.005 | 3.16 | 3.64 | 7.4 | 80 | 6.44 | 9.5 |
| VA45H | 0.004 | <0.005 | 0.119 | 0.326 | 6.6 | 61 | 7.22 | 10.2 |
| VA45G | 0.116 | <0.005 | 4.51 | 5.7 | 7.7 | 92 | 6.18 | 9.6 |
| *South Fork* | | | | | | | | |
| VA45E | 0.084 | <0.005 | 6.62 | 7.41 | 7.3 | 93 | 6.63 | 10 |
| VA45C | 0.130 | <0.005 | 6.47 | 7.12 | 8.7 | 103 | 5.97 | 9.8 |
| *Mainstem* | | | | | | | | |
| VA45R | 0.254 | <0.005 | 5.65 | 6.4 | 8.3 | 100 | 6.85 | 9.3 |
| VA45B | - | <0.005 | 5.59 | 6.38 | 8.6 | 98 | 6.07 | 9.6 |
| VA45A | - | <0.005 | 5.52 | 6.24 | 8.3 | 100 | 7.05 | 9.3 |
| **Tributary to south of Mileta** | | | | | | | | |
| VA45Q | 0.039 | 0.0072 | 0.469 | 1.39 | 9.2 | 102 | 5.97 | 9.5 |
| VA45J | 0.013 | <0.005 | 0.249 | 0.813 | 8.9 | 155 | 6.11 | 9.7 |
| VA45O | 0.082 | 0.0058 | 0.36 | 1.04 | 7.9 | 121 | 6.27 | 9.7 |
| **Southernmost tributary** | | | | | | | | |
| VA45P | 0.057 | 0.0324 | 0.584 | 1.19 | 7.4 | 150 | 7.34 | 10.3 |

*"<" – indicates laboratory result was less than the Method Detection Limit (MDL) shown.*

*"-" – indicates "Not measured".*

*NH4-N = Ammonium Nitrogen, NO32-N = Nitrate plus Nitrite Nitrogen, TN = Total nitrogen, DO = Dissolved Oxygen, SC = Specific Conductance, pH = negative log of the hydrogen ion concentration, T = Temperature.*

The nitrate concentration at the routine water quality monitoring station on Mileta Creek (VA45A) had already fallen to 5.52 mg/L since the concentration of 8.82 mg/L at VA45A was measured on November 2. However, the concentration dropped only slightly to 5.41 mg/L by December 7, 2010 when the December routine monthly sample was collected at this station.

The highest nitrate concentrations were consistently measured on Mileta Creek (3.16 to 6.62 mg/L) with one exception – 0.119 mg/L measured at Station VA45H on the northernmost fork of the creek (Figure 8). The highest concentration (6.62 mg/L) was measured near the headwaters of the main southern branch of the creek at Station VA45E (see Figure 8). The nitrate concentration measured at the station just to the north of VA45H on a separate fork of Mileta Creek (Station VA45I) was 3.16 mg/L.

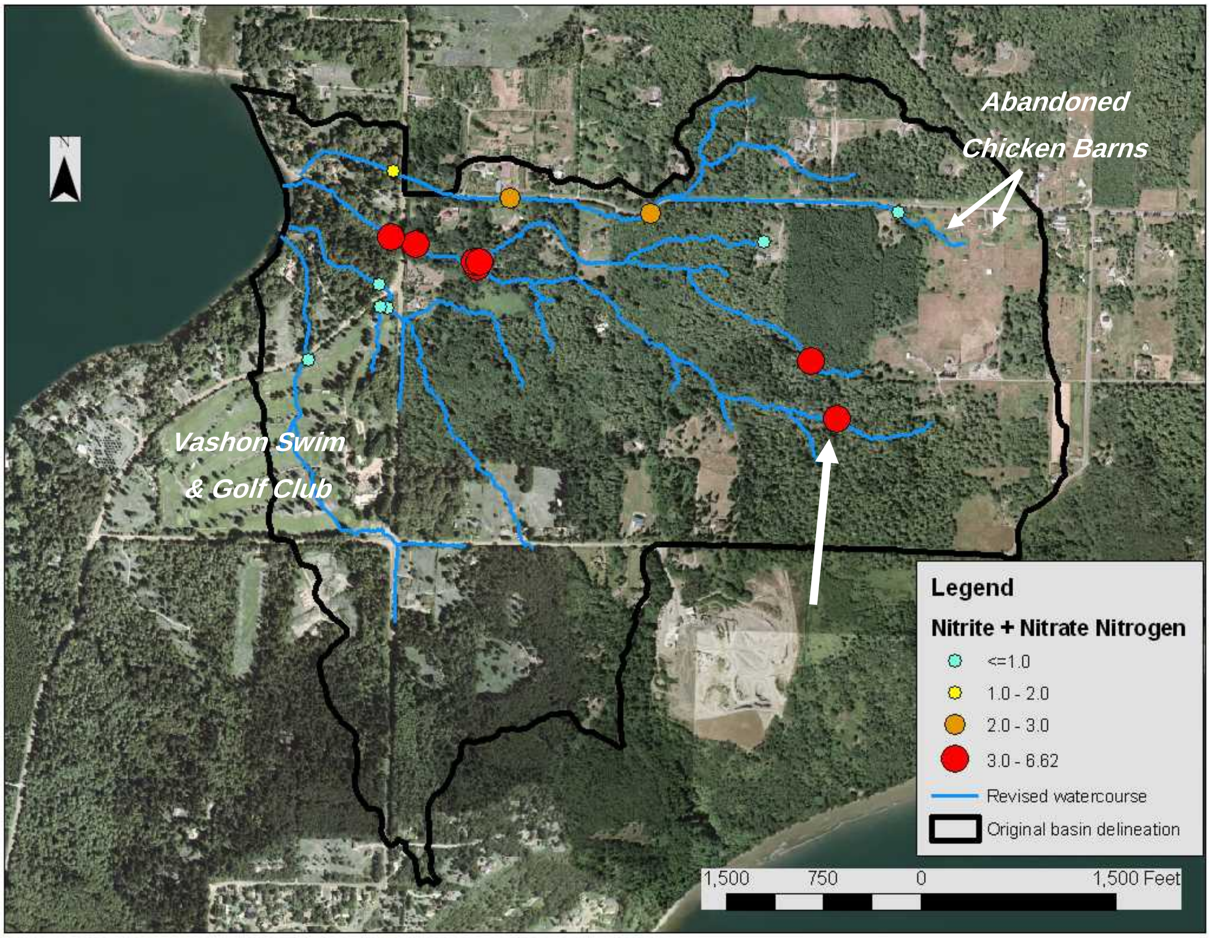


**Figure 8. Map showing range of Nitrate plus Nitrite Nitrogen concentrations measured during the Mileta Creek Nitrogen Source Tracking Study conducted on November 17, 2010.**

*Note: White arrow indicates the location of the highest concentration observed (6.62 mg/L) at a location near the headwaters of the southern fork of Mileta Creek (station VA45E).*

A range of nitrate concentrations were observed in the tributary to the north of Mileta Creek (0.439 to 2.45 mg/L). The highest nitrate concentration was measured at Station VA45L – the station downstream of the headwater Station VA45M on this tributary. The relatively low nitrate concentration at VA45M of 0.439 mg/L is worth noting as this station is just downstream of two abandoned chicken barns. The two small tributaries draining portions of the Vashon Swim & Golf Club had consistently lower levels of nitrate – between 0.249 and 0.584 mg/L (Figure 8).

Generally there was no relationship between the measured nitrate concentrations and the other water quality parameters with the exception of a strong positive correlation between nitrate and total nitrogen (Pearson r = 0.995). Ammonium nitrogen concentrations were generally low – below the method detection limit (MDL) of 0.005 mg/L at 11 of the 16 stations (see Table 2). The highest measured concentration of ammonium nitrogen (0.0324 mg/L) was found at Station VA45P, which was the southernmost tributary sampled.

Lowest dissolved oxygen (6.6 mg/L) and lowest specific conductance (61 µS/cm) were measured at the same station at the northern headwaters of Mileta Creek with the lowest observed nitrate concentration (Station VA45H). The pH of the stream waters sampled ranged from 5.97 to 7.34 with no apparent relationship with stream nitrate concentration. The highest pH was measured at the same location with the lowest dissolved oxygen and specific conductance (VA45P). The range of observed temperatures was relatively narrow (9.1-10.3 $^{o}$C) and typical of island streams in November.

## 3.1 Estimated Nitrate Loading

Nitrate loading estimates are summarized in Table 3. Nitrate loading estimated for the two tributaries to the south of Mileta Creek were consistently low – less than 0.100 kg N day$^{-1}$ as a result of the smaller drainage (and flow) and low nitrate concentrations measured in these two streams (Figure 9). The nitrate load did increase slightly in the tributary to the north of Mileta Creek between the headwater sampling location (VA45M) and the next downstream location (VA45L) – a gain of 0.40 kg N indicating a net source of nitrate between these two locations. However, nitrate loading remained steady from VA45L to the station near the mouth on this creek (VA45D).

Although the nitrate load at the headwater sampling location on Mileta Creek where the highest nitrate concentration was measured (VA45E) was initially also relatively high (1.36 kg day$^{-1}$), additional inputs of nitrate between VA45E and VA45C are suggested even though the nitrate concentration measured at VA45C was slightly lower than that measured at VA45E – nitrate load increased 0.70 kg between these two locations (Table 3). A similar conclusion can be reached by comparing the headwater nitrate loads at the two headwater locations on the headwater forks of the north fork of Mileta Creek (VA45I and VA45H) and the station downstream of these two locations (VA45G), which suggests a net addition of about 0.80 kg of nitrate nitrogen. The inputs from the two Mileta Creek forks qualitatively match the load estimated for the mainstem (3.34 vs 3.51 kg day$^{-1}$) considering the flow and concentration measurement errors.

**Table 3. Estimated nitrate (Nitrate plus Nitrite Nitrogen) loading based on November 17, 2010 source tracking data.**

| LOCATOR | | Flow | Conc. | Load |
|---|---|---|---|---|
| | | cfs | mg/L | kg N $day^{-1}$ |
| **Tributary north of Mileta** | | | | |
| VA45M | us | 0.045 | 0.439 | 0.05 |
| VA45L | | 0.075 | 2.45 | 0.45 |
| VA45K | | 0.070 | 2.04 | 0.35 |
| VA45D | ds | 0.101 | 1.57 | 0.39 |
| **Mileta Creek** | | | | |
| *North fork* | | | | |
| VA45I | us | 0.063 | 3.16 | 0.49 |
| VA45H | us | 0.004 | 0.119 | 0.00 |
| VA45G | ds | 0.116 | 4.51 | 1.28 |
| *South Fork* | | | | |
| VA45E | us | 0.084 | 6.62 | 1.36 |
| VA45C | ds | 0.130 | 6.47 | 2.06 |
| *Mainstem* | | | | |
| VA45R | | 0.254 | 5.65 | 3.51 |
| **Tributary to south of Mileta** | | | | |
| VA45Q | us | 0.039 | 0.469 | 0.04 |
| VA45J | us | 0.013 | 0.249 | 0.01 |
| VA45O | ds | 0.082 | 0.36 | 0.07 |
| **Southernmost tributary** | | | | |
| VA45P | | 0.057 | 0.584 | 0.08 |

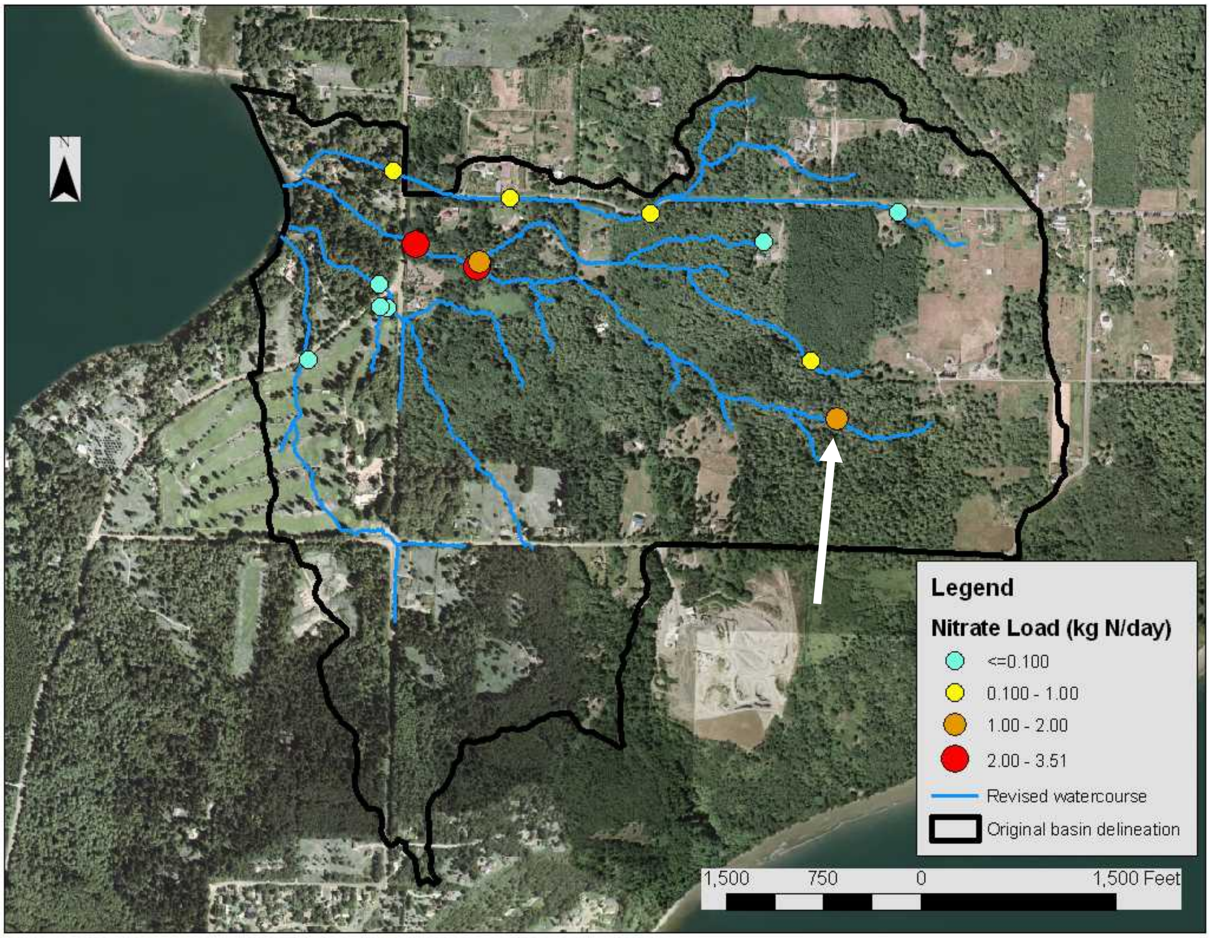


**Figure 9. Map showing range of nitrate load estimates based on flow and concentration measurements made at 16 stations sampled as part of the Mileta Creek Nitrogen Source Tracking Study.**

*Note: White arrow indicates the location of the highest concentration observed (6.62 mg/L) at a location near the headwaters of the southern fork of Mileta Creek (station VA45E).*

# 4.0. SUMMARY AND CONCLUSIONS

Although the elevated concentrations of nitrate observed in Mileta Creek typically occur after the late summer/fall oxygen minimum in Quartermaster Harbor, and are therefore not directly connected to observed oxygen minima, the unusual and consistently high concentrations that have been observed each winter warrant investigation. The source tracking study has eliminated two potential sources (the golf course and the abandoned chicken barns) as the cause of elevated nitrate concentrations observed in Mileta Creek each winter. The actual source remains unknown, but has been isolated to the reaches upstream of the mainstem of Mileta Creek. Surficial geology does not appear to be a factor as high and low nitrate concentrations were observed at stations located on the upland till, although nitrate loads were observed to increase between stations where advance outwash (Qva) is found (Figure 10).

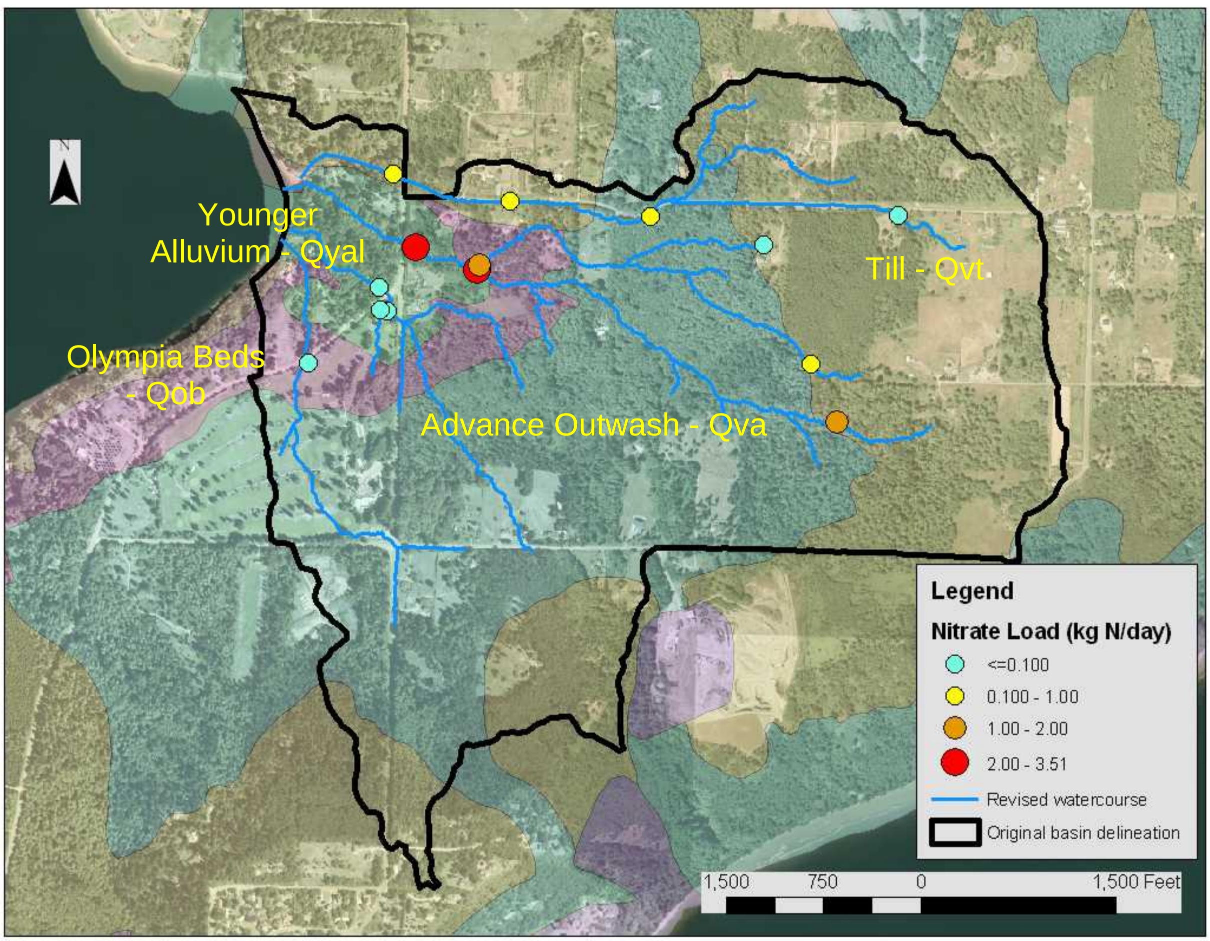


**Figure 10. Map showing range of Nitrate plus Nitrite Nitrogen load estimates based on flow and concentrations measured during the Mileta Creek Nitrogen Source Tracking Study and surficial geology across the basin.**

Potential sources include human activities (historic or current) in the upland reaches of the watershed or nitrate derived from nitrogen fixing plants such as red alder (Steinberg et al. 2010). The timing and shape of the nitrate peak in Mileta Creek is similar to that in Shingle Mill, Judd, and Fisher creeks – particularly Fisher Creek (see Figure 6), but the peak concentration is of significantly greater magnitude. Studies in other Pacific Northwest streams and rivers have noted this phenomenon of a pulse of nitrate input associated with the beginning of winter rains that finally saturate surface soils that remained relatively dry during the summer (Bechtold et al. 2003, Compton et al. 2003, Cairns and Lajtha 2005, Steinberg et al. 2010, Ward et al. 2010). Ward et al. (2010) indicated that this pulse is due to the accumulation of dissolved nitrate in surface soils during summer which are flushed out during initial winter storms eventually depleting the supply of stored nitrate. Generally, basins with a greater amount of nitrogen fixing red alder (a species of tree that commonly colonizes disturbed or harvested forest land) store greater amounts of nitrate in soil during summer and yield greater amounts of nitrate to streams and rivers in the winter (Compton et al. 2003, Steinberg et al. 2010).

Although nitrogen fixing plants such as red alder may be a significant source of nitrate nitrogen in this basin, there does not appear to be an obvious relationship between the distribution of deciduous and mixed forest and longitudinal patterns in nitrate loading. Reaches over which gains in nitrate were apparent did traverse land classified as deciduous forest based on the 2001 National Land Cover Data (Figure 11). Forest classified as deciduous likely includes some red alder. According to Compton et al. (2003) leaching of nitrate from upland alder stands plays an important role in watershed nitrogen export so the upland deciduous forest cover in the south fork of Mileta Creek may explain the elevated nitrate concentration in the upstream branch of this creek. However, deciduous forest cover is also identified upstream of the sampling stations on the tributary just to the south of Mileta Creek which had consistently low nitrate concentrations and loading (see Figure 11).

Forest clearing, especially clearing of red alder stands, is another potential source of nitrate to Mileta Creek (Likens et al. 1970, Gravelle et al. 2009), although review of digital orthophotos of the basin going back as far as 1998 do not indicate the clearing of any large tracts of land in the headwaters of Mileta Creek.

Another potential source of nitrogen suggested during a presentation to the Vashon-Maury Island community in October 2011 was excreta from a historic heron rookery located in the basin. According to Rayna Holtz[3], the rookery was located in a stand of alders between the two forks of Mileta Creek downstream of the location where the highest concentration of nitrate was observed in this study (see white arrow in Figure 11). However, the rookery was last occupied in 1996 or 1997. Although the former heron rookery does not appear to be the source of the elevated nitrate in the headwaters of the southern fork of Mileta Creek, it might be interesting to see if any vestiges of the rookery remain and pinpoint its location.

[3] E-mail communication on December 8, 2011, with Jennifer Vanderhoof, Senior Ecologist, King County Water and Land Resources Division, Seattle, WA.

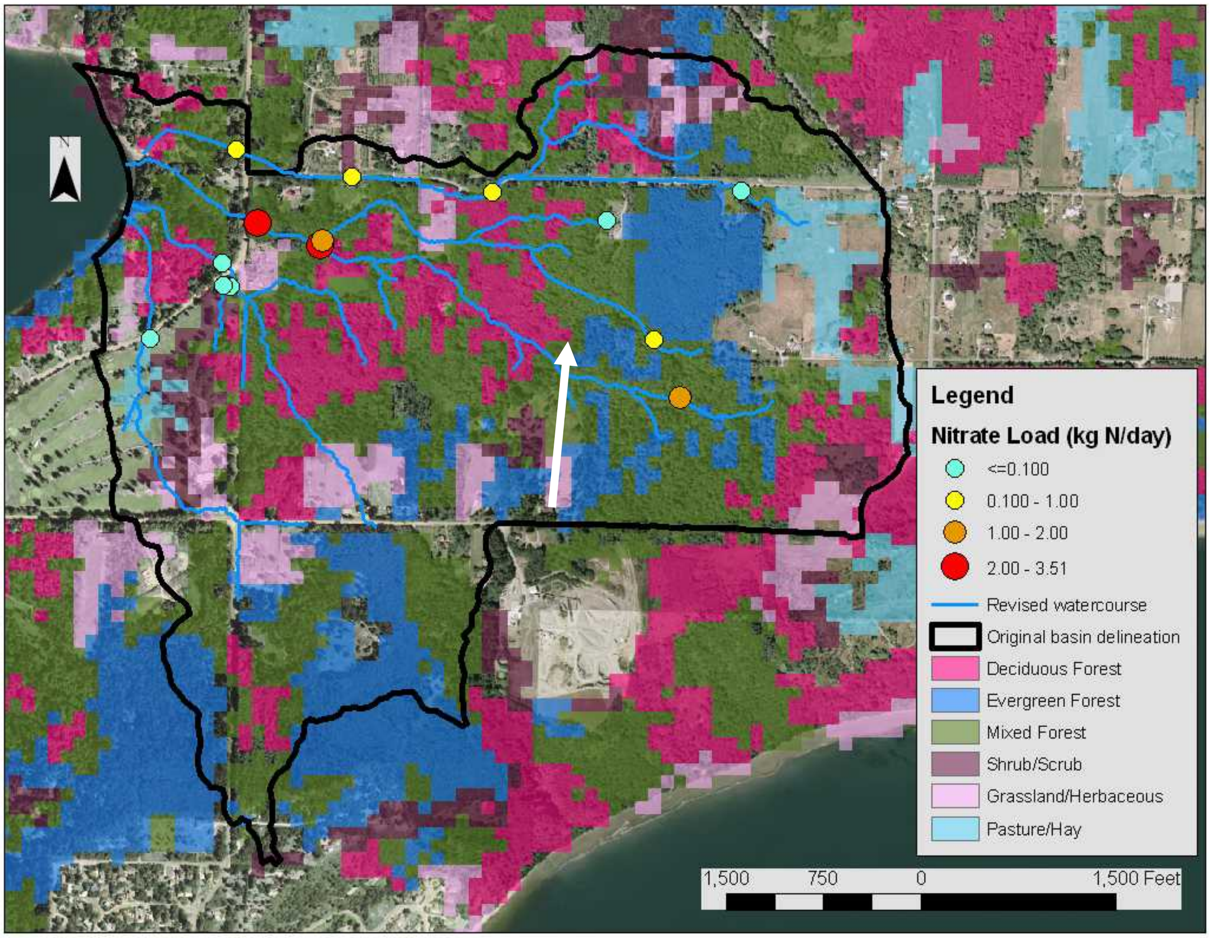


**Figure 11. Map showing range of Nitrate plus Nitrite Nitrogen load estimates based on flow and concentrations measured during the Mileta Creek Nitrogen Source Tracking Study and 2001 National Land Cover Data (NLCD) across the basin.**

*Note: White arrow indicates the approximate location of the historic heron rookery.*

Further attempts to isolate the source(s) of elevated winter nitrate concentrations in Mileta Creek should include a more rapid way to identify the timing of peak nitrate concentrations so that the synoptic sampling effort can best capture the basinwide distribution of peak nitrate concentrations. Focus should be on the longitudinal variation of nitrate in the two forks of Mileta Creek upstream from the mainstem. A broad-scale effort to identify other small creeks with similarly elevated nitrate concentrations through synoptic sampling might also help to determine if elevated nitrate concentrations are isolated to Mileta Creek or are more widespread and associated with a particular combination of land cover and surface soil or subsurface geologic characteristics. More detailed classification of forest stand character beyond separation of evergreen, deciduous, and mixed forest to a quantification of red alder density would provide a means of more directly relating the amount of red alder to observed nitrate concentrations and loads in streams across a forest disturbance gradient.

# 5.0. REFERENCES


Albertson, S.L., K. Erickson, J.A. Newton, G. Pelletier, R.A. Reynolds, and M. Roberts. 2002. South Puget Sound Water Quality Study. Phase 1. Washington State Department of Ecology, Olympia, WA. Publication No. 02-03-021. http://www.ecy.wa.gov/biblio/0203021.html, accessed September 21, 2011.

Bechtold, J.S., R.T. Edwards, and R.J. Naiman. 2003. Biotic versus hydrologic control over seasonal nitrate leaching in a floodplain forest. Biogeochemistry 63:53-72.

Cairns, M.A. and K. Lajtha. 2005. Effects of succession on nitrogen export in the West-Central Cascades, Oregon. Ecosystems 8:583-601.

Compton, J.E., M.R. Church, S.T. Larned, and W.E. Hogsett. 2003. Nitrogen export from forested watersheds in the Oregon Coast Range: The role of $N_2$-fixing red alder. Ecosystems 6:773-785.

Gravelle, J.A., G. Ice, T.E. Link, and D.L. Cook. 2009. Nutrient concentration dynamics in an inland Pacific Northwest watershed before and after timber harvest. Forest Ecology and Management 257:1663-1675.

Hem, J.D. 1985. Study and interpretation of chemical characteristics of natural water. U.S. Geological Survey Water-Supply Paper 2254. http://pubs.usgs.gov/wsp/wsp2254/

King County. 2005. Green-Duwamish Watershed Water Quality Assessment. Year 2003 Water Quality Data Report. Prepared by Herrera Environmental Consultants, Inc. in association with Anchor Environmental and Northwest Hydraulic Consultants. Water and Land Resources Division, Seattle, WA.

King County. 2007. Green-Duwamish Watershed Water Quality Assessment. Water Quality Statistical and Pollutant Loadings Analysis. Prepared by Herrera Environmental Consultants, Inc. in association with Anchor Environmental and Northwest Hydraulic Consultants. Water and Land Resources Division, Seattle, WA.

King County. 2009a. Quality Assurance Project Plan for Quartermaster Harbor Nitrogen Management Study. A Targeted Watershed Grant under the 2008 Puget Sound Initiative. Prepared in cooperation with University of Washington Tacoma and Washington State Department of Ecology. Water and Land Resources Division, King County, Seattle, WA.

King County. 2009b. Water Quality Status Report for Marine Waters, 2005-2007. King County Department of Natural Resources and Parks, Seattle, WA.

King County. 2010a. Initial Assessment of Nutrient Loading to Quartermaster Harbor. Prepared by Curtis DeGasperi. Water and Land Resources Division, Seattle, Washington.

King County. 2010b. Mileta Creek Nitrogen Source Tracking Study Quality Assurance Project Plan. Part of the Quartermaster Harbor Nitrogen Management Study. Water and Land Resources Division, Seattle, Washington.

Likens, G.E., F.H. Bormann, N.M. Johnson, D.W. Fisher, and R.S. Pierce. 1970. Effects of forest cutting and herbicide treatment on nutrient budgets in the Hubbard Brook watershed-ecosystem. Ecological Monographs 40:23-47.

Long, E.R., M. Dutch, S. Aasen, K.Welch, J. Hameedi, S. Magoon, R.S. Carr, T. Johnson, J. Biedenbach, K.J. Scott, C. Mueller, and J. Anderson. 2002. Sediment Quality in Puget Sound: Year 3, Southern Puget Sound. Washington State Department of Ecology, Olympia, WA. Publication No. 02-03-033. http://www.ecy.wa.gov/biblio/0203033.html, accessed April 19, 2010.

Rensel Associates and PTI. 1991. Nutrients and phytoplankton in Puget Sound. Prepared for U.S. Environmental Protection Agency, Region 10, Seattle, WA. PTI Environmental Services, Bellevue, WA.

Steinberg, P.D., M.T. Brett, J.S. Bechtold, J.E. Richey, L.M. Porensky, and S.N. Smith. 2010. The influence of watershed characteristics on nitrogen export to and marine fate in Hood Canal, Washington, USA. Biogeochemistry DOI:10.1007/s10533-010-9521-7.

University of Washington. 1976. Quartermaster Harbor Marine Park Study. Volumes 1 and 2. Prepared for King County Division of Parks and Recreation. College of Forest Resources, University of Washington, Seattle, WA.

Ward, N.D., J.E. Richey, and R.G. Keil. 2010. Temporal variation in river nutrient and dissolved lignin phenol concentrations and the impact of storm events on nutrient loading to Hood Canal, WA. Presentation to the 2nd Joint Federal Interagency Conference, Las Vegas, NV. June 27-July 1, 2010.