# Nueces Bay Total Maximum Daily Load Project – Year-six Implementation Effectiveness Monitoring Data Report

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# 1.0 INTRODUCTION

## 1.1 Background

The 1998 *Texas Water Quality Inventory and Clean Water Act 303(d) List* of impaired waters initially listed Nueces Bay (Segment 2482) for not meeting the oyster water use. The listing resulted from zinc in oyster tissue levels being greater than the health assessment comparison value (HAC) of 700 mg/kg as defined by the Texas Department of State Health Services (DSHS 2006) necessary to support the oyster water use in Nueces Bay. In response to this listing, the Texas Commission on Environmental Quality (TCEQ) Total Maximum Daily Load (TMDL) Program, in conjunction with the Coastal Management Program (CMP), funded two projects to: 1) develop a Geographic Information System (GIS) zinc loadings model and 2) verify the zinc impairment in oyster tissue through a sampling program.

The GIS zinc loadings model developed by Mrini *et. al* (2003) provided documentation of zinc loadings and an assessment of possible zinc sources entering into Nueces Bay. Modeling of the data indicated that elevated aqueous total zinc concentrations in Nueces Bay might be due to the discharge of Nueces Bay Power Station (NBPS) once-through cooling water drawn from the Corpus Christi Inner Harbor (Segment 2484). The Corpus Christi Inner Harbor segment includes numerous industrial facilities with TCEQ permitted discharges to Inner Harbor waters.

For the sampling program, the collection of total and dissolved zinc data utilized Ultra-Clean sampling methods and analysis (*EPA 1640–modified*) to augment the TCEQ historical zinc database, reduce data variability, and track the effect of possible reduced zinc loadings resulting from the closure of the NBPS in December 2002. Utilizing EPA method 1640 provides lower detection limits that are necessary since zinc is ubiquitous in the environment and is one of the most difficult trace metals to collect and analyze accurately without contamination. The ease of contaminating samples during collection or analysis cannot be overestimated as ambient zinc concentrations in seawater or brackish waters can typically be below one part per billion (µg/L or ppb) making it difficult to get field blanks and method blanks sufficiently low enough to allow accurate determinations of ambient zinc concentrations in seawater. Due to analytical interferences caused by the high salt content of seawater, universal consensus exists in the oceanographic research community that many ambient trace metals (including zinc) can only be accurately determined in seawater using sophisticated analytical techniques such as the pre-concentration techniques described in EPA method 1640. (Batterham et al. 1997; Sohrin et al. 2001).

Historically, as part of the multi-faceted Coastal Bend Bays & Estuaries Program Regional Coastal Assessment Program, the Center for Coastal Studies (CCS) collected water and sediment samples throughout the Coastal Bend region from 2000 through 2004. Aqueous samples were analyzed using EPA method 1640 (and others) for a suite of trace metal parameters. Data from this multiyear study identified dissolved zinc concentrations in Nueces Bay ranged from 0.69 ppb to 19.90 ppb, with a mean concentration of 6.40 ppb

(Nicolau and Nuñez 2004; Nicolau and Nuñez 2005a; Nicolau and Nuñez 2005b; Nicolau 2006a).

TCEQ initiated the present study to collect new data, with Year-one data representing zinc concentrations from four sampling events between June 2004 – May 2005 (Nicolau and Nuñez 2005b). Additional data collected in Year-two represents four sampling events that took place from September 2005 – July 2006 (Nicolau 2006b). Results of the first two years facilitated development of the current TMDL to allocate the allowable zinc load in Nueces Bay (TCEQ 2006).

On 1 November 2006, TCEQ approved one TMDL for Nueces Bay (segment 2482) to address the zinc impairment associated with the oyster waters use listed on the draft 2004 State of Texas Clean Water Act 303(d) list (TCEQ 2006). The U.S. Environmental Protection Agency (EPA) approved the TMDL on 15 December 2006 and TCEQ approved the Implementation Plan on 24 October 2007 (TCEQ 2007). As part of determining the Implementation Plan success, sampling occurred biannually for zinc in water, sediment, and tissue in Year-three from April 2008 – August 2008, Year-four from January 2010 – August 2010 (Nicolau and Hill 2010), Year-five sampling events took place from February 2011 – August 2011 (Nicolau and Hill 2011), and in Year-six sampling occurred from November 2011 – June 2012.

## 1.2 Project Objectives

As stated in the Implementation Plan (TCEQ 2007) the ultimate goals are to:

- "Ensure levels of zinc in oyster tissue attenuate to levels below the health assessment comparison value (HAC) of 700 mg/kg that supports the oyster water use in Nueces Bay (DSHS 2006)."

- "Adopt a criterion for zinc in water that is more appropriate and protective of human health via the pathway of ingestion of oysters. Zinc concentrations in the surface water of Nueces Bay are below the current criterion; however, zinc resulting from legacy sources exists in oyster tissue at levels that could result in adverse health effects from regular or long-term consumption (DSHS 2006). For this reason, a revised criterion for total zinc of 29 µg/L (ppb) was calculated to ensure the protection of human health."

Project objectives for Year-six of the Nueces Bay Zinc TMDL Implementation Effectiveness Monitoring are to continue sampling Nueces Bay (Segment 2482), the Corpus Christi Inner Harbor (Segment 2484), and the Nueces River tidal (Segment 2101) to track water, sediment, and oyster tissue zinc levels. This report summarizes the data collected during Year-six of this this multi-year sampling program. The goal is to provide TCEQ with sufficient data to address the zinc questions in Nueces Bay, to determine if the designated uses are being met, and to track zinc loadings to Nueces Bay (i.e. TMDL implementation) and the effect these loadings have on water and sediment quality and ultimately in oyster tissue.

# 2.0 METHODS

## 2.1 Sampling Process Design and Modifications

The original sample design of the TMDL Program required collecting data of sufficient quality to characterize zinc in water and zinc in sediment within Nueces Bay (Segment 2482), Nueces River Tidal (Segment 2101), and the Corpus Christi Inner Harbor (Segment 2484). The design had to be flexible to accommodate possible modifications, such as the addition or deletion of stations or increased sampling frequency, as results from previous sampling years became available.

In Year-one the CCS sampled eight (8) sites in Nueces Bay, two (2) sites in the Nueces River, and four (4) sites in the Corpus Christi Inner Harbor for four (4) water and two (2) sediment sampling events (Figure 2.1). In Year-one, sediment was collected from the surficial layer (2 to <5 cm) and anaerobic layer (>5 to 9 cm) and analyzed for total zinc, total organic carbon (TOC), and sediment grain size. Sampling of the deeper, anaerobic sediment layer would determine if lower or higher sediment zinc concentrations existed and possibly identify a "legacy" layer with higher concentrations providing a source of zinc from re-suspension (i.e. wind and wave, boat/ship activity, scouring). Data analysis of two sediment events conducted in Year-one, and one event conducted in Year-two did yield higher concentrations existing at lower depths (mean surficial = 91.4 mg/kg and mean anaerobic = 110.9 mg/kg). However, no statistically significant difference existed for zinc concentrations between depths (all Stations $p$ = 0.62, Corpus Christi Inner Harbor Stations $p$ = 0.89, Nueces Bay Stations $p$ = 0.70, Nueces River Tidal Stations $p$ = 0.70).

Initially, Year-two sampling protocol was to duplicate that of Year-one. However, after meeting with TCEQ TMDL personnel on 18 January 2006, the decision was to discontinue sampling the anaerobic sediment layer portion and redirect resources towards two new sampling efforts identified as important in the TMDL process. The first effort was to investigate the concentration of total and dissolved zinc in water at deeper depths within the Corpus Christi Inner Harbor (Year-two April and July 2006 events). This effort would determine if samples taken at the surface are representative of the NBPS intake pipe located at approximately 7.0 m below the surface and thereby closer to the bottom sediments and possible influence of sediments re-suspended by ship propellers. Data analysis showed no statistical difference between the two depths for total ($p$ = 0.78) or dissolved zinc ($p$ = 0.80) and TCEQ TMDL personnel and CCS agreed surface samples were representative of the water body.

Secondly, TCEQ TMDL personnel and CCS researchers agreed sampling in the western portion of Nueces Bay was necessary since this area lacks current zinc information. This portion of the bay is located adjacent to a historical brine point source discharge facility and is directly downwind from the Inner Harbor industrial complex. Station 18866 (Figure 2.1) was added to the sampling program in April 2006 after agreement this station would be beneficial to the project. Sampling continues at Station 18866 as part of the Implementation and Effectiveness Monitoring Plan for the Nueces Bay TMDL study.

In Year-three, modifications to the sampling plan included a reduction in the number of stations sampled from fifteen to ten and the number of yearly sampling events was reduced from four to two. In addition, oyster tissue sampling took place for zinc concentrations at five (5) stations in Nueces Bay. Please note that DSHS, not TCEQ, has the administrative and assessment authority for the National Shellfish Sanitation Program for Texas, zinc in oyster tissue data collected for the Implementation Effectiveness Monitoring Program is for informational purposes and TCEQ does not intend for it to be included for assessment purposes.

For Year-four, Year-five, and Year-six, sampling occurred for all parameters described in the Quality Assurance Project Plan (QAPP) and listed in Table 2.1. All data collected underwent quality assurance and is compliant with TCEQ Data Management protocols.

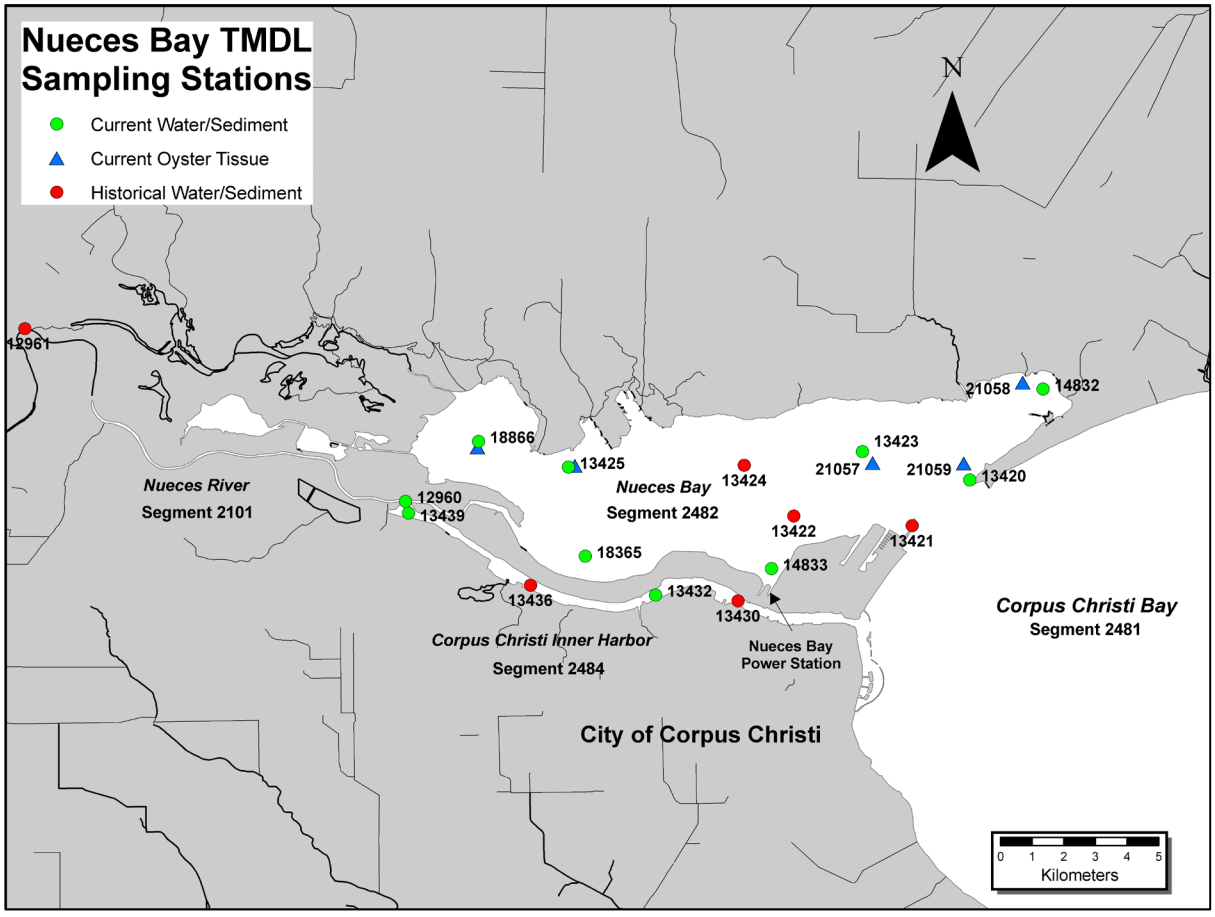


Figure 2.1. Map of current and historical Center for Coastal Studies Nueces Bay TMDL sampling locations.

## 2.2 Parameters Sampled

Table 2.1. Parameters analyzed for the Nueces Bay TMDL project.

| FIELD PARAMETERS (Water) | Units | TCEQ Parameter Codes |
|---|---|---|
| Total Depth | Meters | 82903 |
| Depth Sample Collected (Grab) | Meters | 13850 |
| Water Temperature (Grab) | °C | 00010 |
| Dissolved Oxygen Saturation (Grab) | % | 00301 |
| Dissolved Oxygen (Grab) | mg/L | 00300 |
| Conductivity (Grab) | µS/cm | 00094 |
| Salinity (Grab) | Practical Salinity Units | 00480 |
| pH (Grab) | su | 00400 |
| Turbidity | Visual assessment | 88842 |
| Turbidity | NTU | 82078 |
| Secchi Depth | Meters | 00078 |
| Tide Stage | DNR Tide Gauge | 89972 |
| Water Color | Visual assessment | 89969 |
| Water Odor | Olfactory assessment | 89971 |
| Water Surface | Visual assessment | 89968 |
| **FIELD PARAMETERS (Weather)** | **Units** | **TCEQ Parameter Codes** |
| Air Temperature | °C | 00020 |
| Barometric Pressure | mm/Hg | NA |
| Cloud Cover | % | NA |
| Dew Point | °C | NA |
| Heat Index | °C | NA |
| Present Weather | Visual assessment | 89966 |
| Rainfall (Days since last) | Days | 72053 |
| Rainfall (Inches past 1 day) | Inches | 82553 |
| Rainfall (Inches past 7days) | Inches | 82554 |
| Relative Humidity | % | NA |
| Wind Chill | °C | NA |
| Wind Direction | Compass Direction | 89010 |
| Wind Speed | MPH | NA |

Table 2.1. (continued).

| TRACE METALS IN WATER | Units | TCEQ Parameter Codes |
|---|---|---|
| Zinc (Dissolved) | µg/L or ppb | 01090 |
| Zinc (Total) | µg/L or ppb | 01092 |
| **TRACE METALS IN SEDIMENT** | **Units** | **TCEQ Parameter Codes** |
| Zinc | mg/kg dry weight | 01093 |
| **ORGANICS** | **Units** | **TCEQ Parameter Codes** |
| Total Organic Carbon (TOC) | mg/kg dry weight | 81951 |
| Total Solids | % | 81373 |
| **SEDIMENT GRAIN SIZE** | **Units** | **TCEQ Parameter Codes** |
| SGS Clay (<0.0039 mm) | % dry weight | 82009 |
| SGS Silt (0.0039 to 0.0625 mm) | % dry weight | 82008 |
| SGS Sand (0.0625 to 2.0 mm) | % dry weight | 89991 |
| SGS Gravel (>2.0 mm) | % dry weight | 80256 |
| **ROUTINE CHEMISTRY (Water)** | **Units** | **TCEQ Parameter Codes** |
| Total Suspended Solids (TSS) | mg/L | 00530 |

## 2.3 Sampling Methods

The CCS followed sampling procedures for all parameters documented in the TCEQ-approved QAPPs for this project (CCS 2004, 2005, 2007, 2009, 2010, 2011a, and 2011b). A three-person field crew conducted water and sediment sampling from a 21'fiberglass boat on a quarterly or biannual basis. At each sampling site, field crews collected a core set of data and field samples following methods and protocols described in the TCEQ *Surface Water Quality Monitoring Procedures Volume 1: Physical and Chemical Monitoring Methods for Water, Sediment and Tissue* (TCEQ RG-415) or the CCS QAPP applicable for that sampling year. Core field data/samples included those specified in Table 2.1 and listed below, with further detail provided in the chapters of this document.

1. Routine field parameters such as ambient weather conditions (air temperature, wind speed and direction, cloud cover, etc.).
2. Instantaneous water column profile (dissolved oxygen, pH, salinity, temperature, depth, etc.).
3. Routine chemical parameters (total suspended solids).
4. Total and dissolved zinc in water.
5. Zinc, total organic carbon, and grain size in sediment.

Note: Zinc in oyster tissue sampling is conducted separate from water and sediment sampling events.

Additional aspects outlined below are requirements for specific sampling parameters and/or provide additional clarification. The following sections describe the general methods and procedures for each core sampling activity that occurred at the sampling sites.

### *2.3.1. Field Sampling Procedures*

The CCS followed sampling procedures documented in the current TCEQ *Surface Water Quality Monitoring Procedures Volume 1: Physical and Chemical Monitoring Methods for Water, Sediment, and Tissue* available for that year of sampling (see TCEQ 2008 for most current reference). For trace element sampling, EPA Method 1669: *Sampling Ambient Water for Trace Metals at EPA Water Quality Criteria Levels* (EPA 1999) provides additional sampling guidance. Additional procedures for field sampling outlined in this section are specific requirements for this TMDL Project and provide additional clarification.

### *2.3.2. Site Location*

As required through TMDL implementation, data collection efforts involved sampling water, sediment, and oyster tissue to monitor and determine effects of zinc loadings to Nueces Bay. Guidelines exist for selecting sampling sites with consideration given to site accessibility and sampling crew safety. Sampling site locations were established prior to field sampling with selection based on criteria described in the TCEQ *Surface Water Quality Monitoring Procedures Volume 1: Physical and Chemical Monitoring Methods for Water, Sediment, and Tissue* (TCEQ 2008). Development of all monitoring activities was coordinated with the TCEQ TMDL Project Manager. See Data Table 7.1.1 for station location information.

### *2.3.3. Water Column Measurements*

Routine field observations, ambient weather, and water conditions were conducted first upon arriving at each station. Water column measurements followed, as these data/samples require collection before disturbing the sediment. Water column measurements were taken using a multiparameter sonde (e.g., YSI 6920 Multiprobe) connected by cable to a display unit and included: water temperature (°C), dissolved oxygen (mg/L), conductivity (μmhos), salinity (Practical Salinity Units or PSU), pH (standard units or su), and turbidity (Nephelometric Turbidity Units or NTU). Water column profiles were conducted when depth was > 1.5 m, and according to TCEQ requirements for vertical depth profiles. Secchi depth measurements were collected at each station using a standard 20-cm diameter black and white secchi disc.

### *2.3.4. Routine Conventional Chemistry*

Total Suspended Solids.

One (1) L of unfiltered seawater was collected at 0.3 m at each station during all sampling years with additional water samples collected at ≈ 7.0 m at the four (4) Corpus Christi Inner Harbor stations July 2006. TSS samples were collected in 1 L polypropylene bottles, placed on wet ice in the field, and stored at 4ºC before laboratory analysis commenced.

### *2.3.5. Trace Metals in Water (Total and Dissolved Zinc)*

All CCS personnel received prior field training from Dr. Paul N. Boothe of Albion Environmental on EPA sampling methods, the "clean hands – dirty hands" technique, for collecting trace metals samples. Avoiding contamination during field sampling is extremely important for the accuracy of clean metals data. Reducing potential for contamination is essential during sampling events, as the primary sources of sample contamination comes from airborne particulates and sample contact of contaminated surfaces. CCS personnel have been successfully performing these sampling procedures since March 2000 (Nicolau and Nuñez 2004; Nicolau and Nuñez 2005a; Nicolau and Nuñez 2005b; Nicolau 2006a).

CCS field crews used specialized sampling kits developed by Albion Environmental and a peristaltic pump to obtain grab samples. Each sampling kit came individually bagged and separate from the clean boxes. The actual collection of the water sample took place in a clean box used as a hood to minimize air particulates entering the sample. Certified LDPE sample bottle had a unique identifying number provided by Albion Environmental. Teflon inlet tubing inserted into a particle-free 4.6 m PVC pole allowed for water collection upstream of the sampling boat. Dissolved zinc samples were filtered through a pre-cleaned (Albion) Single Sample 0.45 µm large capacity capsule filter; with a new filter used for each dissolved sample taken. Samples collected for total zinc followed the same procedures as dissolved zinc but without the filter. To verify no contamination occurred during field sampling, one field blank and one field duplicate sample were taken for each sampling event.

Please note that the above description is a simplified version of the sampling process. Additional sampling details are found in EPA Method 1669 *Sampling ambient water for trace metals at EPA water quality criteria levels* (USEPA 1999) and Albion Environmental Standard Operating Procedures modified after EPA Method 1669. Both documents are available upon request to the CCS Project Manager.

### *2.3.6. Composited Sediments*

At each site, a modified 0.04 $m^2$ Van Veen sampler was used to collect a minimum of three sediment grab samples to ensure enough material for the analyses of total zinc, total organic carbon (TOC), and sediment grain size determinations. A plastic scoop was used to obtain the surficial sediment layer (2 to <5 cm) from each grab sample and composited in a clean, high-grade stainless steel bucket. Continually mixing the sediment from each grab sample ensured a homogenous sample and placement of the bucket containing the sediment material on ice and covering with a lid protected the sample material from contamination. Sub-samples for the various analyses took place as follows:

Inorganic chemical contaminants (Zinc, TOC, and Sediment Grain Size)

Approximately 114 g of composited sediment was placed into three individual clean, pre-labeled, wide-mouth LDPE jars and placed on wet ice in the field. Upon transfer from field to lab, the sample was held at 4°C until laboratory processing commenced.

### *2.3.7. Oyster Sampling*

Oysters were collected at selected sites from shallow reefs using a standard dredge towed behind the boat then placed in Ziploc bags and stored on wet ice. Five samples were collected at each location, yielding 25 samples per sampling event. Each sample consisted of 25 to 30 oysters of market length (2 to 3 inches) to yield >15 g per sample. Upon return to CCS, field staff placed the oysters on fresh wet ice and shipped overnight to GEL laboratories for analysis.

# 3.0 WATER MONITORING

## 3.1 TCEQ Criteria and Screening Levels

TCEQ uses many physical, chemical, and biological characteristics in assessing support of designated uses and criteria of a water body (Segment). Primarily, comparison of individual parameter values to either numerical criteria or screening levels determines the number of exceedances. Based on number of exceedances, the assessment classifies a segment as either being in full support, partial support, or not supportive of the designated use. Similar exceedances of numerical screening levels identify segments with no concerns or concerns for impairment.

As defined in the *Guidance for Assessing and Reporting Surface Water Quality in Texas 2010* (TCEQ 2010) the identification of impairment relates directly to criteria adopted in the *Texas Surface Water Quality Standards* (TSWQS) that protects the designated use of a water body. The 303(*d*) list contains Segments with impairments while water bodies with concerns appear on the 305(*b*) report. Typically, areas exhibiting concerns will receive more frequent and possible additional monitoring of the parameter in concern (TCEQ 2010).

To establish whether impairments exist, and if support of aquatic life uses exist, TCEQ developed criteria for toxic substances in water. TCEQ developed criteria for 26 organic substances and a suite of 12 metals in dissolved and total forms with zinc concentrations based on a dissolved Tidal Water Chronic (TWC) criterion of 84.20 ppb and a Tidal Water Acute (TWA) criterion of 92.70 ppb. TCEQ has no criterion or screening level to evaluate total zinc concentrations in water, <u>except</u> in Nueces Bay where under this TMDL a revised criterion of 29 ppb calculated for total zinc ensures protection of human health.

## 3.2 Field Data

A select list of individual field parameter concentrations and descriptive statistics for stations sampled during Year-six appears in Chapter 7-Data Tables 7.2.1 and 7.2.2, and 7.3.1 through 7.3.5, respectively.

During Year-one, salinity ranged from 0.32 to 3.29 PSU in the Nueces River Tidal segment (Table 3.1). Salinity at several Nueces Bay stations was <10.00 PSU for the first two sampling events in 2004 due to precipitation and freshwater river inflows but by the end of Year-one, salinity increased to >20.00 PSU in Nueces Bay. Salinities in the Corpus Christi Inner Harbor remained >20.00 PSU and ranged as high as 30.88 PSU with mean salinity values greatest in the Corpus Christi Inner Harbor for the year. Mean salinity for all stations sampled in Year-one was 18.15 PSU. Lack of significant rainfall during Year-two resulted in salinity ranging from 0.67 to 37.50 PSU in the three segments (Table 3.1). Mean salinity concentrations were greater in the Corpus Christi Inner Harbor, followed by Nueces Bay, and the Nueces River Tidal segment. Overall mean salinity was >30.15 PSU for all stations sampled in Year-two.

Year-three salinity ranged from 4.02 to 36.36 PSU and in Year-four from 4.57 to 32.53 PSU, respectively (Table 3.1). Mean salinity for all stations sampled was higher in Year-three at

28.66 PSU than Year-four at 24.02 PSU. Lower salinity in Year-four was due to increased precipitation within the region. However, salinity increased in Year-five as drought conditions persisted throughout the region and ranged from 12.43 to 41.34 PSU. Nueces Bay stations had the highest mean salinity at 34.76 PSU, followed by the Corpus Christi Inner Harbor at 30.19 PSU, and the Nueces River Tidal segment at 21.45 PSU (Table 3.1). Mean salinity for all stations sampled in Year-five was 32.98 PSU.

Year-six showed continued increases in salinity for all three segments as drought conditions persisted throughout the area. Salinities ranged from 11.19 PSU in the Nueces River Tidal segment to 47.49 PSU in Nueces Bay (Table 3.1). As seen in previous years, mean salinity was greater in Nueces Bay at 38.92 PSU, followed by the Corpus Christi Inner Harbor at 36.95 PSU, and the Nueces River Tidal segment at 22.08 PSU. (Table 3.1; Data Tables 7.2.1 and 7.3.1). Mean salinity for all stations sampled in Year-six was 36.84 PSU.

Table 3.1. Salinity (PSU) descriptive statistics, listed by sampling year and TCEQ segment for all Nueces Bay TMDL stations sampled.

| Year | Segment | Segment Name | n | Min | Max | Mean |
|---|---|---|---|---|---|---|
| 1 | 2101 | Nueces River Tidal | 8 | 0.32 | 3.29 | 0.81 |
| 2 | | | 8 | 0.67 | 14.01 | 6.57 |
| 3 | | | 2 | 4.02 | 8.56 | 6.29 |
| 4 | | | 2 | 4.57 | 6.18 | 5.38 |
| 5 | | | 2 | 12.43 | 30.46 | 21.45 |
| 6 | | | 2 | 11.19 | 32.96 | 22.08 |
| 1 | 2482 | Nueces Bay | 32 | 1.94 | 28.85 | 17.57 |
| 2 | | | 34 | 22.44 | 37.50 | 33.40 |
| 3 | | | 14 | 27.10 | 36.36 | 30.87 |
| 4 | | | 14 | 13.45 | 30.58 | 23.18 |
| 5 | | | 14 | 29.34 | 41.34 | 34.76 |
| 6 | | | 14 | 31.37 | 47.49 | 38.92 |
| 1 | 2484 | Corpus Christi Inner Harbor | 16 | 22.73 | 30.88 | 28.00 |
| 2 | | | 16 | 32.51 | 37.41 | 35.03 |
| 3 | | | 4 | 29.53 | 34.95 | 32.09 |
| 4 | | | 4 | 28.03 | 32.53 | 30.19 |
| 6 | | | 4 | 33.06 | 40.86 | 36.95 |

Dissolved oxygen (DO) concentrations during Year-one were all >5.00 mg/L and ranged from 5.06 to 10.53 mg/L (Table 3.2). In Year-two, DO ranged from 4.63 to 11.06 mg/L. Except for Nueces Bay station 13422 which DO measured 4.63 mg/L during the July 2006 sampling event, all DO measurements were >5.00 mg/L.

Year-three DO concentrations were similar to Year-two, and ranged from 4.77 mg/L recorded at Station 13432 in the Corpus Christi Inner Harbor in August 2008 to 8.99 mg/L at Station 12960 in the Nueces River Tidal segment in April 2008 (Table 3.2). Except for the low DO at Station 13432 all concentrations were >5.00 mg/L. Year-four had similar concentrations and ranged from 4.66 mg/L at Station 12960 in August 2010 to 12.68 mg/L at Station 14833 in Nueces Bay in January 2010. As seen in Year-three, except for the one low value in Year-four all DO values were >5.0 mg/L.

In Year-five, DO ranged from 4.78 mg/L to 11.62 mg/L at Station 12960 in the Nueces River Tidal segment (Table 3.2). DO concentrations were > 5.00 mg/L except at Station 12960 (4.78 mg/L) in the Nueces River and Station 13432 (4.90 mg/L) in the Corpus Christi Inner Harbor during the May/June 2012 sampling event. When compared to Year-four mean DO concentrations decreased in Nueces Bay and the Corpus Christi Inner Harbor.

During Year-six, dissolved oxygen ranged from 7.03 mg/L in the Corpus Christi Inner Harbor to 10.19 mg/L in the Nueces River Tidal Segment (Table 3.2; Data Tables 7.2.1 and 7.3.2). Mean DO concentrations increased in all segments in Year-six from values recorded in Year-five. Mean DO for all stations sampled in Year-six was 8.34 mg/L.

Table 3.2. Dissolved Oxygen (mg/L) descriptive statistics, listed by sampling year and TCEQ segment for all Nueces Bay TMDL stations sampled.

| Year | Segment | Segment Name | n | Min | Max | Mean |
|---|---|---|---|---|---|---|
| 1 | 2101 | Nueces River Tidal | 8 | 5.65 | 9.08 | 7.70 |
| 2 | | | 8 | 7.08 | 11.06 | 9.15 |
| 3 | | | 2 | 6.63 | 8.99 | 7.81 |
| 4 | | | 2 | 4.66 | 11.35 | 8.01 |
| 5 | | | 2 | 4.78 | 11.62 | 8.20 |
| 6 | | | 2 | 7.83 | 10.19 | 9.01 |
| 1 | 2482 | Nueces Bay | 32 | 7.15 | 9.51 | 8.02 |
| 2 | | | 34 | 4.63 | 10.37 | 7.40 |
| 3 | | | 14 | 5.16 | 8.67 | 6.82 |
| 4 | | | 14 | 4.66 | 12.68 | 8.95 |
| 5 | | | 14 | 5.67 | 8.98 | 7.05 |
| 6 | | | 14 | 7.31 | 9.09 | 8.39 |
| 1 | 2484 | Corpus Christi Inner Harbor | 16 | 5.06 | 10.53 | 7.48 |
| 2 | | | 16 | 5.28 | 9.71 | 7.22 |
| 3 | | | 4 | 4.77 | 7.44 | 6.28 |
| 4 | | | 4 | 5.29 | 9.84 | 7.58 |
| 5 | | | 4 | 4.90 | 7.56 | 6.44 |
| 6 | | | 4 | 7.03 | 8.63 | 7.80 |

Water depth, typically <1.50 m, coupled with high wind speeds, define the usual turbid nature of Nueces Bay, where visibility is often <0.5 m. Mean turbidity recorded during all sampling events, except for Year-four and Year-six were higher in Nueces Bay and lowest in the Corpus Christi Inner Harbor (Table 3.3). During the January 2010 sampling event in Year-four, turbidity was low due to a winter "norther" passing through the area, which was followed by several days of calm to no winds. These conditions allowed suspended sediment to drop out of the water column thereby producing exceptional water clarity, >1.5 m at some stations. These conditions were also repeated during the November 2011 sampling event in Year-Six.

In Year-six, turbidity ranged from 0.00 NTU at Station 13439 in the Corpus Christi Inner Harbor to 25.80 NTU at Station 18365 in Nueces Bay (Table 3.3; Data Tables 7.2.1 and 7.3.4). Over the six-year study, 80.1% of surface water turbidity measurements in Nueces Bay have been <30.00 NTU and 90.6% have been <50.00 NTU, but some measurements have reached as high as 135.9 NTU. Overall turbidity means for the Corpus Christi Inner Harbor, Nueces River Tidal, and Nueces Bay segments are 2.72, 18.60, and25.56 NTU, respectively.

Table 3.3. Turbidity (NTU) descriptive statistics, listed by sampling year and TCEQ segment for all Nueces Bay TMDL stations sampled.

| Year | Segment | Segment Name | n | Min | Max | Mean |
|---|---|---|---|---|---|---|
| 1 | 2101 | Nueces River Tidal | 6 | 16.10 | 44.00 | 27.47 |
| 2 | | | 8 | 3.90 | 38.30 | 15.71 |
| 3 | | | 2 | 15.90 | 17.70 | 16.80 |
| 4 | | | 2 | 10.10 | 26.00 | 18.05 |
| 5 | | | 2 | 8.90 | 17.90 | 13.40 |
| 6 | | | 2 | 7.30 | 15.00 | 11.15 |
| 1 | 2482 | Nueces Bay | 24 | 6.10 | 135.90 | 36.18 |
| 2 | | | 28 | 2.00 | 121.00 | 26.89 |
| 3 | | | 14 | 8.40 | 112.60 | 31.39 |
| 4 | | | 14 | 0.10 | 33.30 | 6.87 |
| 5 | | | 14 | 10.10 | 102.60 | 35.86 |
| 6 | | | 14 | 0.10 | 25.80 | 8.44 |
| 1 | 2484 | Corpus Christi Inner Harbor | 15 | 0.09 | 13.40 | 3.57 |
| 2 | | | 12 | 0.00 | 9.00 | 3.89 |
| 3 | | | 4 | 1.10 | 2.80 | 1.68 |
| 4 | | | 4 | 0.70 | 2.60 | 1.10 |
| 5 | | | 4 | 0.00 | 1.90 | 0.95 |
| 6 | | | 4 | 0.00 | 1.90 | 0.40 |

## 3.3 TCEQ Routine Conventional Water Chemistry – Total Suspended Solids (TSS)

A complete list of individual TSS concentrations for Year-six, along with descriptive statistics, appears in Chapter 7-Data Tables 7.4.1 and 7.5.1.

During the first three years, TSS concentrations were lowest in the Corpus Christi Inner Harbor and highest in Nueces Bay, with concentrations ranging from 5.00 mg/L to 232 mg/L (Table 3.4). In Year-four, TSS concentrations were lower at most stations compared to Year-three due to the exceptional water clarity observed during the January 2010 sampling event. Year-four TSS concentrations ranged from 5.00 to 37.00 mg/L (Table 3.4) and mean concentrations were the lowest recorded for Nueces Bay over the six-year sampling period (Table 3.4. As seen in previous years, TSS concentrations in Year-four were lowest in the Corpus Christi Inner Harbor and highest in Nueces Bay.

In Year-five, mean TSS levels were the highest recorded for all sampling years, most notably in Nueces Bay. Year-six TSS concentrations ranged from 10.6 mg/L to 56.8 mg/L in Nueces Bay (Table 3.4) and TSS concentrations for all segments were lower than those concentrations recorded in Year-five (Table 3.4; Data Tables 7.4.1 and 7.5.1). Figures 3.1 and 3.2 depict individual TSS concentrations for each Year-six sampling event and Figure 3.3 depicts mean TSS concentrations for both sampling events in Year-six.

Table 3.4. Total Suspended Solids (mg/L) descriptive statistics, listed by sampling year and TCEQ segment for all Nueces Bay TMDL stations sampled.

| Year | Segment | Segment Name | n | Min | Max | Mean |
|---|---|---|---|---|---|---|
| 1 | 2101 | Nueces River Tidal | 8 | 10.00 | 80.00 | 30.75 |
| 2 | | | 8 | 7.00 | 77.00 | 23.63 |
| 3 | | | 2 | 20.00 | 29.00 | 24.50 |
| 4 | | | 2 | 13.00 | 25.00 | 19.00 |
| 5 | | | 2 | 38.40 | 59.00 | 48.70 |
| 6 | | | 2 | 20.80 | 26.40 | 23.60 |
| 1 | 2482 | Nueces Bay | 32 | 12.00 | 232.00 | 46.69 |
| 2 | | | 34 | 5.00 | 205.00 | 41.00 |
| 3 | | | 14 | 11.00 | 200.00 | 50.86 |
| 4 | | | 14 | 5.00 | 37.00 | 12.21 |
| 5 | | | 14 | 32.00 | 292.00 | 110.11 |
| 6 | | | 14 | 10.40 | 56.80 | 36.57 |
| 1 | 2484 | Corpus Christi Inner Harbor | 16 | 9.00 | 28.00 | 16.38 |
| 2 | | | 16 | 4.00 | 22.00 | 10.88 |
| 2 | | | 4 | 3.00 | 9.00 | 6.50 |
| 3 | | | 4 | 6.00 | 25.00 | 11.25 |
| 4 | | | 4 | 6.00 | 10.00 | 8.50 |
| 5 | | | 4 | 12.80 | 53.20 | 28.10 |
| 6 | | | 4 | 15.60 | 32.40 | 22.80 |

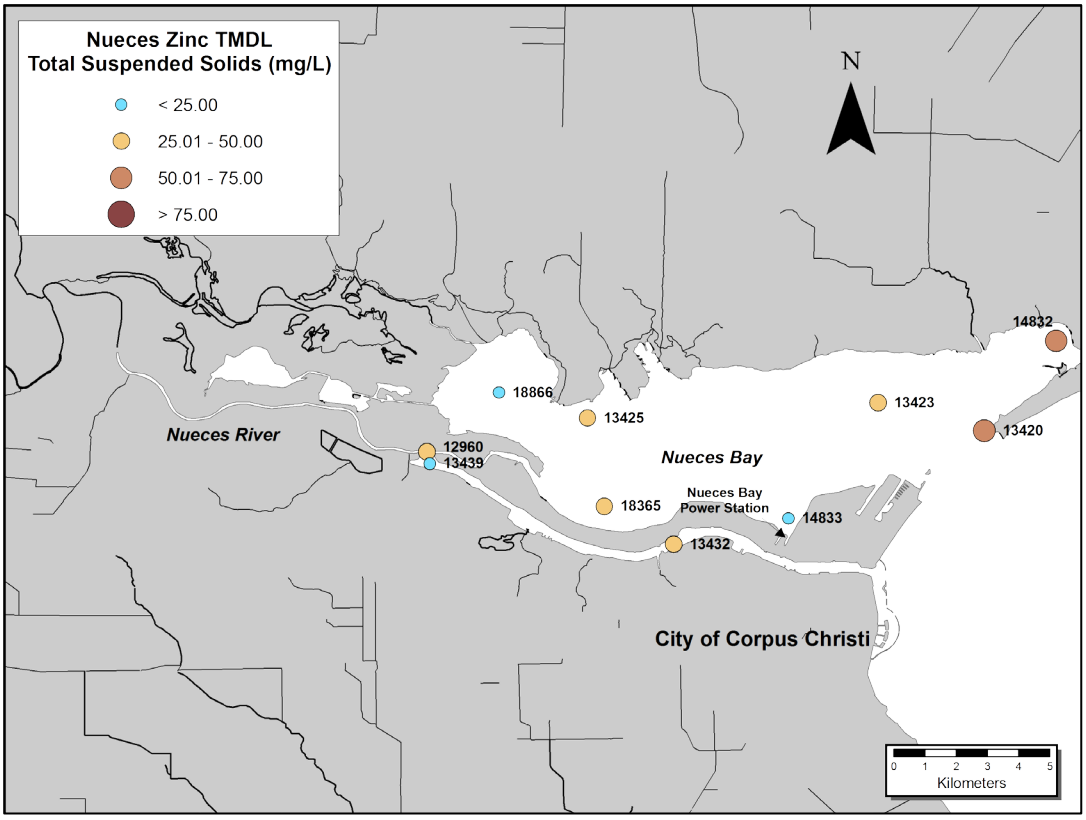


Figure 3.1. TSS concentrations (mg/L) for Year-six November 2011 sampling.

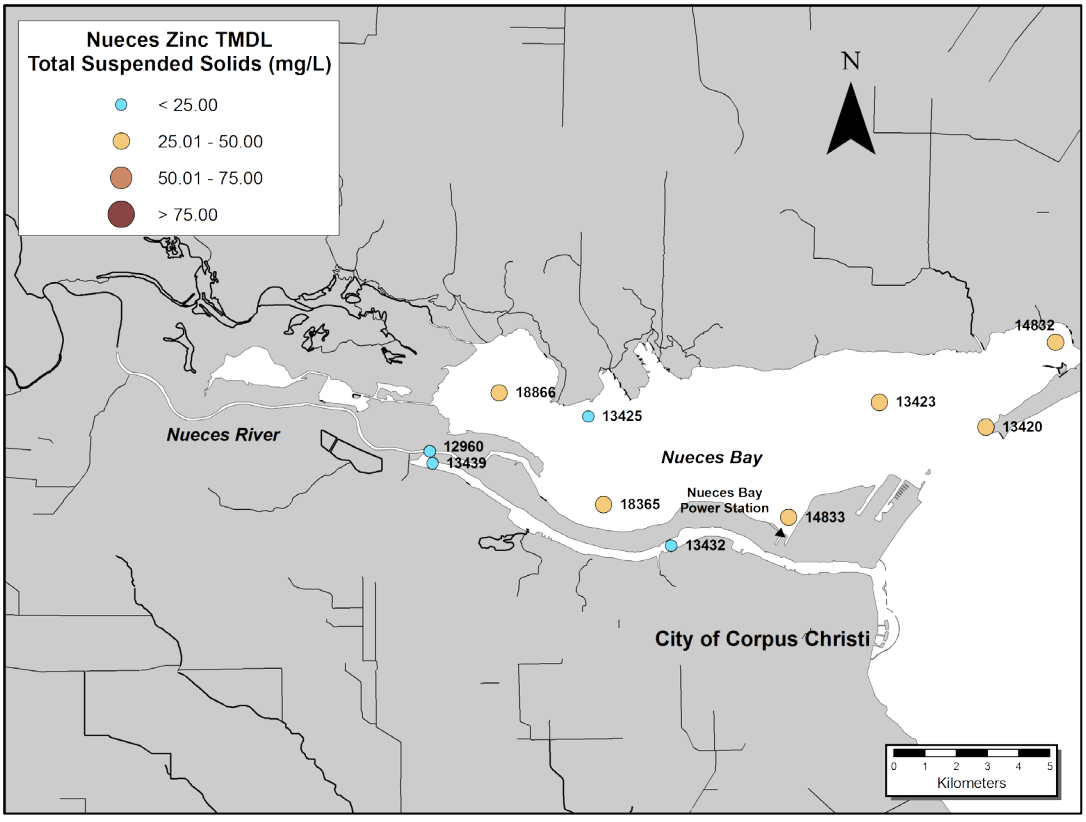


Figure 3.2. TSS concentrations (mg/L) for Year-six May/June 2012 sampling.

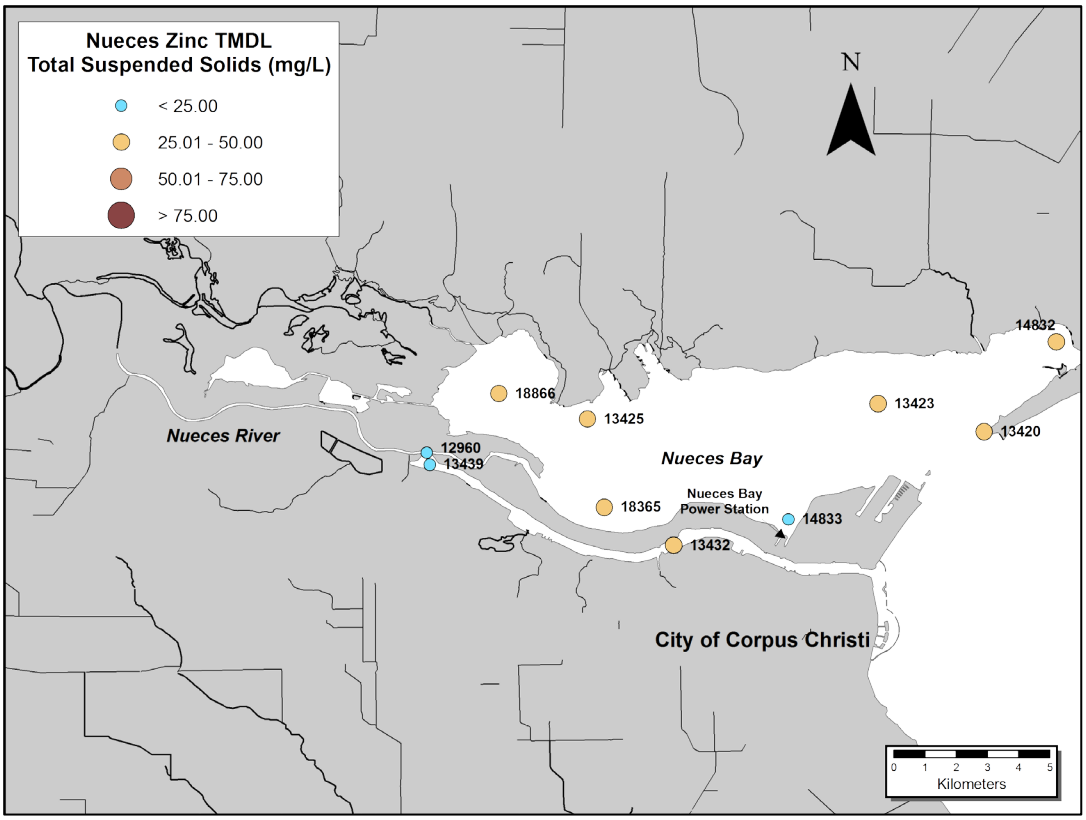


Figure 3.3. Mean TSS concentrations (mg/L) for Year-six sampling.

## 3.4 Zinc in Water

*Dissolved Zinc*

A complete list of individual dissolved zinc concentrations for Year-six, along with descriptive statistics, appears in Chapter 7-Data Tables 7.6.1 and 7.7.1.

Since sampling began, individual samples for dissolved zinc in water have not exceeded the TCEQ criterion. Typically, over the six-years, highest dissolved zinc concentrations recorded occurred in the Corpus Christi Inner Harbor and lowest concentrations occurred in the Nueces River Tidal segment (Table 3.5). The highest concentration recorded over the six-year sampling period was at Station 13432 in the Corpus Christi Inner Harbor during Year-five. However, this concentration of 18.80 ppb was 4.5 times less than the chronic criterion of 84.20 ppb and 4.9 times less that the acute criterion of 92.70 ppb.

Dissolved zinc concentrations in Year-six ranged from 0.43 ppb at Station 12960 in the Nueces River Tidal segment to 11.40 ppb at Station 13432 in the Corpus Christi Inner Harbor (Table 3.5; Data Tables 7.6.1 and 7.7.1). Figures 3.4 and 3.5 depict individual dissolved zinc concentrations for each Year-six sampling event and Figure 3.6 depicts mean dissolved zinc concentrations for both sampling events in Year-six.

Table 3.5. Dissolved zinc (ppb) descriptive statistics, listed by sampling year and TCEQ segment for all Nueces Bay TMDL stations sampled.

| Year | Segment | Segment Name | n | Min | Max | Mean |
|---|---|---|---|---|---|---|
| 1 | 2101 | Nueces River Tidal | 8 | 0.10 | 0.40 | 0.21 |
| 2 | | | 8 | 0.20 | 0.72 | 0.37 |
| 3 | | | 2 | 0.23 | 0.24 | 0.23 |
| 4 | | | 2 | 0.89 | 1.72 | 1.31 |
| 5 | | | 2 | 1.67 | 1.70 | 1.69 |
| 6 | | | 2 | 0.43 | 1.03 | 0.73 |
| 1 | 2482 | Nueces Bay | 32 | 0.34 | 2.40 | 1.11 |
| 2 | | | 34 | 0.61 | 4.88 | 2.38 |
| 3 | | | 14 | 0.77 | 2.63 | 1.70 |
| 4 | | | 14 | 0.64 | 2.95 | 1.26 |
| 5 | | | 14 | 0.84 | 6.33 | 2.60 |
| 6 | | | 14 | 0.62 | 4.87 | 2.02 |
| 1 | 2484 | Corpus Christi Inner Harbor | 16 | 1.67 | 10.80 | 5.12 |
| 2 | | | 16 | 2.69 | 12.90 | 7.42 |
| 2 | | | 8 | 4.35 | 12.20 | 8.13 |
| 3 | | | 4 | 2.59 | 7.73 | 5.24 |
| 4 | | | 4 | 2.08 | 8.44 | 5.66 |
| 5 | | | 4 | 1.74 | 18.80 | 9.82 |
| 6 | | | 4 | 7.56 | 11.40 | 9.05 |

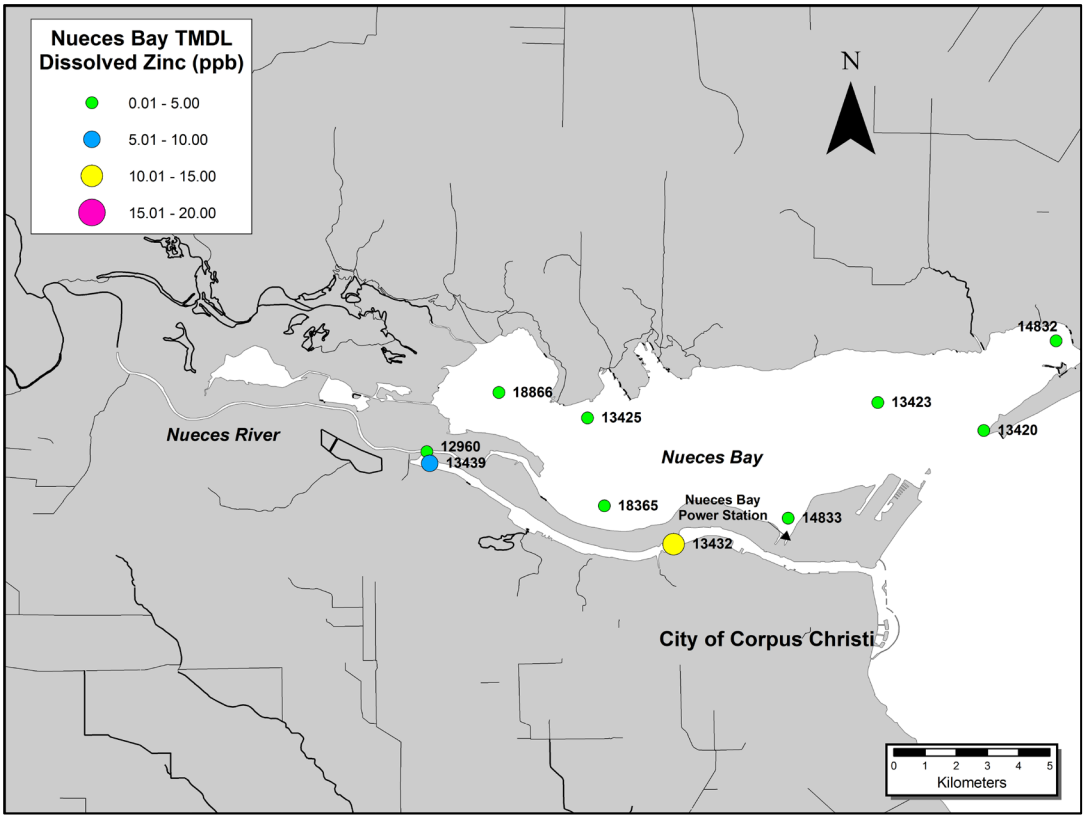


Figure 3.4. Dissolved zinc concentrations (ppb) for Year-six November 2011 sampling.

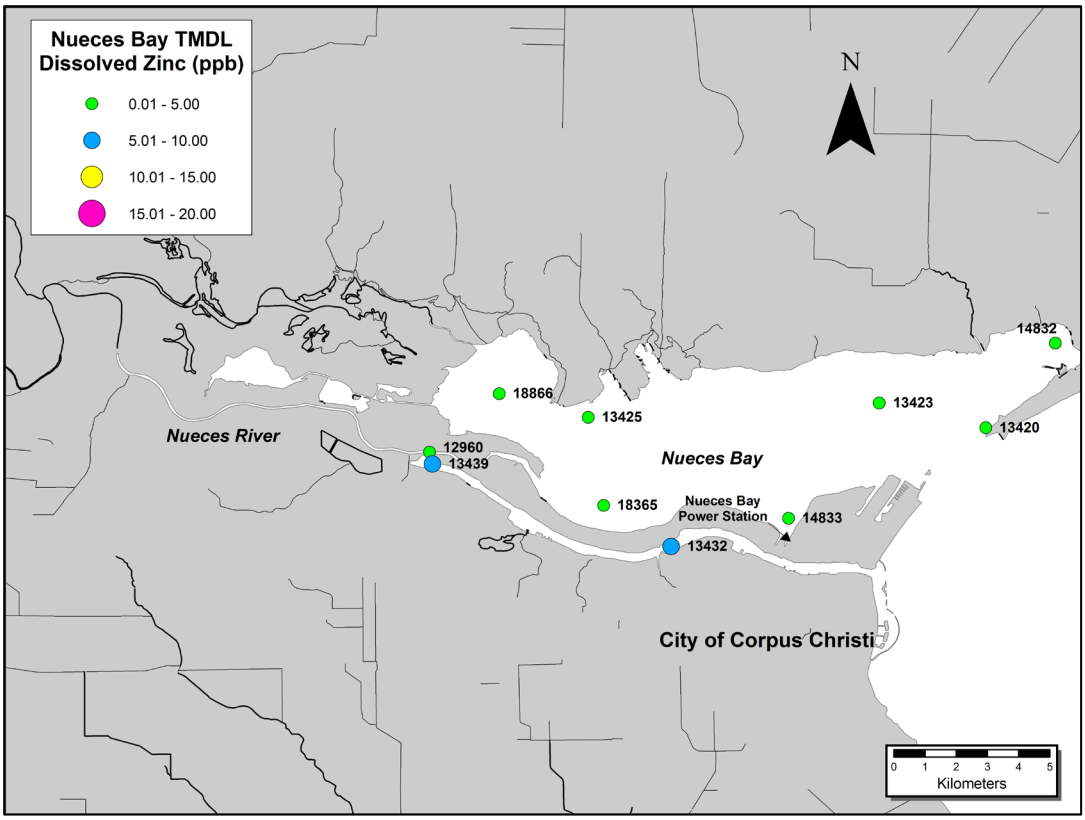


Figure 3.5. Dissolved zinc concentrations (ppb) for Year-six May/June 2012 sampling.

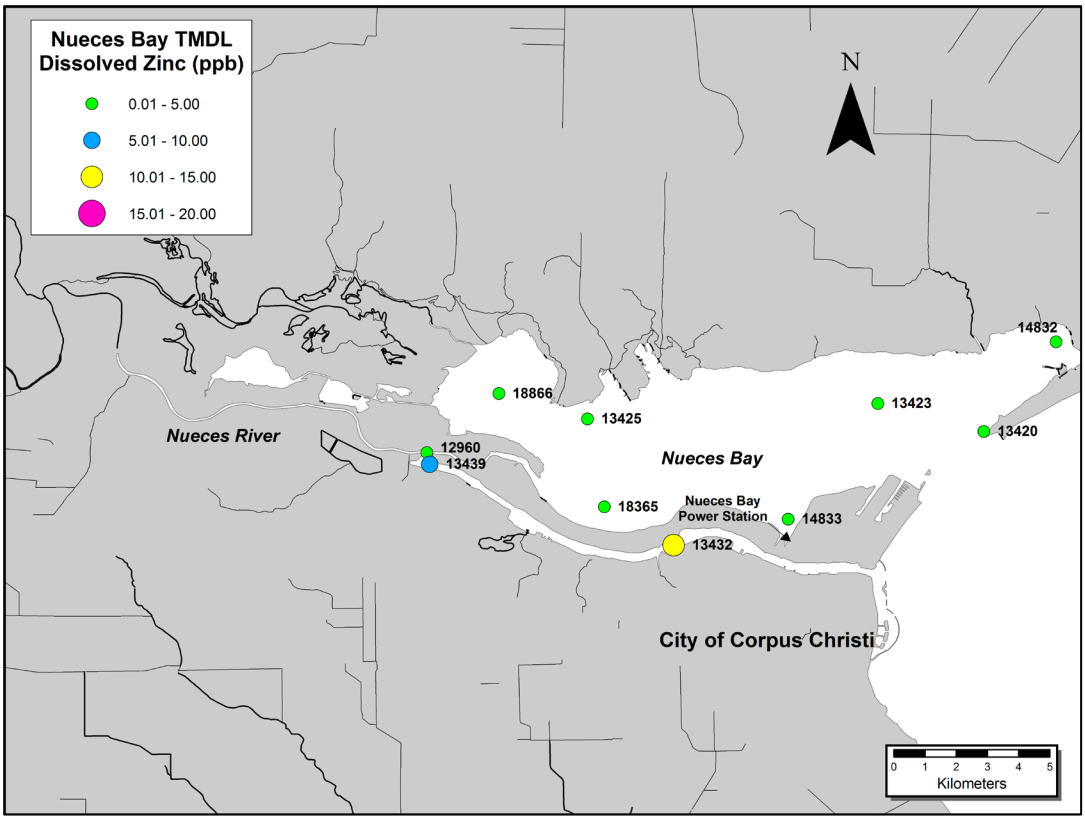


Figure 3.6. Mean dissolved zinc concentrations (ppb) for Year-six sampling.

*Total Zinc*

A complete list of individual total zinc concentrations in water for Year-six, along with descriptive statistics, appears in Chapter 7-Data Tables 7.6.1 and 7.7.1.

Since 2004, individual total zinc concentrations at Nueces Bay stations have exceeded the TCEQ TMDL criterion for total zinc only four times (3.3%) out of 122 samples taken. One exceedance occurred in Year-one at Station 13423 in May 2005 with a concentration of 43.40 ppb. TSS concentrations at Station 13423 in May 2005 were 232.00 mg/L, signifying very turbid conditions and high amounts of re-suspended sediments.

In Year-two, two exceedances occurred during the April 2006 sampling event. Total zinc and TSS concentrations at Station 18866 were 36.30 ppb and 178 mg/L and at Station 18365, they were 46.10 ppb and 205 mg/L, respectively. The fourth exceedance occurred during the February 2011 sampling event at Station 13423 when the total zinc concentration was 32.70 ppb with a corresponding TSS concentration of 255 mg/L.

Overall, the highest mean total zinc concentrations have occurred in the Corpus Christi Inner Harbor segment for all years except Year-one and lowest concentrations occurred in the Nueces River Tidal segment except in Year-four (Table 3.6). Total zinc concentration during Year-six ranged from 1.75 ppb at Station 13423 in Nueces Bay to 20.10 ppb at Station 13423 in the Corpus Christi Inner Harbor (Data Table 7.6.1). Mean total zinc concentrations were highest in the Corpus Christi Inner Harbor during both events in Year-Six (Data Table 7.7.1).

Due to the shallow nature of Nueces Bay and predominate southeast wind direction, the bay is typically turbid and zinc concentrations are affected by weather conditions preceding sample collection. Because of the turbid nature of Nueces Bay, zinc sequestered in the sediment can be re-suspended with higher total zinc levels typically associated with higher water column TSS concentrations ($r^2$ = 0.82). The largest source of variability in zinc concentrations relates to the form of TSS. Specifically, how much of the TSS is phytoplankton or zooplankton (biotic) material and how much is suspended, fine-grained, clay like sediment (abiotic) to which zinc is adsorbed.

While total zinc concentrations in the Corpus Christi Inner Harbor are below the TMDL criteria of 29 ppb, concentrations are still equal and often higher than concentrations from the turbid waters of Nueces Bay. The total depth in the Corpus Christi Inner Harbor is >14 m and TSS and turbidity concentrations are low. These data show zinc is clearly entering the inner harbor from sources other than sediment re-suspension and has no association with TSS concentrations. Consequently, inner harbor stations tend to have higher total zinc, but lower TSS levels compared to the other stations sampled in this study. Figures 3.7 and 3.8 depict individual total zinc concentrations for each Year-six sampling event and Figure 3.9 depicts mean total zinc concentrations for both sampling events in Year-six.

Table 3.6. Total zinc (ppb) descriptive statistics, listed by sampling year and TCEQ segment for all Nueces Bay TMDL stations sampled.

| Year | Segment | Segment Name | n | Min | Max | Mean |
|---|---|---|---|---|---|---|
| 1 | 2101 | Nueces River Tidal | 8 | 1.30 | 8.79 | 4.63 |
| 2 | | | 8 | 0.97 | 17.70 | 3.97 |
| 3 | | | 2 | 2.74 | 5.38 | 4.06 |
| 4 | | | 2 | 2.48 | 5.45 | 3.97 |
| 5 | | | 2 | 3.24 | 4.64 | 3.94 |
| 6 | | | 2 | 1.90 | 2.04 | 1.97 |
| 1 | 2482 | Nueces Bay | 32 | 3.00 | 43.40 | 10.15 |
| 2 | | | 34 | 1.78 | 46.10 | 10.17 |
| 3 | | | 14 | 4.16 | 24.00 | 9.57 |
| 4 | | | 14 | 0.87 | 7.28 | 3.02 |
| 5 | | | 14 | 4.88 | 32.70 | 12.26 |
| 6 | | | 14 | 1.75 | 7.45 | 3.95 |
| 1 | 2484 | Corpus Christi Inner Harbor | 16 | 3.68 | 12.40 | 7.93 |
| 2 | | | 16 | 4.66 | 23.40 | 10.71 |
| 3 | | | 4 | 4.78 | 9.07 | 7.03 |
| 4 | | | 4 | 4.36 | 9.73 | 7.60 |
| 5 | | | 4 | 3.93 | 23.00 | 13.14 |
| 6 | | | 4 | 9.21 | 20.10 | 15.08 |

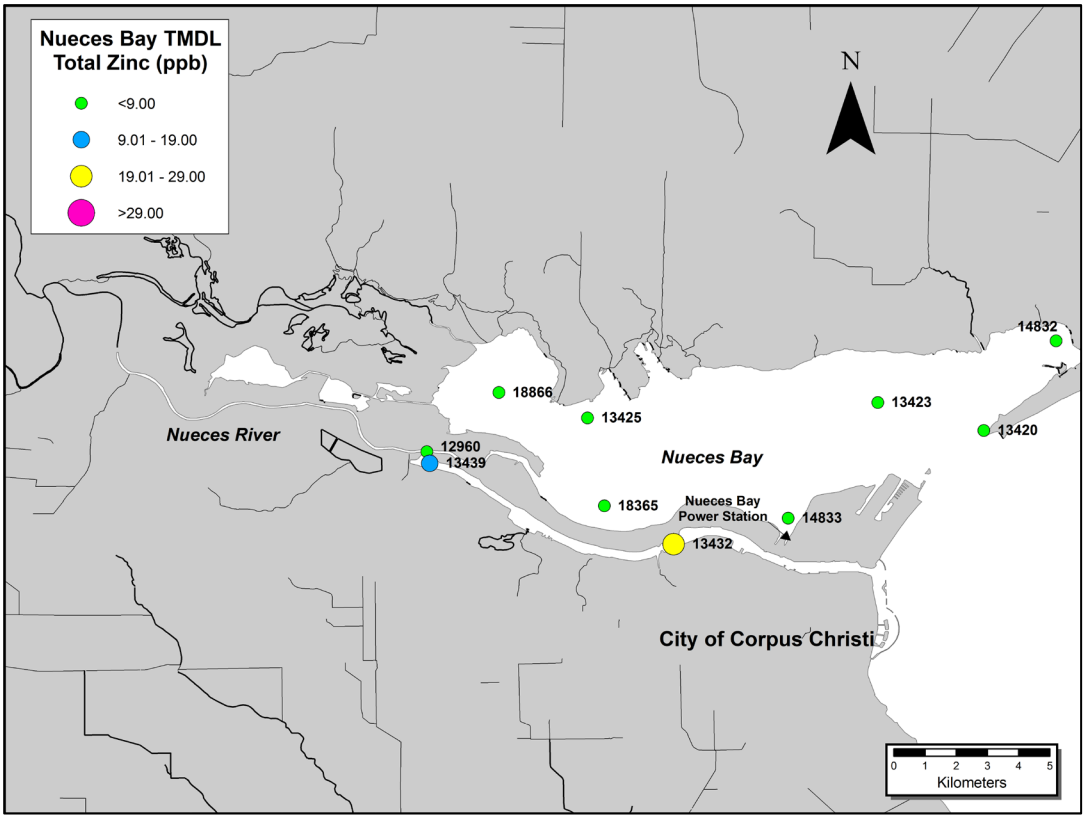


Figure 3.7. Total zinc concentrations (ppb) for Year-six November 2011 sampling.

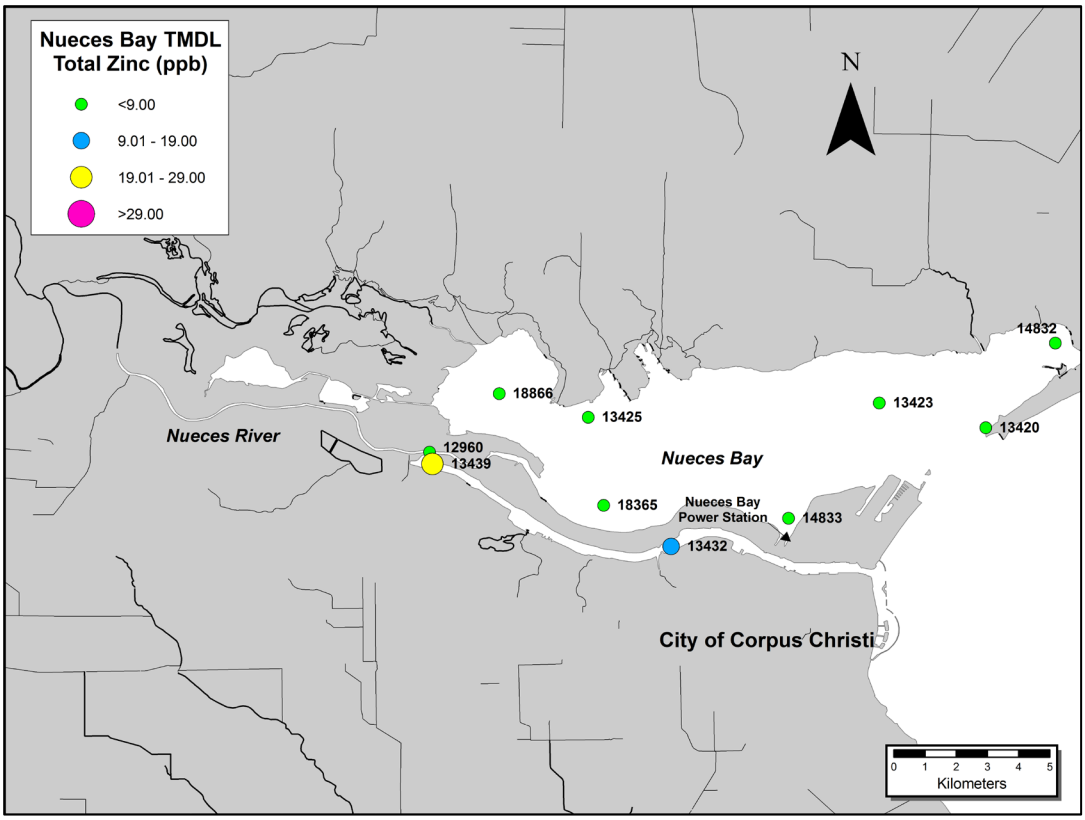


Figure 3.8. Total zinc concentrations (ppb) for Year-six May/June 2012 sampling.

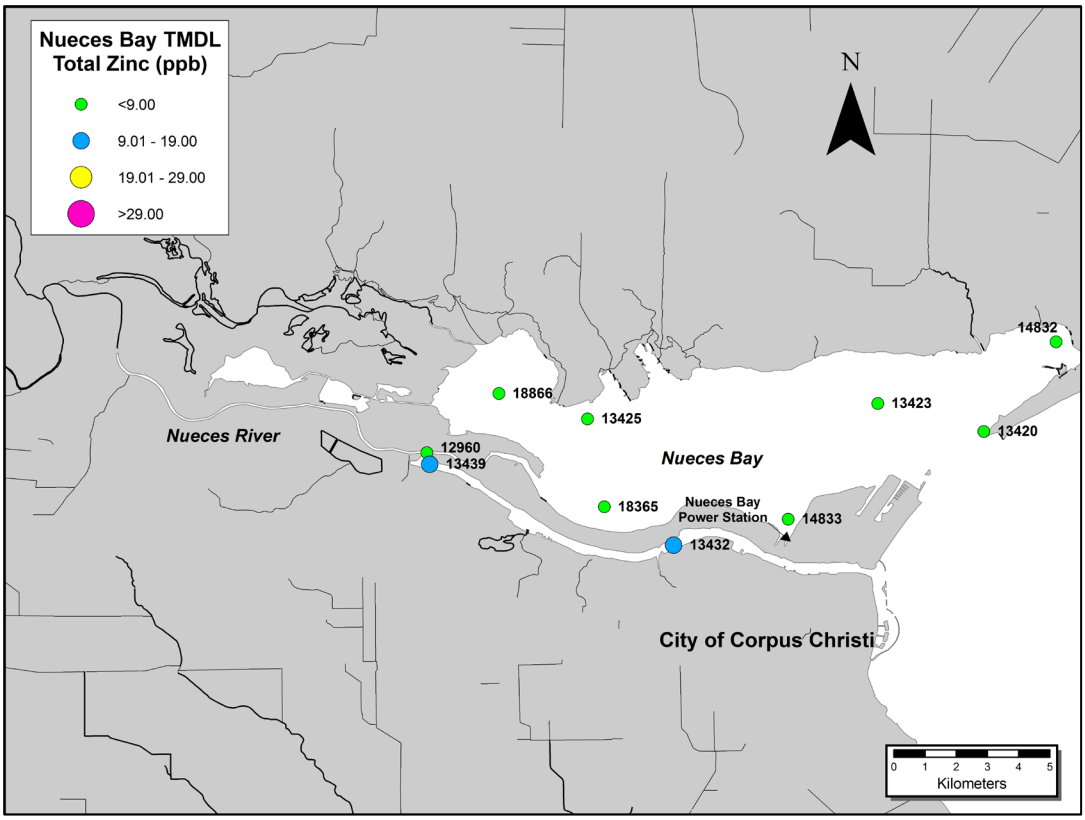


Figure 3.9. Mean total zinc concentrations (ppb) for Year-six sampling.

## 4.0 SEDIMENT MONITORING

Two events in Year-one and the first event of Year-two, the upper (2 to <5.0 cm) sediment layer was collected along with the lower (>5 to 9 cm) to determine if increased zinc concentrations could be attributed to legacy deposition. Zinc data was log transformed and subjected to a One-Way ANOVA ($p \leq 0.05$) to compare mean concentrations of upper and lower sediment samples. As previously stated, data showed higher concentrations at lower depths, but data analysis showed no statistically significant difference between sampling depths (all Stations $p = 0.62$, Corpus Christi Inner Harbor Stations $p = 0.89$, Nueces River Tidal Stations $p = 0.70$, and Nueces Bay Stations $p = 0.70$). Since no statistically significant difference existed, we discontinued this portion of the sampling protocol. A complete list of individual sediment characteristics and zinc concentrations, along with descriptive statistics for Year-six, appears in Chapter 7-Data Tables 7.8.1 and 7.9.1 and 7.9.2.

### 4.1 TCEQ Sediment Quality Screening Levels

Currently, there are no regulatory criteria for the majority of sediment contaminants. However, TCEQ does employ sediment-screening levels for metal and organic substances proven to have adverse ecological effects. Comparison of sample contaminant concentrations are compared to screening levels developed by TCEQs Ecological Assessment Program and based on guidelines developed by the National Oceanic and Atmospheric Administration (NOAA) through its National Status and Trends Program. Currently the established TCEQ screening level for zinc in sediment is 410 mg/kg, which is also the Effects Range Median (ERM) as defined by NOAA. A concern for aquatic life exists if more than 20 percent of the contaminant samples exceed the zinc screening level of 410 mg/kg.

NOAA sediment guidelines are derived from a multitude of nationwide datasets of sediment contamination and corresponding biological effects compiled by Long et al. (1995). Based on comparable datasets, but calculated differently (Long et al. 1995; MacDonald et al. 1996), the classification of these levels and their corresponding increasing effect thresholds applies to the following terminology:

| | | |
|---|---|---|
| Threshold Effects Level | TEL (124 mg/kg) | *Rare* adverse effects observed |
| Effects Range Low | ERL (150 mg/kg) | Effects begin to occur in sensitive species |
| Probable Effects Level | PEL (271 mg/kg) | *Frequent* adverse effects observed |
| Effects Range-Median | ERM (410 mg/kg) | Median concentration of compiled toxic data |

The only effects level TCEQ validates on a regulatory basis for zinc in sediment is the Effects Range-Median. While concentrations above the Threshold Effects Level (TEL) do not support TCEQ in identifying concerns, they provide a baseline reference indicating when concentrations have changed. Depending on which of the four effects level is used, a wide range of interpretations is possible. Not considered regulatory criteria or standards, these screening levels and guidelines serve as a non-regulatory interpretive aid for sediment data.

## 4.2 Sediment Characteristics

Total organic carbon (TOC) provides a relative measure of organic matter contained in sediments and is the sum of particulate organic carbon and dissolved organic carbon. Decaying detrital particulate organic material not only serves as a site for bacterial activity, but also provides binding sites for both metal and organic contaminants (Simpson et al. 2005).

Typically, elevated TOC concentrations are associated with sediments high in Silt-Clay content. Generally, TOC values <20,000 mg/kg indicate low enrichment, >20,000 mg/kg but <50,000 mg/kg indicates moderate enrichment, and >50,000 mg/kg indicates high enrichment.

Most Nueces Bay stations have TOC concentrations indicative of low enrichment. In Year-six, TOC values in Nueces Bay ranged from 2430 mg/kg at Station 14833 to 16,900 mg/kg at Station 13420. In the Nueces River Tidal segment, the range was from 14,700 to 33,900 mg/kg at Station 12960. While in the Corpus Christi Inner Harbor TOC ranged from 6740 mg/kg at Station 13432 to 18,000 mg/kg at Station 13439 (Table 4.1; Data Table 7.8.1 and 7.9.1). Mean concentrations for all stations sampled within the three segments have been <20,000 mg/kg, except Station 12960 in the Nueces River Tidal segment which was 20900 mg/kg in Year-four and 24,300 in Year-Six.

TOC concentrations and spatial distribution patterns were similar during all years, with highest mean concentrations in Nueces River Tidal, followed by Corpus Christi Inner Harbor, and Nueces Bay, respectively (Table 4.1). Figures 4.1 and 4.2 depict individual TOC concentrations in the surficial sediment layer for each Year-six sampling event and Figure 4.3 depicts mean TOC values for both sampling events in Year-six.

Table 4.1. Total Organic Carbon (mg/kg) descriptive statistics, listed by sampling year and TCEQ segment for all Nueces Bay TMDL stations sampled.

| Year | Segment | Segment Name | n | Min | Max | Mean |
|---|---|---|---|---|---|---|
| 1 | 2101 | Nueces River Tidal | 4 | 6500 | 12000 | 8075 |
| 2 | | | 4 | 5930 | 25200 | 15683 |
| 3 | | | 2 | 19100 | 20400 | 19750 |
| 4 | | | 2 | 20100 | 21700 | 20900 |
| 5 | | | 2 | 16000 | 19600 | 17800 |
| 6 | | | 2 | 14700 | 33900 | 24300 |
| 1 | 2482 | Nueces Bay | 16 | 270 | 10000 | 4519 |
| 2 | | | 17 | 1320 | 10400 | 5554 |
| 3 | | | 14 | 3670 | 14700 | 8003 |
| 4 | | | 14 | 1710 | 23400 | 8206 |
| 5 | | | 14 | 357 | 7400 | 4251 |
| 6 | | | 14 | 2430 | 16900 | 5924 |
| 1 | 2484 | Corpus Christi Inner Harbor | 8 | 1500 | 12000 | 7850 |
| 2 | | | 8 | 2990 | 17400 | 11275 |
| 3 | | | 4 | 13100 | 22900 | 16950 |
| 4 | | | 4 | 4980 | 20000 | 12545 |
| 5 | | | 4 | 5350 | 10800 | 8208 |
| 6 | | | 4 | 6740 | 18000 | 9968 |

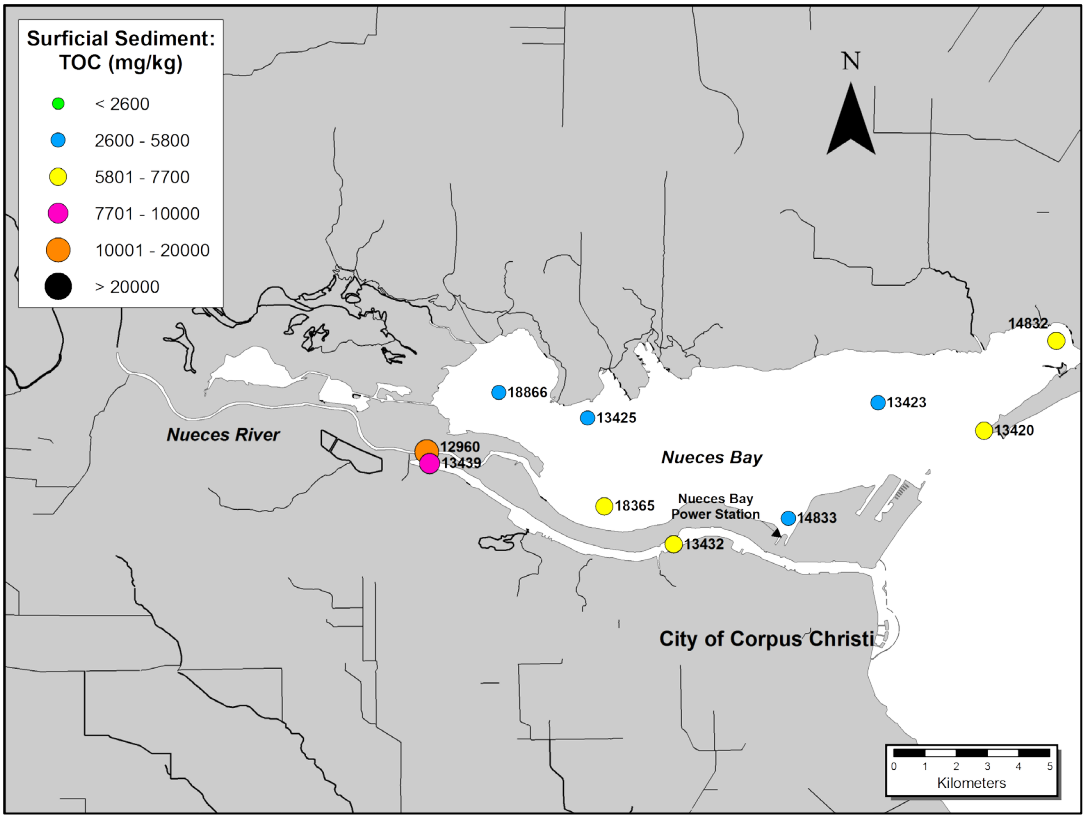


Figure 4.1. TOC concentrations (mg/kg) for Year-six November 2011 sampling.

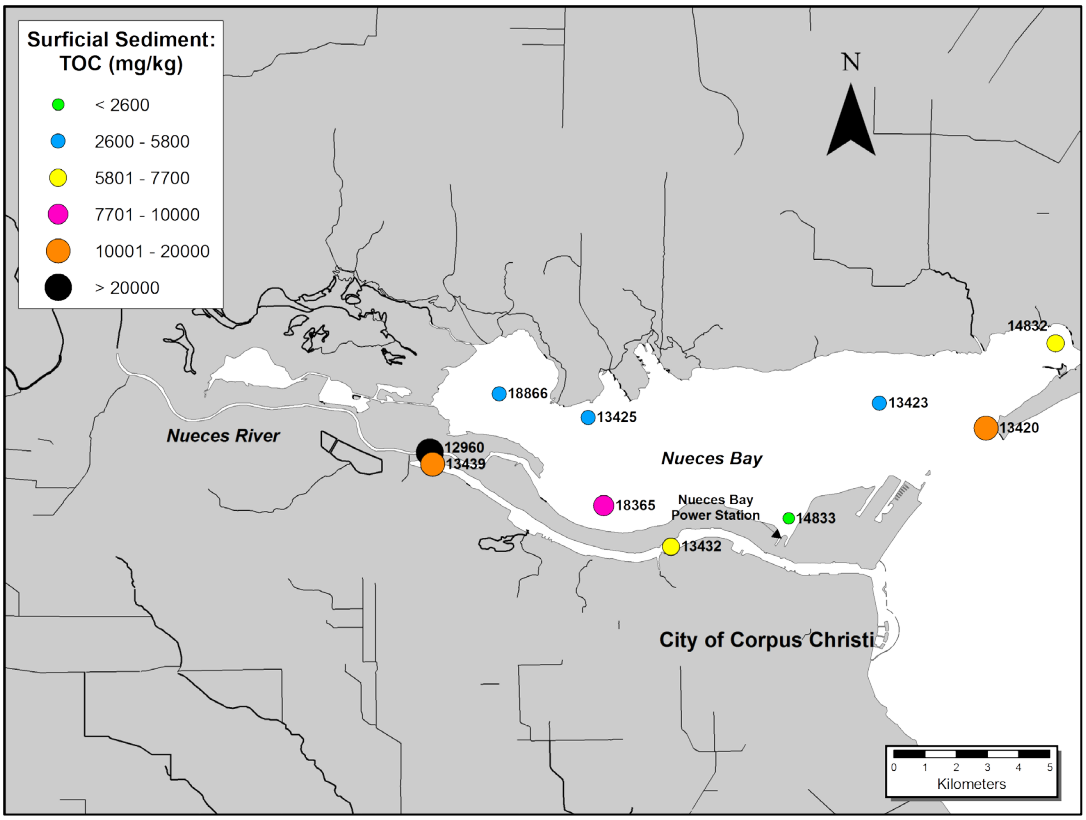


Figure 4.2. TOC concentrations (mg/kg) for Year-six May/June 2012 sampling.

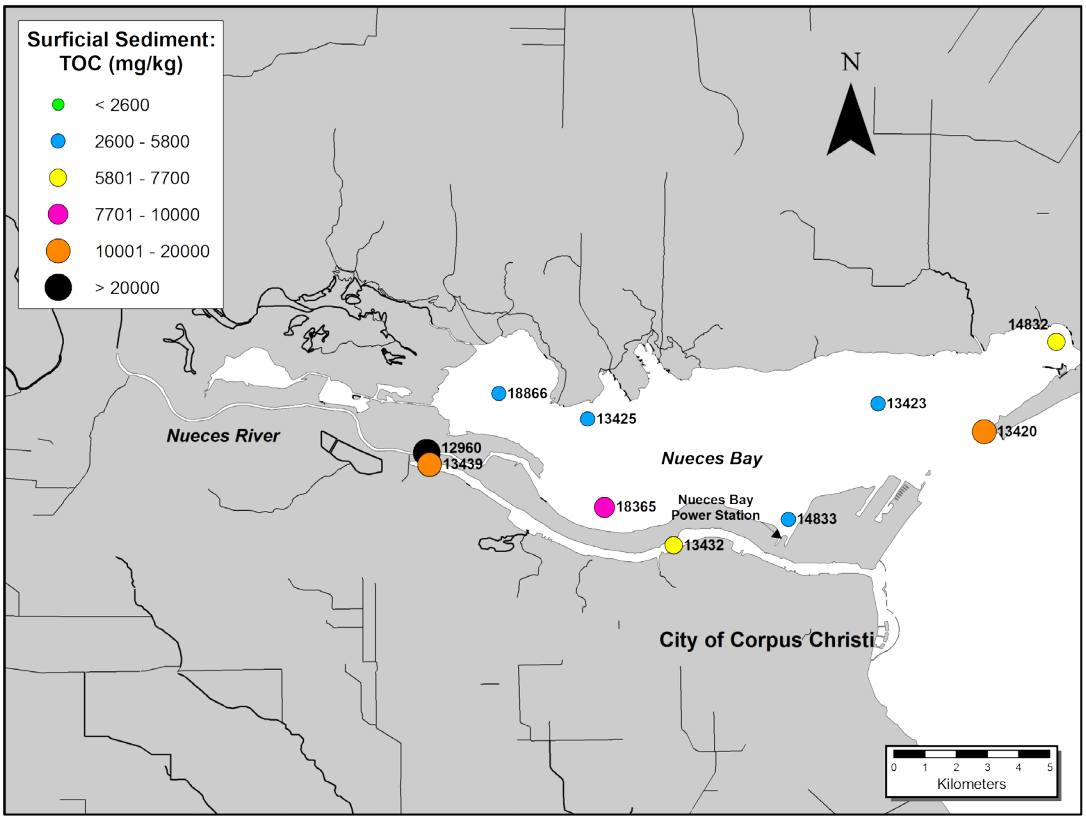


Figure 4.3. Mean TOC concentrations (mg/kg) for Year-six sampling.

The percentage of mud (Silt-Clay) within sediments is an important factor in assessing estuarine conditions. Typically, as sediment grain size decreases, the risk of contamination increases due to the strong affinity metals have to adsorb to Silt-Clay particles. As stated previously, elevated TOC concentrations are typically associated with sediment high in Silt-Clay and the spatial distribution pattern of Silt-Clay was the same as TOC, with highest concentrations in the Nueces River Tidal, followed by the Corpus Christi Inner Harbor, and Nueces Bay, respectively (Table 4.2).

During Year-six, Silt-Clay values in the surficial sediment layer ranged from 34.50% at Station 18866 in Nueces Bay to 96.50% at Station 12960 in the Nueces River Tidal segment (Table 4.2; Data Table 7.8.1). Silt-Clay values in the Corpus Christi Inner Harbor ranged from 42.20% to 85.80% at Station 13432 and Station 13439, respectively (Data Table 7.8.1). Mean Silt-Clay concentrations were highest in the Nueces River Tidal segment for both sampling events of Year-six (Data Table 7.9.2). Figures 4.4 and 4.5 depict individual Silt-Clay values in the surficial sediment layer for Year-six sampling events and Figure 4.6 depicts mean Silt-Clay values in the surficial sediment layer for both Year-six sampling events.

Table 4.2. Silt-Clay (%) descriptive statistics, listed by sampling year and TCEQ segment for all Nueces Bay TMDL stations sampled.

| Year | Segment | Segment Name | n | Min | Max | Mean |
|---|---|---|---|---|---|---|
| 1 | 2101 | Nueces River Tidal | 4 | 62.34 | 95.09 | 76.45 |
| 2 | | | 4 | 45.94 | 78.13 | 65.43 |
| 3 | | | 2 | 68.46 | 96.08 | 82.27 |
| 4 | | | 2 | 83.29 | 94.44 | 88.87 |
| 5 | | | 2 | 94.50 | 98.30 | 96.40 |
| 6 | | | 2 | 96.40 | 96.50 | 96.45 |
| 1 | 2482 | Nueces Bay | 16 | 4.61 | 93.71 | 41.98 |
| 2 | | | 17 | 2.53 | 88.36 | 37.79 |
| 3 | | | 14 | 8.11 | 70.11 | 41.85 |
| 4 | | | 14 | 5.86 | 74.43 | 41.95 |
| 5 | | | 14 | 7.12 | 96.00 | 52.58 |
| 6 | | | 14 | 34.50 | 94.70 | 59.12 |
| 1 | 2484 | Corpus Christi Inner Harbor | 8 | 12.80 | 87.49 | 57.03 |
| 2 | | | 8 | 19.44 | 90.82 | 59.24 |
| 3 | | | 4 | 59.28 | 88.46 | 68.54 |
| 4 | | | 4 | 39.63 | 74.13 | 59.52 |
| 5 | | | 4 | 35.90 | 88.10 | 61.43 |
| 6 | | | 4 | 42.20 | 85.80 | 60.15 |

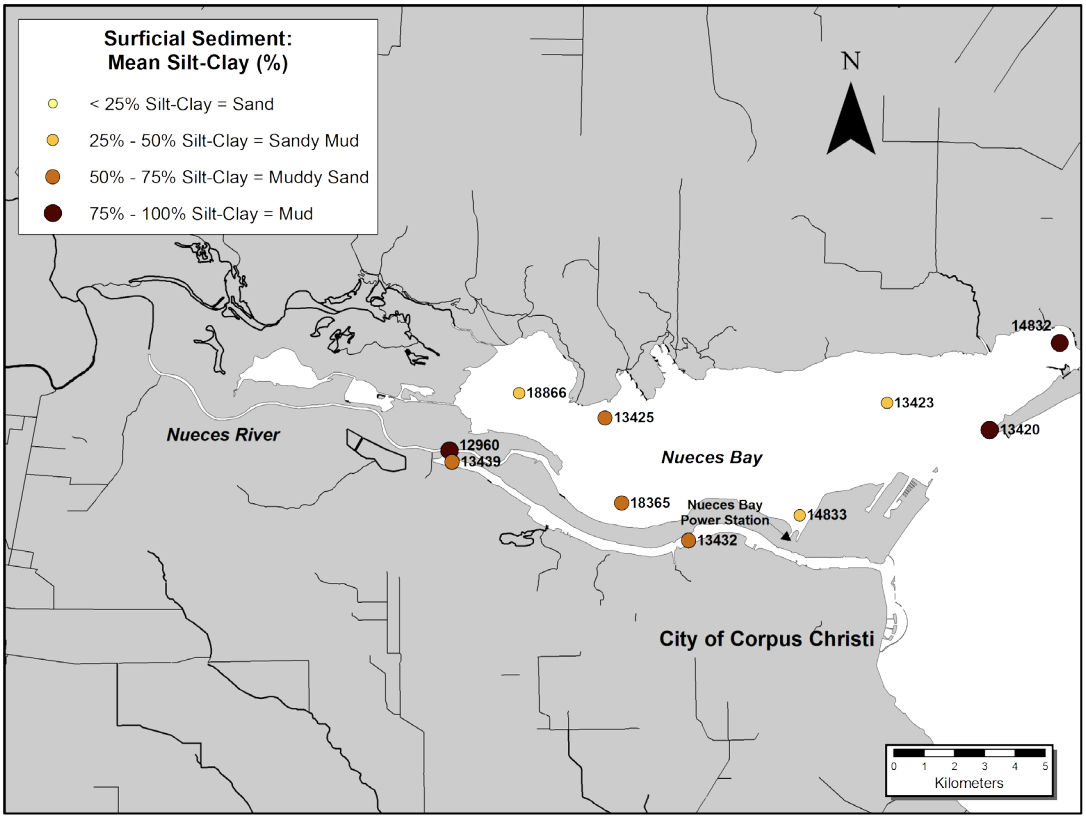


Figure 4.4. Silt-Clay proportions (%) for Year-six November 2011 sampling.

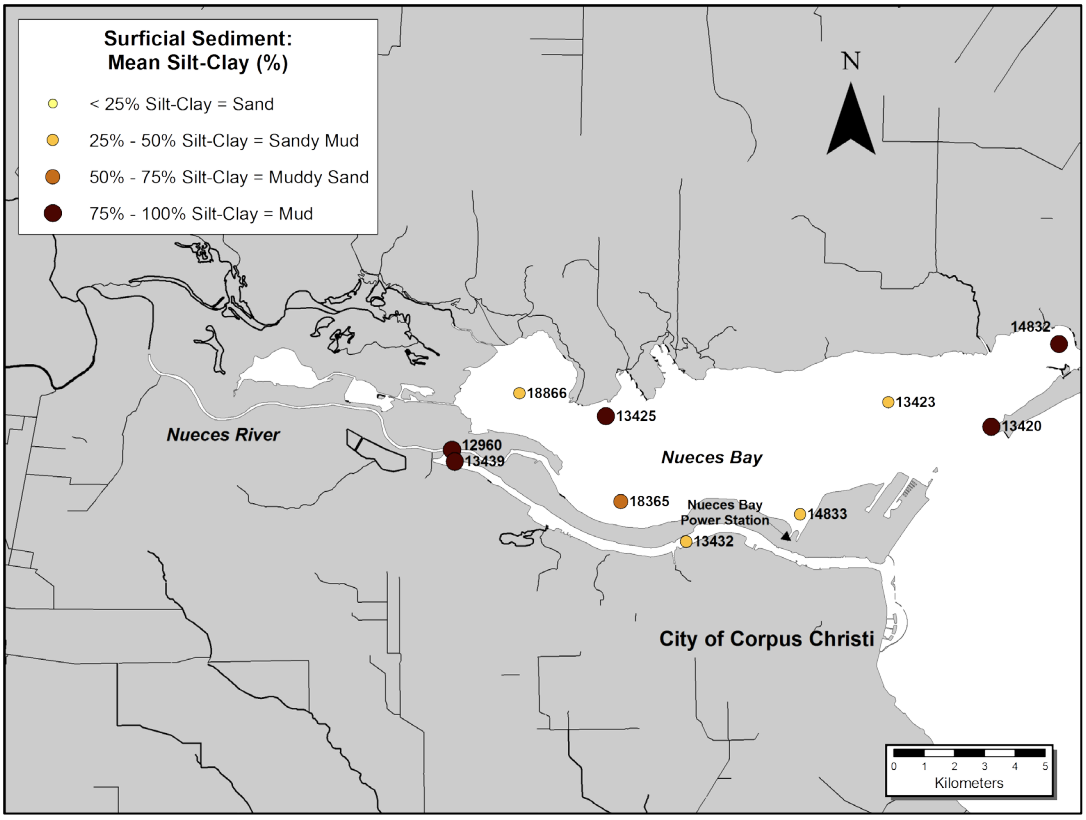


Figure 4.5. Silt-Clay proportions (%) for Year-six May/June 2012 sampling.

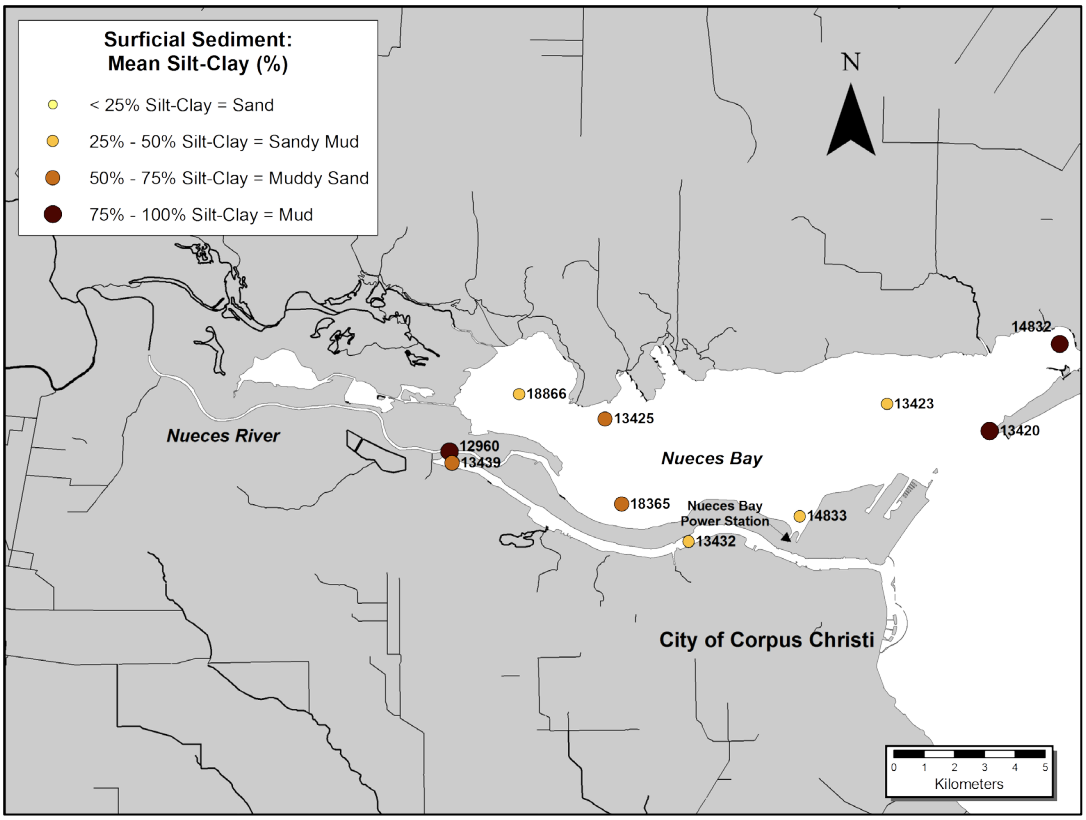


Figure 4.6. Mean Silt-Clay proportions (%) for Year-six sampling.

## 4.3 Zinc in Sediment

In Year-one, sediment zinc concentrations ranged from 8.00 mg/kg at Station 13421 in Nueces Bay to 485 mg/kg at Station 12961 in the Nueces River Tidal segment. Mean sediment zinc concentrations were highest in the Nueces River Tidal segment followed by the Corpus Christi Inner Harbor and Nueces Bay (Table 4.3). The elevated sediment zinc concentration in September 2004 at the Nueces River Tidal Station 12961was likely due to metal debris recovered from the sampling location. Sediment grabs at 12961 took place downstream of the I-37 Bridge and were adjacent to the area where Corpus Christi Police discovered three submerged cars in July 2005. This large amount of metal may have contributed to the high zinc concentrations recorded. The second event in Year-one took place in May 2005 and sampled upstream of the I-37 Bridge (approximately 300 feet from the September site) and yielded a concentration of 36.90 mg/kg.

For Year-two, sediment zinc concentrations ranged from 13.50 mg/kg at Station 13421 in Nueces Bay to 221.4 mg/kg at Station 13432 in the Corpus Christi Inner Harbor segment and mean concentrations were highest in the Inner Harbor followed by the Nueces River Tidal and Nueces Bay segments, respectively (Table 4.3). Two sampling events in Year-two at Station 12961 yielded sediment zinc concentrations of 34.70 mg/kg and 41.60 mg/kg, respectively. While no longer sampled as part of the current program, the variability in zinc

concentrations at Station 12961 shows the patchiness of contaminants often encountered in an urban watershed. The same spatial distribution pattern for mean sediment zinc concentrations occurred in Year-three and concentrations ranged from 16.20 mg/kg at Station 14833 in Nueces Bay to 201.40 mg/kg at Station 13439 in the Corpus Christi Inner Harbor (Table 4.3). In Year-four the Nueces river Tidal Segment had the highest mean sediment zinc concentrations and zinc concentrations ranged from 12.10 mg/kg at Station 14833 in Nueces Bay to 185.00 mg/kg at Station 13439 in the Corpus Christi Inner Harbor (Table 4.3).

Year-five zinc concentrations in the surficial sediment layer were variable within all three segments and ranged from 13.20 mg/kg at Station 14833 in Nueces Bay to 176.00 mg/kg at Station 13439 in the Corpus Christi Inner Harbor segment. Sediment zinc concentrations in the Corpus Christi Inner Harbor ranged from 114.00 to 176.00 mg/kg and mean concentrations were slightly higher in Year-five than Year-four. Year-five mean sediment zinc concentrations in Nueces Bay were the lowest values recorded for the six-year sampling period (Table 4.3).

Year-six mean zinc concentrations increased from year-five within all three segments and ranged from 25.00 mg/kg at Station 18866 in Nueces Bay to 279.00 mg/kg at Station 13439 in the Corpus Christi Inner Harbor segment. Sediment zinc concentrations in Nueces Bay were the lowest values recorded for the five-year sampling period and ranged from 13.20 to 69.00 mg/kg (Table 4.3; Data Tables 7.8.1 and 7.9.1). Mean zinc in sediment concentrations over the course of the six year study show highest concentrations are found in the Corpus Christi Inner Harbor segment with 154.91 mg/kg (n=32), followed by the Nueces River Tidal segment with 122.52 mg/kg (n=16), and the Nueces Bay segment with 47.22 mg/kg (n=89).

Except for one exceedance at Station 12961 in Year-one, all sediment zinc concentrations for this project remain below the ERM screening value of 410 mg/kg and except for Station 13439, with concentration of 279 mg/kg in Year-six, all values have been below the PEL value of 271 mg/kg. Values that have exceeded the lowest thresholds of the TEL (124 mg/kg) are in the Corpus Christi Inner Harbor segment and at Station 12960 in the Nueces River Tidal segment, which is adjacent to Station 13439 located in the Viola Turning Basin at the end of the Corpus Christi Inner Harbor channel (See Fig 2.1). Figures 4.7 and 4.8 depict individual zinc concentrations in the surficial sediment layer for each Year-six sampling event and Figure 4.9 depicts mean zinc concentrations in the surficial sediment layer for both sampling events in Year-six.

Table 4.3. Zinc in surficial sediment (mg/kg) descriptive statistics, listed by sampling year and TCEQ segment for all Nueces Bay TMDL stations sampled.

| Year | Segment | Segment Name | n | Min | Max | Mean |
|---|---|---|---|---|---|---|
| 1 | 2101 | Nueces River Tidal | 4 | 36.90 | 485.00 | 180.20 |
| 2 | | | 4 | 34.70 | 161.40 | 70.78 |
| 3 | | | 2 | 19.60 | 106.80 | 63.20 |
| 4 | | | 2 | 151.00 | 166.00 | 158.50 |
| 5 | | | 2 | 110.00 | 121.00 | 115.50 |
| 6 | | | 2 | 130.00 | 152.00 | 141.00 |
| 1 | 2482 | Nueces Bay | 16 | 8.00 | 115.80 | 55.29 |
| 2 | | | 17 | 13.50 | 120.80 | 53.68 |
| 3 | | | 14 | 16.20 | 75.90 | 42.61 |
| 4 | | | 14 | 12.10 | 92.20 | 45.81 |
| 5 | | | 14 | 13.20 | 69.00 | 37.92 |
| 6 | | | 14 | 25.00 | 76.80 | 45.48 |
| 1 | 2484 | Corpus Christi Inner Harbor | 8 | 63.40 | 164.80 | 129.78 |
| 2 | | | 8 | 51.10 | 221.40 | 166.01 |
| 3 | | | 4 | 158.30 | 201.50 | 183.55 |
| 4 | | | 4 | 72.70 | 185.00 | 134.68 |
| 5 | | | 4 | 114.00 | 176.00 | 143.50 |
| 6 | | | 4 | 126.00 | 279.00 | 186.00 |

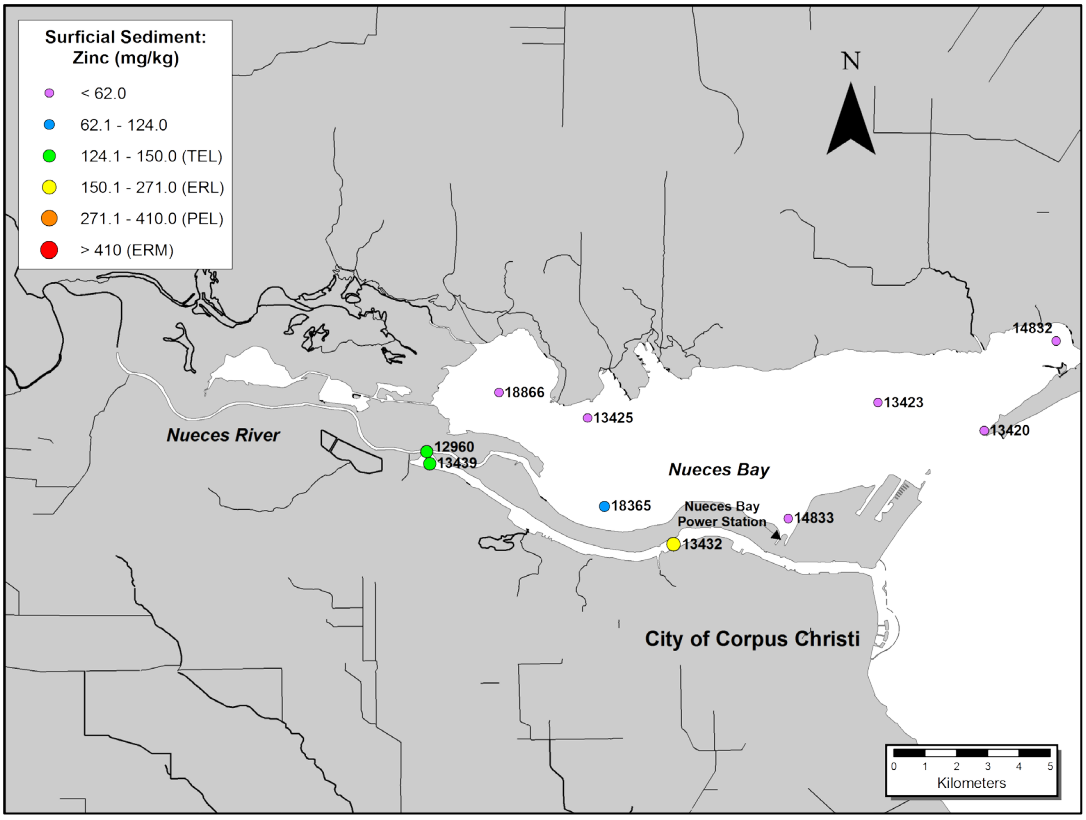


Figure 4.7. Zinc sediment concentrations (mg/kg) for Year-six November 2011 sampling.

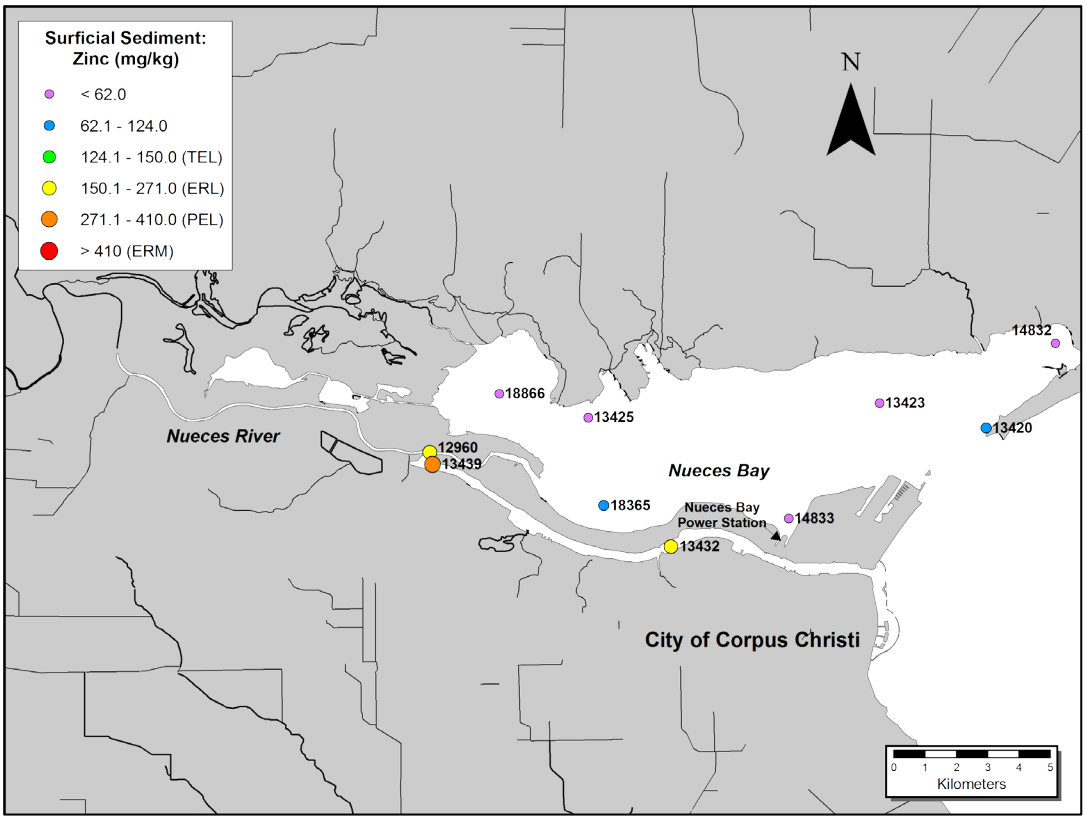


Figure 4.8. Zinc sediment concentrations (mg/kg) for Year-six May/June 2012 sampling.

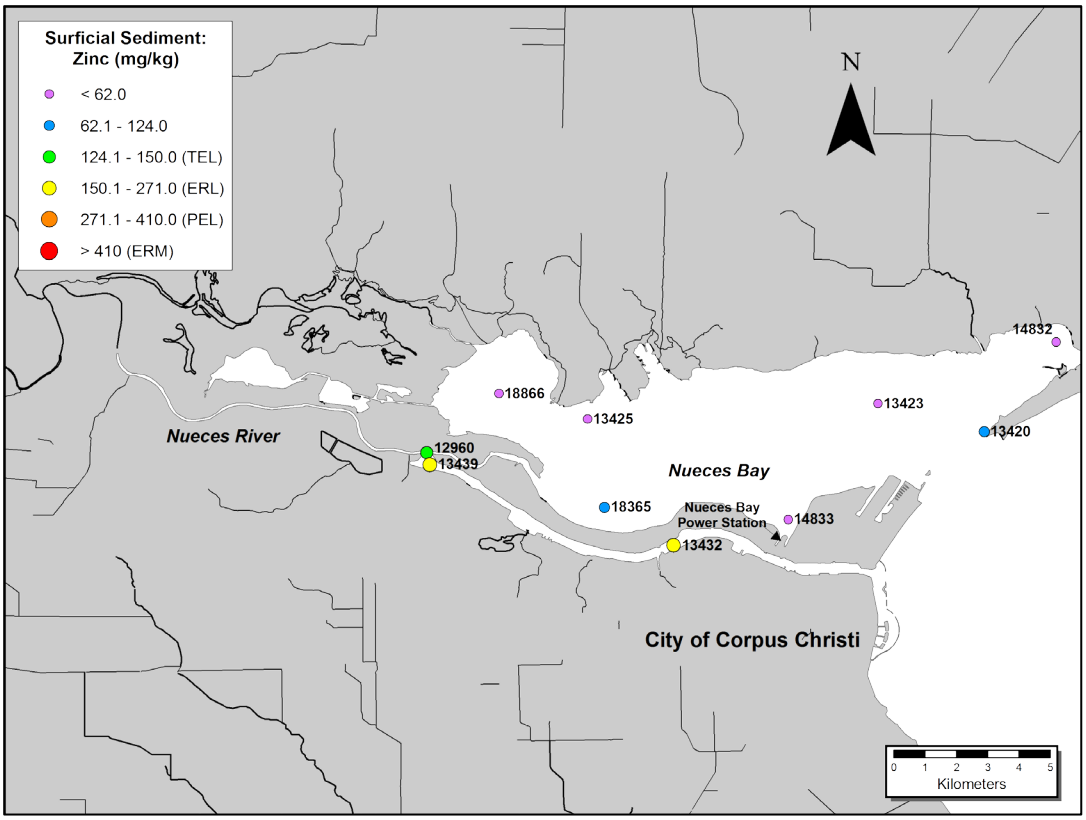


Figure 4.9. Mean zinc sediment concentrations (mg/kg) for Year-six sampling.

## 5.0 TISSUE SAMPLING

Oysters contain naturally high levels of zinc compared to other food items, such as beef, and they are highly efficient filter feeders and effectively accumulate and sequester zinc and other metals in the environment, often to extremely high concentrations. In general, accumulation of zinc and other trace metals into marine organisms is by the direct uptake of contaminated water, sediment, or through trophic transfer (USEPA 2004; Wang et al 2011). Once an organism absorbs a contaminant, the concentration in animal tissue can increase significantly through subsequent contamination (i.e. bioaccumulation). This same bioaccumulation pattern also happens when humans eat contaminated tissue thereby effecting human health.

### 5.1 TCEQ Tissue Screening Levels

As stated in TCEQ guidance documentation (TCEQ 2010), the DSHS is the regulatory authority that issues fish and shellfish consumption advisories and aquatic life closures for specific contaminants or classes of chemicals in Texas surface waters. If the health assessment comparison value of <700 mg/kg has not been met in a segment, DSHS issues an advisory and warns the public that consumption of aquatic organisms from the area may be toxic to human health. As these advisories constitute a violation of Texas Surface Water Quality Standards, TCEQ endeavors to ensure that not only the TCEQ segment containing the DSHS sampling site, but also any appropriate connected segments are listed for the contaminant. TCEQ utilizes DSHS Risk Characterization data and advisory sampling information along with TCEQ water body information to determine which segments are impaired.

### 5.2 Zinc in Oyster Tissue

As previously stated, as TCEQ does not have the administrative and assessment authority for the National Shellfish Sanitation Program for Texas, zinc in oyster tissue data presented here is for informational and not assessment purposes. A complete list of individual zinc in oyster tissue concentrations for Year-six appears in Chapter 7-Data Table 7.10.1 and 7.10.2.

During Year-three, multiple attempts to collect oysters occurred during the sampling year. However, high sediment deposition during flooding events on the Nueces River resulted in layers of silt covering many oyster beds in Nueces Bay. This silt and extreme fluctuations in salinity resulted in no viable (alive or market size) oysters available for collection.

In Year-four, an attempt to collect oysters occurred during the January 2010 event. Oysters were found on some reefs but were all <1 inch in size and thereby did meet the required size for collection and analysis. However, a second event in August 2010 yielded adequate size oysters and sampling took place at three of the sampling stations described in the QAPP and at two other stations outside the TCEQ 1250 ft. station site radius of established stations. All sampling locations were geo-located using a Garmin MAP76 GPS.

While the oysters collected during the August 2010 event were market size (2 to 3 inches) when the oysters were being prepared (removed from shell) for analysis at GEL laboratories it was found that the actual oyster tissue was small despite the size of the shell and tissue growth appeared stunted. Rather than yielding the necessary >200 g (weight limit established by DSHS during Risk Characterization studies) of material per sample the typical sample wet weight was approximately 30 g.

Oysters were inspected for possible disease, such as *Perkinsus marinus*, a prevalent oyster pathogen known to occur in Nueces Bay that causes proteolytic degradation of oyster tissues. No visible signs of disease existed and the oysters were characterized as healthy in appearance but extremely small. A possible reason for this small tissue to shell size ratio may have been related to stressful environmental conditions due to sediment deposition from flooding and salinity fluctuations (1.94 to 37.5 PSU) over the last several years, but more investigation is required.

As data from this oyster tissue analysis will not be used for assessment purposes, the decision was made to analyze the oysters regardless of the weight to gather zinc in oyster tissue concentration data. However, the data and station locations were not submitted into TCEQ's Surface Water Quality Monitoring Information System (SWQMIS) database. Tissue analysis revealed high levels of zinc ranging from 675 mg/kg to 3340 mg/kg. Highest mean levels were at Station 21057 in the eastern portion of Nueces Bay and at Station 18866 in the western portion of Nueces Bay. Lowest zinc concentration levels were in the northeastern portion of the bay at Station 21058 (Table 5.1). Zinc concentrations during this study were higher than past DSHS characterization studies where DSHS values ranged from 479 mg/kg to 1405 mg/kg (DSHS 2003; DSHS 2005), but as previously stated the oyster sizes were not representative of that typically sold for human consumption.

One sampling event took place in Year-five on 10 August 2011 for oysters. Mean salinity was greater than Year-four (22.9 PSU vs. 42.4 PSU), and expectations of finding live oysters was low. The individual oysters collected during this event were the largest and healthiest collected thus far for this project. However, the total number of oysters collected was still low with the total weights of the five samples collected at each station <200 g.

The laboratory performing the analysis for this project only required <10 g of tissue material for analysis, so an inquiry was made to DSHS for a clarification on the amount of sample material needed. Results of this inquiry revealed that the >200 g requirement was established based on DSHS analyzing for multiple parameters during their investigations of Nueces Bay. Therefore the QAPP for this project was amended to change the sample amount of oysters for analysis from >200 g to >15 g per composite sample. Combined sample weights ranged from 48.7 g to 108.7 g for Year-five.

During Year-five, zinc in oyster tissue ranged from 293 mg/kg to 3340 mg/kg (Table 5.1). Highest mean levels were at Station 13425 in the western portion of Nueces Bay near Whites Point. Lowest concentration levels observed were in the northeastern portion of the

bay at Station 21058 (Table 5.1). Zinc oyster tissue levels continued to exceed the HAC value of 700 mg/kg but overall mean concentrations declined from Year-four.

Two sampling events occurred in Year-six with zinc in oyster tissue ranging from 367 mg/kg to 3340 mg/kg (Table 5.1; Data Table 7.10.1 and Data Table 7.10.2). Highest mean levels were at Station 21057 in the eastern portion of Nueces Bay. Lowest concentration levels observed were in the northeastern portion of the bay at Station 21058 (Table 5.1 and Figs. 5.1 through 5.3).

Zinc oyster tissue levels continued to exceed the HAC value of 700 mg/kg and except for a 13.8% increase in mean concentrations recorded at Station 21058, overall mean concentrations continue to decline with each year. Mean values for all samples analyzed in Year-four was 2107 mg/kg (n=25), for Year-five 1394 mg/kg (n=25), and in Year-six mean concentrations were 1085 mg/kg (n=50). This data continues to be presented for informational purposes and will not be used in the DSHS assessment process. Data collection for zinc in oyster tissue will continue in Year-seven since the need to monitor concentrations in oyster tissue still exist.

Table 5.1. Zinc in oyster tissue concentrations (mg/kg) descriptive statistics and % change in mean concentrations from previous year, listed by sampling year for all Nueces Bay TMDL stations sampled. No samples collected during Year-three.

| Year | Segment | Segment Name | TCEQ ID | n | Min | Max | Mean | % change |
|---|---|---|---|---|---|---|---|---|
| 3 | 2482 | Nueces Bay | 18866 | - | - | - | - | |
| | | | 13425 | - | - | - | - | |
| | | | 21057 | - | - | - | - | |
| | | | 21058 | - | - | - | - | |
| | | | 21059 | - | - | - | - | |
| 4 | 2482 | Nueces Bay | 18866 | 5 | 675 | 3310 | 2467 | |
| | | | 13425 | 5 | 1250 | 3000 | 2000 | |
| | | | 21057 | 5 | 2280 | 3340 | 2674 | |
| | | | 21058 | 5 | 1360 | 1930 | 1594 | |
| | | | 21059 | 5 | 821 | 2470 | 1802 | |
| 5 | 2482 | Nueces Bay | 18866 | 5 | 1060 | 2810 | 1710 | -30.7 |
| | | | 13425 | 5 | 1140 | 2550 | 1950 | -2.5 |
| | | | 21057 | 5 | 957 | 2150 | 1629 | -39.1 |
| | | | 21058 | 5 | 293 | 1140 | 732 | -54.1 |
| | | | 21059 | 5 | 492 | 1880 | 947 | -47.5 |
| 6 | 2482 | Nueces Bay | 18866 | 10 | 367 | 1720 | 857 | -49.9 |
| | | | 13425 | 10 | 652 | 3340 | 1245 | -36.2 |
| | | | 21057 | 10 | 858 | 3050 | 1562 | -4.1 |
| | | | 21058 | 10 | 435 | 1200 | 833 | +13.8 |
| | | | 21059 | 10 | 545 | 1350 | 930 | -1.8 |

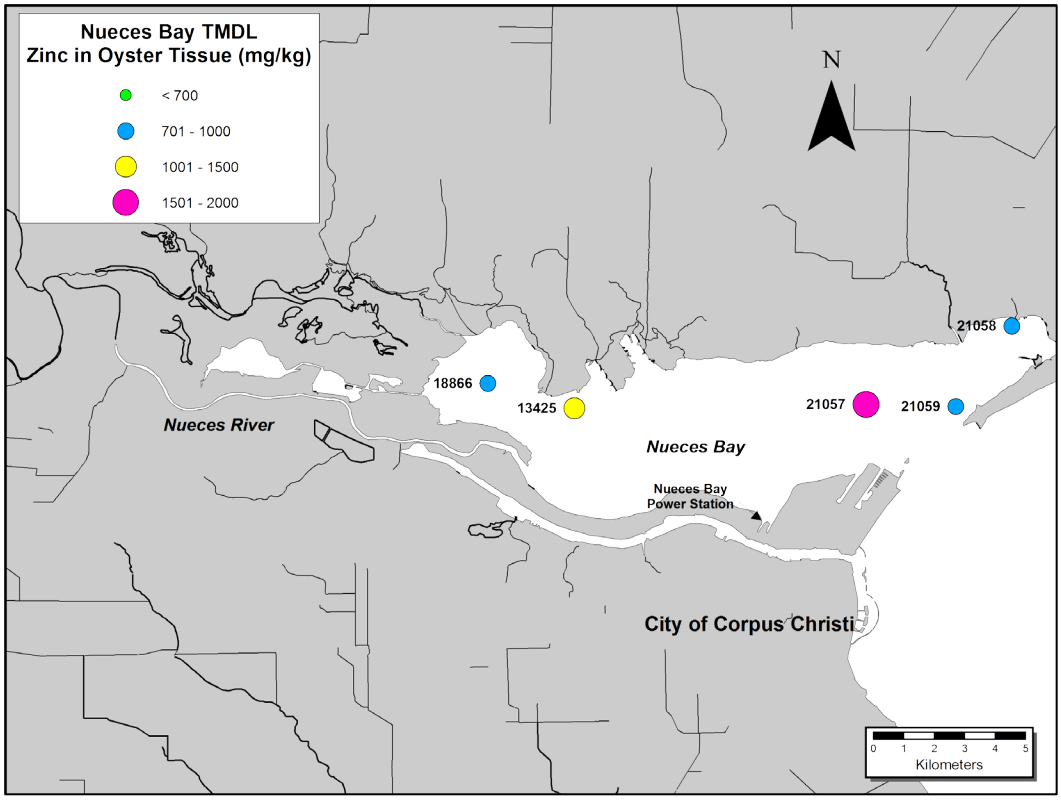


Figure 5.1. Mean zinc in oyster tissue concentrations (mg/kg) for Year-six February 2012 sampling.

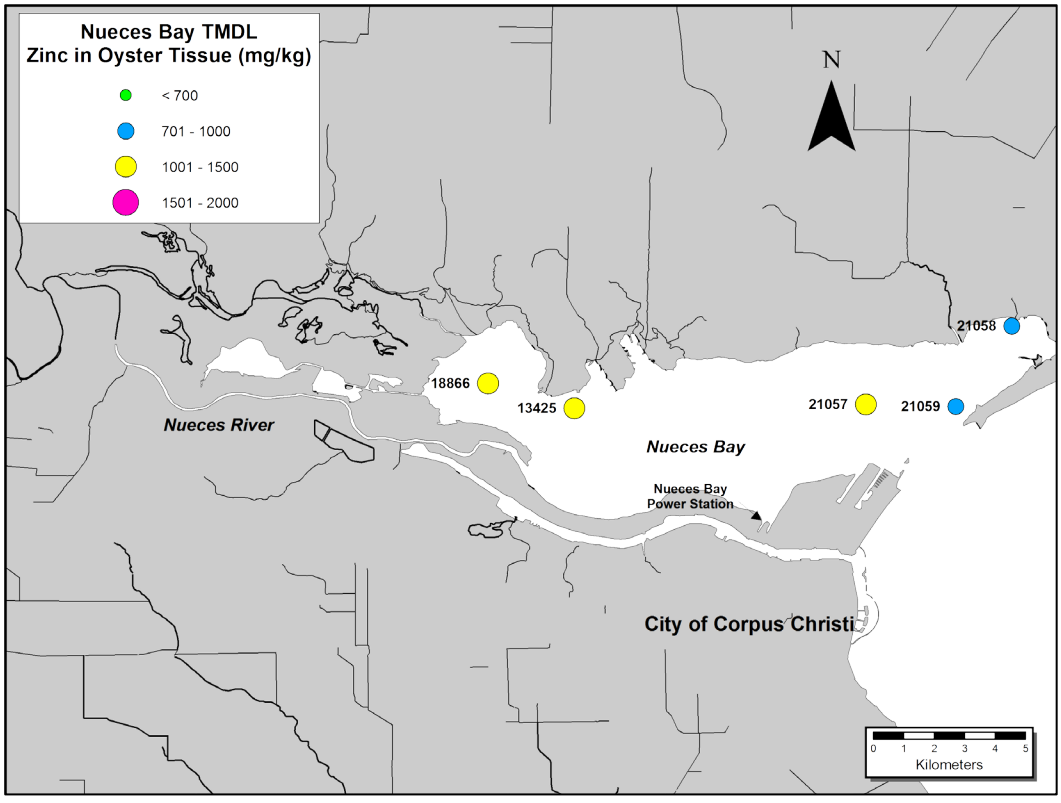


Figure 5.2. Mean zinc in oyster tissue concentrations (mg/kg) for Year-six May 2012 sampling.

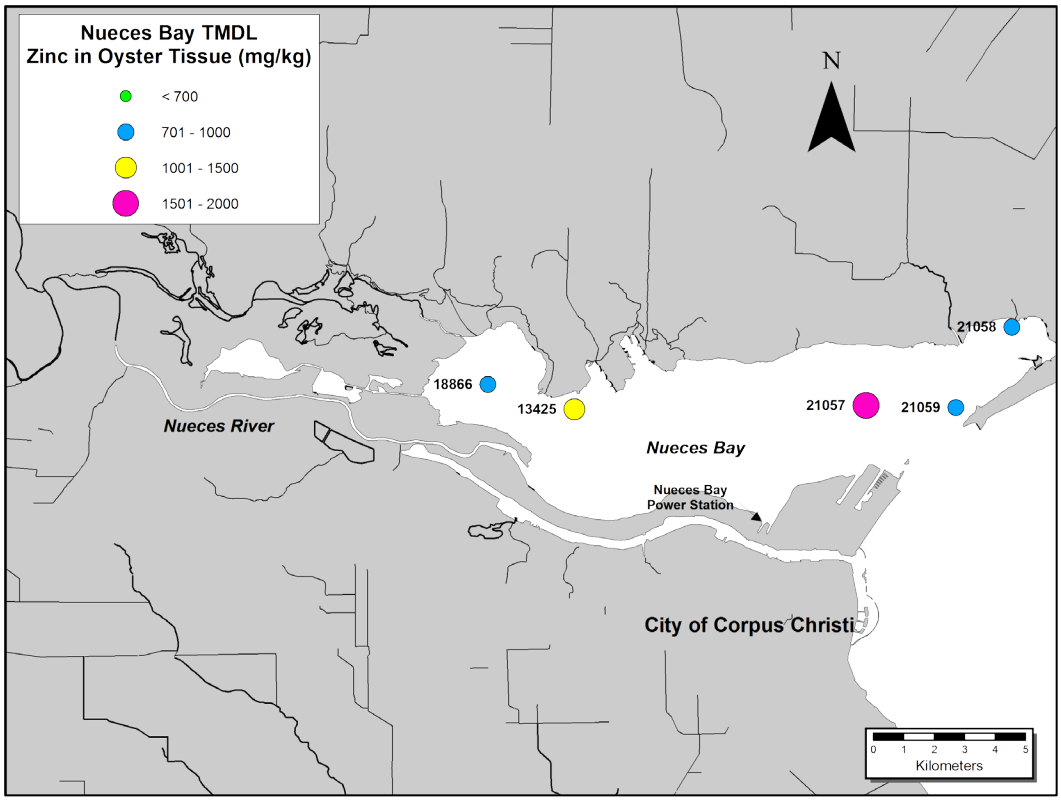


Figure 5.3. Mean zinc in oyster tissue concentrations (mg/kg) for Year-six sampling.

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# 7.0 DATA TABLES

## 7.1 Station Information

Table 7.1.1. Segment designation, TCEQ Station ID, sample type, and station location coordinates for Nueces Bay TMDL stations. Sampling took place for FD = Field Data, RC = Routine Conventional Water Chemistry, and TM = Trace Metals-Water, TMSED = Trace Metals-Sediment for two events (November 2011 and May/June 2012).

| Segment Number | Segment Name | TCEQ ID | Latitude (dd) | Longitude (dd) |
|---|---|---|---|---|
| 2101 | Nueces River Tidal | 12960 | 27.84667 | -97.52084 |
| 2482 | Nueces Bay | 13420 | 27.85278 | -97.36028 |
| | | 13423 | 27.86083 | -97.39083 |
| | | 13425 | 27.85639 | -97.47450 |
| | | 14832 | 27.87861 | -97.33944 |
| | | 14833 | 27.82750 | -97.41670 |
| | | 18365 | 27.83104 | -97.46967 |
| | | 18866 | 27.86372 | -97.50007 |
| 2484 | Corpus Christi Inner Harbor | 13432 | 27.82000 | -97.44972 |
| | | 13439 | 27.84333 | -97.52000 |

## 7.2 Field Parameters – Individual Concentrations for grab samples taken at surface (0.30 m)

Table 7.2.1. Field Parameter concentrations at Nueces Bay TMDL stations for Sampling Event 1 (November 2011) and Sampling Event 2 (May/June 2012).

| Nov. 2011 | Segment | Segment Name | TCEQ_ID | Cond. (µmhos) | DO (mg/L) | DO Sat. (%) | pH (su) | Salinity (PSU) | Secchi Depth (m) | Total Depth (m) | Turbidity (NTU) | Water Temp (°C) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2101 | Nueces River Tidal | 12960 | 49897 | 7.83 | 98.70 | 8.31 | 32.96 | 0.30 | 0.90 | 7.30 | 17.28 |
| | 2482 | Nueces Bay | 13420 | 66496 | 9.09 | 127.10 | 8.46 | 45.27 | 0.50 | 0.80 | 3.70 | 18.54 |
| | 2482 | | 13423 | 63307 | 8.79 | 122.20 | 8.28 | 42.79 | 1.00 | 1.80 | 0.10 | 18.95 |
| | 2482 | | 13425 | 67473 | 8.44 | 116.20 | 8.06 | 45.99 | 0.60 | 1.00 | 3.20 | 17.57 |
| | 2482 | | 14832 | 65412 | 8.91 | 124.60 | 8.45 | 44.40 | 0.80 | 1.40 | 0.10 | 18.84 |
| | 2482 | | 14833 | 62737 | 8.95 | 123.50 | 8.24 | 42.36 | 0.80 | 1.10 | 1.00 | 18.70 |
| | 2482 | | 18365 | 66204 | 8.48 | 118.10 | 8.19 | 45.02 | 0.30 | 1.50 | 10.00 | 18.37 |
| | 2482 | | 18866 | 69449 | 8.35 | 115.50 | 8.11 | 47.49 | 0.40 | 1.20 | 4.10 | 17.16 |
| | 2484 | Corpus Christi Inner Harbor | 13432 | 60777 | 8.63 | 120.30 | 8.16 | 40.86 | 2.00 | 14.70 | 1.90 | 19.77 |
| | 2484 | | 13439 | 59795 | 8.13 | 113.00 | 7.99 | 40.13 | 1.80 | 14.70 | 0.70 | 19.87 |
| **May/Jun. 2012** | **Segment** | **Segment Name** | **TCEQ_ID** | **Cond. (µmhos)** | **DO (mg/L)** | **DO Sat. (%)** | **pH (su)** | **Salinity (PSU)** | **Secchi Depth (m)** | **Total Depth (m)** | **Turbidity (NTU)** | **Water Temp (°C)** |
| | 2101 | Nueces River Tidal | 12960 | 18920 | 10.19 | 130.10 | 8.73 | 11.19 | 0.25 | 1.20 | 15.00 | 24.54 |
| | 2482 | Nueces Bay | 13420 | 50889 | 8.53 | 126.50 | 8.28 | 33.35 | 0.30 | 1.00 | 9.60 | 25.80 |
| | 2482 | | 13423 | 51155 | 8.24 | 121.80 | 8.18 | 33.57 | 0.40 | 1.80 | 14.20 | 25.55 |
| | 2482 | | 13425 | 50817 | 8.11 | 118.10 | 8.13 | 33.36 | 0.40 | 1.30 | 11.50 | 24.80 |
| | 2482 | | 14832 | 51309 | 8.50 | 126.10 | 8.33 | 33.69 | 0.40 | 1.30 | 10.40 | 25.97 |
| | 2482 | | 14833 | 52758 | 7.31 | 118.60 | 8.13 | 34.58 | 0.50 | 0.90 | 10.20 | 31.04 |
| | 2482 | | 18365 | 48158 | 8.06 | 118.20 | 8.30 | 31.37 | 0.30 | 1.60 | 25.80 | 25.80 |
| | 2482 | | 18866 | 48525 | 7.74 | 111.60 | 8.14 | 31.67 | 0.40 | 1.20 | 14.20 | 24.67 |
| | 2484 | Corpus Christi Inner Harbor | 13432 | 51514 | 7.03 | 109.80 | 8.04 | 33.75 | 1.10 | 14.60 | 0.10 | 28.75 |
| | 2484 | | 13439 | 50585 | 7.39 | 115.10 | 8.06 | 33.06 | 1.50 | 14.60 | 0.00 | 28.95 |

## 7.3 Field Parameters – Descriptive Statistics based on grab samples taken at surface (0.30 m)

Table 7.3.1 Conductivity (µmhos) and Salinity (PSU) descriptive statistics, listed by TCEQ Segment, at Nueces Bay TMDL stations for Sampling Event 1 (November 2011) and Sampling Event 2 (May/June 2012). **Bold** = highest recorded mean concentrations for the event.

| Parameter | Date | Segment | Segment Name | n (stations) | Min | Max | Mean |
|---|---|---|---|---|---|---|---|
| Conductivity | Event 1 | 2101 | Nueces River Tidal | 1 | - | - | 49897 |
| (µmhos) | (November 2011) | 2482 | Nueces Bay | 7 | 62737 | 69449 | **65868** |
| | | 2484 | Corpus Christi Inner Harbor | 2 | 59795 | 60777 | 60286 |
| | Event 2 | 2101 | Nueces River Tidal | 1 | - | - | 18920 |
| | (May/June 2012) | 2482 | Nueces Bay | 7 | 48158 | 52758 | 50516 |
| | | 2484 | Corpus Christi Inner Harbor | 2 | 50585 | 51514 | **51050** |
| **Parameter** | **Date** | **Segment** | **Segment Name** | **n (stations)** | **Min** | **Max** | **Mean** |
| Salinity | Event 1 | 2101 | Nueces River Tidal | 1 | - | - | 32.96 |
| (PSU) | (November 2011) | 2482 | Nueces Bay | 7 | 42.36 | 47.49 | **44.76** |
| | | 2484 | Corpus Christi Inner Harbor | 2 | 40.13 | 40.86 | 40.50 |
| | Event 2 | 2101 | Nueces River Tidal | 1 | - | - | 11.19 |
| | (May/June 2012) | 2482 | Nueces Bay | 7 | 31.37 | 34.58 | 33.08 |
| | | 2484 | Corpus Christi Inner Harbor | 2 | 33.06 | 33.75 | **33.41** |

Table 7.3.2. Dissolved Oxygen (mg/L and % Saturation) descriptive statistics, listed by TCEQ Segment, at Nueces Bay TMDL stations for Sampling Event 1 (November 2011) and Sampling Event 2 (May/June 2012). **Bold** = highest recorded mean concentrations for the event.

| Parameter | Date | Segment | Segment Name | n (stations) | Min | Max | Mean |
|---|---|---|---|---|---|---|---|
| Dissolved Oxygen | Event 1 | 2101 | Nueces River Tidal | 1 | - | - | 7.83 |
| (mg/L) | (November 2011) | 2482 | Nueces Bay | 7 | 8.35 | 9.09 | **8.72** |
| | | 2484 | Corpus Christi Inner Harbor | 2 | 8.13 | 8.63 | 8.38 |
| | Event 2 | 2101 | Nueces River Tidal | 1 | - | - | **10.19** |
| | (May/June 2012) | 2482 | Nueces Bay | 7 | 7.31 | 8.53 | 8.07 |
| | | 2484 | Corpus Christi Inner Harbor | 2 | 7.03 | 7.39 | 7.21 |
| **Parameter** | **Date** | **Segment** | **Segment Name** | **n (stations)** | **Min** | **Max** | **Mean** |
| Dissolved Oxygen | Event 1 | 2101 | Nueces River Tidal | 1 | - | - | 98.70 |
| (% Saturation) | (November 2011) | 2482 | Nueces Bay | 7 | 115.50 | 127.10 | **121.03** |
| | | 2484 | Corpus Christi Inner Harbor | 2 | 113.00 | 120.30 | 116.65 |
| | Event 2 | 2101 | Nueces River Tidal | 1 | - | - | **130.10** |
| | (May/June 2012) | 2482 | Nueces Bay | 7 | 111.60 | 126.50 | 120.13 |
| | | 2484 | Corpus Christi Inner Harbor | 2 | 109.80 | 115.10 | 112.45 |

Table 7.3.3. pH (su) and Water Temperature (°C) descriptive statistics, listed by TCEQ Segment, at Nueces Bay TMDL stations for Sampling Event 1 (November 2011) and Sampling Event 2 (May/June 2012). **Bold** = highest recorded mean concentrations for the event.

| Parameter | Date | Segment | Segment Name | n (stations) | Min | Max | Mean |
|---|---|---|---|---|---|---|---|
| pH | Event 1 | 2101 | Nueces River Tidal | 1 | - | - | **8.31** |
| (su) | (November 2011) | 2482 | Nueces Bay | 7 | 8.06 | 8.46 | 8.26 |
| | | 2484 | Corpus Christi Inner Harbor | 2 | 7.99 | 8.16 | 8.08 |
| | Event 2 | 2101 | Nueces River Tidal | 1 | - | - | **8.73** |
| | (May/June 2012) | 2482 | Nueces Bay | 7 | 8.13 | 8.33 | 8.21 |
| | | 2484 | Corpus Christi Inner Harbor | 2 | 8.04 | 8.06 | 8.05 |
| **Parameter** | **Date** | **Segment** | **Segment Name** | **n (stations)** | Min | Max | Mean |
| Water Temperature | Event 1 | 2101 | Nueces River Tidal | 1 | - | - | 17.28 |
| (°C) | (November 2011) | 2482 | Nueces Bay | 7 | 17.16 | 18.95 | 18.30 |
| | | 2484 | Corpus Christi Inner Harbor | 2 | 19.77 | 19.87 | **19.82** |
| | Event 2 | 2101 | Nueces River Tidal | 1 | - | - | 24.54 |
| | (May/June 2012) | 2482 | Nueces Bay | 7 | 24.67 | 31.04 | 26.23 |
| | | 2484 | Corpus Christi Inner Harbor | 2 | 28.75 | 28.95 | **28.85** |

Table 7.3.4. Secchi Depth (m) and Turbidity (NTU) descriptive statistics, listed by TCEQ Segment, at Nueces Bay TMDL stations for Sampling Event 1 (November 2011) and Sampling Event 2 (May/June 2012). **Bold** = highest recorded mean concentrations for the event.

| Parameter | Date | Segment | Segment Name | n (stations) | Min | Max | Mean |
|---|---|---|---|---|---|---|---|
| Secchi Depth | Event 1 | 2101 | Nueces River Tidal | 1 | - | - | 0.30 |
| (m) | (November 2011) | 2482 | Nueces Bay | 7 | 0.30 | 1.00 | 0.63 |
| | | 2484 | Corpus Christi Inner Harbor | 2 | 1.80 | 2.00 | **1.90** |
| | Event 2 | 2101 | Nueces River Tidal | 1 | - | - | 0.25 |
| | (May/June 2012) | 2482 | Nueces Bay | 7 | 0.30 | 0.50 | 0.39 |
| | | 2484 | Corpus Christi Inner Harbor | 2 | 1.10 | 1.50 | **1.30** |
| **Parameter** | **Date** | **Segment** | **Segment Name** | **n (stations)** | **Min** | **Max** | **Mean** |
| Turbidity | Event 1 | 2101 | Nueces River Tidal | 1 | - | - | **7.30** |
| (NTU) | (November 2011) | 2482 | Nueces Bay | 7 | 0.10 | 10.00 | 3.17 |
| | | 2484 | Corpus Christi Inner Harbor | 1 | 0.70 | 1.90 | 1.30 |
| | Event 2 | 2101 | Nueces River Tidal | 1 | - | - | **15.00** |
| | (May/June 2012) | 2482 | Nueces Bay | 7 | 9.60 | 25.80 | 13.70 |
| | | 2484 | Corpus Christi Inner Harbor | 2 | 0.00 | 0.10 | 0.05 |

Table 7.3.5. Total Depth (m) descriptive statistics, listed by TCEQ Segment, at Nueces Bay TMDL stations for Sampling Event 1 (November 2011) and Sampling Event 2 (May/June 2012). **Bold** = highest recorded mean concentrations for the event.

| Parameter | Date | Segment | Segment Name | n (stations) | Min | Max | Mean |
|---|---|---|---|---|---|---|---|
| Total Depth | Event 1 | 2101 | Nueces River Tidal | 1 | - | - | 0.90 |
| (m) | (November 2011) | 2482 | Nueces Bay | 7 | 0.80 | 1.80 | 1.26 |
| | | 2484 | Corpus Christi Inner Harbor | 2 | 14.70 | 14.70 | **14.70** |
| | Event 2 | 2101 | Nueces River Tidal | 1 | - | - | 1.20 |
| | (May/June 2012) | 2482 | Nueces Bay | 7 | 0.90 | 1.80 | 1.30 |
| | | 2484 | Corpus Christi Inner Harbor | 2 | 14.60 | 14.60 | **14.60** |

## 7.4 Routine Conventional Water Chemistry – Individual Concentrations for grab samples taken at surface (0.30 m)

Table 7.4.1. Total Suspended Solid concentrations (mg/L or ppm) at Nueces Bay TMDL stations for Sampling Event 1 (November 2011) and Sampling Event 2 (May/June 2012). **Bold** = highest recorded concentrations for the event.

| Segment | Segment Name | TCEQ ID | November 2011 (Event 1) | May/June 2012 (Event 2) | Mean of all Events |
|---|---|---|---|---|---|
| 2101 | Nueces River Tidal | 12960 | 26.40 | 20.80 | 23.60 |
| 2482 | Nueces Bay | 13420 | 52.40 | **40.00** | **46.20** |
| 2482 | | 13423 | 42.00 | 39.60 | 40.80 |
| 2482 | | 13425 | 39.60 | 22.80 | 31.20 |
| 2482 | | 14832 | **56.80** | 34.40 | 45.60 |
| 2482 | | 14833 | 10.40 | 32.00 | 21.20 |
| 2482 | | 18365 | 48.80 | 38.80 | 43.80 |
| 2482 | | 18866 | 23.60 | 30.80 | 27.20 |
| 2484 | Corpus Christi Inner Harbor | 13432 | 32.40 | 19.20 | 25.80 |
| 2484 | | 13439 | 15.60 | 24.00 | 19.80 |

## 7.5 Routine Conventional Water Chemistry –Descriptive Statistics based on grab samples taken at surface (0.30 m)

Table 7.5.1. Total Suspended Solids (mg/L) descriptive statistics, listed by TCEQ Segment, at Nueces Bay TMDL stations for Sampling Event 1 (November 2011) and Sampling Event 2 (May/June 2012). **Bold** = highest recorded mean concentrations for the event.

| Parameter | Date | Segment | Segment Name | n (stations) | Min | Max | Mean |
|---|---|---|---|---|---|---|---|
| **Total** | Event 1 | 2101 | Nueces River Tidal | 1 | - | - | 26.40 |
| **Suspended** | (November 2011) | 2482 | Nueces Bay | 7 | 10.40 | 56.80 | **39.09** |
| **Solids** | | 2484 | Corpus Christi Inner Harbor | 2 | 15.60 | 32.40 | 24.00 |
| **(TSS)** | Event 2 | 2101 | Nueces River Tidal | 1 | - | - | 20.80 |
| | (May/June 2012) | 2482 | Nueces Bay | 7 | 22.80 | 40.00 | **34.06** |
| | | 2484 | Corpus Christi Inner Harbor | 2 | 19.20 | 24.00 | 21.60 |

## 7.6 Trace Metals in Water – Individual Concentrations for pumped grab samples taken at surface (0.30 m)

Table 7.6.1. Individual zinc concentrations (ppb) at Nueces Bay TMDL stations for Sampling Event 1 (November 2011) and Sampling Event 2 (May/June 2012). D = Dissolved Zinc and T = Total Zinc, TWC = Tidal Water Chronic for Dissolved Zinc. Shaded = value exceeded TCEQ Total Zinc Nueces Bay TMDL criteria level. **Bold** = highest recorded concentration for the event.

| Parameter | Segment | Segment Name | TCEQ ID | November 2011 (Event 1) | | May/June 2012 (Event 2) | |
|---|---|---|---|---|---|---|---|
| | | | | T | D | T | D |
| **Dissolved Zinc** | 2101 | Nueces River Tidal | 12960 | 1.90 | 0.43 | 2.04 | 1.03 |
| **TWC = 84.20** | 2482 | Nueces Bay | 13420 | 2.18 | 0.66 | 4.30 | 0.95 |
| **Nueces Bay = NA** | 2482 | | 13423 | 1.75 | 0.95 | 5.69 | 2.73 |
| | 2482 | | 13425 | 3.20 | 2.25 | 3.88 | 2.51 |
| | 2482 | | 14832 | 2.23 | 0.74 | 2.03 | 0.62 |
| **Total Zinc** | 2482 | | 14833 | 2.37 | 1.77 | 6.96 | 4.87 |
| **TWC = NA** | 2482 | | 18365 | 7.45 | 2.94 | 6.43 | 3.83 |
| **Nueces Bay = 29.00** | 2482 | | 18866 | 3.18 | 1.66 | 3.69 | 1.86 |
| | 2484 | Corpus Christi Inner Harbor | 13432 | **20.10** | **11.40** | 11.20 | **8.63** |
| | 2484 | | 13439 | 9.21 | 8.62 | **19.80** | 7.56 |

## 7.7 Trace Metals in Water – Descriptive Statistics based on pumped grab samples taken at surface (0.30 m)

Table 7.7.1. Total and Dissolved Zinc (ppb) descriptive statistics, listed by TCEQ Segment, for Nueces Bay TMDL stations. Shaded = value exceeded Total Zinc Nueces Bay TMDL criteria level. **Bold** = highest recorded mean concentrations for the event. TWC = Tidal Water Chronic.

| Parameter | Date | Segment | Segment Name | n (stations) | Min | Max | Mean |
|---|---|---|---|---|---|---|---|
| **Total Zinc** | Event 1 | 2101 | Nueces River Tidal | 1 | - | - | 1.90 |
| | (November 2011) | 2482 | Nueces Bay | 7 | 1.75 | 7.45 | 3.19 |
| **TWC = NA** | | 2484 | Corpus Christi Inner Harbor | 2 | 9.21 | 20.10 | **14.66** |
| **Nueces Bay = 29.00** | Event 2 | 2101 | Nueces River Tidal | 1 | - | - | 2.04 |
| | (May/June 2012) | 2482 | Nueces Bay | 7 | 2.03 | 6.96 | 4.71 |
| | | 2484 | Corpus Christi Inner Harbor | 2 | 11.20 | 19.80 | **15.50** |
| **Parameter** | **Date** | **Segment** | **Segment Name** | **n (stations)** | **Min** | **Max** | **Mean** |
| **Dissolved Zinc** | Event 1 | 2101 | Nueces River Tidal | 1 | - | - | 0.43 |
| | (November 2011) | 2482 | Nueces Bay | 7 | 0.66 | 2.94 | 1.57 |
| **TWC = 84.20** | | 2484 | Corpus Christi Inner Harbor | 2 | 8.62 | 11.40 | **10.01** |
| **Nueces Bay = NA** | Event 2 | 2101 | Nueces River Tidal | 1 | - | - | 1.03 |
| | (May/June 2012) | 2482 | Nueces Bay | 7 | 0.62 | 4.87 | 2.48 |
| | | 2484 | Corpus Christi Inner Harbor | 2 | 7.56 | 8.63 | **8.10** |



## 7.8 Trace Metals in Sediment and Sediment Characteristics – Individual Concentrations

Table 7.8.1. Zinc, Total Organic Carbon (TOC) concentration (mg/kg), and sediment characteristic concentrations (%) at Nueces Bay TMDL stations for Sampling Event 1 (November 2011) and Sampling Event 2 (May/June 2012). Shaded = value exceeded TCEQ ERM screening level. **Bold** = highest recorded concentration for the event.

| November 2011 | Segment | Segment Name | TCEQ ID | Zn | TOC | Gravel/Shell | Sand | Silt-Clay |
|---|---|---|---|---|---|---|---|---|
| **Zinc (Zn)** | 2101 | Nueces River Tidal | 12960 | 130.00 | **14700** | 0.00 | 3.60 | **96.40** |
| ERM = 410.0 | 2482 | Nueces Bay | 13420 | 49.50 | 6770 | 0.00 | 14.20 | 85.80 |
| | 2482 | | 13423 | 35.50 | 3160 | 0.90 | 56.40 | 42.70 |
| | 2482 | | 13425 | 42.10 | 5100 | **3.00** | 31.10 | 65.90 |
| | 2482 | | 14832 | 32.90 | 5890 | 0.00 | 23.80 | 76.20 |
| | 2482 | | 14833 | 50.70 | 4170 | 0.00 | 55.10 | 44.90 |
| | 2482 | | 18365 | 66.90 | 7470 | 1.00 | 42.70 | 56.30 |
| | 2482 | | 18866 | 25.00 | 2870 | 0.00 | **65.50** | 34.50 |
| | 2484 | CC Inner Harbor | 13432 | **154.00** | 6740 | 0.00 | 47.20 | 52.80 |
| | 2484 | | 13439 | 126.00 | 8230 | 0.70 | 39.50 | 59.80 |
| **May/June 2012** | **Segment** | **Segment Name** | **TCEQ ID** | **Zn** | **TOC** | **Gravel/Shell** | **Sand** | **Silt-Clay** |
| **Zinc (Zn)** | 2101 | Nueces River Tidal | 12960 | 152.00 | **33900** | 0.00 | 3.50 | **96.50** |
| ERM = 410.0 | 2482 | Nueces Bay | 13420 | 75.10 | 16900 | 0.00 | 5.30 | 94.70 |
| | 2482 | | 13423 | 40.20 | 3490 | **0.30** | 60.70 | 39.00 |
| | 2482 | | 13425 | 40.90 | 5370 | 0.00 | 17.10 | 82.90 |
| | 2482 | | 14832 | 46.60 | 7390 | 0.00 | 24.00 | 76.00 |
| | 2482 | | 14833 | 28.70 | 2430 | 0.00 | 63.70 | 36.60 |
| | 2482 | | 18365 | 76.80 | 9030 | 0.00 | 43.40 | 56.60 |
| | 2482 | | 18866 | 25.80 | 2900 | 0.00 | **64.40** | 35.60 |
| | 2484 | CC Inner Harbor | 13432 | 185.00 | 6900 | 0.00 | 57.80 | 42.20 |
| | 2484 | | 13439 | **279.00** | 18000 | 0.00 | 14.20 | 85.80 |



## 7.9 Trace Metals in Sediment – Descriptive Statistics

Table 7.9.1. Zinc and Total Organic Carbon (mg/kg), in sediment descriptive statistics, listed by TCEQ Segments, for Nueces Bay TMDL Stations for Sampling Event 1 (November 2011) and Sampling Event 2 (May/June 2012). **Bold** = highest recorded mean concentrations for the event.

| Parameter | Date | Segment | Segment Name | n (stations) | Min | Max | Mean |
|---|---|---|---|---|---|---|---|
| **ZINC** (mg/kg) | Event 1 (November 2011) | 2101 | Nueces River Tidal | 1 | - | - | 130.00 |
| | | 2482 | Nueces Bay | 7 | 25.00 | 66.90 | 43.23 |
| | | 2484 | Corpus Christi Inner Harbor | 2 | 126.00 | 154.00 | **140.00** |
| **Parameter** | **Date** | **Segment** | **Segment Name** | **n (stations)** | **Min** | **Max** | **Mean** |
| **ZINC** (mg/kg) | Event 2 (May/June 2012) | 2101 | Nueces River Tidal | 1 | - | - | 152.00 |
| | | 2482 | Nueces Bay | 7 | 25.80 | 76.80 | 47.73 |
| | | 2484 | Corpus Christi Inner Harbor | 2 | 185.00 | 279.00 | **232.00** |
| **Parameter** | **Date** | **Segment** | **Segment Name** | **n (stations)** | **Min** | **Max** | **Mean** |
| **TOC** (mg/kg) | Event 1 (November 2011) | 2101 | Nueces River Tidal | 1 | - | - | **14700** |
| | | 2482 | Nueces Bay | 7 | 2870 | 7470 | 5061 |
| | | 2484 | Corpus Christi Inner Harbor | 2 | 6740 | 8230 | 7485 |
| **Parameter** | **Date** | **Segment** | **Segment Name** | **n (stations)** | **Min** | **Max** | **Mean** |
| **TOC** (mg/kg) | Event 2 (May/June 2012) | 2101 | Nueces River Tidal | 1 | - | - | **33900** |
| | | 2482 | Nueces Bay | 7 | 2430 | 16900 | 6787 |
| | | 2484 | Corpus Christi Inner Harbor | 2 | 6900 | 18000 | 12450 |

Table 7.9.2. Percent Sand and Percent Silt-Clay in sediment descriptive statistics listed by TCEQ Segments, for Nueces Bay TMDL Stations for Sampling Event 1 (November 2011) and for Sampling Event 2 (May/June 2012). **Bold** = highest recorded mean concentrations for the event.

| Parameter | Date | Segment | Segment Name | n (stations) | Min | Max | Mean |
|---|---|---|---|---|---|---|---|
| **Percent Sand** (0.0625 - 2.00 mm) | Event 1 (November 2011) | 2101 | Nueces River Tidal | 1 | - | - | 3.60 |
| | | 2482 | Nueces Bay | 7 | 14.20 | 65.50 | 41.26 |
| | | 2484 | Corpus Christi Inner Harbor | 2 | 39.50 | 47.20 | **43.35** |
| **Parameter** | **Date** | **Segment** | **Segment Name** | **n (stations)** | **Min** | **Max** | **Mean** |
| **Percent Sand** (0.0625 - 2.00 mm) | Event 2 (May/June 2012) | 2101 | Nueces River Tidal | 1 | - | - | 3.50 |
| | | 2482 | Nueces Bay | 7 | 5.30 | 64.40 | **39.80** |
| | | 2484 | Corpus Christi Inner Harbor | 2 | 14.20 | 57.80 | 36.00 |
| **Parameter** | **Date** | **Segment** | **Segment Name** | **n (stations)** | **Min** | **Max** | **Mean** |
| **Percent Silt-Clay** (< 0.0625 mm) | Event 1 (November 2011) | 2101 | Nueces River Tidal | 1 | - | - | **96.40** |
| | | 2482 | Nueces Bay | 7 | 34.50 | 85.80 | 58.04 |
| | | 2484 | Corpus Christi Inner Harbor | 2 | 52.80 | 59.80 | 56.30 |
| **Parameter** | **Date** | **Segment** | **Segment Name** | **n (stations)** | **Min** | **Max** | **Mean** |
| **Percent Silt-Clay** (< 0.0625 mm) | Event 2 (May/June 2012) | 2101 | Nueces River Tidal | 1 | - | - | **96.50** |
| | | 2482 | Nueces Bay | 7 | 35.60 | 94.70 | 60.20 |
| | | 2484 | Corpus Christi Inner Harbor | 2 | 42.20 | 85.80 | 64.00 |

## 7.10 Trace Metals in Oyster Tissue – Individual Concentrations

Table 7.10.1. Zinc in oyster tissue concentrations (mg/kg) at Nueces Bay TMDL stations for February 2012 sampling event. **Bold** = highest recorded concentration at each sampling station and *Italics* = values below the 700 mg/kg criteria.

| Segment | Segment Name | TCEQ ID* | Sample | February 2012 | Mean of all samples |
|---|---|---|---|---|---|
| 2482 | Nueces Bay | 18866 | 1 | *367* | |
| | | | 2 | *443* | |
| | | | 3 | 794 | 706 |
| | | | 4 | **1090** | |
| | | | 5 | 838 | |
| **Segment** | **Segment Name** | **TCEQ ID*** | **Sample** | **February 2012** | |
| 2482 | Nueces Bay | 13425 | 1 | **3340** | |
| | | | 2 | *652* | |
| | | | 3 | 1010 | 1322 |
| | | | 4 | 945 | |
| | | | 5 | *661* | |
| **Segment** | **Segment Name** | **TCEQ ID*** | **Sample** | **February 2012** | |
| 2482 | Nueces Bay | 21057 | 1 | 1130 | |
| | | | 2 | 858 | |
| | | | 3 | 1760 | **1724** |
| | | | 4 | **3050** | |
| | | | 5 | 1820 | |
| **Segment** | **Segment Name** | **TCEQ ID*** | **Sample** | **February 2012** | |
| 2482 | Nueces Bay | 21058 | 1 | **1200** | |
| | | | 2 | 739 | |
| | | | 3 | 858 | 931 |
| | | | 4 | 770 | |
| | | | 5 | 1090 | |
| **Segment** | **Segment Name** | **TCEQ ID*** | **Sample** | **February 2012** | |
| 2482 | Nueces Bay | 21059 | 1 | *545* | |
| | | | 2 | *650* | |
| | | | 3 | 907 | 882 |
| | | | 4 | 956 | |
| | | | 5 | **1350** | |

Table 7.10.2. Zinc in oyster tissue concentrations (mg/kg) at Nueces Bay TMDL stations for May 2012 sampling event. **Bold** = highest recorded concentration at each sampling station and *Italics* = values below the 700 mg/kg criteria.

| Segment | Segment Name | TCEQ ID* | Sample | May 2012 | Mean of all samples |
|---|---|---|---|---|---|
| 2482 | Nueces Bay | 18866 | 1 | 1000 | |
| | | | 2 | 763 | |
| | | | 3 | 819 | 1007 |
| | | | 4 | 731 | |
| | | | 5 | **1720** | |
| **Segment** | **Segment Name** | **TCEQ ID*** | **Sample** | **May 2012** | |
| 2482 | Nueces Bay | 13425 | 1 | 903 | |
| | | | 2 | 753 | |
| | | | 3 | **2200** | 1169 |
| | | | 4 | 1220 | |
| | | | 5 | 768 | |
| **Segment** | **Segment Name** | **TCEQ ID*** | **Sample** | **May 2012** | |
| 2482 | Nueces Bay | 21057 | 1 | 861 | |
| | | | 2 | 1590 | |
| | | | 3 | 1390 | **1400** |
| | | | 4 | **1750** | |
| | | | 5 | 1410 | |
| **Segment** | **Segment Name** | **TCEQ ID*** | **Sample** | **May 2012** | |
| 2482 | Nueces Bay | 21058 | 1 | *546* | |
| | | | 2 | *435* | |
| | | | 3 | 897 | 734 |
| | | | 4 | *660* | |
| | | | 5 | **1130** | |
| **Segment** | **Segment Name** | **TCEQ ID*** | **Sample** | **May 2012** | |
| 2482 | Nueces Bay | 21059 | 1 | 777 | |
| | | | 2 | **1270** | |
| | | | 3 | 1030 | 978 |
| | | | 4 | 1180 | |
| | | | 5 | *635* | |