Quartermaster Harbor Nearshore Freshwater Inflows Assessment

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King County

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Quartermaster Harbor Nearshore Freshwater Inflows Assessment

Prepared for:

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

Submitted by:

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Acknowledgements

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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 Nearshore Freshwater Inputs Assessment was conducted to identify small previously unmonitored streams and pipes discharging to Quartermaster Harbor that might have relatively high nitrate concentrations. The study was conducted on October 6, 2010 at 21 locations along the perimeter of the harbor. This information will be incorporated into the overall study identifying nitrogen loading sources and potential management strategies of those sources.

The median nitrate concentration range measured in October 2010 in small freshwater inflows to Quartermaster Harbor was similar to the median nitrate concentration measured in October in the three largest tributary streams to Quartermaster Harbor from 2007 to 2010. The data presented in this study suggest some spatial variability in nitrate inputs from these previously unmonitored sources. However, the single freshwater input sampling event does not provide a means to extrapolate estimates from these locations to other times of the year.

The initial estimate of total freshwater inflow nitrate loading to the harbor used an average areal loading from routinely monitored tributaries to estimate loading from the unmonitored portion of the Quartermaster Harbor drainage basin (King County 2010a). The total estimated October 2010 nitrate loading from Judd, Fisher and Mileta creeks was 6.3 kg/d and the total estimated loading from the previously unmonitored freshwater inputs was 3.1 kg/d. Judd, Fisher and Mileta Creeks represent drainage from approximately half of the total drainage to the harbor, so based on an areal extrapolation approach; the total load from the remainder of the basin would be approximately 6 kg/d in October 2010. The discrepancy between the load extrapolated to the previously unmonitored drainage and that estimated during this study is attributed to the fact that not all of the previously unmonitored drainage was sampled. It is suggested that roughly half of the previously unmonitored drainage was sampled in this study, which is consistent with the difference between the extrapolated load and the load estimated based on the sampling data (6 vs. 3.1 kg/d).

1.0. INTRODUCTION

In 2008, Region 10 of the United States Environmental Protection Agency (EPA) awarded King County a West Coast Estuaries Initiative (WEI) grant to conduct the Quartermaster Harbor Nitrogen Management Study, which is funded through the end of 2012. 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). This project supports the enhancement of aquatic resource protection in an area threatened by population growth pressures. This report describes the Nearshore Freshwater Inflows Assessment conducted as part of the Quartermaster Harbor Nitrogen Management Study (King County 2009a).

1.1 Project Overview

Dissolved oxygen levels below the Washington State marine water quality standard have been observed in Quartermaster Harbor over the last five years by King County (Figure 1). Oxygen concentrations are typically lowest in September or October. Dissolved oxygen is essential for fish and other marine life - when levels fall below critical thresholds marine life can become stressed or killed or forced to escape to more oxygenated waters if possible. Low dissolved oxygen levels and the occurrence of nitrate nitrogen in VMI groundwater and streams, combined with the high habitat value of Quartermaster Harbor and ongoing population growth, make this project a high priority for King County.

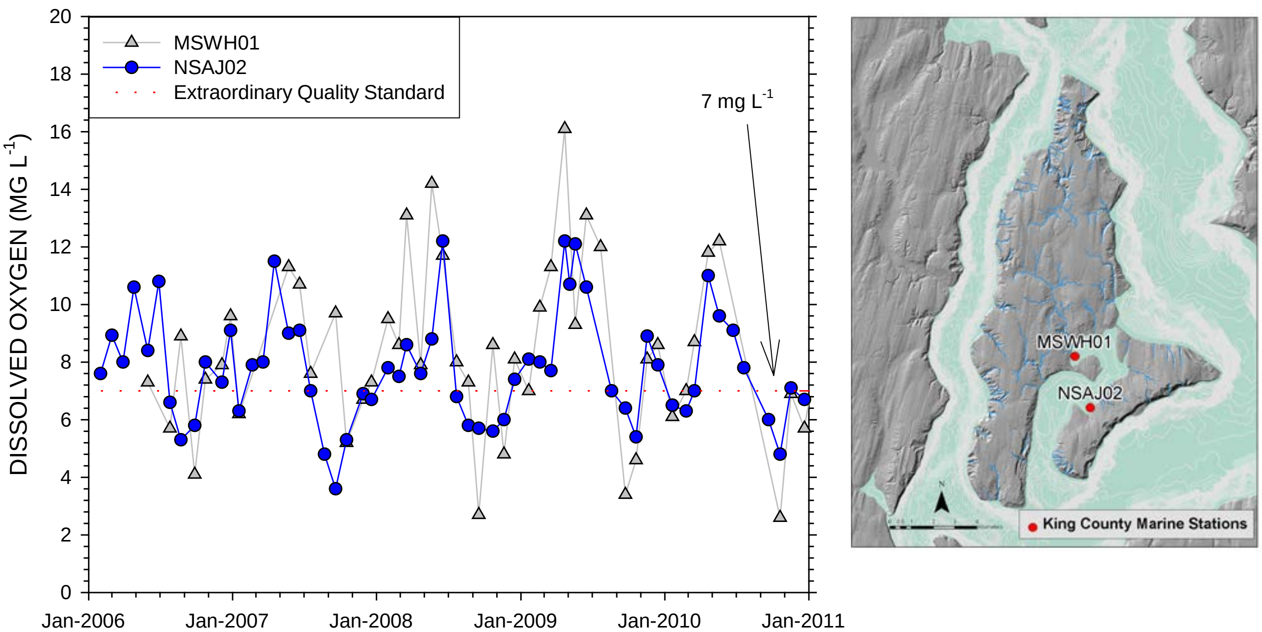

Figure 1. Monthly dissolved oxygen concentrations measured in bottom waters of Quartermaster Harbor by King County.

Quartermaster Harbor was one of 19 areas of Puget Sound judged to be relatively sensitive to anthropogenic nutrient inputs (Rensel Associates and PTI 1991). Nitrogen and phosphorus are essential nutrients for marine plants and phytoplankton. 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). 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 evidence that phytoplankton growth in the harbor is limited by nitrogen and that additional inputs of nitrogen have the potential to fuel additional algal growth, causing even lower oxygen levels when the algae die and are decomposed in the water column and sediments.

1.2 Study Area

Quartermaster Harbor, located between the Vashon and Maury portions of Vashon-Maury Island in Puget Sound, is sheltered from the wind and waves and receives runoff from about 40 percent of Vashon-Maury Island (Figure 4). It is a shallow, embayment that comprises approximately 12.1 km^2 (3,000 acres) of water surface area in an inner and outer harbor. 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 a greatest depth of about 5 to 6 meters. Outer Quartermaster Harbor water depths range from about 11 to 46 meters.

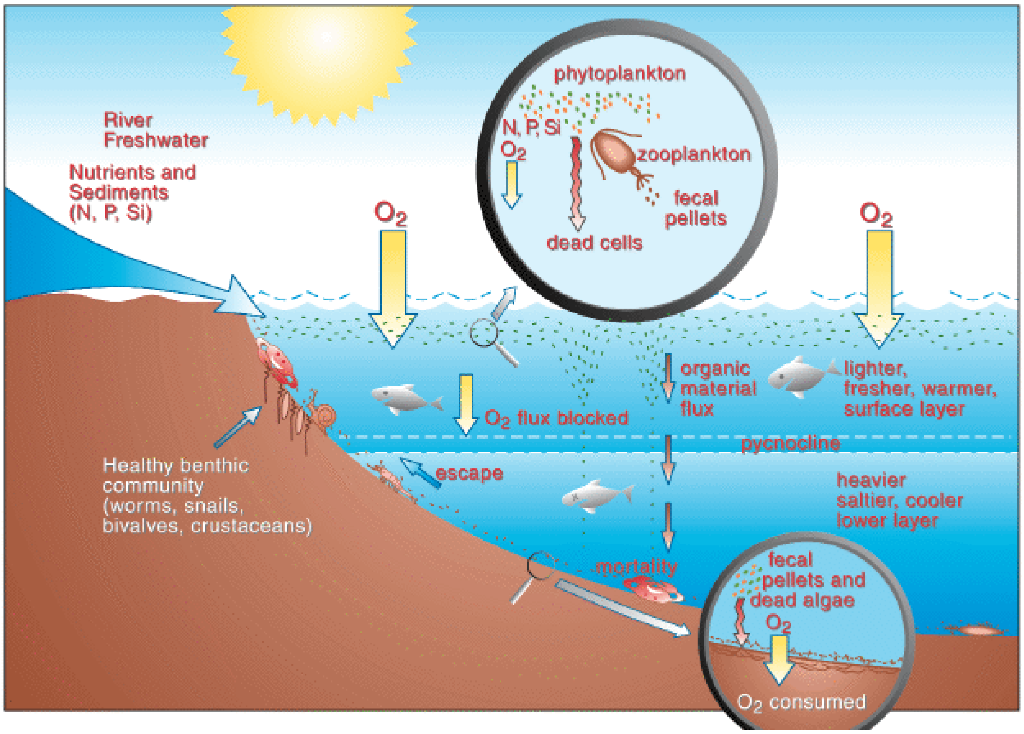

Figure 2. Conceptual diagram of marine nutrient-oxygen dynamics (Source: Downing JA, et al. Gulf of Mexico hypoxia: land and sea interactions.

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)

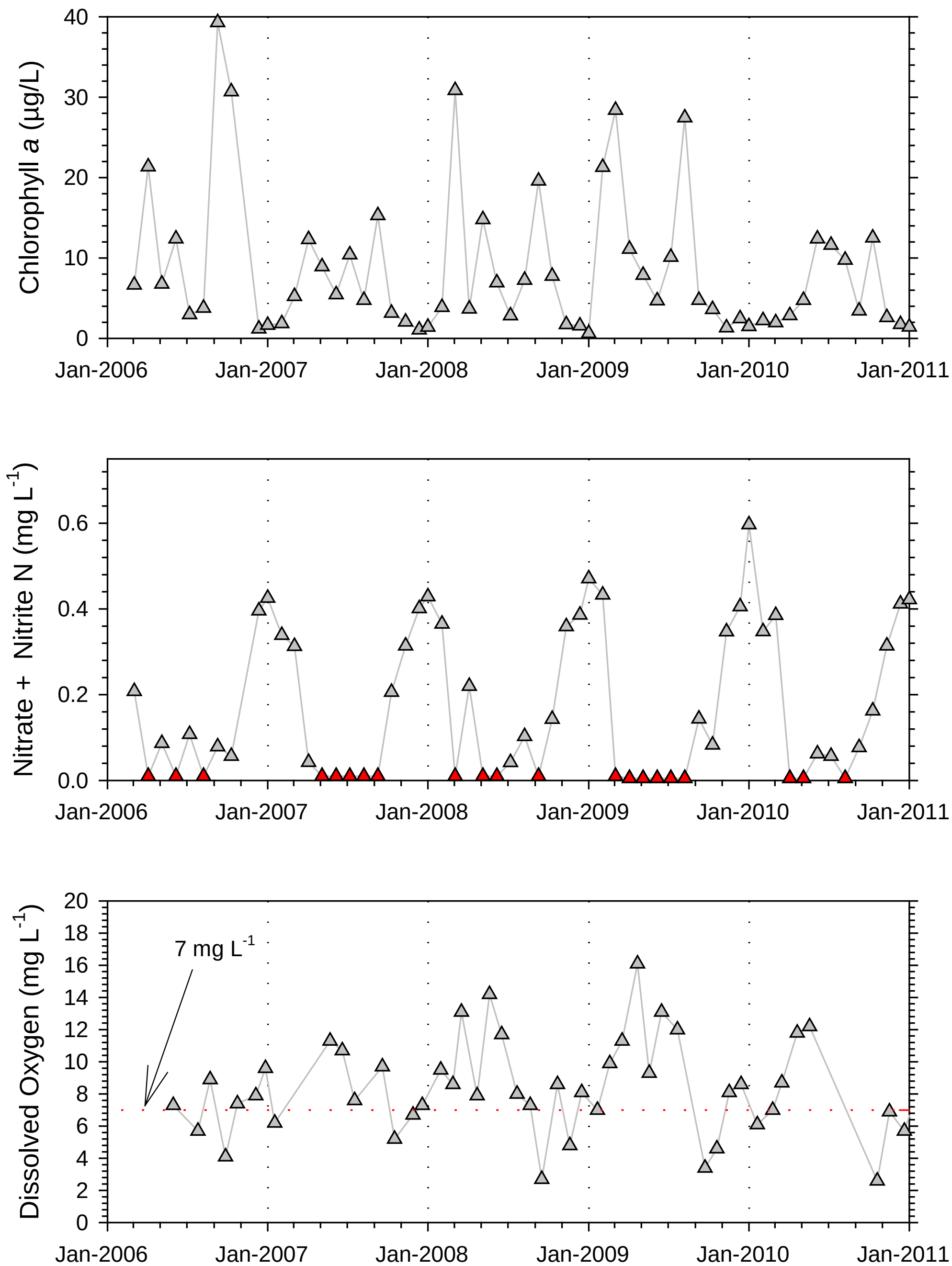

Figure 3. Monthly concentrations of surface water algal biomass (based on measurements of chlorophyll *a*), surface concentrations of nitrate nitrogen, and bottom water dissolved oxygen concentrations at Stations MSWH01 in Inner Quartermaster Harbor.

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.

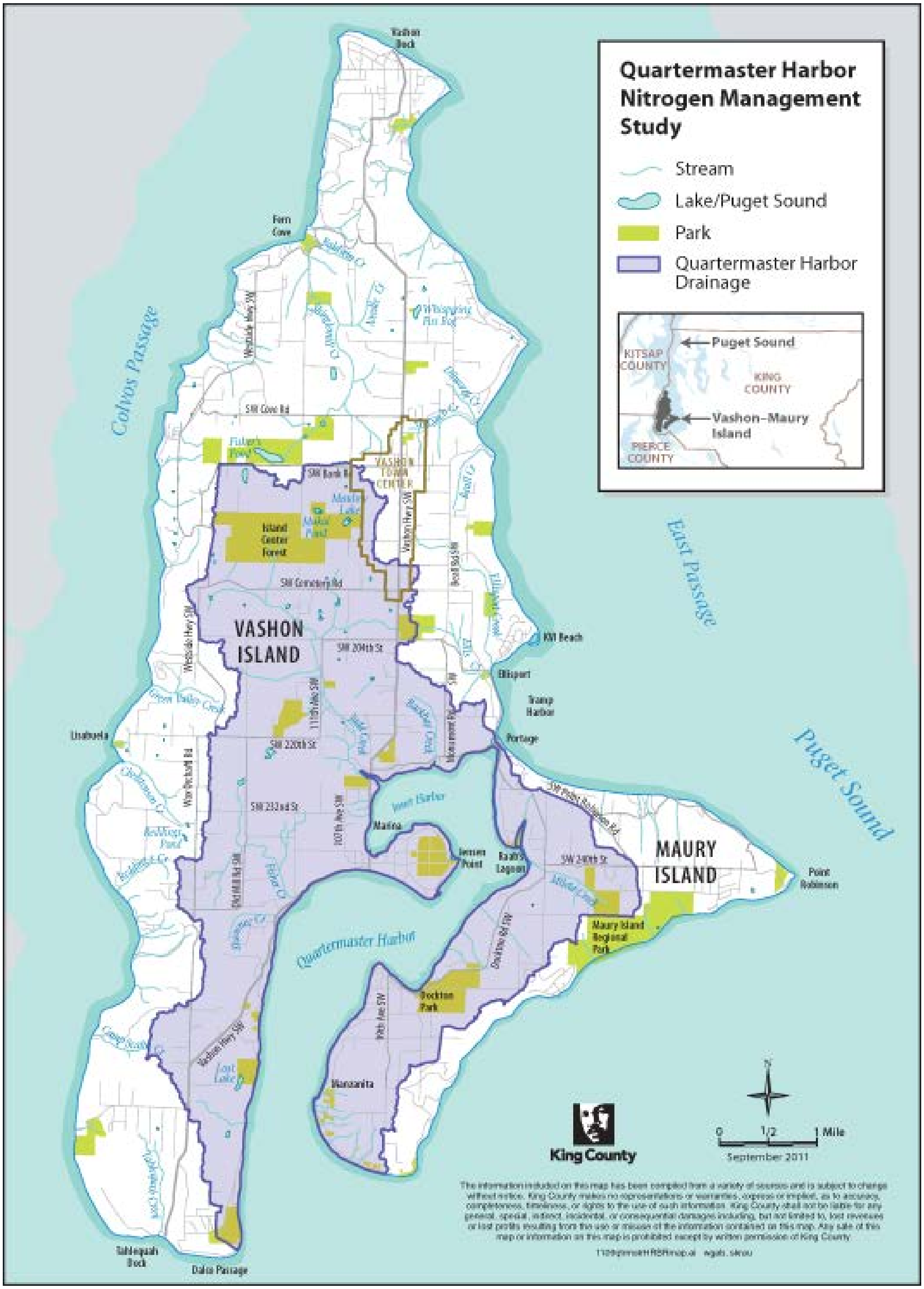

Figure 4. Map of Vashon-Maury Island highlighting the drainage area to Quartermaster Harbor.

1.3 Background

Three tributaries to Quartermaster Harbor (Judd, Fisher, and Mileta creeks) have been sampled monthly since November 2006 for a variety of water quality parameters, including nitrate+nitrite nitrogen (hereafter referred to as nitrate) and continuous flow measurements are also made near the mouths of these streams (Figure 5). Based on the available data, tributary nitrate concentrations are generally lowest in September and October when harbor oxygen concentrations are also at their lowest levels (Figure 6).

Although, these tributaries represent about half of the terrestrial drainage to Quartermaster Harbor (King County, 2010a), there are clearly a number of other small tributaries, pipes, culverts and seeps that drain to the harbor. Many of these have been inventoried in previous studies (Anchor Environmental 2004, Johannessen et al. 2005; Figure 7), but they have not been sampled for water quality analysis – particularly nitrogen compounds.

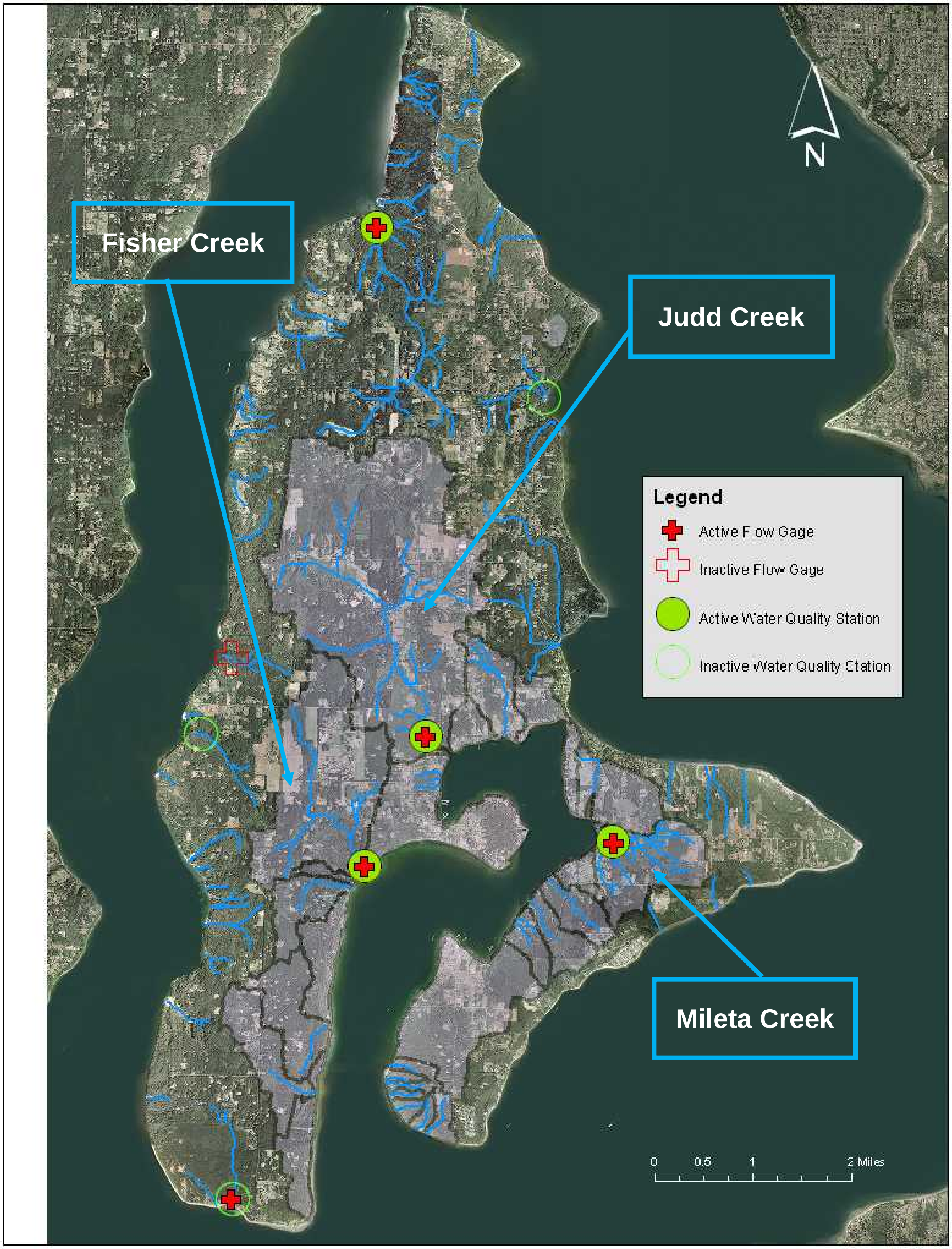

Figure 5. Location of routine ambient monitoring stations on Vashon-Maury Island where monthly water quality grab samples and continuous flow gage recording is conducted.

Note: Currently inactive stations are also shown on the map.

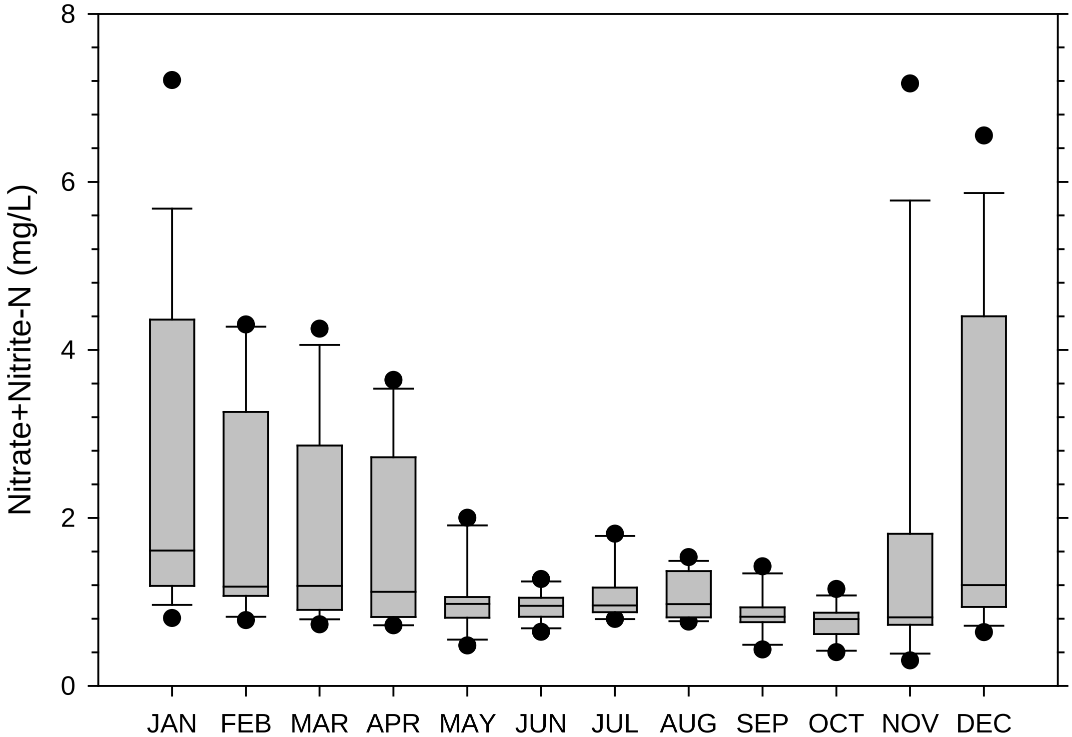

Figure 6. Box plot of monthly (November 2006 through December 2010) nitrate+nitrite nitrogen concentrations measured in routine monthly water quality samples from the three creeks that discharge directly to Quartermaster Harbor (Judd, Fisher, and Mileta creeks).

Note: Gray boxes define the median and lower and upper quartiles, while the whiskers denote the upper and lower 95th percentiles of the data for a particular month. The black circles identify the observed concentrations that are higher or lower than the 95th percentile.

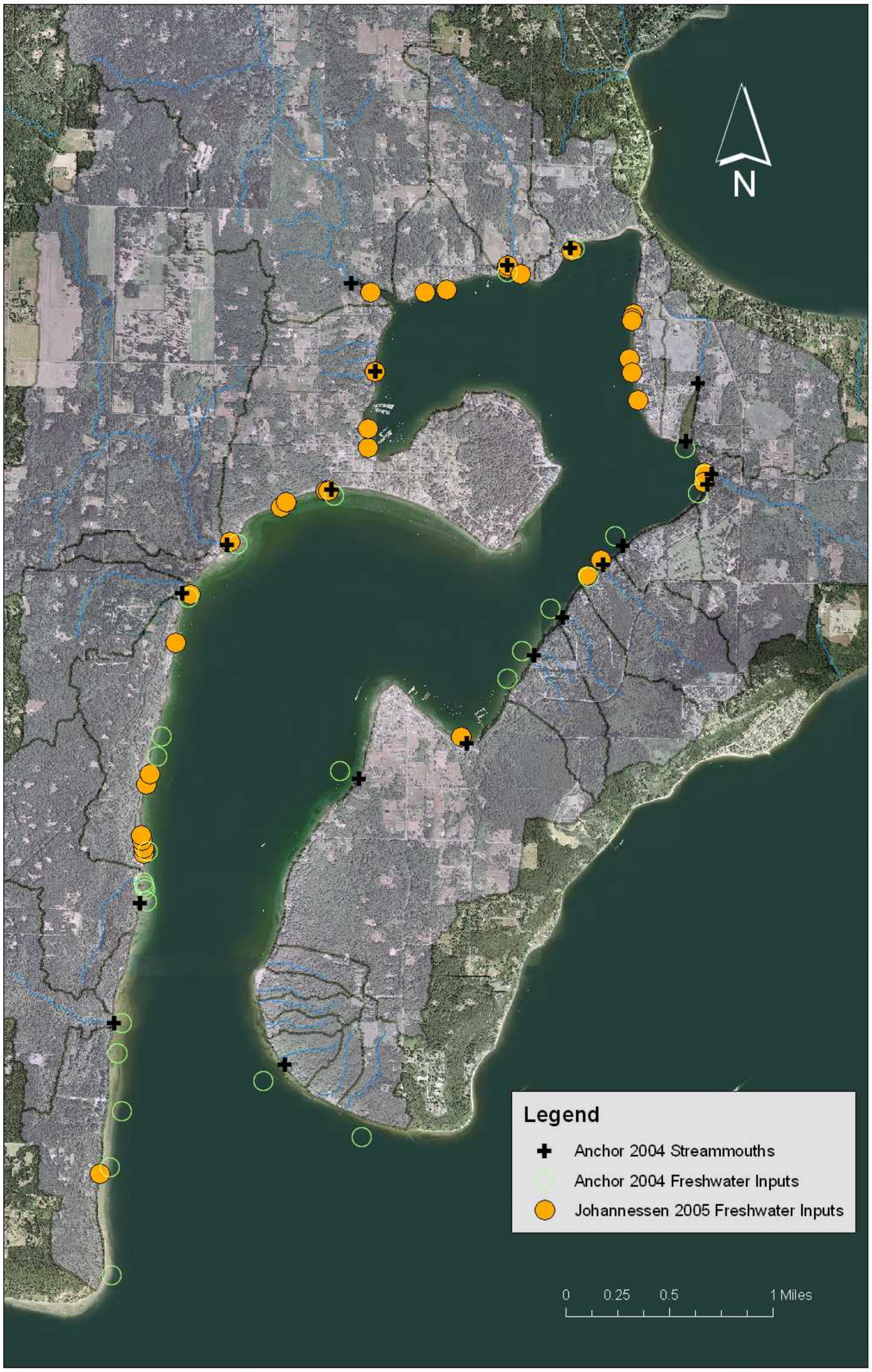

Figure 7. Map of freshwater inputs to Quartermaster Harbor identified in previous studies.

Note: Points shown on map based on surveys conducted in 2003 and 2004 documented in Anchor Environmental (2004) and Johannessen et al. (2005), respectively.

1.4 Study Goal

As part of a preliminary estimate of nutrient loading to Quartermaster Harbor, a recommendation was made to conduct synoptic sampling of small freshwater inputs to Quartermaster Harbor that had not previously been sampled (King County 2010a).

The purpose of this study was to measure nitrogen inputs from previously unmonitored fresh surface water inputs to Quartermaster Harbor by measuring nitrate, ammonia and total nitrogen and flow rate in tributary streams and small pipes discharging to Quartermaster Harbor. This information will be incorporated into the overall study to help identify nitrogen 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 some conclusions are provided in the Summary and Conclusions section.

2.0. METHODS

Details of the study design are provided in the Quartermaster Harbor Nearshore Freshwater Inflows Assessment Quality Assurance Project Plan (King County 2010b). A general description of the study methods follows.

Samples from small tributaries and pipes before they entered the nearshore marine environment of the harbor were taken at 21 locations on October 6, 2010 to help identify areas within the basin where elevated levels of nitrogen might be entering the waterway.

Because the critical period for dissolved oxygen occurs in the late summer/early fall, tributary sampling was planned during this period. 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+nitrite nitrogen (identified as nitrate for convenience throughout the report[1]); ammonia nitrogen and total nitrogen. Stream flow was estimated at 19 of the 21 sites using a bucket and stop watch when discharge was from an elevated pipe or culvert or by measuring velocity using a ping pong ball and stopwatch coupled with measurements of the average width and depth of the stream channel.

Flow was measured so that the flux (i.e., loading) of nitrate could be estimated. The estimated loads could then be used to visualize spatial patterns in nitrate input and to evaluate the relative contribution between the routinely monitored streams and these previously unmonitored sources. Nitrate loading was calculated by multiplying the measured flow in cfs by the concentration measured in mg/L and multiplying the result by a conversion factor (2.45) so the final result of this calculation is in units of kg N day^{-1}.

Sampling locations are shown in Figure 8 and coordinates for each sampling site are summarized in Table 1.

[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.

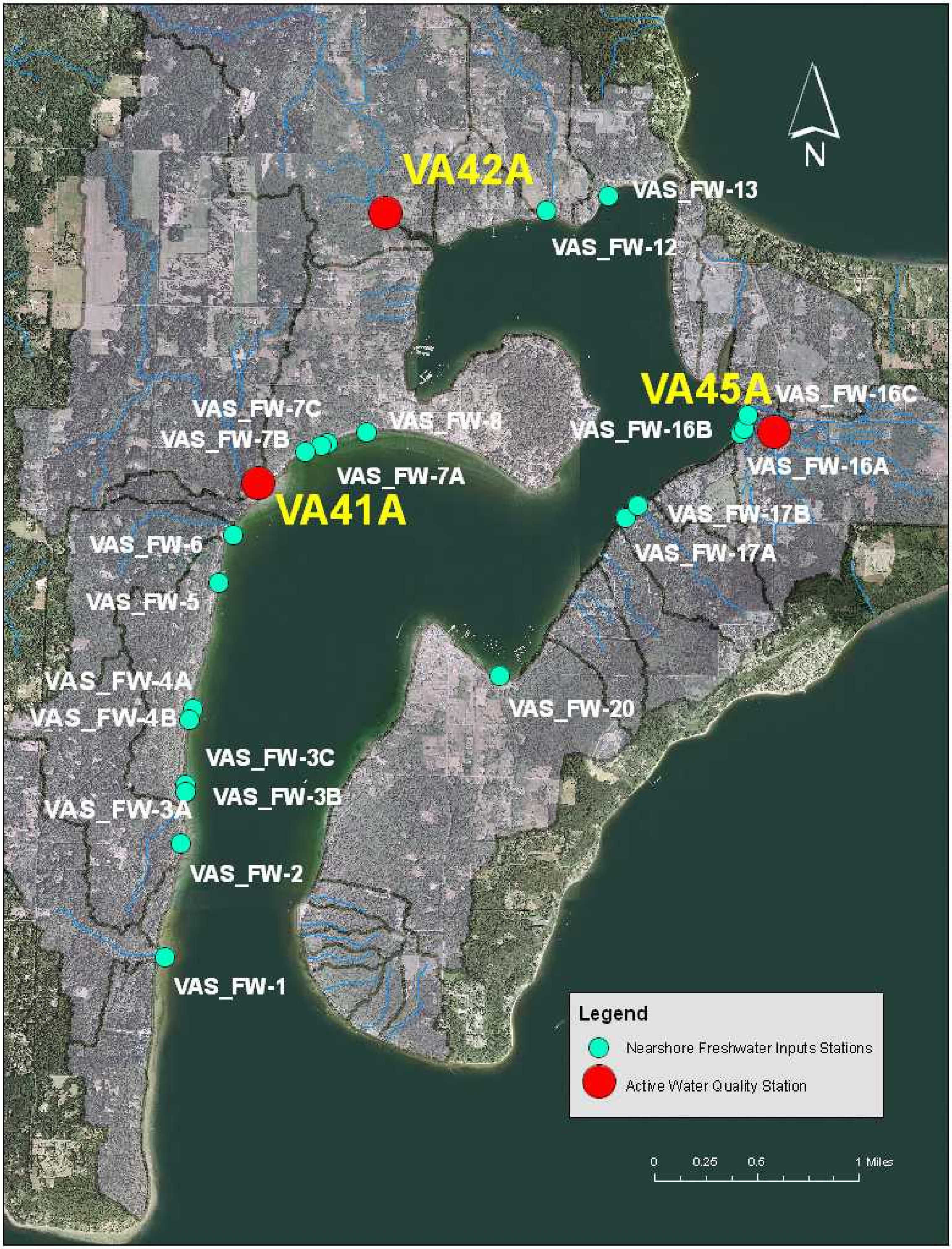

Figure 8. Map showing locations of Nearshore Freshwater Input Assessment sampling locations.

Note: Locations of routine monthly tributary monitoring locations on Judd, Fisher and Mileta creeks also shown.

Table 1. Nearshore Freshwater Inputs Assessment sampling station coordinates.

Locator	Description	Coordinates (Easting/Northing)[a]	
VAS_FW-1	CHEN CREEK AREA	1229744	132198
VAS_FW-2	LOST LAKE CREEK AREA	1230168	135138
VAS_FW-3A	HARBOR HEIGHTS AREA	1230284	136658
VAS_FW-3B	HARBOR HEIGHTS AREA	1230295	136473
VAS_FW-3C	HARBOR HEIGHTS AREA	1230295	136463
VAS_FW-4A	WESLEYAN WAY AREA	1230457	138609
VAS_FW-4B	WESLEYAN WAY AREA	1230364	138322
VAS_FW-5	MAGNOLIA BEACH AREA	1231148	141874
VAS_FW-6	SHAWNEE CREEK AREA	1231505	143115
VAS_FW-7A	115TH AVE AREA	1233955	145474
VAS_FW-7B	115TH AVE AREA	1233786	145398
VAS_FW-7C	115TH AVE AREA	1233374	145244
VAS_FW-8	SOUTH OF BURTON	1234961	145750
VAS_FW-12	TAUGWALLA CREEK AREA	1239604	151476
VAS_FW-13	WEST PORTAGE AREA	1241226	151865
VAS_FW-16A	MILETA CREEK AREA	1244621	145729
VAS_FW-16B	MILETA CREEK AREA	1244711	145866
VAS_FW-16C	MILETA CREEK AREA	1244823	146197
VAS_FW-17A	NORTH DOCKTON CREEK AREA	1241656	143532
VAS_FW-17B	NORTH DOCKTON CREEK AREA	1241979	143854
VAS_FW-20	DOCKTON PARK AREA	1238413	139480

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

3.0. RESULTS

Field sampling at the 21 freshwater input locations was conducted between 8:36 AM and 2:00 PM local time on October 6, 2010. The study results are provided in Table 2. Routine monthly monitoring of island tributary streams took place on October 5, 2010, including sampling of Judd, Fisher and Mileta creeks. The relevant laboratory and field results (and daily average flow recorded on October 6) for the three routinely monitored tributaries are provided in Table 2 for comparison.

Although 0.01 inches of precipitation was observed on September 30, 2010 at more than one of the five precipitation gauges on the island, no rain was observed at any of these gauges in the days prior to sampling. Therefore, the samples generally represent inputs from shallow soils and groundwater and do not represent stormwater runoff. However, one sample appeared to be a mixture of salt and fresh water. The sample collected from Backbay Creek (Station VAS_FW-12) had a specific conductance value of 2,030 µS/cm and one of the lowest measured nitrate concentrations. Observations by the field sampling team indicated that the sample was collected downstream of a waterfront pond that may have received input of saline harbor water on high tides.

Nitrate concentrations ranged from 0.06 to 2.24 mg/L, which bracketed the concentrations measured in the three routinely monitored streams the day before (~0.6-0.8 mg/L) (Table 2). Even when the October 2010 nearshore freshwater input data are compared to all data collected in October since 2007 in the three routinely monitored streams, there is clearly a larger range in concentrations observed in this study relative to the larger tributary inputs. However, the median concentrations are quite similar (~0.8 mg/L; Figure 9).

Although there was no distinctive spatial pattern, the highest four observed concentrations were measured in springs that discharged along the western shoreline just south of the Burton Peninsula (Figure 10). It is worth noting that these springs are below the Burton Springs and Burton Group A water supply system that has experienced an increase in nitrate levels as the result of historical land management activities associated with land now managed by Misty Isle Farms (CDM 2007).

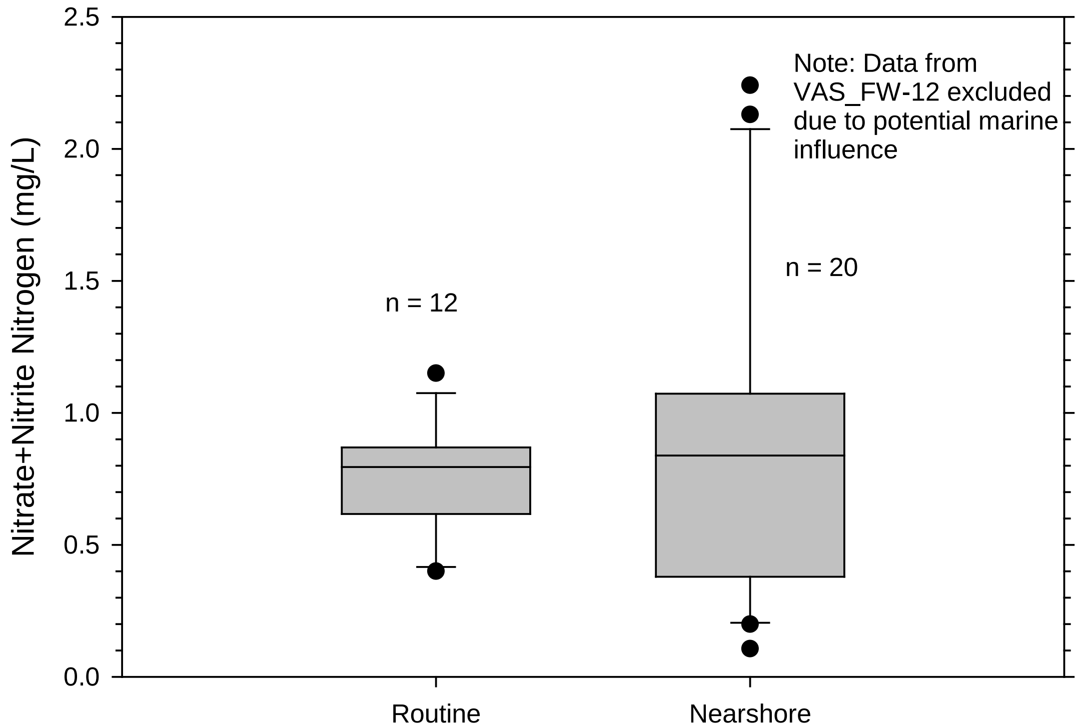

Figure 9. Box plot comparing nitrate concentrations observed at the locations sampled during this study and the concentrations measured in October since 2007 in the three routinely monitored tributaries – Fisher, Judd and Mileta creeks.

Note: Gray boxes define the median and lower and upper quartiles, while the whiskers denote the upper and lower 95th percentiles of the data for a particular month. The black circles identify the observed concentrations that are higher or lower than the 95th percentile.

Table 2. Field and laboratory sampling results from the Nearshore Freshwater Inputs Assessment conducted on October 6, 2010.

LOCATOR	Flow	NH3-N	NO32-N	TN	DO	SC	T	pH
	cfs		mg/L			µS/cm	°C	
VAS_FW-1	0.19	0.0058	1.05	1.24	10.5	166	11.7	7.80
VAS_FW-1	0.19	0.0061	1.05	1.21	10.5	165	11.79	7.80
VAS_FW-2	0.15	<0.005	0.106	0.269	10.4	140	10.27	7.29
VAS_FW-3A	0.06	<0.005	0.707	0.793	11.3	158	10.78	7.82
VAS_FW-3B	0.11	<0.005	0.593	0.647	10.3	174	11.86	6.85
VAS_FW-3C	nm	<0.005	0.574	0.648	10.8	168	11.28	7.66
VAS_FW-4A	0.52	0.0511	0.0648	0.213	10.5	161	12.8	7.50
VAS_FW-4B	0.016	0.0256	0.173	0.38	10.3	150	12.3	7.34
VAS_FW-5	0.02	<0.005	0.57	0.595	11.1	176	10.57	7.53
VAS_FW-6	0.004	<0.005	1.01	1.25	10.8	127	12.0	7.70
VAS_FW-6	0.03	<0.005	1.01	1.15	10.9	127	11.85	7.68
VAS_FW-7A	0.03	<0.005	1.58	1.67	10.4	190	10.76	6.89
VAS_FW-7B	0.03	<0.005	1.57	1.68	10.3	187	12.04	7.62
VAS_FW-7C	0.02	<0.005	2.13	2.23	10.5	185	11.17	7.29
VAS_FW-8	0.005	<0.005	2.24	2.33	9.9	198	11.26	7.36
VAS_FW-12	0.40	0.164	0.193	0.998	9.5	**2,030**	15.35	7.87
VAS_FW-13	0.19	0.0349	0.26	0.595	8.8	226	11.89	7.39
VAS_FW-16A	0.07	<0.005	0.315	0.597	10.8	193	11.85	7.84
VAS_FW-16B	nm	0.0062	0.255	0.555	9.9	212	11.26	7.59
VAS_FW-16C	0.06	0.0094	0.711	0.927	10.4	185	11.06	7.43
VAS_FW-17A	0.04	0.0194	0.199	0.367	9.7	221	10.79	7.58
VAS_FW-17B	0.16	0.0066	1.08	1.29	10.3	208	10.57	7.78
VAS_FW-20	0.10	0.0237	0.966	1.08	10.9	245	10.97	7.87
Fisher (VA41A)	0.74	0.006	0.779	0.96	10.11	154	10.5	7.52
Judd (VA42A)	2.04	0.005	0.785	1.0	9.99	165	10.7	7.68
Mileta (VA45A)	nm	0.0083	0.608	0.902	11.48	125	10.0	7.12

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

"-" – indicates "Not measured".

NH3-N = Ammonia 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.

Note: Laboratory results for the three routinely monitored tributaries (Fisher, Judd, and Mileta) are based on samples collected on October 5, 2010.

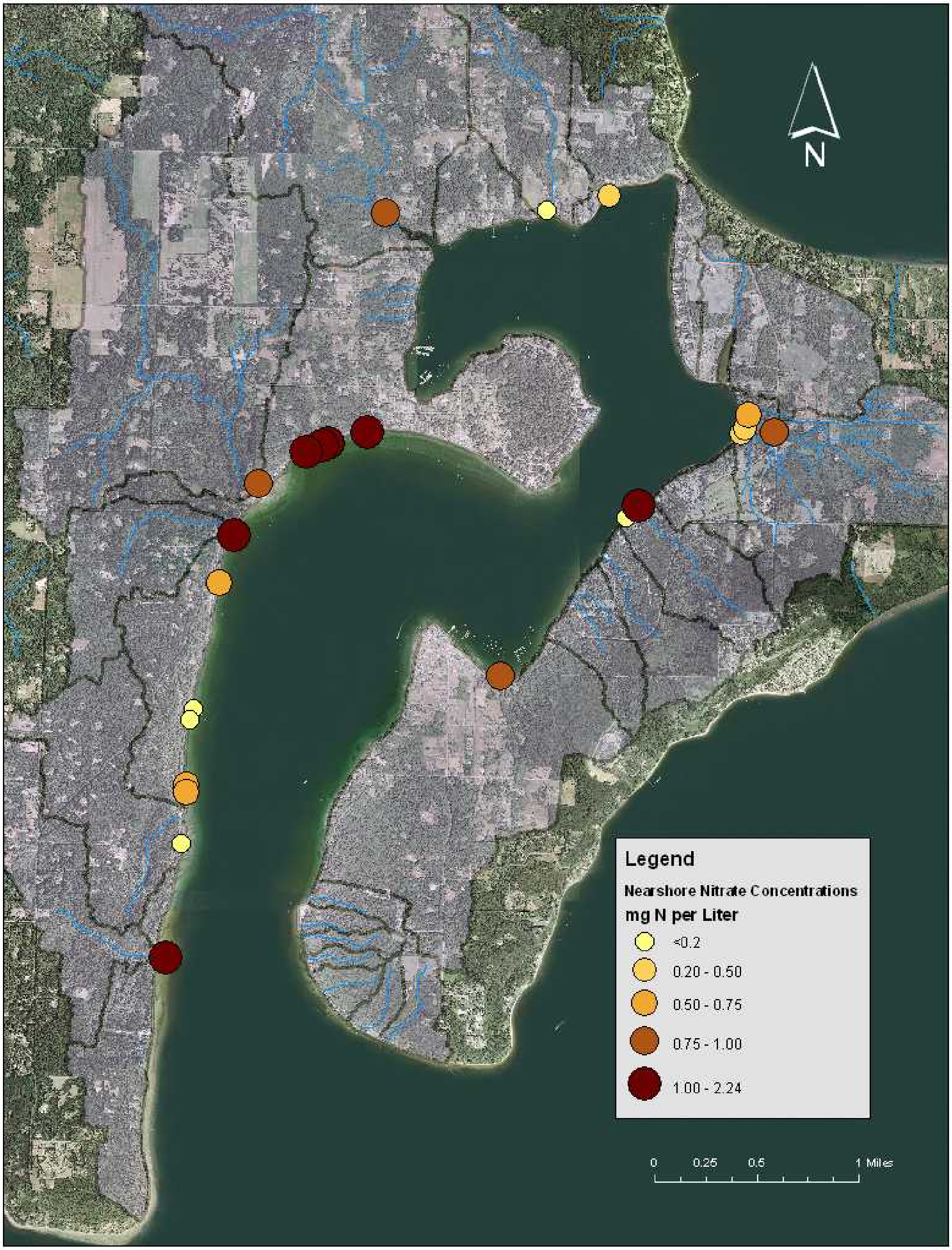

Figure 10. Map showing range of nitrate plus nitrite nitrogen concentrations (mg/L) measured during the Nearshore Freshwater Inputs Assessment conducted on October 6, 2010.

Note: Sampling results for Judd, Fisher and Mileta creeks from October 5, 2006 also shown.

3.1 Estimated Nitrate Loading

Nitrate loads were estimated for the sampling locations where flow was also measured and loads were also estimated for the three routinely monitored tributaries using the laboratory results from October 5 and the daily average flow recorded at each tributary gauge on October 6, the date on which the nearshore freshwater input sampling occurred.

Because of the higher flow rates coming from the three routinely monitored tributary basins, estimated nitrate loading from Fisher, Judd and Mileta creeks were higher than the estimated individual loads from the small nearshore freshwater inputs sampled for both flow and nitrate concentration on October 6, 2010 (Table 3 and Figure 11). Note that the freshwater inputs on the western shore to the south of the Burton Peninsula that had the highest nitrate concentrations contributed relatively smaller loads of nitrate to the harbor due to the relatively small flows associated with those inputs (Table 3 and Figure 11).

Table 3. Nitrogen loading estimates from the Nearshore Freshwater Inputs Assessment conducted on October 6, 2010.

LOCATOR	Description	Flow	NO32-N	DIN	TN
		cfs	kg per day		
VAS_FW-1	CHEN CREEK AREA	0.193	0.50	0.50	0.59
VAS_FW-1	CHEN CREEK field replicate	0.193	0.50	0.50	0.57
VAS_FW-2	LOST LAKE CREEK AREA	0.149	0.04	0.04	0.10
VAS_FW-3A	HARBOR HEIGHTS AREA	0.065	0.11	0.11	0.13
VAS_FW-3B	HARBOR HEIGHTS AREA	0.109	0.16	0.16	0.17
VAS_FW-3C	HARBOR HEIGHTS AREA	-			
VAS_FW-4A	WESLEYAN WAY AREA	0.518	0.08	0.15	0.27
VAS_FW-4B	WESLEYAN WAY AREA	0.016	0.01	0.01	0.01
VAS_FW-5	MAGNOLIA BEACH AREA	0.004	0.01	0.01	0.01
VAS_FW-6	SHAWNEE CREEK AREA	0.034	0.08	0.08	0.10
VAS_FW-6	SHAWNEE CREEK field replicate	0.034	0.08	0.08	0.09
VAS_FW-7A	115TH AVE AREA	0.031	0.12	0.12	0.13
VAS_FW-7B	115TH AVE AREA	0.032	0.12	0.12	0.13
VAS_FW-7C	115TH AVE AREA	0.018	0.10	0.10	0.10
VAS_FW-8	SOUTH OF BURTON	0.005	0.03	0.03	0.03
VAS_FW-12	TAUGWALLA CREEK AREA	0.401	0.19	0.35	0.98
VAS_FW-13	WEST PORTAGE AREA	0.190	0.12	0.14	0.28
VAS_FW-16A	MILETA CREEK AREA	0.075	0.06	0.06	0.11
VAS_FW-16B	MILETA CREEK AREA	-			
VAS_FW-16C	MILETA CREEK AREA	0.056	0.10	0.10	0.13
VAS_FW-17A	NORTH DOCKTON CREEK AREA	0.038	0.02	0.02	0.03
VAS_FW-17B	NORTH DOCKTON CREEK AREA	0.160	0.42	0.43	0.51
VAS_FW-20	DOCKTON PARK AREA	0.099	0.23	0.24	0.26
Fisher (VA41A)		0.740	1.50	1.51	1.84
Judd (VA42A)		2.060	4.05	4.08	5.21
Mileta (VA45A)		0.740	0.65	0.66	0.84

NO32-N = Nitrate plus Nitrite Nitrogen, DIN = Dissolved Inorganic Nitrogen (sum of NO32-N and NH3-N), TN = Total Nitrogen

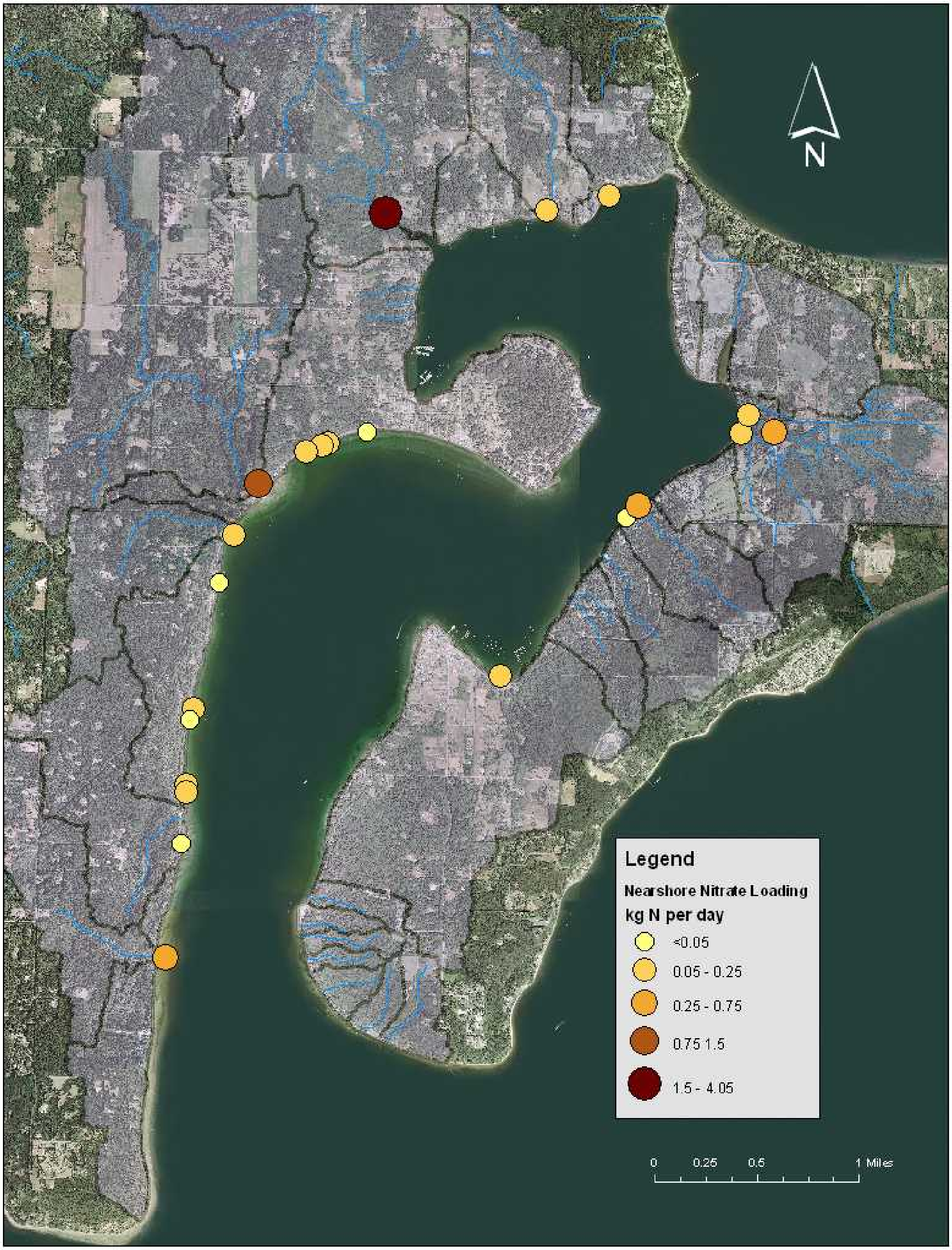

Figure 11. Map showing range of nitrate load estimates based on flow and concentration measurements at the 21 locations sampled on October 6, 2010.

Note: Nitrate loading from Judd, Fisher and Mileta creeks sampled on October 5, 2006 also shown.

4.0. SUMMARY AND CONCLUSIONS

The median nitrate concentration range measured in October 2010 in small freshwater inflows to Quartermaster Harbor was similar to the median nitrate concentration measured in October in the three largest tributary streams to Quartermaster Harbor from 2007 to 2010. The data presented in this study suggest some spatial variability in nitrate inputs from these previously unmonitored sources. However, the single freshwater input sampling event does not provide a means to extrapolate estimates from these locations to other times of the year.

The initial estimate of total freshwater inflow nitrate loading to the harbor used an average areal loading from routinely monitored tributaries to estimate loading from the unmonitored portion of the Quartermaster Harbor drainage basin (King County 2010a). The total estimated October 2010 nitrate loading from Judd, Fisher and Mileta creeks was 6.3 kg/d and the total estimated loading from the previously unmonitored freshwater inputs was 3.1 kg/d. Judd, Fisher, and Mileta Creeks represent drainage from approximately half of the total drainage to the harbor, so based on an areal extrapolation approach, the total load from the remainder of the basin would be approximately 6 kg/d in October 2010.

The small freshwater inputs monitored in this study do not represent all of the previously unmonitored drainage and the portion represented is not currently known due to the difficulties associated with delineating the small drainage areas of every inflow. However, a cursory visual examination of the basin area not represented by any sampling point (see Figure 11) suggests that this monitoring effort captured about half of the previously unmonitored drainage area to the harbor. This is consistent with the estimated load of 3.1 kg/d, which is about half of the estimated load from the three routinely monitored drainages. Therefore, an extrapolation based on observed areal loading from the three routinely monitored basins should provide a reasonable first approximation of nitrate loading from the harbor drainage area that is not routinely monitored, at least during the critical period when dissolved oxygen concentrations in the harbor are lowest.

5.0. REFERENCES

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