RUTGERS THE STATE UNIVERSITY OF NEW JERSEY – DEPARTMENT OF EARTH AND ENVIRONMENTAL SCIENCES – MEADOWLANDS ENVIRONMENTAL RESEARCH INSTITUTE

Spatial and temporal distribution of priority pollutants and contaminants in the lower Raritan River.

To Complement Historical Baselines of Sediment Contamination and Provide Information from Areas With No Official Records of Sediment Samples

MERI-Rutgers

6/21/2018

Abstract: The main objective of this proposal to start filling in data gaps in river and marsh sediment contamination in the Lower Raritan River. Main tasks of this study are: 1, Measure trace metal and organic contaminant levels in surficial sediments along 20 km of the lower Raritan River; 2, Visualize the spatial distribution of trace metal and organic pollutants in surficial sediments using spatial interpolation techniques; 3, Extract cores from three marsh sites (1) proximal, (2) central and (3) distal to traditional industrial and agricultural sites; 4, Reconstruct pre-industrial environmental reference conditions.

SPATIAL AND TEMPORAL DISTRIBUTION OF INDUSTRIAL AND AGRICULTURAL CONTAMINANTS IN THE RARITAN RIVER

TO COMPLEMENT HISTORICAL BASELINES OF SEDIMENT CONTAMINATION AND PROVIDE INFORMATION FROM AREAS WITH NO OFFICIAL RECORDS OF SEDIMENT SAMPLES

RUTGERS THE STATE UNIVERSITY OF NEW JERSEY – DEPARTMENT OF EARTH AND ENVIRONMENTAL SCIENCES – MEADOWLANDS ENVIRONMENTAL RESEARCH INSTITUTE

Authors

Francisco Artigas, Ildiko C. Pechmann, Margaret Christie

06/05/2018

Lyndhurst, NJ

Table of Contents

Table of Figures

Introduction

The challenge for agencies and wetland managers is to sustain the quality and integrity of wetlands by eliminating threats from natural and human causes. The role of monitoring is to detect meaningful levels of change that exceed acceptable historical or natural limits. The proposed study looks at sediment chemistry and contamination in the Lower Raritan River in an effort to promote understanding of levels and extent of heavy metal and organic compound pollution in the river sediment. This study complements historical sediment data collected by various state agencies and NGOs and provide new and updated information critical to the future enhancement and management of this highly impacted urban coastal area.

The objective of this study was to design and implement a sediment sampling system that would be spatially representative of the main stem of the Lower Raritan and cover the previously measured heavy metal and organic compound hotspots. The Raritan River basin is well known for the historical industrial and related commercial uses that left a legacy contamination along its banks that impacts the quality of the ecosystems both in the river, and the surrounding wetlands in the bay. The collaborative restoration effort of the watershed started when under the umbrella of the 1984 renewed Clean Water Act the Hudson-Raritan Estuary had become a national watershed and in 1988 the estuary was accepted into the National Estuary Program (HRECRP, 2014). Ever since, numerous efforts have been dedicated to gage the levels and extent of the legacy contamination in the estuary as the health of the river is central to the quality of life in the region (Rutgers, 2009). 22 municipalities share the main stem of the Raritan River, however 5 counties encompassing 103 municipalities live on the watershed.

Between 2012 and 2015 the U.S. Environmental Protection Agency through a cooperative agreement funded the EPA Rutgers Raritan River project to compile all existing data from superfund sites, brown fields, known contaminated sites and point and non-point sources of pollution into a comprehensive database of the Raritan River watershed. These datasets are meant to assist federal, Sstate and local stakeholders in making decisions related to environmental cleanup but have only a limited number of samples from the main channel of the lower Raritan that were collected between 2000 and 2006. The Data Compilation and Integration Report (2015)[1] concluded that for a successful restoration of the Raritan River "A

[1] http://cues.rutgers.edu/sustainable-raritan-river/pdfs/EPARutgersRaritanDataReport%20_09292015.pdf

more comprehensive monitoring program needs to be completed on the Lower Raritan to collect water and sediment samples and analyze these samples for priority pollutants and contaminants." The proposed study is designed to start filling in these data gaps following a sampling and analysis strategy that meets NJDEP and EPA quality assurance criteria.

The study has two components. ***Component I*** – *river sediment quality* –measured metal and organic contaminants associated with surficial sediment in the Lower Raritan River. The study is designed to complement historical baselines of sediment contamination measured between 2000 and 2006 (STORET 2016)[2] and provides new and updated information from areas where there are no official records of sediment samples in state or federal environmental datasets. The main tasks of this component included: 1, Measure trace metal and organic contaminant levels in surficial sediments along 20 km of the lower Raritan River using a transversal transect sampling design. 2, Measure water quality parameters at two depths (surface and channel bottom) utilizing the same surficial sediment sampling design. 3, Visualize the spatial distribution of trace metal and organic pollutants in surficial sediments using spatial interpolation techniques. In ***Component II*** – *salt marsh sediment assessment* – sediment cores from salt marsh environment were analyzed to assess the environmental impacts of pollutants across space and time. The main tasks of this component included: 1, Extract cores from three marsh sites (1) proximal, (2) central and (3) distal to traditional industrial and agricultural sites, while capturing the elevation gradient within the marsh surface by sampling (a) high- (b) mid- and (c) low-marsh environments at each site. 2, Reconstruct pre-industrial environmental reference conditions and natural variability prior to significant anthropogenic disturbance and identify the distribution and longevity of industrial and agricultural pollution retained within the salt-marsh environments by radiocarbon dating and geochemical analysis of the core sample; 3, observe any ecological shifts that occurred due to the disposal and deposition of pollutants in the Raritan River by assessing diatom and pollen abundance in the core sample.

[2] https://www.epa.gov/waterdata/storage-and-retrieval-and-water-quality-exchange

1. Component I – River Sediment Quality

1.1 Introduction

The objective was to design and implement a sediment sampling campaign that would be spatially representative of the main stem of the lower Raritan river and also re-sample the previously identified heavy metal and organic contaminant hotspots from 2000-2006.

Component I. is divided into three main tasks: 1.- surficial sediment sampling and surface water quality measurements, 2.- chemical analysis and 3.- data visualization and reporting.

Surficial sediment sampling/surface water quality measurements

The main stem of the Lower Raritan River between New Brunswick and the Raritan bay was sampled according to the design presented in Figure 1. The design includes the seven locations already in the STORET dataset (sampled between 2000 and 2006) and adds 33 new samples along transects covering areas with data gaps. This approach is designed to capture a shore to shore general pattern of contaminant distribution with sufficient resolution to understand the overall pattern and possibly guide future collections around problem areas at even greater resolutions. Surficial sediments were collected using a ponar grab sampler from a boat equipped with a capstan winch and survey grade GPS to record coordinates for each sampling location. In an attempt to eliminate the influence from the bay sampling took place during the ebb cycle of the tide. Each sediment sample was a composite of three ponar grabs. Collected samples were registered in a chain of custody form and transported to the lab in a cooler in pre-labeled Ziploc bags. Along with the sediment sampling, surface water quality parameters (salinity, conductivity, dissolved oxygen (DO), oxygen reduction potential (ORP), pH, turbidity, and temperature) were measured at each sediment sampling location (when depth permitted) on the surface and close to the channel bottom using a calibrated YSI 6920 V2-2 multi-parameter water quality sonde. Water quality measurements were recorded in a field note book and later entered in Microsoft Excel for further analysis.

Chemical analysis

Metal contaminates were analyzed at MERI's Environmental Chemistry lab using ICP-MS. Determinations were made for the following priority pollutants: Antimony, Arsenic, Beryllium, Cadmium, Chromium, Copper, Lead, Mercury, Nickel, Selenium, Silver, Thallium and Zinc.

Total organic matter was determined by weight loss-on-ignition (LOI) method following Wang (2012). Particle size distribution was determined from 100 gram samples from each of the sampling stations. The major persistent organic pollutants (POPs) including 109 PCB congeners and 18 OCPs were analyzed on an Agilent 6890 gas chromatograph equipped with electron capture detector (ECD). Certified reference marine sediment (MESS-1) for soils was run every tenth sample, and a method blank were run every sixth sample during the gas chromatographic analysis.

Data visualization and reporting

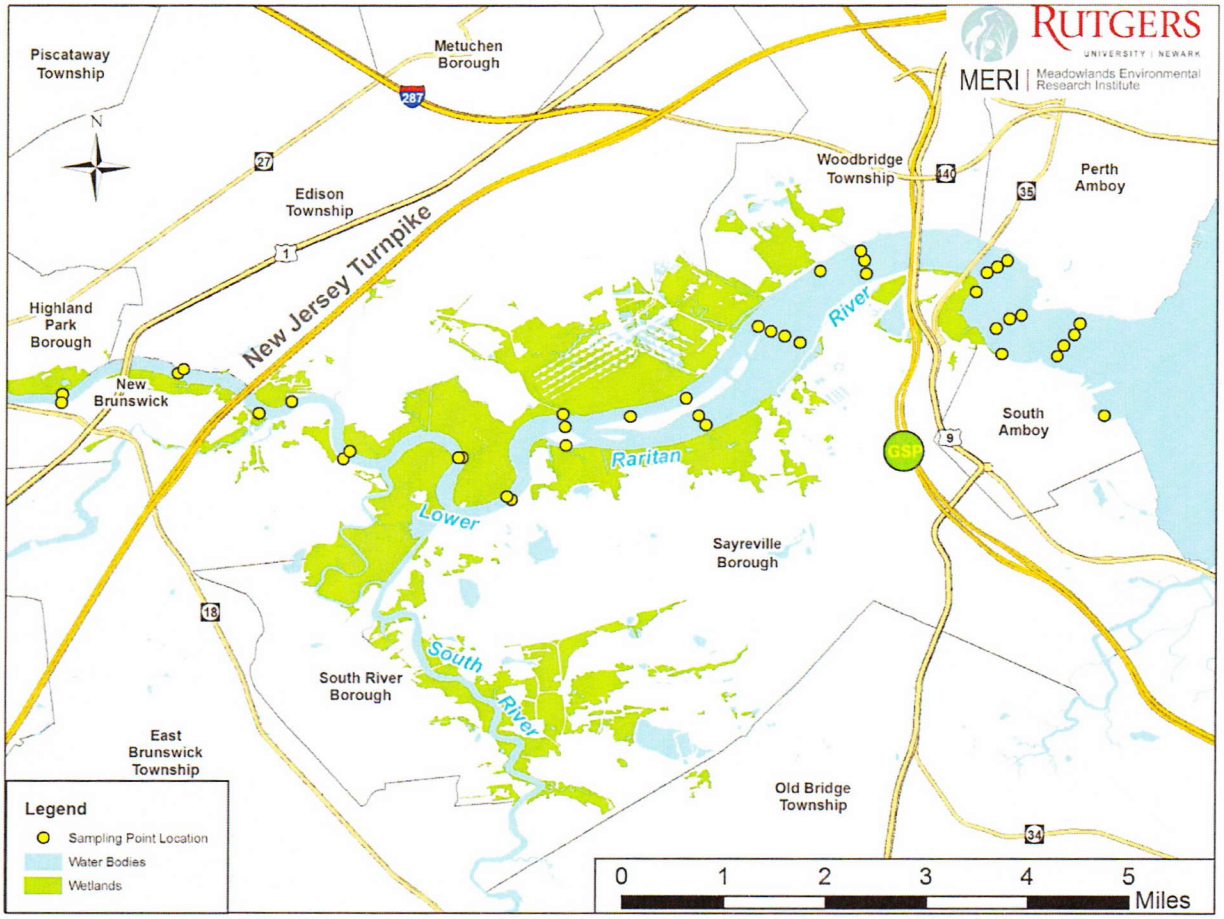
The concentration values that resulted from the sediment chemical analysis were used to visualize the distribution of contaminants of the main channel utilizing spatial interpolation techniques. A spatial analyst toolset from ArcGIS software was run to interpolate concentrations from measured locations at each of the 40 sampling points and fill in concentrations (with known variance) for the entire main channel of the river. We chose to utilize the Inverse Distance Weighted (IDW) raster interpolation technique as it references the observed concentration sampling point values to predict values for cells that are in close proximity. This IDW process assumes each sample point has a local influence that weakens with increasing distance. The raster interpolation helps to visualize concentration gradients or hotspots of priority pollutants and persistent organic pollutants in the channel. The geochemical index (Igeo) for each metal was calculated by comparing the measured concentration to natural background levels according to the local geology. The geochemical index value symbolizes the degree of contaminant enrichment beyond the natural background value. Finally, IDW interpolation of the cumulative trace metal pollutants at the 40 sampling points were mapped for visualization. This process took the sum of all the priority pollutants at each sampling location and created a ranking system to render which of these sampling locations are most impaired with respect to heavy metals

1.2 Methods

1.2.1 The study sites

Surface sediment samples were taken at 40 sampling locations (Figure 1) and analyzed for major contaminants of concern. State of the art interpolation techniques were then used to extend the point data over the entire study area and provide estimation of levels and distribution of contaminants in the sediment.

Figure 1: Map of the study area and the sampling plan



1.2.2 Surficial sediment sampling and surface water quality measurements

Sampling was completed in two separate missions. On April 10th, 2017 the Rutger's Research Vehicle boat (Rutgers RV) was used to sample the majority of the points at rising tide. A second outing on April 26th was necessary to reach the shallow sampling points.

Water Quality Sampling

A YSI 6600 EDS multi-parameter water quality monitor was used at each sampling location to obtain the following data: Turbidity, Temperature, Conductivity, Salinity, pH, DO, and ORP. The sensor is certified by the NJDEP for all listed parameters and was calibrated before the outing according to NJDEP guidelines. At each site location, the sensor was submerged into the water one foot deep for surface measurements and approximately 1 foot above the river bottom for deep measurements. The monitor is attached to an YSI 650 MDS reader and the instantaneous results on the screen are recorded in a field notebook.

Sediment Sampling

For the first round of sampling we used the RV Rutgers that is equipped with a capstan winch (a revolving cylinder with a vertical axis) used for winding a rope or cable, powered by an onboard 5kw generator and operated by foot pedal on a swing arm thus allowing for the quick retrieval of the Ponar (clamshell) grab sampler after each surficial sediment grab. Each sample collected is a composite of three Ponar sediment grabs. The planned sampling points based on the sampling design were loaded into the RV Rutgers Garmin 1040xs radar/plotter/sounder, making accurate navigation to each point possible. The RV Rutgers also used the Rio Grande Acoustic Doppler Current Profiler to record the path that the boat took.

The second sampling mission was accomplished using a Go-Devil boat equipped with a mud motor that allowed access to the shallow water areas. Samples were again taken with a ponar grab sampler.

At each sampling location, three sediment samples were collected in labeled sample bags and combined into one composite sample to ensure that the sediment sample is representative of that site. Samples were then brought back to the lab and stored in a refrigerator set at 4 ^{o}C. Samples were analyzed for: percent moisture, percent organic matter, metals, polychlorinated biphenyls (PCBs), and organochlorine pesticides (OCPs).

The GPS location of each sample site was recorded within a one to two meter vicinity of the actual collection location. The locations were determined using a Trimble GeoXH 6000 Series handheld GPS. Sampling locations were post-processed using GPS Pathfinder Office version 5.40 in order to achieve decimeter horizontal accuracy. Sampling locations were later associated with the results from the chemical analysis and this spatial information was used to generate thematic maps showing contamination distribution in the river sediment.

1.2.3 Chemical analysis

PCB and OCP Sample Preparation:

An accelerated solvent extractor (ASE 100, Dionex, USA) was used to extract PCBs and OCPs from the sediment samples by using a mixture of hexane and acetone in a 1:1 ratio. After extraction, gel permeation chromatography (GPC, Autoprep 2000, O I Analytical, USA) was used to clean the samples before GC-ECD. The extracts were concentrated to 1mL by rotary evaporation at a temperature 30°C. The extracted samples were fractioned by florisil column (10mm i.d. x 300 mm length) filled with 10 g of florisil (60-100 mesh; J.T Baker, NJ, activated at 550 °C for 4 hours), and then partially deactivated by the addition of deionized H2O (2.5% by wt.). The sample was loaded into the head of the florisil column and covered with a layer of sodium sulfate to a depth of 10mm. The concentrated extracts were transferred to the florisil column and subsequently eluted with 35 mL of hexane for PCB analysis. A second fraction for OCPs analysis was eluted with 50 mL of dichloromethane and hexane in a 1:1 ratio and collected in a separate vial. Each fraction was solvent exchanged into hexane while concentrated to 5 mL via rotary evaporation. Each sample was finally reduced to 1 mL using a gentle stream of dry nitrogen evaporator (N-EVAP 111, OA-SYS). All samples for 109 PCB congeners and 18 OCPs were analyzed on a gas chromatograph equipped with 63 Ni electron capture detectors (GC-ECD, Hewlett Packard 6890, Santa Clara, CA) with DB-5 (60m x 250 μm in inner diameter x 0.25 μm film thickness, J&W Scientific, CA). The temperature program of GC oven condition was as follows: 100 oC held for 2 minutes; 4 oC/min to 170 oC, 2 oC/min to 280 oC, 1 oC/min to 290 oC; total time, 84.5 minutes. Daily single point calibration was used to generate response factors for each congener relative to internal standards. Congeners were identified based on

relative retention time, and PCBs and OCPs surrogates were spiked for QC recovery check.

Metal Sample Preparation

Metal concentrations were analyzed for the sediment samples with particle size less than 63μm using microwave assisted digestion and Inductively Coupled Plasma Mass Spectrometry (ICP-MS). Dried sediment samples went through the 63μm sieve first, and then about 0.2 g of sediment sample was collected and digested with 10 mL of ultrapure nitric acid (HNO3, 67-70%, w/w, EMD) in a microwave digestion system (MiniWave microwave digestion, SCP science). Standard reference material 1944 (New York/New Jersey Waterway Sediment, NIST) was digested with samples for quality control. After digestion, the samples were diluted to 50 mL with ultrapure DI water and stored in polypropylene centrifuge tubes at 4°C for further analysis. Solutions were analyzed using an ICP-MS (Agilent ICP-MS 7700X), and helium collision mode with kinetic energy discrimination (KED) was used to effectively remove the multiple polyatomic interferences in ICP-MS. Li, Sc, Ge, Y, In, Tb, and Bi were used as internal standards for calibration. The recovery rates of quality control (QC) sample are 90-110%.

1.2.4 Data visualization

Following the chemical analysis of the Raritan samples, concentrations of the sampled sediments were inputted into ArcGIS 10.3 geospatial software to visualize the sediment contaminants of the main channel of the Lower Raritan River. The Spatial Analyst toolset was used to take the sediment concentrations in parts per million (ppm) at our 40 sampling points and extrapolate values in between these sampling transects to create a continuous surface of sediment contaminant information for the lower Raritan. We chose the Inverse Distance Weighted (IDW) linear raster interpolation tool for this visualization. The IDW spatial analyst tool inputs the observed concentration sampling point values from the shapefile to predict and generate values for cells that are surrounding it. The product of this IDW interpolation is a raster layer with each pixel representing a contaminant concentration value. This is done using a linear algorithm built within the tool that assumes a decrease in target value with increasing distance from an input

point until it gets influenced by a neighboring input point. The raster interpolation helps to visualize concentration gradients or hotspots of trace metal or organic pollutants in the designated area of interest. In addition to visualizing the sediment concentrations, the Geochemical Index (Igeo) of these samples was calculated by finding available background sediment concentration values derived from the local geology. This index value represents the degree of contaminant enrichment of the observed sediment beyond the natural background value from the local geology. The Geoaccumulation Index formula (Forstner&Muller, 1981) is calculated below (Eq. 1):

$$I_{geo} = \log_2 \frac{C_n}{1.5 \cdot B_n}$$

Equation 1. Geoaccmulation Index

The index is the logarithmic ratio of the observed concentration value to the background geologic source concentrations. The background values referenced for these calculations were documented in 'Characterization of Ambient Levels of Selected Metals and Other Analytes in New Jersey Soils: Year 1, Urban Piedmont Region' (BEM Systems Inc., 1997). The Igeo values fall into several classes that describe the degree of sediment contamination, below (Figure 2):

Figure 2. Geoaccmulation Index Classes

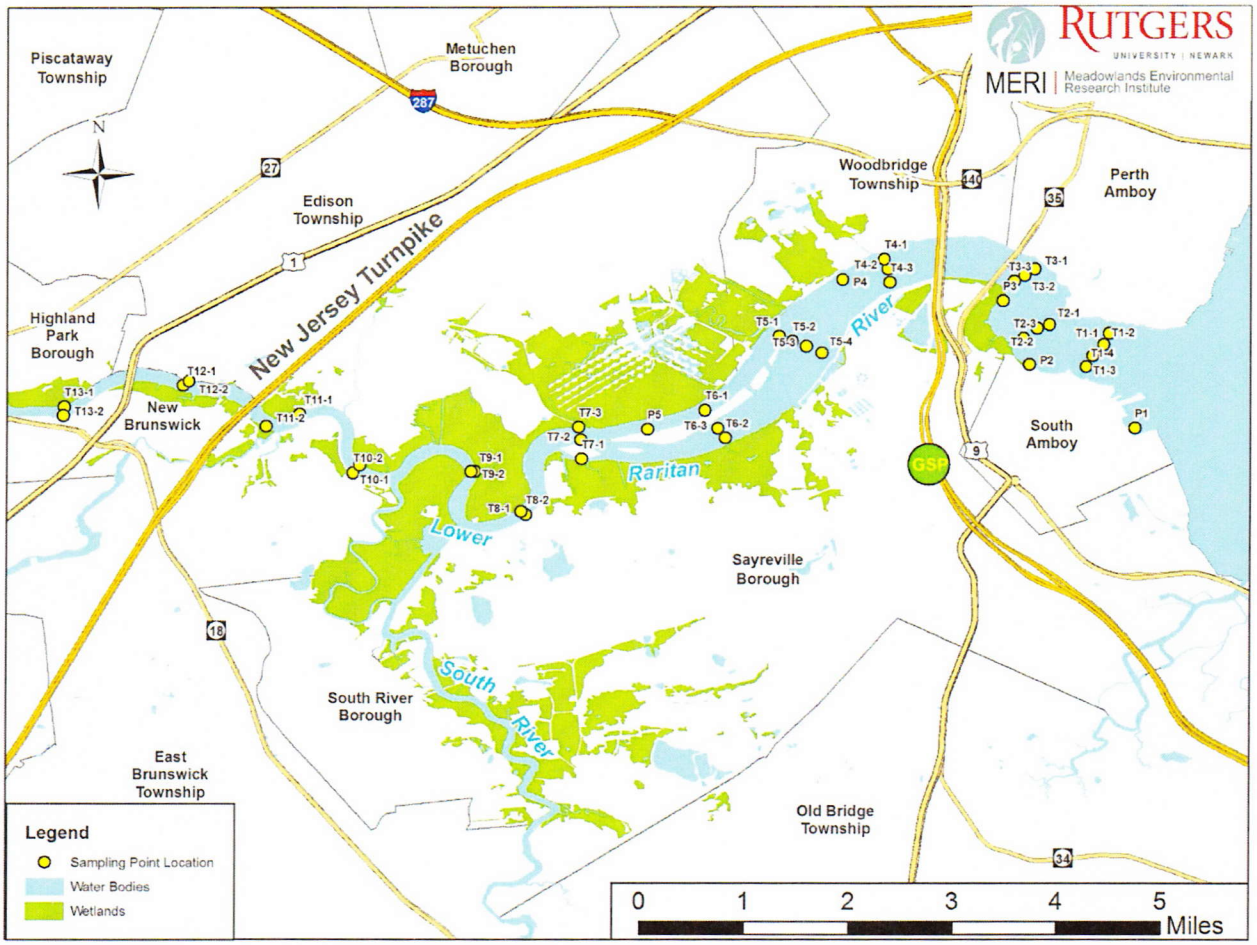
Index of Geoaccumulation, Igeo	Designation of Sediment Quality
> 3	Contaminated
2 - 3	Moderately Contaminated
1 - 2	Mildly Contaminated
< 1	Practically Uncontaminated

The Geoaccmulation Index was also interpolated using the IDW raster interpolation tool in ArcGIS. This generated raster outputs that represent the degree of sediment contamination compared to the natural geologic background values, and represent the amount of anthropogenic influence on sediments in the Lower Raritan.

1.3 Results

Figure 3 shows the locations of the final sampling sites. Several points more upriver had to be moved 10-30 feet compared to the original design as the water become shallower and the bottom more rocky making it hard to collect enough sediment samples for the chemical analysis.

Figure 3. Study are map showing the labelled, final sampling locations



1.3.1 Water Quality in the Raritan River

The results of the water quality data show as expected that there is a decreasing gradient of Total Dissolved Solids (TDS), salinity (Figure 4) and conductivity from the mouth of the river (P1) to the final sampling point (T13-2). Turbidity exhibits the same trend from P1 through T13-2 (Figure 5). Dissolved oxygen (DO) remained about the same throughout the extent of the study

area and at about 90% saturation (9.4 ppm, Figure 6). pH (Figure 7) follows similar trends with a median of 7.5. The Oxygen Reduction Potential (ORP) measurements show a more oxidative environment as one moves upriver from the bay. ORP measurements were in the vicinity of 200 mV. No negative ORP readings were found. (Figure 8). Table 1 summarizes the water quality data. There were a few sampling locations where the water was too shallow to submerge the sonde's sensors and reliably conduct water quality measurements. Hence water quality data from locations T5-2, T7-1, T11-2, T12-2, T13-1 were not recorded. In case of T11-1, T12-1, T13-2 the water was deep enough to conduct surface measurements however not deep enough to warrant the bottom measurements and thus deep water quality records are missing from these locations. We observe that differences between deep and surface samples are greater near the bay than up river, especially for salinity. All other parameter measurements were similar at depth and on the surface indicating a fully mixed system.

Figure 4. Salinity in the water column as well as from the bay to New Brunswick

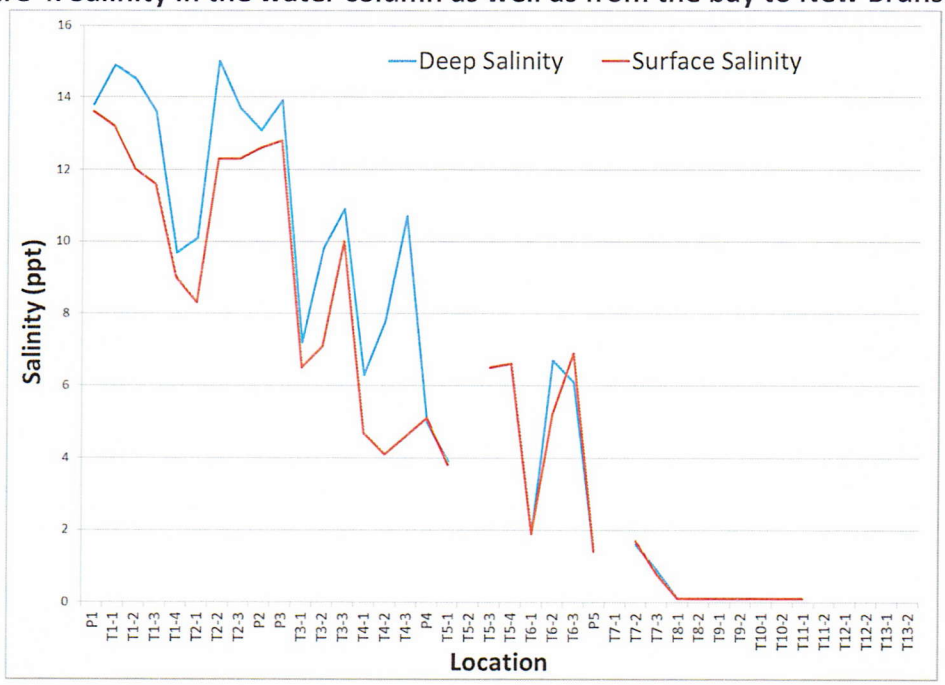


Figure 5. Turbidity in the water column as well as from the bay to New Brunswick.

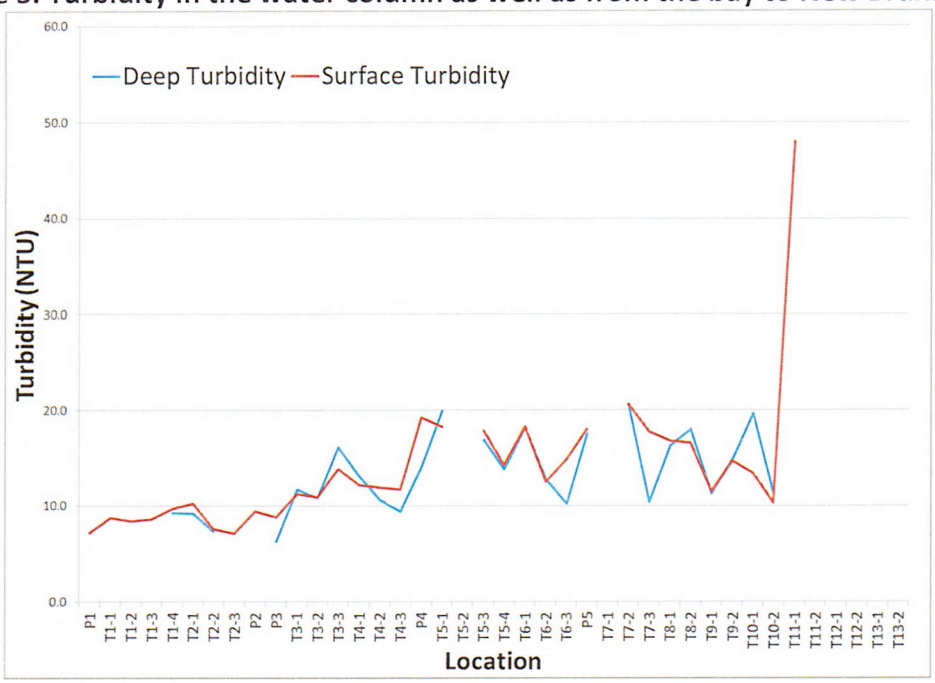


Figure 6. Dissolved Oxygen in the water column as well as from the bay to New Brunswick.

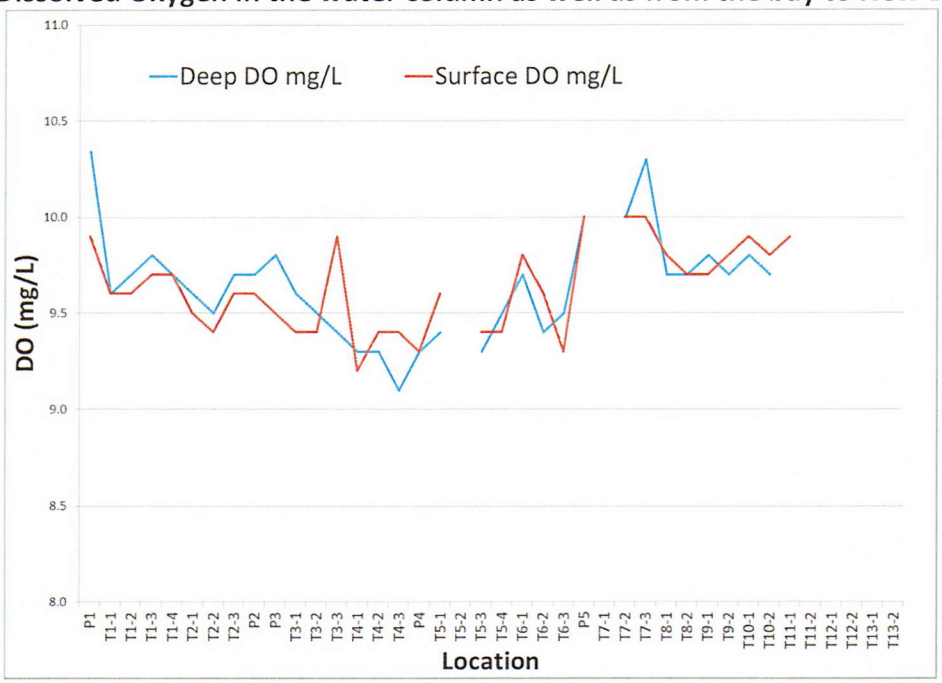


Figure 7. pH in the water column as well as from the bay to New Brunswick.

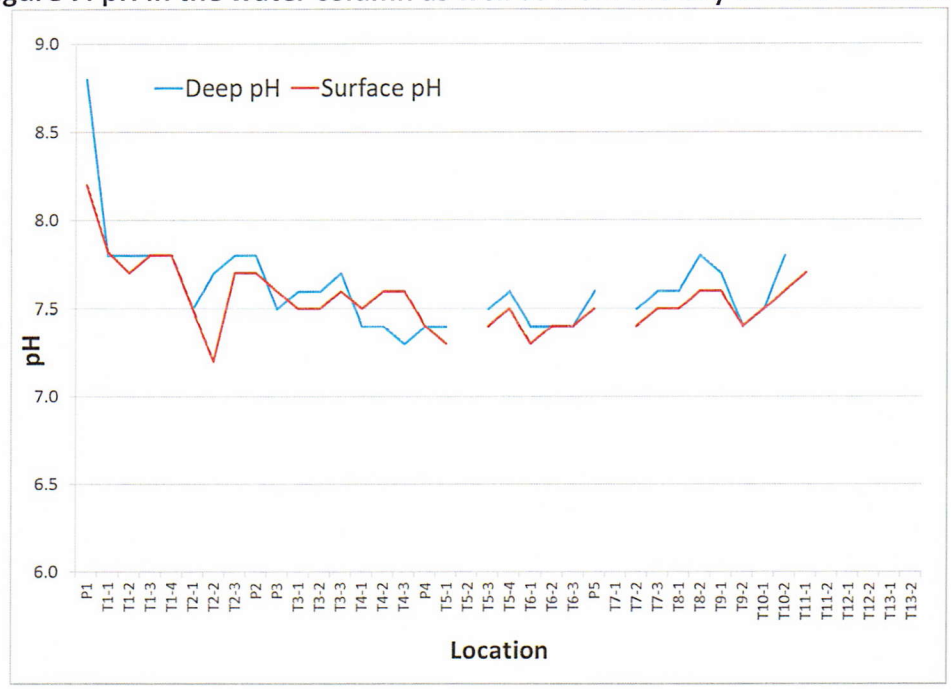


Figure 8. Oxygen Reduction Potential in the water column as well as from the bay through New Brunswick.

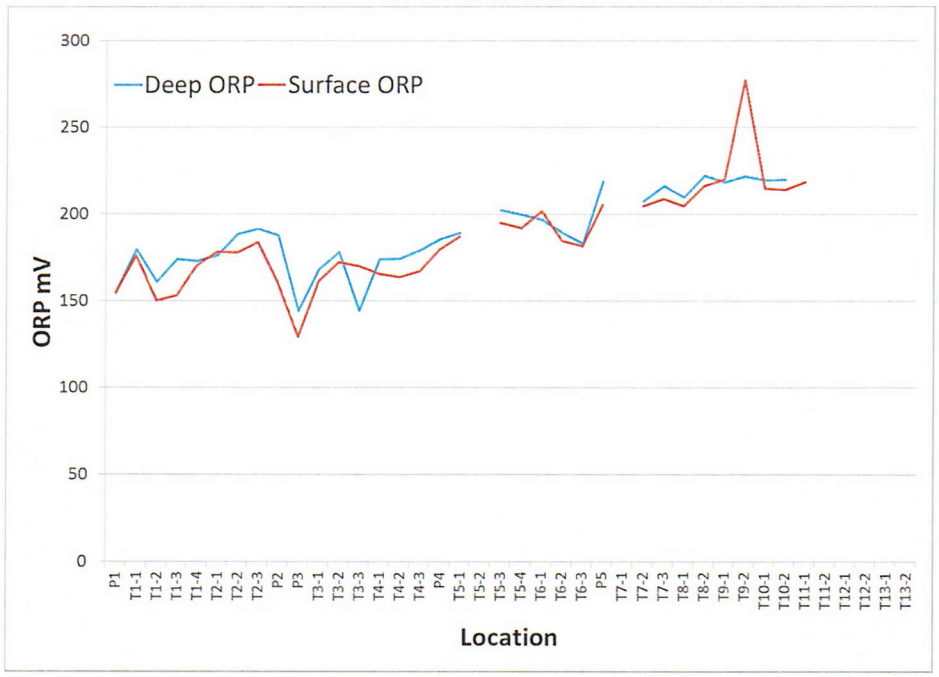


Table 1. Summary table of onsite water quality measurements at the lower Raritan River

Location	Temp oC	Cond S/m	TDS mg/L	Sal ppt	pH	ORP mV	Turb NTU	DO%	DO mg/L	Temp oC	Cond S/m	TDS mg/L	Sal ppt	pH	ORP mV	Turb NTU	DO%	DO mg/L
P1	8.6	22.9	14.9	13.8	8.8	155	7.6	97.2	10.3	8.6	22.7	14.7	13.6	8.2	155	7.2	93.2	9.9
P2	8.7	21.9	14.2	13.1	7.8	188	N/A	91.7	9.7	9.2	19.4	12.6	12.6	7.7	160	9.4	90.7	9.6
P3	8.9	23.0	14.9	13.9	7.5	145	6.3	92.8	9.8	9.2	21.4	13.9	12.8	7.6	129	8.8	90.8	9.5
P4	9.9	10.3	6.7	5.0	7.4	186	14.1	96.1	9.3	10.3	9.1	5.9	5.1	7.4	180	19.2	82.7	9.3
P5	11.5	2.8	1.8	1.4	7.6	219	17.5	93.1	10.0	11.5	2.6	1.7	1.4	7.5	206	18.0	93.2	10.0
T1-1	8.3	24.6	16.0	14.9	7.8	180	N/A	90.7	9.6	8.7	28.3	14.4	13.2	7.8	176	8.7	90.1	9.6
T1-2	8.3	23.9	15.6	14.5	7.8	161	N/A	91.5	9.7	9.0	20.1	13.1	12.0	7.7	150	8.4	90.4	9.6
T1-3	8.5	22.7	14.7	13.6	7.8	174	N/A	92.0	9.8	9.0	19.6	12.7	11.6	7.8	153	8.6	90.7	9.7
T1-4	9.0	18.5	11.3	9.7	7.8	173	9.3	90.9	9.7	9.3	15.4	10.0	9.0	7.8	171	9.7	90.5	9.7
T2-1	9.7	17.2	11.2	10.1	7.5	176	9.2	90.2	9.6	10.0	14.3	9.3	8.3	7.5	178	10.2	88.8	9.5
T2-2	8.4	22.9	14.3	15.0	7.7	189	7.4	89.8	9.5	9.5	20.6	13.4	12.3	7.2	178	7.6	90.0	9.4
T2-3	8.6	22.8	14.7	13.7	7.8	192	N/A	91.5	9.7	9.7	20.6	13.4	12.3	7.7	184	7.1	91.5	9.6
T3-1	10.2	12.6	8.2	7.2	7.6	168	11.7	86.6	9.6	10.5	11.5	7.4	6.5	7.5	161	11.2	88.3	9.4
T3-2	9.5	15.1	9.8	9.8	7.6	178	10.8	88.9	9.5	10.3	12.4	8.0	7.1	7.5	172	10.9	88.6	9.4
T3-3	9.1	18.4	11.9	10.9	7.7	144	16.2	88.3	9.4	9.9	17.0	11.0	10.0	7.6	170	13.9	87.6	9.9
T4-1	9.8	11.5	7.6	6.3	7.4	174	13.1	86.2	9.3	10.6	8.5	5.5	4.7	7.5	166	12.2	86.4	9.2
T4-2	10.0	13.6	8.8	7.8	7.4	174	10.6	86.6	9.3	11.2	7.8	4.9	4.1	7.6	164	11.9	88.6	9.4
T4-3	9.1	18.0	11.7	10.7	7.3	179	9.4	84.7	9.1	10.5	8.3	5.8	4.6	7.6	167	11.7	86.9	9.4
T5-1	10.8	7.1	4.6	3.9	7.4	189	20.0	87.4	9.4	10.8	7.0	4.5	3.8	7.3	187	18.3	89.1	9.6
T5-2	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
T5-3	10.5	11.4	7.4	6.5	7.5	203	16.9	88.3	9.3	10.5	11.5	7.4	6.5	7.4	195	17.9	88.5	9.4
T5-4	10.3	11.0	7.5	6.6	7.6	200	13.9	89.3	9.5	10.3	11.6	7.5	6.6	7.5	192	14.3	88.2	9.4
T6-1	11.1	9.6	2.3	1.9	7.4	197	18.2	83.2	9.7	11.2	3.6	2.3	1.9	7.3	202	18.3	80.3	9.8
T6-2	10.9	10.0	6.5	6.7	7.4	189	12.8	89.1	9.4	11.0	8.9	5.9	5.2	7.4	185	12.5	89.9	9.6
T6-3	10.4	10.8	6.9	6.1	7.4	183	10.2	87.0	9.5	10.4	10.4	6.8	6.9	7.4	182	14.9	87.3	9.3
T7-1	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
T7-2	11.6	3.2	2.0	1.6	7.5	208	20.6	93.7	10.0	11.6	3.2	2.1	1.7	7.4	205	20.6	93.1	10.0
T7-3	11.8	1.7	1.1	0.9	7.6	216	10.4	95.6	10.3	11.2	1.7	1.1	0.8	7.5	209	17.7	93.0	10.0
T8-1	12.0	0.3	0.2	0.1	7.6	210	16.3	90.2	9.7	12.1	0.3	0.2	0.1	7.5	205	16.8	91.8	9.8
T8-2	12.0	0.3	0.2	0.1	7.8	222	18.0	91.1	9.7	12.0	0.3	0.2	0.1	7.6	216	16.6	90.8	9.7
T9-1	11.9	0.3	0.2	0.1	7.7	219	11.3	91.1	9.8	12.0	0.3	0.2	0.1	7.6	220	11.5	90.8	9.7
T9-2	12.5	0.3	0.2	0.1	7.4	222	14.9	92.2	9.7	12.5	0.3	0.2	0.1	7.4	277	14.7	92.6	9.8
T10-1	12.1	0.3	0.2	0.1	7.5	220	19.6	92.6	9.8	12.3	0.3	0.2	0.1	7.5	215	13.4	93.4	9.9
T10-2	11.8	0.3	0.2	0.1	7.8	220	11.4	90.0	9.7	11.8	0.3	0.2	0.1	7.6	214	10.3	91.1	9.8
T11-1	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	12.4	0.3	0.1	0.1	7.7	219	48.0	93.3	9.9
T11-2	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
T12-1	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	13.9	0.3	0.2	0.1	7.8	217	22.5	97.4	10.0
T12-2	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
T13-1	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
T13-2	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	14.4	0.3	0.1	0.1	7.9	233	41.0	104	10.6

*N/A – the readings were below the sensor's detection limit

*N/R – no water quality readings recorded due to too shallow water