2016 SEDIMENT AND WATER QUALITY AND MONITORING REPORT

Penobscot River Phase III Engineering Study
Penobscot River, Maine

Prepared for:

United States District Court

District Of Maine

Prepared by:

Amec Foster Wheeler
Environment & Infrastructure, Inc.

511 Congress Street
Portland, ME 04101

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Project No. 3616166052

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LIST OF ACRONYMS

Alpha	Alpha Analytical
Amec Foster Wheeler	Amec Foster Wheeler Environment & Infrastructure, Inc.
ANCOVA	analysis of covariance
ASTM	American Society for Testing and Materials
BO	Brewer-Orrington
cm	centimeters
Court	U.S. District Court for the District of Maine
CTD	conductivity-temperature-depth
DI	deionized
DO	dissolved oxygen
DOC	dissolved organic carbon
EB	equipment blank
EPA	Environmental Protection Agency
ES	estuary
Estuary	Penobscot River Estuary
Eurofins	Eurofins Frontier Global
FDR	Field Data Record
fntu	Formazin Nephelometric Turbidity Units
FSP	Field Sampling Plan
HASP	Health and Safety Plan
Hg	mercury
J	estimated
MDL	method detection limit
ME	Maine
mg/L	milligrams per liter
MLLW	mean low low water level
MM	Mendall Marsh
MS	Matrix Spike
MSD	Matrix Spike Duplicate
ng/g	nanograms per gram
ng/L	nanograms per liter
OV	Orono-Veazie
OB	Orrington-Bucksport
Plan	Draft Sediment and Water Quality Monitoring Plan
PRMS	Penobscot River Mercury Study
PRMSP	Penobscot River Mercury Study Panel

LIST OF ACRONYMS (cont.)

QAPP	Quality Assurance Project Plan
QA/QC	Quality Assurance/Quality Control
RL	reporting limits
RPD	relative percent difference
SOP	Standard Operating Procedure
SSC	Suspended Sediment Concentration
TOC	total organic carbon
TSS	total suspended solids
µg/gdw	micrograms per gram dry weight
U	non-detected
U.S.	United States
USGS	U.S. Geological Survey
vs.	versus
W	Wetland

EXECUTIVE SUMMARY

The Penobscot River Mercury Study (PRMS) has conducted routine monitoring of mercury concentrations in sediment and surface water to document mercury concentrations in the lower reaches of the Penobscot River Estuary from Veazie to Fort Point in Stockton Springs, Maine. The 2016 sediment and water quality monitoring followed the streamlined program of 2012 to provide strategic analysis of common locations over time. The objectives of this Sediment and Water Quality Monitoring Report are to: 1) present the results from 2016 monitoring of sediment and water quality; 2) evaluate potential trending of mercury and methyl mercury concentrations in sediment and surface water over time using data collected from the estuary since 2006; and 3) make recommendations regarding the current sediment and water quality monitoring program. Evaluation of the mercury concentrations at periodic intervals is one tool used to help establish the recovery rate of the estuary from mercury contamination.

Amec Foster Wheeler collected 27 sediment samples in late July 2016 in intertidal, subtidal, and wetland/marsh environments for the 2016 monitoring. An additional eight sediment samples were collected from the wetlands W-61 and W-63 in early November 2016 as a result of improved information on historic locations. 2016 sediment samples were collected in the locations chosen based on the sampling locations reported in the 2012 PRMS Monitoring Report (PRMS 2013a). The analytical results are evaluated by zone because each zone has unique characteristics of vegetation, sediment deposition rates, and wetting / drying cycles. Marked spatial trends in mercury and methyl mercury sediment concentrations were observed.

As expected, sediments upriver of the former Veazie Dam have lower total and methyl mercury concentrations than sediments in the vicinity of Bangor. Total mercury concentrations in 2016 sediments ranged from 29 to 46 nanograms per gram (ng/g) in the Addison River background station and upstream locations at Veazie. In contrast, within the estuary, intertidal total mercury sediment concentrations ranged from 42 to 1,420 ng/g (with the highest concentrations in the vicinity of the former Holtrachem Manufacturing Company, LLC facility). Total mercury in subtidal sediments within Fort Point Cove ranged from 513 to 1,100 ng/g. Wetland total mercury sediment concentrations ranged from 17 to 962 ng/g.

No consistent time trends in sediment mercury concentrations were evident based on the statistical assessment of the data. Linear regressions at intertidal sediment sampling locations showed statistically significant decreasing mercury concentrations in intertidal sediments at several locations; however, after mercury concentrations were normalized by total organic carbon (TOC), mercury concentrations at the same locations lacked any statistically significant trend at a 95 percent level of confidence. Thus, after accounting for the effect of TOC on mercury concentrations in sediments, there is little evidence for statistically significant trends over the period 2006 - 2016 for total mercury.

Methyl mercury concentrations in intertidal and subtidal sediments were the highest in the river channel east of Verona Island (22 ng/g at station ES-02). The second highest methyl mercury concentration measured in 2016 intertidal and subtidal sediments was 17 ng/g at station ES-13 in a cove on southeast Verona Island. These two locations on the east side of Verona Island are locations where wood debris accumulates and intermingles with sediments. In wetland sediments, the three highest methyl mercury concentrations were associated with the top three total mercury concentrations, at sampling locations in a Frankfort Flats high marsh, a low marsh on the southeast side of Verona Island, and a high elevation in Mendall Marsh. The fraction methylated at the three wetland sites with the highest methyl mercury were all approximately 2 percent methyl mercury of total mercury.

Methyl mercury concentrations did not significantly decline through time for intertidal, subtidal or wetland sediments monitored during the period 2006-2016. After methyl mercury concentrations were normalized by TOC, there were no observable trends in methyl mercury concentrations over time at any intertidal sediment locations.

Surface water was sampled monthly in 2016 between May and October to evaluate potential seasonal changes in mercury and methyl mercury concentrations. Surface water was collected at seven monitoring locations from above the former Veazie Dam to Fort Point, including the Easter Channel (east of Verona Island). It should be noted that the precipitation recorded at Bangor, Maine between the months of April and October 2016 was anomalously low (16.9 inches versus a 17-year average of 26.2 inches).

The water column data show typical estuarine mixing and flocculation patterns. Dissolved organic carbon (DOC) concentrations are higher in the incoming river water, and lower in the most saline waters. Between those sample locations, plots of DOC versus salinity indicate removal by flocculation, consistent with particle formation documented in Chapter 4 of the PRMS Phase II Study Report. In contrast to DOC, dissolved mercury concentrations were mostly constant (ranging from non-detect to 3 nanograms per liter [ng/L]) between upstream and downstream sample locations. Dissolved mercury concentrations were anomalously high compared to the rest of the data in this study at Winterport in July and at Orrington in October. Dissolved mercury also enters the estuary from watershed sources along with DOC; however, any removal of dissolved mercury by flocculation appears to be balanced by internal inputs. This likely reflects the presence of mercury-contaminated sediments within the estuary.

Mercury concentrations in surface water showed no statistically significant trends over time in the period from 2006 through 2016. Total (unfiltered) mercury concentrations in surface water were typically between 2 and 20 ng/L, and methyl mercury (unfiltered) concentrations were usually between 0.05 and 0.5 ng/L. Unfiltered total mercury and methyl mercury in water (ng/L) varied in response to TSS and particulate mercury concentrations. Dissolved total mercury concentrations were typically between 1 and 3 ng/L, and dissolved methyl mercury concentrations were usually between 0.05 and 0.2 ng/L. Concentrations of mercury in particles coming into the estuary from the river flow at Veazie Dam were consistent over time, between 0.2 and 0.4 micrograms per gram dry weight (µg/gdw), while particulate mercury concentrations in the river water below Veazie Dam were generally greater and much more variable, with total mercury values ranging between 0.2 and 1.3 µg/gdw.

The low concentrations of unfiltered total mercury and dissolved total mercury at Veazie (location OV-02), and the consistent non-detects of TSS at that location in 2016, make the calculation of particulate mercury an estimate at best for that location. Turbidity measurements at Veazie averaged 0.9 milligrams per liter (mg/L) in 2016, compared to a range of turbidity readings in Phase II samples between 1.6 and 2.8 mg/L. The below average precipitation in 2016 may have resulted in lower turbidity and suspended solids during sampling events.

Amec Foster Wheeler recommends that the sediment and water quality monitoring program in 2017 focus on sediment monitoring to support remedial design. The water monitoring data generated to-date have advanced the conceptual site model; however, additional water monitoring by the same approach is not essential on a monthly frequency

The highest priority uncertainty related to water monitoring is the input rate of new sediment to the estuary, and the associated mercury concentrations and loads. Refined monitoring techniques, including isokinetic sampling, inter-calibration of turbidity with suspended sediments, and direct filtration to analyze suspended particulate mercury are recommended for the future to provide better estimates of input loads. Results from those refined monitoring tools are not essential to completion of the Alternatives Evaluation report, and are therefore not prioritized for completion during the Phase III study. Rather, the refinements are recommended for consideration in the development of a long term monitoring strategy for the Penobscot River.

To support ongoing data gathering for sediment input modeling, Amec Foster Wheeler recommends that the continuous turbidity monitoring program be continued. Continuous turbidity measurements should be calibrated with suspended solids concentrations (SSC) measurements. Continuing this part of the monitoring program would proceed concurrently with the pilot studies and methods development described above.

Regarding sediment monitoring in the Penobscot River, Amec Foster Wheeler recommends continuing the 2017 monitoring with a base program consistent with the 2016 program. There is value in returning to the same stations over time to detect trends. Additionally, it is recommended that 2017 sediment monitoring include screening of the collected sediments with a #40 sieve to evaluate the percentage of wood debris in the samples as a means of evaluating heterogeneity impacts on analytical results (see WO 4A-020). There is value in adding a randomized stratified sampling component, to help reduce uncertainties about within-system heterogeneity and potential source areas.

Amec Foster Wheeler also recommends that future on-water monitoring work include regular conductivity-temperature-depth (CTD) casts. Including a CTD adds substantial information value to the field effort, because it increases the data density of salinity profiles under varying conditions of season, tide and weather. A long-term record of water properties assists conceptual and numeric model development with limited and manageable impact on field effort.

Lastly, the effect of using hot aqua regia digestion on total mercury results for sediments collected from the Estuary during the Phase III Study and the application of a two-fold adjustment factor for Phase III Study samples analyzed for methylmercury improved the reliability of the data for quantitative trends analysis. Findings indicate spatial distribution of data is unchanged, total mercury concentration trends remain unchanged, and methylmercury concentration trends changed slightly for one location. Significant downward trends in carbon-normalized mercury and / or methylmercury were detected at six locations. Five of the six locations are in the Mendall Marsh, which suggests that area may be recovering faster than other parts of the system.

1.0 INTRODUCTION

1.1 Purpose, Scope, and Objectives

This report describes the results of water and sediment quality monitoring for mercury and ancillary physical parameters in the Penobscot River Estuary (Estuary) in 2016. The purpose of the monitoring is to continue documenting patterns of mercury contamination within the Estuary, with the objective of evaluating the recovery of the system under current conditions. This work is being carried out concurrently with the development of an engineering feasibility evaluation for the remediation of the estuary.

Beginning in 1967, a chlor-alkali plant located in Orrington, Maine (ME) released mercury into the Penobscot River. The amount of mercury released annually decreased between 1970 and 1982, and decreased further when the plant was closed in 2000. The Penobscot River in northern ME is the second-largest river in New England. The Estuary has a surface area of approximately 35 square miles and extends 22 miles southward from Bangor, ME to about Searsport, ME, with Penobscot Bay extending further southward (**Figure 1-1**).

In January 2016, the United States (U.S.) District Court for the District of Maine (the Court) selected Amec Foster Wheeler Environment & Infrastructure, Inc. (Amec Foster Wheeler) to conduct the Phase III Engineering Study to identify and evaluate potential effective and cost-effective measures to remediate mercury present in the Penobscot River, from the former Veazie Dam south to Upper Penobscot Bay, including Mendall Marsh and the Orland River. As a component of this work, the Court contracted with Amec Foster Wheeler the task to conduct water quality and sediment monitoring in 2016, to continue the monitoring conducted between 2006 and 2012 in the Penobscot River Mercury Study (PRMS). A Draft Sediment and Water Quality Monitoring Plan (Plan) was prepared by Amec Foster Wheeler and issued to the Court on July 27, 2016 (Amec Foster Wheeler 2016a). The Plan details six rounds of monthly water sampling, one round of sediment sampling, and the installation of a turbidity meter near the former Veazie Dam location.

The PRMS monitored mercury levels in sediment, surface water, and various biota between 2006 and 2012 (Penobscot River Mercury Study Panel [PRMSP] 2013a). The most recent report of sediment, surface water, and biota monitoring data was presented in the 2012 Monitoring Report (PRMSP 2013b). This 2016 Monitoring Report focuses upon the collection of sediment and water quality monitoring activities and resulting data for the sampling period of May 2016 through October 2016. An additional component of 2016 monitoring presented in this report includes the installation of a turbidity meter above the former Veazie Dam location, as well as collection of river stage data from the U.S. Geological Survey (USGS) Streamflow Station 01036390, to provide data on upstream input to the study area. It should be noted that this is the first annual monitoring of sediment and water quality conducted since the removal of the Veazie Dam in 2013.

The 2016 sediment and water quality monitoring results presented in this report are also used in conjunction with the historical data to assess potential temporal, seasonal, and geographical (spatial) patterns of mercury and methyl mercury concentrations in the sediments and waters of the Penobscot River and Estuary. Relation to physical parameters (e.g., total suspended solids [TSS], organic carbon, and salinity) helps identify the effect of normal estuarine processes such as mixing, floc formation, and sediment resuspension. The 2016 biota monitoring is addressed in a separate monitoring report also prepared by Amec Foster Wheeler.

1.2 Report Organization

- Section 1.0 - Introduction presents the purpose and organization of this 2016 Sediment and Water Quality Monitoring Report.
- Section 2.0 - Approach, Methods, and Criteria summarizes the process, plan, criteria, and rationale for sampling.
- Section 3.0 - 2016 Sediment and Water Quality Analytical Results presents the analytical results.
- Section 4.0 - Temporal and Geographic Distribution of Mercury and Methyl Mercury presents the statistical analysis comparing 2016 results temporally with historical data spanning back to 2006, 2016 seasonal data, and spatial distribution of the mercury and methyl mercury within the river estuary system.
- Section 5.0 - Uncertainties presents some of the uncertainties associated with the sediment and water quality monitoring data, for 2016 and historical sampling events.
- Section 6.0 - Conclusions and Recommendations presents the significant findings of the results presented in Section 3.0 and evaluations conducted in Section 4.0, as well as recommends any changes for the next round of monitoring.
- Section 7.0 - References provides references to documents cited within this report.

2.0 APPROACH, METHODS, AND CRITERIA

Amec Foster Wheeler developed and implemented a Sediment and Water Quality Monitoring Plan (Amec Foster Wheeler 2016a) for renewal of the sample collection for monitoring the changes in the ecosystem over time. The most recent annual monitoring conducted for the study area was in 2012, documented in the Penobscot River Mercury Study Results of 2012 Monitoring of Mercury in Penobscot River and Bay with Comparisons to Previous Years (PRMSP 2013a). Locations for 2016 monitoring were selected based on review of the 2012 monitoring report, as well as the Penobscot River Mercury Study Final Report (April 2013). The study reaches are generally denoted in the sample identification using the reach acronyms (OV: Orono-Veazie; BO: Brewer-Orrington; OB: Orrington-Bucksport; ES: estuary; MM: Mendall Marsh; W: Wetland). Site agreements were obtained with property owners to provide legal access to the sample locations on private land. A site-specific Health and Safety Plan (HASP) was implemented to provide for the safety of on-Site workers and to protect the public during field work (Amec Foster Wheeler 2016b).

Amec Foster Wheeler developed a Quality Assurance Project Plan (QAPP) for investigations to be conducted as part of the Penobscot River Estuary Phase III – Engineering Study (Amec Foster Wheeler 2016c). The QAPP defines investigation objectives, procedures, and quality assurance and quality control (QA/QC) for this program. The QAPP is used to formalize a consistent approach, which is documented in the associated Field Sampling Plan (FSP) (Amec Foster Wheeler 2016d), as well as task-specific Work Orders. Standard operating procedures (SOPs), also documented in the QAPP, were developed for field sample collection procedures and laboratory analytical procedures. The field sampling SOPs are provided in Appendix A of the QAPP, and the Laboratory Analytical SOPs in Appendix C of the QAPP.

Laboratories that were selected to perform project-related analyses are as follows:

<u>Sediments</u>

- Eurofins Frontier Global Sciences of Bothell, WA (Eurofins) performed both low level mercury analysis (Environmental Protection Agency [EPA] methods 1631e) and methyl mercury analysis (EPA method 1630).
- Alpha Analytical of Mansfield, MA (Alpha) performed Total Organic Carbon (TOC) analysis (Lloyd-Kahn method).
- The grain size analyses (American Society for Testing and Materials [ASTM] D422 plus #230 sieve) and Total Organic Content (ASTM D2974-C) were performed by Amec Foster Wheeler of Durham, NC.

<u>Surface Water</u>

- Eurofins performed both medium level total and dissolved mercury analysis (EPA method 1631e) and total and dissolved methyl mercury analysis (EPA method 1630).

- Alpha performed TOC and Dissolved Organic Carbon (DOC) analysis (Method SW-846 9060), as well as Total Suspended Solids (TSS) analysis (modified standard method 2450D).

2.1 2016 Sediment Sample Collection

Amec Foster Wheeler collected 27 sediment samples in late July 2016 in intertidal, subtidal, and wetland/marsh environments for the 2016 monitoring. An additional eight sediment samples were collected from wetlands W-61 and W-63 in early November 2016 based on improved information on historic locations. Sediment samples were collected in the locations chosen based on the sampling locations reported in the 2012 PRMS Monitoring Report (PRMS 2013a). The sediments have been sorted into primary categories of environments, or zones that have distinct characteristics, as presented below. The effects of weather and atmospheric conditions affect these environments differently; therefore, the analytical results are presented by zone.

1. ***Subtidal Zone -*** The subtidal zone, including the main and side channels, refers to the main channel of the river and separate side channels (e.g., Mendall Marsh, the Orland River, and lesser tributaries) that are submerged (below mean lower low water levels [MLLW]). Some of these areas are relatively shallow with average depths ranging from 1 to 5 feet below MLLW; the majority of these areas have average depths ranging from approximately 20 to 30 feet below MLLW; and portions of the river channels are much deeper with average depths ranging from 50 to 80 feet below MLLW, and in the Verona Narrows reaching 90 feet below MLLW.

2. ***Intertidal Zone -*** The intertidal zone refers to the portion of the ecosystem that is subjected to varying tide levels during each tidal cycle and is generally located between the mean high water and mean low water levels. These areas are alternately submerged and exposed twice daily due to tidal fluctuations. During low tide the entire sediment surface of the intertidal zone is exposed, while at high tide the area is completely submerged.

3. ***Marsh Platform -*** The marsh platform is the generally flat, vegetated marsh surface that is at or just above the mean high water level, and is inundated regularly by high tides (minimally during neap and more substantially during spring tides).

Table 2-1 presents a listing of the sediment samples collected as part of the 2016 monitoring. Former background sediment location SG-01 was not sampled in 2016. In its' place, an intertidal sediment sample was collected from the Pleasant River in Addison, ME for a background location, as this data can also be used as reference to biota sampling in the Addison location. Although proposed in the 2016 Sediment and Water Quality Monitoring Plan (Amec Foster Wheeler 2016a), OB-01 was not collected as a subtidal sediment sample, as the location was mistakenly collected to the north as an intertidal co-located biota sample (sample location MMPOLY-01). The results of the analytical sample collected at MMPOLY-01 will be presented in the 2016 Biota Monitoring Report.

Sediment sampling was conducted in accordance with SOP S-6 Sediment Sampling (Amec Foster Wheeler 2016c). Sediment samples were collected by a variety of techniques depending on the physical location; Ponar, hand augers, shovels, and spoons were utilized for collection of samples (see **Section 2.1.1**). Decontamination of equipment between samples was consistent with SOP S-17 of the QAPP (Amec Foster Wheeler 2016c). Field Data Records (FDRs) for each sediment sample are contained in **Appendix A-1**. Bulk samples were homogenized in the field, placed into labeled sample containers, and frozen in the Field Office freezers prior to shipment to the laboratories. Field personnel followed the QAPP guidance on sediment sample container requirements, sample labeling and tracking requirements, as well as packaging and shipping. Sediment samples were analyzed as indicated in **Table 2-1**.

Field Quality Control (QC) samples were collected in accordance with procedures identified in the QAPP (Amec Foster Wheeler 2016c). The field duplicates were collected at a frequency of 10% (1 in every 10) for samples submitted to the analytical laboratory for the analysis of the target compounds. The field duplicates are used as replicate samples for consistency and comparability of the analytical process. Matrix Spike (MS) and Matrix Spike Duplicate (MSD) material was collected and submitted for laboratory equipment check of analytical performance. The extra sediment volume was provided to the laboratory for MS/MSD at a frequency of 5% (1 in every 20) for samples submitted to the analytical laboratory for the analysis of the target compounds. The MS/MSD results are used to evaluate accuracy by the ability to measure percent recovery of surrogate for the spiked analysis of laboratory instrumentation. Equipment blanks (EB) or rinsate blanks were collected at a rate of 2 per sample event to evaluate effectiveness of rinsing procedures used during sample collection. EBs were collected using laboratory provided de-ionized (DI) water after the equipment was decontaminated using the methods identified in the QAPP (Amec Foster Wheeler 2016c).

The following subsections describe the sediment collection processes for three sediment zones.

2.1.1 Subtidal Sediment

Subtidal sediment samples were collected from three sites along the E-01 transect (latitude 44.482), which crosses Fort Point Cove from west to east (see **Figure 2-1**). Locations sampled are listed below:

E-01-01
E-01-03
E-01-04

Samples were collected using a stainless steel Ponar collection device. Recovery in the deployed Ponar dredge samples was approximately one foot in thickness. A portion of the top 0.3 feet of sediment was sampled from the contents of the Ponar, homogenized, and placed into sample containers.

2.1.2 Intertidal Sediment

Intertidal sediment samples were collected at low tide from 13 locations throughout the estuary, plus one background location (ADD-02) on the Pleasant River in Addison, ME (see **Figure 2-1)**. These intertidal sediments include those adjacent to wetlands which were sampled as part of the 2016 monitoring. Locations sampled are listed below:

ADD-02
BO-05
ES-02
E S-04
ES-13
OB-05
OV-01
OV-02
OV-04
W-17-Intertidal
W-21-Intertidal
W-61-Intertidal
W-63-Intertidal
W-65-Intertidal

Samples were collected by hand using stainless steel scoops, hand augers, or ponar samplers from the top 0.3 feet of the sediment, homogenized, and placed into sample containers.

2.1.3 Wetland Sediment

A total of 19 wetland sediment samples were collected from two wetlands (W-17 and W-63) in the OB reach, from one wetland (W-61) in the upper ES reach, and from Mendall Marsh (W-21 and W-65) (see **Figure 2-1**). The wetland sites were sampled at four elevations specifically denoted as High, Mid, Low, and Intertidal. Intertidal samples associated with wetlands are discussed in **Section 2.1.2**, and the remaining wetland zones sampled are defined as follows:

1) <u>High</u> - the upper edge of the marsh platform just below the border with the adjacent upland, visually identified by the presence of woody shrubs and trees;
2) <u>Mid</u> - the outer edge of the marsh platform immediately above the slope down to the mudflat (mid marsh); and
3) <u>Low</u> - on the marsh slope at the outer edge of the marsh vegetation just above the mean high water.

Consistent with previous PRMS sampling, the high marsh elevation at W-21 and W-65 were approximately 45 feet inland from the outer edge of the marsh platform, rather than at the uplands border sampled at other high elevation marsh sites. On the broad marsh platform at Mendall Marsh, additional wetland sediment samples were collected at four sites with the initial designation W-21-UM. Locations of wetlands sampled are listed below:

W-17-High
W-17-Mid
W-17-Low
W-21-High
W-21-Mid
W-21-Low
W-21-UM-Central-C
W-21-UM-East-C
W-21-UM-South
W-21-UM-West-A
W-61-High
W-61-Mid
W-61-Low
W-63-High
W-63-Mid
W-63-Low
W-65-High
W-65-Mid
W-65-Low

Sediment samples were collected with stainless steel hand augers, spoons, or shovel, homogenized, and placed into sample containers. Large gravel/rocks, roots, sticks, and vegetative debris were removed prior to homogenization of sediments.

2.2 2016 Water Quality Monitoring Sample Collection

The water quality monitoring consisted of surface water collected to characterize the concentrations of dissolved and particulate mercury in the water column. Monthly sampling was conducted at seven locations that encompass the upstream-to-downstream range of the study area (See **Table 2-2**). The locations were chosen based on the sampling locations reported in the 2012 PRMSP Monitoring Report (PRMSP 2013a). Six rounds of monthly water quality sampling were conducted in the months of May through October. Surface water monitoring sample locations are presented on **Figure 2-2**, and consist of the following seven locations: OV-02, WQ1b-C, WQ2-C, WQ3-L, WQ-ECH, ES-15 and WQ-FPT. The locations represented on **Figure 2-2** show sampling locations for May through July 2016, and a second location for each sample point from August through October 2016, except for OV-02 which was sampled consistently in the same location throughout 2016. The distance between the sample points in the two time periods is less than the width of the Penobscot River at these locations, and are therefore considered to be representative of the water quality in the vicinity of the different locations over the two time periods.

Samples for water quality monitoring were collected on the ebb tide for consistency with previous sampling efforts of the PRMS. **Table 2-3** presents the sampling times and tidal phase for each sample collected in 2016. Water quality monitoring was conducted in accordance with SOP S-4 - Surface Water Sampling and SOP S-5 - Clean Hands/Dirty Hands Surface Water Sampling of the QAPP (Amec Foster Wheeler 2016c). Surface water samples were collected at a depth of approximately 1 foot below the water surface with a peristaltic pump, equipped with pre-cleaned and certified sample tubing from the analytical laboratory. New, pre-cleaned tubing from the analytical laboratory was used at each sample location and disposed of after use. Surface water sample container requirements, sample labeling and tracking requirements, as well as packaging and shipping requirements are specified in the FSP (Amec Foster Wheeler 2016d) and QAPP (Amec Foster Wheeler 2016c). FDRs for each water quality sample are contained in **Appendix A-2**.

Surface water samples were analyzed as presented in **Table 2-2**. Equipment blanks were collected starting in June 2016 for surface water using laboratory supplied pre-cleaned disposable tubing and DI water. The new designated laboratory pre-cleaned tubing was used once at each location and then disposed. The field duplicates were collected monthly at a frequency of 10% (1 per every 10 field samples) of samples submitted to the laboratory for the analysis of the target compounds. The field duplicates are used as replicate samples for consistency and comparability of the analytical process. Additional volume was collected for MS and MD at a frequency of 5% (1 per every 20) samples collected. The locations for the additional material collection for MS/MD were selected in the field. Field parameters were collected for water temperature, pH, specific conductivity, dissolved oxygen, oxidation reduction potential, turbidity and salinity, in addition to the laboratory analyses. Equipment calibration logs for water quality monitoring instrumentation are presented in **Appendix A-3**.

2.3 Turbidity Monitoring

A turbidity meter with continuous monitoring capabilities was installed on September 9, 2016 near the former boat landing in Eddington, ME. The turbidity meter was installed to provide information on suspended solids entering the estuary from the Penobscot River above the tidally influenced waters. Prior to August 22, 2013, the turbidity measurements were collected by USGS Streamflow Station #01036390, Latitude 44°49'36", Longitude 68°41'48", North American Datum of 1983. Amec Foster Wheeler arranged and established an access agreement with the town of Eddington to install the cabled sensor in the river downstream from the (former) Eddington boat landing, and upstream from water quality monitoring point OV-02, USGS Station #01036390, and the former Veazie Dam (see **Figure 2-2**).

A Campbell Scientific OBS-501 Smart Turbidity Meter with sidescatter and backscatter capabilities was installed 50 feet from the eastern shore into the Penobscot River. At the time the meter was installed, the probe head was set at six inches above the riverbed in a water depth of four feet. The OBS-501 probe head is protected from river debris by a fabricated metal mesh enclosure. The sensor within the probe uses an infrared, monochromatic light source for measuring turbidity in Formazin Nephelometric Units (fntu). A ½ inch galvanized steel conduit runs from the OBS-501 in the river to a protective garden box located approximately 50 feet east of the river’s shore. Within the garden box is a Campbell Scientific CS300 Datalogger, battery, and wireless Raven XT Airlink cellular digital modem. There is a 10-watt solar panel mounted to a grounded 10-foot tripod that sits above the garden box to continuously recharge the instrument battery. The datalogger is set to collect sidescatter, backscatter, water temperature, and wet/dry reading every two hours. The data is stored on the CS300 datalogger.

The 10-watt solar charger did not provide adequate charging of the battery from November 8, 2016 to December 1, 2016, which caused the programming to terminate data collection. To reduce the load on the battery and allow for optimal charging, Amec Foster Wheeler created a revised software program for data access, reduced data collection to every 2 hours, and reduced data transmittal from the unit to the web-based data storage location to once per day.

Every day at 12:05 PM a dedicated computer, with the program Loggernet, contacts the Raven XT Cellular Modem and downloads the data from the Datalogger to a dedicated Amec Foster Wheeler computer in the Portland, ME office. On Mondays and Fridays of each week, the data is collected from the dedicated computer and processed to ensure the turbidity sensor, Datalogger systems, and battery are functional and data is being properly collected. The turbidity meter has functioned properly since December 2, 2016.

2.4 Laboratory Data Deliverables and Data Validation

Full analytical data deliverable packages equivalent to a Contract Laboratory Program data package are provided in **Appendices B-1 and B-2**. The analytical data packages consist of forms summarizing samples analytical results, QC blank results, raw data, and forms summarizing QC measurement parameters including the sample preparation logs. Data packages were provided by the laboratories in portable document format and an electronic data deliverable.

In addition to laboratory analytical data, data on grain size and organic content of sediment samples collected under the 2016 monitoring are presented in **Appendix B-3**. Analyses of the sediment samples for these parameters was performed by Amec Foster Wheeler's geotechnical laboratory in Durham, North Carolina.

Amec Foster Wheeler utilized the laboratory analytical data packages to perform data validation using a technical review for accuracy and completeness. Stage 2B data validation was performed for 90% of project data and Stage 3 validation for the remaining 10% of analytical laboratory deliverable packages. The Stage 2B validation included review of quality control information and summary forms. The Stage 3 validation included review of raw data and supporting documentation. The Stage 3 level of validation allowed the validator to uncover any potential data quality issues pertaining to laboratory analysis. If severe non-compliant QC issues were identified, the laboratory was required to correct the problem. In the case of the 2016 sediment and water quality monitoring samples, non-compliant QC issues were not identified. The data validation process is outlined in Worksheets #35, #36, and #37 in the QAPP (Amec Foster Wheeler 2016c). The Amec Foster Wheeler validators identified potential data quality issues pertaining to laboratory analysis and either required actions by the laboratory to correct, or the data were qualified accordingly. Data validation reports are provided in **Appendix C**.

The project laboratory reported results using a combination of two detection limits including the reporting limit (RL) and the method detection limit (MDL). Results for compounds that are not detected in samples are reported as U qualified results at the RL. Positive detections between the MDL and RL are qualified as estimated (J) by the laboratory.

The following qualifiers as applied during data validation or reported by the laboratory that are included in the final data set:

J = the reported concentration is considered an estimated value
U = the target compound was not detected above the RL

Validation reason codes were applied to results associated with QC measurements outside project QC goals. The following data validation reason codes were applied to one or more sample results:

BL1 = Method blank contamination
FD = Field duplicate limit exceeded
HT-G = Holding time for prep or analysis grossly exceeded
MS-H = MS and/or MSD recovery high
MS-L = MS and/or MSD recovery low
MS-RPD(relative percent difference) = MS/MSD relative percent difference limit exceeded

2.5 Sample Re-analysis and Data Adjustment

Amec Foster Wheeler performed an analytical methods comparison for total mercury. The study showed that in Penobscot River sediments, especially sediments having high amounts of wood waste, total mercury analyses may be underestimated if the samples are digested at room temperature, which is the standard procedure for mercury analysis in sediments by EPA method 1631e. Heating on a hot block or with a microwave provides greater recovery of total mercury from sediments that have wood waste present. Since the amount of wood waste in any given sample is variable and unpredictable, it was decided that the Phase III Study sediment samples would be analyzed using EPA method 1631e modified to include a heated digestion step, consistent with the digestion approach prescribed in EPA Method 7474.

Results from both approaches are included in this report; however, the hot acid digestion results are used for data interpretation. The 2016 Annual Monitoring program sediment samples were re-analyzed in triplicate, to account for the substantial heterogeneity present in sediments with large amounts of wood waste. Individual replicate results are presented in the results section. Data interpretations are performed on the average of three replicates.

Secondly, the Penobscot River Phase II Study documented that analysis of methylmercury in sediments by chemical extraction using methylene chloride yields results that are approximately two-fold lower compared to results obtained when methylmercury is extracted from sediments via physical distillation. Therefore, the Phase II Study group adjusted results for methylmercury in by applying a two-fold multiplier for analyses performed by methylene chloride extraction, to make the results comparable to results obtained by distillation. The Phase III engineering study has applied a similar two-fold adjustment for methylmercury results obtained by methylene chloride extraction, to be consistent with the Phase II Study approach. The original and adjusted data are presented in this report; however, the adjusted data are used for interpretation. **Section 4.0** includes a summary describing how using adjusted data for statistical analysis affects the findings.

3.0 2016 SEDIMENT AND WATER QUALITY ANALYTICAL RESULTS

This section summarizes the results of the 2016 Sediment and Water Quality Monitoring. First, results of analytical quality control samples are briefly summarized to characterize usability and limitations of the data. Next, sediment results are presented and discussed, with an emphasis on broad-scale spatial concentration gradients and correlation between mercury and organic carbon. This section concludes with a summary of water data, with a discussion of estuarine mixing and transport processes as they relate to mercury, and an assessment of mercury concentrations of suspended particulate matter. Assessment of spatial gradients in sediment concentrations help in understanding how mercury is spatially distributed in the system. Suspended particulate mercury data help in understanding how present day suspended particulate matter entering the estuary increases in mercury concentration upon mixing with estuarine sediments. These factors are important parts of the existing baseline conditions in the absence of active remediation.

3.1 Summary of Quality Assurance/Quality Control Evaluations and Implications for Data Usability

Understanding the meaning of quality control data helps establish limits on the appropriate use of data. Quality control data are discussed separately below by media (sediment versus [vs.] water). Although there are qualifications to some of the data reported by the laboratories, none of the data have been rejected, and the data is considered useable to meet the objectives of evaluating mercury, methyl mercury, and organic carbon distribution and concentrations in the estuary.

3.1.1 Sediment Quality Control Evaluations

Data validation reports for sediment are in **Appendix C-1**. All total mercury data are considered usable as reported by the laboratory. Methyl mercury concentration data from sediment samples collected at two locations (OV-01 and W-17-Low) were flagged as estimated due to the duplicate RPD exceeding the QC limit of 50. For total organic carbon analyses, the percent recoveries for MS/MSDs associated with samples from locations W-21-UM-West-A and W-21-Low were outside of criteria, but no validation action was necessary. A sample replicate performed on the sample from location W-63-High had a TOC RPD greater than 30 percent and was qualified J. Sediment sample heterogeneity was noted as a root cause for precision checks falling outside of control limits in the data validation reports from the 2016 sediment monitoring work (**Appendix C-1**). Measures to address sampling processes affected by heterogeneity are the subject of WO-04A-010 and WO-04A-020, and are outside the scope of this report. Percent solids results for 2016 sediment samples were qualified J due to samples exceeding hold time.

The presence of abundant wood waste in subtidal, intertidal, and wetland sediments became more obvious as a result of June 2016 sediment sampling of the mobile sediment pool and October 2016 sediment sampling (and subsequent processing of those samples in January/February 2017). The processing of sediment samples conducted in January/February 2017 raises the potential of wood waste being present in some of the 2016 sediment monitoring samples, which was confirmed in samples from ES-13, W-17-Intertidal, and W-61-Intertidal (see

Appendix A-1). The potential impact of the heterogeneity resulting from wood debris containing mercury and methyl mercury adds some uncertainty to the 2016 sediment analytical results presented in this report. The impact of wood debris on sample heterogeneity and analytical results of sediment samples is being evaluated under Amec Foster Wheeler's Work Orders 4A-010 and 4A-020, and preliminary findings of these evaluations are anticipated to be available in late April 2017.

In summary, 2016 sediment data was qualified in only a few instances, and is considered useable to meet the objectives of evaluating mercury, methyl mercury, and organic carbon concentrations in the estuary sediments.

3.1.2 Water Quality Control Evaluations

Data validation reports for surface water are located in **Appendix C-2**.

Water samples are several orders of magnitude lower in mercury concentration compared to sediment samples, and so blank levels become critical factors affecting data usability. Method blanks are run at the laboratory using highly purified water; the method blank reflects the baseline mercury concentration that would be measured in any sample due to the common presence of background mercury concentrations in air. The method blank for a batch of analyses establishes an action level that is five times the method blank. Samples with concentrations exceeding the action level are reported as the concentration submitted by the laboratory. Samples with concentrations below the action level are qualified as non-detect (U) at the reporting limit, with the reason code given as "BL1" (analyte detected in method blank).

The highest mercury concentrations in method blanks in 2016 typically ranged from 0.14 to 0.40 nanograms per liter (ng/L). For context, unfiltered water samples range from 1 to 2 ng/L at the upstream and downstream sample locations of Veazie and Fort Point, and from 5 ng/L to as high as 35 ng/L in between. Thus, typical method blanks resulted in most of the unfiltered total mercury data being reported as detected and quantified. In the August sampling event, the highest method blank was 2.79 ng/L, which led to qualifying a total of six results from that sample analysis batch. Filtered water samples, on the other hand, have much lower concentrations (1-2 ng/L), and so calculations and assessments that rely on filtered water data need to account for the relative uncertainty of the measurement compared to blank levels.

Method blanks for methyl mercury were generally lower than total mercury results, as were sample results. The blank concentrations for methyl mercury were typically between 0.01 ng/L to 0.04 ng/L. Only 15 of 42 samples analyzed had reportable filtered methyl mercury concentrations above the method detection limit; whereas 30 of the 42 had unfiltered methyl mercury concentrations above the detection limit.

Equipment blanks help understand whether handling procedures in the field pose a risk of biasing water sample results with inadvertent mercury contamination. Equipment blanks are collected by pouring purified water supplied by Eurofins over sampling equipment that has been decontaminated following the same procedures as regular samples. Equipment blanks were collected on each water sampling event except for May, 2016. Equipment blanks were consistently non-detect for methyl mercury (<0.05 ng/L) and mercury (<0.5 ng/L).

The blank levels and detection limits affect the usability of the data. Water monitoring data from this program are usable for characterizing the spatial distribution of unfiltered total mercury, and for evaluating relationships between unfiltered total mercury and TSS. Mercury-TSS correlations are useful for estimating mid-estuarine concentrations of suspended particulate mercury. Spatial distributions of dissolved mercury are difficult to discern, as dissolved mercury concentrations are typically close to blank levels and detection limits in this program. The low concentrations of unfiltered total mercury and dissolved total mercury at Veazie, and the consistent non-detects of TSS at that location, make the calculation of particulate mercury an estimate at best. Recommendations to improve monitoring to quantify the particulate mercury concentration of new sediment entering the estuary are discussed in **Section 6.0** (Conclusions and Recommendations).

In summary, 2016 water quality monitoring data was qualified in only a few instances, and is considered useable to meet the objectives of evaluating mercury, methyl mercury, TSS, and organic carbon concentrations in the waters of the estuary. However, there is some uncertainty associated with mercury in filtered water samples due to concentrations being comparable to blank levels.

3.2 2016 Sediment Geographic Distributions and Processes

This subsection describes the geographic distributions and processes affecting mercury and methyl mercury concentrations in sediments that can be discerned in the data. **Subsection 3.2.1** below describes overall spatial gradients. **Subsection 3.2.2** presents correlation analysis to help understand how sediment texture explains some of the variability of mercury and methyl mercury. **Subsection 3.2.3** summarizes the observations and draws brief comparisons to findings of the Phase II Study results.

3.2.1 2016 Sediment Geographic Distributions

There is a clear north-south spatial gradient of total mercury concentrations in the subtidal and intertidal sediments in the Penobscot River Estuary (**Figure 3-1**). Total mercury concentrations in sediments ranged from 22 to 63 nanograms per gram (ng/g) in the Addison River background station and upstream locations at Veazie (**Table 3-1**)[1]. In contrast, within the estuary, subtidal stations ranged from 570 to 1,200 ng/g, intertidal stations ranged from 42 to 1,800 ng/g, and wetland sediments ranged from 37 to 1500 ng/g total mercury.

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[1] Results in the text are truncated to 2 significant figures, compared to Table 3-1, for clarity.

Methyl mercury has a similar spatial gradient to total mercury (**Figure 3-1**. Background and upstream sites have lower concentrations (0.02 to 7.4 ng/g) compared to subtidal (13 to 25 ng/g), intertidal (0.4 to 44 ng/g), and wetland (0.02 to 44 ng/g) sediments (**Table 3-1**).

Methyl mercury to total mercury ratios are used as indicators of methylation efficiency. Sediments having one to three percent methyl mercury are commonly found wherever there is sediment in contact with water (Krabbenhoft et al. 1999). Sediments having methyl mercury to total mercury ratios in excess of ten percent may indicate areas with higher net methylation efficiencies. Interestingly, the highest percent methyl mercury is observed in the Addison River background station (ADD-01, 15 per cent), and the next highest percent methyl mercury is observed at sample OV-02 (12 per cent) collected upstream, near Veazie (**Figure 3-1**).

In subtidal sediments, the methyl mercury / total mercury ratio ranges from 2 to 3 percent. In intertidal sediments, the ratio ranges from 1 to 8 percent. Wetland sediments are comparable to intertidal sediments, with methyl mercury to total mercury ratios ranging from 0.0 to 5 percent.

The two highest methyl mercury concentrations of intertidal and subtidal sediments are found east of Verona Island (**Figure 3-1 and Table 3-1**). The highest methyl mercury concentration measured in 2016 intertidal and subtidal sediments was 44 ng/g at station ES-02 (Verona Northeast). The high methyl mercury concentration at ES-02 is present in a sample with a relatively high total mercury concentration (960 ng/g). Also, the fraction methylated was 4.6 percent, which is the second highest percent methylated in the 2016 subtidal / intertidal data (not counting the background and upstream samples). The second highest methyl mercury concentration measured in 2016 intertidal and subtidal sediments was 34 ng/g at station ES-13 (Verona East). This station has lower total mercury (420 ng/g) compared to ES-02, but a higher fraction methylated (8.1 percent). ES-13 is in a shallow cove on the east side of Verona Island, and is a location where wood debris accumulates and intermingles with sediments.

The third highest intertidal and subtidal methyl mercury concentration (24 ng/g) was also located in a cove, at E-01-01 (Fort Point Cove). Although the fraction methylated was somewhat low (2 percent), the total mercury concentration was relatively high (1,200 ng/g).

In wetland sediments (**Figure 3-2**), the highest methyl mercury concentration (44ng/g) is associated with the highest total mercury concentrations (1,300 ng/g). This sample is located at W-17-High (Frankfort Flats high marsh). The fraction methylated at each of this location was approximately 3.5 percent.

3.2.2 2016 Sediment Correlation Analysis

Graphical correlation analysis helps understand some of the basic physical properties that affect the observed variation of total mercury in sediments in the Penobscot River Estuary. About 77 percent of the variation of total mercury concentrations in intertidal sediments from 2016 is explained ($P<0.001$) by variation in TOC (**Figure 3-3**). At ten percent organic carbon, the best fit regression line predicts a total mercury concentration of about 1,300 ng/g. In contrast to the main estuary, the reference sample at the Addison River and the upstream locations have relatively low mercury concentrations regardless of the TOC concentration (filled circles in **Figure 3-3**). In contrast to TOC, fines do not show a significant correlation with total mercury (P = 0.17).

Wetland sediment total mercury concentrations showed no significant correlation with TOC (P = 0.95) or with fines (P = 0.3). In the sediment types sampled in 2016, methyl mercury was not significantly correlated with TOC (P = 0.65 in wetlands, P = 0.26 intertidal and subtidal) or fines (P = 0.98 in wetlands; P = 0.44 in intertidal and subtidal). Methyl mercury was not correlated with total mercury in the intertidal and subtidal sediments (P = 0.23). In wetlands, on the other hand (**Figure 3-4**), approximately 32 percent of methyl mercury variation is explained by total mercury variation (P = 0.01).

3.2.3 Comparison to Phase II Study Findings

The results of sediment monitoring from 2016 are comparable to findings of the Phase II Study in many ways. Total mercury concentrations in sediment increase below Veazie as a result of historic releases. Within the intertidal and subtidal sediments much of the variation in total mercury concentrations is explained by total organic carbon. This is also consistent with observations documented in the Phase II Study. The “one at ten” rule of thumb applies to both the sediment data from 2016 and prior evaluations of mobile pool sediments: one can expect approximately one part per million (ppm) mercury (=1,000 ng/g) at ten percent organic carbon.

The Phase II study concluded that methyl mercury was correlated with total mercury in intertidal sediments and wetlands of the estuary. No such correlation was observed in the intertidal and subtidal sediments during the 2016 study. Part of the reason for that may be the smaller data set in the 2016 study relative to the Phase II data set used to develop the correlations. Correlation analysis integrating both the 2016 monitoring and the Phase II study data is discussed in **Section 4** below. In wetland sediment samples collected in 2016, methyl mercury was correlated with total mercury (**Figure 3-4**).

3.3 2016 Water Quality Monitoring Results

The following subsections present a summary of water quality monitoring analytical results for 2016, as well as an assessment of the effects of salinity, TSS, and organic carbon on the transport of mercury and methyl mercury within the estuary. **Table 3-2** presents the 2016 water quality monitoring analytical results and field parameters. Particulate mercury concentrations presented in **Table 3-2** were calculated as follows:

$$[\mathrm{Hg}]_{p} = \{([\mathrm{Hg}]_{unf} – [\mathrm{Hg}]_{filt})(\mathrm{ng/L}) / \mathrm{TSS}\ (\mathrm{mg/L})\} \times 1000\ (\mathrm{mg/g})$$

Or in verbal terms, the particulate concentration (ng/g) is equal to the unfiltered concentration (ng/L) minus the filtered concentration (ng/L), divided by the TSS concentration (mg/L), multiplied by 1,000 mg/g.

3.3.1 2016 Water Quality Monitoring Results Summary

The analytical results presented in **Table 3-2** show a fair amount of variability at individual sampling locations from month to month over the course of the 2016 monitoring program. At the Orrington (WQ1b-C) and Winterport (WQ2-C) locations total mercury (Hg) concentrations vary by month over a range greater than 30 ng/L. The monthly total mercury variability at other locations is significantly less; for example, at Veazie (OV-02) and Fort Point (WQ-FPT), the maximum variabilities over the six-month period are 1.7 ng/L and 0.4 ng/L, respectively. There appears to be moderately strong correlation between the total mercury and TSS concentrations (R = 0.72), but the relationship is not statistically significant (P = 0.085). Similarly, the monthly total methyl mercury variability is greatest at Orrington and Winterport, and less at Veazie and Fort Point. **Table 3-3** presents the average concentrations/results for the 6-month 2016 monitoring program, inclusive of all seven of the monitoring points. The highest average concentrations of total mercury and particulate mercury were found during May, while the highest average dissolved mercury concentration was during the month of July. The lowest average results for total mercury, dissolved mercury, and particulate mercury were in September, May, and June, respectively. Methyl mercury average monthly concentrations were greatest in July (dissolved methyl mercury) and August (total and particulate methyl mercury) (**Table 3-3**). The lowest average concentrations of total mercury, dissolved methyl mercury, and particulate methyl mercury were found during September, May, and June, respectively. For total methyl mercury, there is strong correlation with TSS (R = 0.88, P = 0.011) and temperature (R = 0.81, P = 0.035).

For the purposes of discussing results by location, **Table 3-4** presents the average concentrations/results at each of the seven water quality monitoring sample locations over the 2016 six-month monitoring period for mercury, methyl mercury, TOC, DOC, TSS, dissolved oxygen (DO), ORP, turbidity, specific conductivity, and salinity. Discussions of concentrations and results in this subsection refer to the average concentrations/results presented in **Table 3-4**.

Water quality monitoring sample point OV-02 is above the former Veazie Dam. The salinity measured here suggests this location is above the influence of tides, and as such may be considered background outside the impact of the Holtrachem mercury release to the Penobscot River. The results for the monitoring period May through October 2016 for OV-02 indicate that the average total mercury by month at this location is the lowest of the monitoring points. The average results for TOC and DOC are higher for OV-02 than at other monitoring locations.

For total, dissolved, and particulate mercury and methyl mercury, the maximum of the average concentrations were found in the OV-02 location in the Veazie reach, the WQ1b-C location in the Orrington reach, and the WQ2-C location in the Winterport reach (see **Figures 3-5** and **3-6**). The single exception to these three upriver locations having the highest average concentrations of mercury and methyl mercury was OV-02, which had the lowest average total mercury result of 1.6 ng/L (**Table 3-3**. Total and particulate mercury and methyl mercury average results were highest in the WQ1b-C location in the Orrington reach, immediately down river of the former Holtrachem facility. The WQ1b-C location also exhibited the highest average TSS and turbidity results.

The WQ-FPT location at Fort Point had the lowest average results for total, dissolved, and particulate mercury and methyl mercury (except for total mercury), as well as the lowest average DO result (7.4 mg/L). The WQ-FPT also had the highest average specific conductivity (39.7 mg/L) and salinity (25.3 parts per thousand) due to its proximity to the marine waters of Penobscot Bay.

Average results for TOC and DOC generally decreased from the upriver location OV-02 to the downriver location at WQ-FPT (see **Table 3-3**), indicative of more suspended organic carbon in the waters above the tidal influence at the former Veazie Dam location, decreasing with distance down river and a corresponding increase in salinity.

3.3.2 Summary of Water Data and Estuarine Transport Processes

Graphical analysis of water data relationships reveals estuarine mixing and geochemical transformation. **Figure 3-7** shows that the estuarine profile of DOC vs. salinity for the 2016 monitoring data is typical of estuarine mixing and particle formation processes. The river end-member (OV-02), near zero salinity, has much higher DOC compared to the seawater end member above 25 salinity (WQ-FPT). If river inflow mixed with seawater with no removal of DOC from the dissolved state to particles, mid-estuarine concentrations near salinity 8 to 10 would reflect a mix of the two end-members, with concentrations falling along the dashed theoretical dilution line in **Figure 3-7**.

Instead, the concave up shape is evidence for removal of dissolved organic carbon by flocculation. This is a common estuarine process caused by the binding of humic and fulvic acid charged functional groups with calcium and magnesium present in seawater, reducing the solubility of DOC (Sholkovitz 1976). The difference between the dashed theoretical dilution line and the actual data represented by the solid line represents the reduced DOC concentration that results from flocculation. Multiplying the loss in DOC concentration by river inflow over the period of monitoring would yield the mass of DOC transferred to particulate matter over the course of the monitoring period.

This process was simulated in mixing studies conducted by the Phase II Study team and documented in Chapter 4 of the Phase II Study final report (PRMSP 2013b). That report concluded that particle formation by DOC flocculation could also scavenge dissolved mercury onto particulate matter. The study concluded that particles formed by DOC flocculation could increase TSS by as much as 1 to 2 mg/L, a small amount relative to the median TSS concentration for points downriver of OV-02 of 10 mg/L measured in 2016. The Phase II study further concluded that flocculation could lead to mercury concentrations in newly formed particles ranging from 30 to 200 ng/g. Given the small concentration of TSS formed by new particles (< 5 mg/L) compared to estuarine TSS (average of 13 to 18 mg/L in mid-estuary segments in 2016), coagulation of mercury along with DOC would have a negligible additive effect on the concentration of mercury in Penobscot River Estuary sediments compared to the existing concentrations in sediments resulting from historic discharges.

If dissolved mercury is removed by a similar process to DOC, it would be reasonable to expect that dissolved mercury would show a similar concave up profile when plotted vs. salinity. Instead, **Figure 3-8** shows an essentially flat distribution with salinity, with single outliers at Orrington in October and Winterport in July. Most of the dissolved mercury measurements are between 0.5 and 2 ng/L, and the detection limit is 0.5 ng/L.

Accounting for analytical uncertainties puts appropriate limitations on the use of monitoring data. The detection limit is three times the standard deviation of a low measurement. Therefore, measurements close to the detection limit (0.5 ng/L in this case) have analytical uncertainty about equal to the magnitude of the detection limit. Therefore, it would be difficult to discern the difference between a flat distribution vs. salinity, a straight-line dilution relationship, or a concave-up profile when the profile is based on mercury concentrations ranging from 0.5 to 2 ng/L with an uncertainty of +/- 0.5 ng/L.

Sediment re-suspension drives unfiltered total mercury concentrations. Variation in TSS accounts for 78 percent of the variation in unfiltered total mercury concentrations (**Figure 3-9**). The slope of the regression line, 0.62 ng Hg / mg TSS (= 620 ng/g) gives an estimate of the mercury concentrations in suspended sediments, and is consistent with mercury monitoring data for bottom sediments from the 2016 monitoring event and the Phase II Study.

Suspended particulate mercury concentrations reported in **Table 3-2** are also consistent with bottom sediment concentrations reported in **Section 3.2** and the Phase II Study, as well as the slope of the regression line in **Figure 3-9**.

Again, accounting for analytical uncertainties puts appropriate limitations on the use of monitoring data. Particulate mercury concentrations at Veazie (OV-02) were calculated based on data at or below detection limits for mercury and for TSS. This means that the estimates for particulate Hg at Veazie shown in **Table 3-2** are based on a difference of mercury concentrations that are either near the detection limit, or below the detection limit and estimated as ½ the detection limit. The difference, which inherently contains large relative uncertainty, is then divided by ½ the detection limit for TSS (i.e., 2.5 mg/L). The calculated particulate Hg concentrations in **Table 3-2** should be qualified as uncertain estimates, as they are based on concentrations near or below detection limits for unfiltered total Hg and / or TSS. The calculation is less sensitive to uncertainties for filtered (i.e., dissolved) Hg when TSS and unfiltered Hg are well above detection limits, but under those circumstances the results are essentially the same as estimating particulate Hg from the best fit regression of unfiltered Hg vs. TSS as shown in **Figure 3-9**.

3.4 Summary of Flow and Turbidity Monitoring Results

Table 3-4 presents 2016 river stage data and estimated discharge rates from the USGS gaging station #01036390 at Eddington, ME. Discharge rates were estimated based on a USGS table of values of stage height vs. river flow. Turbidity data readings for the probe installed in fall 2016 by Amec Foster Wheeler at the former Eddington boat ramp are provided in **Table 3-5**. The limited 2016 turbidity is depicted on **Figure 3-10**, as well as the river discharge and stage. Historical data from the USGS monitoring station indicates that a rapid rise in stage typically resulted in an increase in turbidity. Due to the limited turbidity monitoring period in 2016, there is as yet not enough data to determine a possible correlation of turbidity with river stage.

During the time when both USGS gaging station and the Amec Foster Wheeler turbidity meter were operating (Sept 10 thru Dec 31, 2016), the weather appears to be relatively dry, with few rain events. One storm and subsequent rise in river stage was noted on December 1, 2016 which produced significant rain, snow melt, and runoff. The turbidity and flow rate data recorded the event with elevated turbidity of 4.70 fntu. During the referenced period, the flow rate peaked on December 3, 2016 with a gage height of 5.90 feet above the datum, which is approximately equivalent to a discharge rate of 17,567 cubic feet per second, which correlates with the relatively high turbidity readings exceeding 3 fntu surrounding this date.

The cumulative precipitation recorded at Bangor, ME between the months of April and October 2016 was anomalously low, leading to lower than average gage heights and discharge. A comparison of gage height for the years 2012 and 2016 is provided in **Figure 3-11**, and illustrates the significant differences in gage height between the most recent year of monitoring (2012) and 2016. **Figure 3-12** presents a chart of the monthly precipitation amounts between the months of April and October for the years 2000 through 2016. During that period, the average total precipitation for the 7-month period from 2000 through 2016 was 26.2 inches, with a maximum of 39.0 inches in 2005, and a minimum of 14.0 inches in 2001. By comparison, the total precipitation for the period April through October 2016 was the second lowest, at 16.9 inches, over the 17-year period.

4.0 TEMPORAL AND GEOGRAPHIC DISTRIBUTION OF MERCURY AND METHYL MERCURY

Section 4.0 presents an assessment of the temporal and geographic trends of mercury and methyl mercury concentrations in sediment and surface water using data from the period 2006 through 2016.

4.1 Sediment Temporal and Geographic Trends Assessment

4.1.1 Sediment Assessment Methods

Historical data were evaluated by number of samples and years to determine which sampling locations had multiple years of data that would result in a robust exploratory data evaluation. The data used in the statistical evaluation included data from the years 2006 to 2012 and 2016. Sampling locations by sediment type include:

- Subtidal: E-01-01, E-01-03, E-01-04
- Intertidal: OV-04, OV-01, OV-02, OB-05, W-17-Intertidal, W-21-Intertidal, ES-02, ES-13
- Wetlands: W-21-UM-Central-C, W-21-UM-East-C, W-21-UM-South, W-21-UM-West-A, W-21-High, W-21-Mid, W-21-Low, W-63-High, W-17-Low

Historical sediment data were paired with sediment data collected in 2016 at selected monitoring stations as indicated in **Figure 2-1**. Field duplicates were not included in the data set. Data from other sampling stations within the estuary were not evaluated due to the limited number of years when samples were collected. Results from samples collected at the same location on the same date at multiple depths were averaged using weighted averaging. The depth intervals of historical samples used in the evaluation were limited to the 0 to 0.3 foot below ground surface interval. If multiple samples were collected at the same depth on the same day at the same location, the results of these samples were averaged. Data were evaluated based on sediment type: subtidal, intertidal (including wetland intertidal), wetland high elevation, wetland mid elevation, and wetland low elevation.

Trends analysis using depth intervals to 0.3 feet (= 9.1 centimeters [cm]) can be confounded by vertical gradients of mercury concentrations, as depths to 9 cm may represent older, more contaminated sediments in some areas. This should be kept in mind when evaluating data to determine whether or not trends over time are detected. Where trends are not detected, it may be because older, deeper sediments within the 9 cm interval confound the observation of change in surface sediments. Where trends are detected in sediment samples collected to a 9 cm interval that may indicate areas where deposition rates of new sediment are high relative to other areas of the estuary.

Total mercury and methyl mercury results were normalized for percent TOC, using the TOC concentrations analyzed via the Lloyd Khan method. Normalization of mercury and methyl mercury concentrations by TOC was conducted for each sediment type (i.e., subtidal, intertidal, and wetland) by dividing the individual mercury concentration by individual TOC, and then multiplying by the median TOC for that sediment type. The central tendency of the TOC (median rather than the average) of the dataset was used to scale ("normalize") each data point. An example calculation using only three samples from the data is provided here:

Sample	Mercury (ng/g)	TOC (percent)	Normalized Mercury (ng/g)
1	994	7.3	994
2	1104	6.2	1300
3	1247	7.3	1247

Median TOC = 7.3

Example calculation: (1104 ng/g) / (6.2 %) * 7.3 % = 1,300 ng/g

The statistical evaluation of sediment data was conducted using the publicly available statistical software package "R", version 3.3.2 (R Core Team 2016). Code and output are presented in **Appendix E**. Data were tested for normality where applicable and transformed if possible. Non-parametric statistical evaluations were conducted because data were not typically normally distributed. An alpha value of 0.05 was used to determine statistical significance where $p < 0.05$ indicates a rejection of the null hypothesis of no difference. Statistical methods for exploratory data evaluations were adapted from EPA's Unified Guidance (USEPA 2009), Conaway et al. (2007), and Bolker (2008).

<u>Subtidal Sediments</u>. Total mercury and methyl mercury concentrations were evaluated for differences between river reaches using a Kruskal Wallis Rank Sum test. If the Kruskal Wallis Rank Sum test indicated a significant difference between reaches, a Kruskal-Nemenyi post-hoc comparison test with a Chi-squared distribution, to account for ties in the data was conducted, to determine significance between groups. Total and methyl mercury concentrations also were evaluated by TOC and reach using an Analysis of Covariance (ANCOVA) to determine if the relationship of total and methyl mercury concentrations to TOC differs by river reach.

Total mercury and methyl mercury concentrations were evaluated per location against year to determine if sediment concentrations differ by year. Due to a significant relationship between total mercury and TOC, and methyl mercury and TOC, data were normalized for TOC and also regressed with time.

<u>Intertidal Sediments</u>. Total mercury and methyl mercury concentrations were evaluated for differences among river reaches using a Kruskal Wallis Rank Sum test. If the Kruskal Wallis Rank Sum test indicated a significant difference between reaches, a Kruskal-Nemenyi post-hoc comparison test with a Chi-squared distribution to account for ties in the data was conducted to determine significance between groups. Total mercury and methyl mercury showed significant differences between Veazie and downstream reaches, so the data were pooled into an upstream

(Veazie) and downstream (below Veazie) category. Total mercury and methyl mercury concentrations were evaluated by TOC and upstream/downstream using an ANCOVA to determine if the relationship of total mercury and methyl mercury concentrations to TOC differs between upstream and downstream.

Total mercury and methyl mercury concentrations were evaluated per location against year to determine if sediment concentrations differ by year. Due to a significant relationship between total mercury and TOC, and methyl mercury and TOC, data were normalized for TOC and also regressed with time.

Wetland Sediments. Total mercury and methyl mercury concentrations in each wetland elevation were evaluated for differences among reaches using a Kruskal Wallis Rank Sum test. If the Kruskal Wallis Rank Sum test indicated a significant difference between river reaches, a Kruskal-Nemenyi post-hoc comparison test with a Chi-squared distribution to account for ties in the data was conducted to determine significance between groups.

Total mercury and methyl mercury concentrations were evaluated per location against year to determine if sediment concentrations differ by year. Due to a significant relationship between total mercury and TOC, and methyl mercury and TOC, data were normalized for TOC and also regressed with time.

4.1.2 Sediment Assessment Results

Subtidal Sediments. Mercury, methyl mercury, and TOC were different between reaches (includes all years of available data) (**Figures 4.1-1** through **4.1-6**). Kruskal-Wallis rank sum tests (**Tables 4.1-1 and 4.1-2**) confirm that observed differences are statistically significant. Mercury concentrations and percent TOC were approximately two times higher in Fort Point Cove than in the Upper Penobscot Bay reach, and methyl mercury concentrations were approximately four times higher in Fort Point Cove than in the Upper Penobscot Bay reach (**Table 4.1-3**), consistent with the expected difference of a depositional (i.e., Fort Point Cove) compared to an area subject to more estuarine circulation and flow i.e., Upper Penobscot Bay) environment. Mercury was significantly related to TOC, but the relationship did not differ by reach (**Table 4.1-4**). Methyl mercury was significantly related to TOC and the relationship differed by reach (**Table 4.1-4**).

Linear regressions by sampling location help test for trends over time – are mercury concentrations in sediments changing at a rate that is statistically significant for the data set analyzed? Using a linear or log-linear regression model, mercury and methyl mercury concentrations in subtidal sediments did not show significant change through time (**Table 4.1-5**, **Figures 4.1-7)**, except at E-01-04 where methyl mercury concentrations appear to be increasing through time due to samples collected in 2012 and 2016 (**Figure 4.1-8**). Normalizing mercury to organic carbon did not change the lack of trend (**Figure 4.1-9**). After methyl mercury concentrations were normalized by TOC, the increase at E-01-04 is still significant as determined by a linear regression model.

Rank-order tests for trends help vet the impact of outliers, which can substantially impact linear regression models. **Table 4.1-5** includes a Kendall's rank order probability (p-Tau) for statistically significant trends. Although the normalized methyl mercury trend is significant by linear regression at E-01-04, the p-Tau values (0.660 and 0.245, respectively) mean that a significant trend was not indicated by the Kendall rank order test. This suggests that the trend of methylmercury and carbon-normalized methylmercury identified by a log linear regression model is driven by the 2016 outlying data point.

The re-analysis of total mercury using hot acid digestion did not affect conclusions regarding spatial distributions in subtidal sediments, nor the observed lack of trends in total mercury concentrations over time. The mercury re-analysis and the two-fold methylmercury adjustment did have minor, inconsequential changes on the identification of outliers in the box and whiskers plots shown in **Figures 4.1-1** through **4.1-6.**

Re-analysis affected trends at subtidal location E-01-03 (Upper Penobscot Bay) for carbon-normalized mercury concentrations. A significant (p=0.04) trend with respect to time was detected using 2016 results obtained by cold aqua regia (513 ng/g). After re-analyzing with a hot aqua regia digestion, the slight increase in the 2016 result (567 ng/g) meant that the trend did not meet the significance threshold (p=0.06). The Kendall's rank order tests agreed with the linear regression tests: significant downward trend (p= 04) when the cold aqua regia 2016 result of 513 ng/g is applied, but not a significant trend when the hot aqua regia result of 567 ng/g is applied (p=0.06). In both tests for trends, the small (about 10 percent) increase resulting from the analytical change moves the resulting p from just below the significance threshold (p <0.05) to just above it. This gives a feel for the sensitivity of significant trends to specific details of analytical procedures.

Also, at station E-01-04 (Upper Penobscot Bay), carbon-normalized methylmercury did not show a significant increasing trend (p=0.13) without the two-fold methylmercury adjustment. Applying the two-fold adjustment led to a significant (p=0.02) increasing trend by linear regression. The Kendall's rank order test result was not significant (p-Tau = 0.32 and 0.25 for unadjusted and adjusted methylmercury data, respectively), which suggests that the trend by linear regression is affected by the 2016 outlier data point. This is also reflected in the relatively large confidence interval at the end of the regression (**Figure 4.1-10**, plot of normalized methylmercury at E-01-04).

<u>Intertidal Sediments</u>. Mercury, methyl mercury, and percent TOC were significantly different in intertidal sediments among reaches (**Table 4.1-1**, **Figures 4.1-11** through **4.1-16**). Mercury and methyl mercury concentrations were significantly different between the intertidal sediments in the Veazie reach compared to the Orrington and Verona (Verona East and Verona Northeast) reaches (**Tables 4.1-6, 4.1-7**). Veazie sediment mercury concentrations are lowest, increasing towards the Orrington reach and peaking in both Verona reaches. Percent TOC did not differ significantly between reaches (**Table 4.1-6**); thus, incoming sediments that are sampled from the Veazie reach, which indicate incoming sediment characteristics, have organic carbon

concentrations comparable to sediments from the estuary between Orrington and Verona, but much lower mercury concentrations.

Mercury and methyl mercury were significantly related to TOC, and the relationships differed by reach (**Table 4.1-8**) as well as by separation of upstream to downstream (**Table 4.1-9**).

Time trends analysis using linear regression models on intertidal sediment sampling locations showed significantly decreasing ($p < 0.05$) mercury concentrations at OV-04, ES-02, and ES-13 through time, but not at OV-01 (p=0.78) , OV-02 (p=0.054) , or OB-05 (P=0.13) (**Table 4.1-5, Figure 4.1-17**). Methyl mercury concentrations did not significantly decline through time (**Figure 4.1-18**) at any of the sample locations. Carbon normalized mercury (**Figure 4.1-19**) showed a downward trend (p=0.02) at ES-02 (Verona Northeast), which was consistent with the Kendall rank order test (p-Tau = 0.03). Normalized methyl mercury concentrations (**Figure 4.1-20**) showed an upward trend at station ES-13 (p=0.04), which is consistent with the Kendall rank order test (p-Tau = 0.04).

After accounting for the known covariance of mercury with organic carbon in intertidal sediments, the samples collected at ES-02 show a downward mercury trend. As with subtidal sediments, rank-order trends analysis helps vet the findings of linear regression models. In the case of intertidal sediments collected from Verona Northeast, the p-Tau statistic (0.03) at ES-02 supports the findings of a downward trend.

Additional site knowledge helps contextualize the findings. The sample location is known to be highly impacted by wood waste, which contributes to sample heterogeneity. There is a risk that the higher sampling density from earlier years skews the trend by providing more data from spatial replicates having relatively high mercury concentrations. Additional monitoring and assessment under way in the summer of 2017 is expected to provide further insight by increasing contemporary data density, and will help either support or reject the tentative finding of a downward trend in mercury sediment concentrations at ES-02.

The re-analysis of mercury using hot acid digestion and the two-fold methylmercury adjustment had inconsequential effects on the bars and whiskers plots shown in **Figures 4.1-11** through **4.1-16**. Overall conclusions about spatial trends remain unchanged.

> The re-analysis did change the p-value for the time trends regression from significant (<0.05) to just above the threshold for significance (p= 0.054) at OV-02, but these upstream concentrations at Veazie are sufficiently low (30 to 130 ng/g) that trends analysis is not a meaningful exercise (compare the range of data at OV-02 in relation to other intertidal stations shown in **Figure 4.1-17**). The decision to use a two-fold adjusted methylmercury concentration did not alter the finding of no significant trends in methylmercury results at most intertidal sample locations, with the exception of ES-13 (Verona East). At that location, a two-fold adjustment of the 2016 methylmercury concentration resulted in an increasing trend (p=0.04) for both the linear regression model and the Kendall's rank order model.

Wetland sediments. Mercury concentrations were not significantly different among reaches for any elevation as a category (**Table 4.1-1**, **Figures 4.1-21 and 4.1-22**). The highest mercury concentrations (Frankfort Flats, 1,300 ng/g) and the lowest (Orrington, 230 ng/g) have only one sample each represented in **Figure 4.1-21** and **Table 4-1.10**. Additional monitoring results from the 2017 monitoring program will help characterize the range and central tendencies of these new wetland monitoring locations.

Methyl mercury concentrations were significantly different in high elevation wetland sediments (**Table 4.1-1**), but not in wetland sediments at other elevations (**Figures 4.1-23** and **4.1-24**). Mendall Marsh had significantly higher methyl mercury concentrations than sediments in the Orrington and Verona East reaches, but did not differ from high wetland sediments the Frankfort Flats reach (**Table 4.1-12**). The other reaches were similar in methyl mercury concentrations in high wetland sediments (**Table 4.1-10**), but again, these comparisons are preliminary for the new locations.

Percent TOC was significantly different in wetland high, wetland low, and wetland intertidal sediments among reaches (**Table 4.1-1**, **Figures 4.1-25** and **4.1-26**). Percent TOC in wetland high sediments in the Orrington reach was approximately three to nearly five times lower than in high elevation wetland sediments in the Mendall Marsh and Verona East reaches (**Table 4.1-10**). Percent TOC in wetland low sediments in the Mendall Marsh reach was significantly lower than in low elevation wetland sediments in the Frankfort Flats and Verona East reaches, but did not differ from the Verona East reach sediments despite the very similar percent TOC values of Verona East and Frankfort Flats (**Table 4.1-11**). While wetland intertidal sediments were significantly different according to the Kruskal Wallis Rank Sum test, the post-hoc Nemenyi comparison did not show a statistically significant different in percent TOC between reaches. The Nemenyi test indicates that there is some separation of percent TOC, but variability overwhelms any differences between intertidal elevation wetland sediments in these reaches (**Table 4.1-13**).

Linear regressions at wetland sediment sampling locations showed significantly decreasing mercury and TOC normalized mercury concentrations at W-21 in intertidal and low wetland sediments, but not in mid or high elevation wetland sediments (**Table 4.1-5**, **Figures 4.1-27** and **4.1-29**). The Mercury and TOC normalized mercury concentrations also decreased significantly at W-21-UM-South, but not the Central, East, or West W-21-UM locations. Mercury concentrations also decreased significantly through time at W-63 high locations, but TOC normalized mercury concentrations did not change through time. Mercury and TOC normalized mercury concentrations did not change significantly at W-17-Intertidal or W-17-Low locations.

Linear regressions at wetland sediment sampling locations showed significantly decreasing methyl mercury and TOC normalized methyl mercury concentrations at W-21 in intertidal and low wetland sediments, but not in mid or high elevation wetland sediments (**Table 4.1-5**, **Figures 4.1-23** and **4.1-24**). W-17-low showed a decreasing trend for methylmercury (p=0.03) but not for normalized methylmercury (p=Decreasing normalized methylmercury concentrations were also detected at W-21-UM-South, W-21-UM-East-C, and W-21-UM-West-A). The scale of change at

W-21-UM-West-A was much smaller (<10 ng/g maximum) compared to initial maxima of approximately 80 and 40 ng/ at the other two upper marsh locations (**Figure 4.1-30**). The other wetland sediments evaluated for methyl mercury and TOC normalized methyl mercury concentrations through time did not show significant trends (P>0.05).

The re-analysis of mercury using hot acid digestion and the two-fold methylmercury adjustment had inconsequential effects on the bars and whiskers plots shown in **Figures 4.1-21** through **4.1-26.** Significant mercury spatial differences between wetlands low were no longer apparent as a result of the hot aqua regia mercury analysis – the Kruskal-Wallis rank sum p increased from 0.01 to 0.053, just exceeding statistical significance at p<0.05.

The re-analysis did not affect mercury trends in wetland sediments; however, methyl mercury trends were affected by the two-fold adjustment. Significant trends of methylmercury at W-21-High (p=0.04) and W-21-UM-Central (p=0.047) were detected prior to adjustment, but not after (p=0.61 and 0.40, respectively). At both of these Mendall Marsh locations, normalized methylmercury did not show a trend before or after the adjustment.

4.1.3 Summary of Spatial and Temporal Trends

A review of trends in **Table 4.1-5** shows one feature: of the six locations where a significant decline in either normalized mercury or normalized methylmercury was detected, five of them are in the Mendall Marsh. The sixth is Verona Northeast. Trends in all six of these areas are qualified as preliminary. In many cases, comparison with the p-Tau indicates no significant trend by Kendall’s rank order test, which indicates the observed log linear correlation results primarily from a single outlier, either in 2006 – 2007, or in 2016, or both. This is evident by inspection of the time series plots shown, as well as the p-Taus in **Table 4.1-5.**

The six areas where normalized mercury or methylmercury concentrations had decreasing trends provide the strongest evidence for trend in this assessment, because the normalization accounts for inherent mercury and methylmercury variation with organic carbon. The careful vetting of effects of analytical methods and assumptions further supports understanding whether the trends observed represent or approximate rates of change in sediment mercury and methylmercury concentrations. If the broad-scale spatial trend observed – that the most frequent occurrence of decreasing trends is in Mendall Marsh – is supported after future monitoring, it would tend to suggest that Mendall Marsh is accumulating newer, cleaner sediments that may accelerate recovery faster relative to other areas assessed.

This would be a coarse-scale approximation, because the sediment depths used for time series in this assessment was 0.3 feet (i.e. about 9 cm), which, depending on local sediment accumulation rates, can represent a long period of time. Work performed in the summer of 2017 will refine our understanding of horizontal and vertical mercury distributions, and the implications for trends and recovery rates.

4.2 Surface Water Temporal and Geographic Trends Assessment

4.2.1 Surface Water Assessment Methods

Historical surface water data (2006-2012) were paired with monthly surface water data collected in 2016 at seven monitoring stations (OV-02, WQ1b-C, WQ2-C, WQ3-L, WQ-ECH, ES-15, and WQ-FPT; **Figure 2-2**). Data from other sampling stations were not evaluated because of a limited number of years of data. Data were limited to unfiltered samples or samples filtered with a 0.45-micron filter. Data from samples filtered with other filter sizes were not used in this data evaluation. Data collected at the same location on the same date at multiple depths were limited to surface water collected in the first 10 feet below the surface. If more than one sample was collected at a location within the top 10 feet, the data were averaged. If multiple samples were collected at the same depth on the same day at the same location, the results of these samples were averaged.

Total mercury and dissolved mercury and methyl mercury concentrations (dependent variables) in surface water were evaluated using general linear (Bolker 2008). Specifically, multiple linear regression models, including interaction terms, were used to evaluate how the dependent variables change due to the independent variables of year, season, and location. Where a group (independent variable) suggests significance, a Kruskal-Nemenyi post-hoc comparison test was conducted to determine significance among groups for location and season. If significance among years was noted, a linear regression was used to evaluate the relationship of total or dissolved mercury or methyl mercury to year.

Total mercury and dissolved mercury and methyl mercury concentrations were evaluated by TSS and upstream/downstream using an ANCOVA to determine if the relationship of total mercury and methyl mercury concentrations to TSS differs between upstream and downstream sampling locations.

4.2.2 Surface Water Assessment Results

Total mercury surface water concentrations differed by location, but not significantly by season or year, and did not show interactions of any combination of these variables (**Table 4.2-1**, **Figure 4.2-1**). Surface water total mercury concentrations were lowest at WQ-FPT, followed by Veazie (**Table 4.2-2**). Concentrations at these two locations were significantly different than at WQ2-C, which had the highest total mercury concentrations. Total mercury concentrations at Fort Point were also significantly lower than WQ1b-C. The difference in concentrations may be due to only one year of data at Fort Point and more years of data at the other two locations. Other comparisons showed similarity in surface water total mercury concentrations.

Dissolved mercury concentrations differed by location, season, and year, but did not show interactions of any combination of these variables (**Table 4.2-4**, **Figure 4.2-2**). By season, spring and summer dissolved mercury concentrations were similar, but fall differed from spring and summer (**Table 4.2-5**). Dissolved mercury concentrations show a significant decline through time, even when the two locations added in 2016 (i.e., WQ-FPT and WQ-ECH) were excluded from the regression. Surface water dissolved mercury concentrations (regardless of season or year) were lowest (mean and median) at WQ-FPT and then WQ-ECH while the highest concentrations (mean and median) were detected at OV-02 (**Table 4.2-2**). Veazie dissolved mercury concentrations were significantly higher by approximately 2 to 8 times than ES-15, WQ-FPT, WQ-ECH, and WQ3-L, the lower portion of the study area (**Table 4.2-2**). Other comparisons showed similarity in surface water total mercury concentrations.

Total methyl mercury concentrations differed by year (when interaction terms were removed from the generalized linear model, but not by season, location, or interactions of any combination of these variables (**Table 4.2-7**, **Figure 4.2-3**). Total methyl mercury concentrations show a statistically significant decline through time, except when the two locations added in 2016 (i.e., WQ-FPT and WQ-ECH) were not included. This indicates that the low total methyl mercury concentrations in the farthest south part of the system help drive the relationship of total methyl mercury and time.

Dissolved methyl mercury concentrations differed by location and year, but not by season or interactions of any combination of these variables (**Table 4.2-8**, **Figure 4.2-4**). Dissolved methyl mercury concentrations show a significant decline through time, even when the two locations added in 2016 (i.e., WQ-FPT and WQ-ECH) were excluded from the regression. Surface water dissolved methyl mercury concentrations (regardless of season or year) were lowest (mean and median) at WQ-FPT, WQ-ECH, and WQ3-L with ES-15 being very similar while the highest concentrations (mean and median) were detected at Veazie (**Table 4.2-2**). Veazie dissolved methyl mercury concentrations were significantly higher by approximately 3 to 5 times than ES-15, Fort Point, East Channel, and WQ3-L, the lower portion of the study area (**Table 4.2-9**). Other comparisons showed similarity in surface water total mercury concentrations.

Given the designation of Veazie as a reference location, and the differences seen with dissolved mercury and methyl mercury between OV-02 and locations in the downstream portion of the system, an ANCOVA to test the relationships of total mercury, total methyl mercury, dissolved mercury, and dissolved methyl mercury to TSS was conducted using the designation of upstream (i.e., OV-02) and downstream (locations downstream of OV-02). The interaction of TSS and upstream/downstream location was significant, indicating that the relationship of total mercury and TSS differed by upstream/downstream location (**Table 4.2-10**). The linear relationship of TSS and total mercury was also significant, and there was a significant interaction of upstream/downstream location with the effect of TSS on total mercury. Although total mercury did vary significantly among years, the response of mercury to TSS did not show a significant interaction with year as a category. This indicates that there was no evidence for a statistically significant trend in suspended particulate mercury over time, assuming that the coefficient of the mercury / TSS relationship is an estimate of mercury concentrations on suspended solids.

TSS had a significant effect on unfiltered methylmercury in water (**Table 4.2-11**) and dissolved methylmercury in water (**Table 4.2-13**). In contrast, TSS did not have a significant effect on dissolved mercury in water (**Table 4.2-12**).

5.0 UNCERTAINTIES

Assessing uncertainties helps define data needs and next steps. This section presents a summary of the uncertainties associated with the 2016 sediment and water quality monitoring data.

Validation results for sediment analytical data indicated that analytical data were useable for the purposes intended for this report; however, the potential impact of the heterogeneity resulting from wood debris containing mercury and methyl mercury adds some uncertainty to the 2016 sediment analytical results presented in this report.

One of the chief limitations resulting from sediment sample heterogeneity is the impact on the ability to detect time trends. Time trend analysis needs to account for covariance of mercury with TOC. Total mercury and TOC are analyzed separately, from two different subsamples. Heterogeneity means that there may not be an exact match between the composition of the two different subsamples despite homogenization, which may obscure the covariance with random error. This in turn limits the ability to detect change over time in the mercury concentrations of sediments.

Validation results for water analytical data indicated that analytical data is useable for the purposes intended for this report; however, there is some uncertainty associated with mercury in filtered and unfiltered water samples at low concentrations (e.g., below 2.5 ng/L), due to concentrations being comparable to blank levels and close to detection limits (0.5 ng/L). This has implications for calculations of particulate mercury concentrations, which are used to estimate mercury in new particles entering the estuary. Calculations of particulate mercury entering the estuary at Veazie from this 2016 data set are considered estimates because the total mercury, dissolved mercury, and TSS measurements used to calculate particulate mercury are all close to, or below, detection limits.

The purpose of flow and turbidity monitoring is to generate data to support estimates of the annual sediment load entering the estuary. Flow data from the USGS gauging station are considered sufficiently robust for this purpose. However, the turbidity monitoring period in 2016 was limited due to installation of the turbidity meter in late fall 2016, and equipment downtime, so there are insufficient data to develop turbidity - stage correlations that are typically used to estimate fluvial sediment loads.

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

Sediment monitoring results from 2016 reveal a consistent pattern of mercury concentrations increasing with distance downriver from Veazie, that has been previously observed in the Phase II Study (PRMSP, 2013a). The range of mercury concentrations in sediments observed (300 to 1,100 ng/g), and the strong covariance with TOC, is also consistent with Phase II Study observations.

No consistent trends in mercury concentrations over time were observed in the data. Sometimes there was a significant positive correlation with time (increasing mercury concentrations), sometimes there was evidence of a decreasing trend, but most times there was not a significant correlation. Given the heterogeneity of the wood debris-sediment mix, and the half-time for recovery estimated in the Phase II Study (20 to 30 years), the time frame 2006 to 2016 is not long enough to reasonably expect to develop meaningful trends by simple linear regression against time with a limited data set. Improving the sediment sampling procedure to address the native heterogeneity of Penobscot River Estuary sediments may improve the ability to detect change over time. The current database of sediment measurements is best used to develop average total mercury concentrations and mercury-TOC correlations by segment, aggregating historic data within a reach of the Estuary and assuming little change over time.

Water monitoring shows that the Penobscot system functions like a typical estuary. Mixing of river water with seawater is accompanied by flocculation of DOC, which leads to removal and a non-linear distribution of DOC with salinity. The main observable factor affecting total mercury concentrations in the estuary is correlation with suspended sediments. The mercury concentration of suspended sediments within the estuary is roughly 600 ng/g, based on unfiltered mercury to TSS correlations. The April to October 2016 period was very dry in terms of precipitation totals, which may have led to very low concentrations of mercury and TSS in the Veazie reach.

6.2 Recommendations

Reviewing monitoring goals helps focus monitoring program design. Prior to implementing additional annual monitoring, the driving study questions should be revisited, and the approach tailored based on lessons learned. Monitoring questions and associated lessons learned are summarized below, each followed by a specific recommendation. The monitoring questions below are based on the observations of 2016 monitoring data, as well as a review of the PRMSP Phase II Study Report, in particular Chapter 13 - Plan for long-term monitoring of mercury in sediments and biota in Penobscot River and Bay (PRMSP, 2013b).

Monitoring Question 1: Are mercury concentrations in Penobscot River sediments changing over time fast enough to make monitored natural attenuation a viable strategy?

A working hypothesis following the 2016 field season and mobile sediment pool investigations is that the mobile sediment-wood debris is acting as an ongoing source of mercury to intertidal and wetland sediments. In addition, the observed heterogeneity of sediments and the presence of wood debris in sediment samples outside of the mobile pool make time trend analysis difficult due the variability of sample results from the same aliquot. The heterogeneity impact on time trend analysis can be overcome with a refinement of sediment sample collection, processing, and analytical procedures appropriate to the conditions encountered. This is the subject of work order WO 4A-020 currently under way. One recommendation for 2017 sediment monitoring is to screen the collected sediments with a #40 sieve to evaluate the percentage of wood debris in the samples.

Monitoring Question 2: What is the average concentration of mercury found in incoming suspended sediments?

This is related to the recovery of the estuary, because incoming sediments establish a floor of mercury concentrations in sediment that could be reasonably and foreseeably attained. As noted, water column data collected in 2016 have too much uncertainty to provide meaningful estimates of particulate mercury concentrations entering the estuary. The uncertainty comes from measurements close to the detection limits for filtered and unfiltered mercury as well as TSS.

The concentration of TSS entering the estuary at Veazie will likely continue to be relatively low, based on watershed characteristics and historic observations. Subsequently, the total mercury concentration will also continue to be relatively low, and detection limits will remain a challenge. With some effort, mercury detection limits can be reduced by diligently controlling blank levels. Lowering the detection limit for TSS can be achieved by filtering larger volumes of water to obtain greater volumes of solids.

A better approach would be to measure particulate mercury more directly as the parameter of interest. Instead of measuring unfiltered and filtered mercury separately and calculating particulate mercury by difference, it would reduce uncertainty to filter water and collect particles onto a trace metal clean filter. The filter would then be dried and weighed to determine the mass of suspended particles collected, and subsequently digested to measure the mercury concentration of particles collected.

This approach also requires effort to control and measure blank concentrations. The advantage is that sample signal to blank ratios can be increased to usable levels by increasing the sample volume filtered. Some methods development would be needed to refine the details of this approach, but it is more likely to answer this monitoring question than continuing to rely on estimates based on differences between small numbers with large relative uncertainty.

Additionally, collection of conductivity, temperature, and depth (CTD) profiles at each sample location for each sampling event would add to the body of data on physical profiles, and is a long-term benefit to hydrodynamic modeling, as well as conceptual model refinement.

Monitoring Question 3: What is the annual sediment load entering the estuary?

This information, in conjunction with monitoring question 2 above, helps in understanding the recovery rate of the estuary. This requires calibration of continuous turbidity measurements with grab samples for suspended sediment concentration (SSC), as was done in the Phase II Study (see Chapter 7 of the PRMS Phase II Study Report).

For this type of fluvial sediment transport, measurement of SSC is more scientifically robust than TSS. The ramifications of collecting TSS versus SSC samples are discussed by Gray et al (2000). Briefly, measuring SSC in a sample requires specific procedures for both collection and analysis. Collection of an SSC sample needs to be conducted with an isokinetic sampler that eliminates biasing the particle size distribution of water samples resulting from flow around the sampler orifice. The sampler should be operated in a way that provides representative sampling of the stream/river cross-section.

Analysis needs to be performed by filtering the entire sample collected, not just an aliquot of the sample. Filtering the entire sample, including triple rinsing the bottle to capture any coarse sediment lost to settling, reduces low bias caused by sedimentation in the bottle. Measuring SSC is more labor intensive than TSS, but can be very helpful in developing accurate estimates of fluvial sediment loads.

Summary of Recommendations

The monitoring questions should drive the scope and schedule of any future annual monitoring.

Amec Foster Wheeler recommends that the water quality monitoring program in 2017 focus on sediment monitoring to support remedial design. The water monitoring data generated to date have advanced the conceptual site model; however, additional water monitoring by the same approach is not essential on a monthly frequency. Sediment concentrations control water concentrations, and sediment trends appear to be on a more decadal time scale in this estuary. Regarding sediment monitoring in the Penobscot River, Amec Foster Wheeler recommends continuing the 2017 monitoring with a base program consistent with the 2016 program. There is value in returning to the same stations over time to detect trends.

The highest priority water monitoring uncertainty is the input rate of new sediment to the estuary, and the associated mercury concentrations and loads. Addressing that data gap seriously requires refined monitoring techniques, including isokinetic sampling, inter-calibration of turbidity with suspended sediments, and direct filtration to analyze suspended particulate mercury. Some pilot work on those refinements can be accomplished this year, such as methods development for large volume filtration and suspended sediment inter-calibration. But characterizing the long term fluvial transport of mercury to the Penobscot River Estuary is a project that exceeds the duration of this Phase III Engineering Study. The data gap of new sediment input merits thoughtful design in the long-term monitoring approach.

Amec Foster Wheeler recommends that refinements to the water monitoring program should be included as detailed monitoring recommendations for the Phase III Engineering Study Final Report. Specific pilot tasks that can be executed in 2017 to support those recommendations include developing procedures to directly filter river water for analysis of suspended particulate mercury, evaluation of field blanks and other quality control metrics for direct filtration, development of isokinetic sampling protocols, and development of Standard Operating Procedures documenting these refinements.

To support ongoing data gathering for sediment input modeling, Amec Foster Wheeler recommends that the continuous turbidity monitoring program be continued. Continuous turbidity measurements should be calibrated with suspended solids concentrations (SSC) measurements. Continuing this part of the monitoring program would proceed concurrently with the pilot studies and methods development described above.

Finally, Amec Foster Wheeler recommends that future on-water monitoring work include regular CTD casts. Including a CTD adds substantial information value to the field effort, because it increases the data density of salinity profiles under varying conditions of season, tide and weather. A long-term record of water properties assists conceptual and numeric model development with limited and manageable impact on field effort.

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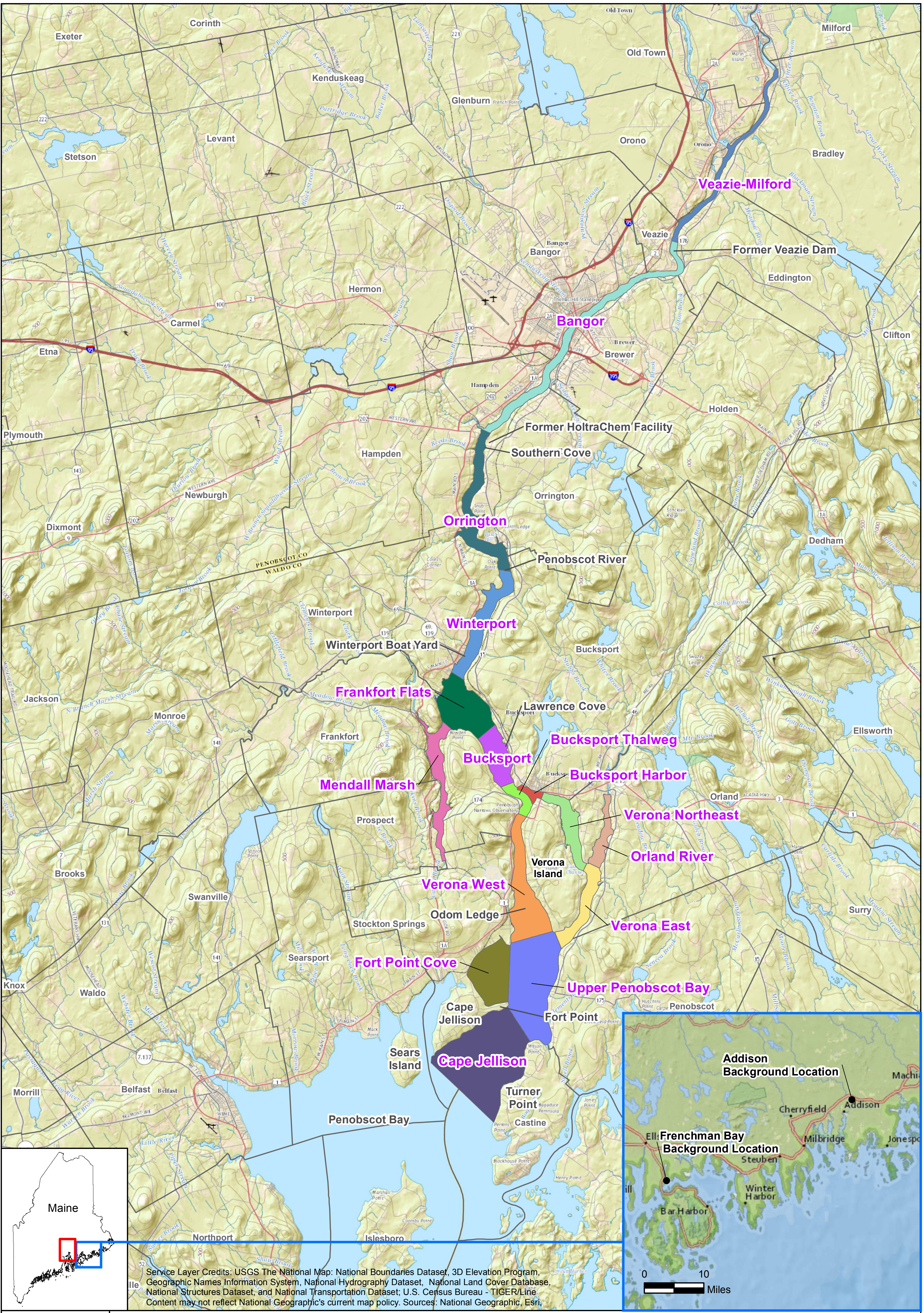
FIGURES



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Content may not reflect National Geographic's current map policy. Sources: National Geographic, Esri,

Legend

■ Bangor	■ Bucksport Thalweg	■ Frankfort Flats	■ Orrington	■ Verona East	■ Winterport
■ Bucksport	■ Cape Jellison	■ Mendall Marsh	■ Upper Penobscot Bay	■ Verona Northeast	
■ Bucksport Harbor	■ Fort Point Cove	■ Orland River	■ Veazie-Milford	■ Verona West	

N
0 1 2 3
Miles

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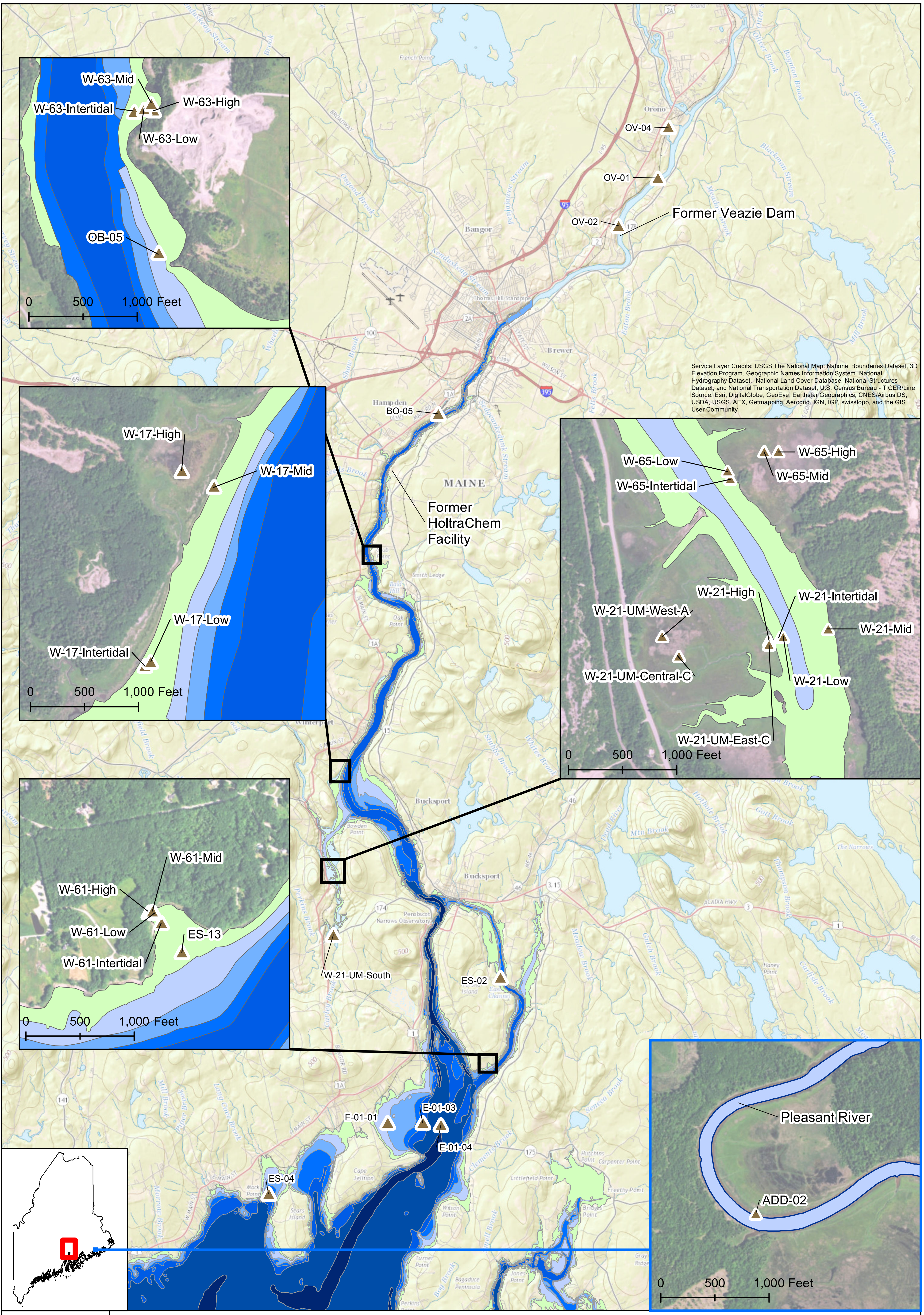
Figure 1-1
Site Location and Reaches

2016 Sediment and Water Quality Monitoring Report
Penobscot River
Phase III Engineering Study

Project: 3616166052 | Prepared/Date: ICD 02/07/17 | Checked/Date: BPW 02/07/17 | NAD83 State Plane Maine East, US Survey Feet

Document: P:\Projects\USDC - Penobscot River\4.0_Deliverables\4.5_Databases\GIS\Master\MapDocuments\Project_Location_11x17P_Index.mxd PDF: P D F : \\ PLD2 -F S1\Project\Project\USDC-PenobscotRiver\4.0_Deliverables\4.5_Databases\GIS\PreliminaryWork\Figures\SedimentSampling\Figur e_1_Proposed_Sed_Mon_locs.pdf 02/07/2016 11:48 AM ian.desjarlais



Service Layer Credits: USGS The National Map: National Boundaries Dataset, 3D Elevation Program, Geographic Names Information System, National Hydrography Dataset, National Land Cover Database, National Structures Dataset, and National Transportation Dataset; U.S. Census Bureau - TIGER/Line Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

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Legend

- ▲ Annual Sediment Sampling Location
- 🟩 Intertidal Zone

Bathymetry

Water Depth feet (MLLW)

0 6 12 18 30 60 120 600

N

0 2 Miles

Figure 2-1
2016 Sediment Monitoring Locations

2016 Sediment and Water Quality Monitoring Report
Penobscot River Estuary
Phase III Engineering Evaluation

Project: 3616166052	Prepared/Date: ICD 02/14/17	Checked/Date: BPW 02/14/17	NAD83 State Plane Maine East, US Survey Feet

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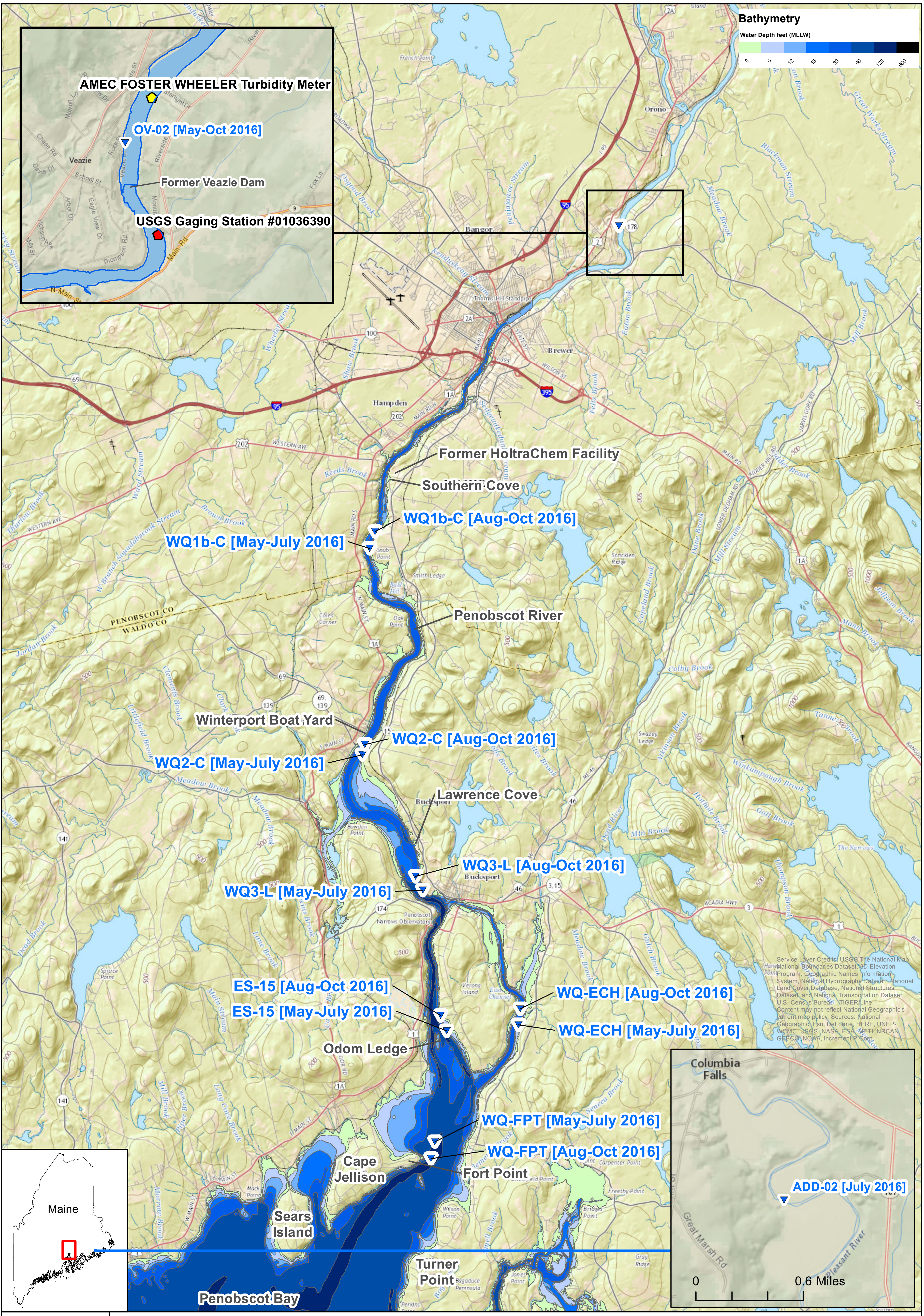

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Legend

⬟ AMEC FOSTER WHEELER Turbidity Meter
⬟ USGS Gaging Station #01036390
▼ Water Quality Monitoring Locations

N

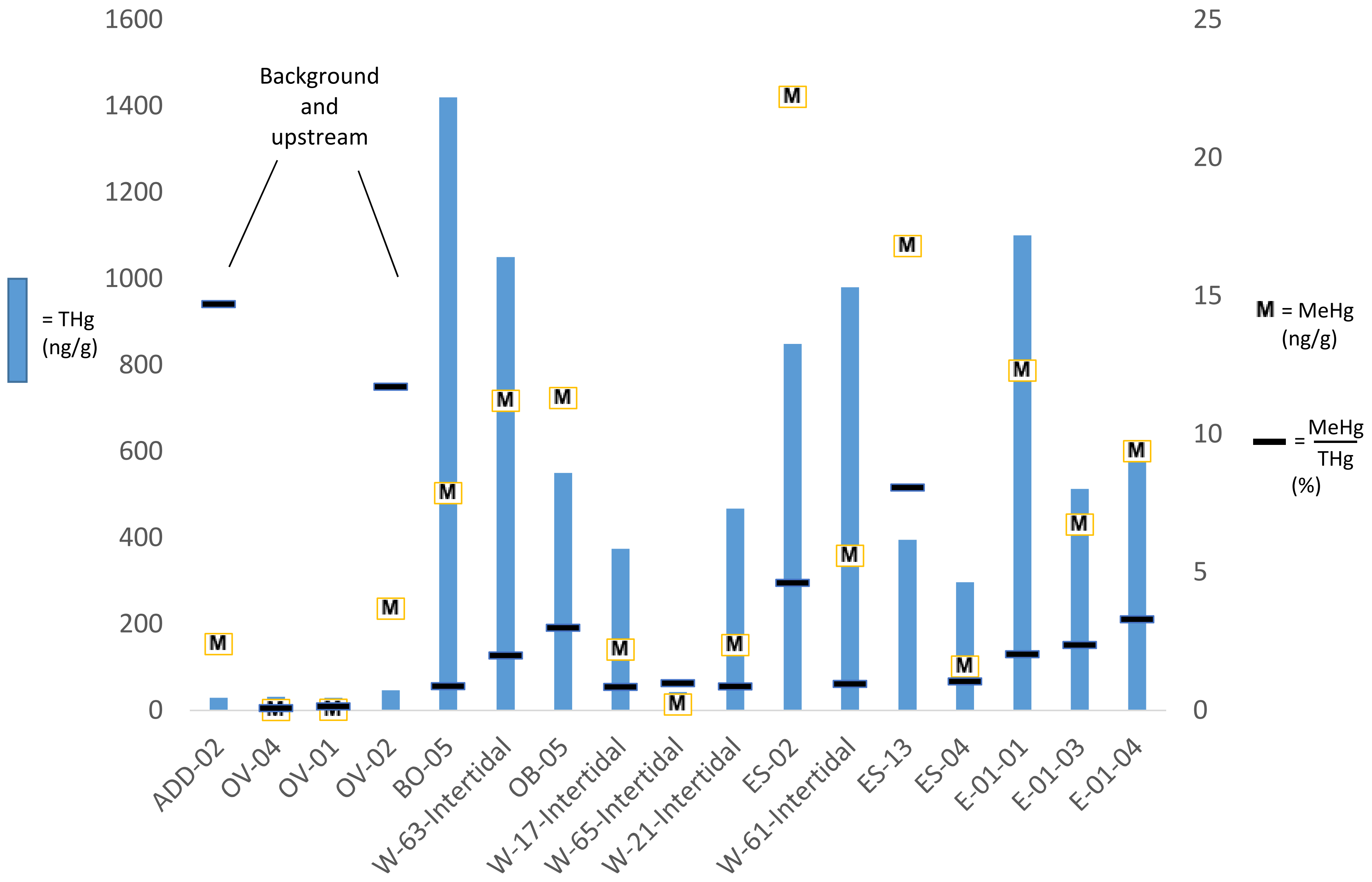
0 1 2 3 Miles

Figure 2-2
2016 Surface Water Locations

2016 Sediment and Water Quallity Monitoring Report
Penobscot River
Phase III Engineering Study

Project: 3616166052	Prepared/Date: ICD 02/24/17	Checked/Date: BPW 02/24/17	NAD83 State Plane Maine East, US Survey Feet

Figure 3-1. Total Mercury, Methylmercury, and Percent Methylmercury in Intertidal and Subtidal Sediments



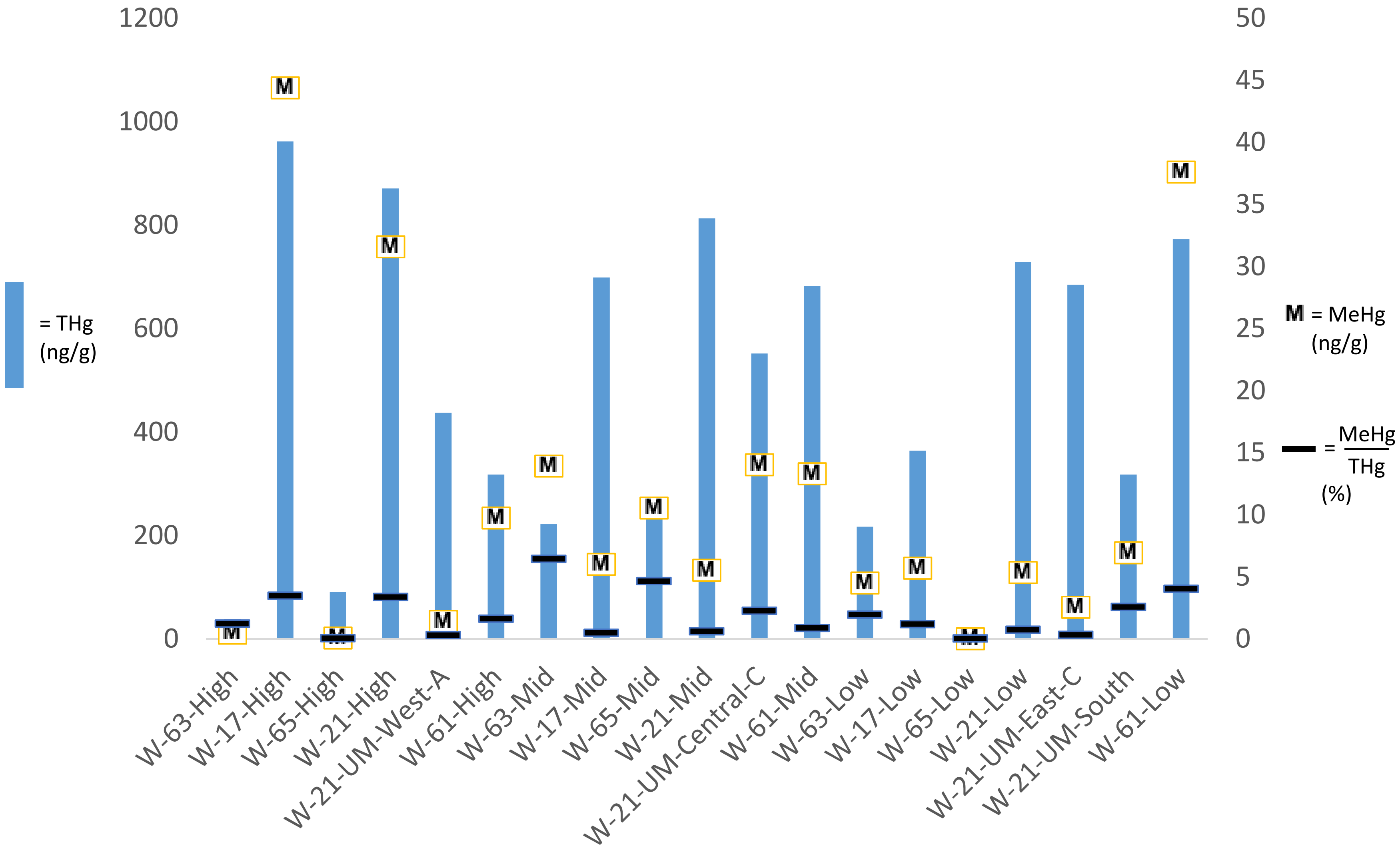
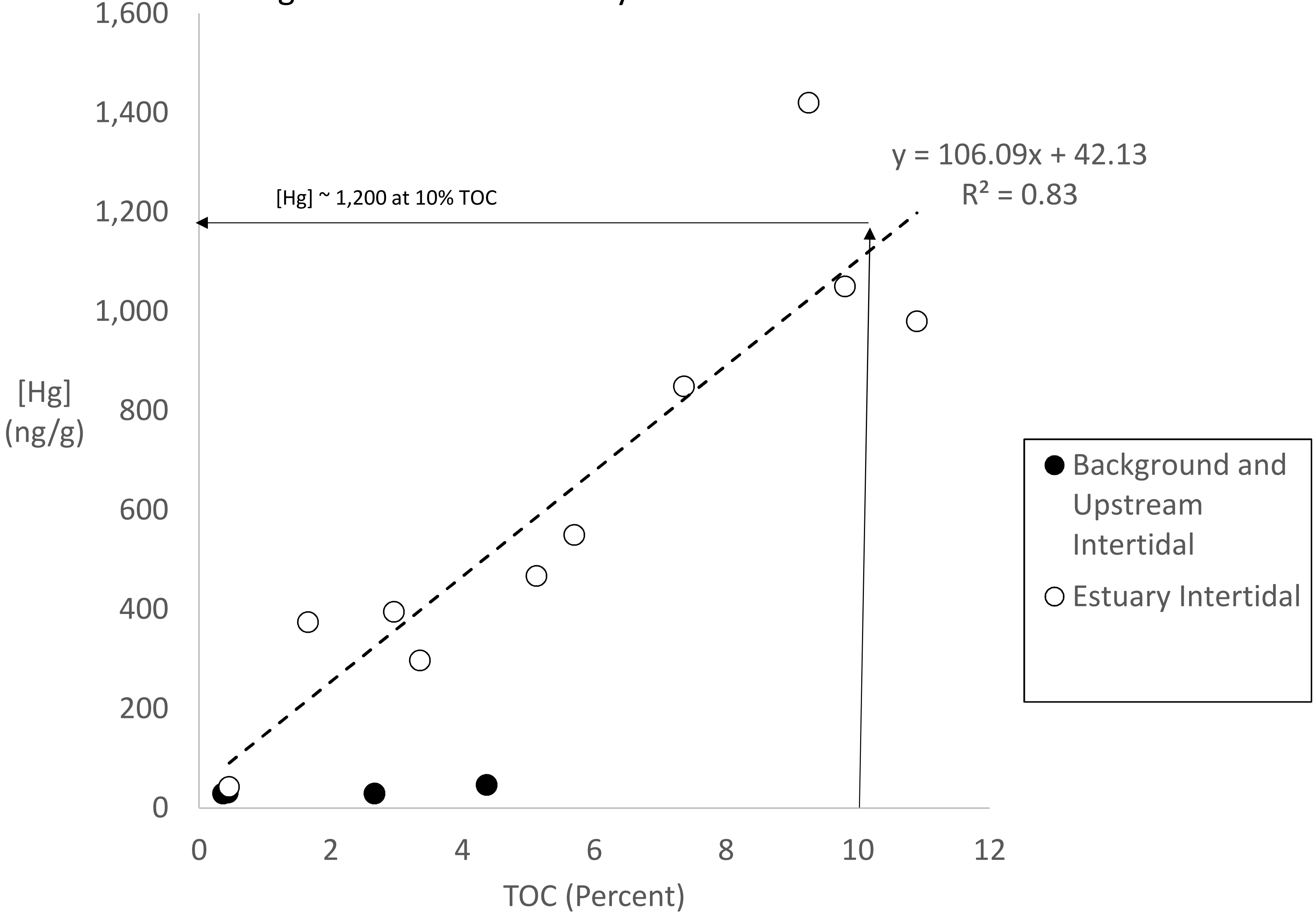


Figure 3-2. Total Mercury, Methylmercury, and Percent Methylmercury in Wetland Sediments

Figure 3-3. Total Mercury in Intertidal Sediments vs. TOC



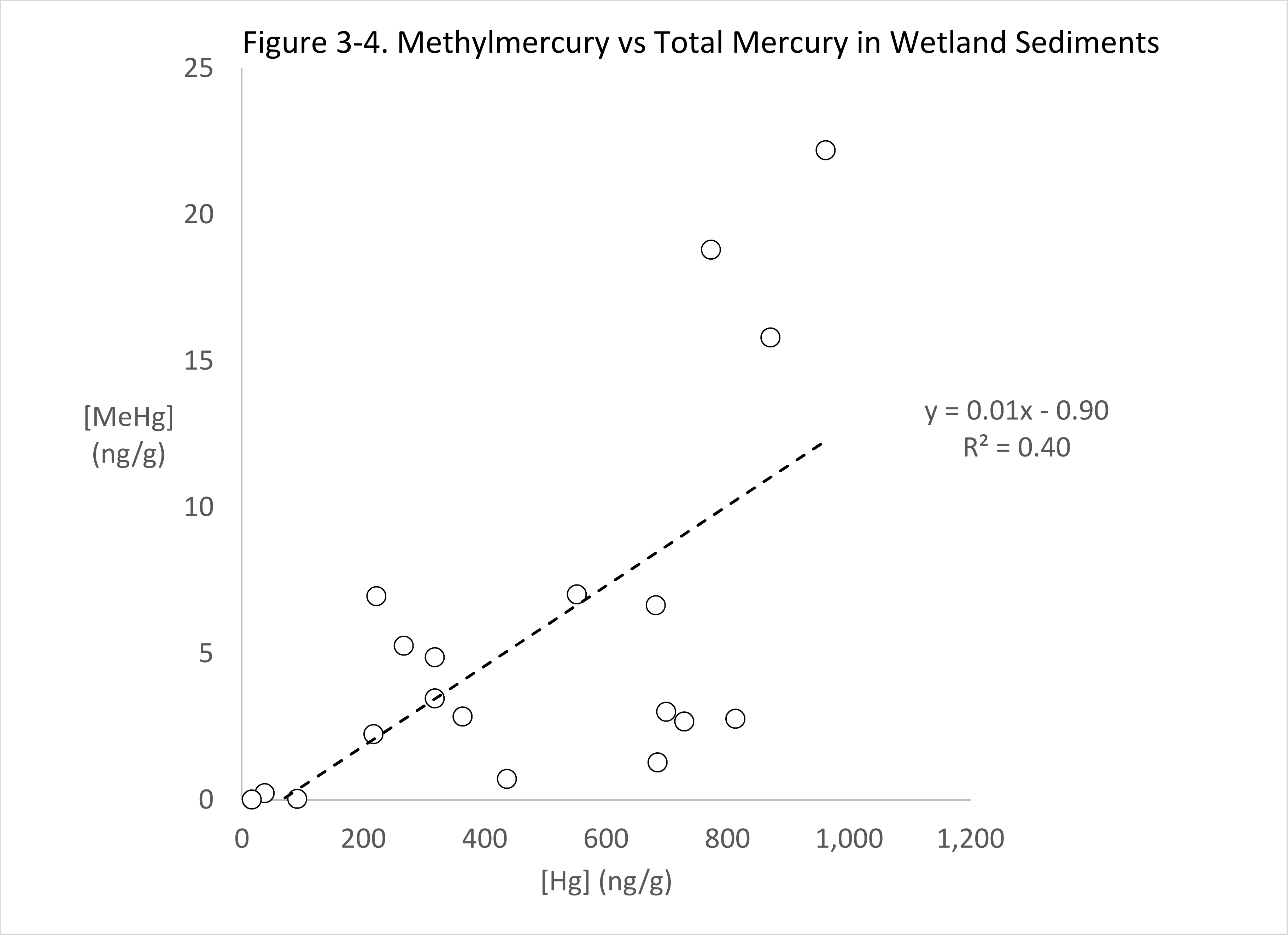


Figure 3-4. Methylmercury vs Total Mercury in Wetland Sediments

Figure 3-5 2016 Average Mercury Water Quality Monitoring Results by Location

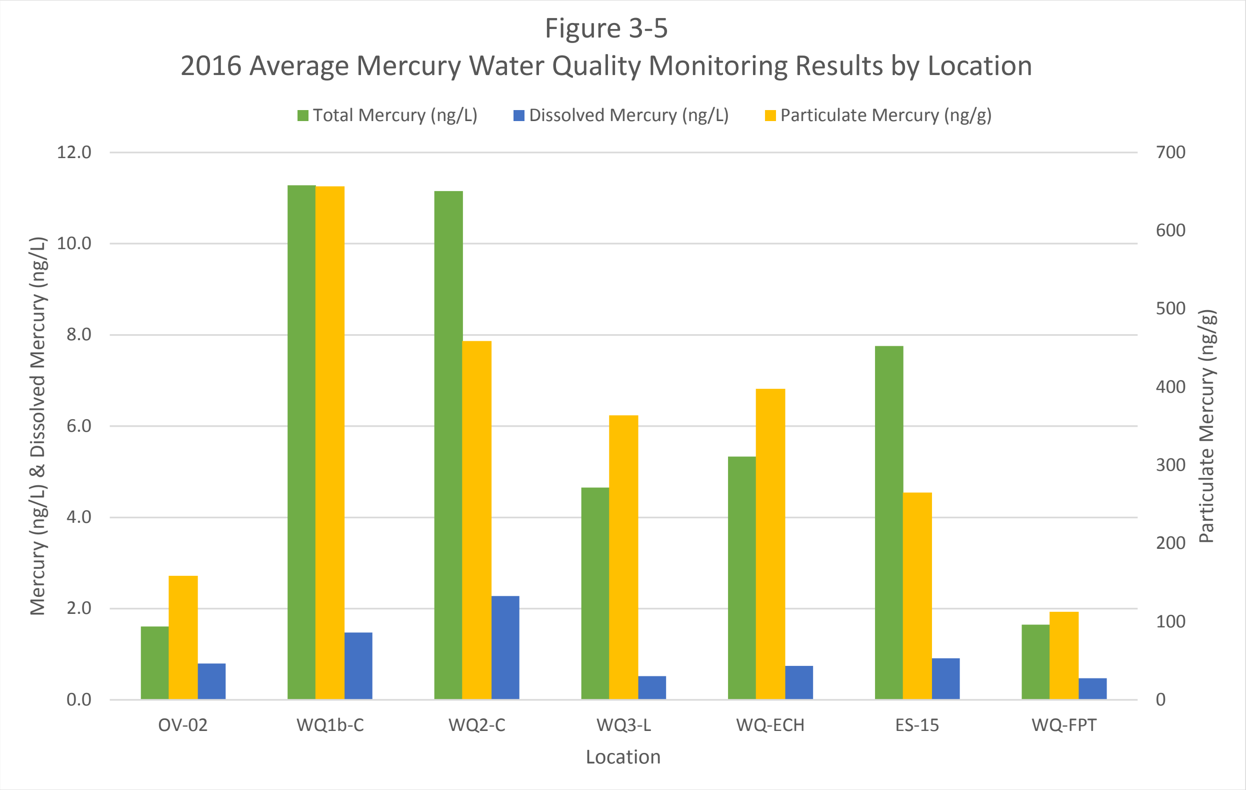
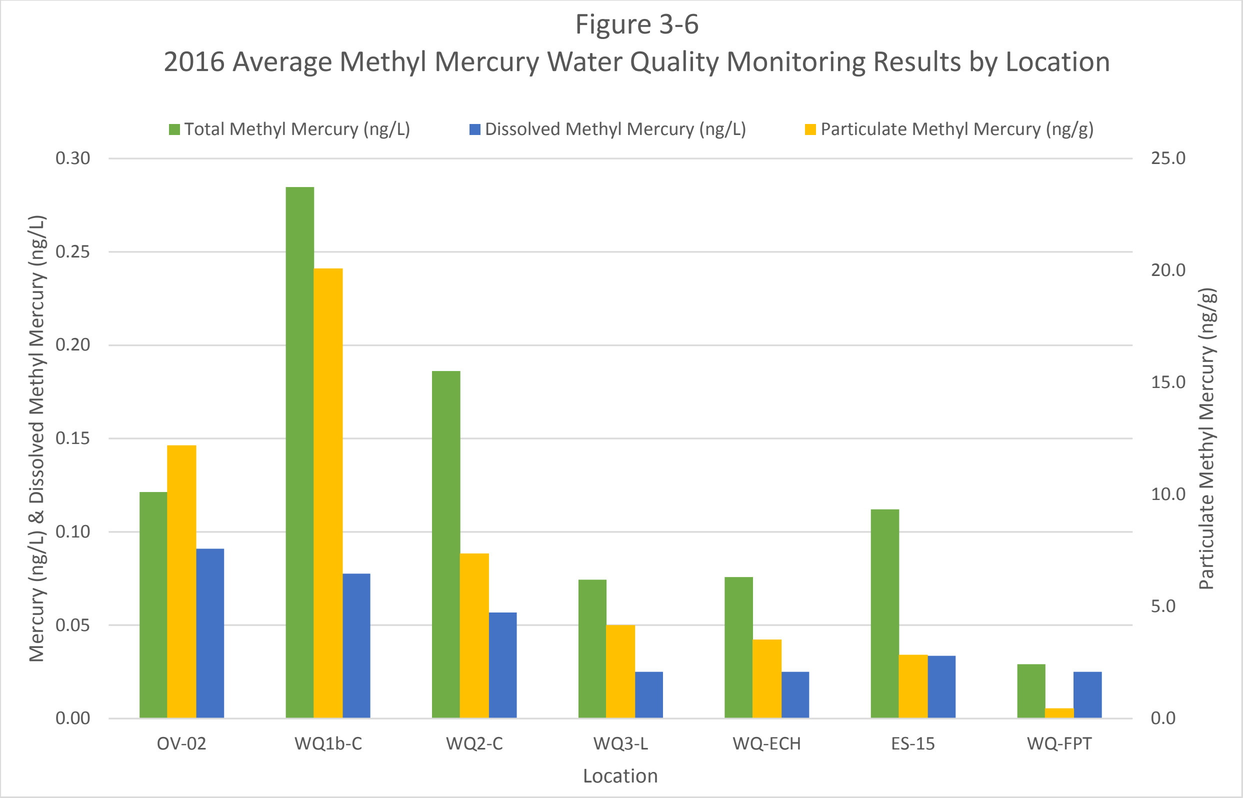


Figure 3-6 2016 Average Methyl Mercury Water Quality Monitoring Results by Location



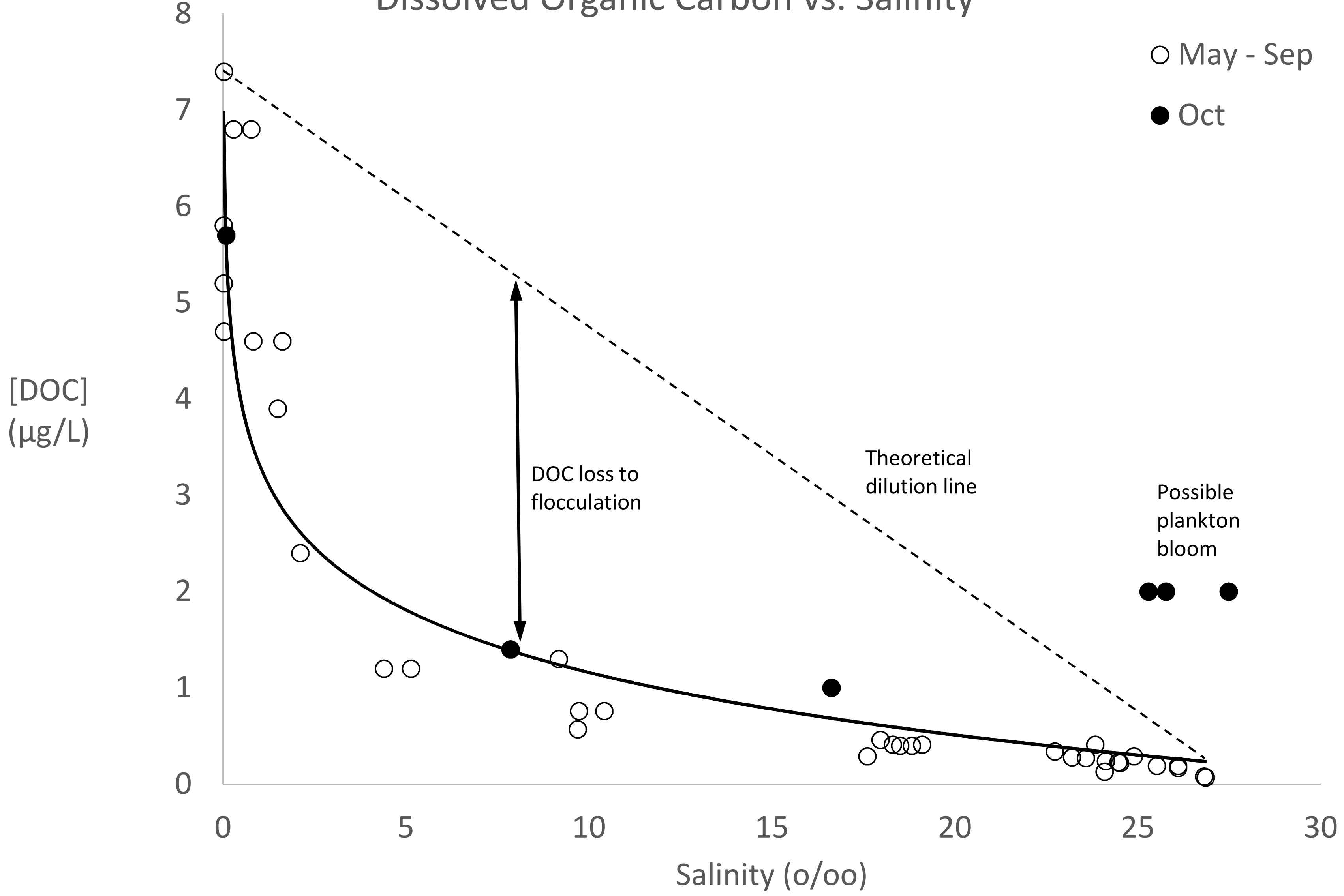


Figure 3-7
Dissolved Organic Carbon vs. Salinity

Figure 3-8. Filtered (Dissolved) Total Mercury in Water vs. Salinity

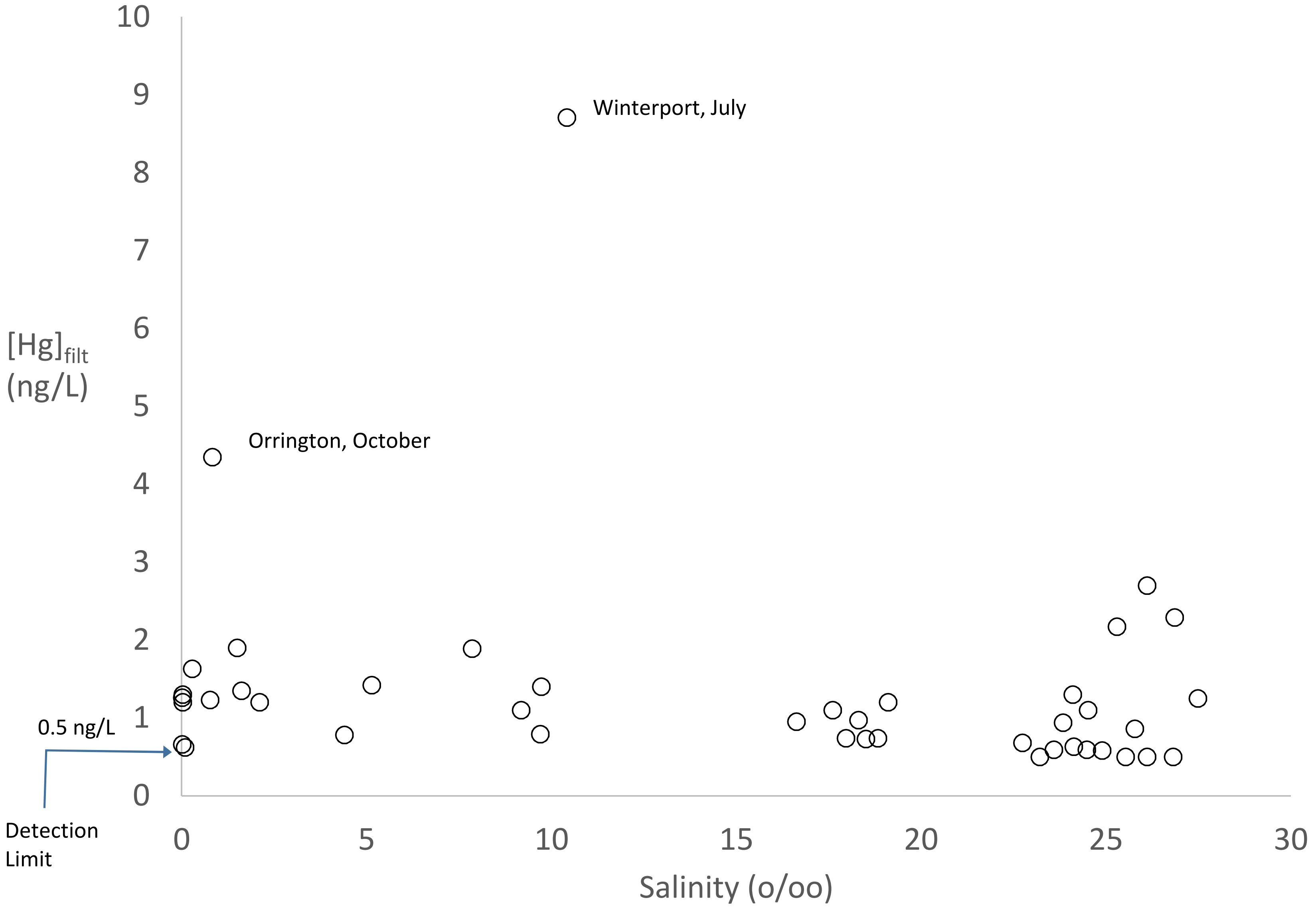


Figure 3-9 Unfiltered Total Mercury in Water vs. TSS

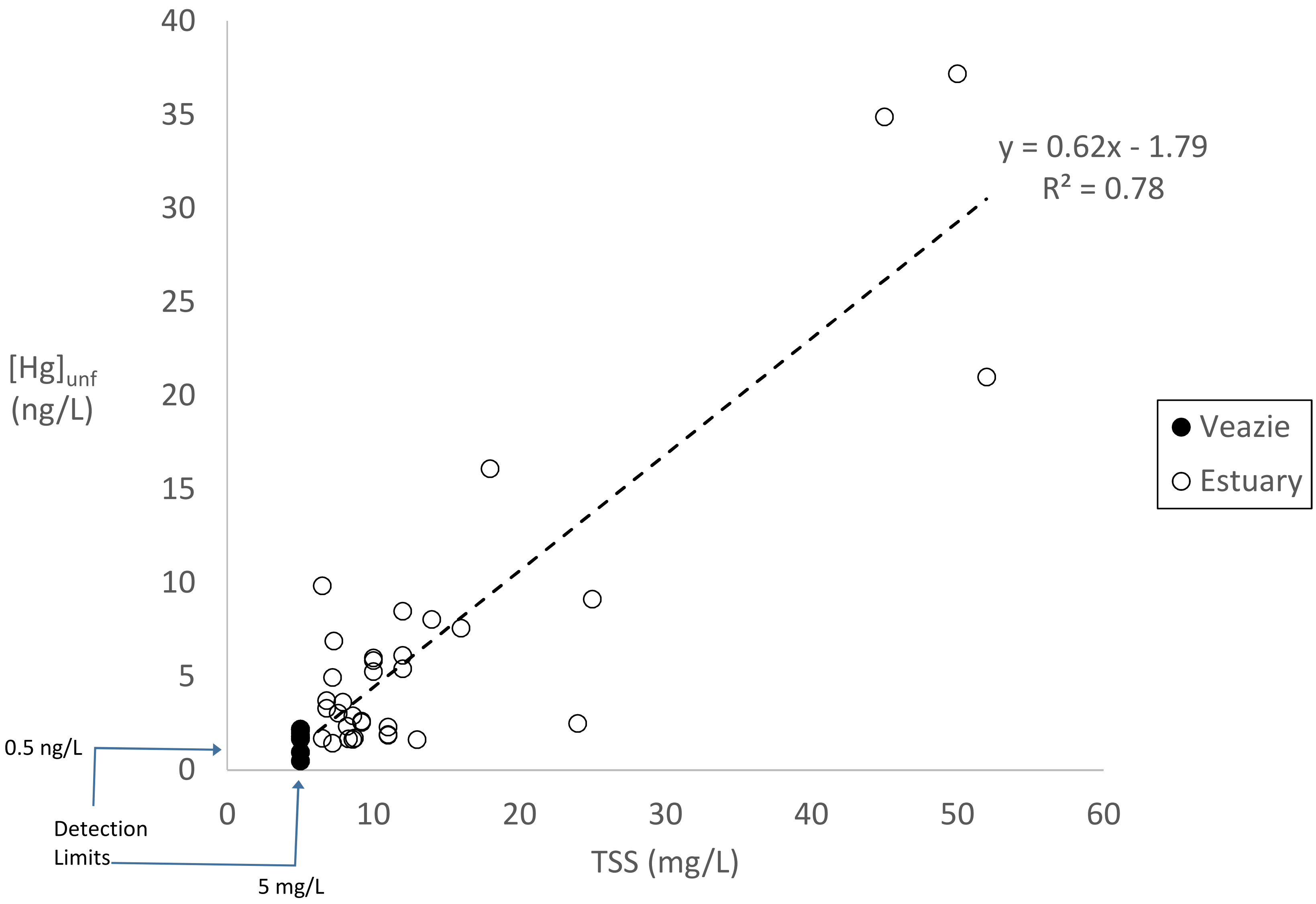


Figure 3-10
2016 River Discharge, Gage Height, and Turbidity

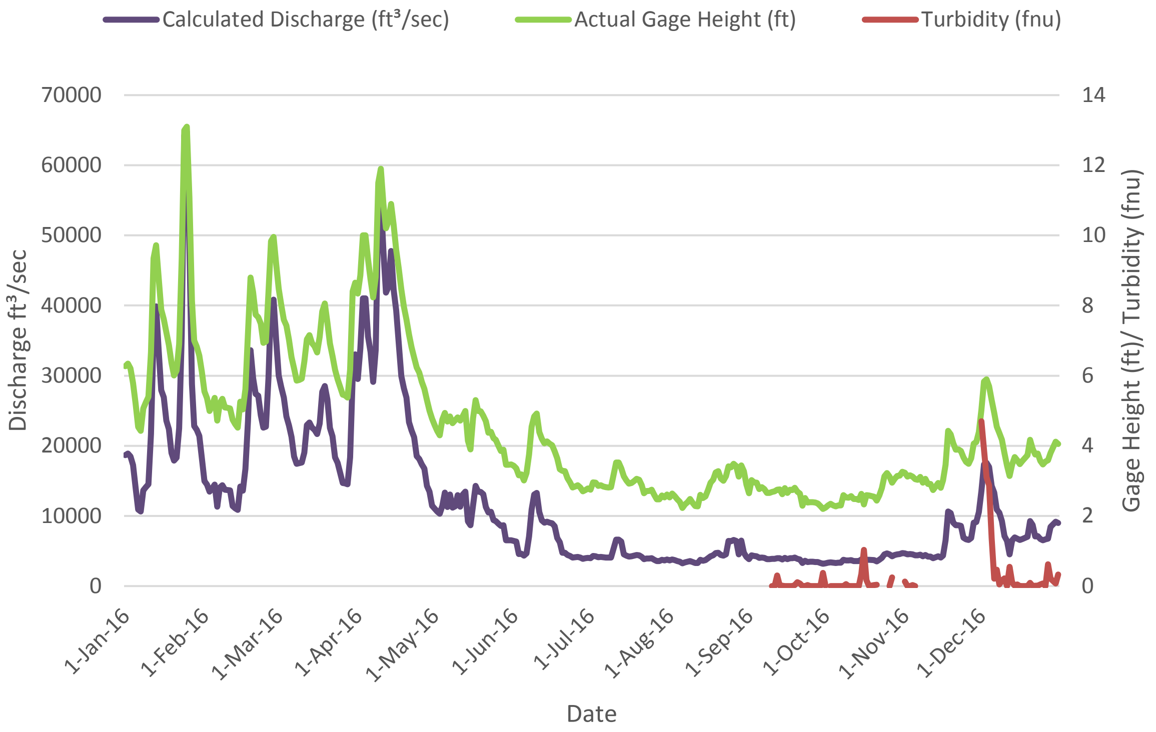
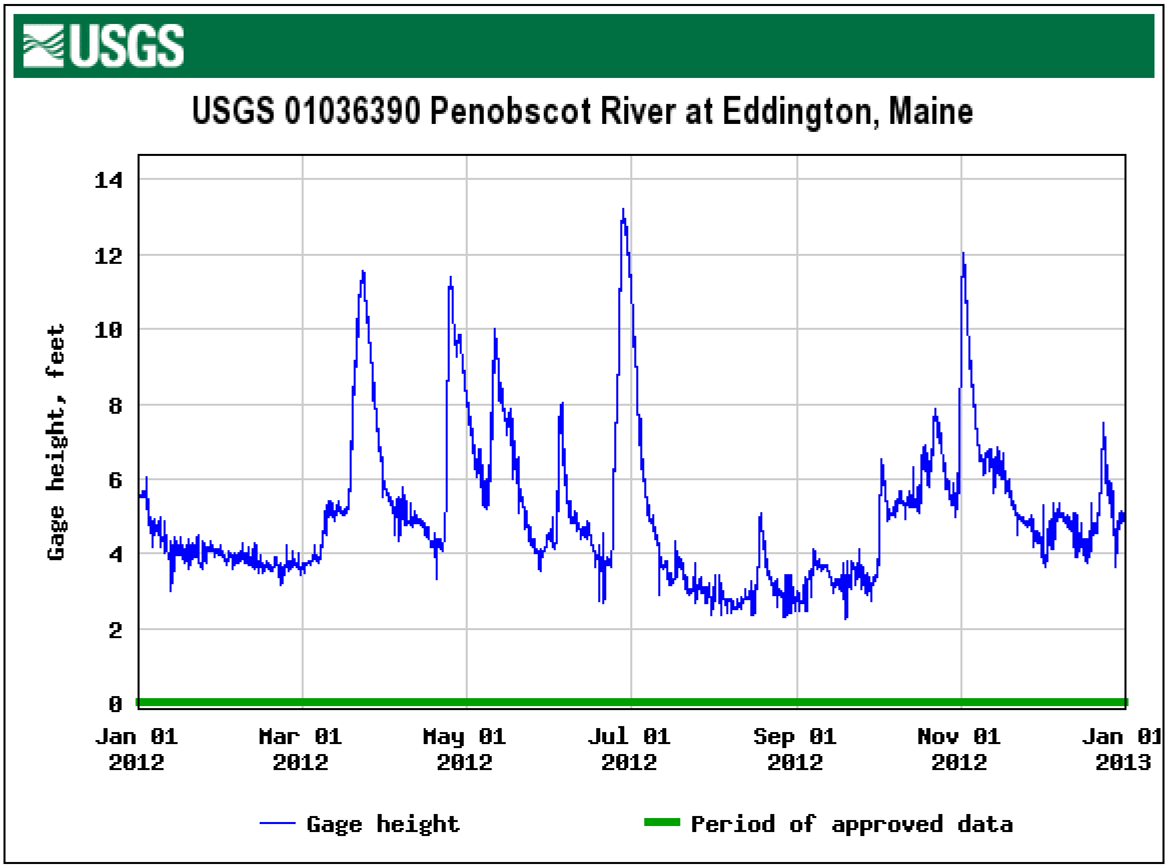


Figure 3-11
Comparison of 2012 vs. 2016 Penobscot River Gage Height



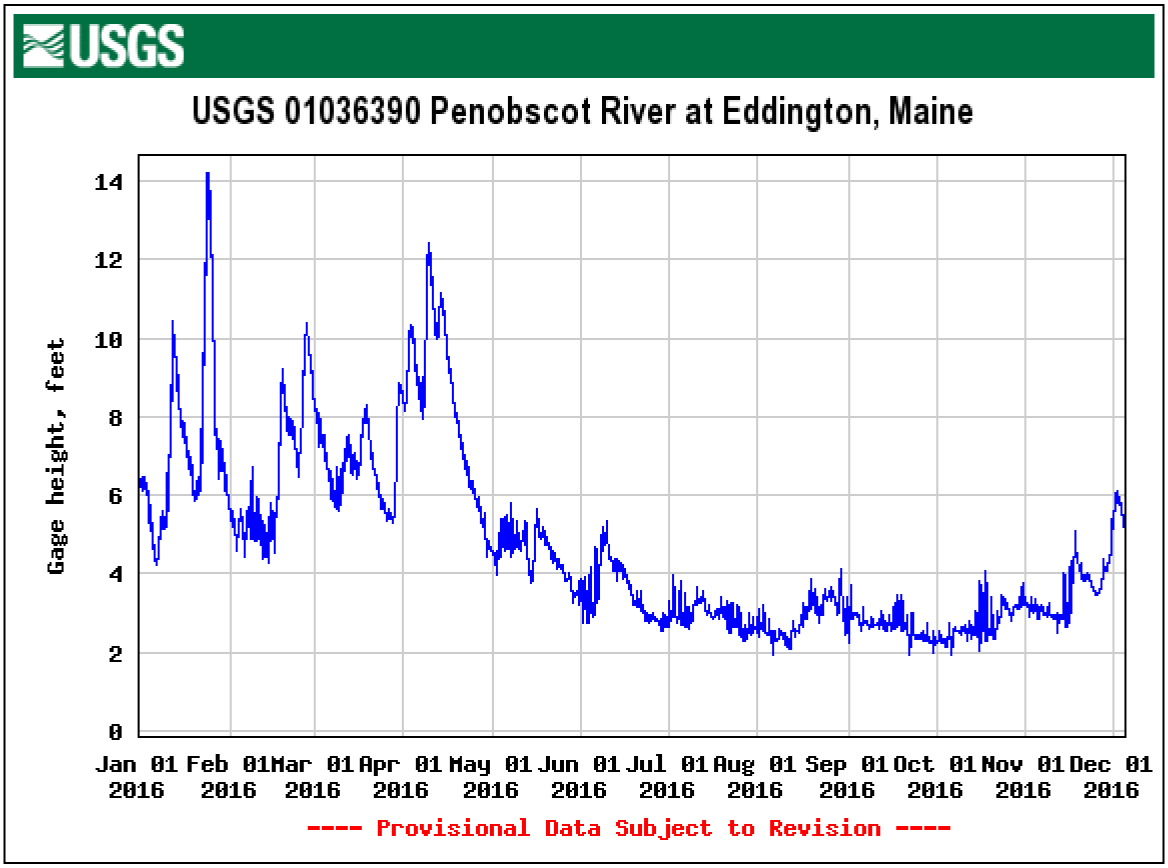
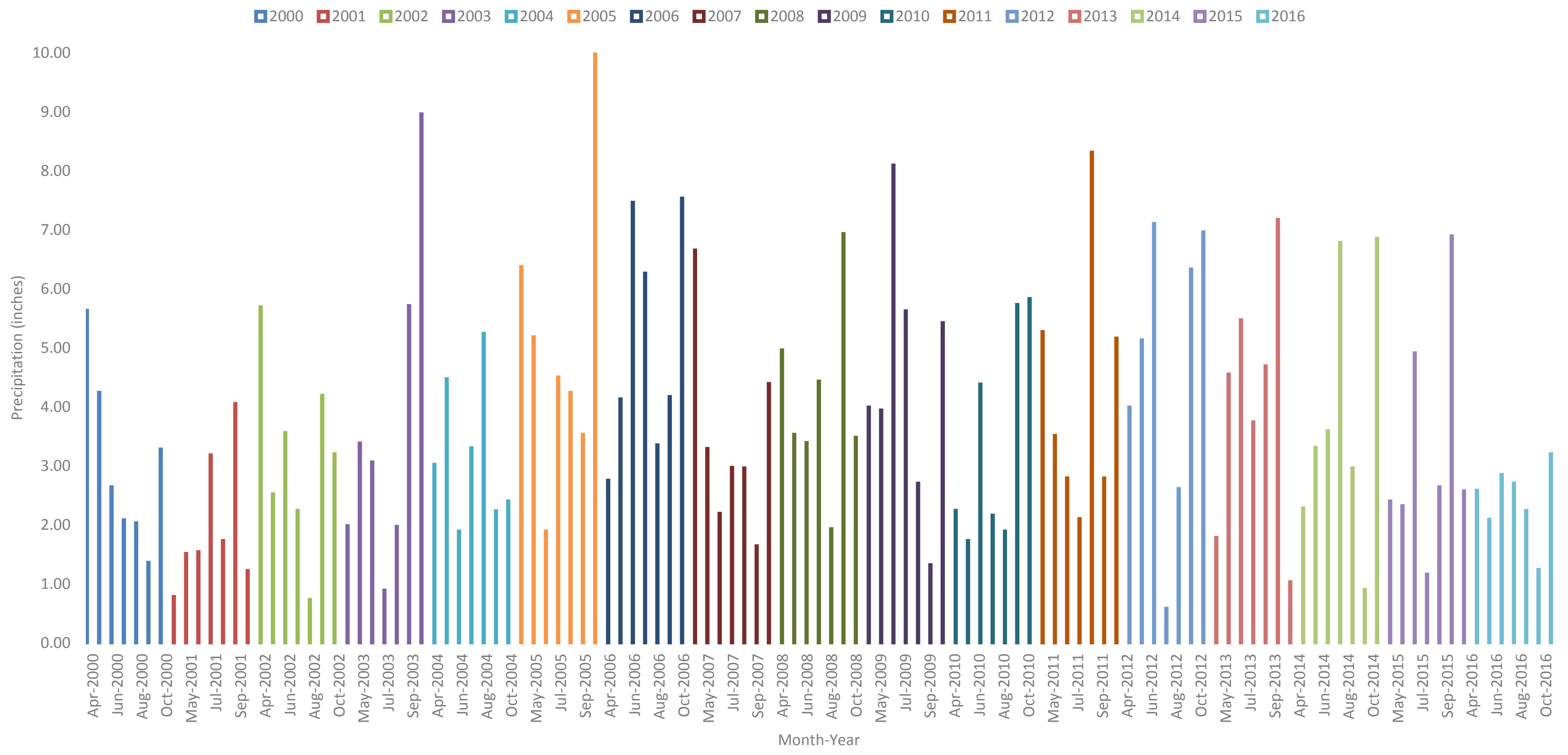


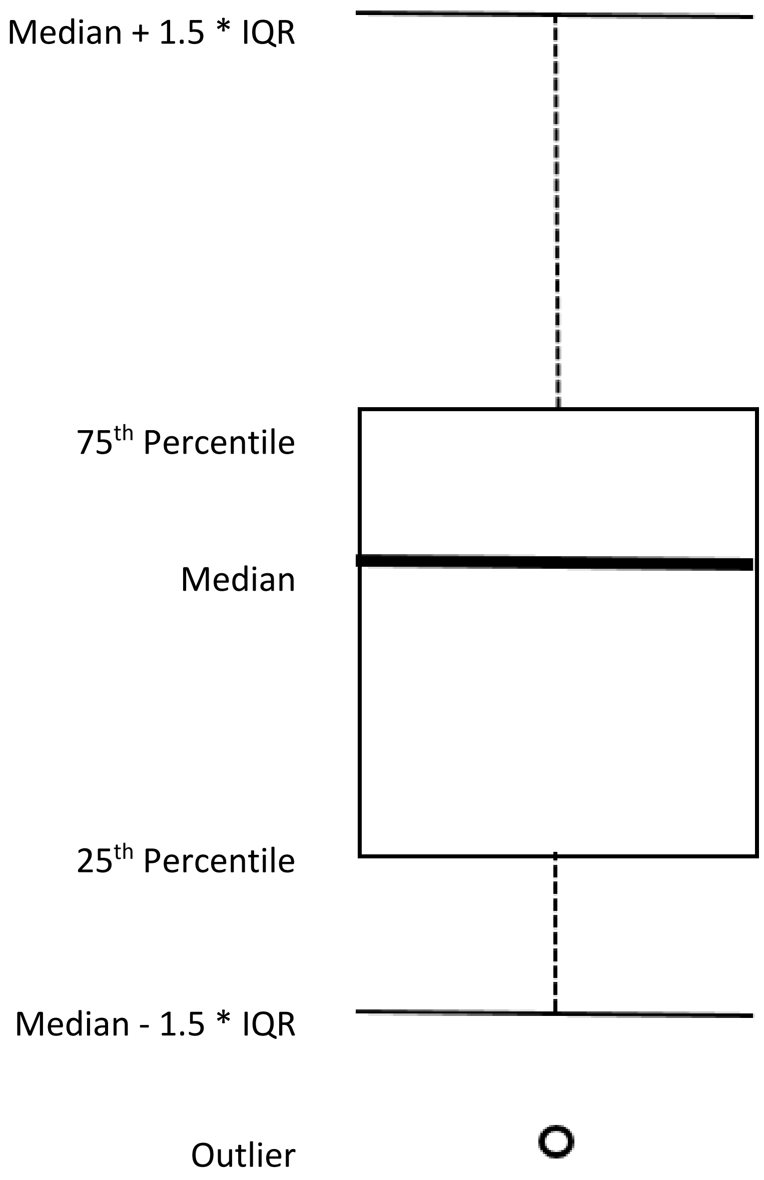
Figure 3-12

2000-2016 April through October Precipitation Record – Bangor, Maine



Section 4.1 Figures

Legend Description



IQR = interquartile range (which is 75 percentile - 25 percentile)

Figure 4.1-1

Subtidal Sediment Mercury by River Reach

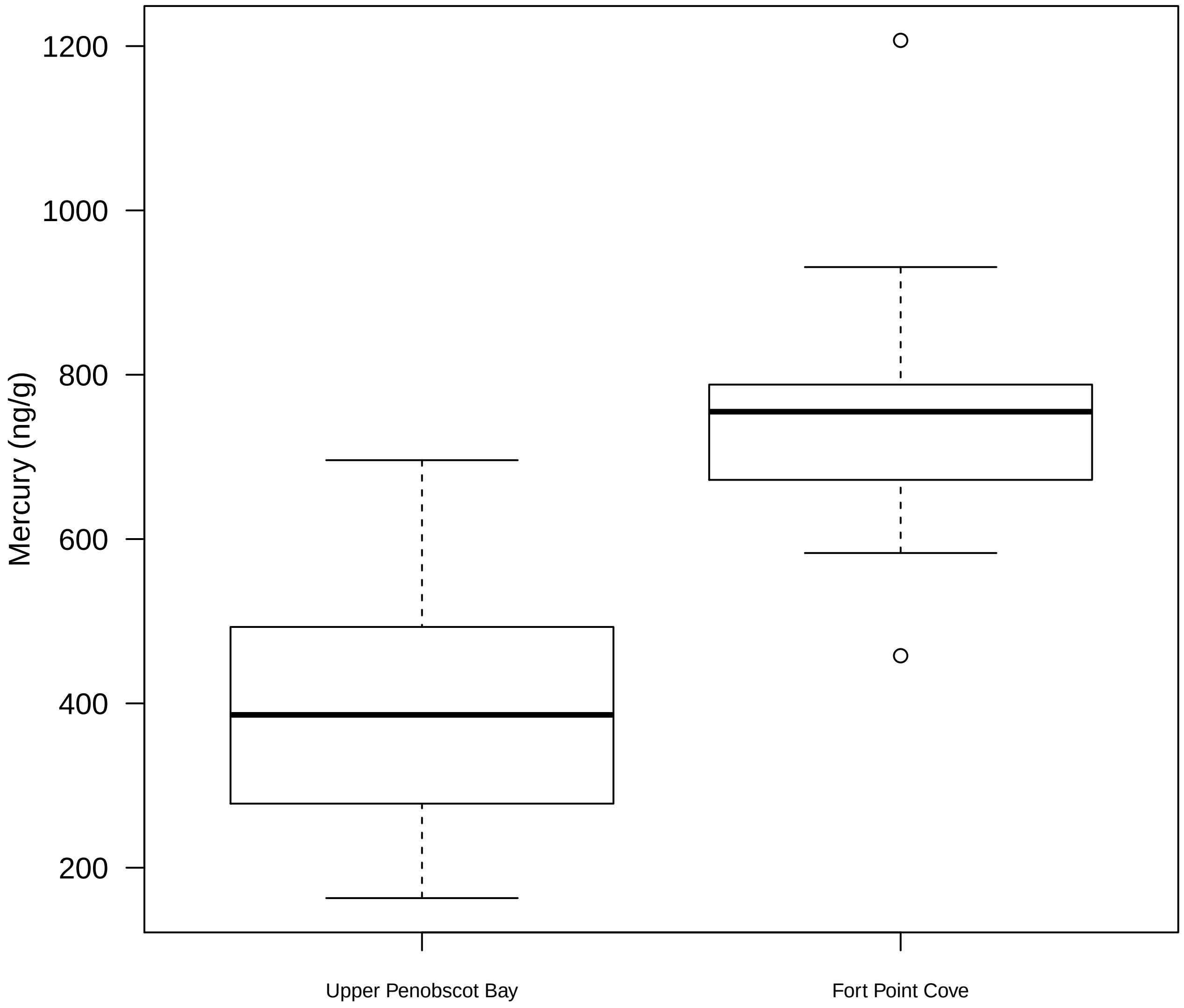


Figure 4.1-2

Subtidal Sediment Mercury by Sample Location

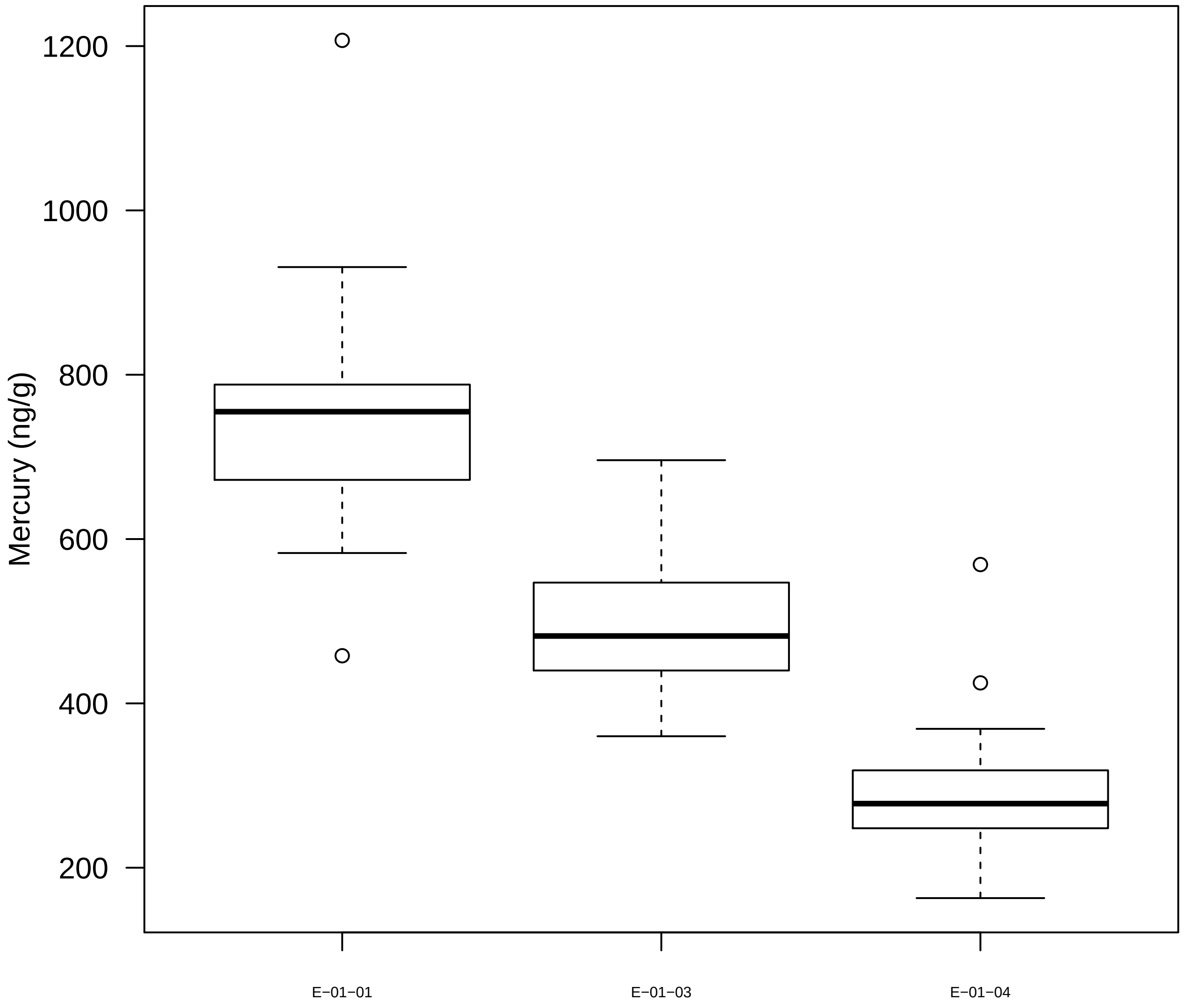


Figure 4.1-3

Subtidal Sediment Methyl Mercury by River Reach

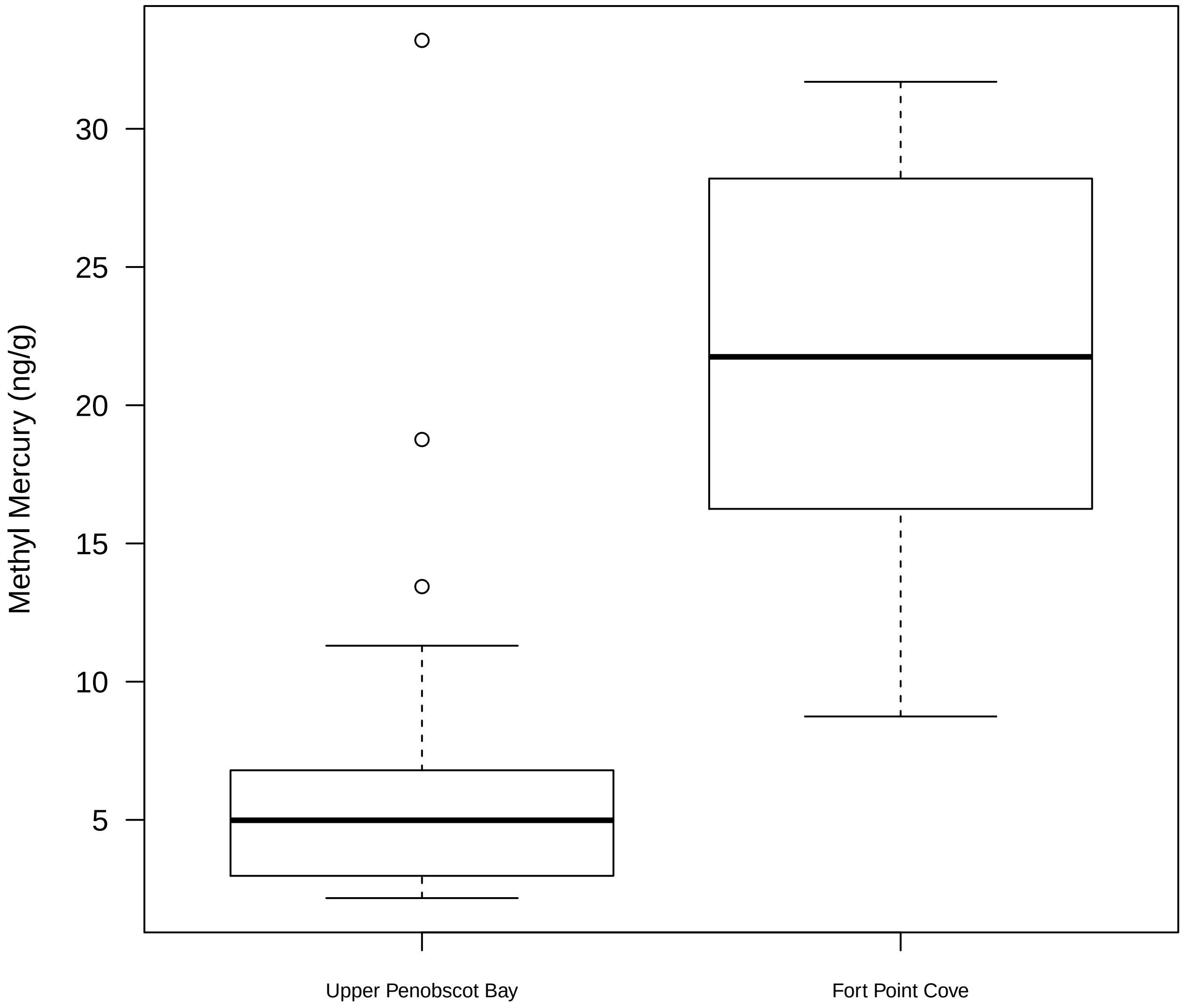


Figure 4.1-4

Subtidal Sediment Methyl Mercury by Sample Location

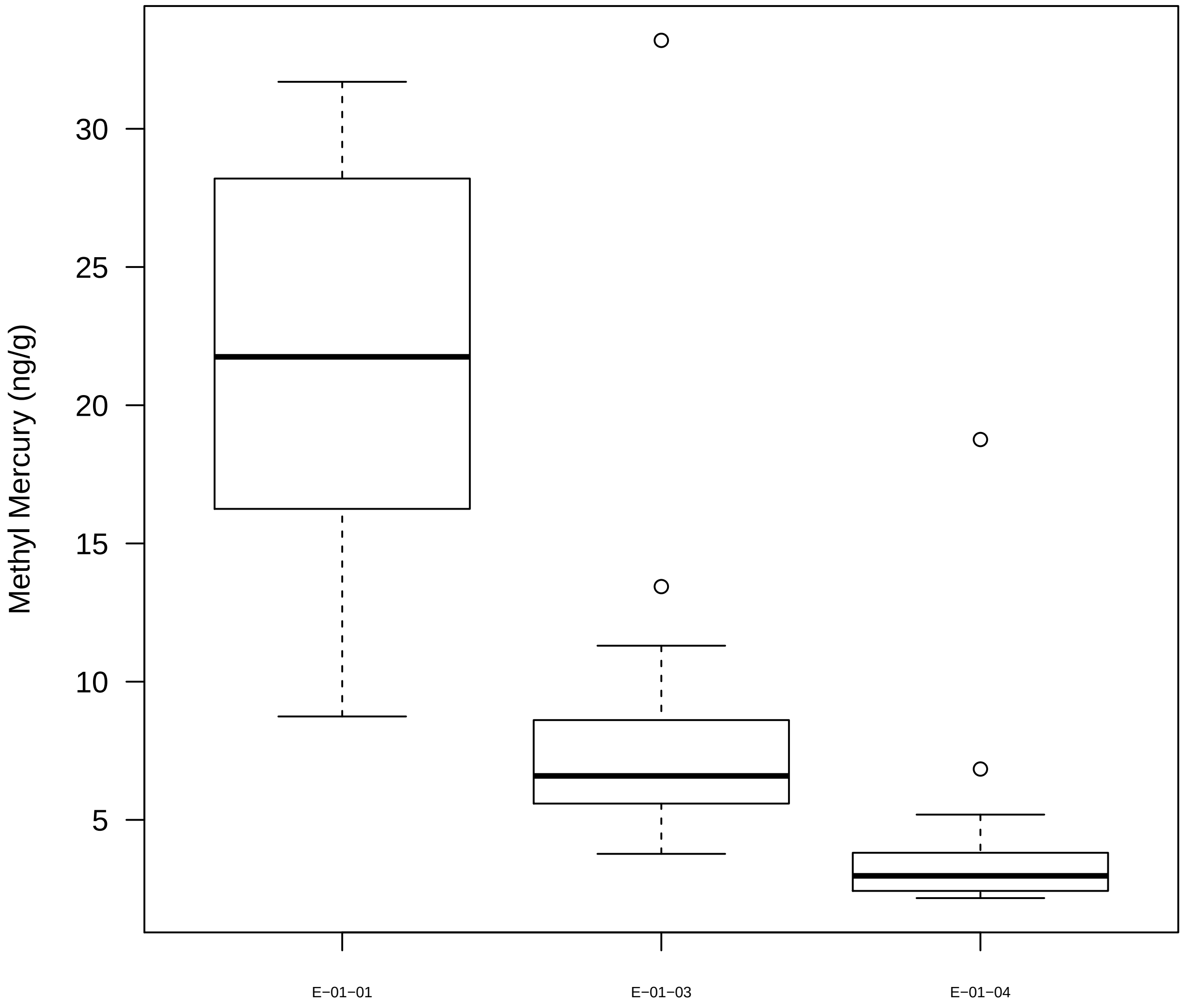


Figure 4.1-5

Subtidal Sediment Total Organic Carbon by River Reach

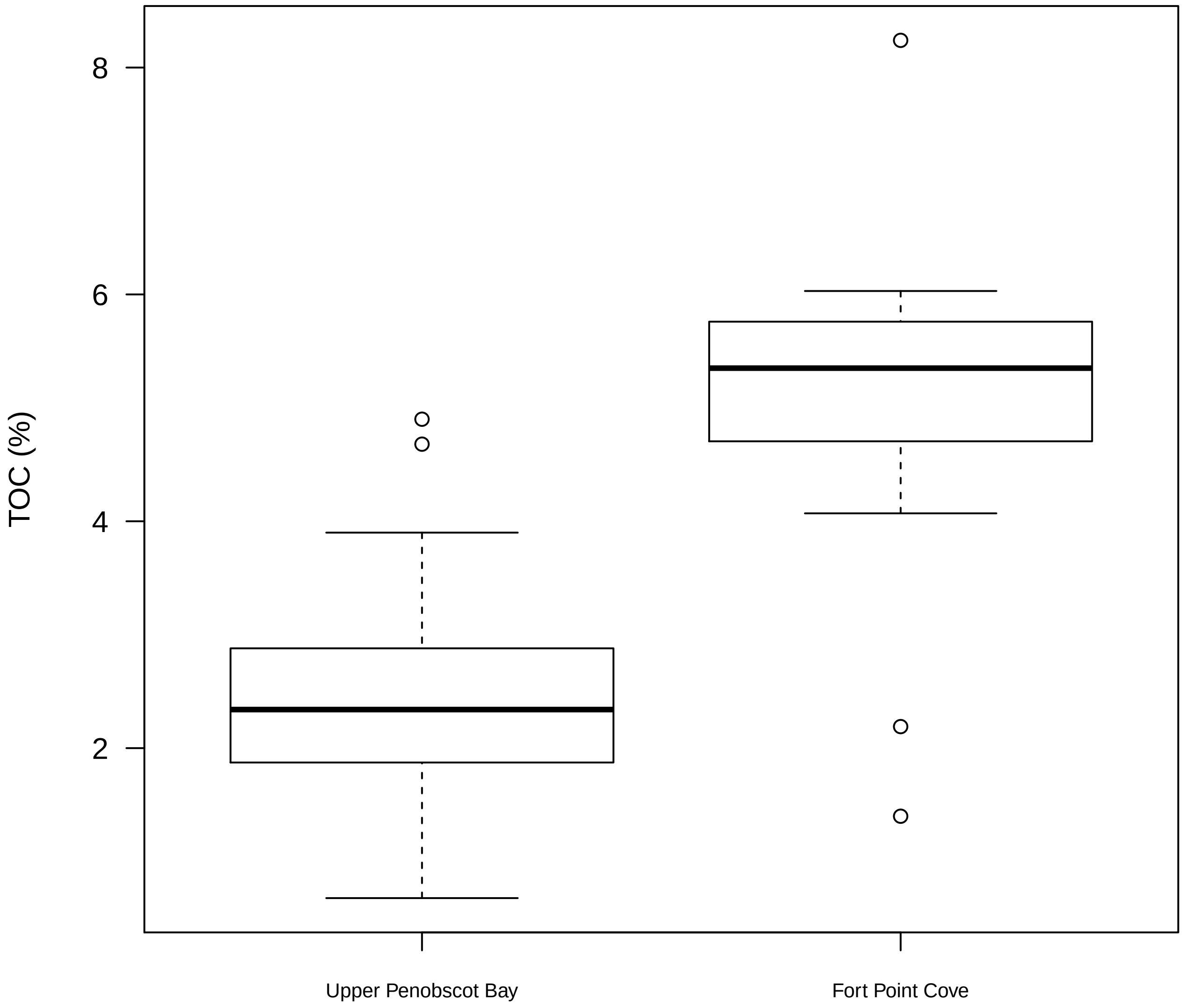


Figure 4.1-6

Subtidal Sediment Total Organic Carbon by Sample Location

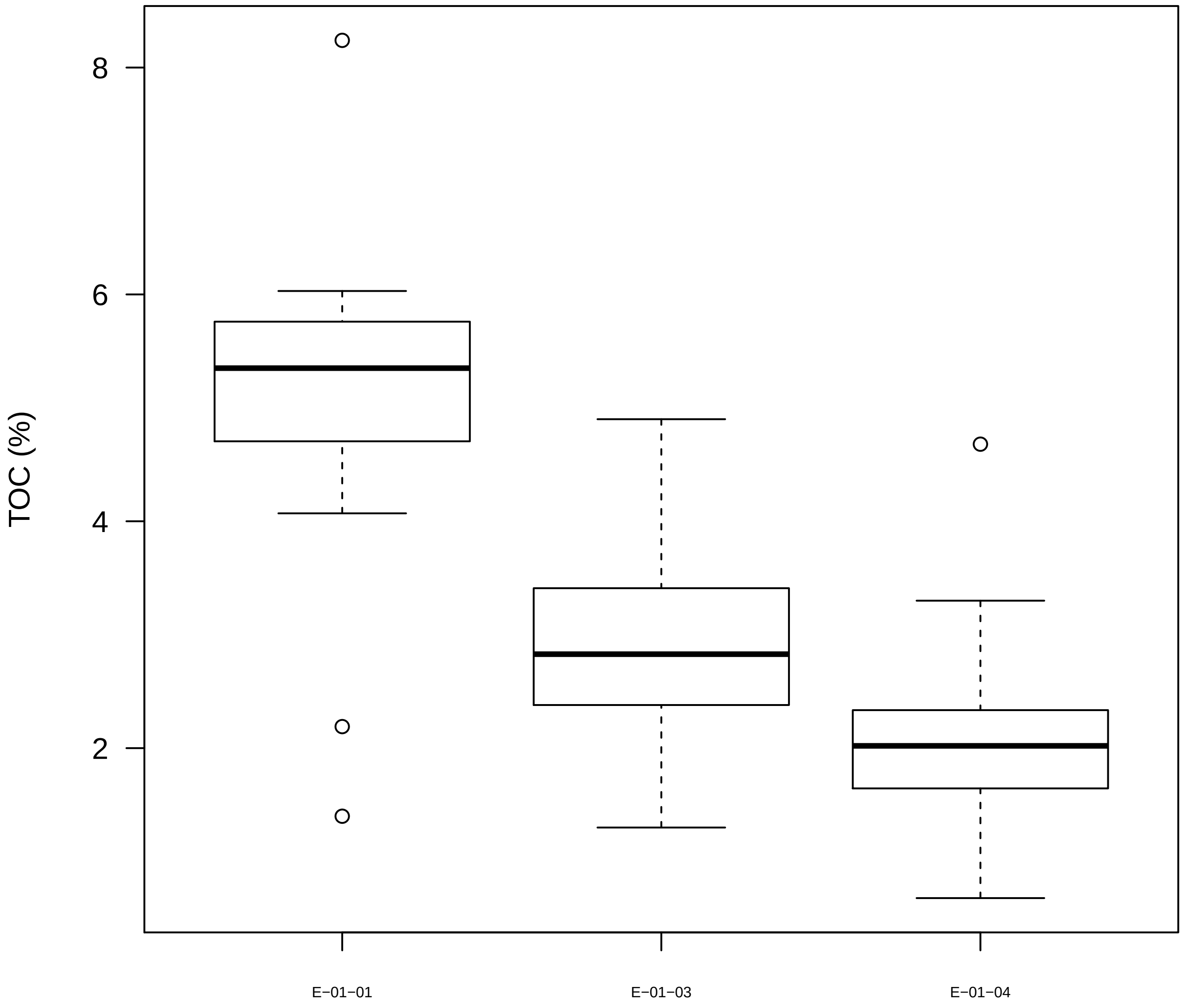


Figure 4.1-7

Temporal Subtidal Sediment Mercury

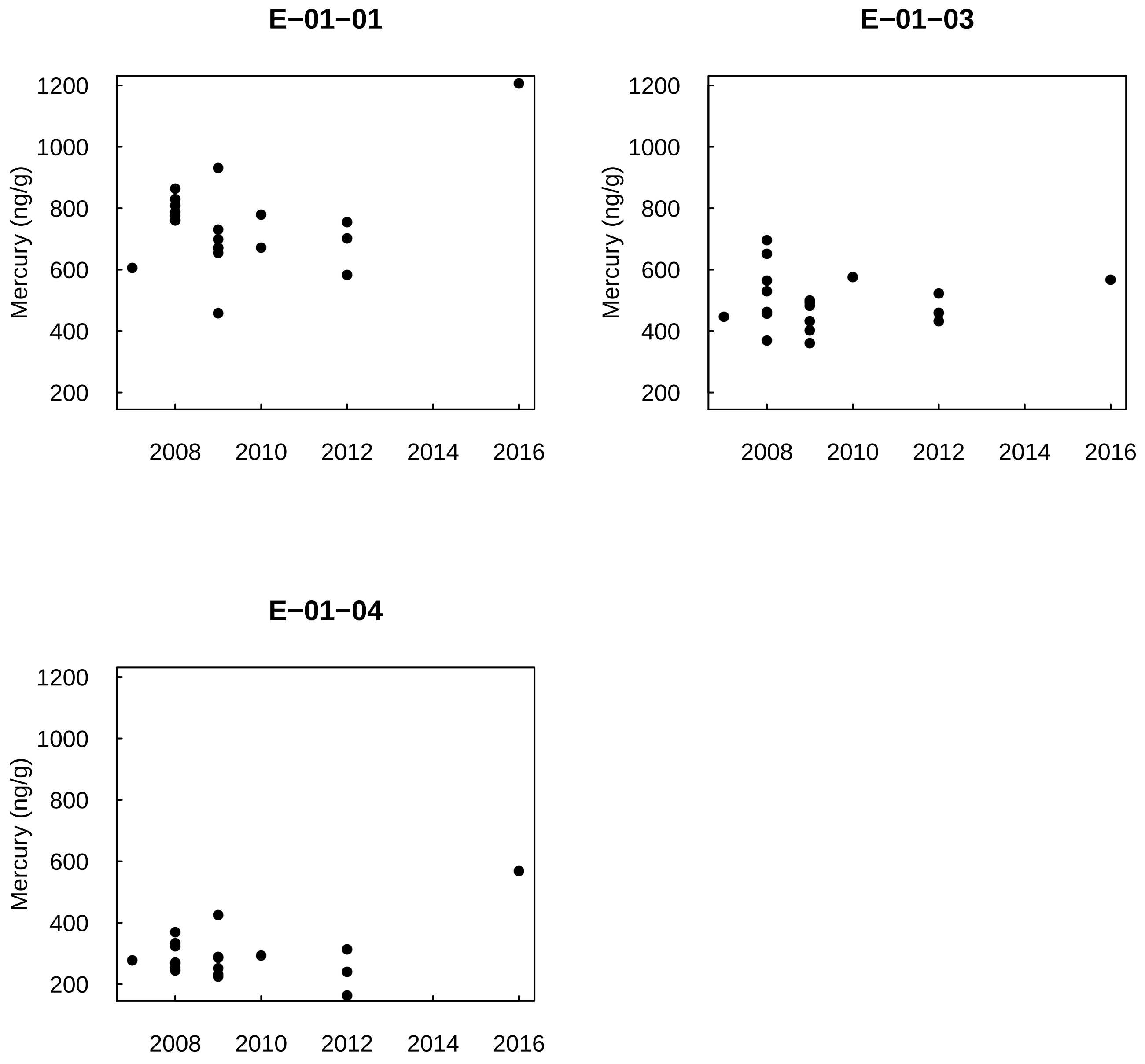
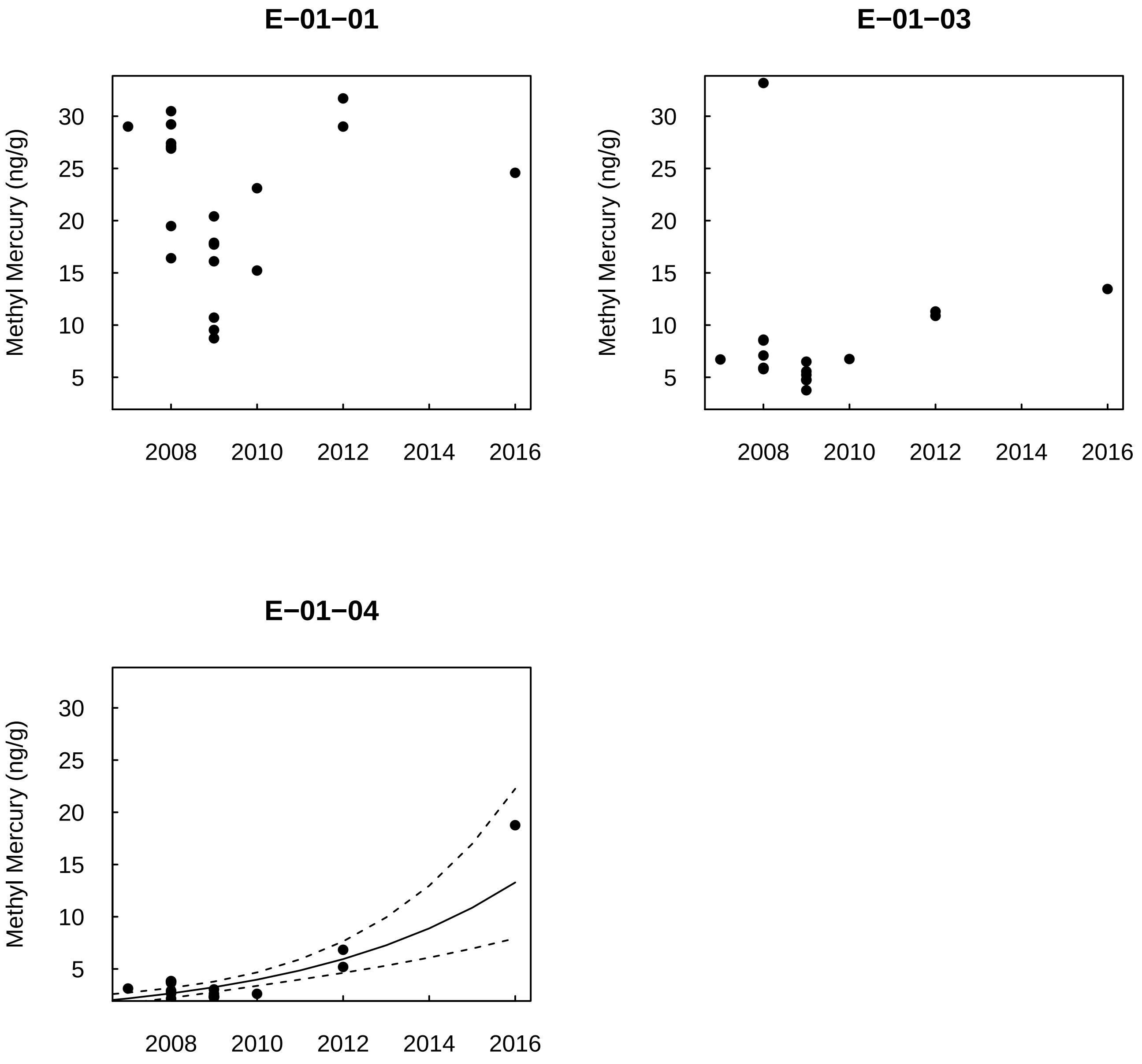


Figure 4.1-8

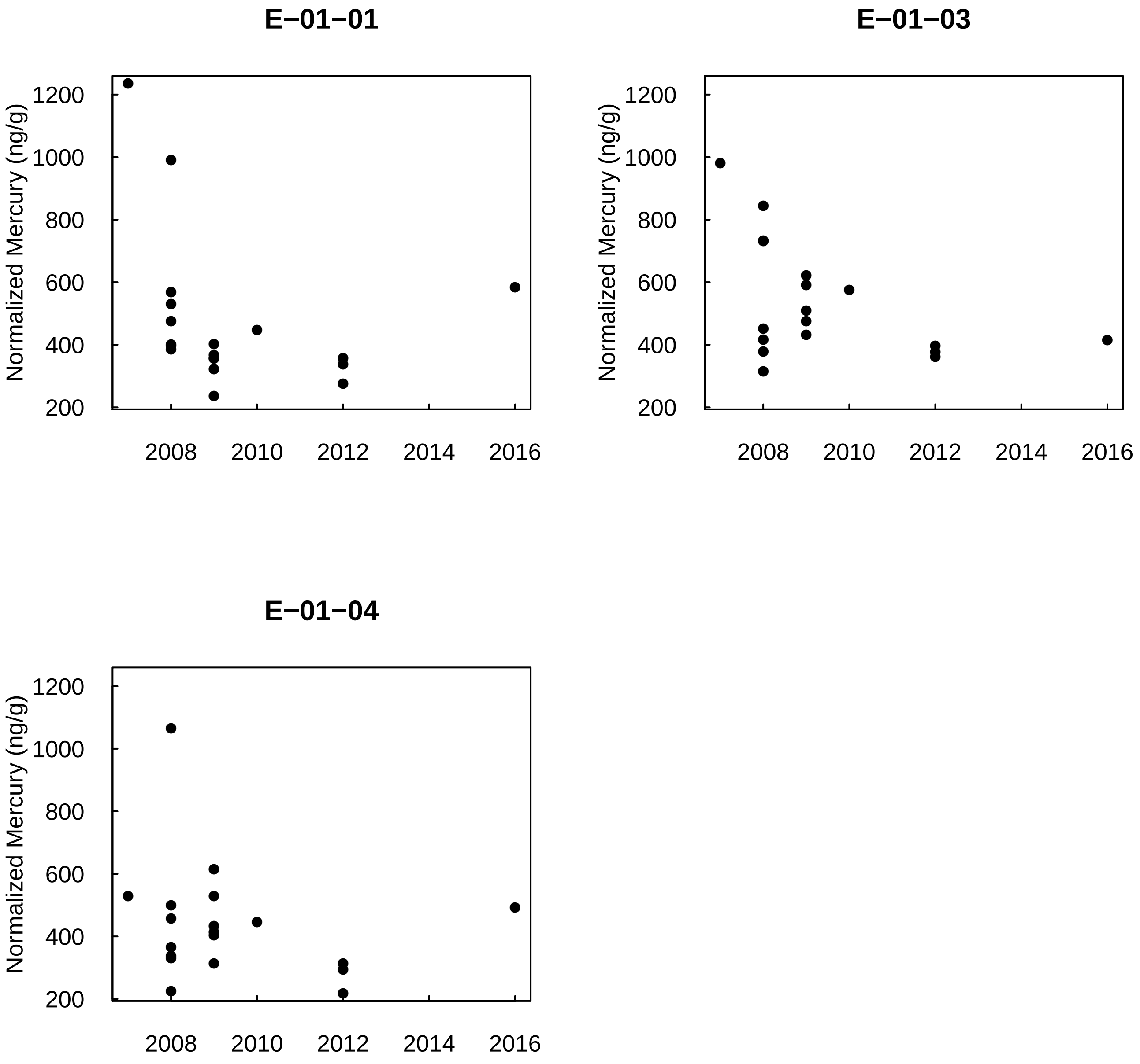
Temporal Subtidal Sediment Methyl Mercury



Line indicates regression slope is significantly different than 0 (p<0.05). Dashed lines indicate 95% confidence interval of regression.
Regressions performed on log−transfmormed data, but data are presented un−transformed for clarity.

Figure 4.1-9

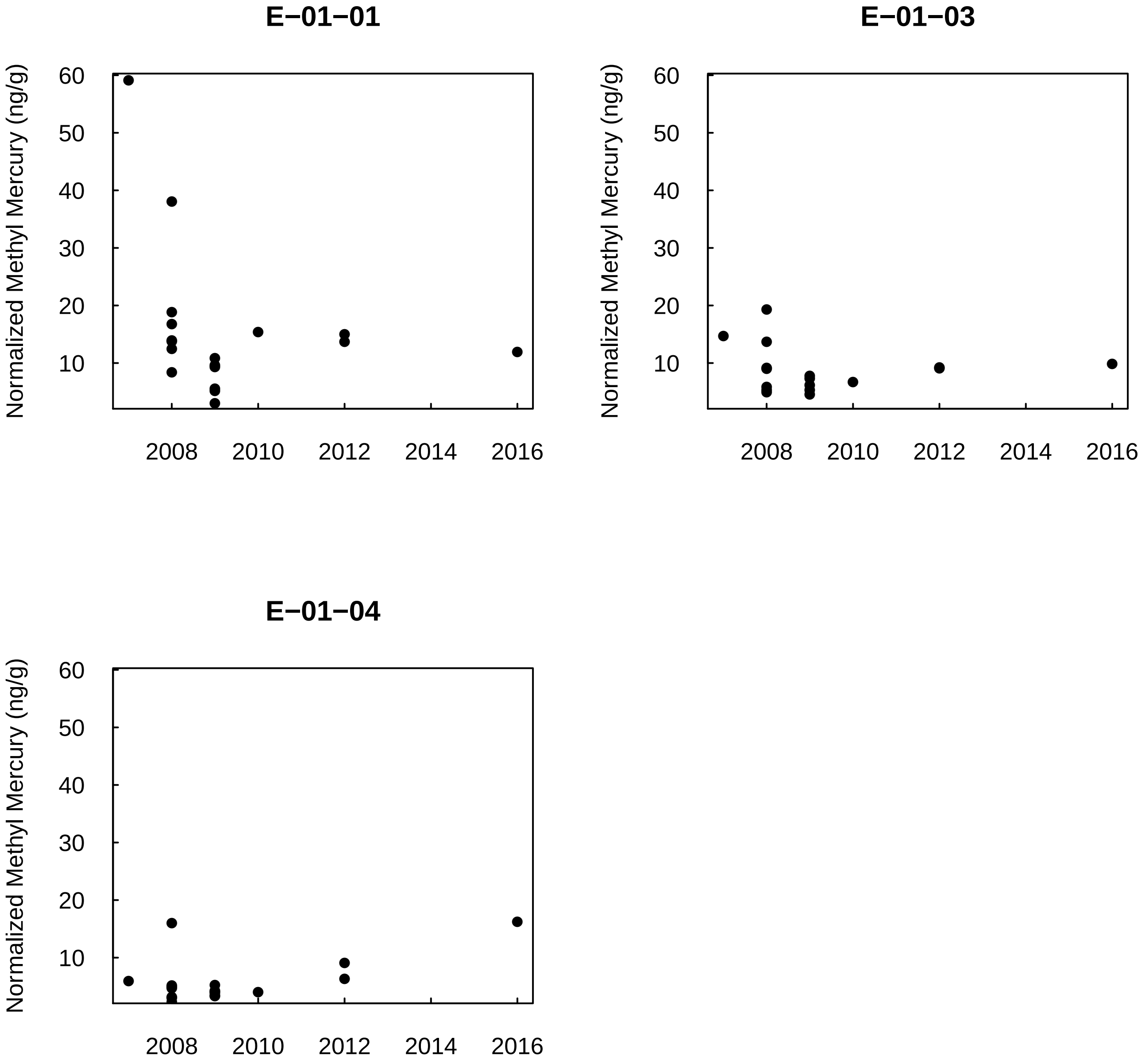
Temporal Subtidal Sediment Normalized Mercury



Line indicates regression slope is significantly different than 0 ($p<0.05$). Dashed lines indicate 95% confidence interval of regression.
Regressions performed on log−transfmormed data, but data are presented un−transformed for clarity.

Figure 4.1-10

Temporal Subtidal Sediment Normalized Methyl Mercury



Line indicates regression slope is significantly different than 0 (p<0.05). Dashed lines indicate 95% confidence interval of regression.
Regressions performed on log−transfmormed data, but data are presented un−transformed for clarity.

Figure 4.1-11

Intertidal Sediment Mercury by River Reach

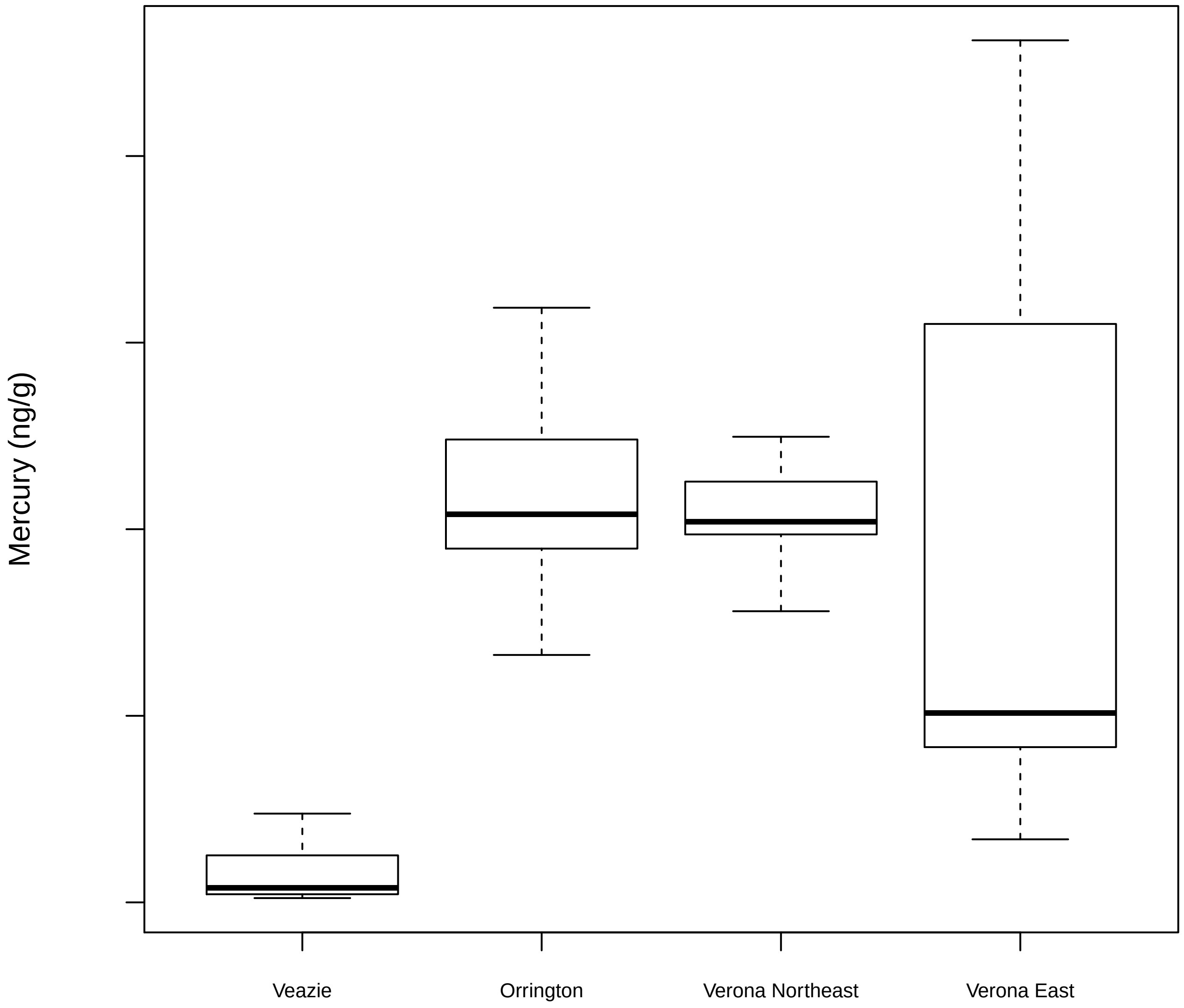


Figure 4.1-12

Intertidal Sediment Mercury by Sample Location

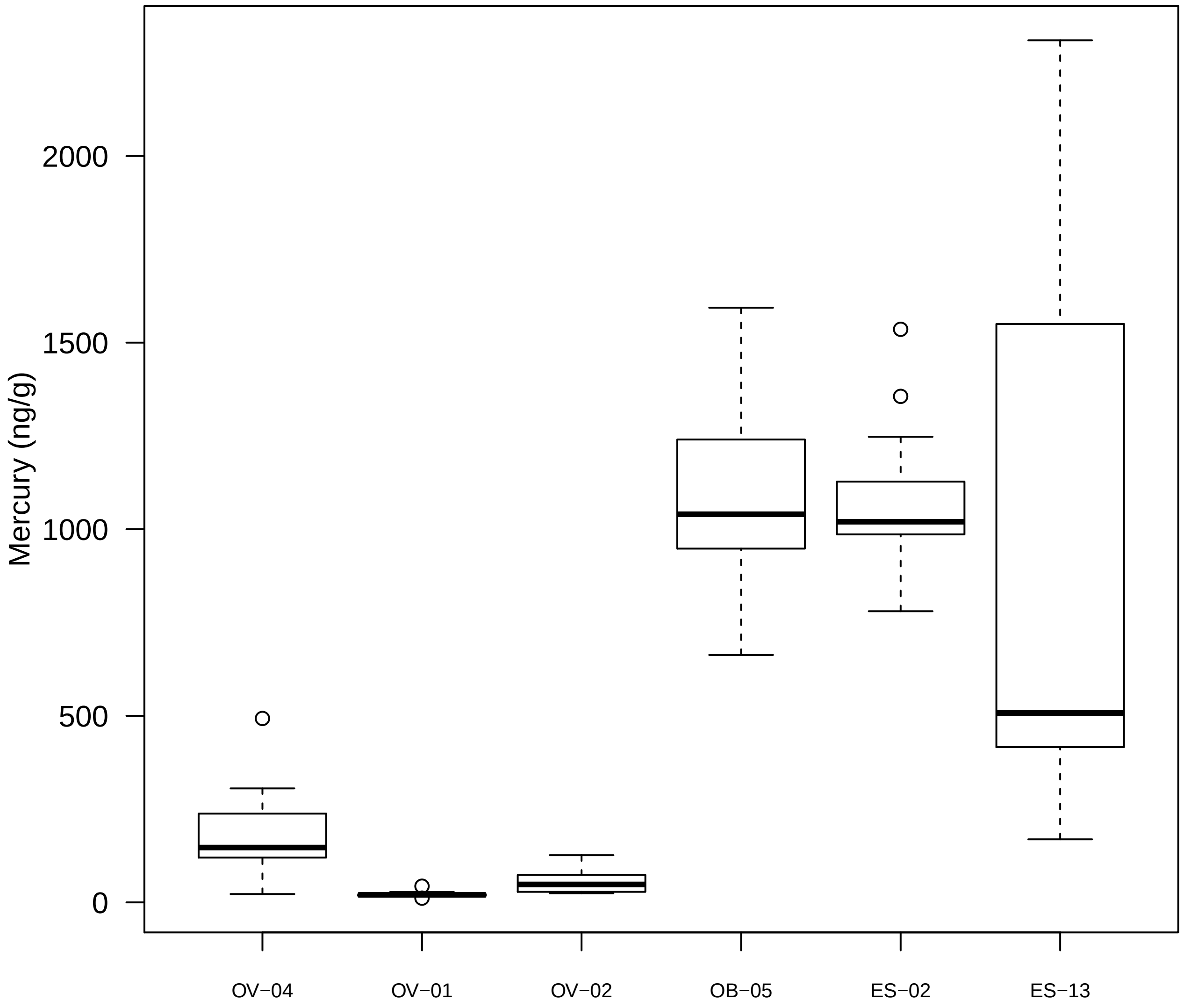


Figure 4.1-13

Intertidal Sediment Methyl Mercury by River Reach

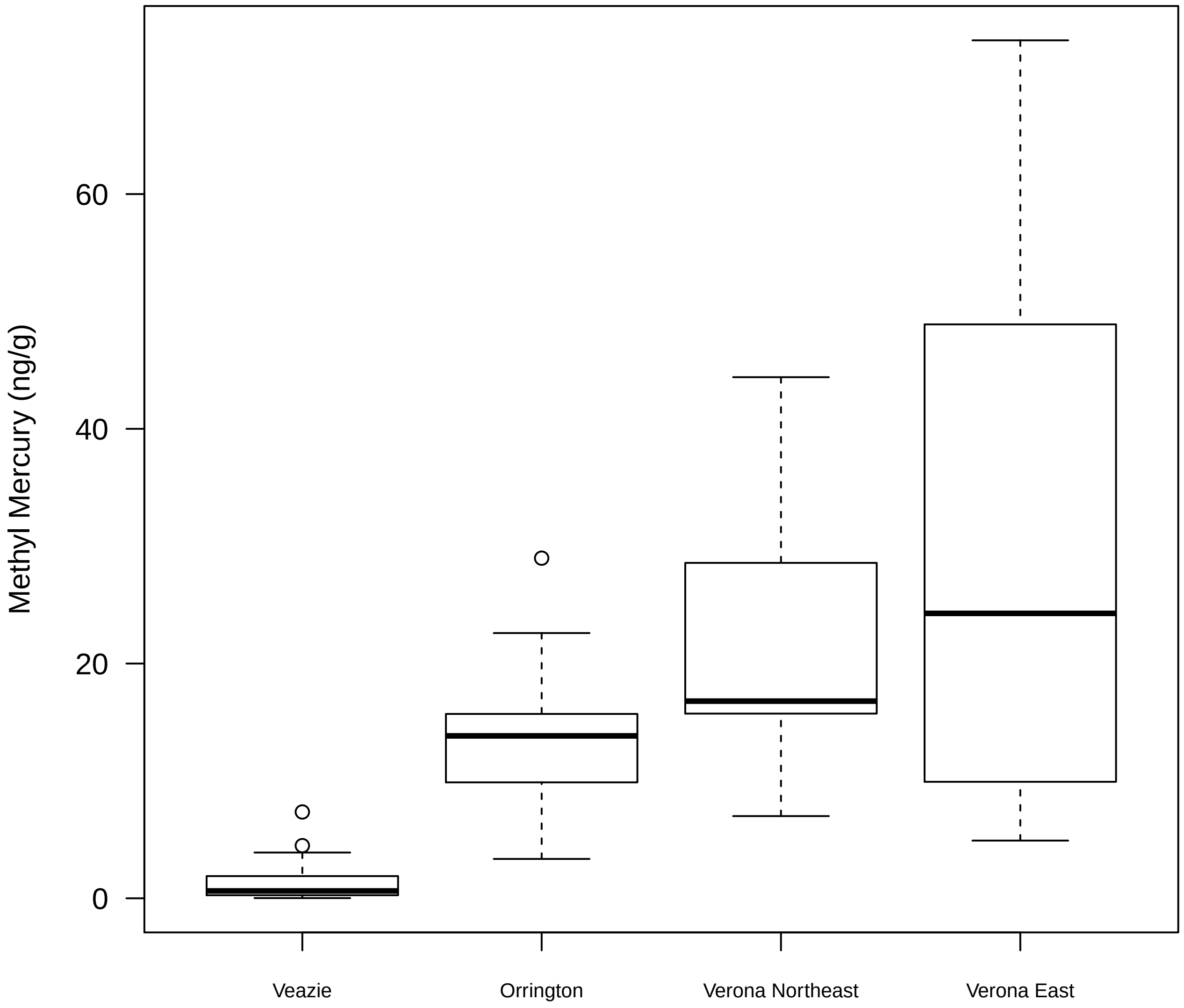


Figure 4.1-14

Intertidal Sediment Methyl Mercury by Sample Location

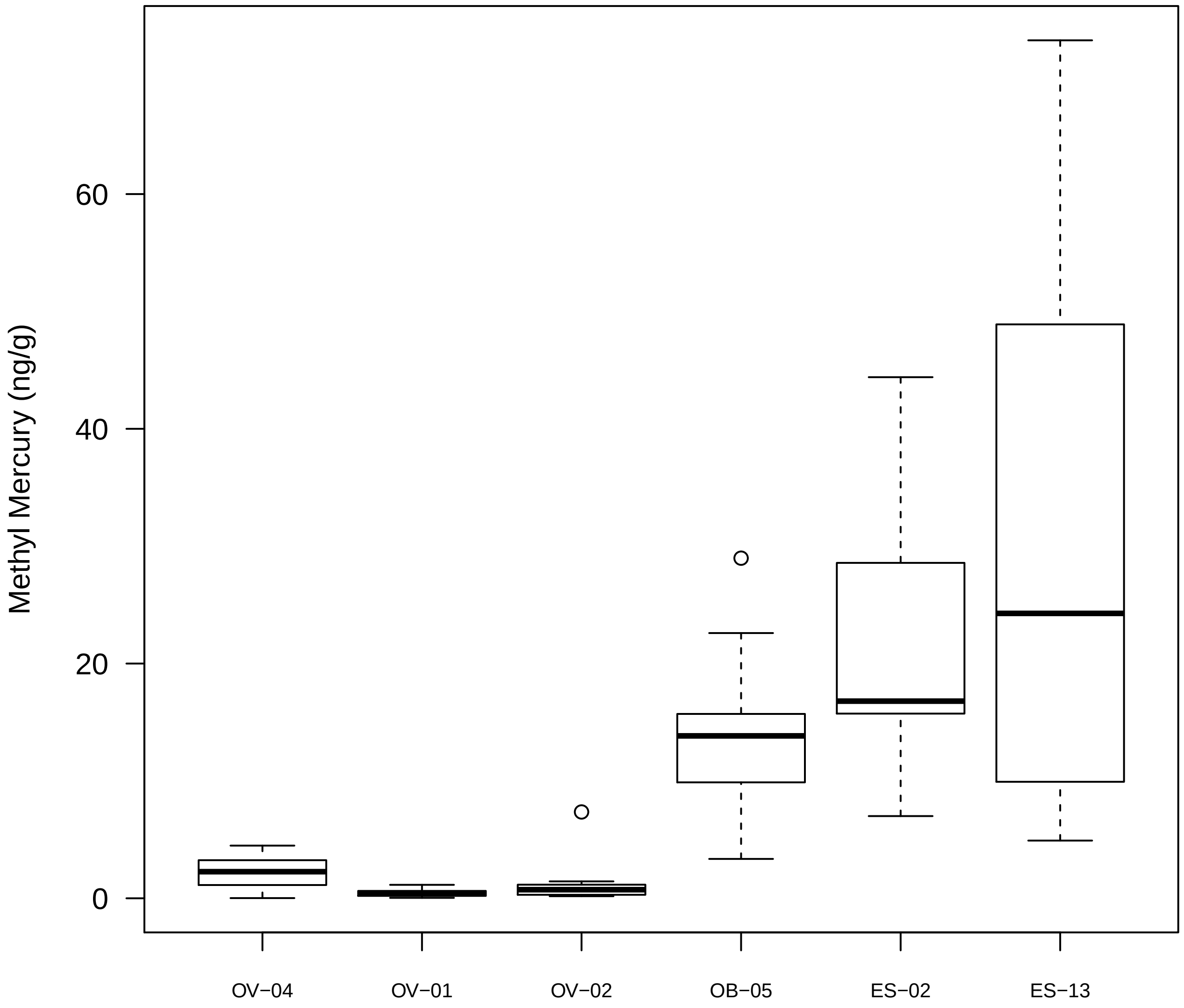


Figure 4.1-15

Intertidal Sediment Total Organic Carbon by River Reach

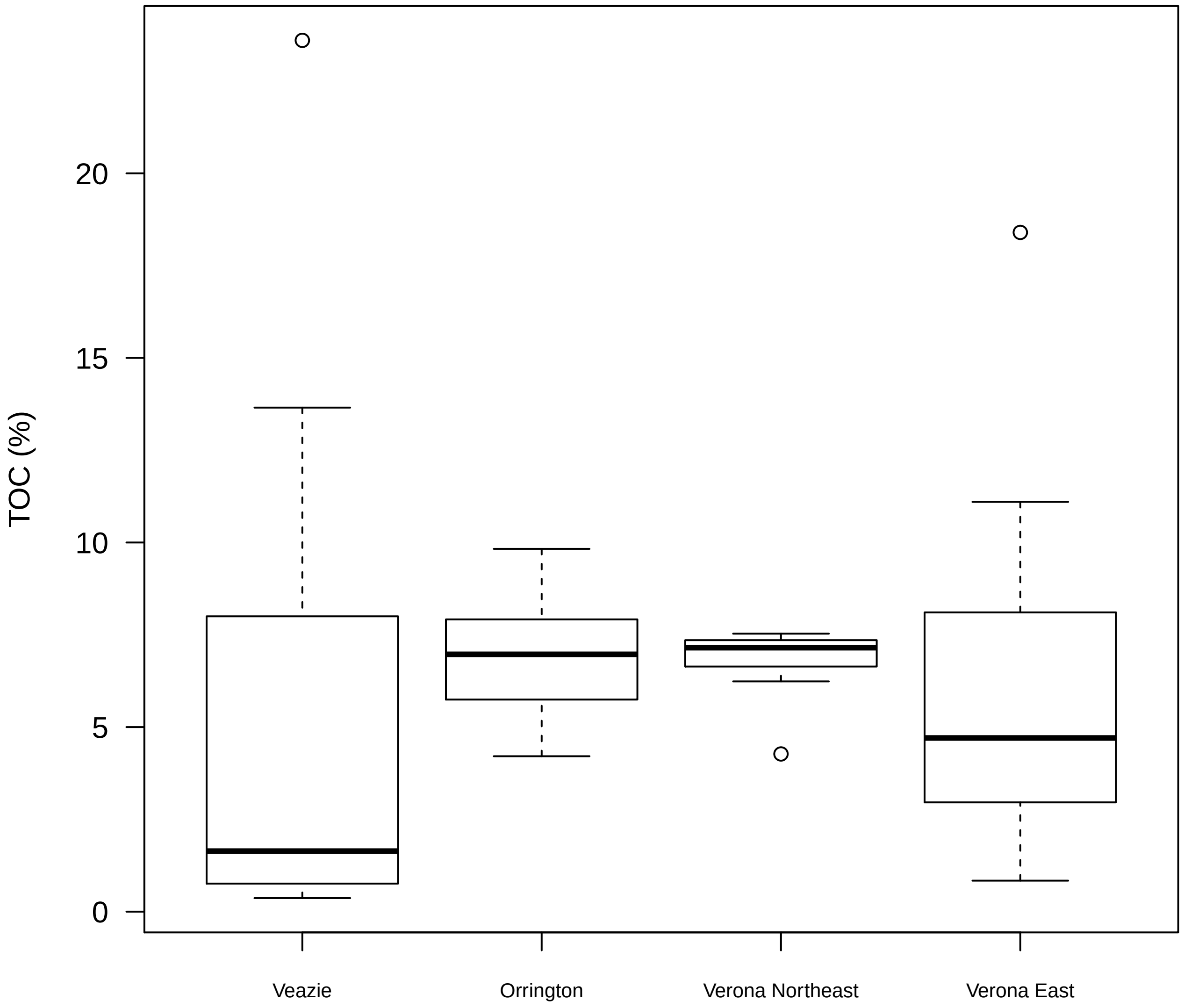


Figure 4.1-16

Intertidal Sediment Total Organic Carbon by Sample Location

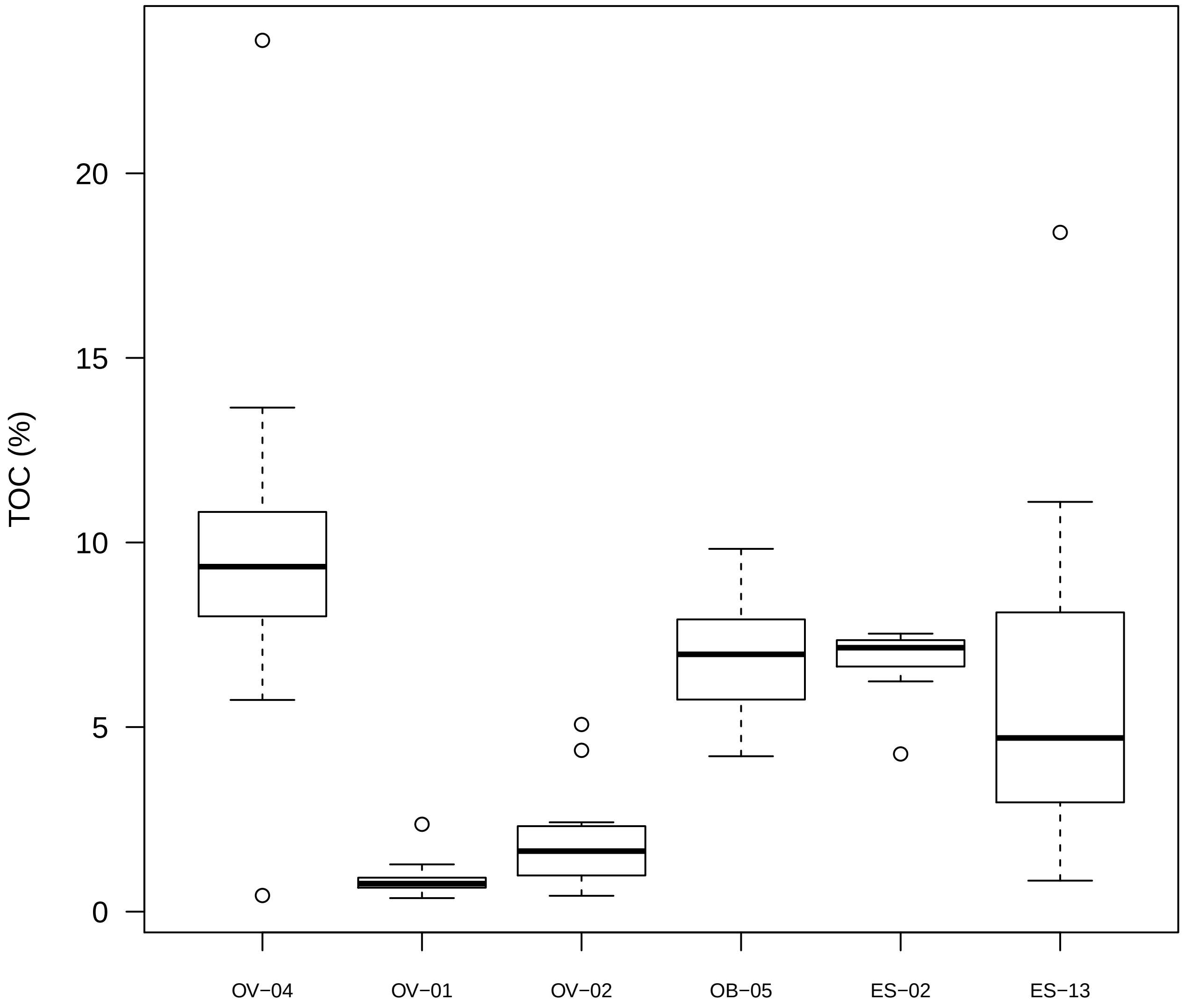
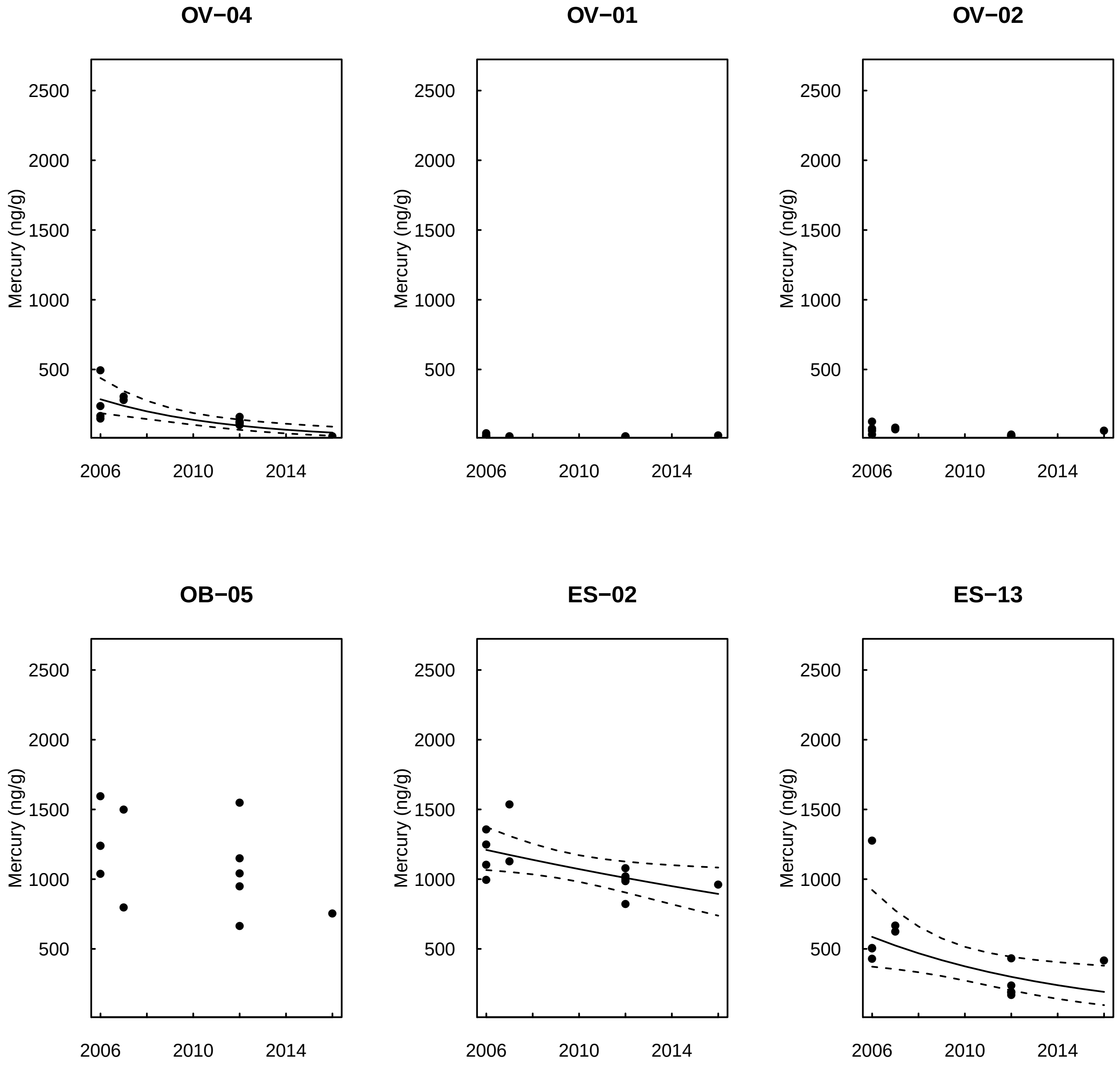


Figure 4.1-17

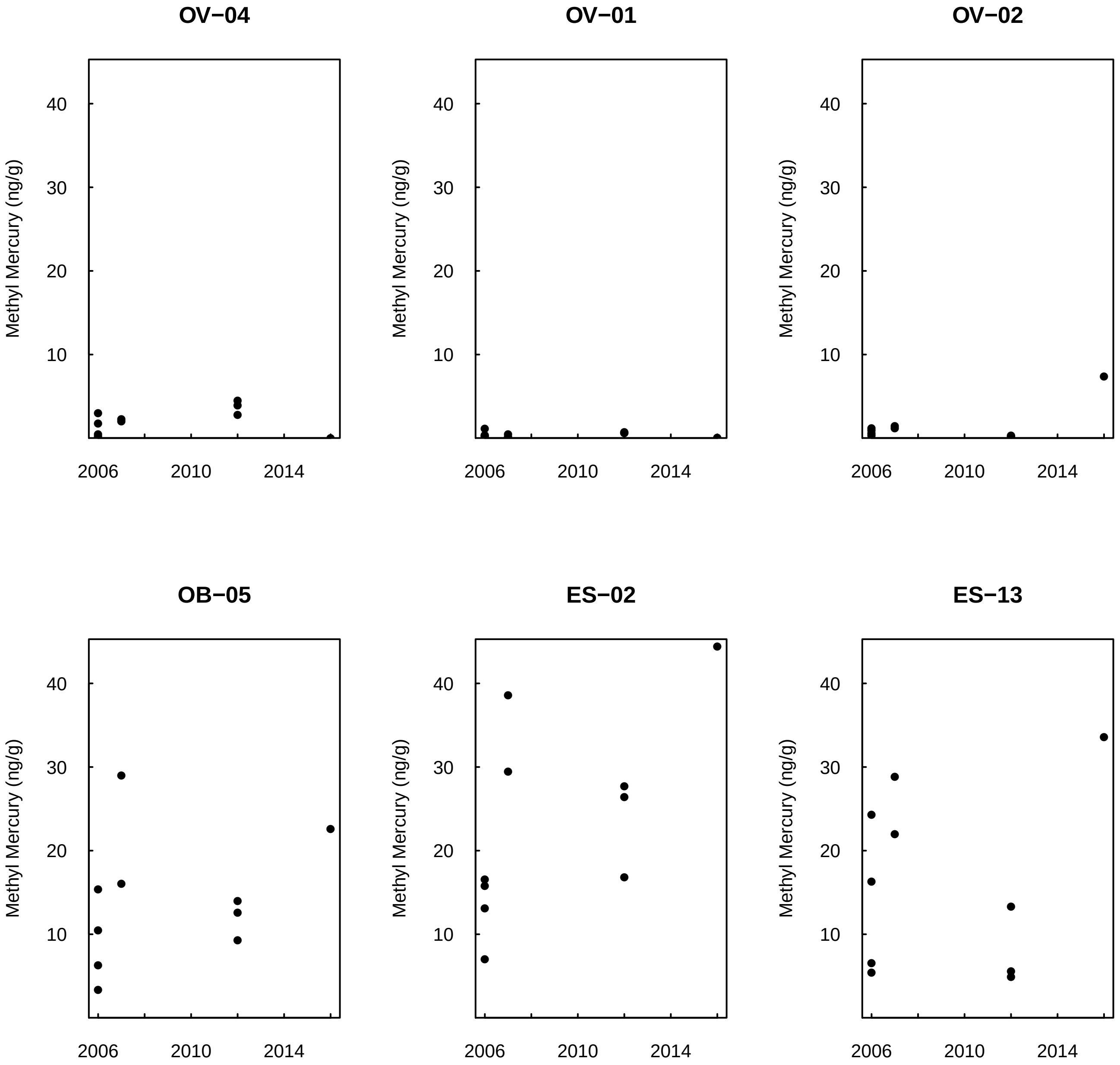
Temporal Intertidal Sediment Mercury



Line indicates regression slope is significantly different than 0 (p<0.05). Dashed lines indicate 95% confidence interval of regression.
Regressions performed on log−transfmormed data, but data are presented un−transformed for clarity.

Figure 4.1-18

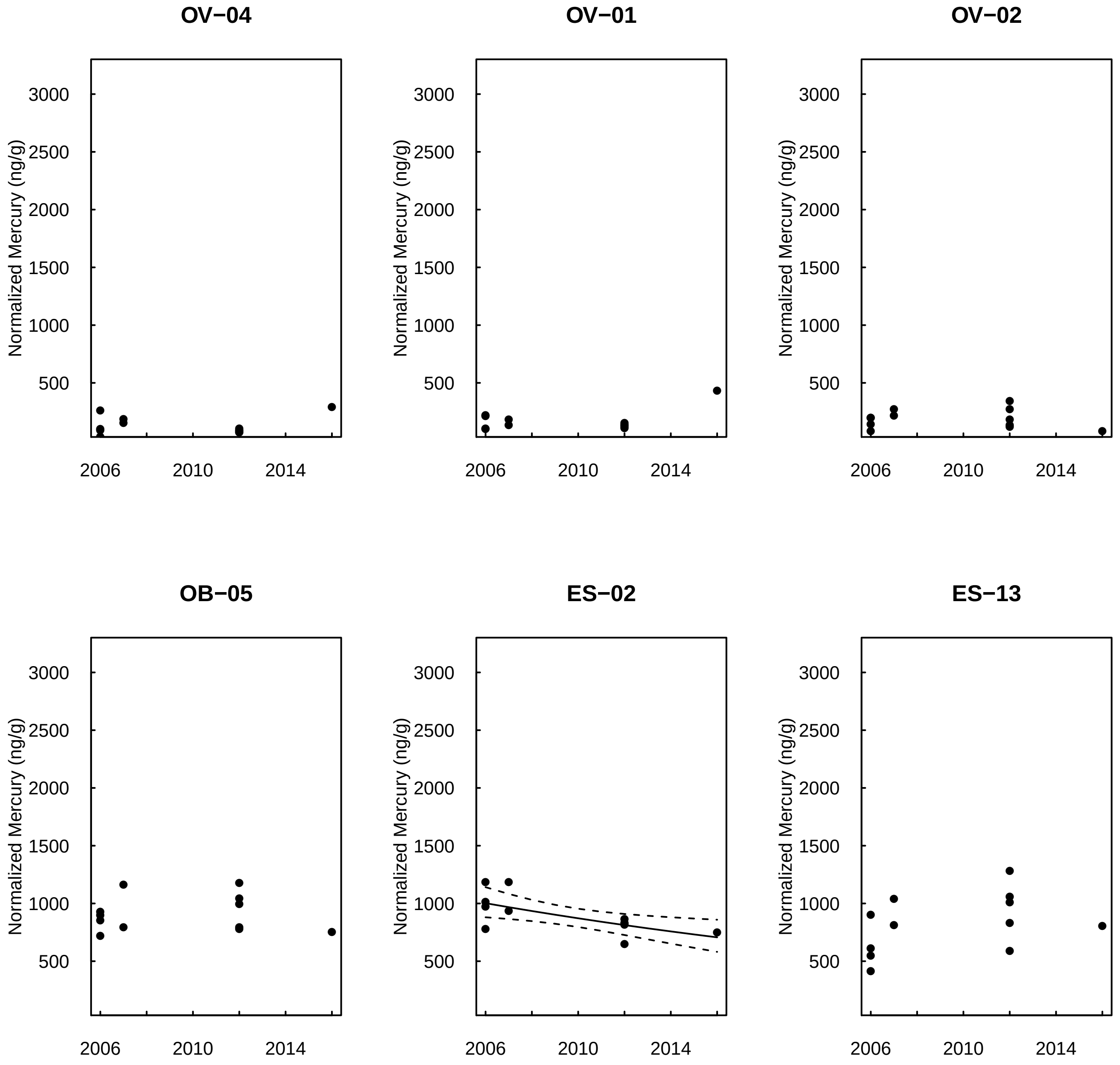
Temporal Intertidal Sediment Methyl Mercury



Line indicates regression slope is significantly different than 0 ($p<0.05$). Dashed lines indicate 95% confidence interval of regression.
Regressions performed on log−transfmormed data, but data are presented un−transformed for clarity.

Figure 4.1-19

Temporal Intertidal Sediment Normalized Mercury



Line indicates regression slope is significantly different than 0 (p<0.05). Dashed lines indicate 95% confidence interval of regression.
Regressions performed on log−transfmormed data, but data are presented un−transformed for clarity.

Figure 4.1-20

Temporal Intertidal Sediment Normalized Methyl Mercury

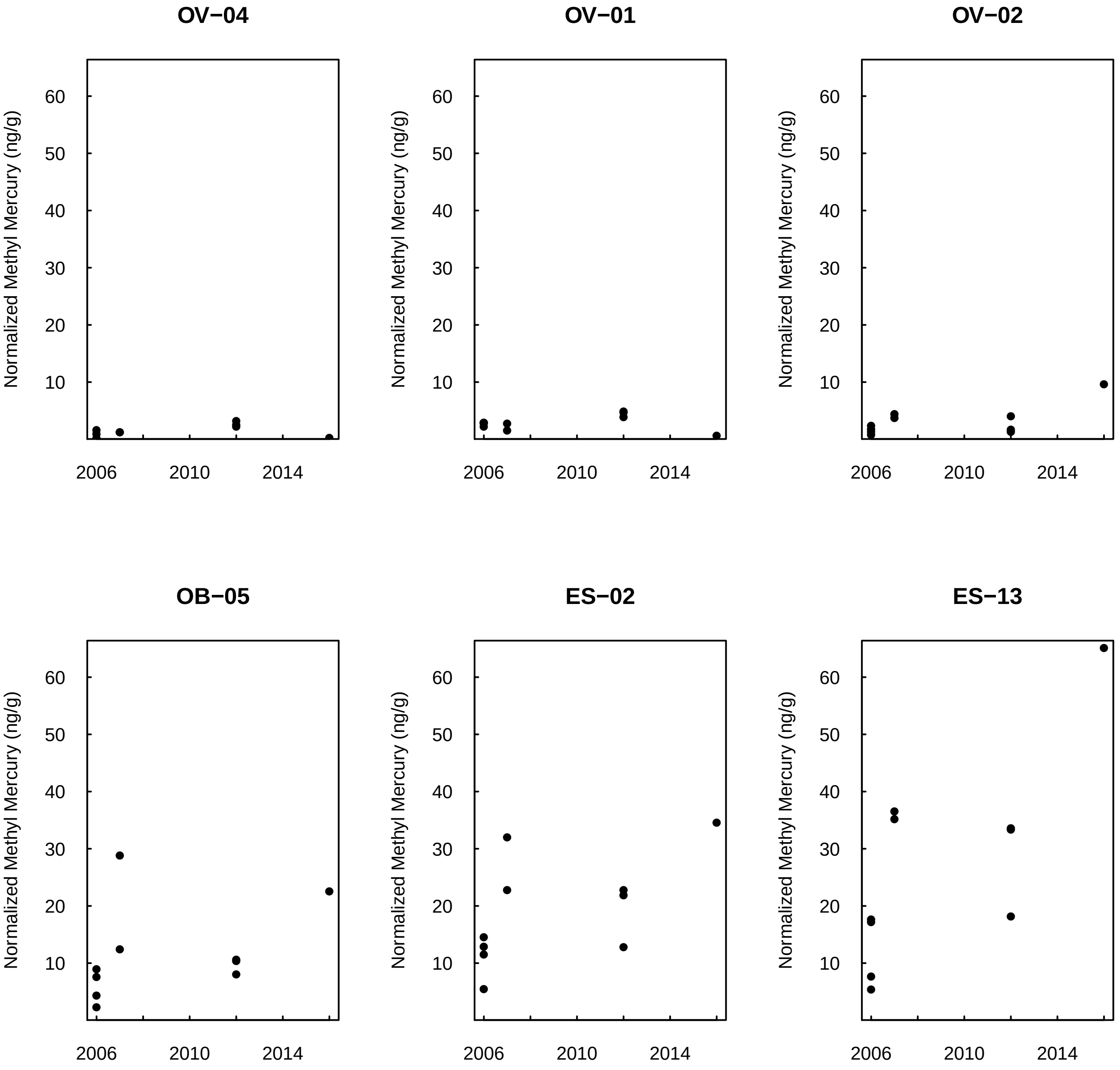


Figure 4.1-21

Wetland Sediment Mercury by River Reach

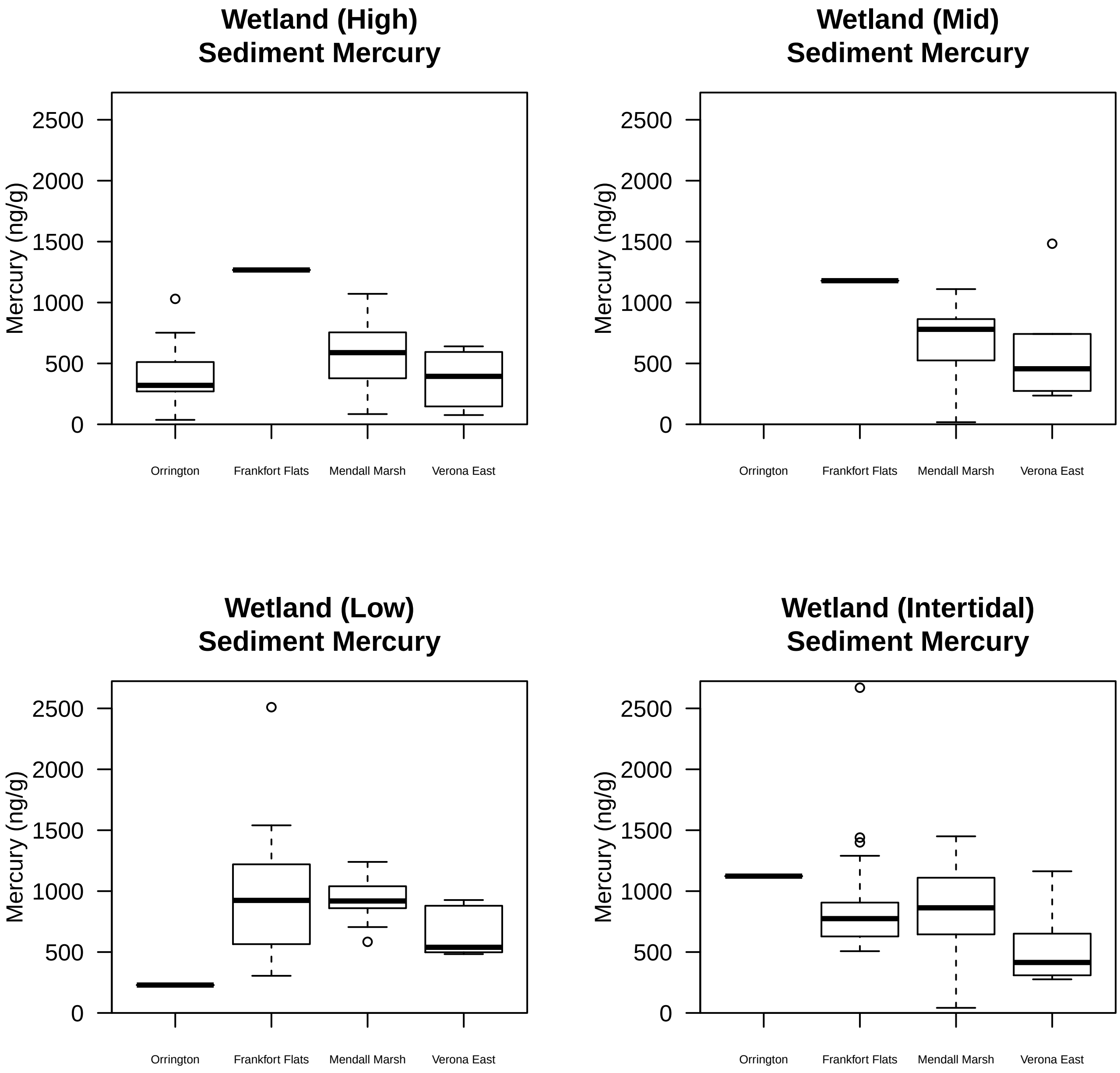
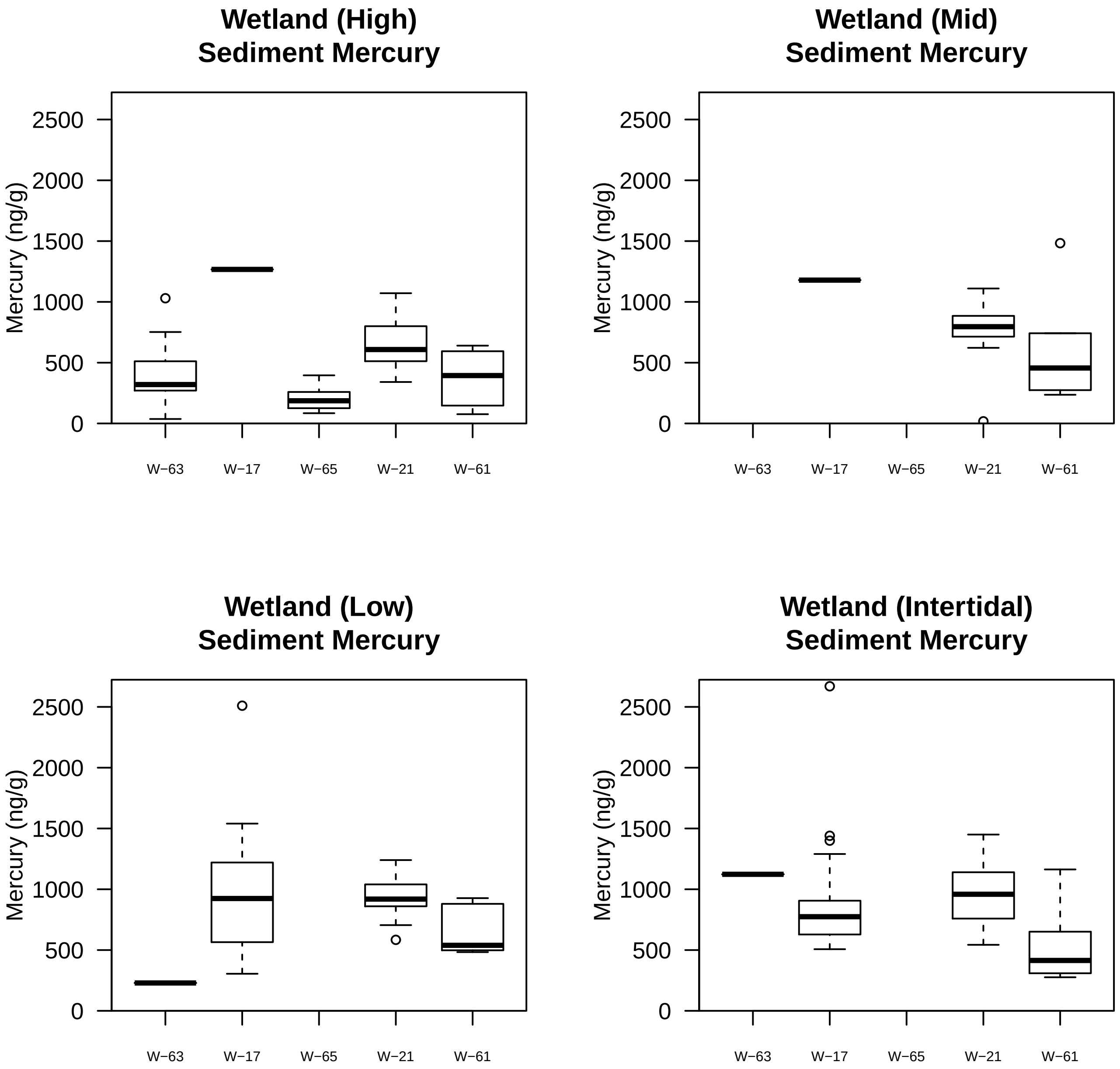


Figure 4.1-22

Wetland Sediment Mercury by Sample Location


Wetland (High) Sediment Mercury

Wetland (Mid) Sediment Mercury

Wetland (Low) Sediment Mercury

Wetland (Intertidal) Sediment Mercury

Figure 4.1-23

Wetland Sediment Methyl Mercury by River Reach

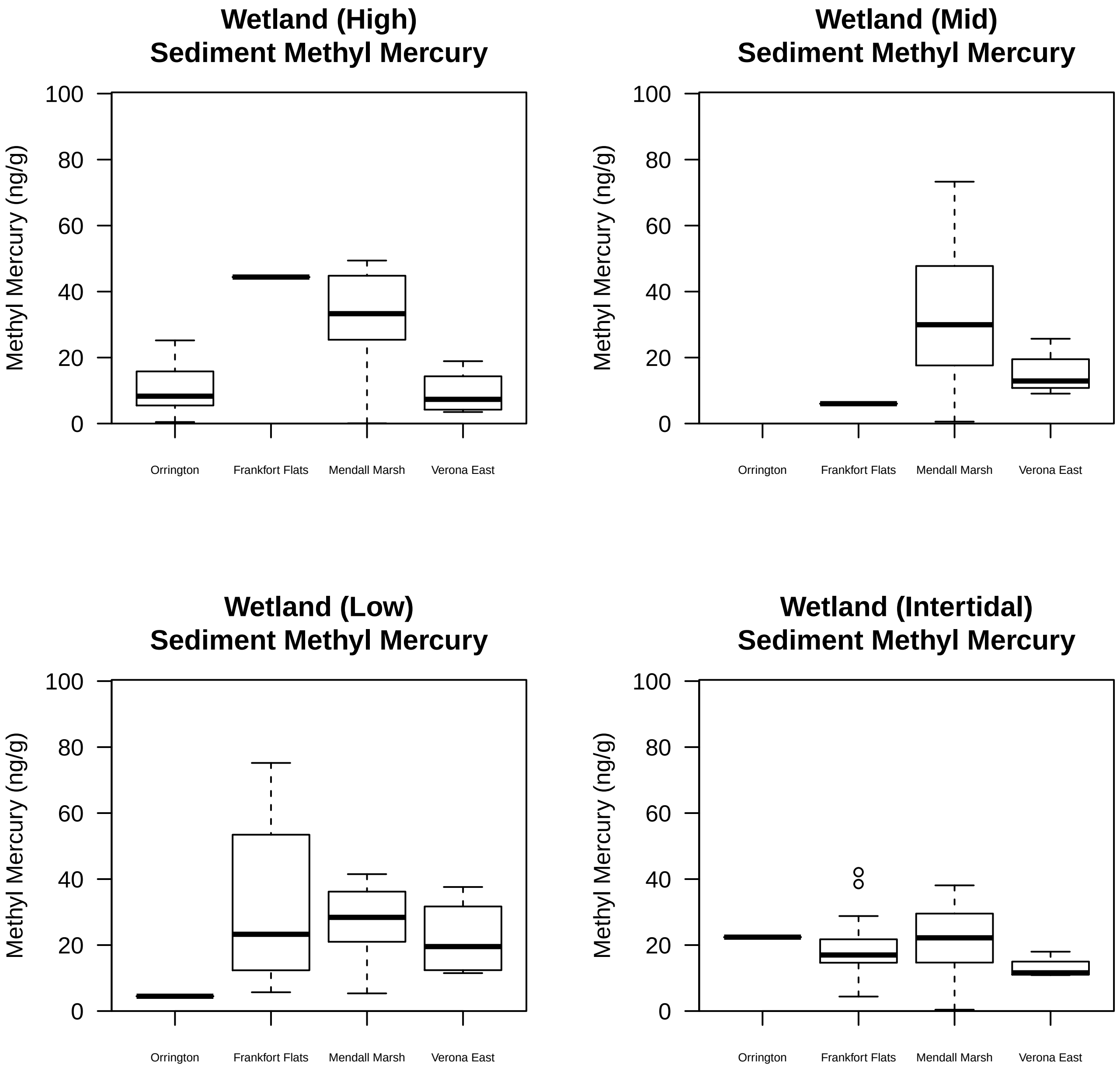


Figure 4.1-24

Wetland Sediment Methyl Mercury by Sample Location

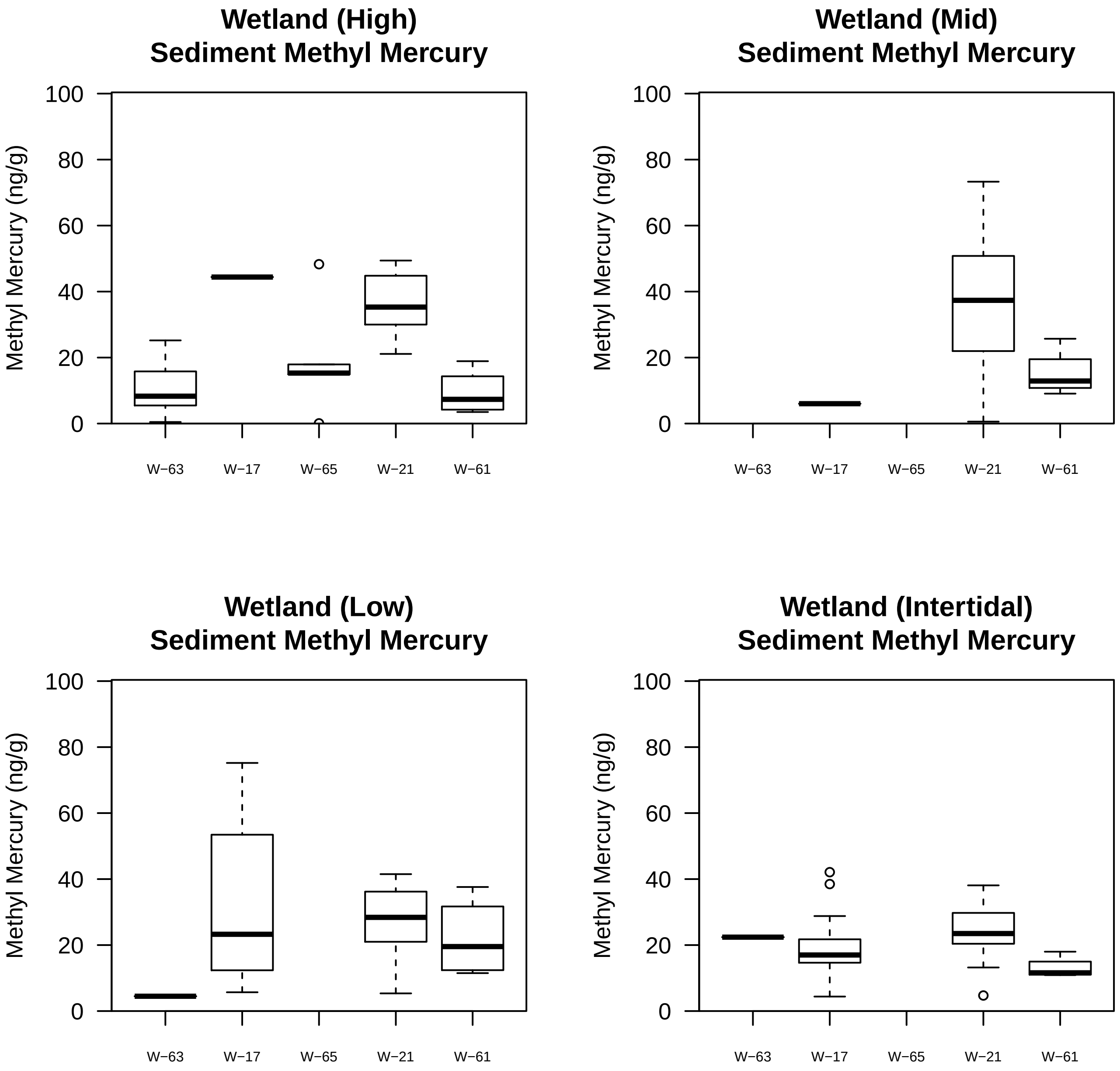
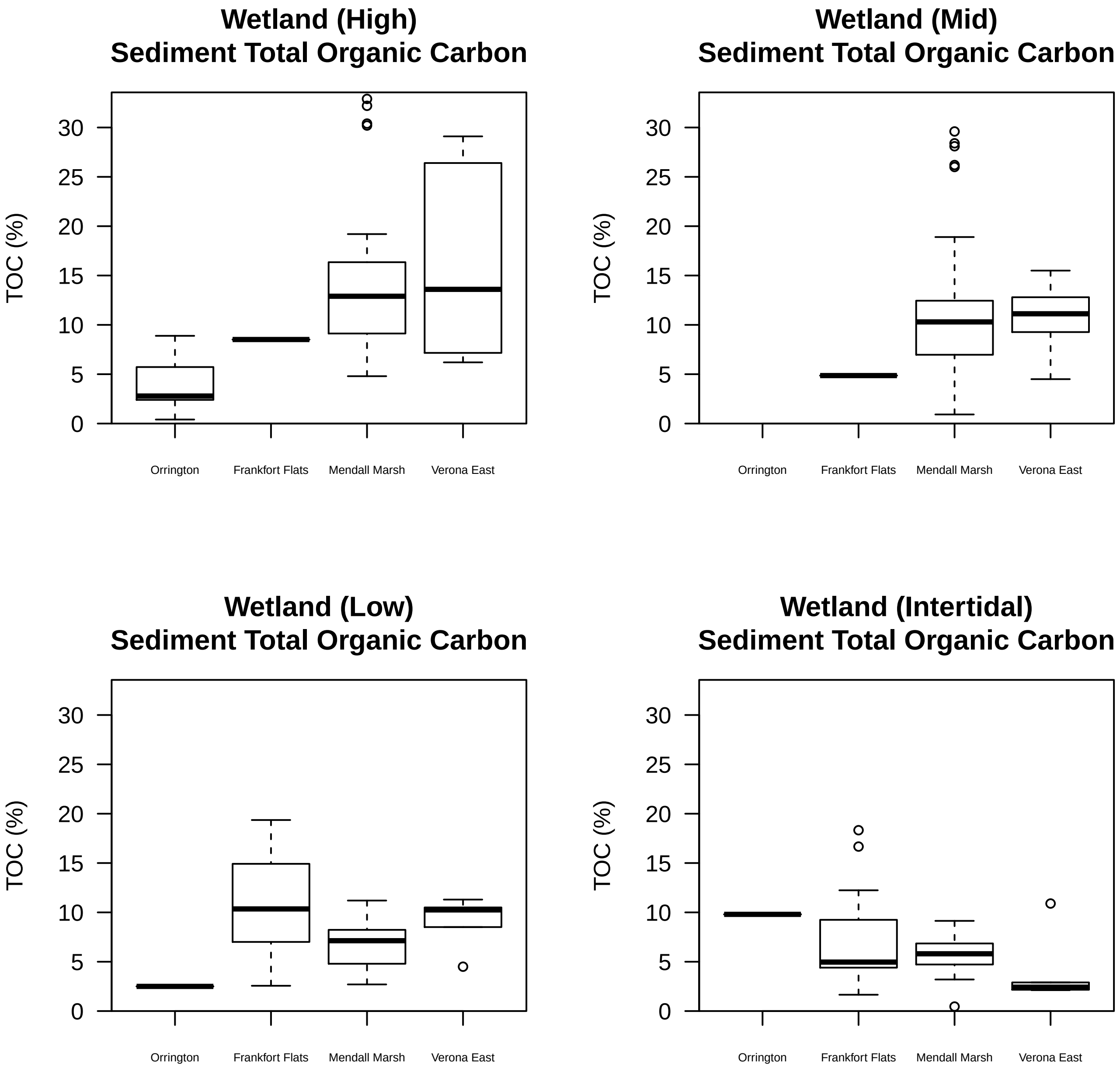


Figure 4.1-25

Wetland Sediment TOC by River Reach



Wetland (High)
Sediment Total Organic Carbon

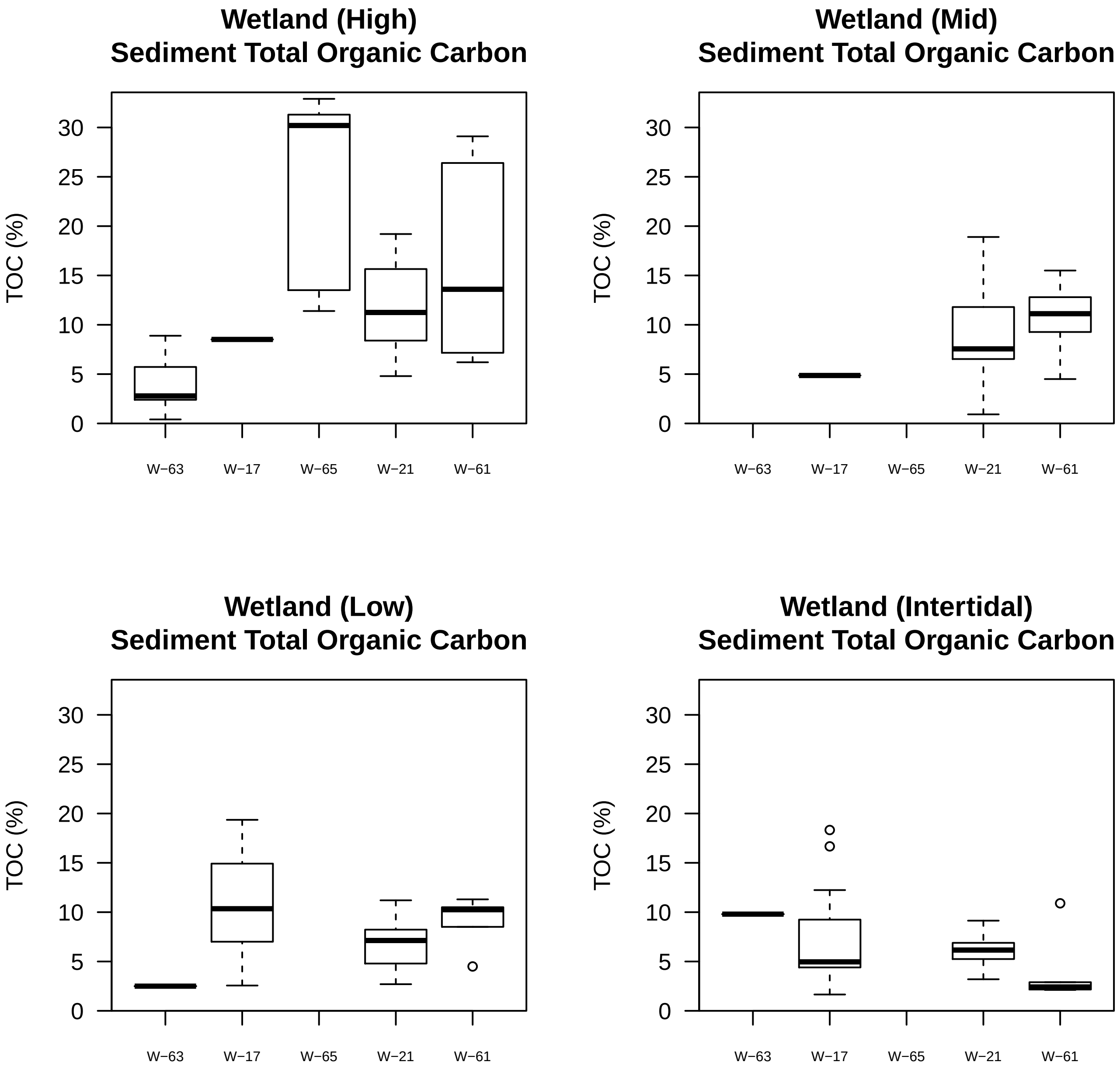
Wetland (Mid)
Sediment Total Organic Carbon

Wetland (Low)
Sediment Total Organic Carbon

Wetland (Intertidal)
Sediment Total Organic Carbon

Figure 4.1-26

Wetland Sediment TOC by Sample Location


Wetland (High) Sediment Total Organic Carbon

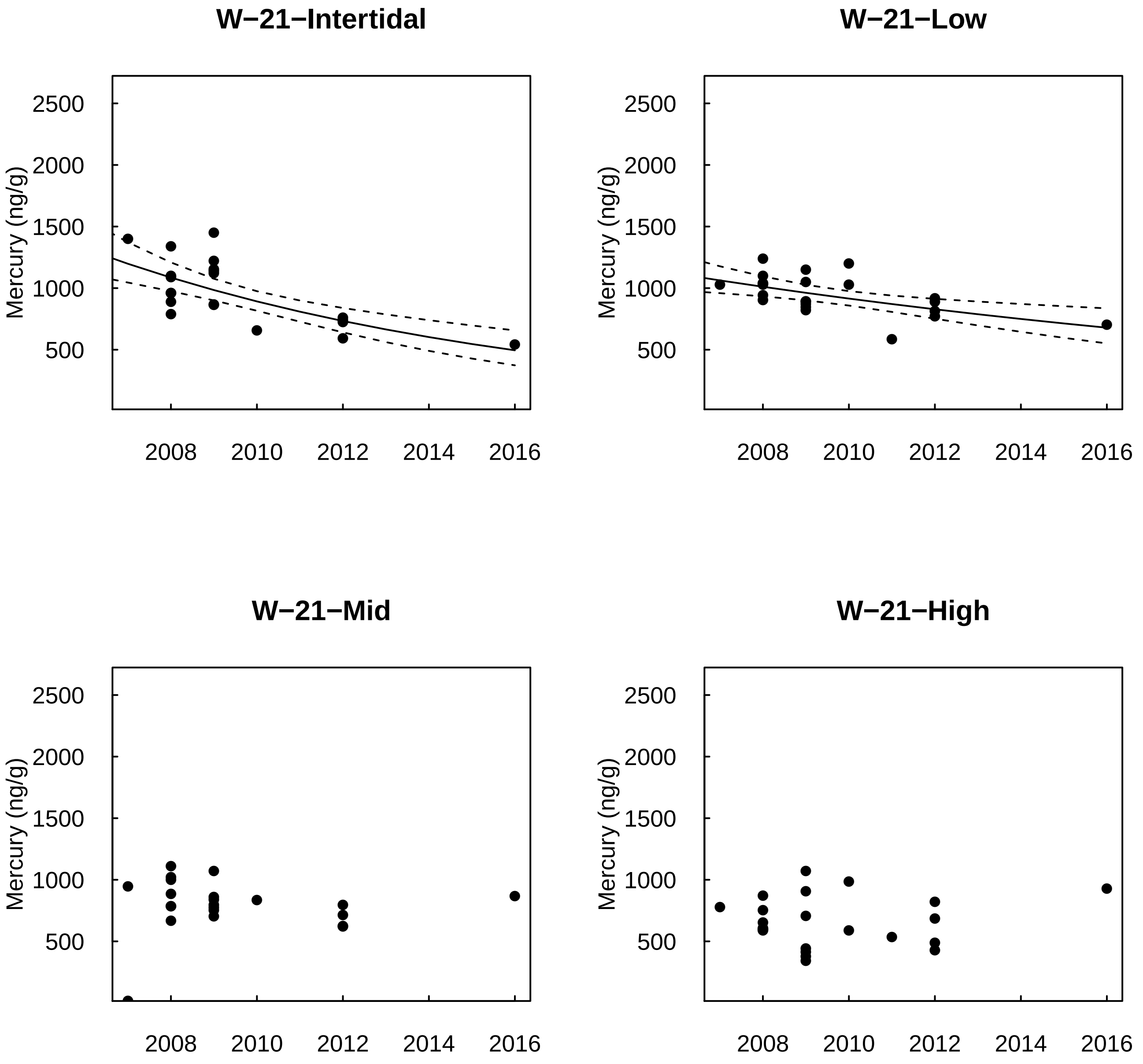
Wetland (Mid) Sediment Total Organic Carbon

Wetland (Low) Sediment Total Organic Carbon

Wetland (Intertidal) Sediment Total Organic Carbon

Figure 4.1-27

Temporal Wetland Sediment Mercury



Line indicates regression slope is significantly different than 0 (p<0.05). Dashed lines indicate 95% confidence interval of regression.
Regressions performed on log−transfmormed data, but data are presented un−transformed for clarity.

Figure 4.1-27 (cont.)

Temporal Wetland Sediment Mercury

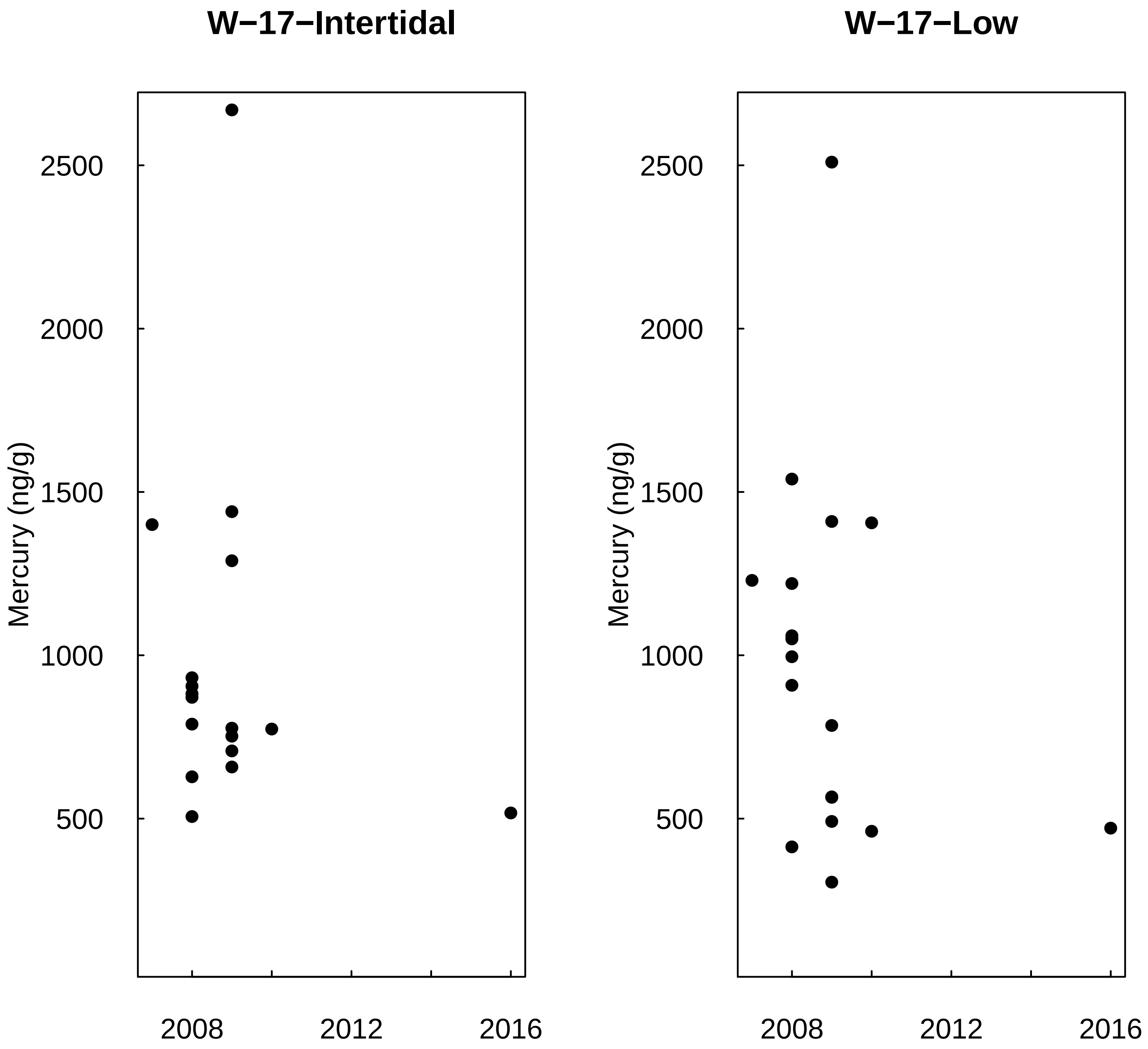
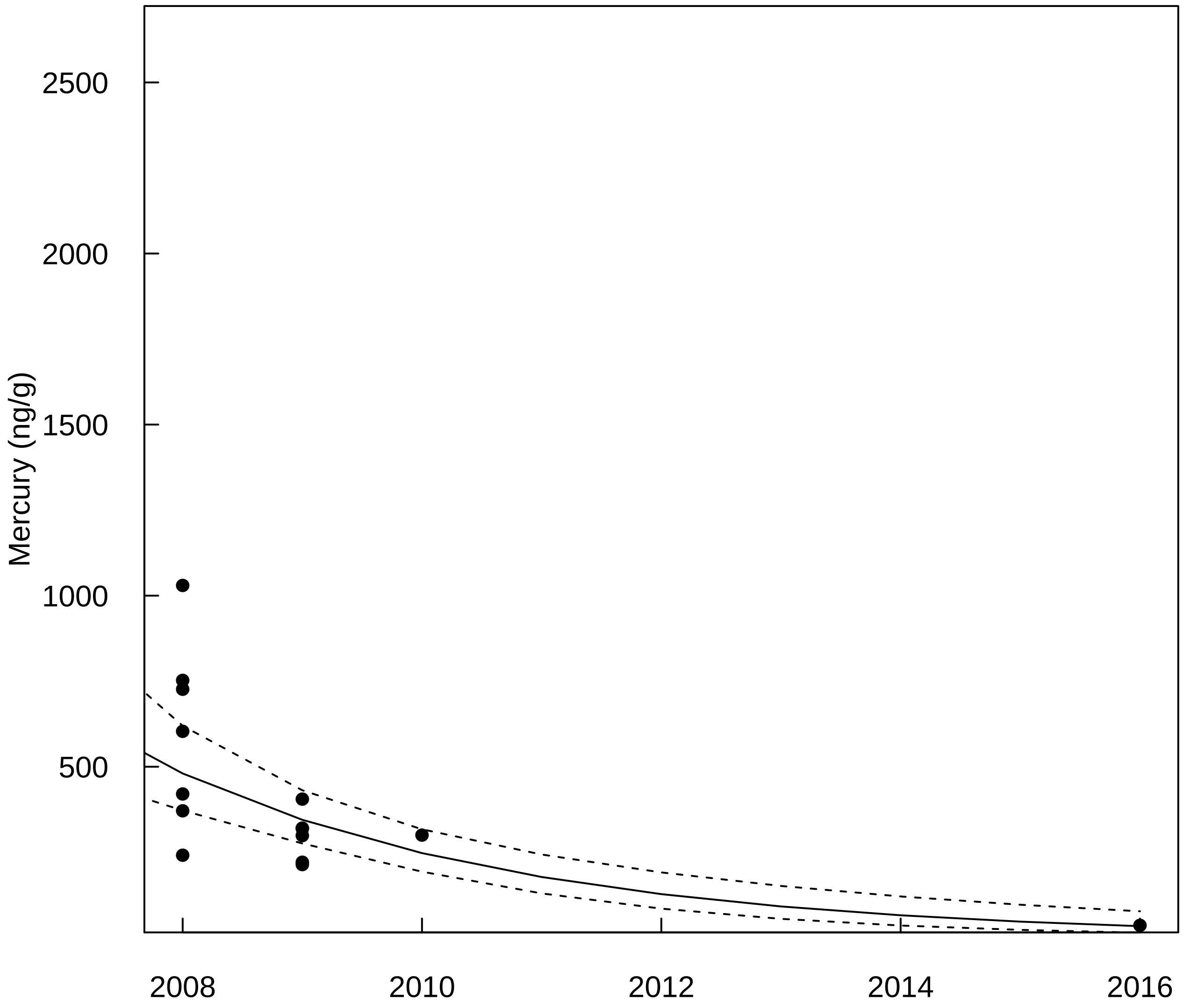


Figure 4.1-27 (cont.)

Temporal Wetland Sediment Mercury

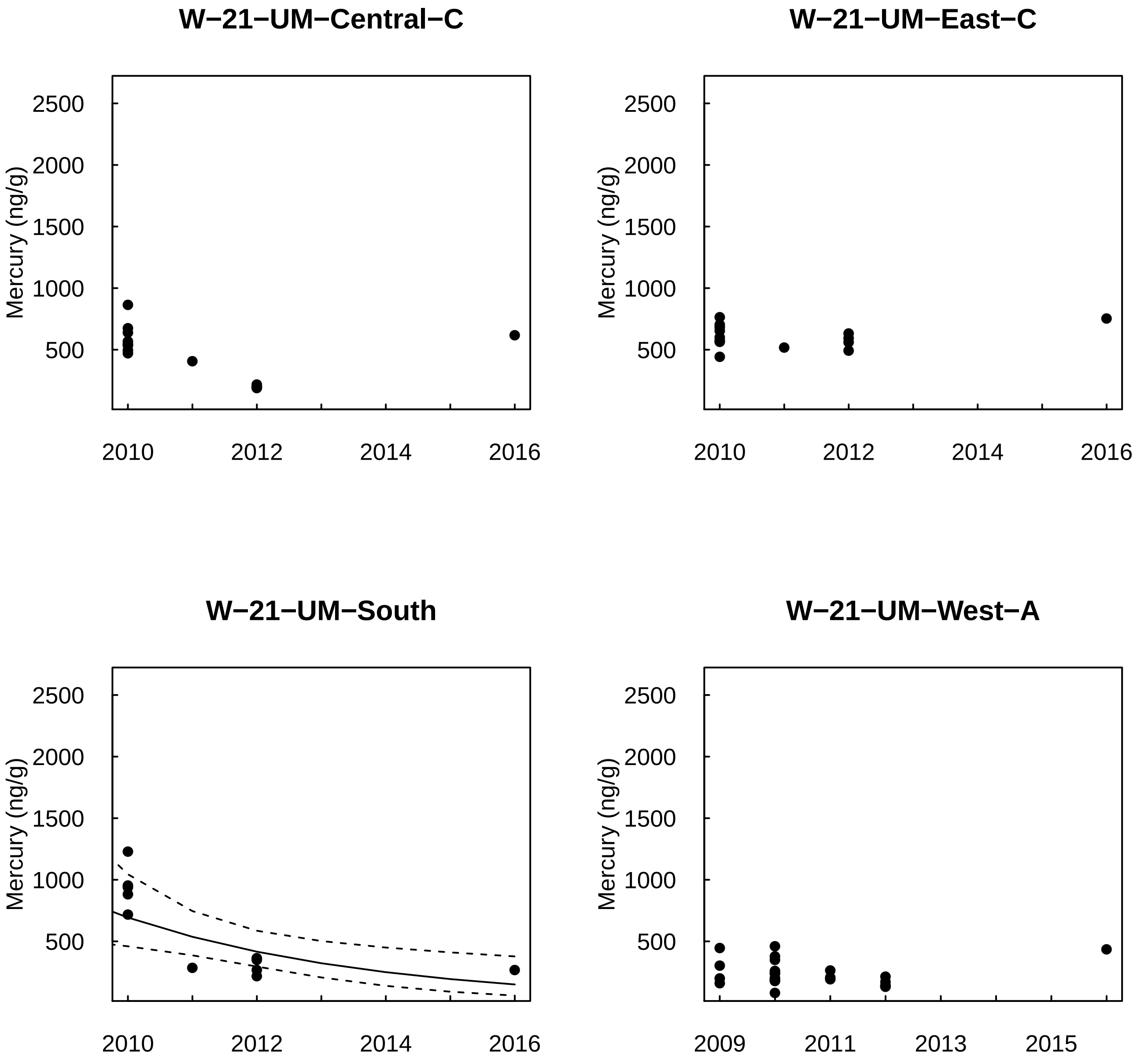
W−63−High



Line indicates regression slope is significantly different than 0 (p<0.05). Dashed lines indicate 95% confidence interval of regression.
Regressions performed on log−transfmormed data, but data are presented un−transformed for clarity.

Figure 4.1-27 (cont.)

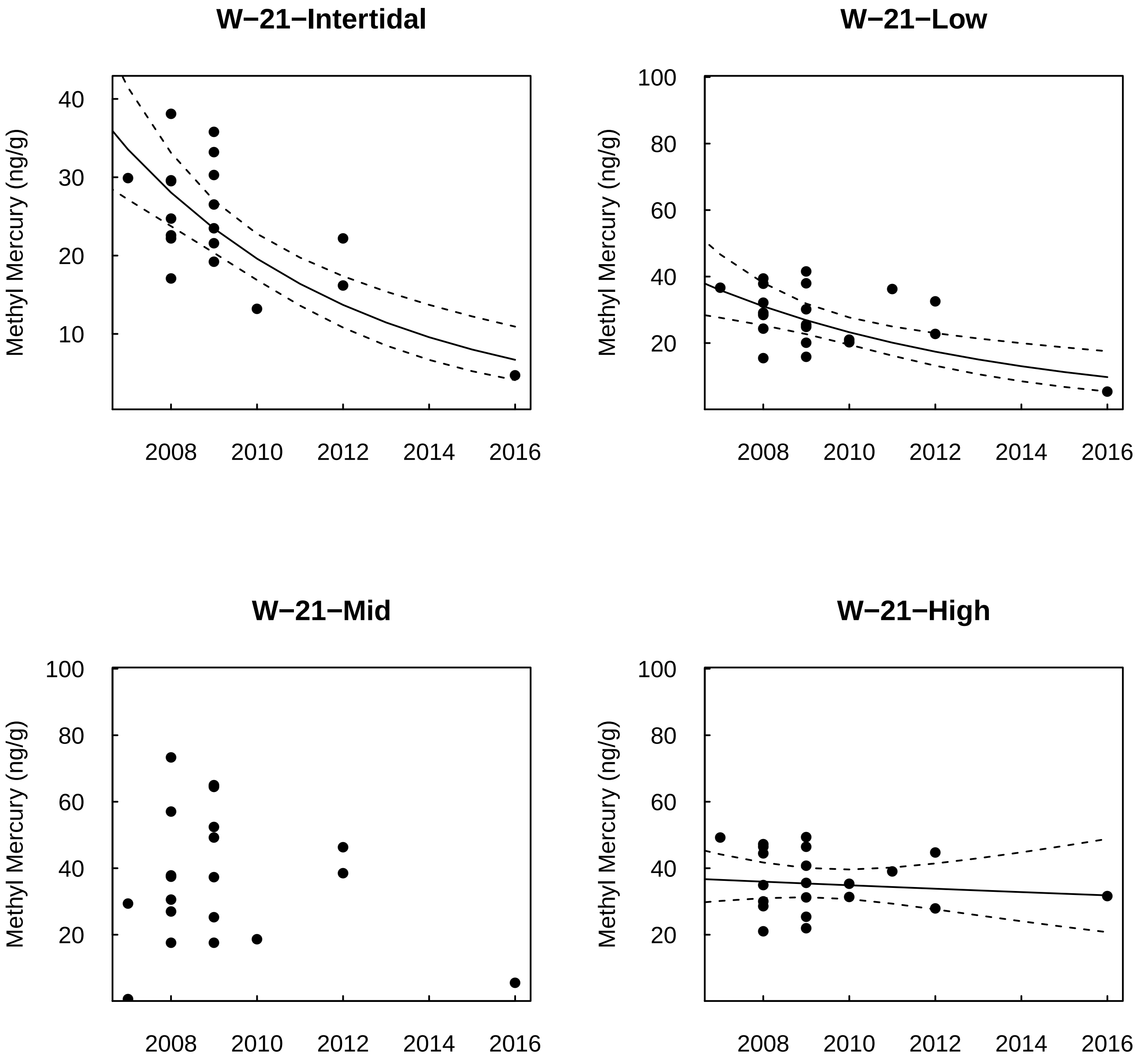
Temporal Wetland Sediment Mercury



Line indicates regression slope is significantly different than 0 (p<0.05). Dashed lines indicate 95% confidence interval of regression.
Regressions performed on log−transfmormed data, but data are presented un−transformed for clarity.

Figure 4.1-28

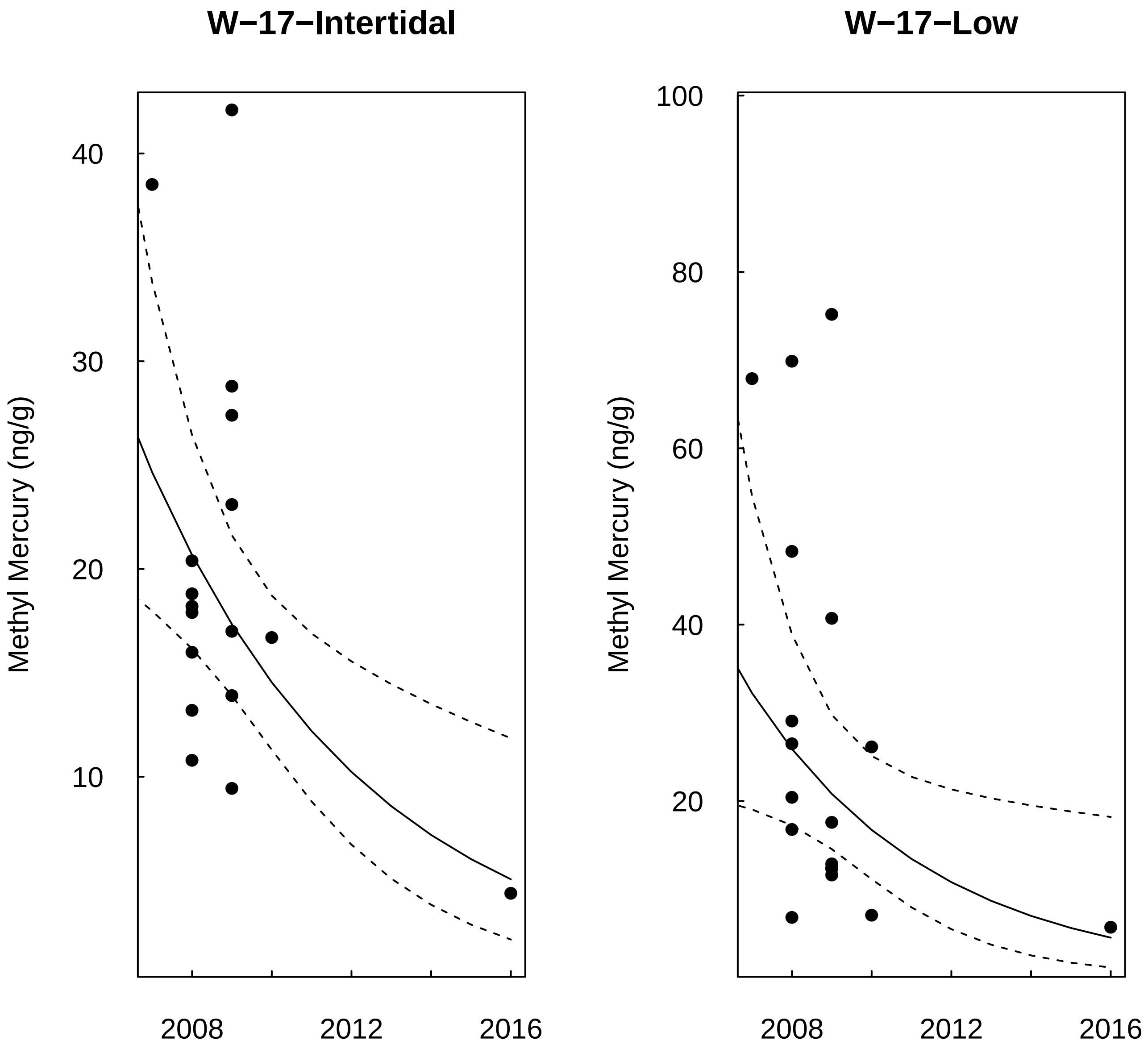
Temporal Wetland Sediment Normalized Mercury



Line indicates regression slope is significantly different than 0 (p<0.05). Dashed lines indicate 95% confidence interval of regression.
Regressions performed on log−transfmormed data, but data are presented un−transformed for clarity.

Figure 4.1-28 (cont.)

Temporal Wetland Sediment Normalized Mercury



W−17−Intertidal

W−17−Low

Line indicates regression slope is significantly different than 0 (p<0.05). Dashed lines indicate 95% confidence interval of regression.
Regressions performed on log−transfmormed data, but data are presented un−transformed for clarity.

Figure 4.1-28 (cont.)

Temporal Wetland Sediment Normalized Mercury

W−63−High

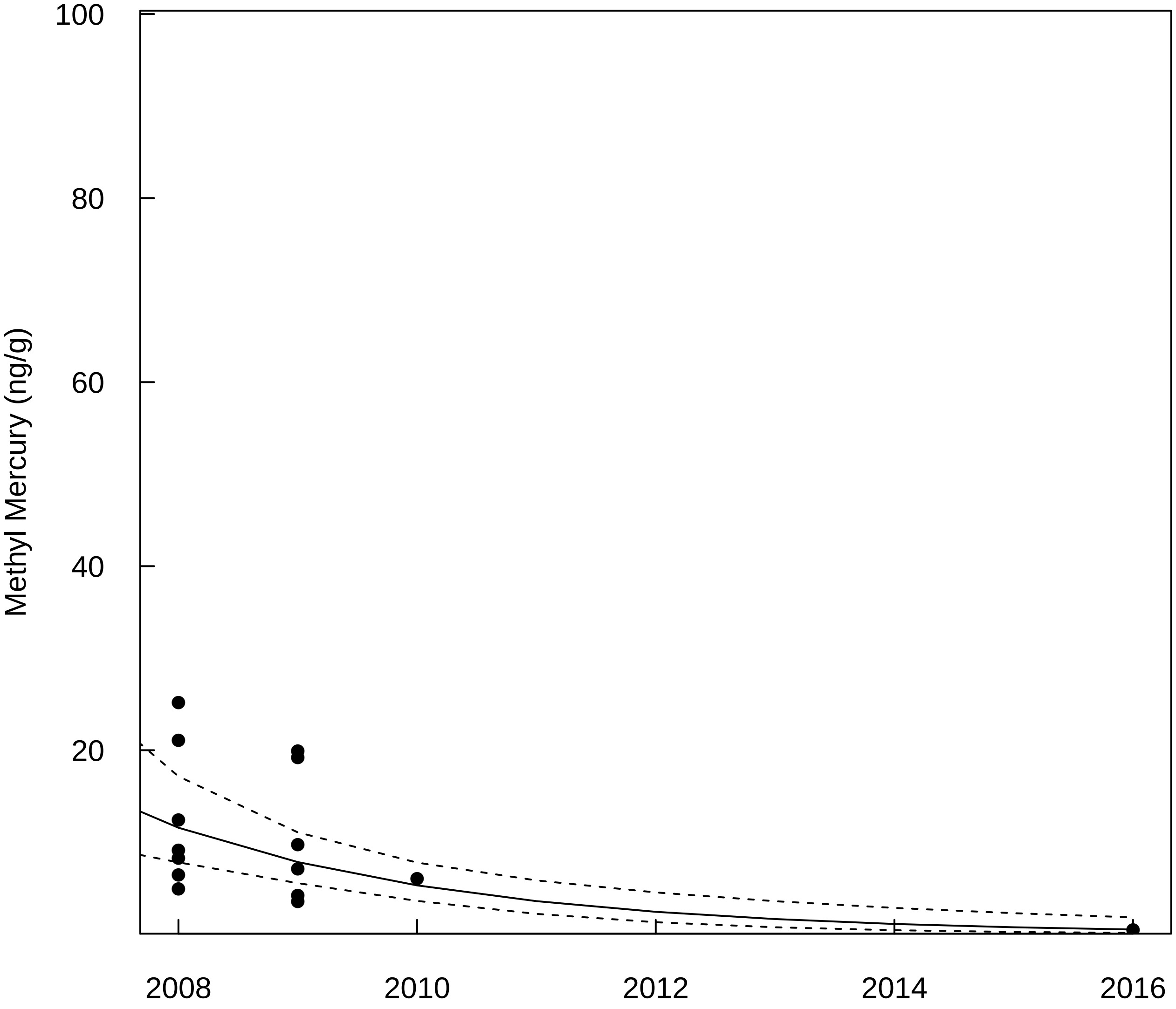
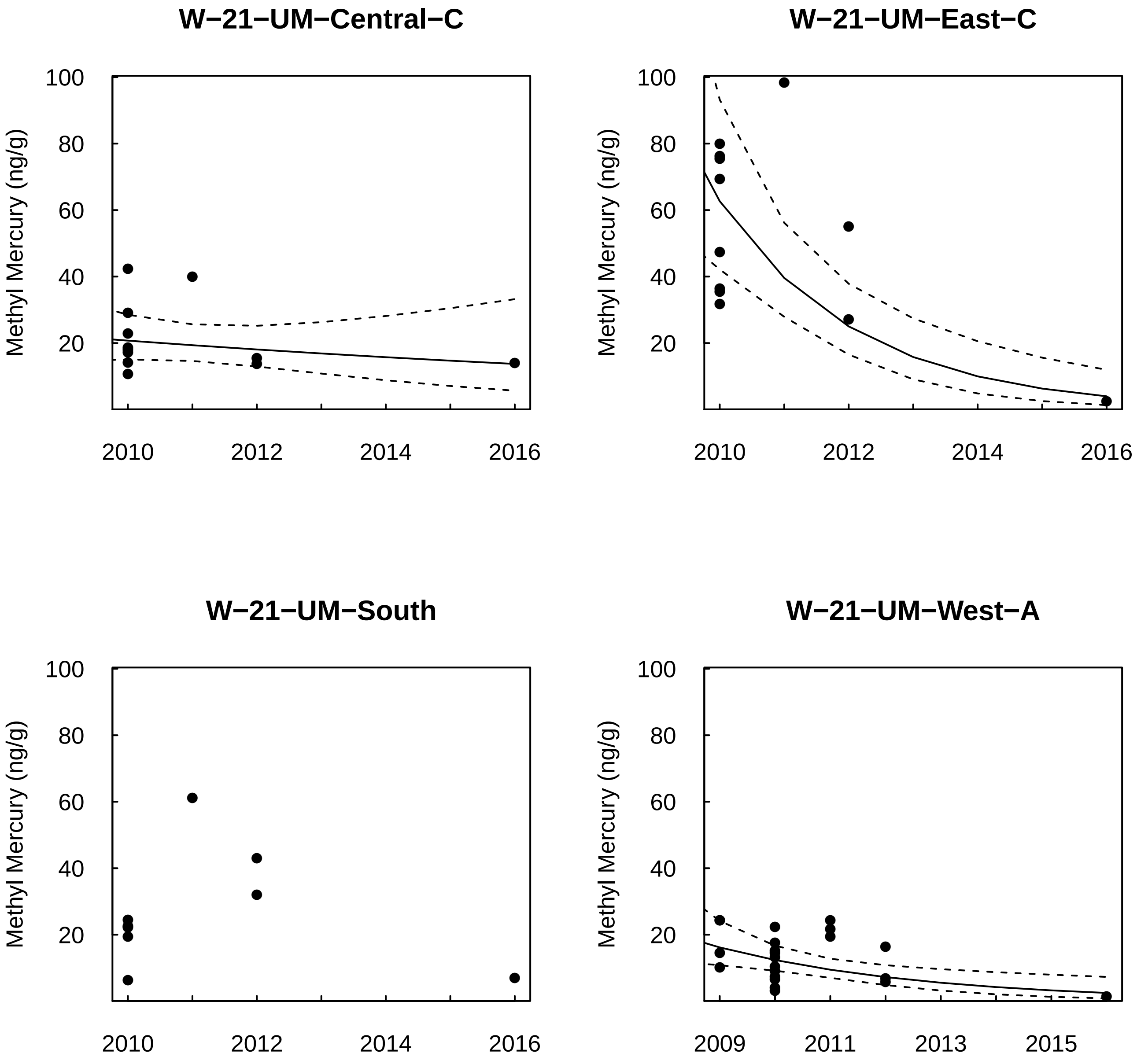


Figure 4.1-28 (cont.)

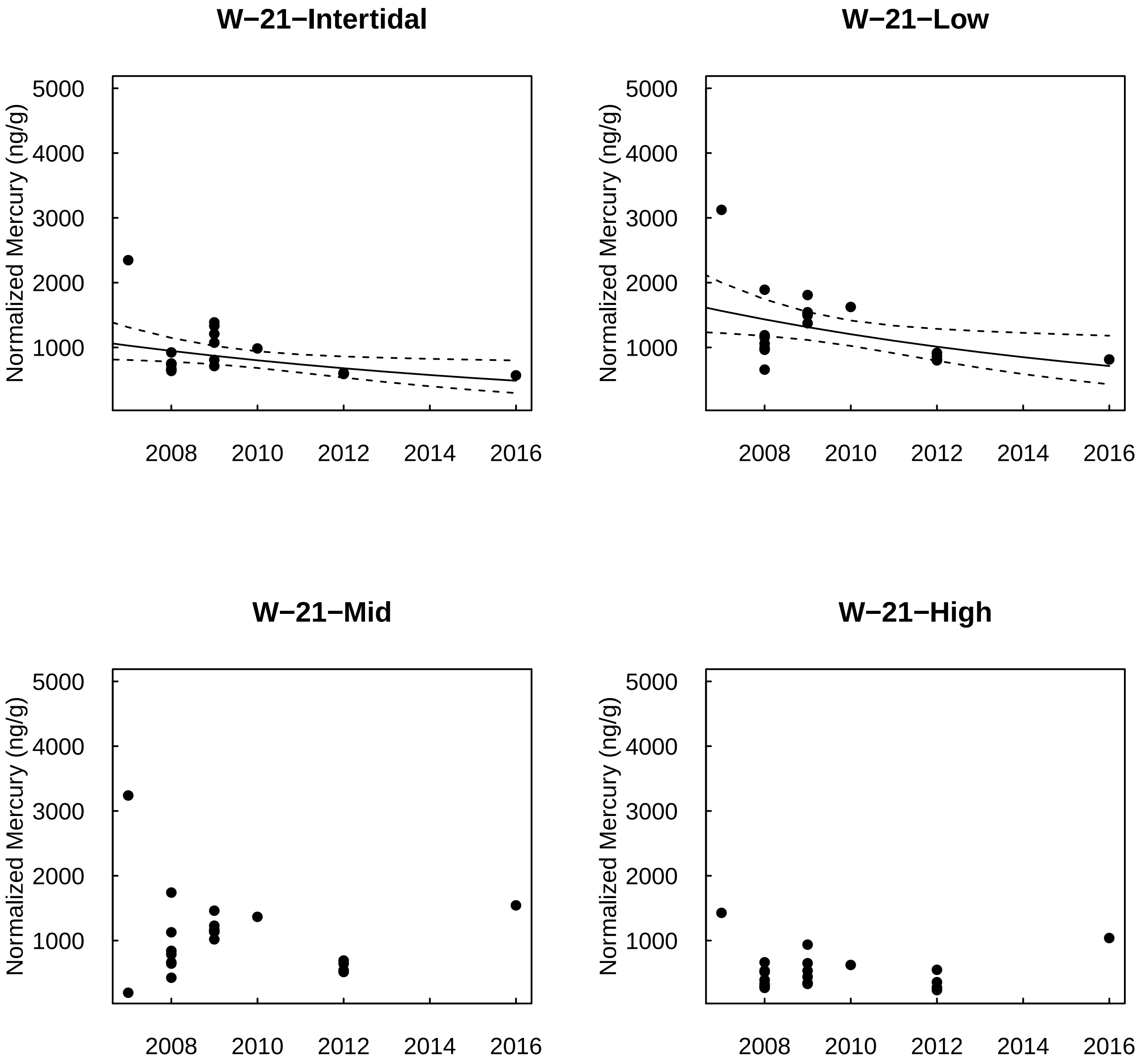
Temporal Wetland Sediment Normalized Mercury



Line indicates regression slope is significantly different than 0 (p<0.05). Dashed lines indicate 95% confidence interval of regression.
Regressions performed on log−transfmormed data, but data are presented un−transformed for clarity.

Figure 4.1-29

Temporal Wetland Sediment Methyl Mercury



Line indicates regression slope is significantly different than 0 (p<0.05). Dashed lines indicate 95% confidence interval of regression.
Regressions performed on log−transfmormed data, but data are presented un−transformed for clarity.

Figure 4.1-29 (cont.)

Temporal Wetland Sediment Methyl Mercury

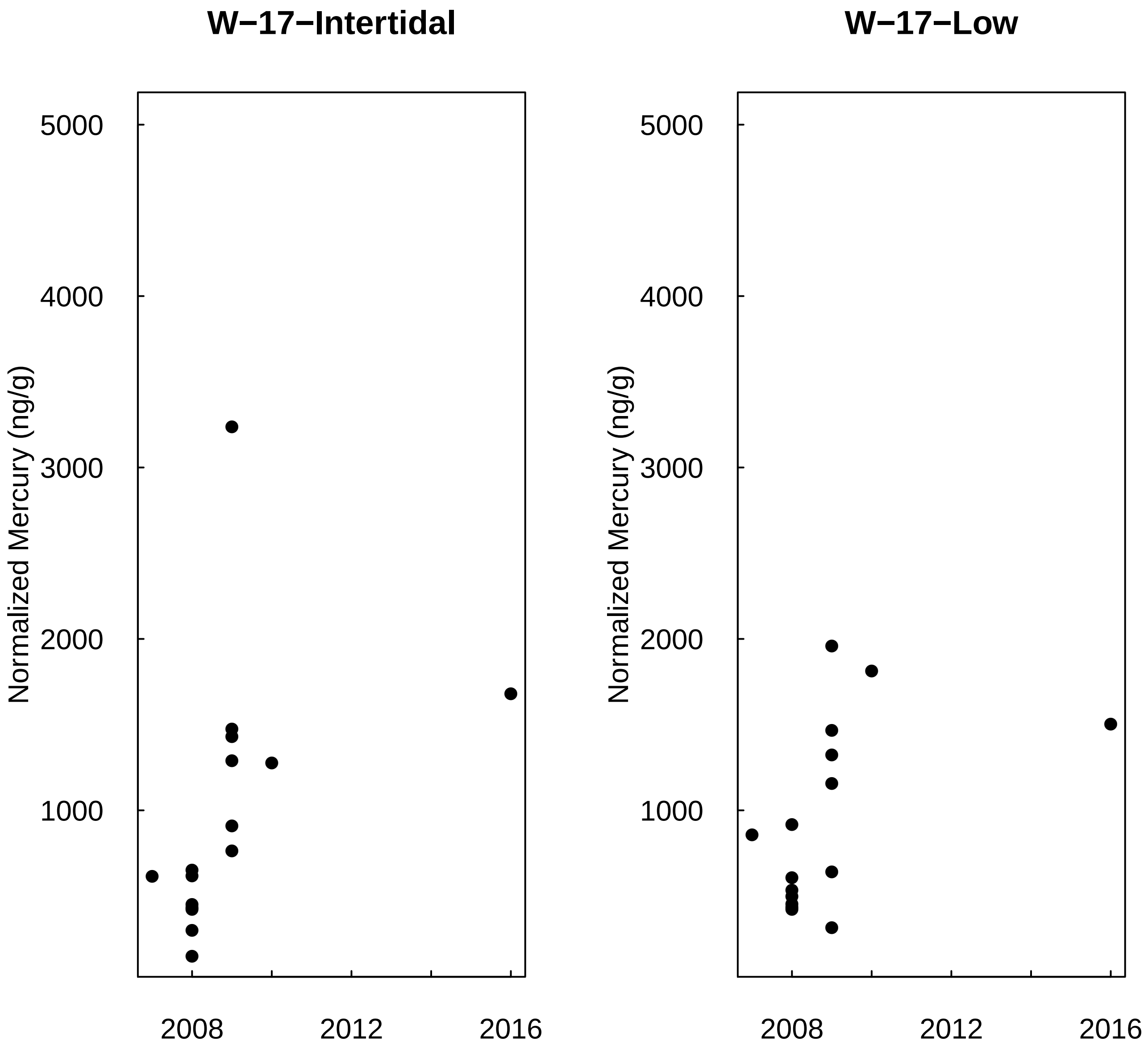


Figure 4.1-29 (cont.)

Temporal Wetland Sediment Methyl Mercury

W−63−High

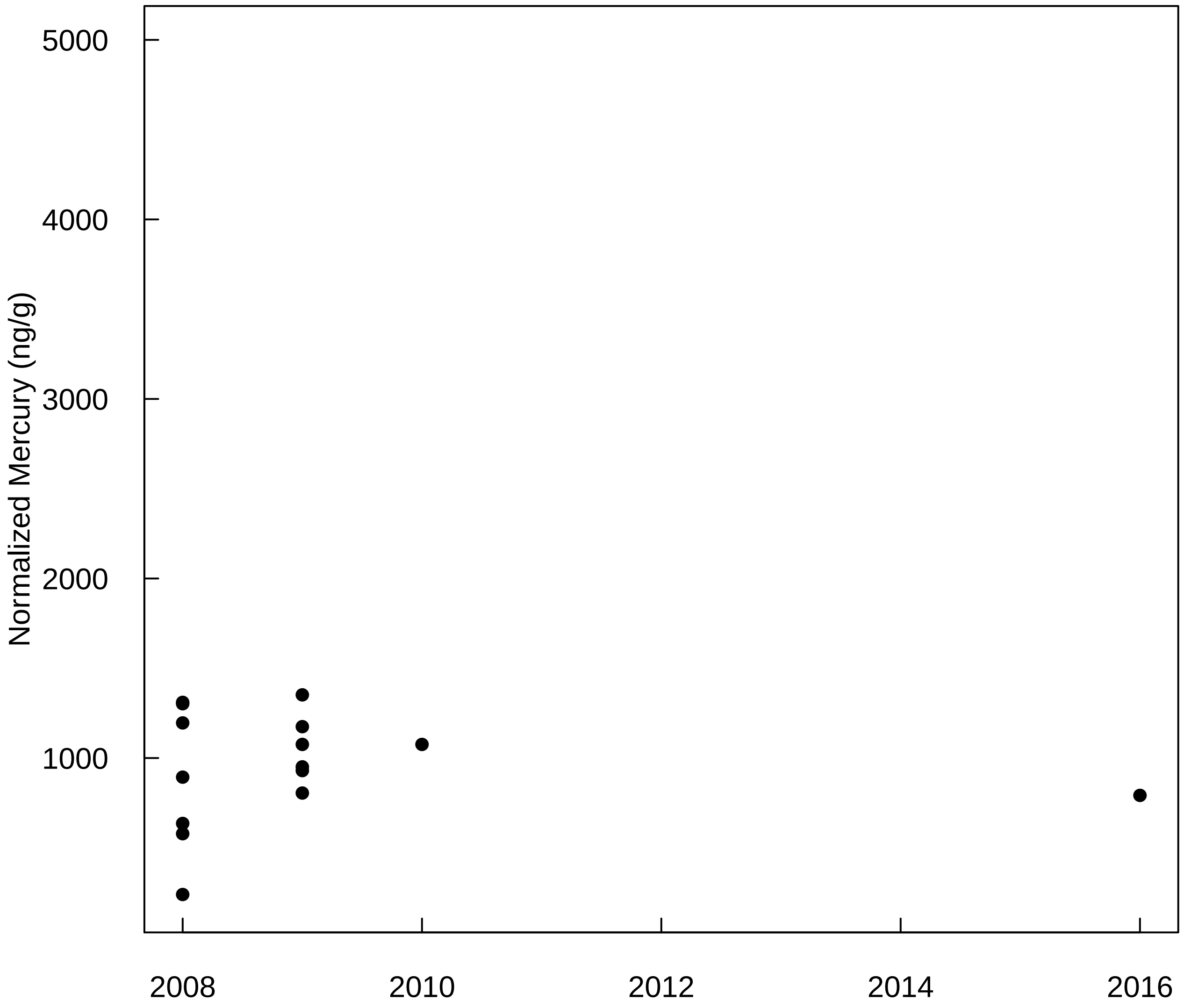
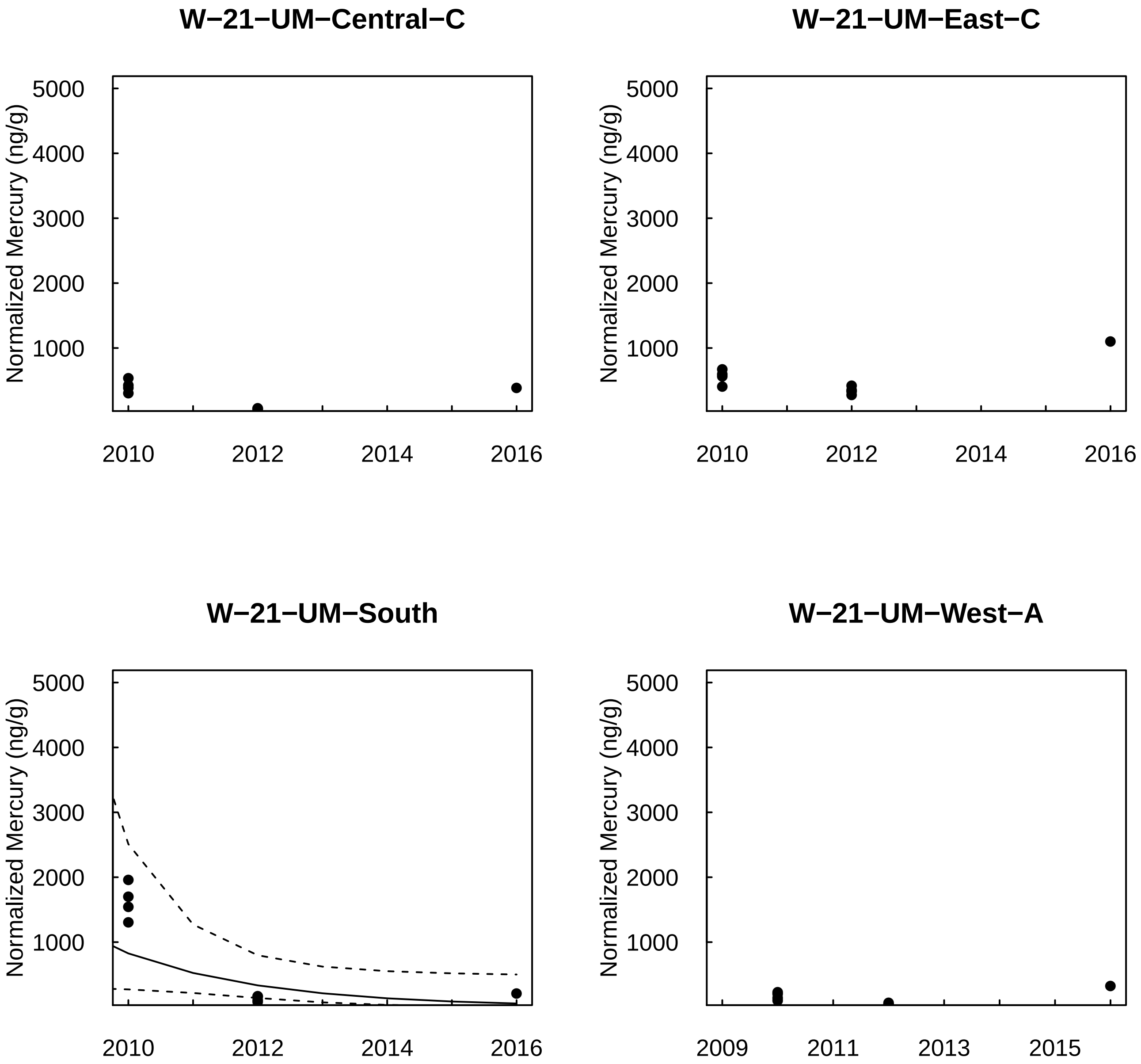


Figure 4.1-29 (cont.)

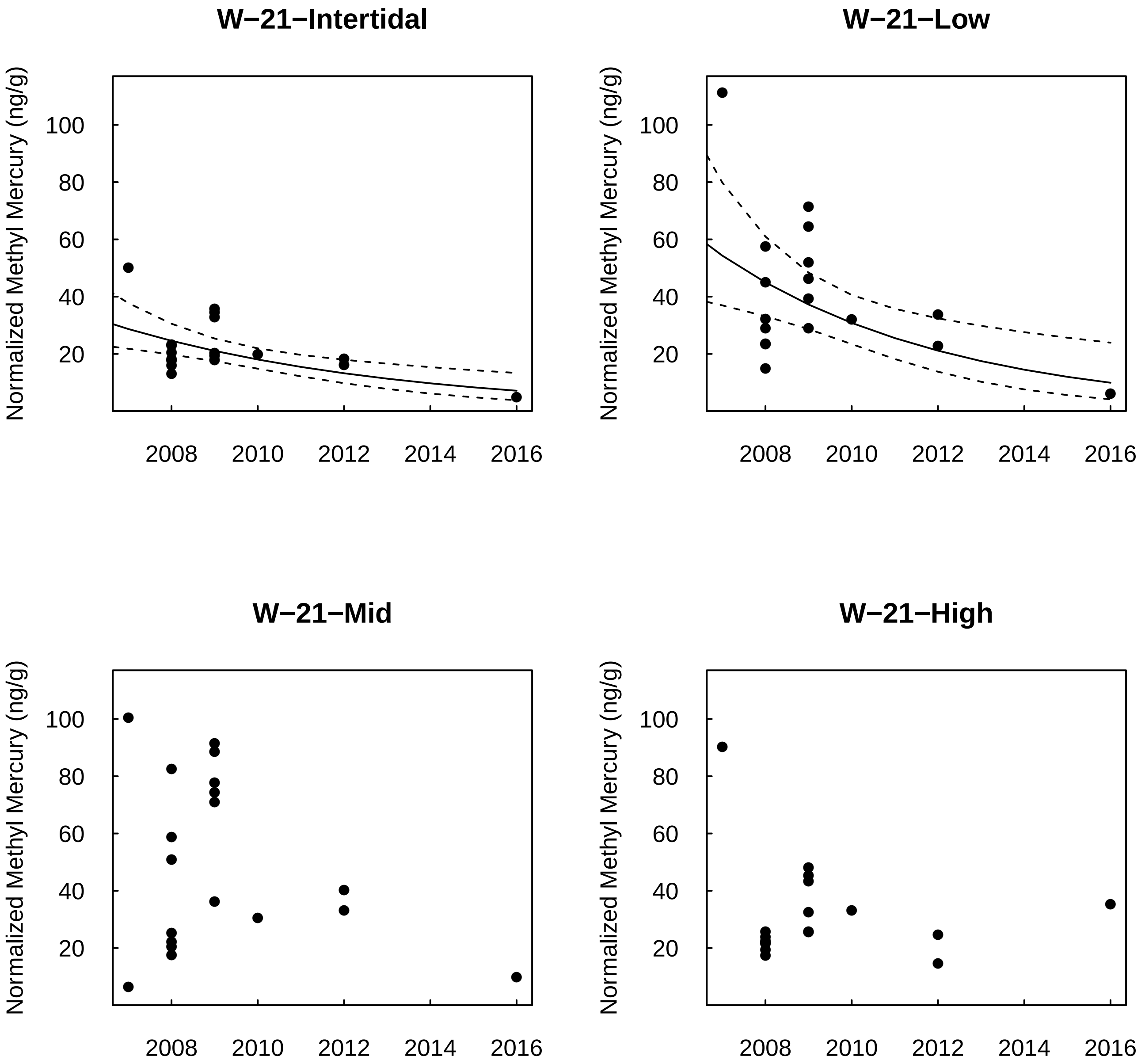
Temporal Wetland Sediment Methyl Mercury



Line indicates regression slope is significantly different than 0 ($p<0.05$). Dashed lines indicate 95% confidence interval of regression.
Regressions performed on log−transfmormed data, but data are presented un−transformed for clarity.

Figure 4.1-30

Temporal Wetland Sediment Normalized Methyl Mercury



Line indicates regression slope is significantly different than 0 (p<0.05). Dashed lines indicate 95% confidence interval of regression.
Regressions performed on log−transfmormed data, but data are presented un−transformed for clarity.

Figure 4.1-30 (cont.)

Temporal Wetland Sediment Normalized Methyl Mercury

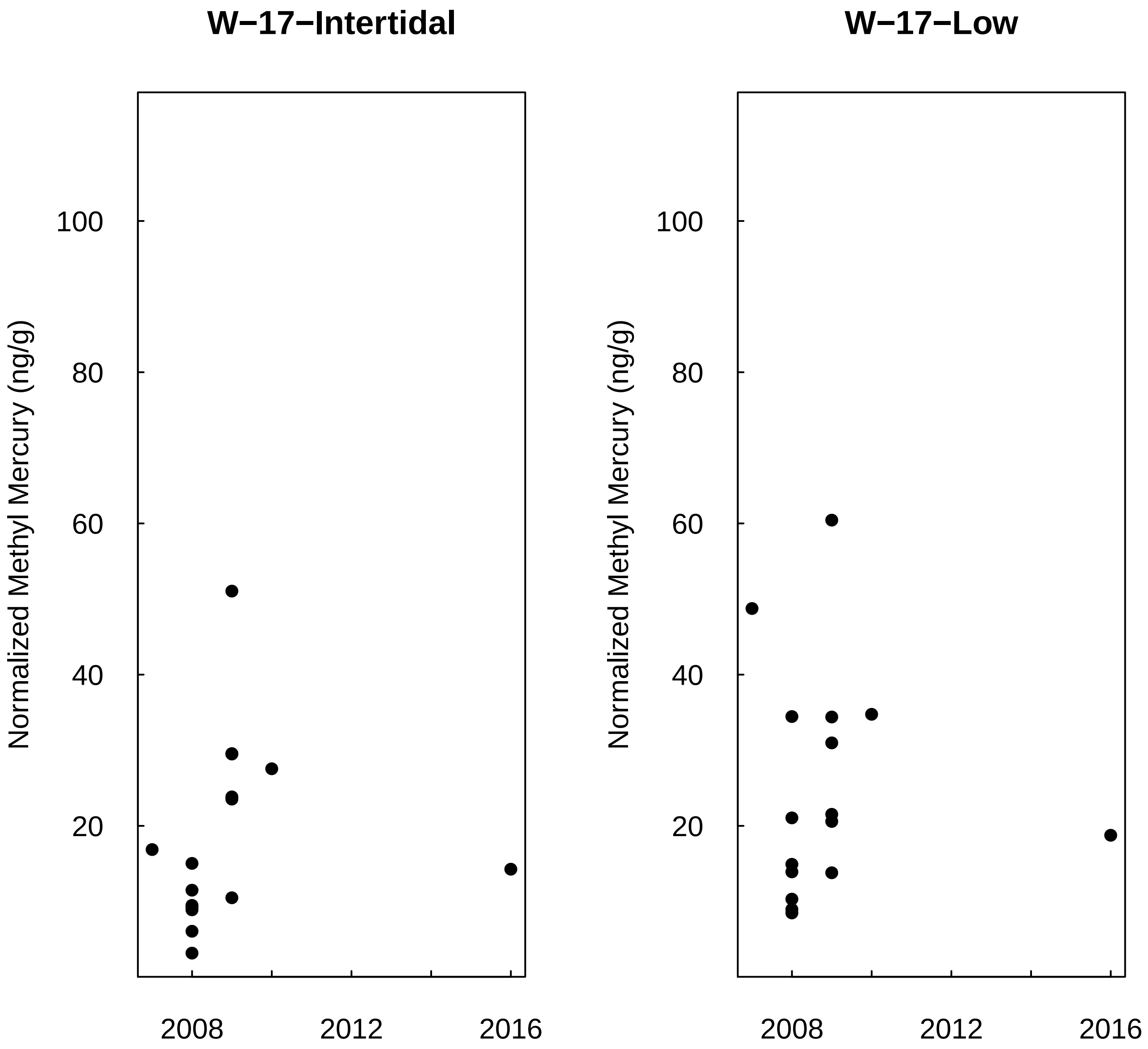


Figure 4.1-30 (cont.)

Temporal Wetland Sediment Normalized Methyl Mercury

W−63−High

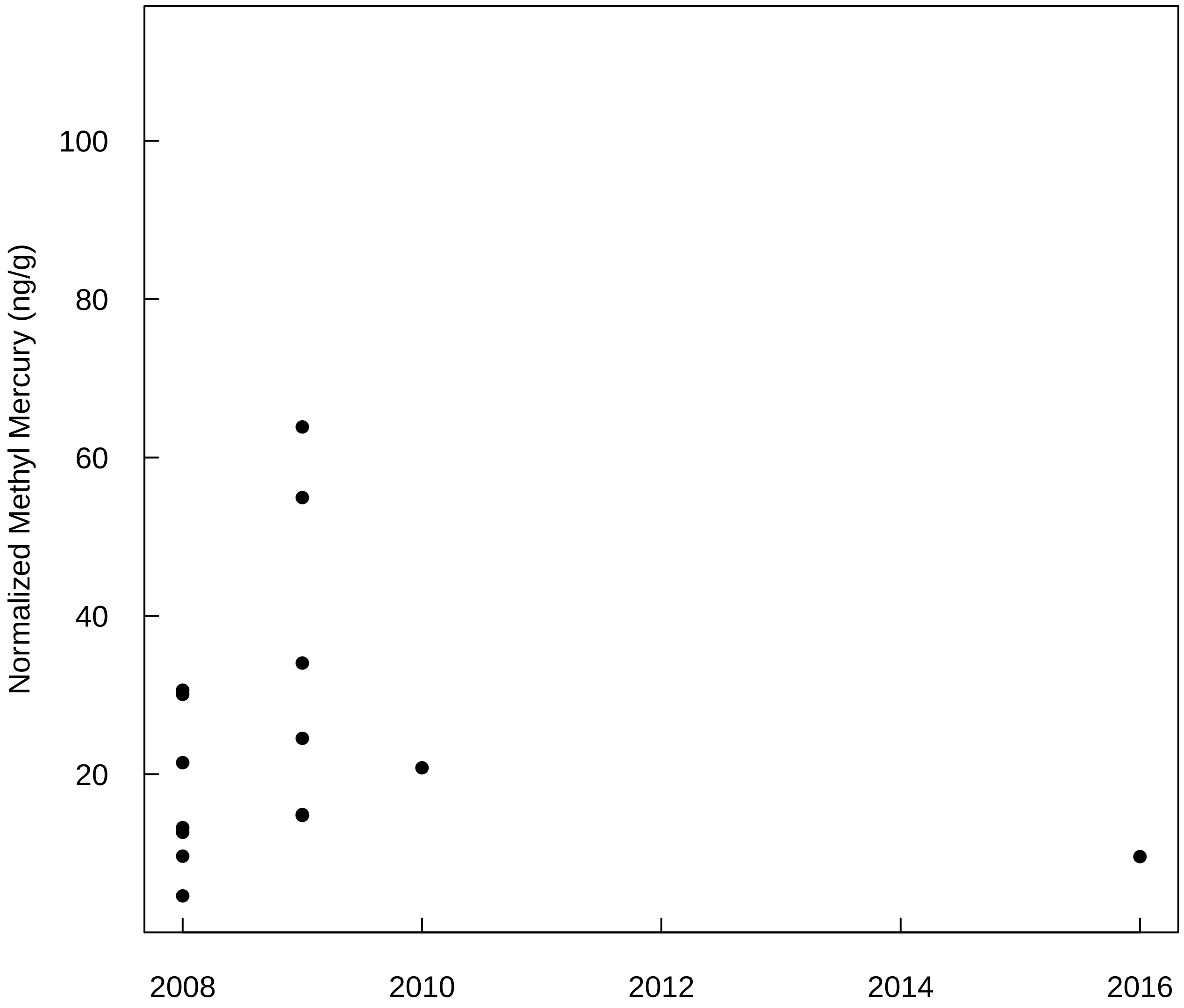
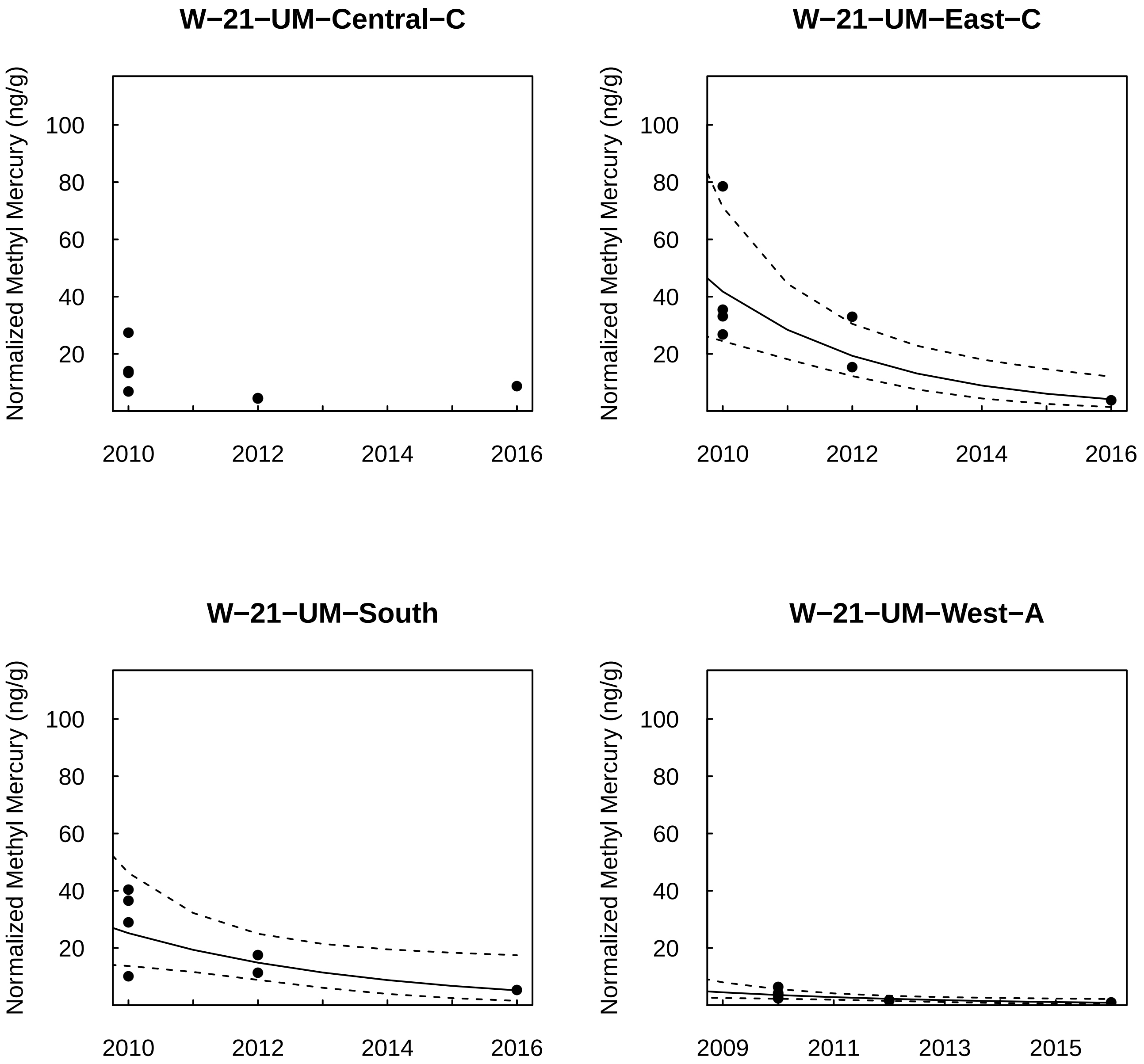


Figure 4.1-30 (cont.)

Temporal Wetland Sediment Normalized Methyl Mercury



Line indicates regression slope is significantly different than 0 (p<0.05). Dashed lines indicate 95% confidence interval of regression.
Regressions performed on log−transfmormed data, but data are presented un−transformed for clarity.

Figure 4.2-1
Total Mercury Concentrations - Surface Water

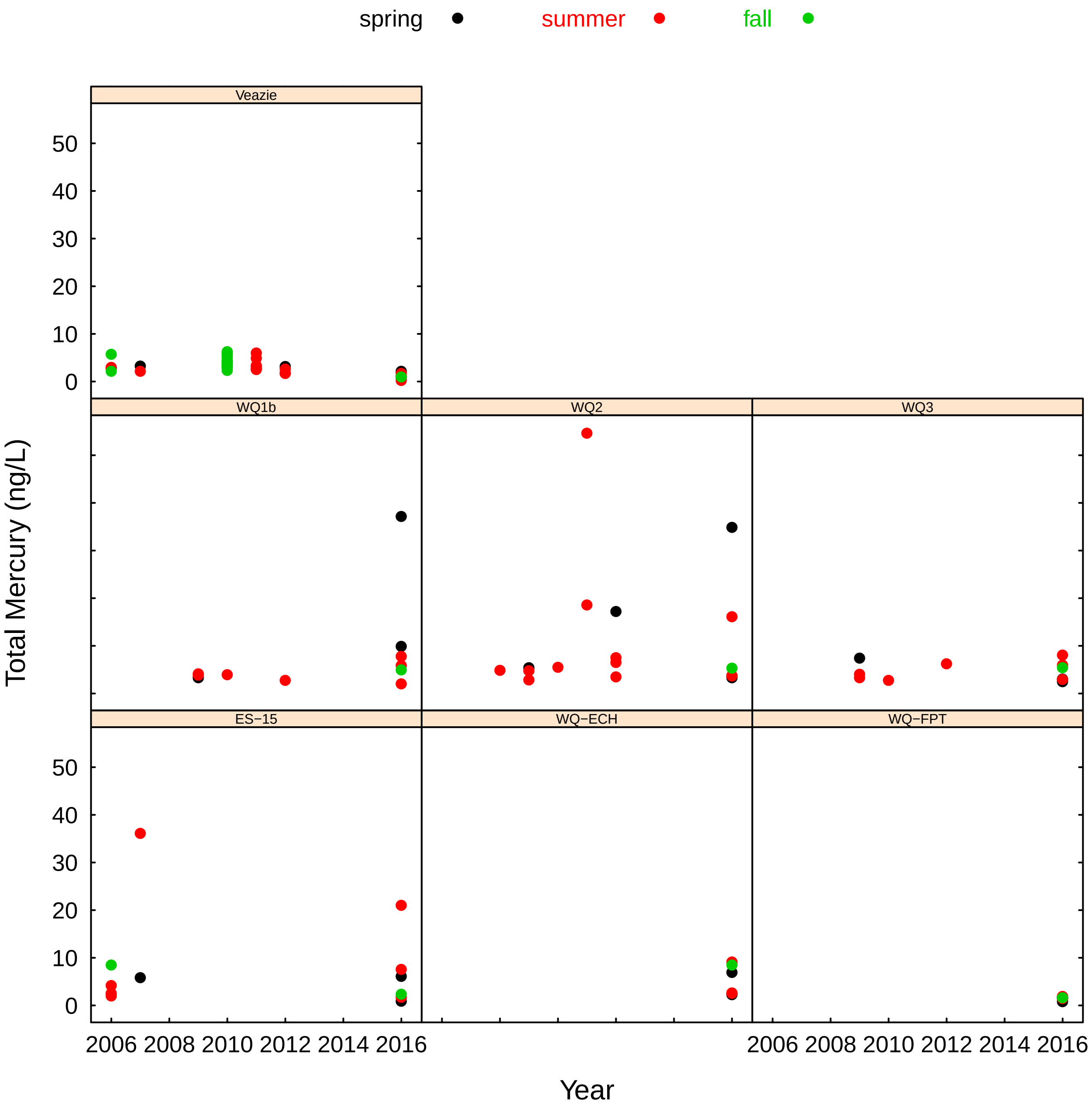


Figure 4.2-2
Dissolved Total Mercury Concentrations - Surface Water

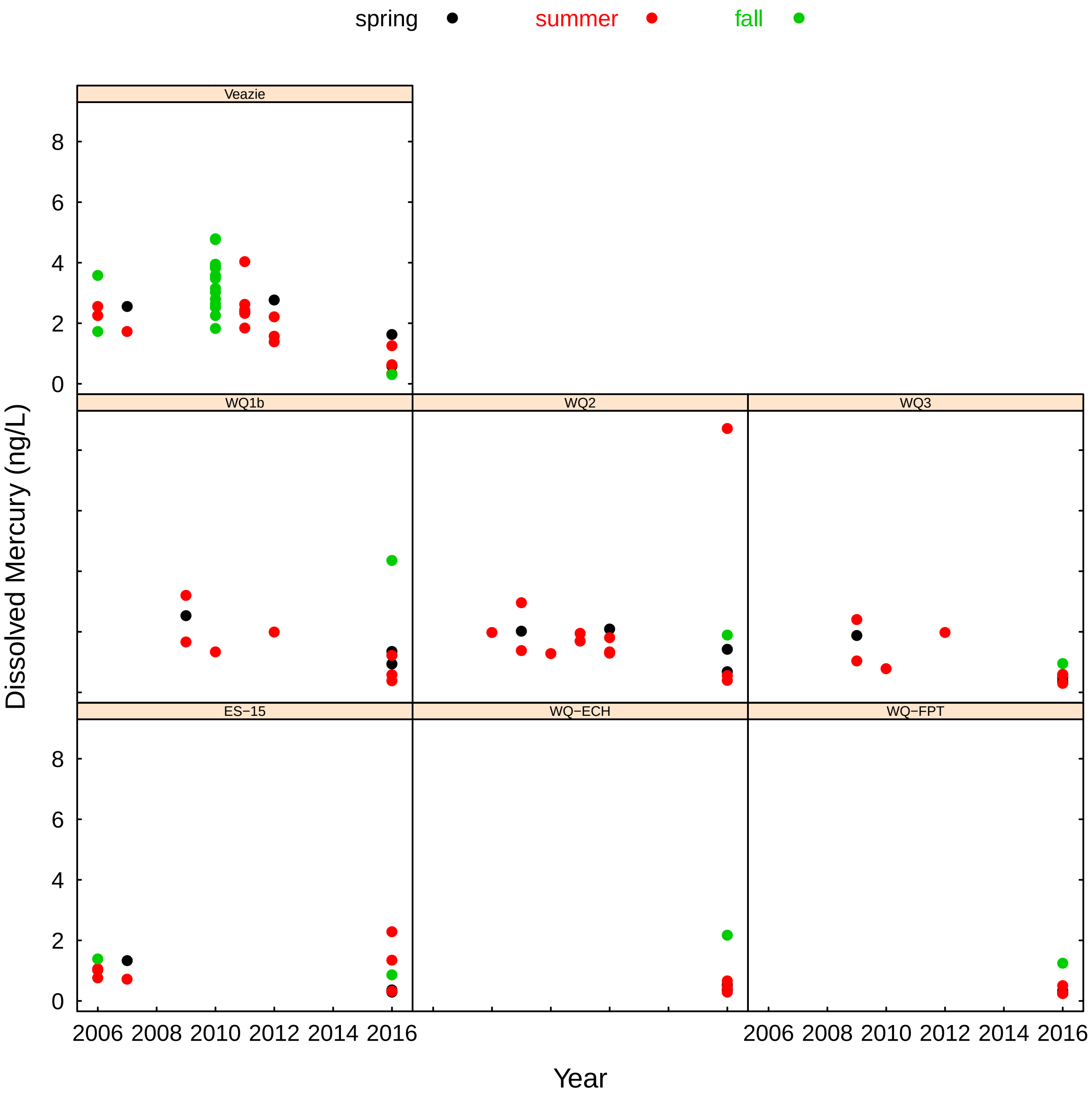


Figure 4.2-3
Methyl Mercury Concentrations - Surface Water

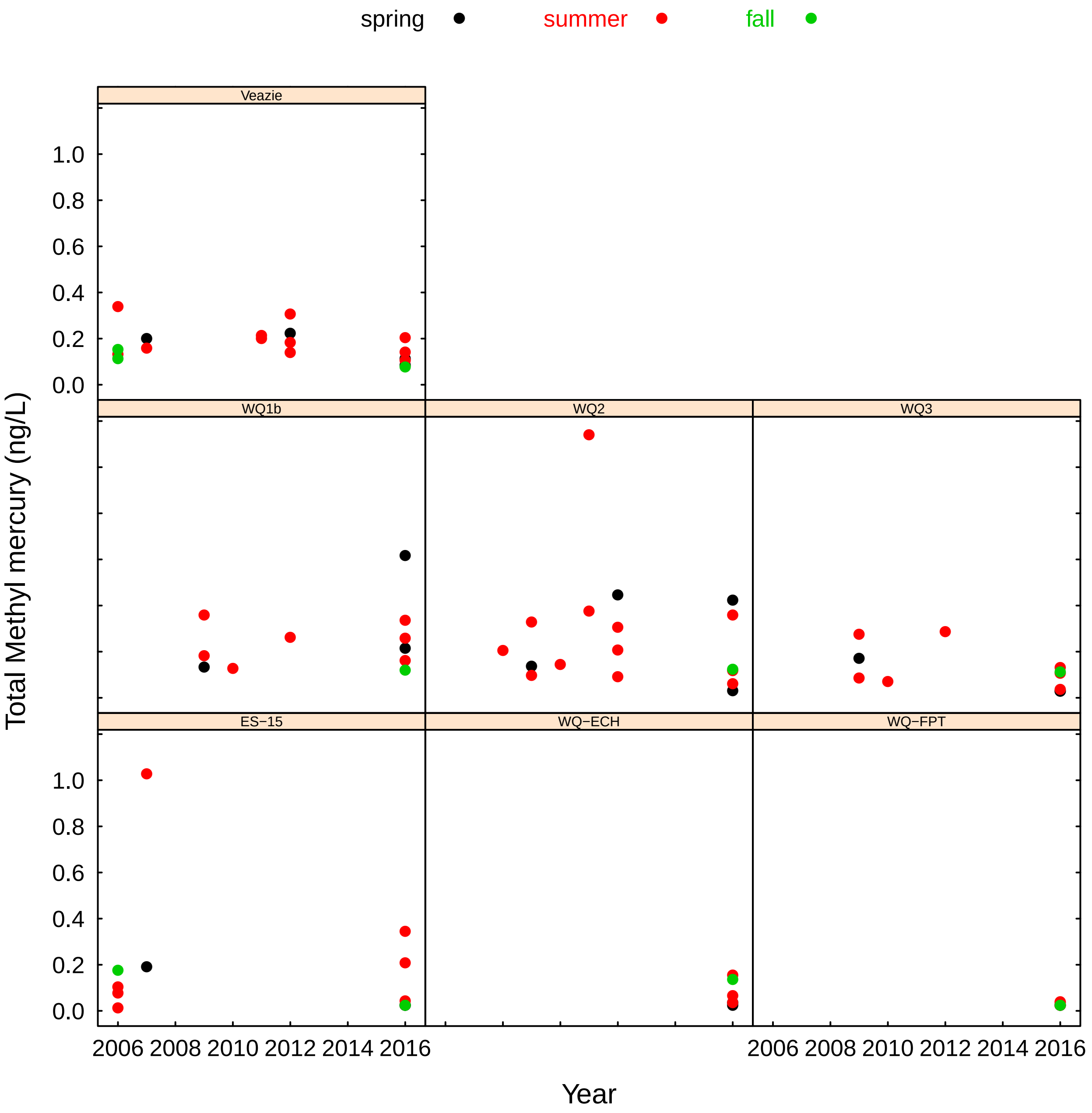
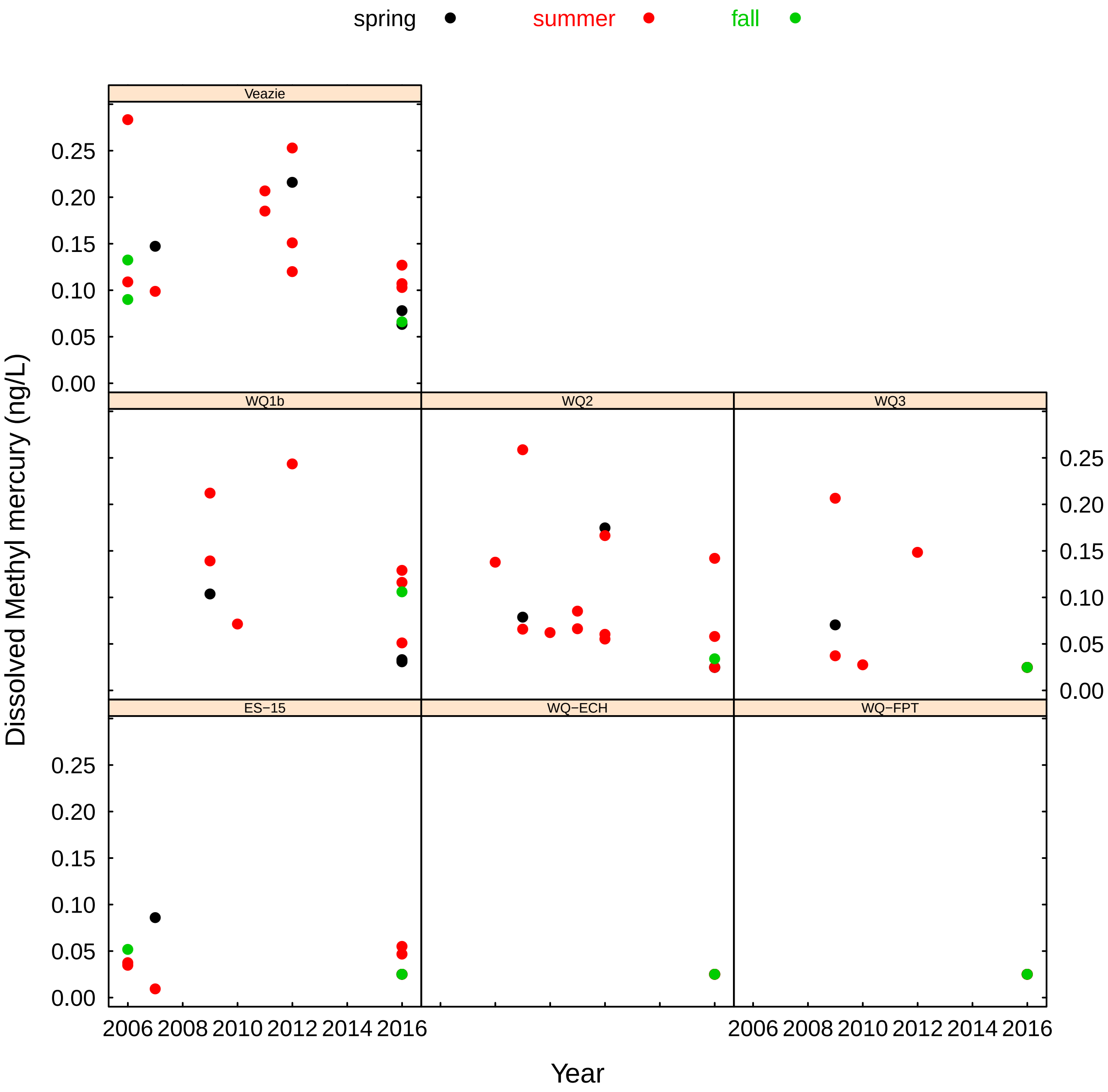


Figure 4.2-4
Dissolved Methyl Mercury Concentrations
- Surface Water



TABLES

TABLE 2-1
2016 SEDIMENT ANALYTICAL MATRIX

2016 SEDIMENT AND WATER QUALITY MONITORING REPORT
PENOBSCOT RIVER ESTUARY PHASE III - ENGINEERING STUDY

Media	Sample Date	Location ID	Longitude/Latitude			Sediment					Collection Method	Bottom Depth (ft)
					Analyte	**Mercury**	**Methyl-mercury**	**Total Organic Carbon**	**Organic Content**	**Grain Size**		
					Method	**1631e**	**1630**	**Lloyd-Kahn**	**ASTM D2974-C**	**ASTM D422 + #230 sieve Hydrometer**		
					Container	**4 oz Plastic**	**4 oz Plastic**	**4 oz AG**	**1 gal Ziploc®**			
					Preservation	**4° C**	**Frozen**	**4° C**	**N/A**	**N/A**		
					Field Sample ID							
Subtidal Sediment	7/28/2016	E-01-01	-68.8278	44.4823	E-01-01_072816_SED_03	1	1	1	1	1	Ponar	0.3
	7/28/2016	E-01-03	-68.8085	44.4824	E-01-03_072816_SED_03	1	1	1	1	1	Ponar	0.3
	7/28/2016	E-01-04	-68.7985	44.4816	E-01-04_072816_SED_03	1	1	1	1	1	Ponar	0.3
Intertidal Sediment	7/22/2016	ADD-02	-67.7201	44.6431	ADD-02_072216_SED_03	1	1	1	1	1	SS Spoon	0.3
	7/20/2016	BO-05	-68.8014	44.7628	BO-05_072016_SED_03	1	1	1	1	1	Hand Auger	0.5
	7/26/2016	OB-05	-68.8379	44.7055	OB-05_072616_SED_03	1	1	1	1	1	SS Spoon	0.3
	7/27/2016	ES-02	-68.7659	44.5399	ES-02_072716_SED_03	1	1	1	1	1	Ponar	0.3
	7/28/2016	ES-04	-68.8935	44.454	ES-04_072816_SED_03	1	1	1	1	1	Ponar	0.3
	7/27/2016	ES-13	-68.7717	44.5049	ES-13_072716_SED_03	1	1	1	1	1	SS Spoon	0.3
	7/22/2016	OV-01	-68.6797	44.8564	OV-01_072216_SED_03	1	1	1	1	1	SS Spoon	0.3
	7/22/2016	OV-02	-68.7015	44.8375	OV-02_072216_SED_03	1	1	1	1	1	SS Spoon	0.2
	7/22/2016	OV-04	-68.6739	44.8765	OV-04_072216_SED_03	1	1	1	1	1	SS Spoon	0.3
	7/26/2016	W-17-Intertidal	-68.856	44.6185	W-17-INTERTIDAL_072616_SED_03	1	1	1	1	1	Ponar	0.3
	7/25/2016	W-21-Intertidal	-68.8573	44.5808	W-21-INTERTIDAL_072516_SED_03	1	1	1	1	1	Ponar	0.3
	11/8/2016	W-61-Intertidal	-68.772433	44.505647	W-61-INT_110816_SED_03	1	1	1	1	1	Push Core	0.3
	11/8/2016	W-63-Intertidal	-68.838799	44.709058	W-63-INT_110816_SED_03	1	1	1	1	1	Push Core	0.3
	7/25/2016	W-65-Intertidal	-68.8591	44.5848	W-65-INTERTIDAL_072516_SED_03	1	1	1	1	1	Ponar	0.3
Wetland Sediment	7/21/2016	W-17-High	-68.8547	44.6234	W-17-HIGH_072116_SED_03	1	1	1	1	1	SS Spoon	0.3
	7/21/2016	W-17-Mid	-68.8536	44.6231	W-17-MID_072116_SED_03	1	1	1	1	1	Hand Auger	0.5
	7/26/2016	W-17-Low	-68.8558	44.6186	W-17-LOW_072616_SED_03	1	1	1	1	1	Ponar	0.3
	7/25/2016	W-21-High	-68.8577	44.5807	W-21-HIGH_072516_SED_03	1	1	1	1	1	Hand Auger	0.3
	7/25/2016	W-21-Mid	-68.8556	44.581	W-21-MID_072516_SED_03	1	1	1	1	1	Hand Auger	0.3
	7/25/2016	W-21-Low	-68.8572	44.5808	W-21-LOW_072516_SED_03	1	1	1	1	1	Ponar	0.3
	7/27/2016	W-21-UM-West-A	-68.8615	44.5808	W-21UM-WEST-A_07/27/16_SED_03	1	1	1	1	1	Shovel	0.3
	7/27/2016	W-21-UM-Central-C	-68.8609	44.5803	W-21UM-CENTRAL-C_072716_SED_03	1	1	1	1	1	Shovel	0.4
	7/25/2016	W-21-UM-East-C	-68.8577	44.5806	W-21UM-EAST-C_072516_SED_03	1	1	1	1	1	Hand Auger	0.3
	7/27/2016	W-21-UM-South	-68.8584	44.5565	W-21UM-SOUTH_072716_SED_03	1	1	1	1	1	Shovel	0.3
	11/8/2016	W-61-High	-68.772878	44.505910	W-61-HIGH_110816_SED_03	1	1	1	1	1	SS Spoon	0.3
	11/8/2016	W-61-Mid	-68.772748	44.505930	W-61-MID_110816_SED_03	1	1	1	1	1	SS Spoon	0.3
	11/8/2016	W-61-Low	-68.772698	44.505902	W-61-LOW_110816_SED_03	1	1	1	1	1	SS Spoon	0.3
	11/8/2016	W-63-High	-68.838098	44.709091	W-63-HIGH_110816_SED_03	1	1	1	1	1	SS Spoon	0.3
	11/8/2016	W-63-Mid	-68.838186	44.709258	W-63-MID_110816_SED_03	1	1	1	1	1	SS Spoon	0.3
	11/8/2016	W-63-Low	-68.838439	44.709122	W-63-LOW_110816_SED_03	1	1	1	1	1	SS Spoon	0.3
	7/25/2016	W-65-High	-68.8574	44.5855	W-65-HIGH_072516_SED_03	1	1	1	1	1	Hand Auger	0.3
	7/25/2016	W-65-Mid	-68.8579	44.5855	W-65-MID_072516_SED_03	1	1	1	1	1	Hand Auger	0.3
	7/25/2016	W-65-Low	-68.8592	44.585	W-65-LOW_072516_SED_03	1	1	1	1	1	Hand Auger	0.3

Created by: BPW 12/20/16
Checked by: DRP 2/17/17

Notes:

AG - Amber Glass
N/A - Not applicable
TOC - Total Organic Carbon
Equipment Blanks for sediment- collected one from field equipment (Ponar dredge) and one from sample mixing equipment (mixing paddle) and analyzed for for total mercury and total methylmercury.
Dup/MS/MSD locations were selected in the field dependent on sample volume available
Duplicate samples were collected at a rate of one per 10 field samples
MS/MSD samples were collected at a rate of one per 20 field samples

Created by: BPW 12/20/16
Checked by: DRP 2/17/17

TABLE 2-2
2016 WATER QUALITY MONITORING ANALYTICAL MATRIX

2016 SEDIMENT AND WATER QUALITY MONITORING REPORT
PENOBSCOT RIVER ESTUARY PHASE III - ENGINEERING STUDY

Location ID	Sample Date	Longitude/Latitude			Surface Water							
				Analyte	**Mercury**		**Methylmercury**		**TOC**	**DOC**	**TSS**	**Salinity/pH/Temp/Cond/DO/ORP**
				Method	**Total Unfiltered 1631e**	**Dissolved Field Filtered 1631e**	**Total Unfiltered 1630**	**Dissolved Field Filtered 1630**	**Total Unfiltered SW-846 9060**	**Dissolved Field Filtered SW-846 9060**	**Modified Method 2450D**	**YSI 556**
				Container	**250 ml PETG**	**250 ml PETG**	**250 ml BSG**	**250 ml BSG**	**3X40 ml glass**	**3X40 ml glass**	**1 L plastic**	**N/A**
				Preservation	**4° C**	**4° C**	**H_2SO_4/4° C**	**H_2SO_4/4° C**	**H_2SO_4/4° C**	**H_2SO_4/4° C**	**4° C**	**N/A**
				Sample I.D.								
ES-15	5/26/2016	-68.7982	44.5251	ES-15_052616_SW_10	1	1	1	1		1	1	1
OV-02	5/26/2016	-68.7015	44.8375	OV-02_052616_SW_10	1	1	1	1		1	1	1
WQ1b-C	5/26/2016	-68.8362	44.7162	WQ1b-c_052616_SW_10	1	1	1	1		1	1	1
WQ2-C	5/27/2016	-68.8418	44.6320	WQ2-c_052716_SW_10	1	1	1	1		1	1	1
WQ3-L	5/26/2016	-68.8133	44.5800	WQ3-L_052616_SW_10	1	1	1	1		1	1	1
WQ-ECH	5/26/2016	-68.7550	44.5276	WQ-ECH_052616_SW_10	1	1	1	1		1	1	1
WQ-FPT	5/26/2016	-68.8044	44.4684	WQ-FPT_052616_SW_10	1	1	1	1		1	1	1
ES-15	6/29/2016	-68.7982	44.5251	ES-15_062916_SW_10	1	1	1	1		1	1	1
OV-02	6/29/2016	-68.7015	44.8375	OV-02_062916_SW_10	1	1	1	1		1	1	1
WQ1b-C	6/29/2016	-68.8362	44.7162	WQ1b-c_062916_SW_10	1	1	1	1		1	1	1
WQ2-C	6/30/2016	-68.8418	44.6320	WQ2-c_063016_SW_10	1	1	1	1		1	1	1
WQ3-L	6/29/2016	-68.8133	44.5800	WQ3-L_062916_SW_10	1	1	1	1		1	1	1
WQ-ECH	6/29/2016	-68.7550	44.5276	WQ-ECH_062916_SW_10	1	1	1	1		1	1	1
WQ-FPT	6/29/2016	-68.8044	44.4684	WQ-FPT_062816_SW_10	1	1	1	1		1	1	1
ADD-02*	7/22/2016	-67.7201	44.6431	ADD-02_072216_SW_10	1	1	1	1		1	1	1
ES-15	7/18/2016	-68.7982	44.5251	ES-15_071816_SW_10	1	1	1	1		1	1	1
OV-02	7/18/2016	-68.7015	44.8375	OV-02_071816_SW_10	1	1	1	1		1	1	1
WQ1b-C	7/18/2016	-68.8362	44.7162	WQ1b-c_071816_SW_10	1	1	1	1		1	1	1
WQ2-C	7/18/2016	-68.8418	44.6320	WQ2-c_071816_SW_10	1	1	1	1		1	1	1
WQ3-L	7/18/2016	-68.8133	44.5800	WQ3-L_071816_SW_10	1	1	1	1		1	1	1
WQ-ECH	7/18/2016	-68.7550	44.5276	WQ-ECH_071816_SW_10	1	1	1	1		1	1	1
WQ-FPT	7/18/2016	-68.8044	44.4684	WQ-FPT_071816_SW_10	1	1	1	1		1	1	1
ES-15	8/29/2016	-68.7990	44.5251	ES-15_082916_SW_10	1	1	1	1	1	1	1	1
OV-02	8/29/2016	-68.7015	44.8375	OV-02_082916_SW_10	1	1	1	1	1	1	1	1
WQ1b-C	8/30/2016	-68.8363	44.7162	WQ1b-c_083016_SW_10	1	1	1	1	1	1	1	1
WQ2-C	8/30/2016	-68.8416	44.6321	WQ2-c_083016_SW_10	1	1	1	1	1	1	1	1
WQ3-L	8/30/2016	-68.8132	44.5800	WQ3-L_083016_SW_10	1	1	1	1	1	1	1	1
WQ-ECH	8/29/2016	-68.7550	44.5278	WQ-ECH_082916_SW_10	1	1	1	1	1	1	1	1
WQ-FPT	8/30/2016	-68.8041	44.4685	WQ-FPT_083016_SW_10	1	1	1	1	1	1	1	1

Created by: BPW 12/20/16
Checked by: DRP 2/17/17

TABLE 2-2
2016 WATER QUALITY MONITORING ANALYTICAL MATRIX

2016 SEDIMENT AND WATER QUALITY MONITORING REPORT
PENOBSCOT RIVER ESTUARY PHASE III - ENGINEERING STUDY

					Surface Water							
Location ID	Sample Date	Longitude/Latitude		Analyte	Mercury		Methylmercury		TOC	DOC	TSS	Salinity/pH/ Temp/Cond/ DO/ORP
				Method	Total Unfiltered 1631e	Dissolved Field Filtered 1631e	Total Unfiltered 1630	Dissolved Field Filtered 1630	Total Unfiltered SW-846 9060	Dissolved Field Filtered SW-846 9060	Modified Method 2450D	YSI 556
				Container	250 ml PETG	250 ml PETG	250 ml BSG	250 ml BSG	3X40 ml glass	3X40 ml glass	1 L plastic	N/A
				Preservation	4° C	4° C	H_2SO_4/4° C	H_2SO_4/4° C	H_2SO_4/4° C	H_2SO_4/4° C	4° C	N/A
				Sample I.D.								
ES-15	9/26/2016	-68.7990	44.5251	ES-15_092616_SW_10	1	1	1	1	1	1	1	1
OV-02	9/27/2016	-68.7015	44.8375	OV-02_092716_SW_10	1	1	1	1	1	1	1	1
WQ1b-C	9/27/2016	-68.8363	44.7162	WQ1b-c_092716_SW_10	1	1	1	1	1	1	1	1
WQ2-C	9/26/2016	-68.8416	44.6321	WQ2-c_092616_SW_10	1	1	1	1	1	1	1	1
WQ3-L	9/26/2016	-68.8132	44.5800	WQ3-L_092616_SW_10	1	1	1	1	1	1	1	1
WQ-ECH	9/26/2016	-68.7550	44.5278	WQ-ECH_092616_SW_10	1	1	1	1	1	1	1	1
WQ-FPT	9/26/2016	-68.8041	44.4685	WQ-FPT_092616_SW_10	1	1	1	1	1	1	1	1
ES-15	10/26/2016	-68.7990	44.5251	ES-15_102616_SW_10	1	1	1	1	1	1	1	1
OV-02	10/26/2016	-68.7015	44.8375	OV-02_102616_SW_10	1	1	1	1	1	1	1	1
WQ1b-C	10/25/2016	-68.8363	44.7162	WQ1b-c_102516_SW_10	1	1	1	1	1	1	1	1
WQ2-C	10/26/2016	-68.8416	44.6321	WQ2-c_102616_SW_10	1	1	1	1	1	1	1	1
WQ3-L	10/26/2016	-68.8132	44.5800	WQ3-L_102616_SW_10	1	1	1	1	1	1	1	1
WQ-ECH	10/26/2016	-68.7550	44.5278	WQ-ECH_1026148_SW_10	1	1	1	1	1	1	1	1
WQ-FPT	10/26/2016	-68.8041	44.4685	WQ-FPT_102616_SW_10	1	1	1	1	1	1	1	1

Notes:
DOC - Dissolved Organic Carbon
L - liter
mL - milliliter
N/A - Not applicable
Temp - Temperature
TOC - Total Organic Carbon
TSS - Total Suspended Solids
Field-filtered samples were filtered using a 45 micron disposable filter

Created by: BPW 12/20/16
Checked by: DRP 2/17/17

TABLE 2-3
WATER QUALITY MONITORING TIMES AND TIDAL PHASE

2016 SEDIMENT AND WATER QUALITY MONITORING REPORT
PENOBSCOT RIVER ESTUARY PHASE III - ENGINEERING STUDY

Locations	Sample Date and Time		Hours after High Tide	Time of High Tide (24 hr format)	Reference Location
May					
OV-02	5/26/2016	13:00		NA	
WQ1b-c	5/26/2016	16:20	1:43	14:37	Winterport
WQ2-c	5/27/2016	8:00	5:15	2:45	Winterport
WQ3-L	5/26/2016	15:10	0:33	14:37	Winterport
ES-15	5/26/2016	8:50	6:50	2:00	Winterport
WQ-ECH	5/26/2016	7:05	5:05	2:00	Winterport
WQ-FPT	5/26/2016	8:10	6:10	2:00	Winterport
June					
OV-02	6/29/2016	15:00		NA	
WQ1b-c	6/29/2016	10:40	4:28	6:12	Winterport
WQ2-c	6/30/2016	9:00	1:43	7:17	Winterport
WQ3-L	6/29/2016	9:35	3:23	6:12	Winterport
ES-15	6/29/2016	9:00	2:48	6:12	Winterport
WQ-ECH	6/29/2016	7:45	1:33	6:12	Winterport
WQ-FPT	6/29/2016	8:25	2:13	6:12	Winterport
July					
OV-02	7/18/2016	7:45		NA	
WQ1b-c	7/18/2016	16:30	6:07	10:23	Winterport
WQ2-c	7/18/2016	15:15	4:52	10:23	Winterport
WQ3-L	7/18/2016	14:00	3:37	10:23	Winterport
ES-15	7/18/2016	13:15	2:52	10:23	Winterport
WQ-ECH	7/18/2016	12:00	1:37	10:23	Winterport
WQ-FPT	7/18/2016	11:00	0:37	10:23	Winterport
ADD-02	7/22/2016	16:38	3:51	12:47	Milbridge
August					
OV-02	8/29/2016	17:00		NA	
WQ1b-c	8/30/2016	13:25	3:32	9:53	Winterport
WQ2-c	8/30/2016	12:20	2:27	9:53	Winterport
WQ3-L	8/30/2016	11:02	1:09	9:53	Winterport
ES-15	8/29/2016	14:00	5:01	8:59	Winterport
WQ-ECH	8/29/2016	11:50	2:51	8:59	Winterport
WQ-FPT	8/30/2016	10:20	0:27	9:53	Winterport
September					
OV-02	9/27/2016	16:10		NA	
WQ1b-c	9/27/2016	11:30	2:46	8:44	Winterport
WQ2-c	9/26/2016	14:10	6:24	7:46	Winterport
WQ3-L	9/26/2016	13:30	5:44	7:46	Winterport
ES-15	9/26/2016	12:45	4:59	7:46	Winterport
WQ-ECH	9/26/2016	11:00	3:14	7:46	Winterport
WQ-FPT	9/26/2016	11:55	4:09	7:46	Winterport

Prepared by KCB
Checked by DRP

TABLE 2-3
WATER QUALITY MONITORING TIMES AND TIDAL PHASE

2016 SEDIMENT AND WATER QUALITY MONITORING REPORT
PENOBSCOT RIVER ESTUARY PHASE III - ENGINEERING STUDY

Locations	Sample Date and Time		Hours after High Tide	Time of High Tide (24 hr format)	Reference Location
October					
OV-02	10/26/2016	17:50		NA	
WQ1b-c	10/25/2016	12:03	4:38	7:25	Winterport
WQ2-c	10/26/2016	14:05	5:44	8:21	Winterport
WQ3-L	10/26/2016	13:30	5:09	8:21	Winterport
ES-15	10/26/2016	11:00	2:39	8:21	Winterport
WQ-ECH	10/26/2016	12:30	4:09	8:21	Winterport
WQ-FPT	10/26/2016	11:45	3:24	8:21	Winterport

Notes:

Ebb tide conditions were confirmed by sampling crew at time of sampling.

NA - time of high tide not applicable as sample location is upriver of tidal influence

Prepared by KCB
Checked by DRP

TABLE 3-1
2016 SEDIMENT MONITORING ANALYTICAL RESULTS

2016 SEDIMENT AND WATER QUALITY MONITORING REPORT
PENOBSCOT RIVER ESTUARY PHASE III - ENGINEERING STUDY

					Parameter	Mercury Cold Aqua Regia		Mercury Hot Aqua Regia		Mercury Hot Aqua Regia		Mercury Hot Aqua Regia		Mercury Hot Aqua Regia		Methylmercury		Adjusted Methylmercury		Methylmercury / Total Mercury	Total Organic Carbon		Total Organic Content		Solids, Residual		% Fines
					Method Code	1631e		1631e AVG		Rep1		Rep2		Rep3		Avg		Avg			Lloyd-Kahn		ASTM D2974-C		ASTM D422		
					Units	ng/g		ng/g		ng/g		ng/g		ng/g		ng/g		ng/g		Percent	%		%		%		percent
Media	**Location**	**River Reach**	**Sample Date**	**Sample ID**	**QC Code**	**Result**	**Qual**	**Result**	**Qual**	**Result**	**Qual**	**Result**	**Qual**	**Result**	**Qual**	**Result**	**Qual**	**Result**	**Qual**	**Result**	**Result**	**Qual**	**Result**	**Qual**	**Result**	**Qual**	**Result**
Background Sediment	ADD-02	Addison River	07/22/16	ADD-02_072216_SED_03	FS	28.9		32.6		31.7		32.4		33.8		2.4		4.8		14.7	2.7		6.6		37.6		98.5
	OV-04	Veazie	07/22/16	OV-04_072216_SED_03	FS	31.1		22.3		22.5		19.2		25.3		0.009	U	0.018	2x	0.1	0.4		0.7		77.4		6.2
	OV-01	Veazie	07/22/16	OV-01_072216_SED_03	FS	29.3		27.7		12.9		14.7		55.4		0.02	J	0.04	2x	0.1	0.4		0.8		89.2		3.2
	OV-02	Veazie	07/22/16	OV-02_072216_SED_03	FS	46.5		62.8		61.3		62.3		64.9		3.68		7.36	2x	11.7	4.4		9.4		40.2		48.6
Intertidal Sediment - Estuary	BO-05	Bangor	07/20/16	BO-05_072016_SED_03	FS	1420		1793.3		1920		1700		1760		7.86		15.72	2x	0.9	9.3		9.4		20.6		88.9
	W-63-Intertidal	Orrington	11/08/16	W-63-INT_110816_SED_03	FS	1050		1123.3		1140		1210		1020		11.2		22.4	2x	2.0	9.8		15.9		29.9		93
	OB-05	Orrington	07/26/16	OB-05_072616_SED_03	FS	550		755.0		779		748		738		11.3		22.6	2x	3.0	5.7		0.4		43.2		87.1
	W-17-Intertidal	Frankfort Flats	07/26/16	W-17-INTERTIDAL_072616_SED_03	FS	374		518.3		596		462		497		2.2		4.4	2x	0.8	1.7		5.0		62.2		80.8
	W-65-Intertidal	Mendall Marsh	07/25/16	W-65-INTERTIDAL_072516_SED_03	FS	42.2		41.8		41.2		37.8		46.3		0.207		0.414	2x	1.0	0.5		1.7		72.6		12.1
	W-21-Intertidal	Mendall Marsh	07/25/16	W-21-INTERTIDAL_072516_SED_03	FS	467		543.3		552		524		554		2.36		4.72	2x	0.9	5.1		4.7		42.2		63.8
	ES-02	Verona Northeast	07/27/16	ES-02_072716_SED_03	FS	849		961.0		990		988		905		22.2		44.4	2x	4.6	7.4		6.6		33.7		87.8
	W-61-Intertidal	Verona East	11/08/16	W-61-INT_110816_SED_03	FS	980		1163.3		1130		1180		1180		5.59		11.18	2x	1.0	10.9		1.7		27.8		32.6
	ES-13	Verona East	07/27/16	ES-13_072716_SED_03	FS	395		416.3		403		401		445		16.8		33.6	2x	8.1	3.0		4.1		48.8		43
	ES-04	Out - Searsport	07/28/16	ES-04_072816_SED_03	FS	297		300.7		312		293		297		1.58		3.16	2x	1.1	3.4	J	4.9		31		97.9
Wetland Sediment	W-63-High	Orrington	11/08/16	W-63-HIGH_110816_SED_03	FS	37.9		36.8		36.4		37.5		36.5		0.232		0.464	2x	1.3	0.4	J	2.1		29.5		32.3
	W-17-High	Frankfort Flats	07/21/16	W-17-HIGH_072116_SED_03	FS	962		1266.7		1220		1300		1280		22.2		44.4	2x	3.5	8.5		8.6		31.2		87
	W-65-High	Mendall Marsh	07/25/16	W-65-HIGH_072516_SED_03	FS	91.5		84.3		102		65.8		85.1		0.034	U	0.068	2x	0.08	15.3		27.9		15.1		16.30
	W-21-High	Mendall Marsh	07/25/16	W-21-HIGH_072516_SED_03	FS	871		929.0		892		961		934		15.8		31.6	2x	3.4	7.9		10.4		26.8		93
	W-21-UM-West-A	Mendall Marsh	07/27/16	W-21UM-WEST-A_07/27/16_SED_03	FS	437		434.3		431		440		432		0.713		1.426	2x	0.3	11.4		30.0		14.4		91.20
	W-61-High	Verona East	11/08/16	W-61-HIGH_110816_SED_03	FS	318		593.7		297		384		1100		4.87		9.74	2x	1.6	15.8		5.5		30.9		66.9
	W-63-Mid	Orrington	11/08/16	W-63-MID_110816_SED_03	FS	222		215.3		215		182		249		6.96		13.92	2x	6.5	4.6		2.8		59.5		22
	W-17-Mid	Frankfort Flats	07/21/16	W-17-MID_072116_SED_03	FS	699		1179.3		1430		1150		958		3.01		6.02	2x	0.5	4.9		8.9		46.4		86.9
	W-65-Mid	Mendall Marsh	07/25/16	W-65-MID_072516_SED_03	FS	267		225.7		173		124		380		5.27		10.54	2x	4.7	26.0		32.2		16.2		89.9
	W-21-Mid	Mendall Marsh	07/25/16	W-21-MID_072516_SED_03	FS	813		869.0		801		796		1010		2.77		5.54	2x	0.6	5.8		4.9		39.4		87.0
	W-21-UM-Central-C	Mendall Marsh	07/27/16	W-21UM-CENTRAL-C_072716_SED_03	FS	552		617.3		603		673		576		7.02		14.04	2x	2.3	13.5		8.1		20.5		54.5
	W-61-Mid	Verona East	11/08/16	W-61-MID_110816_SED_03	FS	682		1483.3		402		388		3660		6.65		13.3	2x	0.9	12.1		2.3		39.6		21.6
	W-63-Low	Orrington	11/08/16	W-63-LOW_110816_SED_03	FS	217		229.0		228		242		217		2.25		4.5	2x	2.0	2.5		13.5		50.9		21.7
	W-17-Low	Frankfort Flats	07/26/16	W-17-LOW_072616_SED_03	FS	364		471.0		491		462		460		2.85	J	5.7	2x	1.2	2.6		5.9		47.4		94
	W-65-Low	Mendall Marsh	07/25/16	W-65-LOW_072516_SED_03	FS	16.7		32.6		17.2		15.9		64.6		0.01	U	0.02	2x	0.1	2.4		2.9		63.7		41.30
	W-21-Low	Mendall Marsh	07/25/16	W-21-LOW_072516_SED_03	FS	729		704.7		763		681		670		2.68		5.36	2x	0.8	7.1		8.0		45.5		85.1
	W-21-UM-East-C	Mendall Marsh	07/25/16	W-21UM-EAST-C_072516_SED_03	FS	685		751.7		739		753		763		1.28		2.56	2x	0.3	5.8		41.4		32.2		92.7
	W-21-UM-South	Mendall Marsh	07/27/16	W-21UM-SOUTH_072716_SED_03	FS	318		267.0		295		251		255		3.47		6.94	2x	2.6	10.9		31.5		24.9		78.3
	W-61-Low	Verona East	11/08/16	W-61-LOW_110816_SED_03	FS	773		926.7		934		976		870		18.8		37.6	2x	4.1	8.5		2.3		40.6		13
Subtidal Sediment	E-01-01	Fort Point Cove	07/28/16	E-01-01_072816_SED_03	FS	1100		1206.7		1220		1210		1190		12.3		24.6	2x	2.0	5.9	J	4.9		31.7		97.4
	E-01-03	Upper Penobscot Bay	07/28/16	E-01-03_072816_SED_03	FS	513		567.0		607		535		559		6.72		13.44	2x	2.4	3.9	J	3.4		33.9		91.8
	E-01-04	Upper Penobscot Bay	07/28/16	E-01-04_072816_SED_03	FS	579		568.7		518		621		567		9.38		18.76	2x	3.3	3.3	J	3.8		45		39.8

Notes:
FS = field sample
ng/g = nanograms per gram
ng/g-c = nanograms per gram of carbon

Flags:
U = Value not detected above reporting limit
J = Estimated value
2x = adjusted to MeHg by distillation via 2x multiplier

TABLE 3-2
2016 WATER QUALITY MONITORING ANALYTICAL RESULTS

2016 SEDIMENT AND WATER QUALITY MONITORING REPORT
PENOBSCOT RIVER ESTUARY PHASE III - ENGINEERING STUDY

				Parameter	Mercury						Methyl Mercury						Total Organic Carbon		Dissolved Organic Carbon		Total Suspended Solids		Temper-ature	pH (units)	Specific Electrical Conductance	DO	ORP	Turbidity	Salinity
					Total		Dissolved		Particulate*		Total		Dissolved		Particulate*														
				Method Code	1631e		1631e		Calc*		1630		1630		Calc*		SW-846 9060		SW-846 9060		Modified SM 2450D								
				Units	NG/L		NG/L		NG/G		NG/L		NG/L		NG/G		MG/L		MG/L		MG/L		°C	units	mS/cm	mg/L	mV	NTU	ppt
Location	Reach	Sample Date	Sample ID	QC Code	Result	Qual	Result	Qual	Result	Note	Result	Qual	Result	Qual	Result	Note	Result	Qual	Result	Qual	Result	Qual							
OV-02	Veazie	05/26/16	OV02_052616_SW_10	FS	2.18		1.63		220	b	0.11		0.08		14.0	b	NS		6.8		5	U	21.3	8.18	0.433	7.9	100.2	1.03	0.29
OV-02	Veazie	06/29/16	OV-02_062916_SW_10	FS	1.80	U	1.20	U	126	a,b	0.170	U	0.130	U	8.4	a,b	NS		4.7	J	5.0	U	23.42	7.69	0.077	7.33	180	1.59	0.03
OV-02	Veazie	07/18/16	OV-02_071816_SW_10	FS	1.68		1.26		168	b	0.141		0.107		13.6	b	NS		5.8	J	5.0	U	23.82	7.24	0.056	6.69	180	0.9	0.02
OV-02	Veazie	08/29/16	OV-02_082916_SW_10	FS	2.20	U	1.30	U	178	a,b	0.205		0.127		31.2	b	7		7.4		5.0	U	24.04	8.08	0.063	8.24	62.2	1.22	0.03
OV-02	Veazie	09/27/16	OV-02_092716_SW_10	FS	0.50	U	0.66	U	0	c	0.106	J	0.103	J	1.2	b	5.5	J	5.2	J	5.0	U	17.02	7.48	0.044	10.11	65.8	0.61	0.02
OV-02	Veazie	10/26/16	OV-02_102616_SW_10	FS	0.96		0.62	U	260	a,b	0.078	J	0.066	J	4.8	b	5.3		5.7		5.0	U	9.6	8.7	0.243	12.25	71.3	0	0.09
WQ1b-C	Orrington	05/26/16	WQ1b-C_052616_SW_10	FS	9.85		1.35		1308		0.21		0.03	J	28.2		NS		4.6		6.5		20.59	7.98	3.051	7.66	92.6	5.79	1.62
WQ1b-C	Orrington	06/29/16	WQ1b-C_062916_SW_10	FS	37.20		1.90	U	725	a	0.617		0.066	U	11.7	a	NS		3.9	J	50.0		22.65	8.02	2.71	6.98	200	29.3	1.5
WQ1b-C	Orrington	07/18/16	WQ1b-C_071816_SW_10	FS	5.86		1.20	U	528	a	0.259		0.116		14.3		NS		2.4	J	10.0		24.21	7.84	4.052	6.7	120	5.37	2.11
WQ1b-C	Orrington	08/30/16	WQ1b-C_083016_SW_10	FS	7.83		1.23		NA		0.336		0.129		NA		6.3		6.8		NA		23.45	8.01	1.29	8.15	-7.9	7.35	0.77
WQ1b-C	Orrington	09/27/16	WQ1b-C_092716_SW_10	FS	1.99		0.78	U	640	a,b	0.162	J	0.051	J	44.4	b	2.8	J	1.2	J	5.0	U	16.76	6.82	7.894	6.4	210	3.92	4.4
WQ1b-C	Orrington	10/25/16	WQ1b-C_102516_SW_10	FS	4.95		4.35		83		0.120	J	0.106	J	1.9		4.6		4.6		7.2		11.11	7.26	1.627	10.65	200	4.65	0.83
WQ2-C	Winterport	05/27/16	WQ2-C_052716_SW_10	FS	34.9		1.42		744		0.42		0.05	U	8.84	a	NS		1.2		45		16.74	7.14	9.163	8.53	250	21	5.14
WQ2-C	Winterport	06/30/16	WQ2-C_063016_SW_10	FS	3.31		1.40	U	385	a	0.060	U	0.050	U	0.7	a	NS		0.8	J	6.8		20.51	7.27	16.3	7.30	240	5.32	9.73
WQ2-C	Winterport	07/18/16	WQ2-C_071816_SW_10	FS	16.10		8.71		411		0.360		0.142		12.1		NS		0.8	J	18.0		21.56	7.72	17.81	7.48	130	9.77	10.42
WQ2-C	Winterport	08/30/16	WQ2-C_083016_SW_10	FS	3.72		1.10	U	466	a	0.118		0.058		8.8		1.5		1.3		6.8		21.78	7.8	15.7	8.5	15.1	6.94	9.18
WQ2-C	Winterport	09/26/16	WQ2-C_092616_SW_10	FS	3.63		0.79	U	409	a	0.062	J	0.050	U	4.7	a	1.7	J	0.6	J	7.9		18.17	7.55	16.51	7.05	99.2	5.94	9.7
WQ2-C	Winterport	10/26/16	WQ2-C_102616_SW_10	FS	5.27		1.89		338		0.124	J	0.034	J	9.0		1.9		1.4		10.0		11.13	8.19	13.51	9.84	160	3.81	7.86
WQ3-L	Bucksport	05/26/16	WQ3-L_052616_SW_10	FS	3.04		0.73	U	352	a		J	0.05	U	0.53	a	NS		0.4	J	7.6		14.83	7.77	29.78	9.55	190	4.45	18.51
WQ3-L	Bucksport	06/29/16	WQ3-L_062916_SW_10	6	2.50		0.97	U	84	a	0.060	U	0.050	U	0.2	a	NS		0.4	J	24.0		17.03	7.86	29.5	8.23	220	4.64	18.31
WQ3-L	Bucksport	07/18/16	WQ3-L_071816_SW_10	FS	8.05		1.20	U	532	a	0.132		0.050	U	7.6	a	NS		0.4	J	14.0		18.66	7.8	30.88	7.48	120	3.52	19.11
WQ3-L	Bucksport	08/30/16	WQ3-L_083016_SW_10	FS	6.00		0.59	U	571	a	0.106		0.050	U	8.1	a	0.38	J	0.2	J	10.0		17.82	7.85	38.42	7.7	10.3	8.73	24.48
WQ3-L	Bucksport	09/26/16	WQ3-L_092616_SW_10	FS	2.91		1.10	U	273	a	0.036	J	0.050	U	1.3	a	0.81	J	0.3	J	8.6		17.28	7.7	28.5	7.14	69.2	4.93	17.61
WQ3-L	Bucksport	10/26/16	WQ3-L_102616_SW_10	FS	5.42		0.95		373		0.113	J	0.050	U	7.3	a	1	U	1.0	U	12.0		11.19	8.05	27.22	10.29	170	7.7	16.63
WQ-ECH	Verona East	05/26/16	WQ-ECH_052616_SW_10	FS	6.9		0.74	U	895	a	0.05	U	0.05	U	0	a	NS		0.4	J	7.3		13.26	7.7	30.27	8.75	240	9.79	18.83
WQ-ECH	Verona East	06/29/16	WQ-ECH_062916_SW_10	FS	2.30		1.10	U	161	a	0.071	U	0.050	U	1.0	a	NS		0.2	J	11.0		15.5	7.41	38.3	7.98	290	3.77	24.52
WQ-ECH	Verona East	07/18/16	WQ-ECH_071816_SW_10	FS	2.55		0.58	U	246	a	0.067		0.050	U	4.6	a	NS		0.3	J	9.2		16.2	7.81	39.09	7.93	120	3.99	24.9
WQ-ECH	Verona East	08/29/16	WQ-ECH_082916_SW_10	FS	9.14		0.94	U	347	a	0.155		0.050	U	5.2	a	0.39	J	0.4	J	25.0		18.87	7.81	37.79	8.84	73.5	6.46	23.84
WQ-ECH	Verona East	09/26/16	WQ-ECH_092616_SW_10	FS	2.62		1.30	U	212	a	0.036	J	0.050	U	1.2	a	0.50	UJ	0.1	J	9.2		15.41	7.33	37.85	37.79	250	4.57	24.1
WQ-ECH	Verona East	10/26/16	WQ-ECH_102616_SW_10	FS	8.49		2.17		527		0.136	J	0.050	U	9.3	a	1	U	2.0	U	12.0		11.63	8.08	39.54	8.88	140	10.4	25.3
ES-15	Verona West	05/26/16	ES-15_052616_SW_10	FS	6.13		0.74	U	480	a	0.05	U	0.05	U	0.000	a	NS		0.46	J	12		12.63	7.95	29.09	8.5	190.2	5.93	17.97
ES-15	Verona West	06/29/16	ES-15_062916_SW_10	FS	1.90	U	0.59	U	58	a	0.050	U	0.050	U	0.0	a	NS		0.3	J	11.0		15.24	7.91	37.1	8.43	220	2.87	23.59
ES-15	Verona West	07/18/16	ES-15_071816_SW_10	FS	1.72		0.63	U	161	a	0.043	J	0.047	J	0.0	c	NS		0.2	J	8.7		16.36	7.83	37.86	7.82	100	3.06	24.13
ES-15	Verona West	08/29/16	ES-15_082916_SW_10	FS	21.00		2.70	U	378	a	0.345		0.055		5.6		0.36	J	0.2	J	52.0		17.73	7.82	40.72	7.3	68.8	15.4	26.11
ES-15	Verona West	09/26/16	ES-15_092616_SW_10	FS	7.59		2.29		331		0.209	J	0.050	U	11.5	a	0.50	UJ	0.1	J	16.0		15.49	7.71	41.84	7.07	150	9.67	26.86
ES-15	Verona West	10/26/16	ES-15_102616_SW_10	FS	2.35		0.86		182		0.050	U	0.050	U	0.0	a	0.5	U	2.0	U	8.2		11.27	8.04	40.33	9.47	190	2.81	25.78
WQ-FPT	Fort Point	05/26/16	WQ-FPT_052616_SW_10	FS	1.67		0.5	U	171	a	0.05	U	0.05	U	0	a	NS		0.28	J	8.3		11.59	7.99	36.62	8.99	190	3.42	23.21
WQ-FPT	Fort Point	06/29/16	WQ-FPT_062916_SW_10	FS	1.70	U	0.68	U	76	a	0.050	U	0.050	U	0.0	a	NS		0.3	J	6.5		15.53	7.86	36.0	8.02	220	3.04	22.74
WQ-FPT	Fort Point	07/18/16	WQ-FPT_071816_SW_10	FS	1.44		0.50		131		0.035	J	0.050	U	1.4	a	NS		0.2	J	7.2		15.51	7.82	39.92	8.49	190	2.08	25.53
WQ-FPT	Fort Point	08/30/16	WQ_FPT_083016_SW_10	FS	1.87		0.50	U	147	a	0.040	J	0.050	U	1.4	a	0.31	J	0.2	J	11.0		16.93	7.77	40.67	1.1	40.5	3.04	26.11
WQ-FPT	Fort Point	09/26/16	WQ-FPT_092616_SW_10	FS	1.63		0.50	U	106	a	0.050	U	0.050	U	0.0	a	0.5	UJ	0.1	J	13.0		15.46	7.73	41.9	8.24	180	2.87	26.82
WQ-FPT	Fort Point	10/26/16	WQ-FPT_102616_SW_10	FS	1.64		1.25		45		0.050	U	0.050	U	0.0	a	0.5	U	2.0	U	8.6		11.42	8.11	42.89	9.7	98.1	1.6	27.49

TABLE 3-2
2016 WATER QUALITY MONITORING ANALYTICAL RESULTS

2016 SEDIMENT AND WATER QUALITY MONITORING REPORT
PENOBSCOT RIVER ESTUARY PHASE III - ENGINEERING STUDY

PREPARED BY/DATE: NSR 1/13/17
CHECKED BY/DATE: DRP 2/27/17

Notes:

* Particulate Hg/MeHg concentrations (ng/g) were calculated using the following equation: Particulate Hg/MeHg Concentration (ng/g) = (Total Hg/MeHg [ng/L] - Dissolved Hg/MeHg [ng/L]) / Total Suspended Solids * 1000 mg/g

a) Particulate Hg/MeHg concentration calculated using one or more non-detect surface water Hg/MeHg concentration(s); 1/2 reporting limit used for non-detect concentrations.

b) Total Suspended Solids concentration non-detect; 1/2 reporting limit used for non-detect concentrations for Particulate Hg/MeHg concentration calculations.

c) Dissolved value estimated exceeds total value - qualified result

°C = Degrees celsius
DO = Dissolved Oxygen
mg/L = milligrams per liter
mS/cm - Microsiemens per
mV - Millivolt
ng/L = nanograms per liter
ng/g = nanograms per gram
NTU = Nephelometric Turbidity
ORP = Oxygen Reduction Poten
ppt = parts per trillion
< = less than
NS = Not Sampled
NA = Not Analyzed

Flags:

U = Value not detected above reporting limit
J = Estimated value

TABLE 3-3
2016 WATER QUALITY MONITORING - AVERAGE ANALYTICAL AND FIELD PARAMETER RESULTS BY LOCATION

2016 SEDIMENT AND WATER QUALITY MONITORING REPORT
PENOBSCOT RIVER ESTUARY PHASE III - ENGINEERING STUDY

		Mercury			Methyl Mercury												
Location	**Reach**	**Total Mercury (ng/L)**	**Dissolved Mercury (ng/L)**	**Particulate Mercury (ng/g)**	**Total Methyl Mercury (ng/L)**	**Dissolved Methyl Mercury (ng/L)**	**Particulate Methyl Mercury (ng/g)**	**TOC (mg/L)**	**DOC (mg/L)**	**TSS (mg/L)**	**DO (mg/L)**	**ORP (mV)**	**Turbidity (NTU)**	**Specific Conductivity (mS/cm)**	**Salinity (ppt)**	**Temp**	**pH**
OV-02	Veazie	1.6	0.80	159	0.12	0.09	12.2	5.93	5.93	2.50	8.8	109.9	0.9	0.15	0.1	19.87	7.90
WQ1b-C	Orrington	11.3	1.48	657	0.28	0.08	20.1	4.57	3.92	18.43	7.8	135.8	9.4	3.44	1.9	19.80	7.66
WQ2-C	Winterport	11.2	2.28	459	0.19	0.06	7.37	1.70	1.00	15.75	8.1	149.1	8.8	14.82	8.7	18.32	7.61
WQ3-L	Bucksport	4.7	0.52	364	0.07	0.03	4.17	0.60	0.35	12.70	8.4	129.9	5.7	30.72	19.1	16.14	7.84
WQ-ECH	Verona East	5.3	0.74	398	0.08	0.03	3.53	0.45	0.29	12.28	8.5	185.6	6.5	37.14	23.6	15.15	7.69
ES-15	Verona West	7.8	0.91	265	0.11	0.03	2.85	0.43	0.25	17.98	8.1	153.2	6.6	37.83	24.1	14.79	7.88
WQ-FPT	Fort Point	1.7	0.47	113	0.03	0.03	0.46	0.41	0.21	9.10	7.4	153.1	2.7	39.66	25.3	14.41	7.88

Notes: Minimum average value
Maximum average value
°C = degrees celsius
DO = dissolved oxygen
mg/L = milligrams per liter
mS/cm - microSiemens per
mV - millivolt
ng/L = nanograms per liter
ng/g = nanograms per gram
NTU = Nephelometric Turbidity Unit
ORP = Oxygen Reduction Potential
ppt = parts per thousand

TABLE 3-4
2016 PENOBSCOT RIVER STAGE DATA - USGS GAGING STATION 01036390

2016 SEDIMENT AND WATER QUALITY MONITORING REPORT
PENOBSCOT RIVER ESTUARY PHASE III - ENGINEERING STUDY

DATE	Jan 2016	Feb 2016	Mar 2016	Apr 2016	May 2016	Jun 2016	Jul 2016	Aug 2016	Sep 2016	Oct 2016	Nov 2016	Dec 2016
1	6.27	5.55	8.48	8.34	4.59	3.43	2.75	2.53	2.65	2.24	3.23	5.03
2	6.34	5.36	8.01	8.86	4.43	3.36	2.96	2.64	3.02	2.30	3.12	5.83
3	6.21	4.99	7.59	10.00	4.30	3.16	2.95	2.57	2.96	2.35	3.16	5.90
4	5.79	5.16	7.43	10.00	4.75	3.19	2.86	2.47	2.95	2.30	3.12	5.70
5	5.20	5.37	7.03	9.32	4.94	3.01	2.88	2.40	2.77	2.27	3.05	5.30
6	4.54	4.72	6.53	8.73	4.69	3.22	2.84	2.23	2.82	2.30	3.03	4.94
7	4.43	5.21	6.21	8.23	4.84	3.75	2.82	2.33	2.77	2.30	3.11	4.55
8	5.07	5.34	5.86	8.82	4.65	4.55	2.81	2.39	2.66	2.59	2.95	4.36
9	5.24	5.09	5.88	11.50	4.73	4.84	2.82	2.48	2.66	2.53	3.06	4.17
10	5.39	5.08	5.91	11.90	4.81	4.92	---	2.37	2.68	2.52	2.91	3.79
11	6.66	5.07	6.40	10.90	4.72	4.39	3.34	2.28	2.70	2.57	2.91	3.43
12	9.35	4.75	7.04	10.20	4.85	4.20	3.31	2.27	2.75	2.48	2.74	3.14
13	9.72	4.62	7.16	10.40	4.99	4.07	3.36	2.60	2.76	2.48	2.84	3.47
14	8.80	4.52	6.93	10.90	4.14	4.13	3.13	2.51	2.62	2.46	2.94	3.68
15	7.89	5.26	6.84	10.30	3.90	4.06	3.01	2.56	2.79	2.63	2.80	3.59
16	7.61	5.04	6.66	9.58	4.78	4.02	2.92	2.74	2.66	2.33	3.01	3.48
17	7.24	5.61	7.11	9.05	5.30	3.84	2.94	2.95	2.75	2.59	3.46	3.57
18	6.87	7.21	7.83	8.46	4.99	3.64	2.99	3.03	2.74	2.58	4.43	---
19	6.37	8.80	8.06	7.97	4.98	3.33	3.06	3.24	2.80	---	4.33	3.73
20	6.01	8.38	7.52	7.60	4.86	3.29	3.03	3.28	2.69	2.55	4.07	4.17
21	6.14	7.74	6.92	7.17	4.70	3.28	2.88	3.07	2.64	2.44	3.89	3.92
22	6.90	7.67	6.56	6.81	4.37	3.08	2.65	3.00	2.29	2.58	3.90	3.75
23	9.33	7.48	6.17	6.52	4.40	2.96	2.71	3.13	2.51	2.79	3.85	3.78
24	13.00	6.94	5.90	6.23	4.22	2.81	2.71	3.41	2.38	3.13	3.67	3.57
25	13.10	6.97	---	6.09	4.17	2.84	2.75	3.39	2.39	3.22	3.54	3.47
26	11.10	8.37	5.46	5.82	4.01	2.88	2.60	3.49	2.39	3.12	3.49	3.55
27	8.13	9.84	5.44	5.62	3.85	2.81	2.47	3.42	2.38	2.95	3.64	3.59
28	7.00	9.96	5.38	5.30	3.89	2.70	2.47	3.12	2.36	3.06	4.06	3.80
29	6.83	9.19	6.17	5.00	3.46	2.74	2.58	3.44	2.28	3.14	4.11	---
30	6.57		8.41	4.77	3.46	2.78	2.53	3.28	2.20	3.15	4.39	4.12
31	6.11		8.65		3.47		2.61	2.89		3.26		4.05
COUNT days	**31**	**29**	**30**	**30**	**31**	**30**	**30**	**31**	**30**	**30**	**30**	**29**
MAX Gage Ht (ft)	**13.17**	**9.96**	**8.65**	**11.90**	**5.30**	**4.92**	**3.36**	**3.49**	**3.02**	**3.26**	**4.43**	**5.90**
MAX Estimated Discharge (ft^3/s)	65,100	40,846	33,045	55,483	16,712	13,265	6,330	6,575	4,366	6,141	10,643	17,567
MIN Gage Ht (ft)	**4.43**	**4.52**	**5.38**	**4.77**	**3.46**	**2.70**	**2.47**	**2.23**	**2.20**	**2.24**	**2.74**	**3.14**
MIN Estimated Discharge (ft^3/s)	10,643	10,859	16,965	12,861	6,518	3,903	3,571	2,659	2,624	2,671	3,961	4,539

USGS Data [1]	
Gage Height (ft)	**River Flow (ft^3/s)**
1	994
2	2385
3	4337
3.5	6594
4	8904
4.5	10811
5	13481
5.5	17343
5.82	17515
6	17865
7	22810
8	28316
9	34382
10	41010
11	48199
12	55949
13	64260
13.41	67870
14	75552
15	82180
16	88808
17	95436
18	102064
19	108692
20	115320
21	121948
22	128576
23	135203
24	141831
25	148459
26	155087
27	161715

TABLE 3-4
2016 PENOBSCOT RIVER STAGE DATA - USGS GAGING STATION 01036390

2016 SEDIMENT AND WATER QUALITY MONITORING REPORT
PENOBSCOT RIVER ESTUARY PHASE III - ENGINEERING STUDY

Notes:

Flow rate = Channel area (ft²) *river velocity (ft/s)
ft - Feet
s - Second
ft³/s - Cubic Feet Per Second
Water Quality Monitoring Sample Date
Blue shaded cells represent days when monthly surface water monitoring was conducted

Data Source: http://waterdata.usgs.gov/usa/nwis/uv?01036390; data is provisional and subject to revision

1 = USGS Gauging Station 01036390 Penobscot River at Eddington, Maine Coordinates: Lat. 44°49'36", Long. 68°41'48" (NAD83)

TABLE 3-5
2016 TURBIDITY DATA

2016 SEDIMENT AND WATER QUALITY MONITORING REPORT
PENOBSCOT RIVER ESTUARY PHASE III - ENGINEERING STUDY

DATE	Sep 2016	Oct 2016	Nov 2016	Dec 2016
1		**0.01**	**0.13**	**4.70**
2		--	0.00	**3.90**
3		0.00	0.00	**3.10**
4		0.00	**0.03**	**2.88**
5		0.00	0.00	**1.36**
6		0.00	--	**0.21**
7		0.00	0.00	**0.47**
8		0.00	--	**0.05**
9		**0.06**	--	**0.16**
10	0.00	0.00	--	**0.22**
11	0.00	0.00	--	0.00
12	**0.30**	0.00	--	**0.55**
13	**0.02**	0.00	--	**0.10**
14	**0.01**	0.00	--	**0.01**
15	0.00	**0.35**	--	**0.05**
16	0.00	**1.03**	--	0.00
17	0.00	**0.17**	--	0.00
18	0.00	0.00	--	--
19	0.03	--	--	0.00
20	0.11	0.03	--	0.09
21	0.07	0.04	--	0.00
22	0.00	--	--	0.01
23	0.00	--	--	0.01
24	0.03	--	--	0.05
25	0.00	--	--	0.07
26	0.00	0.00	--	0.00
27	0.00	0.25	--	0.62
28	0.00	--	--	0.21
29	0.00	--	--	--
30	0.38	--	--	0.07
31		--		0.33
COUNT days	**21**	**21**	**6**	**29**
MAX Turbidity (fnu)	**0.38**	**1.03**	**0.13**	**4.7**
MIN Turbidity (fnu)	**0.00**	**0.00**	**0.00**	**0.00**

Notes:

- Turbidity readings are in Formazin Nephelometric Turbidity Units (fnu)
- Turbidity Meter Location; Latitude 44.842628 Longitude -68.696594
- Turbidity Meter Install- September 9, 2016
- November 8, 2016 - Dead battery in turbidity meter
- December 1, 2016 - Replace dead battery in turbidity meter and upload battery saver program.

-- = Not recorded

Bolded values indicate turbidity measurement > 0

Prepared by: BPW
Checked by: DRP

TABLE 4.1-1
KRUSKAL-WALLIS RANK SUM TEST RESULTS - SEDIMENT

2016 SEDIMENT AND WATER QUALITY MONITORING REPORT
PENOBSCOT RIVER ESTUARY PHASE III - ENGINEERING STUDY

Sediment Type	Analyte	Kruskal Wallis Chi-squared Value	Degrees of Freedom	p-value
Subtidal	Mercury	35.8	1	<0.001
	Methyl Mercury	30.5	1	<0.001
	Total Organic Carbon	25.1	1	<0.001
Intertidal	Mercury	58.4	3	<0.001
	Methyl Mercury	50.5	3	<0.001
	Total Organic Carbon	11.0	3	0.012
Wetlands High	Mercury	6.86	3	0.077
	Methyl Mercury	24.4	3	<0.001
	Total Organic Carbon	28.5	3	<0.001
Wetlands Mid	Mercury	3.64	2	0.16
	Methyl Mercury	5.15	2	0.076
	Total Organic Carbon	1.96	2	0.38
Wetlands Low	Mercury	7.70	3	0.053
	Methyl Mercury	3.64	3	0.30
	Total Organic Carbon	12.26	3	0.007
Wetlands Intertidal	Mercury	6.02	3	0.111
	Methyl Mercury	4.43	3	0.22
	Total Organic Carbon	7.52	3	0.057

TABLE 4.1-2
P-VALUES FOR NEMENYI CHI-SQUARED APPROXIMATION FOR INDEPENDENT SAMPLES IN SUBTIDAL SEDIMENT

2016 SEDIMENT AND WATER QUALITY MONITORING REPORT
PENOBSCOT RIVER ESTUARY PHASE III - ENGINEERING STUDY

Analyte	River Reach	Fort Point Cove
Mercury	Upper Penobscot Bay	<0.001
Methyl Mercury		<0.001
Total Organic Carbon		<0.001

TABLE 4.1-3
SUMMARY OF MEAN SUBTIDAL SEDIMENT CONCENTRATIONS IN EACH REACH

2016 SEDIMENT AND WATER QUALITY MONITORING REPORT
PENOBSCOT RIVER ESTUARY PHASE III - ENGINEERING STUDY

River Reach	Mercury (ng/g)	Methyl Mercury (ng/g)	Total Organic Carbon (%)
Fort Point Cove	748	21.5	5.1
Upper Penobscot Bay	396	6.36	2.5

TABLE 4.1-4

SUMMARY OF ANALYSIS OF COVARIANCE (ANCOVA) RESULTS FOR SUBTIDAL SEDIMENTS

2016 SEDIMENT AND WATER QUALITY MONITORING REPORT

PENOBSCOT RIVER ESTUARY PHASE III - ENGINEERING STUDY

Mercury					
	DF	**Sum Sq**	**Mean Sq**	**F value**	**P-value (>F)**
Total Organic Carbon	1	1479610	1479610	90.2	<0.001
Reach	1	274031	274031	16.7	<0.001
Total Organic Carbon: Reach interaction	1	46137	46137	2.81	0.100
Residuals	52	852880	16402		
Methyl Mercury					
	DF	**Sum Sq**	**Mean Sq**	**F value**	**P-value (>F)**
Total Organic Carbon	1	1884	1884	62.9	<0.001
Reach	1	1062	1062	35.5	<0.001
Total Organic Carbon: Reach interaction	1	641.0	641.0	21.4	<0.001
Residuals	49	1467	30.0		

TABLE 4.1-5
TEMPORAL LOGLINEAR TREND RESULTS

2016 SEDIMENT AND WATER QUALITY MONITORING REPORT
PENOBSCOT RIVER ESTUARY PHASE III - ENGINEERING STUDY

Sediment Type	Location	Analyte	Intercept Coefficient	Year Coefficient	R-Squared	p-value (log-linear model)	p-value (Kendall's Tau)
Subtidal	E-01-01	Mercury	-52.4	0.16	0.10	0.159	0.487
		Methyl Mercury	-36.5	0.02	0.01	0.672	0.413
		Normalized Mercury	96.3	-0.04	0.06	0.316	0.021
		Normalized Methyl Mercury	105.8	-0.05	0.03	0.521	0.118
	E-01-03	Mercury	-7.6	0.01	0.01	0.728	1.000
		Methyl Mercury	-145.1	0.07	0.10	0.205	0.841
		Normalized Mercury	134.9	-0.06	0.20	0.064	0.056
		Normalized Methyl Mercury	-8.6	0.01	0.00	0.912	1.000
	E-01-04	Mercury	-61.3	0.03	0.07	0.257	0.854
		Methyl Mercury	-402.7	0.20	0.68	< 0.001	0.660
		Normalized Mercury	75.8	-0.03	0.04	0.399	0.287
		Normalized Methyl Mercury	-278.1	0.14	0.32	0.015	0.245
Intertidal	OV-04	Mercury	367.3	-0.18	0.68	0.001	0.013
		Methyl Mercury	298.9	-0.15	0.10	0.375	0.344
		Normalized Mercury	-37.7	0.02	0.02	0.699	1.000
		Normalized Methyl Mercury	-166.8	0.08	0.05	0.524	0.130
	OV-01	Mercury	19.9	-0.01	0.01	0.779	0.378
		Methyl Mercury	176.3	-0.09	0.12	0.337	1.000
		Normalized Mercury	-69.2	0.04	0.10	0.321	0.769
		Normalized Methyl Mercury	76.9	-0.04	0.05	0.525	0.850
	OV-02	Mercury	184.7	-0.09	0.32	0.054	0.079
		Methyl Mercury	-75.4	0.04	0.01	0.738	1.000
		Normalized Mercury	46.0	-0.02	0.02	0.629	1.000
		Normalized Methyl Mercury	-209.5	0.10	0.27	0.128	0.130
	OB-05	Mercury	83.8	-0.04	0.22	0.127	0.143
		Methyl Mercury	-120.7	0.06	0.13	0.307	0.256
		Normalized Mercury	6.9	0.00	0.00	0.997	1.000
		Normalized Methyl Mercury	-178.8	0.09	0.21	0.189	0.088
	W-17-Intertidal	Mercury	133.5	-0.06	0.09	0.246	0.396
		Methyl Mercury	356.2	-0.18	0.41	0.006	0.503
		Normalized Mercury	-359.2	0.18	0.23	0.059	0.002
		Normalized Methyl Mercury	-135.6	0.07	0.04	0.462	0.046
	W-21-Intertidal	Mercury	204.1	-0.10	0.56	< 0.001	0.006
		Methyl Mercury	362.9	-0.18	0.63	< 0.001	0.045
		Normalized Mercury	173.9	-0.08	0.24	0.028	0.062
		Normalized Methyl Mercury	313.7	-0.15	0.46	0.002	0.317
	ES-02	Mercury	67.7	-0.03	0.40	0.028	0.040
		Methyl Mercury	-172.3	0.09	0.33	0.084	0.037
		Normalized Mercury	77.0	-0.03	0.46	0.016	0.028
		Normalized Methyl Mercury	-161.0	0.08	0.29	0.109	0.058
	ES-13	Mercury	230.6	-0.11	0.42	0.024	0.057
		Methyl Mercury	-10.2	0.01	0.00	0.933	0.850
		Normalized Mercury	-72.3	0.04	0.18	0.174	0.187
		Normalized Methyl Mercury	-271.0	0.14	0.43	0.041	0.037

TABLE 4.1-5
TEMPORAL LOGLINEAR TREND RESULTS

2016 SEDIMENT AND WATER QUALITY MONITORING REPORT
PENOBSCOT RIVER ESTUARY PHASE III - ENGINEERING STUDY

Sediment Type	Location	Analyte	Intercept Coefficient	Year Coefficient	R-Squared	p-value (log-linear model)	p-value (Kendall's Tau)
Wetlands	W-21-UM-Central-C	Mercury	210.0	-0.10	0.11	0.252	0.025
		Methyl Mercury	141.1	-0.07	0.08	0.375	0.321
		Normalized Mercury	239.7	-0.12	0.05	0.553	0.132
		Normalized Methyl Mercury	226.8	-0.11	0.14	0.405	0.234
	W-21-UM-East-C	Mercury	-31.5	0.02	0.04	0.489	0.710
		Methyl Mercury	927.3	-0.46	0.71	< 0.001	0.321
		Normalized Mercury	-143.3	0.07	0.12	0.370	0.563
		Normalized Methyl Mercury	778.0	-0.39	0.81	0.006	0.062
	W-21-UM-South	Mercury	519.3	-0.26	0.51	0.013	0.011
		Methyl Mercury	221.6	-0.11	0.08	0.455	0.486
		Normalized Mercury	918.9	-0.45	0.43	0.053	0.083
		Normalized Methyl Mercury	532.3	-0.26	0.61	0.038	0.126
	W-21-UM-West-A	Mercury	5.3	0.00	0.00	1.000	0.234
		Methyl Mercury	539.6	-0.27	0.30	0.008	0.259
		Normalized Mercury	-50.9	0.03	0.00	0.873	0.418
		Normalized Methyl Mercury	469.8	-0.23	0.69	0.021	0.027
	W-21-High	Mercury	-18.4	0.01	0.01	0.717	0.763
		Methyl Mercury	34.1	-0.02	0.01	0.613	0.592
		Normalized Mercury	-2.2	0.00	0.00	0.937	0.919
		Normalized Methyl Mercury	33.6	-0.02	0.01	0.770	0.400
	W-63-High	Mercury	671.8	-0.33	0.75	< 0.001	0.006
		Methyl Mercury	784.9	-0.39	0.63	< 0.001	0.102
		Normalized Mercury	-7.4	0.01	0.00	0.910	0.913
		Normalized Methyl Mercury	105.7	-0.05	0.02	0.598	0.512
	W-21-Mid	Mercury	-132.6	0.07	0.03	0.427	0.264
		Methyl Mercury	85.8	-0.04	0.01	0.741	0.811
		Normalized Mercury	-1.0	0.00	0.00	0.950	0.802
		Normalized Methyl Mercury	187.3	-0.09	0.06	0.304	0.941
	W-21-Low	Mercury	107.0	-0.05	0.35	0.003	0.007
		Methyl Mercury	294.1	-0.14	0.40	0.002	0.196
		Normalized Mercury	182.3	-0.09	0.25	0.024	0.186
		Normalized Methyl Mercury	383.0	-0.19	0.39	0.006	0.447
	W-17-Low	Mercury	196.9	-0.09	0.10	0.192	0.156
		Methyl Mercury	442.5	-0.22	0.27	0.029	0.039
		Normalized Mercury	-254.8	0.13	0.20	0.081	0.028
		Normalized Methyl Mercury	-21.9	0.01	0.00	0.876	0.354

Notes:

Coefficients provided are for a loglinear regression equation: y = m * ln(x) + b

TABLE 4.1-6
P-VALUES FOR NEMENYI CHI-SQUARED APPROXIMATION FOR INDEPENDENT SAMPLES IN INTERTIDAL SEDIMENT

2016 SEDIMENT AND WATER QUALITY MONITORING REPORT
PENOBSCOT RIVER ESTUARY PHASE III - ENGINEERING STUDY

Analyte	River Reach	Orrington	Veazie	Verona East
Mercury	Veazie	<0.001	-	-
	Verona East	0.8	<0.001	-
	Verona Northeast	1.0	<0.001	0.86
Methyl Mercury	Veazie	0.0013	-	-
	Verona East	0.75	<0.001	-
	Verona Northeast	0.80	<0.001	1.0
Total Organic Carbon	Veazie	0.066	-	-
	Verona East	0.73	0.52	-
	Verona Northeast	1.0	0.094	0.80

TABLE 4.1-7
SUMMARY OF MEAN INTERTIDAL SEDIMENT CONCENTRATIONS IN EACH RIVER REACH

2016 SEDIMENT AND WATER QUALITY MONITORING REPORT
PENOBSCOT RIVER ESTUARY PHASE III - ENGINEERING STUDY

River Reach	Mercury (ng/g)	Methyl Mercury (ng/g)	Total Organic Carbon (%)
Veazie	88.6	1.300	4.28
Orrington	738	12	5.31
Verona East	668	22.2	8.18
Verona Northeast	1078	22.9	6.83

TABLE 4.1-8
SUMMARY OF ANALYSIS OF COVARIANCE (ANCOVA) RESULTS FOR INTERTIDAL SEDIMENTS BY REACH

2016 SEDIMENT AND WATER QUALITY MONITORING REPORT
PENOBSCOT RIVER ESTUARY PHASE III - ENGINEERING STUDY

Mercury					
	DF	**Sum Sq**	**Mean Sq**	**F value**	**P-value (>F)**
Total Organic Carbon	1	7558584	7558584	219.4	<0.001
Reach	3	12693844	4231281	122.8	<0.001
Total Organic Carbon: Reach interaction	3	3795076	1265025	36.7	<0.001
Residuals	73	2514700	34448		

Methyl Mercury					
	DF	**Sum Sq**	**Mean Sq**	**F value**	**P-value (>F)**
Total Organic Carbon	1	2252	2252	21.8	<0.001
Reach	3	8213	2737	26.6	<0.001
Total Organic Carbon: Reach interaction	3	2146	715	6.90	<0.001
Residuals	61	6288	103		

TABLE 4.1-9
SUMMARY OF ANALYSIS OF COVARIANCE (ANCOVA) RESULTS FOR INTERTIDAL SEDIMENTS

2016 SEDIMENT AND WATER QUALITY MONITORING REPORT
PENOBSCOT RIVER ESTUARY PHASE III - ENGINEERING STUDY

Mercury					
	DF	**Sum Sq**	**Mean Sq**	**F value**	**P-value (>F)**
Total Organic Carbon	1	7558584	7558584	220.8	<0.001
up/downstream	1	12288905	12288905	359.0	<0.001
Total Organic Carbon: up/downstream interaction	1	4078863	4078863	119.2	<0.001
Residuals	77	2635851	34232		

Methyl Mercury					
	DF	**Sum Sq**	**Mean Sq**	**F value**	**P-value (>F)**
Total Organic Carbon	1	2252	2252	16.3	<0.001
up/downstream	1	6442	6442	46.6	<0.001
Total Organic Carbon: up/downstream interaction	1	1217	1217	8.8	0.001
Residuals	65	8988	138		

TABLE 4.1-10

SUMMARY OF WETLAND SEDIMENT CONCENTRATIONS IN EACH RIVER REACH

2016 SEDIMENT AND WATER QUALITY MONITORING REPORT
PENOBSCOT RIVER ESTUARY PHASE III - ENGINEERING STUDY

Elevation	Reach	Total Mercury (ng/g)		Total Methyl Mercury (ng/g)		Total Organic Carbon (%)	
		Median	Mean	Median	Mean	Median	Mean
High	Frankfort Flats	1267	44.4	44.4	44.4	8.52	8.52
	Mendall Marsh	589	33.1	33.3	33.1	12.9	14.8
	Orrington	320	10.5	8.29	10.5	2.79	3.96
	Verona East	394	9.27	7.34	9.27	13.6	16.0
Mid	Frankfort Flats	1179	1179	6.02	6.02	4.86	4.86
	Mendall Marsh	780	688	30.0	33.0	10.3	12.4
	Orrington	-	-	-	-	-	-
	Verona East	456	608	12.9	15.1	11.1	10.7
Low	Frankfort Flats	924	959	23.3	31.4	10.4	10.7
	Mendall Marsh	919	946	28.4	27.5	7.13	6.62
	Orrington	229.0	229.0	4.5	4.5	2.5	2.5
	Verona East	539	644	19.6	22.1	10.3	9.2
Intertidal	Frankfort Flats	774	898	17.0	19.3	4.97	7.07
	Mendall Marsh	863	847	22.2	21.4	5.81	5.66
	Orrington	1123.0	1123.0	22.4	22.4	9.8	9.8
	Verona East	415	538	11.6	13.0	2.42	3.82

ng/g = nanograms per gram

% = percent

TABLE 4.1-11
P-VALUES FOR NEMENYI CHI-SQUARED APPROXIMATION FOR INDEPENDENT SAMPLES IN LOW ELEVATION WETLAND SEDIMENTS

2016 SEDIMENT AND WATER QUALITY MONITORING REPORT
PENOBSCOT RIVER ESTUARY PHASE III - ENGINEERING STUDY

Analyte	River Reach	Low Elevation Wetlands		
		Frankfort Flats	Mendall Marsh	Orrington
Total Mercury	Mendall Marsh	0.98	-	-
	Orrington	0.40	0.33	-
	Verona East	0.31	0.190	0.88
Total Organic Carbon	Mendall Marsh	0.04	-	-
	Orrington	0.23	0.712	-
	Verona East	1.00	0.3	0.306

TABLE 4.1-12
P-VALUES FOR NEMENYI CHI-SQUARED APPROXIMATION FOR INDEPENDENT SAMPLES IN HIGH ELEVATION WETLAND SEDIMENTS

2016 SEDIMENT AND WATER QUALITY MONITORING REPORT
PENOBSCOT RIVER ESTUARY PHASE III - ENGINEERING STUDY

Analyte	River Reach	High Elevation Wetlands		
		Frankfort Flats	**Mendall Marsh**	**Orrington**
Methyl Mercury	Mendall Marsh	0.97	-	-
	Orrington	0.33	<0.001	-
	Verona East	0.35	0.040	1.00
Total Organic Carbon	Mendall Marsh	0.94	-	-
	Orrington	0.82	<0.001	-
	Verona East	0.96	1.0	0.012

TABLE 4.1-13
P-VALUES FOR NEMENYI CHI-SQUARED APPROXIMATION FOR INDEPENDENT SAMPLES IN INTERIDAL ELEVATION WETLAND SEDIMENTS

2016 SEDIMENT AND WATER QUALITY MONITORING REPORT
PENOBSCOT RIVER ESTUARY PHASE III - ENGINEERING STUDY

Analyte	River Reach	Intertidal Elevation Wetlands		
		Frankfort Flats	Mendall Marsh	Orrington
Total Organic Carbon	Mendall Marsh	0.98	-	-
	Orrington	0.72	0.7	-
	Verona East	0.16	0.160	0.23

TABLE 4.2-1
SUMMARY OF GENERALIZED LINEAR MODEL RESULTS FOR TOTAL MERCURY IN SURFACE WATER

2016 SEDIMENT AND WATER QUALITY MONITORING REPORT
PENOBSCOT RIVER ESTUARY PHASE III - ENGINEERING STUDY

	DF	Sum Sq	Mean Sq	F value	P-value (>F)
Year	1	1.6	1.61	0.024	0.877
Location	6	1054	175.6	2.62	0.024
Season	2	35.8	17.92	0.267	0.766
Year: location interaction	4	196.7	49.17	0.734	0.572
Year: season interaction	2	54.4	27.21	0.406	0.668
Location: season interaction	12	475.6	39.64	0.591	0.841
Year: location: season interaction	5	241.6	48.33	0.721	0.610
Residuals	66	4423	67.02	--	--

TABLE 4.2-2
SUMMARY OF SURFACE WATER CONCENTRATIONS AT EACH SAMPLING LOCATION

2016 SEDIMENT AND WATER QUALITY MONITORING REPORT
PENOBSCOT RIVER ESTUARY PHASE III - ENGINEERING STUDY

Location	Total Mercury (ng/L)		Dissolved Mercury (ng/L)		Total Methyl Mercury (ng/L)		Dissolved Methyl Mercury (ng/L)	
	Median	Mean	Median	Mean	Median	Mean	Median	Mean
ES-15	5.00	8.24	0.940	0.982	0.0913	0.189	0.0349	0.0384
Veazie	3.05	3.25	2.49	2.48	0.155	0.172	0.124	0.141
WQ-ECH	4.76	5.33	0.500	0.750	0.0515	0.0758	0.0250	0.0250
WQ-FPT	1.64	1.51	0.295	0.473	0.0250	0.0292	0.0250	0.0250
WQ1b	4.12	7.79	1.35	1.78	0.214	0.252	0.106	0.112
WQ2	5.40	11.7	1.69	1.97	0.205	0.270	0.0660	0.0895
WQ3	4.07	4.70	0.790	1.03	0.106	0.122	0.0250	0.0582

ng/L = nanograms per liter

TABLE 4.2-3

P-VALUES FOR NEMENYI CHI-SQUARED APPROXIMATION FOR INDEPENDENT SAMPLES IN SURFACE WATER BY LOCATION: TOTAL MERCURY

2016 SEDIMENT AND WATER QUALITY MONITORING REPORT
PENOBSCOT RIVER ESTUARY PHASE III - ENGINEERING STUDY

	ES-15	**Veazie**	**WQ-ECH**	**WQ-FPT**	**WQ1b**	**WQ2**
Veazie	0.86	-	-	-	-	-
WQ-ECH	1.0	0.94	-	-	-	-
WQ-FPT	0.11	0.44	0.22	-	-	-
WQ1b	1.0	0.55	1.0	0.041	-	-
WQ2	0.91	0.03	0.98	0.0022	1.0	-
WQ3	1.0	0.79	1.0	0.089	1.0	0.96

TABLE 4.2-4
SUMMARY OF GENERALIZED LINEAR MODEL RESULTS FOR DISSOLVED MERCURY SURFACE WATER

2016 SEDIMENT AND WATER QUALITY MONITORING REPORT
PENOBSCOT RIVER ESTUARY PHASE III - ENGINEERING STUDY

	DF	Sum Sq	Mean Sq	F value	P-value (>F)
Year	1	25.3	25.3	19.9	<0.001
Location	6	31.7	5.29	4.16	0.001
Season	2	13.7	6.84	5.39	0.007
Year: location interaction	4	6.63	1.66	1.30	0.277
Year: season interaction	2	1.41	0.707	0.556	0.576
Location: season interaction	12	10.6	0.883	0.694	0.751
Year: location: season interaction	5	2.11	0.421	0.332	0.892
Residuals	66	83.9	1.27	--	--

TABLE 4.2-5

P-VALUES FOR NEMENYI CHI-SQUARED APPROXIMATION FOR INDEPENDENT SAMPLES IN SURFACE WATER BY SEASON: DISSOLVED MERCURY

2016 SEDIMENT AND WATER QUALITY MONITORING REPORT
PENOBSCOT RIVER ESTUARY PHASE III - ENGINEERING STUDY

	Spring	Summer
Summer	0.63	-
Fall	0.00037	0.00064

TABLE 4.2-6
P-VALUES FOR NEMENYI CHI-SQUARED APPROXIMATION FOR INDEPENDENT SAMPLES IN SURFACE WATER BY LOCATION: DISSOLVED MERCURY

2016 SEDIMENT AND WATER QUALITY MONITORING REPORT
PENOBSCOT RIVER ESTUARY PHASE III - ENGINEERING STUDY

	ES-15	Veazie	WQ-ECH	WQ-FPT	WQ1b	WQ2
Veazie	0.024	-	-	-	-	-
WQ-ECH	1.0	0.049	-	-	-	-
WQ-FPT	0.91	0.0023	1.0	-	-	-
WQ1b	0.85	0.81	0.72	0.27	-	-
WQ2	0.75	0.71	0.63	0.18	1.0	-
WQ3	1.0	0.049	1.0	0.89	0.90	0.83

TABLE 4.2-7
SUMMARY OF GENERALIZED LINEAR MODEL RESULTS FOR TOTAL METHYL MERCURY IN SURFACE WATER

2016 SEDIMENT AND WATER QUALITY MONITORING REPORT
PENOBSCOT RIVER ESTUARY PHASE III - ENGINEERING STUDY

	DF	Sum Sq	Mean Sq	F value	P-value (>F)
Year	1	0.145	0.145	3.40	0.071
Location	6	0.352	0.0586	1.38	0.243
Season	2	0.053	0.0266	0.625	0.540
Year: location interaction	4	0.061	0.0152	0.358	0.837
Year: season interaction	2	0.003	0.0015	0.0362	0.964
Location: season interaction	12	0.096	0.0080	0.188	0.998
Year: location: season interaction	5	0.048	0.0096	0.226	0.949
Residuals	48	2.04	0.0425	--	--

TABLE 4.2-8

SUMMARY OF GENERALIZED LINEAR MODEL RESULTS FOR DISSOLVED METHYL MERCURY IN SURFACE WATER

2016 SEDIMENT AND WATER QUALITY MONITORING REPORT
PENOBSCOT RIVER ESTUARY PHASE III - ENGINEERING STUDY

	DF	Sum Sq	Mean Sq	F value	P-value (>F)
Year	1	0.0682	0.0682	21.3	<0.001
Location	6	0.104	0.0173	5.40	<0.001
Season	2	0.0114	0.00570	1.78	0.180
Year: location interaction	4	0.0099	0.00248	0.776	0.546
Year: season interaction	2	0.0032	0.00159	0.496	0.612
Location: season interaction	12	0.0161	0.00134	0.418	0.949
Year: location: season interaction	5	0.0029	0.00058	0.180	0.969
Residuals	47	0.150	0.00320	--	--

TABLE 4.2-9
P-VALUES FROM NEMENYI CHI-SQUARED APPROXIMATION FOR INDEPENDENT SAMPLES IN SURFACE WATER BY LOCATION: DISSOLVED METHYL MERCURY

2016 SEDIMENT AND WATER QUALITY MONITORING REPORT
PENOBSCOT RIVER ESTUARY PHASE III - ENGINEERING STUDY

	ES-15	**Veazie**	**WQ-ECH**	**WQ-FPT**	**WQ1b**	**WQ2**
Veazie	0.0092	-	-	-	-	-
WQ-ECH	0.99	0.0035	-	-	-	-
WQ-FPT	0.99	0.0035	1.0	-	-	-
WQ1b	0.22	0.99	0.073	0.073	-	-
WQ2	0.54	0.62	0.22	0.22	0.99	-
WQ3	1.00	0.044	0.93	0.93	0.45	0.82

TABLE 4.2-10
SUMMARY OF ANALYSIS OF COVARIANCE (ANCOVA) RESULTS FOR TOTAL MERCURY IN SURFACE WATER

2016 SEDIMENT AND WATER QUALITY MONITORING REPORT
PENOBSCOT RIVER ESTUARY PHASE III - ENGINEERING STUDY

	DF	Sum Sq	Mean Sq	F value	P-value (>F)
Total Suspended Solids	1	4968	4968	350	<0.001
up/downstream	1	16.3	16.3	1.15	0.287
Total Suspended Solids: up/downstream interaction	1	175	175	12.3	0.001
Residuals	90	1278	14.2		

TABLE 4.2-11

SUMMARY OF ANALYSIS OF COVARIANCE (ANCOVA) RESULTS FOR TOTAL METHYL MERCURY IN SURFACE WATER

2016 SEDIMENT AND WATER QUALITY MONITORING REPORT
PENOBSCOT RIVER ESTUARY PHASE III - ENGINEERING STUDY

	DF	Sum Sq	Mean Sq	F value	P-value (>F)
Total Suspended Solids	1	1.26	1.26	69.1	<0.001
up/downstream	1	0.146	0.146	7.98	0.00611
Total Suspended Solids: up/downstream interaction	1	0.0261	0.0261	1.43	0.236
Residuals	72	1.32	0.0183		

TABLE 4.2-12
SUMMARY OF ANALYSIS OF COVARIANCE (ANCOVA) RESULTS FOR DISSOLVED MERCURY IN SURFACE WATER

2016 SEDIMENT AND WATER QUALITY MONITORING REPORT
PENOBSCOT RIVER ESTUARY PHASE III - ENGINEERING STUDY

	DF	Sum Sq	Mean Sq	F value	P-value (>F)
Total Suspended Solids	1	0.909	0.909	0.635	0.428
up/downstream	1	29.1	29.1	20.4	<0.001
Total Suspended Solids: up/downstream interaction	1	14.1	14.1	9.84	0.002
Residuals	90	129	1.43		

TABLE 4.2-13
SUMMARY OF ANALYSIS OF COVARIANCE (ANCOVA) RESULTS FOR DISSOLVED METHYL MERCURY IN SURFACE WATER

2016 SEDIMENT AND WATER QUALITY MONITORING REPORT
PENOBSCOT RIVER ESTUARY PHASE III - ENGINEERING STUDY

	DF	Sum Sq	Mean Sq	F value	P-value (>F)
Total Suspended Solids	1	0.0432	0.0432	11.6	0.001
up/downstream	1	0.0505	0.0505	13.6	<0.001
Total Suspended Solids: up/downstream interaction	1	0.00164	0.00164	0.441	0.509
Residuals	71	0.263	0.00371		