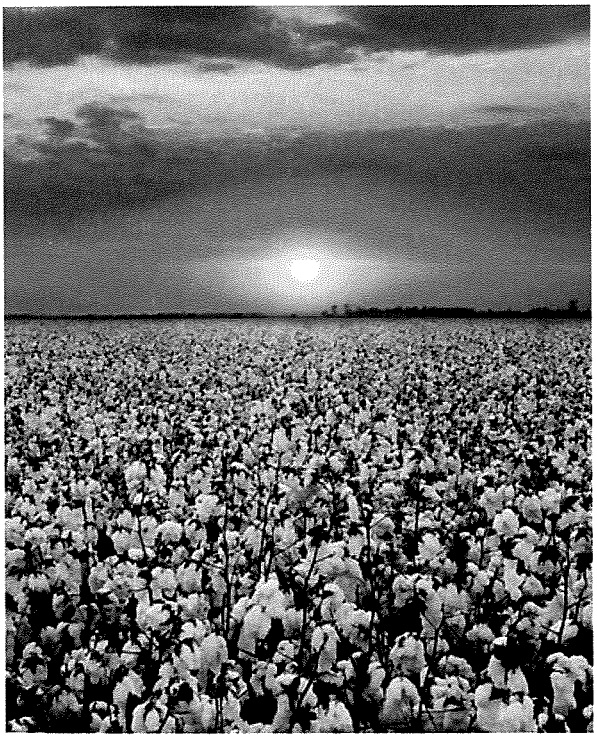
PURSUANT TO SENATE BILL 1 AS APPROVED BY THE 83RD TEXAS LEGISLATURE, THIS STUDY REPORT WAS FUNDED FOR THE PURPOSE OF STUDYING ENVIRONMENTAL FLOW NEEDS FOR TEXAS RIVERS AND ESTUARIES AS PART OF THE ADAPTIVE MANAGEMENT PHASE OF THE SENATE BILL 3 PROCESS FOR ENVIRONMENTAL FLOWS ESTABLISHED BY THE 80TH TEXAS LEGISLATURE. THE VIEWS AND CONCLUSIONS EXPRESSED HEREIN ARE THOSE OF THE AUTHOR(S) AND DO NOT NECESSARILY REFLECT THE VIEWS OF THE TEXAS WATER DEVELOPMENT BOARD.



Nueces BBASC Work Plan Study No. 3

Nueces Watershed Pre- and Post-Development Nutrient Budgets

Texas Water Development Board

Nueces River and Corpus Christi and Baffin Bays Basin and Bay Area Stakeholder Committee (Nueces BBASC)

August 2015

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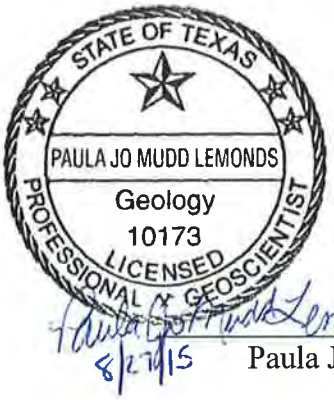
Prepared for:
Texas Water Development Board

Nueces River and Corpus Christi and Baffin Bays Basin and Bay Area Stakeholder Committee (Nueces BBASC)

Prepared by:

HDR

TBPE Firm No. F-754
TBPG Firm No. 50226



Paula Jo Mudd Lemonds 8/27/15 Paula Jo Mudd Lemonds, P.E., P.G. 8/27/15

August 2015

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Common Abbreviations

acft	acre-feet
acft/yr	acre-feet per year
AIC	Akaike Information Criterion
Avg	Average
BBASC	Basin and Bay Area Stakeholders Committee
BBEST	Basin and Bay Expert Science Team
CBBEP	Coastal Bend Bays and Estuary Program
CCEFN	Consensus Criteria for Environmental Flow Needs
CCR	Choke Canyon Reservoir
chl-a	chlorophyll-a
DO	dissolved oxygen
EPA	Environmental Protection Agency
HRI	Harte Research Institute
LCC	Lake Corpus Christi
LOADEST	Load Estimator (USGS modeling tool)
LRA	linear regression analysis
msl	Mean sea level
NBBASC	Nueces Basin and Bay Area Stakeholders Committee
NEAC	Nueces Estuary Advisory Committee
NH_4	ammonium
NH_3	ammonia
NOx	nitrate+nitrite
NRA	Nueces River Authority
PO4	orthophosphate
POR	Period of record
SB2	Senate Bill 2
SB3	Senate Bill 3
TCEQ	Texas Commission on Environmental Quality
TKN	total kjeldahl nitrogen
TN	total nitrogen
TP	total phosphorus
TPDES	Texas Pollutant Discharge Elimination System
TPWD	Texas Parks and Wildlife Department
TWDB	Texas Water Development Board
USGS	United States Geological Survey
WWTP	wastewater treatment plant

Executive Summary

The primary goals of this nutrient budget study, as described in the Nueces River and Corpus Christi and Baffin Bays Basin and Bay Area Stakeholders Committee Work Plan for Adaptive Management (Nueces BBASC, 2012b) are to:

- Develop nutrient budgets based on quantitative understanding of natural supply of nutrients and anthropogenic changes in these supplies over time for the Nueces Bay watershed; and
- Determine annual loads for both the pre-development and present condition.

As described in the 2011 Nueces BBEST Recommendations Report, a nutrient study was conducted to understand the relationship between freshwater inflow and nutrients in the Nueces Bay. The study evaluated fourteen stations that had been sampled since 2001. The nutrient analytes included nitrate plus nitrite, silicate, ammonium, and phosphate. The sampling stations were located in the Rincon Bayou, Nueces Bay, and included one riverine station, the Nueces River at Calallen (USGS station 08211500).

The Nueces BBASC wrote in the 2012 Work Plan for Adaptive Management that they believe there is a need for a "watershed approach to effective management of these resources." According to studies of the Nueces Estuary performed by the Texas Water Development Board (TWDB), approximately 85 percent of historical fresh water inflows were contributed by water that originated upstream of Lake Corpus Christi (TWDB, 2015b).[1] This nutrient budget study is the first step in developing an understanding of nutrient dynamics at the watershed scale.

The study included the following tasks:

Task 1 – Data Compilation

- Compile Water Quality and Hydrologic Data

Task 2 –Data Evaluation and Modeling Analyses

- Perform Data Evaluation
- Complete Linear Regression and USGS LOADEST Model Analyses
- Estimate Reservoir Influence Sink/Sources
- Complete Water Quality Correlations to Anthropogenic Changes
- Determine Pre- and Post-Development Loadings

This report describes the methods applied during the study and discusses results of the nutrient loadings regression analyses modeling.

Study Area

The Nueces River Basin is located in a relatively arid region of Texas and has the third lowest average annual watershed yield among major river basins of Texas (TWDB, 2015a). From the headwaters in Edwards, Real, and Bandera counties, the Nueces River and its tributaries flow to Nueces Bay, which, in turn, is part of the Nueces Estuary system and hydraulically connected to

[1] Approximate percentage is calculated as the long-term (1941-2009) average of Gage flow adjusted for losses between Mathis and Calallen (aka. adjusted Gage flow) divided by the sum of adjusted Gage flow plus Ungaged flow.

the Gulf of Mexico. The total basin drainage area is approximately 17,000 square miles, encompassing all or part of 23 counties in South-Central Texas (Nueces River Authority, 2013a). The Nueces River Basin is an important source of water supply for entities in the Nueces-Rio Grande and San Antonio-Nueces Coastal Basin, including the City of Corpus Christi, San Patricio Municipal Water District, and South Texas Water Authority.

Basis for Study

Several documents produced by watershed stakeholders suggest the need for the better understanding of nutrient dynamics within the watershed as a whole. These documents and the pertinent sections are as follows:

- Nueces BBASC Work Plan for Adaptive Management: Tier 2b Recommendation
- Nueces BBEST, BBEST Recommendations Report: Sec. 5.2 Nutrient Considerations
- Nueces BBASC, BBASC Recommendations Report: Sec. 4.3.2 Nutrient Considerations

Compiled Data

Numerous sets of readily available and accessible data were compiled for the study. Data included, but were not limited to, water quality, streamflow, land use, and wastewater treatment plant (WWTP) location data. Water quality data included nutrients and response variables, including chlorophyll *a*, and nitrogen and phosphorus species from numerous sources. Sources of data included Texas Commission on Environmental Quality (TCEQ), U.S. Geological Survey (USGS), Clean Rivers Program (CRP) monitoring reports by the Nueces River Authority, and data previously collected or compiled by the Harte Research Institute (HRI). Land use and population data were compiled to support the regression analyses.

This study focused on nutrient contributions to Nueces Bay from the Nueces Watershed. The Nueces Bay receives additional loadings from smaller subwatersheds around the Nueces Bay and from WWTP effluent contributions, which are discussed in this report.

Land Use and Population

According to the 2016 Coastal Bend Regional Water Plan (HDR Engineering and Coastal Bend Regional Water Planning Group, 2015), the population of the Coastal Bend Region was estimated to be 581,100 in 2013. This does not include the upper reaches of the Nueces Basin, which consists primarily of low population centers. Uvalde, with a 2013 population of 16,284, is the largest city in the upper Nueces Basin. The City of Corpus Christi, which had a population of 266,383 in 1990, grew to 316,381 people in 2013. Major crops in the basin include cotton and grain sorghum, and livestock include primarily cattle.

Regression Analysis of Water Quality Data

The objective of the data analysis is to evaluate pre- and post-development nutrient conditions in the Nueces River Basin as well as to assess any impacts of the operations of Choke Canyon Reservoir (CCR). HDR performed the data evaluation and modeling analysis using available flow and nutrient data from TCEQ and USGS water monitoring locations. An in-house data analysis package was used for linear regression analyses and compared to LOADEST (USGS load estimating tool) modeling outputs. Regression figures, cross-correlation plots (constituents versus flow), as well as time-series plots of the estimated values versus observed data for both concentrations and loads were generated using information from the linear regression analysis

and LOADEST modeling tools. Analysis of nutrients from 1970 through 2015 did not, in general, reveal statistically significant relationships between flow and the above mentioned variables. Analysis of water quality and reservoir operations from 1970 through 2015 indicate water quality constituents have not changed to a statistically significant degree since CCR construction.

Pre- and Post-Development Nutrient Loadings

Annual nutrient loadings for four locations representing the upper, middle, and lower Nueces River Basin were calculated. The four locations for which annual nutrient loads were calculated included:

- Atascosa River, Whitsett (USGS 08208000, TCEQ 12980)
- Nueces River, Laguna (USGS 08190000, TCEQ 12999)
- Nueces River, Three Rivers (USGS 08210000, TCEQ 12979)
- Nueces River, Mathis (USGS 08211000, TCEQ 12965).

Nueces River at Laguna (station 12999) represents the upper Nueces River basin. Nueces River at Three Rivers (station 12979) and Nueces River at Mathis (station 12965) represent the lower basin. Nueces River at Tilden, Frio River at Tilden, and San Miguel Creek at Tilden (stations 12973, 13023, and 12983, respectively) can be considered the boundary between the middle and lower basin, Atascosa River at Whitsett (station 12980) could be considered middle or lower, depending on the analysis.

For comparison purposes, annual loads representing the upper and lower Nueces Basin were calculated using the respective Environmental Protection Agency (EPA) subecoregion reference condition concentrations and gaged streamflow located in the specific subecoregion. The most upstream ecoregion in the Nueces Basin is Subecoregion 30, Edwards Plateau. Loads were calculated using the reported ambient subecoregion nutrient concentrations flow from Nueces River at Laguna, which is located in Subecoregion 30. The most downstream ecoregion in the Nueces Basin is Subecoregion 34, Western Gulf Coastal Plain. Loads were calculated using the reported ambient subecoregion nutrient concentrations and flow from Nueces River at Mathis, which is located in Subecoregion 34.

Annual nutrient loadings were calculated for wet, dry, and average years before and after the construction of Choke Canyon Reservoir. Nutrient loadings were calculated for total phosphorus (TP), total kjeldahl nitrogen (TKN), and nitrate plus nitrite (NOx), and the total nitrogen (TN), which was calculated as the TKN plus NOx loadings. As expected, the most upstream and undeveloped portions of the Nueces Basin exhibit the lowest nutrient loads. Loads increase in the downstream direction.

Percent change at Three Rivers (station 12979) for the time periods representing pre- and post-construction and the percent change from Three Rivers to Mathis (station 12965) representing changes that occur in Lake Corpus Christi were calculated. The percent changes show that both TP and TN decreased at the Three Rivers station throughout the flow regime in the time period after 1986, after construction of CCR. The percent change calculated from the Three Rivers station downstream of CCR to the Mathis station downstream of LCC shows an increase in TP. Total nitrogen decreased in average and wet years, but increased almost 30 percent in the dry period.

The most upstream and undeveloped portions of the Nueces watershed exhibit the lowest nutrient loads. The calculated annual loads compare well with both the upstream and downstream EPA ecoregional reference condition calculated loads for TP. In general, nitrogen species loads at Three Rivers are greater than downstream at Mathis and greater than the EPA ecoregional reference conditions. This could indicate nutrient enrichment at Three Rivers and nutrient uptake between Three Rivers and Mathis, most likely from Lake Corpus Christi, although further analysis is necessary to confirm the effects of Lake Corpus Christi.

Conclusions

Conclusions that can be made from this nutrient budget study include the following:

1. Calculated nutrient loadings show that the most upstream, undeveloped portions of the Nueces watershed exhibit the lowest nutrient loads. An analysis in the 2011 South Central Texas Regional Water Plan (HDR and South Central Texas Regional Water Planning Group, 2010) shows that about 10% of streamflow in the upper reaches of the Nueces watershed is delivered downstream as inflow to the Nueces Estuary. The relatively small effect that the upstream portion of the Nueces Basin above the Edwards Aquifer Recharge Zone has on nutrient deliveries to the Nueces Bay indicates that future studies can focus on areas downstream. This downstream extent could include CCR and areas downstream to the Nueces Delta.
2. Nutrient loads are calculated by multiplying concentration by flow. With the drought conditions experienced in the Nueces Basin since construction of CCR, including a new drought of record, conclusions of the effects of CCR construction on nutrient loadings cannot be made. It can be stated that nutrient loadings at Three Rivers have decreased since 1986, the year in which CCR filled and the year chosen to represent post construction effects on nutrient loadings. However, it can not be concluded that construction or operations of CCR are the sole cause of decreased nutrient loading, when specifically examining the Three Rivers sampling location. Similarly, the changes in nutrient loadings at Three Rivers cannot necessarily be translated to the nutrient loadings into the Nueces Bay.
3. Changes in nutrient loadings from Three Rivers to Mathis vary among parameters. Total phosphorus loads at Three Rivers are slightly less than downstream at Mathis and slightly greater than the EPA ecoregional reference conditions.

   In general, nitrogen species, including TKN, NOx, and TN, loads at Three Rivers are greater than downstream at Mathis and greater than the EPA ecoregional reference conditions. This could indicate nutrient enrichment at Three Rivers and nutrient uptake between Three Rivers and Mathis, most likely from Lake Corpus Christi, although further analysis is necessary to fully characterize the effects of the CCR/LCC System.

   Explanation for these changes is not able to be determined from the nutrient budget analyses completed as part of this study. Potential causes for the changes in nutrient loadings include land use activities (i.e., extensive cultivated crop acreage causing phosphorus enrichment) in the intervening watershed between Three Rivers and Mathis, and the presence of Lake Corpus Christi, which could be acting as a nitrogen sink and providing for additional processing of nitrogen species.

4. This work does not address the relationship between nutrient loadings and ecosystem health or species abundance.

As stated in the Nueces BBASC Work Plan for Adaptive Management (Nueces BBASC, 2012b), there is a need for a "watershed approach to effective management of these resources." Previous nutrient studies in the Nueces watershed have focused on downstream (Nueces Delta) portions of the watershed, and while these are important contributions to Nueces Bay, understanding nutrient contributions from the watershed as a whole is important, as well. As described in the Work Plan, the existing studies have allowed for some broad understanding and a little specific information, but much is still unknown about historical and current nutrient supplies in Nueces Bay and their relationship to the ecological health of Nueces Bay.

Nutrient budgets based on quantitative analysis of compiled existing data has increased understanding of the natural supply of nutrients and anthropogenic changes in these supplies over time for Nueces Bay watershed. To understand nutrient balances and biological productivity in Nueces Bay, nutrient fate and transport in the Nueces Basin must be understood.

Recommendations

Specific recommendations based on the work completed in the study include the following.

- Quantify the effects of seasonality on nutrient loadings. This study showed that adequate data to develop statistically significant relationships are limited. However, for stations where data are available, organizing and analyzing the data around seasonal timeframes could further clarify the watershed-scale nutrient dynamics.
- To better determine sources and sinks of nutrients in the CCR and LCC, a study to measure N-cycling and uptake experiments in the reservoirs is recommended.
- Further quantify the effects of the CCR/LCC System. This study focused on nutrients. It is recommended that the effects of sediment transport, dissolved oxygen, and temperature, for example, on nutrient fate and transport in the downstream portions of the Nueces watershed be better understood. For example, sediment transport is important in relation to phosphorus transport, as phosphorus readily sorbs to sediment. Examining the relationships of these constituents to the nutrient parameters assessed as part of this study could inform decisions regarding operations of the CCR/LCC System, particularly if this analysis was completed in conjunction with the quantification of the effects of seasonality on nutrient loadings.
- To continue the progress of evaluating the nutrient loadings delivered to Nueces Bay, the loadings in the subwatersheds surrounding Nueces Bay could similarly be assessed. For example, the Nueces River Authority Basin Summary Report (Nueces River Authority, 2013a) shows several additional contributions to the Nueces Bay, including several WWTP outfalls. Existing studies have focused on measurement of nutrients in Nueces Bay, not estimation of loads delivered. These load estimates could be completed in addition to the nutrient loading estimations completed for the Nueces watershed in this study. This work could include calculation of the nutrient loads delivered from the contributing wastewater discharges in both the Nueces River tidal (Segment 2101) and Nueces Bay (Segment 2482) subwatersheds, including City of Corpus Christi's Allison WWTP, San Patricio County MUD No. 1, City of Odem WWTP, and City of Portland

WWTP discharges. Nutrient concentration and flow data are available in monthly discharge monitoring reports submitted to TCEQ.

- The Nueces BBASC Work Plan for Adaptive Management includes as Priority #2 evaluating the potential for Allison WWTP effluent to improve environmental health of the Rincon Bayou delta. The nutrient budget study is linked in the Work Plan to the Priority #2 study. With the nutrient loading calculations completed in this study, it would be possible to estimate the loadings available from Allison WWTP given current discharge quantity and quality data. As described in the Work Plan, an evaluation of nutrient loads pre- vs. post-reservoir construction might indicate a change in management decisions on effluent releases to the Nueces Delta and Bay.

Further science-based studies are necessary to develop an integrated, interdisciplinary, and strategic approach to resource planning and decision making regarding the nutrient balance and biological productivity of the Nueces Bay system.

1 Introduction

The primary goals of this nutrient budget study, as described in the Nueces River and Corpus Christi and Baffin Bays Basin and Bay Area Stakeholders Committee Work Plan for Adaptive Management (Nueces BBASC, 2012b) are to:

- Develop nutrient budgets based on quantitative understanding of natural supply of nutrients and anthropogenic changes in these supplies over time for the Nueces Bay watershed and
- Determine annual loads for both the pre-development and present condition.

1.1 Agreement with HDR

HDR Engineering, Inc. (HDR) contracted with the Texas Water Development Board (TWDB) to provide consulting services related to the goals described in the previous section. HDR's services were initiated in June 2014 and included the following:

Task 1 – Data Compilation

- Compile Water Quality and Hydrologic Data

Task 2 – Perform Data Evaluation and Modeling Analyses

- Perform Data Evaluation
- Complete Linear Regression and USGS LOADEST Model Analyses
- Estimate Reservoir Influence Sink/Sources
- Complete Water Quality Correlations to Anthropogenic Changes
- Determine Pre- and Post-Development Loadings

This report describes the methods that were completed during the study effort to achieve the goals and discusses results of the nutrient loading modeling. The report discusses future implications of the study on the Nueces watershed study area with recommendations for additional investigation.

2 Background

2.1 Watershed Description

The Nueces Basin (Figure 2-1) occupies a relatively arid region of Texas, resulting in the third lowest value of average annual watershed yield among major river basins of Texas (TWDB, 2015a). From headwaters in Edwards and Real and Bandera counties, the Nueces River flows to Nueces Bay, which drains to the Gulf of Mexico. The total basin drainage area covers approximately 17,000 square miles, encompassing all or part of 23 counties in South-Central Texas (Nueces River Authority, 2013a). Other streams within the basin include the Leona, Frio, Sabinal and Atascosa Rivers and Seco, Hondo, and San Miguel Creeks. The basin is an important water supply for portions of the San Antonio – Nueces Coastal Basin and the Nueces-Rio Grande Coastal Basin, including the city of Corpus Christi. The Nueces Delta region is characterized by high humidity and summer temperatures, low rainfall, and high wind speeds (Heinsch *et al*., 2004).

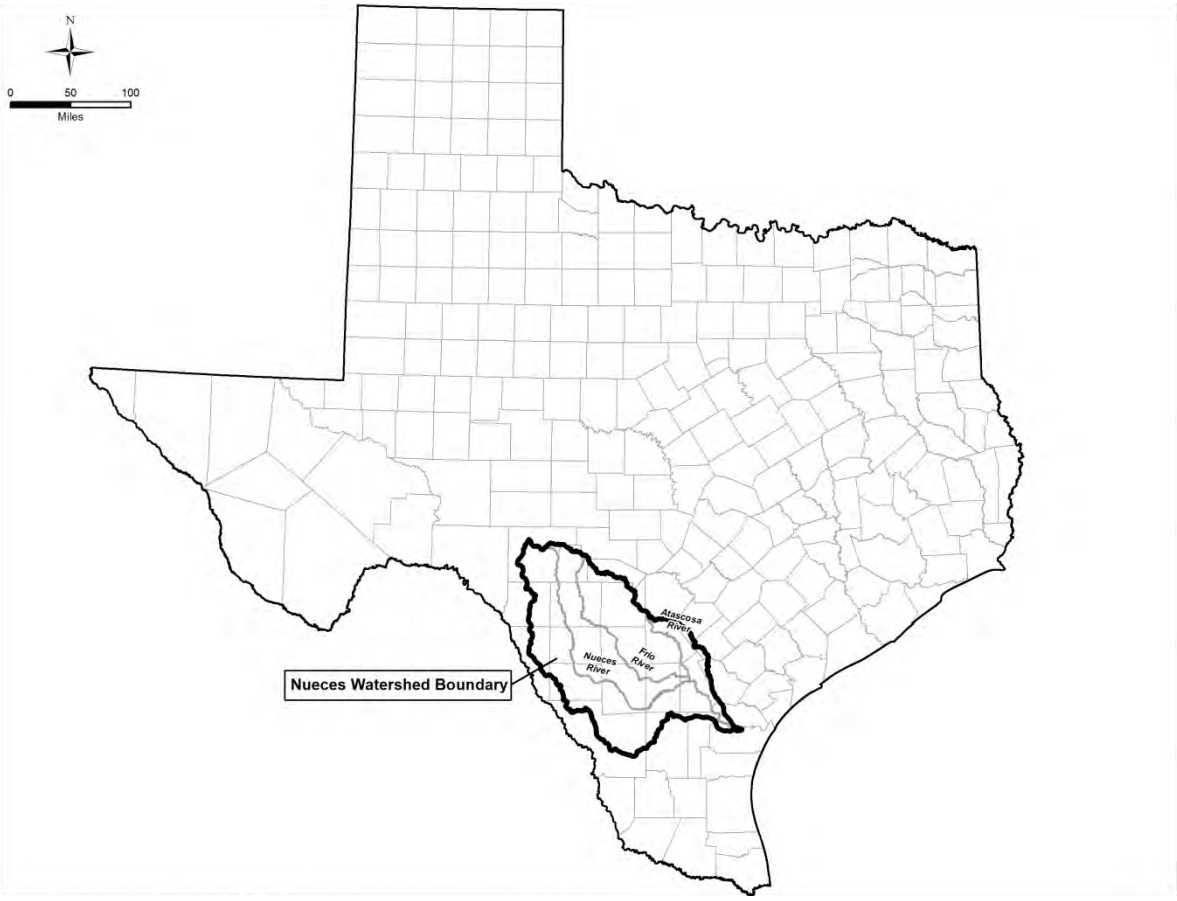

Figure 2-1. Nueces Basin

2.1.1 Nueces Basin Water Quality

The Nueces Basin headwaters located in the Edwards Plateau include several spring fed creeks and the Nueces, Frio, and Sabinal rivers. Very few water quality concerns or impairments exist in this area. As the Nueces and its tributaries flow through the Southern Texas Plains, flows become increasingly dependent on precipitation events to sustain river flows. Soils become finer and sediment loads build increasing turbidity. Salts and other minerals increase in concentration under low stream flow conditions. In times of moderate or extreme drought conditions, flows in the Nueces and Frio rivers may stop completely. Biological communities survive in isolated pools until flows resume. Dissolved oxygen (DO) concentrations can be low, especially in the summer months where high temperatures decrease available oxygen to fish and other aquatic species (Nueces River Authority, 2013a).

The Nueces River Authority works with TCEQ through the Clean Rivers Program (CRP) to characterize water quality in the Nueces Basin. Table 2-1 shows Nueces River Basin water quality concerns and impairments from the 2012 Texas 303(d) List. This list was approved for submission by TCEQ on February 13, 2013. It was submitted to EPA on February 21, 2013 and approved on May 9, 2013 (TCEQ, 2013).

Table 2-1. Nueces River Basin water quality concerns and impairments from 2012 Integrated Report (TCEQ, 2013)

Nueces River Basin Segment ID and Description	Concerns and Impairments
Segment 2101 – Nueces River Tidal	Concerns: chlorophyll-a
Segment 2102 – Nueces River Below Lake Corpus Christi	Concerns: chlorophyll-a
	Impairments: total dissolved solids (TDS)
Segment 2103 – Lake Corpus Christi	Concerns: chlorophyll-a, total phosphorus
	Impairments: TDS
Segment 2104 – Nueces River Above Frio	Concerns: low dissolved oxygen (DO), impaired fish community, impaired macrobenthic community
Segment 2105 – Nueces River Above Holland Dam	Concerns: low DO, chlorophyll-a
	Impairments: low DO
Segment 2106 – Nueces River / Lower Frio	Impairments: TDS
Segment 2107 – Atascosa River	Concerns: low DO, chlorophyll-a, impaired habitat
	Impairments: low DO, bacteria, impaired fish community, impaired macrobenthic community
Segment 2108 – San Miguel River	Impairments: bacteria
Segment 2109 – Leona River	Concerns: nitrates
	Impairments: bacteria
Segment 2110 – Lower Sabinal River	Impairments: nitrates
Segment 2111 – Upper Sabinal River	No concerns or impairments
Segment 2112 – Upper Nueces River	No concerns or impairments
Segment 2113 – Upper Frio River	Concerns: impaired habitat, impaired fish community
	Impairments: impaired macrobenthic community, impaired fish community
Segment 2114 – Hondo Creek	Concerns: nitrates
	Impairments: chloride
Segment 2115 – Seco Creek	No concerns or impairments
Segment 2116 – Choke Canyon Reservoir	Concerns: chlorophyll-a
Segment 2117 – Frio River Above Choke Canyon Reservoir	Concerns: low DO, bacteria, nitrates
	Impairments: bacteria

2.2 Watershed Approach to Nutrient Management

The ecology and health of estuarine ecosystems are significantly affected by nutrient inputs. The United States Environmental Protection Agency (USEPA) has encouraged states to quantitatively address nutrients with the promulgation of numerical criteria for nutrients replacing the current narrative format of the rules. A watershed approach can be an effective management tool for estuarine resources and in assessing productivity. As the *Nueces River and Corpus Christi and Baffin Bays Basin and Bay Area Stakeholder Committee (Nueces BBASC) Work Plan* describes, a fundamental aspect of a watershed approach is acknowledgment that

nutrient loading can be high enough to degrade some aspects of water quality or artificially reduced to levels that can adversely affect ecological productivity.

The Nueces BBASC is requesting that this project be completed to evaluate pre-development and current conditions nutrient budgets, quantify differences between these budgets, assess potential causes of these differences (e.g., reservoir operations, frequent and extended drought periods, etc.), and facilitate consideration of metrics for identification of a desired future condition for estuarine productivity. Once nutrient relationships are identified through the nutrient budgeting process, cost-effective strategies may be developed.

3 Previous Work

3.1 Nueces BBEST Recommendations Report

The 2011 Nueces BBEST Recommendations Report (Nueces River and Corpus Christi and Baffin Bays Basin and Bay Expert Science Team, 2011) was written to address its original charge pursuant to Section §11.02362(m) of the Texas Water Code. The following summary is an excerpt from the 2011 Nueces BBEST Recommendations Report:

> *Each basin and bay expert science team shall develop environmental flow analyses and a recommended environmental flow regime for the river basin and bay system for which the team is established through a collaborative process designed to achieve a consensus. In developing the analyses and recommendations, the science team must consider all reasonably available science, without regard to the need for the water for other uses, and the science team's recommendations must be based solely on the best science available.*

Section 5.2 of the report describes the nutrient considerations related to this responsibility to develop environmental flow analyses and a recommended environmental flow regime. The entirety of this section is included to provide background on the completed project. Figures 5.2.1 through 5.2.6 in the BBEST report are presented in this report as Figure 3-1 through 3-6, respectively.

> *5.2 Nutrient Considerations*
>
> *The Science Advisory Committee in the "Methodology for Establishing Freshwater Inflow Regime for Texas Estuaries" (Science Advisory Committee - 2009-03) charged the BBEST to conduct a nutrient overlay. Below is a summary of the relationship between freshwater inflow and nutrients in the Nueces Bay region.*
>
> *Methods*
>
> *Fourteen stations have been consistently sampled (mostly monthly) since 2001 or earlier by researchers from the University of Texas Marine Science Institute and Texas A&M University-Corpus Christi (see Montagna, et al., 2009; Dunton, et al., 2011; Figure 5.2.1). Physical parameters such as salinity and temperature were measured with a YSI 6920 multiprobe sonde although nutrients and chlorophyll were also sampled. The majority of the nutrient samples were taken by hand and put on ice (< 4.0°C). Water for chlorophyll-a analysis was filtered onto Whatman GF/F 25 mm glass 157 fiber filters and placed on ice. Nutrient samples were filtered to remove biological activity (0.45 µm polycarbonate filters). Chlorophyll-a was extracted overnight and read on a Turner Model 10-AU fluorometer using a non-acidification technique (USEPA, 1997;*

Welschmeyer, 1994). Nutrient analysis was conducted using a LaChat QC 8000 ion analyzer with computer controlled sample selection and peak processing. Nutrients measured were (Quikchem method) nitrate+nitrate (31-107-04-1-A), silicate (31-114-27-1-B), ammonium (31-107-06-5-A) and phosphate (31-115-01-3-A).

Station means (± standard error) of each parameter were compared both spatially and versus salinity, a proxy for inflow effects, to determine effects of inflow spatially. Nueces River flow (USGS station 08211500, Nueces River at Calallen, TX) was compared with nutrient concentrations in the Nueces River below the salt- water dam/weir (station 168H) to determine changes in nutrients over different flow volumes.

Results

As expected, salinity increases down the Nueces River, although reverse estuary conditions occur within Rincon Bayou due to lack of freshwater flows that flow into upper Rincon Bayou (Figure 5.2.1A). Upper Rincon Bayou experiences high concentrations of ammonium (Figure 5.2.1, Figure 5.2.3 and Figure 5.2.5) and chlorophyll (Figure 5.2.2, Figure 5.2.4, and Figure 5.2.6), which can partially be attributed to the low flow rates that occur there. Low flows in the Nueces River also cause stagnation and phytoplankton blooms (high chlorophyll-a concentrations, Figure 5.2.6).

High phosphate concentrations occur in the Nueces River, downstream of the Allison Wastewater Treatment Plant discharge point. Nitrate plus nitrite (Figure 5.2.2, Figure 5.2.4 and Figure 5.2.6), and phosphates (Figure 5.2.1, Figure 5.2.3 and Figure 5.2.5) are higher in Nueces Bay than Rincon Bayou, despite having similar salinities.

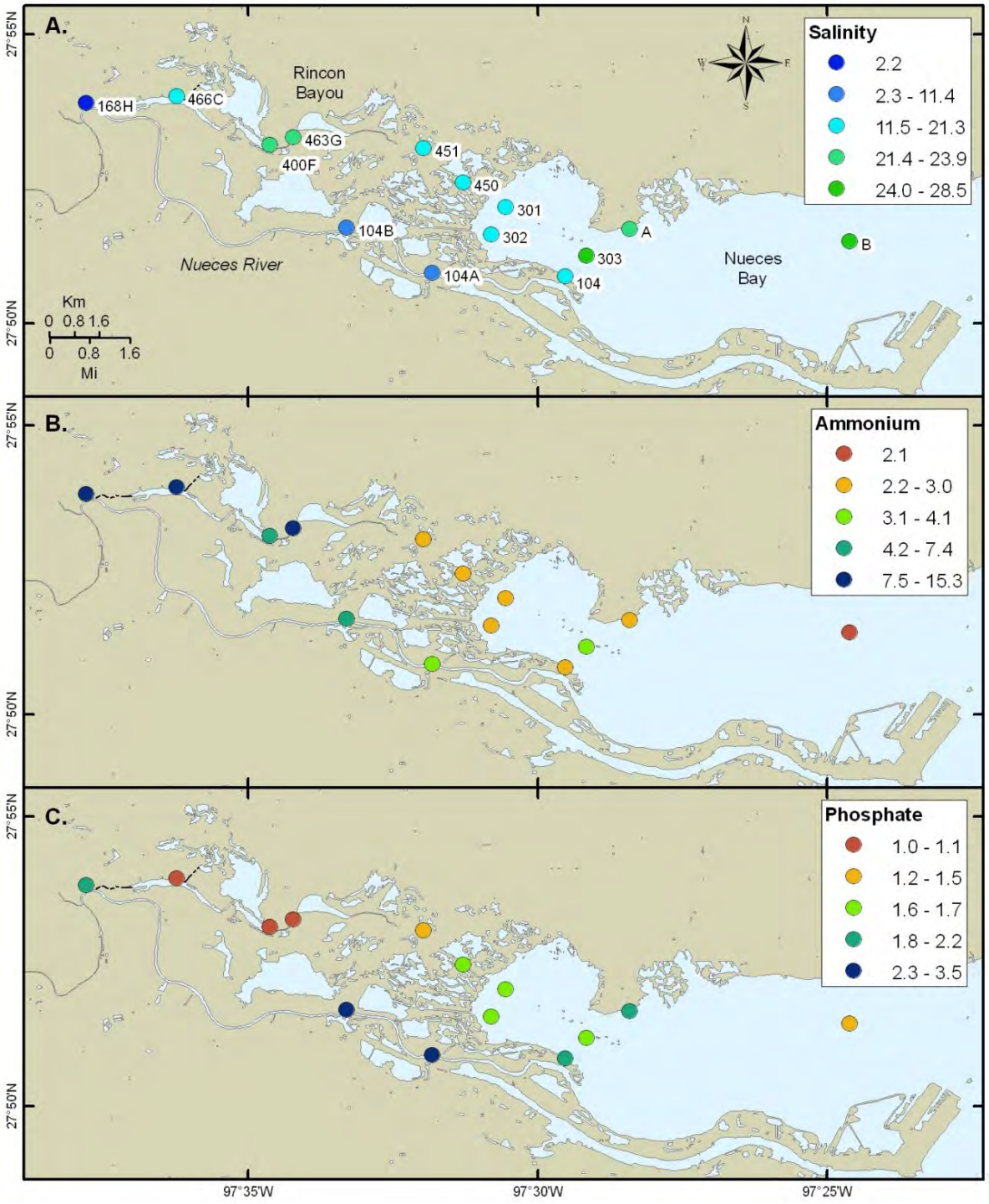

Figure 3-1. Mean salinity (A), ammonium (B) and phosphate (C) concentrations at sampling stations in the upper Nueces Estuary. Except for salinity, all parameters are measured in µM (originally Figure 5.2.1 in report (Nueces River and Corpus Christi and Baffin Bays Basin and Bay Expert Science Team, 2011)).

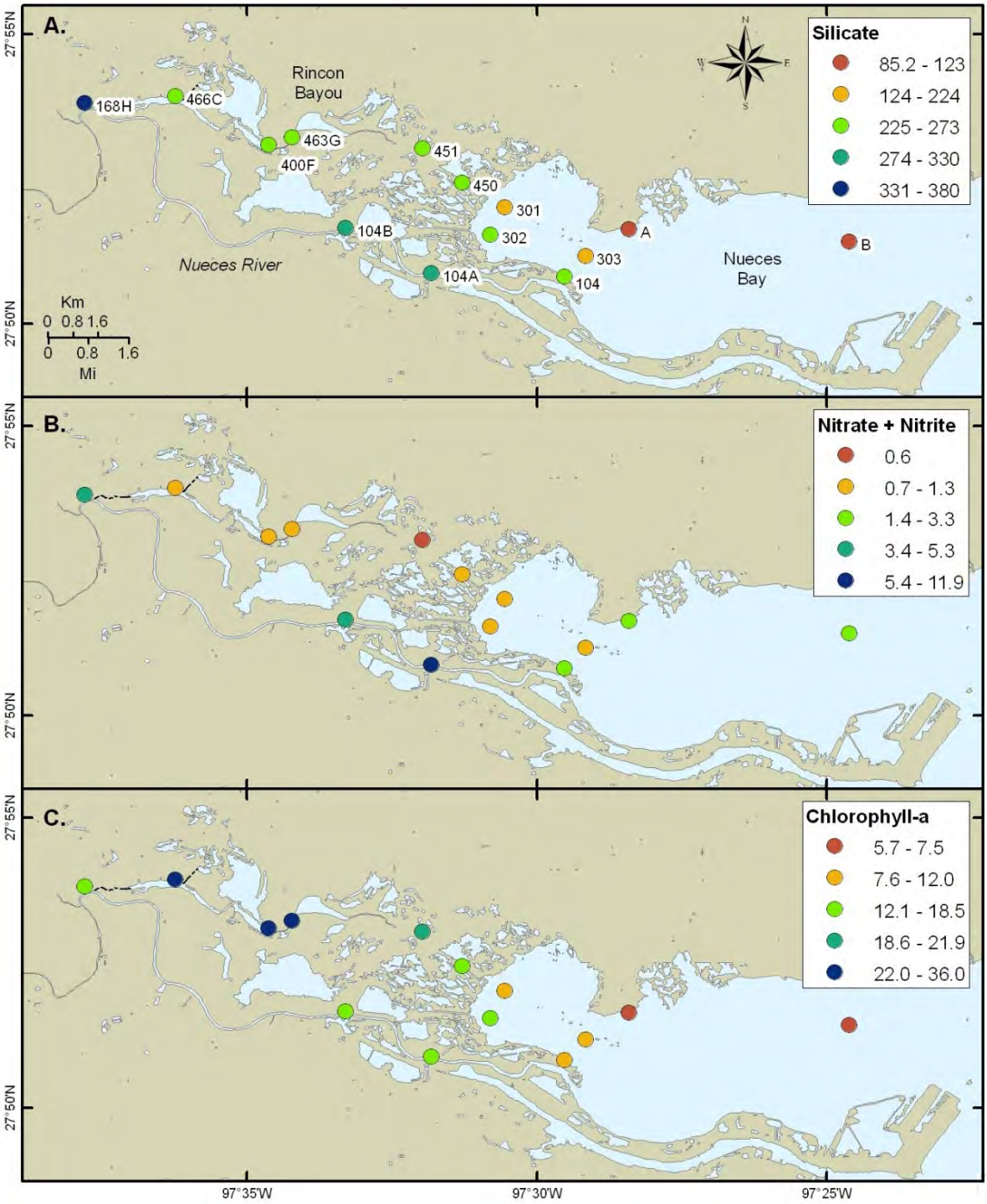

Figure 3-2. Mean silicate (A), nitrate plus nitrite (B) and chlorophyll (C) at sampling stations in the upper Nueces Estuary. All parameters are measured in µM (originally Figure 5.2.2. in report (Nueces River and Corpus Christi and Baffin Bays Basin and Bay Expert Science Team, 2011)).

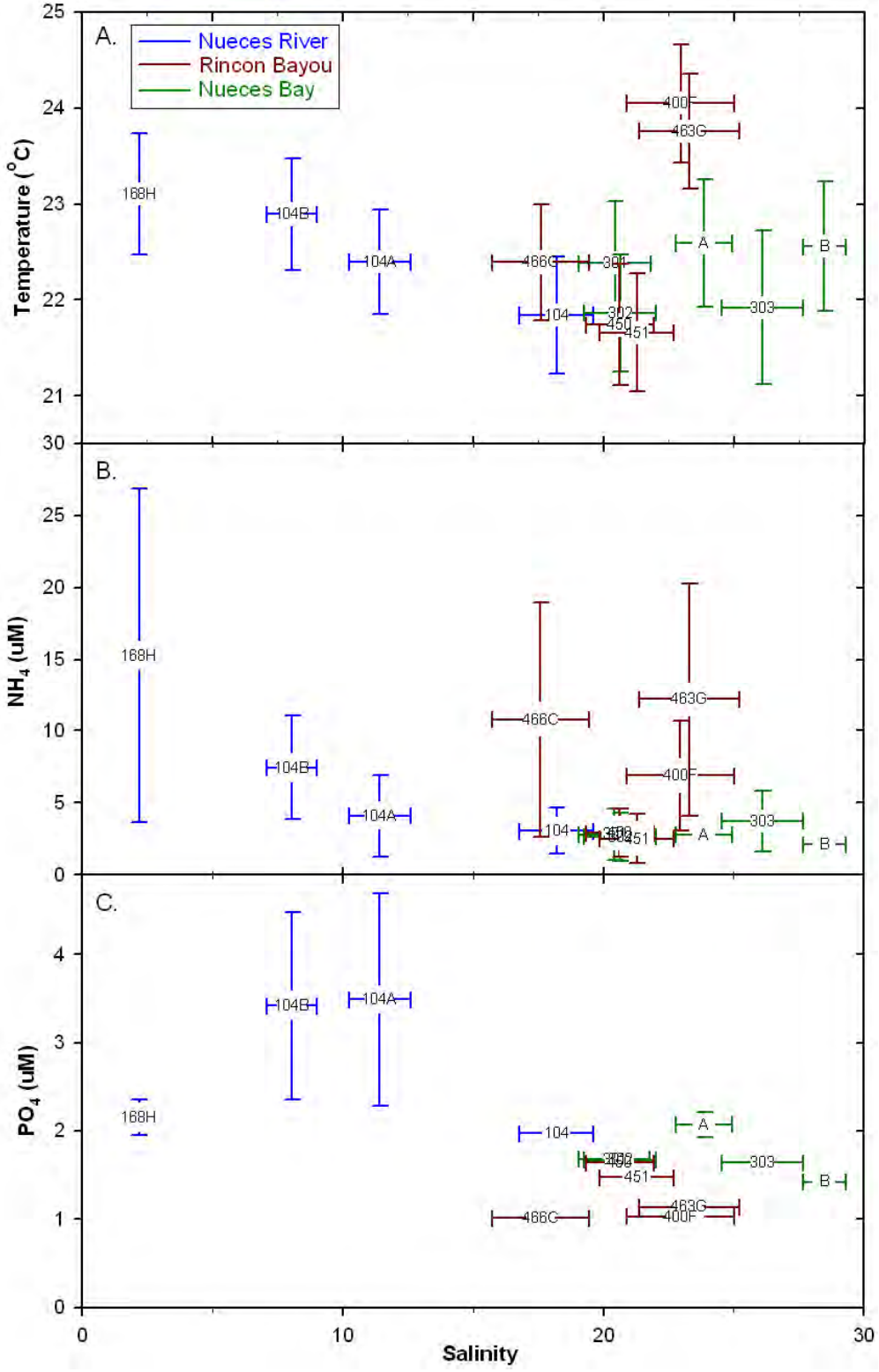

Figure 3-3. Temperature (A), ammonium (B) and phosphate (C) concentrations versus salinity in the upper Nueces Estuary. Each plotted point is the mean and standard error (error bars) of a station. Locations of each station are shown in Figure 3-1 (Figure 5.2.1 in original report) and Figure 3-2 (Figure 5.2.2 in original report) (originally Figure 5.2.3 in report (Nueces River and Corpus Christi and Baffin Bays Basin and Bay Expert Science Team, 2011)).

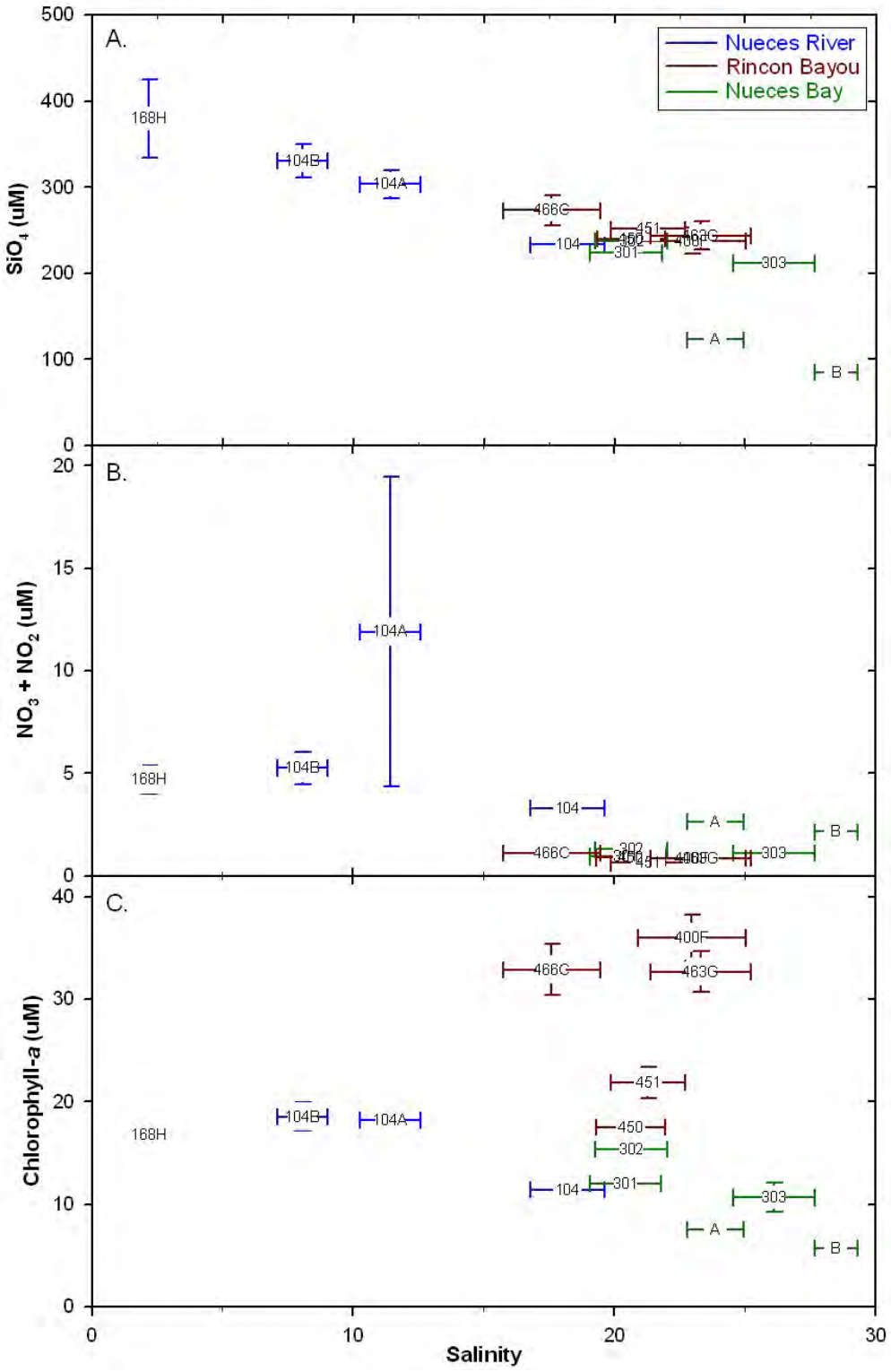

Figure 3-4. Silicate (A), nitrate plus nitrite (B), and chlorophyll (C) concentrations versus salinity in the upper Nueces Estuary. Each plotted point is the mean and standard error (error bars) of a station. Locations of each station are shown in Figure 3-1 (Figure 5.2.1 in original report) and Figure 3-2 (Figure 5.2.2 in original report) (originally Figure 5.2.4. in report (Nueces River and Corpus Christi and Baffin Bays Basin and Bay Expert Science Team, 2011)).

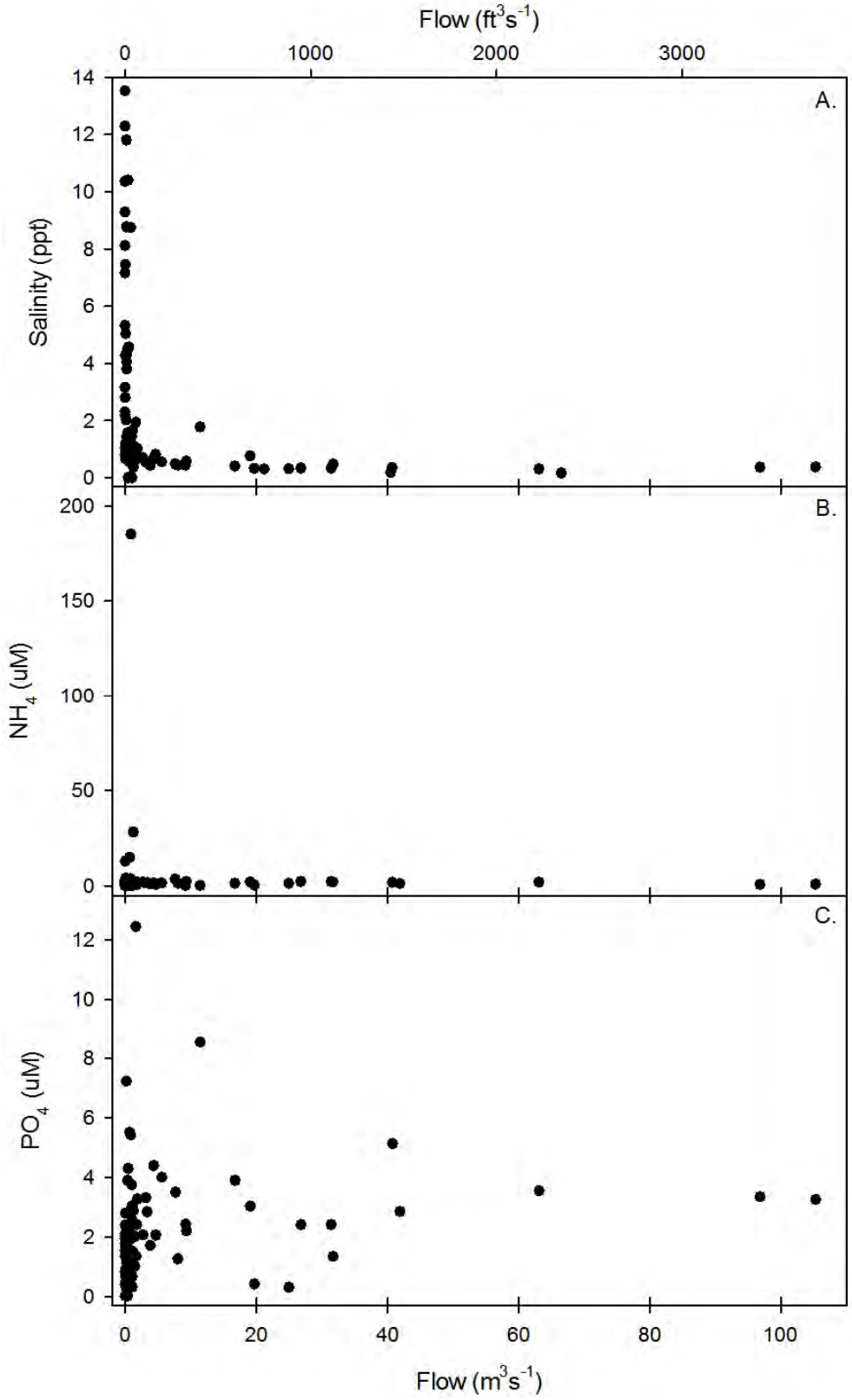

Figure 3-5. Salinity (A), ammonium (B) and phosphate (C) in the Nueces River (station 168H) versus Nueces River flow (Calallen gage) (originally Figure 5.2.5. in report (Nueces River and Corpus Christi and Baffin Bays Basin and Bay Expert Science Team, 2011)).

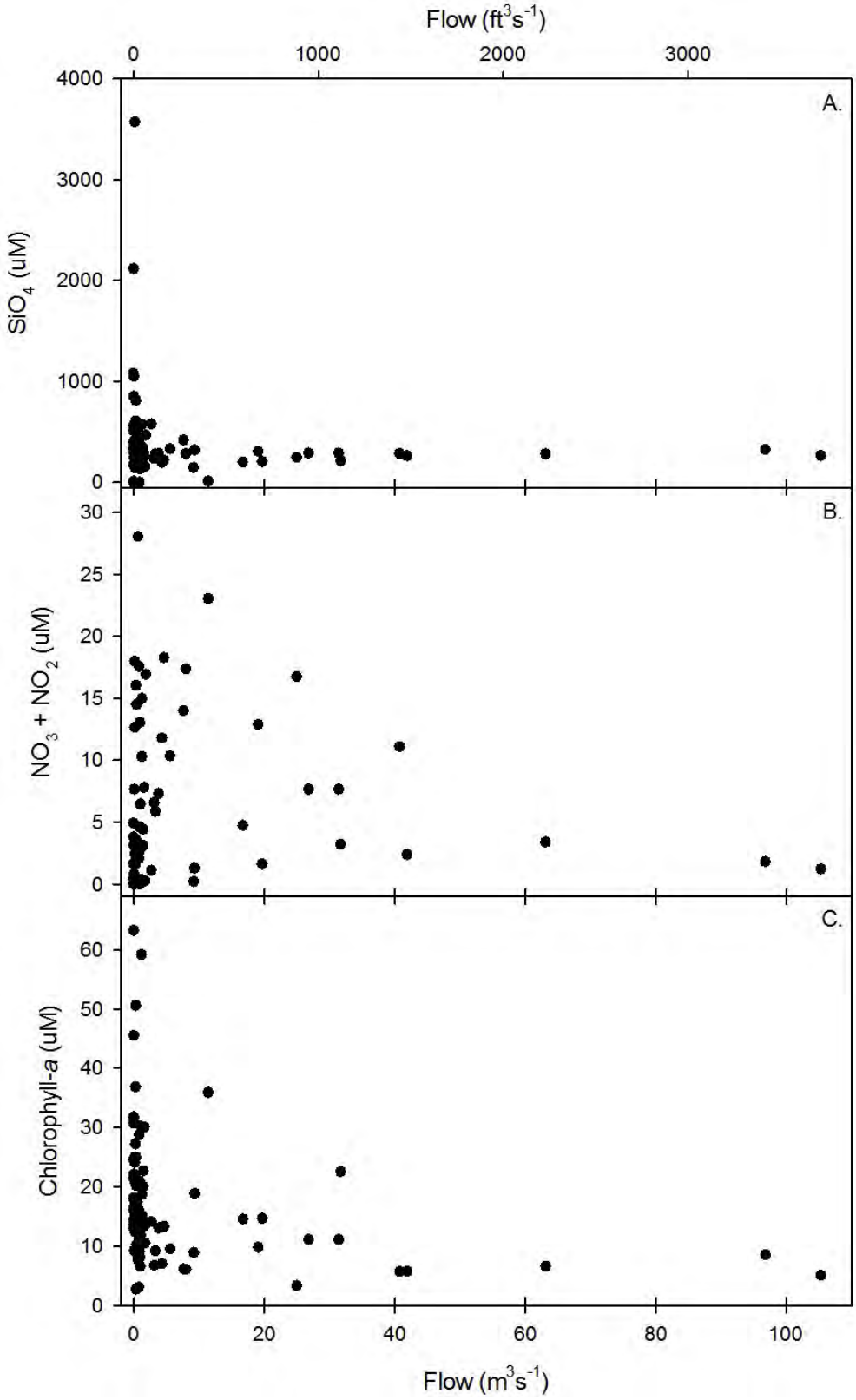

Figure 3-6. Silicate (A), nitrate plus nitrite (B) and chlorophyll (C) in the Nueces River (station 168H) versus Nueces River flow (at Calallen gauge site) (originally Figure 5.2.6. in report (Nueces River and Corpus Christi and Baffin Bays Basin and Bay Expert Science Team, 2011)).

Conclusions

Low flows at the Calallen streamflow gaging station allow water stagnation and phytoplankton blooms to occur within the Nueces River downstream of the saltwater barrier dam. The historical low flows to Rincon Bayou allow ammonium concentrations to increase in Rincon Bayou. The current flow volume that enters the Nueces Estuary from the Nueces River is now so small that the addition of nutrients from the river minimally affects Corpus Christi Bay. Increased flows would increase phosphates in Nueces Bay. Thus, our freshwater inflow recommendations (see Section 4.5) will improve nutrient regulation for the Nueces Bay and Delta.

3.2 Nueces BBASC Recommendations Report

Senate Bill 3 (SB3) passed by the 80th Texas Legislature in 2007 instituted a process for development and implementation of environmental flow standards for river and estuary systems in Texas. The Nueces River and Corpus Christi and Baffin Bays system was identified as a priority basin and bay system. The Nueces Basin and Bay Area Stakeholder Committee (BBASC) produced a report of recommendations. According to the Texas Water Code, "the Texas Commission on Environmental Quality (TCEQ) considers the BBEST recommendations, BBASC recommendations, and other factors including economic factors and human, as well as other competing needs for water in adopting environmental flow standards" (TWC Section 11.471(b)).

Section 4.2 of the 2012 BBASC Recommendations Report (Nueces River and Corpus Christi and Baffin Bay Basin and Bay Area Stakeholder Committee, 2012a) describes the nutrient considerations related to this responsibility to develop environmental flow analyses and a recommended environmental flow regime. The entirety of this section is included to provide background on the completed project.

Sec. 4.3.2 Nutrient Considerations

4.3.2 Sediment and Nutrient Considerations

4.3.2.1 Instream Geomorphic (Sediment Transport) Analysis

The TWDB, on behalf of the Nueces BBASC, analyzed changes in sediment transport that might occur in the Nueces basin with changes in flow patterns under different hypothetical water development project scenarios. The TWDB report of its analysis is included in Appendix L with a technical presentation included in Appendix J that was given to the BBASC. Analyzes were conducted for the Nueces River at Laguna, at Cotulla, and at Three Rivers. These analyses generally indicate how changes in flow due to hypothetical projects may affect sediment movement with a comparison of historical conditions and Nueces BBEST flow recommendations. These results were also used by the Nueces BBASC to make decisions on modifying the Nueces BBEST instream flow recommendations to meet human water needs.

A more detailed review of these results and decisions can be found in the Analysis Performed for the Nueces BBASC Section 3.3 of this report.

4.3.2.2 Nueces Bay and Delta Analysis

The Nueces BBASC acknowledges the importance of both sediment and nutrient loads transported by rivers and streams to the water quality in estuaries and bays and the health of these coastal ecosystems. The Nueces BBASC recognizes the issues raised by the Nueces BBEST that the Nueces River is the most significant source of sediment and nutrients to Nueces Bay and Delta. Below is a discussion on the importance of each constituent from the perspective of the Nueces BBASC.

Sediment

The Nueces BBEST described previous studies showing that Lake Corpus Christi is trapping 97% of the sediment transported by the Nueces River, the major source of flows and sediments into Nueces Bay. This is sediment that before the construction of Wesley E. Seale Dam and impoundment of water in Lake Corpus Christi would have reached the Nueces Estuary. The Nueces BBEST summarized the latest studies by Ockerman and Heitmuller 2010 which also suggest that current sediment supply to the Nueces Bay has been significantly reduced. The Nueces BBASC generally agrees with the Nueces BBEST that, due to Lake Corpus Christi's location of less than 50 miles from the mouth of Nueces Bay, and the fact that it effectively traps most of the sediment being transported by the Nueces River, instream flow recommendations made by the Nueces BBEST in the geomorphic overlay for upland river reaches are not likely to provide the necessary sediment inflows to maintain existing river deltas and tidal channels in the tidal marshes and subtidal environments.

The Nueces BBASC also agrees that overbanking events are beneficial for the ecological function of the river, bay, and delta, but the Nueces BBASC is not recommending the obligation of permit conditions to protect overbanking flows, rather that these types of events will occur naturally during storm events. Several factors influencing this decision include: 1) the reservoirs are not currently designed to release enough water needed to flow out of the banks of the river; 2) human development currently exists along the banks of the river; and 3) the quantity of water needed to create an overbanking event typically only occurs during natural storm events.

While sediment load downstream of Lake Corpus Christi has appeared to decrease, detailed impacts, benefits, deficiencies or needs associated with these reduced sediment loads have not been clearly defined by existing studies. Future considerations might include investigations that address spatial extent or location of impact (e.g., in the vicinity of the dam, along the Nueces River between the dam and the estuary, near the City of Corpus Christi water supply intake, and/or within the Nueces Delta) and should also address magnitude and character of sediment needs (i.e. daily or annual volumes of particular sediment grain size classes). Other studies may relate sediment loads to ecological needs, which may be species-specific and may include marsh maintenance, in-stream turbidity/clarity, and in-stream habitat including channel bed characteristics.

However, the Nueces BBEST did not attempt to quantify the sediment loadings necessary to maintain current bay and delta conditions. The Nueces BBASC agrees that this should be a major item of study included in the adaptive management section of this report.

Nutrients

The Nueces BBEST briefly described the relationship between freshwater inflow and nutrients in the Nueces River below the Calallen Dam. The data used in a study to explain the relationships came from fourteen monitoring stations that have been consistently sampled (mostly monthly) since 2001. Data showed that low flow (approx. 10 m3s-1, 700 acft d-1) in the Nueces River below Calallen Dam causes stagnation and phytoplankton blooms (high chlorophyll-a concentrations).

As noted by the Nueces BBEST, nutrients are needed to sustain life and that excess nutrient loads from human activities may cause unbalanced and unhealthy changes in water quality that are harmful to aquatic organisms. Based on the limited nutrient data available, the Stakeholder Committee would like there to be ongoing studies designed to help characterize both sediment and nutrient load transported into Nueces Bay as related to localized periods of high flow and releases of water from reservoirs upstream in the watershed. Consistent with our approach for sediment loadings, the Stakeholder Committee has acknowledged the importance of nutrients but has not recommended any specific restrictions on diversion or impoundment based on nutrient loading.

3.3 Nueces BBASC Work Plan for Adaptive Management

In 2012 after publication of the Nueces BBASC Recommendations Report, the Nueces BBASC published the Work Plan for Adaptive Management (Nueces River and Corpus Christi and Baffin Bays Basin and Bay Area Stakeholders Committee, 2012b). As part of Senate Bill 3 (SB3) of the 80th Texas Legislature, the Nueces BBASC was directed to develop a Work Plan to be submitted to the Environmental Flows Advisory Group (EFAG) for approval. Section 11.02362(p) states:

In recognition of the importance of adaptive management, after submitting its recommendations regarding environmental flow standards and strategies to meet the environmental flow standards to the commission, each basin and bay area stakeholders committee, with the assistance of the pertinent basin and bay expert science team, shall prepare and submit for approval by the advisory group a work plan. The work plan must:

(1) establish a periodic review of the basin and bay environmental flow analyses and environmental flow regime recommendations, environmental flow standards, and strategies, to occur at least once every 10 years;
(2) prescribe specific monitoring, studies, and activities; and
(3) establish a schedule for continuing the validation or refinement of the basin and bay environmental flow analyses and environmental flow regime recommendations, the environmental flow standards adopted by the commission, and the strategies to achieve those standards.

In the Work Plan, studies were prioritized. Tier 1 included studies that were most critical. Tier 2 included the development of pre- and post-development nutrient budgets. An excerpt from the Work Plan describing this study is included below. Figure 4 as referenced in the BBASC report is presented as Figure 3-7 in this report.

Tier 2b Recommendation

Nueces watershed pre- and post-development nutrient budgets

What: Develop a nutrient budget for both pre- and post-development for the Nueces watershed.

Why: Nutrient inputs to coastal waters are an important element in the ecology and health of estuarine ecosystems. EPA has been encouraging states to address nutrients in a quantitative manner, and particularly favors establishment of numerical criteria for nutrients. The Nueces BBASC agrees that there is certainly a potential for nutrient levels to affect aquatic plants and biological resources and believes there is a need for a watershed approach to effective management of these resources. A fundamental aspect of this approach is recognition that not only can nutrient loading be high enough to degrade some aspects of water quality but that nutrient loading may also have been artificially reduced to levels that adversely affect ecological productivity. Management means first identifying problems resulting from nutrient loading that is too high or too low for a particular resource. Once problems are identified, there is a need to formulate cost-effective strategies to solving the problems.

Figure 4 shows trends in chlorophyll a data in the Texas Coastal Bend area. The data indicate a probable decrease in chlorophyll a concentration in Nueces Bay and a possible decrease in much of Corpus Christi Bay since the early 1970s. During this period there was considerable population growth and increase in wastewater nutrient loads. But there was also navigation channel deepening, upstream reservoir development (Choke Canyon was completed in 1982), and diversion of a small part of the municipal wastewater flow from the Nueces River to the delta. The net effect has been a probable reduction in primary productivity in Nueces Bay.

The overall situation is that while we have some broad understanding and a little specific information, there is much we do not know about both historical and current nutrient supplies in Nueces Bay and their relationship to ecological health of the bay. EPA is correct--there is a need to address nutrients. What is needed is a quantitative understanding of historical or natural supplies of all nutrient forms, along with anthropogenic changes in these supplies, in order to facilitate building consensus on a desired future condition in terms of chlorophyll a and other measures of estuarine productivity. When we have consensus on a goal, we can formulate appropriate management measures for nutrients. This will probably require some level of quantitative analysis or modeling to quantify the effects of various measures.

Where: Lower Nueces River to Nueces Bay and Delta.

How: It would be possible to produce nutrient budgets for the Nueces watershed for both the present and pre-development condition. We have an extensive network of stream gauges and monitoring data, and workable estimates can be made of the nutrients contained in macro-detritus that has not been measured in a systematic fashion. Having annual loads for both the pre-development and present condition would provide a strong indication of trends and potential problems. While the data exist to perform that type of analysis, it would require some effort and expense.

When: Nutrient data compilation could begin as soon as funds become available, allowing 1 year to analyze data and develop a pre-development and post-development nutrient budget for the Nueces system.

Who: USGS, TCEQ, Harte Research Institute for Gulf of Mexico Studies (HRI), CBBEP, and technical consultants.

Cost: To be refined, likely to range between $50,000 to $100,000.

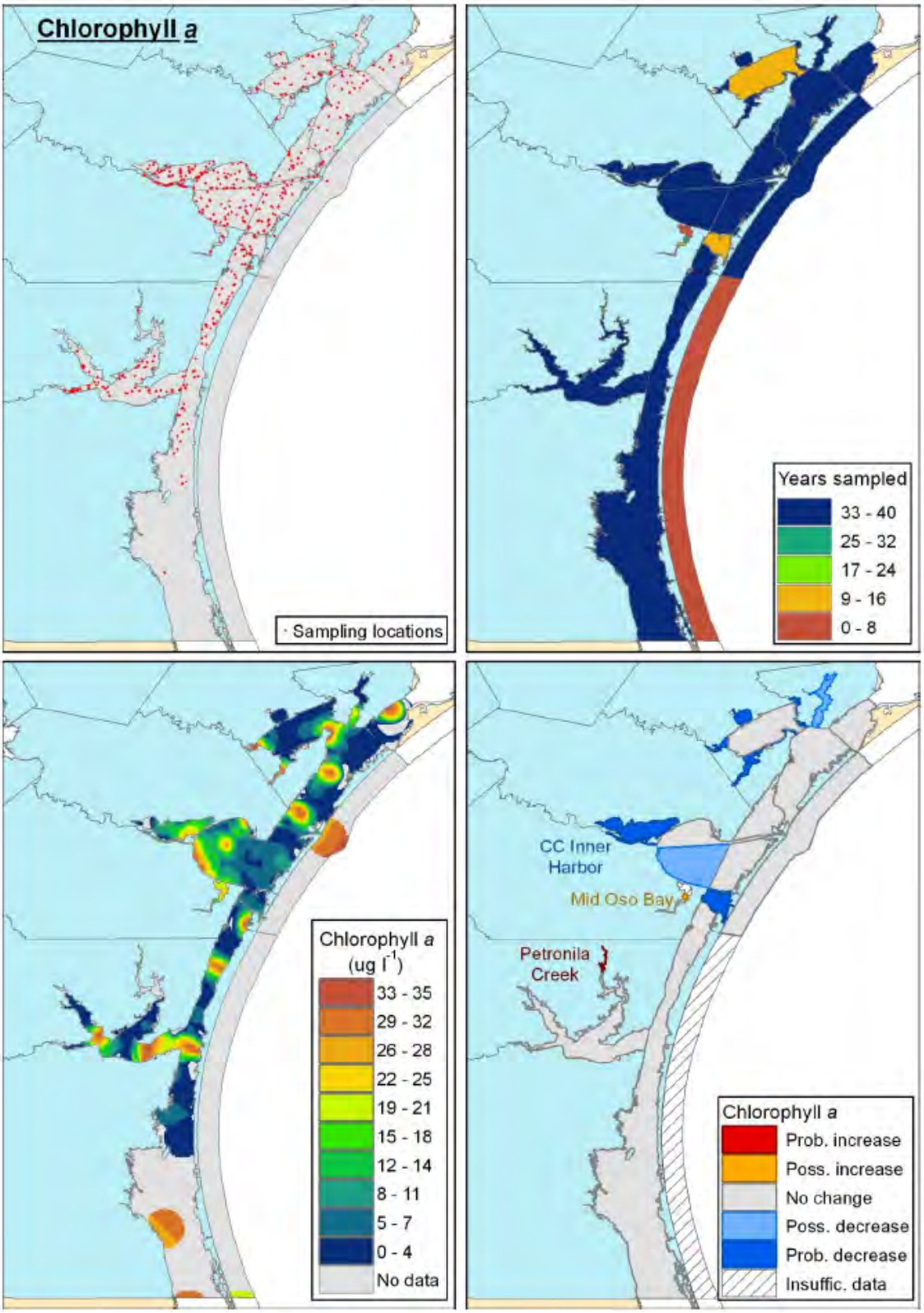

Figure 3-7. Spatio-temporal patterns of chlorophyll-a concentrations in CBBEP waters. (Montagna and Palmer, 2012) (originally Figure 4 in report).

4 Project Organization

Previous studies of nutrients in the Nueces Watershed have focused on the downstream portion of the basin and the delta area. This study analyzes nutrients concentrations and associated loadings from the entire Nueces watershed. This section describes the study approach, as well as stakeholder input during the project.

4.1 Approach

Project work was divided into two major tasks: Data compilation and evaluation, and modeling analyses. One project hypotheses included being able to develop nutrient budgets with existing data, including but not limited to water quality, streamflow, and land use data. Another hypothesis was that adequate data would be available to develop statistically significant relationships between measured streamflow and nutrient concentrations in the Nueces Watershed so that nutrients loadings could be calculated.

First data were compiled and evaluated. The objective was to evaluate pre- and post-development nutrient conditions in the Nueces Watershed as well as to address the impact of the construction of Choke Canyon Reservoir. HDR performed the data evaluation and modeling analysis using available flow and nutrient data from existing TCEQ and USGS water monitoring locations. An in-house data analysis package was used for linear regression analyses and compared to a USGS modeling tool.

Results of the regression analyses were analyzed and compared to population centers, including locations of wastewater treatment plants (WWTPs), which are considered to be nutrient sources to streamflow, and to land use / land cover data. The subsequent sections describe work completed during the study.

4.2 Stakeholder Interaction

Study objectives and results were presented at stakeholder meetings and workshops in Corpus Christi. The first meeting occurred on June 16, 2014, to the Nueces Estuary Advisory Committee (NEAC) in Corpus Christi, TX. This meeting focused presenting the scope of the project and the goals of the project. Input was solicited and received from stakeholders on their perception of desired outcomes. The presentation from this meeting can be found in Appendix A.

Two subsequent meetings were attended to present preliminary results to the NEAC. The first meeting on October 20, 2014, coincided with a regularly scheduled NEAC meeting and included attendees from TCEQ, Coastal Bend Bays and Estuaries Program (CBBEP), Nueces River Authority, Sherwin Alumina, Texas Water Development Board (TWDB), Port of Corpus Christi Authority, Center for Coastal Studies, Harte Research Institute (HRI), City of Corpus Christi, Texas Parks and Wildlife Department (TPWD), and the South Texas Water Authority, among others. The study presentation from this meeting can be found in Appendix A. This presentation focused on data collection efforts and description of outlier analysis.

A second results meeting occurred on February 23, 2015, at a regularly scheduled NEAC meeting in Corpus Christi. The meeting included attendees from CBBEP, Nueces River Authority, TWDB, TCEQ, Port of Corpus Christi Authority, Center for Coastal Studies, HRI, City of Corpus Christi, Naismith Engineering, RPS Group, and the South Texas Water Authority, and others. The study presentation from this meeting can be found in Appendix A.

The presentation for this meeting focused on explaining the preliminary results for Task 1 including preliminary results of the LOADEST modeling and land use analysis.

A third meeting occurred on June 22, 2015, at a regularly scheduled NEAC meeting in Corpus Christi. The meeting included attendees from CBBEP, Nueces River Authority, TWDB, TCEQ, Port of Corpus Christi Authority, Center for Coastal Studies, HRI, City of Corpus Christi, Naismith Engineering, RPS Group, and others. The study presentation from this meeting can be found in Appendix A. The presentation for this meeting focused on explaining the results of the study to attendees.

Stakeholders also had the opportunity to review the draft report. These comments were submitted to the TWDB. The TWDB Executive Administrator's draft report comments are located in Appendix F.

5 Data Compilation

Numerous sets of data were compiled for the study. Data included but was not limited to water quality, streamflow, and land use data. Sources of data included TCEQ, USGS, Clean Rivers Program (CRP) monitoring reports by the Nueces River Authority, and data previously collected or compiled by the HRI. Land use and population data were compiled to support the regression analyses.

Water quality data included nutrients and response variables chlorophyll *a*, nitrogen and phosphorus species from numerous sources. In addition, historical water use data from the City of Corpus Christi were compiled. Measured nutrient observations were not associated with the data.

Macrodetritus data were described as one of the potential data in the Nueces BBASC's Work Plan for Adaptive Management. An attempt to compile this data type was made. However, no macrodetritus data were located. Texas Department of Water Resources (1979) discusses the potential effects of detritus deposited in salt marshes by floods, their conversion by primary producers into nutrients, and the transportation of nutrients to a bay system, but the report does not contain macrodetritus data.

Periphyton, or benthic algae, was described as a potential source of data to identify where nutrient uptake may be occurring in the watershed. However, no periphyton observational data was located.

5.1 TCEQ Data

Through the Surface Water Quality Monitoring Information System (SWQMIS) database, the TCEQ has water quality data available for the state of Texas. The information available includes data that were collected under a TCEQ-approved quality assurance project plan (QAPP) and met the requirements of NELAP (National Environmental Laboratory Accreditation Program, July 2008) for select laboratory analyses. Texas water quality data are available from as early as January 1, 1968, in the TCEQ database.

5.1.1 Nueces Watershed

Through the Storage and Retrieval (STORET) database, the TCEQ has water quality data available for the Nueces watershed. Data are available from September 1968 to the present for the Nueces watershed.

Water quality data are available in the STORET database for numerous stations in the study area. Figure 5-1 depicts surface water quality monitoring stations in the Nueces watershed.

Appendix B1 shows time series figures of water quality constituents related to nutrients for the Nueces watershed, which is classified as Basin 21 by TCEQ. The figures are organized by TCEQ stream segment identification numbers, which begin with "21" and have a two-digit identifier following the basin identifier. Time series of numerous water quality constituents related to nutrients were completed to gain an understanding of the availability of data on both temporal and spatial scales.

5.1.2 San Antonio – Nueces Coastal and Nueces – Rio Grande Coastal Watersheds

Data for the neighboring San Antonio – Nueces Coastal and Nueces – Rio Grande Coastal watersheds were compiled. One of the initial hypotheses for the study was that one or both of these basins could be a useful surrogate for a pre-development scenario, as both are relatively less developed than the Nueces watershed.

Appendix B2 shows time series figures of water quality constituents related to nutrients for the San Antonio – Nueces Coastal watershed, which is classified as Basin 20 by TCEQ. The figures are organized by TCEQ stream segment identification numbers, which begin with "20" and have a two-digit identifier following the basin identifier. The primary rivers in this watershed are the Mission and Aransas rivers. Time series of numerous water quality constituents related to nutrients were completed to gain an understanding of the availability of data on both temporal and spatial scales. Figure 5-2 shows surface water quality monitoring stations in the San Antonio – Nueces Coastal watershed.

Appendix B3 shows time series figures of water quality constituents related to nutrients for the Nueces – Rio Grande Coastal watershed, which is classified as Basin 22 by TCEQ. The figures are organized by TCEQ stream segment identification numbers, which begin with "22" and have a two-digit identifier following the basin identifier. The primary streams in this watershed are the Oso, Petronila Creek, and San Fernando Creeks. Time series of numerous water quality constituents related to nutrients were completed to gain an understanding of the availability of data on both temporal and spatial scales. Figure 5-3 shows the surface water quality monitoring stations in the Nueces – Rio Grande Coastal watershed.

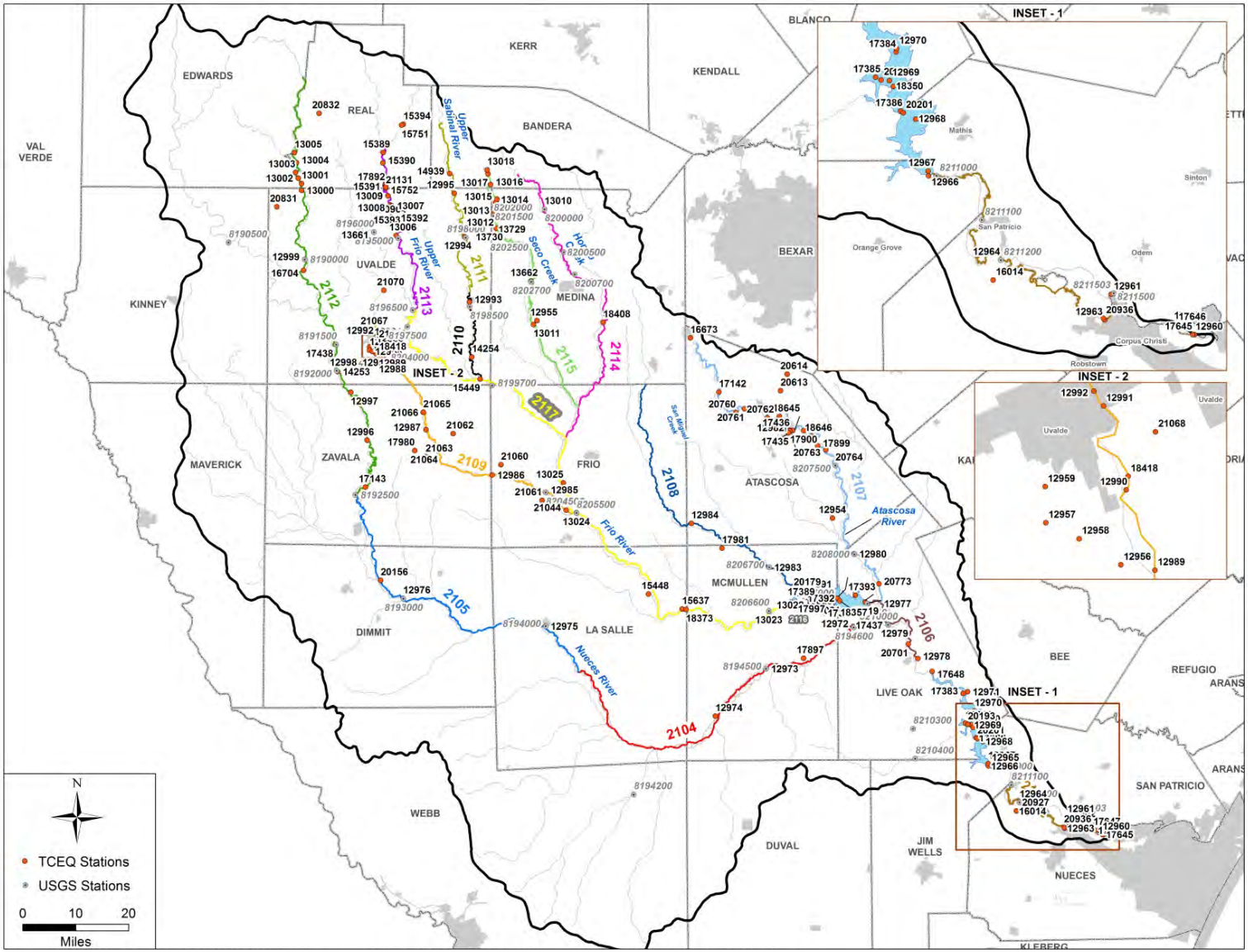

Figure 5-1. Surface water quality monitoring stations in the Nueces watershed labeled by TCEQ stream segment identification number. The varied segment colors represent distinct stream segments.

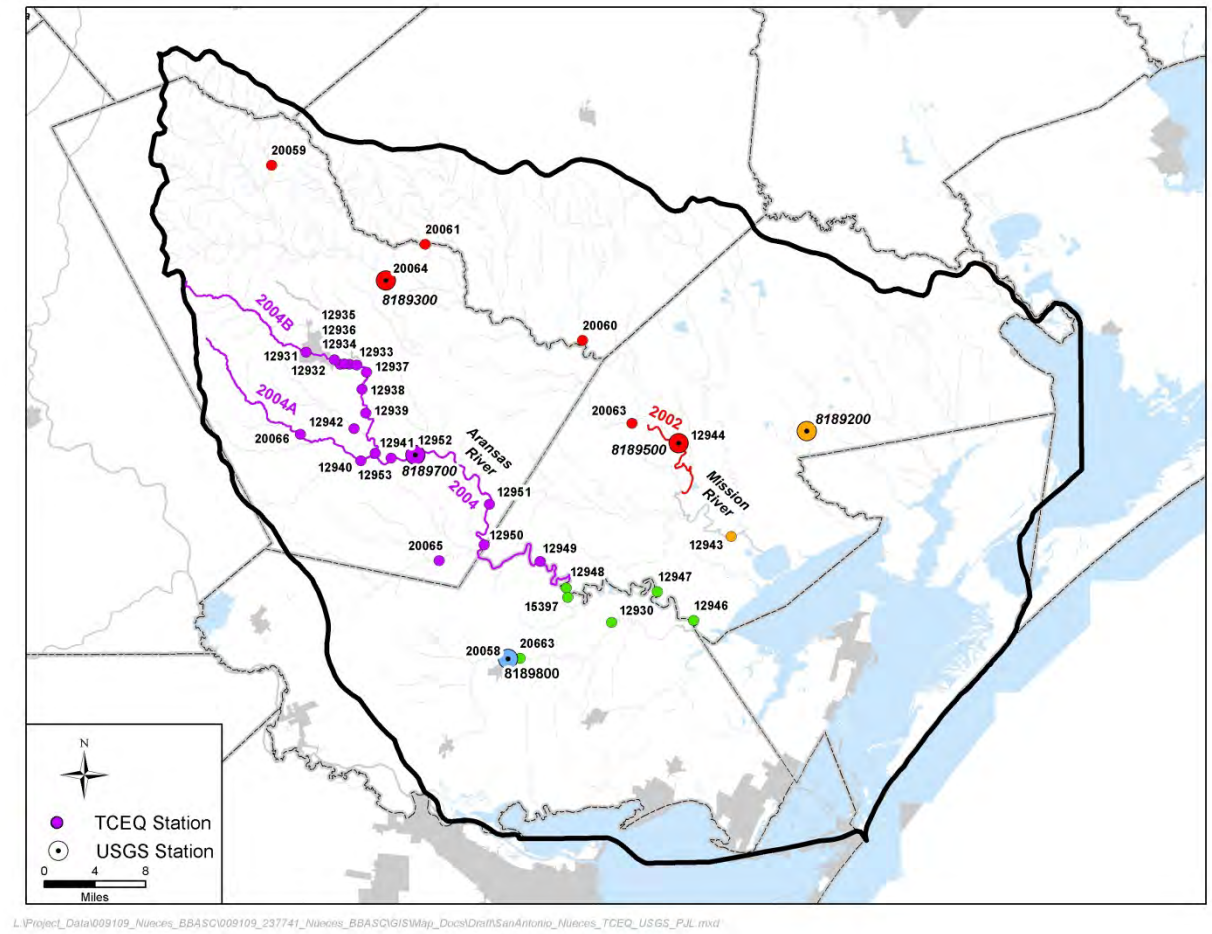

Figure 5-2. Surface water quality monitoring stations in the San Antonio – Nueces Coastal watershed labeled by TCEQ stream segment identification number. The varied segment colors represent distinct stream segments.

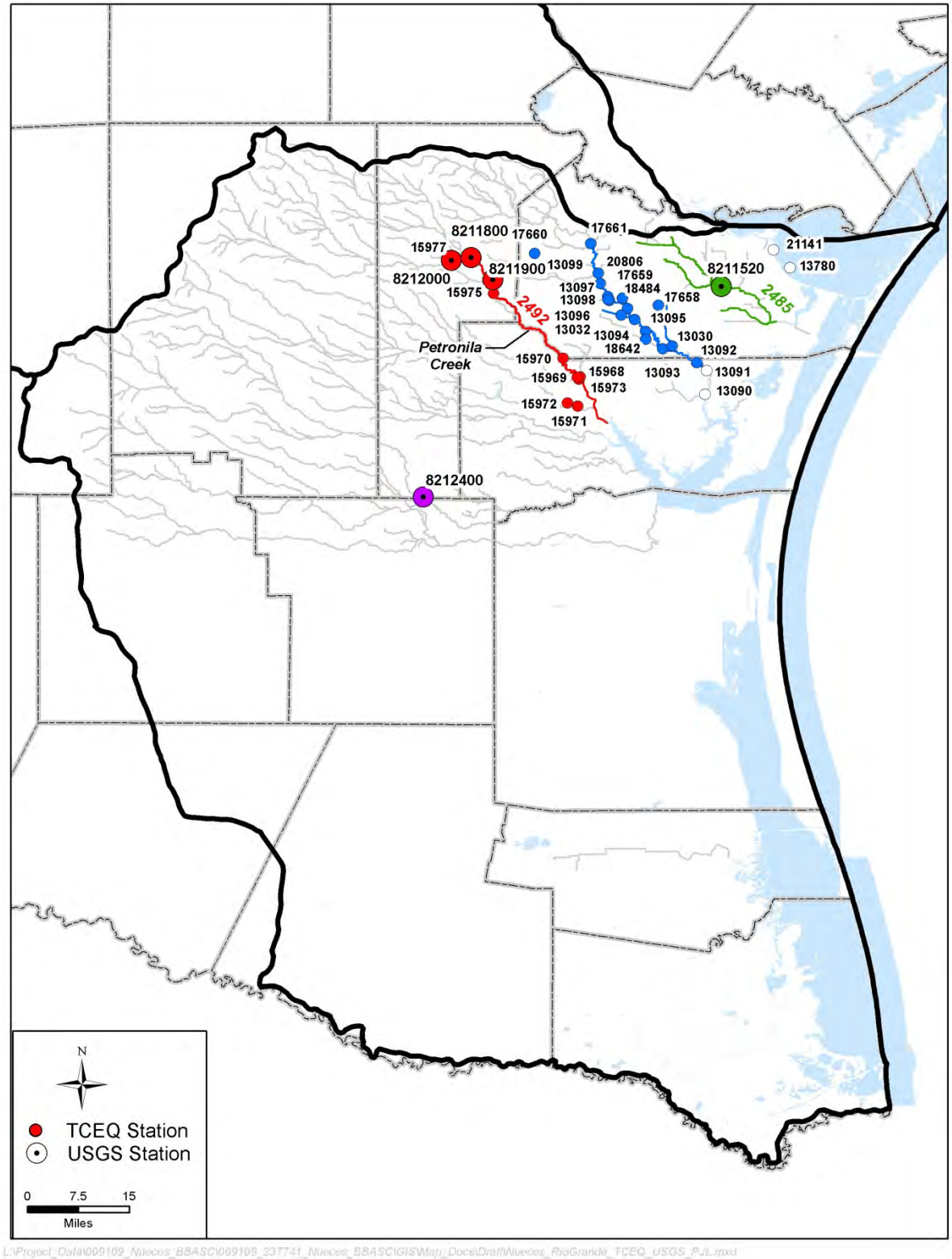

Figure 5-3. Surface water quality monitoring stations in the Nueces – Rio Grande Coastal watershed labeled by TCEQ stream segment identification number. The varied segment colors represent distinct stream segments.

5.2 USGS Data

United States Geological Survey (USGS) maintains water quality and streamflow data for the Nueces, San Antonio – Nueces Coastal, and Nueces – Rio Grande Coastal watersheds. Figures 5-1, 5-2, 5-3 show the USGS gaging stations within each watershed.

The USGS included data that predated the availability of TCEQ, which begins in 1968. However, this water quality data did not include instantaneous flow measurements, which are necessary for calculating load. It was determined that this sparse data available before 1968 could not be used with the constituent concentration data values that did not instantaneous flow values associated with them. Appendix C shows the nutrient data available before 1968.

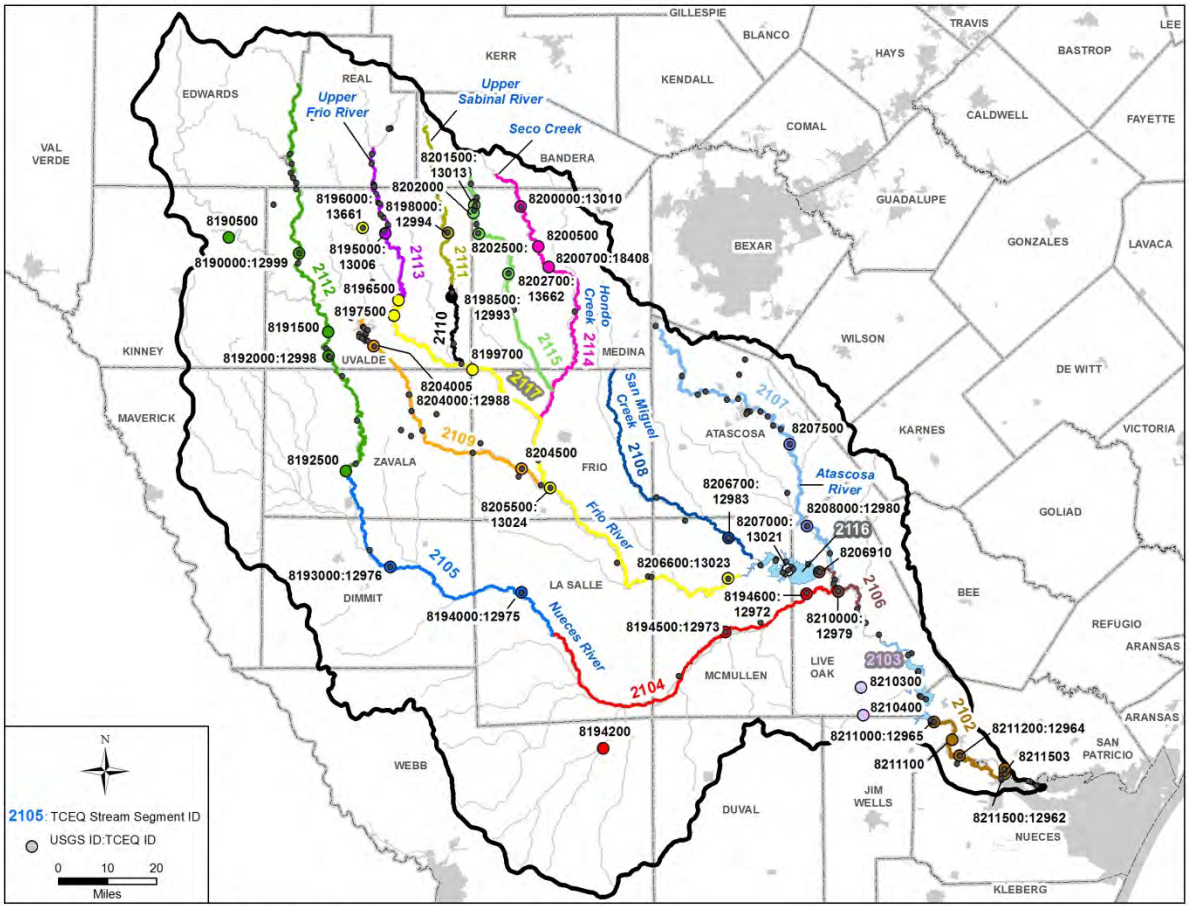

Figure 5-4. USGS gaging stations in the Nueces watershed.

5.3 Land Use

Land use / land cover data were compiled for years 1992 and 2011 with the goal of being able to compare land use changes through time for the Nueces watershed. The earliest year that national landcover data are available is 1992. The 1992 National Land Cover Dataset (NLCD 1992) is a 21-class land cover classification scheme applied across the lower 48 United States at a 30-meters spatial resolution (Vogelmann *et al.*, 2001). According to the dataset developers, the 1992 dataset is based primarily on the unsupervised classification of Landsat Thematic Mapper (TM) circa 1990's satellite data. Other data sources used to generate these data included topography,

census, and agricultural statistics, soil characteristics, and other types of land cover and wetland maps.

National Land Cover Database 2001 (NLCD 2001) is a 16-class land cover classification scheme applied across the 50 United States and Puerto Rico at a spatial resolution of 30 meters (Homer *et al.*, 2007). According to the dataset developers, NLCD 2001 is based primarily on a decision-tree classification of circa 2001 Landsat satellite data.

National Land Cover Database 2006 (NLCD 2006) is a 16-class land cover classification scheme applied across the conterminous United States at a spatial resolution of 30 meters (Fry *et al.*, 2011). According to the dataset developers, NLCD 2006 is based primarily on a decision-tree classification of circa 2006 Landsat satellite data.

The 2011 National Land Cover Database (NLCD 2011) is the most recent national land cover data developed by the Multi-Resolution Land Characteristics (MRLC) Consortium (Homer *et al.*, 2015). NLCD 2011 uses the same 16-class land cover classification scheme that has been applied consistently across the United States at a spatial resolution of 30 meters. According to the developers of the data, NLCD 2011 is based primarily on a decision-tree classification of circa 2011 Landsat satellite data.

Figures 5-5 through 5-8 show the NLCD land cover data for 1992, 2001, 2006, and 2011, respectively. The data are useful for comparing land use changes. However, the temporal range of data (from 1992 to 2011) does not extend far enough into the past to capture changes that occurred before development. Although the NLCD does not extend as far back as the water quality data, alternatively, population data from the mid-1960s to current shows similar trends in development of the watershed that are discussed in Section 6. It is important to note that the method for determining land cover in 1992 is different than the method used in determining land cover in 2001, 2006, and 2011. This explains why the land cover in 1992 (Figure 5-5) shows, for example, more evergreen forest cover in the upstream portions of the Nueces Basin than the land cover data for 2001, 2006, and 2011 (Figure 5-6 through 5-8).

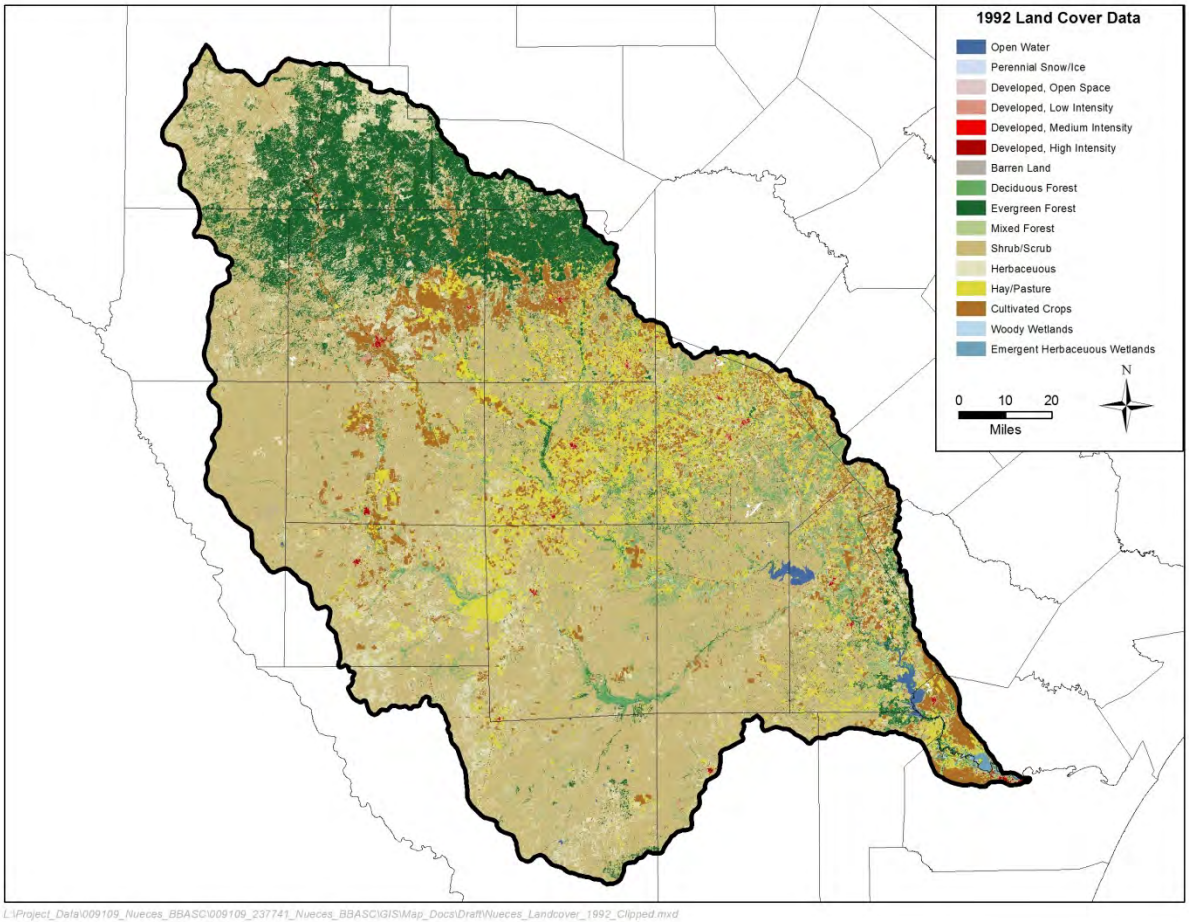

Figure 5-5. 1992 National Land Cover Dataset for the Nueces watershed

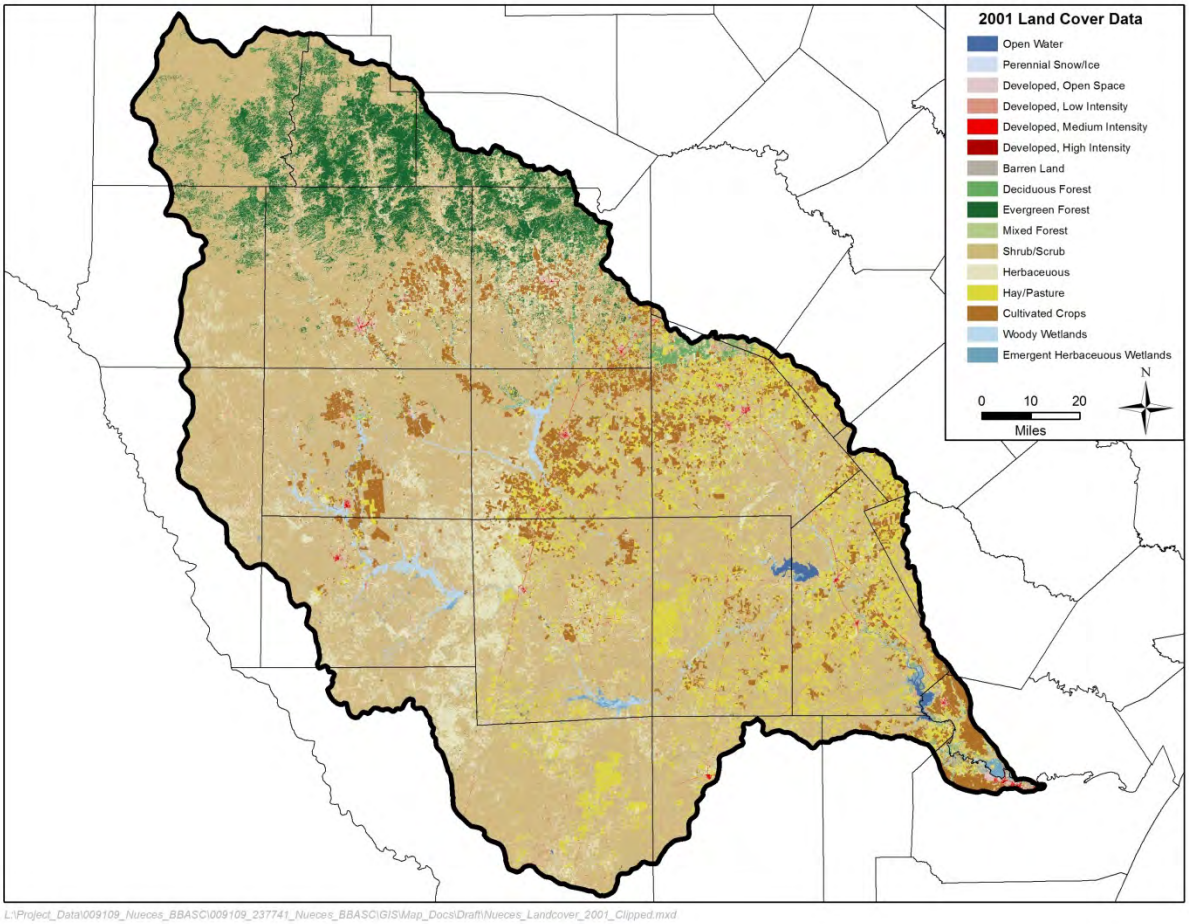

Figure 5-6. 2001 National Land Cover Dataset for the Nueces watershed

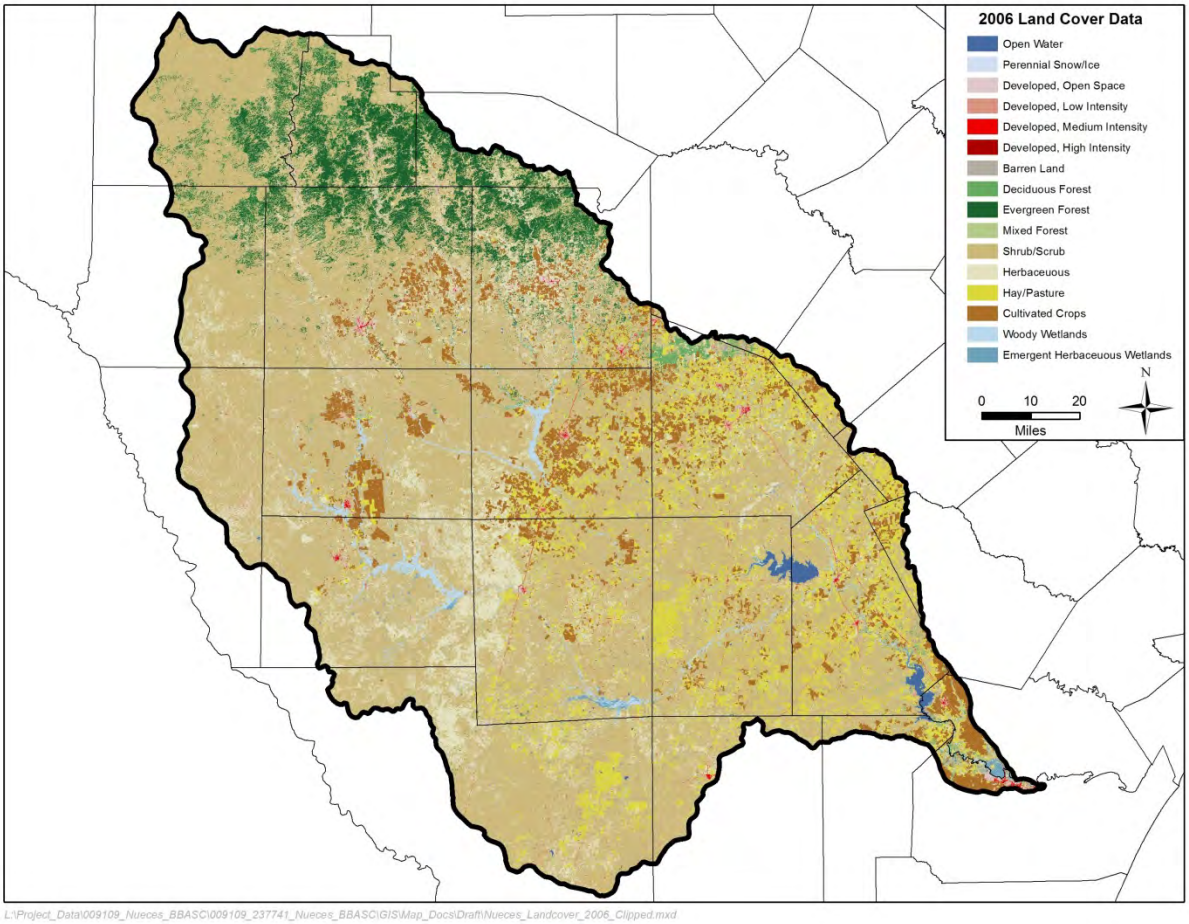

Figure 5-7. 2006 National Land Cover Dataset for the Nueces watershed

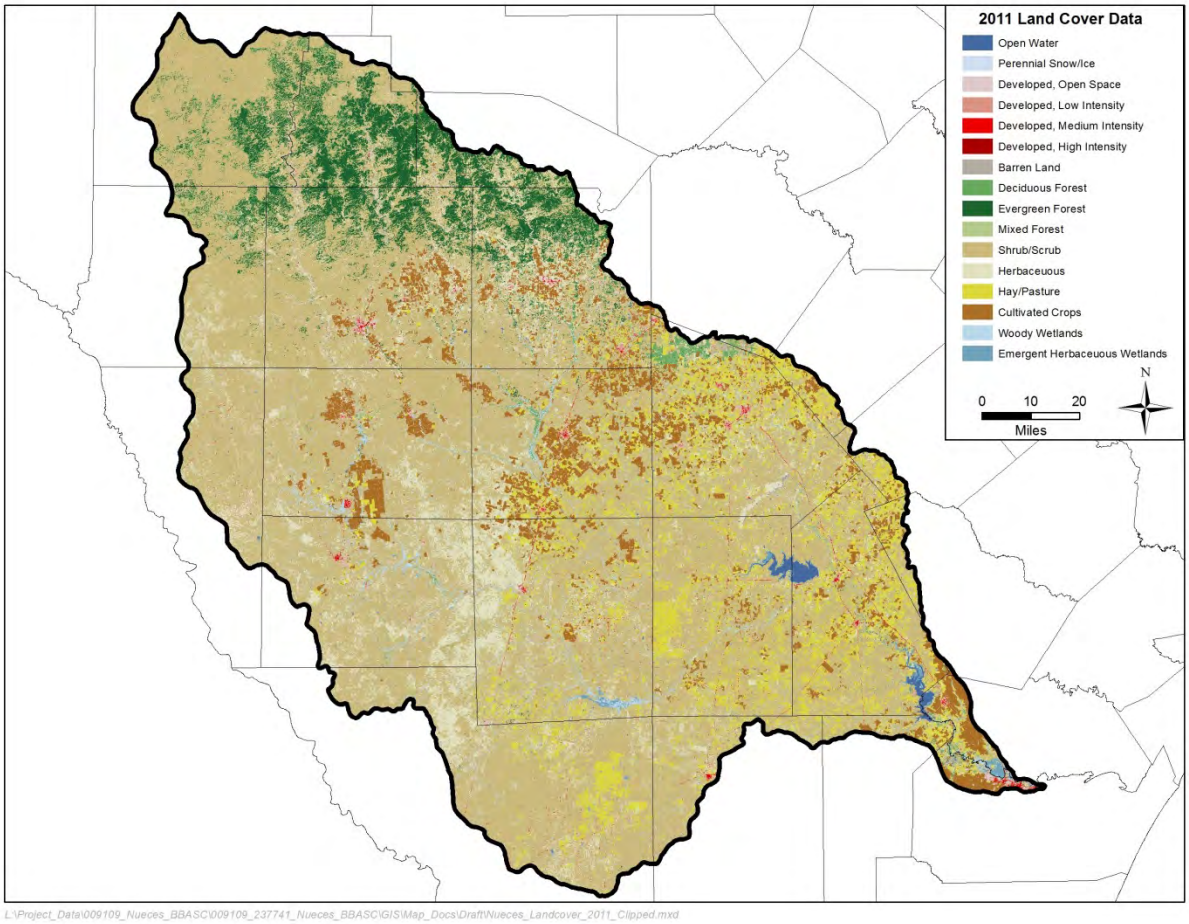

Figure 5-8. 2011 National Land Cover Dataset for the Nueces watershed

5.4 Wastewater Treatment Plant Outfalls

Wastewater treatment plant (WWTP) outfall locations were compiled from TCEQ TPDES data, the Nueces River Authority Basin Summary Report (Nueces River Authority, 2013a), and the 2016 Coastal Bend (Region N) Regional Water Plan Initially Prepared Plan[2] (HDR and Coastal Bend Regional Water Planning Group, 2015). Figure 5-9 shows the location of effluent (wastewater) discharge locations within the Nueces watershed.

WWTP outfall locations were compiled, as they are a known and quantifiable source of nutrients to the Nueces watershed. Nonpoint sources loadings across the watershed were considered only in the evaluation of land use / land cover.

The 2013 Effluent Monitoring Report (Nueces River Authority, 2013b) compiled by the Nueces River Authority (NRA) shows that City of Corpus Christi discharges about 4,600 acft/yr from

[2] Table 5D.5.1 Summary of Annual Permitted Wastewater Discharges for 2012 and 2013 into the Corpus Christi Bay and Nueces Bay System from HDR Engineering and Coastal Bend Regional Water Planning Group, "Coastal Bend Regional Water Planning Area- Executive Summary and Initially Prepared Plan," May 2015.

Broadway WWTP, 12,000 acft/yr from Oso WWTP, 5,700 acft/yr from Greenwood WWTP, and 3,000 acft/yr from Allison WWTP. Several heavy industrial and oil and gas refining company discharges are larger discharges. However, these types of discharges typically do not have a significant nutrient component. In addition, many discharge directly into ship channel and/or Corpus Christi Bay, not affecting watershed calculations.

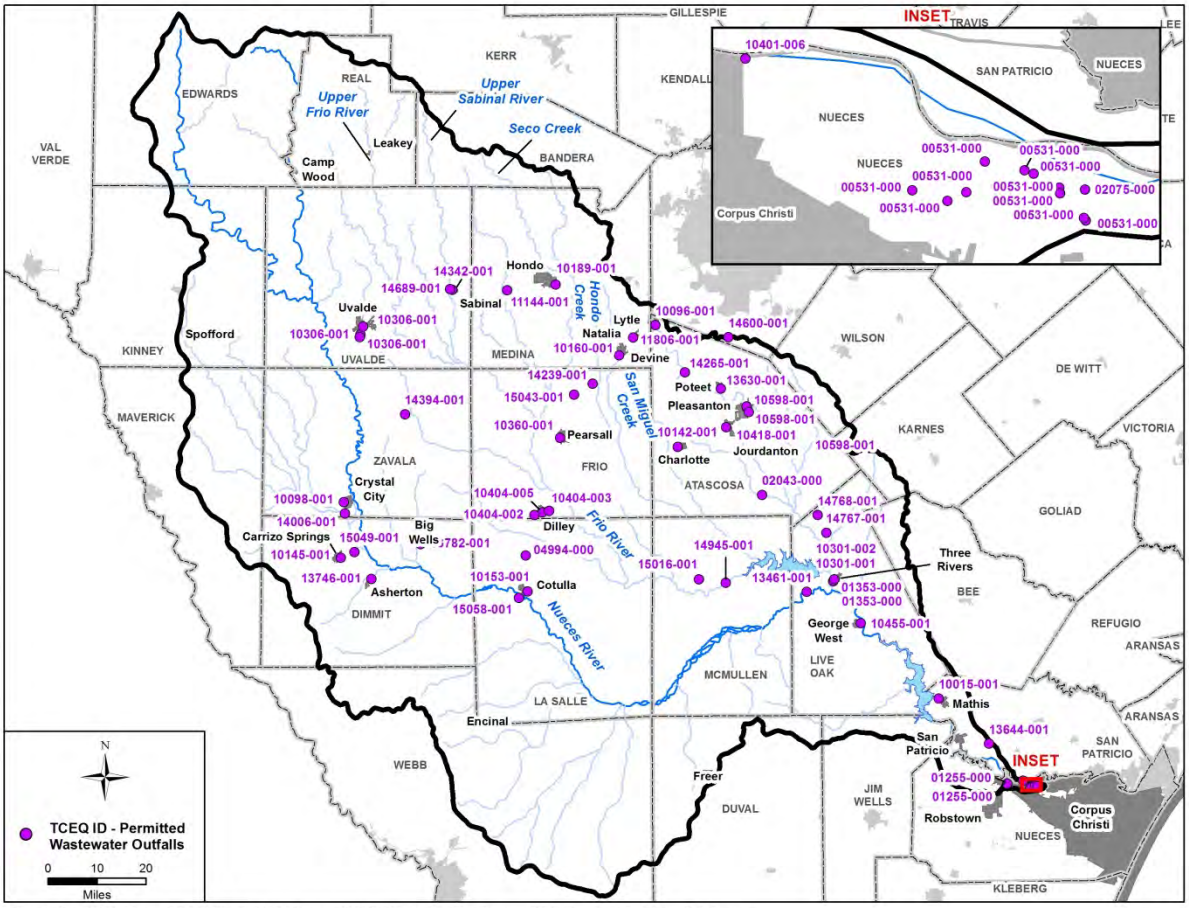

Figure 5-9. Effluent (wastewater) discharge locations within the Nueces watershed

5.4.1 Discharges into Corpus Christi Bay System

Of additional concern and related to this study are discharges into the Corpus Christi Bay System. According to the Initially Prepared 2016 Coastal Bend (Region N) Water Plan, there are 62 active, permitted domestic and industrial WWTP discharges that discharge to the Corpus Christi Bay System in the 11-county Coastal Bend Region. These domestic and industrial discharges totaled about 96,065 ac-ft in 2012 and 88,018 ac-ft in 2013 based on annual discharges summarized in the TCEQ and Nueces River Authority's 2013 Effluent Monitoring Report (Table 5-1).

The 2001 Agreed Order assumes return flows of 54,000 ac-ft/yr to Corpus Christi Bay and other receiving estuaries excluding Nueces Bay and/or the Nueces Delta. A credit of 6,000 ac-ft/yr is provided for return flows delivered to Nueces Bay. Treated wastewater effluent volume exceeding this amount is potentially eligible for recovery and reuse, prior to releasing as return flow.

Figure 5-10 shows the locations of the City of Corpus Christi WWTPs, which are the major municipal discharges into the system. In 2013, of the 88,018 ac-ft discharged, major municipal/domestic discharges generated about 51,090 ac-ft/yr (58 percent), while industrial discharges generated about 36,928 ac-ft/yr (42 percent).

Table 5-1. Summary of Annual Permitted Wastewater Discharges for 2012 and 2013 into the Corpus Christi Bay and Nueces Bay System [1,2]

Facility	2012 Discharge (ac-ft/yr)	2013 Discharge (ac-ft/yr)
Town of Woodsboro	127.30	139.24
City of Sinton	398.22	391.74
Texas Department of Transportation	1.85	N/A
Rob & Bessie Welder Park	6.91	4.73
St. Paul WSC	20.22	23.32
Citgo Refining and Chemicals	4,781.94	1,891.69
City of Corpus Christi - Allison	3,012.11	3,006.28
San Patricio County MUD #1	15.78	17.77
City of Agua Dulce	26.74	24.31
City of Orange Grove	142.99	148.44
City of Driscoll	41.77	54.91
Nueces County WCID #5	522.59	16.94
Bishop CISD	1.74	0.95
LCS Nueces Detention Facility	79.40	82.15
City of Rockport	1,044.80	859.84
Holiday Beach WSC	44.43	40.29
City of Taft	295.55	295.26
Town of Bayside	12.97	2.73
E.I. Du Pont De Nemours and Co.	13,863.59	9,758.11
U.S. Department of the Navy - Corpus Christi NAS	526.83	369.31
Occidental Chemical Corp.	1,389.25	1,395.45
Texas A&M University System Shrimp Mariculture Research	51.64	164.70
City of Gregory	103.73	99.55
City of Ingleside	781.25	746.69
Nueces County WCID #4 Mustang Island North Plant	1,027.43	1,109.56
City of Odem	156.49	172.87
City of Portland	1,637.74	1,632.92
Sublight Enterprises, Inc.	1.64	N/A
City of Aransas Pass	202.16	234.19
Gulf Marine Fabricators	7.63	7.43
Martin Operating Partnership LP	0.67	N/A
American Chrome and Chemicals	5,134.86	5,802.44
Flint Hills Resources	1,146.72	1,098.29
Valero Refining, East Plant	1,702.77	1,638.48

Facility	2012 Discharge (ac-ft/yr)	2013 Discharge (ac-ft/yr)
Citgo Refining and Chemicals	2,813.71	2,835.28
Citgo Refining and Chemicals	18,230.05	9,187.91
Valero Refining, Texas LP	4,109.65	3,768.35
Equistar Chemicals, LP	1,198.09	915.76
Trigeant Ltd.	23.65	24.24
Markwest Company	0.00	0.00
John Bludworth Shipward	753.82	640.39
City of Corpus Christi - Broadway	4,641.69	4,433.62
City of Corpus Christi - Oso	12,127.32	12,552.36
City of Robstown	1,253.64	1,344.17
City of Corpus Christi - Greenwood	5,733.91	5,770.12
Corpus Christi Peoples Baptist Church	9.07	8.38
Tennessee Pipeline Construction Company	20.22	17.80
City of Corpus Christi - Laguna Madre	1,675.61	1,464.47
City of Corpus Christi - Whitecap	952.73	9,002.16
Duval County CRD	5.91	9.42
Kleberg County	4.21	N/A
Riveria WCID	0.00	0.00
Kleberg County	16.32	28.91
Coil Tubing Services	0.46	N/A
San Diego MUD #1	341.45	383.61
City of Bishop	182.11	155.10
City of Alice	1,229.53	1,335.03
City of Alice	679.47	767.25
City of Kingsville	1,252.93	1,631.79
City of Kingsville	435.75	431.03
U.S. Department of the Navy - Kingsville NAS	62.47	80.07
Total Discharges	96,065	88,018

[1] These wastewater dischargers are recognized by the Nueces River Authority and the TCEQ as contributors to freshwater inflows to the Nueces Estuary System.
[2] Annual wastewater discharged, in ac-ft, for 2012 and 2013. Total Municipal/Domestic discharges in 2012 – 45,815 ac-ft. Total Industrial Discharges in 2012 – 50,250 ac-ft.
Total Municipal/Domestic discharges in 2013 – 51,090 ac-ft. Total Industrial Discharges in 2013 – 36,928 ac-ft.
Source: TCEQ and Nueces River Authority's 2013 Effluent Monitoring Report.

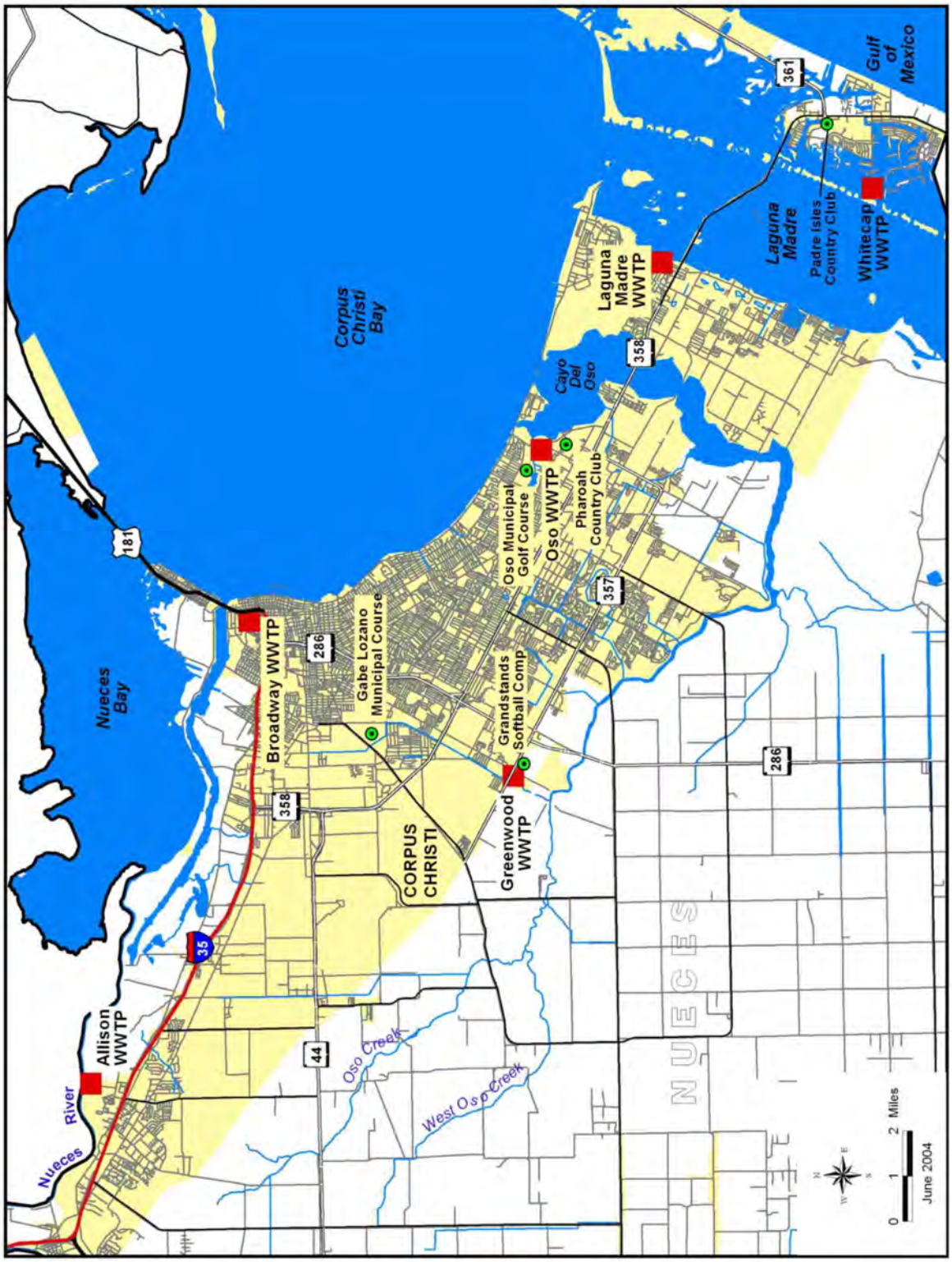

Figure 5-10. City of Corpus Christi Wastewater Treatment Plants (Source: 2016 Coastal Bend Regional Water Plan IPP, 2015)

5.5 Ecoregional Reference Conditions

EPA ecoregional water quality reference conditions were compiled for the watershed. In June 1998, EPA published the National Strategy for Development of Regional Nutrient Criteria. EPA published technical guidance for developing criteria for lakes and reservoirs, rivers and streams, and estuaries and coastal waters and recommended nutrient criteria for most streams and lakes in January 2001. In November 2001, EPA issued a memorandum to the States about planning the development and adoption of nutrient criteria into water quality standards based on ecoregions.

The concept of ecological regions, or ecoregions, is the grouping of areas of similar climate, hydrology, geology, physiography, soils, land use, vegetation, and wildlife. EPA divided the United States into 14 Level I ecoregions and 104 Level III ecoregions. In addition, EPA developed "reference conditions," or conditions that reflect pristine or minimally impacted waters.

Reference conditions were developed for ecoregions in two ways: using the upper 25th percentile (75th percentile) of a reference population of streams in an ecoregion or determining the lower 25^{th} percentile of the population of all streams within a region to attempt to approximate the preferred approach. This means that 25% of all streams surveyed have a certain concentration or lower of the constituent of concern.

Using reference conditions and based on ecoregions, the EPA has established criteria for total phosphorus and total nitrogen for rivers and streams, lakes and reservoirs, and wetlands. Ecoregion criteria are in-stream concentrations, as opposed to effluent limits for point source discharges.

Figure 5-11 depicts the ecoregions of Texas with the Nueces watershed boundary shown for reference. The majority of the Nueces Basin is located in Subecoregion 31. Table 5-2 shows ambient water quality reference conditions for streams in the following Nueces watershed ecoregions:

- Ecoregion IV (Great Plains Grass and Shrublands)
    - Subecoregion 30 (Edwards Plateau)
    - Subecoregion 31 (Southern Texas Plains)
- Ecoregion IX (Great Plains Grass and Shrublands)
    - Subecoregion 33 (East Central Texas Plains)
- Ecoregion X (Texas-Louisiana Coastal and Mississippi Alluvial Plains)
    - Subecoregion 34 (Western Gulf Coastal Plain).

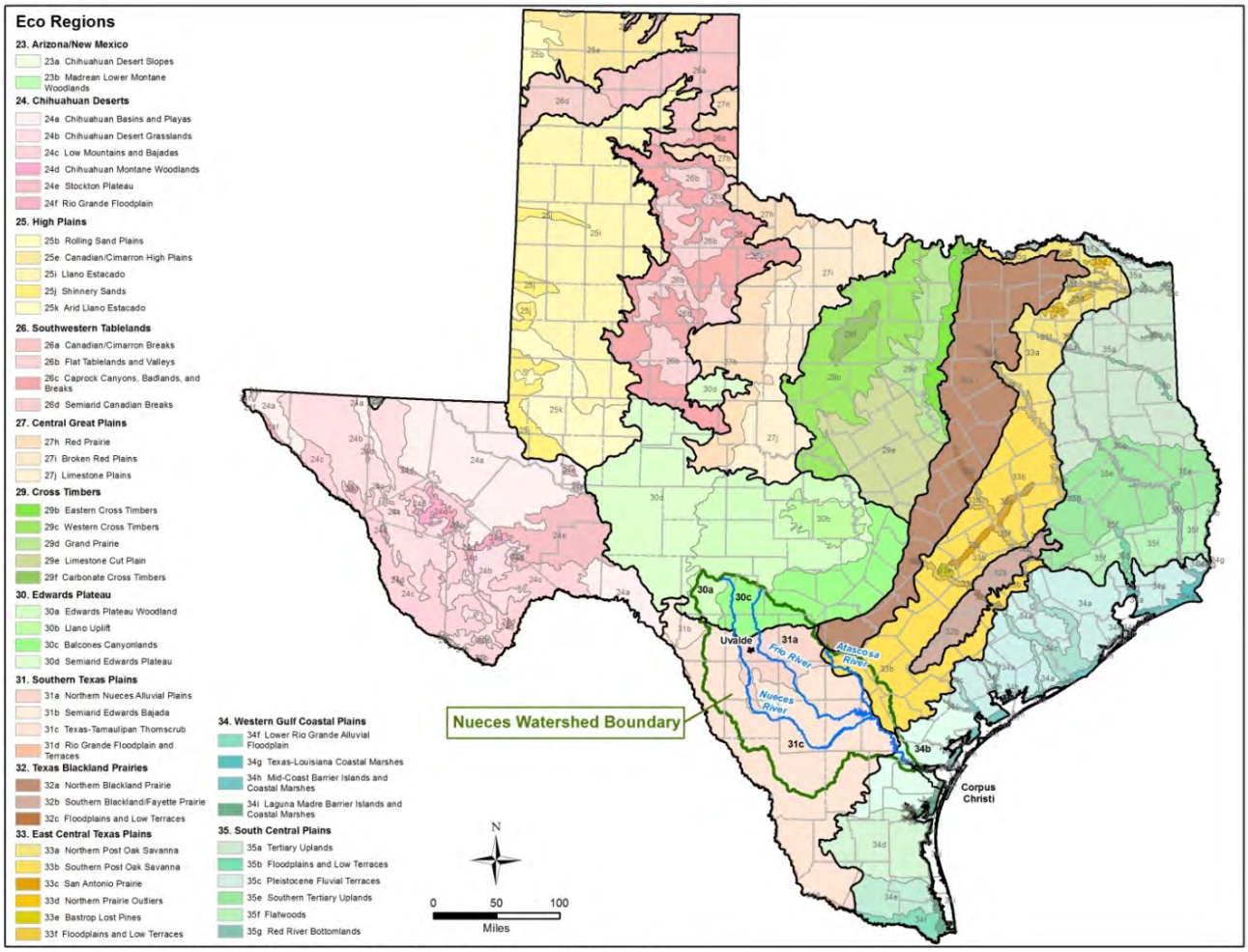

Figure 5-11. Ecoregions of Texas, EPA delineations for the development and adoption of nutrient criteria

Table 5-2. EPA reference conditions and TCEQ screening level criteria for nutrients

Parameter (mg/L)	EPA 25th Percentile Reference Conditions			
	Ecoregion IV, Subecoregion 30[1]	Ecoregion IV, Subecoregion 31[2]	Ecoregion IX, Subecoregion 33[3]	Ecoregion X, Subecoregion 34[4]
Total Phosphorus	0.008	0.028	0.1	0.126
Total Kjeldahl Nitrogen (TKN)	0.18	0.27	0.543	0.74
Total Nitrogen	0.27*, 0.55†	0.49*	0.681*, 0.935†	0.88*, 0.86†
Nitrite + Nitrate - N	0.09	0.22	0.138	0.14
Chlorophyll a**	0.002	0.002	0.000733	0.0021
Turbidity (FTU)	0.73	3.83	10.9	12.27

[1] EPA, 2001a.
[2] EPA, 2001b.
[3] EPA, 2000.
[4] EPA, 2001c.

* Calculated
† Reported
** Chlorophyll a measured by Spectrophotometric method with acid correction

Griffith *et al.* (2007) describe the ecoregions of Texas and their context in water quality planning at the watershed scale. An excerpt describing this potential nexus between ecoregions and watershed management is included below.

> *We encourage TCEQ and other Texas agencies and organizations to consider the analysis of compatible data from these neighboring states, as well as from Mexico, that share ecological regions to help clarify regional conditions and characteristics.*
>
> *A goal of most state water quality agencies is to reclaim polluted waters, to prevent future pollution, and to plan for the future use of the waters of the state. The ecoregion framework is one tool to help implement that goal and develop water quality criteria that will protect designated uses of water bodies. It is a tool that allows for the recognition of natural differences in different areas of the state, and, together with the reference sites, clarifies the regional definition of water quality. Avenues for maintaining or even improving the quality of identified reference streams should be explored, since these are some of the best quality streams remaining.*

According to the authors, the ecoregion-based framework can work in concert with a watershed management approach. The reference conditions shown in Table 5-2 should be a useable resource when determining future numeric nutrient criteria within the Nueces watershed.

5.6 Outlier Analysis

HDR evaluated the compiled data and addressed data quality issues present therein. Data deemed unsuitable were retained, but flagged for exclusion in the regression analysis. Specific consideration was given to the preliminary evaluation of nutrients within the system. Cumulative frequency distribution, time series figures, and precipitation data were used to determine outliers. Approximately 20 points through all nutrient constituents for the period of record were removed

because of concerns for data quality. Documentation of outliers and associated analysis is included in Appendix D.

6 Land Use Analysis

This section describes the analysis of land use and associated population, and the influence of WWTPs in the watershed completed for the study.

6.1 Population / Land Use

According to the 2016 Initially Prepared Coastal Bend Regional Water Plan (HDR Engineering and Coastal Bend Regional Water Planning Group, 2015), in 2013, the population of the Coastal Bend Region was estimated to be 581,100. This does not include the upper reaches of the Nueces basin, which consists primarily of low population centers. Uvalde, with a 2013 population of 16,284, is the largest city in the upper Nueces basin. The City of Corpus Christi, which had a population of 266,383 in 1990, grew to 316,381 people in 2013. Major crops in the basin include cotton and grain sorghum, and livestock include primarily cattle.

Values reported in HDR Engineering, Inc. and Geraghty & Miller, Inc. (May 1991) indicate planted cropland upstream of LCC of 530,000 acres in 1970 and 645,000 acres in 1985. NLCD 2011 shows nearly 1.6 million acres of cultivated crops or pastureland with 660,000 acres of cultivated crops in the Nueces watershed, including downstream of LCC.

Excerpts from HDR Engineering, Inc. and Geraghty & Miller, Inc. (1991) state:

> *Average and median annual streamflow in the Nueces River Basin are about 631,000 acre-feet and 421,000 acre-feet, respectively, as measured at Lake Corpus Christi for the 1934 through 1989 period. This represents about 3 percent of the average annual basin-wide precipitation.*
>
> *Land use within the basin is almost entirely related to agricultural uses, with 10 percent classified as cropland, 6 percent pastureland, and 84 percent rangeland (TSSWCB, 1990a and TSSWCB, 1990b)*
>
> *In relatively arid watersheds, like the Nueces River Basin, it is not uncommon for streamflow characteristics to be influenced over time by changes occurring in the watershed. Examples of these changes may include: 1) Farming techniques intended to reduce runoff such as furrow diking, contour plowing, and terracing; 2) Allowing previously farmed land to revert to pasture or rangeland; 3) Increased groundwater use resulting in lowering of the water table which, in turn, reduces the baseflow of streams and increases natural channel losses; 4) Increased prevalence of certain types of vegetation which enhance evapotransporation losses; and 5) Construction of farm ponds and other water control structures. Each of the above changes tends to decrease runoff, while the converse of the above items may tend to increase runoff.*
>
> *Annual records have been maintained by the Texas Department of Agriculture since 1970 for acres of planted cropland within each county. ...Although total cropland within the basin represents 10 percent of the land area, planted cropland in the counties located upstream of Lake Corpus Christi has varied from about 5 percent in 1970, 1975, and 1980 to about 6 percent of the total drainage area in 1985.*

Planted cropland can vary significantly from year to year depending on many factors, including Federal farm subsidies. Since the percentage of cropland in the basin is small, it is doubtful that planting practices significantly affect streamflows except in localized watersheds where cropland acreage is significant.

6.2 Wastewater Discharge Analysis

The largest quantity of effluent is discharged in the lower Nueces Basin from the City of Corpus Christi's treatment facilities. Effluent discharges in the upper portion of the basin did not appear to be a large contributor of nutrients. In most cases, nutrient concentrations remained consistent from upstream of the outfall location to downstream of the outfall location.

In the Corpus Christi area, significant treated effluent quantities are discharged into streams that flow into the bays and meet a part of the freshwater needs of the Nueces Estuary. The purpose of this section is to describe reclaimed wastewater reuse options and present estimates of the quantities of water supply that may be made available through: 1) wastewater reuse for municipal and industrial non-potable purposes; 2) wastewater diversions to the Nueces Delta to enhance biological productivity of estuarine marshes (in comparison to the present practice of direct discharge of wastewater into the bays and into streams that flow into the bays); and 3) discussions of wastewater reuse and water conservation effects upon estuarine inflows.

Both reuse and diversion to the Nueces Delta present opportunities to increase the Corpus Christi area water supply. In the Interim Order[3] of March 9, 1992, the TCEQ established temporary operational procedures for the City's reservoirs that included a monthly schedule of minimum desired inflows to Nueces Bay. The 1992 Interim Order directed studies of the effects of freshwater releases upon the estuary and the feasibility of relocating wastewater discharges to the upper estuary locations where increased biological productivity could justify an inflow credit computed by multiplying the amount of discharge by a number greater than one. These studies included the Allison Wastewater Treatment Plant (WWTP) Demonstration Project.

On April 28, 1995, the TCEQ replaced the 1992 Interim Order with an Agreed Order[4] (1995 Agreed Order) amending Choke Canyon Reservoir/Lake Corpus Christi (CCR/LCC) System operational procedures. The 1995 Agreed Order directed the Nueces Estuary Advisory Council (NEAC) to continue studying the development of a methodology using a multiplier system for granting credits for specific return flows that increase biological productivity.

On April 17, 2001, the TCEQ issued an amendment to the 1995 Agreed Order to revise operational procedures in accordance with revisions requested by the City of Corpus Christi. Changes

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[3] Interim Order Establishing Operational Procedures Pertaining to Special Condition 5.B, Certificate of Adjudication No. 21-3214, held by the City of Corpus Christi, Nueces River Authority, and the City of Three Rivers, Texas Water Commission (now TCEQ), Austin, Texas, March 9, 1992.

[4] Agreed Order Establishing Operational Procedures Pertaining to Special Condition 5.B., Certificate of Adjudication No. 21-3214, held by the City of Corpus Christi, Nueces River Authority, and the City of Three Rivers, Texas Natural Resource Conservation Commission, Austin, Texas, April 26, 1995.

included: 1) reductions in the passage of inflows to Nueces Bay and Estuary at 40 percent and 30 percent reservoir system capacity upon institution of mandatory outdoor watering restrictions; 2) calculating reservoir system storage capacity based on most recently completed bathymetric surveys; and 3) provisions for operating Rincon Bayou diversions and conveyance facility from Calallen Pool to deliver up to the first 3,000 ac-ft of target pass through to the upper Rincon Bayou in the Nueces Delta to enhance the amount of freshwater to Delta. Nueces Delta projects, such as Rincon Bayou and Allison WWTP Demonstration Projects, include the following potential benefits: increased water supply, increase positive flow events for Nueces Delta, and increased sources of nitrogen and lower salinity levels for the upper delta. A study completed in 2006 (The University of Austin, Marine Science Institute, Port Aransas, Texas and Texas A&M University-Corpus Christi, Center for Coastal Studies, Corpus Christi, Texas, 2006) outlined the positive benefits of the Allison WWTP Demonstration Project. This report concluded that there was an increase in vegetation and creation of additional areas of salt marsh which was accompanied by more shorebirds being attracted to the area. The report also noted that with the additional water diverted to the marsh area, there was an approximately 50 percent removal of wastewater discharge into the Nueces River, reducing the potential for nutrient driven algal blooms. To evaluate the potential benefits, the 2001 Agreed Order included implementation of an ongoing monitoring program to facilitate an adaptive management program for freshwater inflows to the Nueces Estuary. NEAC prepared a recommended monitoring plan in July 2002, which was initiated in 2003 (City of Corpus Christi, 2005). Modifications to the Allison WWTP discharge permit include limitations on ammonia concentrations in the flows to the demonstration project. As a result, the City curtailed these flows in August 2011.

The Rincon Bayou Diversion Pipeline and Pump Station (Rincon pipeline) was constructed by the City of Corpus Christi pursuant to the 2001 Agreed Order and became operational in November 2007. Pursuant to the Agreed Order, the City also reopened the Nueces River Overflow Channel which has become the primary method of delivering flow to the Nueces Delta. The Rincon pipeline pump station includes three 350 horsepower mixed flow submersible pumps capable of delivering up to 60,000 gallons per minute (or 265 ac-ft/day) with all pumps operating. The Rincon pipeline and pump station does not operate continuously, however the City has operated the Rincon pipeline to provide inflow to the Upper Rincon Bayou and participated in studies with the Coastal Bend Bays and Estuaries Program to study the impacts of freshwater pumped through the Rincon pipeline on reducing salinity levels in the Nueces Delta (Coastal Bend Bays and Estuaries Program, 2013). According to USACE studies, pulsed flow at certain times of the year are more beneficial than small pass-throughs in dry months. Salinity monitors have been positioned throughout the estuary to track flow rate and retention time of water diverted through the Rincon Pipeline. The City continues to support programs to monitor salinity and gages.[5]

These agreements and their history are important and must be considered in water supply planning, water reuse options, and water management programs for the Corpus Christi area (HDR and Coastal Bend Regional Water Planning Group, 2015).

[5] City of Corpus Christi staff, April 3, 2015.

6.3 Local Wastewater Treatment Plant Considerations

Since the 1995 Trans-Texas Water Program Study, the City of Corpus Christi has initiated some programs related to their wastewater facilities plan that may impact analyses of alternatives for diversions of effluent to the Nueces Delta. The changes include the construction and operation of the Allison WWTP Nueces Delta Demonstration Project, and considering wastewater treatment plant consolidation at Greenwood WWTP.

In mid-1997, the City began preparing a plan to work with State and Federal agencies involved with the Agreed Order that would provide the freshwater flow needs of the Nueces Bay System during drought conditions through diversions of treated wastewater effluent, rather than the passage of CCR/LCC System inflows. The strategy involved constructing and operating facilities to divert both industrial and municipal wastewater effluents to locations in the Nueces Delta based on the productivity benefits determined by the preliminary findings from the Allison WWTP Project.

In 1997 to 1998, the City constructed a pipeline from the Allison WWTP to the Nueces Delta as part of a demonstration project to assess the impact of the WWTP effluent on the estuary. The Allison WWTP Demonstration Project was completed and in October 1998, the City began diverting approximately 2 million gallons per day (or 2,240 ac-ft/yr) of effluent from Allison WWTP to the Nueces Delta. Intensive data collection programs were conducted for 5 years (from 1999 to 2003) and the final summary report was issued in 2006 summarizing study results (City of Corpus Christi, 2006). At this time, Allison WWTP effluent delivery to the Nueces Delta has been discontinued since effluent quality does not meet current TCEQ water quality standards for receiving bodies.[6]

The 2001 Agreed Order allows the City relief from inflow requirements when the reservoir system is below 30 percent and Drought Condition III has been implemented, however return flows directed at the Nueces Bay and/or Nueces Delta shall continue. The changes in the operating plan maintain the freshwater availability for Nueces Bay through return flows during drought conditions and increase the amount of dependable water supply available from the CCR/LCC System for municipal and industrial use.

An important issue associated with any diversion of domestic wastewater to the Nueces Delta is the level of wastewater treatment necessary for the wastewater diverted. Studies to date have shown that the enhancement of productivity in the Delta is dependent upon the volume of fresh-water flow and concentration of nutrients in the wastewater; therefore, effluent treated to a higher quality may prove to be less effective for primary production in the Delta. Thus, the cost savings in wastewater treatment to remove more nutrients would lower the overall costs of implementing projects to divert wastewater to the Nueces Delta and thereby further reduce the costs of yield recovered from the CCR/LCC System.

In January 2004, a study (Breier, *et al.*, 2004) was conducted to evaluate groundwater discharge to the Nueces Bay and quantify the potential nutrient flow to the Bay from groundwater. Nitrate concentrations were used to measure nutrients. The results indicated between 15,000 to 40,000 kg of nitrate are released to the Nueces Bay through groundwater discharge. This

[6] City of Corpus Christi staff, February 2015.

estimate is only exceeded as a source of nitrogen by treated wastewater return flows (HDR and Coastal Bend Regional Water Planning Group, 2015).

7 Regression Analyses

7.1 Introduction

The objective of this data analysis is to evaluate pre- and post-development nutrient conditions in the Nueces watershed, as well as to address the impact of nutrient transport after the construction of Choke Canyon Reservoir. HDR performed the data evaluation and modeling analysis using available flow and nutrient data from existing TCEQ and USGS water monitoring locations. An in-house data analysis package was used for linear regression analyses and compared to the LOADEST modeling outputs (USGS Fortran modeling tool). Regression figures, cross-correlation plots (constituents versus flow) as well as time-series plots of the estimated values versus the observed data for both concentrations and loads were generated using information from the linear regression analysis and LOADEST modeling tool. The correlation between nutrients such as total kjeldahl nitrogen (TKN), ammonia (NH_3), nitrate+nitrite (NOx), chlorophyll (chl-a), total phosphorus (TP), orthophosphate (PO_4), and flow were completed for the time period from 1970 through 2015.

7.2 Data Evaluation

HDR compiled available flow and water quality data from TCEQ and USGS databases. Figures 5-1, 5-2, and 5-4 depict TCEQ and USGS monitoring station locations that were included in the data analyses.

The TCEQ database has recorded data from more than 140 monitoring stations over 45 years (1970-2015) with varying period of records for individual stations. Table 7-1 shows the number of stations that have at least 20 instantaneous flow/concentration data points available. Data analysis was conducted on the following variables: total kjeldahl nitrogen (TKN), ammonia (NH_3), nitrate+nitrite (NOx), chlorophyll (chl-a), total phosphorus (TP), and orthophosphate (PO_4).

Table 7-1. Data Availability for regression analyses

Variable	Number of stations	Number of stations with greater than 20 data points
Flow	83	32
TKN	83	32
NH_3	104	49
NOx	145	39
TP	108	47
PO_4	25	18
Chl-a	89	36

To perform the regression analyses, the corresponding flow-constituents pairs were identified for 37 stations. Table 7-2 includes the stations that were included in the data analysis.

Table 7-2. List of TCEQ Stations Included in the Data Analysis.

TCEQ Station	USGS Gauge	River	Description	Period of Record	
				Begin	End
12962	8211500	Nueces	Nueces River Near Cunningham WWTP	10/1/1989	Present
12964	8211200	Nueces	Nueces River at Bluntzer	1/26/1966	Present
12965	8211000	Nueces	Nueces River at La Fruta	9/1/1939	Present
12972	8194600	Nueces	Nueces River at FM 1042, Simmons	4/1/1965	10/17/1977
12973	8194500	Nueces	Nueces River at Tilden	12/1/1942	Present
12975	8194000	Nueces	Nueces River at Cotulla	10/1/1926	Present
12976	8193000	Nueces	Nueces River, Asherton	10/1/1939	Present
12978	8210100	Nueces	Nueces River, George West	9/17/84	10/24/02
12979	8210000	Nueces	Nueces River, Three Rivers	7/1/1915	Present
12980	8208000	Atascosa	Atascosa River at Whitsett	6/1/1932	Present
12981		Atascosa	Atascosa River, RR Bridge Pleasanton	5/24/79	7/17/96
12982		Atascosa	Atascosa River at US 281 at Pleasanton	11/12/73	3/14/11
12983	8206700	San Miguel	San Miguel Creek, Tilden	2/1/1964	Present
12985		Leona River	Leona River, Pearsall	9/18/73	10/11/11
12987		Leona River	Leona River, Batesville	2/21/89	10/11/11
12993	8198500	Sabinal River	Sabinal River at US 90	9/1/1952	Present
12994	8198000	Sabinal River	Sabinal River North of Sabinal	10/1/1942	Present
12996		Nueces	Nueces River at US Hwy 57	1/13/75	7/31/08
12997		Nueces	Nueces River at US 83	10/10/73	8/10/04
12999	8190000	Nueces	Nueces River NE of Laguna	10/1/1923	Present
13005		Nueces	Nueces River at Barksdale	10/16/01	5/14/13
13006	8195000	Frio	Frio River at SH 127	11/1/1923	Present
13007		Frio	Frio River at Magers Crossing	11/27/00	6/21/11
13010	8200000	Hondo	Hondo Creek downstream of RR 462, Tarpley	9/1/1952	Present
13013	8201500	Seco Creek	Seco Creek at Miller Ranch	5/1/1961	Present
13021	8207000	Choke Canyon	Choke Canyon C.C State Park	10/1/1924	3/23/1981
13023	8206600	Frio	Frio River at SH 16 in Tilden	7/14/1978	Present
13024	8205500	Frio	Frio River at IH 35 Northbound Bridge North of Dilley	8/1/1915	Present
13025		Frio	Frio River at FM 1581 SW of Pearsall	7/24/72	7/24/86
14253		Nueces	Nueces River at FM 481 SW of Uvalde	2/23/95	2/20/97
17892		Frio	Frio River at Apache Bluffs	8/15/02	5/25/04
17898		Atascosa	Atascosa River Downstream of Hunt Road	8/21/02	6/15/04
17899		Atascosa	Atascosa River at Leal Road	8/21/02	5/18/04
17900		Atascosa	Atascosa River at IH 37	8/21/02	9/28/11
20762		Atascosa	Atascosa River at Granato Road / Taylor Rd	6/16/10	9/28/11
20764		Atascosa	Atascosa River at FM 541	6/16/10	5/19/11
20773		Atascosa	Atascosa River, CR 413, Medina County	6/16/10	9/28/11

Note: Period of record (POR) represents the flow available from the USGS for each specific station. For stations that are not a USGS-monitored station, POR represents the POR of instantaneous flow values available. The POR for individual water quality constituent at a particular station varies by constituent. The POR of flow because it is necessary for calculation of load.

Three major rivers - The Nueces, Frio, and Atascosa rivers were analyzed to determine impacts between undeveloped areas upstream and more developed areas downstream in the river basin.

The analysis was performed using two regression models:

- A simple linear regression model, which considered just the relationships between concentrations and flow; and
- A multiple regression model, which considered a temporal component in addition to flow.

In addition to the linear regression analysis completed, the U.S. Geological Survey (USGS) loading analysis tool LOAD Estimator (LOADEST), which is a FORTRAN program that uses multiple linear regression analysis for estimating constituent loads in streams and rivers, was used in the analysis. Given a time series of stream flow and constituent concentrations, LOADEST develops a regression model for the estimation of constituent load (calibration). There are 10 different regression models preprogrammed in the LOADEST (Runkel et al., 2004). By setting up the LOADEST runs the automated regression model selection option permits the model to choose the "best" regression equation from the set of predefined set of equations. The most often selected regression equations were:

Model number 6:

$$\text{Conc} = a0 + a1\ \ln Q + a2\ \ln Q^2 + a3\ \sin(2\pi dtime) + a4\ \cos(2\pi dtime)$$

where

lnQ=ln(streamflow)

dtime=decimal time

Model number 9:

$$\text{Conc} = a0 + a1\ \ln Q + a2\ \ln Q^2 + a3\ \sin(2\pi dtime) + a4\ \cos(2\pi dtime) + a5 dtime + a6 dtime^2$$

where

lnQ^2=ln(streamflow squared)

dtime^2= (decimal time) squared.

Note that these equations include sine and cosine terms. These terms are often included to account for seasonality in the data. However, in order for these terms to be included and be statistically meaningful, adequate time-series datasets are necessary, which include monthly or bi-monthly sampling. A few, but not all, stations had sufficient data which were adequate in number to provide some estimates of seasonal variability.

LOADEST selects the best regression equation to use based on the Akaike Information Criteria, (Akaike, 1974). The Akaike Information Criterion (AIC) estimates the quality of each model, relative to each of the other models and selects the model with the best quality. Quality in the sense of the AIC is a trade-off between improving the goodness of fit (minimizing the sum of the squares of the errors) versus assessing a penalty for increasing the number of estimated parameters. The penalty discourages overfitting (*i.e.*, increasing the number of parameters in the model almost always improves the goodness of the fit).

Both models can be limited by the quantities and quality of the data. In the case of LOADEST, stations with less than 15 data points did not provide sufficient data with which LOADEST could determine relationships between water quality data and flow and/or time. In many cases, both models were hindered by the quality of the data and, in particular, changes in detection limits over time and perhaps space, as well. For example, some of the data reported for total ammonia for station 12999 (located in the upper Nueces River) in the 1970s were reported as non-detects, but the detection values ranged from 0.01 mg N/L to 0.10 mg N/L. However, there were also some "not-less than" values that were reported as 0.02 mg N/L. Similarly, in the 1990s for

station 12999, some ammonia data were reported as low as 0.02 mg/L, but some non-detect values were reported as 0.05 mg N/L. Similar data reporting exists for other water quality variables and stations. These types of data discrepancies make data analysis, and temporal trend analysis, in particular, challenging. Despite these limitations, useful observations were drawn from the data and analyses presented below. Documentation of the noted detection limit discrepancies and associated analysis is included in Appendix D.

7.3 Nueces River

The study included stations along the Nueces River. Below are the most upstream and downstream stations from TCEQ locations that had the most comprehensive datasets:

- 13005 - Nueces at SH 55 south of Barksdale
- 12999 - Nueces River NE of Laguna
- 12997 - Nueces River at US 83
- 12996 - Nueces River at US Hwy 57
- 12973 - Nueces at SH 16 south of Tilden
- 12972 - Nueces north of Three Rivers
- 12979 - Nueces on US 281 south of Three Rivers

Stations 12965, 12964, and 12962 at Mathis, Bluntzer, and Calallen, respectively, lack complete data, particularly for instantaneous flow/concentrations sets, which are required for regression analyses and estimations of load. For the parameters analyzed, more data are available at station 12965 at Mathis than at the Calallen or Bluntzer stations. Therefore, station 12965 at Mathis was the most downstream location included in the calculation of loads described in Section 8. Appendix E includes the regression analyses for stations in the Nueces watershed.

The scope of work for this study described the completion of linear regression analyses on nutrient data collected at the fall-line (*i.e.*, the most downstream station above the zone of tidal influence) and binning the data at various flow intervals before performing the regression analysis. Regression analyses of the data at station 12962 at Calallen, closest to the fall-line, were completed and results are shown in Appendix E. Because of the lack of data at station 12962 at Calallen (approximately 12 instantaneous flow/concentration pairs), binning of the data at various flow intervals was not possible.

To determine if there is a relationship between constituents from the TCEQ database and paired flow data, the linear regression analysis was performed. Plots of TKN, NH_3, NOx, chl-a, TP and PO_4 versus flow were generated for stations along Nueces River. The plots include the line of best fit (red line) based on the regression analysis. If a plot is not populated in the figures presented, this means that there are not enough instantaneous flow/concentrations pairs to analyze.

As examples, the regression analyses for stations 13005, 12999, 12973 and 12979 are presented in Figures 7-1 through 7-4, respectively. The best correlation, with the coefficient of determination (R^2 value) indicating the strength of the association of the observed data, is for NOx at station 13005 where 64% of the variation in NOx can be explained by the regression equation including only flow as an independent variable. Correlations for NOx, TP, and PO_4 with flow at station 12973 indicate that 28 to 37% (R^2 = 0.28 to 0.37) of the variation can be

explained by the regression equations including only flow as an independent variable. The regression figures for the remaining stations are presented in Appendix E. Several of the stations showed weak relationships between the water quality constituent concentration and flow, therefore, the uncertainty in prediction is large.

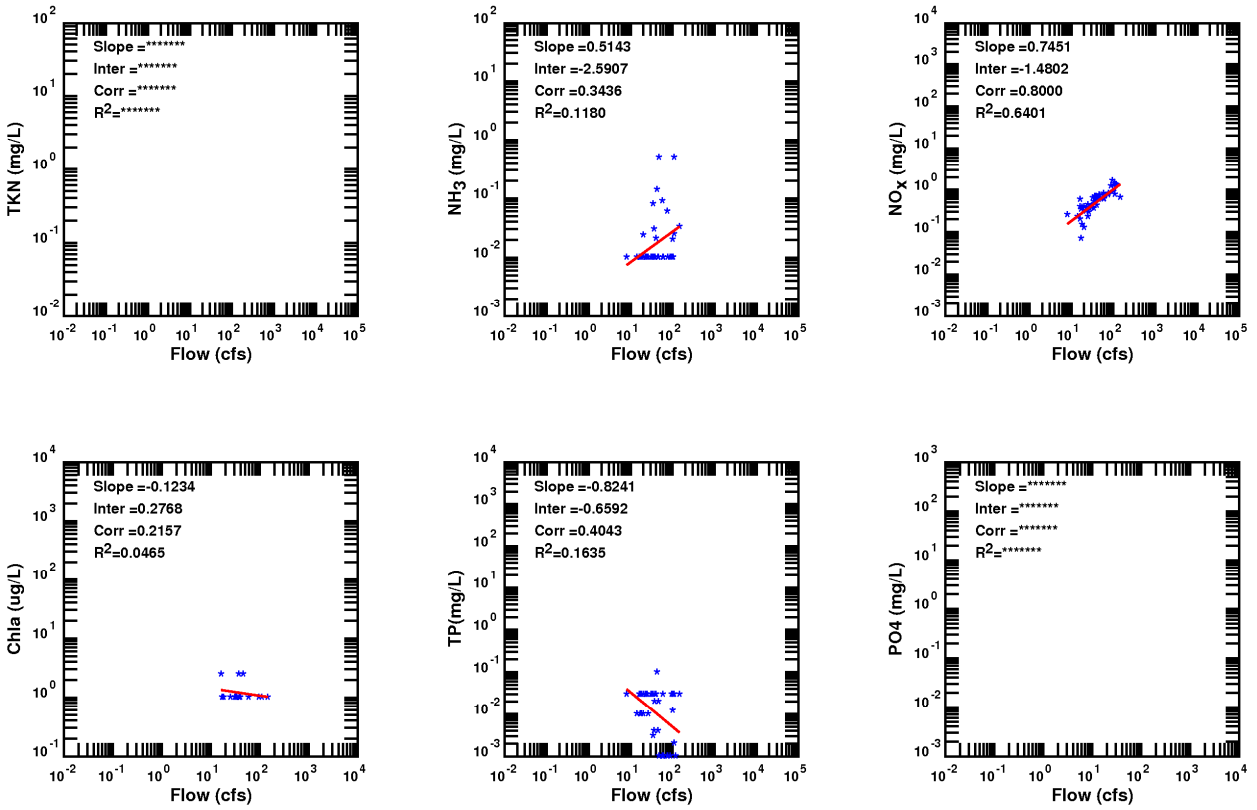

Figure 7-1. Linear Regression Analysis for station 13005 (Nueces at SH 55 south of Barksdale)

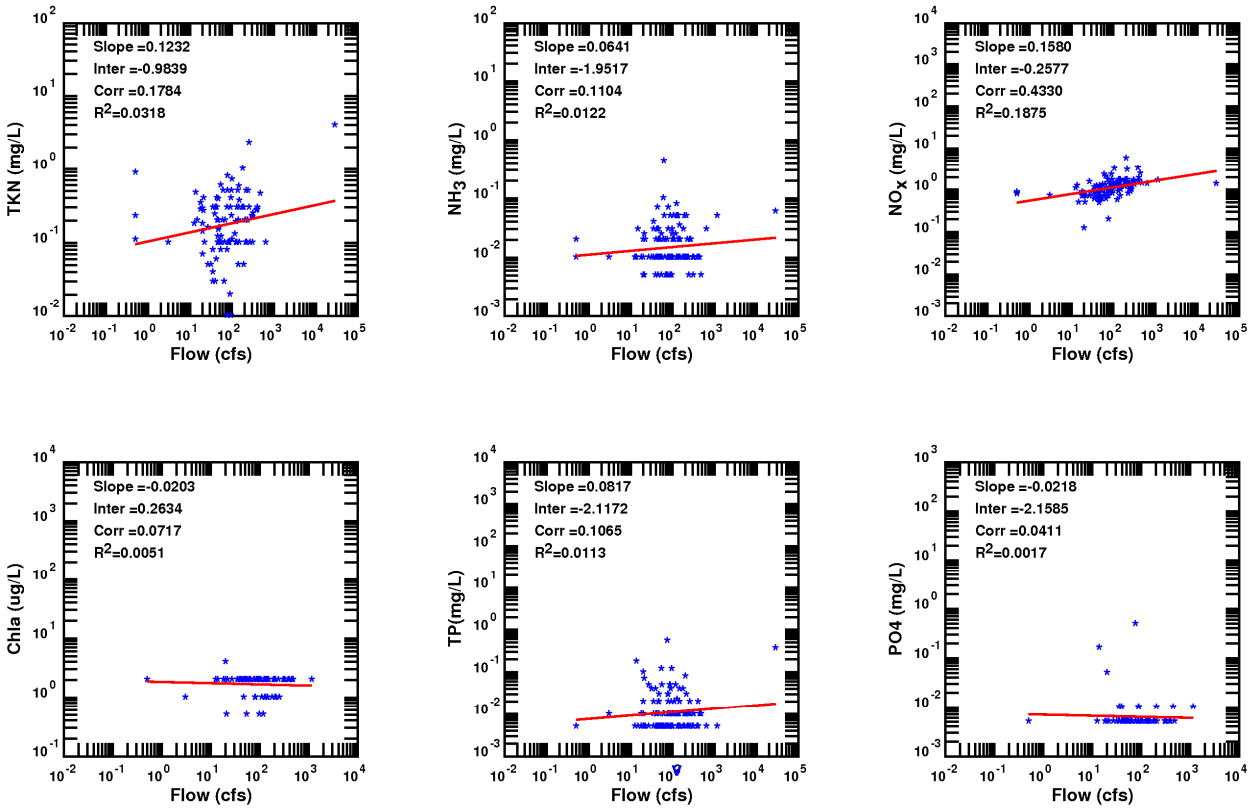

Figure 7-2. Linear Regression Analysis for station 12999 (Nueces River NE of Laguna)

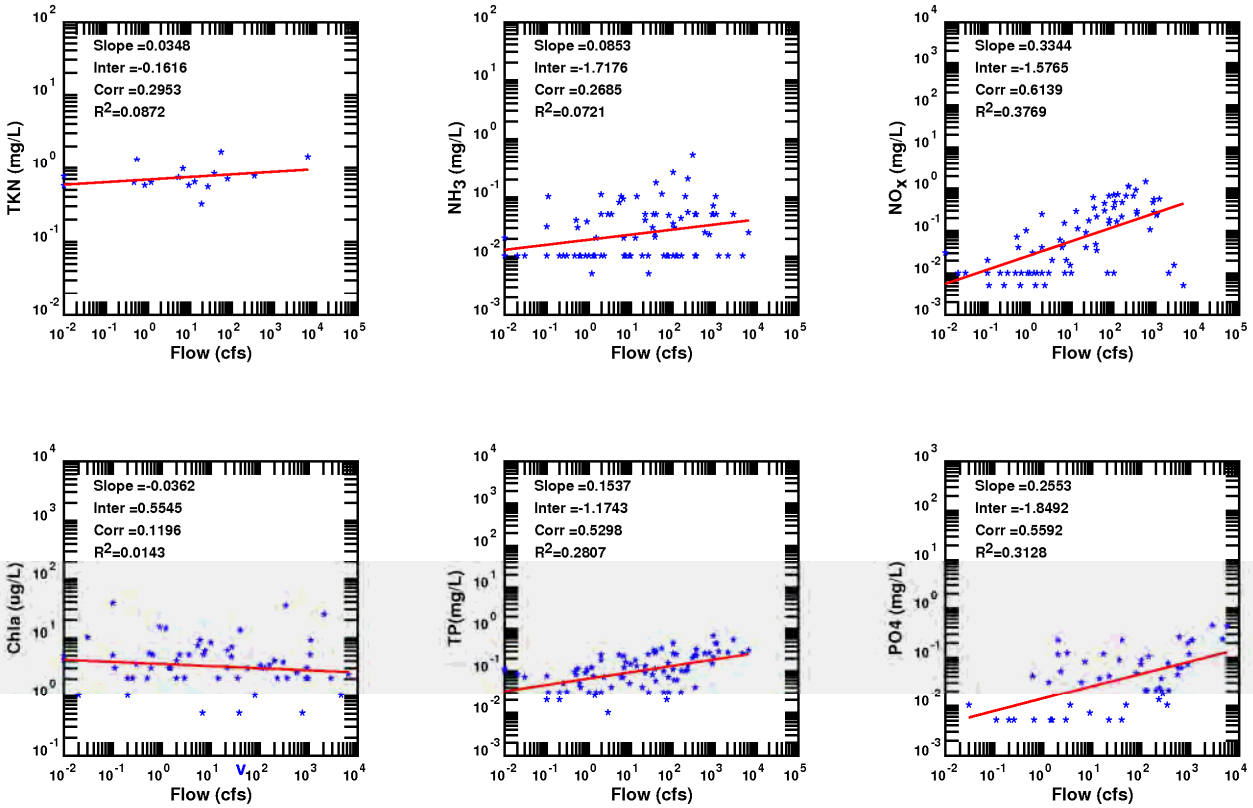

Figure 7-3. Linear Regression Analysis for station 12973 (Nueces at SH 16 south of Tilden)

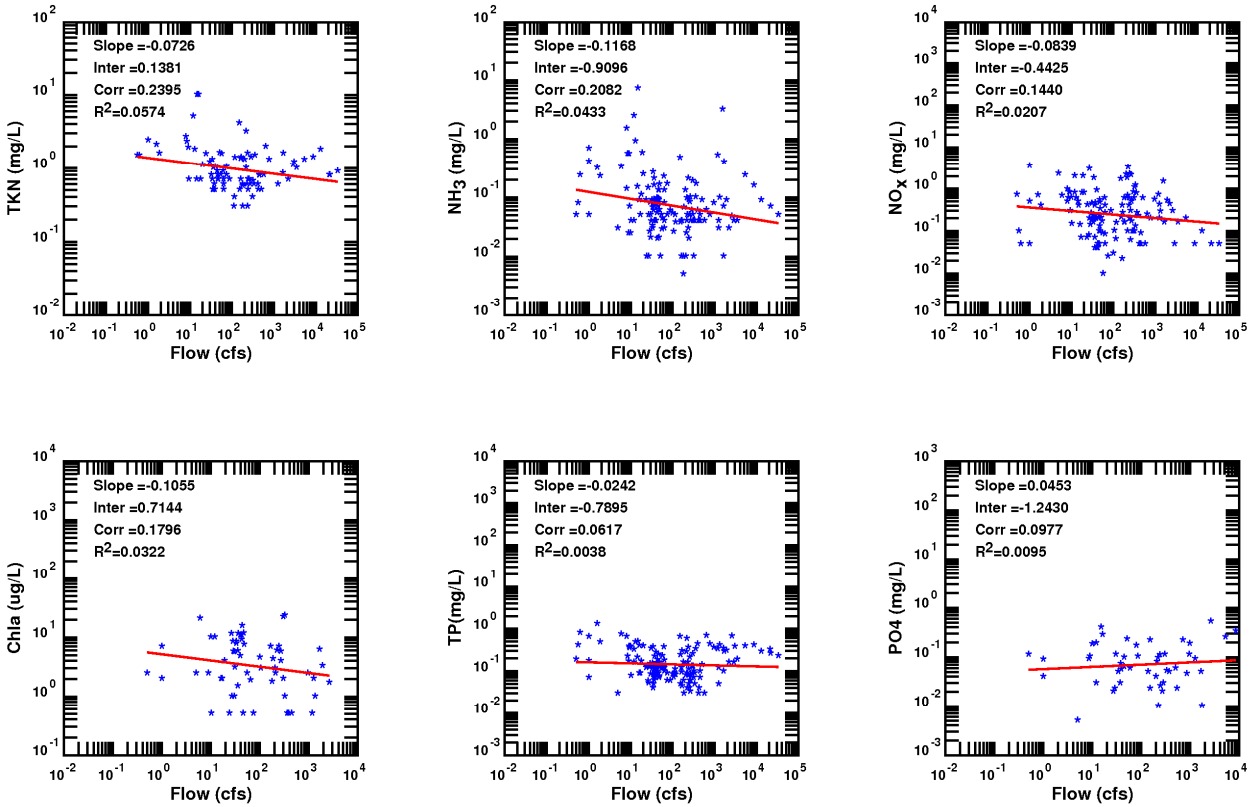

Figure 7-4. Linear Regression Analysis for station 12979 (Nueces on US 281 south of Three Rivers)

7.3.1 Concentration and Load Cross-Correlation

Another way to present the fit of the model to the observed data is to use X versus Y concentration plots of estimated values based on linear regression versus observed data. Figures 7-5 through 7-7 present estimated concentrations versus observed data for TKN, NH_3, NOx, chl-a, TP, and PO_4 for stations 13005, 12973, and 12979, respectively. For those water quality constituents and stations which had poor correlations, the estimated values versus observed data are scattered and do not lie along the 1:1 line. For NOx at station 13005 and NOx, TP, and PO_4 at station 12973, estimated pairs lie along the 1:1 line, but considerable variability still exists.

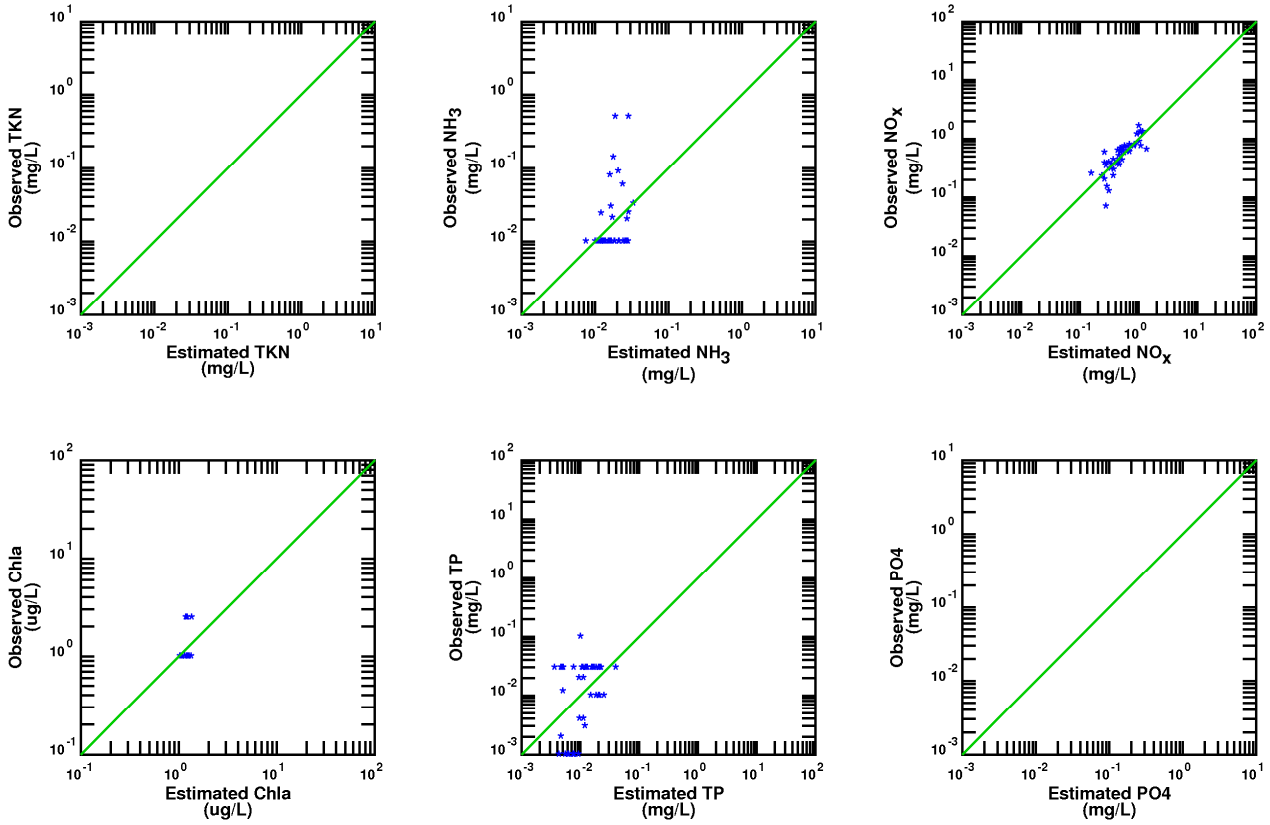

Figure 7-5. Concentrations Cross-Correlation Plots Based on Linear Regression Analysis for station 13005 (Nueces at SH 55 south of Barksdale)

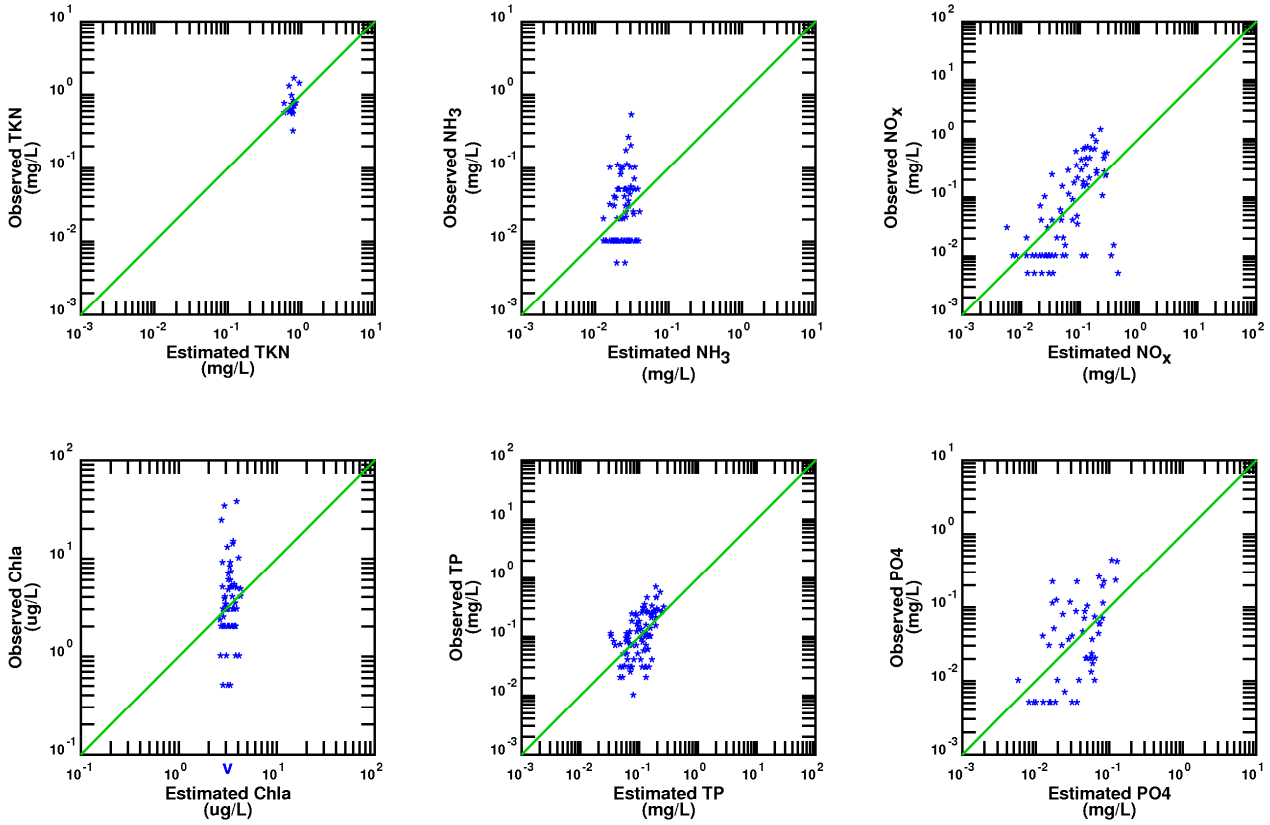

Figure 7-6. Concentrations Cross-Correlation Plots Based on Linear Regression Analysis for station 12973 (Nueces at SH 16 south of Tilden)

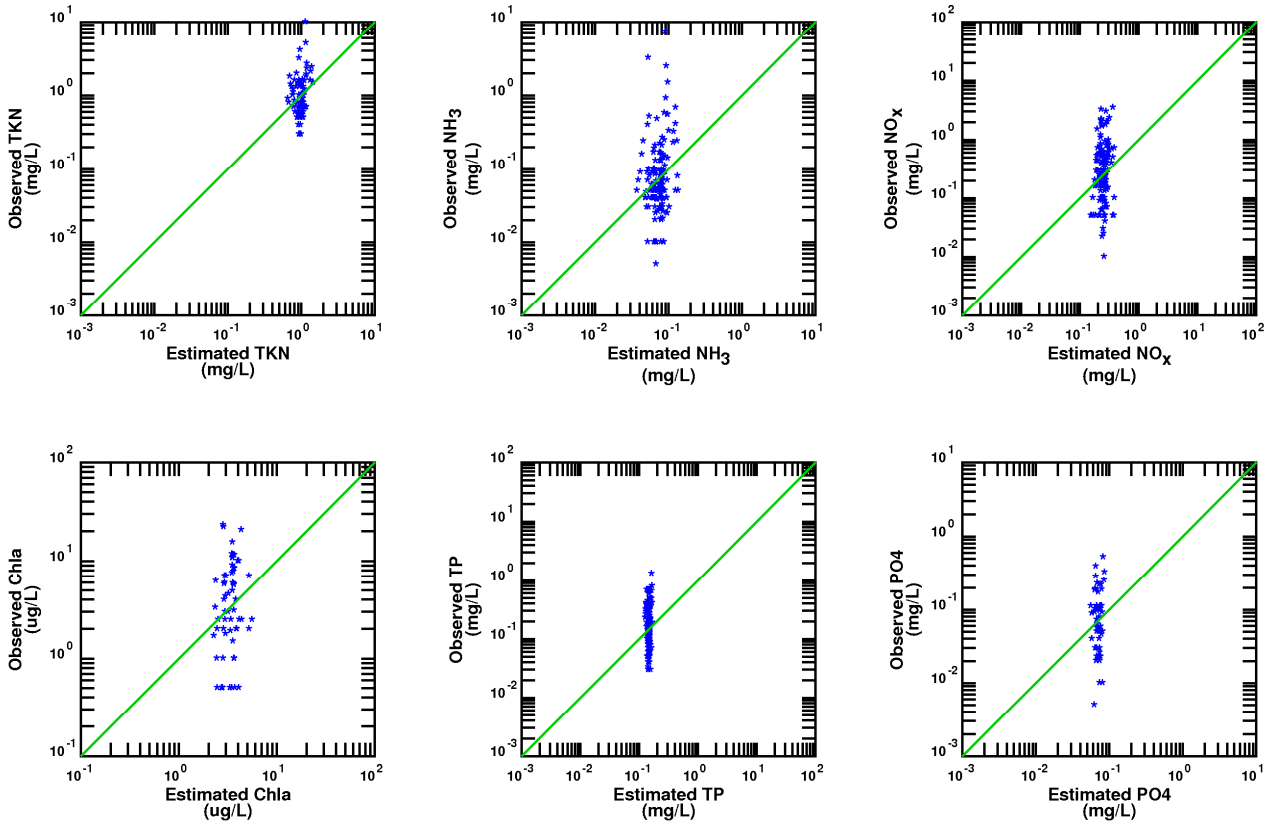

Figure 7-7. Concentrations Cross-Correlation Plots Based on Linear Regression Analysis for station 12979 (Nueces on US 281 south of Three Rivers)

Cross-correlation figures for the same stations, 12973 and 12979, (Figures 7-8 and 7-9) from LOADEST modeling were generated as a comparison to the linear regression. LOADEST results indicate that there is a relationship between flow and some nutrients including TKN and NOx (station 12979) and TP (station 12973). Estimated values line up along the 1:1 line tighter compared to the linear regression analysis.

Next cross-plots of load estimates versus observed loads were generated. Load estimates were computed based on linear regression equations, as well as from LOADEST modeling. Observed loads were based on the product of observed concentration times observed flow. Figure 7-10 and Figure 7-11 show observed loads versus estimated loads for stations 12973 and 12979, respectively. Figure 7-12 and Figure 7-13 present LOADEST observed loads versus estimated loads for stations 12973 and 12979. The cross-plots based on concentration versus flow regression look similar to the LOADEST cross-plots. This occurs because flow is a component in both load computations, so the figure fundamentally shows flow versus flow. The cross-correlation figures for other stations are presented in Appendix E.

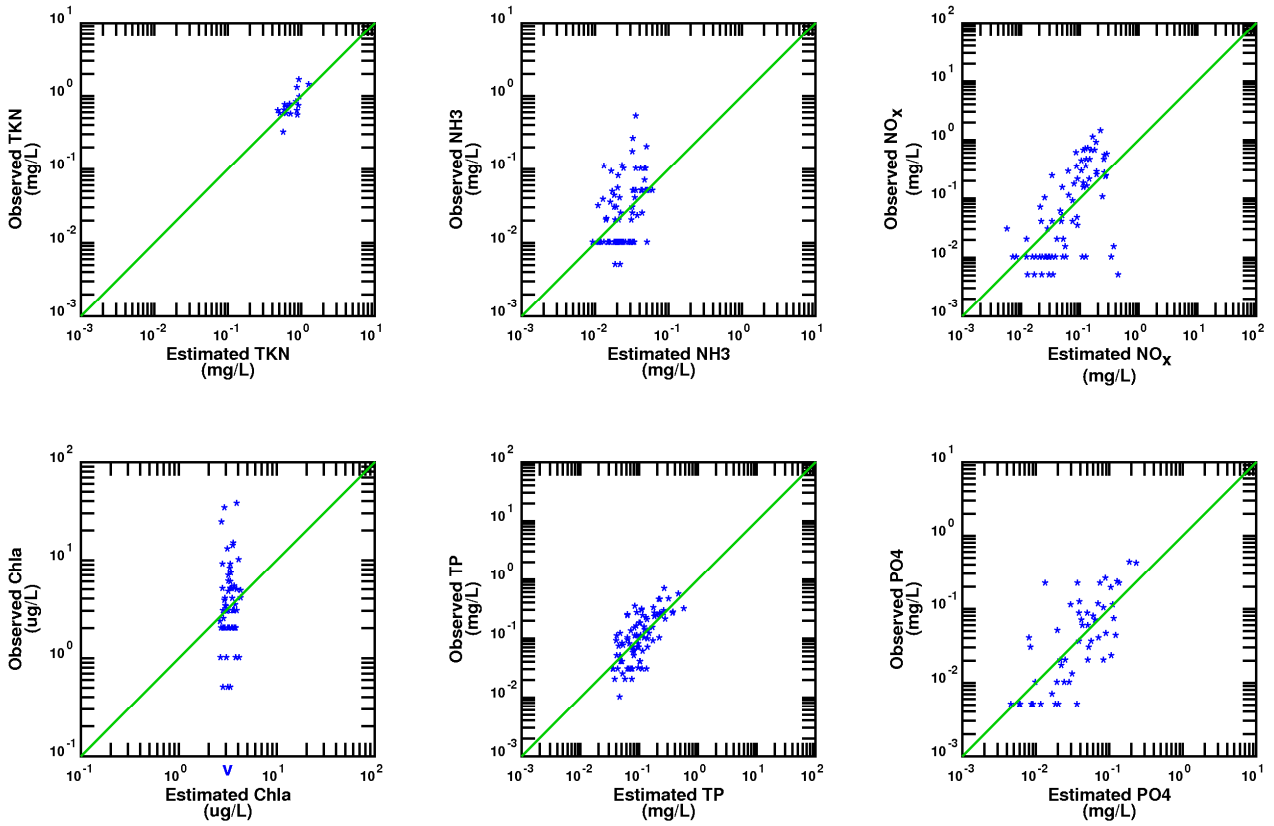

Figure 7-8. Concentrations Cross-Correlation Plots Based on LOADEST Regression Analysis for station 12973 (Nueces at SH 16 south of Tilden)

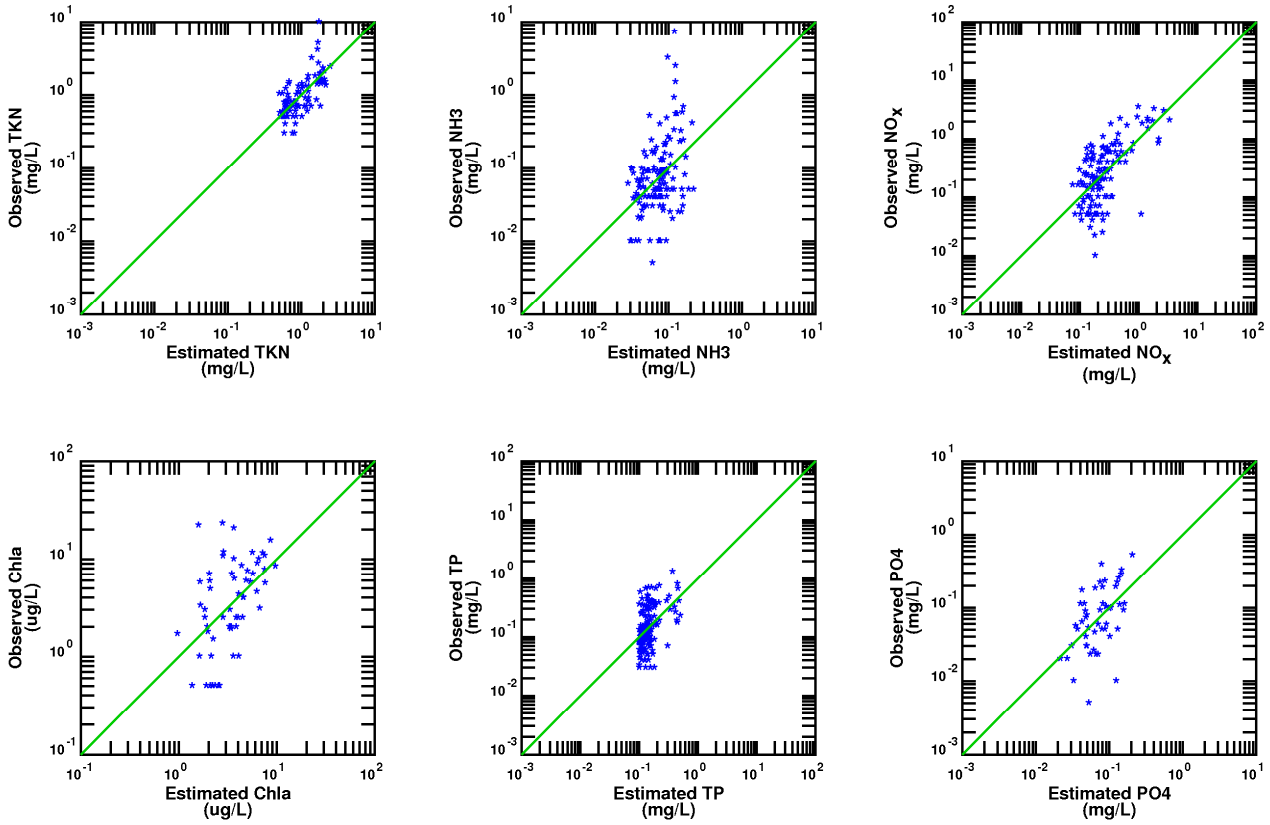

Figure 7-9. Concentrations Cross-Correlation Plots Based on LOADEST Regression Analysis for station 12979 (Nueces on US 281 south of Three Rivers)

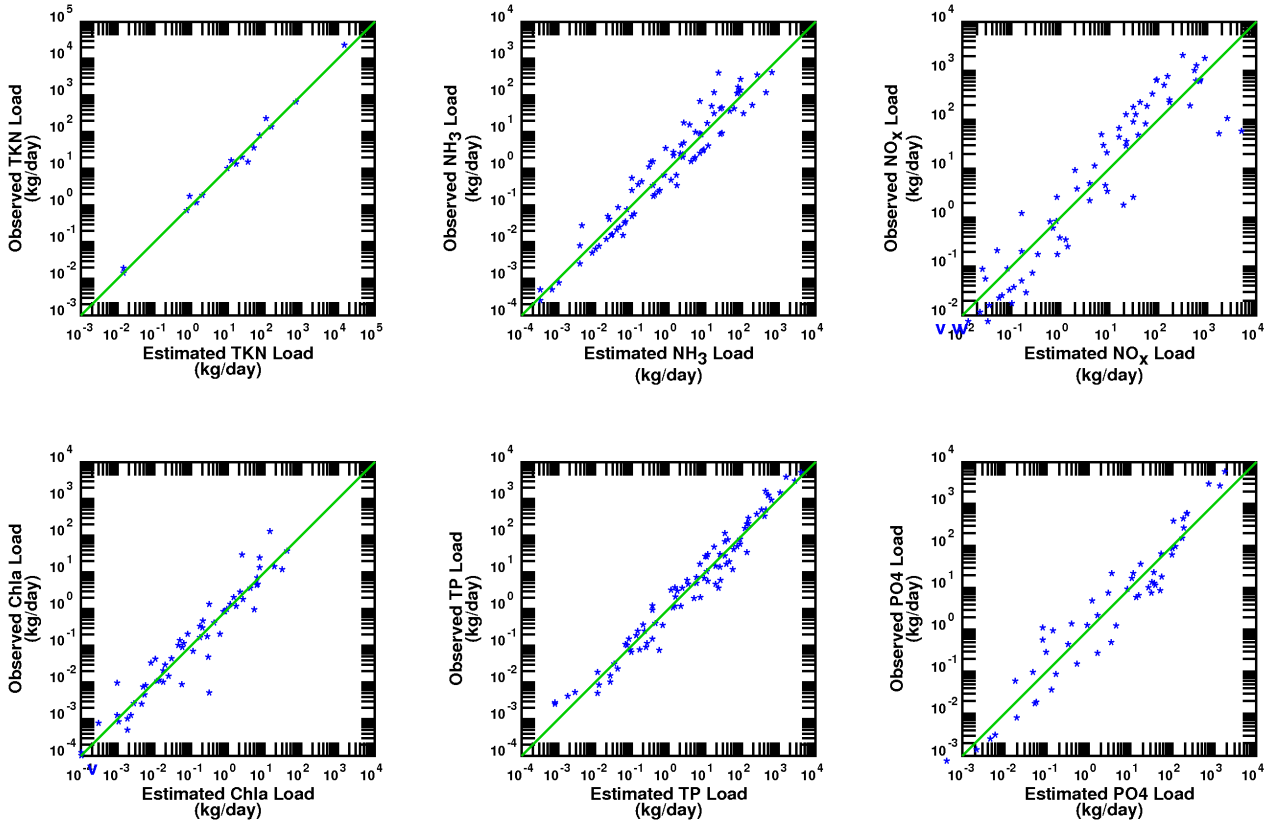

Figure 7-10. Concentrations Cross-Correlation Plots Based on LOADEST Regression Analysis for station 12973 (Nueces at SH 16 south of Tilden)

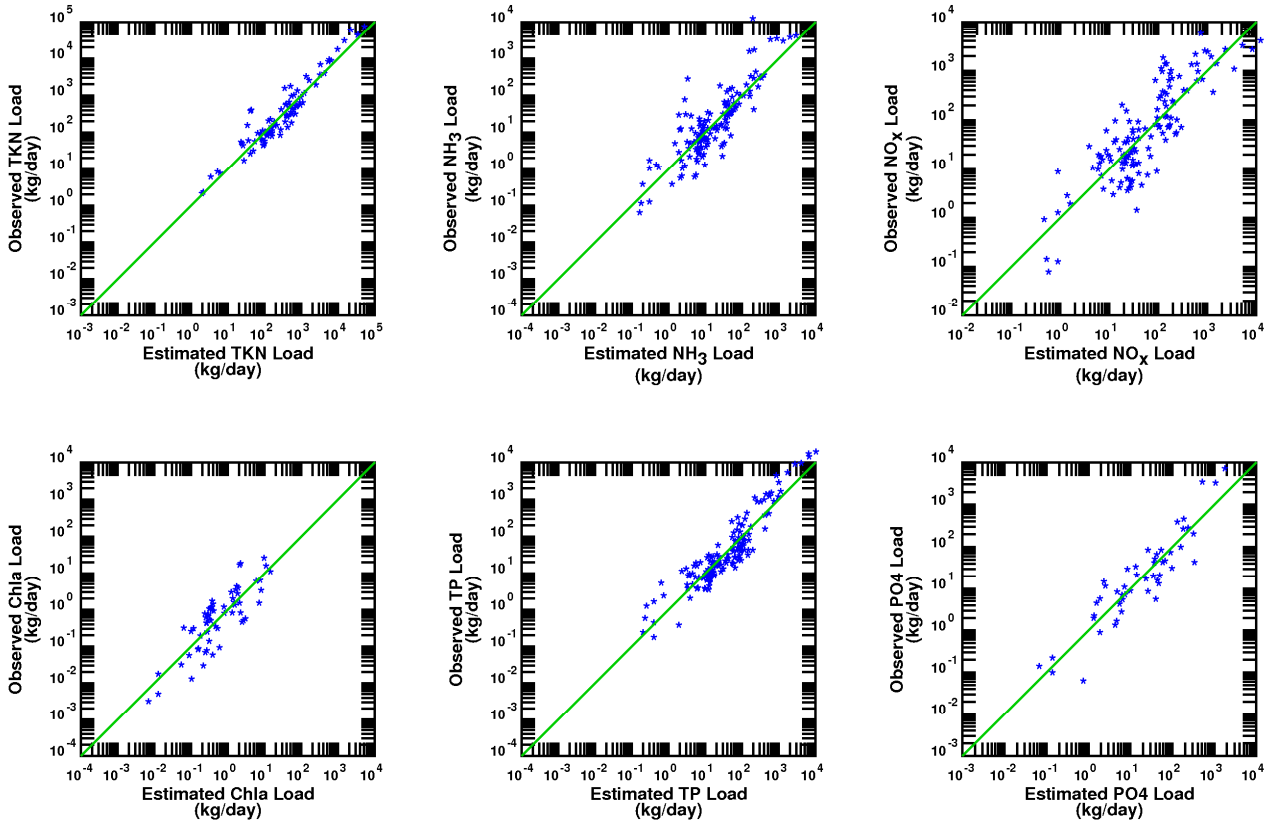

Figure 7-11. Loads Cross-Correlation Plots Based on Linear Regression Analysis for station 12979 (Nueces on US 281 south of Three Rivers)

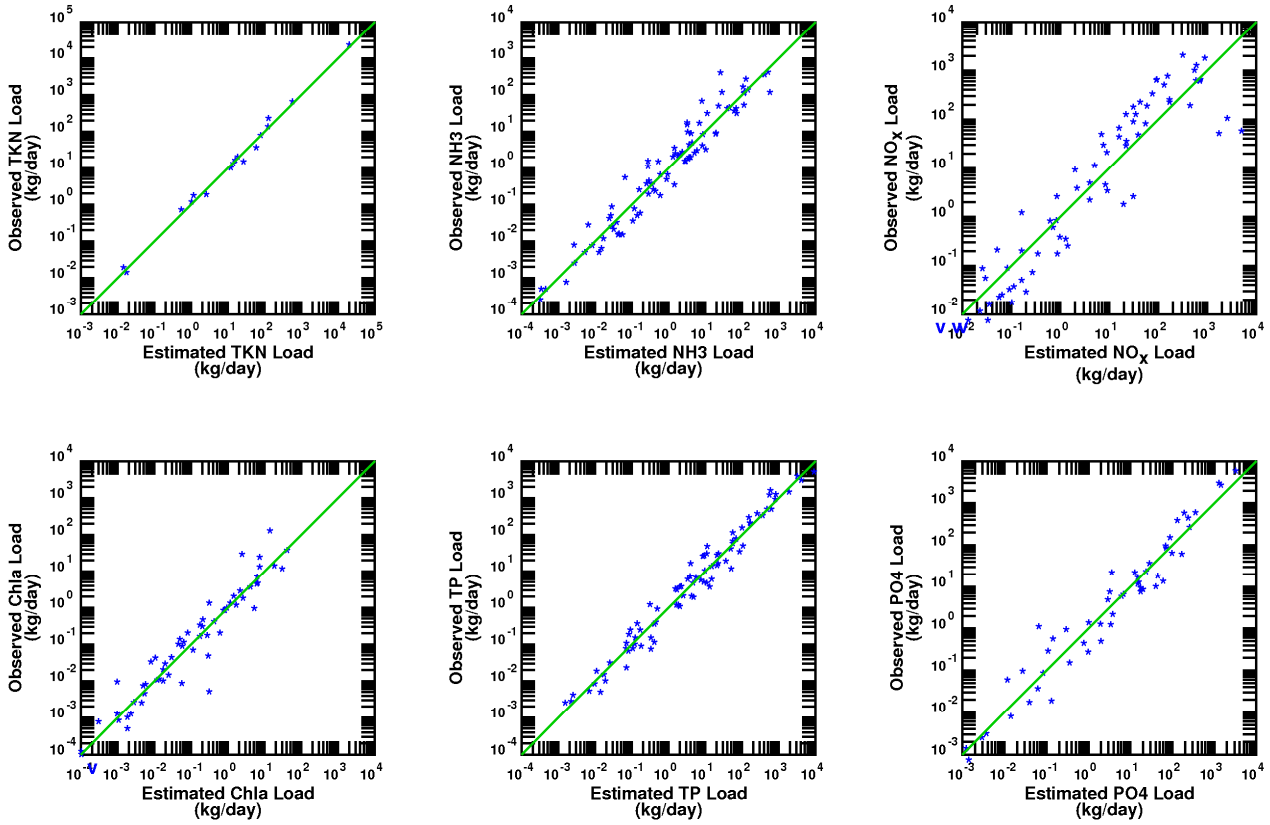

Figure 7-12. Loads Cross-Correlation Plots Based on LOADEST Regression Analysis for station 12973 (Nueces at SH 16 south of Tilden)

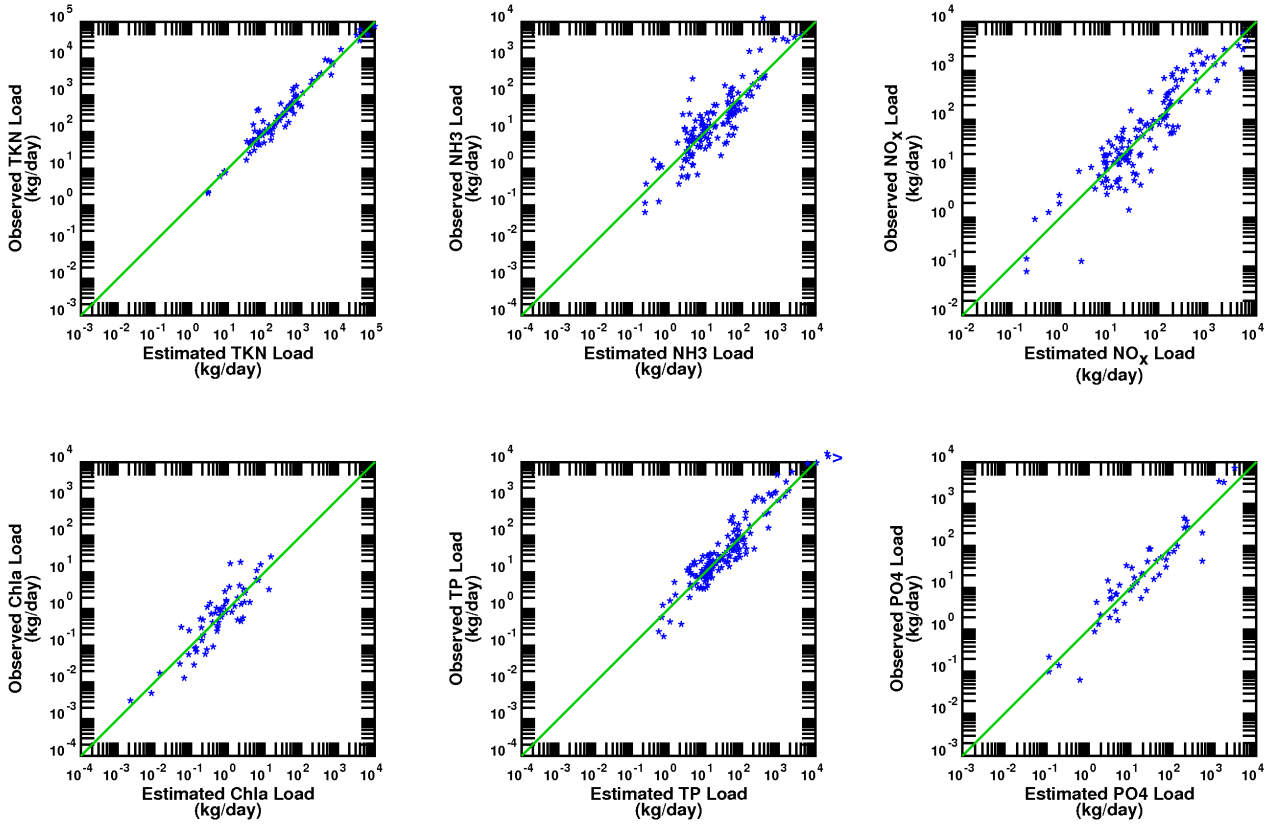

Figure 7-13. Loads Cross-Correlation Plots Based on LOADEST Regression Analysis for station 12979 (Nueces on US 281 south of Three Rivers)

7.3.2 Linear Regression Analysis Estimated Time-Series Concentrations and Loadings

Time-series of estimated concentrations and loadings were computed based on linear regression analysis, which does not include a temporal component in the analysis. For comparison, a similar time-series of estimated concentrations and loadings was generated using the LOADEST modeling, which does include a temporal component.

Figure 7-14 through Figure 7-16 show the observed nutrient data, as well as the estimated concentrations of nutrients computed based on linear regression analysis for the most upstream station (station 12999), the most downstream station not influenced by other rivers (station 12973) and the most downstream station (station 12979), noting that station 12979 is also below the confluence of the Nueces River, Frio River, San Miguel Creek and Atascosa River, so it is not completely clear that any trends are due to changes in the Nueces River or the other subbasins. The chl-a concentration at station 12999 is relatively constant while significant variability in chl-a concentration at station 12979 and station 12973 is exhibited. There is a slight increase in chl-a concentration between the upstream and downstream stations. The same magnitude of increase is shown in NH_3 downstream in the river. An increase by a factor of 10 in TKN, PO_4 and TP concentration is present from upstream to downstream. NOx concentration decreases by a factor of 10 from upstream to downstream. The changes in nutrients appear first at station 12976 (Segment 2105) and remain fairly constant down the river. With this regression analysis, conclusions about the TKN, TP, and PO_4 concentration increases and NOx decrease cannot be made. Estimated loadings lie within the range of observed loads (Figures 7-17 through Figure 7-19). These observed loads are calculated based on observed/measured concentrations. The figure captions use the term “observed load” for brevity.

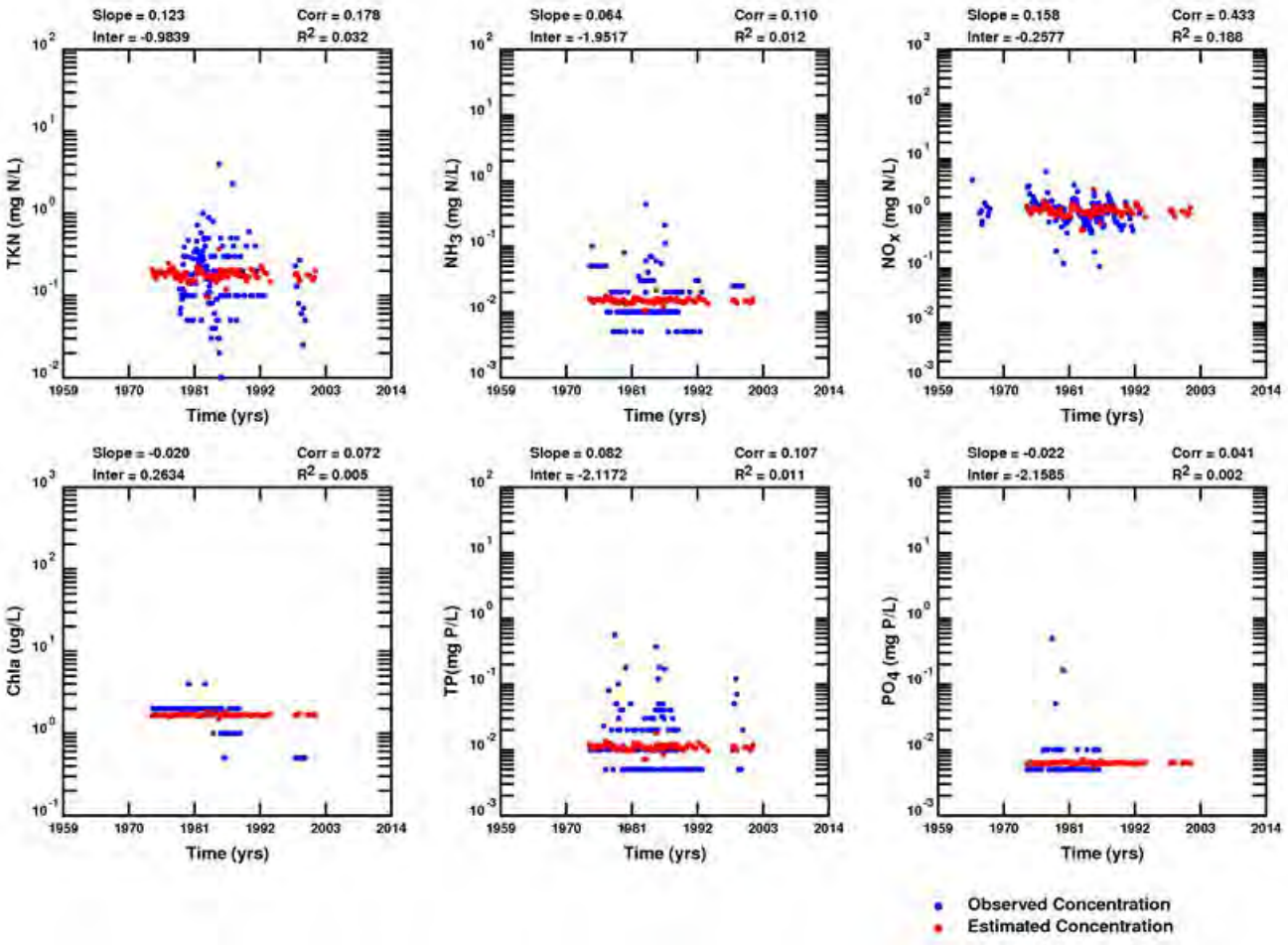

Figure 7-14. Nutrient Estimated Concentrations Based on Linear Regression Analysis for station 12999 (Nueces River NE of Laguna)

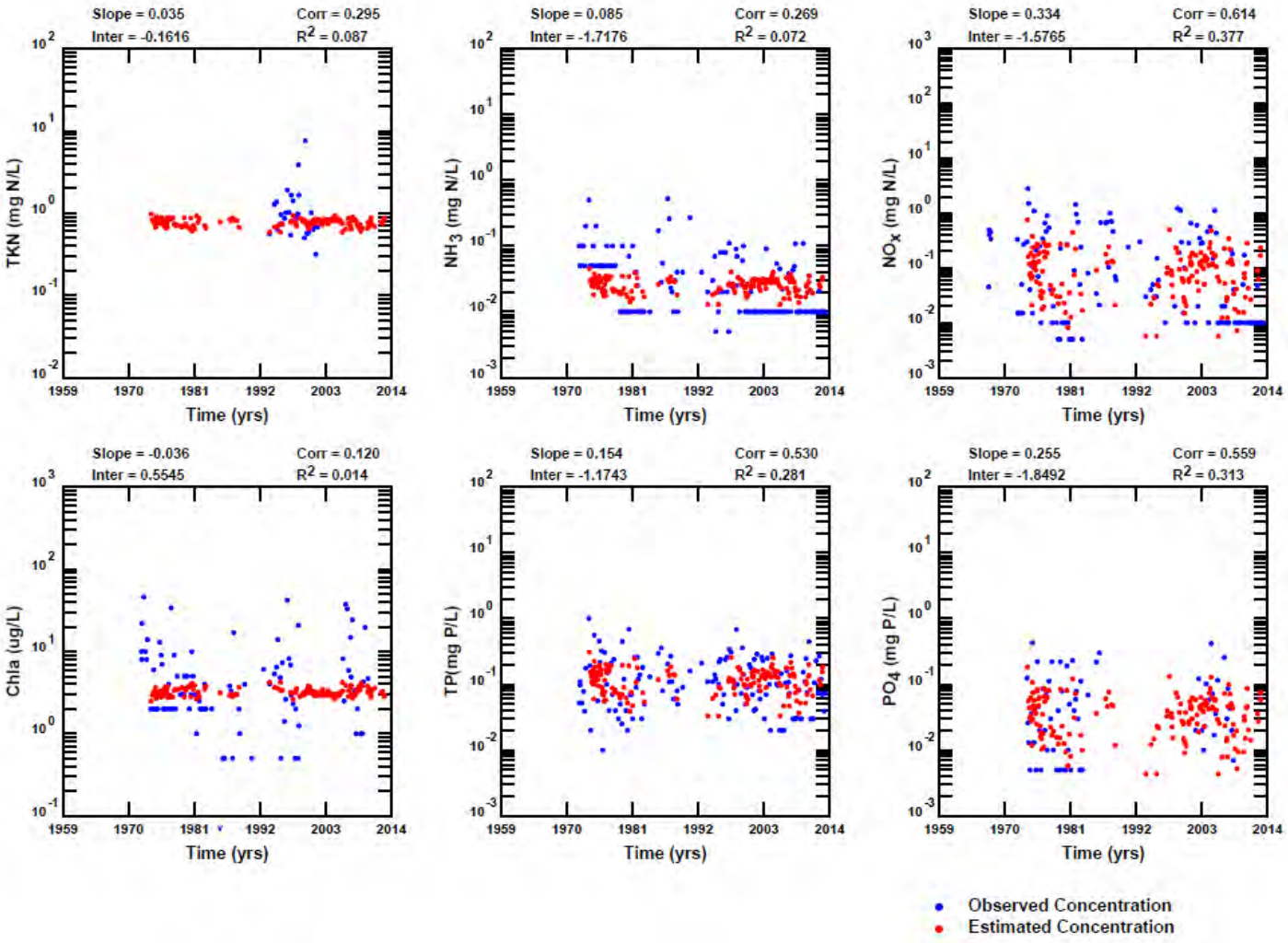

Figure 7-15. Nutrient Estimated Concentrations Based on Linear Regression Analysis for station 12973 (Nueces River at Tilden)

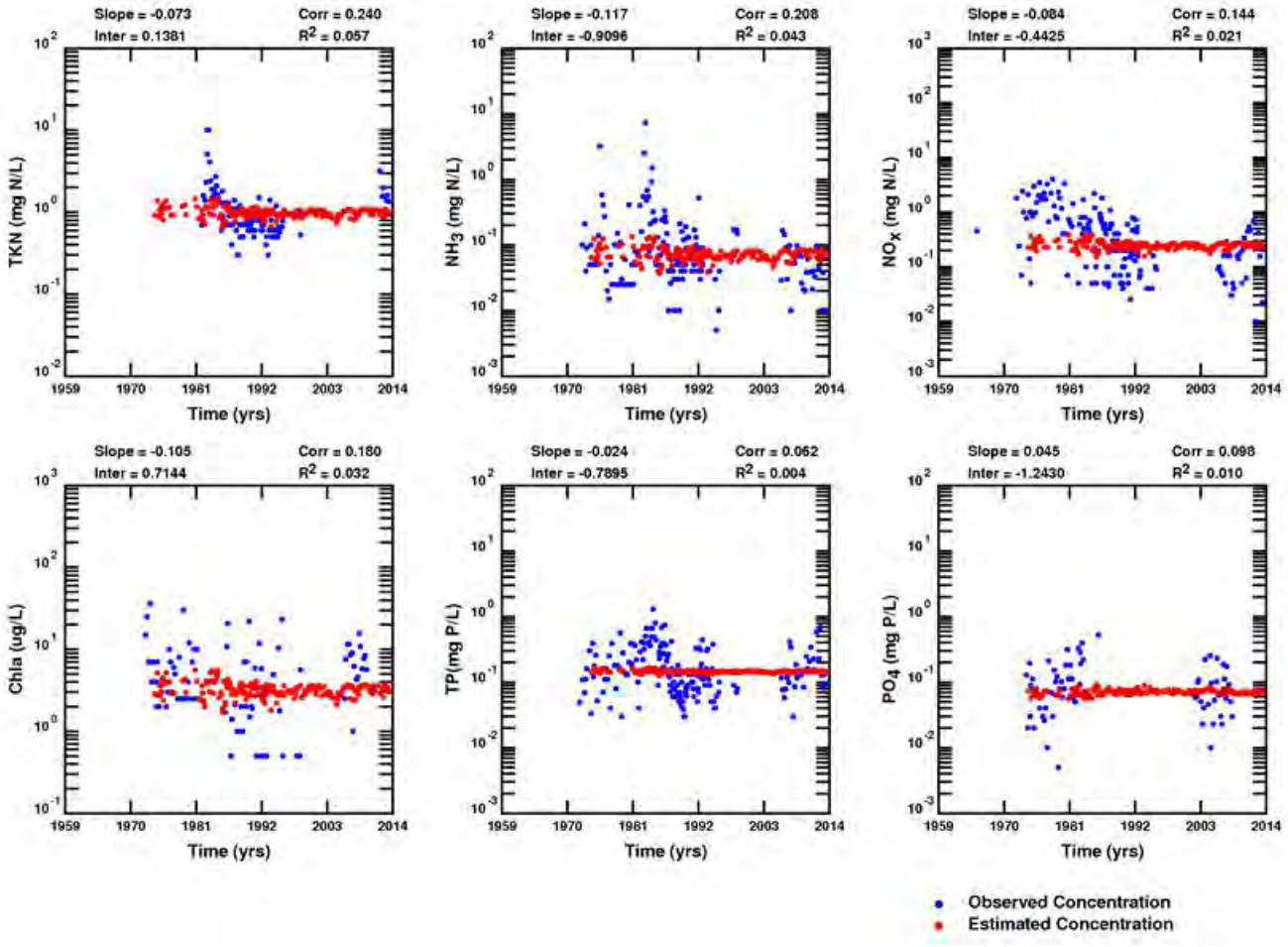

Figure 7-16. Nutrient Estimated Concentrations Based on Linear Regression Analysis for station 12979 (Nueces on US 281 south of Three Rivers)

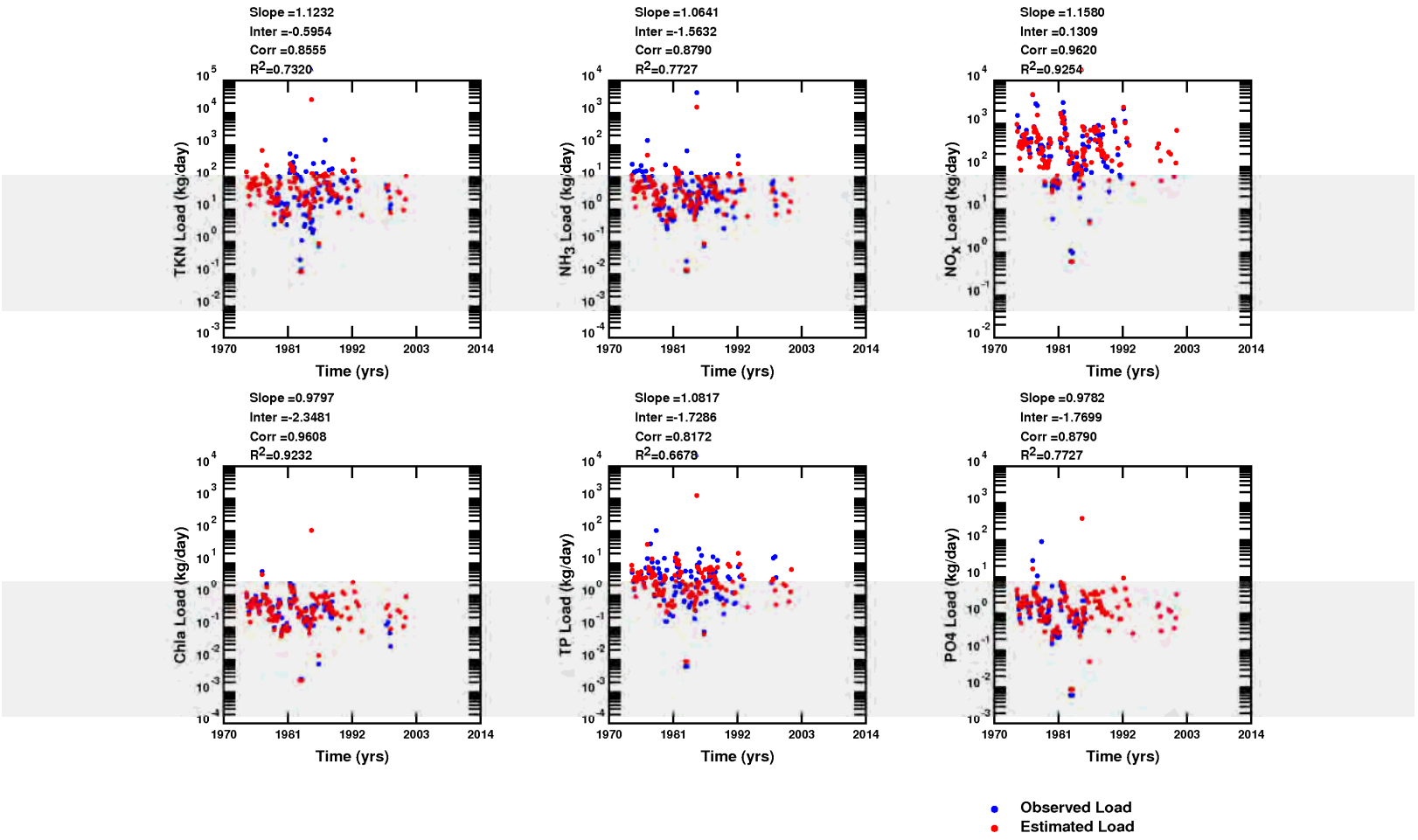

Figure 7-17. Nutrient Estimated Loads Based on Linear Regression Analysis for station 12999 (Nueces River NE of Laguna)

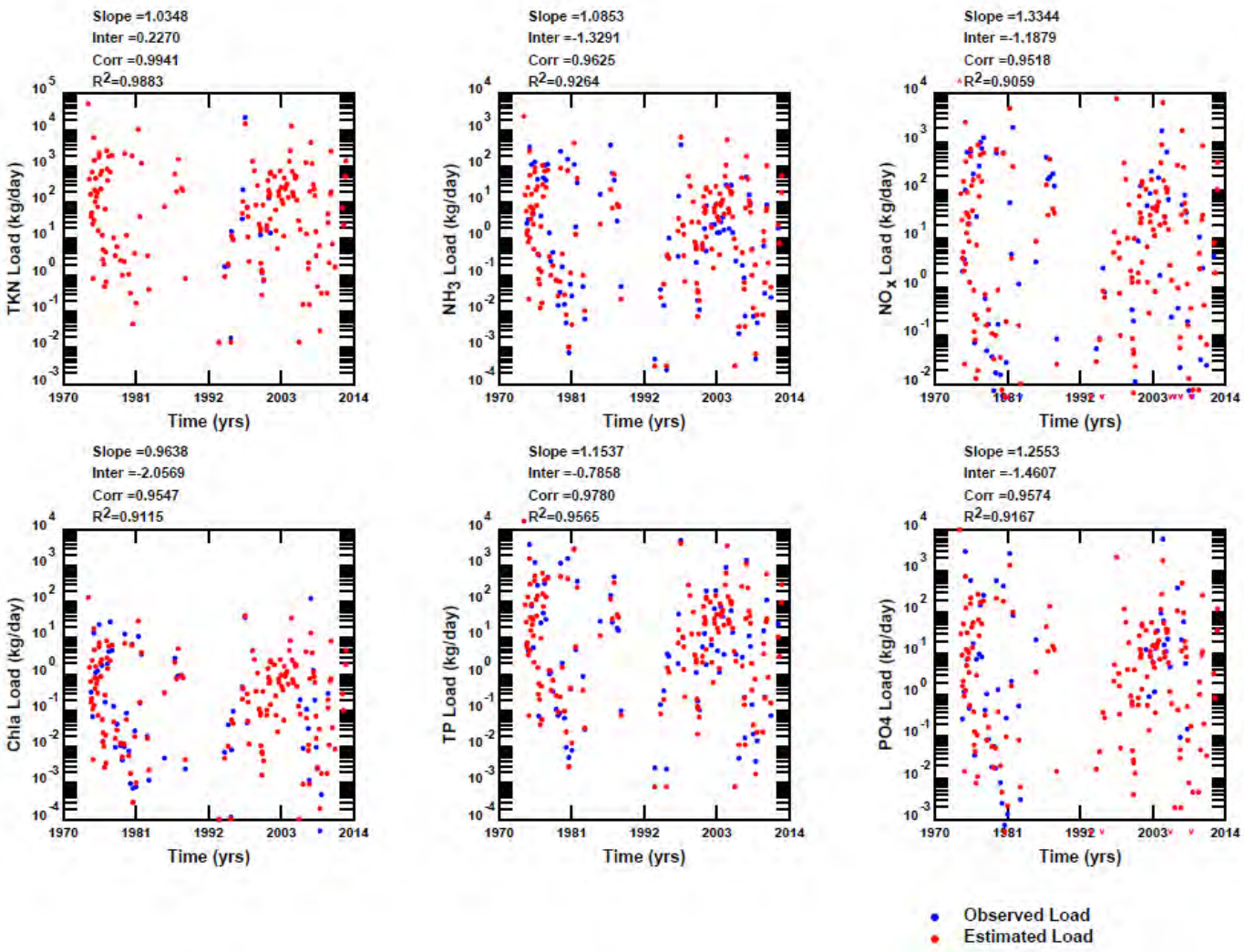

Figure 7-18. Nutrient Estimated Loads Based on Linear Regression Analysis for station 12973 (Nueces River at Tilden)

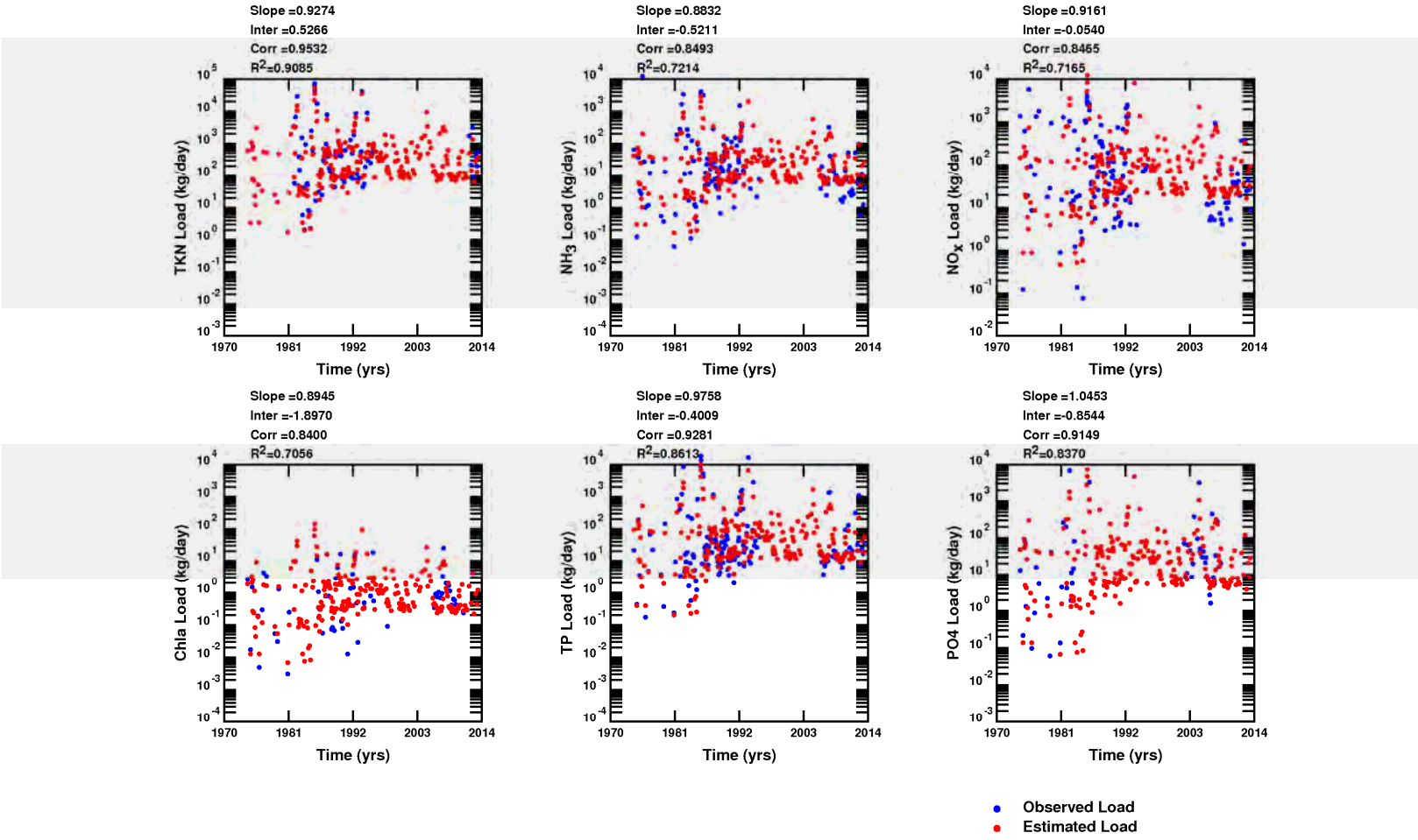

Figure 7-19. Nutrient Estimated Loads Based on Linear Regression Analysis for station 12979 (Nueces on US 281 south of Three Rivers)

7.3.3 LOADEST Estimated Time-Series Concentrations and Loadings

LOADEST-estimated concentrations and loads for TKN, NOx, TP, and PO_4 for station 12999 (Figure 7-20) are similar to the corresponding estimated constituents concentrations from the simple linear regression-reproduce the average of the data. Estimated concentration of chl-a has a non-linear curve that is driven by a single low value in the early 2000s. NH_3 estimated concentrations also have non-linear curves that are driven by detection limit values.

Figures 7-20 through 7-23 show LOADEST concentrations and loads for stations 12979 and 12999. R-squared values of TKN and PO_4 are 0.46 and 0.27, respectively.

The estimated loads from LOADEST look similar to the estimated loads computed from simple linear regression.

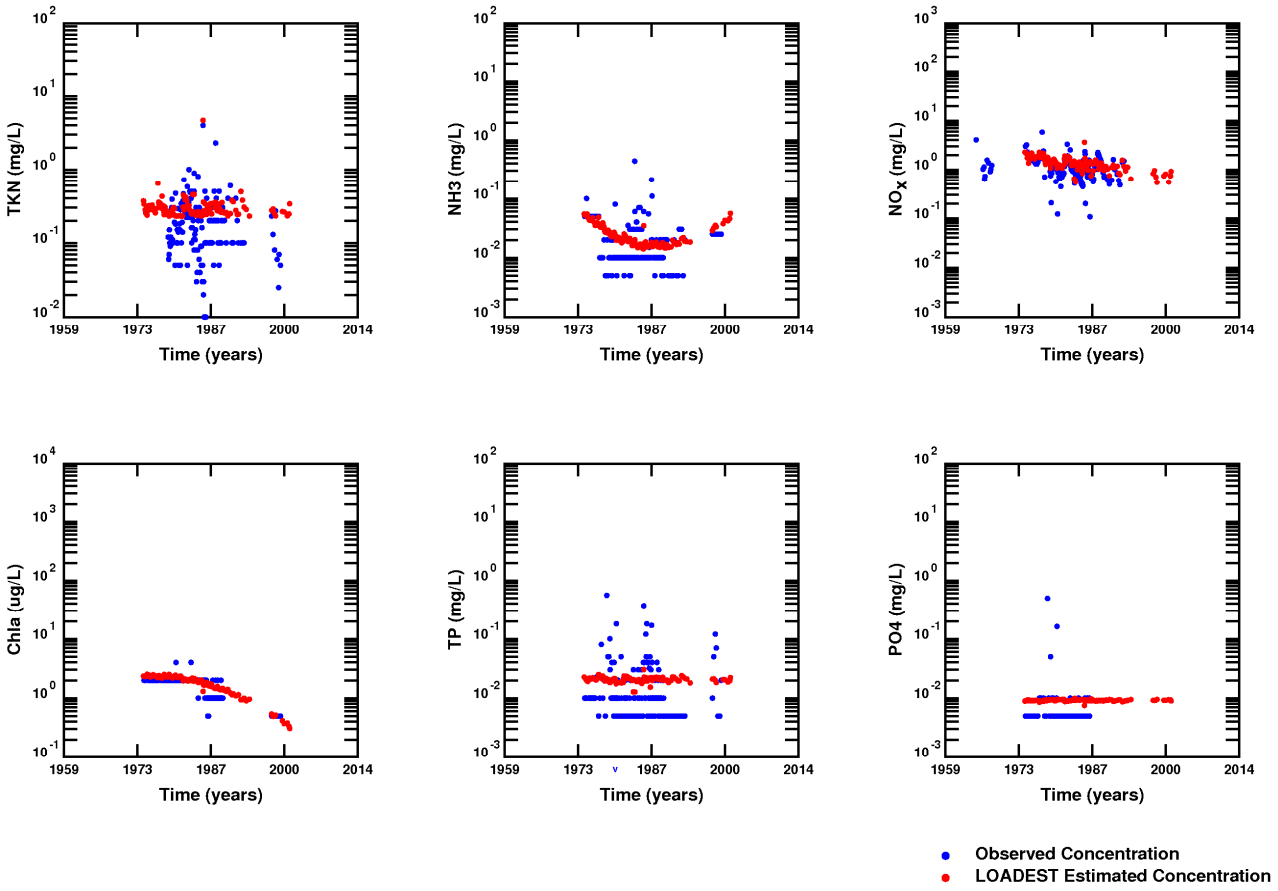

Figure 7-20. Nutrient Estimated Concentrations from LOADEST Regression Analysis for station 12999 (Nueces River NE of Laguna)

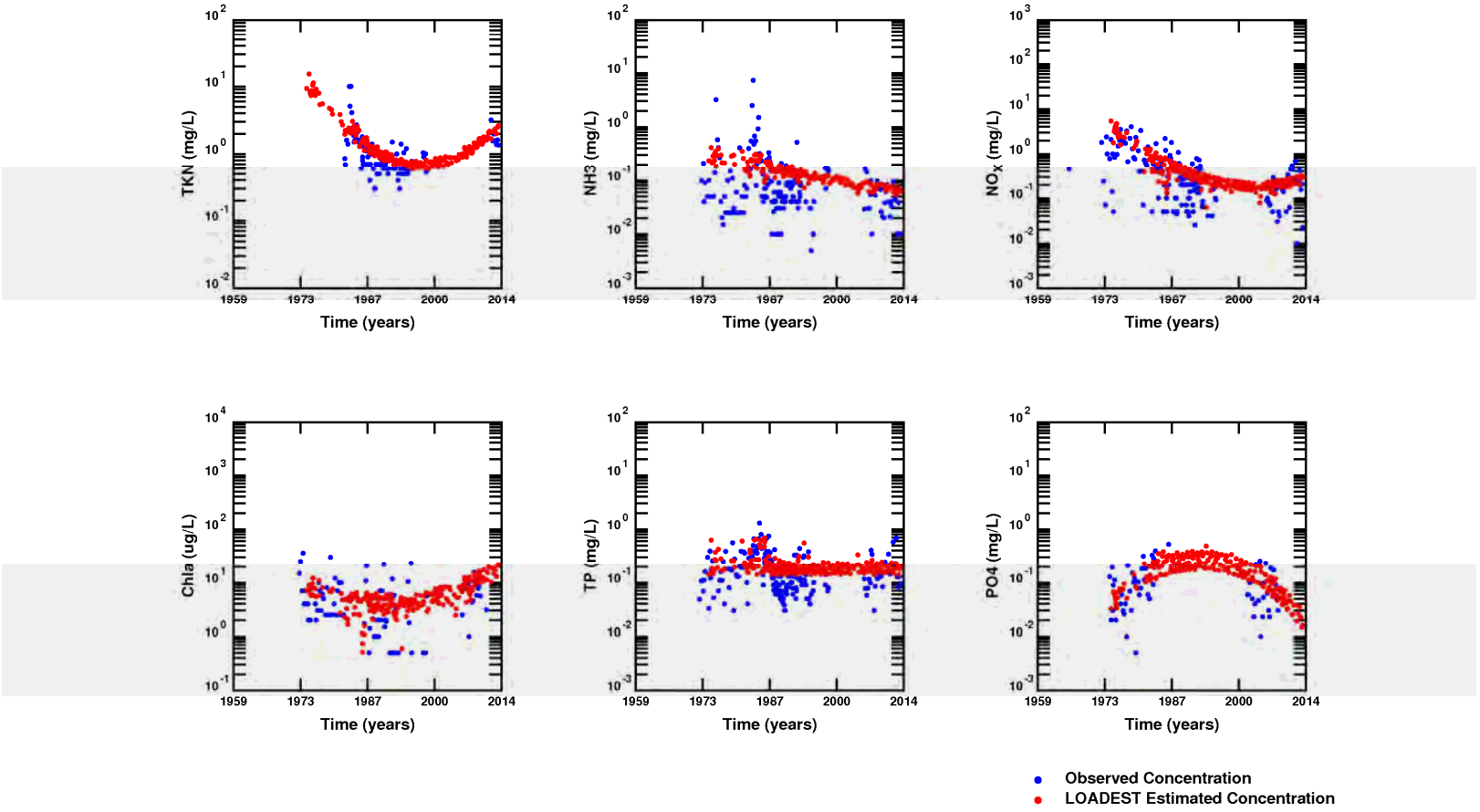

Figure 7-21. Nutrient Estimated Concentrations from LOADEST Regression Analysis for station 12979 (Nueces on US 281 south of Three Rivers)

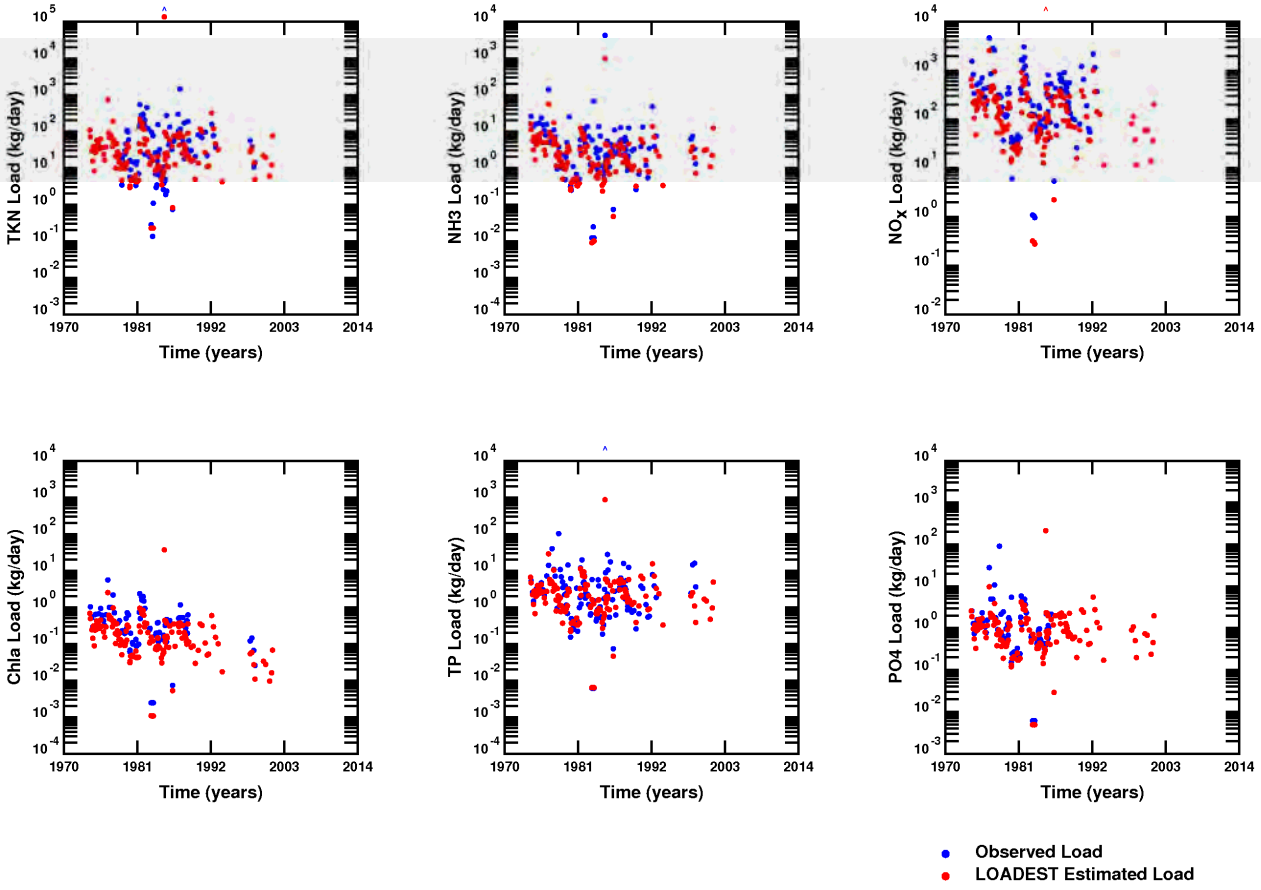

Figure 7-22. Nutrient Estimated Loads from LOADEST Regression Analysis for station 12999 (Nueces River NE of Laguna)

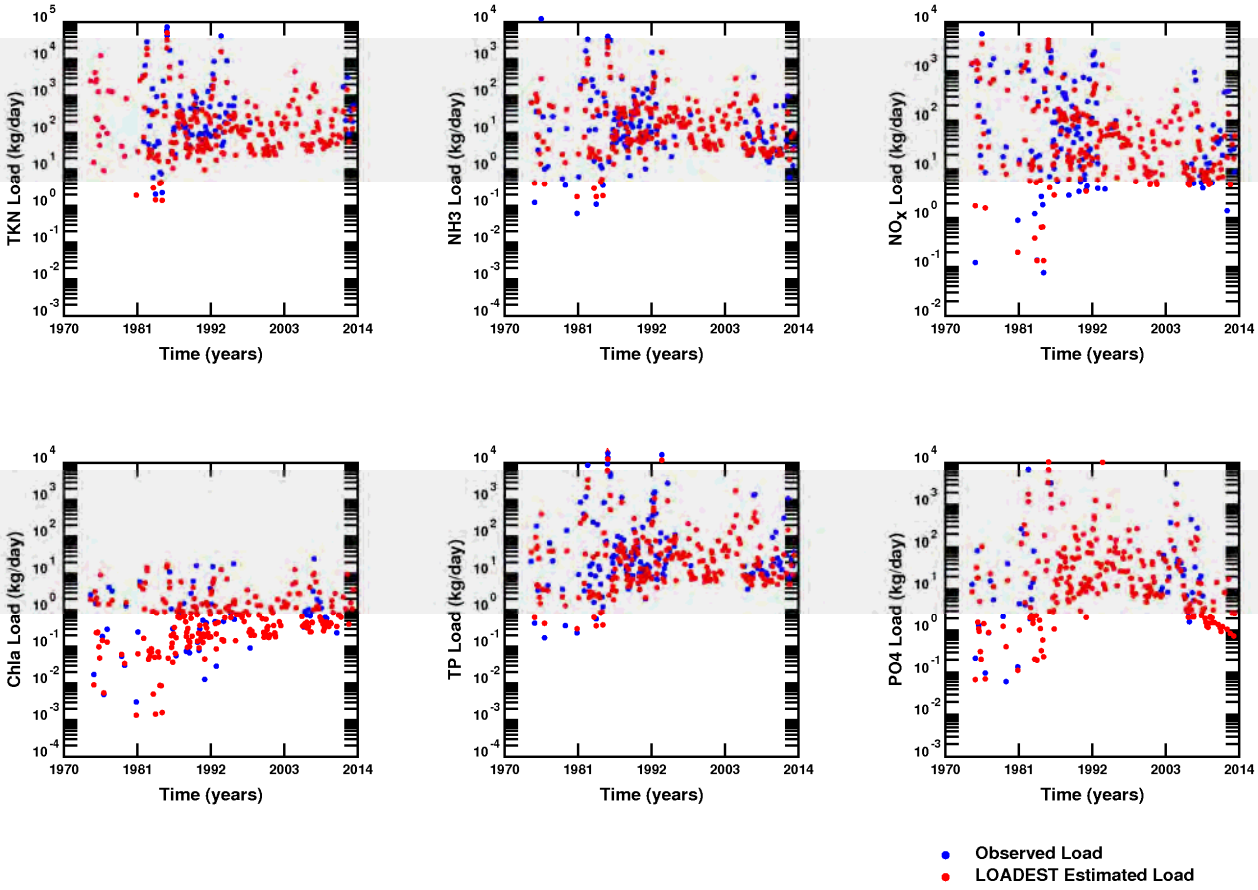

Figure 7-23. Nutrient Estimated Loads from LOADEST Regression Analysis for station 12979 (Nueces on US 281 south of Three Rivers)

7.4 Frio River

Analyses of the Frio River water quality data were completed. The Frio River has five upstream tributaries –Upper Frio River, Upper Sabinal River, Seco Creek, Hondo Creek, and Leona River. Nutrients parameters, including TKN, NH_3, NOx, chl-a, TP, and PO_4 were reviewed and compared to the data from the most downstream station on the Frio River. The stations that had the most comprehensive datasets from the undeveloped region as well as downstream of Frio River are:

- 12987, 12985 - Leona River at Batesville and Pearsall, respectively
- 13006, 13007 - Frio River at Concan, Frio River at Magers Crossing, respectively
- 12994, 12993 - Sabinal River north of Sabinal, Sabinal River at US 90, respectively
- 13013 - Seco Creek at Miller Ranch
- 13010 - Hondo Ck downstream of RR 462, Tarpley
- 13023 Frio River at SH 16 in Tilden.

Appendix E includes the regression analyses for stations in the Frio subwatershed. Figures 7-24 through 7-27 show regression analyses results for stations 12987, 13013, 13010 and 13023, respectively. The R-squared correlation coefficient relationships between NOx and flow at these stations range from 0.34 to 0.67. The R-squared correlation coefficient between NH_3 and flow for station 12987 is 0.28. However, scatter exists in other parameters for these stations.

Figures 7-28 through 7-30 show the estimated concentrations versus observed data for stations 13013, 13010 and 13023 computed based on the simple linear regression. Figures 7-31 through 7-33 show the LOADEST estimated concentrations for stations 13013, 13010 and 13023. LOADEST estimates differ from estimates computed by the linear regression analysis. For example, the linear regression R-squared value of correlation of 0.0091 for chl-a at station 13013 (Figure 7-25) suggests that there is no relationship between the chl-a and flow. This is why estimates are scattered and do not lie along the 1:1 line. As a conclusion, the analysis of the Frio River shows when going from upstream on the western branch of the Frio River to its downstream end the chl-a, TKN, NH_3, and TP concentrations increase while NOx decreases.

LOADEST indicates that there is a time dependent relationship with R-squared value of correlation of 0.54 making estimates lie more closely to the 1:1 line. LOADEST also shows a stronger correlation between TKN, NOx, TP and flow for all stations.

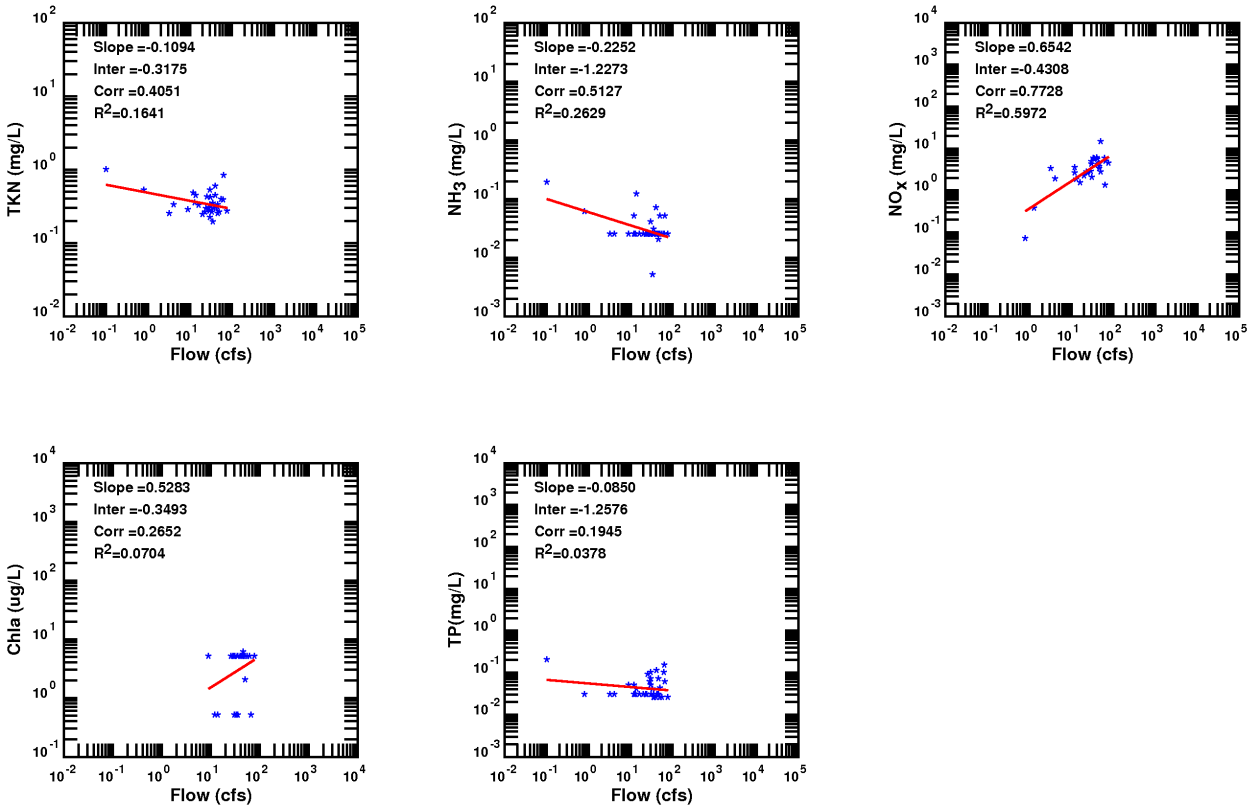

Figure 7-24. Linear Regression Analysis for station 12987 (Leona River at Batesville)

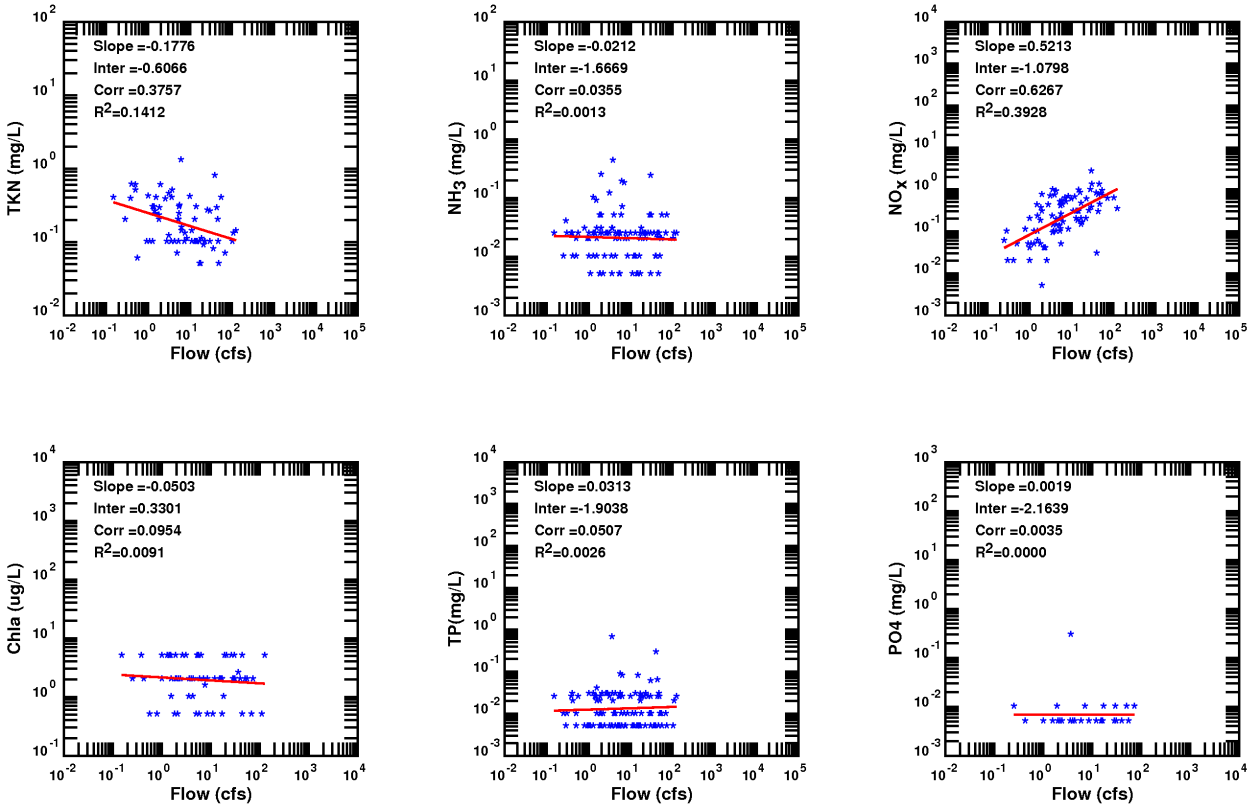

Figure 7-25. Linear Regression Analysis for station 13013 (Seco Creek at Miller Ranch)

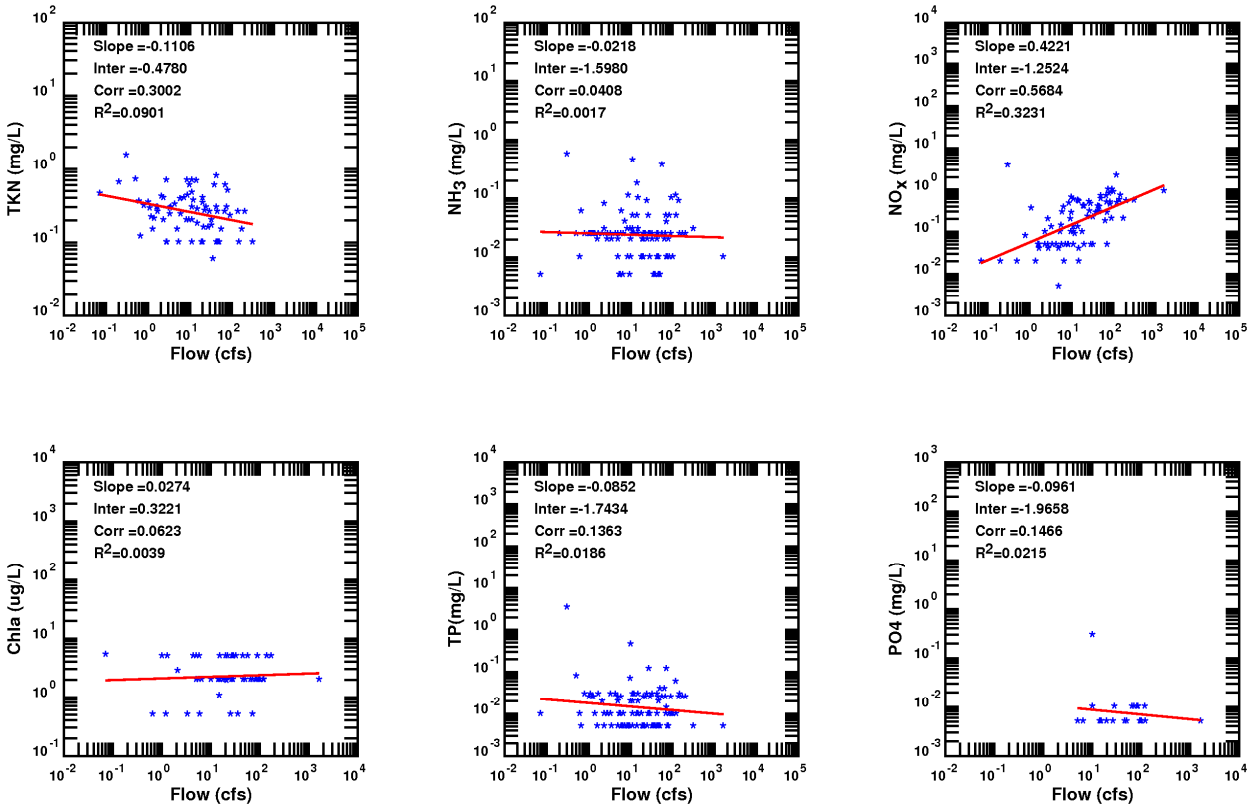

Figure 7-26. Linear Regression Analysis for station 13010 (Hondo Creek downstream of RR 462, Tarpley)

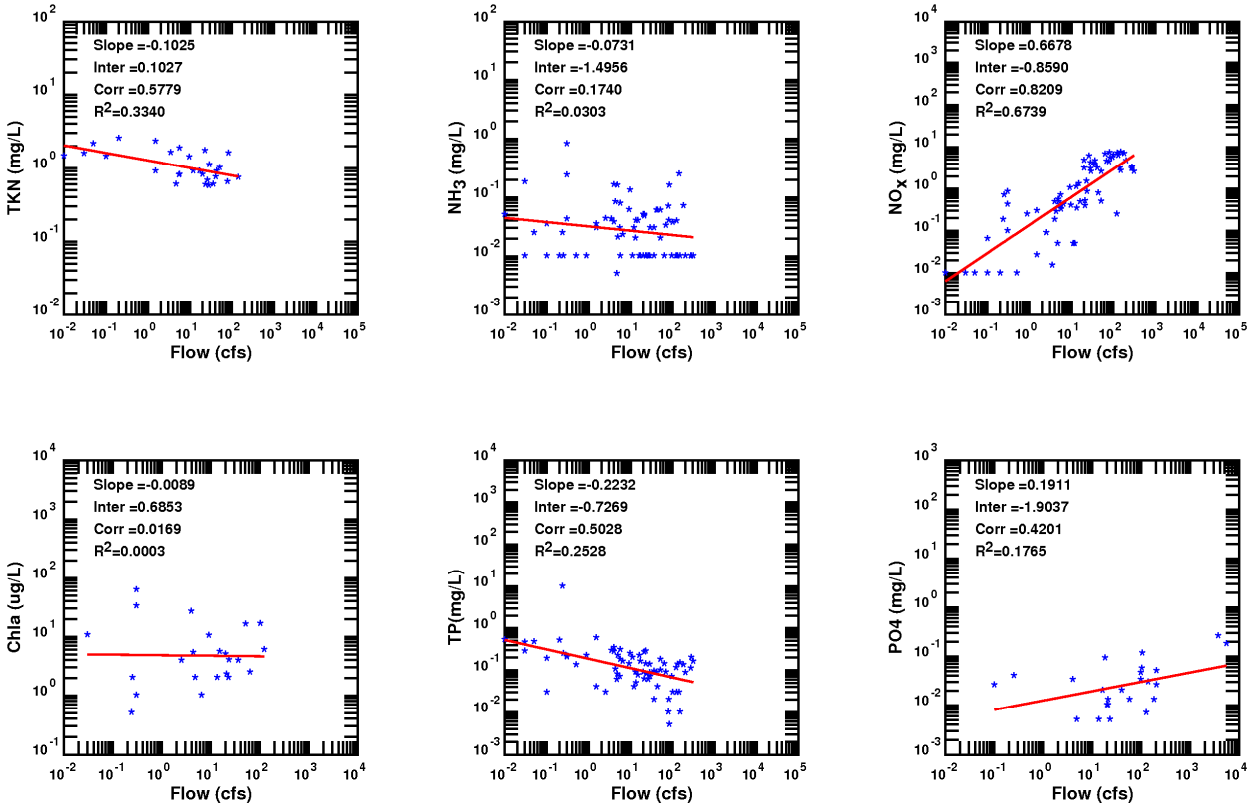

Figure 7-27. Linear Regression Analysis for station 13023 (Frio River at SH 16 in Tilden)

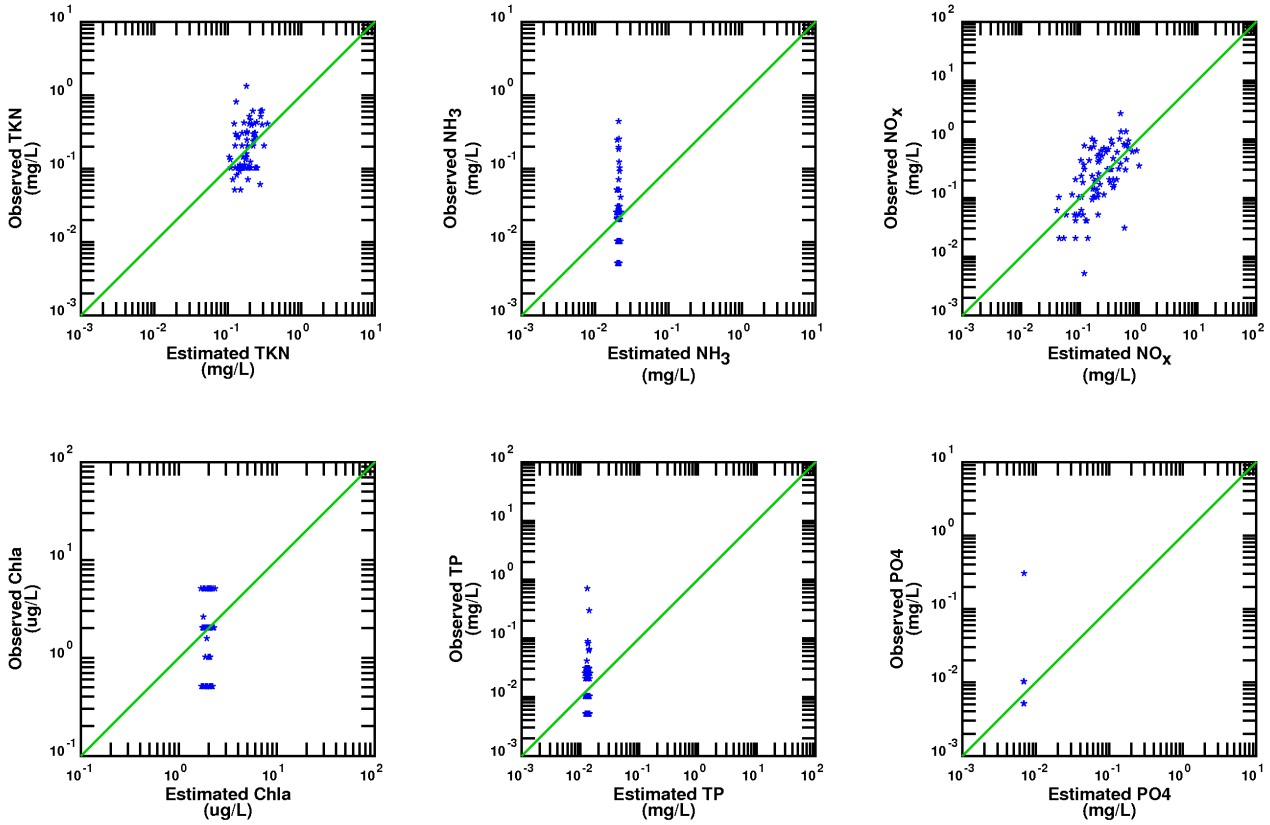

Figure 7-28. Concentrations Cross-Correlation Plots Based on Linear Regression Analysis for station 13013 (Seco Creek at Miller Ranch)

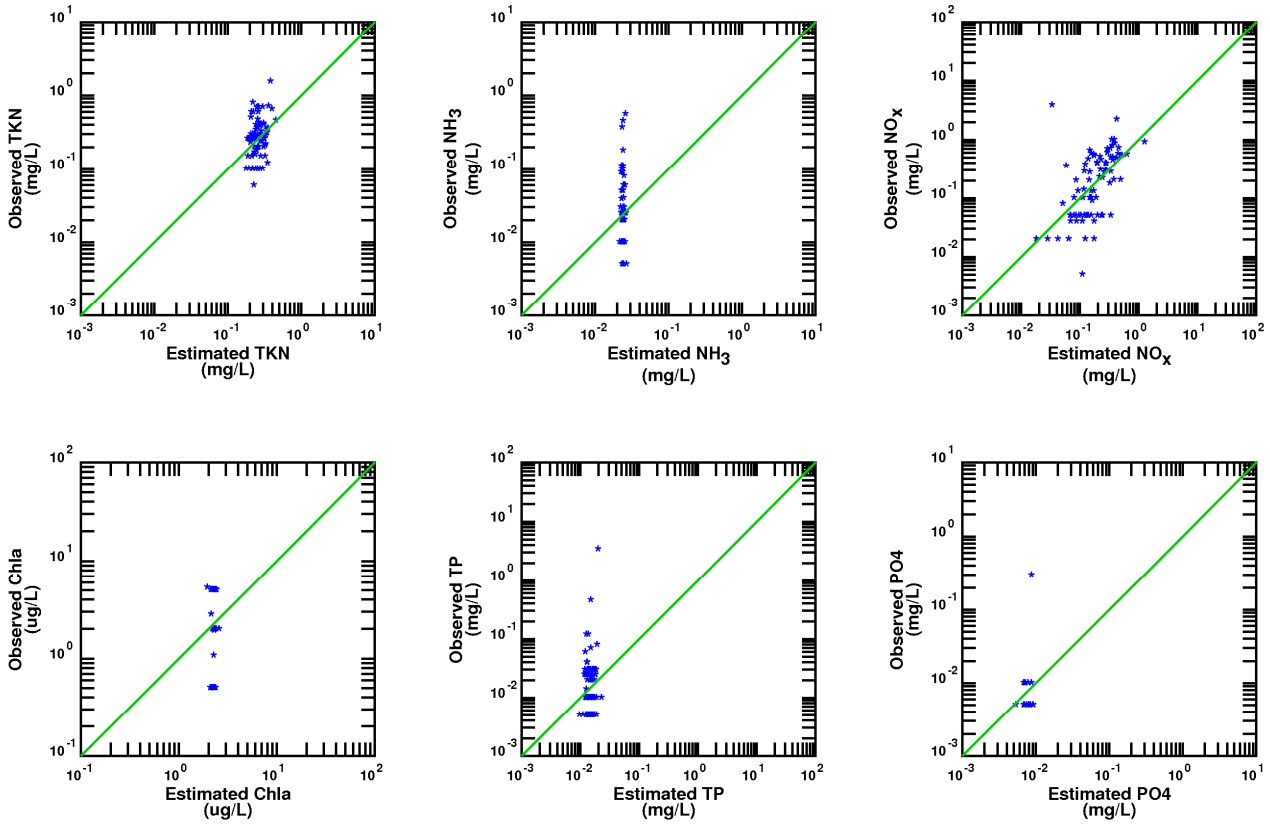

Figure 7-29. Concentrations Cross-Correlation Plots Based on Linear Regression Analysis for station 13010 (Hondo Creek downstream of RR 462, Tarpley)

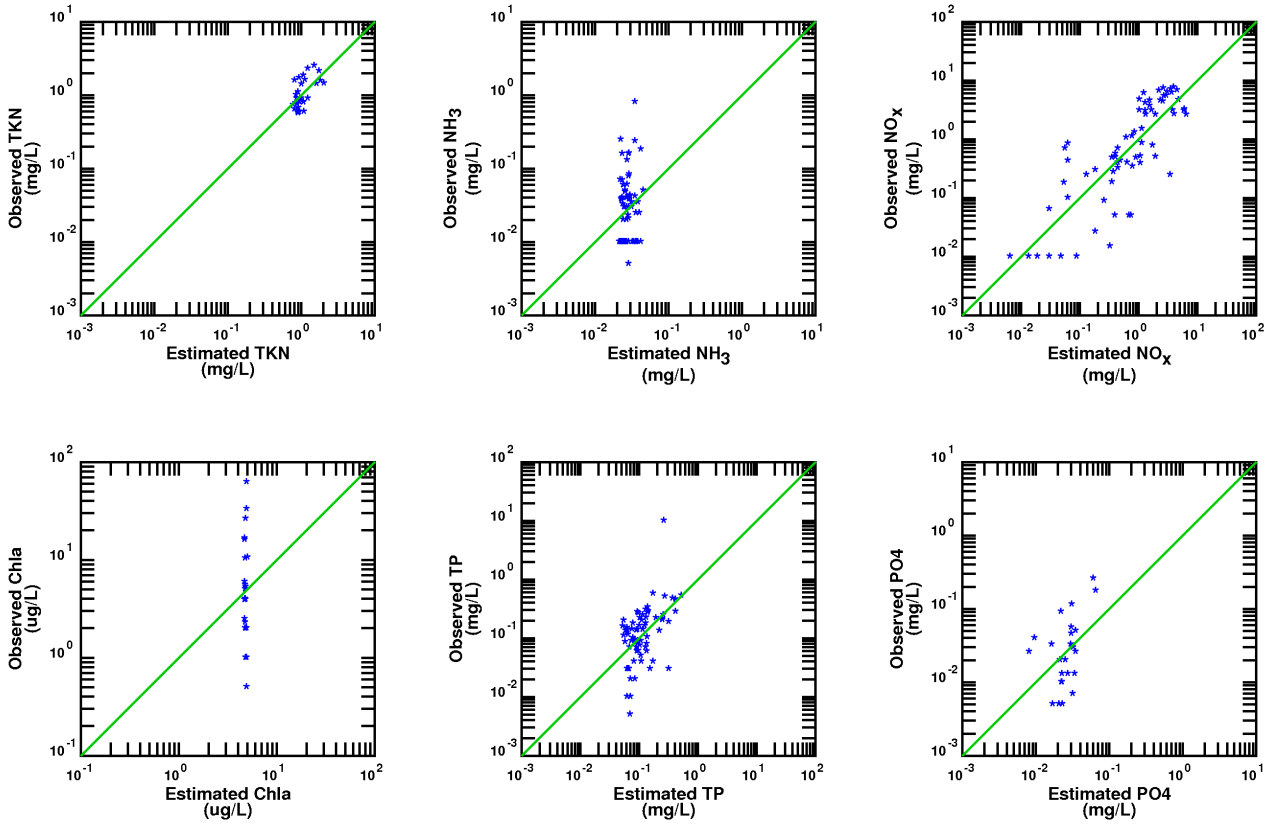

Figure 7-30. Concentrations Cross-Correlation Plots Based on Linear Regression Analysis for station 13023 (Frio River at SH 16 in Tilden)

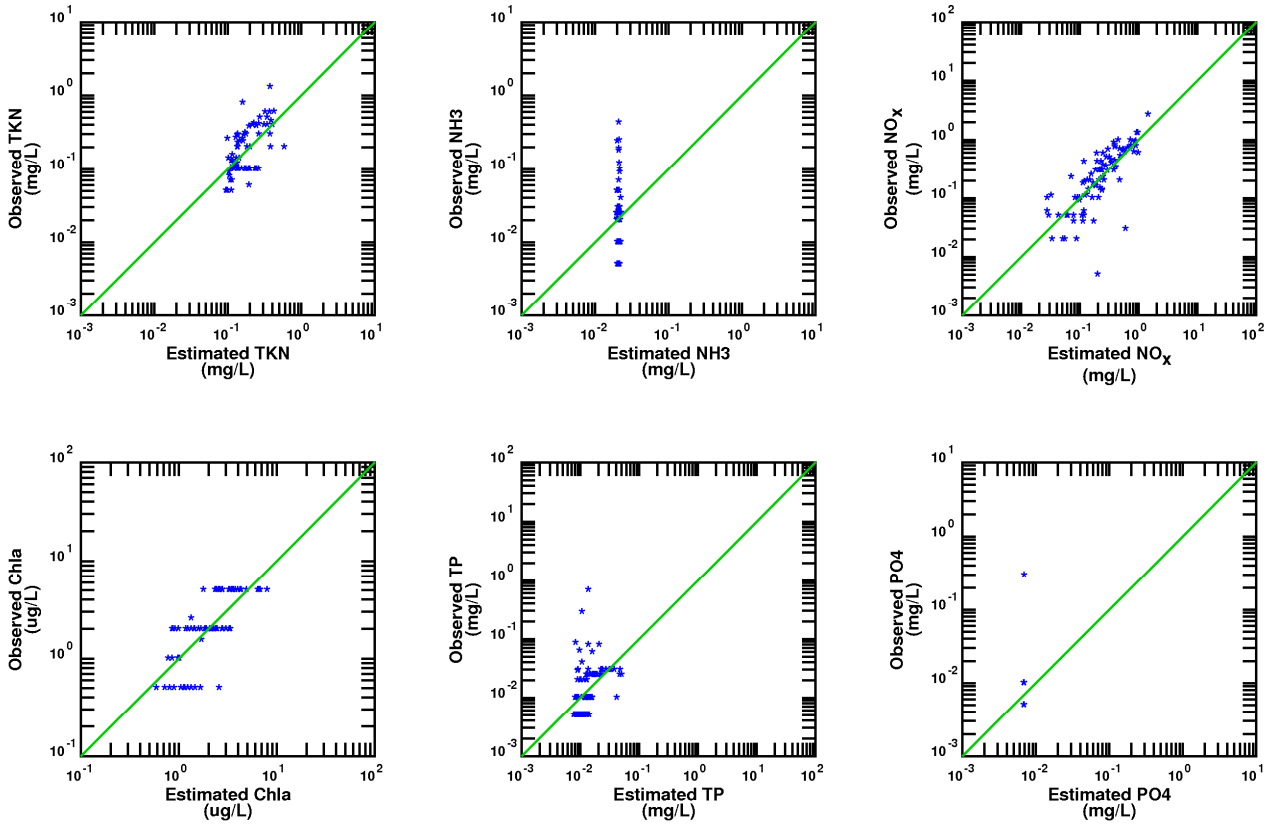

Figure 7-31. Concentrations Cross-Correlation Plots Based on LOADEST Regression Analysis for station 13013 (Seco Creek at Miller Ranch)

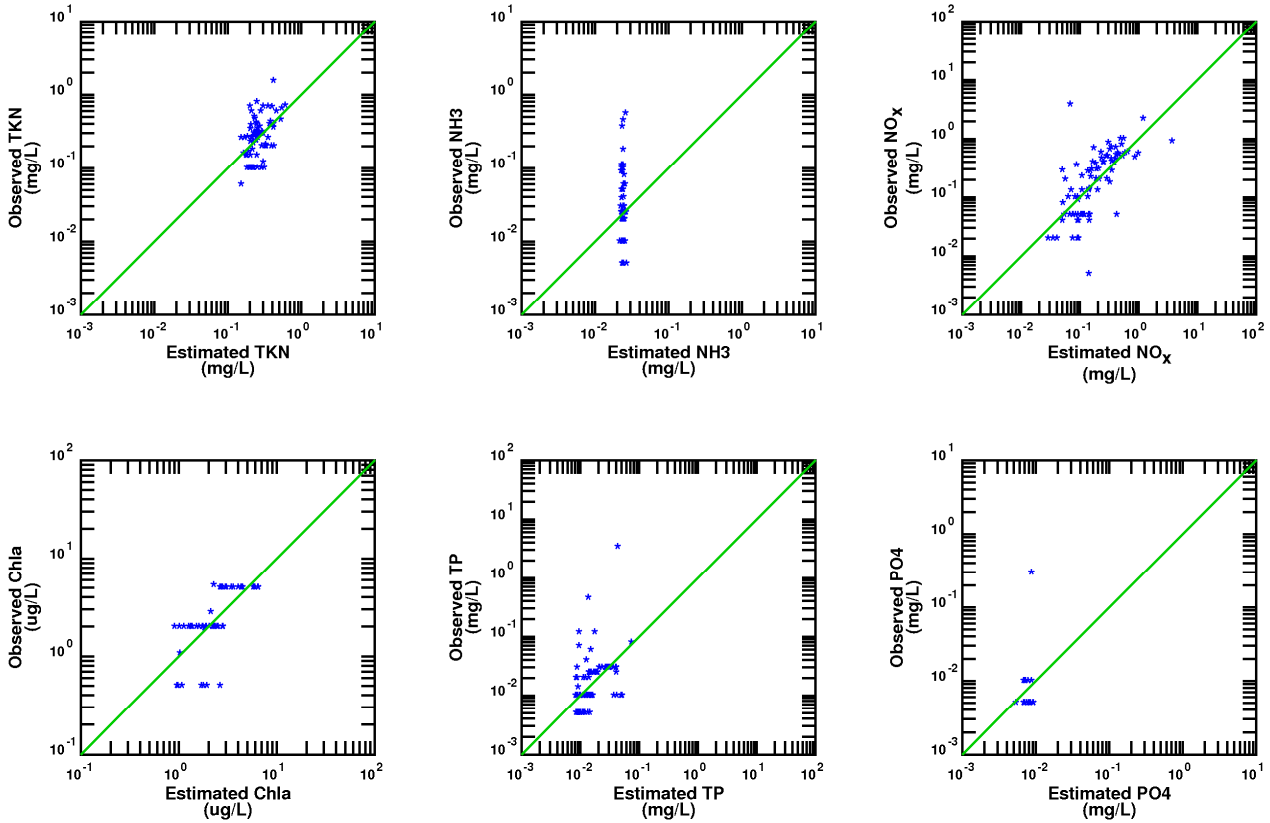

Figure 7-32. Concentrations Cross-Correlation Plots Based on LOADEST Regression Analysis for station 13010 (Hondo Creek downstream of RR 462, Tarpley)

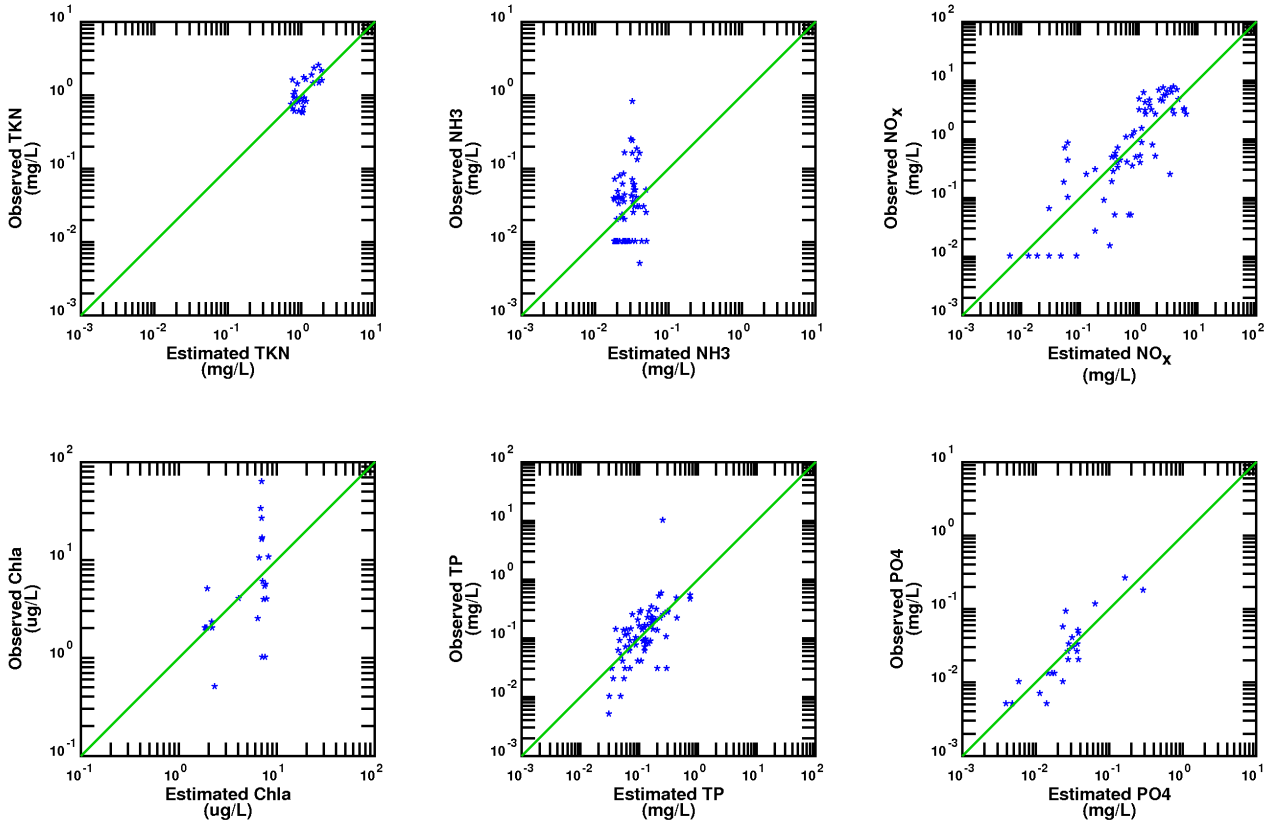

Figure 7-33. Concentrations Cross-Correlation Plots Based on LOADEST Regression Analysis for station 13023 (Frio River at SH 16 in Tilden)

The data show that there are no significant differences in nutrient concentrations at the four upstream tributaries: Upper Frio River (station 13006), Upper Sabinal River (stations 12994 and 12993), Seco Creek (station 13013) and Hondo Creek (station 13010). All nutrients, as well as chl-a concentrations, are similar across these water bodies.

NH_3 and chl-a concentrations at the Leona River (stations 12987 and 12985) have the same magnitude as at the other four tributaries. However, there is a slight increase in TKN, TP and PO_4 by a factor of two. Also the NOx concentration at Leona River and at the lower portion of Upper Sabinal River (station 12993) is 10 times higher than the NOx concentration at the other branches. The same magnitude in TKN, TP and PO_4 was noted at the most downstream station (station 13023) of the Frio River. It seems that the increase in nutrients (TKN, TP, PO_4 and NOx) at the downstream portion of the Frio River originates from two of its branches, the Leona River and the lower portion of the Upper Sabinal River. This could be an indication of influence from the Sabinal WWTP, as well as from the Uvalde WWTP. Note that the Sabinal WWTP was relocated and began operations above the 100-year floodplain at a new facility in July 2011.

Time series of the estimated concentrations were generated from simple linear regression as well as from LOADEST multiple regression analyses and compared to each other.

The estimates do not show any particular trends in nutrient concentrations at station 13006 (Figure 7-34). Since linear regression did not reveal any significant relationships the estimated concentrations have flat trends and stay close to the average concentrations. However, while LOADEST estimated PO_4 and NOx concentrations have the similar trend, the other variable estimates differ significantly. The LOADEST estimation indicates about a slight decrease of the chl-a concentration in recent years (Figure 7-35). The parabolic curve generated by LOADEST for TKN appears to be driven by five to ten low observations in the early 1980s, which makes the computed high estimated concentrations on the left end of the curve unrealistically overestimated.

Similar trends for TKN, NH_3 and NOx for station 12993 are computed by both methods (Figures 7-36 and 7-37). However, LOADEST suggests that there is an increasing trend in TP over time, while linear regression do not see any trends at all. The biggest difference in computations is observed for chl-a and PO_4 concentrations. The parabolic curve estimated by LOADEST for chl-a is driven by some low detection limit values in late 1970 and a couple of high values in recent years, while a linear regression estimates a flat line. In addition, the significant drop in PO_4 concentration computed by LOADEST after 1980 makes these estimated values unrealistically underestimated and questionable.

Very similar trends for NH_3, NOx and PO_4 for station 13013 are computed by both methods (Figures 7-38 and 7-39). The LOADEST TKN curve appears to driven by a few low values in the mid1990s and a few high values in the late 1970s, while linear regression show flat trend with seasonal variability. LOADEST estimates of chl-a are driven by detection limit values that differ from time to time since it is unrealistic that all measurements done in three time periods (pre-1986, 1986-2000 and post-2000) stay constant.

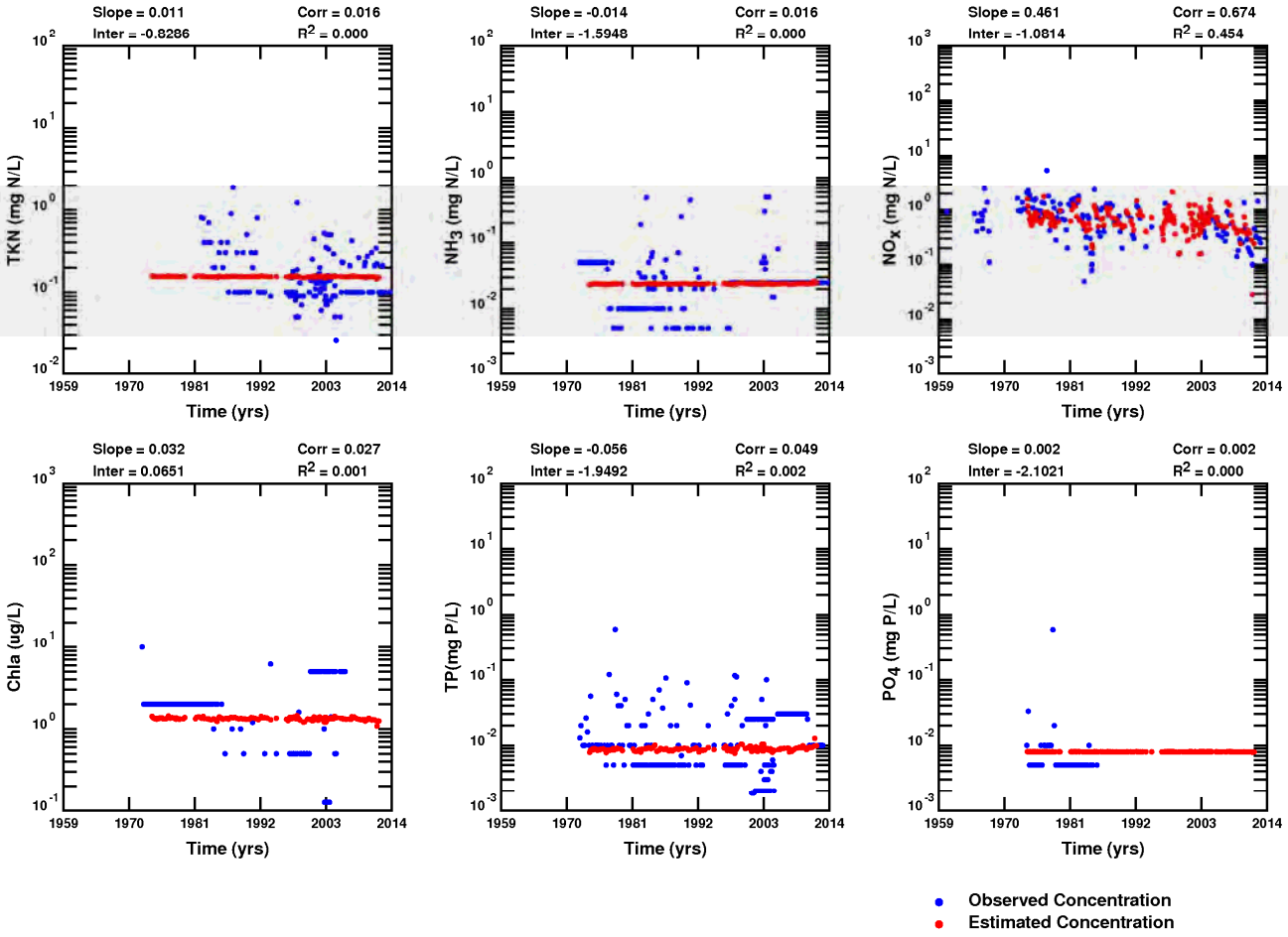

Figure 7-34. Nutrient Estimated Concentrations Based on Linear Regression Analysis for station 13006 (Frio River at SH 127)

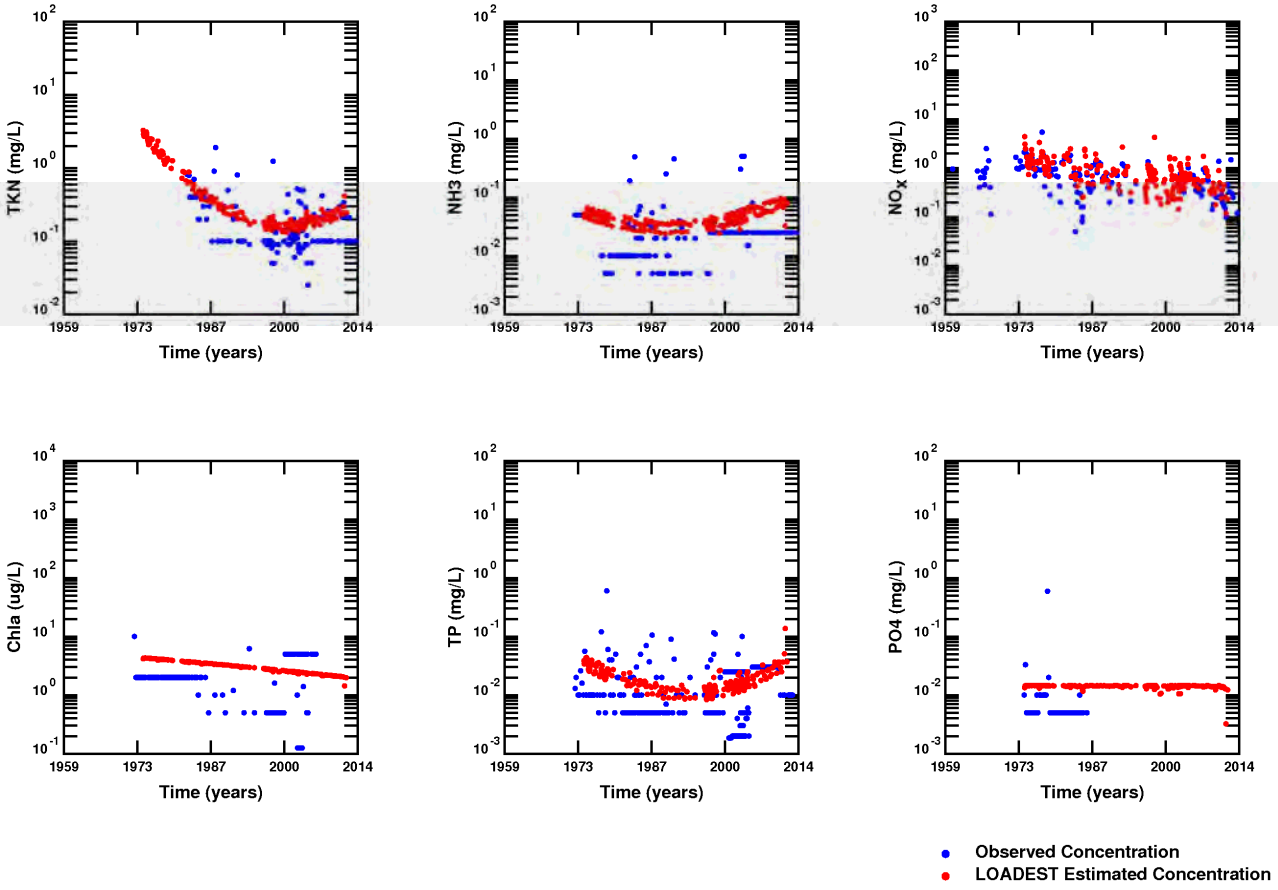

Figure 7-35. Nutrient Estimated Concentrations LOADEST Regression Analysis for station 13006 (Frio River at SH 127)

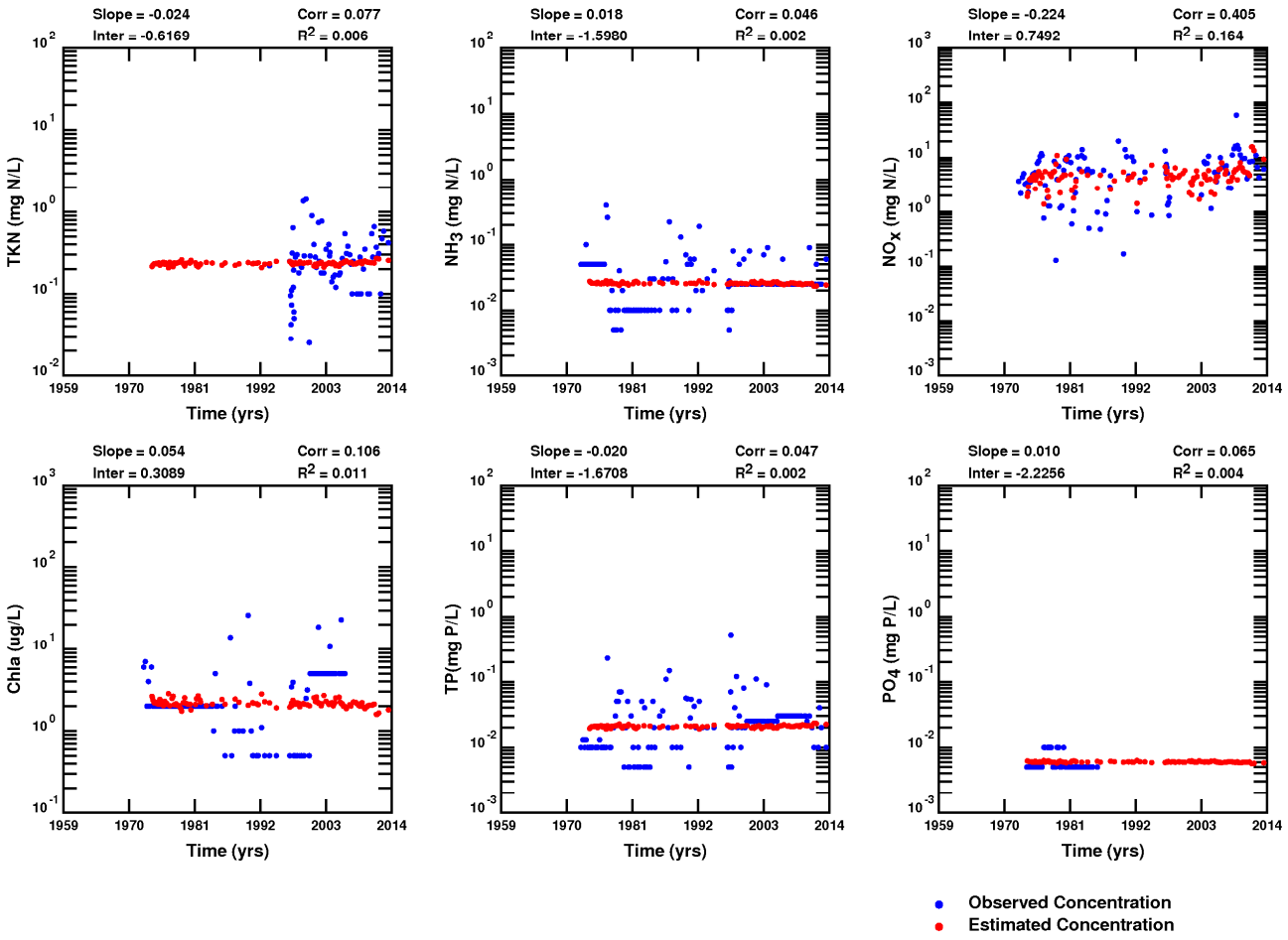

Figure 7-36. Nutrient Estimated Concentrations Based on Linear Regression Analysis for station 12993 (Sabinal River at US 90)

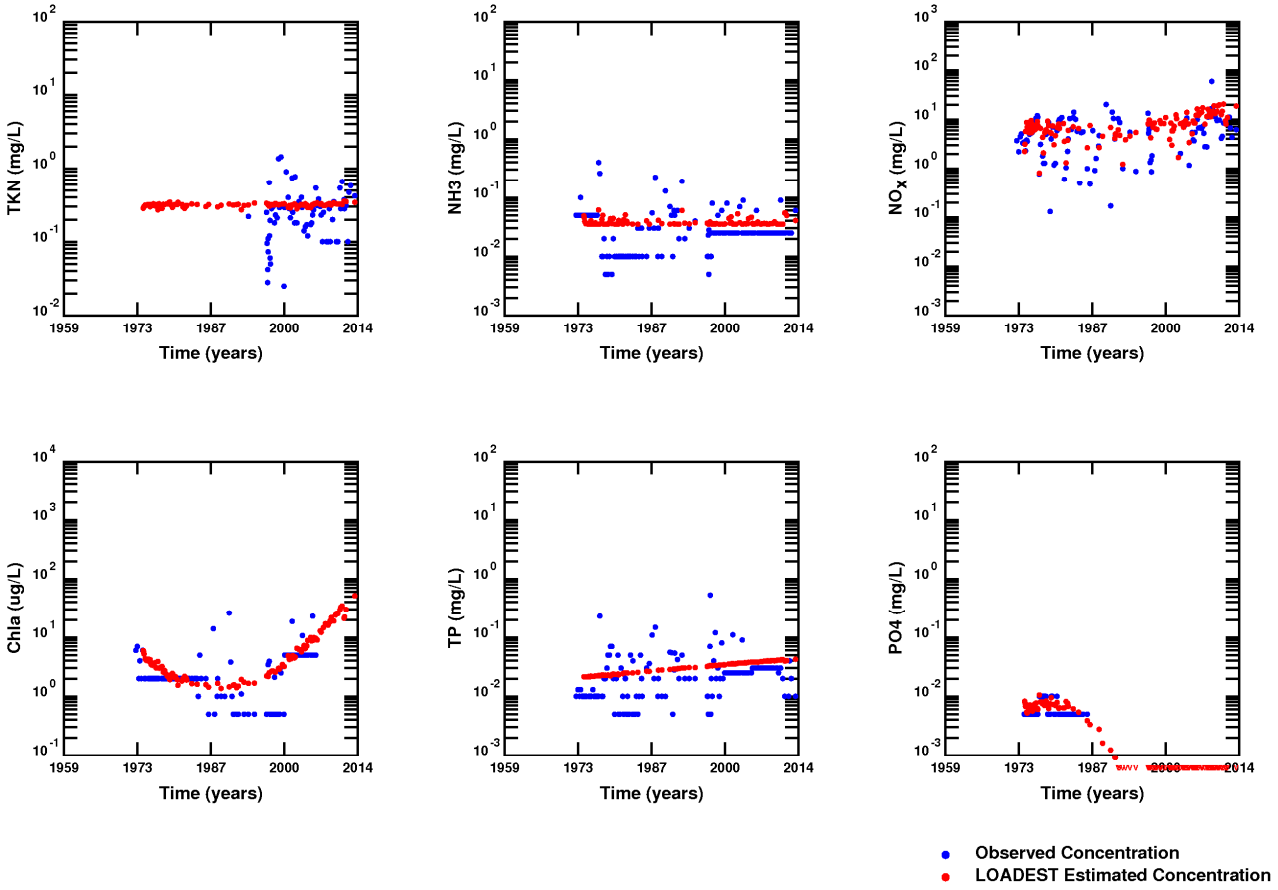

Figure 7-37. Nutrient Estimated Concentrations from LOADEST Regression Analysis for station 12993(Sabinal River at US 90)

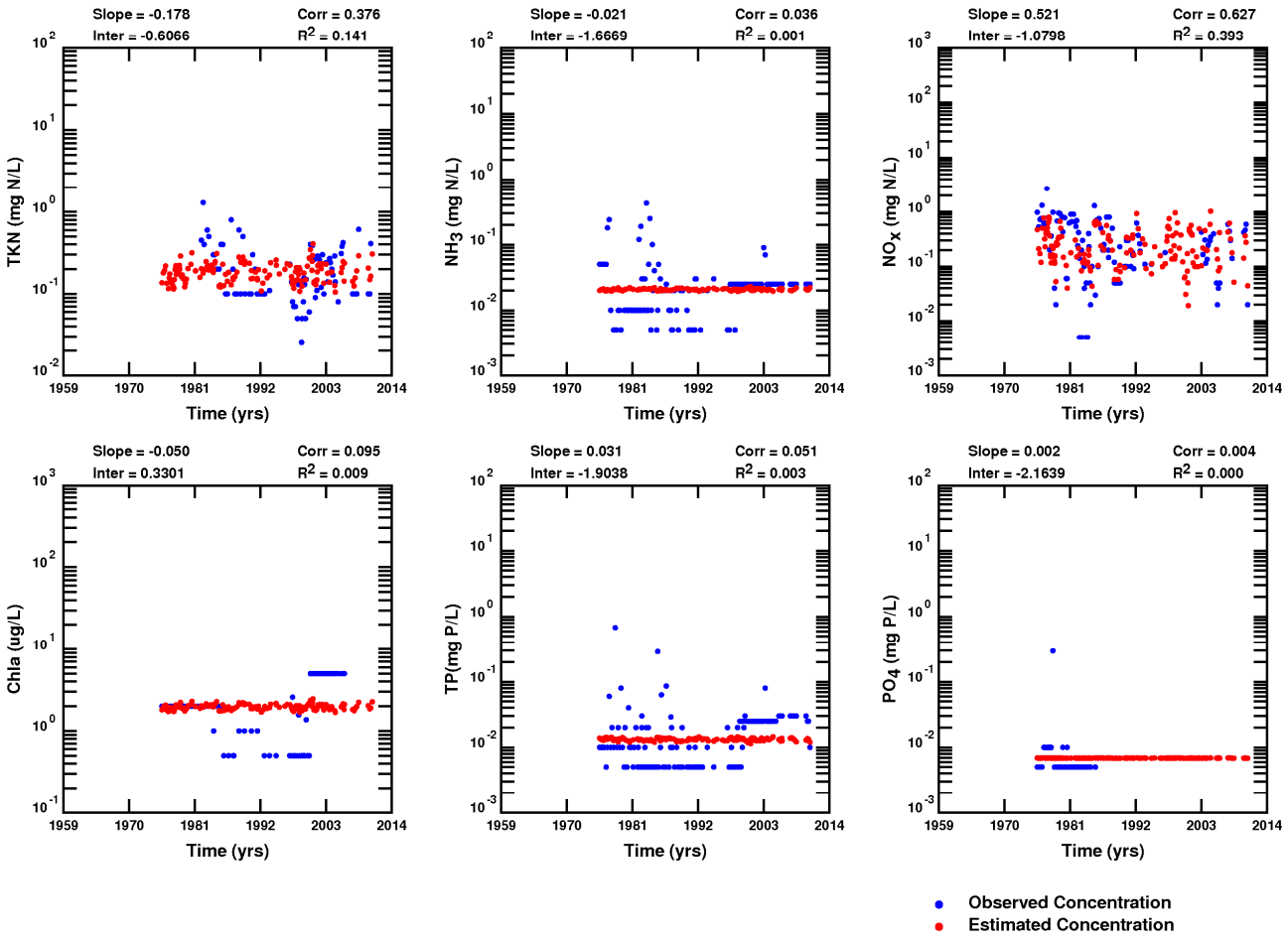

Figure 7-38. Nutrient Estimated Concentrations Based on Linear Regression Analysis for station 13013 (Seco Creek at Miller Ranch)

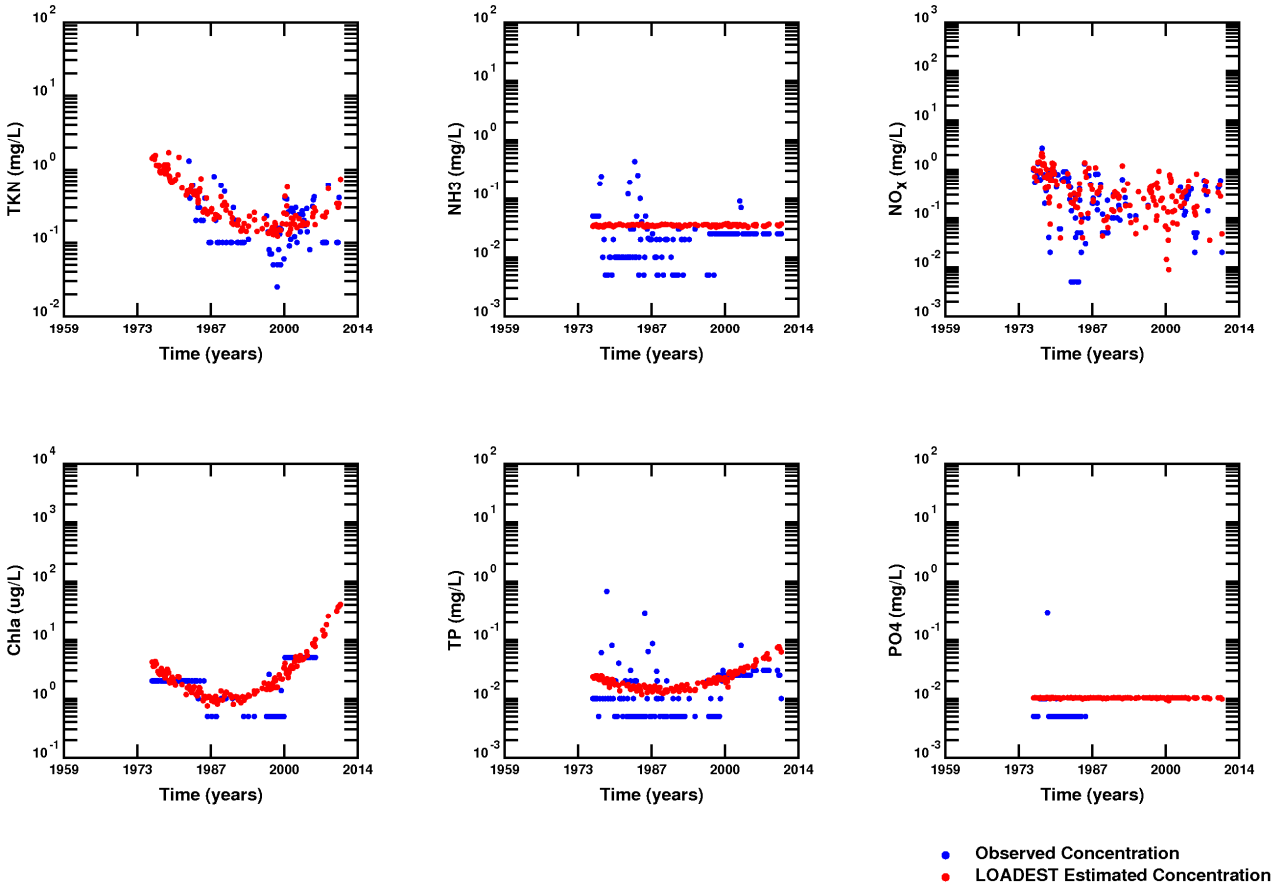

Figure 7-39. Nutrient Estimated Concentrations from LOADEST Regression Analysis for station 13013(Seco Creek at Miller Ranch)

LOADEST and linear regression estimates for station 12985 (Figures 7-40 and 7-41) are similar with the exception of PO_4. LOADEST estimated PO_4 shows an increasing trend with an increasing trend.

There are some limitations for both regression analyses at station 13023 on the Frio River. The linear regression analysis underestimates NH_3 concentration (Figure 7-42), while LOADEST underestimates PO_4 and creates a highly unlikely increasing trend for chl-a (Figure 7-43).

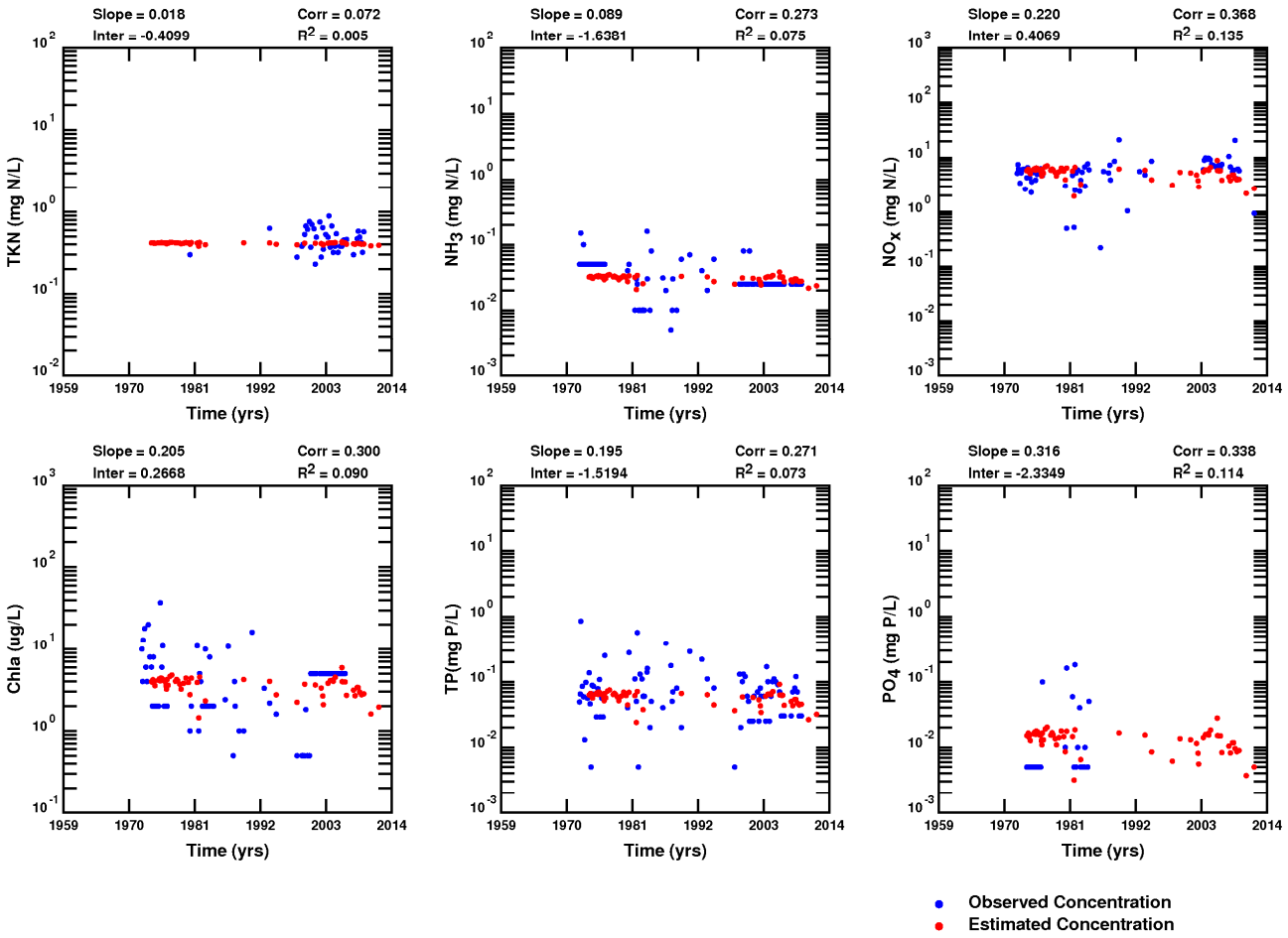

Figure 7-40. Nutrient Estimated Concentrations Based on Linear Regression Analysis for station 12985 (Leona River, Pearsall)

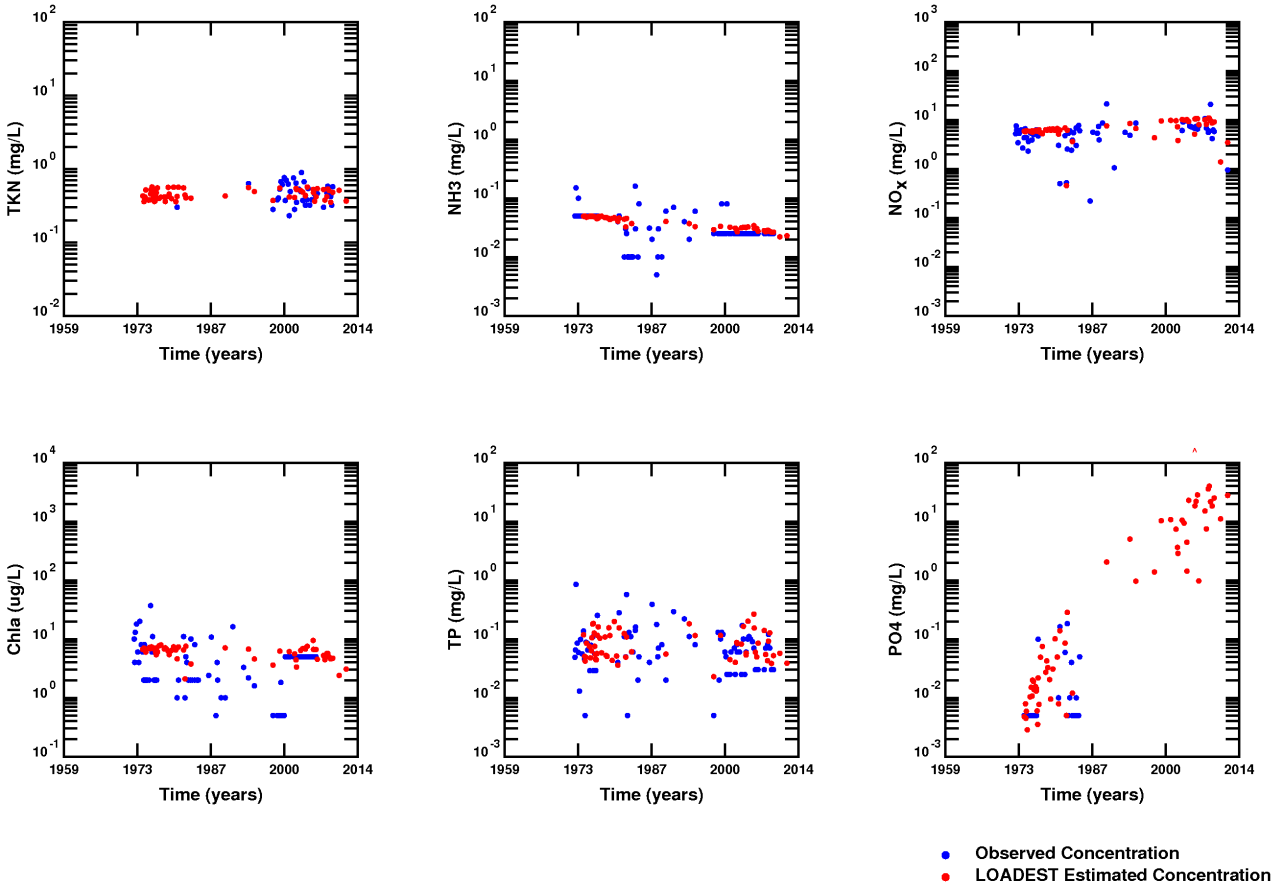

Figure 7-41. Nutrient Estimated Concentrations from LOADEST Regression Analysis for station 12985 (Leona River, Pearsall)

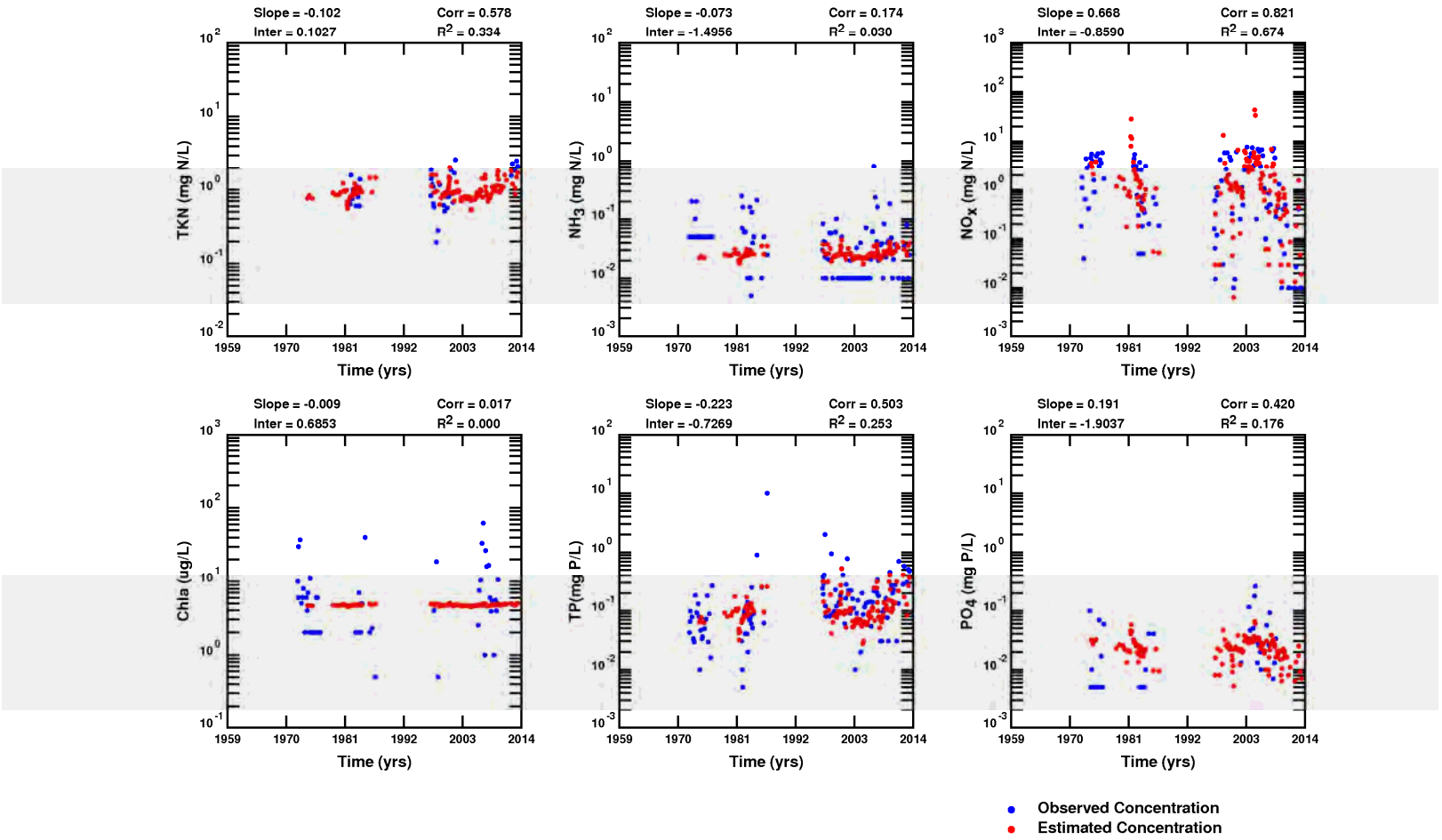

Figure 7-42. Nutrient Estimated Concentrations Based on Linear Regression Analysis for station 13023 (Frio River at SH 16 in Tilden)

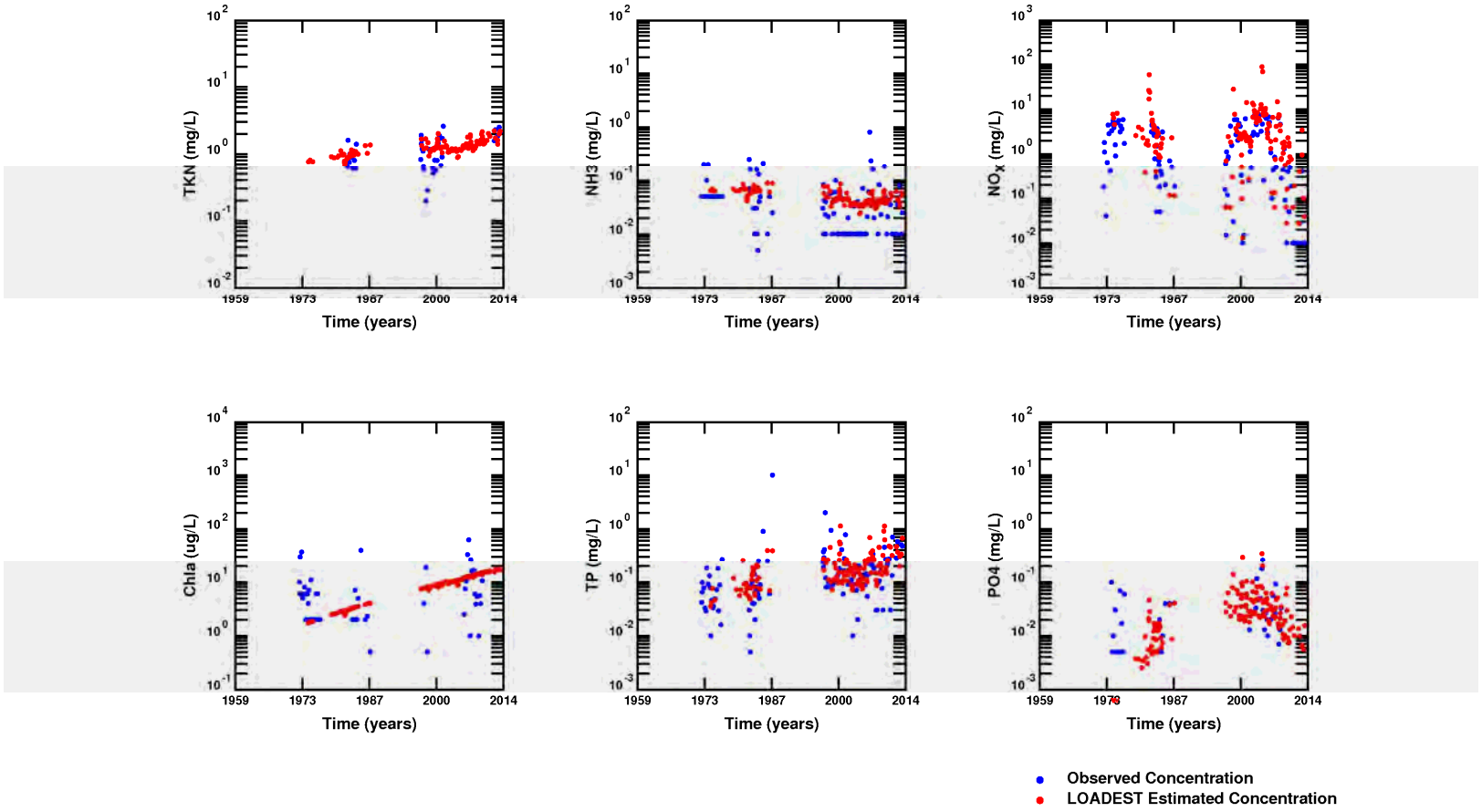

Figure 7-43. Nutrient Estimated Concentrations from LOADEST Regression Analysis for station 13023 (Frio River at SH 16 in Tilden)

7.5 Atascosa River

Data were evaluated for the Atascosa River, which included relatively fewer measured values. From downstream along the length of the river, data from stations listed below were analyzed.

- 20762 - Atascosa River at Granato Road / Taylor Road
- 12981 - Atascosa River, RR Bridge Pleasanton
- 17900 - Atascosa River at IH 37
- 17899 - Atascosa River at Leal Road
- 20764 - Atascosa River at FM 541
- 12980 - Atascosa River at Whitsett
- 20773 - Atascosa, CR 413, Medina County

Appendix E includes the regression analyses for stations in the Atascosa subwatershed. Linear regression indicates that there is a strong relationship between some nutrients and flow for stations 12981 (Figure 7-44), 12980 (Figure 7-45), and 17900 (Figure 7-46). For example, R-squared value for PO_4 of 0.5018 and 0.7235 (stations 12981 and 12980) suggests that 50% and 72% of data is explained. There was insufficient PO4 data for station 17900 (Figure 7-46) making impossible to get paired PO_4-flow data for this regression analysis.

Linear regression indicates that there are no strong relationships between chl-a, NH_3 and flow for station 12981, so the estimates have flat trendlines (Figure 7-47). Decreasing trends in LOADEST chl-a and NH_3 estimated concentrations (Figure 7-48) is evident. Linear regression underestimates NH_3 concentration at Atascosa River, station 12980 (Figure 7-49), while LOADEST overestimates the chl-a concentration (Figure 7-50). NOx and TP estimated concentrations have similar trends from both types of regression analysis. There are insufficient number of paired nutrient-flow data for TKN and PO_4 at stations 12980 and 12981, which makes it impossible to conduct the LOADEST modeling for those variables (Figures 7-48 and 7-50). Estimated loads for both methods also look similar and presented in the Appendix E.

The nutrients time-series from the most sampled upstream station 12981 (Figure 7-47) and downstream station 12980 (Figure 7-48) were reviewed and analyzed. At the most upstream station the data were sampled at two different time periods 1970-1980 and 2000-2014. At the downstream station, sampling was conducted between 1980 and 2000. Since the sampling periods for these two stations do not coincide, it is not possible to make a definite statement that the upstream and downstream station data are different. However, a review of existing data suggests that it is indeed the case. There is a significant decrease in inorganic nutrients from upstream to downstream. The NH_3, NOx, TP and PO_4 concentrations have decreased by a factor of 10. On the contrary, the chl-a concentration in the last two decades has slightly increased. It is possible that algal growth in this portion of the river is occurring. The result is that the phytoplankton take up inorganic nutrients resulting in the decrease in NH_3, NOx, and PO_4 and produce more biomass which would result in an increase in organic nitrogen and organic phosphorus. It is not clear in this analysis, however, why TP shows a decreasing trend.

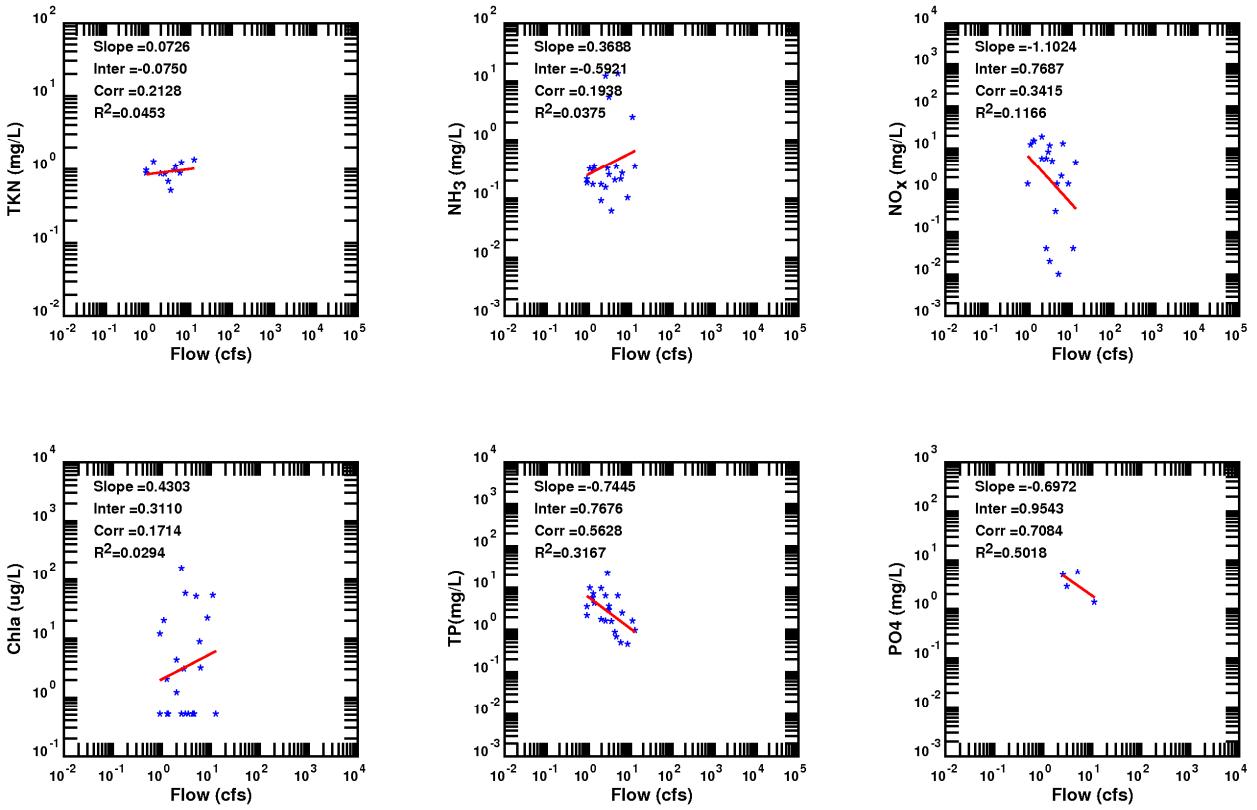

Figure 7-44. Linear Regression Analysis for station 12981 (Atascosa River, RR Bridge Pleasanton)

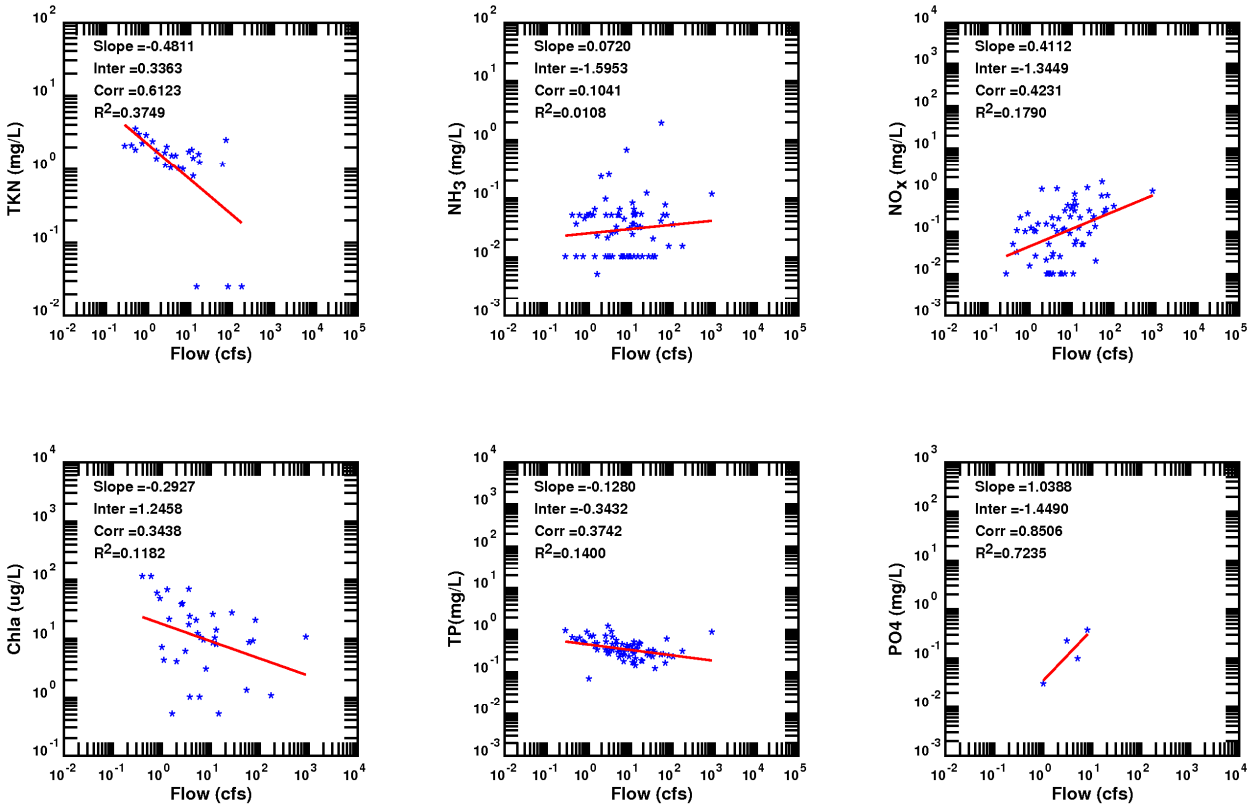

Figure 7-45. Linear Regression Analysis for station 12980 (Atascosa River at Whitsett)

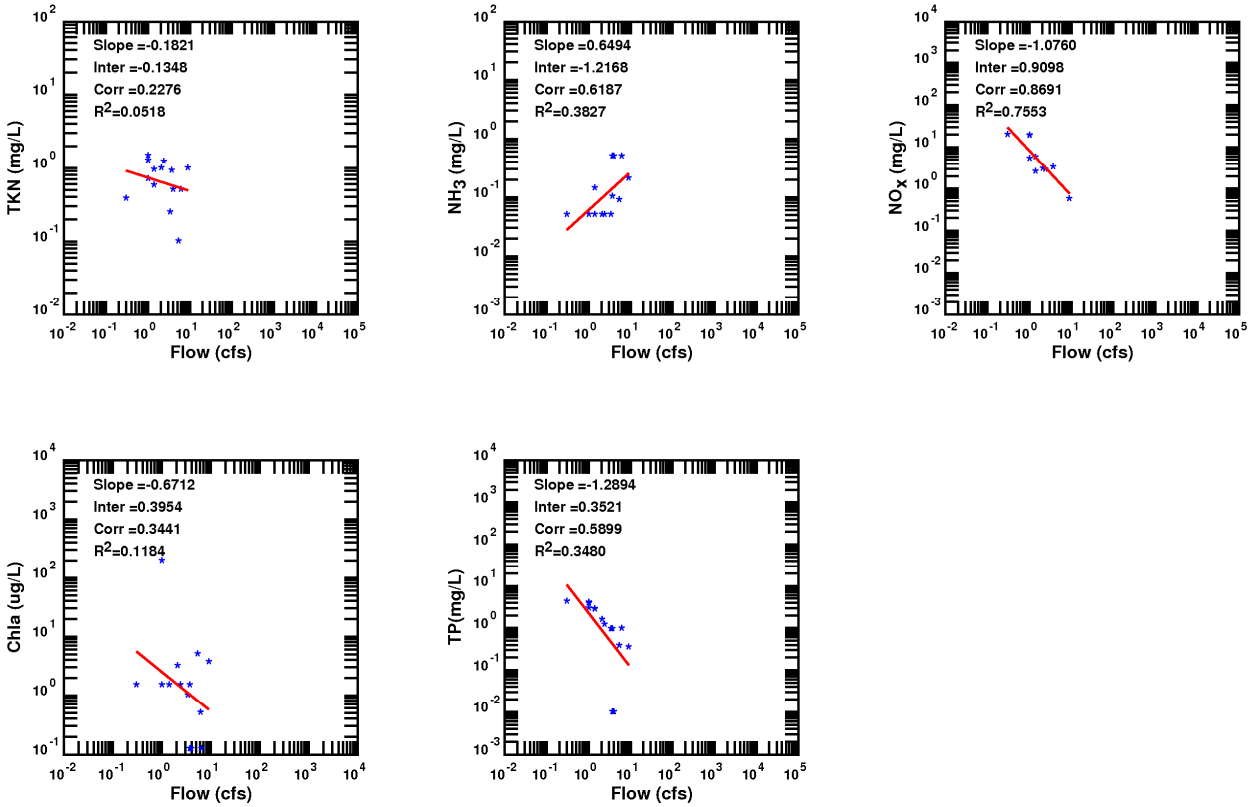

Figure 7-46. Linear Regression Analysis for station 17900 (Atascosa River at IH 37)

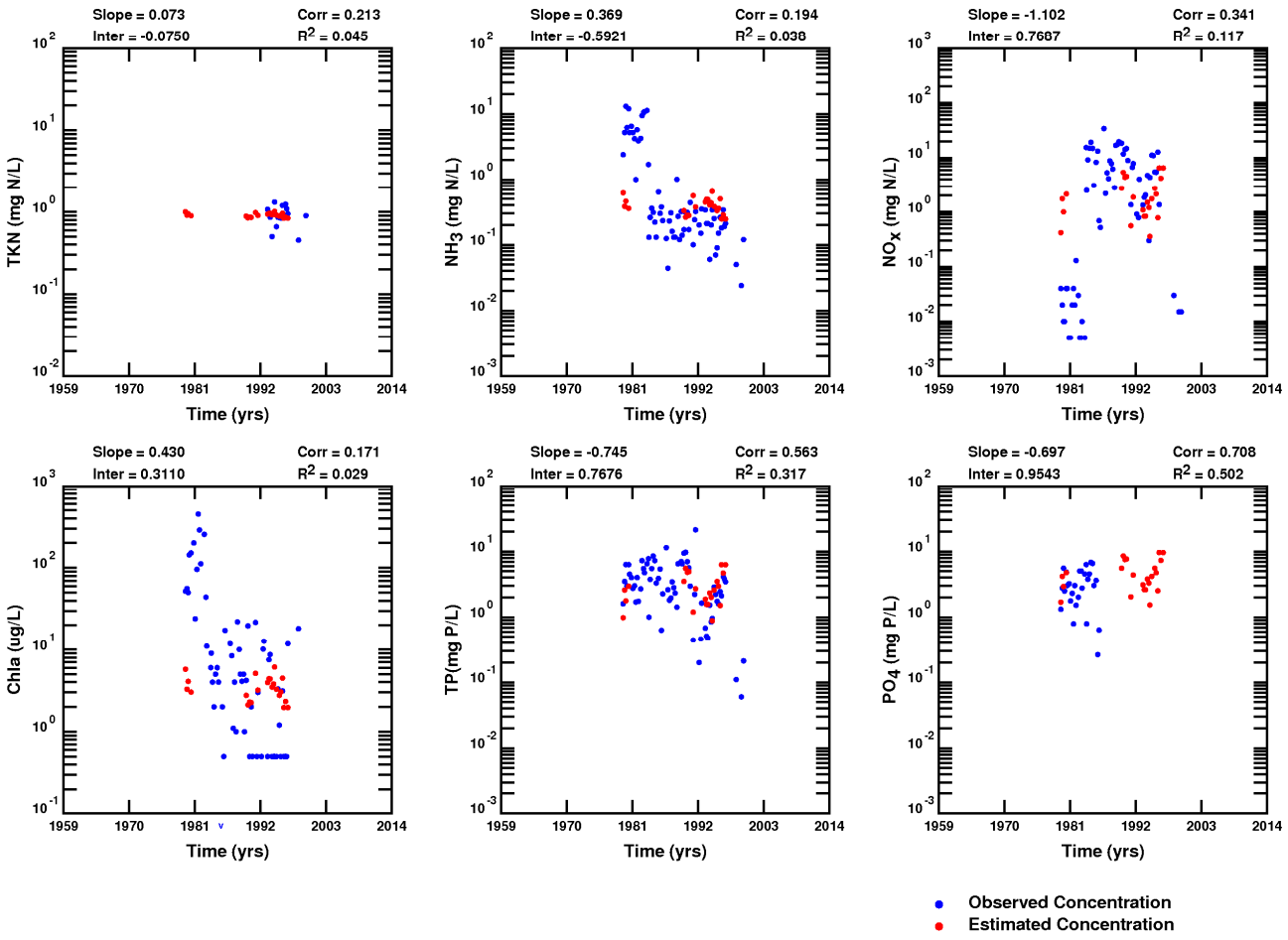

Figure 7-47. Nutrient Estimated Concentrations Based on Linear Regression Analysis for station 12981 (Atascosa River, RR Bridge Pleasanton)

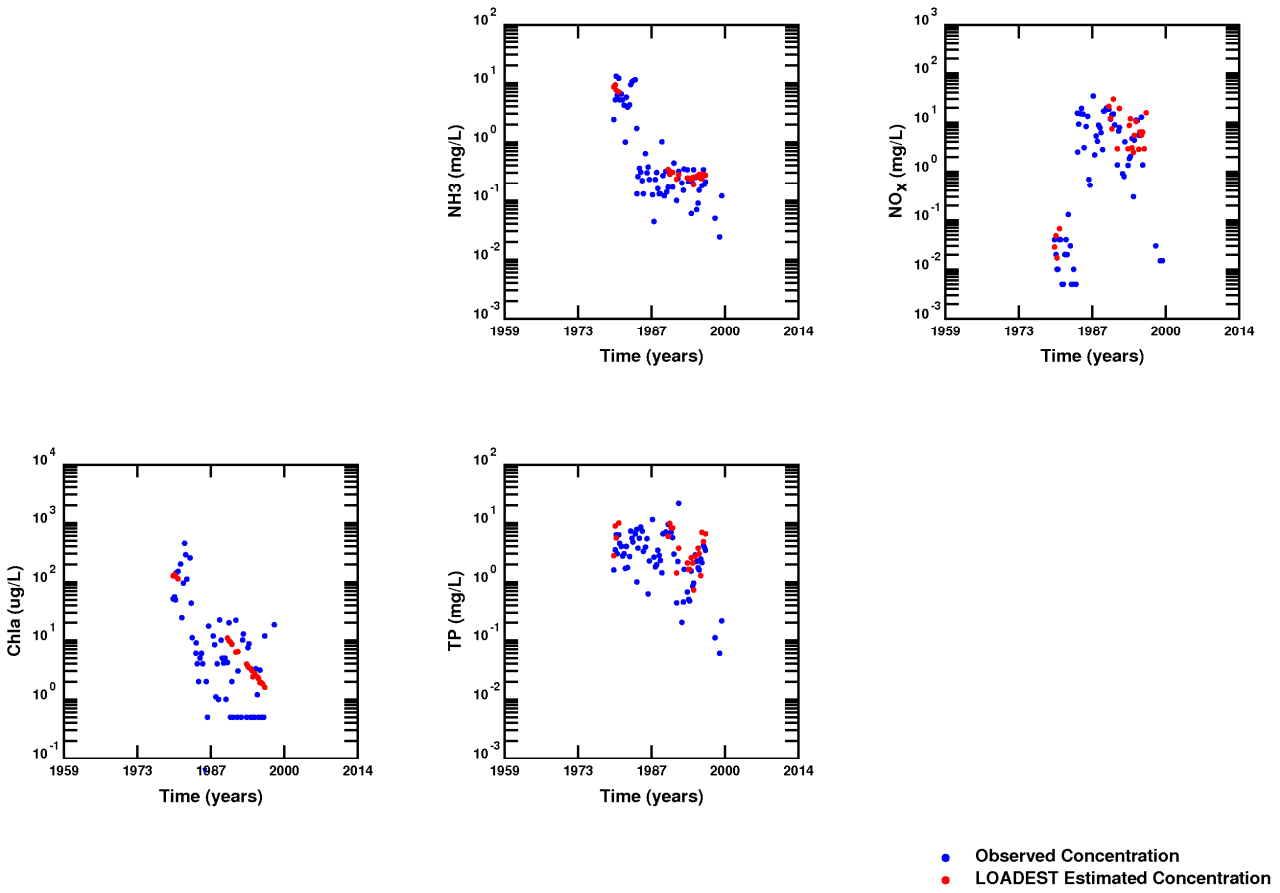

Figure 7-48. Nutrient Estimated Concentrations from LOADEST Regression Analysis for station 12981 (Atascosa River, RR Bridge Pleasanton)

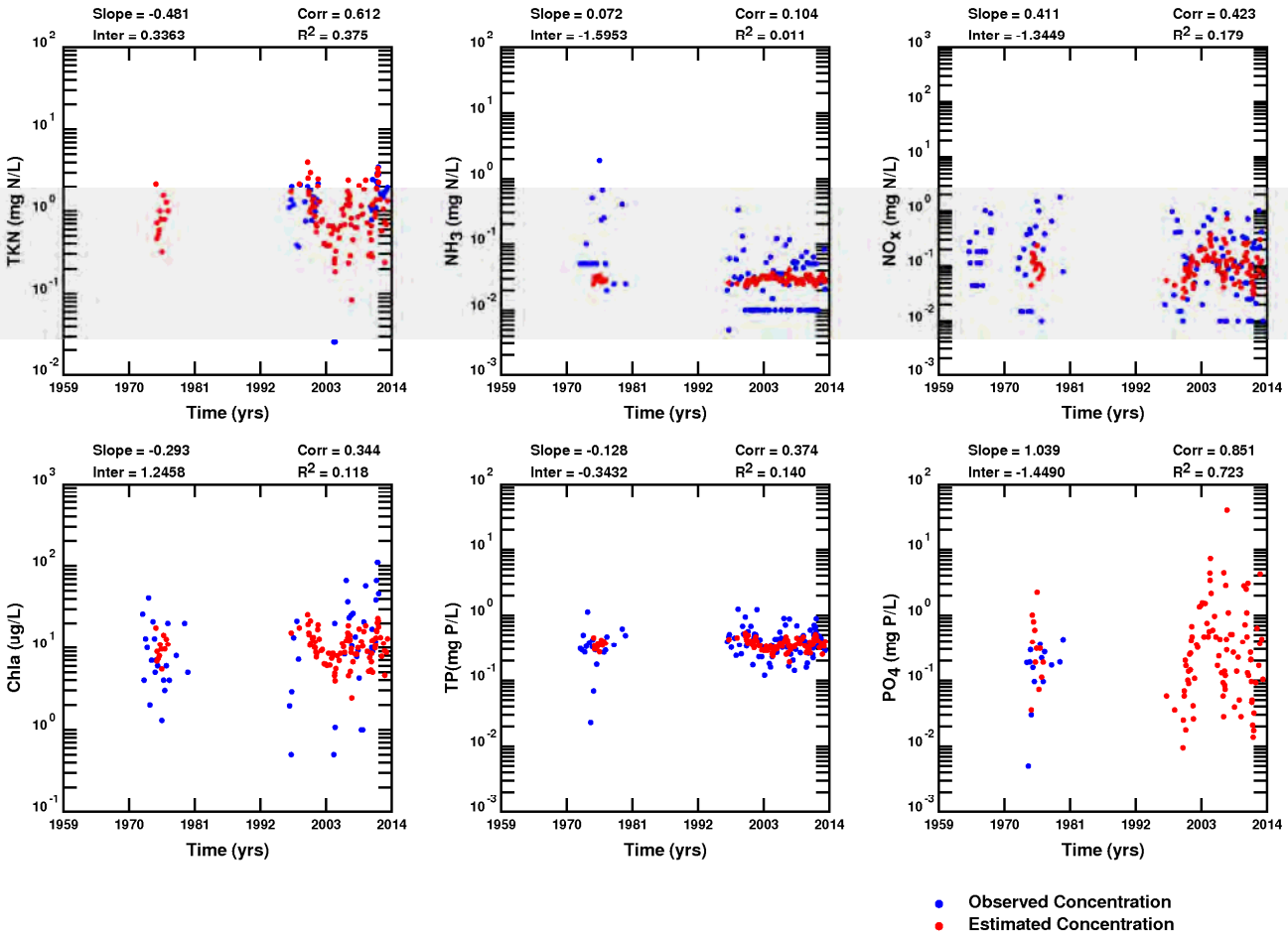

Figure 7-49. Nutrient Estimated Concentrations Based on Linear Regression Analysis for station 12980 (Atascosa River at Whitsett)

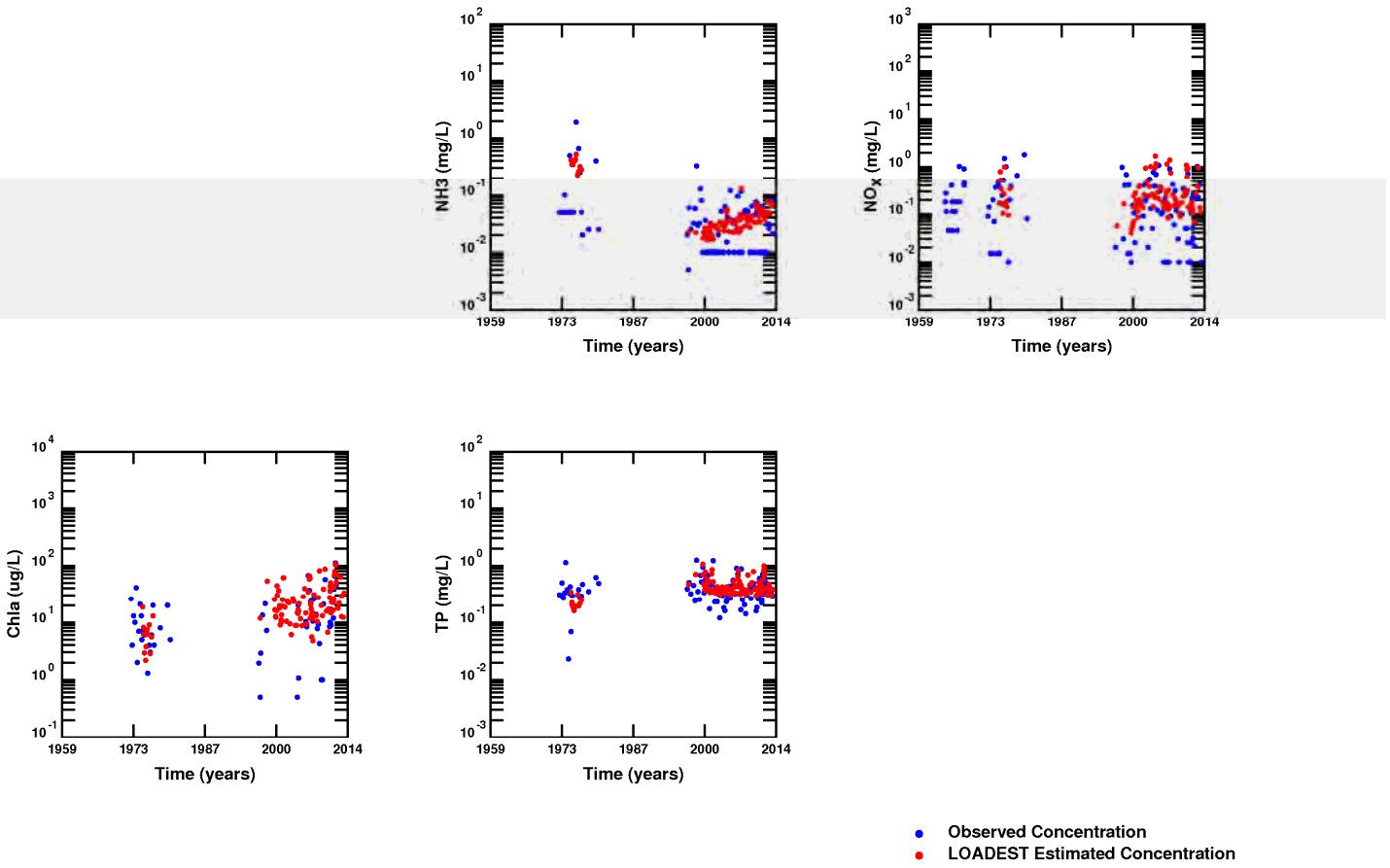

Figure 7-50. Nutrient Estimated Concentrations from LOADEST Regression Analysis for station 12980 (Atascosa River at Whitsett)

7.6 Effects of Choke Canyon Reservoir

Choke Canyon Reservoir (CCR) is 4 miles west of the town of Three Rivers and about 65 miles south of the city of San Antonio. It impounds water from the Frio River and San Miguel Creek shortly before the river's confluence with the Nueces River. Nutrient data from two TCEQ locations, the Frio River, station 13023 (Figure 7-42) and San Miguel Creek, station 12983 (Figure 7-51) upstream from CCR were compared to the data from TCEQ station 12979 at Three Rivers (Figure 7-16), which is just downstream of CCR, and the confluence of the Frio, Atascosa, and Nueces rivers. Also, influences from the Atascosa River and the Nueces River were taken into the account to address the impact of CCR on water quality.

Nutrient data show the same magnitude in TKN and NH_3 concentrations upstream and downstream of the reservoir. A slight increase in chl-a concentration in comparison to other upstream locations is noticed at the Atascosa River, station 12980 (Figure 7-49). While the San Miguel Creek has lower PO_4 concentration by a factor of two, the same levels of PO_4 concentration are observed at the Nueces River, Atascosa River, Frio River and downstream of CCR. The increase in TP concentration after 1986, by a factor of two, was observed at the two upstream stations at San Miguel Creek and Frio River. The same magnitude in TP concentration is coming from Atascosa River, station 12980 (Figure 7-49). But the concentration of TP below the reservoir is lower by a factor of five.

In comparison, the estimated concentrations of nutrients generated by LOADEST for stations 13023, 12983, 12979, and 12980 are shown in Figures 7-43, 7-52, 7-21, and 7-50, respectively.

For station 12979, located downstream of CCR, it seems that LOADEST provides better estimates compared to the linear regression.

There is no impact from reservoir construction according to the linear regression analysis since time component is not included in the analysis, while LOADEST modeling suggests that there is slight increase in chl-a and TKN data and slight decrease in NH_3, PO_4 and NOx after 1986.

The next step to better analyze the data and determine if there was an impact on the Corpus Christi water system from construction of CCR was to break the data analysis into two time periods: pre- and post-Jan1, 1986. The TCEQ data were split at January 1, 1986, to assess the effects of CCR. Linear regression analysis as well as the LOADEST modeling was performed again on the split datasets.

Figures 7-53 through 7-56 present linear regression analyses divided into the two time periods for stations 13023, 12983, 12979, and 12980, respectively. The solid blue line represents the regression line for data sampled before 1986 while the solid red line represents the regression line for data sampled after 1986. The blue and red dashed lines represent the confidence intervals around the regression lines.

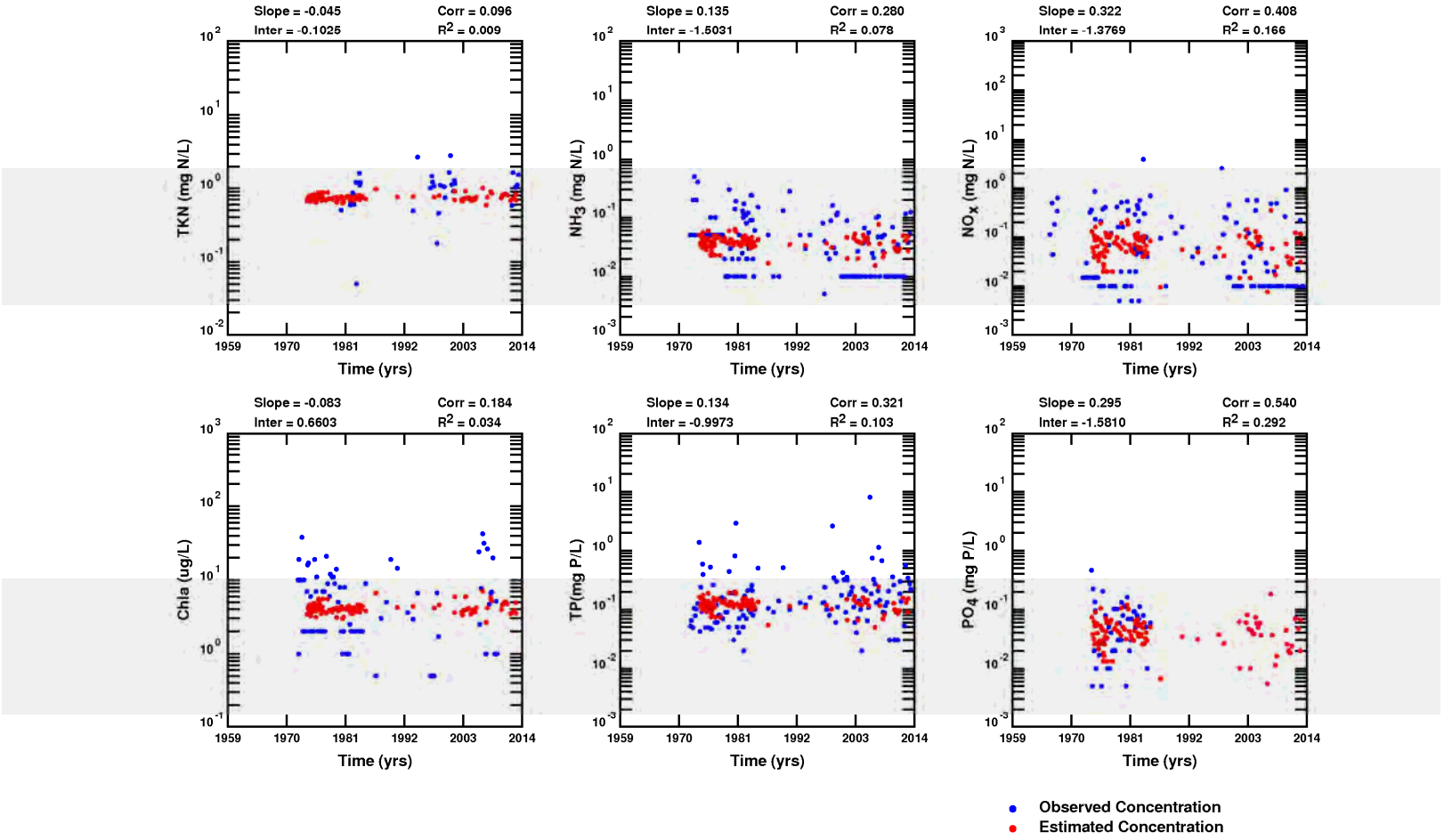

Figure 7-51. Nutrient Estimated Concentrations Based on Linear Regression Analysis for station 12983 (San Miguel Creek, Tilden)

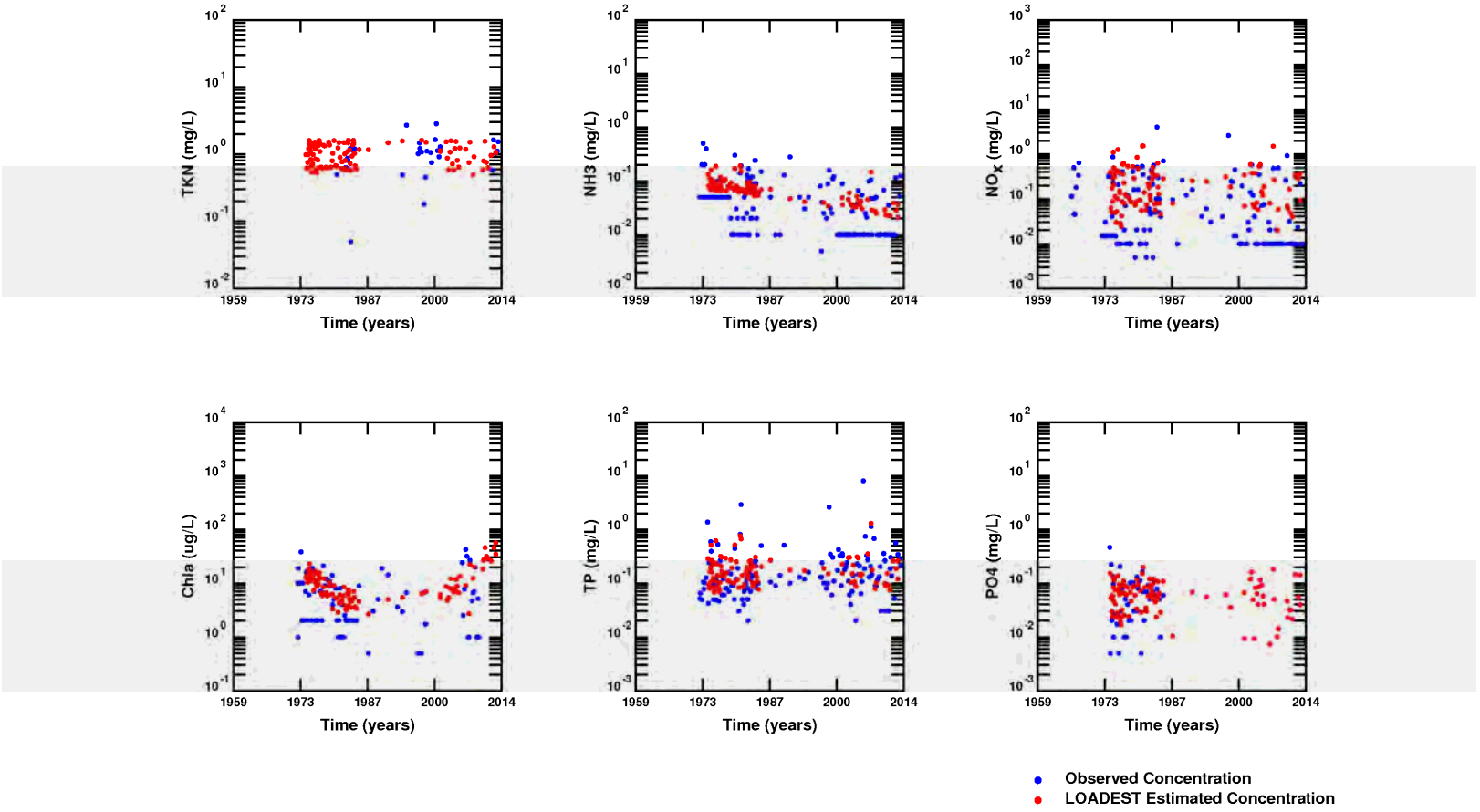

Figure 7-52. Nutrient Estimated Concentrations from LOADEST Regression Analysis for station 12983 (San Miguel Creek, Tilden)

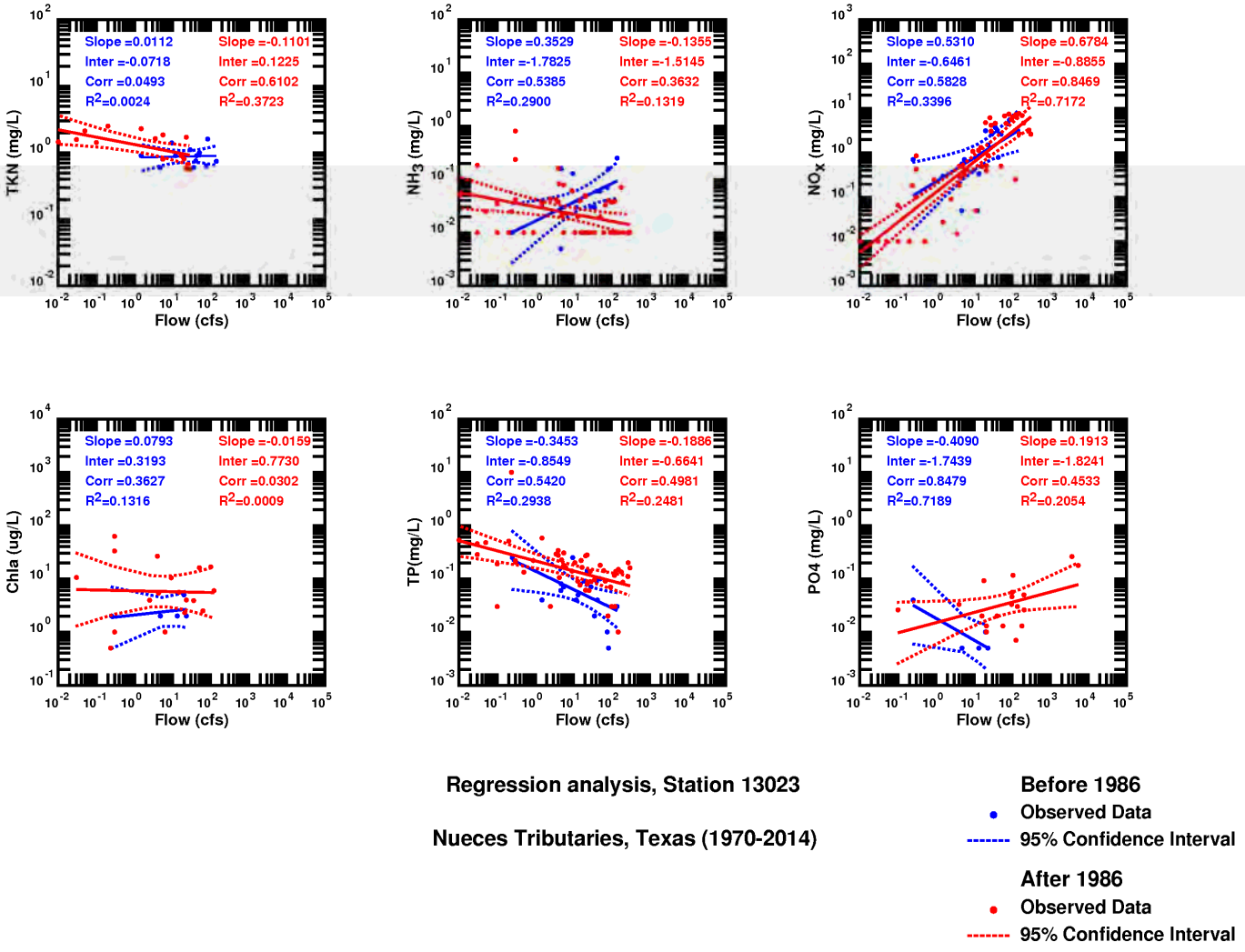

Figure 7-53. Linear Regression Analysis for pre- and post-Jan 1, 1986 for station 13023 (Frio River at SH 16 in Tilden)

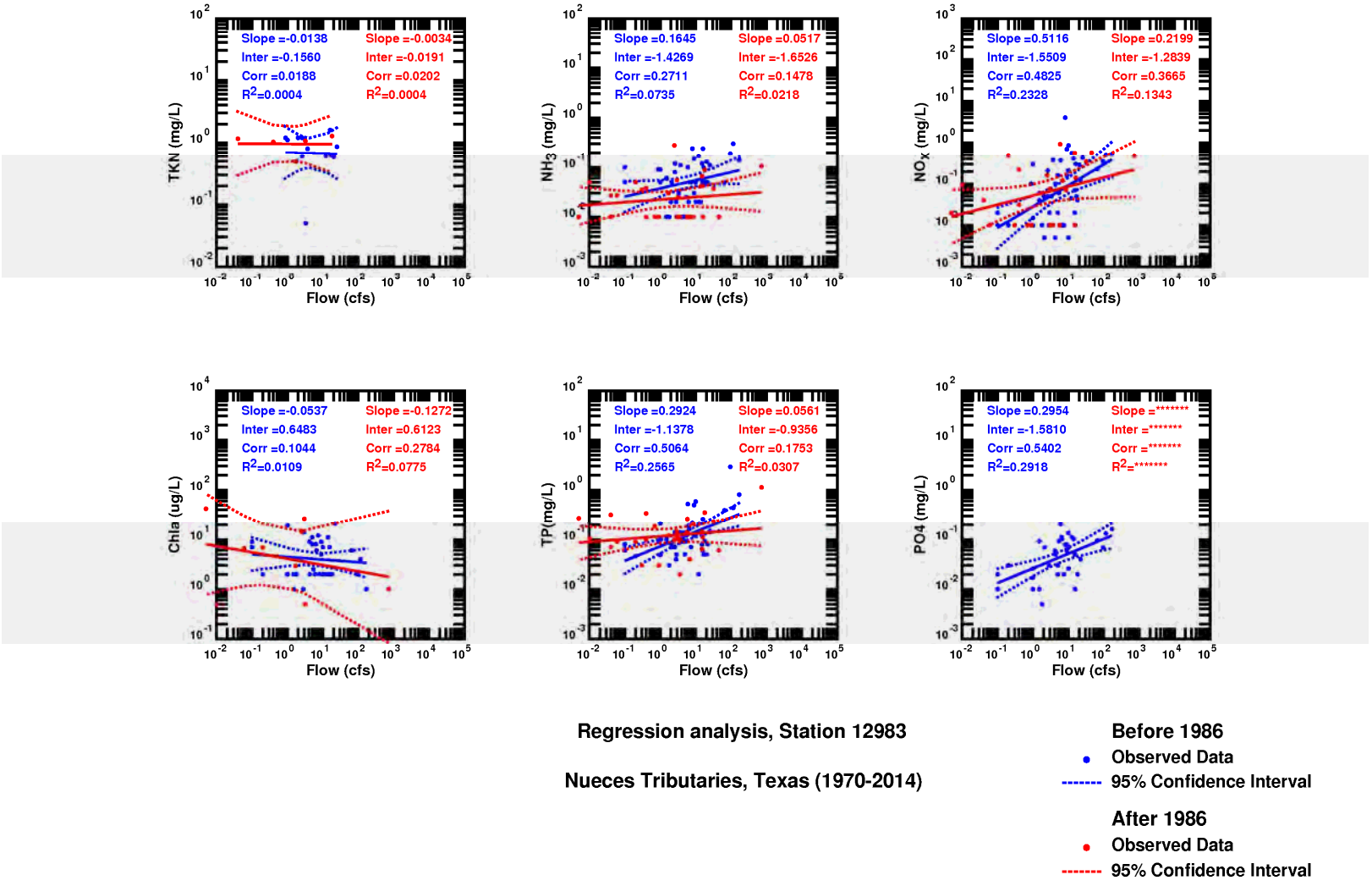

Figure 7-54. Linear Regression Analysis for pre- and post-Jan1, 1986 for station 12983 (San Miguel Creek, Tilden)

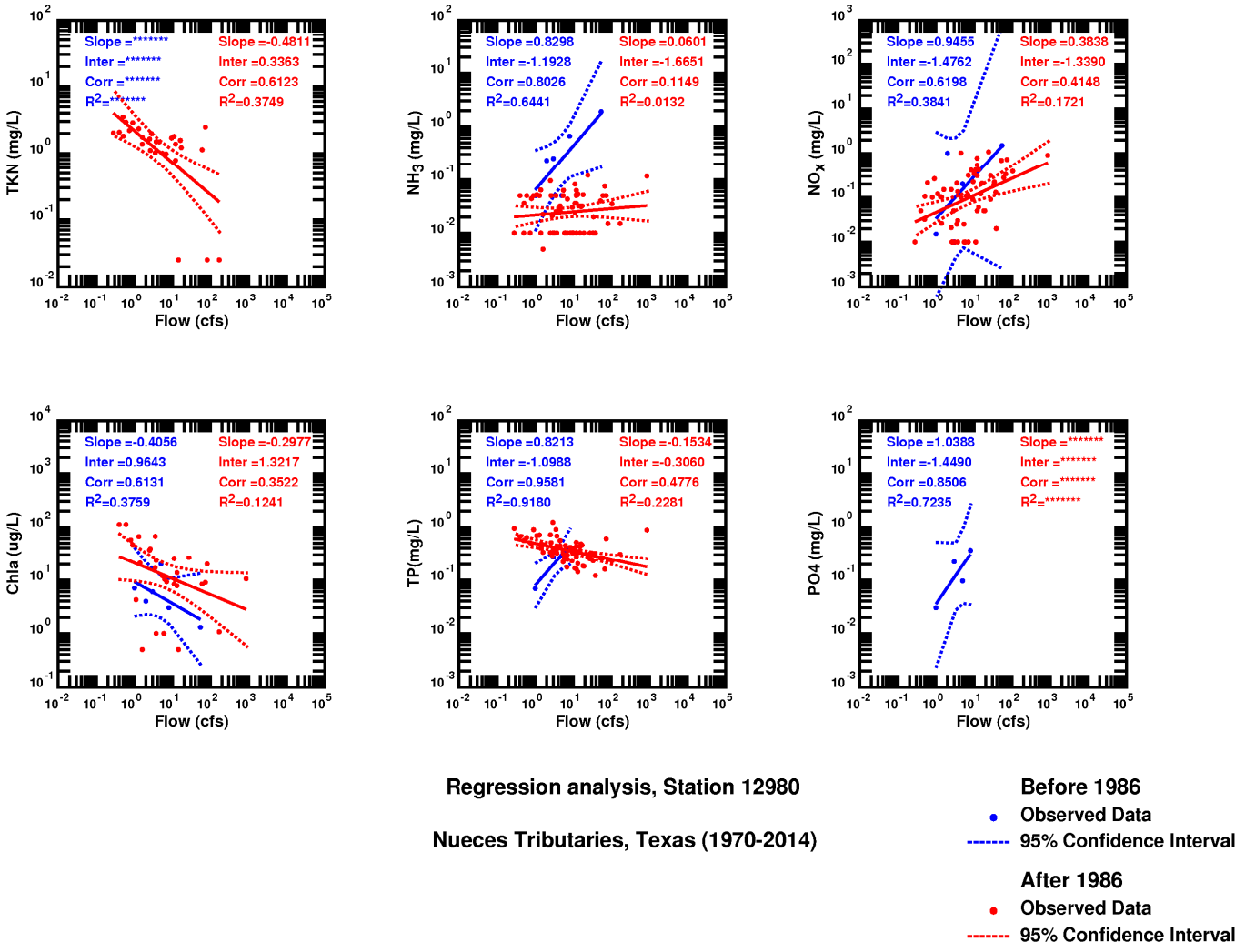

Figure 7-55. Linear Regression Analysis for pre- and post-Jan1, 1986 for station 12980 (Atascosa River at Whitsett)

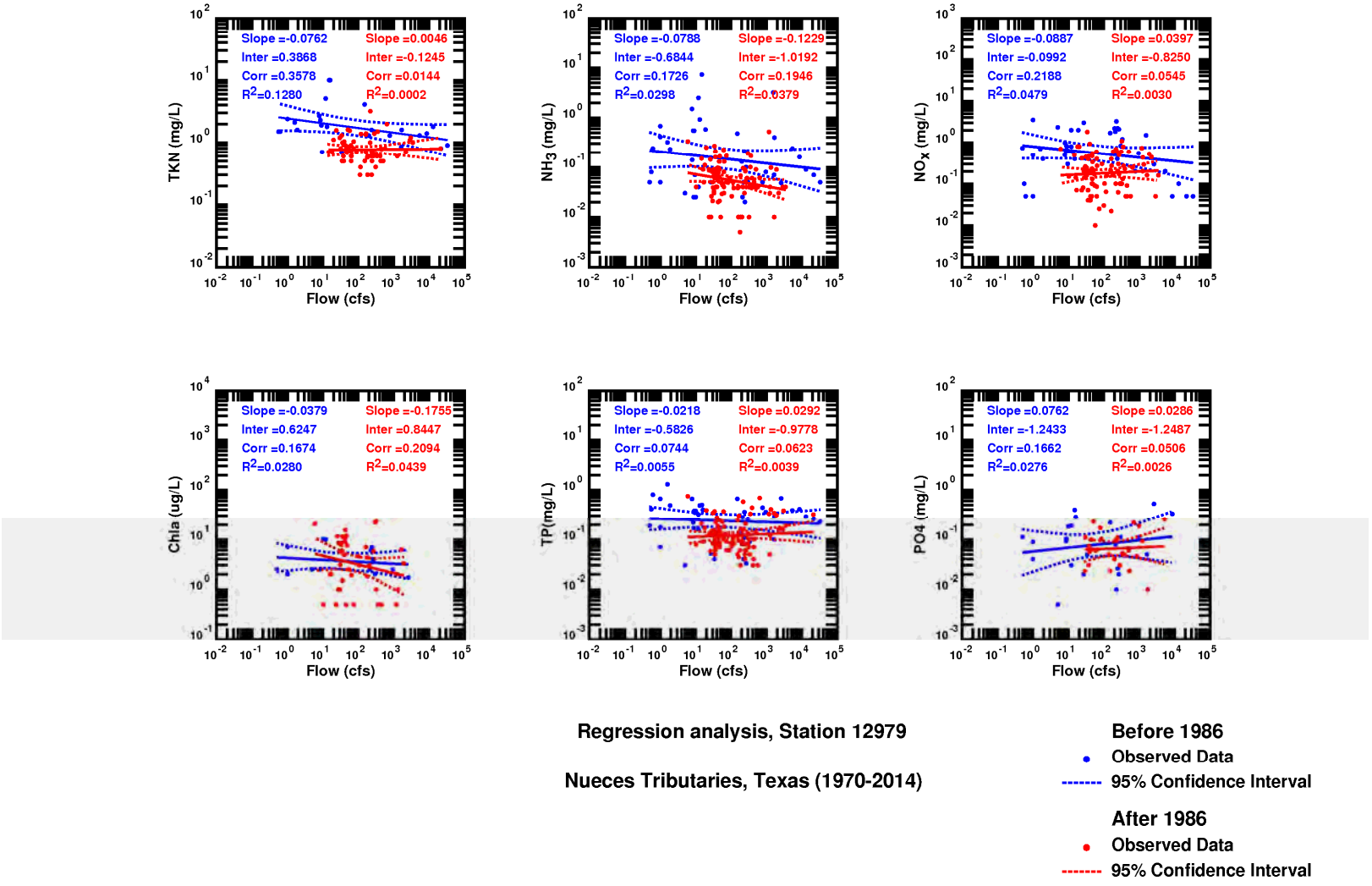

Figure 7-56. Linear Regression Analysis for pre- and post-Jan1, 1986 for station 12979 (Nueces River, Three Rivers)

7.6.1 Loads Before and After CCR Construction

The long term loadings at several stations around CCR were estimated from the few long-term Nueces Basin gages (flow data at USGS locations) using the original regression equations from linear regression analysis and compared to the LOADEST modeling. The corresponding pairs of stations in the data analysis are shown in the Table 7-3.

Table 7-3. Pairs of TCEQ and USGS stations included in the analysis of Choke Canyon Reservoir

TCEQ station	USGS station	Location
13021	8207000	In the Reservoir
13023	8206600	Upstream from the reservoir (Frio River)
13024	8205500	Upstream from the reservoir (Frio River)
12973	8194500	Upstream from the reservoir (Nueces River)
12979	8210000	Downstream from the reservoir (Nueces River)
12980	8208000	Atascosa River
12983	8206700	Upstream from the Reservoir (San Miguel Creek)

The data do not show any significant statistical differences for pre- and post- 1986 data in TKN, NH_3, chl-a and TP, while there is a slight increase in NOx in post-1986 upstream Frio River (station 13024). There is a slight increase after 1986 in TKN, NH_3, chl-a and TP (by a factor of two) downstream Frio River (13023) before entering CCR. In the Atascosa River (station 12980) there is also a slight increase in chl-a concentration while NH_3 concentration decreases over time and the rest of the nutrients remain the same. Nutrients at the Nueces River (station 12973) and San Miguel Creek (station 12983) do not show any trends just seasonal variability.

Upstream data were compared to the data from downstream of CCR (station 12979) where the three rivers, the Nueces River, Atascosa River, and Frio, and flow from CCR are combined. The mean flow at station 12979 decreased by 20% after construction of CCR. The maximum flow decreased by a factor of 3. Performing linear regression analysis on the water quality data and flow data at the downstream station (station 12979) that was separated into two time intervals (pre- and post-1986) did show a difference in the water quality data pre- and post-CCR construction.

Figures 7-57 and 7-58 show the linear regression analyses for pre- and post-CCR construction concentrations for station 12979 for flow, TKN, NH_3, NOx, TN, chl-a, TP, and PO_4.

Figures 7-59 and 7-60 show the LOADEST regression analyses for pre- and post-CCR construction concentrations for station 12979 for flow, TKN, NH_3, NOx, TN, chl-a, TP, and PO_4.

Figure 7-61 and 7-62 depict the linear regression analysis for pre- and post-CCR construction loads for station 12979 for flow, TKN, NH_3, NOx, TN, chl-a, TP, and PO_4.

Figure 7-63 and 7-64 show the LOADEST regression analysis for pre- and post-CCR construction loads for station 12979 for flow, TKN, NH_3, NOx, TN, chl-a, TP, and PO_4.

LOADEST computes a slightly different result for all nutrients with an exception to NH_3. The NH_3 trend looks similar to the trend computed by linear regression. LOADEST indicates a decreasing trend in TKN and NOx before the construction of the reservoir in 1986. Then the concentrations of the same nutrients decreased in 1986. Over the last 30 years, LOADEST shows

an increasing trend in these nutrients. In addition, LOADEST indicates an increasing trend in PO_4 and TP before CCR construction. Chl-a concentrations have a flat-lying trend before the construction of CCR but began to increase after construction.

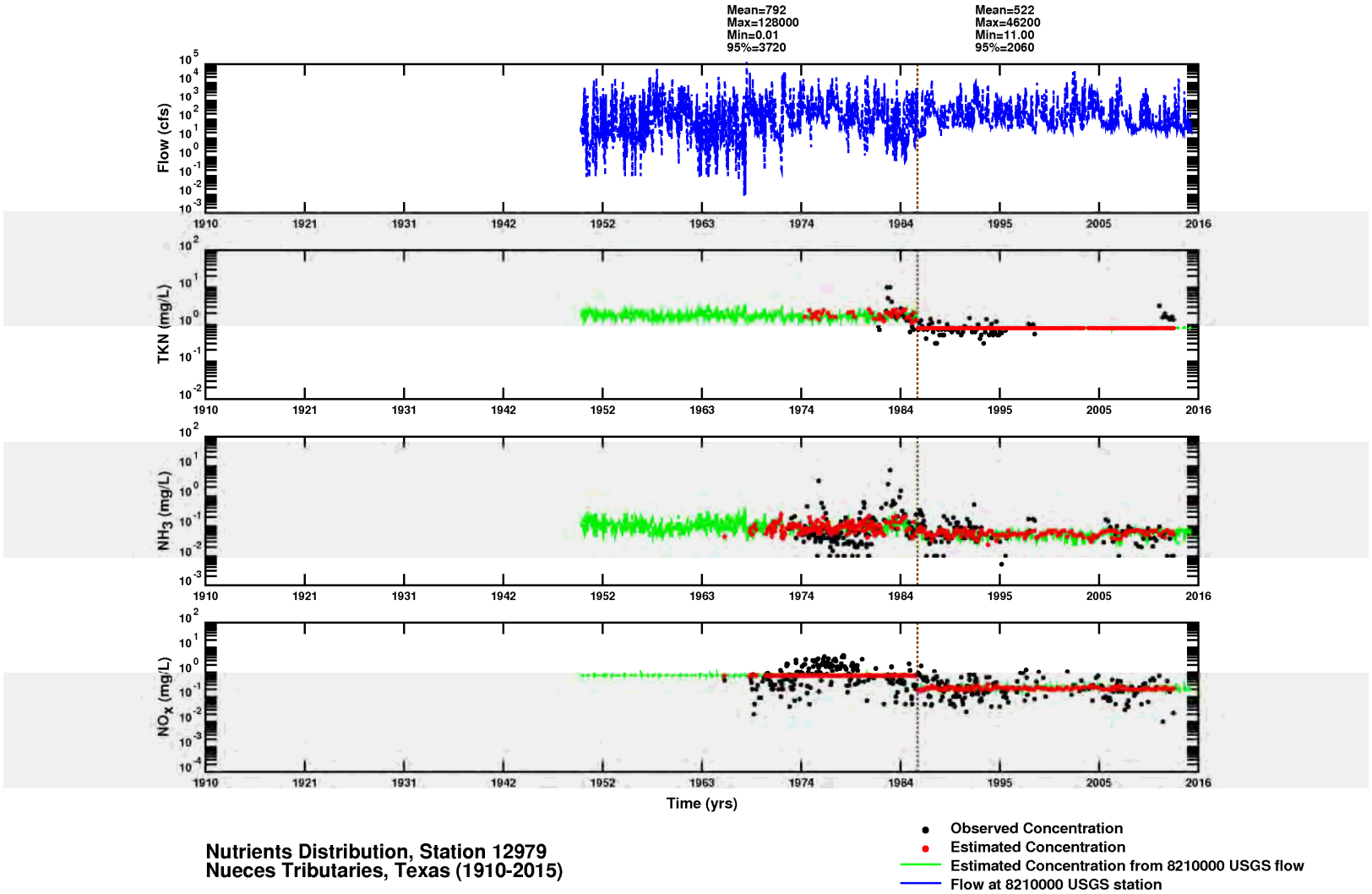

Figure 7-57. Linear Regression Analysis for pre- and post-1986 Concentrations for station 12979 (Nueces on US 281 south of Three Rivers)

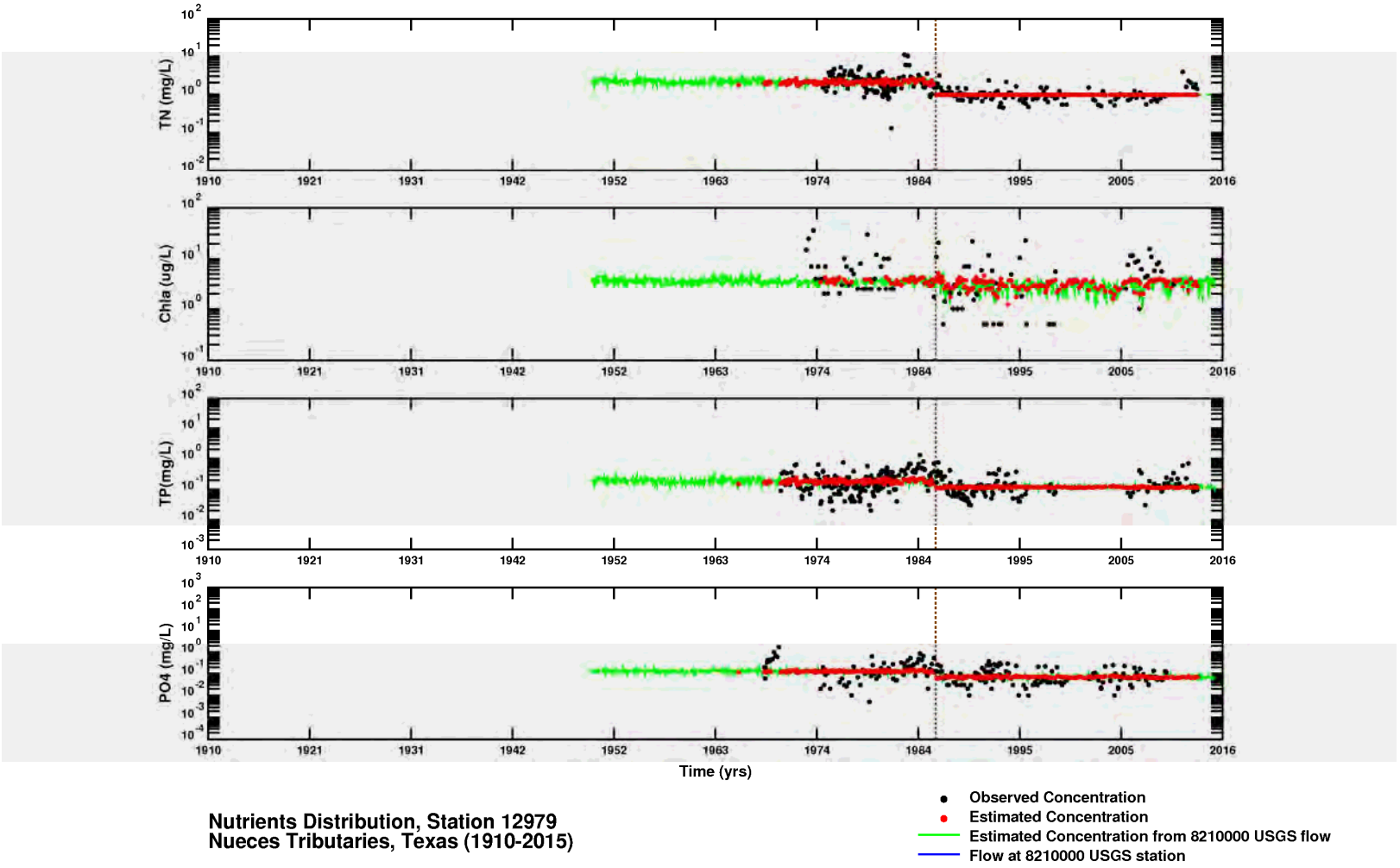

Figure 7-58. Linear Regression Analysis for pre- and post-1986 Concentrations for station 12979 (Nueces on US 281 south of Three Rivers)

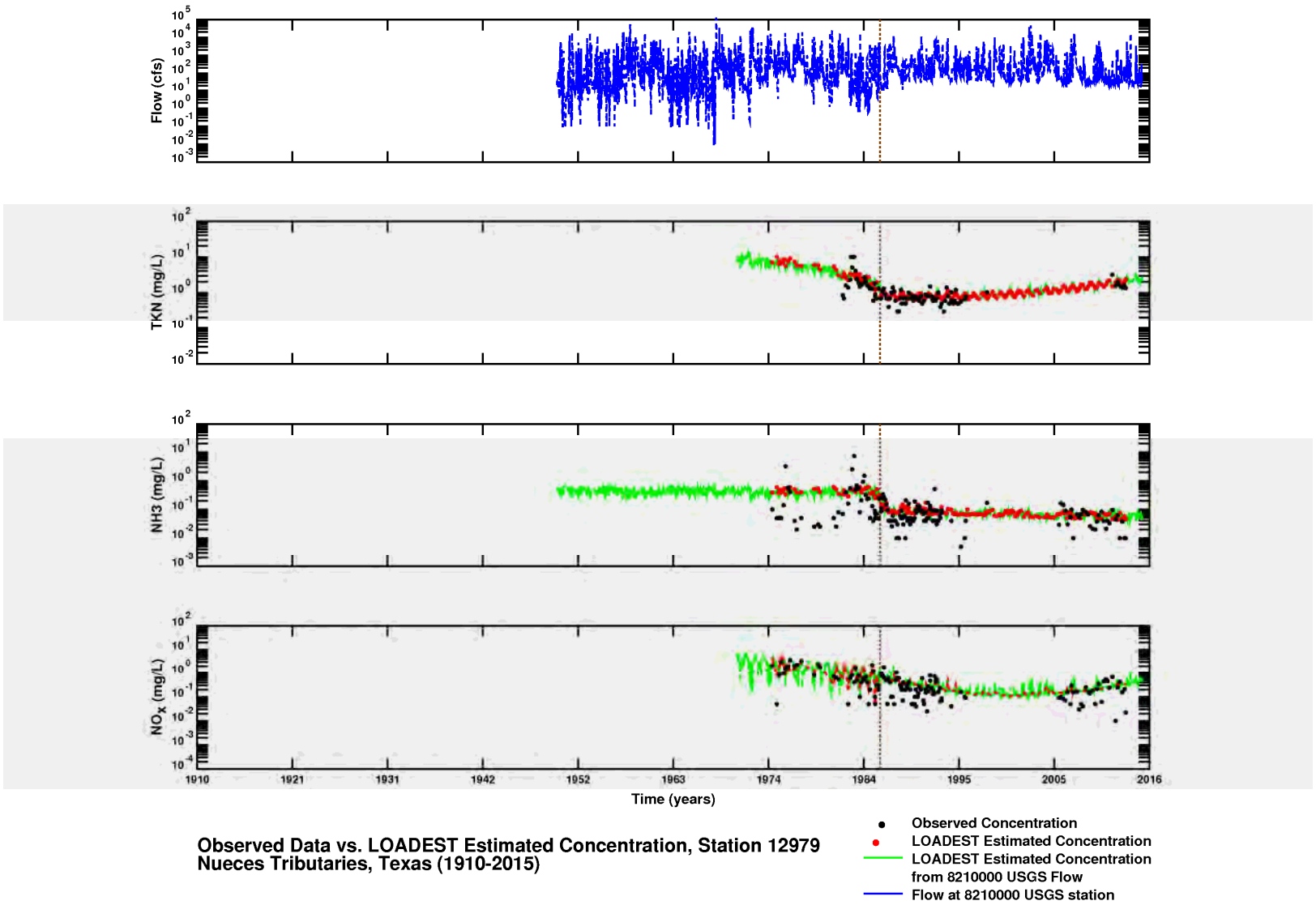

Figure 7-59. LOADEST regression analysis for pre- and post-1986 concentrations for station 12979 (Nueces on US 281 south of Three Rivers) for flow, TKN, NH_3, NOx

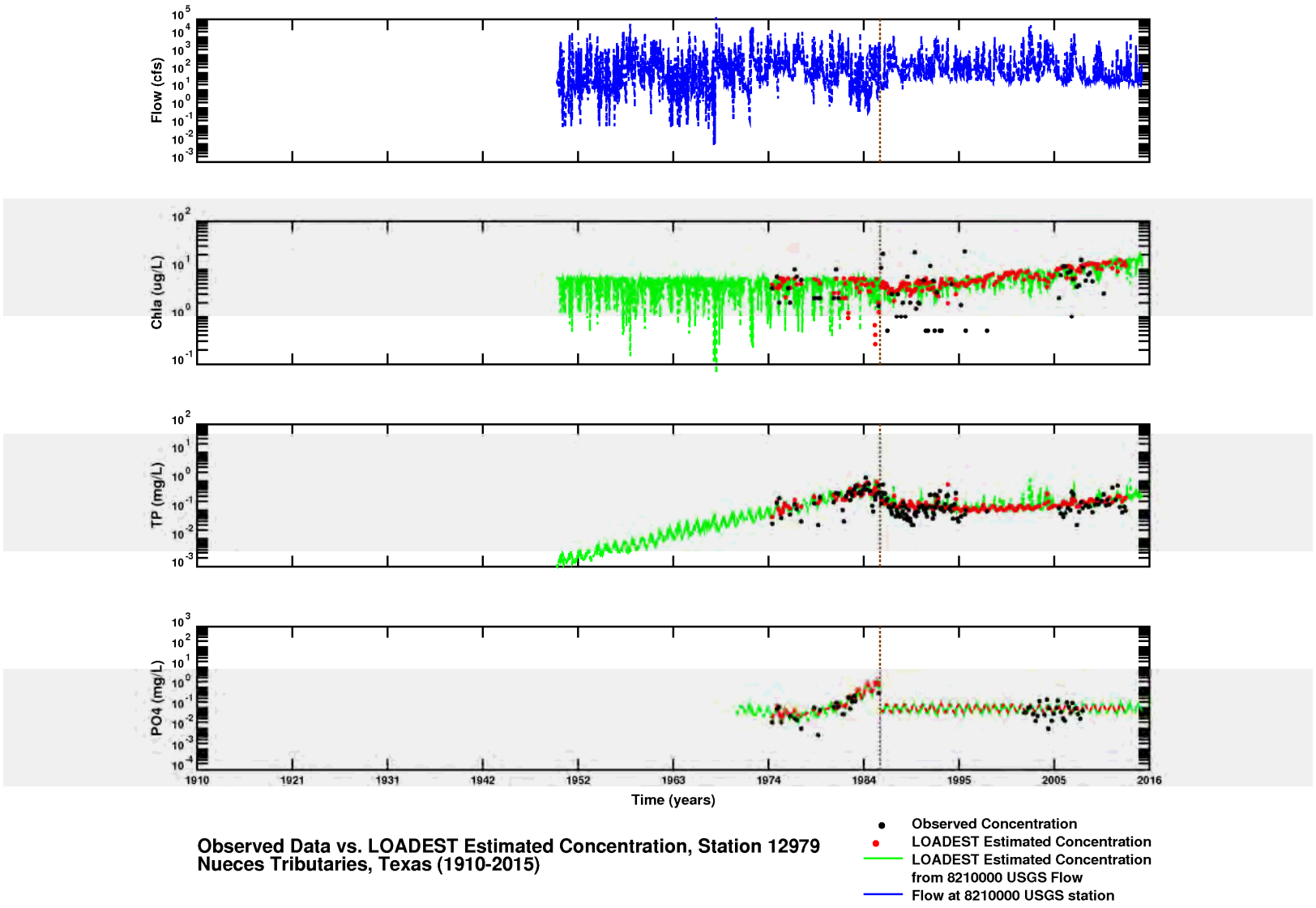

Figure 7-60. LOADEST Regression Analysis for pre- and post-1986 Concentrations for station 12979 (Nueces on US 281 south of Three Rivers) flow, TN, chl-a, TP, and PO_4

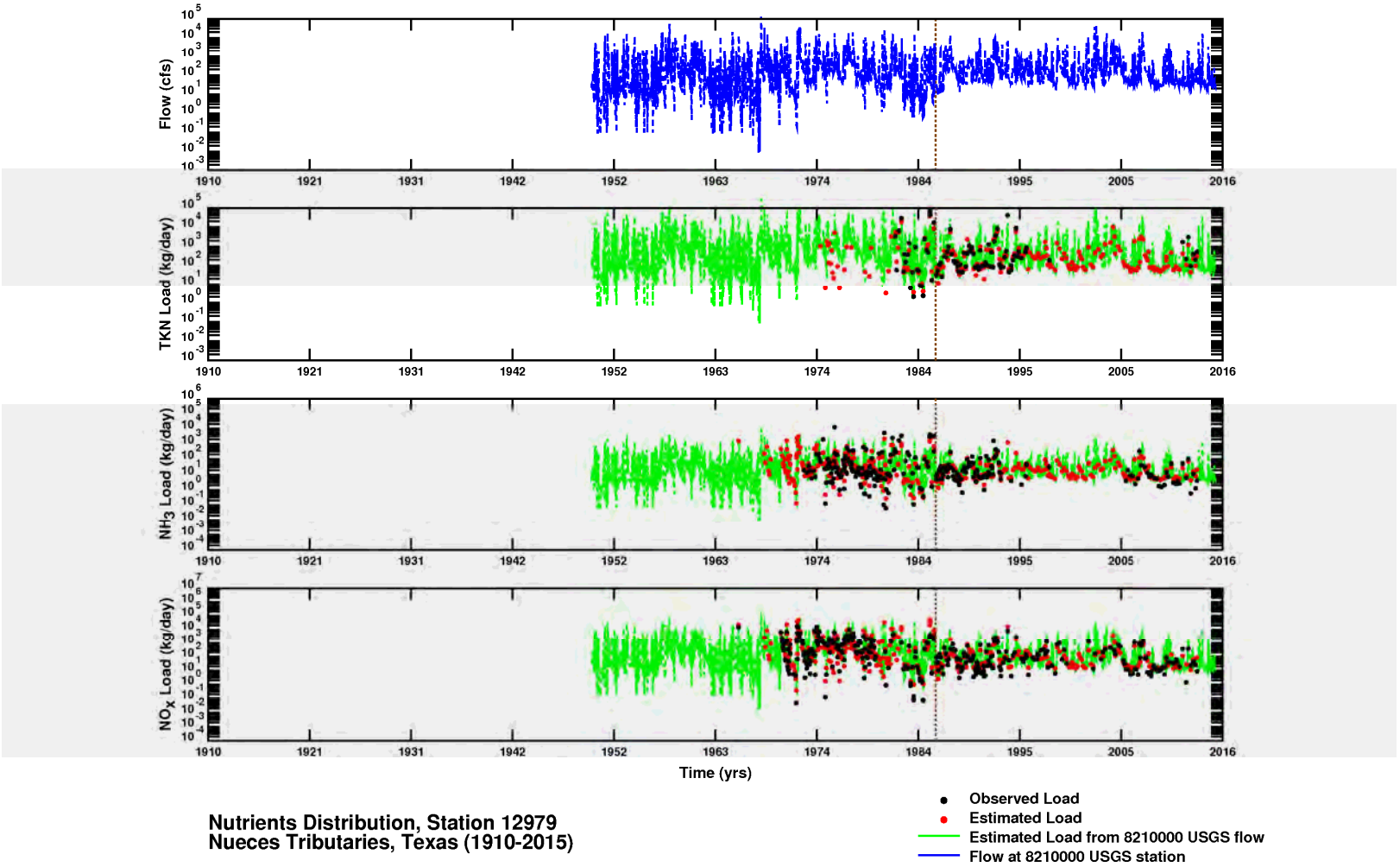

Figure 7-61. Linear Regression Analysis for pre- and post-1986 Loads for station 12979 (Nueces on US 281 south of Three Rivers) for flow, TKN, NH_3, NOx

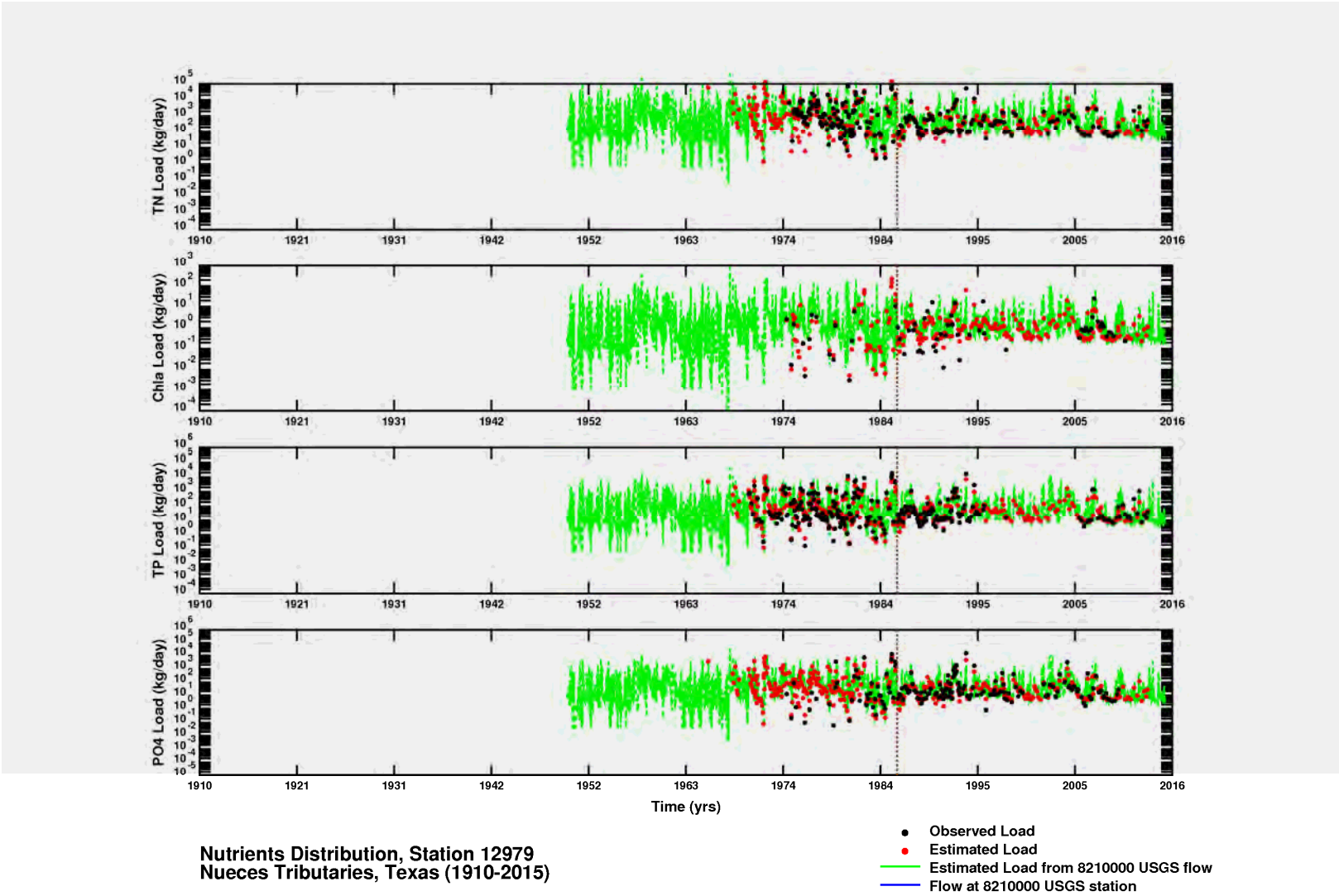

Figure 7-62. Linear Regression Analysis for pre- and post-1986 Loads for station 12979 (Nueces on US 281 south of Three Rivers) for TN, chl-a, TP, and PO_4

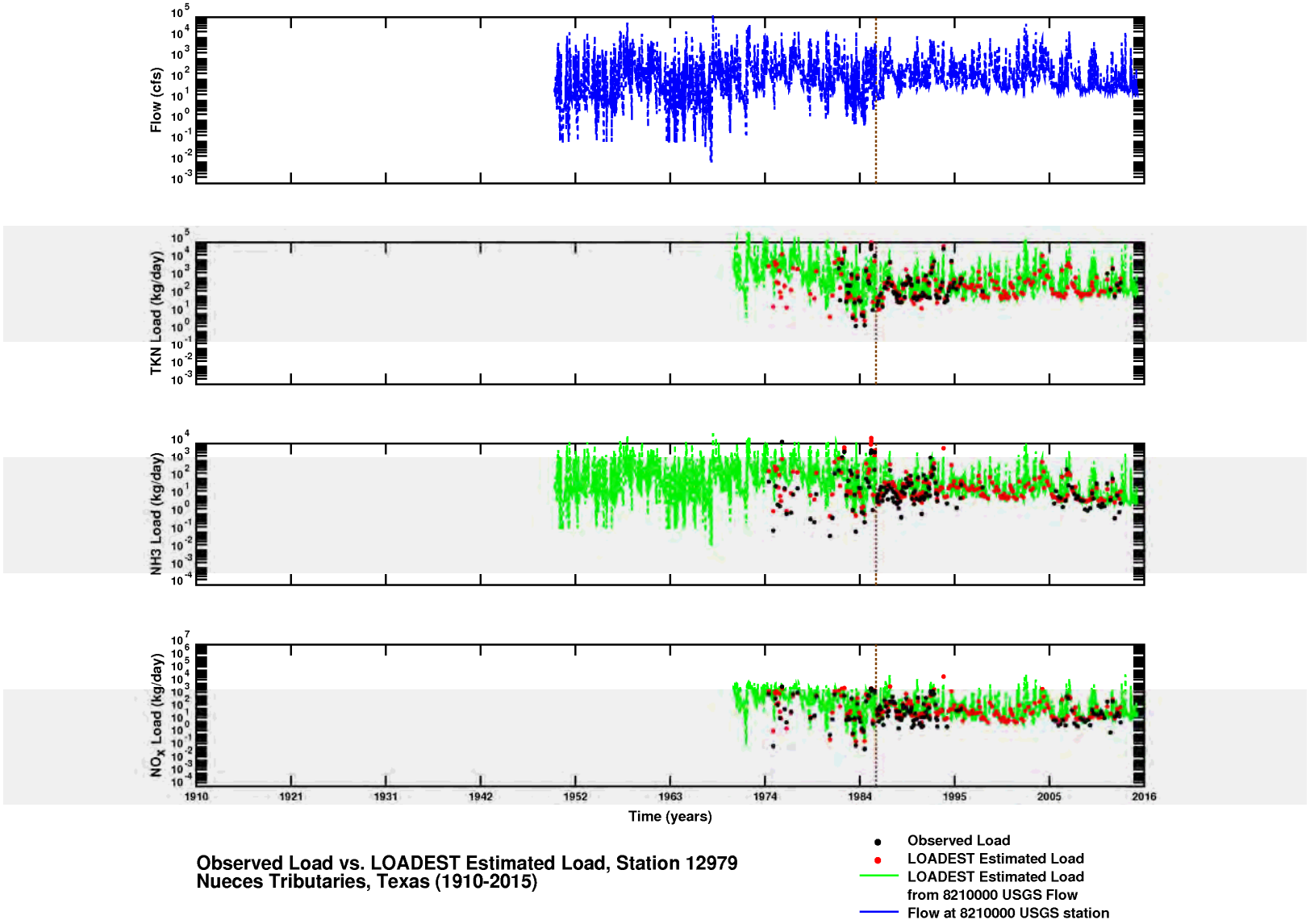

Figure 7-63. LOADEST Regression Analysis for pre- and post-1986 loads for station 12979 (Nueces on US 281 south of Three Rivers) for flow, TKN, NH_3, NOx

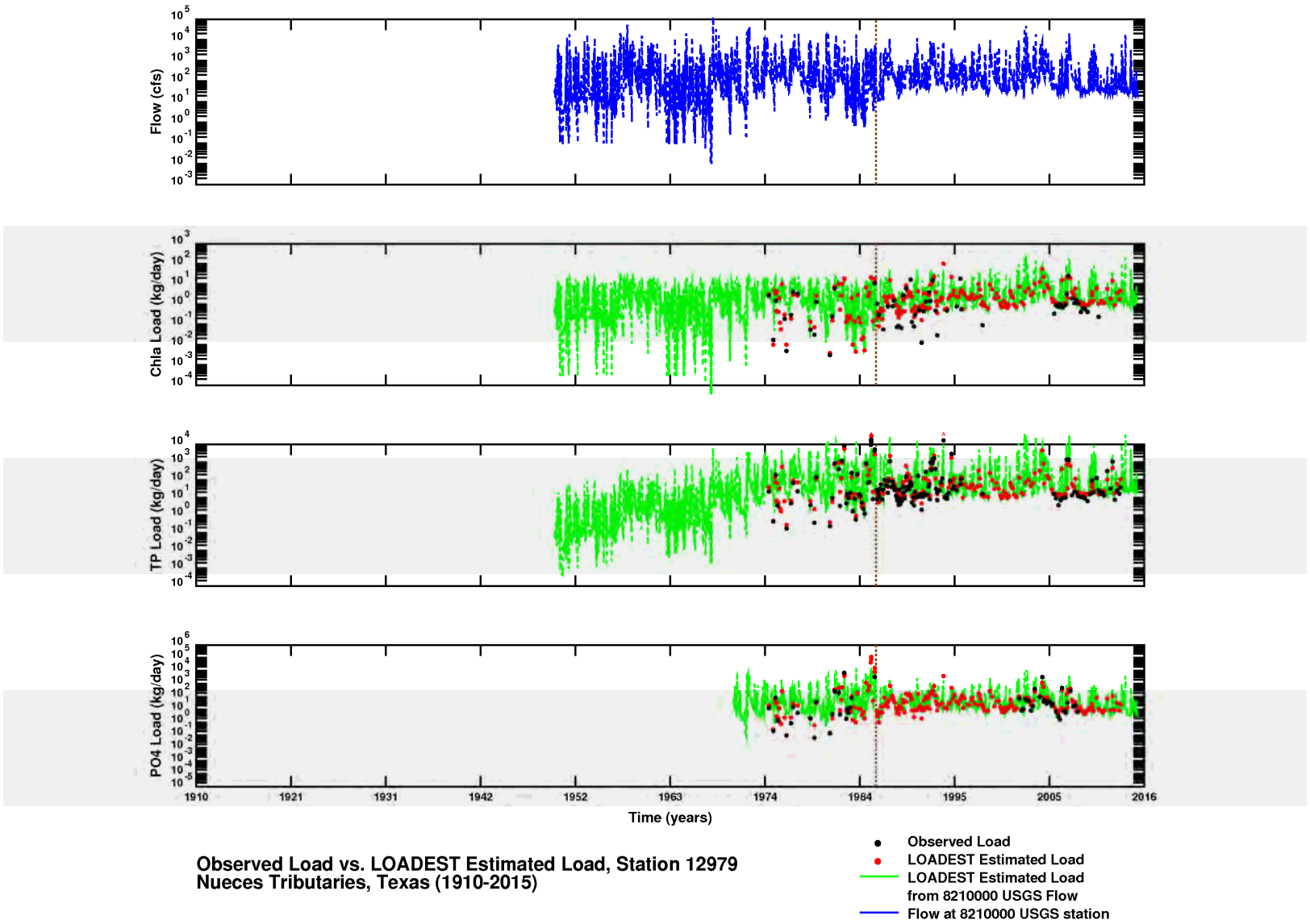

Figure 7-64. LOADEST Regression Analysis for pre- and post-1986 loads for station 12979 (Nueces on US 281 south of Three Rivers) for flow, chl-a, TP, and PO_4

7.7 Analysis of the Mission-Aransas Watershed

The analysis of the neighboring watershed to the northeast, the Mission-Aransas Watershed, or San Antonio-Nueces Coastal Basin, was conducted to serve as a potential surrogate as an undeveloped watershed that could simulate pre-development conditions. Development in the watershed is predominantly agricultural in nature. Figure 7-65 depicts the 2011 land use map of the Nueces and Mission-Aransas Watersheds, which shows the relatively greater proportion of cultivated cropland and pasture in the upper and southwestern portion of the Mission-Aransas watershed.

Linear regression analysis indicates flat-lying trends in nutrients concentrations (Figure 7-66) over the analyzed period (1970-2014) while LOADEST suggests that nutrients have some trends for the same station 12944 (Figure 7-67).

LOADEST modeling indicates that NH_3 and NOx decreases by a factor of ten, while PO_4 and TP concentrations have an increasing trend by a factor of 10. chl-a concentration has a decreasing trend till earlier 1990 and then the concentration started to increase. While LOADEST estimated concentrations of NH_3, NOx and chl-a have better fit to observed data, the estimated concentration of TKN looks overestimated on both sides of the computed parabolic curve (Figure 7-67). Also it seems that LOADEST overestimates TP and PO_4 concentrations over the last 30 years.

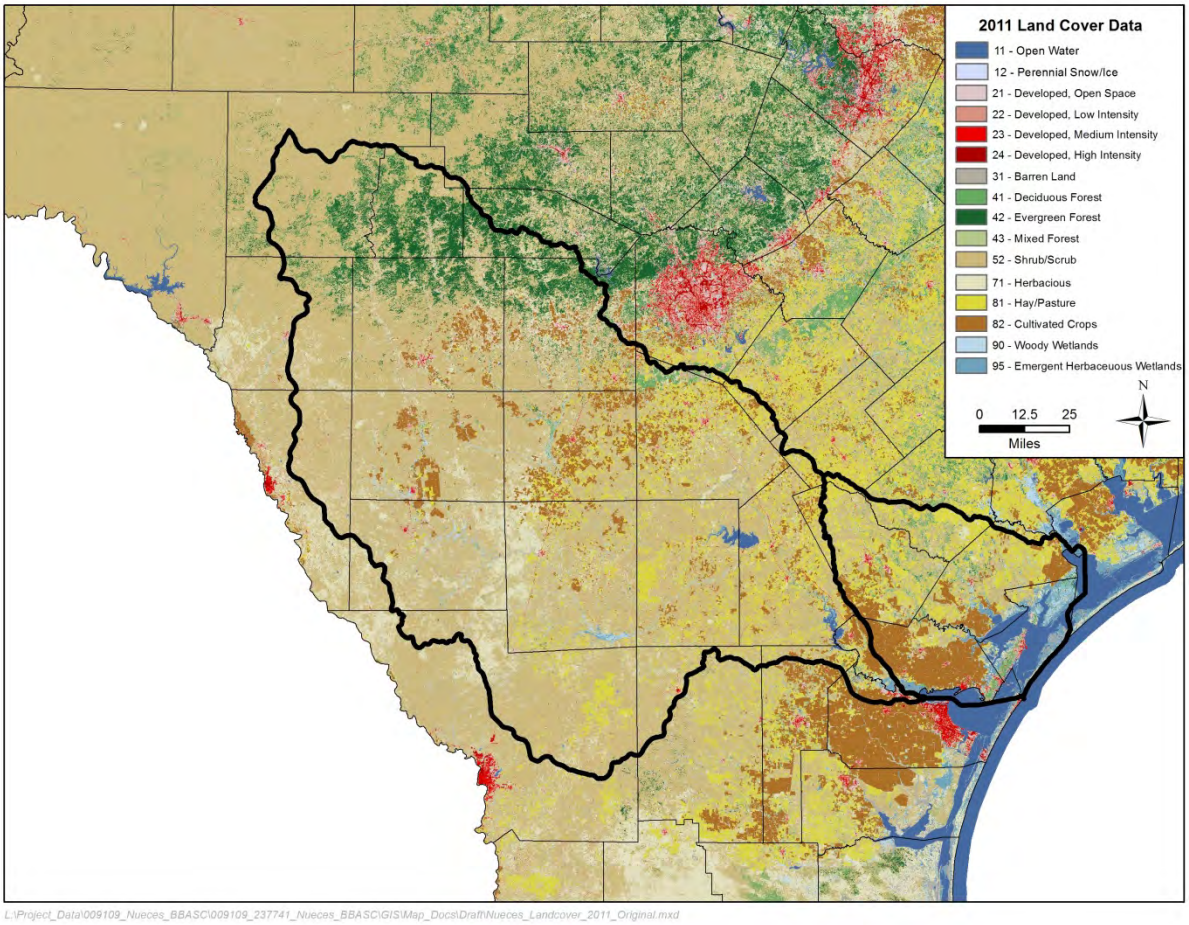

Figure 7-65. 2011 land use map of the Nueces and Mission-Aransas Watersheds

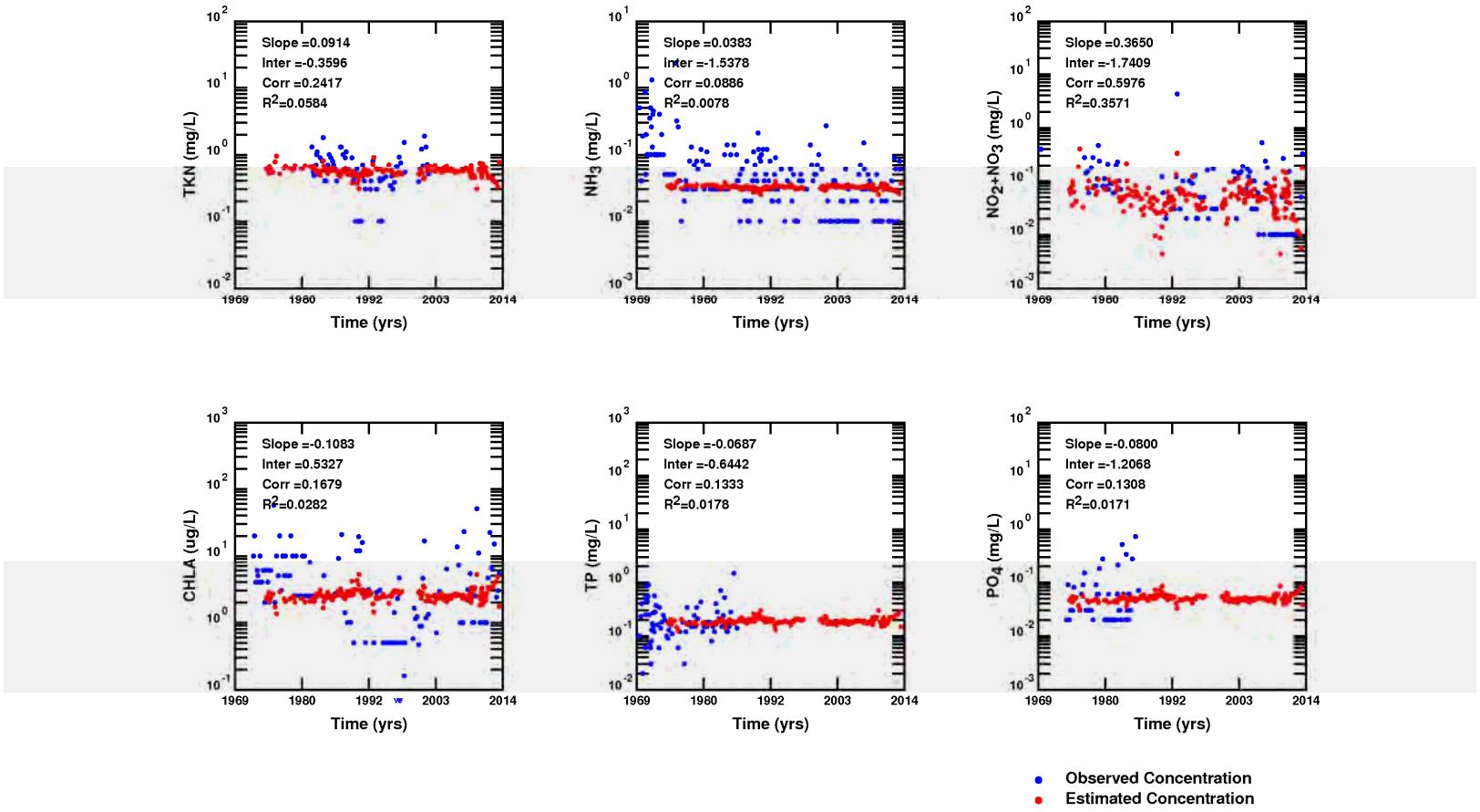

Figure 7-66. Linear Regression Analysis for Basin 20, station 12944 (Mission River at US 77 at Refugio)

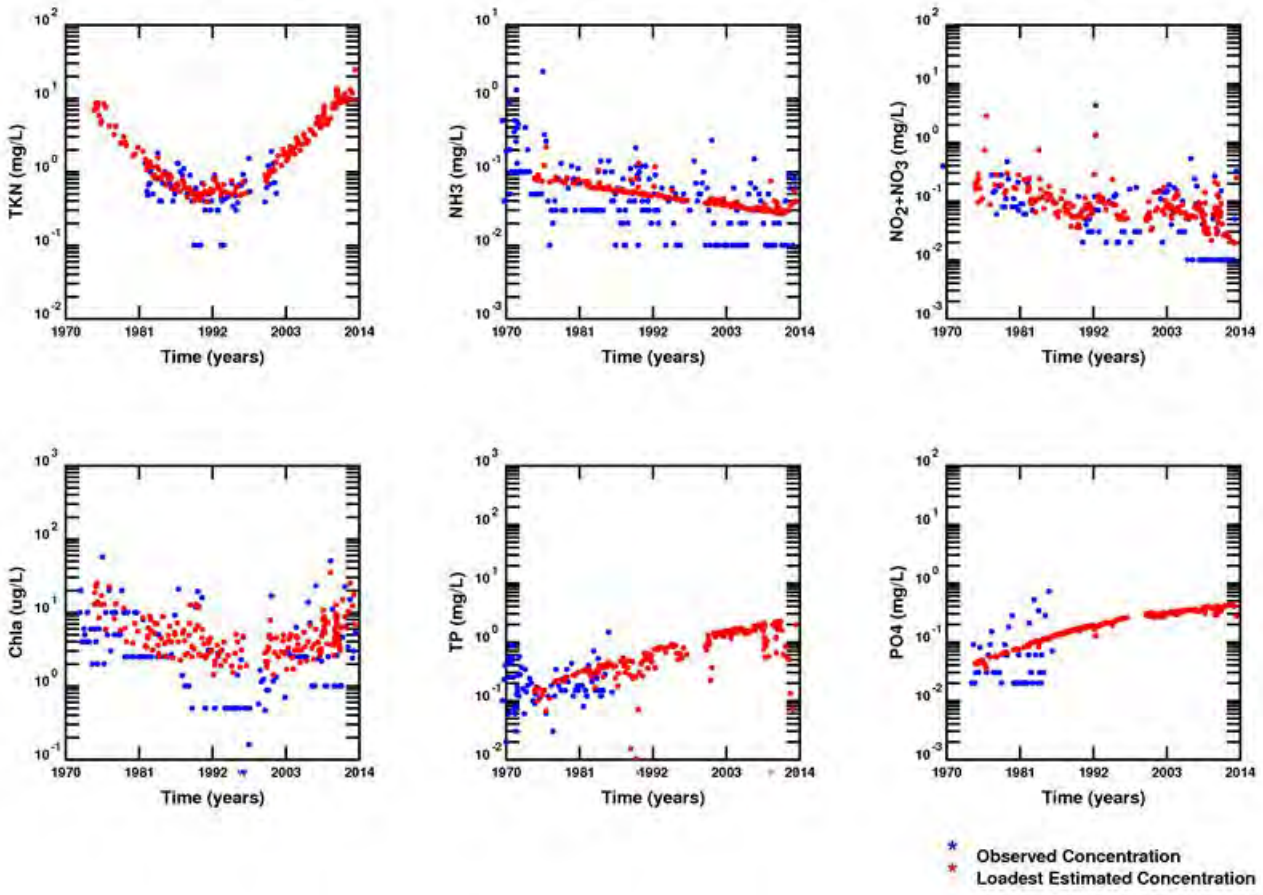

Figure 7-67. LOADEST Regression Analysis for Basin 20, station 12944 (Mission River at US 77 at Refugio)

7.8 Discussion of Regression Analyses

An analysis of nutrient data from the Nueces Watershed and the Mission-Aransas Watershed was conducted. The analysis was performed using two regression models:

- A simple linear regression model, which considered just the relationships between concentrations and flow, and
- A multiple regression model, which considered a temporal component in addition to flow.

The data analysis provided a greater understanding of nutrient loadings at the watershed scale. For nutrient dynamics in the Nueces Bay to be understood, nutrient dynamics in the upgradient watersheds must be understood. Statements in this section are hypotheses based on the regression analyses to provide insights into changing water quality conditions in the subwatersheds. These insights may warrant further investigation before subwatershed management decisions can be made.

7.8.1 Nueces River

For TKN, NH_3, TP, PO_4 and chl-a, an increase in concentrations and loads between the upper undeveloped portion of the watershed, as represented by station 12999, Nueces River, Laguna, and the lower portion of the watershed as represented by stations 12975, 12973, and 12979, Nueces River at Cotulla, at Tilden, and at Three Rivers, respectively, exists. It is more difficult to form conclusions for NOx. Maxima values for NOx are similar both upstream and downstream, but the minima values are lower in the upper portion of the watershed compared to the downstream portion of the watershed. The nature of this occurrence of minima is not clear at this time and could be related to dilution from waters with lower NOx values (*i.e.*, WWTPs that discharge NH_3 preferentially over NOx, or utilization by in-stream benthic algal biomass and/or submerged aquatic vegetation.

The LOADEST scenarios showed a decreasing temporal trend at station 12979 at Three Rivers, but this station is also below the confluence of the Nueces River, Frio River, San Miguel Creek and Atascosa River, so it is not truly clear if this temporal trend is due to changes in the Nueces River or the other river basins. The chl-a concentration at station 12999 is relatively constant while significant variability in chl-a concentration at station 12979 and station 12973, the most downstream station not influenced by other rivers, is exhibited.

7.8.2 Frio River

For TKN, TP, and PO_4 and chl-a, an increase in concentration and loads occurs between the upper tributaries of the Frio River (stations 12987, 12985, 13006, 13007, 12994, 12993, 13013, and 13010; Leona river at Batesville; Leona River at Pearsall; Frio River at Concan; Frio River at Magers Crossing; Sabinal River Sabinal; Sabinal River at US 90; Seco Creek at Miller Ranch; Hondo Creek at Tarpley, respectively) and the lower portion of the Frio River (station 13023, Frio River at Tilden) exists.

There does not appear to be a difference between the upstream and downstream concentrations and loads of NH_3. There may be some differences between the upper portion and lower portions of the Frio River, but it depends on which waterbody is being considered. For example, there

appears to be an increase in the maximum concentrations in Upper Frio River (station 13006) and the lower Frio River (station 13023), but as was observed in the Nueces River, the upstream minima are lower. However, in the Upper Sabinal River (station 12993) the NH_3 maxima are similar to the downstream station.

7.8.3 Atascosa River

It is difficult to make a definitive statement concerning upstream to downstream concentration gradients for the Atascosa River, since the temporal sampling periods do not overlap. The concentrations of NH_3, NOx, TP, PO_4 and perhaps chl-a appear to be higher in the upstream portion of the Atascosa River watershed (station 12981, Atascosa River at Pleasanton) as compared to the downstream portion of the Atascosa River (station 12980). The relatively high values of nutrients at station 12981 suggests that the station could be located downstream of Pleasanton's WWTP outfall. Nueces River Authority (2013a) states that much of the upper Atascosa River is intermittent or ephemeral, and that if flows were not augmented by effluent from the Pleasanton WWTP outfall, the river might be classified as intermittent, except for the lowermost segment. According to information from the City of Pleasanton, the WWTP treats and discharges an average of 760,000 gallons per day with a permit to discharge up to 1,420,000 gallons per day (City of Pleasanton, 2015).

7.8.4 Mission-Aransas Watershed

Data from the neighboring Mission-Aransas watershed were analyzed. There is little development in this watershed, and it was hypothesized that the watershed could be a useful surrogate for a pre-development scenario in the Nueces watershed. Interestingly, station 12944 located on the upper Mission River in Refugio and upstream of the town's WWTP discharge, had higher concentrations of TKN, NH_3, TP, PO_4 and chl-a as compared to upstream stations in the less developed portions of the Nueces Watershed. The concentrations of NOx, however, were higher in the Nueces watershed as compared to data observed in the upper Mission River. Where comparisons could be made, observed nutrient loadings in the upper Aransas River were even higher than observed in the Mission River and the upstream stations in the Nueces watershed. Elevated concentrations of nutrients were observed at stations 12948 and 12942. In addition, elevated chl-a concentrations were noted in stream segment 2003 on the lower Aransas River, including stations 12930 and 12948, Chiltipin Creek northeast of Sinton and Aransas River Tidal at US 77, respectively. One explanation for the difference in nutrient loadings is the land use in the Aransas River subwatershed. This subwatershed's land use is predominantly hay/pasture and cultivated crops. It was determined that the Mission-Aransas watershed would not be a feasible surrogate for pre-development conditions in the Nueces watershed.

7.8.5 Effects of Choke Canyon Reservoir on Nutrient Loading

Another objective of the analysis was to determine if changes to water resources management in the watershed could be observed in the nutrient data, particularly if CCR results in changes in nutrient loads delivered to the Nueces Estuary. To perform this evaluation, data from two stations (stations 13023 on the Frio River and 12983 on San Miguel Creek) upstream of the reservoir were compared to data downstream of the reservoir, at station 12979.

Data were divided into two time intervals, pre- and post-construction of the reservoir. Data pre-1986 represented the pre-construction dataset and data post-1986 represented the post-

construction period. The data analysis is somewhat limited by the availability of data at the three stations. The analysis is further complicated by the fact that station 12979, while located below the reservoir, is also located below the confluence of the Nueces and Atascosa rivers. Therefore, in evaluating the data, it was necessary to consider the influences of these rivers as well.

Nitrogen species

A decline in TKN between the pre- and post- reservoir construction is evident, but it appears as if this decline may have begun prior to the construction of the reservoir. In addition, the concentrations of TKN are lower than the two upstream stations on the Frio River and on San Miguel Creek, but are similar to those observed on the Atascosa River. Therefore, it is not possible without further analysis to determine if the reservoir has had an influence on TKN since the sampling location at station 12979 at Three Rivers is downstream of the confluence of the Frio, Atascosa, and Nueces rivers.

Similar behavior can also be observed for the NH_3 data. Post-CCR construction maxima NH_3 data at station 12979 are lower than pre-CCR, but the pre-CCR maxima at station 12979 are lower than the upstream data.

The reservoir may be influencing concentrations of NOx passing through CCR. Pre- and post-construction maxima in the lower Frio River are on the order of 5 to 8 mg N/L, while NOx maxima in lower San Miguel Creek, lower Atascosa River and lower Nueces River pre- and post-CCR are generally less than 1 mg N/L. Data at the downstream station (station 12979), show a change pre- and post-CCR construction, with pre-CCR maxima on the order of 3 to 5 mg N/L and post-CCR maxima being less than 1 mg N/L. It is important to note that NOx maxima had begun to decline before the construction of CCR.

Phosphorus species

An assessment of the possible changes in TP and PO_4 concentrations as influenced by CCR is inconclusive without further analysis. Some increases in TP and PO_4 in the Frio River and San Miguel Creek after construction of CCR are present and do not appear downstream of the reservoir at station 12979 at Three Rivers. chl-a data at station 12979 do suggest that the maxima concentrations may have declined slightly in recent years, but this downward trend had begun before construction of CCR and continued after construction. The pre- and post-CCR construction regression analysis slopes for chl-a concentration versus flow are different. However, the confidence intervals about the slopes encompass each other, suggesting no significant difference between them.

Flow

Nutrient loads are directly related to flows and are calculated by multiplying concentration by flow. With the drought conditions experienced in the Nueces Basin since construction of CCR, including a new drought of record, conclusions of the effects of CCR construction on nutrient loadings cannot be made. As a result of CCR construction, low flow conditions below the reservoir are more frequent than before the reservoir construction and high flow events have been reduced, which affect nutrient loadings downstream.

8 Determination of Pre- and Post-Development Nutrient Loadings

Discussions with stakeholders at the beginning of the study included how to best define the pre-development condition. The Nueces BBASC Work Plan for Adaptive Management (Nueces BBASC, 2012b) describes development in the Nueces Basin as population growth, increased wastewater nutrient loads, navigation channel deepening, upstream reservoir development (CCR completion), and diversion of a small part of the municipal wastewater flow from the Nueces River to the Nueces Delta. The Nueces BBASC Work Plan for Adaptive Management further stated that the net effect has been a probable reduction in primary productivity in Nueces Bay.

To delineate pre-development loadings, the scope of this nutrient budget study was to use water quality data from stations located in the identified undeveloped portions of the watershed and compare these values to data in the EPA ecoregional studies.

Annual nutrient loadings for four locations representing the upper, middle, and lower Nueces Basin were calculated. Selected locations needed to possess long-term USGS streamflow records and sufficient water quality data with which to develop flow/concentration regressions. The four locations for which annual nutrient loads were calculated included:

- Atascosa River, Whitsett (USGS 08208000, TCEQ 12980)
- Nueces River, Laguna (USGS 08190000, TCEQ 12999)
- Nueces River, Three Rivers (USGS 08210000, TCEQ 12979)
- Nueces River, Mathis (USGS 08211000, TCEQ 12965).

Downstream stations 12965 and 12962 at Mathis and Calallen, respectively, lacked data, particularly for instantaneous flow/concentrations sets, which are required for regression analyses and estimations of load, and in the timeframe before the late 1990s. For the nutrient parameters analyzed, more data were available at Station 12965 at Mathis than at the Calallen location. Therefore, station 12965 at Mathis was the most downstream location included in the calculation of loads. Appendix E includes the regression analyses for stations in the Nueces watershed. Annual nutrient loadings were calculated for wet, dry, and average years before and after the construction of Choke Canyon Reservoir. Data collected before 1986 represent the pre-construction dataset and data collected after 1986 represent the post-construction period. Water quality data are available from 1970 through the present.

The determination of wet, dry, and average years was based on the Nueces River near Mathis (USGS 08211000, TCEQ 12965) gage. This gage was used as the determinant of wet, dry, and average years because, as the most downstream gage with sufficient water quality data, it provides a reflection of the downstream nutrient load from the Nueces Basin.

For the pre-construction timeframe from 1970 through 1985, the years of greatest, least, and geometric average flow (more closely resembling median flow than the arithmetic average) for the Nueces River near Mathis were 1971, 1984, and 1974. For the post-construction timeframe from 1986 through 2014, the years of greatest, least, and geometric average flow for the Nueces River near Mathis were 2002, 2008, and 1993.

In developing the nutrient loads, the simple linear regression analysis were used instead of the LOADEST regressions, which include temporal variability as part of the regression, whereas the linear regression analysis uses flow/concentration sets. With the limited data availability, the

simpler linear regression analysis provided more statistically significant regression for parameters analyzed than LOADEST estimations.

Tables 8-1 through 8-4 and Figures 8-1 through 8-4 show the nutrient loadings calculated for total phosphorus (TP), total kjeldahl nitrogen (TKN), and nitrate plus nitrite (NOx), and the total nitrogen (TN), which was calculated as the TKN plus NOx loadings, in units of thousand lb/year. For reference, nutrient loadings also are shown as annual average values in units of lb/day (Figures 8-5 through 8-8). Values in the table labeled as NA indicate that not enough data existed to complete a linear regression analysis.

As expected, the most upstream and undeveloped portions of the Nueces watershed exhibit the lowest nutrient loads. Loads increase in the downstream direction.

Table 8-5 shows the percent change at Three Rivers (station 12979) for the time periods representing pre- and post-construction and the percent change from Three Rivers to Mathis (station 12965). The percent changes show that both TP and TN decreased at the Three Rivers station through all flow regimes in the time period after 1986. The percent change calculated from the Three Rivers station downstream of CCR to the Mathis station downstream of LCC shows an increase in TP. Total nitrogen decreased in the years representing average and wet periods, but increased almost 30 percent in the dry period.

In general, nitrogen species loads at Three Rivers are greater than downstream at Mathis and greater than the ecoregional reference conditions. This could indicate nutrient enrichment at Three Rivers and nitrogen uptake between Three Rivers and Mathis, most likely from Lake Corpus Christi, although further analysis is necessary to confirm the effects of Lake Corpus Christi and the intervening watershed. It should be noted that few instantaneous flow/concentration sets existed for the TKN regression analysis at Mathis.

8.1 Comparison to EPA Ecoregional Reference Conditions

Annual loads representing the upper and lower Nueces Basin were calculated using the respective EPA ecoregion reference condition concentrations and gaged streamflow located in the specific ecoregion. The most upstream ecoregion in the Nueces Basin is Subecoregion 30, Edwards Plateau. Loads were calculated using the reported ambient ecoregion nutrient concentrations shown in Table 5-2 and flow from Nueces River at Laguna, which is located in Subecoregion 30. The most downstream ecoregion in the Nueces Basin is ecoregion 34, Western Gulf Coastal Plain. Loads were calculated using the reported ambient ecoregion nutrient concentrations shown in Table 5-2 and flow from Nueces River at Mathis, which is located in Subecoregion 34.

Tables 8-1 through 8-4 and Figures 8-1 through 8-8 show the EPA ecoregional reference condition nutrient loadings. As discussed in the scope of this project, data from the undeveloped portions of the watershed are compared to the EPA ecoregional reference condition values. The calculated annual loads do compare well with both the upstream and downstream EPA ecoregional reference condition calculated loads for TP and TKN. The calculated NOx loadings Subecoregion 34 loadings are between the calculated NOx loadings at Three Rivers and Mathis.

Table 8-1. Total phosphorus loading at select Nueces Basin gages and related EPA subecoregional reference condition loadings for time periods of pre- and post-construction of Choke Canyon Reservoir.

TP, (Thousand lb/yr)	Gage (USGS ID, TCEQ ID)	Atascosa River, Whitsett (08208000, 12980)	Nueces River, Laguna (08190000, 12999)	Nueces River, Three Rivers (08210000, 12979)	Nueces River, Mathis (08211000, 12965)	Sub-ecoregion 30*	Sub-ecoregion 34**
Pre-1986	Dry	NA	4.6	60.3	NA	1.4	32.1
	Avg	NA	4.2	168.8	NA	2.2	133.6
	Wet	NA	18.7	976.2	NA	6.0	872.8
Post-1986	Dry	8.6	1.3	19.2	29.5	1.2	25.8
	Avg	45.9	1.2	67.7	79.7	1.0	69.0
	Wet	126.3	2.6	816.9	904.5	2.5	765.6

* Loads calculated using reported ambient ecoregion concentrations shown in Table 5-2 and flow from Nueces River, Laguna (08190000), which is located in Subecoregion 30.
** Loads calculated using reported ambient ecoregion concentrations shown in Table 5-2 and flow from Nueces River, Mathis (08211000), which is located in Subecoregion 34.

Table 8-2. TKN loading at select Nueces Basin gages and related EPA subecoregional reference condition loadings for time periods of pre- and post-construction of Choke Canyon Reservoir.

TKN, (Thousand lb/yr)	Gage (USGS ID, TCEQ ID)	Atascosa River, Whitsett (08208000, 12980)	Nueces River, Laguna (08190000, 12999)	Nueces River, Three Rivers (08210000, 12979)	Nueces River, Mathis (08211000, 12965)	Sub-ecoregion 30*	Sub-ecoregion 34**
Pre-1986	Dry	NA	56	522	NA	32	189
	Avg	NA	59	1457	NA	49	784
	Wet	NA	233	7833	NA	134	5126
Post-1986	Dry	13	25	126	198	26	152
	Avg	28	22	424	245	23	405
	Wet	53	55	4820	337	57	4497

* Loads calculated using reported ambient ecoregion concentrations shown in Table 5-2 and flow from Nueces River, Laguna (08190000), which is located in Subecoregion 30.
** Loads calculated using reported ambient ecoregion concentrations shown in Table 5-2 and flow from Nueces River, Mathis (08211000), which is located in Subecoregion 34.

Table 8-3. Nitrate plus nitrite loading at select Nueces Basin gages and related EPA subecoregional reference condition loadings for time periods of pre- and post-construction of Choke Canyon Reservoir.

NOx (Thousand lb/yr)	Gage (USGS ID, TCEQ ID)	Atascosa River, Whitsett (08208000, 12980)	Nueces River, Laguna (08190000, 12999)	Nueces River, Three Rivers (08210000, 12979)	Nueces River, Mathis (08211000, 12965)	Sub-ecoregion 30*	Sub-ecoregion 34**
Pre-1986	Dry	10	373	253	32	16	36
	Avg	14	370	710	180	24	148
	Wet	21	1535	4535	1496	67	970
Post-1986	Dry	9	129	35	8	13	29
	Avg	302	112	138	24	12	77
	Wet	982	409	1895	347	28	851

* Loads calculated using reported ambient ecoregion concentrations shown in Table 5-2 and flow from Nueces River, Laguna (08190000), which is located in Subecoregion 30.
** Loads calculated using reported ambient ecoregion concentrations shown in Table 5-2 and flow from Nueces River, Mathis (08211000), which is located in Subecoregion 34.

Table 8-4. Total nitrogen loading at select Nueces Basin gages and related EPA subecoregional reference condition loadings for time periods of pre- and post-construction of Choke Canyon Reservoir.

TN (Thousand lb/yr)	Gage (USGS ID, TCEQ ID)	Atascosa River, Whitsett (08208000, 12980)	Nueces River, Laguna (08190000, 12999)	Nueces River, Three Rivers (08210000, 12979)	Nueces River, Mathis (08211000, 12965)	Sub-ecoregion 30*	Sub-ecoregion 34**
Pre-1986	Dry	NA	429	775	NA	48	224
	Avg	NA	428	2167	NA	73	933
	Wet	NA	1768	12367	NA	201	6096
Post-1986	Dry	22	153	161	206	39	180
	Avg	330	134	562	269	35	482
	Wet	1036	464	6714	684	85	5347

* Loads calculated using reported ambient ecoregion concentrations shown in Table 5-2 and flow from Nueces River, Laguna (08190000), which is located in Subecoregion 30.
** Loads calculated using reported ambient ecoregion concentrations shown in Table 5-2 and flow from Nueces River, Mathis (08211000), which is located in Subecoregion 34.

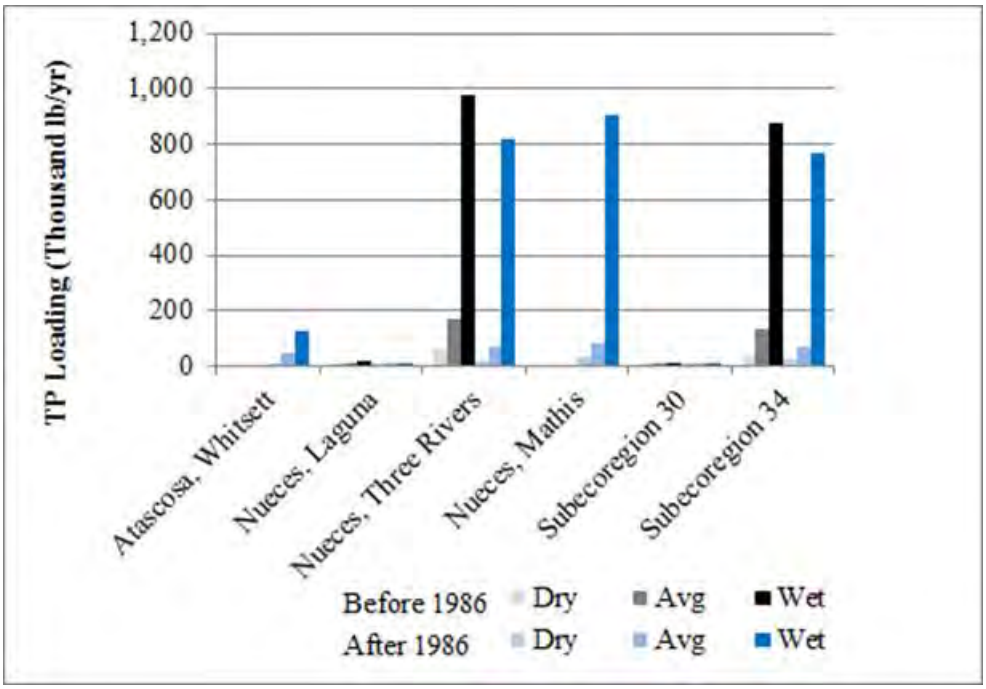

Figure 8-1. Total phosphorus loading at select Nueces Basin gages and related EPA subecoregional reference condition loadings for time periods of pre- and post-construction of Choke Canyon Reservoir.

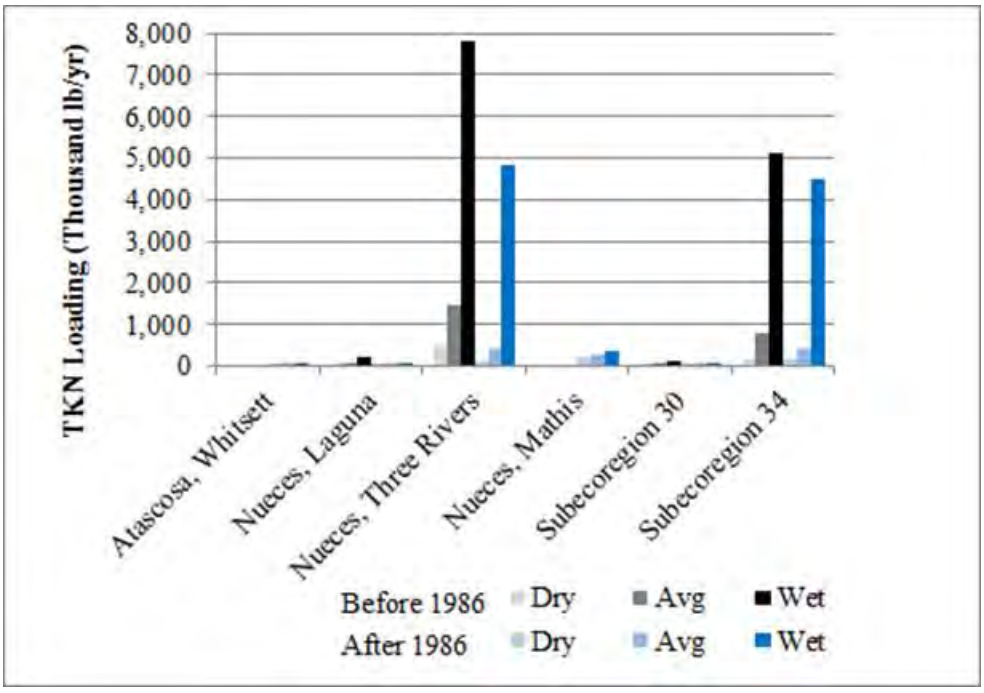

Figure 8-2. TKN loading at select Nueces Basin gages and related EPA subecoregional reference condition loadings for time periods of pre- and post-construction of Choke Canyon Reservoir.

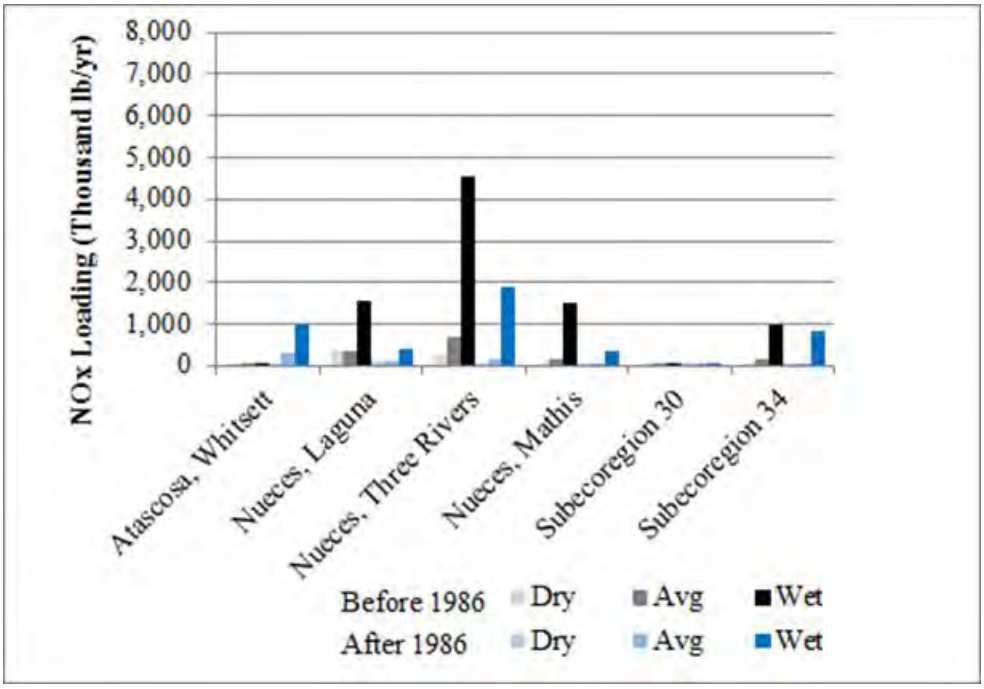

Figure 8-3. Nitrate plus nitrite loading at select Nueces Basin gages and related EPA subecoregional reference condition loadings for time periods of pre- and post-construction of Choke Canyon Reservoir.

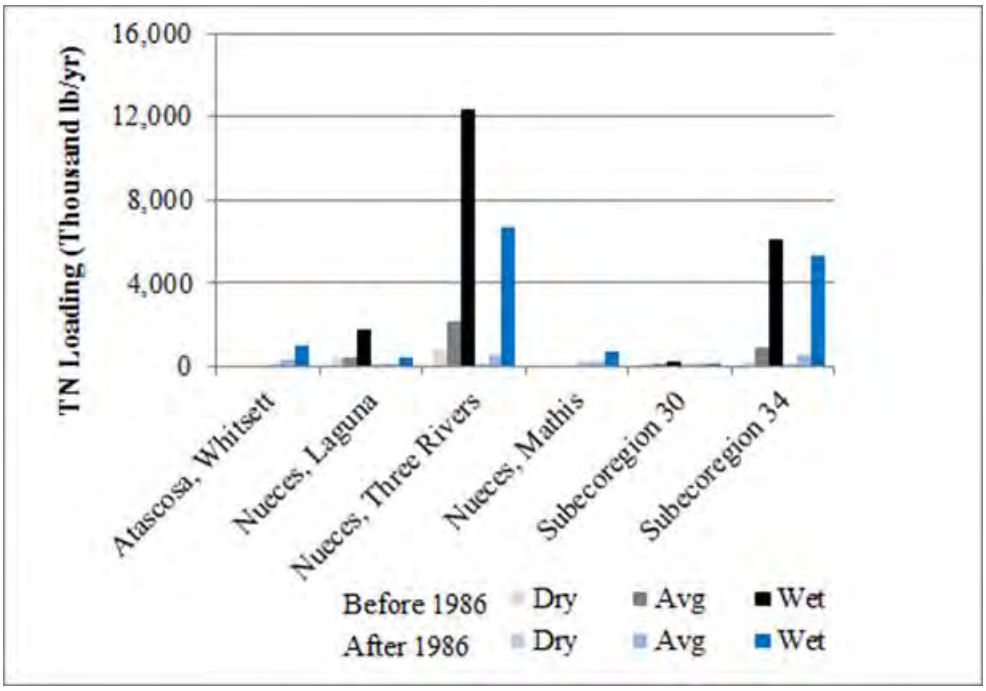

Figure 8-4. Total nitrogen loading at select Nueces Basin gages and related EPA subecoregional reference condition loadings for time periods of pre- and post-construction of Choke Canyon Reservoir.

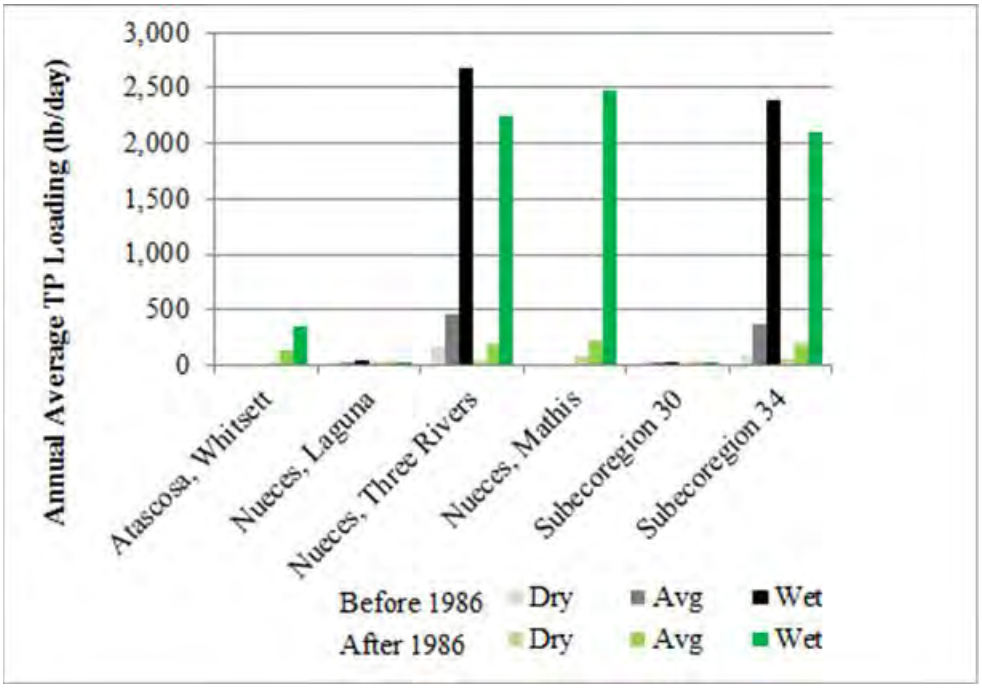

Figure 8-5. Annual average TP loading at select Nueces Basin gages and related EPA subecoregional reference condition loadings for time periods of pre- and post-construction of Choke Canyon Reservoir.

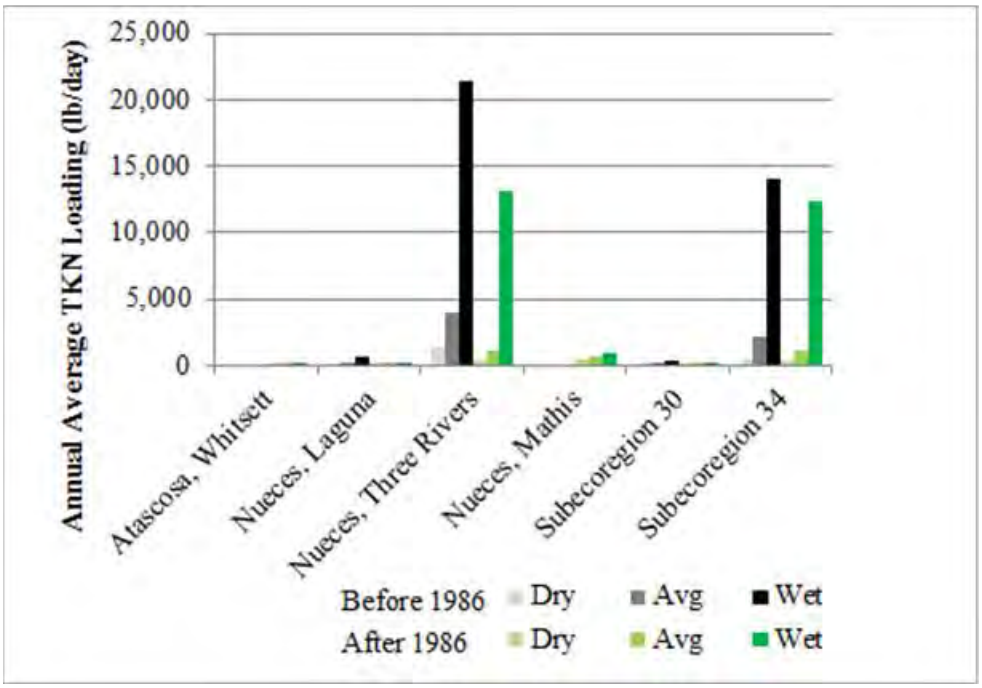

Figure 8-6. Annual average TKN loading at select Nueces Basin gages and related EPA subecoregional reference condition loadings for time periods of pre- and post-construction of Choke Canyon Reservoir.

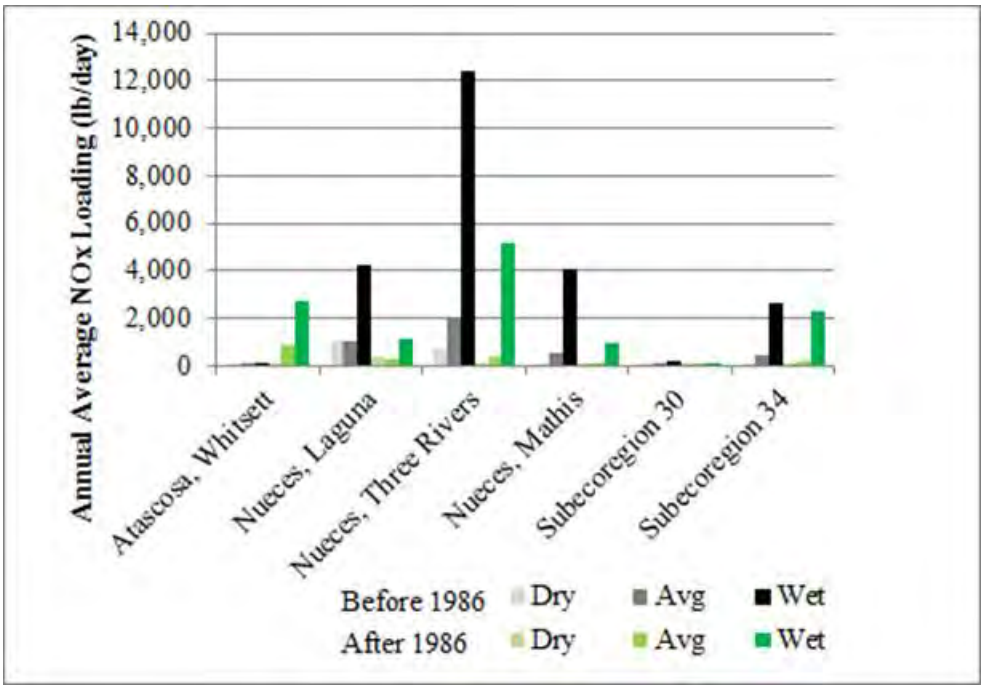

Figure 8-7. Annual average nitrate plus nitrite loading at select Nueces Basin gages and related EPA subecoregional reference condition loadings for time periods of pre- and post-construction of Choke Canyon Reservoir.

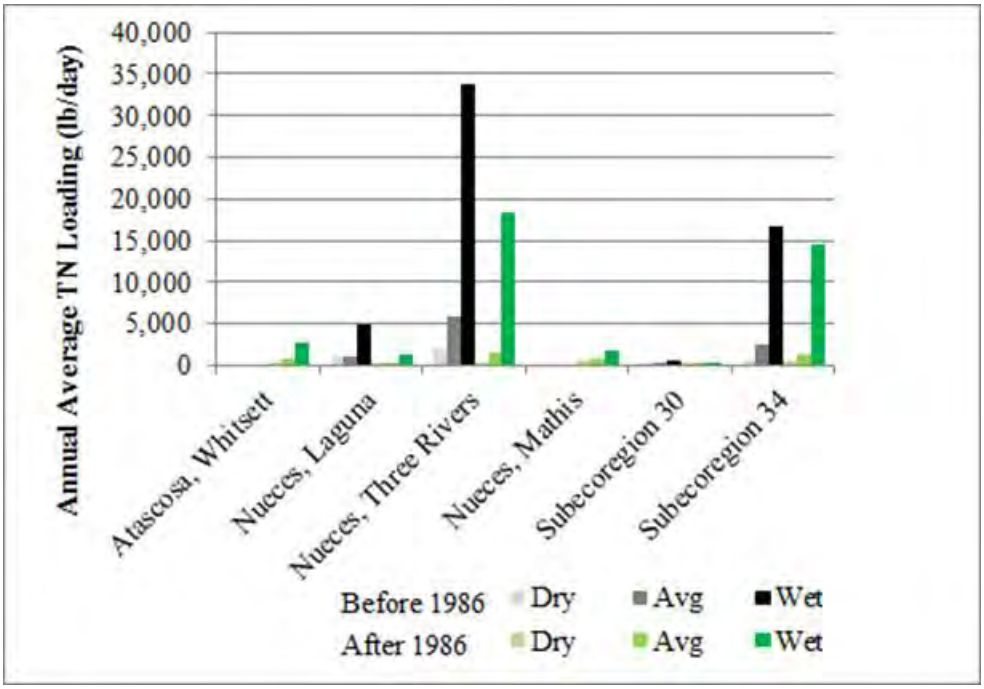

Figure 8-8. Annual average TN loading at select Nueces Basin gages and related EPA subecoregional reference condition loadings for time periods of pre- and post-construction of Choke Canyon Reservoir.

Table 8-5. Percent change in TP and TN loadings at Three Rivers and Mathis locations for time periods pre- and post-construction of Choke Canyon Reservoir.

Scenario	Flow Regime	Change in TP (%)	Change in TN (%)
Pre-1986 to Post-1986 change at Three Rivers (station 12979)	Dry	-68.3%	-79%
	Avg	-59.9%	-74%
	Wet	-16.3%	-46%
Post-1986 change from Three Rivers (station 12979) to Mathis (station 12965)	Dry	54.0%	27.9%
	Avg	17.7%	-52.1%
	Wet	10.7%	-89.8%

9 Conclusions and Recommendations

9.1 Conclusions

Conclusions that can be made in completing this nutrient budget study include the following:

1. Calculated nutrient loadings show that the most upstream, undeveloped portions of the Nueces watershed exhibit the lowest nutrient loads. An analysis in the 2011 South Central Texas Regional Water Plan (HDR and South Central Texas Regional Water Planning Group, 2010) shows that about 10% of streamflow in the upper reaches of the Nueces watershed is delivered downstream as inflow to the Nueces Estuary. The relatively small effect that the upstream portion of the Nueces Basin above the Edwards Aquifer Recharge Zone has on nutrient deliveries to the Nueces Bay indicates that future studies can focus on areas downstream. This downstream extent could include CCR and areas downstream to the Nueces Delta.
2. Nutrient loads are calculated by multiplying concentration by flow. With the drought conditions experienced in the Nueces Basin since construction of CCR, including a new drought of record, conclusions of the effects of CCR construction on nutrient loadings cannot be made. It can be stated that nutrient loadings at Three Rivers have decreased since 1986, the year in which CCR filled and the year chosen to represent post construction effects on nutrient loadings. However, it can not be concluded that construction or operations of CCR are the sole cause of decreased nutrient loading, when specifically examining the Three Rivers sampling location. Similarly, the changes in nutrient loadings at Three Rivers can not necessarily be translated to the nutrient loadings into the Nueces Bay.
3. Changes in nutrient loadings from Three Rivers to Mathis vary among parameters. Total phosphorus loads at Three Rivers are slightly less than downstream at Mathis and slightly greater than the EPA ecoregional reference conditions.

   In general, nitrogen species, including TKN, NOx, and TN, loads at Three Rivers are greater than downstream at Mathis and greater than the EPA ecoregional reference conditions. This could indicate nutrient enrichment at Three Rivers and nutrient uptake between Three Rivers and Mathis, most likely from Lake Corpus Christi, although further analysis is necessary to fully characterize the effects of the CCR/LCC System.

   Explanation for these changes is not able to be determined from the nutrient budget analyses completed as part of this study. Potential causes for the changes in nutrient loadings include land use activities (i.e., extensive cultivated crop acreage causing phosphorus enrichment) in the intervening watershed between Three Rivers and Mathis, and the presence of Lake Corpus Christi, which could be acting as a nitrogen sink and providing for additional processing of nitrogen species.

4. This work does not address the relationship between nutrient loadings and ecosystem health or species abundance.

As stated in the Nueces BBASC Work Plan for Adaptive Management (Nueces BBASC, 2012b), there is a need for a “watershed approach to effective management of these resources.” Previous nutrient studies in the Nueces watershed have focused on downstream (Nueces Delta) portions of

the watershed, and while these are important contributions to Nueces Bay, understanding nutrient contributions from the watershed as a whole is important, as well. As described in the Work Plan, the existing studies have allowed for some broad understanding and a little specific information, but much is still unknown about historical and current nutrient supplies in Nueces Bay and their relationship to the ecological health of Nueces Bay.

Nutrient budgets based on quantitative analysis of compiled existing data has increased understanding of the natural supply of nutrients and anthropogenic changes in these supplies over time for Nueces Bay watershed. To understand nutrient balances and biological productivity in Nueces Bay, nutrient fate and transport in the upstream watershed must be understood.

9.2 Recommendations

Specific recommendations based on the work completed in the study include the following.

- Quantify the effects of seasonality on nutrient loadings. This study showed that adequate data to develop statistically significant relationships are limited. However, for stations where data are available, organizing and analyzing the data around seasonal timeframes could further clarify the watershed-scale nutrient dynamics.
- To better determine sources and sinks of nutrients in the CCR and LCC, a study to measure N-cycling and uptake experiments in the reservoirs is recommended.
- Further quantify the effects of the CCR/LCC System. This study focused on nutrients. It is recommended that the effects of sediment transport, dissolved oxygen, and temperature, for example, on nutrient fate and transport in the downstream portions of the Nueces watershed be better understood. For example, sediment transport is important in relation to phosphorus transport, as phosphorus readily sorbs to sediment. Examining the relationships of these constituents to the nutrient parameters assessed as part of this study could inform decisions regarding operations of the CCR/LCC System, particularly if this analysis was completed in conjunction with the quantification of the effects of seasonality on nutrient loadings.
- To continue the progress of evaluating the nutrient loadings delivered to Nueces Bay, the loadings in the subwatersheds surrounding Nueces Bay could similarly be assessed. For example, the Nueces River Authority Basin Summary Report (Nueces River Authority, 2013a) shows several additional contributions to the Nueces Bay, including several WWTP outfalls. Existing studies have focused on measurement of nutrients in Nueces Bay, not estimation of loads delivered. These load estimates could be completed in addition to the nutrient loading estimations completed for the Nueces watershed.
- The Nueces BBASC Work Plan for Adaptive Management includes as Priority #2 evaluating the potential for Allison WWTP effluent to improve environmental health of the Rincon Bayou delta. The nutrient budget study is linked to the Priority #2 study. With the nutrient loading calculations completed in this study, it would be possible to estimate the loadings available from Allison WWTP given current discharge quantity and quality data. As described in the Work Plan, an evaluation of nutrient loads pre- vs. post-reservoir construction might indicate a change in management decisions on effluent releases to the Nueces Delta and Bay.

Further science-based studies are necessary to develop an integrated, interdisciplinary, and strategic approach to resource planning and decision making regarding the nutrient balance and biological productivity of the Nueces Bay system.

10 Acknowledgments

The authors would like to thank the Texas Water Development Board (TWDB) and the participants of the study, including Texas Commission on Environmental Quality (TCEQ), Nueces Estuary Advisory Council (NEAC), Nueces River and Corpus Christi and Baffin Bays Basin and Bay Area Stakeholder Committee, Nueces (BBASC), Texas Parks and Wildlife Department (TPWD), City of Corpus Christi, Coastal Bend Bays and Estuaries Program (CBBEP), and Coastal Bend Regional Water Planning Group (Coastal Bend RWPG).

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Appendix A. Project update presentations

Study objectives and results were presented at Nueces Estuary Advisory Committee (NEAC) stakeholder meetings in Corpus Christi on June 16, 2014, October 20, 2014, February 23, 2015, and June 22, 2015. Presentations from these meetings are included in this appendix.

Appendix B. Time series figures of water quality constituents related to nutrients for the Nueces, San Antonio – Nueces Coastal, Nueces – Rio Grande Coastal watershed

Appendix B1 shows time series figures of water quality constituents related to nutrients for the Nueces watershed, which is classified as Basin 21 by TCEQ.

Appendix B2 shows time series figures of water quality constituents related to nutrients for the San Antonio – Nueces Coastal watershed, which is classified as Basin 20 by TCEQ.

Appendix B3 shows time series figures of water quality constituents related to nutrients for the Nueces – Rio Grande Coastal watershed, which is classified as Basin 22 by TCEQ.

The figures are organized by TCEQ stream segment identification numbers, which begin with the basin identification (20, 21, or 22) and have a two-digit identifier following the basin identifier.

Appendix C. Graphical summary of USGS nutrient data available before 1968

Appendix D. Summary of outlier analyses

Appendix E. Nueces Basin regression analysis figures.

The appendix is organized into the following sections:

1. Instantaneous flow vs. constituent concentration regressions
    a. x-axis shows flow (cfs); y-axis shows constituent concentration (µg/L for chl-a, mg/L for all other constituents)
2. Linear regression analysis: observed and estimated constituent concentrations
    a. x-axis shows time (yrs); y-axis shows constituent concentration (µg/L for chl-a, mg/L for all other constituents)
3. LOADEST analysis: observed and estimated constituent concentrations
    a. x-axis shows time (yrs); y-axis shows constituent concentration (µg/L for chl-a, mg/L for all other constituents)
4. Linear regression analysis: observed and estimated constituent load
    a. x-axis shows time (yrs); y-axis shows load (kg/day)
5. LOADEST analysis: observed and estimated constituent load
    a. x-axis shows time (yrs); y-axis shows load (kg/day)
6. Linear regression analysis: observed vs. estimated concentrations
    a. x-axis shows estimated constituent concentration (µg/L for chl-a, mg/L for all other constituents); y-axis shows observed constituent concentration (µg/L for chl-a, mg/L for all other constituents)
7. LOADEST analysis: observed vs. estimated concentrations
    a. x-axis shows estimated constituent concentration (µg/L for chl-a, mg/L for all other constituents); y-axis shows observed constituent concentration (µg/L for chl-a, mg/L for all other constituents)
8. Linear regression analysis: observed vs. estimated loads
    a. x-axis shows estimated constituent load (kg/day); y-axis shows observed constituent load (kg/day)
9. LOADEST analysis: observed vs. estimated loads
    a. x-axis shows estimated constituent load (kg/day); y-axis shows observed constituent load (kg/day)
10. Linear regression analysis: observed and estimated constituent concentrations
    a. x-axis shows flow (cfs); y-axis shows constituent concentration (µg/L for chl-a, mg/L for all other constituents)
11. Linear regression analysis: Time series of estimated and observed constituent concentration
    a. x-axis shows time (yrs); y-axis shows constituent concentration (µg/L for chl-a, mg/L for all other constituents)
12. LOADEST analysis: Time series of estimated and observed constituent concentration
    a. x-axis shows time (yrs); y-axis shows constituent concentration (µg/L for chl-a, mg/L for all other constituents)
13. Mission-Aransas (Basin ID 20) linear regression analysis: observed and estimated constituent concentrations

   a. x-axis shows time (yrs); y-axis shows constituent concentration (µg/L for chl-a, mg/L for all other constituents)

14. Mission-Aransas (Basin ID 20) LOADEST analysis: observed and estimated constituent concentrations
   a. x-axis shows time (yrs); y-axis shows constituent concentration (µg/L for chl-a, mg/L for all other constituents)
15. Mission-Aransas (Basin ID 20) linear regression analysis: observed and estimated constituent load
   a. x-axis shows time (yrs); y-axis shows load (kg/day)
16. Mission-Aransas (Basin ID 20) LOADEST analysis: observed and estimated constituent load
   a. x-axis shows time (yrs); y-axis shows load (kg/day)

Appendix F. Executive Administrator's draft report comments

Appendix A. Project update presentations

Study objectives and results were presented at Nueces Estuary Advisory Committee (NEAC) stakeholder meetings in Corpus Christi on June 16, 2014, October 20, 2014, February 23, 2015, and June 22, 2015. Presentations from these meetings are included in this appendix.

NUECES BBASC STUDY #3

NUECES WATERSHED PRE- AND POST-DEVELOPMENT NUTRIENT BUDGETS

NUECES ESTUARY ADVISORY COUNCIL
JUNE 16, 2014
PAULA JO LEMONDS, PE, PG

DISCUSSION

Background

Scope of Work

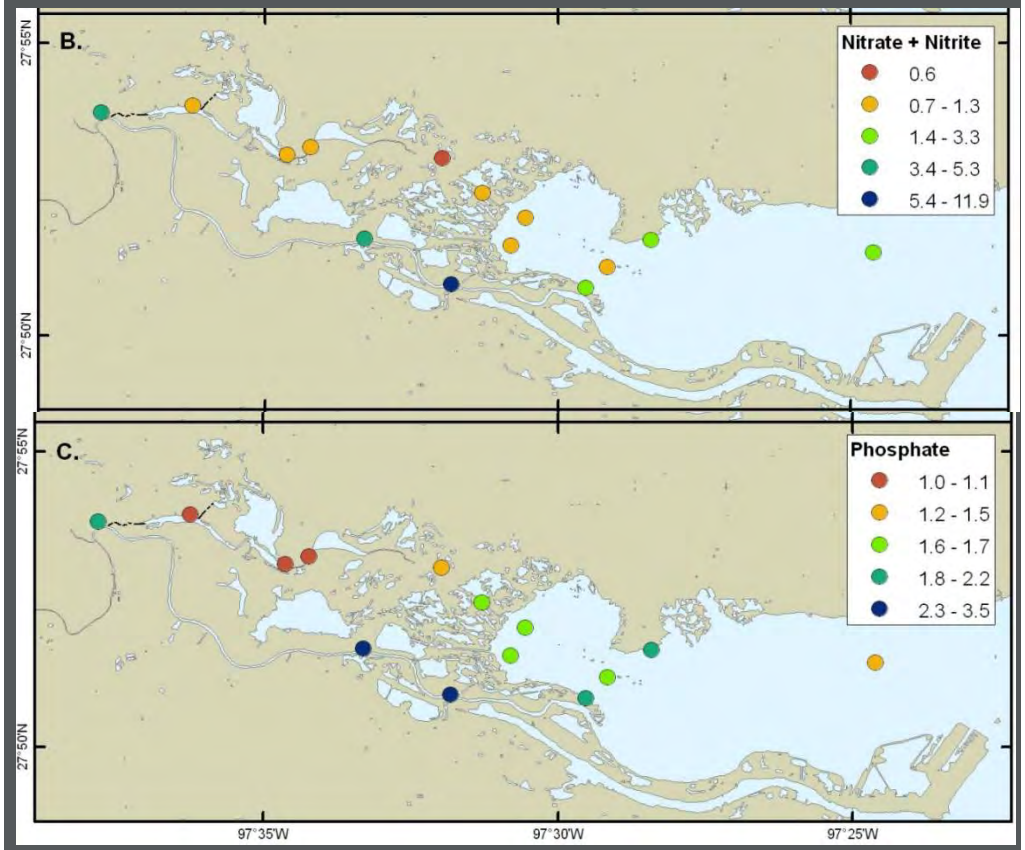
Schedule

BACKGROUND

- Nueces BBASC work plan
  - Tier 2b Recommendation

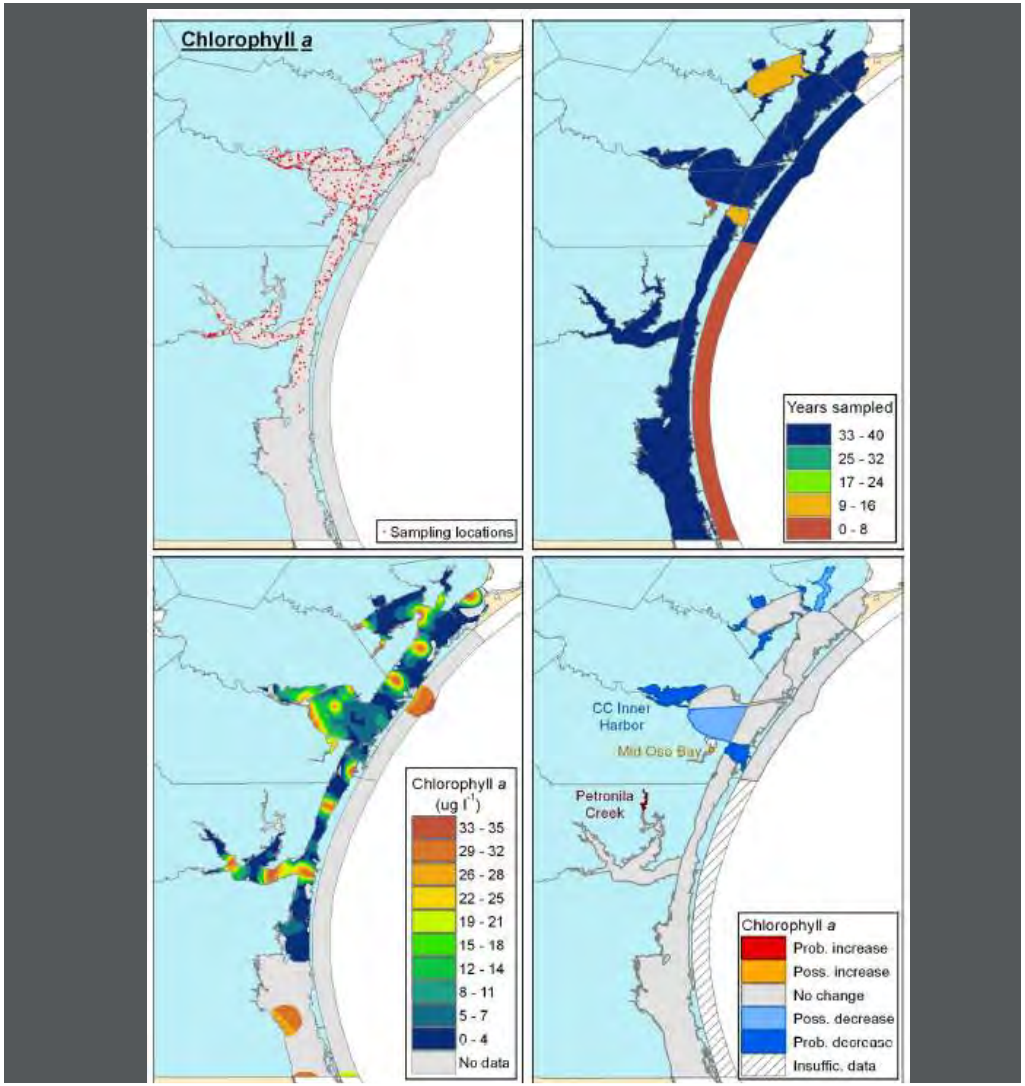
- Nueces BBEST
  - BBEST Recommendations Report
    - Sec. 5.2 Nutrient Considerations

- Nueces BBASC
  - BBASC Recommendations Report
    - Sec. 4.3.2 Nutrient Considerations



Source: BBEST Recommendations Report

BACKGROUND FROM BBASC WORK PLAN



GOALS

- Develop nutrient budgets based on quantitative understanding of natural supply of all nutrient forms and anthropogenic changes in these supplies over time for Nueces Bay watershed

- Determine annual loads for both the pre-development and present condition

Source: Nueces BBASC work plan

SOW

- Task 1 – Compile Data
  - Compile Water Quality and Hydrologic Data
    - Long-term (1934 – 2014)
    - Short-term (1986 – 2014)
    - Recent (2004 – 2014)

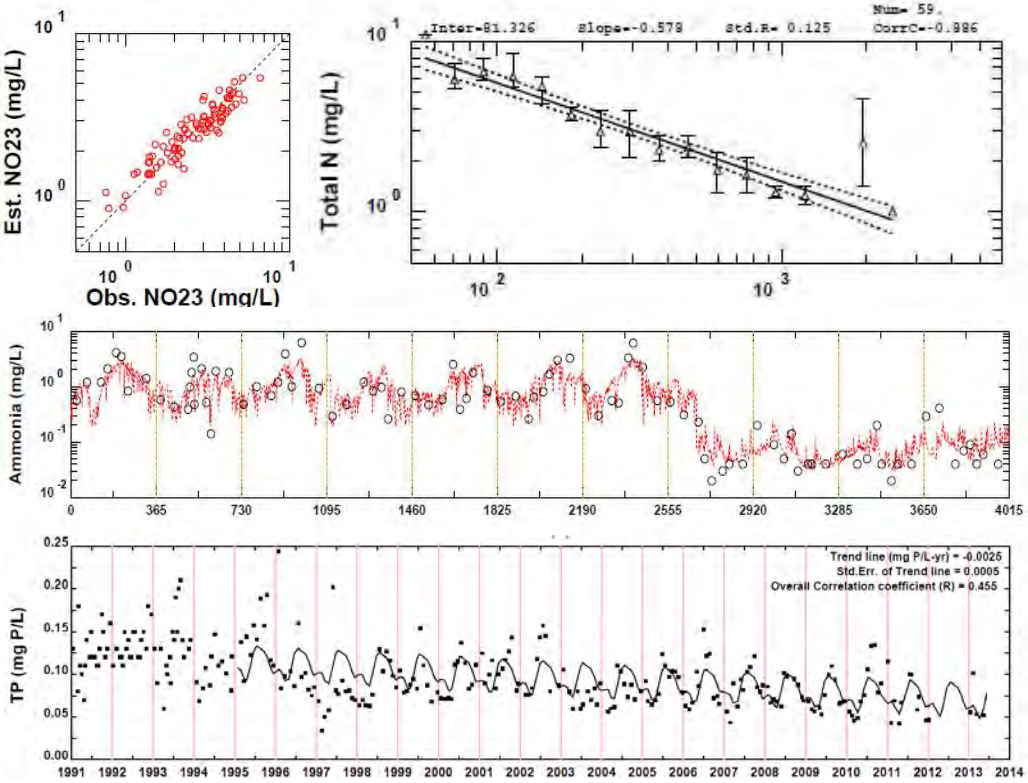
- Task 2 – Perform Data Evaluation and Modeling Analyses
  - Perform Data Evaluation
    - Available data, sampling stations, and subwatersheds
    - Identify appropriate stations

SOW

- Task 2 – Perform Data Evaluation and Modeling Analyses *(continued)*
  - Linear Regression Analyses
  - USGS LOADEST
  - Estimate Reservoir Influence Sink/Sources
  - Water Quality Correlations to Anthropogenic Changes
  - Pre- and Post-Development Loadings
- Task 3 – Meetings and Report
  - Kickoff Meeting (today)
  - Up to 2 more meetings to present results
  - Draft and Final Report

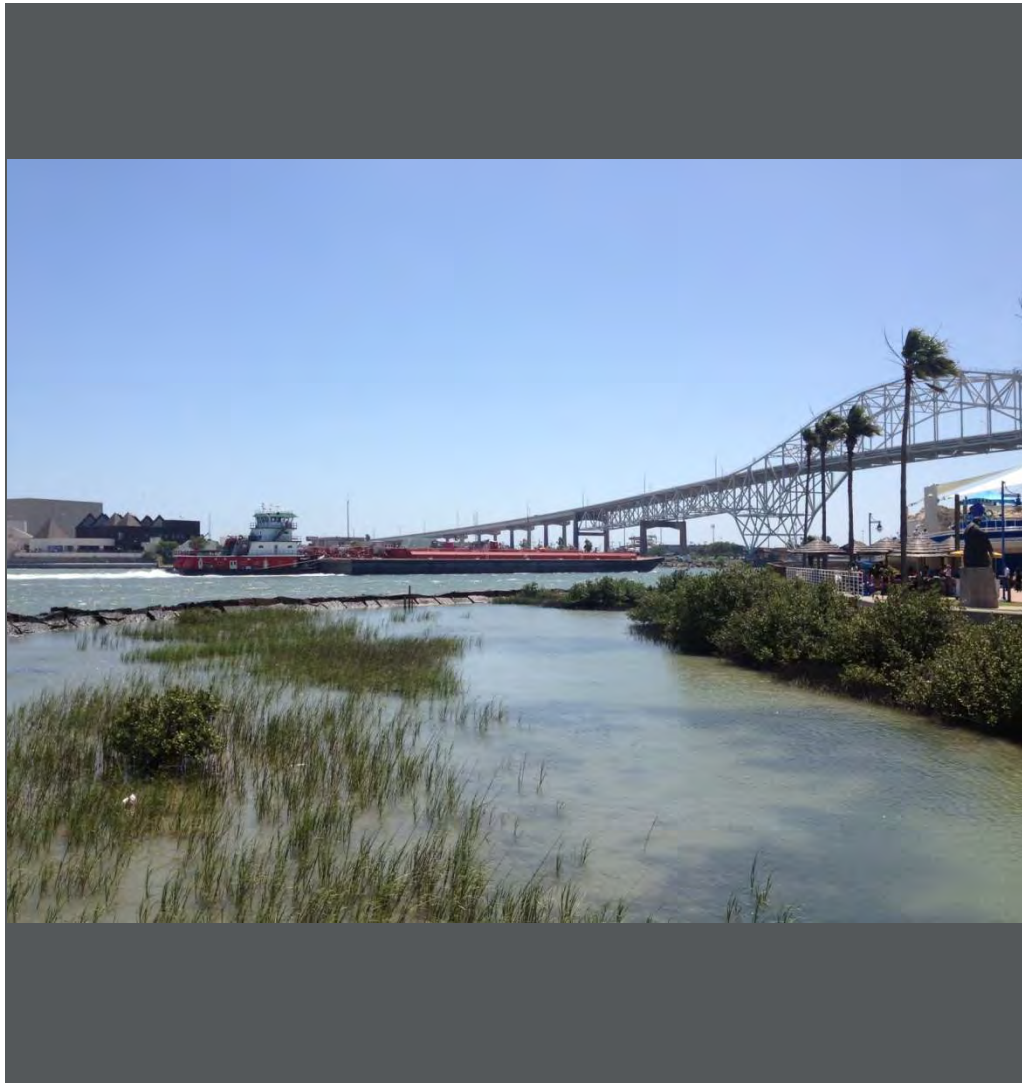
USGS
science for a changing world

LOAD ESTIMATOR (LOADEST):
A FORTRAN PROGRAM FOR ESTIMATING
CONSTITUENT LOADS IN STREAMS AND RIVERS



SCHEDULE

- Waiting on Contract / NTP
- Anticipate 40 weeks to complete analysis
- Draft report after analysis
- Final report due August 2015



NUECES BBASC STUDY #3

NUECES WATERSHED
PRE- AND POST-DEVELOPMENT
NUTRIENT BUDGETS

NUECES ESTUARY ADVISORY COUNCIL
OCTOBER 20, 2014
PAULA JO LEMONDS, PE, PG

DISCUSSION

Background

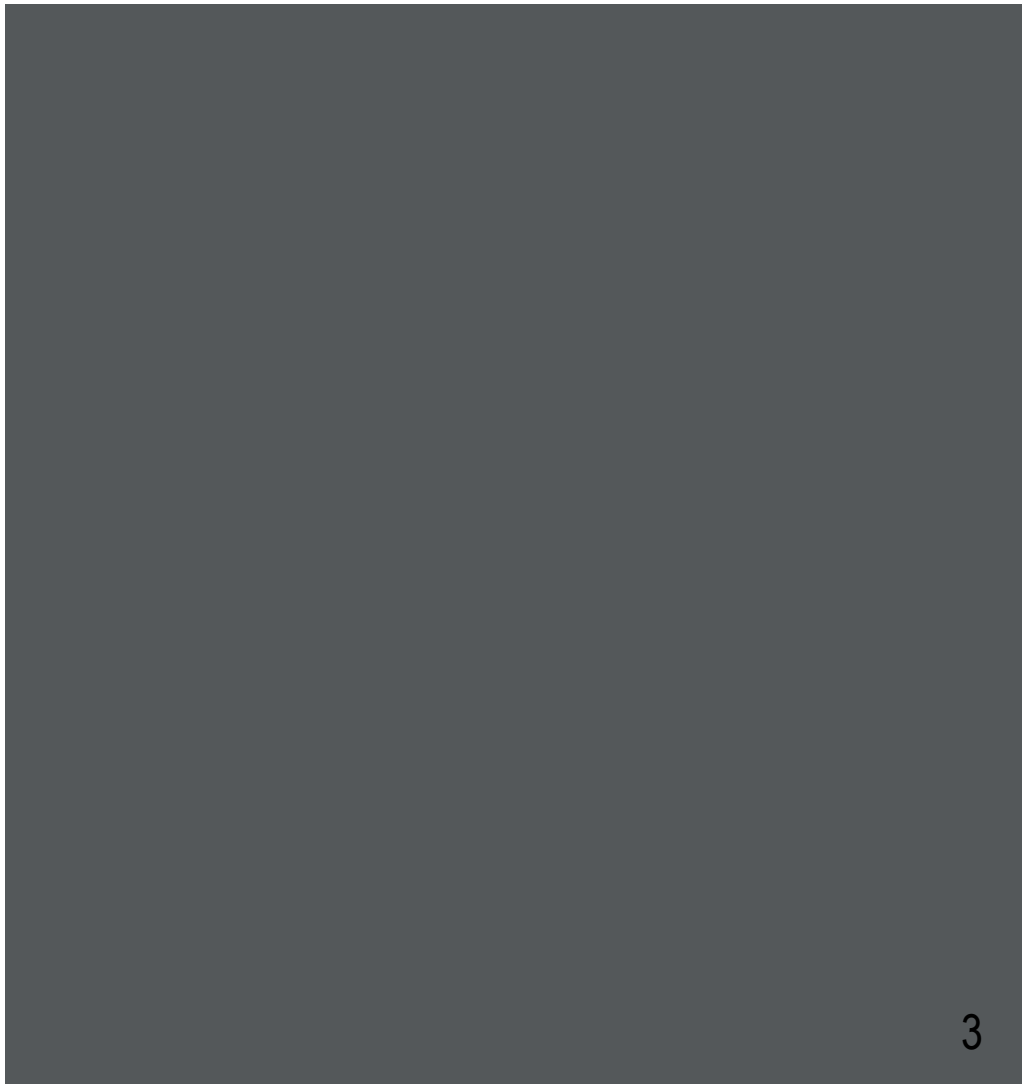
Status

Data Collection Efforts

Schedule

BACKGROUND

- Nueces BBASC work plan
  - Tier 2b Recommendation
- Nueces BBEST
  - BBEST Recommendations Report
    - Sec. 5.2 Nutrient Considerations
- Nueces BBASC
  - BBASC Recommendations Report
    - Sec. 4.3.2 Nutrient Considerations



GOALS

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Source: Nueces BBASC work plan

SCOPE OF WORK

- Task 1 – Compile Data
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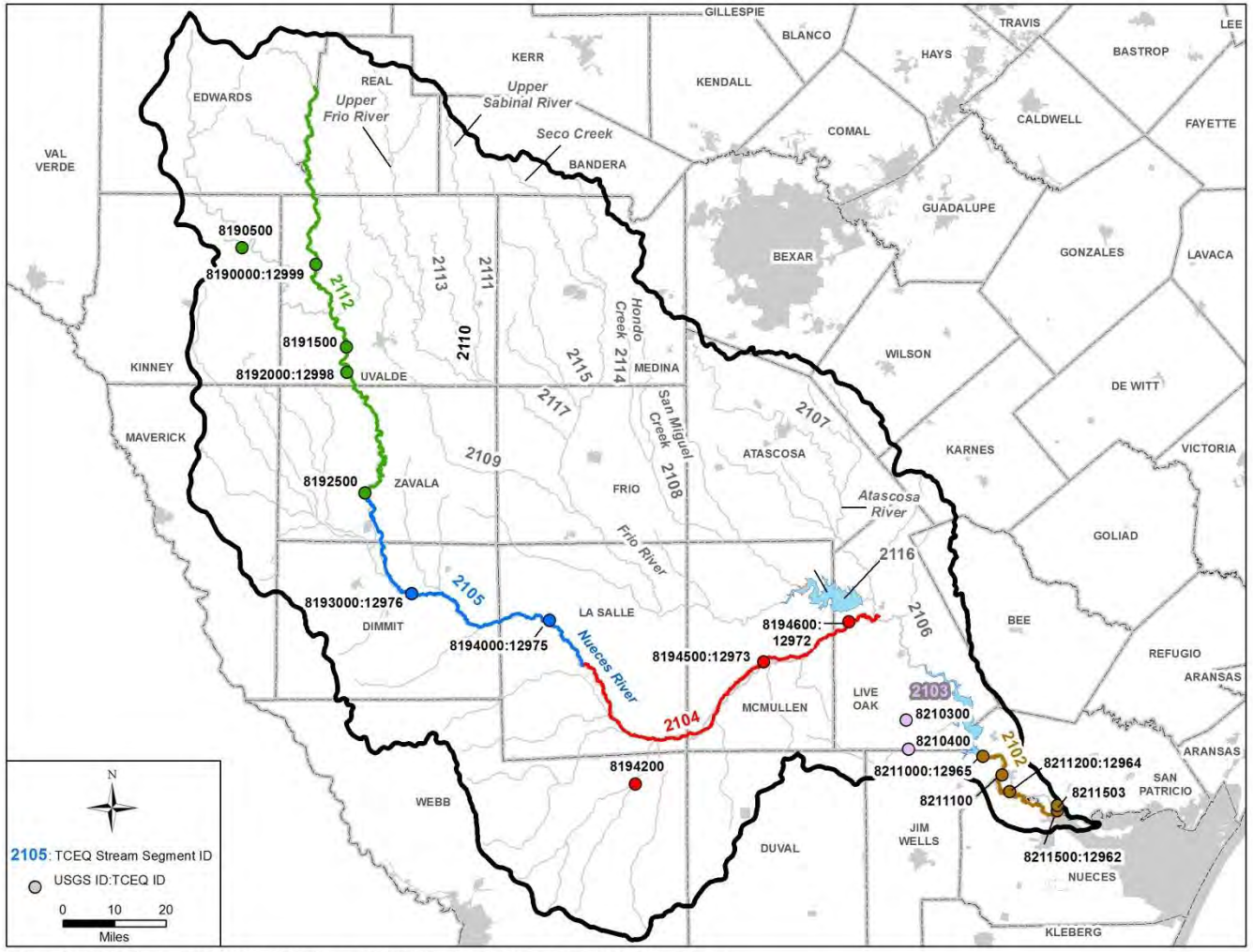
  - Perform Data Evaluation
    - Available data, sampling stations, and subwatersheds
    - Identify appropriate stations


GILLESPIE
KERR
BLANCO
TRAVIS
LEE
HAYS
BASTROP
REAL
EDWARDS
Upper Frio River
Upper Sabinal River
KENDALL
Seco Creek
COMAL
CALDWELL
FAYETTE
VAL VERDE
BANDERA
GUADALUPE
BEXAR
GONZALES
LAVACA
8190500
8190000:12999
2112
2113
2111
2110
Hondo Creek
2114
2115
WILSON
DE WITT
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KINNEY
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UVALDE
MEDINA
2117
San Miguel Creek
2107
MAVERICK
2109
ATASCOSA
KARNES
VICTORIA
8192500
ZAVALA
FRIO
2108
Atascosa River
GOLIAD
Frio River
2116
2105
8193000:12976
LA SALLE
2106
BEE
DIMMIT
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Nueces River
8194600:12972
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REFUGIO
ARANSAS
LIVE OAK
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MCMULLEN
8210300
8210400
2102
ARANSAS
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8211200:12964
SAN PATRICIO
8211100
8211503
WEBB
JIM WELLS
DUVAL
8211500:12962
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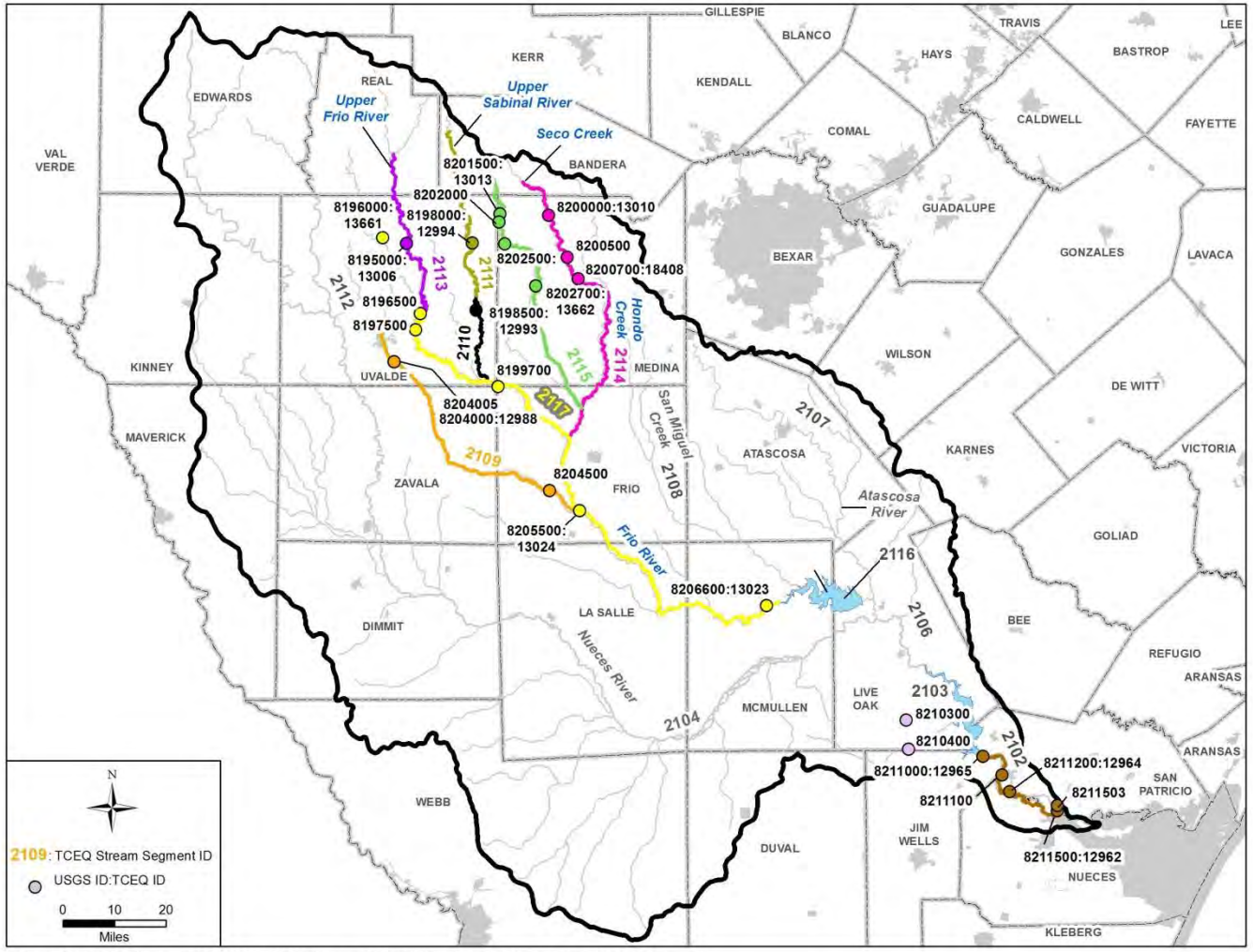

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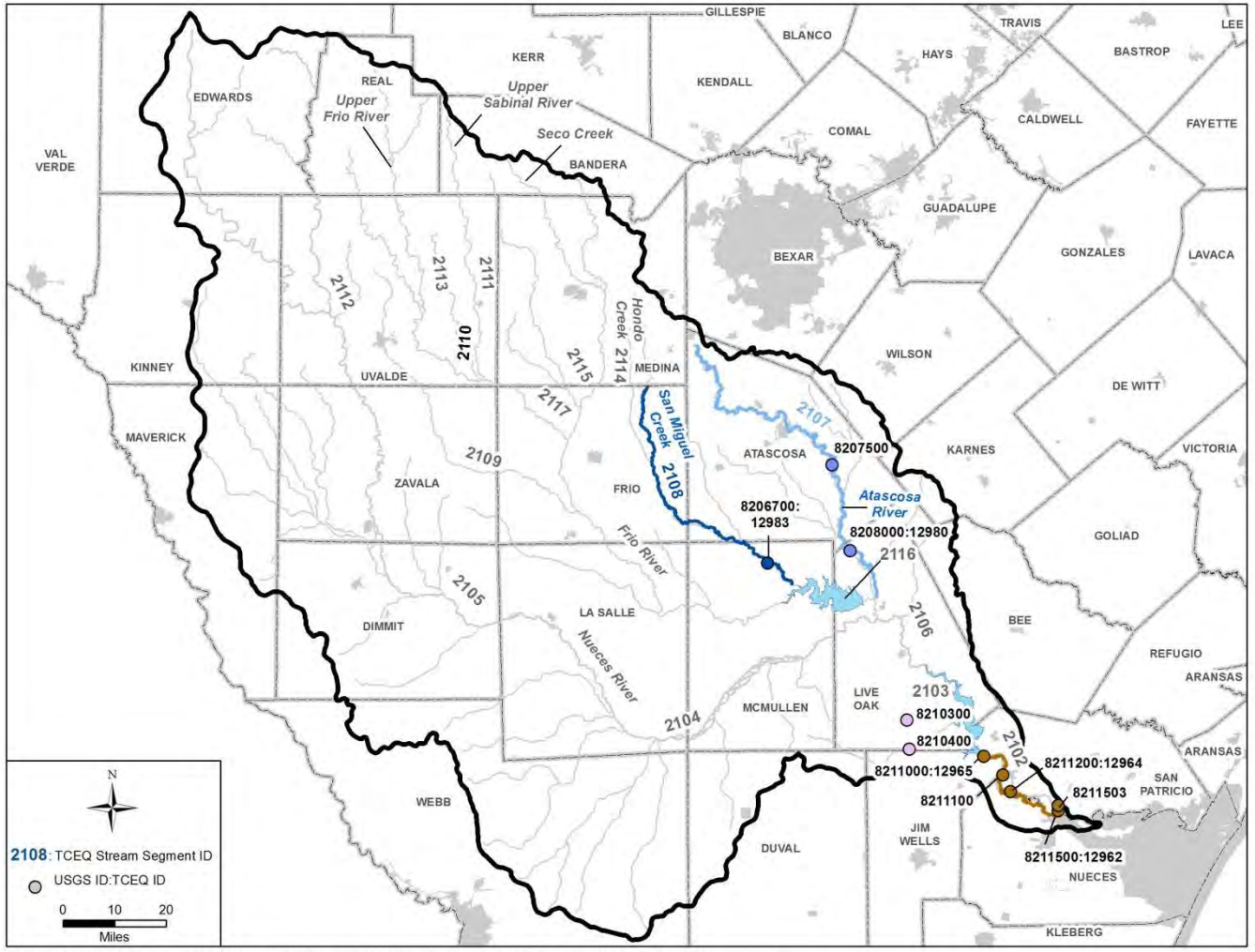

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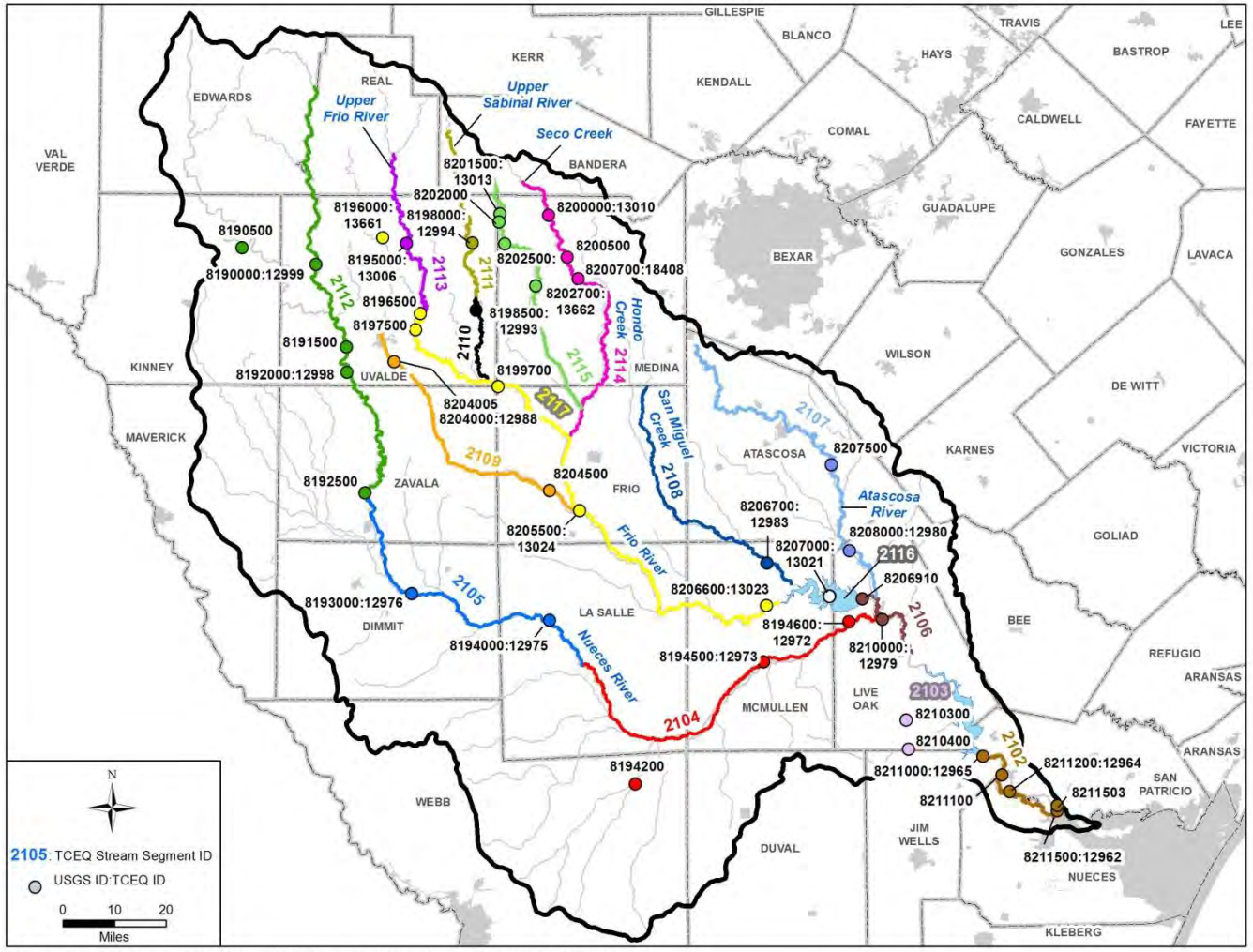

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EXAMPLE DATA ANALYSIS

- Standard statistics on water quality and associated flow
- Outlier Identification

NAME	NUMBER	MEAN	STD DEV	MAXIMUM	MINIMUM	TOTAL	COEF VAR	LN COEF VAR
Note ==> for increased precision try DSTAT or the \D switch on STAT								
&& tp&ROW_INDEX	1672	836.500	482.809	1672.000	1.000	0.140E+07	0.577	-999.000
&& tp&Consituent_(ID)	1672	1500.500	482.811	2336.000	665.000	0.251E+07	0.322	-999.000
&& tp&Consituent_(text)	1672	*** CHARACTER VARIABLE ***						
&& tp&Enddate	1672	*** CHARACTER VARIABLE ***						
&& tp&12960	216	0.448	0.331	2.090	0.020	0.968E+02	0.739	0.340
&& tp&12961	8	0.092	0.037	0.167	0.059	0.739E+00	0.398	0.037
&& tp&12962	76	0.183	0.104	0.840	0.040	0.139E+02	0.571	0.105
&& tp&12963	1	0.170	0.000	0.170	0.170	0.170E+00	0.000	0.000
&& tp&12964	63	0.180	0.087	0.516	0.020	0.113E+02	0.482	0.087
&& tp&12965	63	0.166	0.076	0.530	0.041	0.104E+02	0.458	0.076
&& tp&20936	7	0.172	0.042	0.214	0.088	0.121E+01	0.242	0.042
&& tp&12966	7	0.090	0.010	0.105	0.072	0.633E+00	0.108	0.010
&& tp&12967	130	0.170	0.105	0.930	0.020	0.221E+02	0.620	0.106
&& tp&12968	8	0.155	0.031	0.200	0.105	0.124E+01	0.202	0.031
&& tp&12969	26	0.164	0.034	0.254	0.108	0.427E+01	0.210	0.034
&& tp&12970	12	0.174	0.060	0.296	0.110	0.209E+01	0.344	0.060
&& tp&12971	22	0.151	0.060	0.255	0.039	0.333E+01	0.399	0.060
&& tp&17384	14	0.217	0.099	0.388	0.100	0.304E+01	0.456	0.099
&& tp&17648	43	0.201	0.167	0.723	0.020	0.866E+01	0.831	0.169
&& tp&18350	9	0.134	0.091	0.240	0.020	0.121E+01	0.675	0.091
&& tp&12972	78	0.313	0.505	2.410	0.005	0.244E+02	1.612	0.539
&& tp&12973	139	0.147	0.145	1.013	0.010	0.204E+02	0.985	0.146
&& tp&12974	9	0.136	0.114	0.280	0.005	0.122E+01	0.839	0.114
&& tp&17897	10	0.149	0.122	0.332	0.005	0.149E+01	0.819	0.122
&& tp&12975	95	0.116	0.111	0.710	0.010	0.110E+02	0.958	0.112
&& tp&12976	47	0.138	0.177	0.948	0.010	0.648E+01	1.284	0.178
&& tp&20156	17	0.188	0.161	0.490	0.030	0.320E+01	0.857	0.162
&& tp&12977	90	0.254	1.109	10.600	0.020	0.229E+02	4.366	1.556
&& tp&12978	79	0.221	0.206	1.350	0.020	0.174E+02	0.935	0.208
&& tp&12979	179	0.201	0.181	1.300	0.030	0.360E+02	0.898	0.182
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&& tp&20701	15	0.252	0.228	0.887	0.088	0.378E+01	0.903	0.231
&& tp&12954	1	0.330	0.000	0.330	0.330	0.330E+00	0.000	0.000
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&& tp&12981	69	3.819	3.381	21.300	0.060	0.264E+03	0.885	303.894
&& tp&12982	77	0.175	0.162	1.240	0.016	0.135E+02	0.927	0.163
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&& tp&17899	12	0.261	0.215	0.650	0.005	0.313E+01	0.824	0.218
&& tp&17900	19	1.555	1.462	4.340	0.010	0.295E+02	0.941	2.736
&& tp&20613	2	0.695	0.148	0.800	0.590	0.139E+01	0.214	0.149
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&& tp&20760	2	0.495	0.163	0.610	0.380	0.990E+00	0.329	0.164
&& tp&20761	2	0.205	0.064	0.250	0.160	0.410E+00	0.310	0.064
&& tp&20762	10	1.094	0.816	2.540	0.270	0.109E+02	0.746	0.973
&& tp&20764	7	0.454	0.244	0.810	0.160	0.318E+01	0.538	0.248
&& tp&20773	10	0.506	0.231	0.980	0.220	0.506E+01	0.457	0.234
&& tp&12983	133	0.284	0.771	8.020	0.020	0.378E+02	2.710	0.901
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&& tp&12956	2	2.900	2.263	4.500	1.300	0.580E+01	0.780	12.897
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&& tp&12987	46	0.060	0.083	0.560	0.025	0.275E+01	1.391	0.083
&& tp&12988	48	0.116	0.130	0.660	0.005	0.559E+01	1.117	0.130
&& tp&12989	24	0.059	0.094	0.470	0.025	0.140E+01	1.608	0.094
&& tp&12990	2	0.045	0.049	0.080	0.010	0.900E-01	1.100	0.050
&& tp&12992	1	0.320	0.000	0.320	0.320	0.320E+00	0.000	0.000
&& tp&18418	24	0.052	0.039	0.147	0.020	0.124E+01	0.761	0.039
&& tp&12993	139	0.031	0.052	0.530	0.005	0.432E+01	1.660	0.052
&& tp&12994	176	0.039	0.123	1.275	0.005	0.678E+01	3.199	0.124
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&& tp&14939	16	0.041	0.110	0.450	0.005	0.655E+00	2.682	0.110
&& tp&12999	180	0.023	0.055	0.560	0.001	0.412E+01	2.422	0.055
&& tp&13000	8	0.011	0.005	0.023	0.005	0.910E-01	0.455	0.005
&& tp&13001	1	0.020	0.000	0.020	0.020	0.200E-01	0.000	0.000
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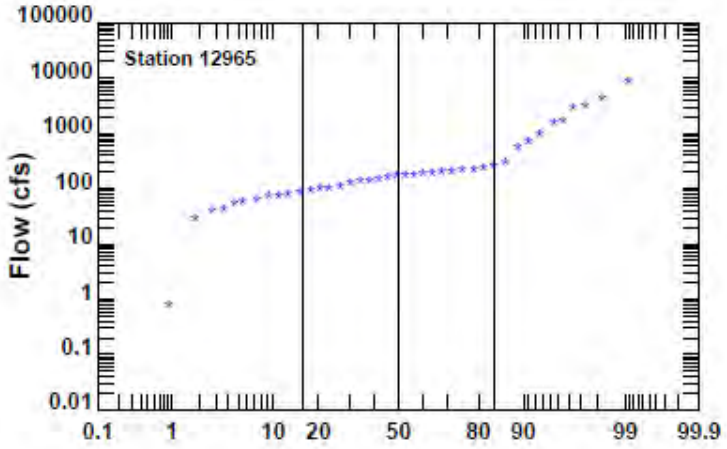
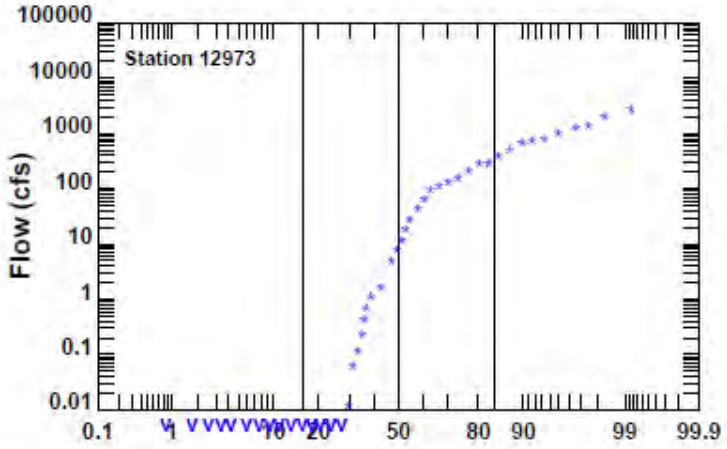
&& tp&13003	1	0.040	0.000	0.040	0.040	0.400E-01	0.000	0.000

FLOW


Station 12965
Flow (cfs)
100000
10000
1000
100
10
1
0.1
0.01
0.1 1 10 20 50 80 90 99 99.9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Flow (cfs)
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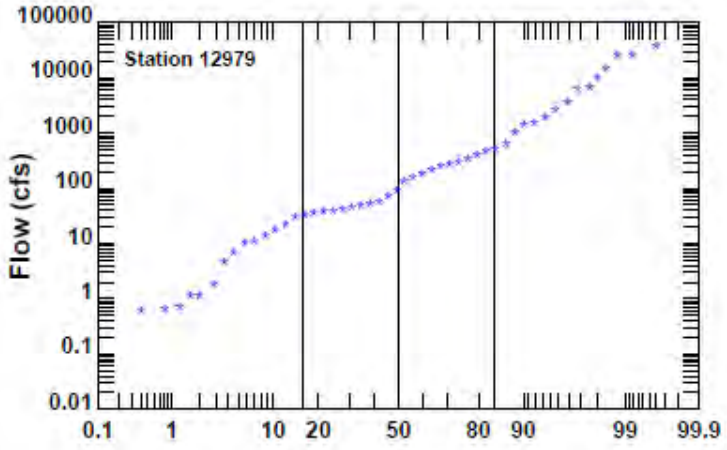
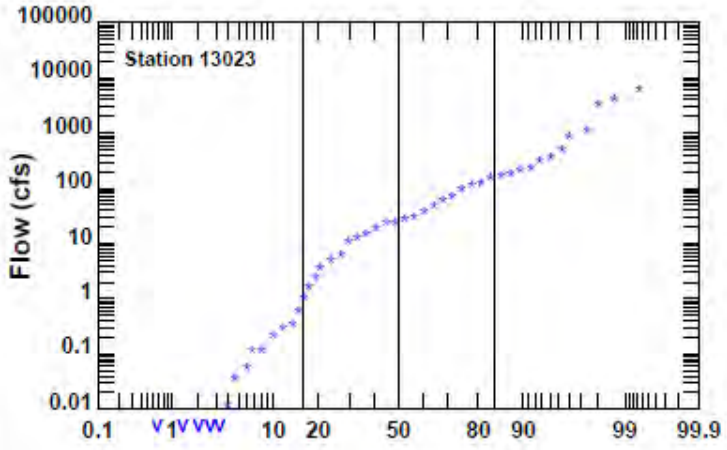
1000
100
10
1
0.1
0.01
0.1 1 10 20 50 80 90 99 99.9


Station 12979
Flow (cfs)
100000
10000
1000
100
10
1
0.1
0.01
0.1 1 10 20 50 80 90 99 99.9


Station 13023
Flow (cfs)
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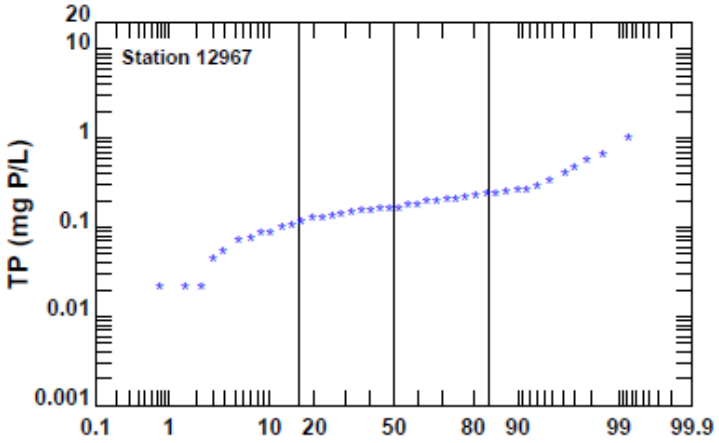
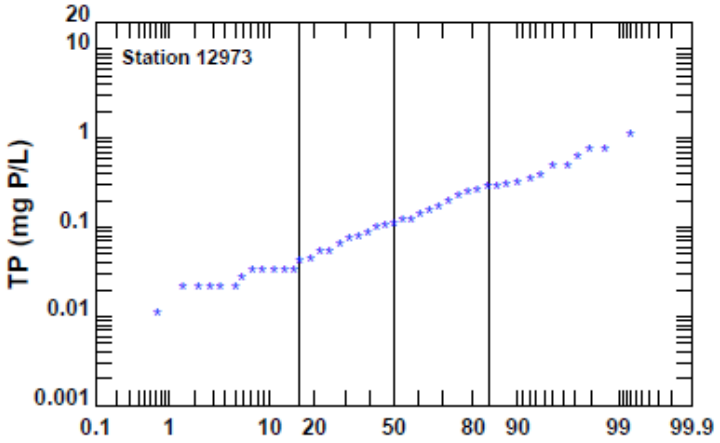
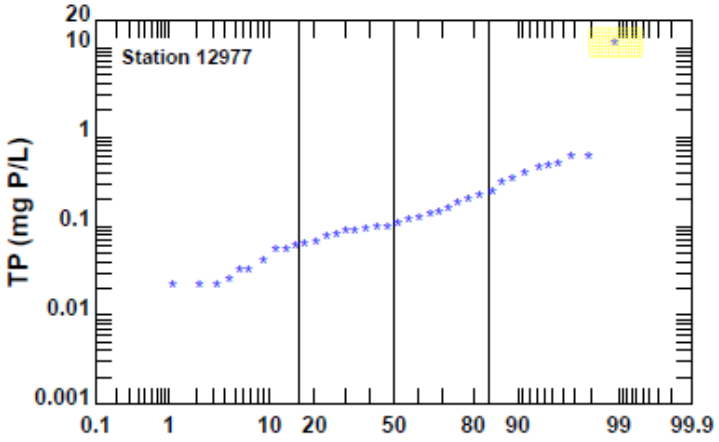
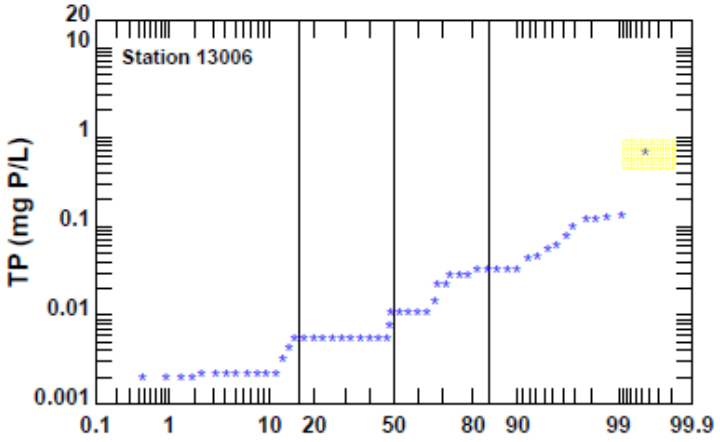
10000
1000
100
10
1
0.1
0.01
0.1 1 10 20 50 80 90 99 99.9

TOTAL PHOSPHORUS

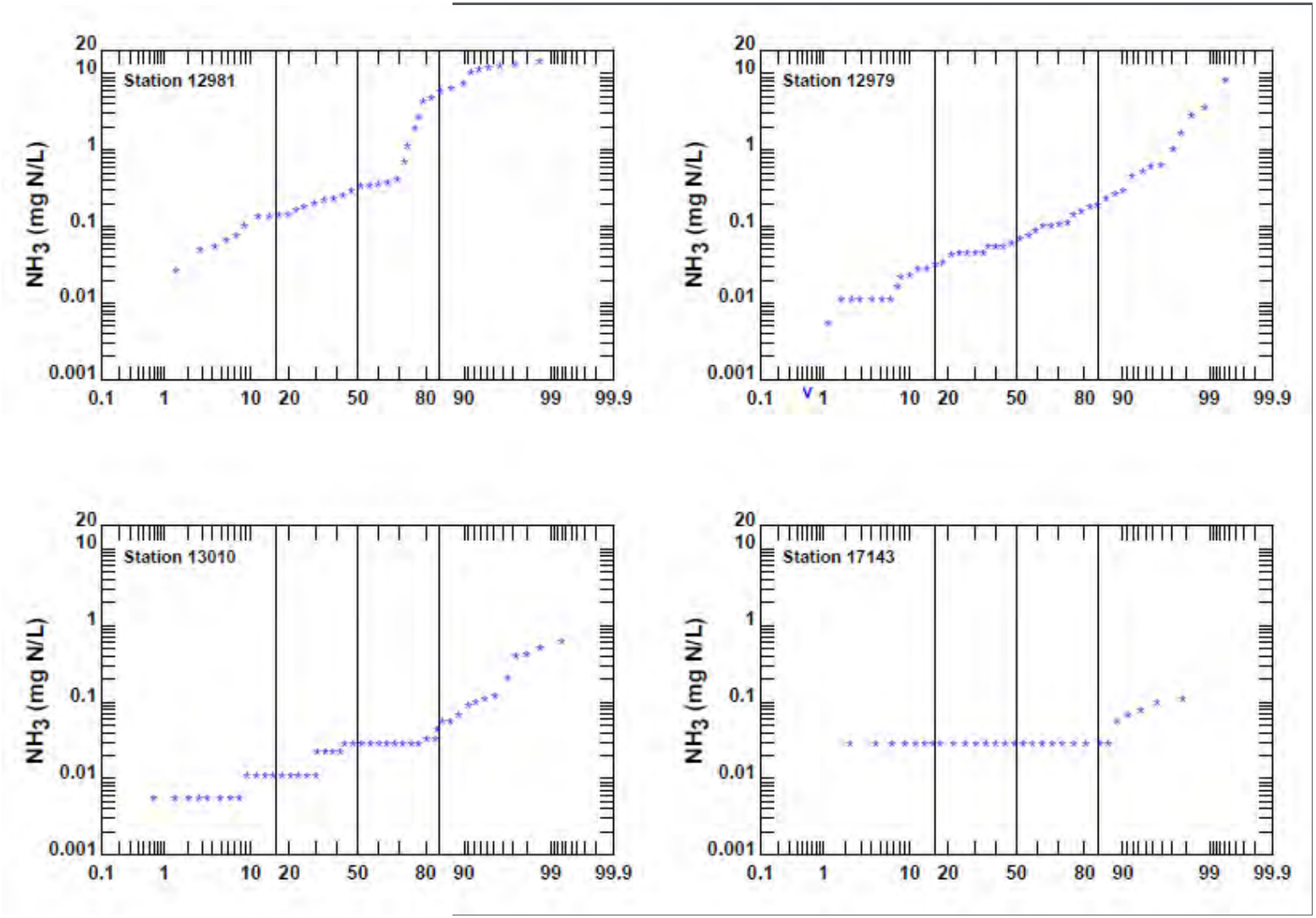








AMMONIA

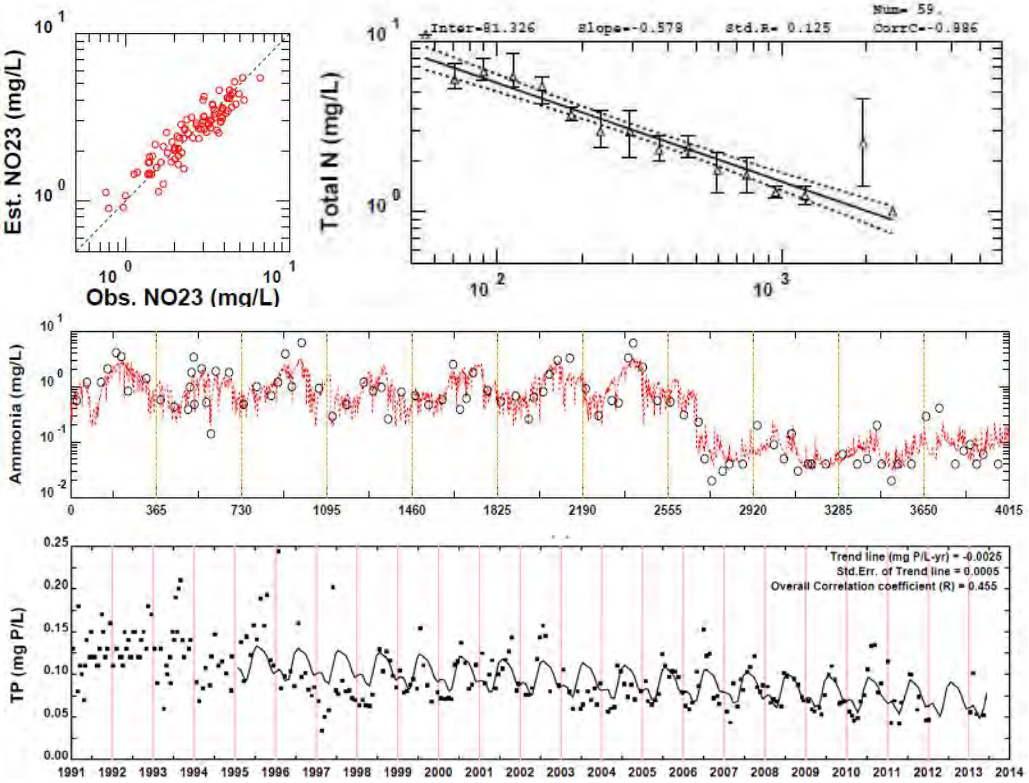

Station 12981
Station 12979
Station 13010
Station 17143
NH3 (mg N/L)
20
10
1
0.1
0.01
0.001
0.1
1
10
20
50
80
90
99
99.9

TASK 2 - NEXT STEPS

- *(continued)* Task 2 – Perform Data Evaluation and Modeling Analyses
  - Linear Regression Analyses
  - USGS LOADEST
  - Estimate Reservoir Influence Sink/Sources
  - Water Quality Correlations to Anthropogenic Changes
  - Pre- and Post-Development Loadings

USGS
science for a changing world

LOAD ESTIMATOR (LOADEST):
A FORTRAN PROGRAM FOR ESTIMATING CONSTITUENT LOADS IN STREAMS AND RIVERS



TASK 3 – MEETINGS AND REPORT

- Task 3 – Meetings and Report
  - NEAC Kickoff Meeting (June 16, 2014)
  - NEAC Meeting Update (October 20, 2014)
  - NEAC Meeting Update (2015)
  - Draft and Final Report (2015)

SCHEDULE

- Complete data analysis Nov 2014
- Current nutrient budget Winter 2014-15
- Pre-development nutrient budget Spring 2015
- Present results at Spring 2015 NEAC meeting
- Draft report after analyses
- Final report due August 2015

NUECES BBASC STUDY #3

NUECES WATERSHED
PRE- AND POST-DEVELOPMENT
NUTRIENT BUDGETS

NUECES ESTUARY ADVISORY COUNCIL
FEBRUARY 23, 2015
PAULA JO LEMONDS, PE, PG

DISCUSSION

Background

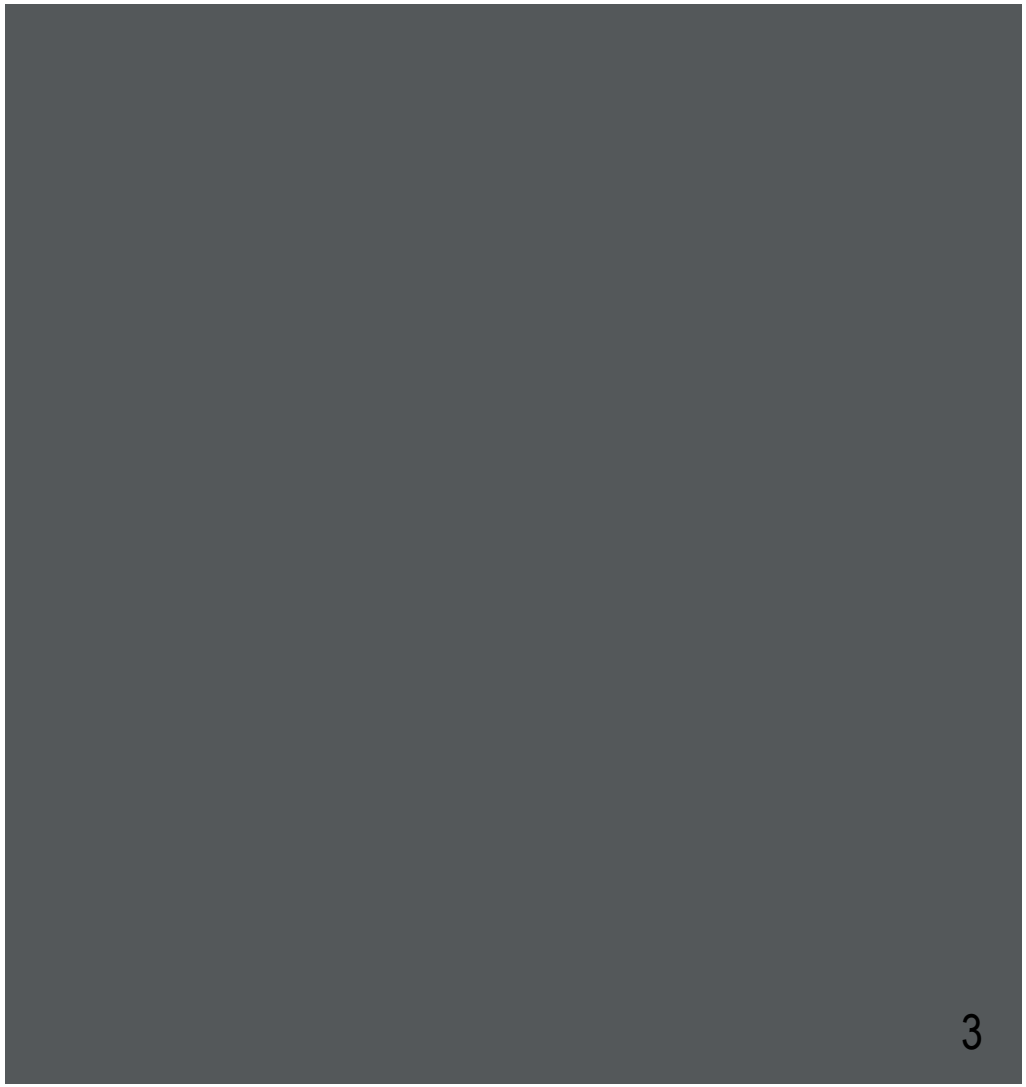
Status

Results

Schedule

BACKGROUND

- Nueces BBASC work plan
  - Tier 2b Recommendation
- Nueces BBEST
  - BBEST Recommendations Report
    - Sec. 5.2 Nutrient Considerations
- Nueces BBASC
  - BBASC Recommendations Report
    - Sec. 4.3.2 Nutrient Considerations



GOALS

- Develop nutrient budgets based on quantitative understanding of natural supply of all nutrient forms and anthropogenic changes in these supplies over time for Nueces Bay watershed

- Determine annual loads for both the pre-development and present condition

Source: Nueces BBASC work plan

SCOPE OF WORK

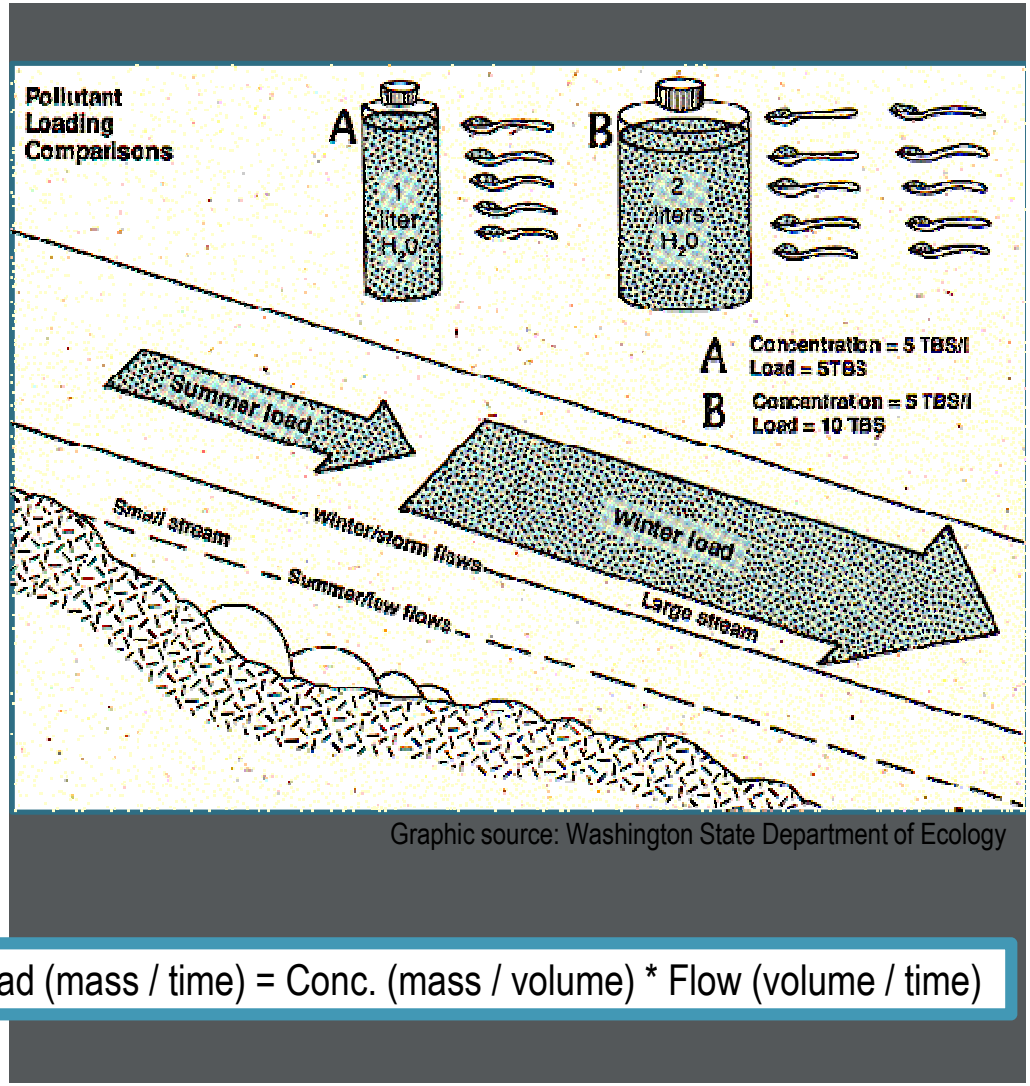
- Task 1 – Compile Data
  - Compile Water Quality and Hydrologic Data
    - Long-term (1934 – 2014)
    - Short-term (1986 – 2014)
    - Recent (2004 – 2014)

- Task 2 – Perform Data Evaluation and Modeling Analyses
  - Perform Data Evaluation
    - Available data, sampling stations, and subwatersheds
    - Identify appropriate stations

DATA ANALYSIS

CONCENTRATION VS. LOAD

- **Concentration** - Mass, weight, or volume of constituent (e.g. phosphorus, sediment, etc.) relative to volume of transporting fluid, or fluid-constituent mixture
  - Typical units - mg/L, µg/L, ppm
- **Flow or Discharge** - Rate of mass, weight, or volume transport of constituent
  - Typical units - tons/day, lbs/day, kg/s, ft^3/s
- **Load** - The cumulative mass, weight, or volume of constituent delivered to some location
  - Typical units - tons, kilograms, pounds

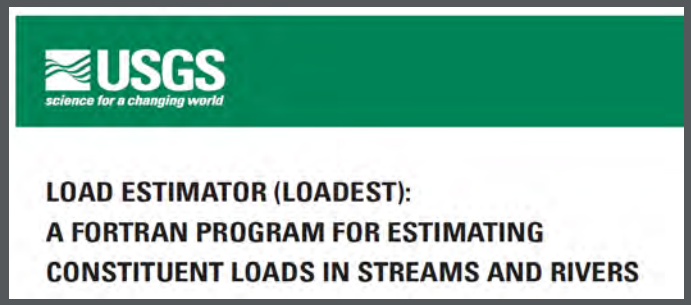


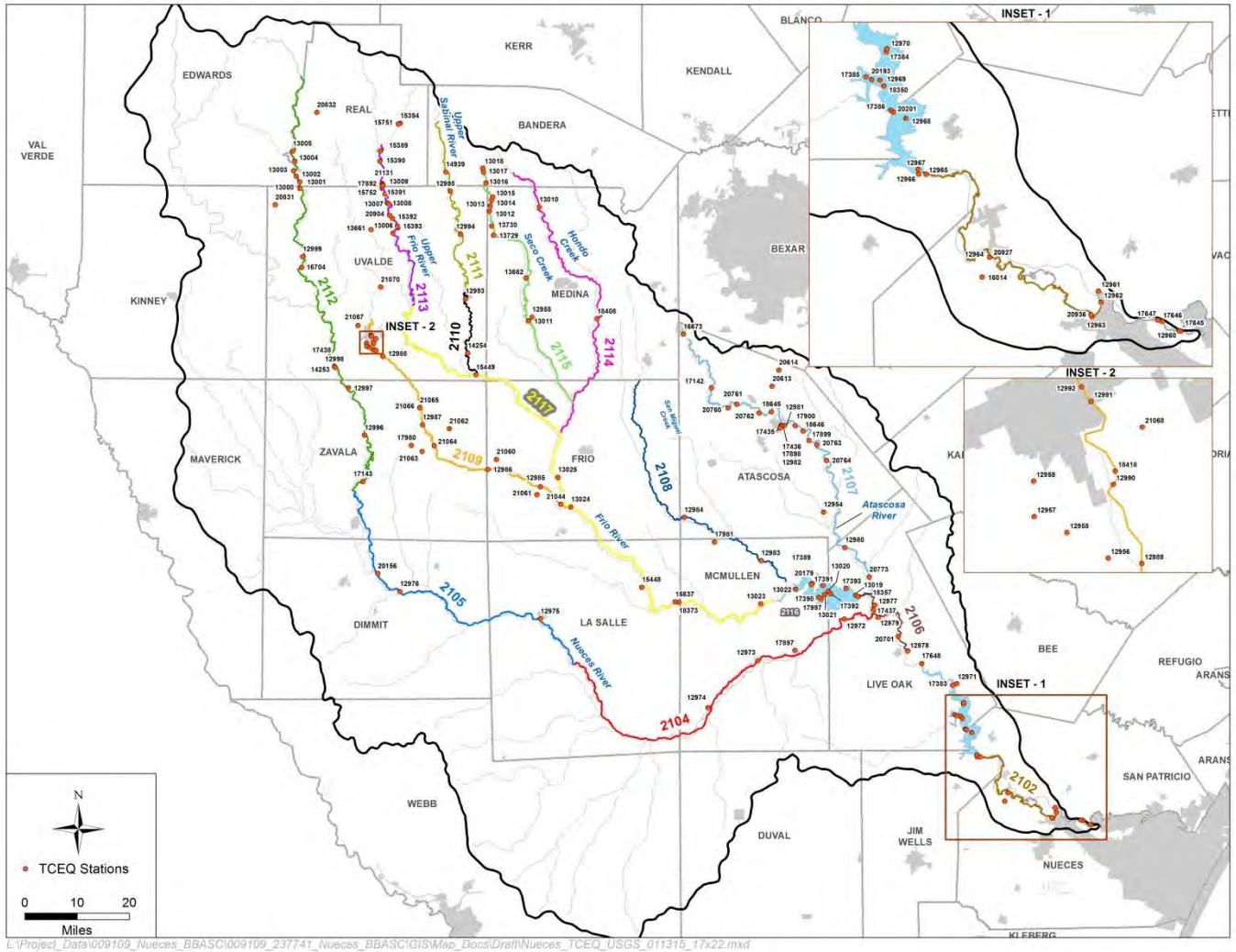
Graphic source: Washington State Department of Ecology

Load (mass / time) = Conc. (mass / volume) * Flow (volume / time)

REGRESSION ANALYSIS

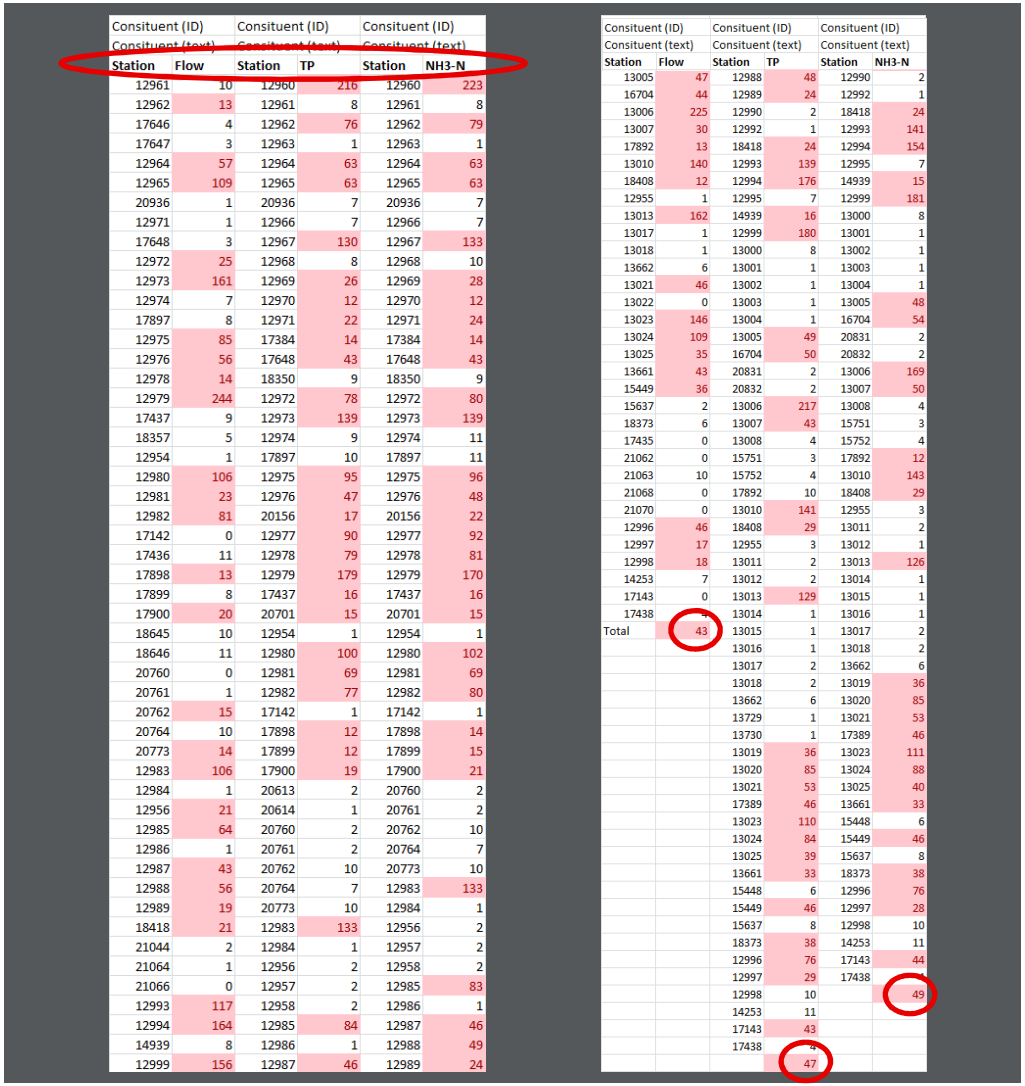
- USGS LOADEST
- HDR linear regression




INSET - 1
INSET - 2
INSET - 1
INSET - 2
EDWARDS
KERR
KENDALL
BLANCO
VAL VERDE
REAL
BANDERA
BEXAR
UVALDE
MEDINA
KINNEY
MAVERICK
ZAVALA
FRIO
ATASCOSA
MCMULLEN
DIMMIT
LA SALLE
LIVE OAK
BEE
REFUGIO
ARANSAS
SAN PATRICIO
WEBB
DUVAL
JIM WELLS
NUECES
KLEBERG
Upper Sabinal River
Upper Frio River
Hondo Creek
Seco Creek
San Miguel Creek
Frio River
Atascosa River
Nueces River
2102
2104
2105
2106
2107
2108
2109
2110
2111
2112
2113
2114
2115
2116
2117
N
TCEQ Stations
0 10 20
Miles
L:\Project_Data\009109_Nueces_BBASC\009109_237741_Nueces_BBASC\GIS\Map_Docs\Draft\Nueces_TCEQ_USGS_011315_17x22.mxd

DATA EVALUATION

- Finding Flow-Constituent pairs



Consituent (ID)		Consituent (ID)		Consituent (ID)	
Consituent (text)		Consituent (text)		Consituent (text)	
Station	Flow	Station	TP	Station	NH3-N
12961	10	12960	216	12960	223
12962	13	12961	8	12961	8
17646	4	12962	76	12962	79
17647	3	12963	1	12963	1
12964	57	12964	63	12964	63
12965	109	12965	63	12965	63
20936	1	20936	7	20936	7
12971	1	12966	7	12966	7
17648	3	12967	130	12967	133
12972	25	12968	8	12968	10
12973	161	12969	26	12969	28
12974	7	12970	12	12970	12
17897	8	12971	22	12971	24
12975	85	17384	14	17384	14
12976	56	17648	43	17648	43
12978	14	18350	9	18350	9
12979	244	12972	78	12972	80
17437	9	12973	139	12973	139
18357	5	12974	9	12974	11
12954	1	17897	10	17897	11
12980	106	12975	95	12975	96
12981	23	12976	47	12976	48
12982	81	20156	17	20156	22
17142	0	12977	90	12977	92
17436	11	12978	79	12978	81
17898	13	12979	179	12979	170
17899	8	17437	16	17437	16
17900	20	20701	15	20701	15
18645	10	12954	1	12954	1
18646	11	12980	100	12980	102
20760	0	12981	69	12981	69
20761	1	12982	77	12982	80
20762	15	17142	1	17142	1
20764	10	17898	12	17898	14
20773	14	17899	12	17899	15
12983	106	17900	19	17900	21
12984	1	20613	2	20760	2
12956	21	20614	1	20761	2
12985	64	20760	2	20762	10
12986	1	20761	2	20764	7
12987	43	20762	10	20773	10
12988	56	20764	7	12983	133
12989	19	20773	10	12984	1
18418	21	12983	133	12956	2
21044	2	12984	1	12957	2
21064	1	12956	2	12958	2
21066	0	12957	2	12985	83
12993	117	12958	2	12986	1
12994	164	12985	84	12987	46
14939	8	12986	1	12988	49
12999	156	12987	46	12989	24

Consituent (ID)		Consituent (ID)		Consituent (ID)	
Consituent (text)		Consituent (text)		Consituent (text)	
Station	Flow	Station	TP	Station	NH3-N
13005	47	12988	48	12990	2
16704	44	12989	24	12992	1
13006	225	12990	2	18418	24
13007	30	12992	1	12993	141
17892	13	18418	24	12994	154
13010	140	12993	139	12995	7
18408	12	12994	176	14939	15
12955	1	12995	7	12999	181
13013	162	14939	16	13000	8
13017	1	12999	180	13001	1
13018	1	13000	8	13002	1
13662	6	13001	1	13003	1
13021	46	13002	1	13004	1
13022	0	13003	1	13005	48
13023	146	13004	1	16704	54
13024	109	13005	49	20831	2
13025	35	16704	50	20832	2
13661	43	20831	2	13006	169
15449	36	20832	2	13007	50
15637	2	13006	217	13008	4
18373	6	13007	43	15751	3
17435	0	13008	4	15752	4
21062	0	15751	3	17892	12
21063	10	15752	4	13010	143
21068	0	17892	10	18408	29
21070	0	13010	141	12955	3
12996	46	18408	29	13011	2
12997	17	12955	3	13012	1
12998	18	13011	2	13013	126
14253	7	13012	2	13014	1
17143	0	13013	129	13015	1
17438	4	13014	1	13016	1
Total	43	13015	1	13017	2
		13016	1	13018	2
		13017	2	13662	6
		13018	2	13019	36
		13662	6	13020	85
		13729	1	13021	53
		13730	1	17389	46
		13019	36	13023	111
		13020	85	13024	88
		13021	53	13025	40
		17389	46	13661	33
		13023	110	15448	6
		13024	84	15449	46
		13025	39	15637	8
		13661	33	18373	38
		15448	6	12996	76
		15449	46	12997	28
		15637	8	12998	10
		18373	38	14253	11
		12996	76	17143	44
		12997	29	17438	4
		12998	10		49
		14253	11		
		17143	43		
		17438	4		
			47		

STATIONS EVALUATED

- Had over 12 flow-constituent pairs

Stationid	River	Description
12962	NUECES	NUECES RIVER AT CORPUS CHRISTI CUNNINGHAM WATER TREATMENT PLANT INTAKE
12964	NUECES	NUECES RIVER AT BLUNTZER BRIDGE ON FM 666
12965	NUECES	NUECES RIVER AT LA FRUTA BRIDGE ON SH 359
12972	NUECES	NUECES RIVER AT FM 1042 BRIDGE 1.2 MILES NORTH OF SIMMONS
12973	NUECES	NUECES RIVER AT SH 16 SOUTH OF TILDEN
12975	NUECES	NUECES RIVER AT INTERSTATE BUSINESS 35C SOUTH OF COTULLA
12976	NUECES	NUECES RIVER BRIDGE ON FM 190 NORTH OF ASHERTON
12978	NUECES	NUECES RIVER AT US 59 EAST OF GEORGE WEST
12979	NUECES	NUECES RIVER BRIDGE ON US 281 SOUTH OF THREE RIVERS
12980	ATASCOSA	ATASCOSA RIVER AT FM 99 BRIDGE WEST OF WHITSETT
12981	ATASCOSA	ATASCOSA RIVER ON DIRT ROAD DIRECTLY EAST OF PLEASANTON AT RAILROAD BRIDGE
12982	ATASCOSA	ATASCOSA RIVER AT US 281 AT PLEASANTON
12983	SAN MIGUEL	SAN MIGUEL CREEK AT SH 16 NORTH OF TILDEN
12985	LEONA RIVER	LEONA RIVER AT FM 1581 SOUTHWEST OF PEARSALL
12987	LEONA RIVER	LEONA RIVER AT US 57 NEAR BATESVILLE
12993	SABINAL RIVER	SABINAL RIVER BRIDGE AT US 90 WEST OF SABINAL
12994	SABINAL RIVER	SABINAL RIVER 12.5 MILES NORTH OF SABINAL AND 2.3 MILES DOWNSTREAMM FROM THE MOUTH OF ONION CREEK 4.13 KM NW OF INTERSECTION OF RM187/FM1796
12996	NUECES	NUECES RIVER 20 M UPSTREAM OF US 57 SOUTH OF UVALDE
12997	NUECES	NUECES RIVER WEST BANK 60 M DOWNSTREAM OF US 83 BRIDGE SOUTH OF UVALDE
12999	NUECES	NUECES RIVER 1 MILE NORTHEAST OF LAGUNA AND 0.54 MILES DOWNSTREAM FROM SYCAMORE CREEK 2.5 MILES UPSTREAM OF ST HWY 55 BRIDGE

STATIONS EVALUATED

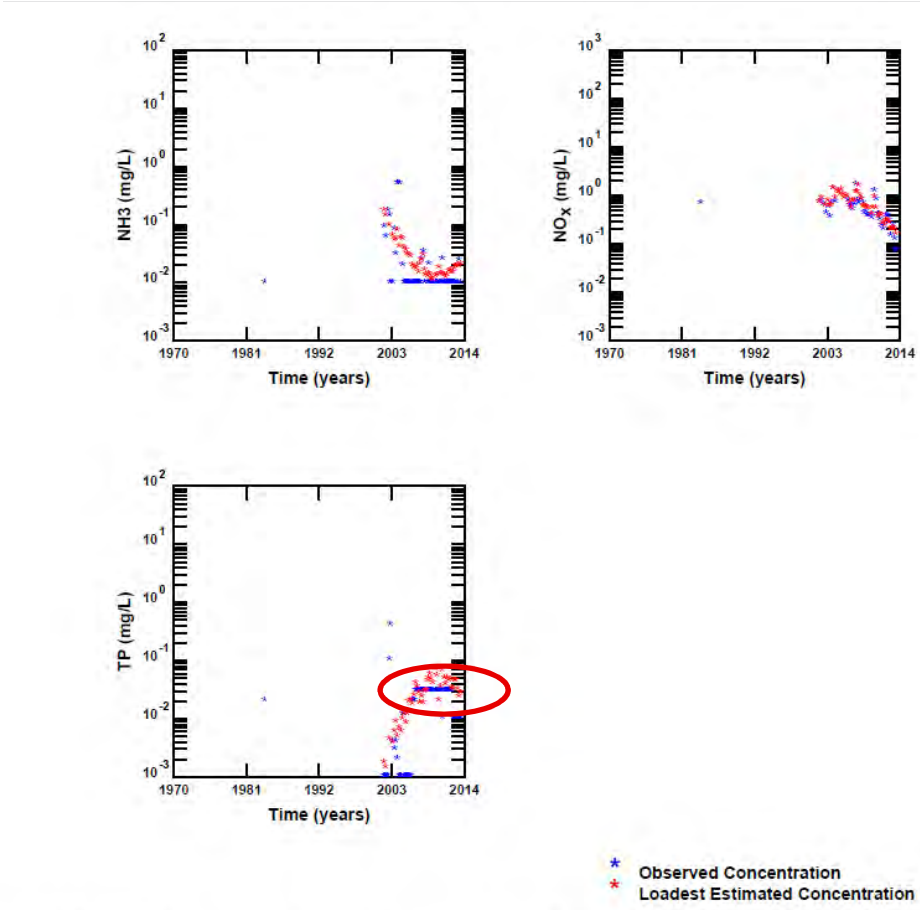
Stationid	River	Description
13005	NUECES	NUECES RIVER AT SH 55 SOUTH OF BARKSDALE
13006	FRIO	FRIO RIVER AT SH 127 EAST OF CONCAN
13007	FRIO	FRIO RIVER AT MAGERS CROSSING/OLD LEAKEY RD 670 M DOWNSTREAM OF GARNER STATE PARK DAM
13010	HONDO	HONDO CREEK 150 M DOWNSTREAM OF RR 462 BRIDGE NEAR TARPLEY
13013	SECO CREEK	SECO CREEK AT MEDINA CR 111 ON MILLER RANCH NEAR UTOPIA AT 4TH CROSSING DOWNSTREAM OF SH 470
13021	CHOKE CANYON	CHOKE CANYON RESERVOIR AT CHOKE CANYON STATE PARK 70 M NORTH OF WESTERN CORNER OF PENINSULA WEST OF CAMPGROUND
13023	FRIO	FRIO RIVER AT SH 16 IN TILDEN
13024	FRIO	FRIO RIVER AT IH 35 NORTHBOUND BRIDGE NORTH OF DILLEY
13025	FRIO	FRIO RIVER AT FM 1581 SOUTHWEST OF PEARSALL
14253	NUECES	NUECES RIVER AT FM 481 SW OF UVALDE
17892	FRIO	FRIO RIVER AT APACHE BLUFFS 450 M UPSTREAM OF FM 1120
17898	ATASCOSA	ATASCOSA RIVER 150 METERS DOWNSTREAM OF HUNT ROAD
17899	ATASCOSA	ATASCOSA RIVER 500 METERS SOUTHWEST OF INTERSECTION OF LEAL RD AND MOPAC RAILROAD
17900	ATASCOSA	ATASCOSA RIVER AT IH 37
20762	ATASCOSA	ATASCOSA RIVER AT GRANATO ROAD / TAYLOR ROAD 1.5 KILOMETERS UPSTREAM OF THE CONFLUENCE WITH SALT BRANCH CREEK IN ATASCOSA COUNTY
20764	ATASCOSA	ATASCOSA RIVER AT FM 541 4.75 KILOMETERS UPSTREAM OF THE CONFLUENCE WITH LIVEOAK CREEK IN ATASCOSA COUNTY
20773	ATASCOSA	ATASCOSA RIVER 650 METERS EAST AND 214 METERS NORTH FROM WHERE THE NORTH END OF LIVE OAK CR 413 DEAD ENDS 1.81 KILOMETERS DOWNSTREAM OF THE CONFLUENCE WITH BRUS

LOADEST RESULTS

- Snapshot of results upstream to downstream along Nueces River:
- 13005 Nueces at SH 55 south of Barksdale
- 12973 Nueces at SH 16 south of Tilden
- 12979 Nueces on US 281 south of Three Rivers
- 12964 Nueces at Bluntzer Bridge on FM 666

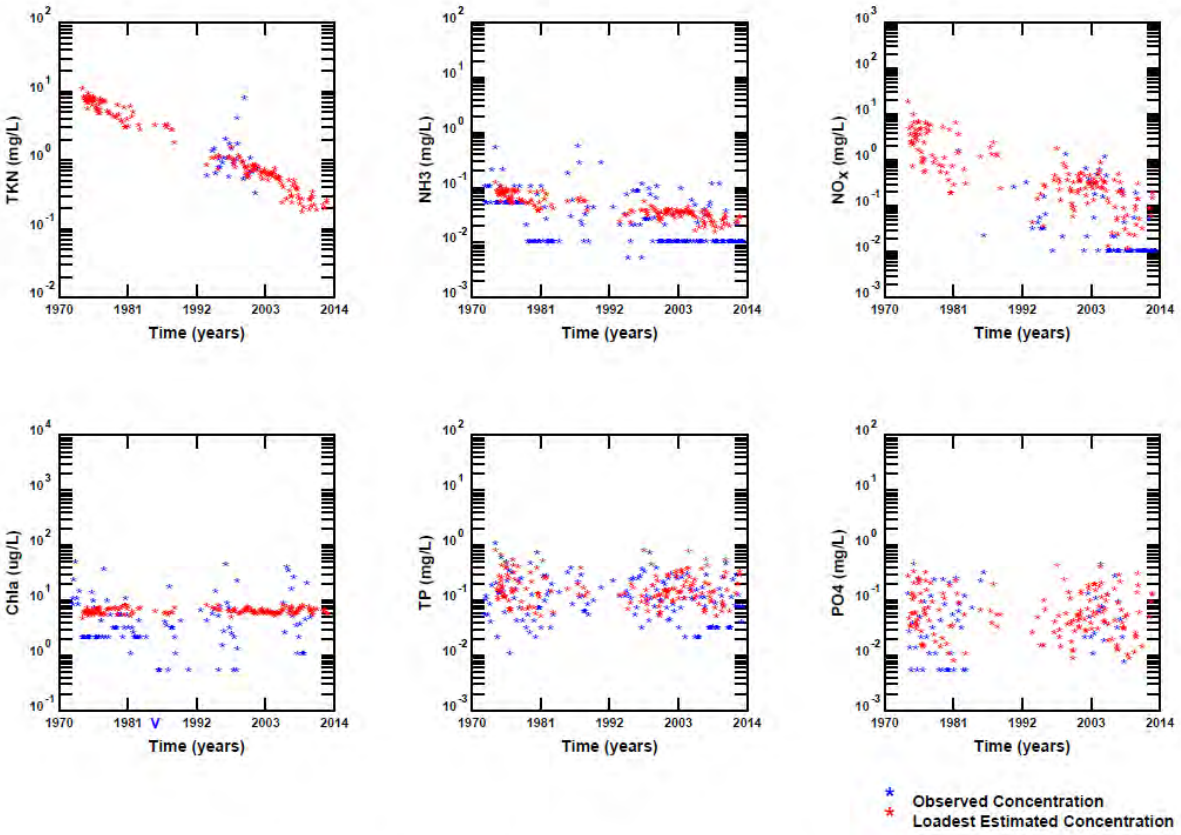
LOADEST RESULTS

Concentration



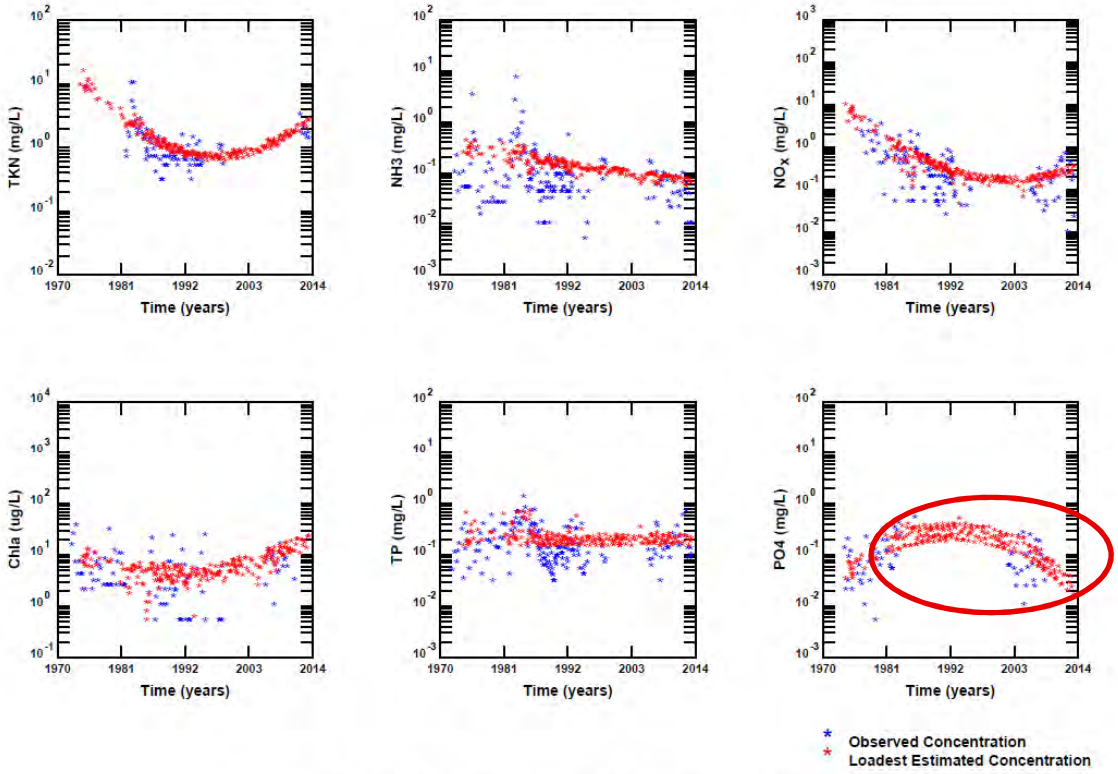
Observed Data vs. Loadest Estimated Concentration, Station 13005

Nueces Tributaries, Texas (1970-2014)



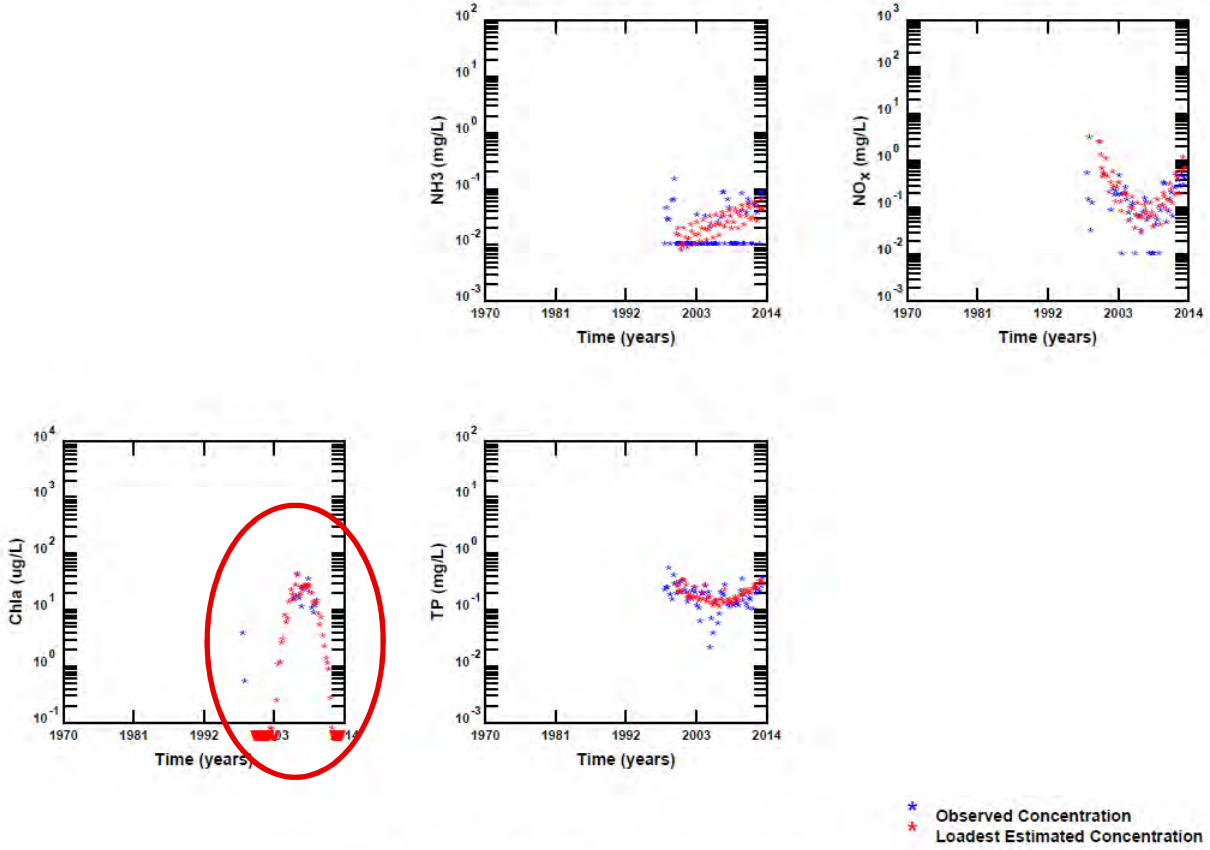
Observed Data vs. Loadest Estimated Concentration, Station 12973

Nueces Tributaries, Texas (1970-2014)



Observed Data vs. Loadest Estimated Concentration, Station 12979

Nueces Tributaries, Texas (1970-2014)

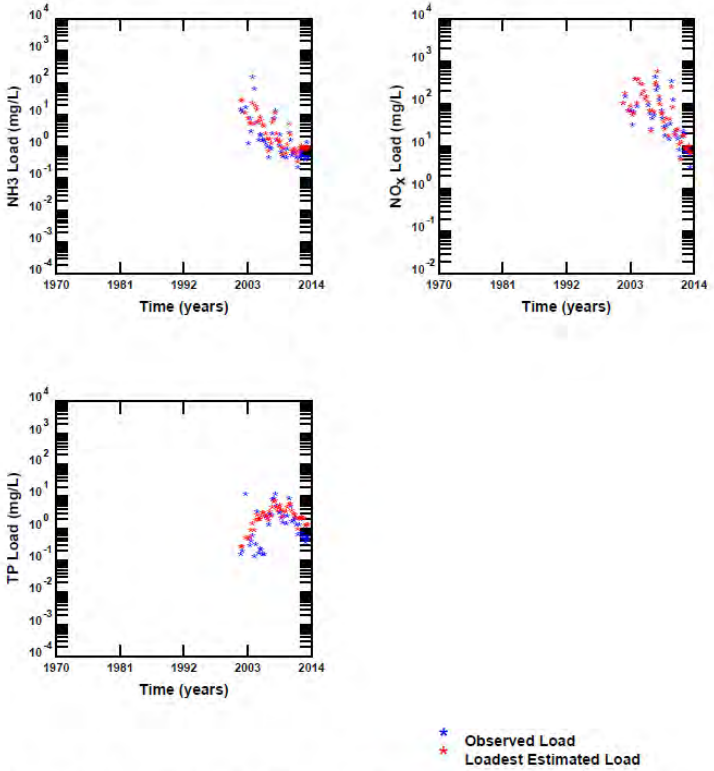


Observed Data vs. Loadest Estimated Concentration, Station 12964

Nueces Tributaries, Texas (1970-2014)

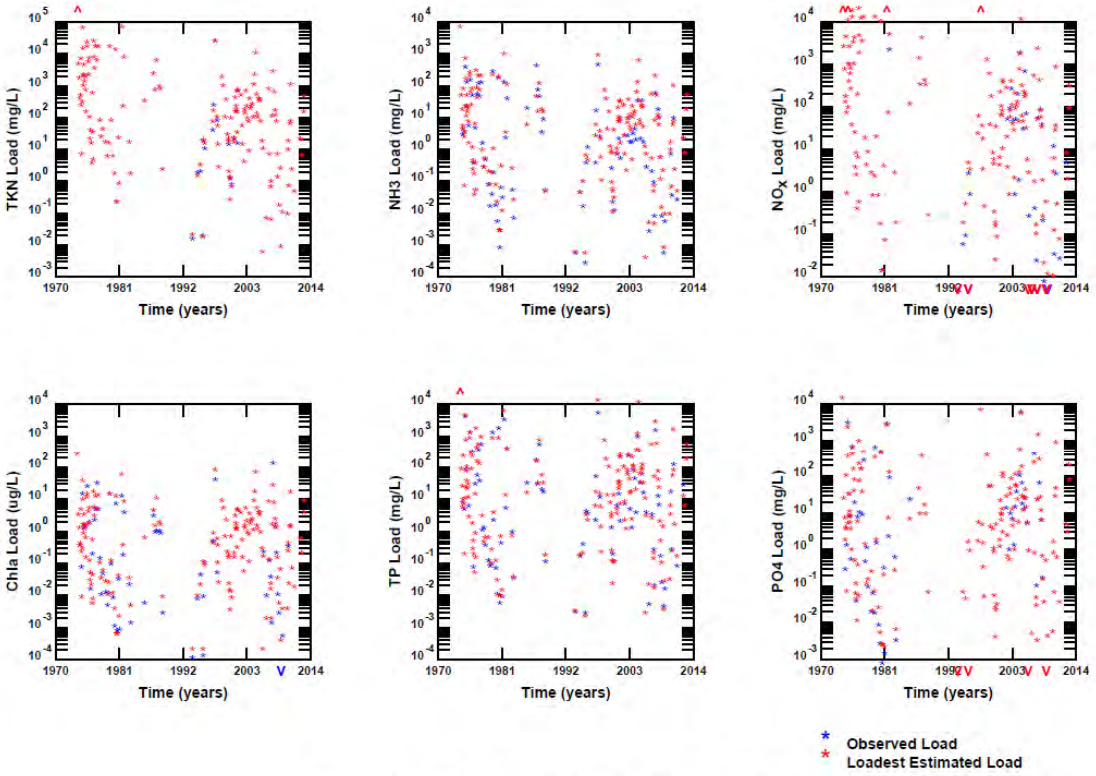
LOADEST RESULTS

Load



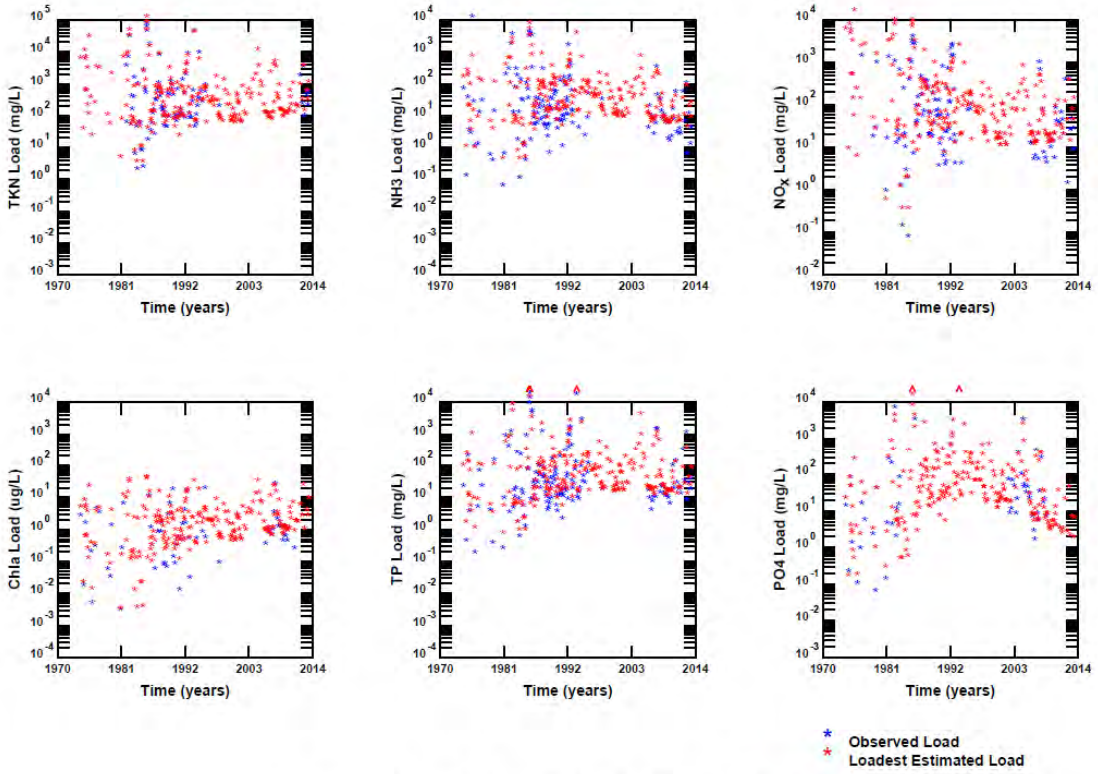
Observed Load vs. Loadest Estimated Load, Station 13005

Nueces Tributaries, Texas (1970-2014)



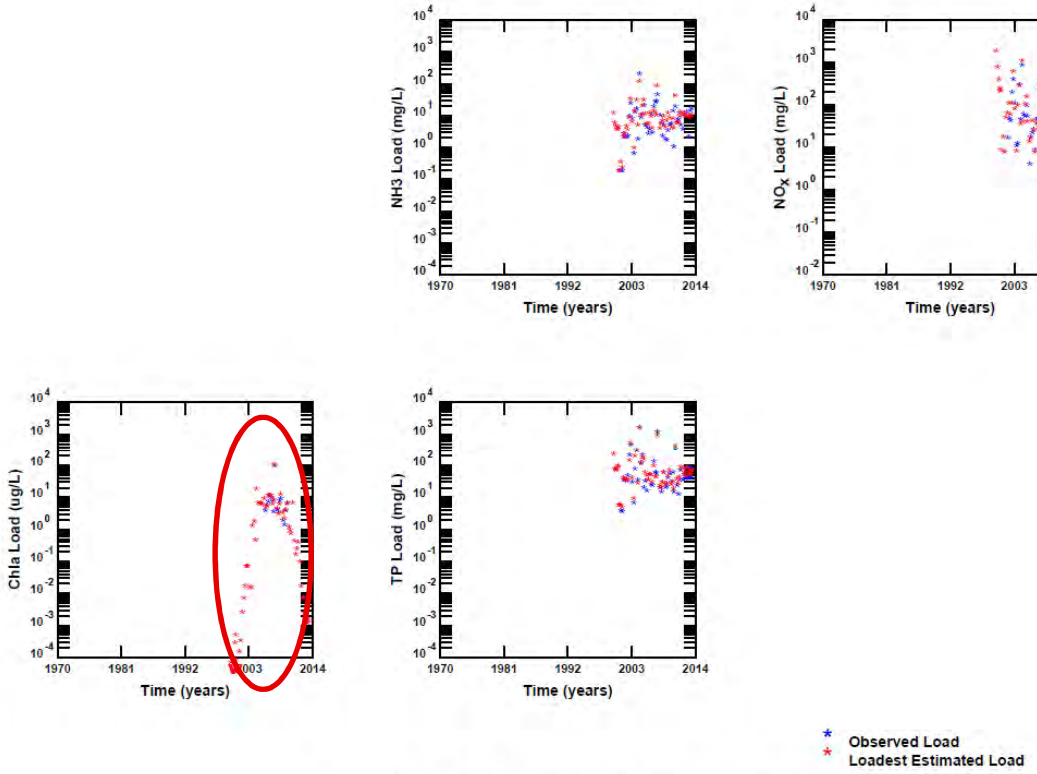
Observed Load vs. Loadest Estimated Load, Station 12973

Nueces Tributaries, Texas (1970-2014)



Observed Load vs. Loadest Estimated Load, Station 12979

Nueces Tributaries, Texas (1970-2014)

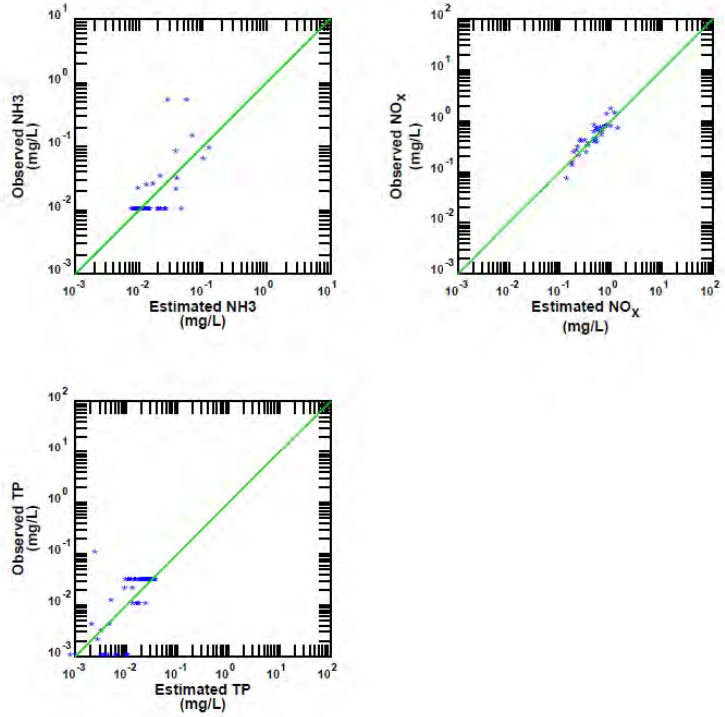


Observed Load vs. Loadest Estimated Load, Station 12964

Nueces Tributaries, Texas (1970-2014)

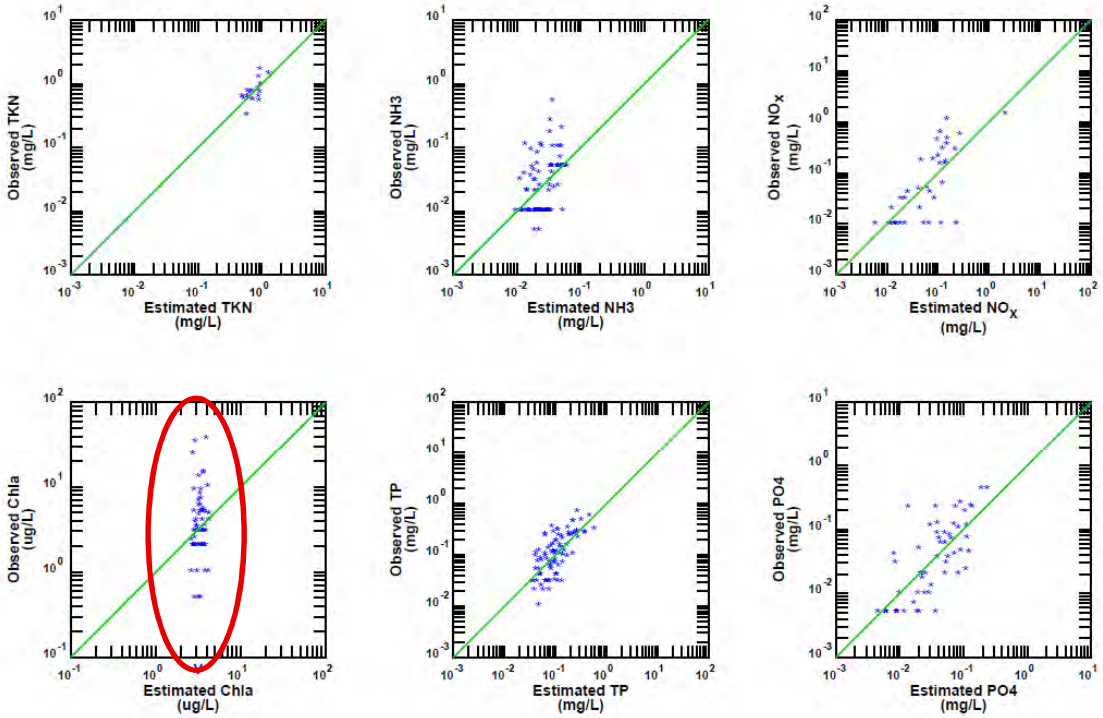
LOADEST RESULTS

Observed vs. Estimated Concentration



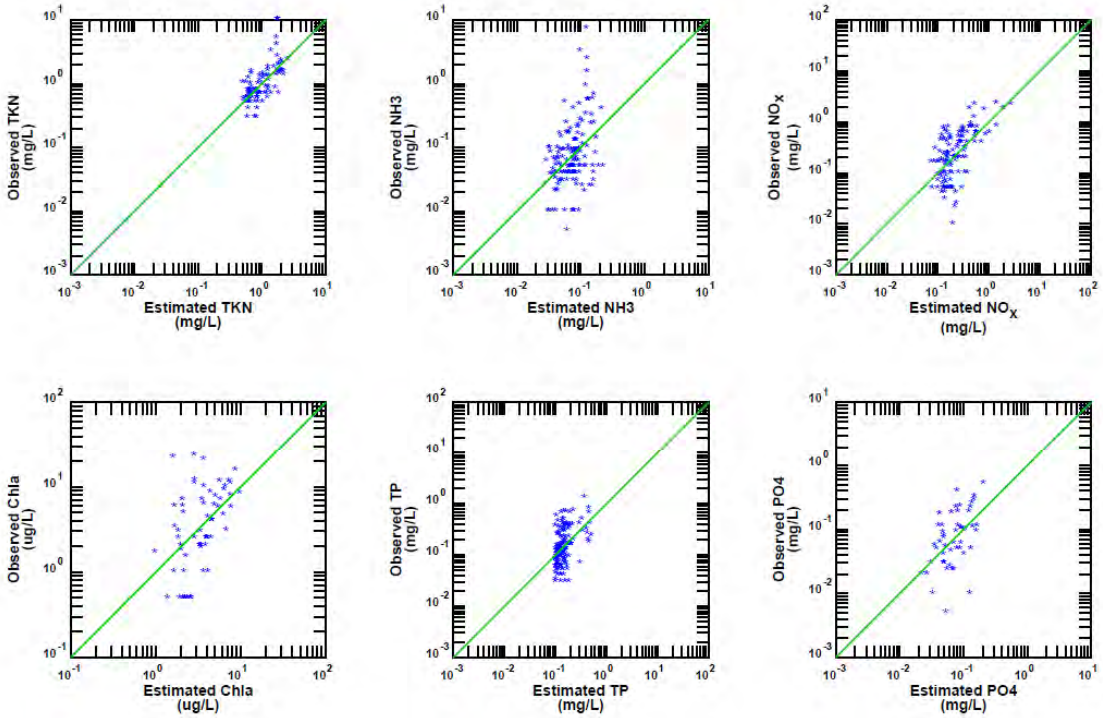
Observed Data vs. Loadest Estimated Concentration, Station 13005

Nueces Tributaries, Texas (1970-2014)



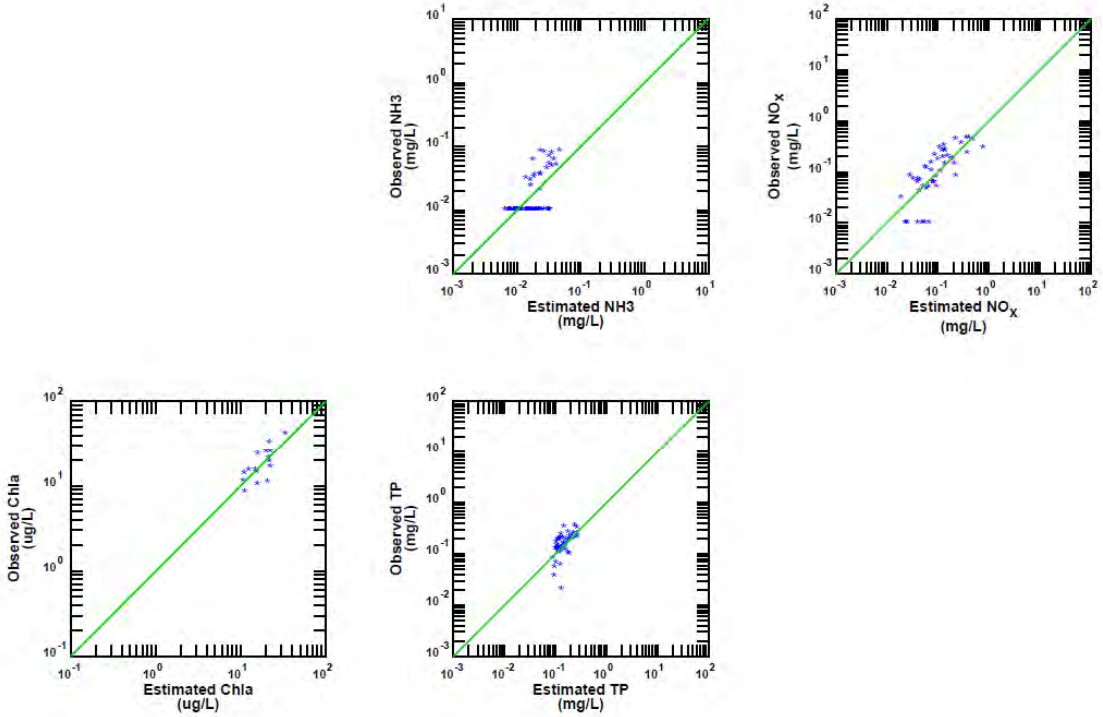
Observed Data vs. Loadest Estimated Concentration, Station 12973

Nueces Tributaries, Texas (1970-2014)



Observed Data vs. Loadest Estimated Concentration, Station 12979

Nueces Tributaries, Texas (1970-2014)

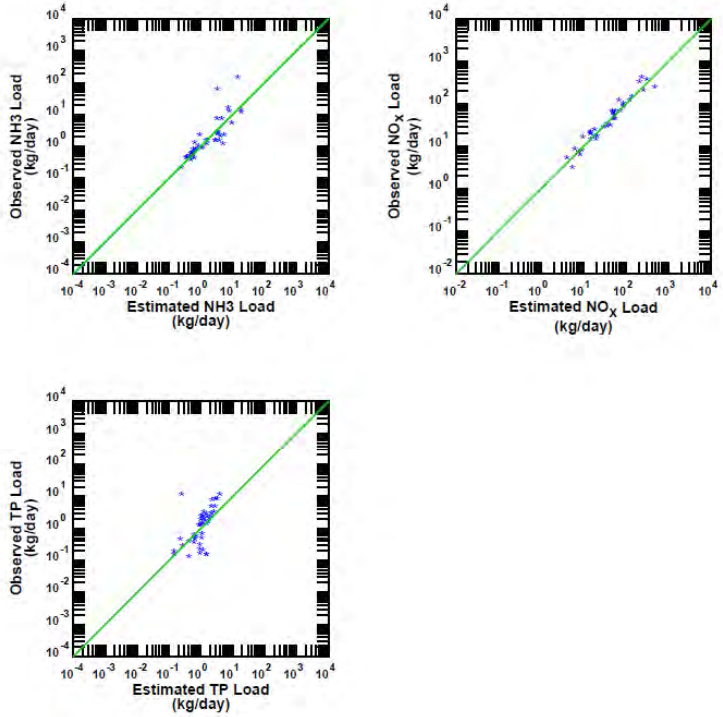


Observed Data vs. Loadest Estimated Concentration, Station 12964

Nueces Tributaries, Texas (1970-2014)

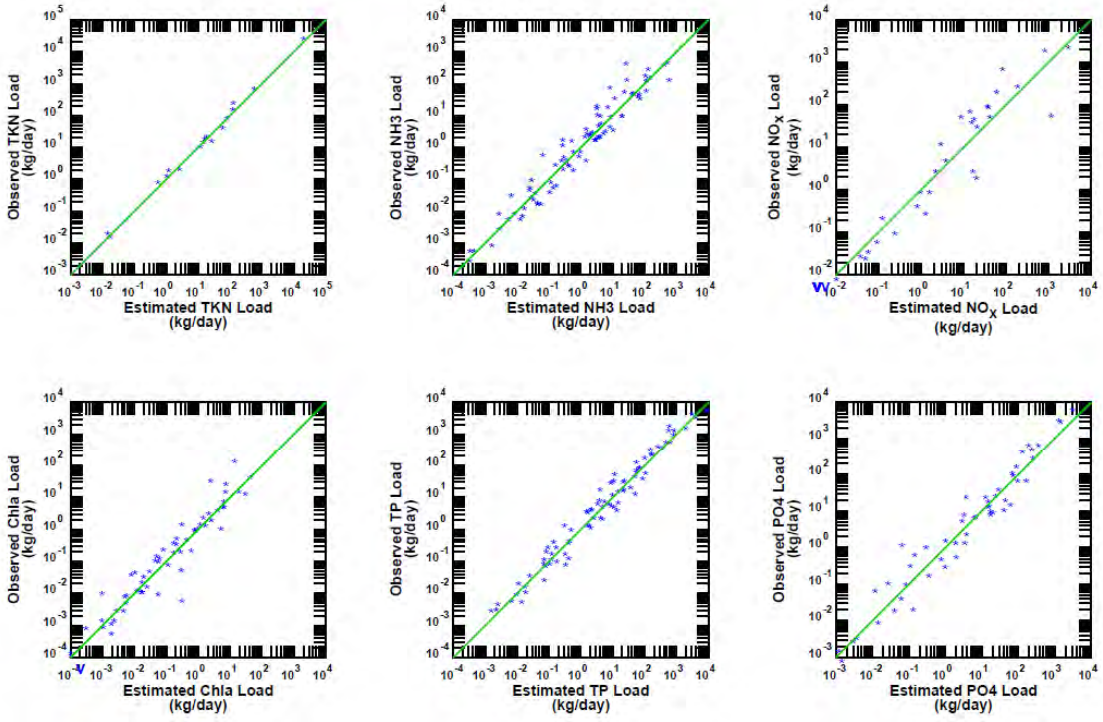
LOADEST RESULTS

Observed vs. Estimated Load



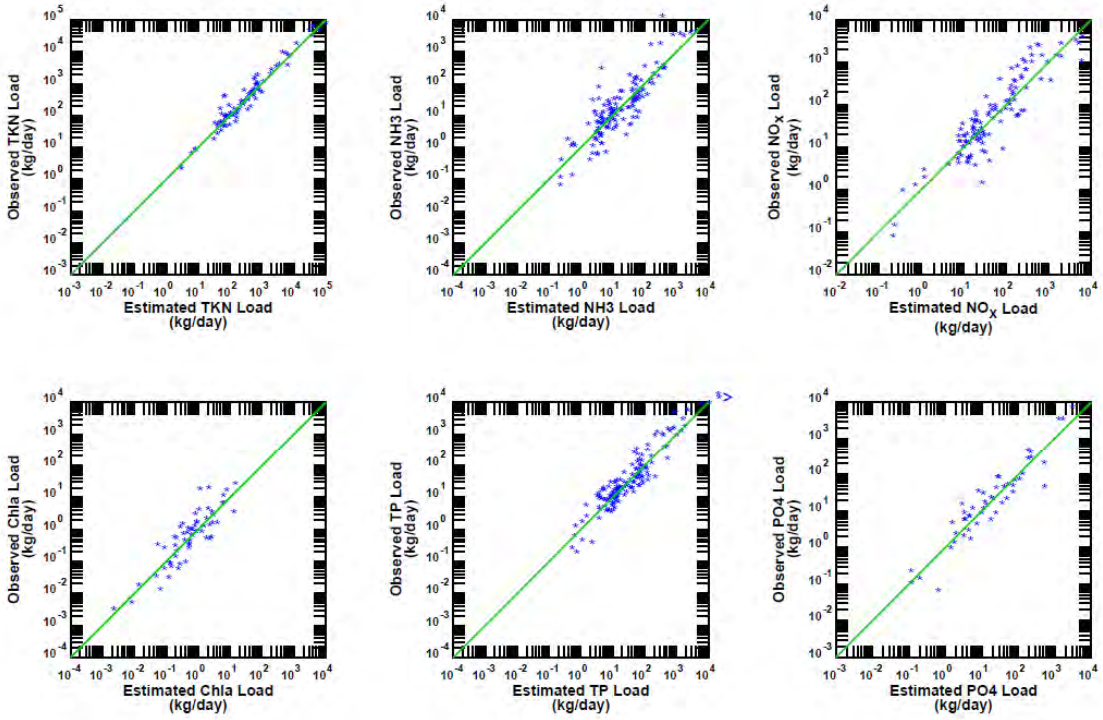
Observed Load vs. Loadest Estimated Load, Station 13005

Nueces Tributaries, Texas (1970-2014)



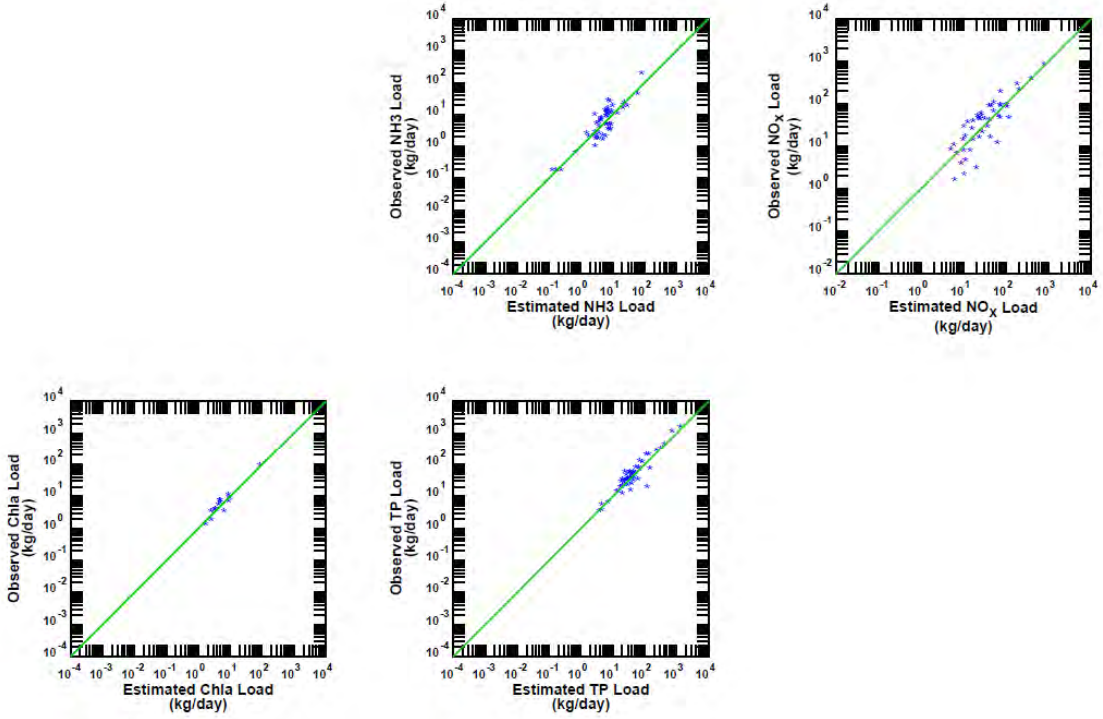
Observed Load vs. Loadest Estimated Load, Station 12973

Nueces Tributaries, Texas (1970-2014)



Observed Load vs. Loadest Estimated Load, Station 12979

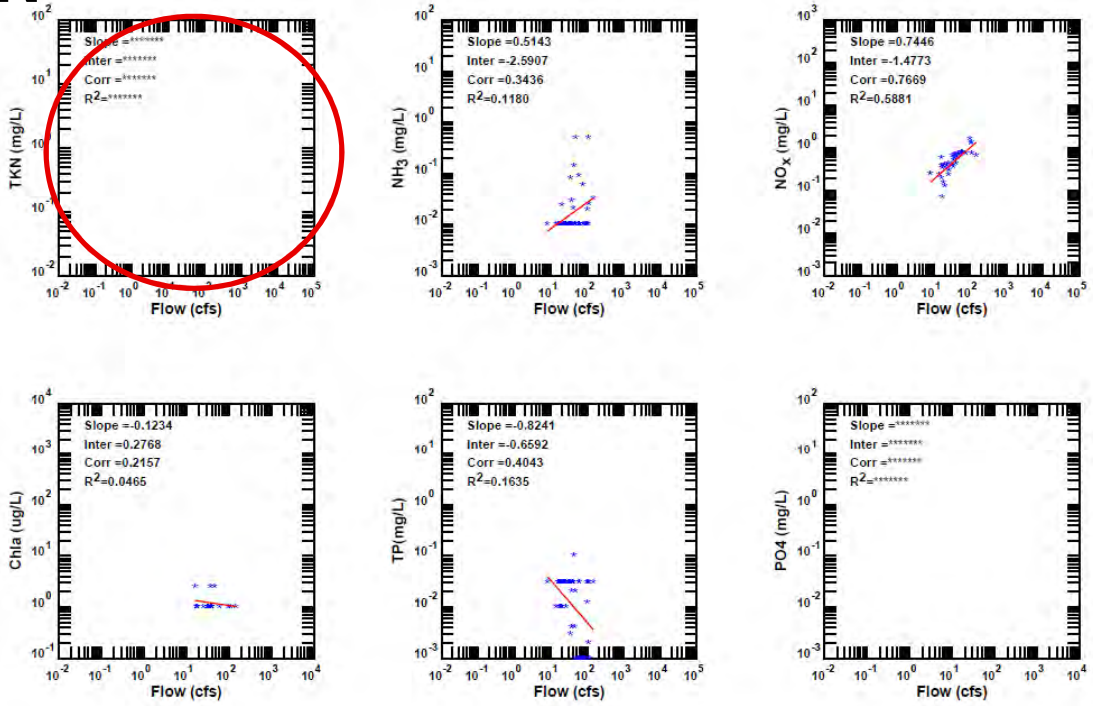
Nueces Tributaries, Texas (1970-2014)



Observed Load vs. Loadest Estimated Load, Station 12964

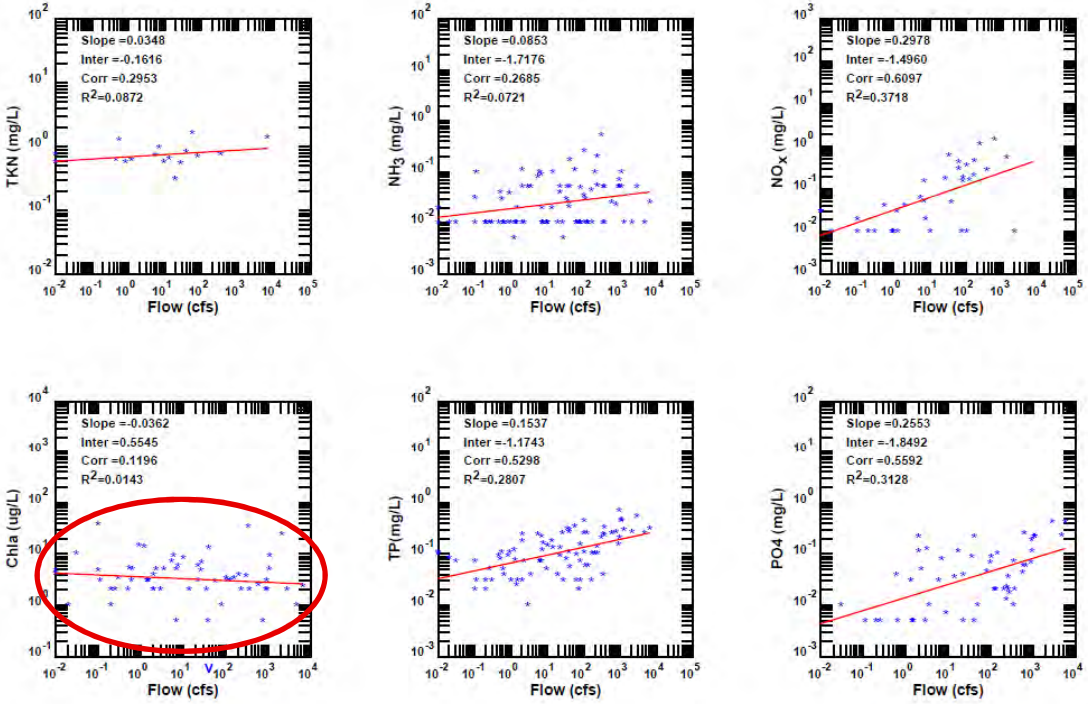
Nueces Tributaries, Texas (1970-2014)

STRAIGHT LINEAR REGRESSION



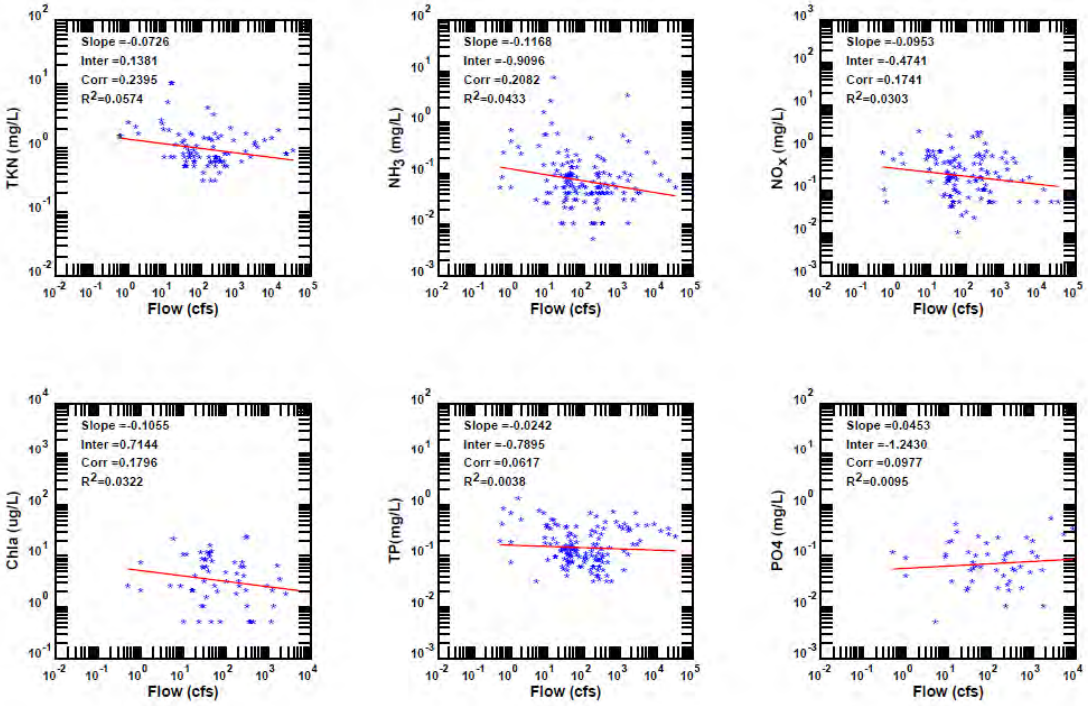
Regression analysis, Station 13005

Nueces Tributaries, Texas (1970-2014)



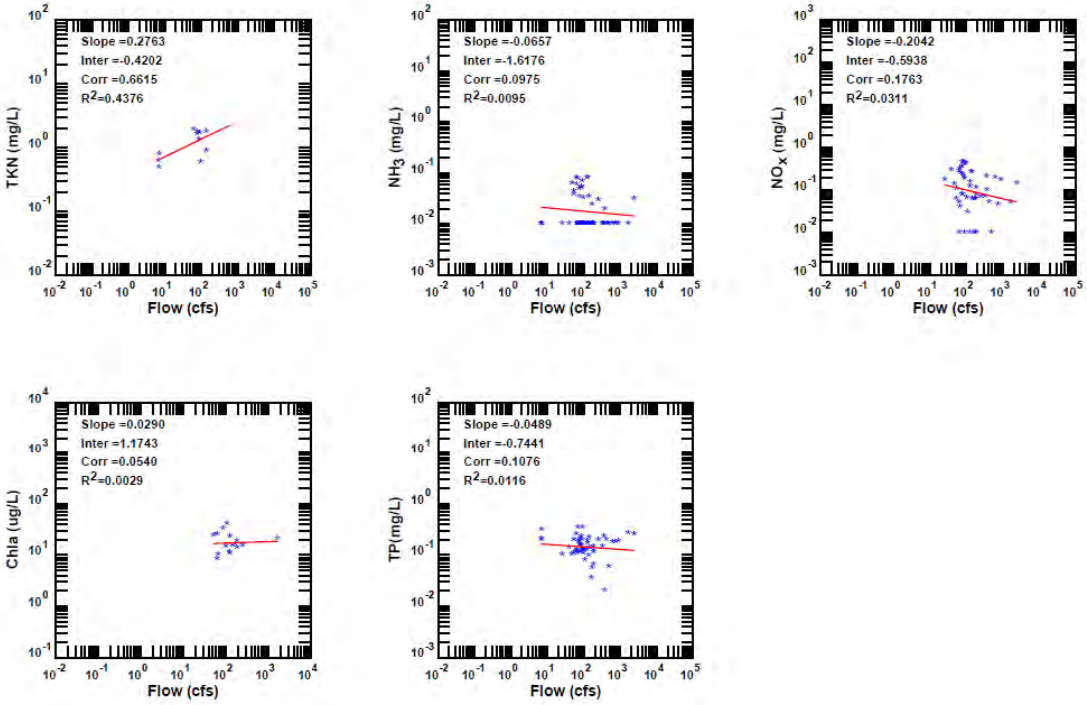
Regression analysis, Station 12973

Nueces Tributaries, Texas (1970-2014)



Regression analysis, Station 12979

Nueces Tributaries, Texas (1970-2014)



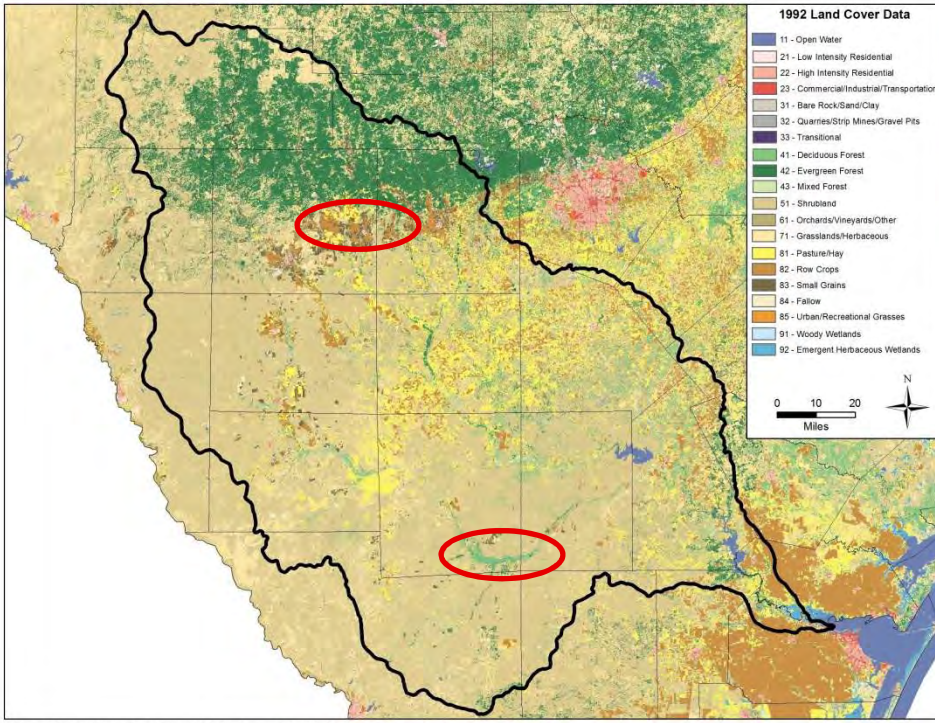
Regression analysis, Station 12964

Nueces Tributaries, Texas (1970-2014)

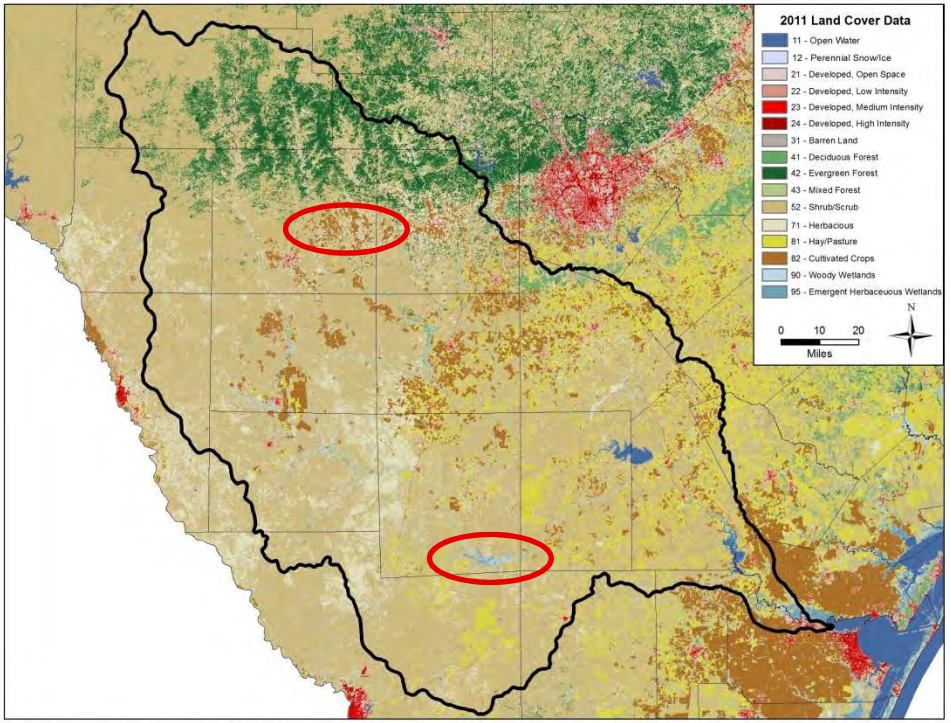
LAND USE ANALYSIS

- Using NLCD to analyze land use changes over time

1992


1992 Land Cover Data
11 - Open Water
21 - Low Intensity Residential
22 - High Intensity Residential
23 - Commercial/Industrial/Transportation
31 - Bare Rock/Sand/Clay
32 - Quarries/Strip Mines/Gravel Pits
33 - Transitional
41 - Deciduous Forest
42 - Evergreen Forest
43 - Mixed Forest
51 - Shrubland
61 - Orchards/Vineyards/Other
71 - Grasslands/Herbaceous
81 - Pasture/Hay
82 - Row Crops
83 - Small Grains
84 - Fallow
85 - Urban/Recreational Grasses
91 - Woody Wetlands
92 - Emergent Herbaceous Wetlands
0 10 20
Miles
N

2011


2011 Land Cover Data
11 - Open Water
12 - Perennial Snow/Ice
21 - Developed, Open Space
22 - Developed, Low Intensity
23 - Developed, Medium Intensity
24 - Developed, High Intensity
31 - Barren Land
41 - Deciduous Forest
42 - Evergreen Forest
43 - Mixed Forest
52 - Shrub/Scrub
71 - Herbacious
81 - Hay/Pasture
82 - Cultivated Crops
90 - Woody Wetlands
95 - Emergent Herbaceous Wetlands
0 10 20
Miles
N

TASK 2 - NEXT STEPS

- *(continued)* Task 2 – Perform Data Evaluation and Modeling Analyses
  - Refine Linear Regression Analyses
  - Estimate Reservoir Influence Sink/Sources
  - Water Quality Correlations to Anthropogenic Changes
  - Pre- and Post-Development Loadings

TASK 3 – MEETINGS AND REPORT

- Task 3 – Meetings and Report
  - NEAC Kickoff Meeting (June 16, 2014)
  - NEAC Meeting Update (October 20, 2014)
  - NEAC Meeting Update (February 23, 2015)
  - Draft and Final Report (2015)
  - Contract Deadline: August 31, 2015

SCHEDULE

- Complete data analysis Nov 2014
- Current nutrient budget Winter 2014-15
- Pre-development nutrient budget Spring 2015
- Present pre-, post-development results at Spring 2015 NEAC meeting
- Draft report after analyses
- Final report due August 2015

NUECES BBASC STUDY #3

NUECES WATERSHED PRE- AND POST-DEVELOPMENT NUTRIENT BUDGETS

NUECES ESTUARY ADVISORY COUNCIL
JUNE 22, 2015
PAULA JO LEMONDS, PE, PG

DISCUSSION

Background

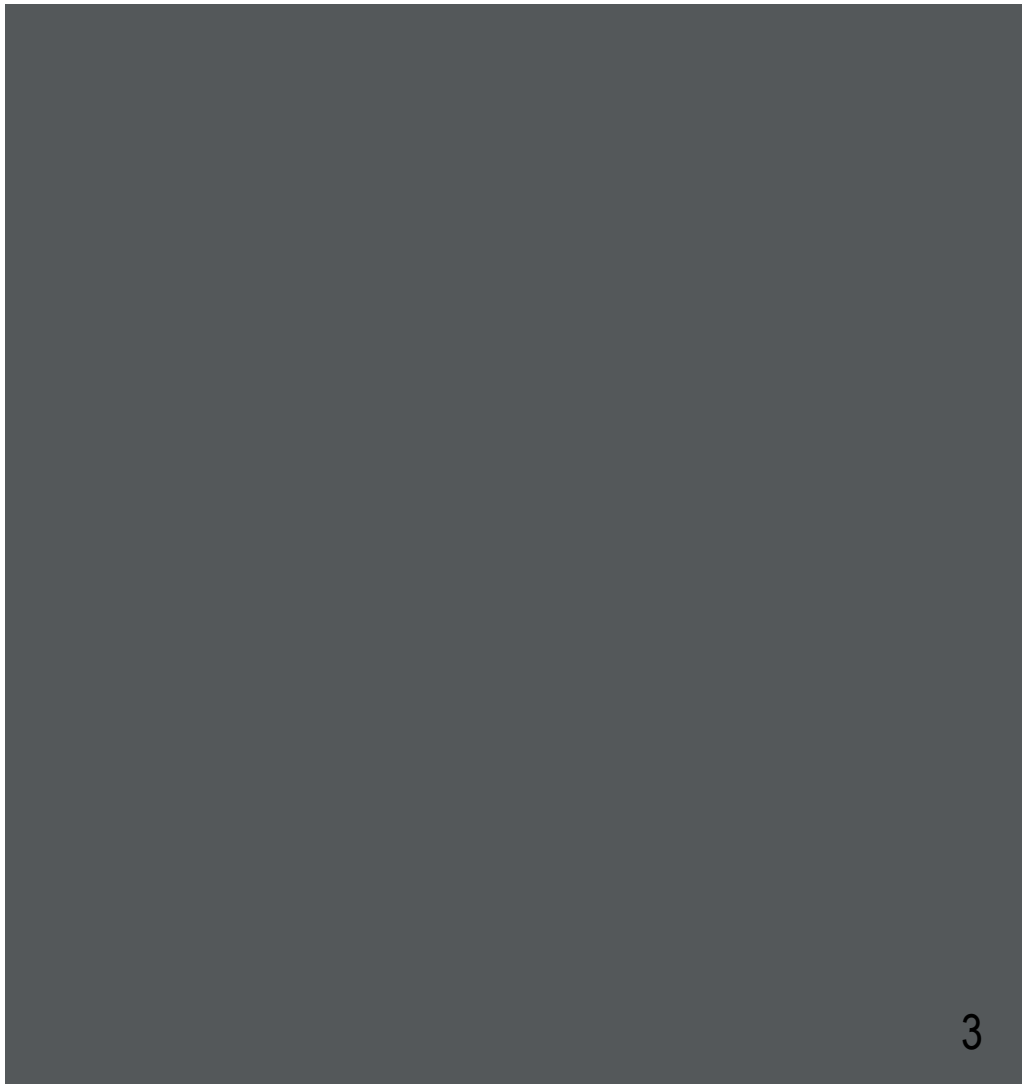
Status

Results

Schedule

BACKGROUND

- Nueces BBASC work plan
  - Tier 2b Recommendation
- Nueces BBEST
  - BBEST Recommendations Report
    - Sec. 5.2 Nutrient Considerations
- Nueces BBASC
  - BBASC Recommendations Report
    - Sec. 4.3.2 Nutrient Considerations



GOALS

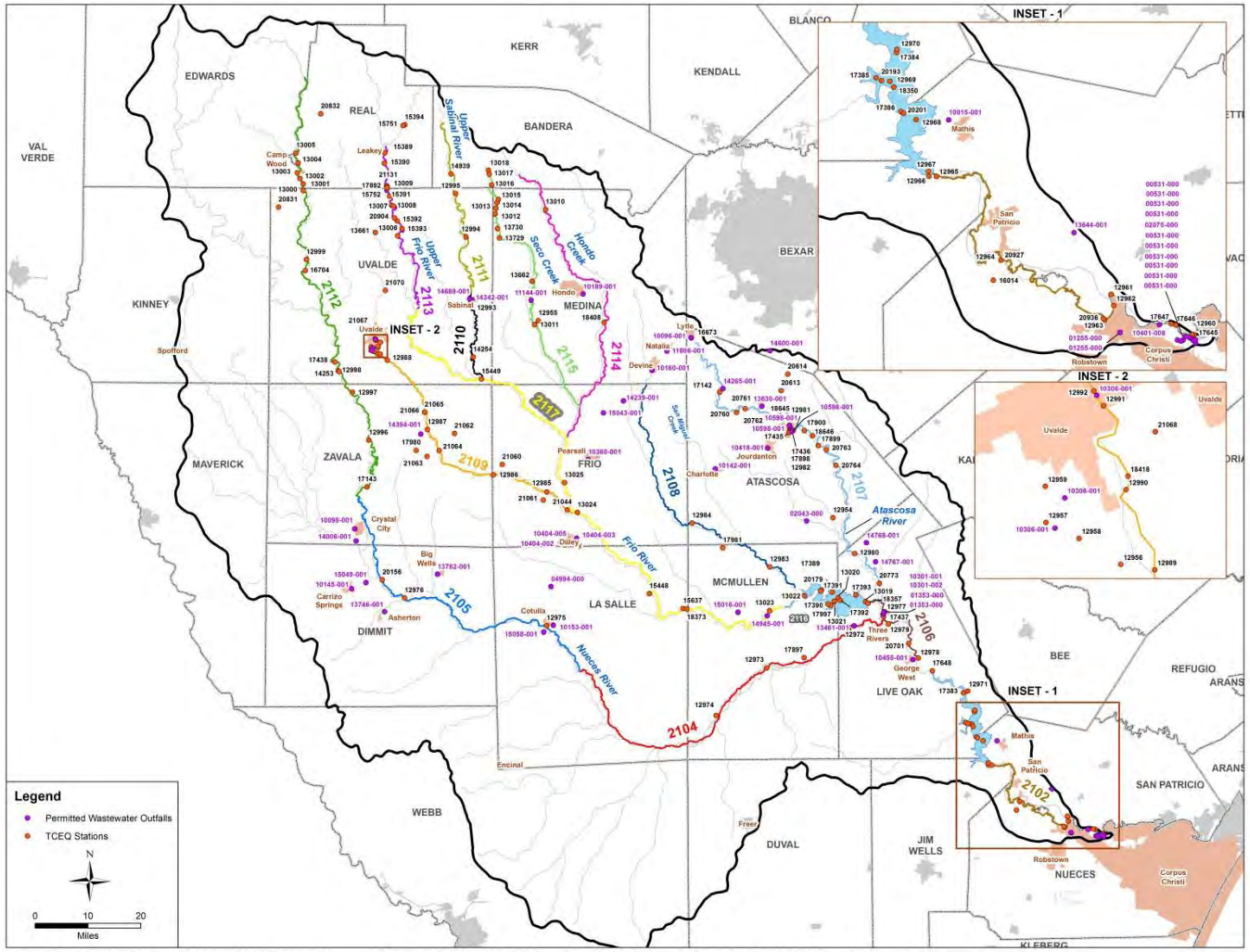
- Develop nutrient budgets based on quantitative understanding of natural supply of all nutrient forms and anthropogenic changes in these supplies over time for Nueces Bay watershed

- Determine annual loads for both the pre-development and present condition

Source: Nueces BBASC work plan

SCOPE OF WORK

- Task 1 – Compile Data
  - Compile Water Quality and Hydrologic Data
- Task 2 – Perform Data Evaluation and Modeling Analyses
  - Perform Data Evaluation
    - Available data, sampling stations, and subwatersheds
    - Identify appropriate stations
  - Refine Linear Regression Analyses
  - Estimate Reservoir Influence Sink/Sources
  - Water Quality Correlations to Anthropogenic Changes
  - Pre- and Post-Development Loadings


INSET - 1
INSET - 2
INSET - 1
INSET - 2
EDWARDS
KERR
KENDALL
BANDERA
REAL
VAL VERDE
UVALDE
KINNEY
MAVERICK
ZAVALA
FRIO
ATASCOSA
MEDINA
BEXAR
MCMULLEN
LA SALLE
DIMMIT
WEBB
DUVAL
JIM WELLS
NUECES
LIVE OAK
BEE
REFUGIO
SAN PATRICIO
Upper Sabinal River
Upper Frio River
Hondo Creek
Seco Creek
San Miguel Creek
Frio River
Atascosa River
Nueces River
2102
2104
2105
2106
2107
2108
2109
2110
2111
2112
2113
2114
2115
2117
Legend
Permitted Wastewater Outfalls
TCEQ Stations
N
0 10 20
Miles
L:\Project_Data\009109_Nueces_BBASC\009109_237741_Nueces_BBASC\GIS\Map_Docs\Draft\Nueces_Permitted_Wastewater_Outfalls_&_TCEQ_Stations_17x22.mxd

ANALYSES

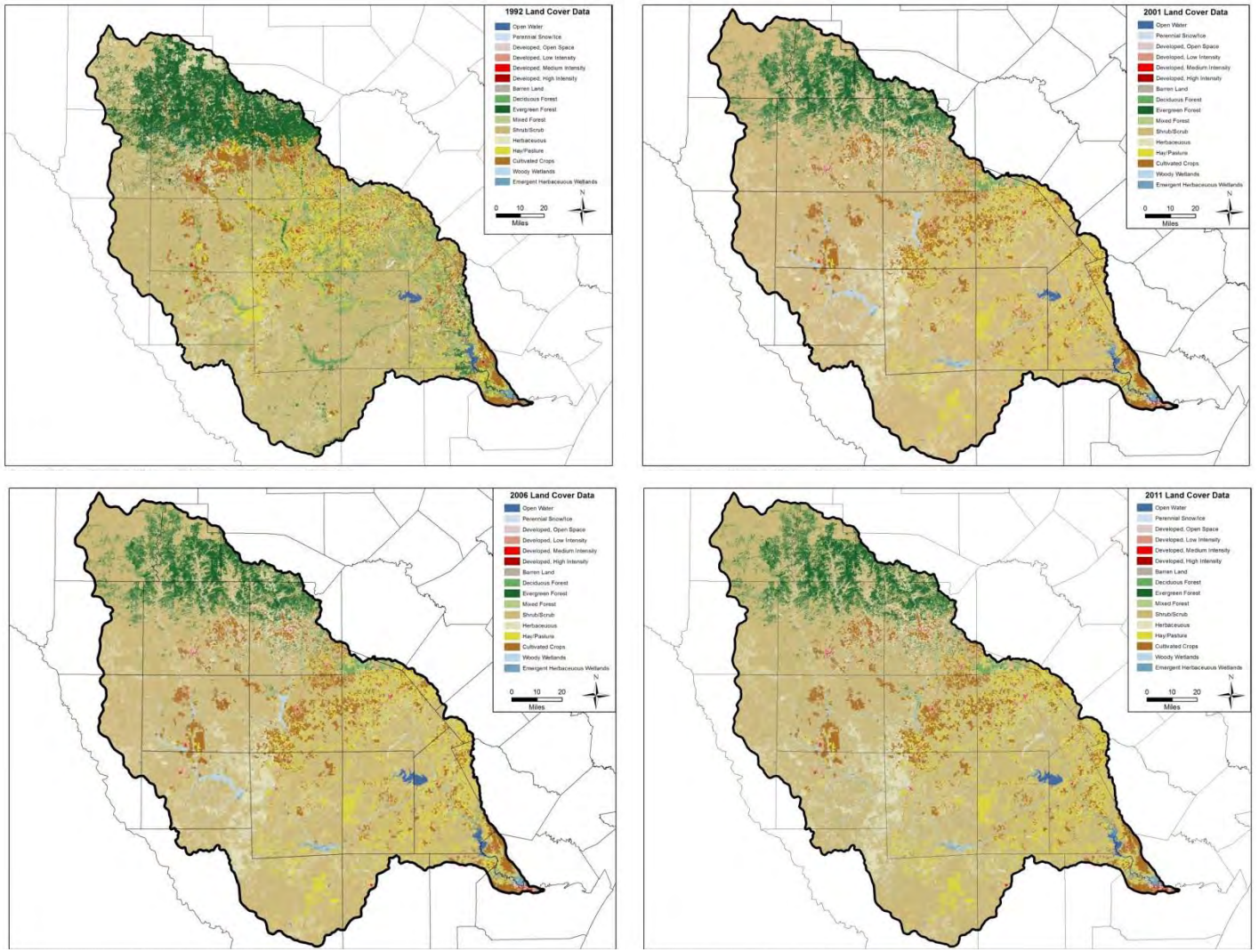
- Land Use
- Mission-Aransas Watershed
- Wastewater Treatment Plant Effects
- Effects of CCR Construction
- Annual Load Calculation for Dry, Average and Wet Years; Pre- and Post-CCR Construction

LAND USE ANALYSIS

- Using NLCD to analyze land use changes over time

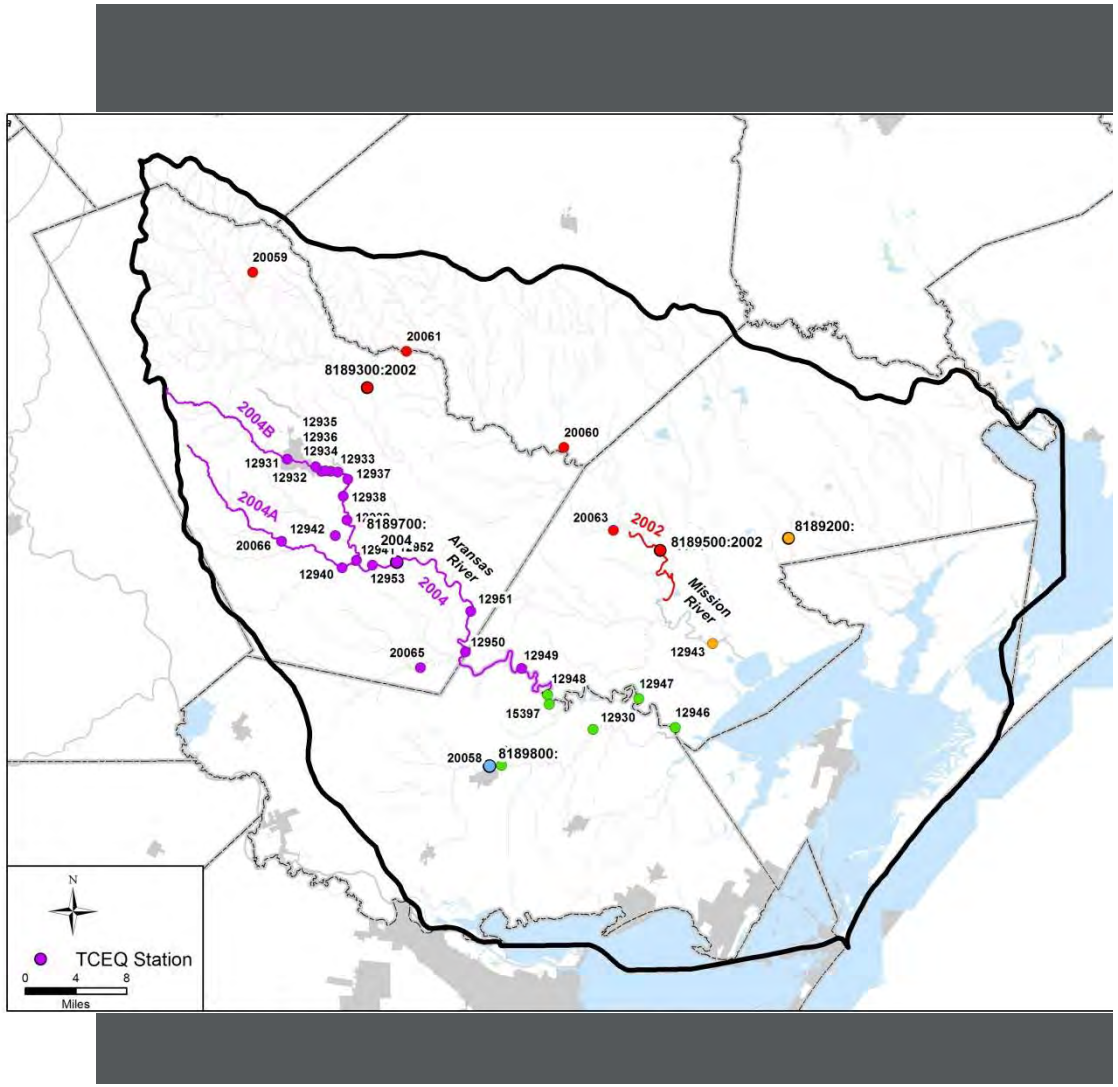
LAND USE

- About 4% increase in urban area over 1992-2011
- Cultivated acres relatively steady



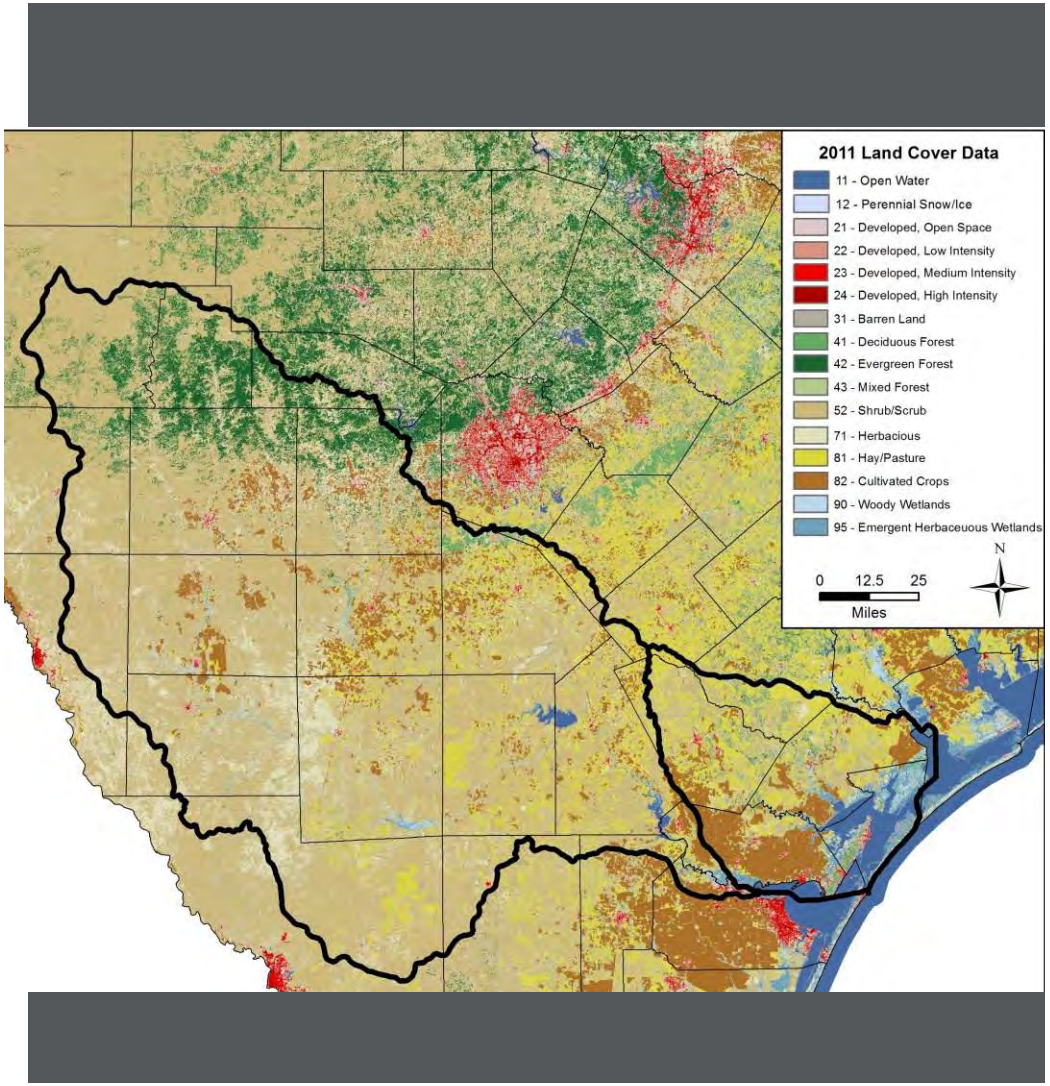
MISSION-ARANSAS WATERSHED ANALYSIS

- Very little development in watershed
- Hypothesized that M-A watershed would provide an additional evaluation as to whether changes in land use could be influencing water quality.

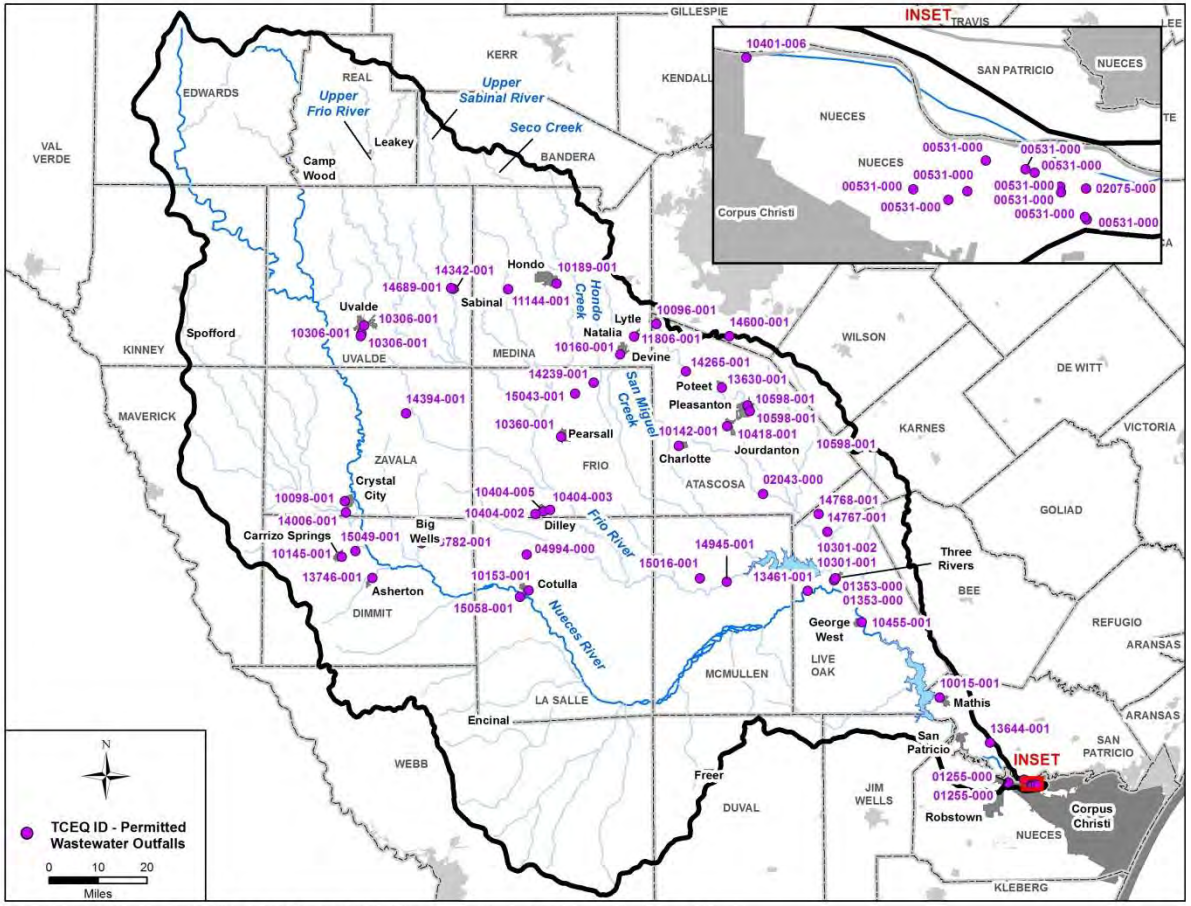


MISSION-ARANSAS WATERSHED ANALYSIS

- Upper Mission River had higher nutrient concentrations than upstream stations in less developed portions of Nueces
  - However, NO_x higher in Nueces compared to upper Mission River
  - Where comparisons possible, observed nutrient loadings in upper Aransas were even higher than observed in Mission River and upstream stations in the Nueces.
- One explanation for difference in nutrient loadings is land use in Aransas River subwatershed.
  - Land use is predominantly hay/pasture and cultivated crops

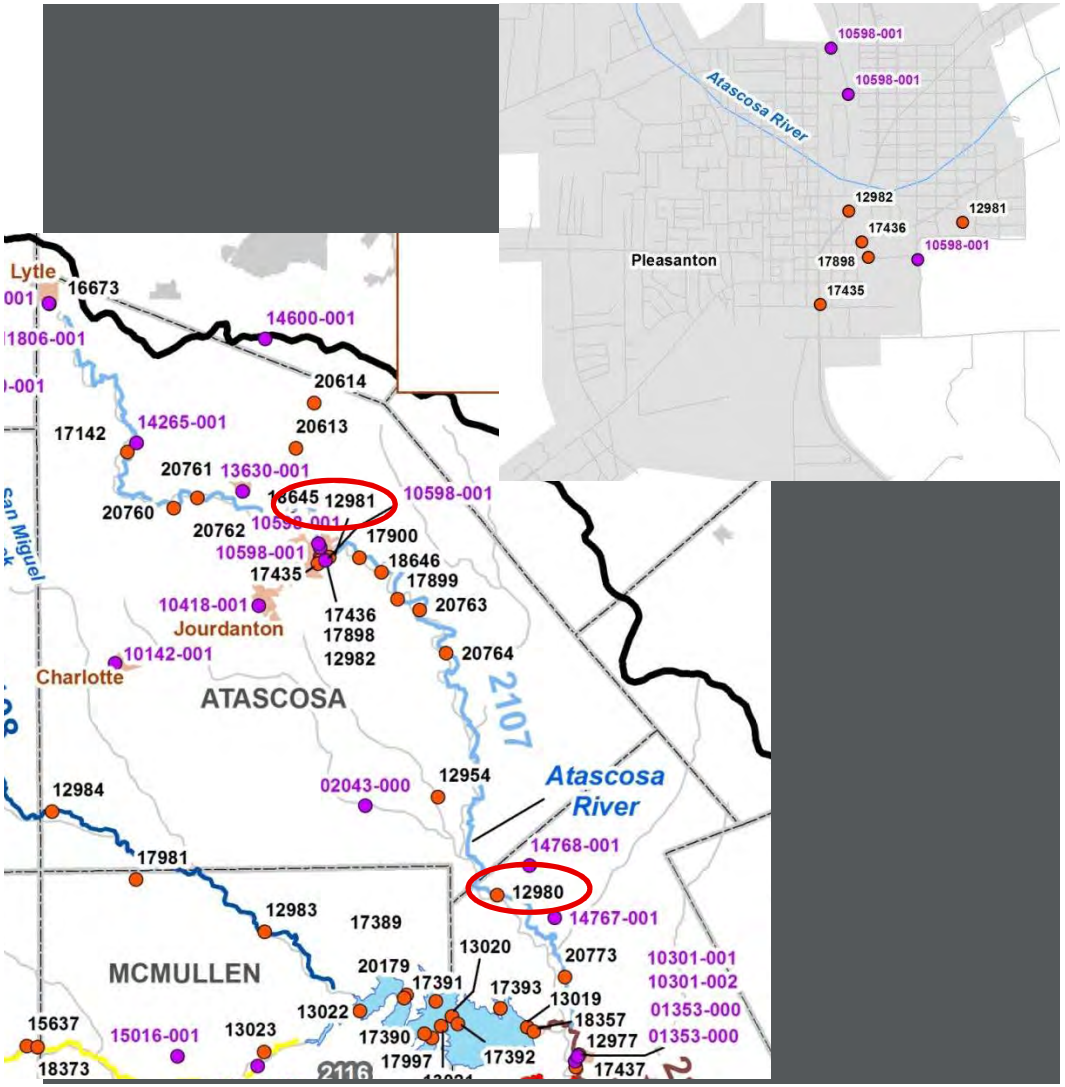


WWTP EFFECTS



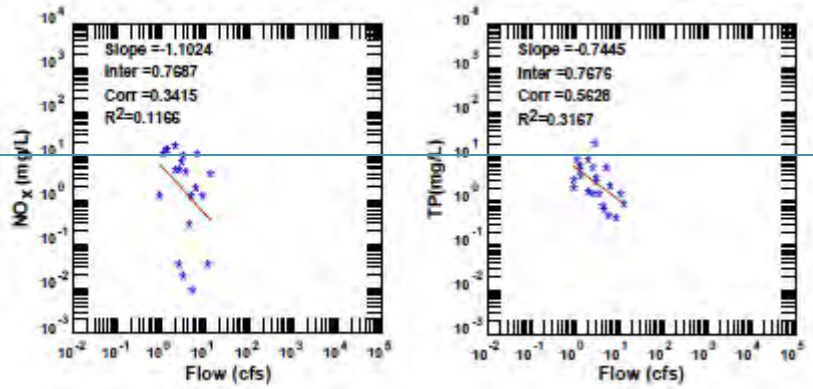
PLEASANTON EXAMPLE

- Station 12981, Atascosa River at Pleasanton
- NH_4, NO_x, TP, PO_4 and perhaps Chl-a higher at 12981 than 12980
- NRA BSR (2013a) states that much of upper Atascosa River is intermittent or ephemeral
  - If flows were not augmented by effluent from the Pleasanton WWTP outfall, river might be classified as intermittent, except for lowermost segment.



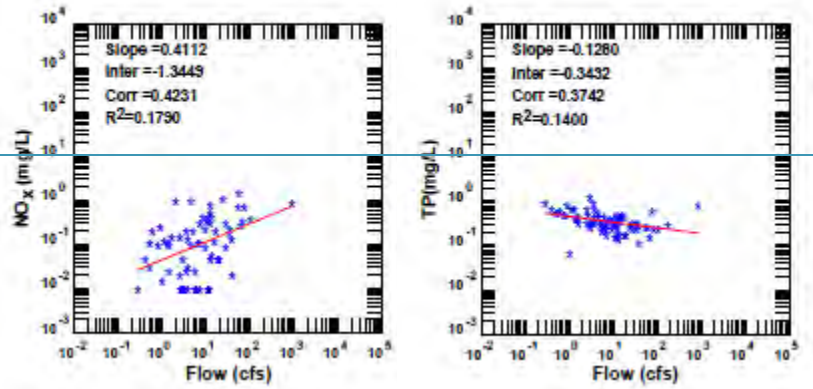
UPSTREAM TO DOWNSTREAM

- 12981 – Pleasanton
- 12980 – Downstream



Regression analysis, Station 12981

Nueces Tributaries, Texas (1970-2014)



Regression analysis, Station 12980

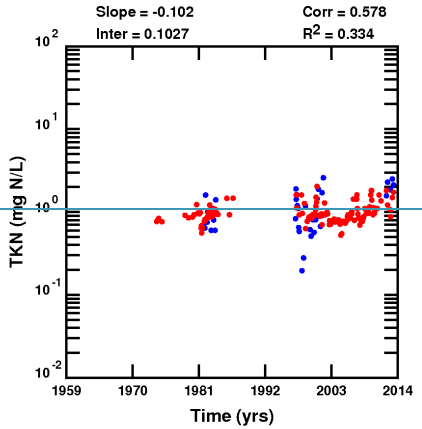
Nueces Tributaries, Texas (1970-2014)

DETERMINING THE EFFECTS OF CCR CONSTRUCTION

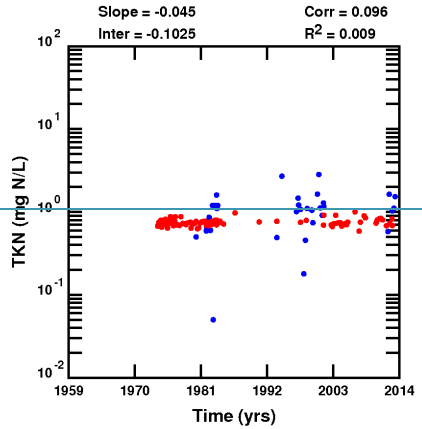
- Assumed data pre-1986 represented pre-construction and data post-1986 represented post-construction period
  - N species decline between pre- and post- reservoir construction
    - TKN decline may have begun prior to construction
  - TP and PO_4: Some increases in TP and PO_4 in the Frio River and San Miguel Creek post-construction that do not appear downstream of the reservoir at Three Rivers
  - Flow: Low flow conditions below CCR are greater than before CCR due to flow management

EFFECTS OF CCR - TKN

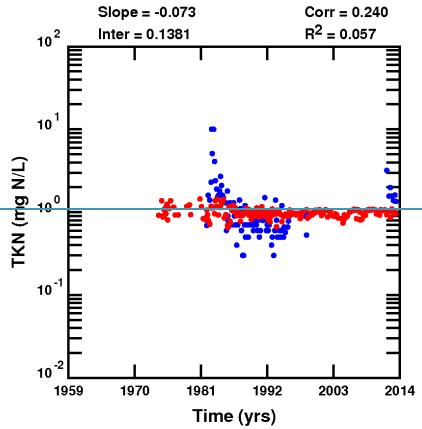
- TKN data from three TCEQ locations
  - Frio River at Tilden, Station 13023
  - San Miguel Creek nr Tilden, Station 12983
  - Three Rivers, Station 12979



Nutrient Distributions, Station 13023



Nutrient Distributions, Station 12983

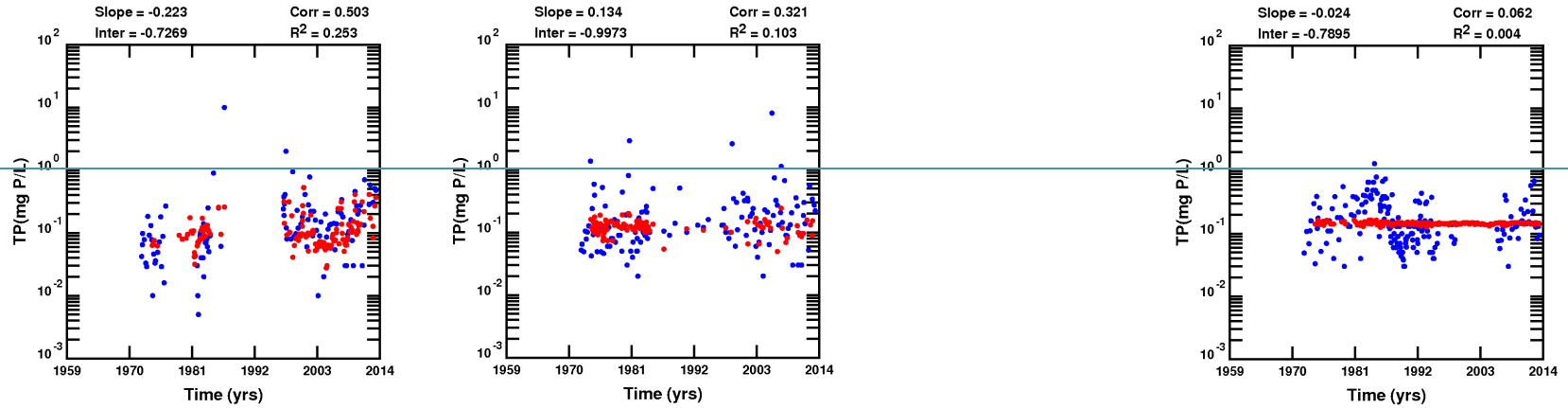


Nutrient Distributions, Station 12979

Observed Concentration
Estimated Concentration

EFFECTS OF CCR - TOTAL PHOSPHORUS

- Nutrient data from two TCEQ locations at
  - Frio River, Station ID 13023 (Figure 7-1) and
  - San Miguel Creek, Station ID 12983 (Figure 7-2)
  - Three Rivers, Station 12979



Nutrient Distributions, Station 13023

Nutrient Distributions, Station 12983

Nutrient Distributions, Station 12979

ANNUAL LOAD CALCULATIONS

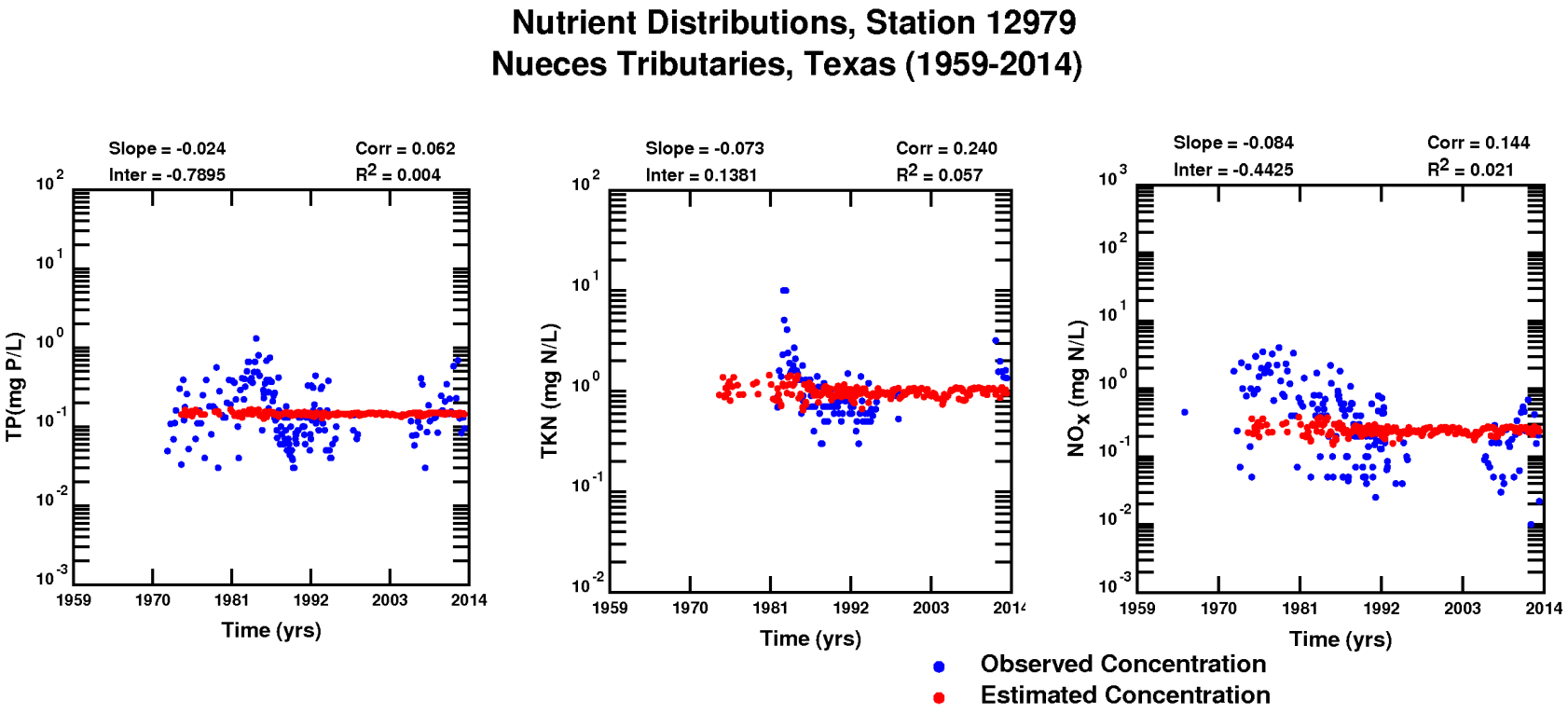
- Load = Concentration x Flow
- Concentration time-series
- Dry, average, wet years of USGS streamflow

Representative flow years based on
Nueces at Mathis (USGS 08211000, TCEQ 12965)

	Dry	Average	Wet
Pre-1986	1984	1974	1971
Post-1986	2008	1993	2002

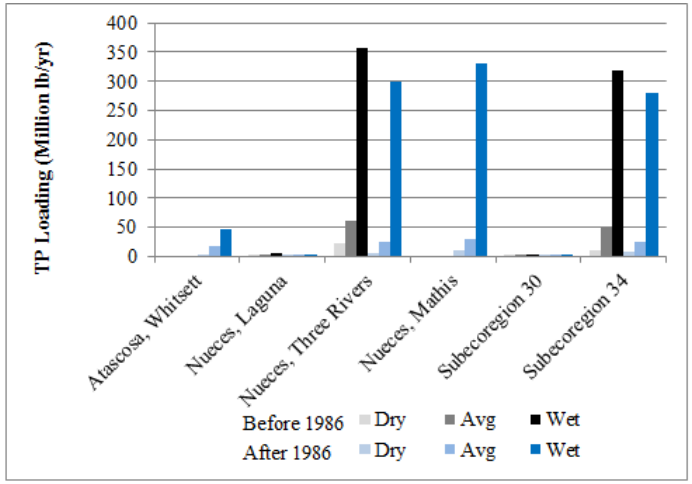
- Indication of nutrient load delivered to Estuary
- Also looked at dry, avg, wet years based on Calallen precip statistics

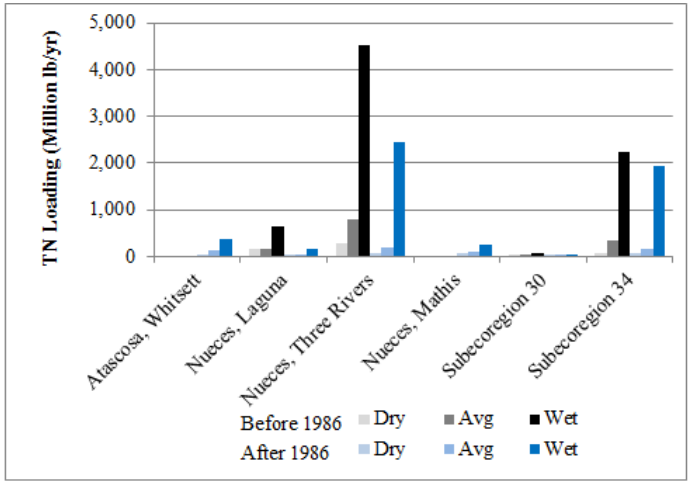
CONCENTRATION TIME-SERIES

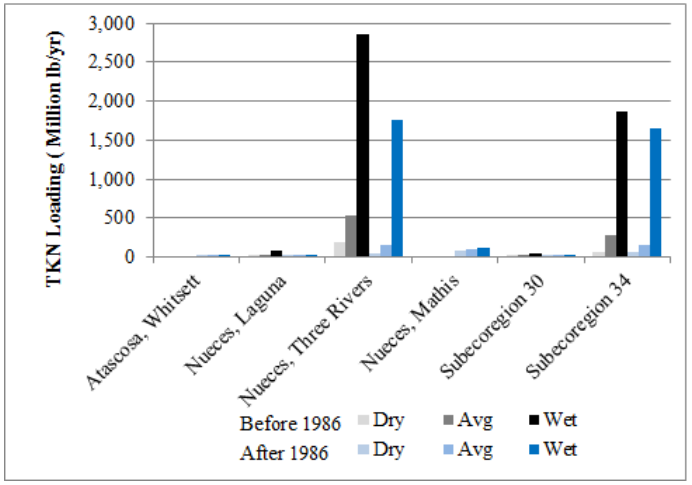


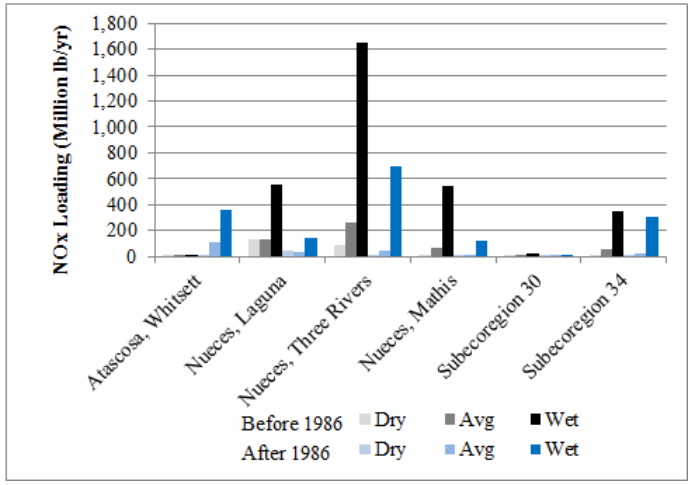
LOADS

- TP, TN, TKN, NOx

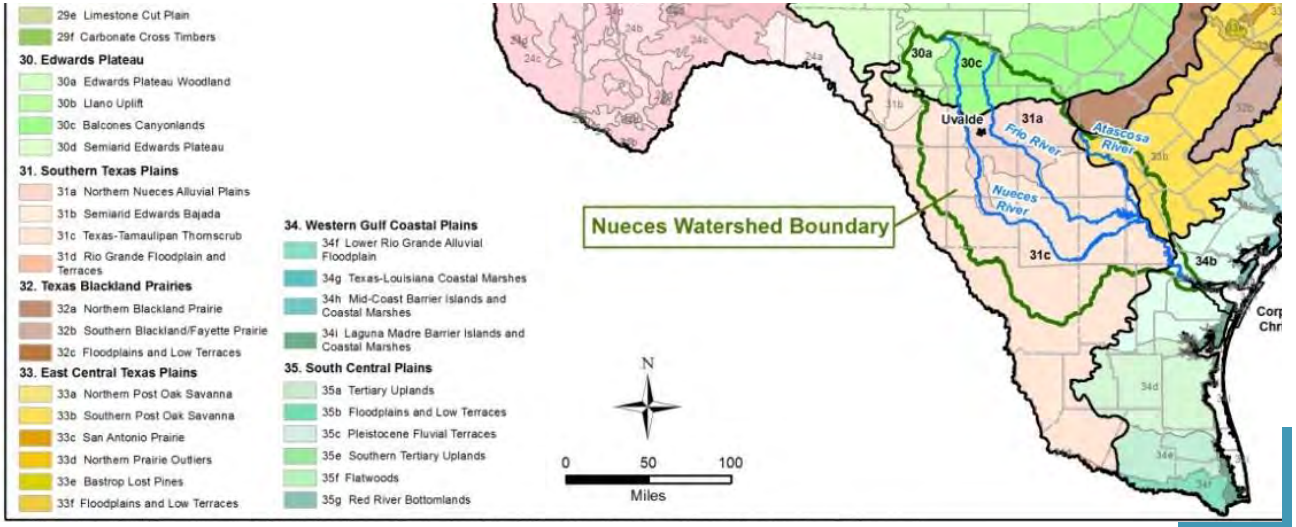








EPA ECOREGION REFERENCE CONDITIONS



Parameter	EPA 25th Percentile Reference Conditions			
(mg/L)	Ecoregion IV, Subecoregion 30[1]	Ecoregion IV, Subecoregion 31[2]	Ecoregion IX, Subecoregion 33[3]	Ecoregion X, Subecoregion 34[4]
Total Phosphorus	0.008	0.028	0.1	0.126
Total Kjedahl Nitrogen (TKN)	0.18	0.27	0.543	0.74
Total Nitrogen	0.27*, 0.55†	0.49*	0.681*, 0.935†	0.88*, 0.86†
Nitrite + Nitrate - N	0.09	0.22	0.138	0.14
Chlorophyll a**	0.002	0.002	0.000733	0.0021
Turbidity (FTU)	0.73	3.83	10.9	12.27
* Calculated				
† Reported				
** Chlorophyll a measured by Spectrophotometric method with acid correction				

CONCLUSIONS

- Land use slowly changing. Urban areas increasing in size. Areas of cultivated crops seem to remain steady (1970 to present).
- Some locations are affected by WWTP discharge.
- Effects of CCR Construction
  - N species decline between pre- and post- reservoir construction
    - TKN decline may have begun prior to the construction
  - TP and PO_4: Appear to be some increases in TP and PO_4 in the Frio River and San Miguel Creek post-construction that do not appear downstream of reservoir at Three Rivers
  - Flow: Low flow conditions below CCR are greater than before CCR due to flow management
- Difficult to determine statistically significant relationships between flow and nutrients
  - Dataset is representative of a range of conditions.
  - Correlations could improve if they were done for specific temporal periods, rising or declining parts of hydrograph, or seasonally.

RECOMMENDATIONS

- Evaluate predictive scenarios of loadings upstream and downstream of CCR with CCR/LCC System operating under different operational schemes
- Evaluate effects of other development scenarios, including future build-out land use conditions, on nutrient loadings
- Quantify effects of seasonality on nutrient loadings.
- Further quantify effects of reservoirs in Nueces Watershed.
  - Fate and transport, nutrient processing uptake, losses, releases, dissolved oxygen
- Identify and quantify nonpoint source component of nutrient loadings in Nueces Watershed
  - One way to accomplish quantification of nonpoint source loadings is with watershed-scale nutrient loading model that takes into account point sources, as well as nonpoint sources.

TASK 3 – MEETINGS AND REPORT

- Task 3 – Meetings and Report
  - NEAC Kickoff Meeting June 16, 2014
  - NEAC Meeting Update October 20, 2014
  - NEAC Meeting Update February 23, 2015
  - NEAC Meeting Update June 22, 2015
  - Draft Report: June 30, 2015
  - Final Report, Contract Deadline: August 31, 2015

Appendix B. Time series figures of water quality constituents related to nutrients for the Nueces, San Antonio – Nueces Coastal, Rio Grande – Nueces Coastal watershed

Appendix B1 shows time series figures of water quality constituents related to nutrients for the Nueces watershed, which is classified as Basin 21 by TCEQ.

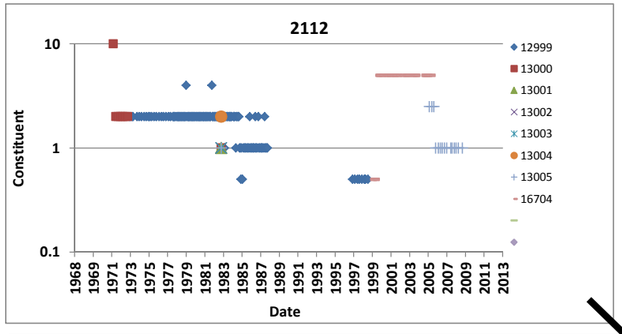
Appendix B2 shows time series figures of water quality constituents related to nutrients for the San Antonio – Nueces Coastal watershed, which is classified as Basin 20 by TCEQ.

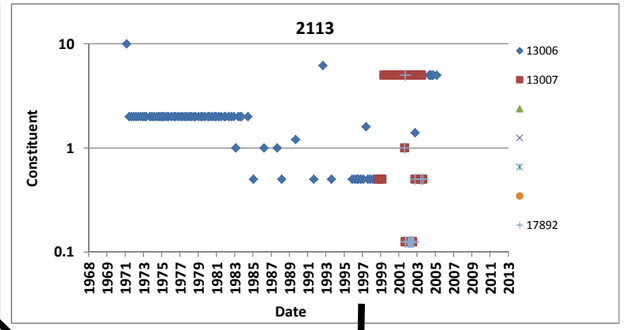
Appendix B3 shows time series figures of water quality constituents related to nutrients for the Rio Grande – Nueces Coastal watershed, which is classified as Basin 22 by TCEQ.

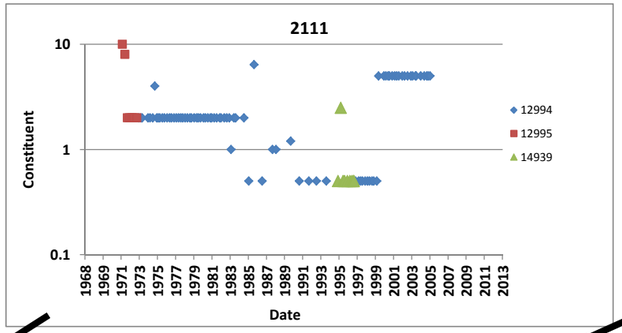
The figures are organized by TCEQ stream segment identification numbers, which begin with the basin identification (20, 21, or 22) and have a two-digit identifier following the basin identifier.

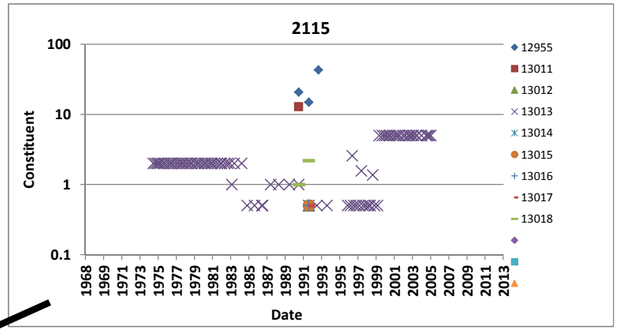
Basin 21: Nueces River Basin

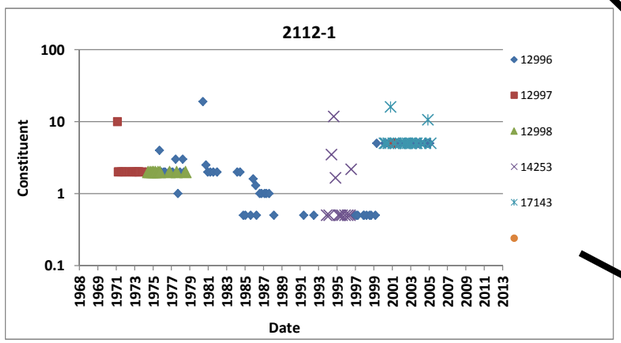
CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH vs Date

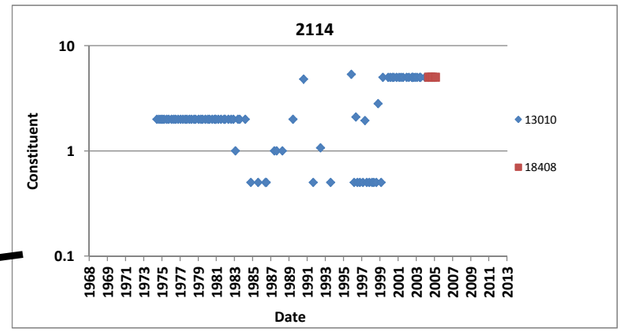


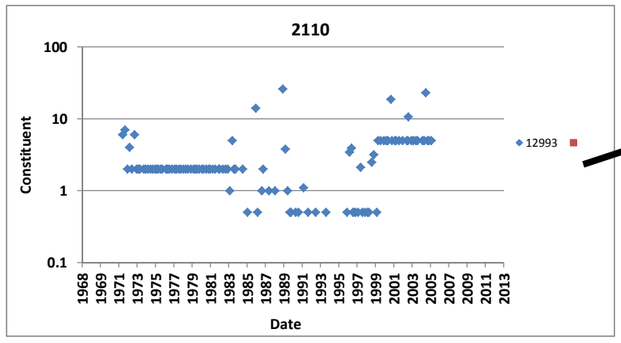


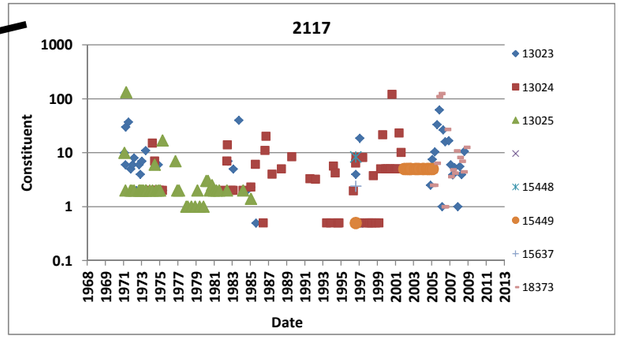


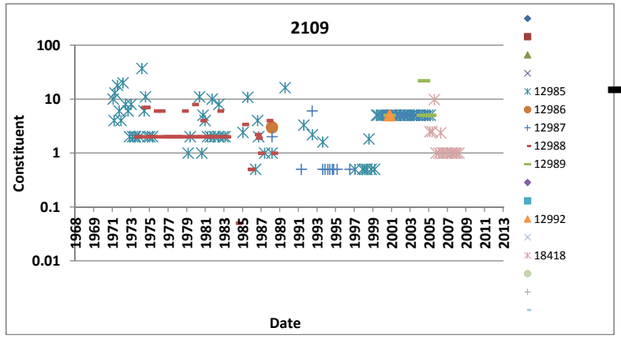


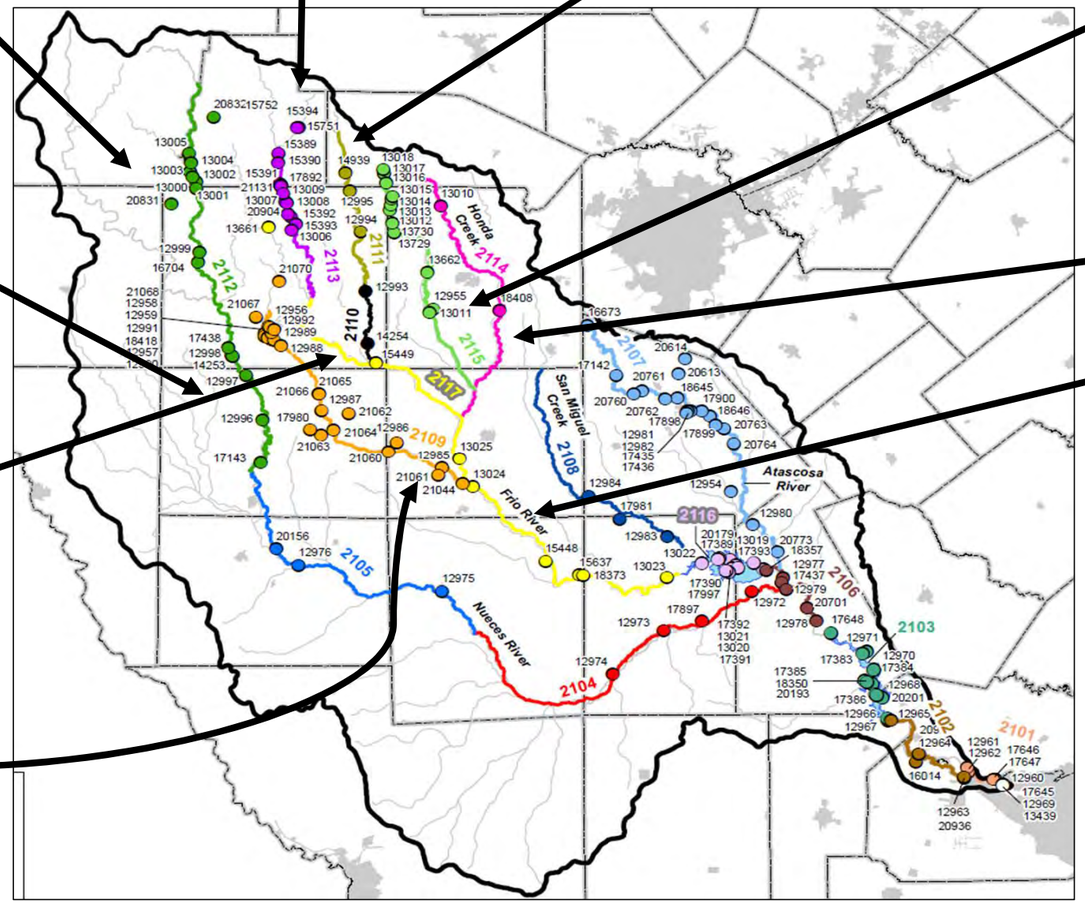






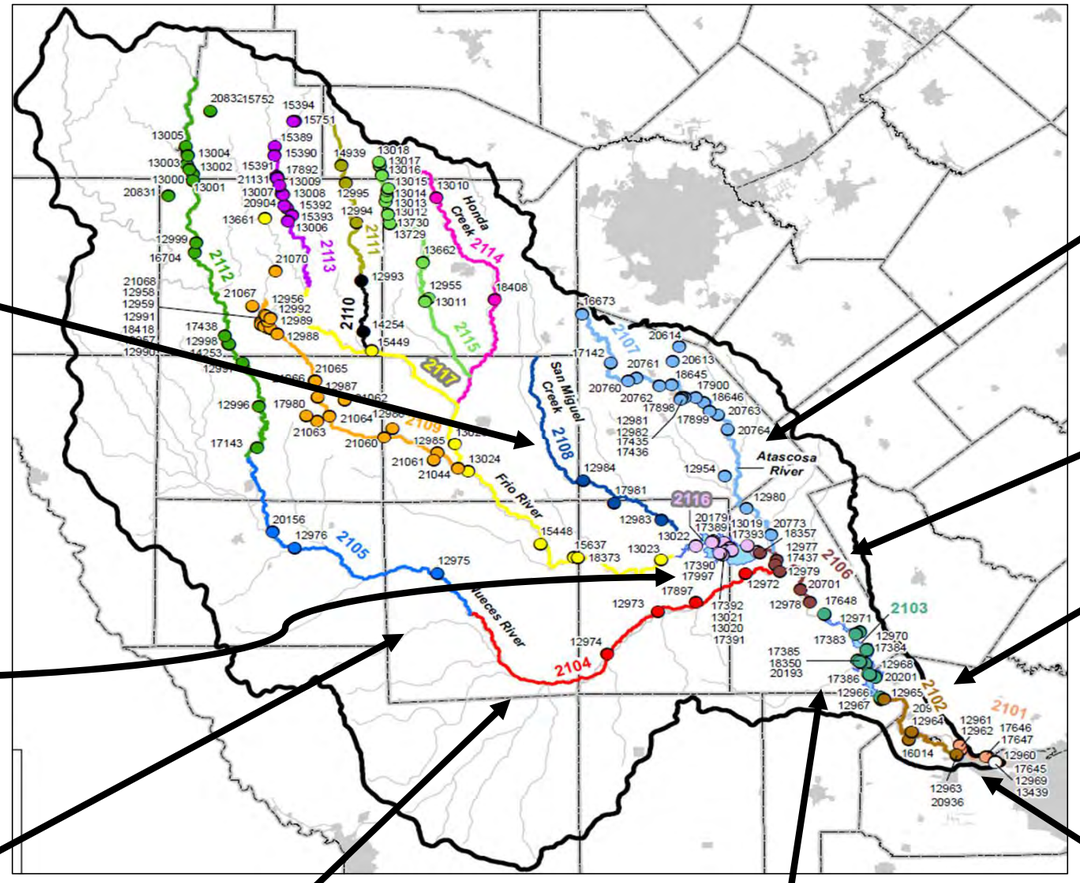


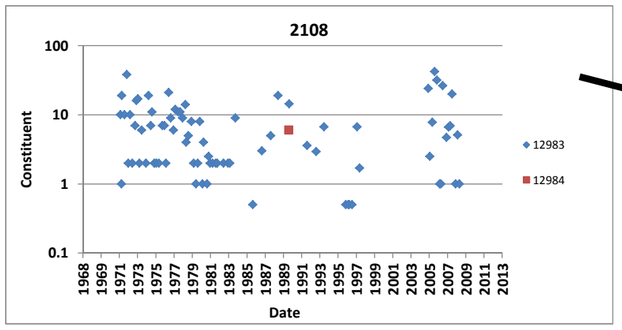


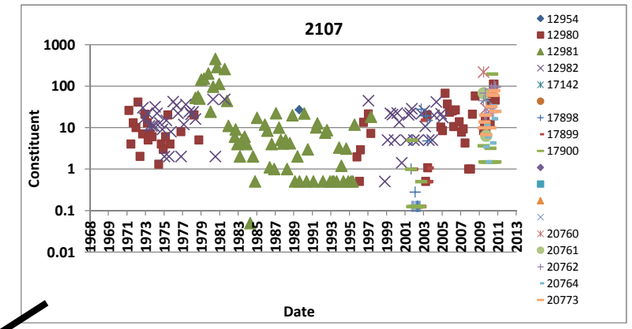


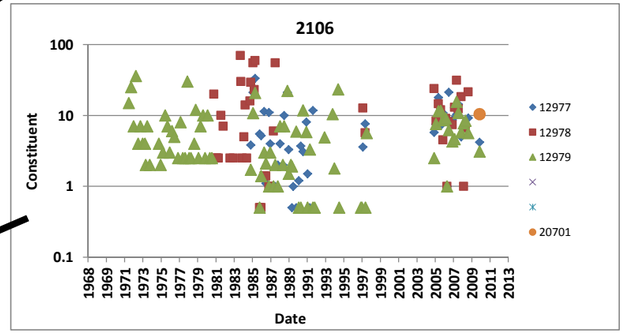
Basin 21: Nueces River Basin

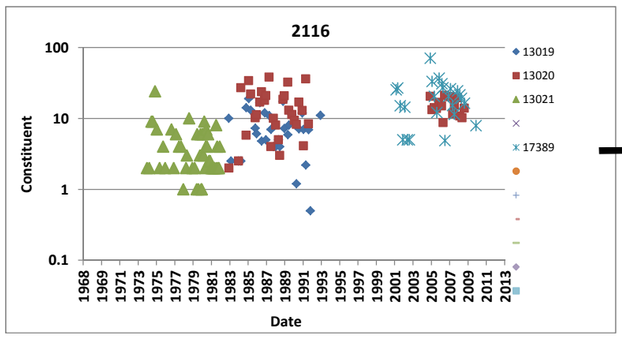
CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH vs Date

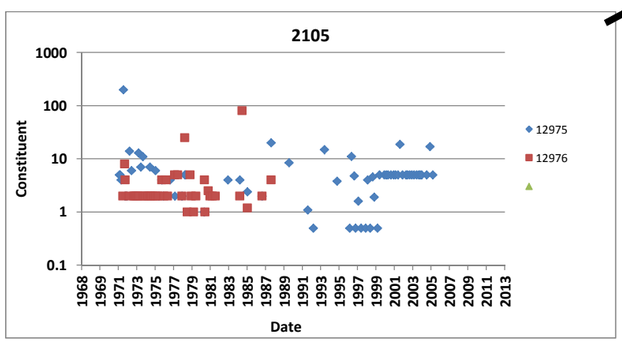


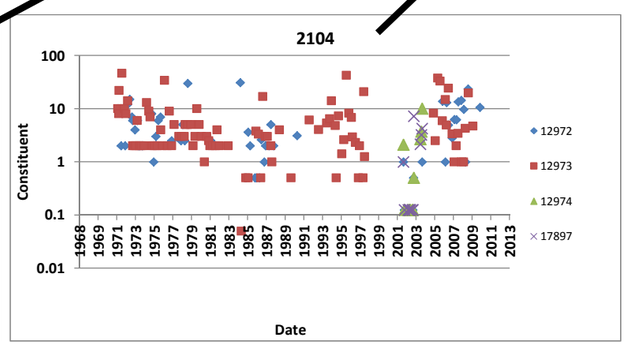


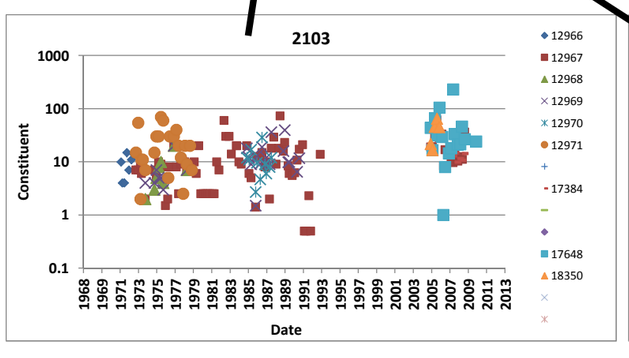


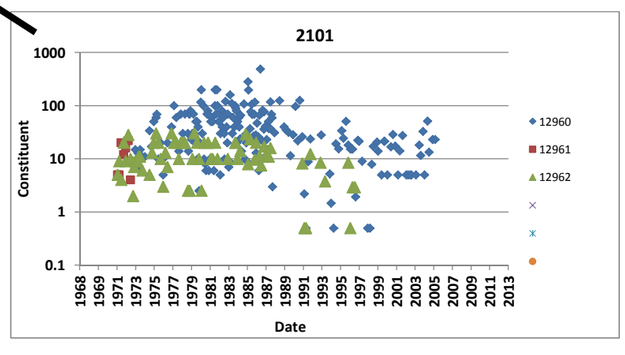






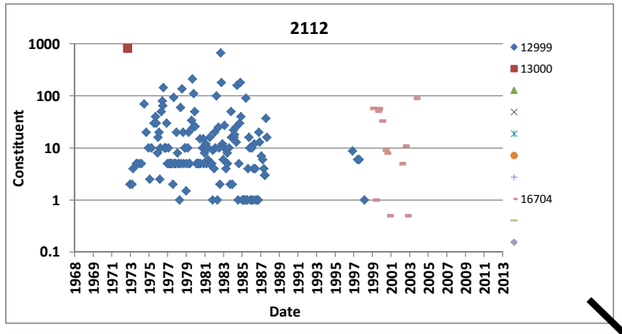


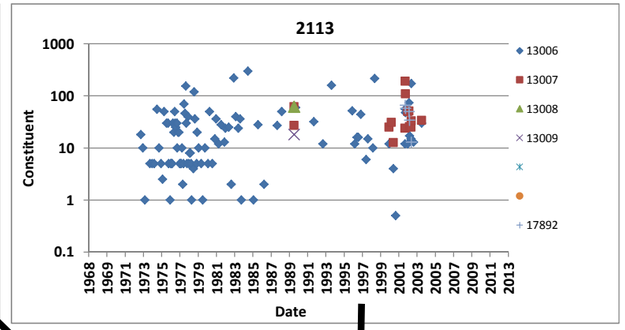


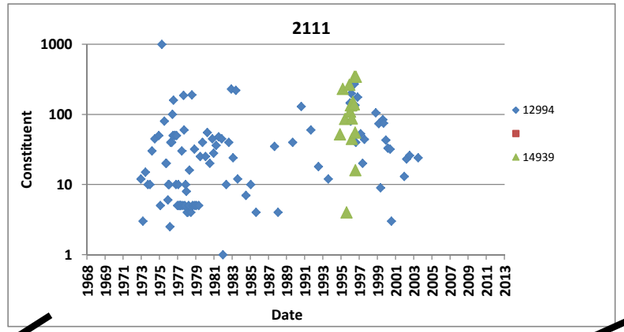


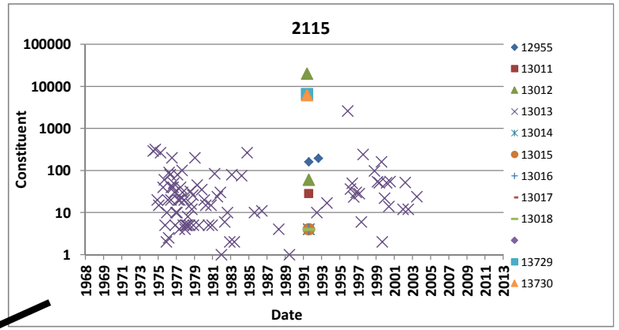
Basin 21: Nueces River Basin

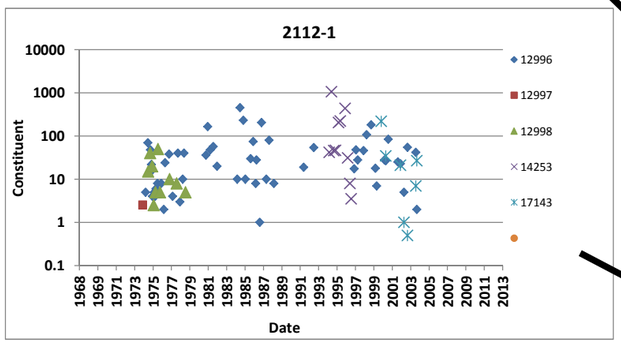
FECAL COLIFORM,MEMBR FILTER,M-FC BROTH, #/100ML vs Date

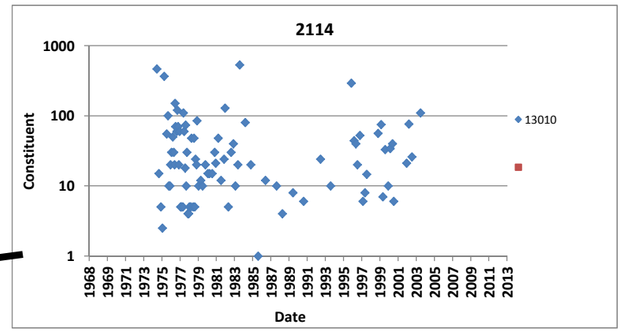


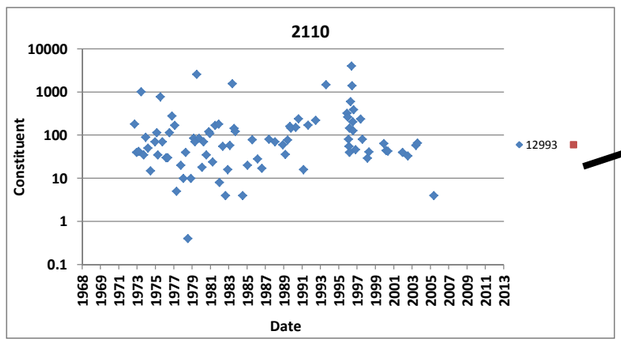


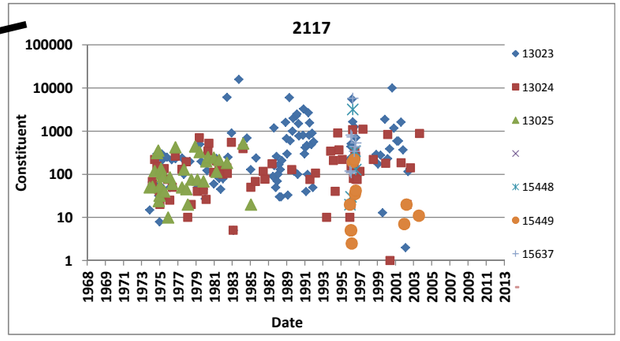


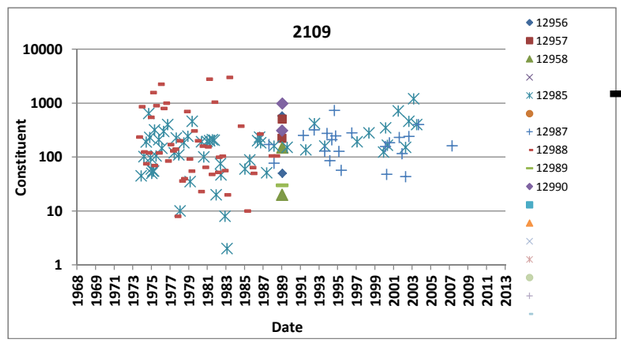


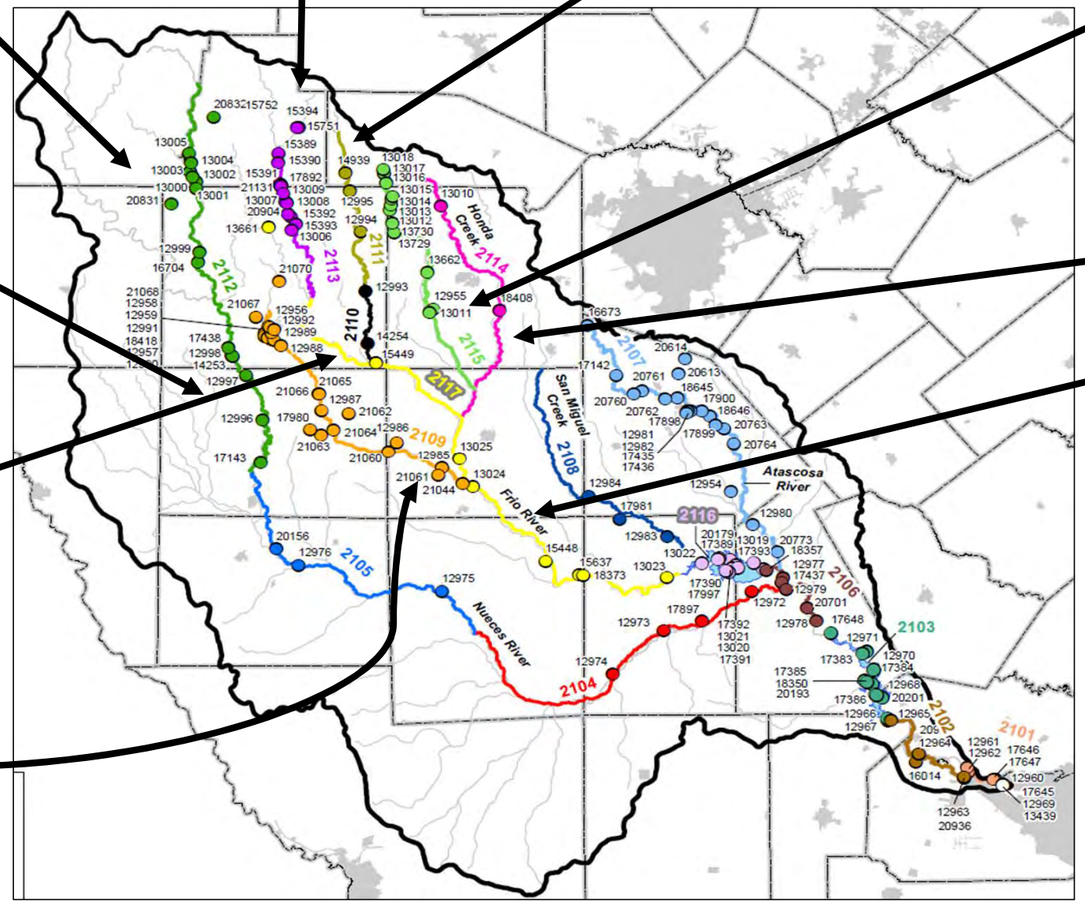






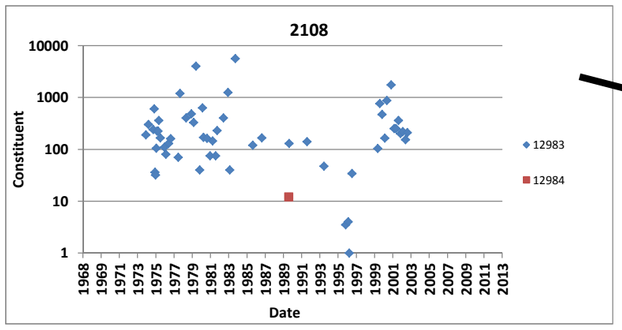


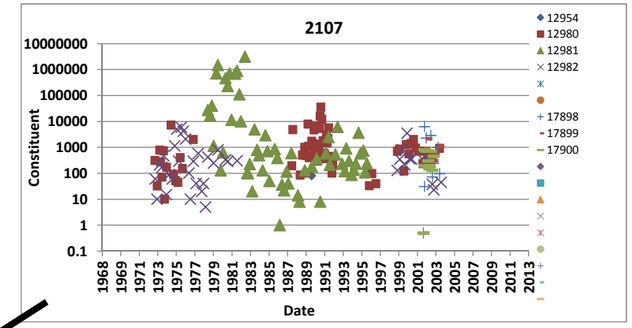


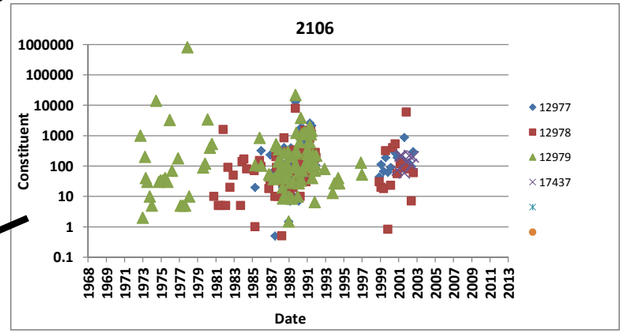


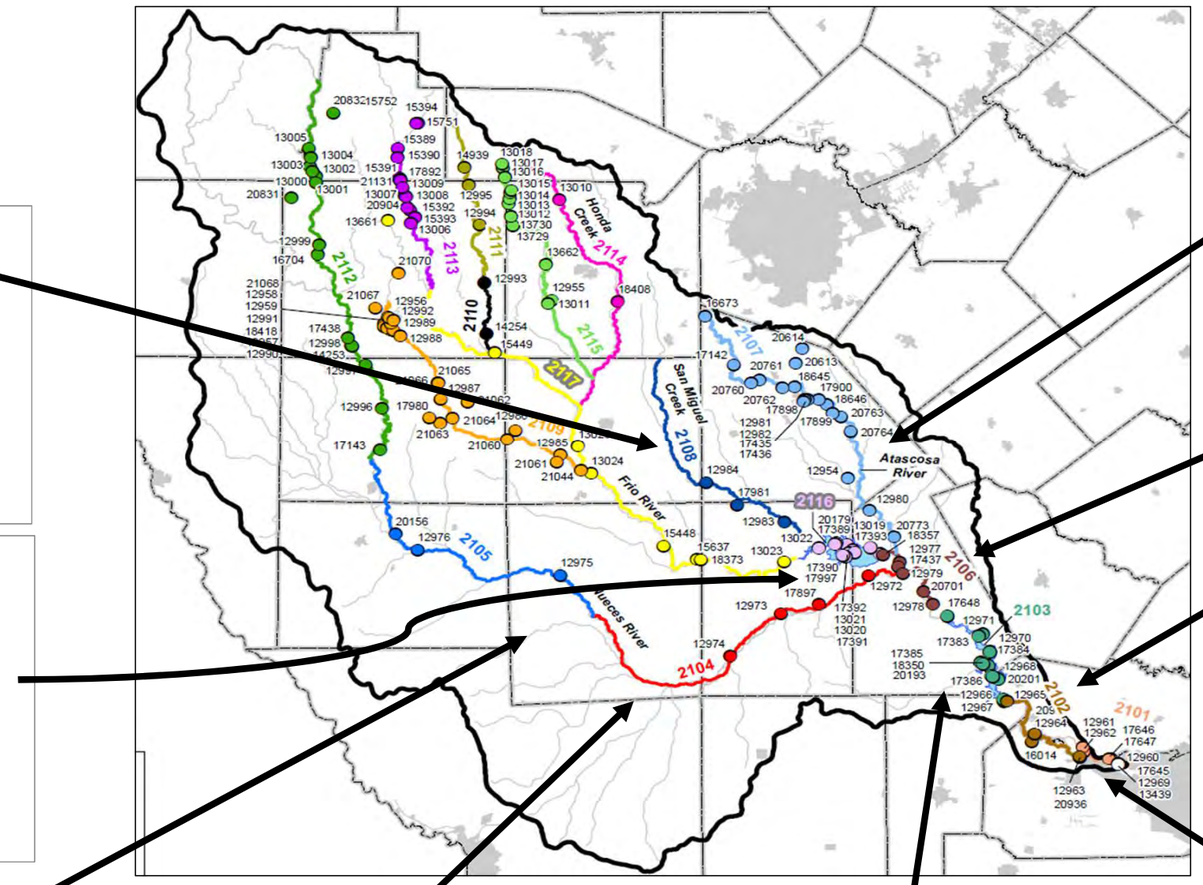
Basin 21: Nueces River Basin

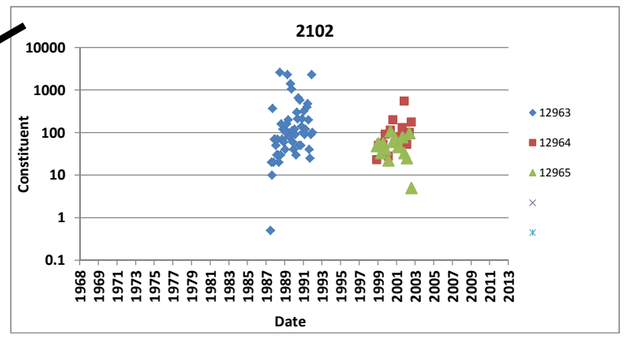
FECAL COLIFORM,MEMBR FILTER,M-FC BROTH, #/100ML vs Date

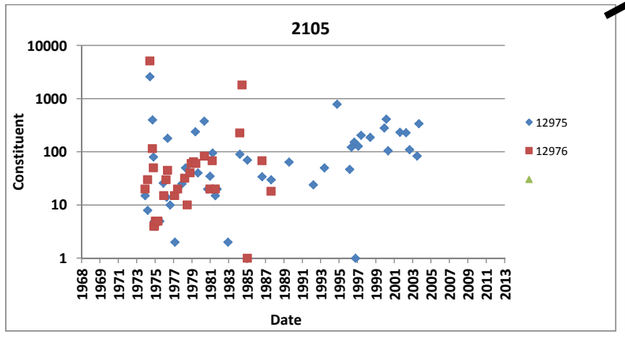


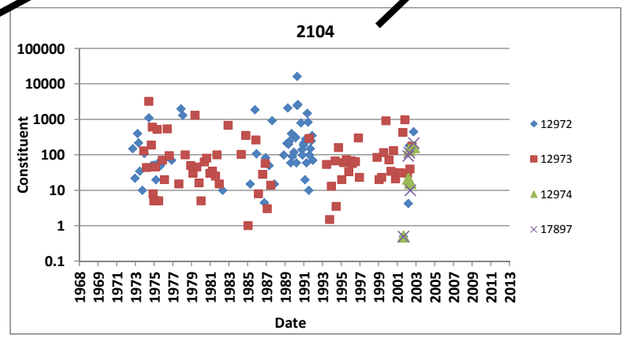


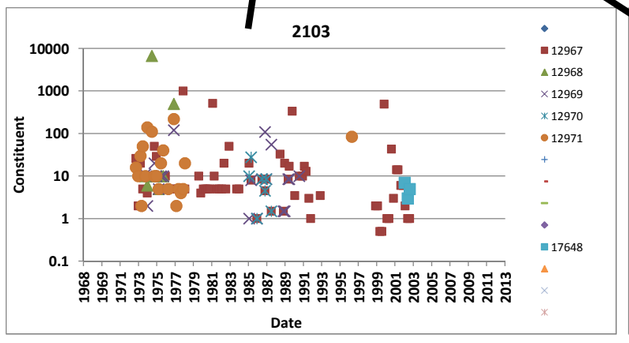


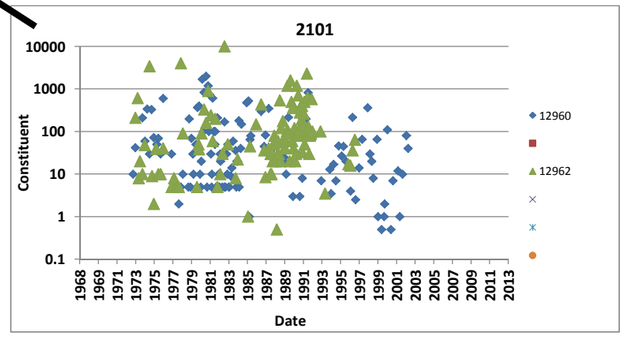




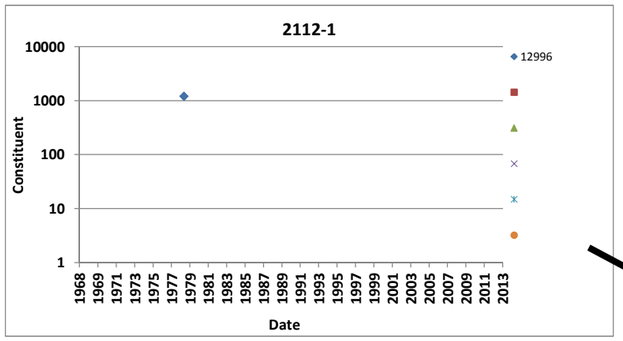


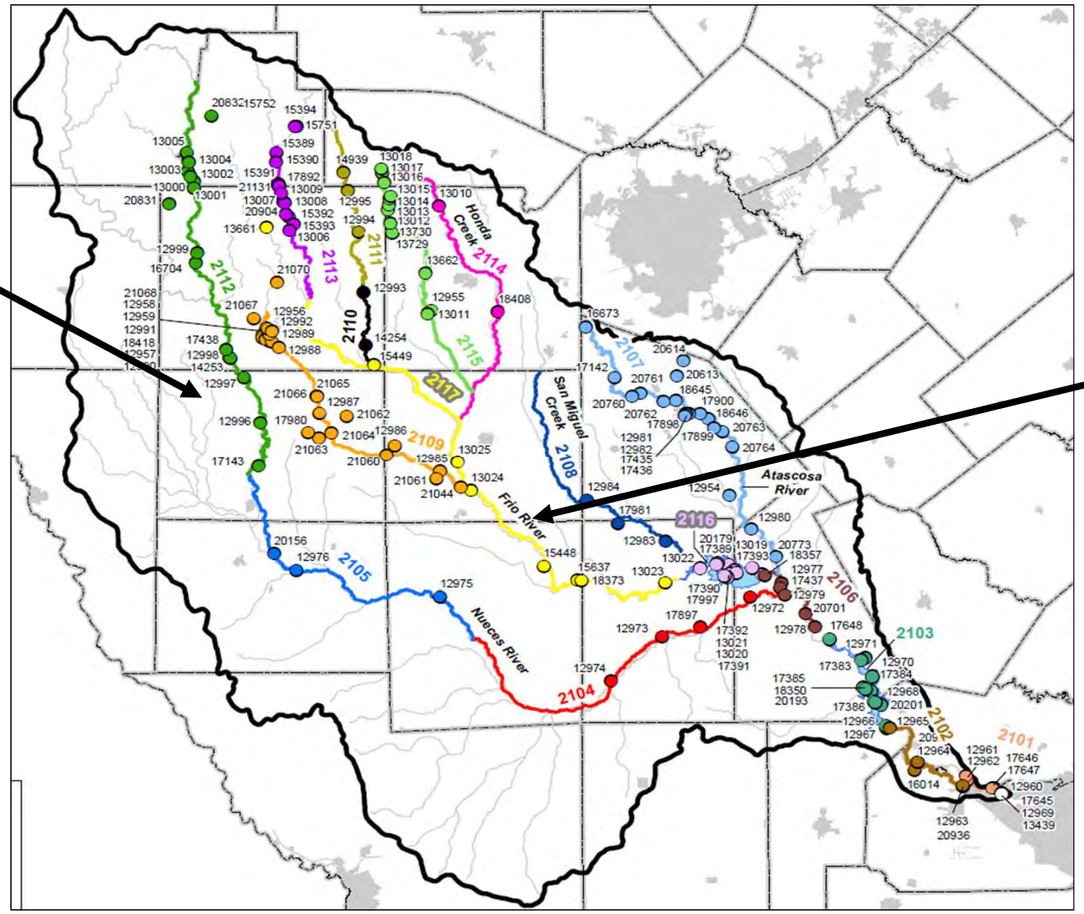


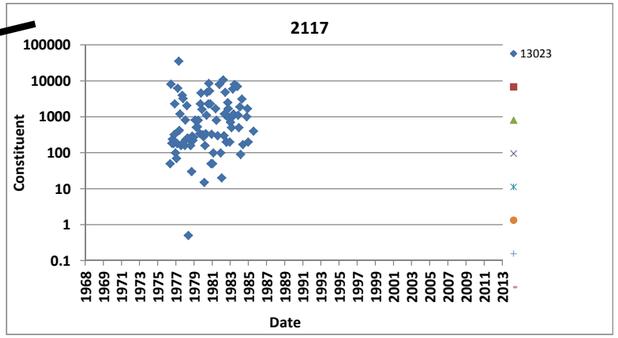




Basin 21: Nueces River Basin
COLIFORM,TOT,MEMBRANE FILTER,IMMED.M-ENDO, vs Date

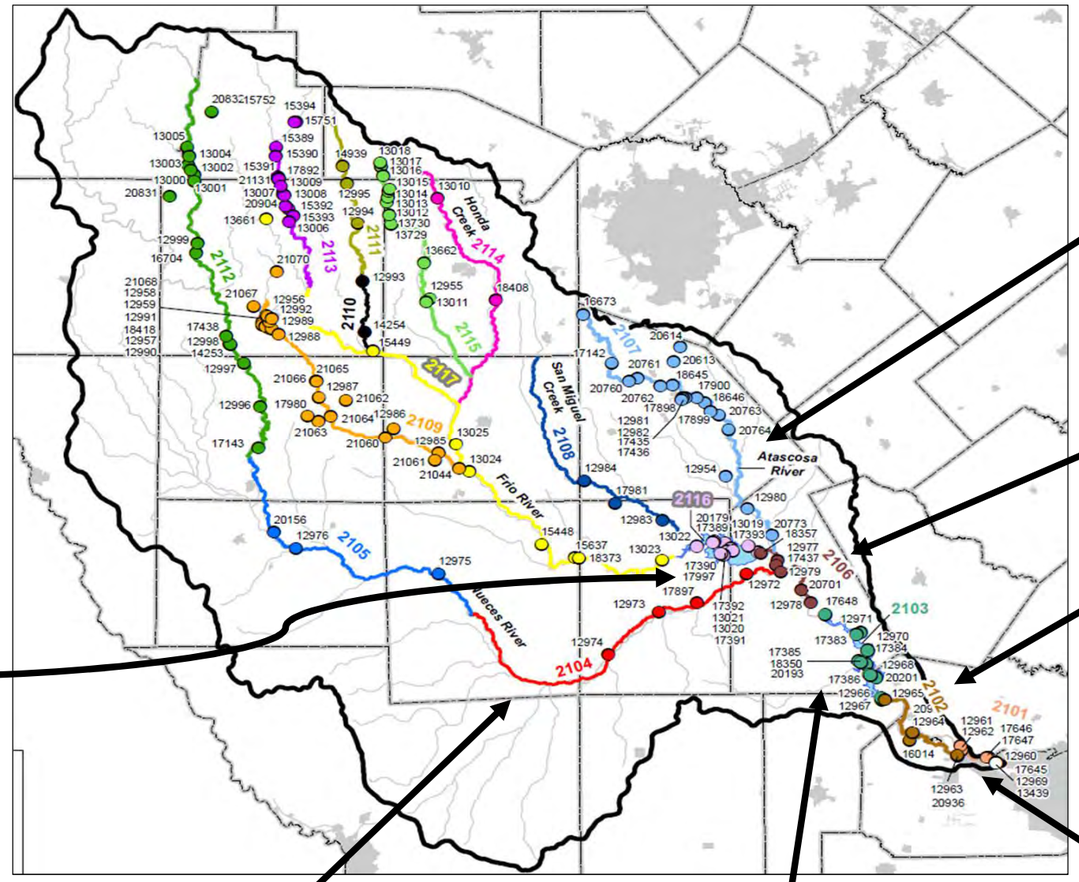


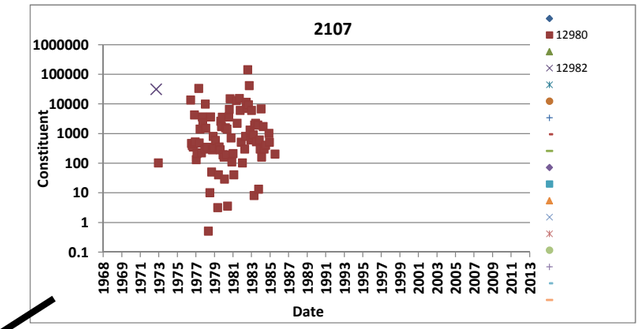


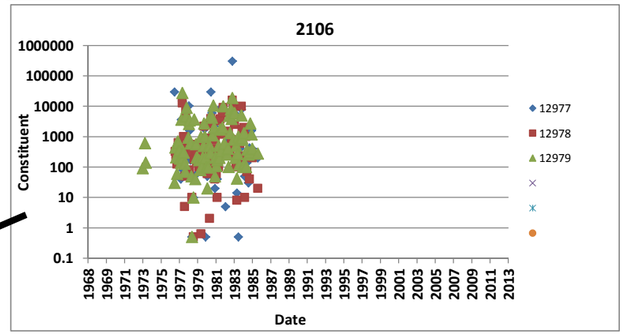


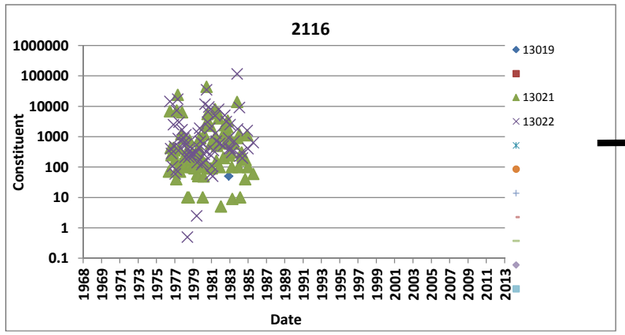
Basin 21: Nueces River Basin

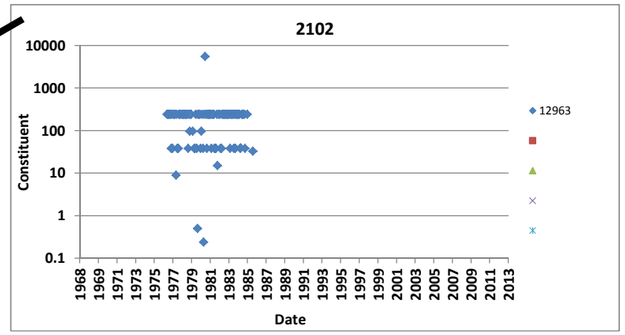
COLIFORM,TOT,MEMBRANE FILTER,IMMED.M-ENDO vs Date

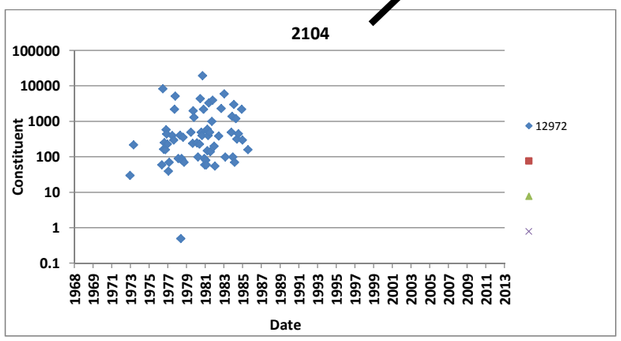


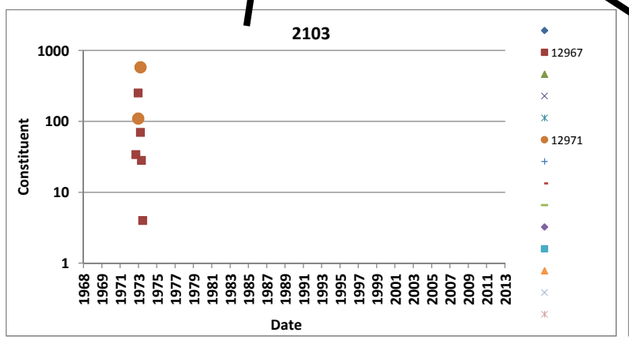


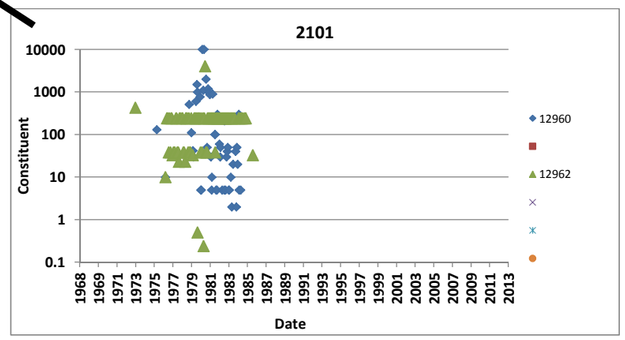




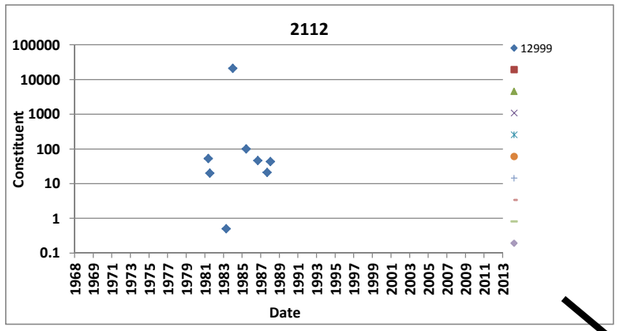


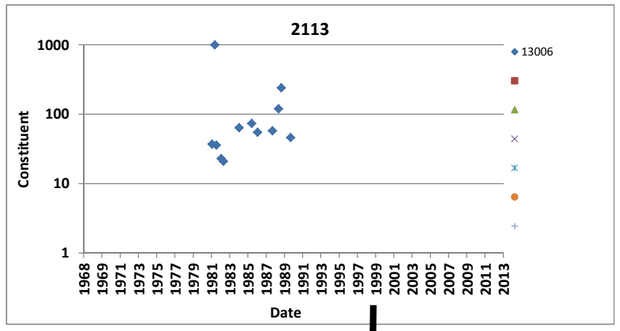


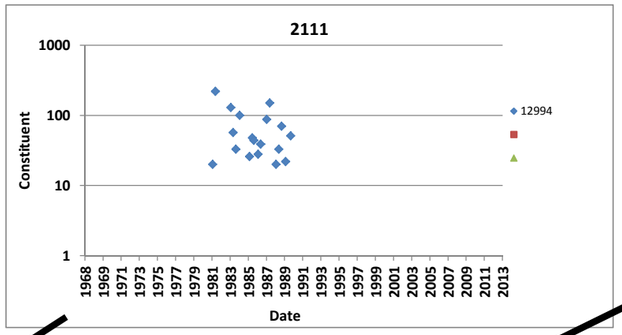


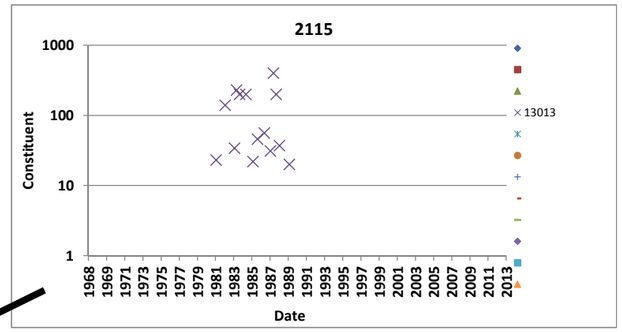


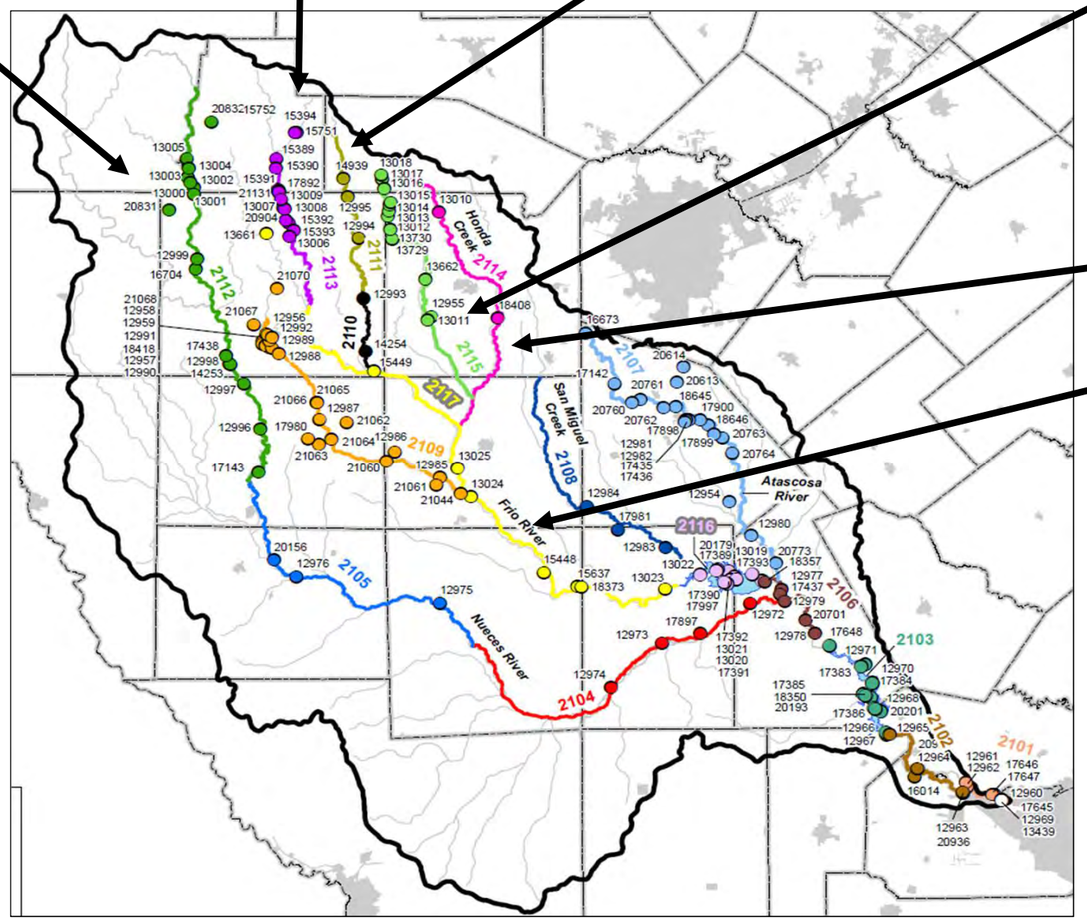
Basin 21: Nueces River Basin
FECAL COLIFORM, MF, M-FC, 0.7 UM vs Date

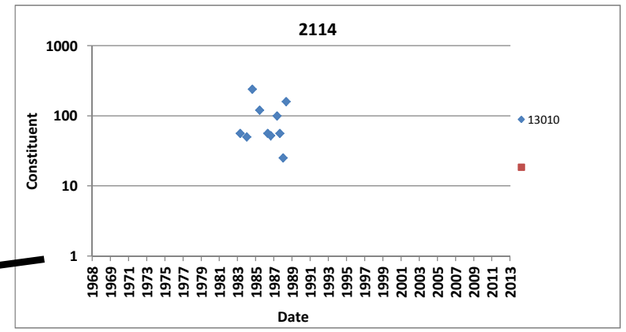


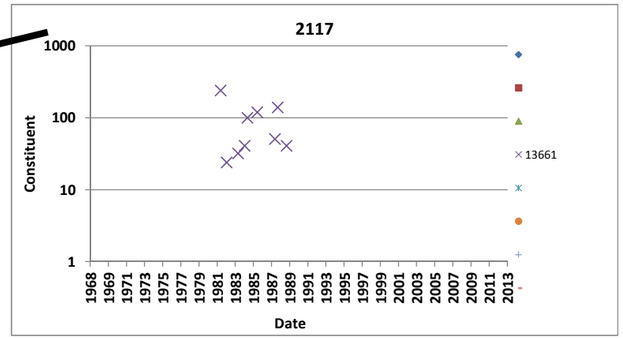




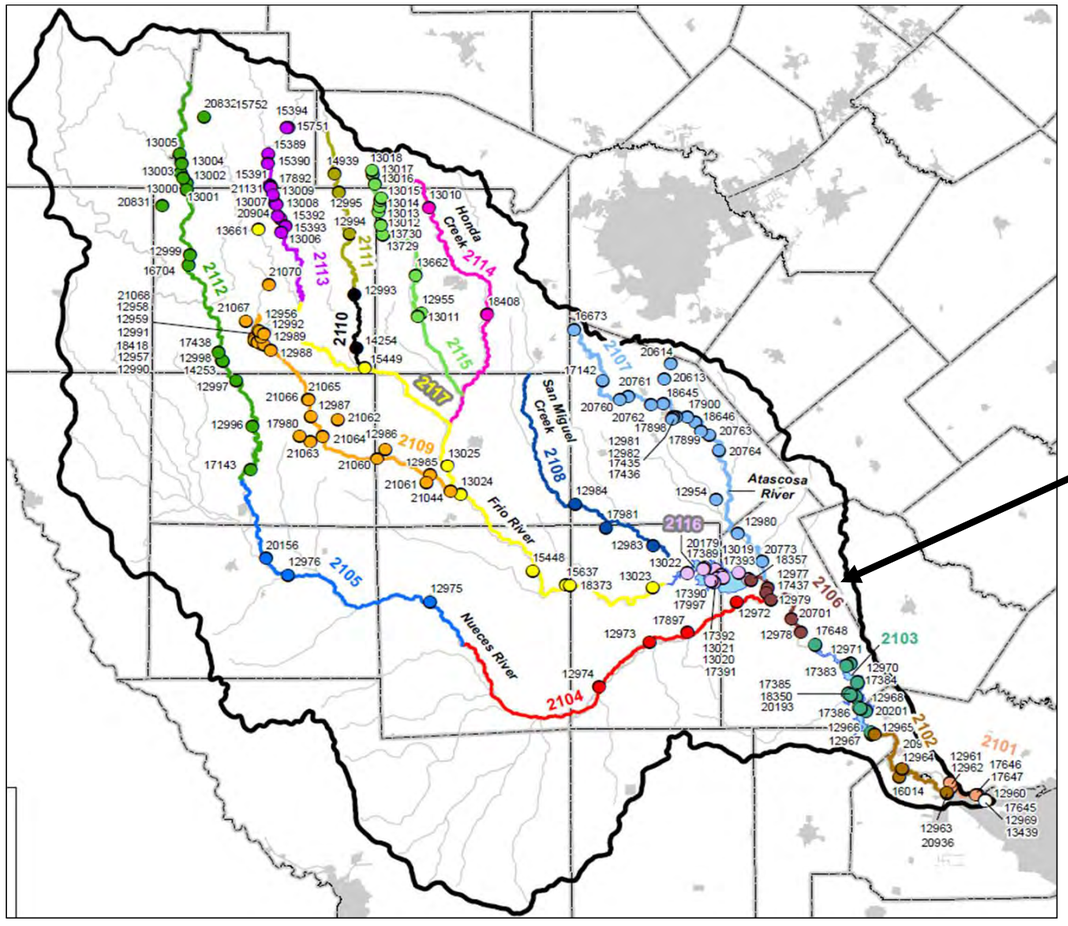






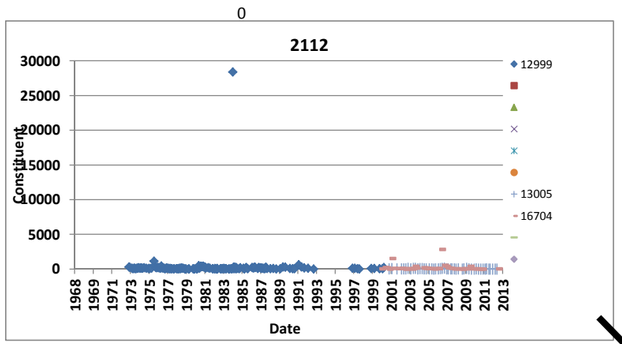


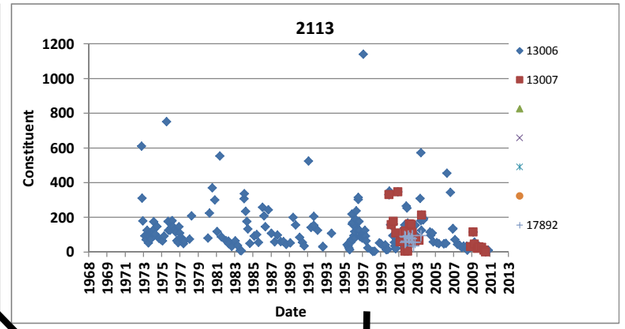
Basin 21: Nueces River Basin
FECAL COLIFORM, MF, M-FC, 0.7 UM vs Date

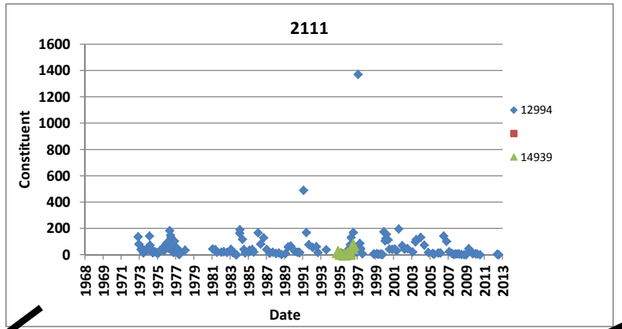


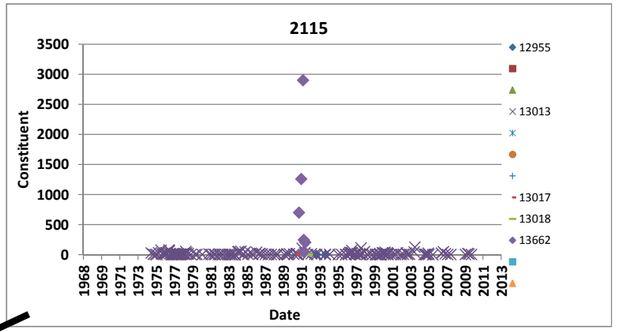
Basin 21: Nueces River

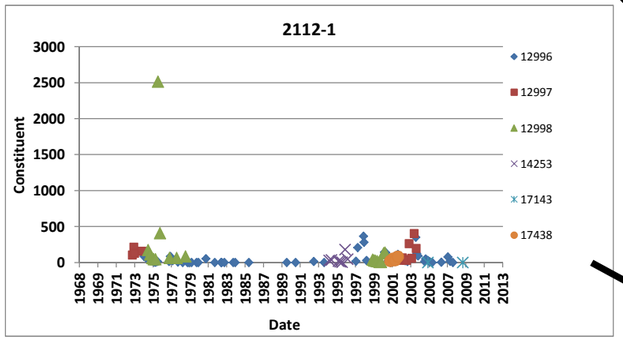
FLOW STREAM, INSTANTANEOUS (CUBIC FEET PER SEC) vs Date

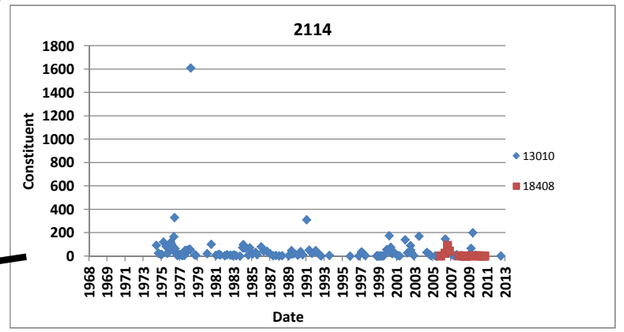


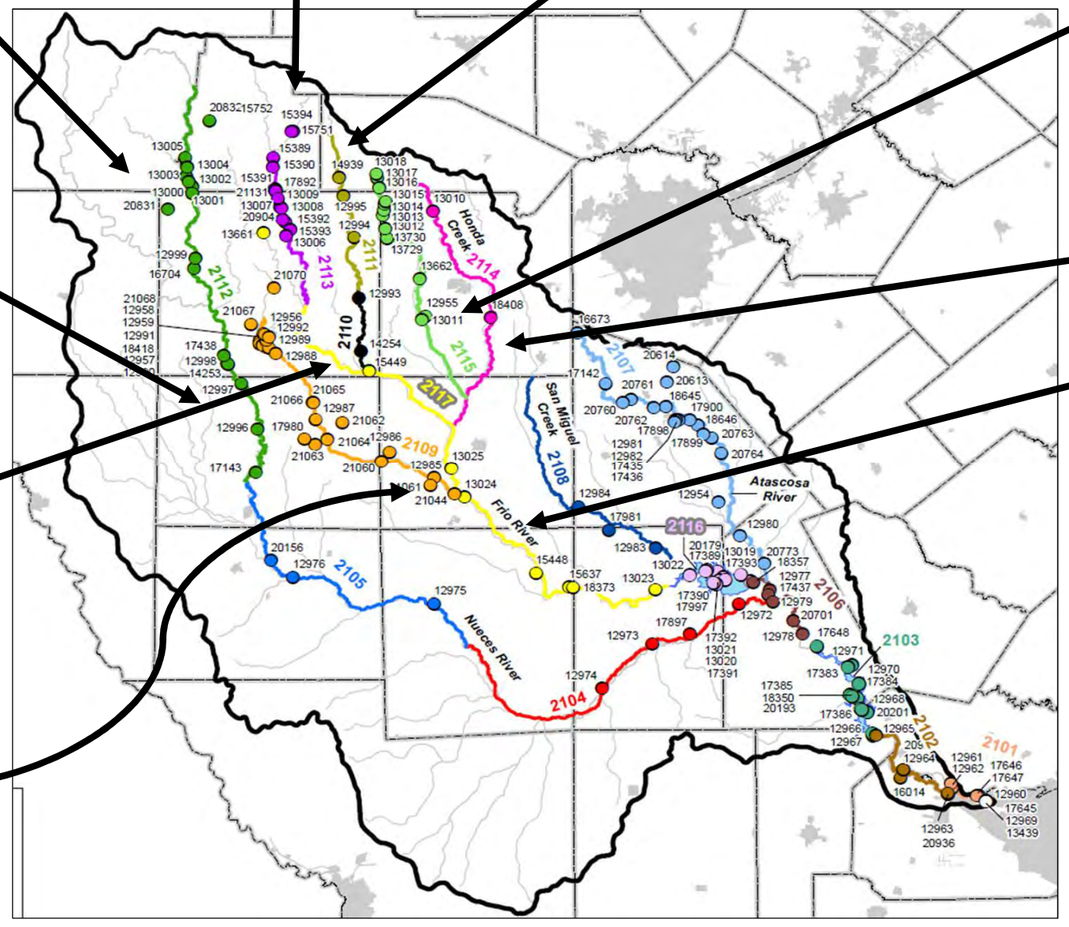


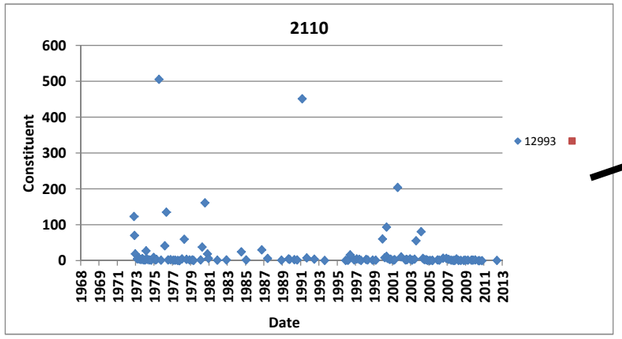


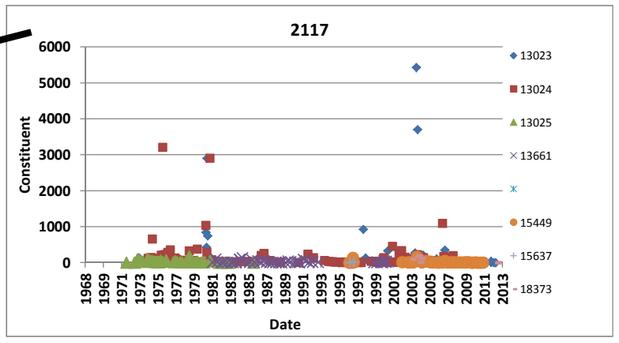


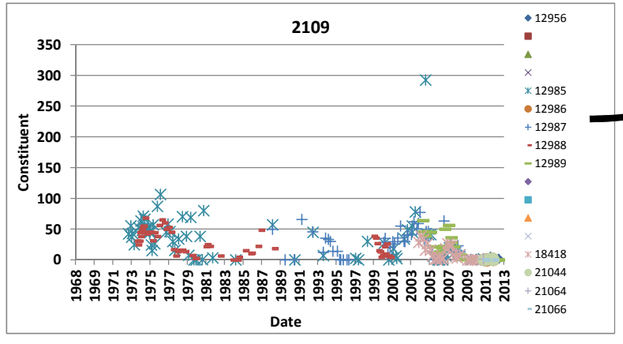






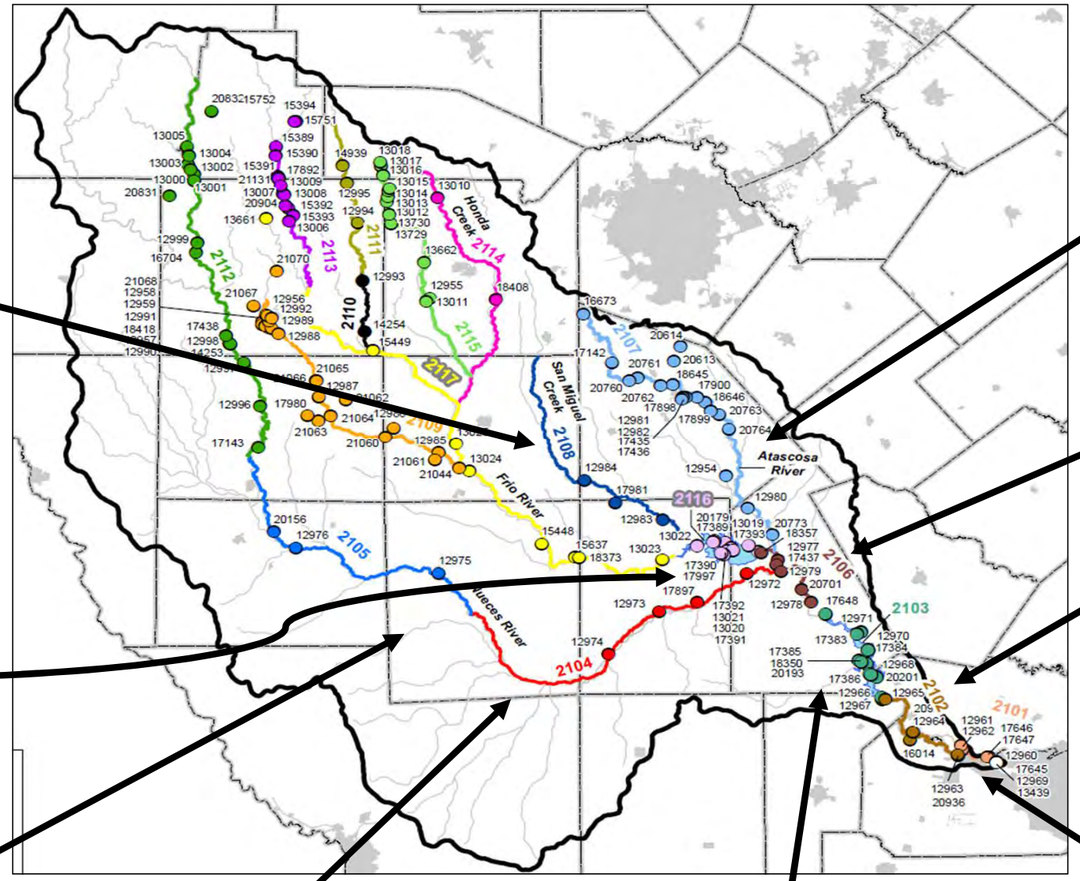


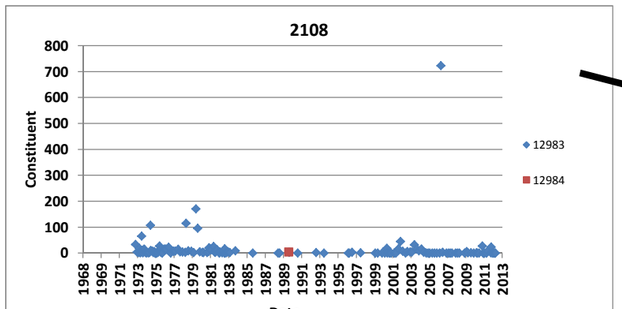


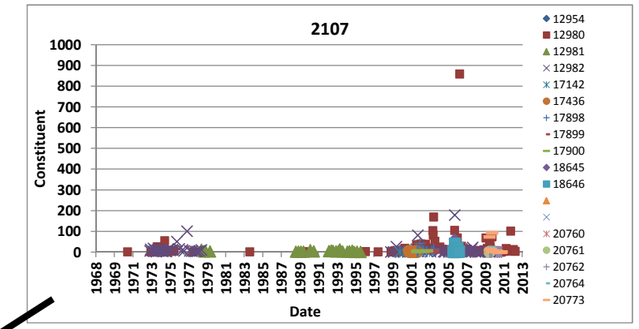


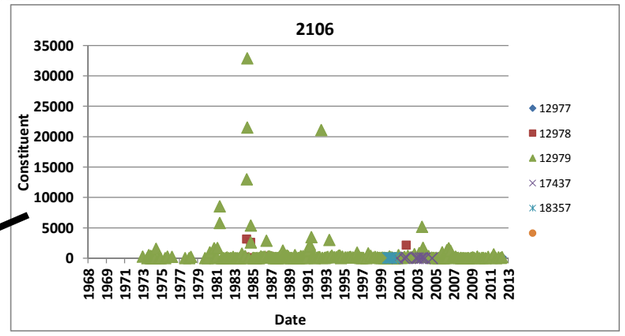
Basin 21: Nueces River

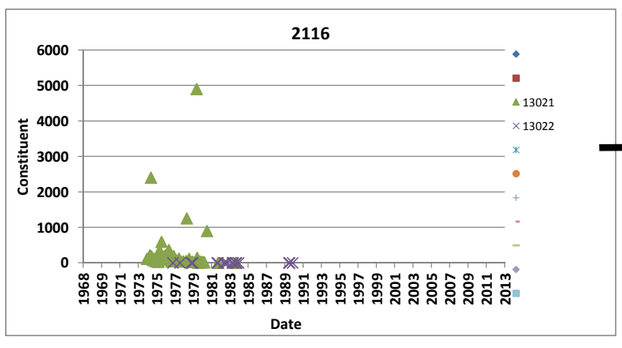
FLOW STREAM, INSTANTANEOUS (CUBIC FEET PER SEC) vs Date

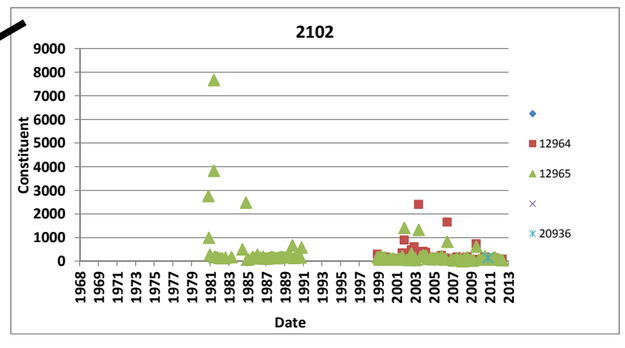


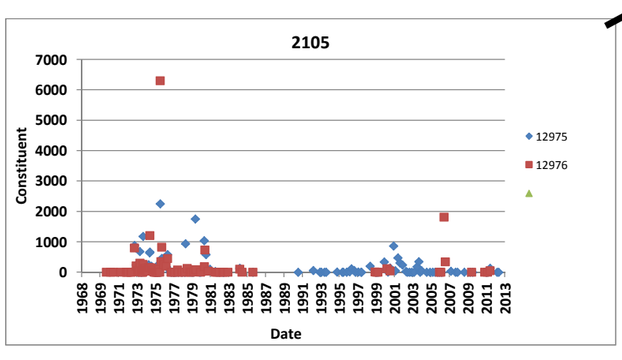


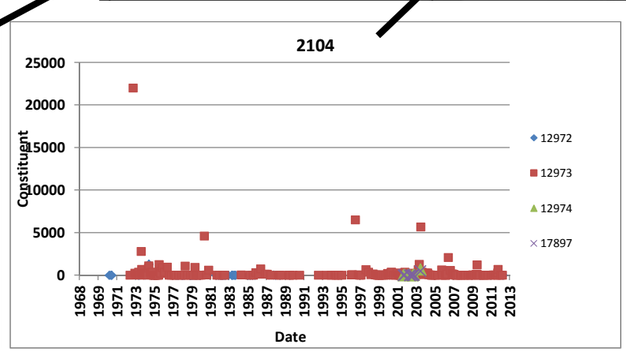


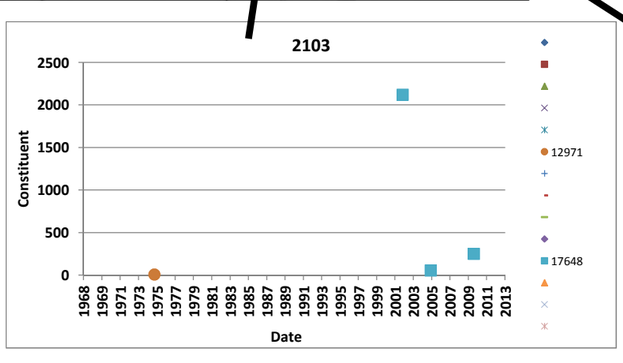


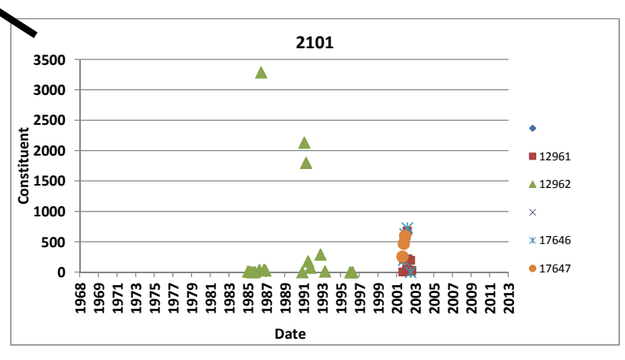






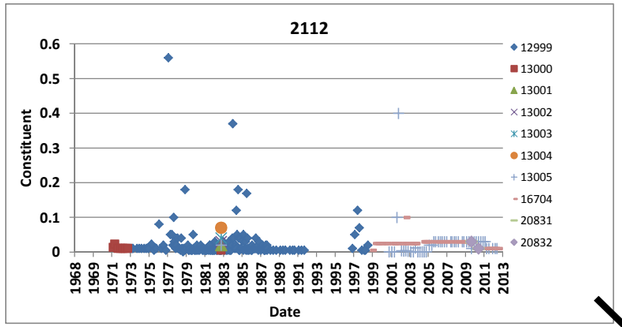


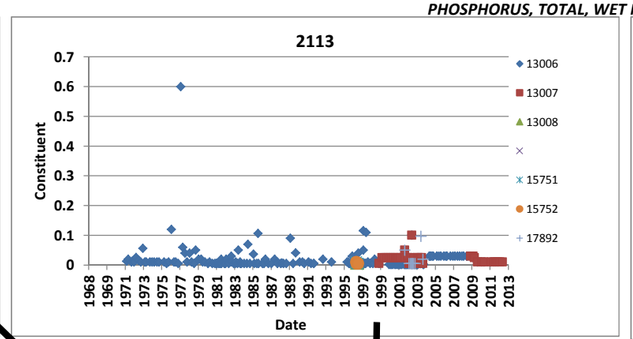


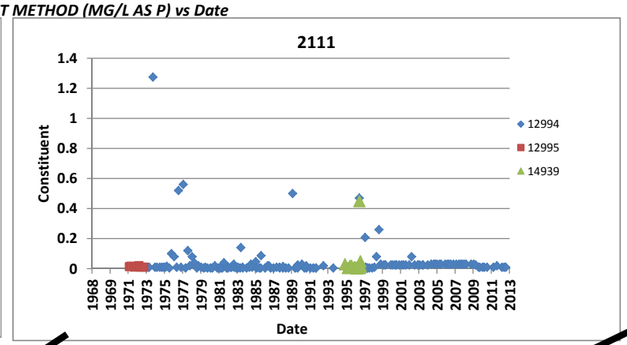


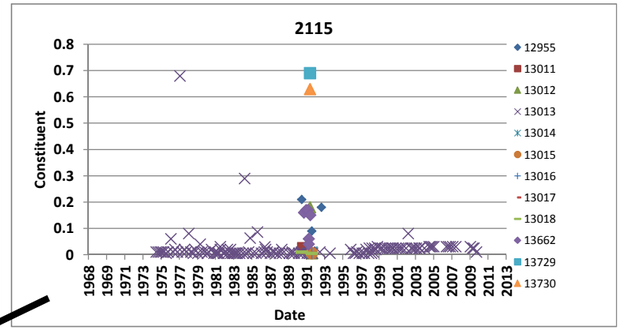
Basin 21: Nueces River

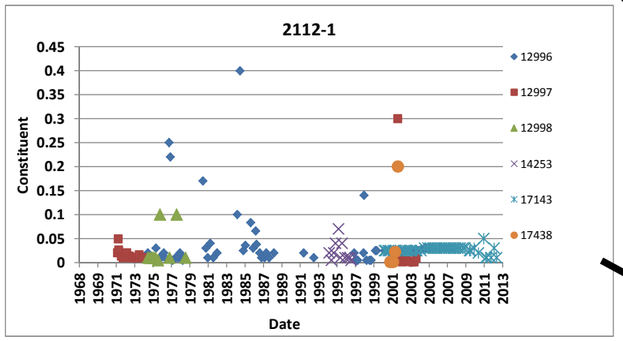
PHOSPHORUS, TOTAL, WET METHOD (MG/L AS P) vs Date

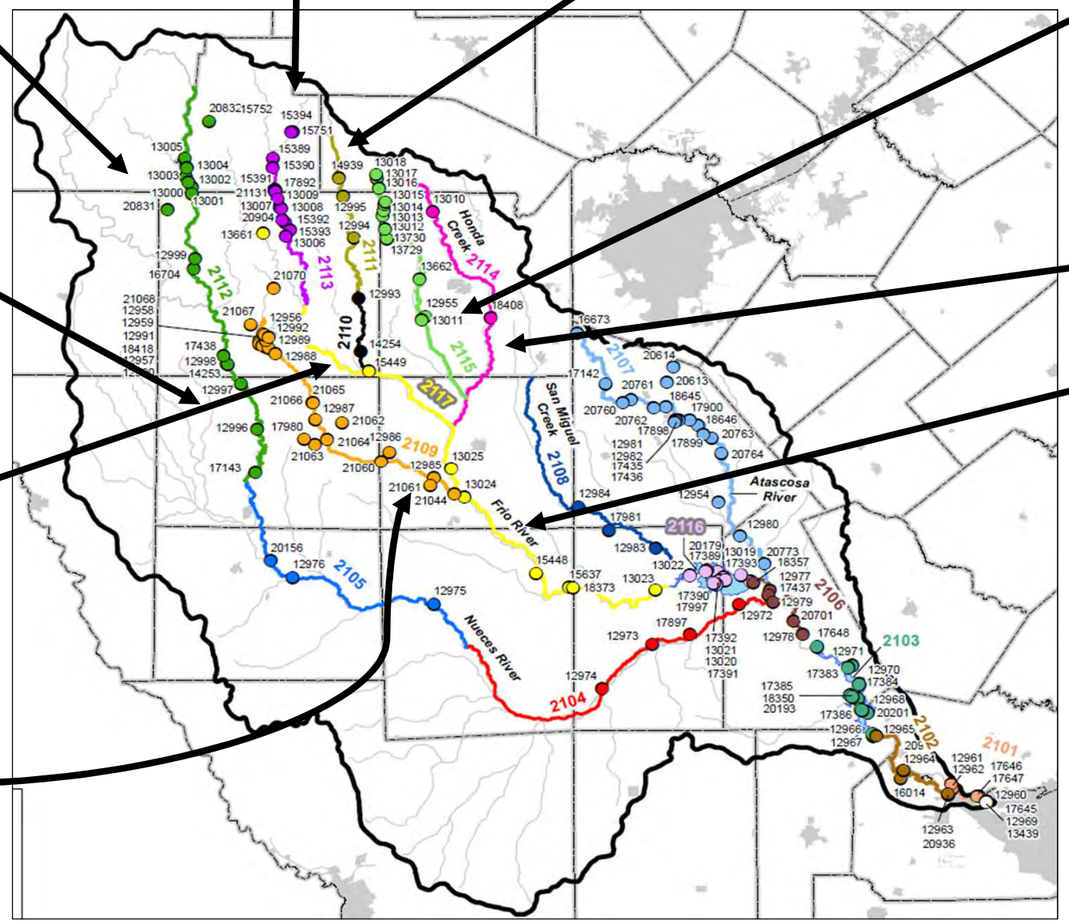


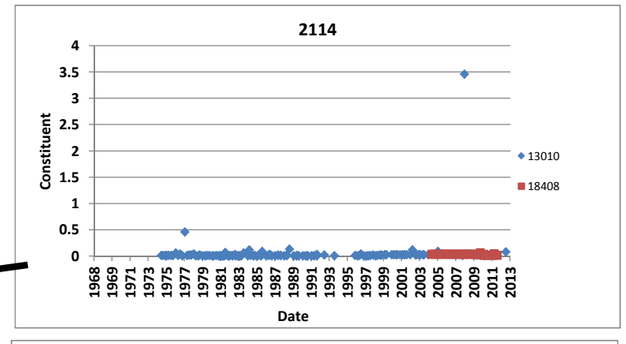


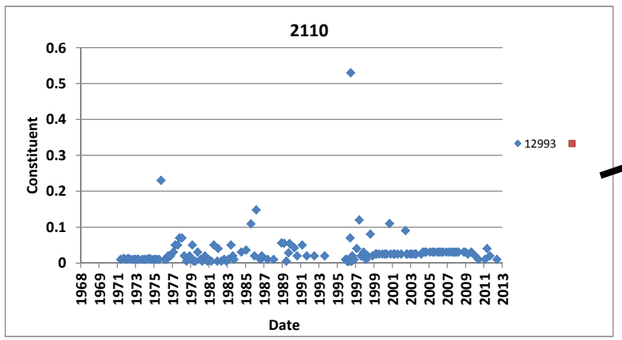


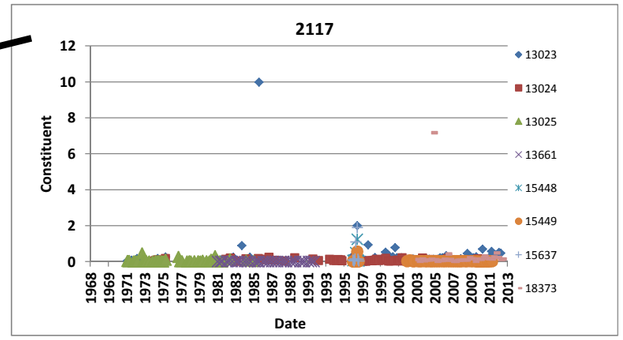


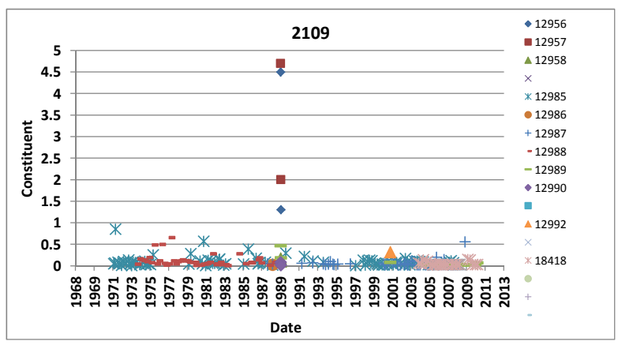




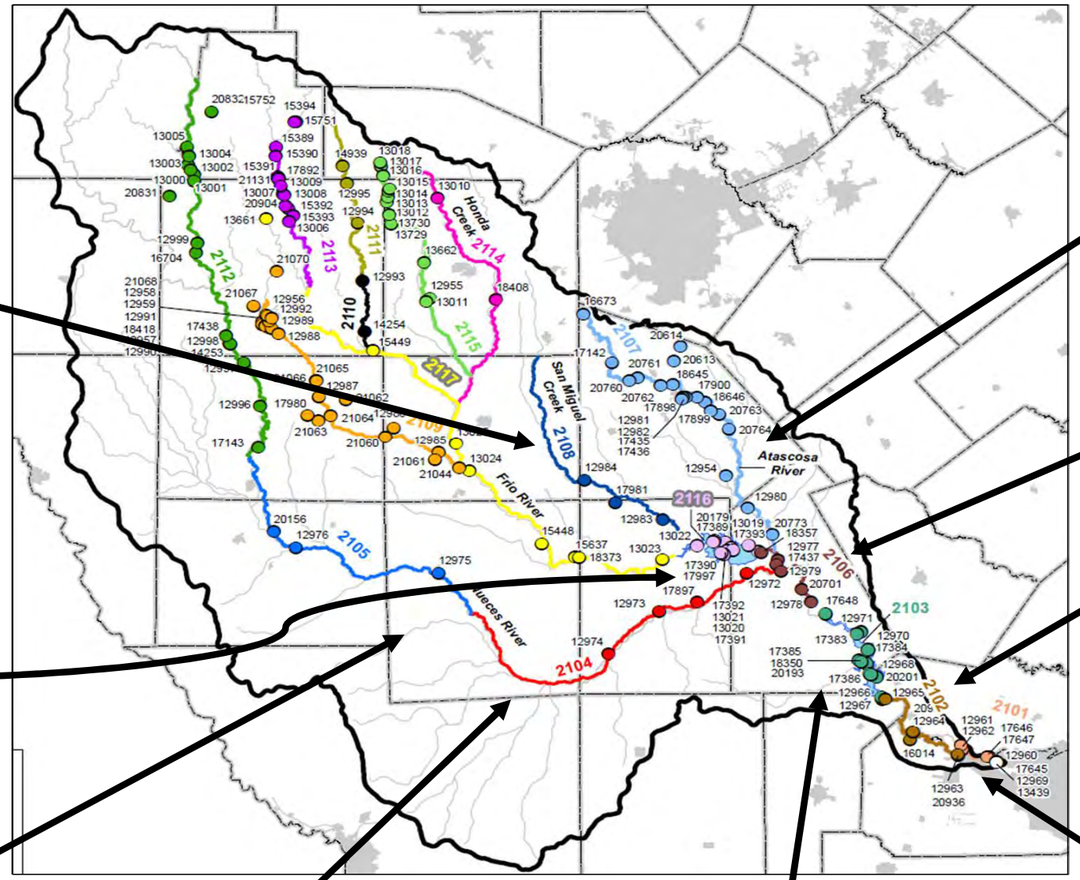


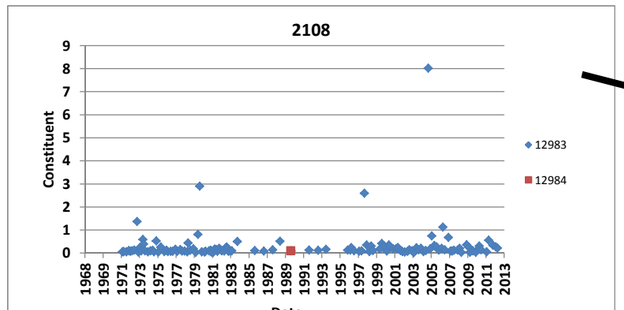


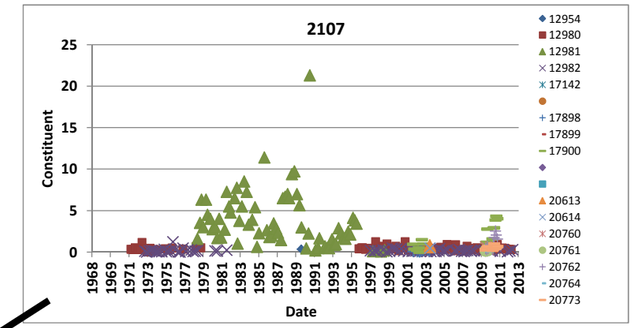


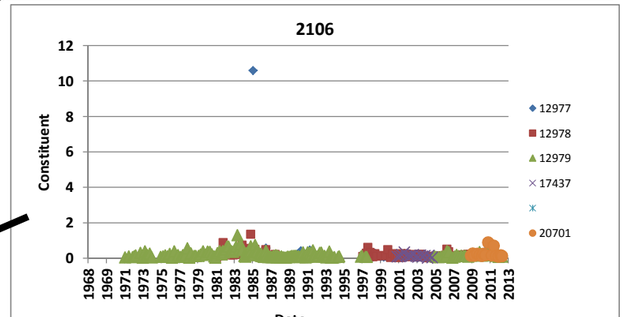


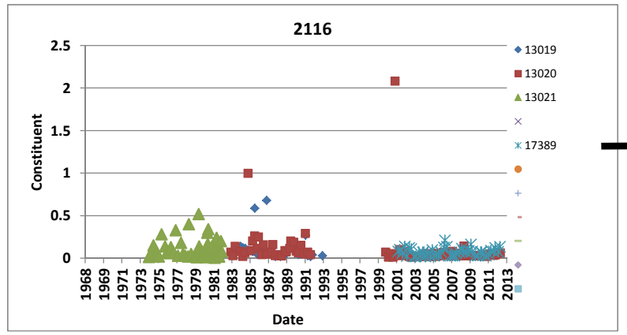
Basin 21: Nueces River
PHOSPHORUS, TOTAL, WET METHOD (MG/L AS P) vs Date

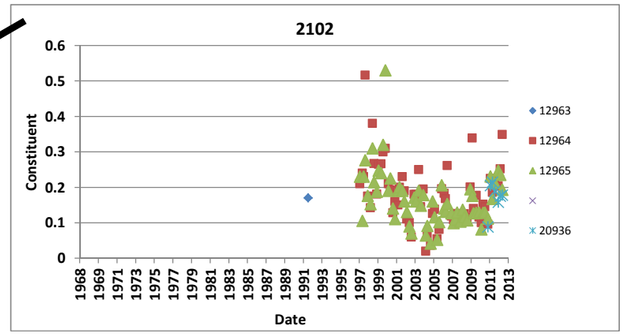


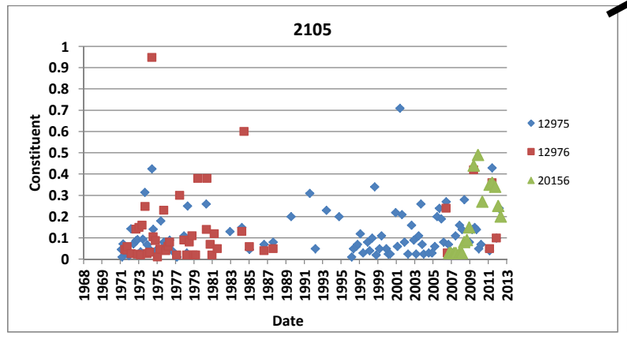


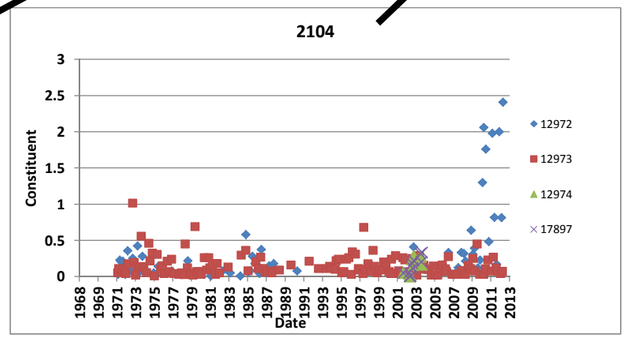


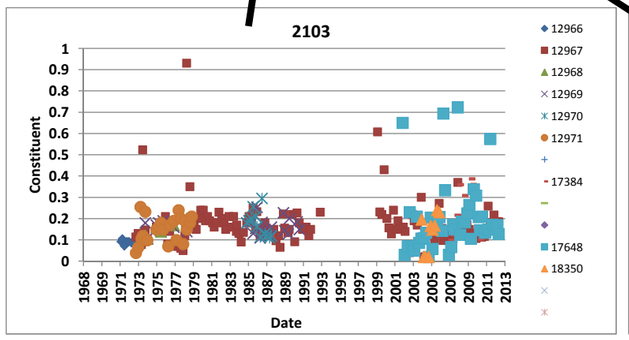


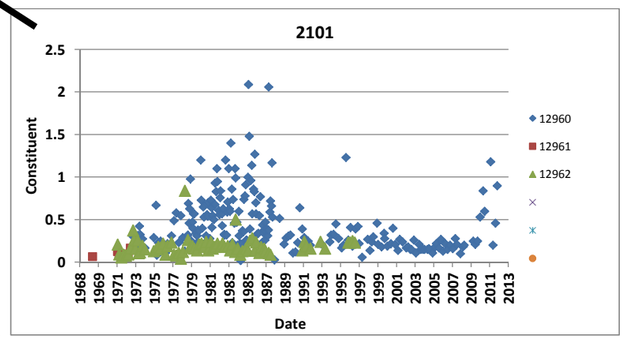






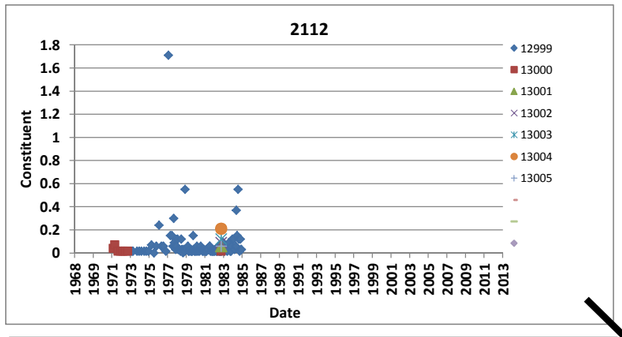


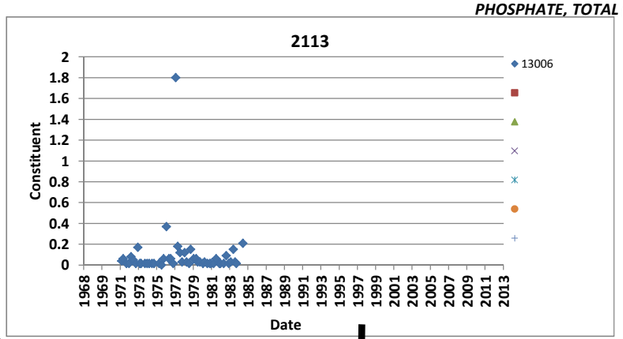


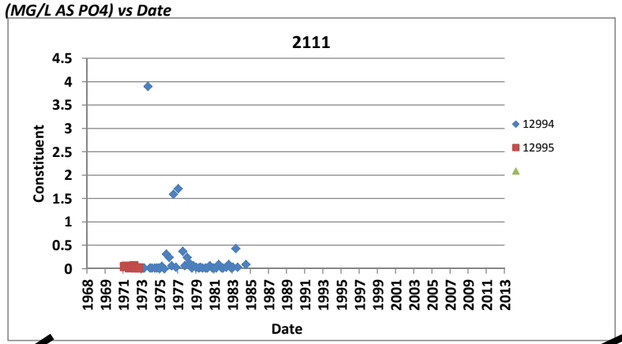


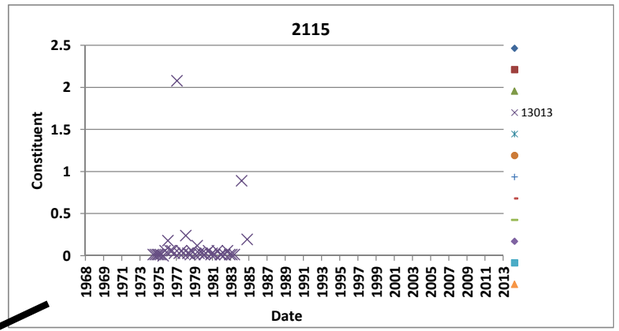
Basin 21: Nueces River

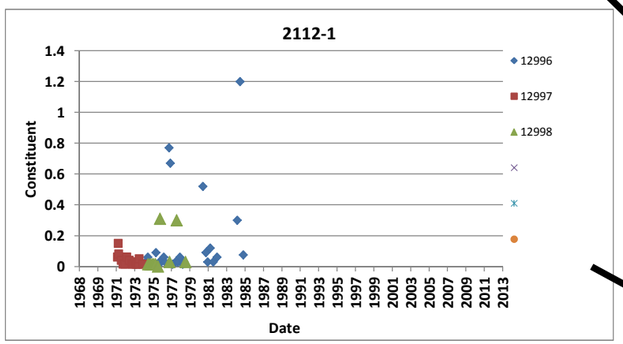
PHOSPHATE, TOTAL (MG/L AS PO4) vs Date

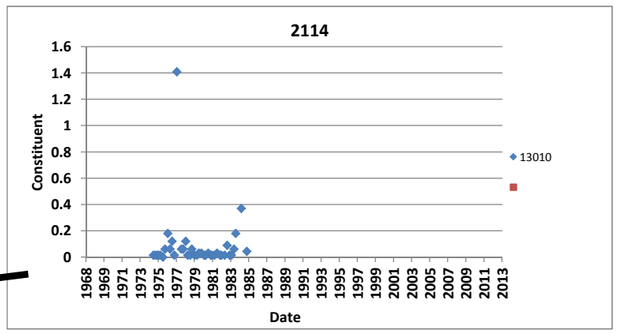


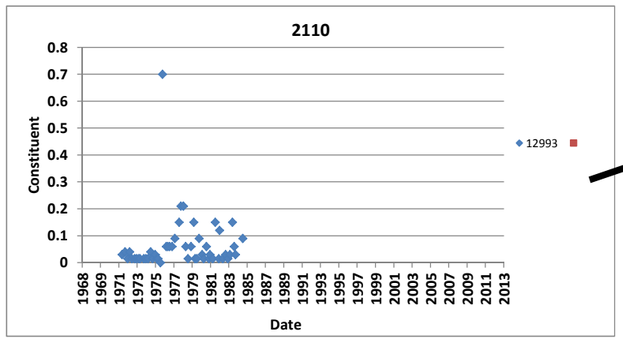


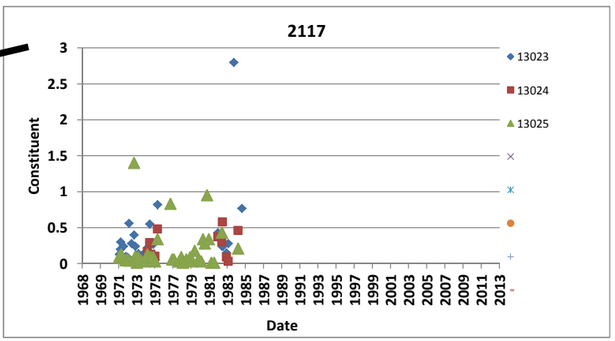


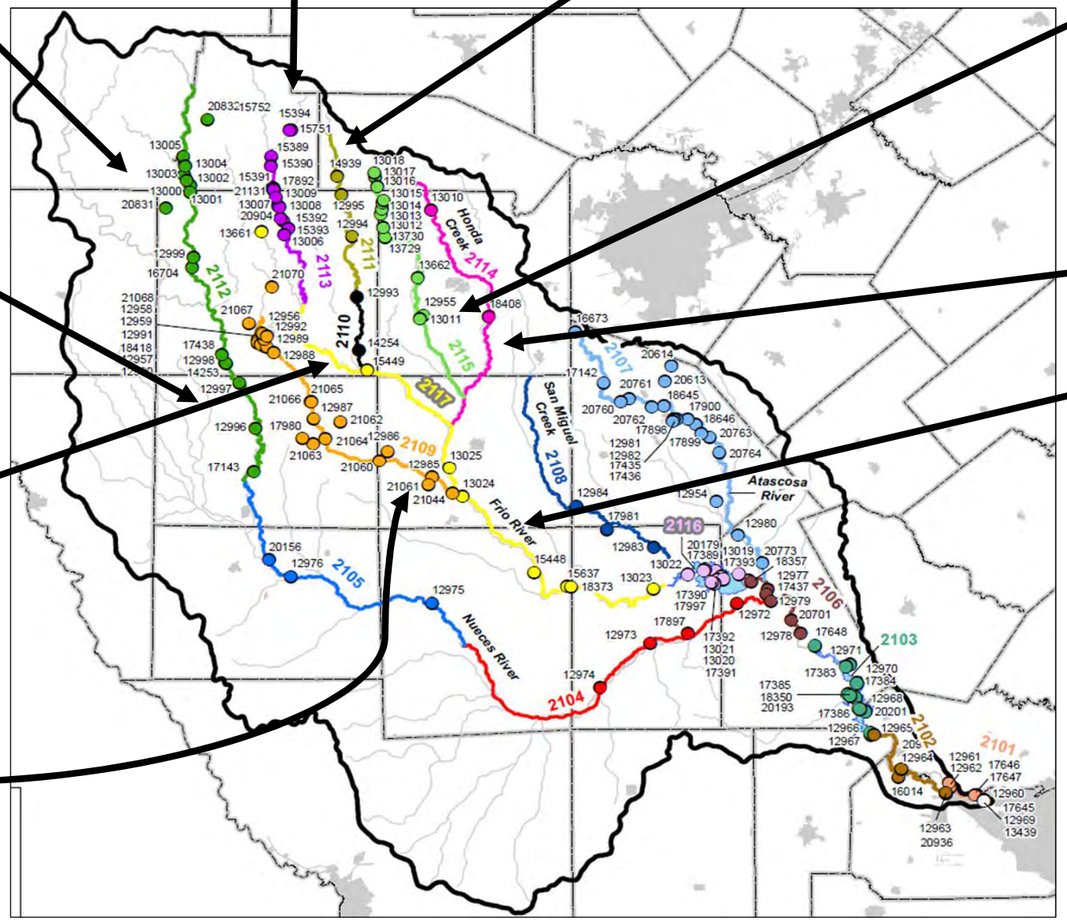


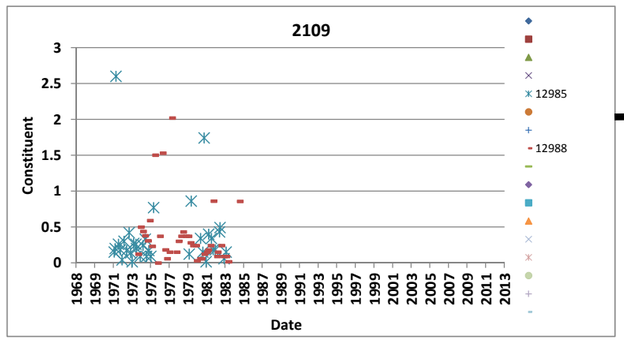




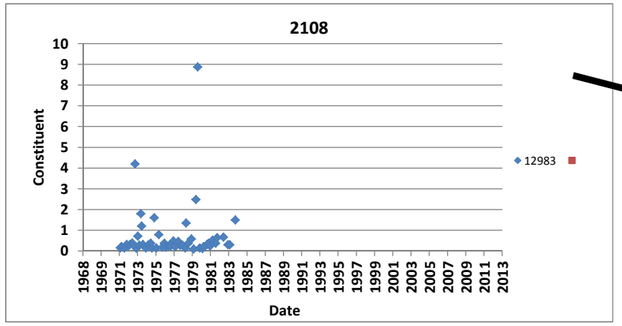


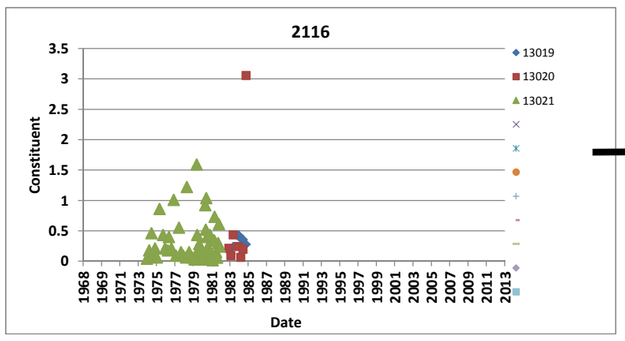


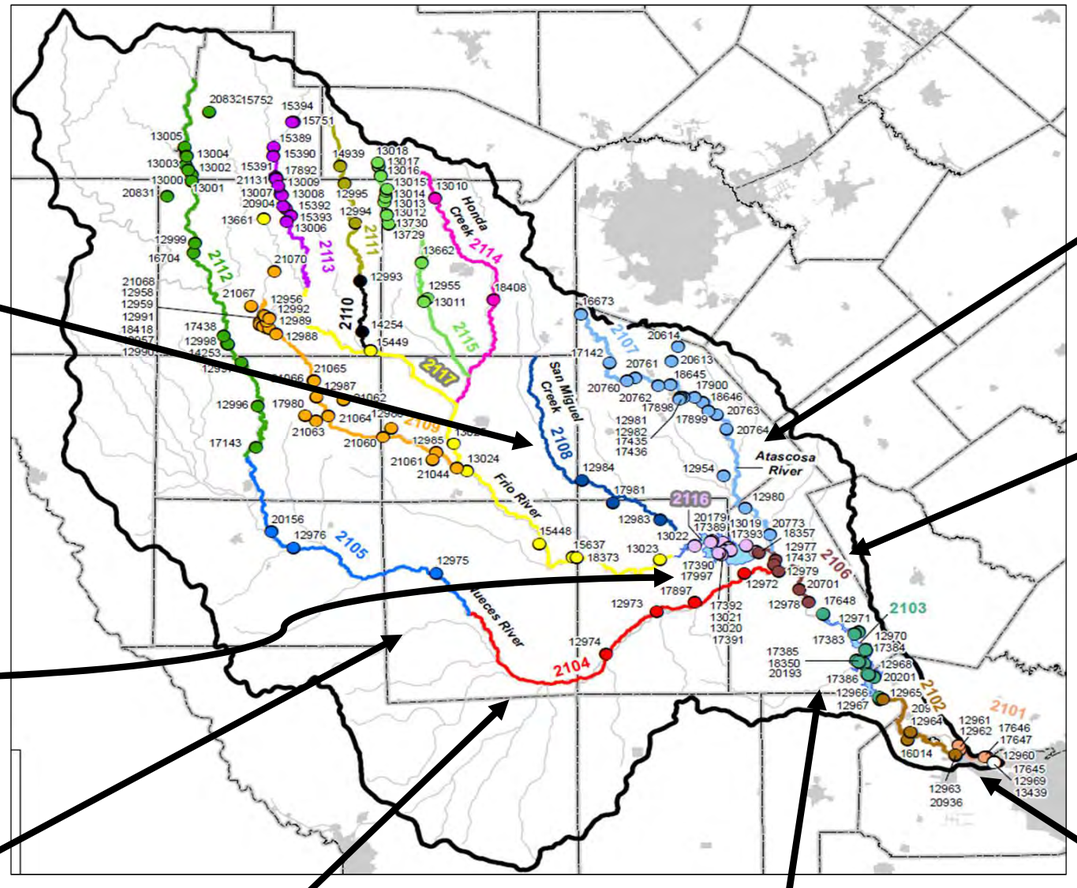


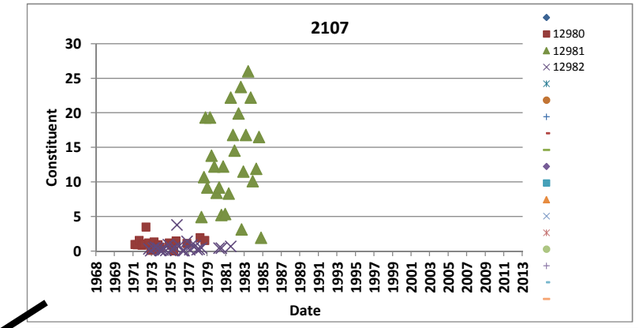


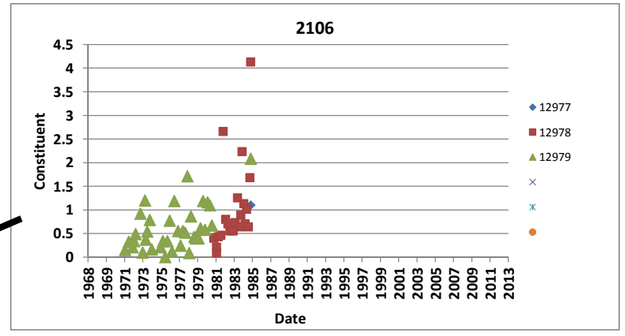
Basin 21: Nueces River
PHOSPHATE, TOTAL (MG/L AS PO4) vs Date

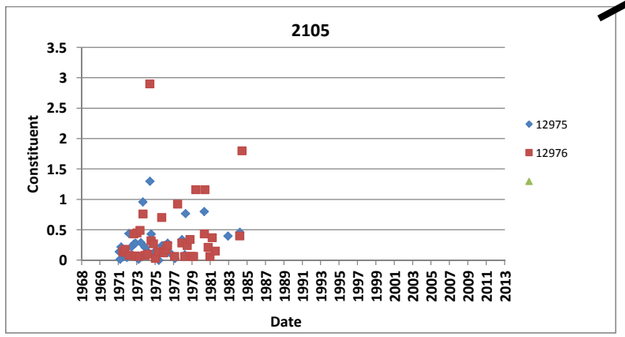


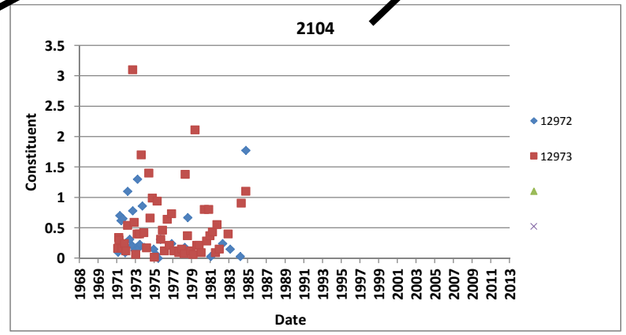


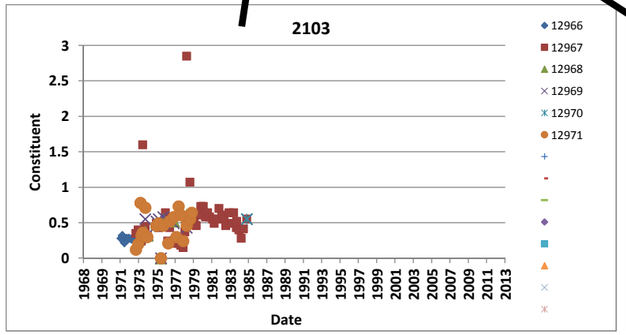


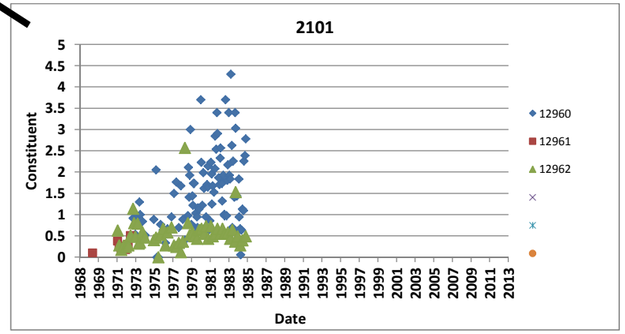






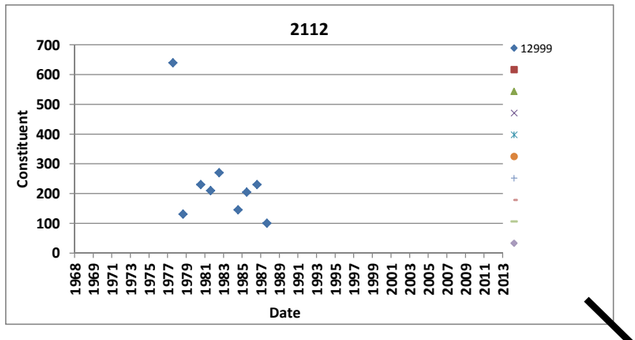


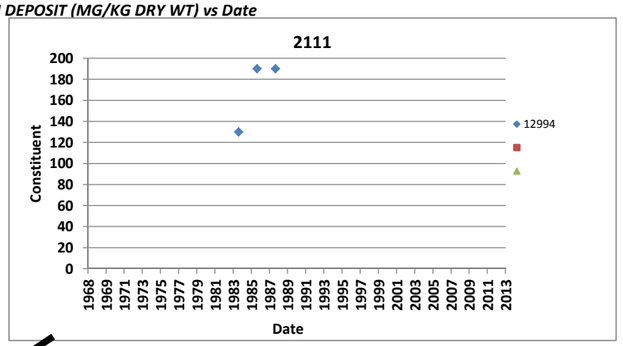


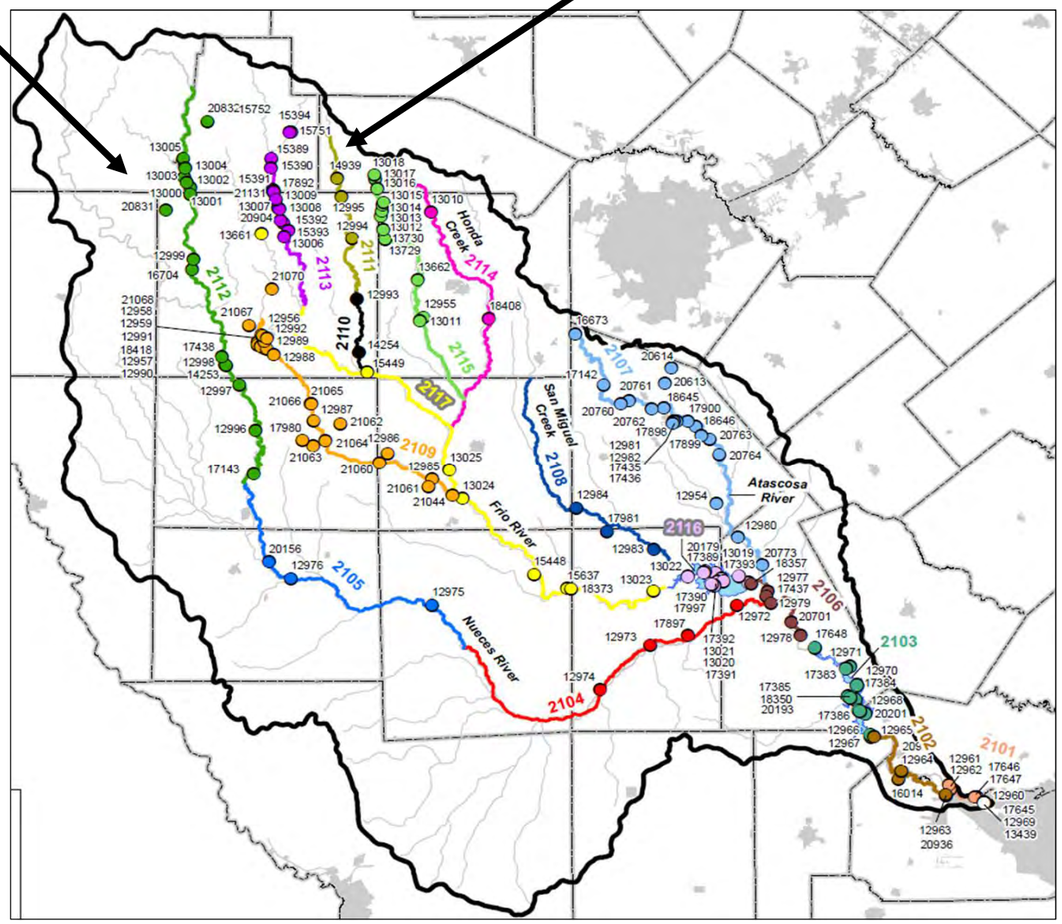


Basin 21: Nueces River

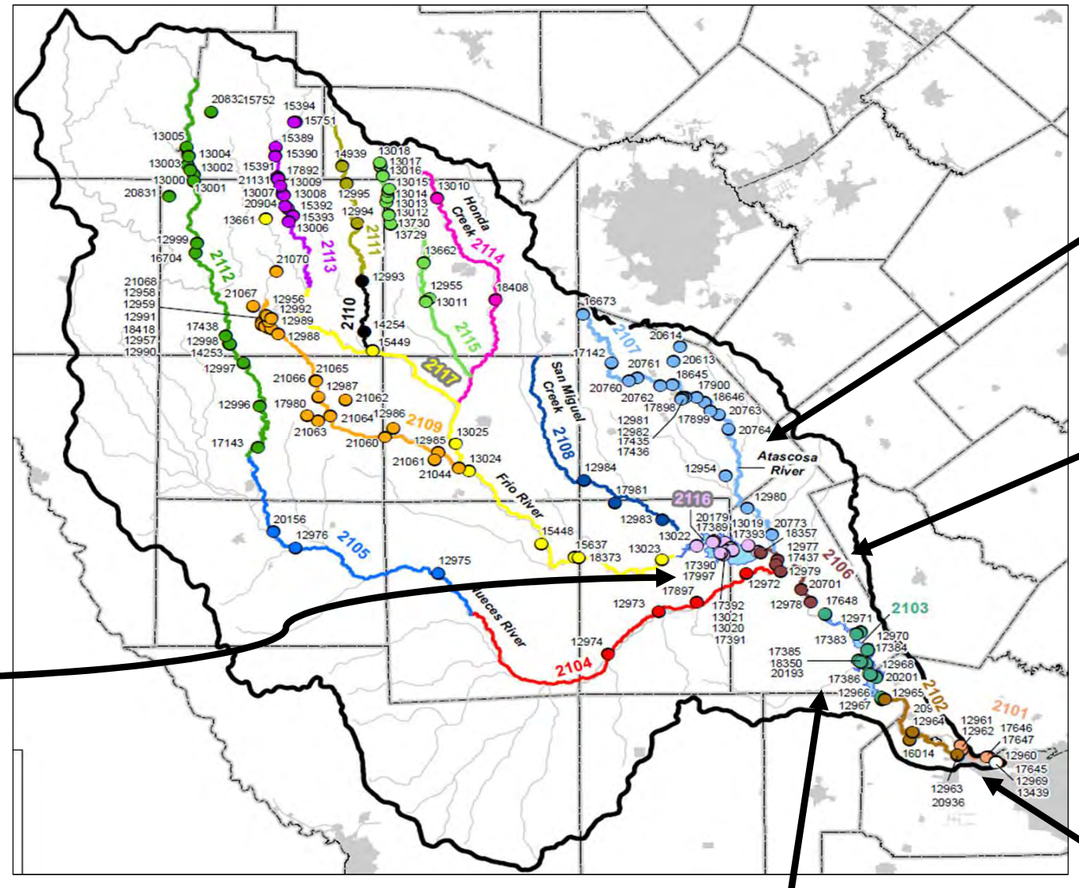
PHOSPHORUS,TOTAL, BOTTOM DEPOSIT (MG/KG DRY WT) vs Date

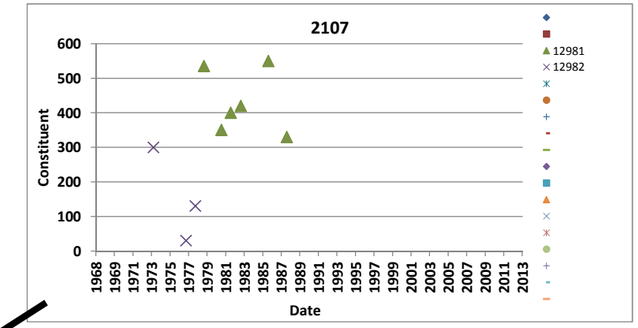


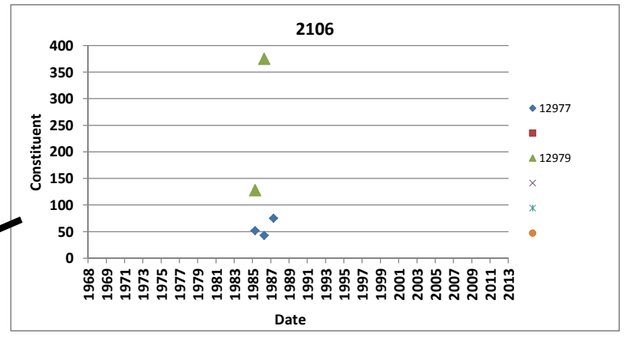


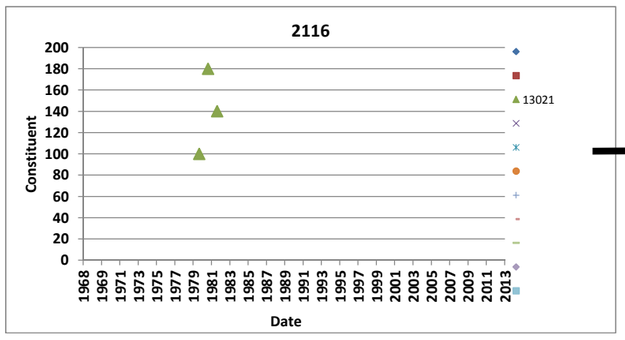


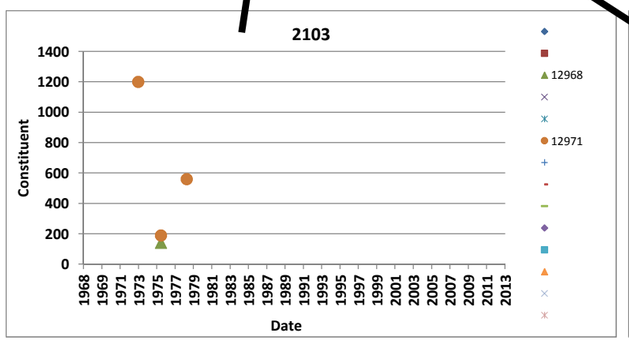
Basin 21: Nueces River
PHOSPHORUS,TOTAL, BOTTOM DEPOSIT (MG/KG DRY WT) vs Date

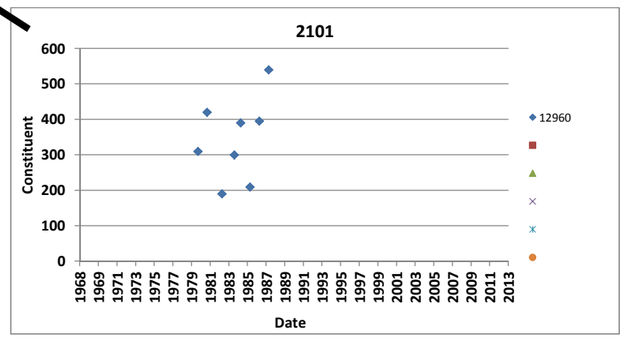




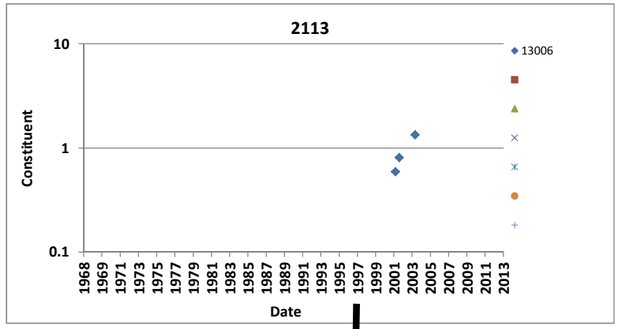


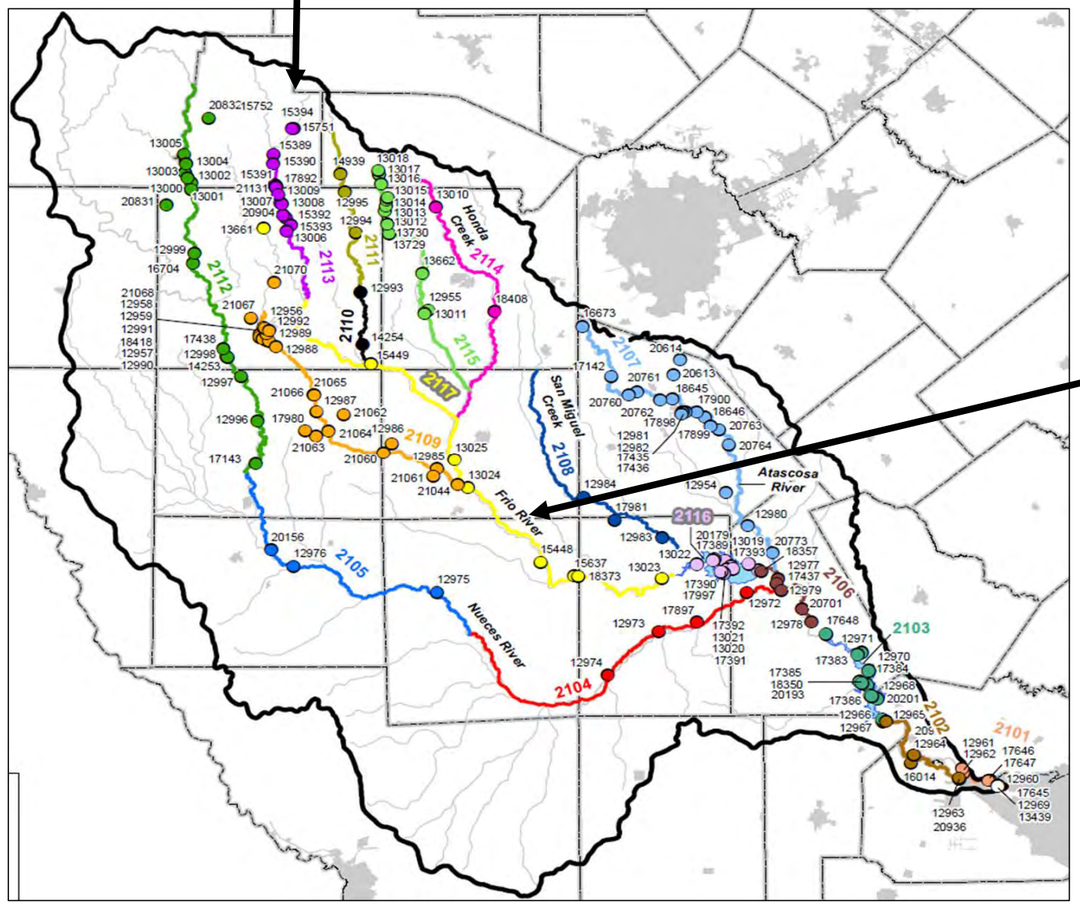


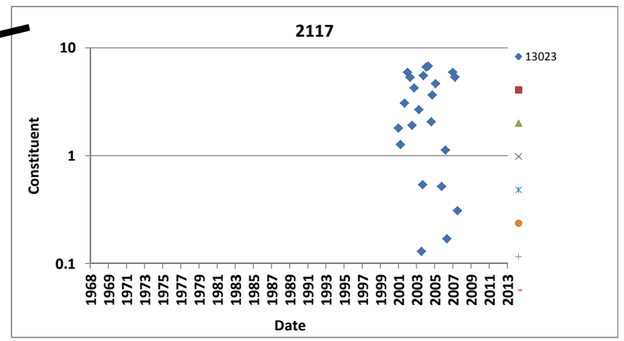




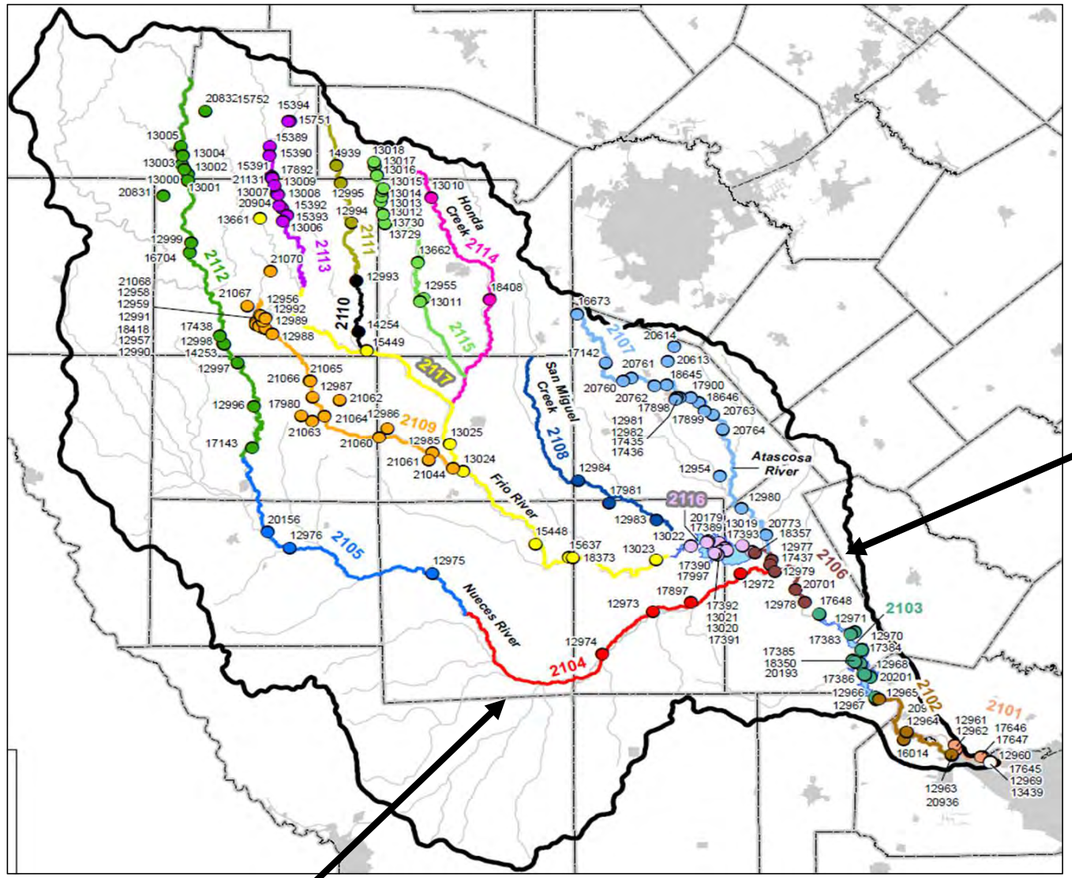
Basin 21: Nueces River Basin
NITRATE NITROGEN, DISSOLVED (MG/L AS N) vs Date

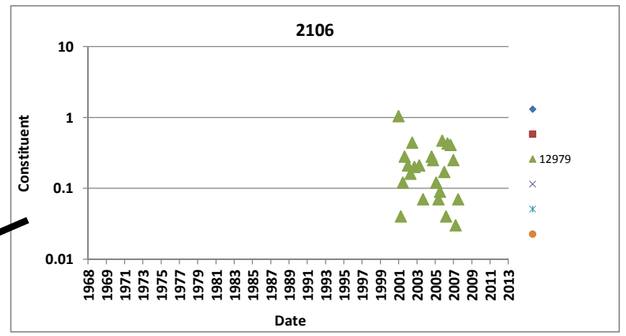


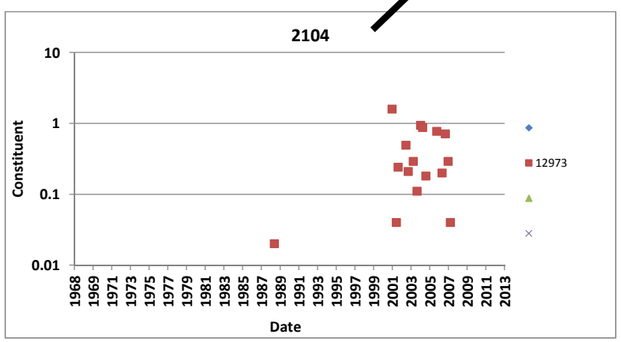




Basin 21: Nueces River Basin
NITRATE NITROGEN, DISSOLVED (MG/L AS N) vs Date

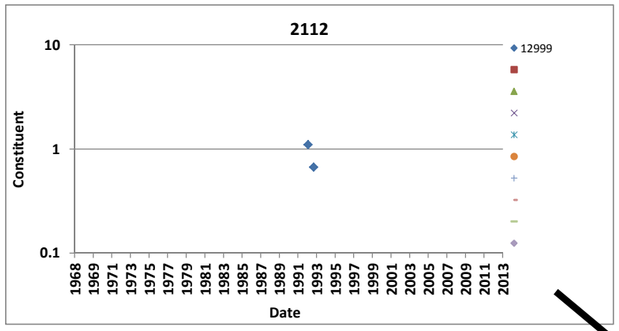


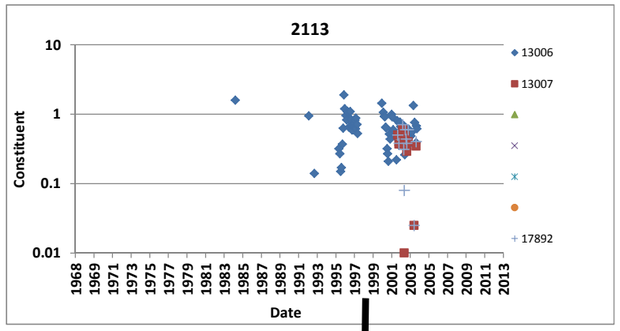


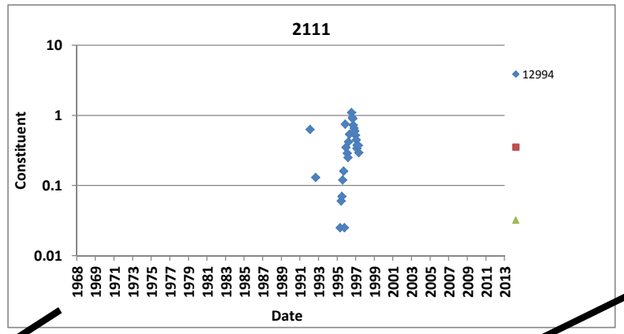


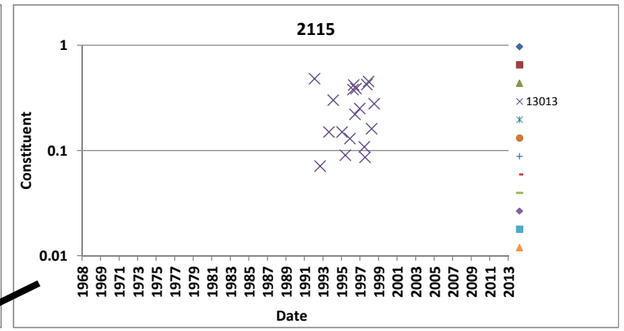
Basin 21: Nueces River Basin

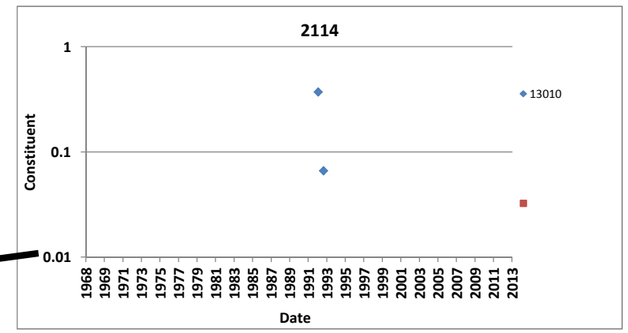
NITRITE PLUS NITRATE, DISS 1 DET. (MG/L AS N) vs Date

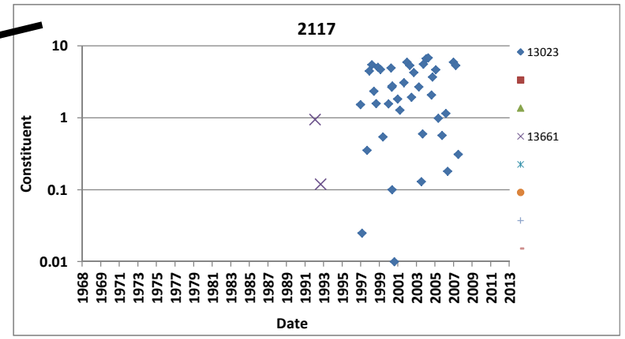


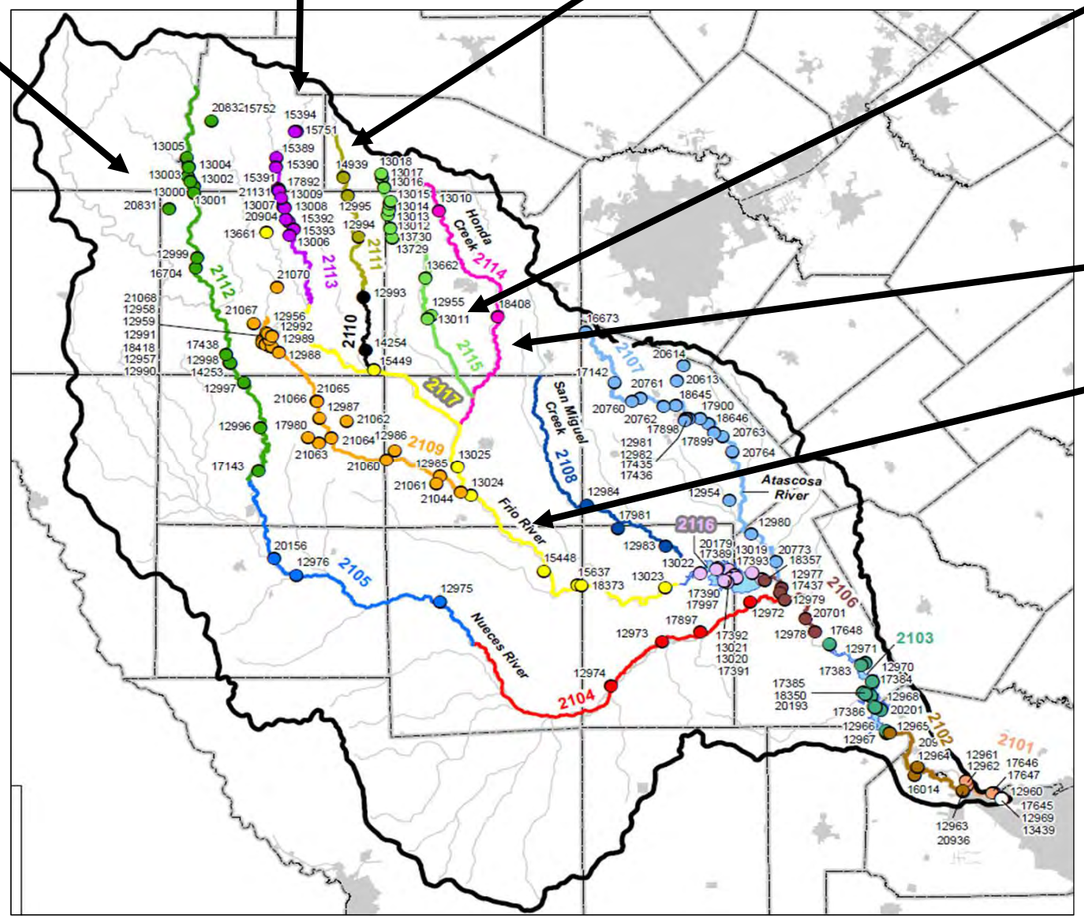






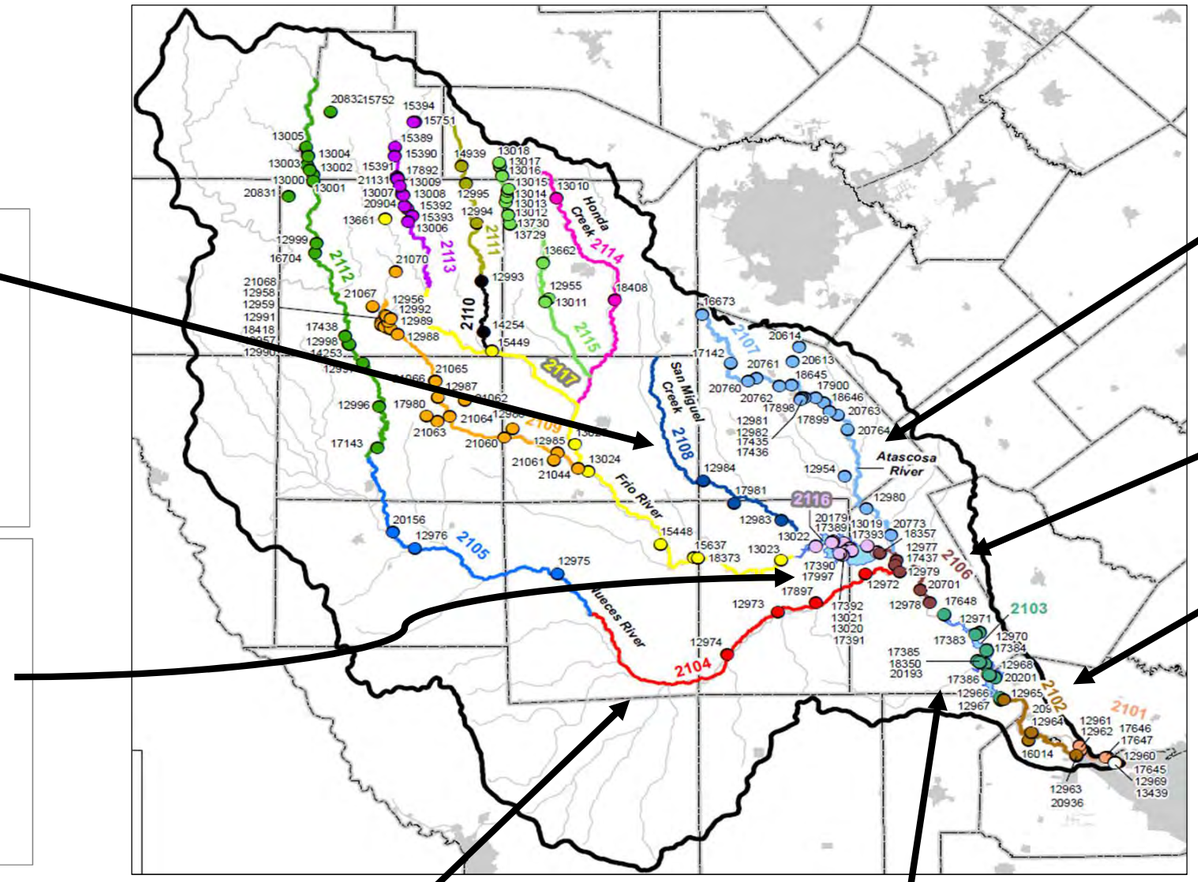


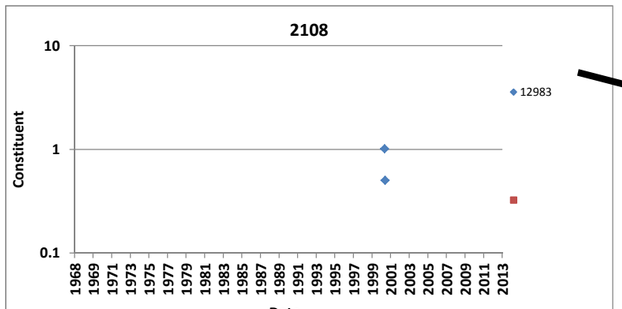


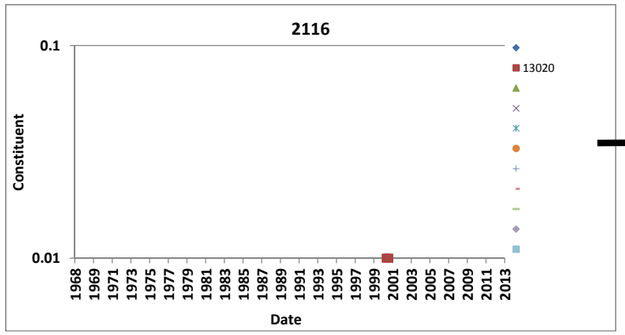


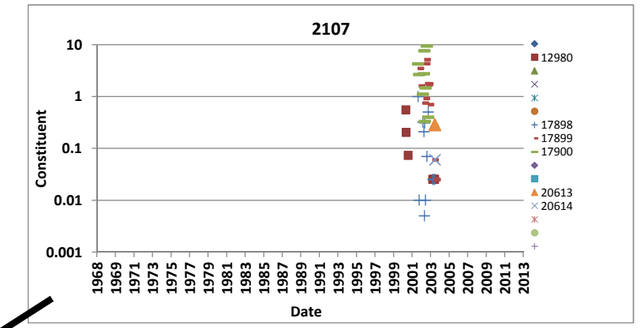
Basin 21: Nueces River Basin

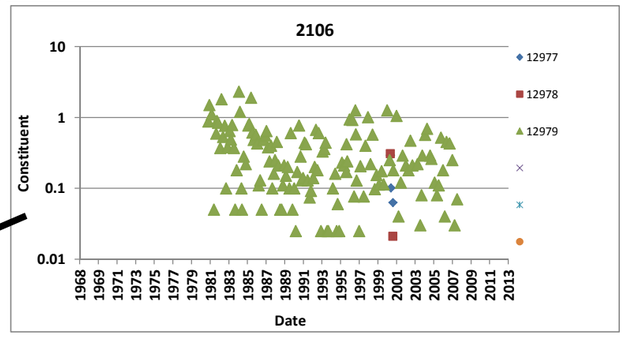
NITRITE PLUS NITRATE, DISS 1 DET. (MG/L AS N) vs Date

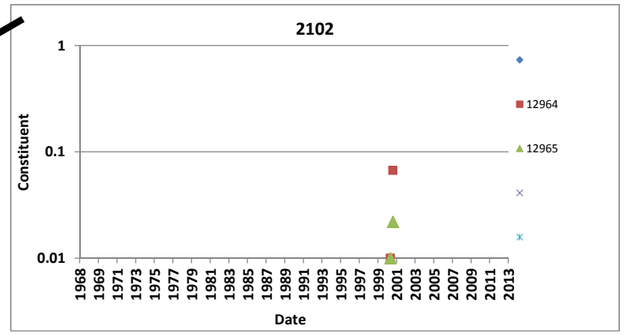


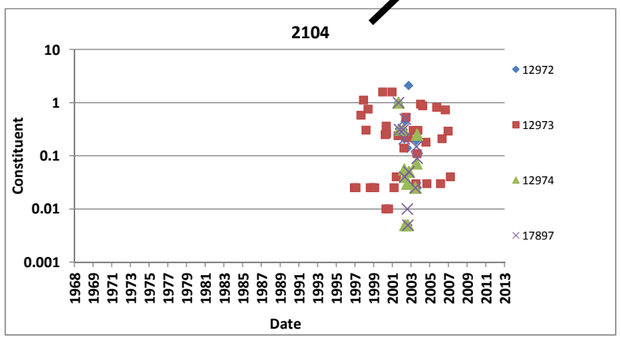


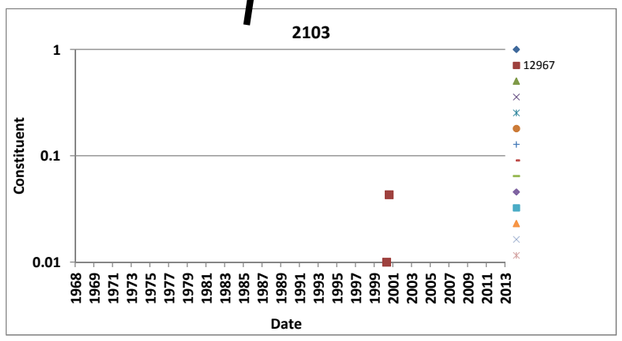




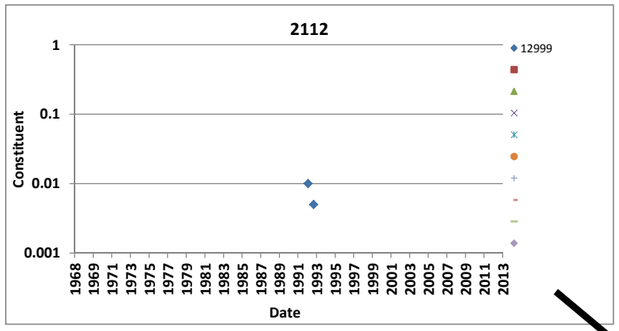


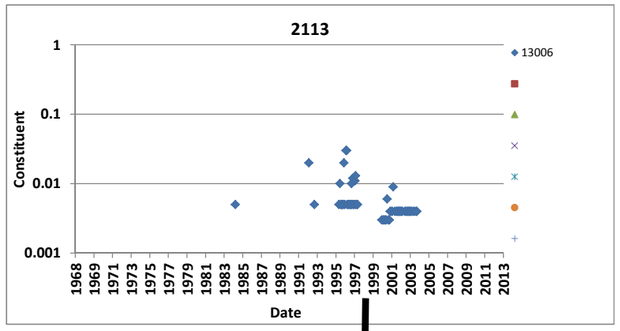


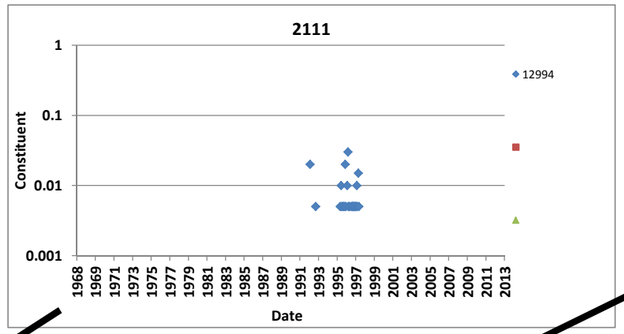


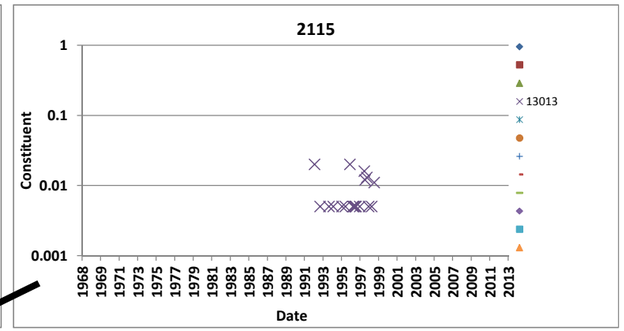


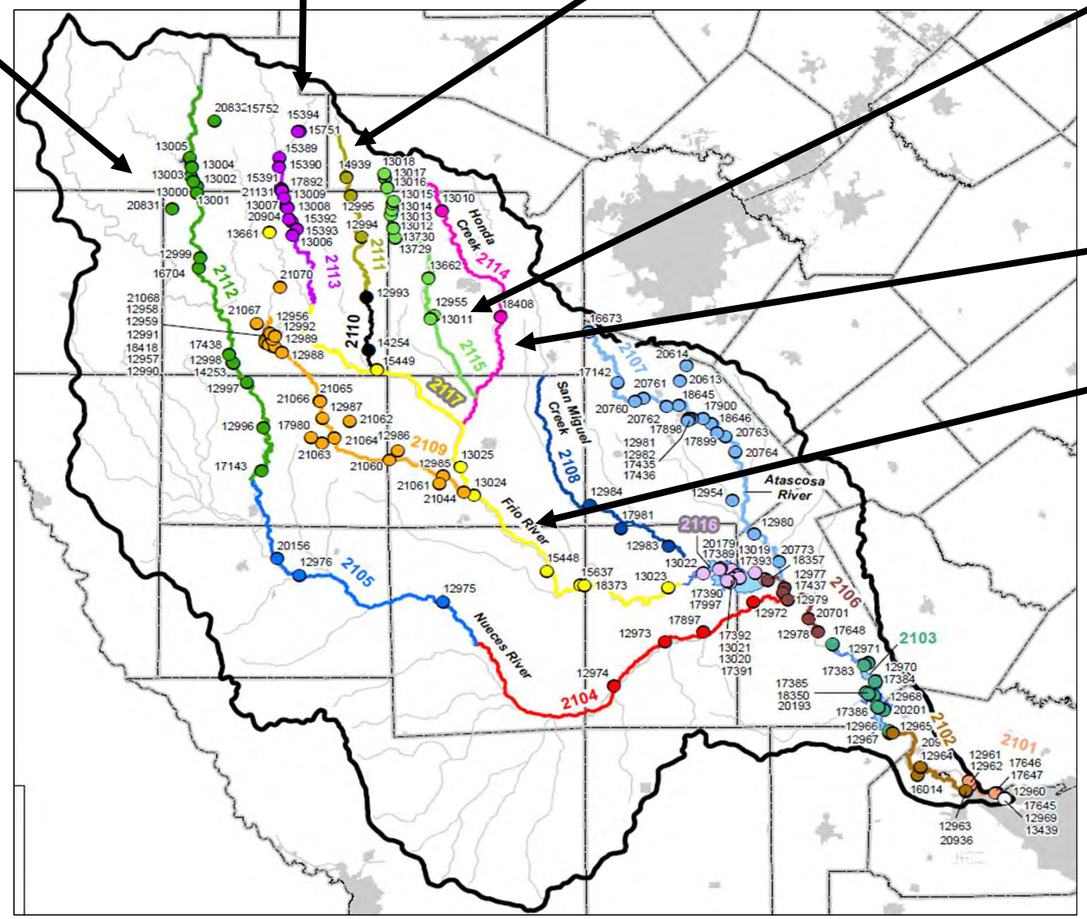
Basin 21: Nueces River Basin
NITRITE, DISSOLVED (MG/L AS N)vs Date

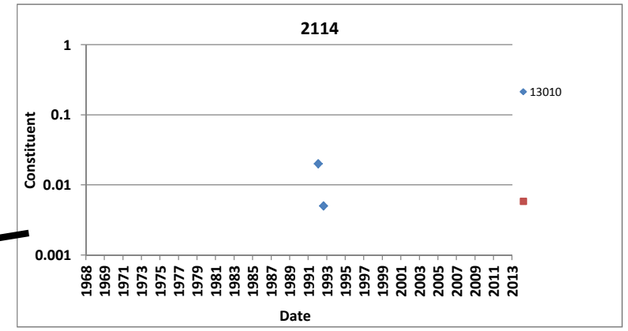


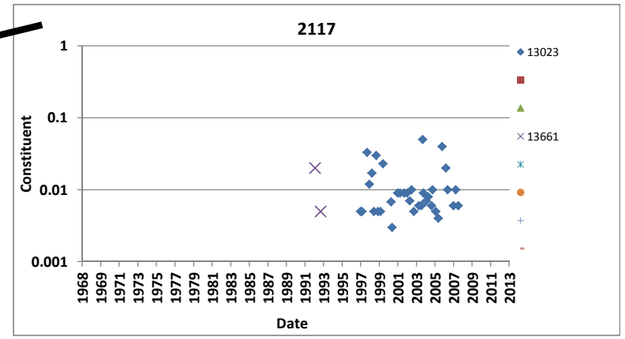




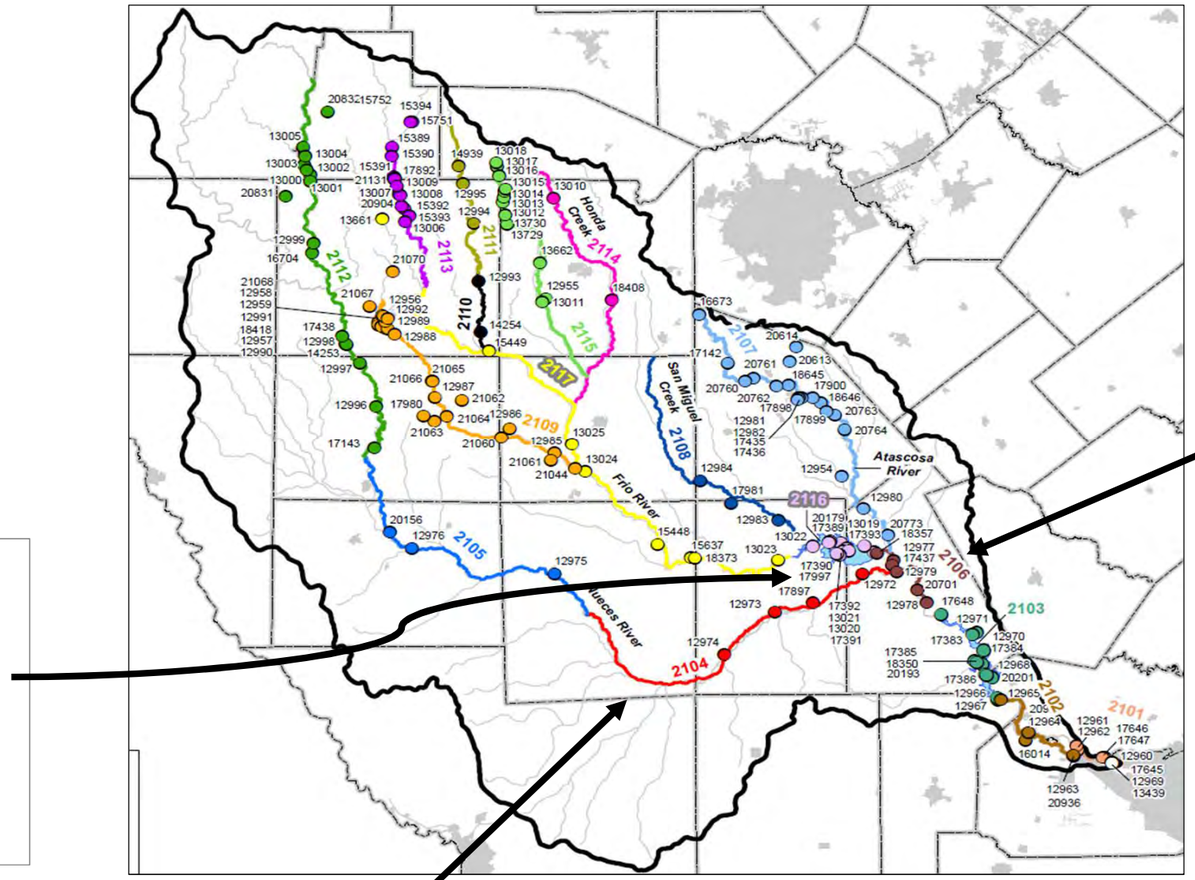


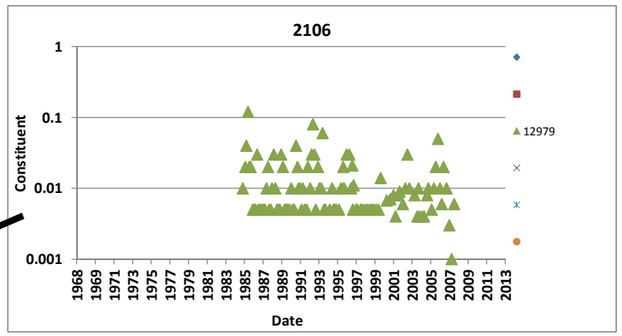


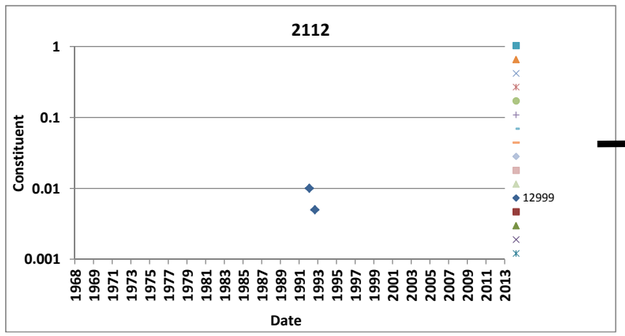


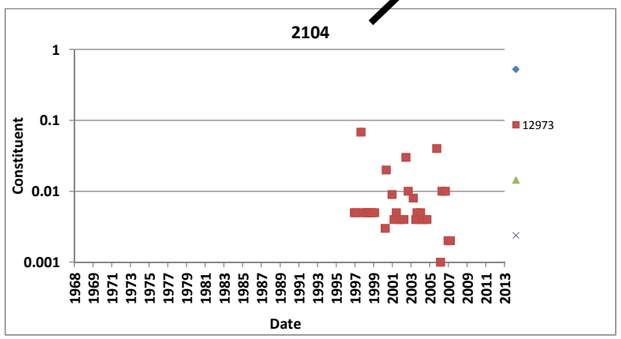


Basin 21: Nueces River Basin
NITRITE, DISSOLVED (MG/L AS N) vs Date

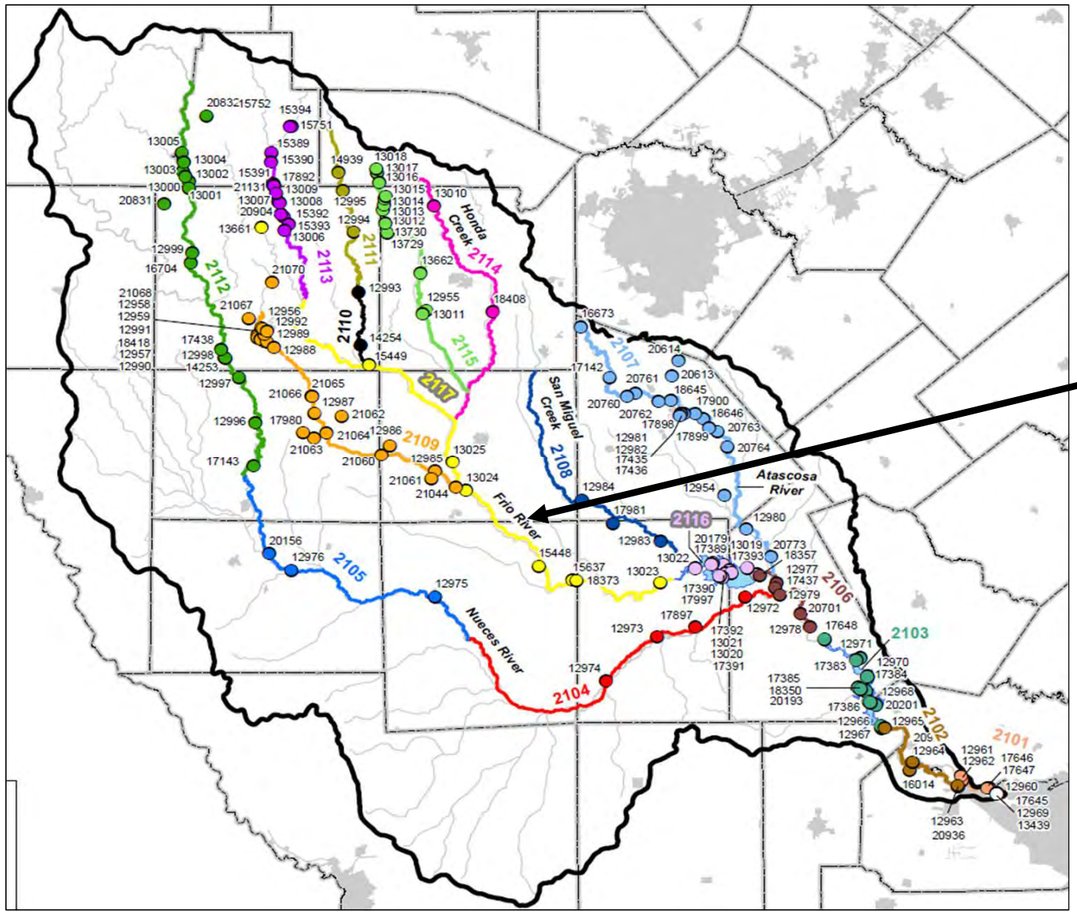


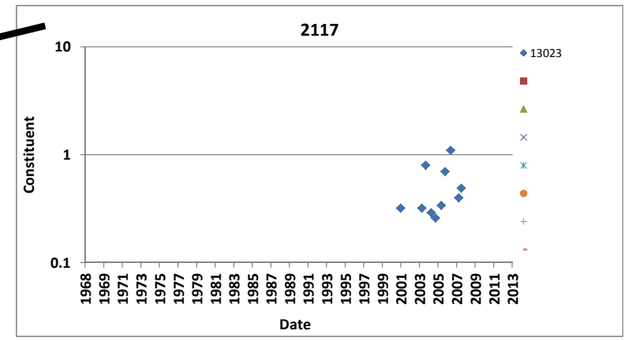




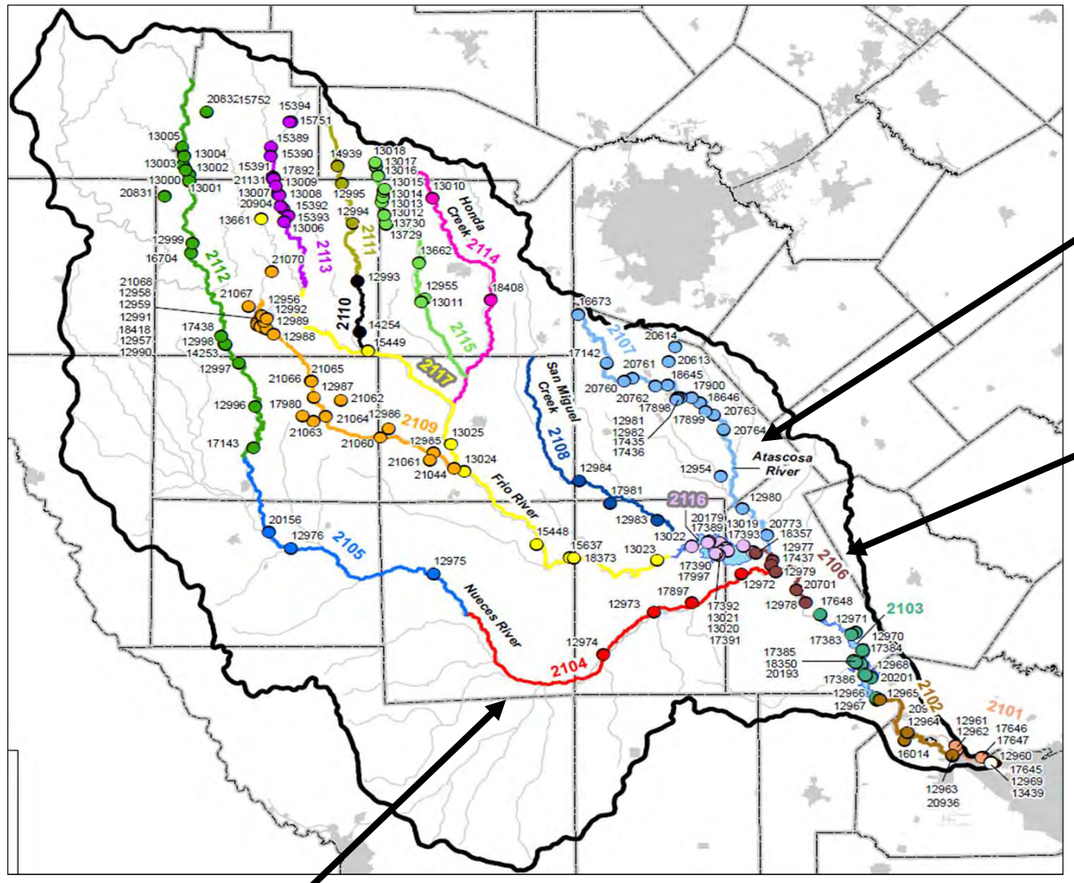


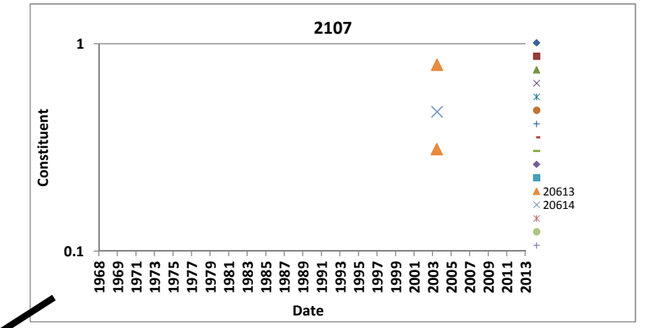
Basin 21: Nueces River Basin
NITROGEN, ORGANIC, DISSOLVED (MG/L AS N) vs Date

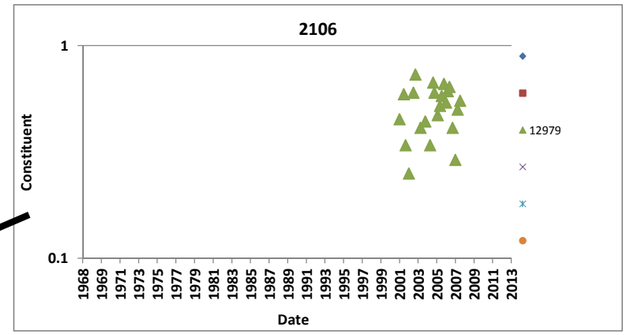


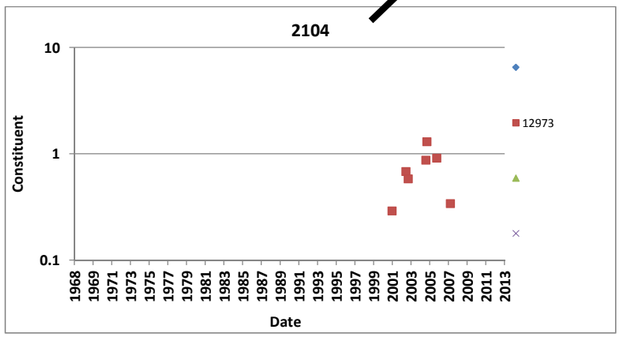


Basin 21: Nueces River Basin
NITROGEN, ORGANIC, DISSOLVED (MG/L AS N) vs Date



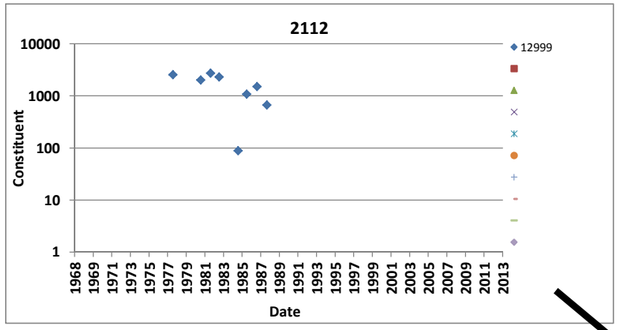


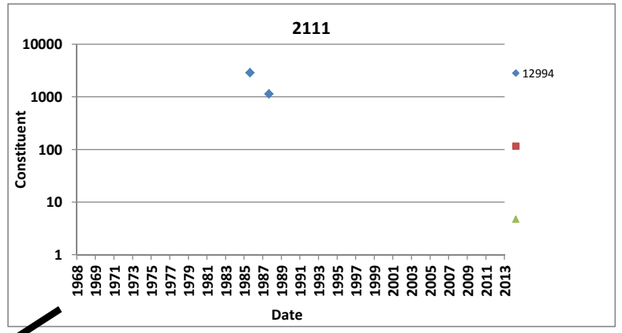


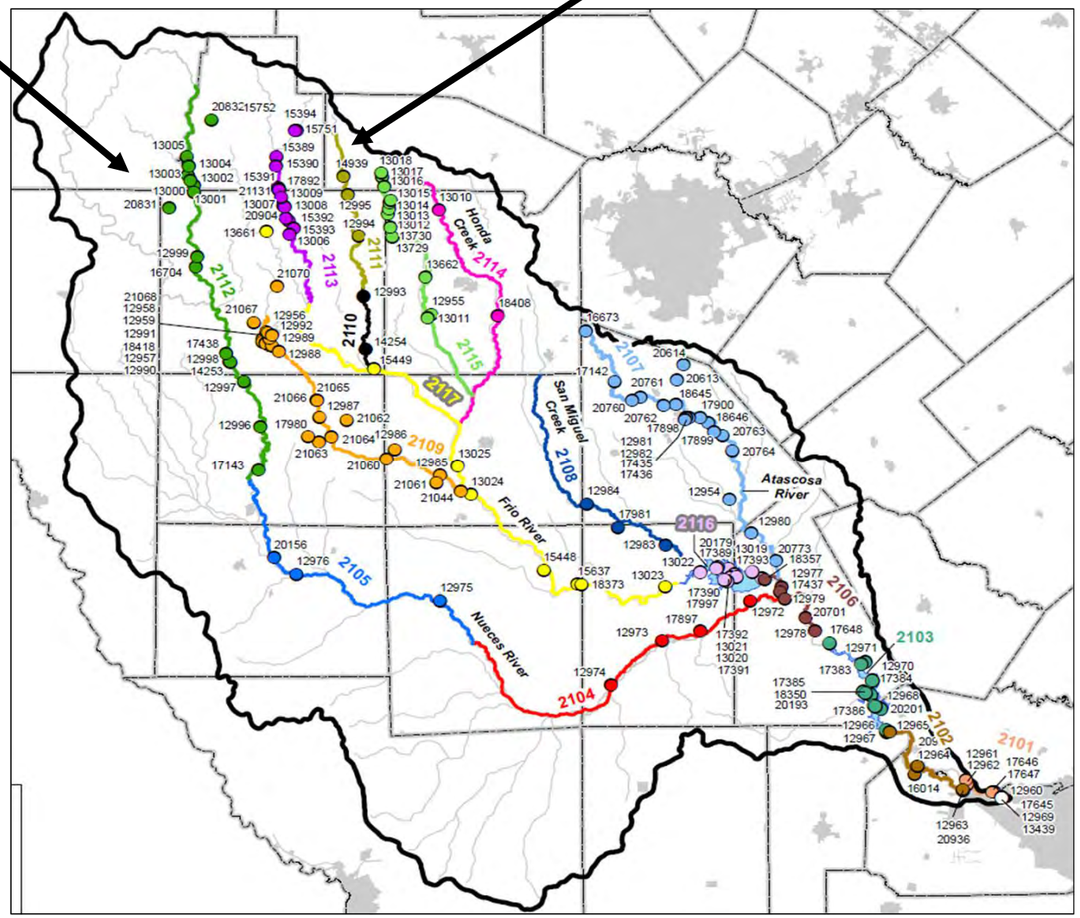


Basin 21: Nueces River Basin

NITROGEN,ORG. KJEL, BOT. DEPOS (MG/KG-N DRY WT) vs Date

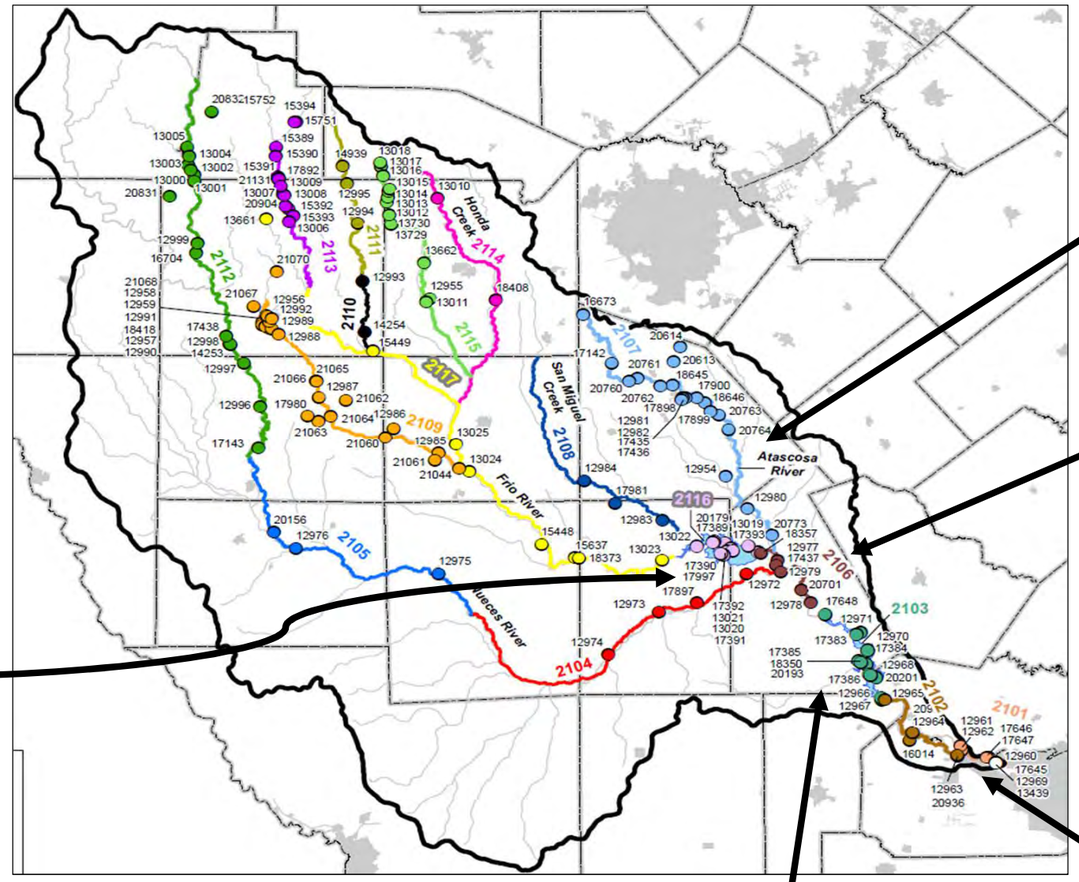


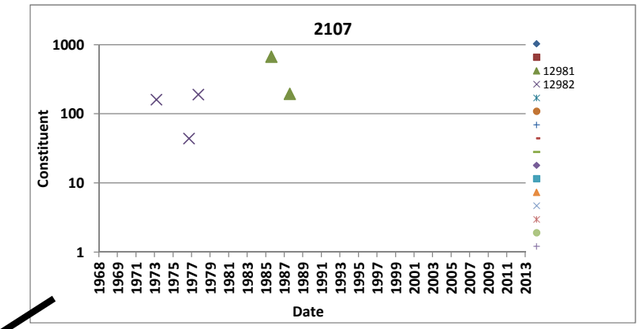


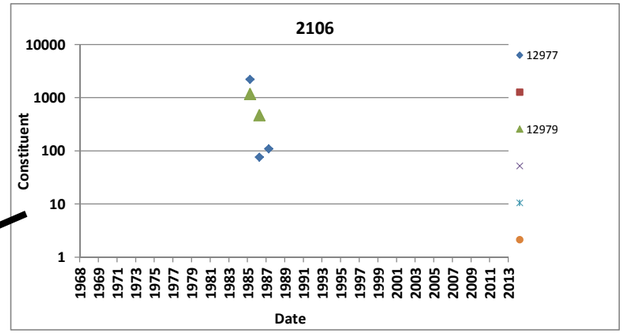


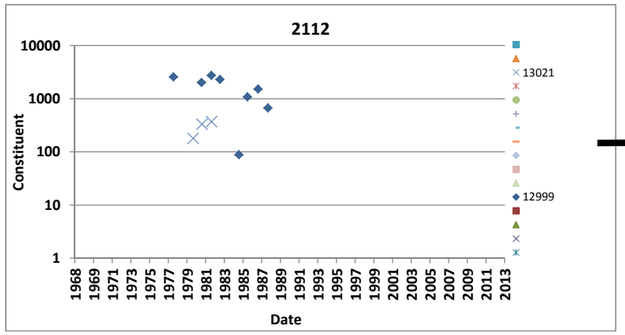
Basin 21: Nueces River Basin

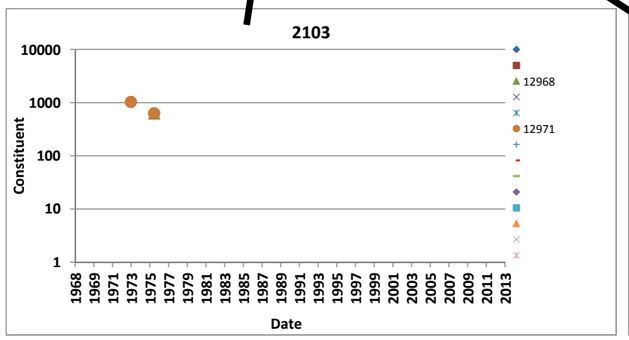
NITROGEN,ORG. KJEL, BOT. DEPOS (MG/KG-N DRY WT)vs Date

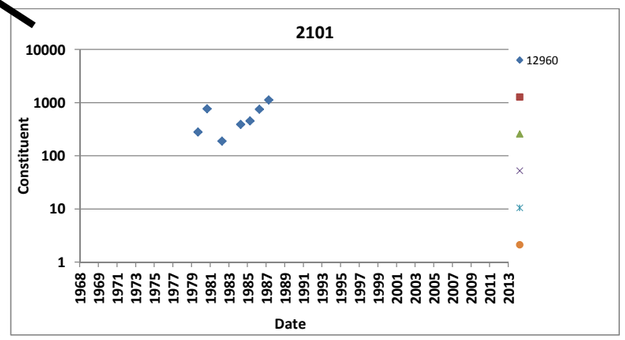




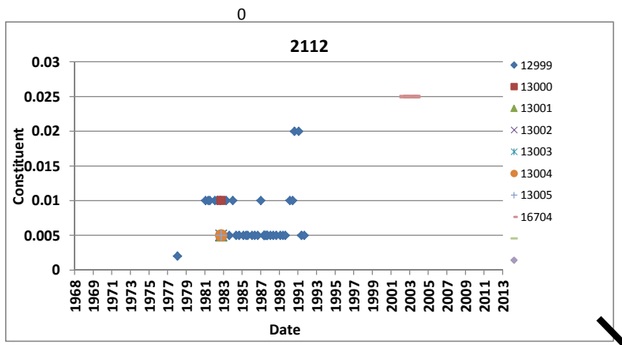


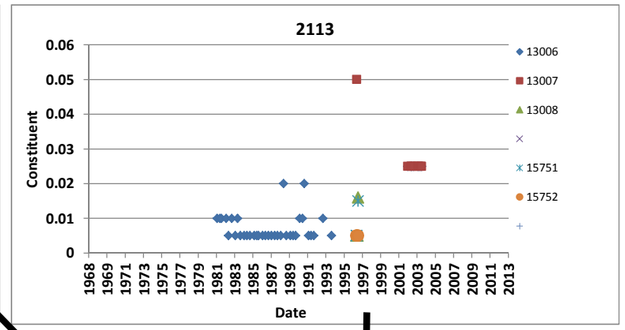


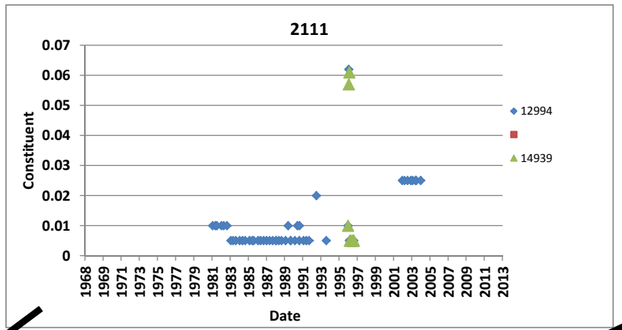


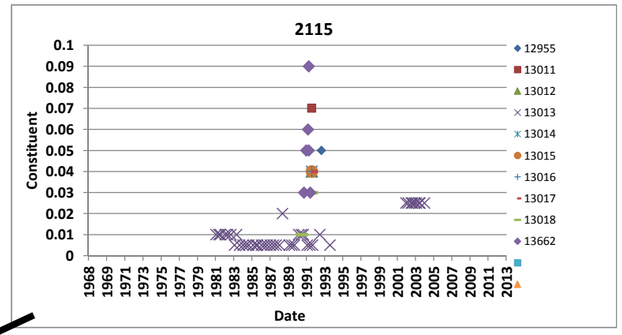


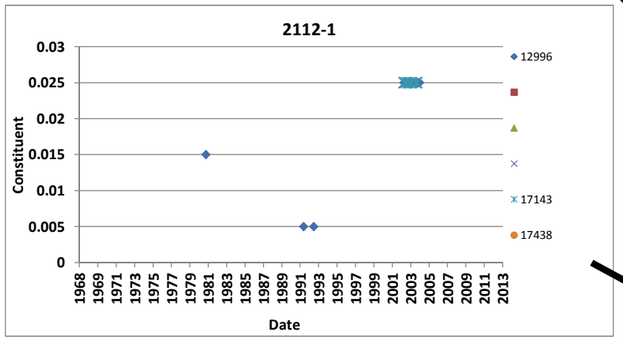
Basin 21: Nueces River
NITRITE NITROGEN, TOTAL (MG/L AS N) vs Date

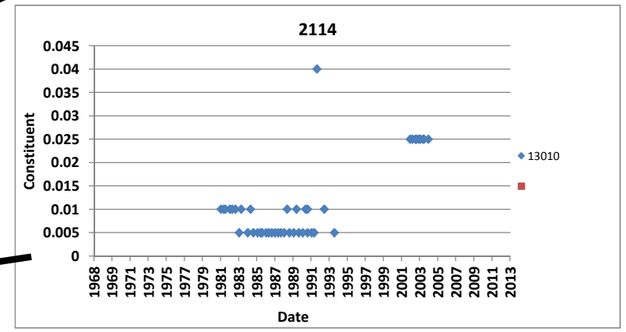


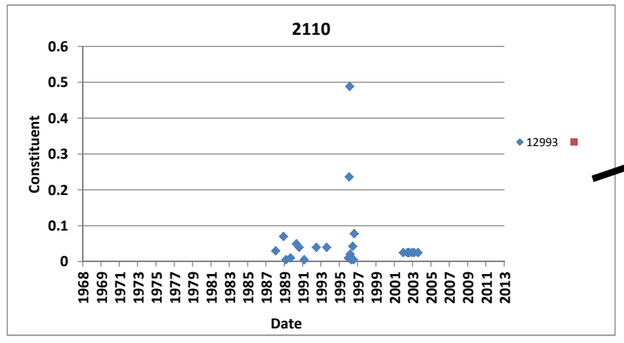


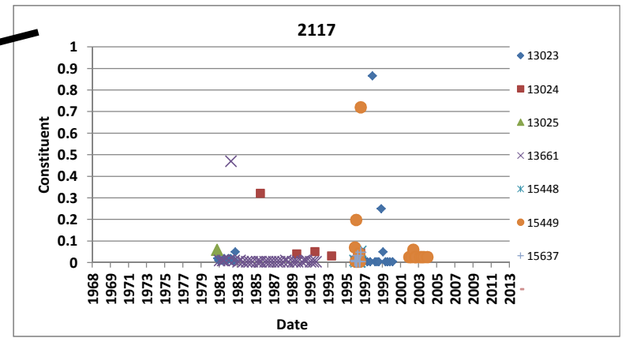


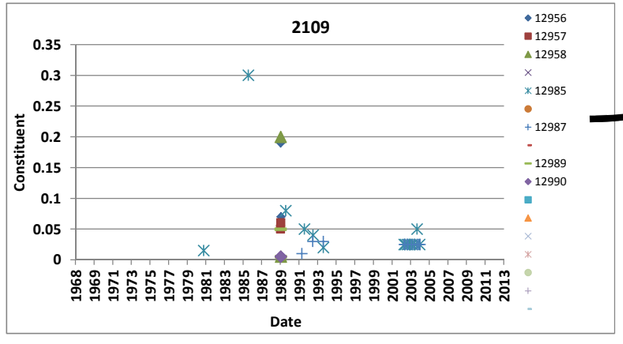


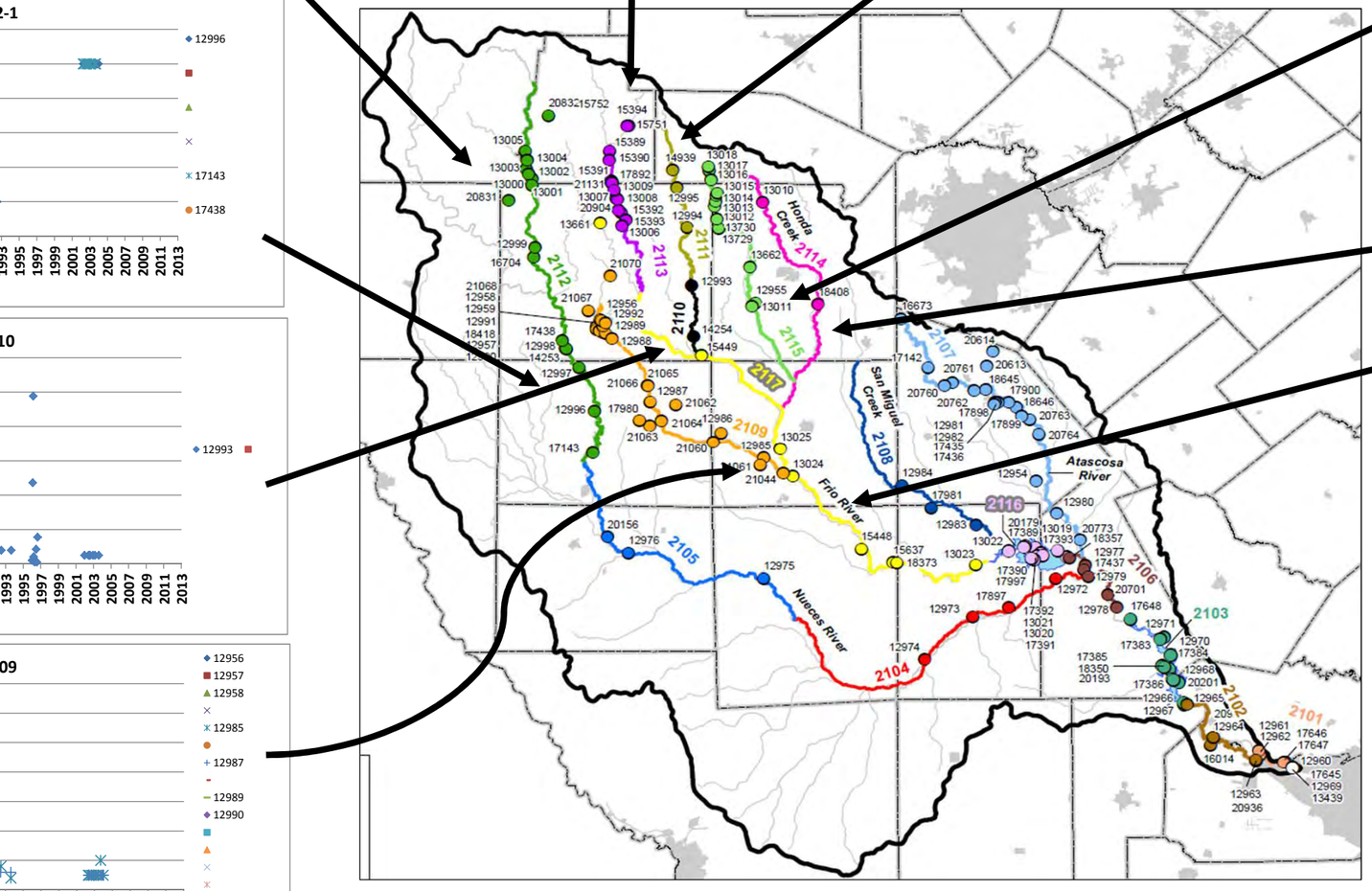




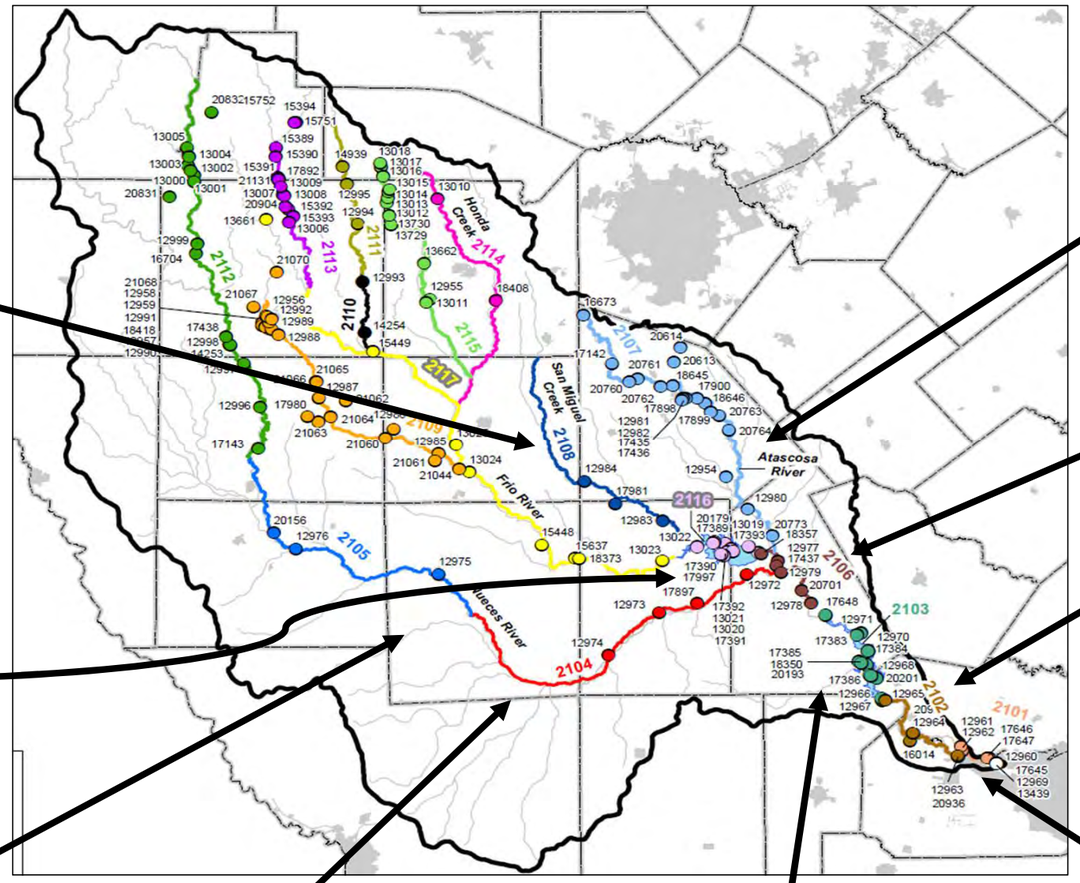


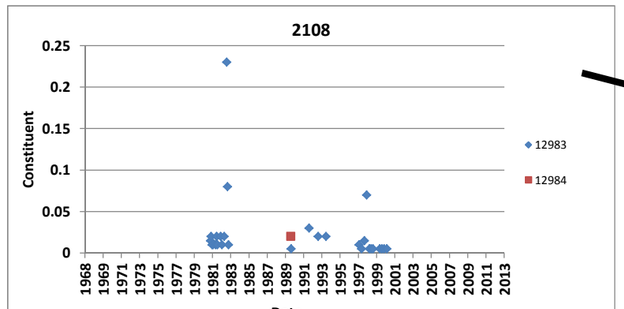


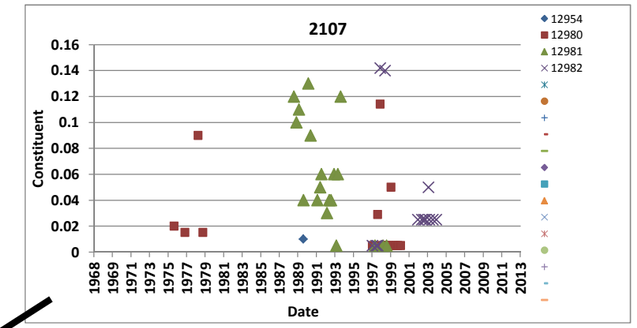


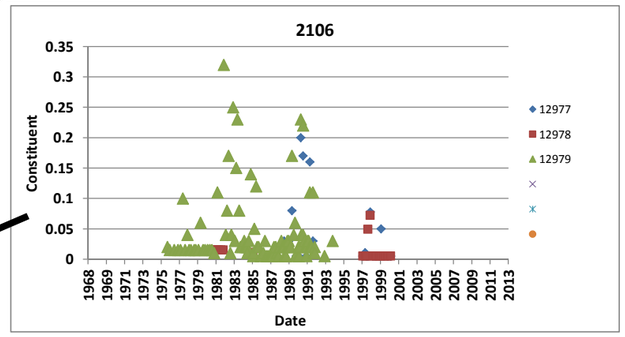


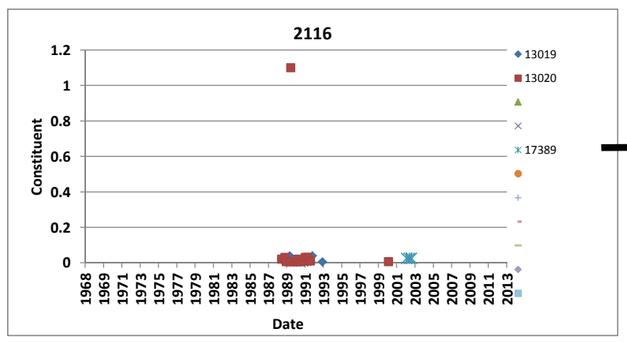
Basin 21: Nueces River
NITRITE NITROGEN, TOTAL (MG/L AS N) vs Date

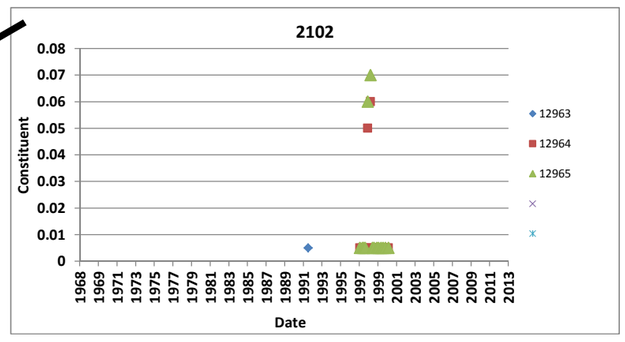


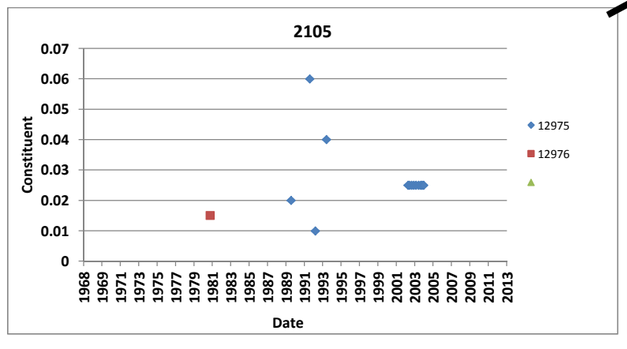


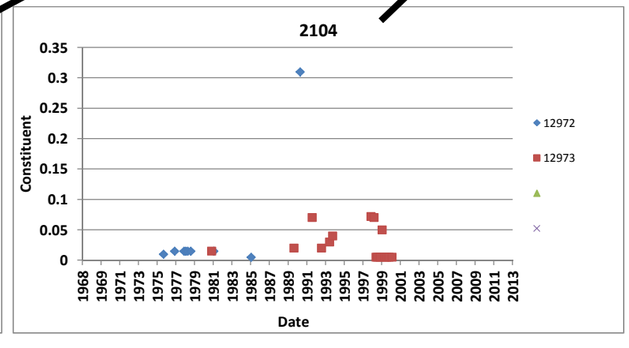


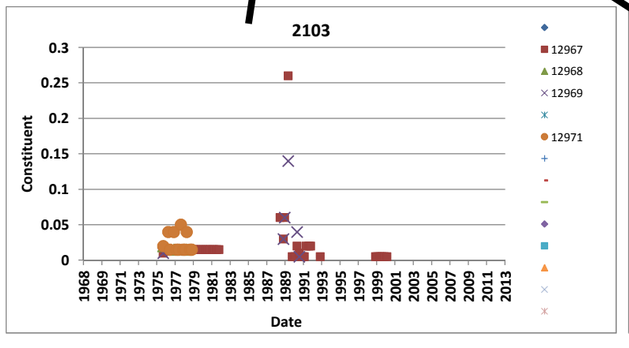


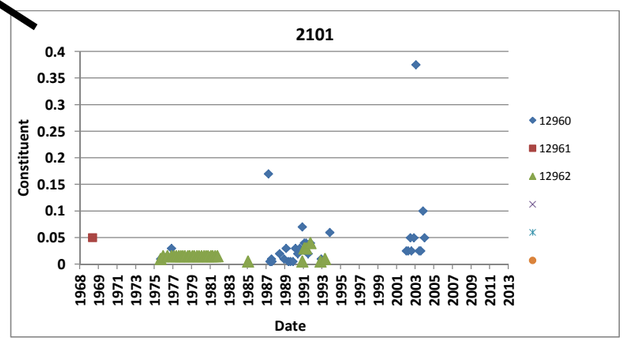






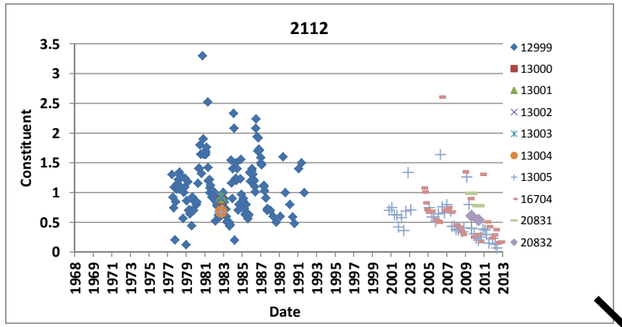


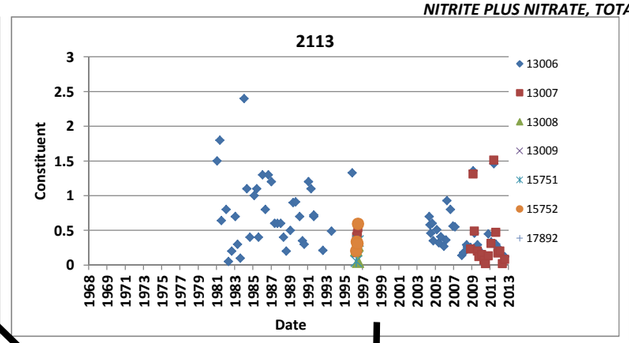


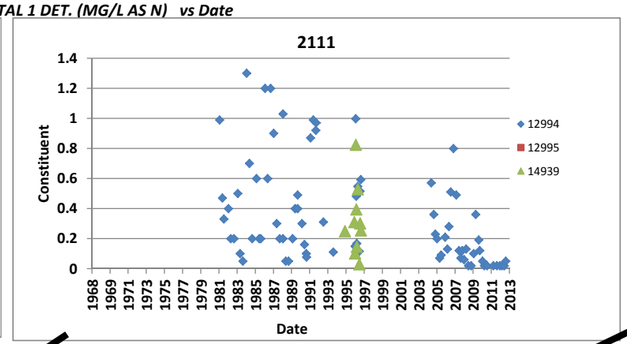


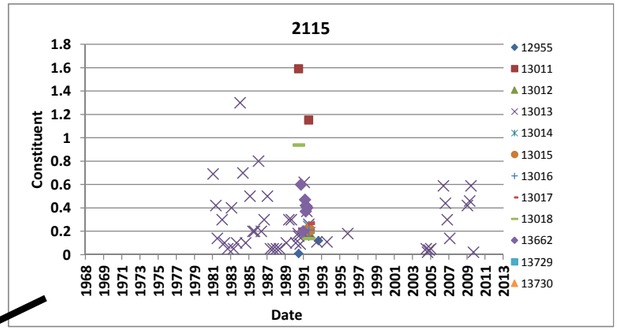
Basin 21: Nueces River

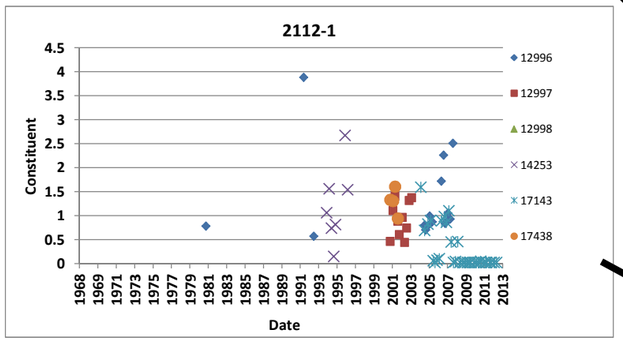
NITRITE PLUS NITRATE, TOTAL 1 DET. (MG/L AS N) vs Date

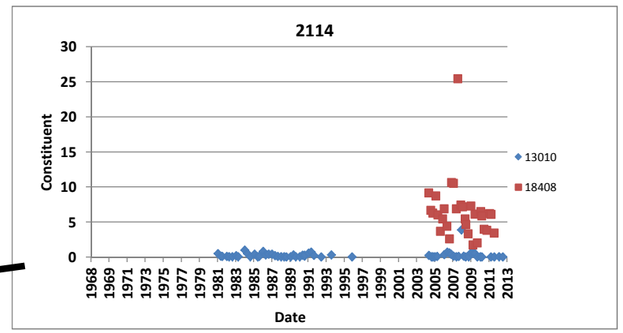


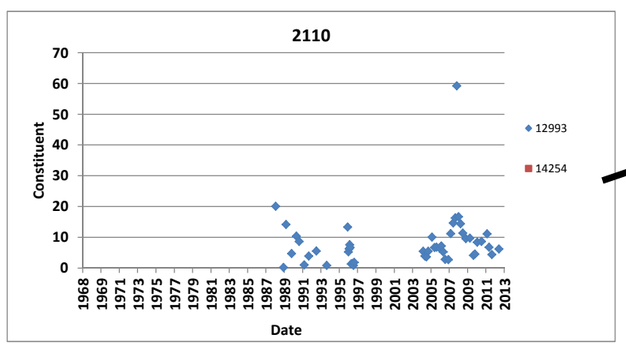


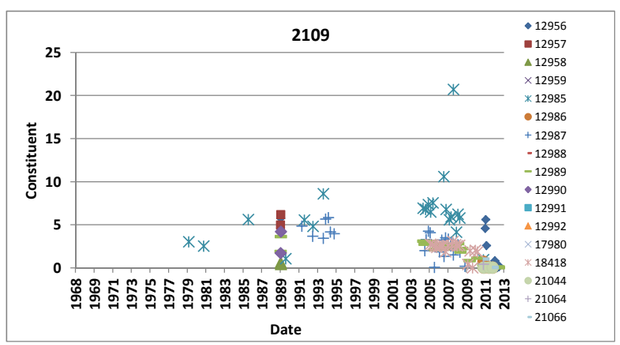


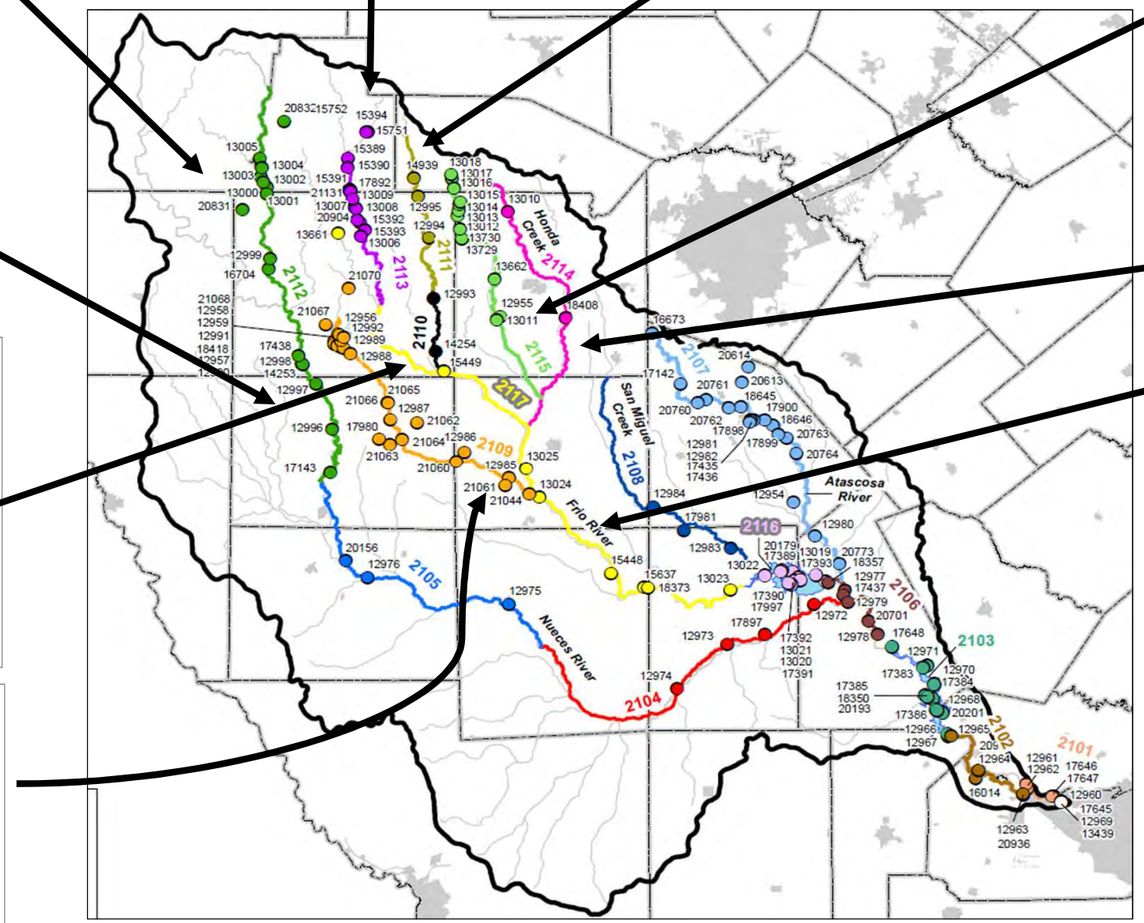


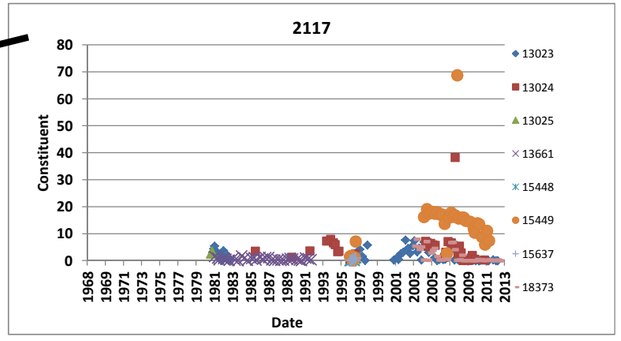






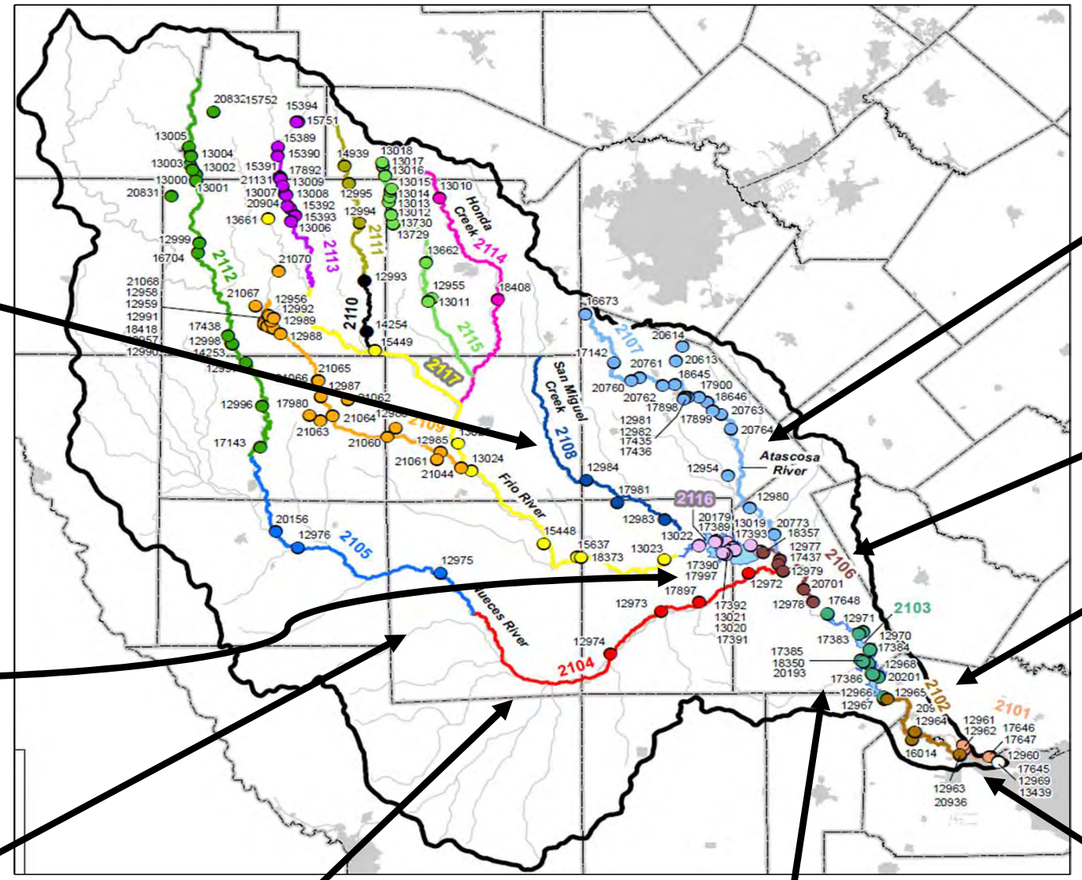


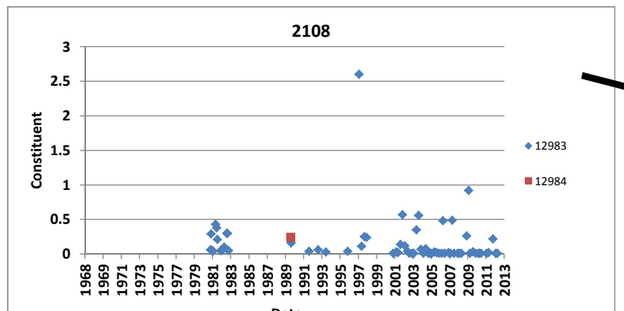


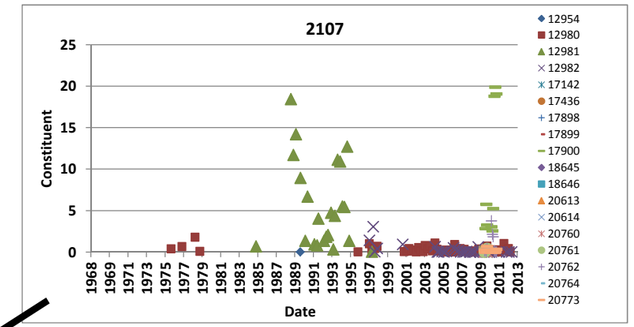


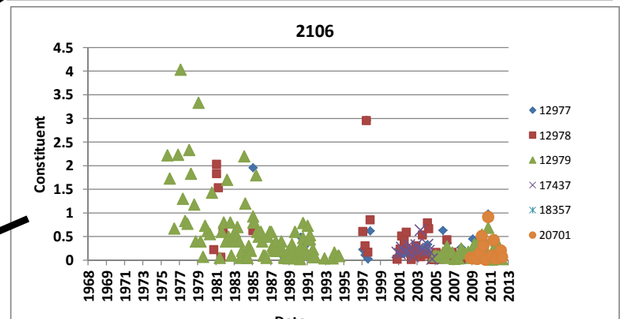
Basin 21: Nueces River

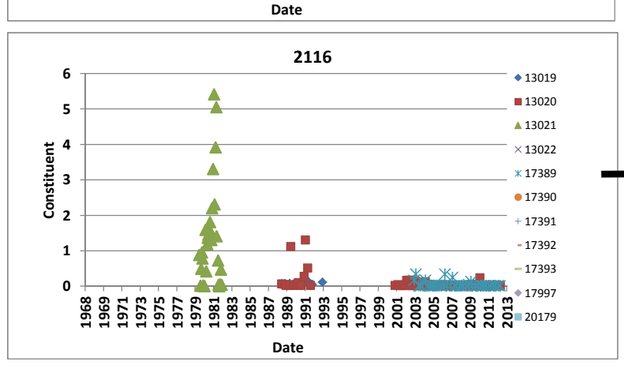
NITRITE PLUS NITRATE, TOTAL 1 DET. (MG/L AS N) vs Date

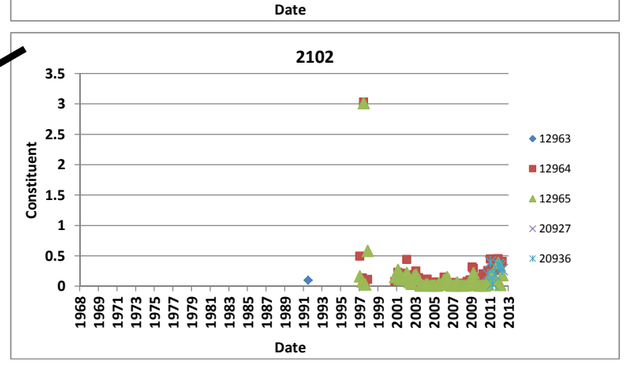


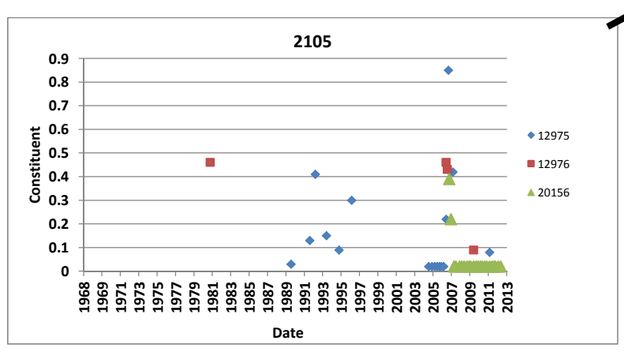


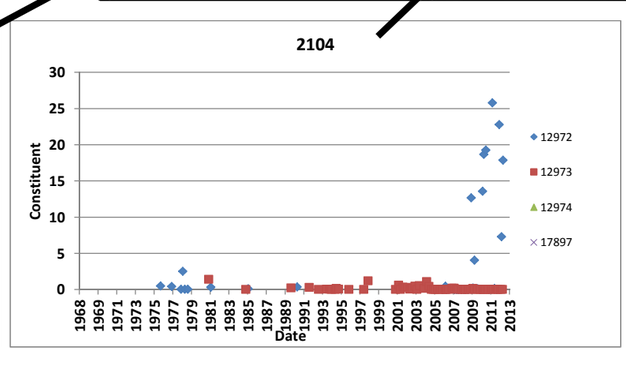


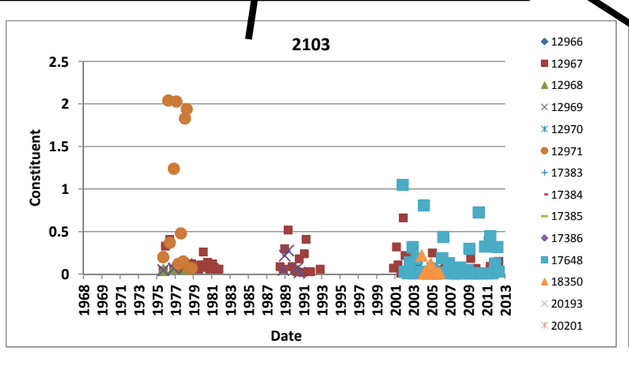


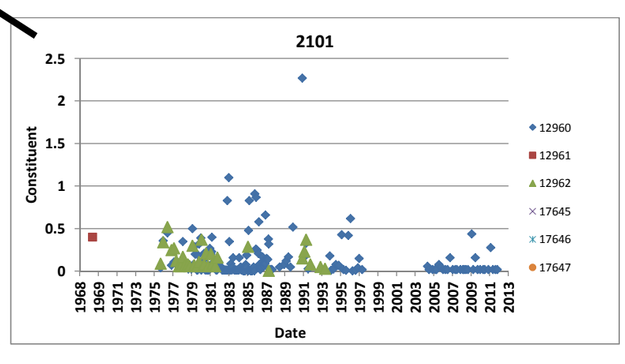






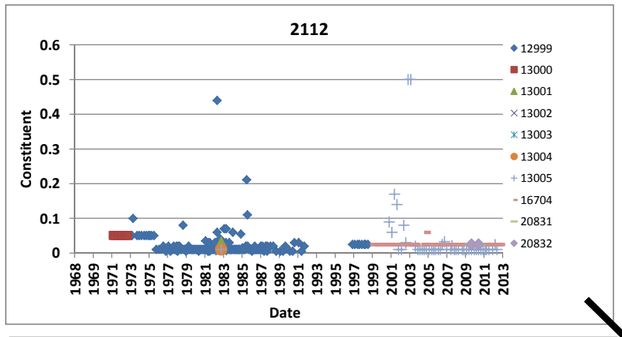


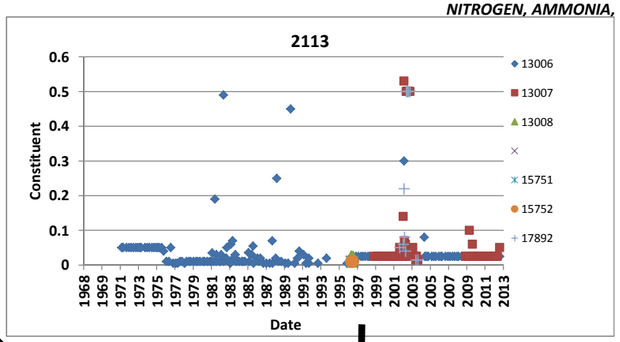


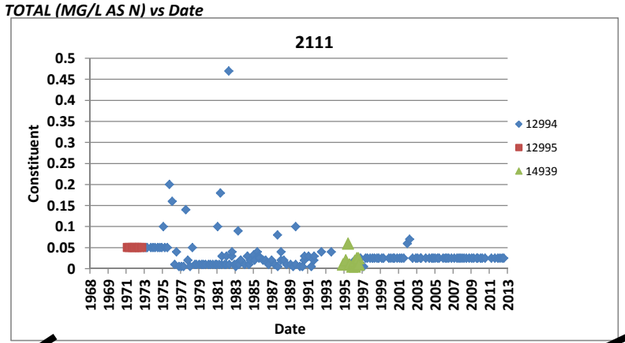


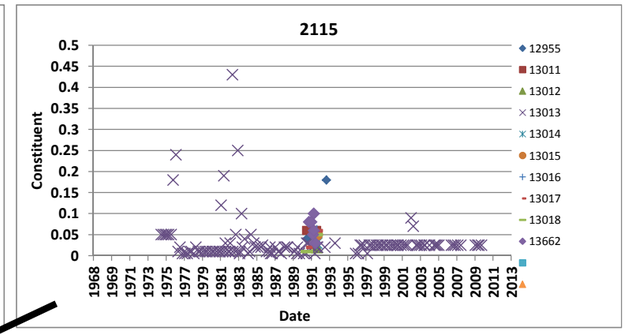
Basin 21: Nueces River

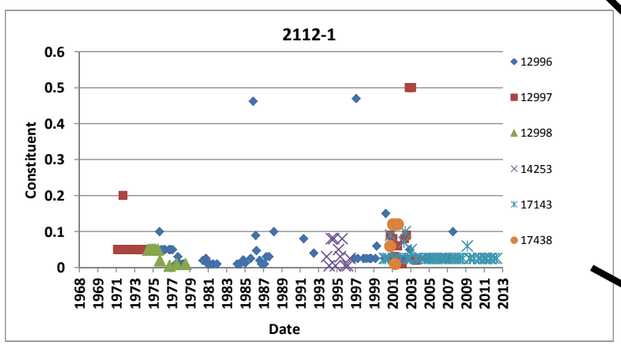
NITROGEN, AMMONIA, TOTAL (MG/L AS N) vs Date

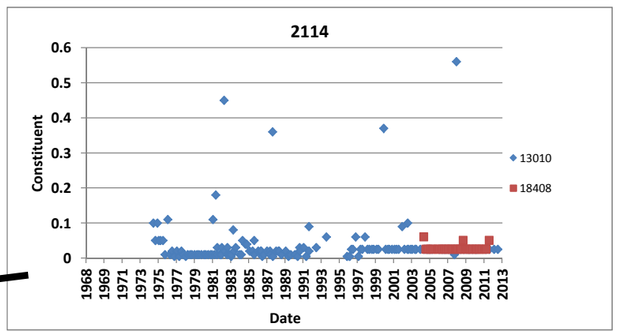


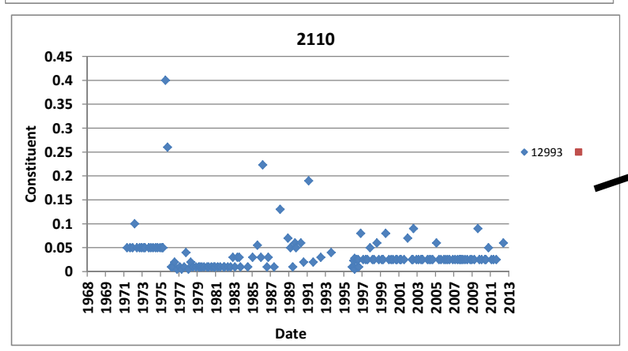


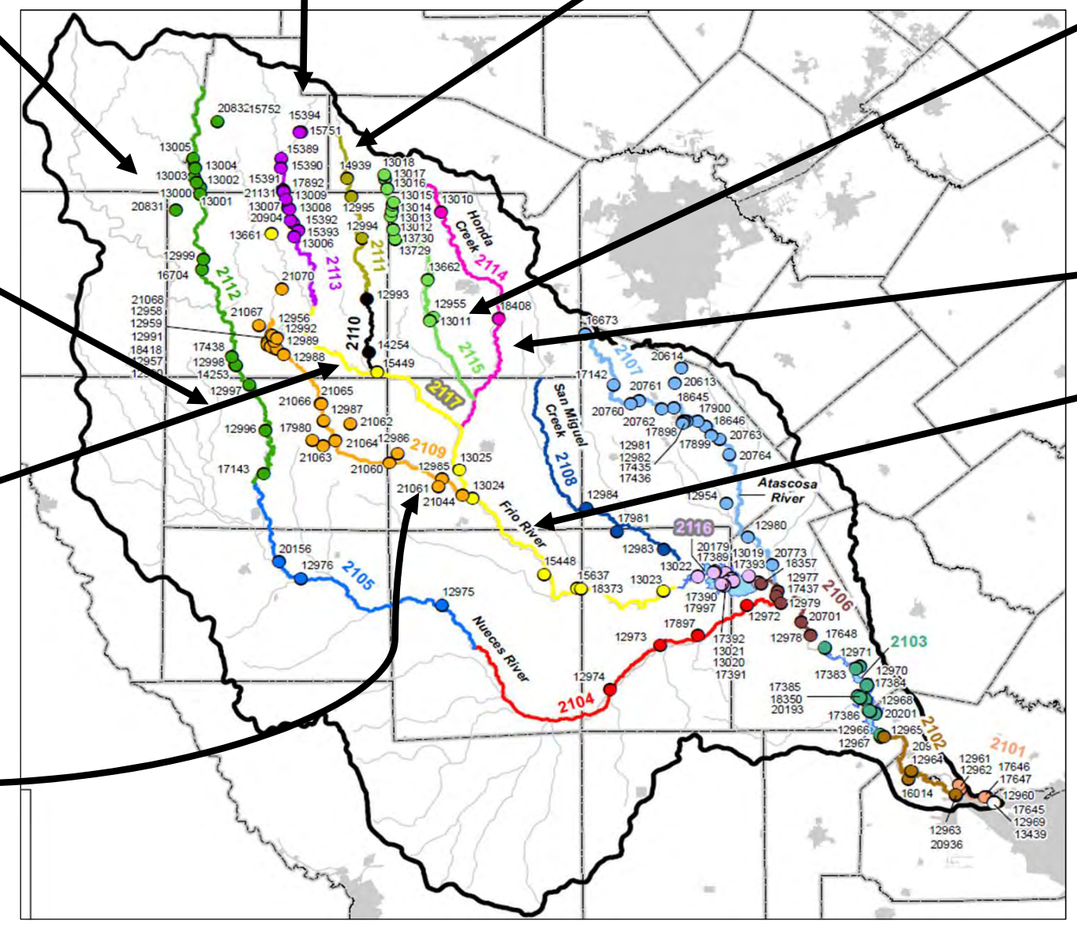


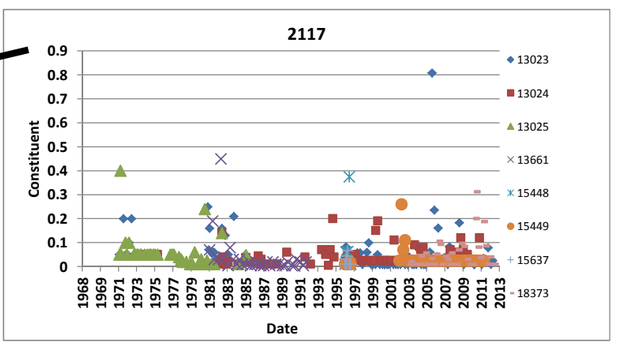


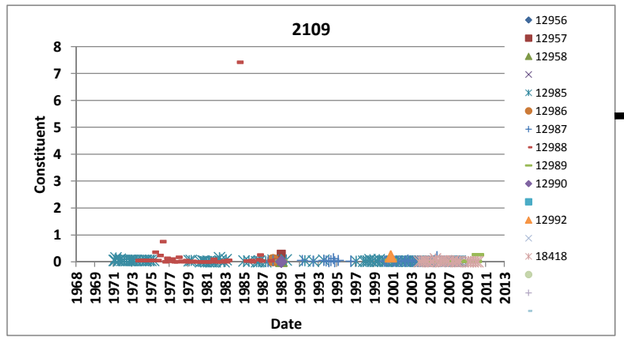




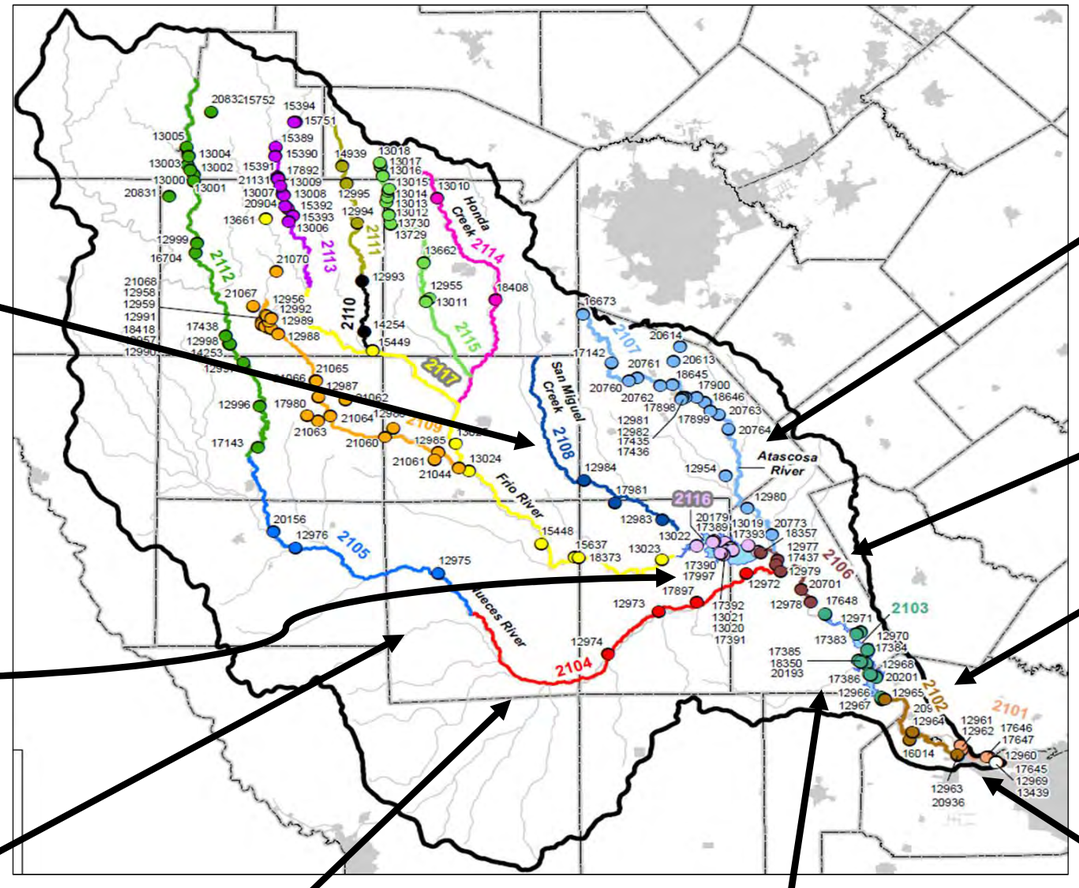


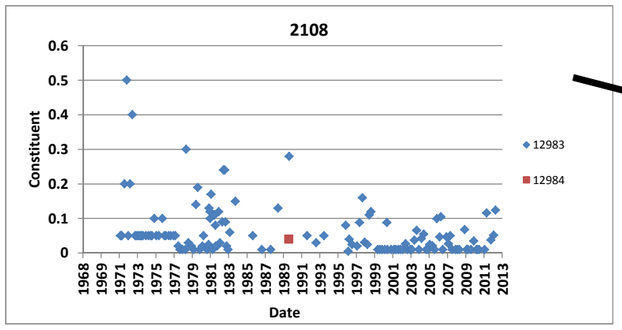


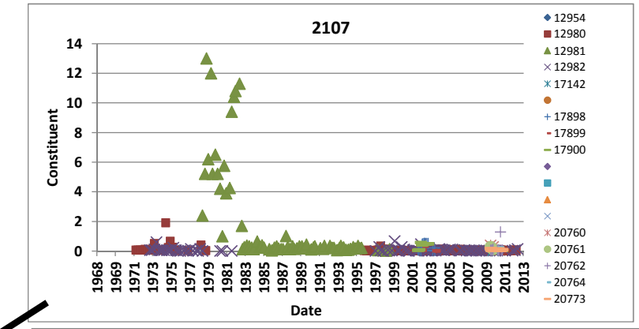


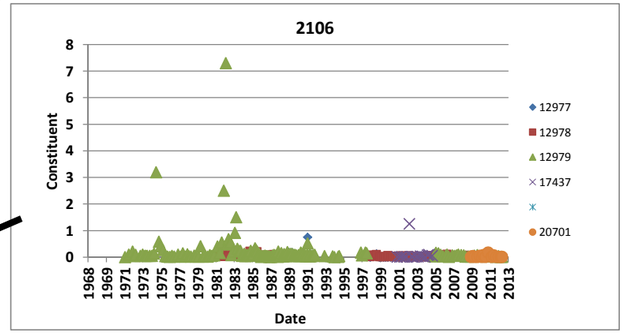


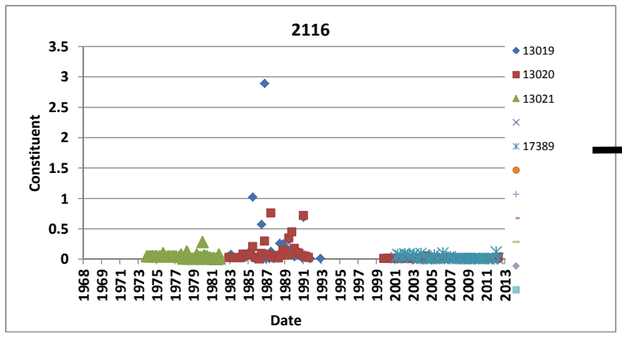
Basin 21: Nueces River
NITROGEN, AMMONIA, TOTAL (MG/L AS N) vs Date

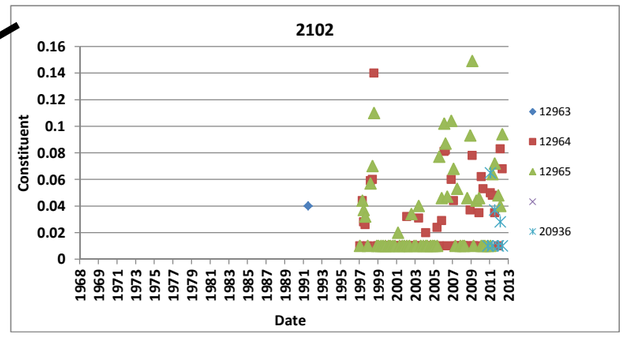


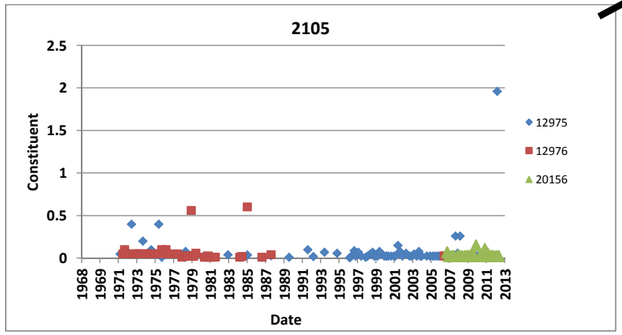


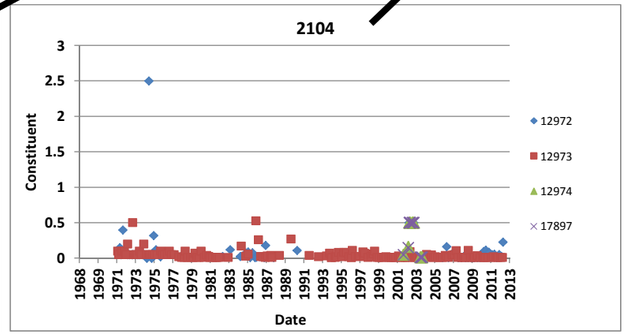


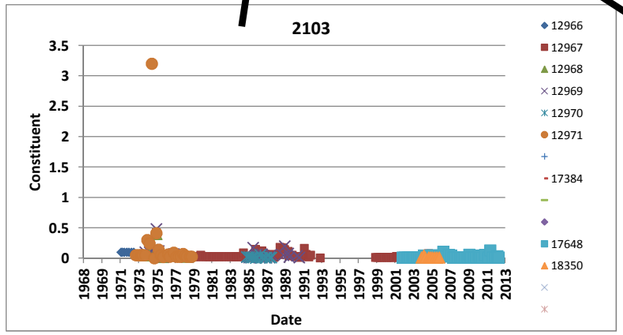


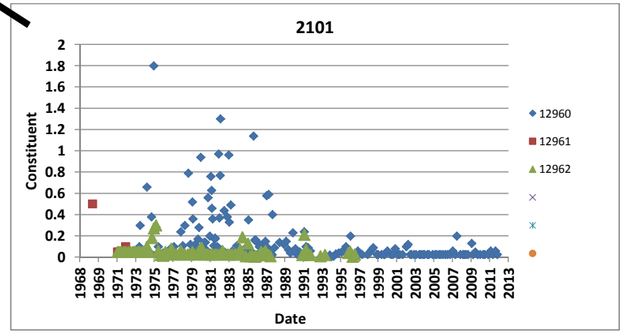






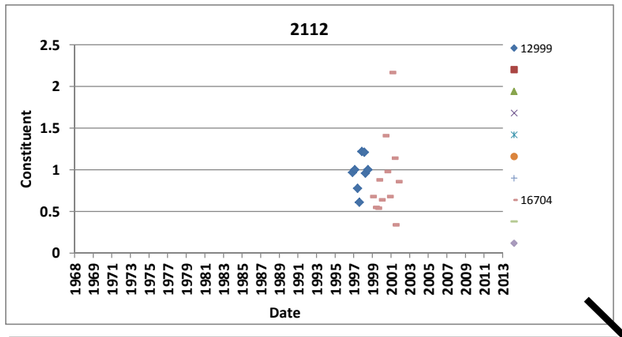


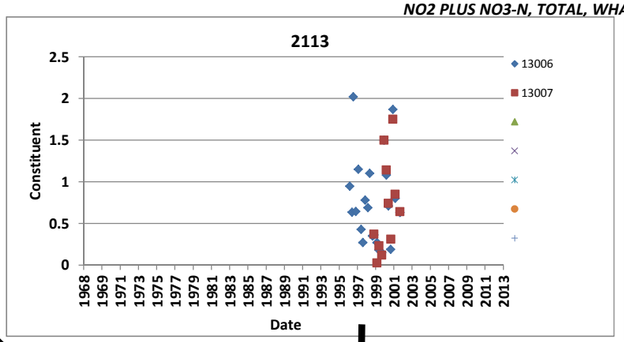


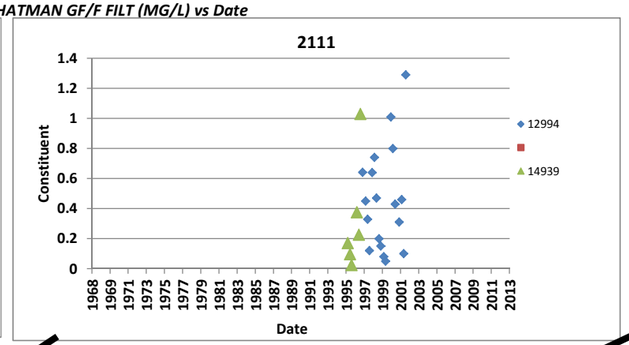


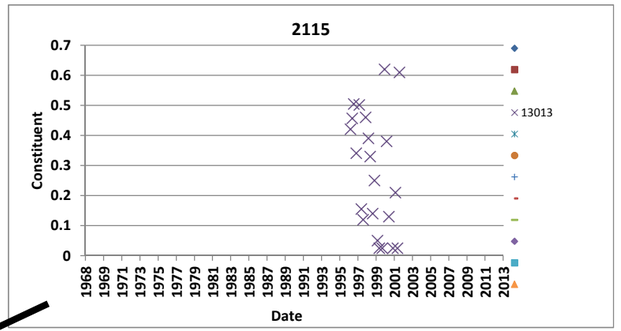
Basin 21: Nueces River

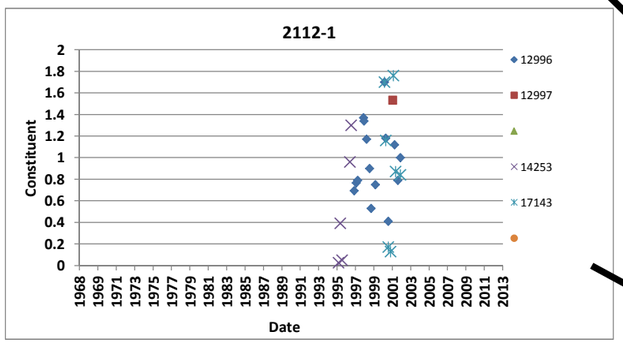
NO2 PLUS NO3-N, TOTAL, WHATMAN GF/F FILT (MG/L) vs Date

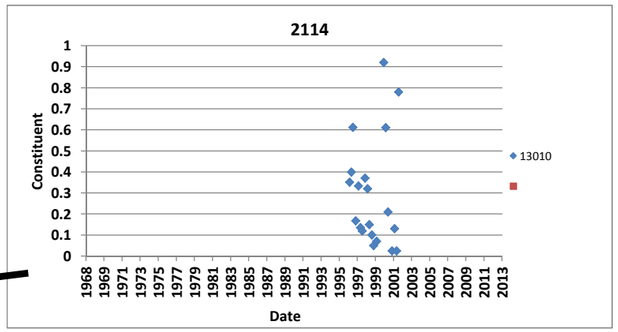


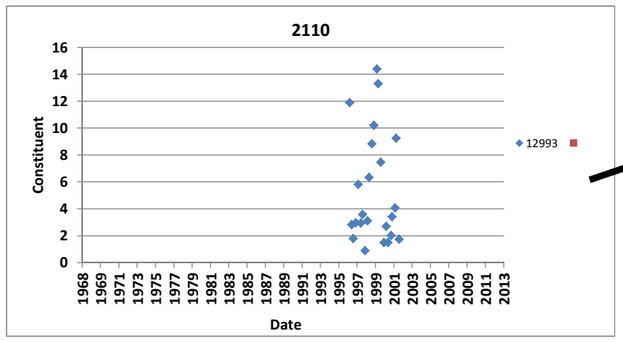


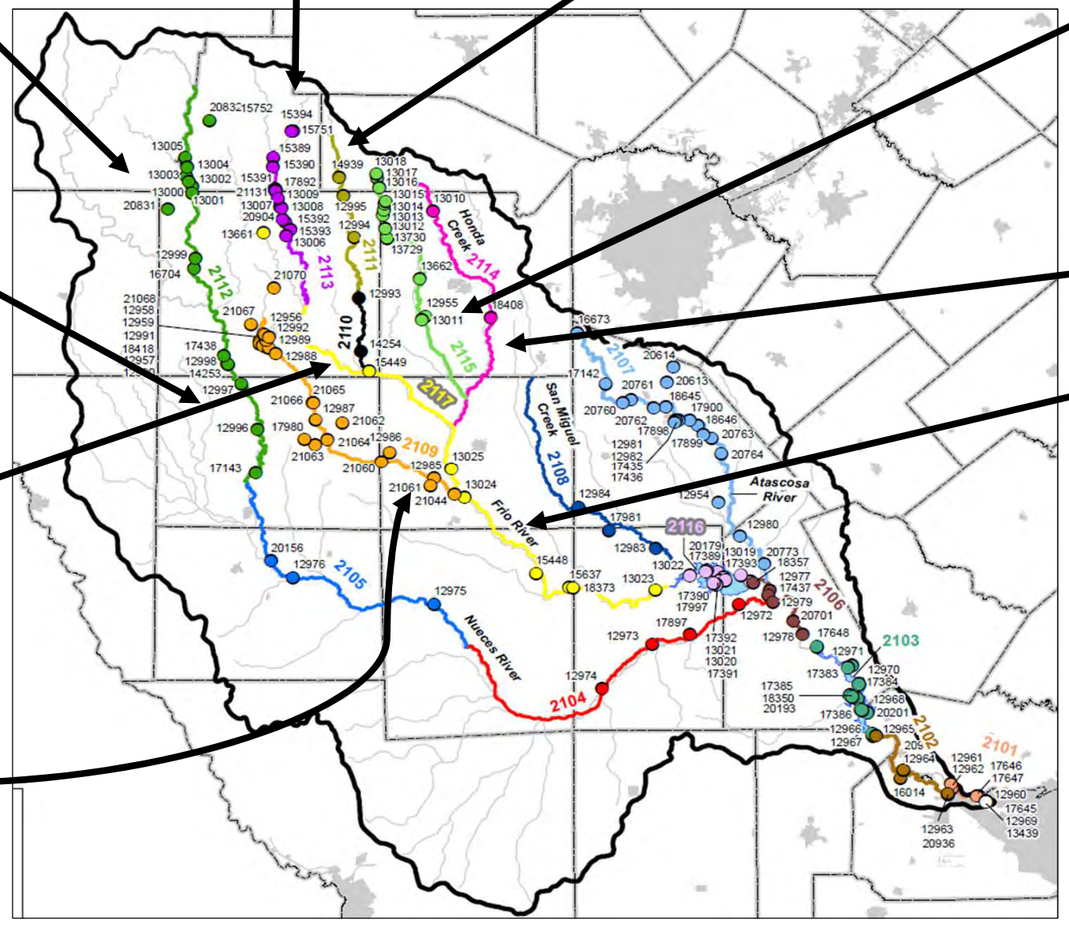


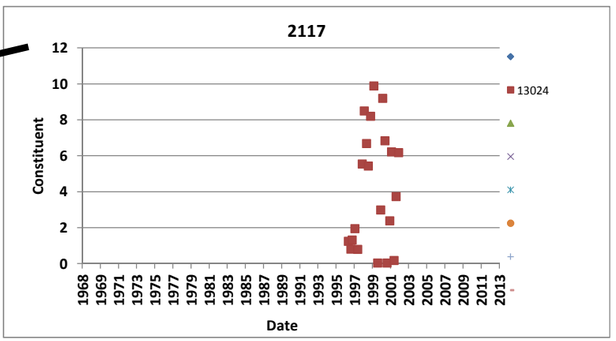


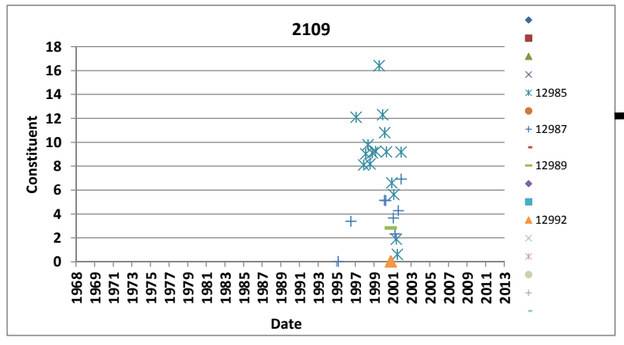




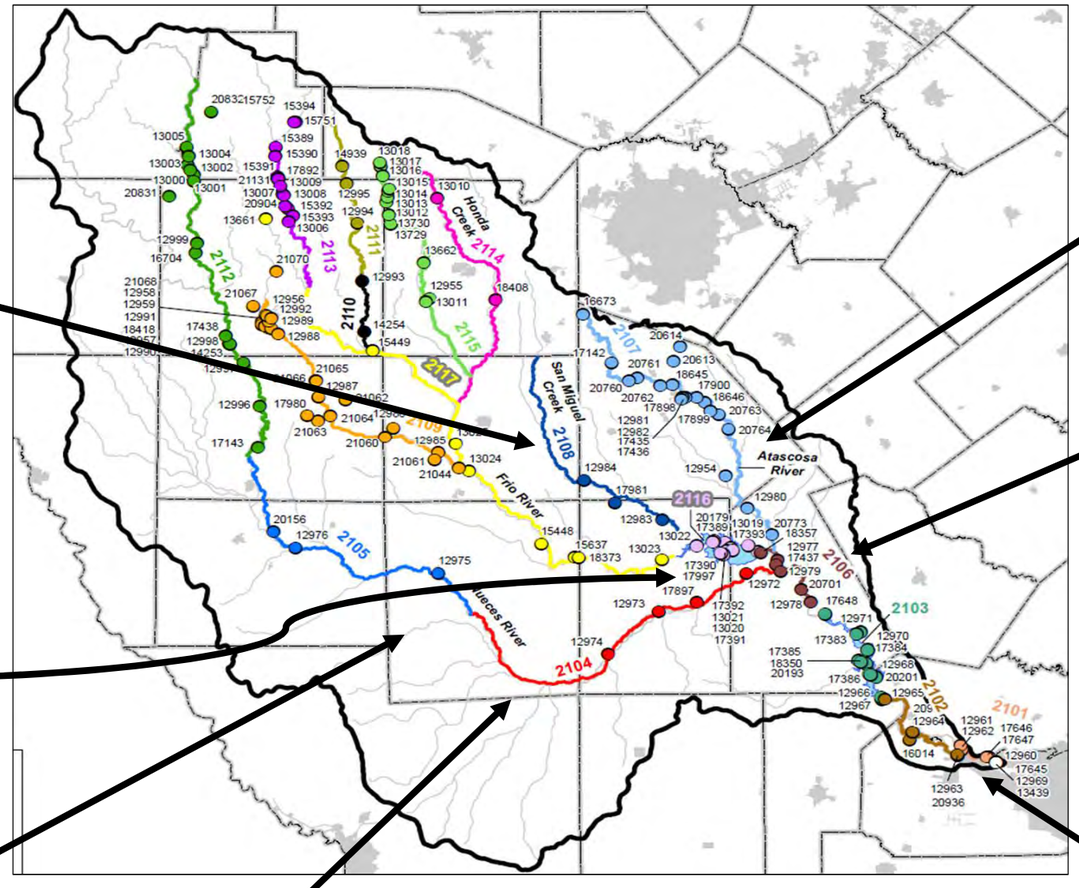


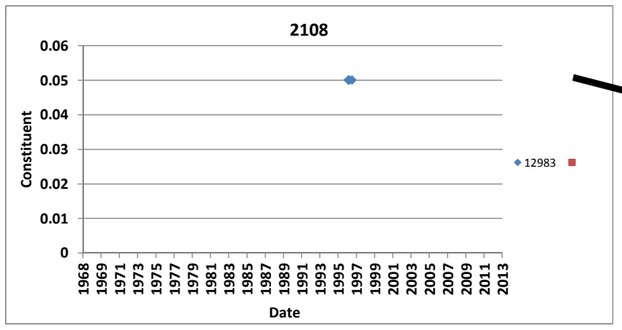


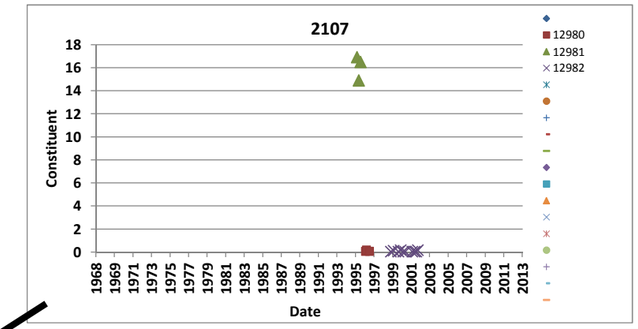


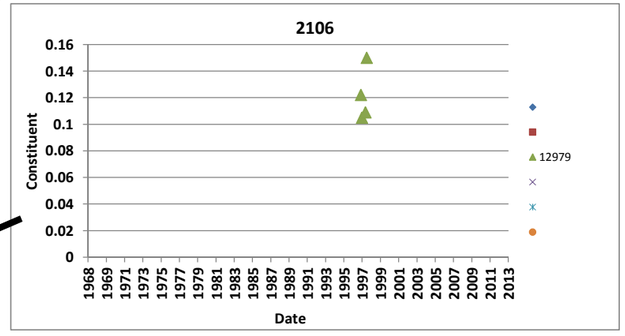


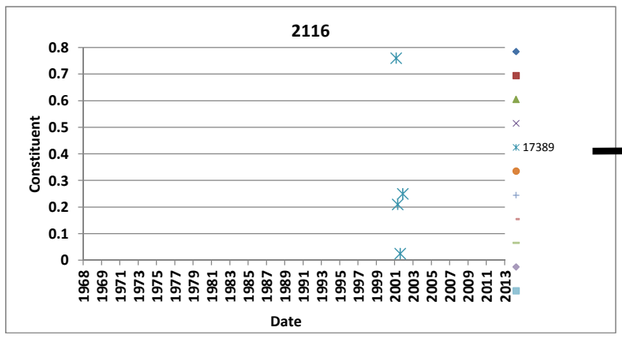
Basin 21: Nueces River
NO2 PLUS NO3-N, TOTAL, WHATMAN GF/F FILT (MG/L) vs Date

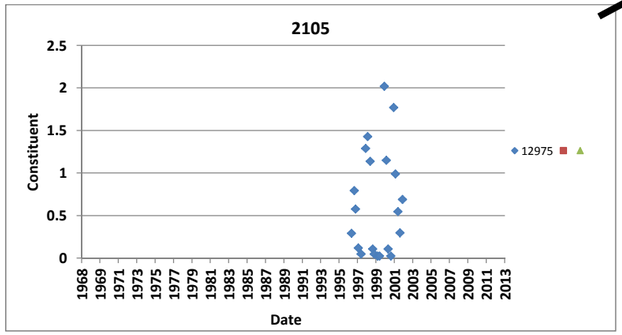


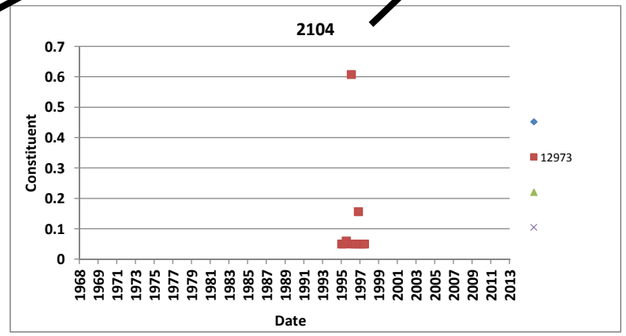


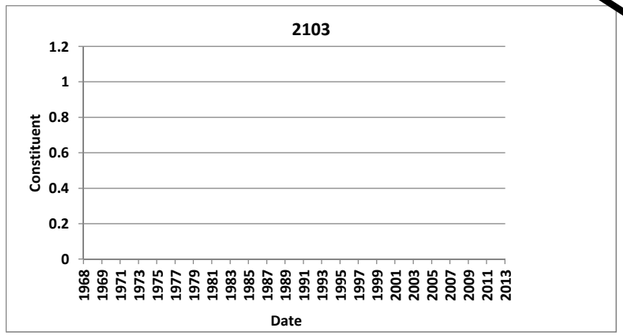


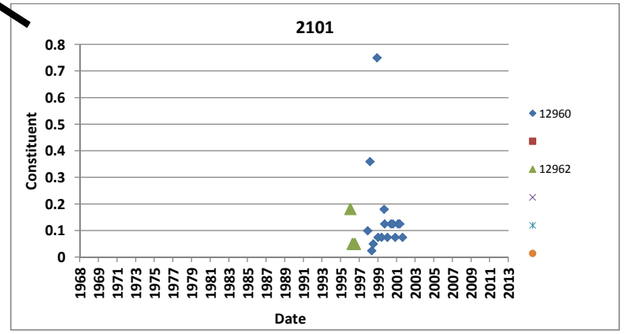








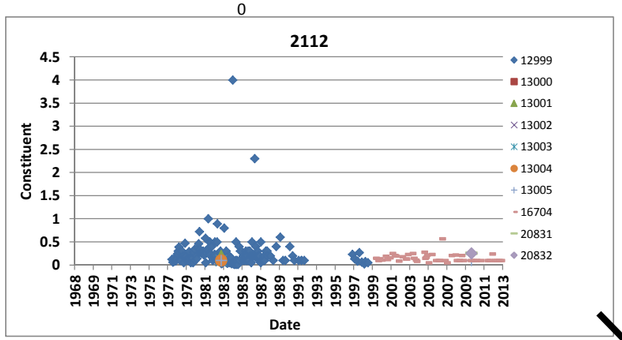


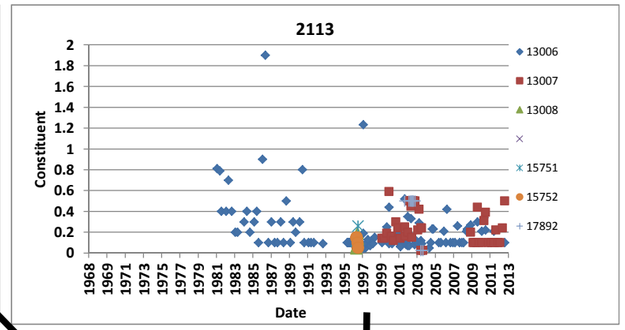


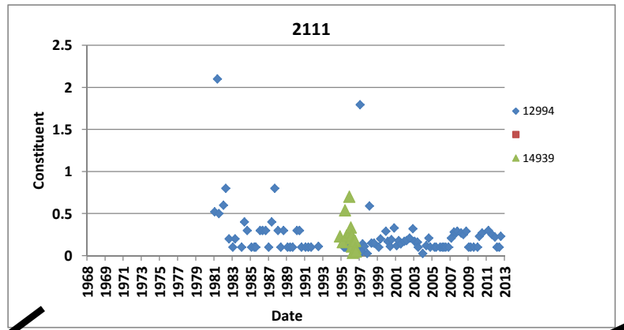
Basin 21: Nueces River

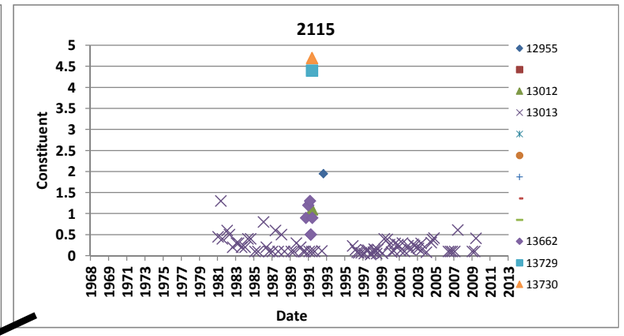
NITROGEN, KJELDAHL, TOTAL (MG/L AS N) vs Date

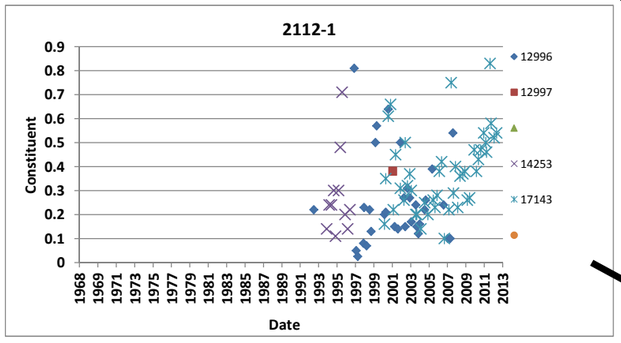
0

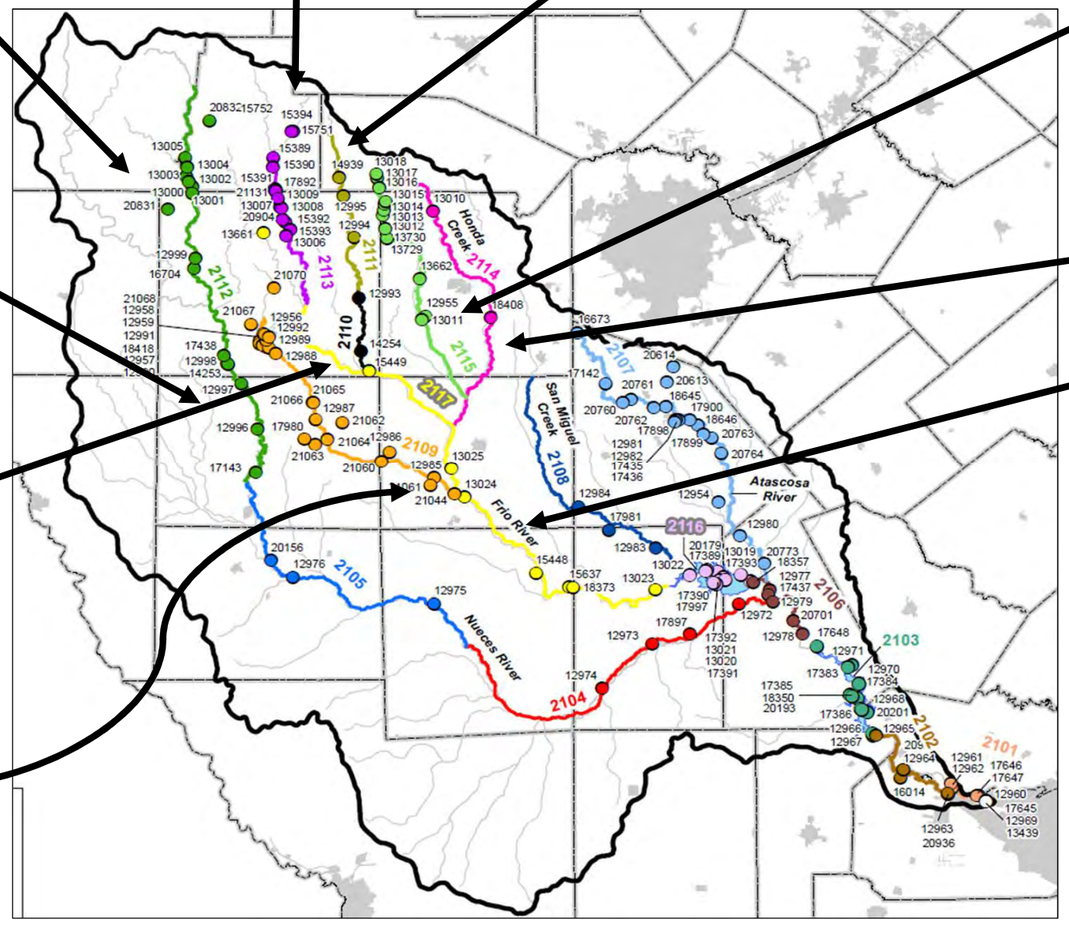


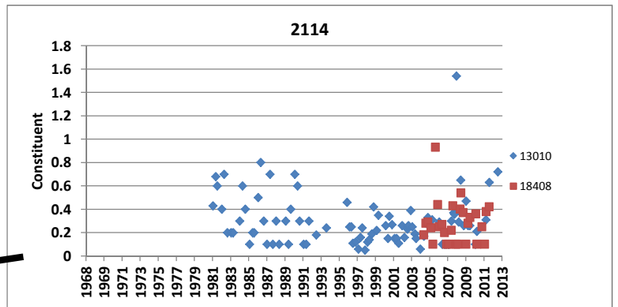


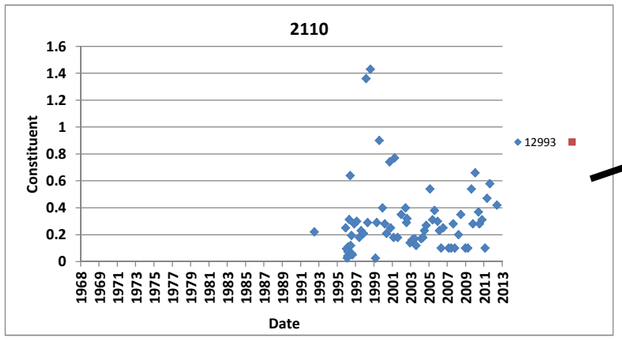


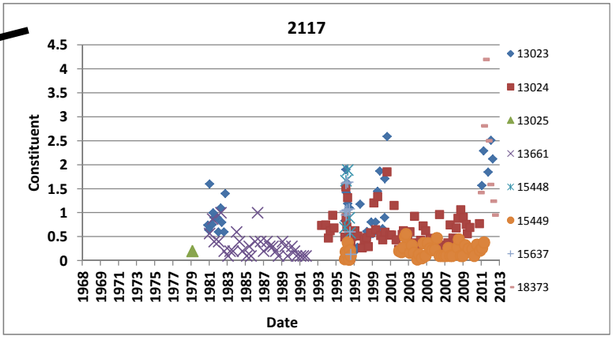


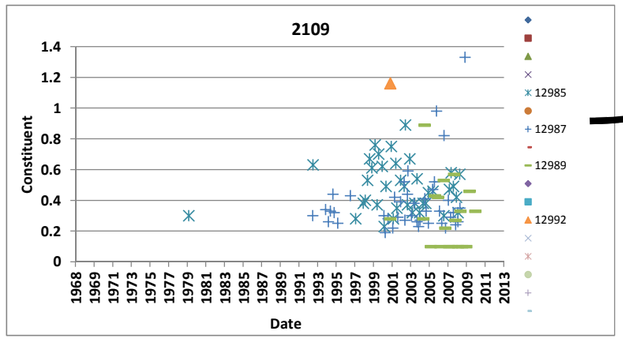




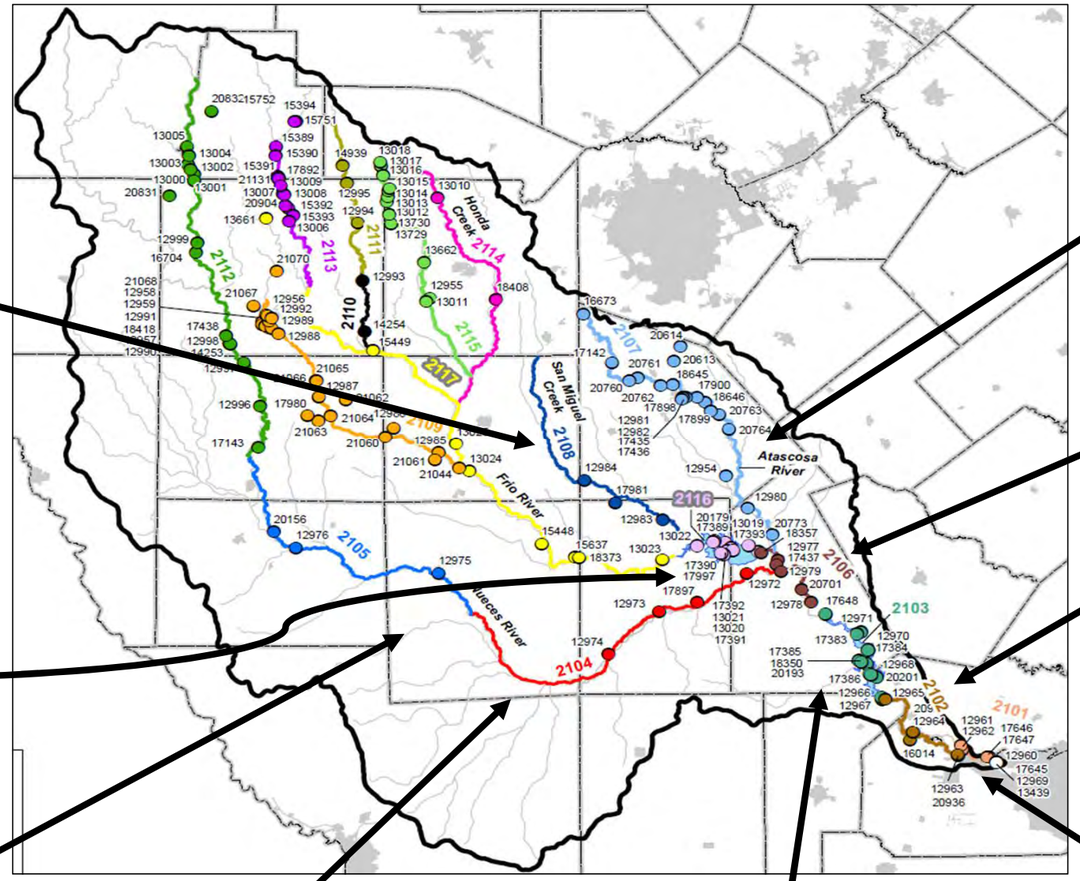


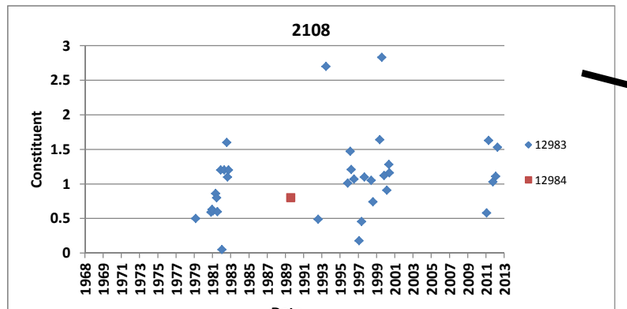


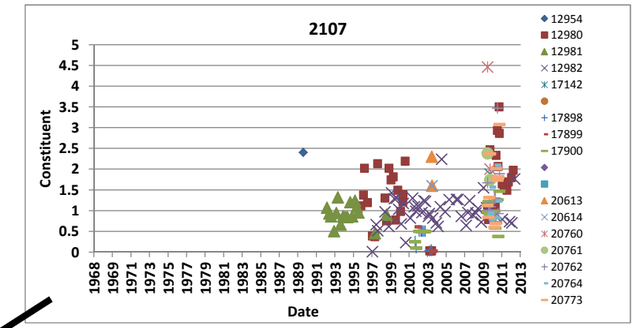


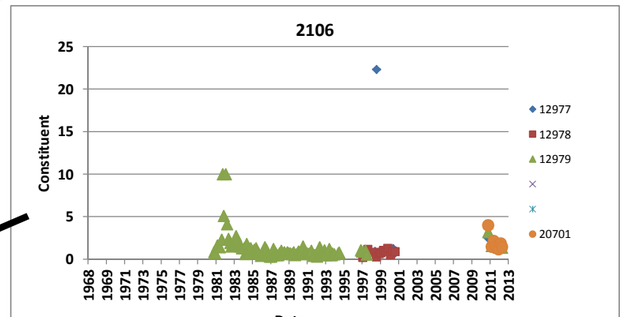


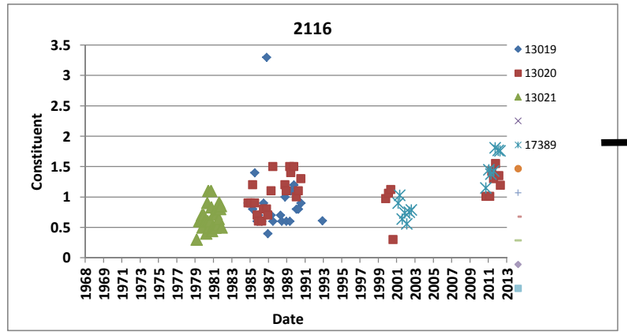
Basin 21: Nueces River
NITROGEN, KJELDAHL, TOTAL (MG/L AS N) vs Date

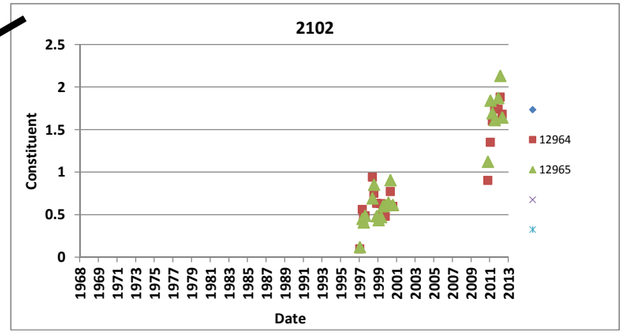


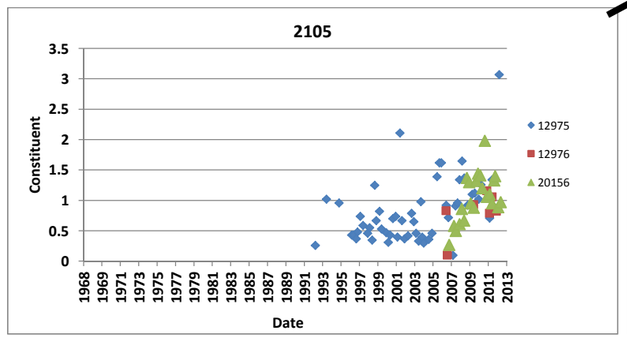


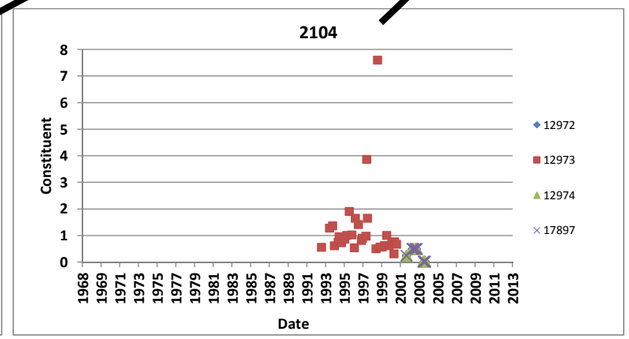


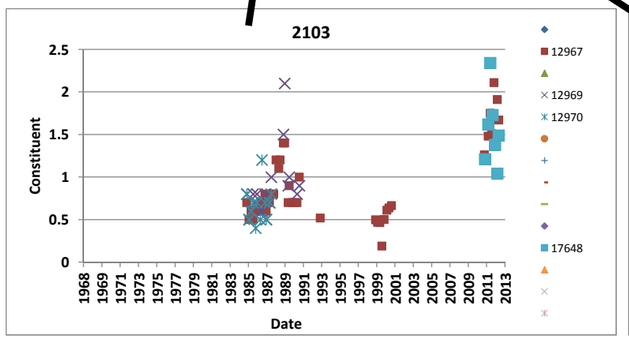


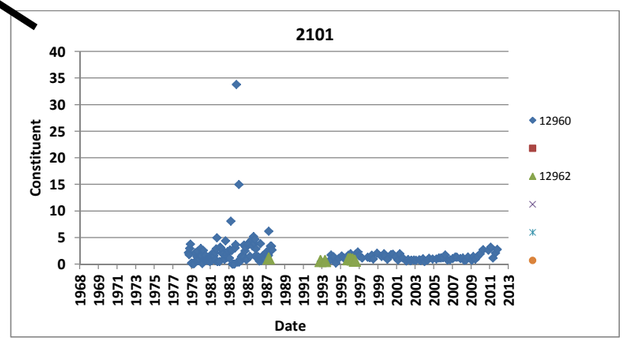






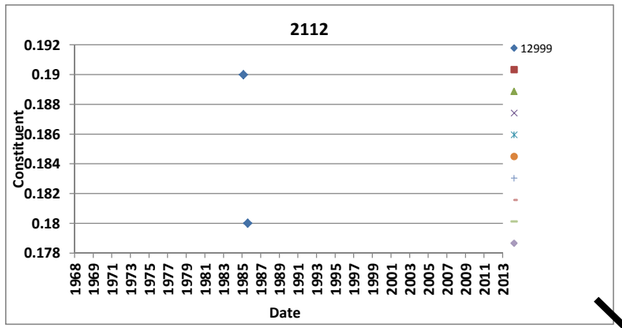


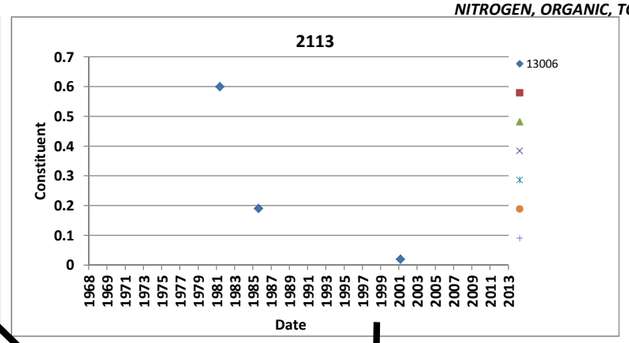


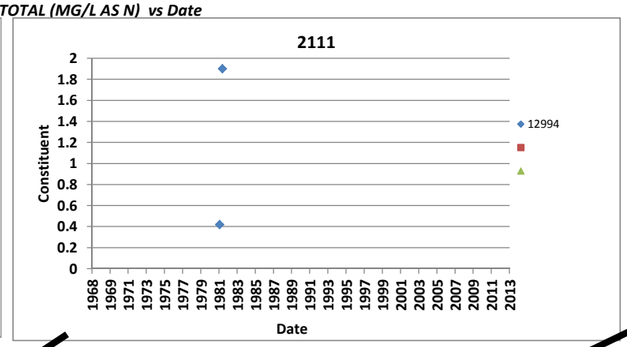


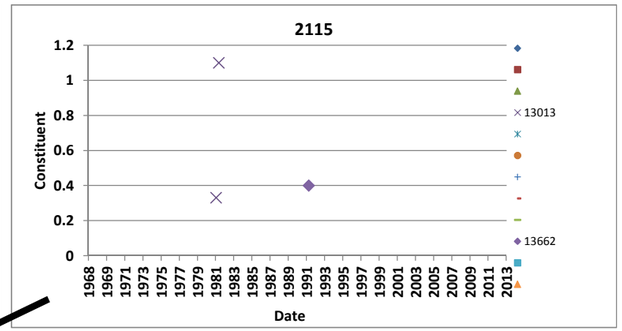
Basin 21: Nueces River

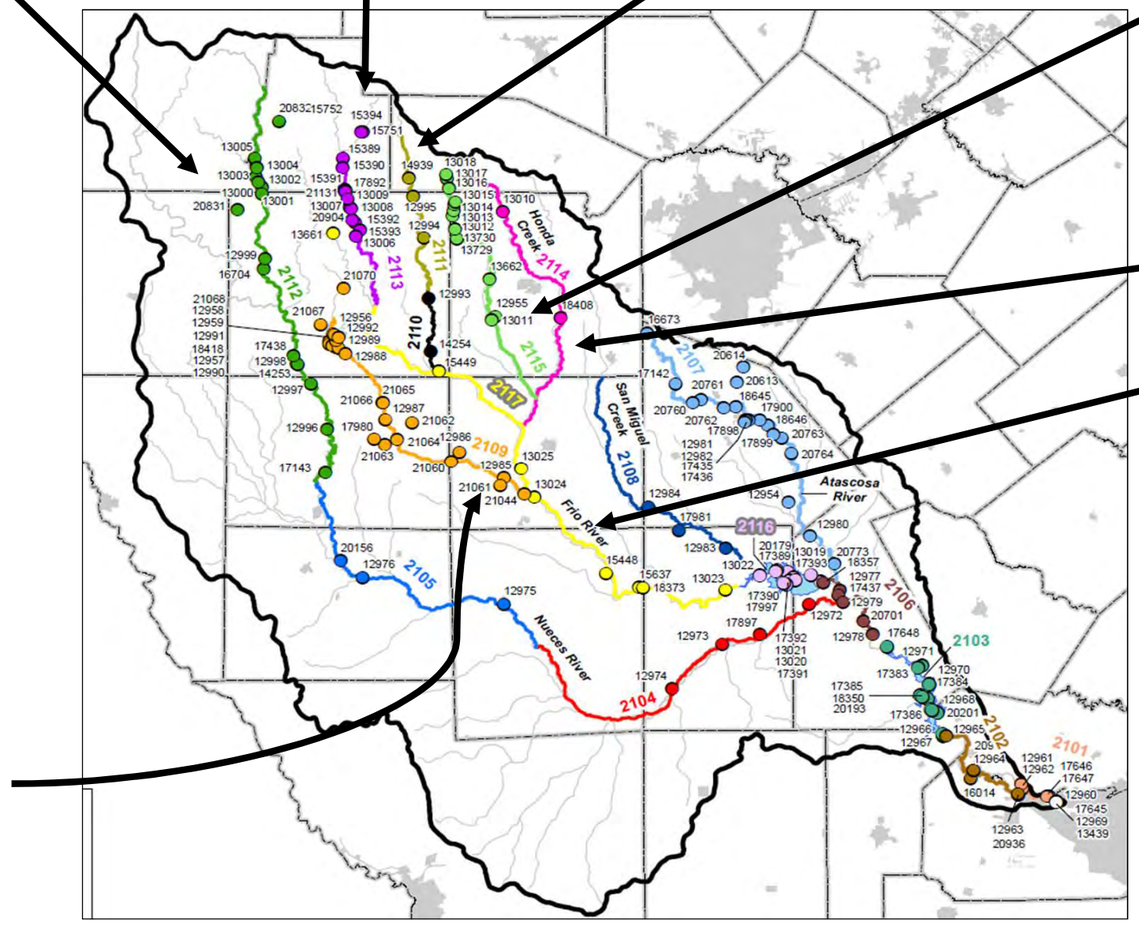
NITROGEN, ORGANIC, TOTAL (MG/L AS N) vs Date

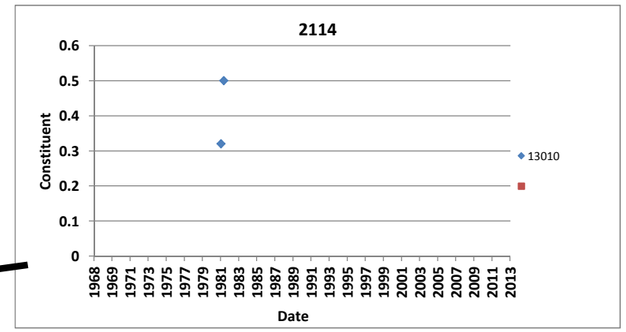


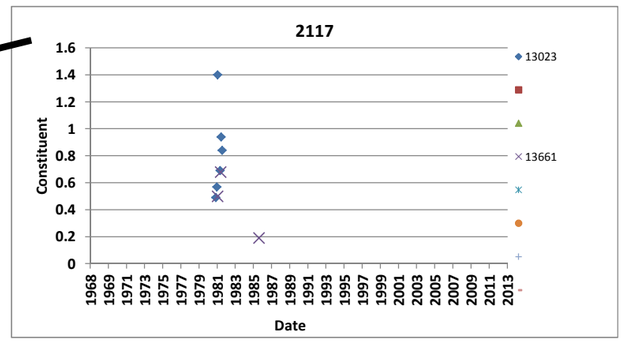




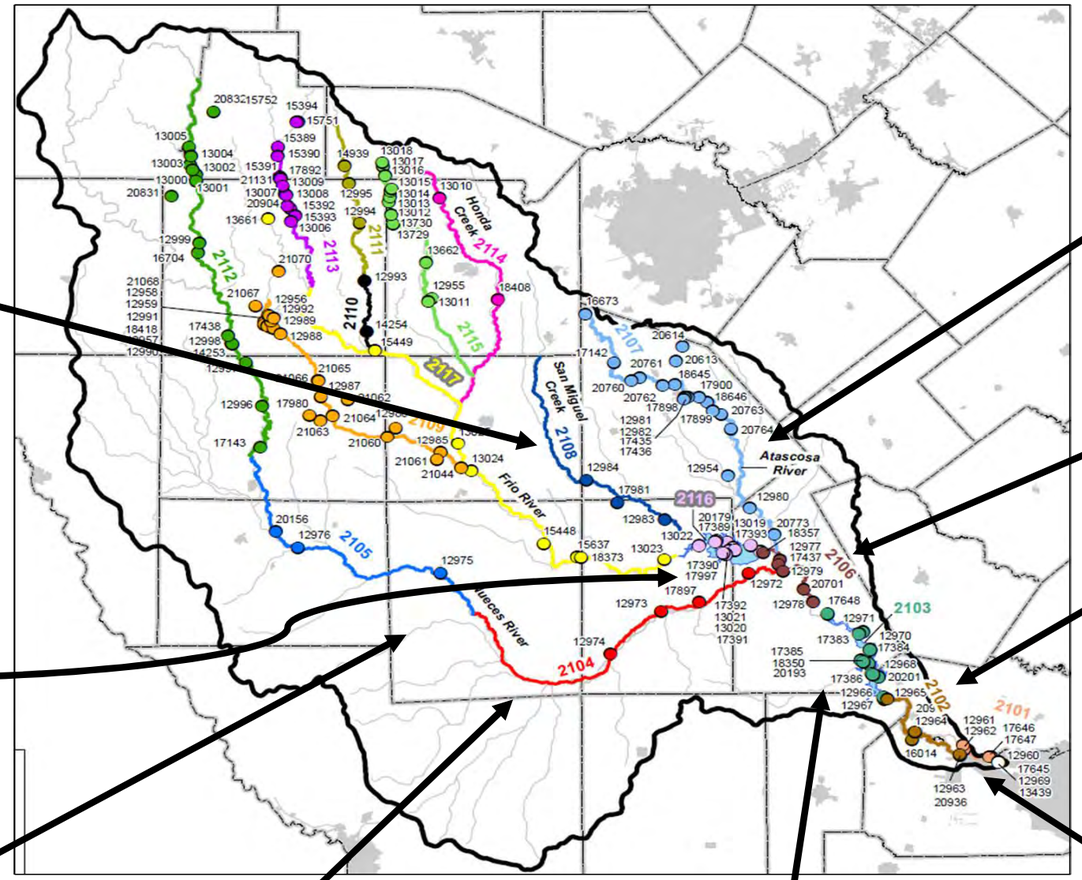


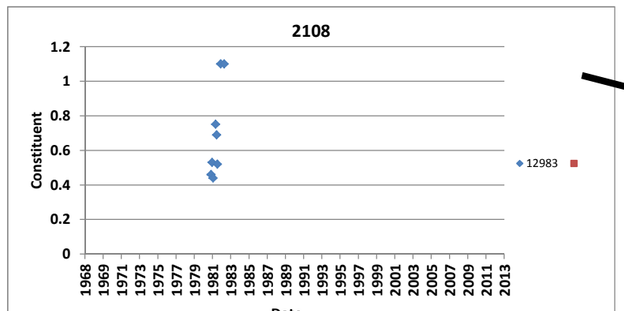


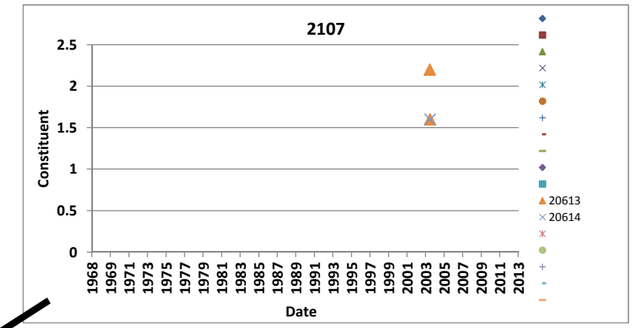


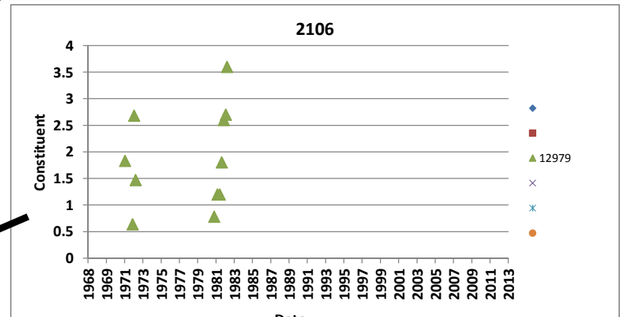


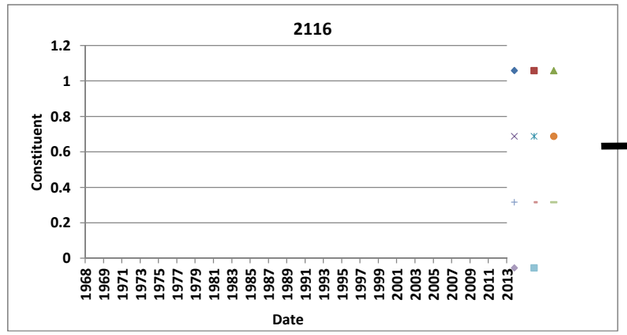
Basin 21: Nueces River
NITROGEN, ORGANIC, TOTAL (MG/L AS N) vs Date

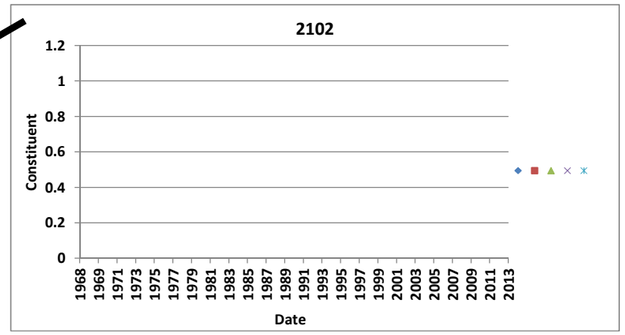


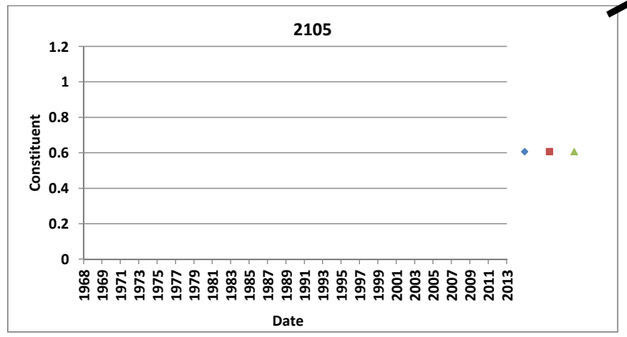


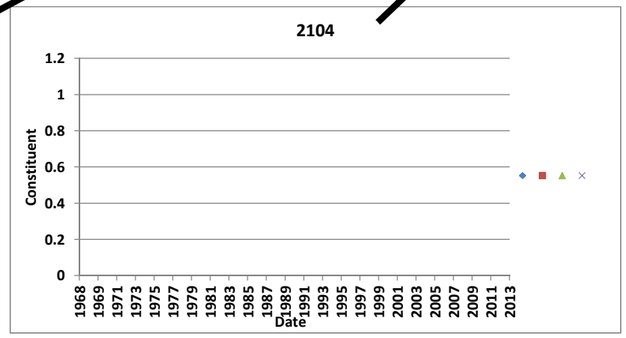


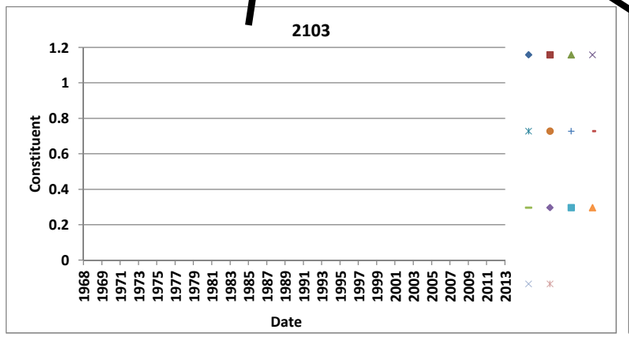


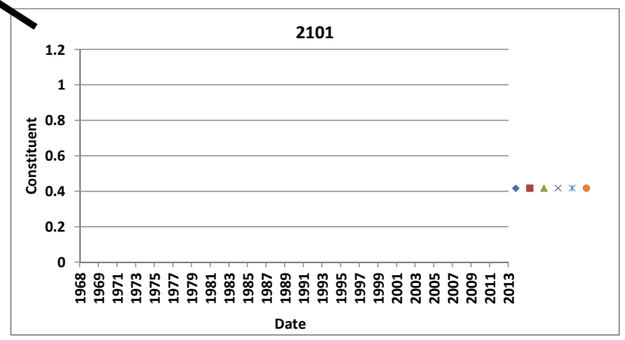






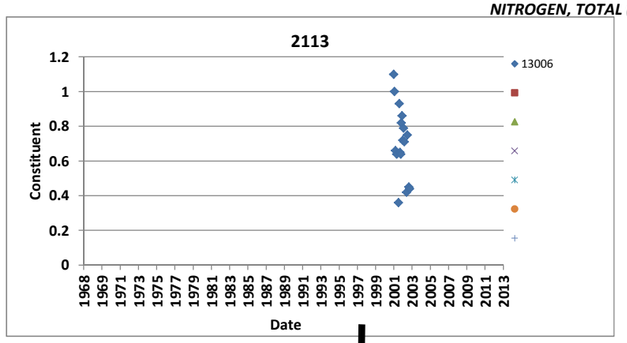


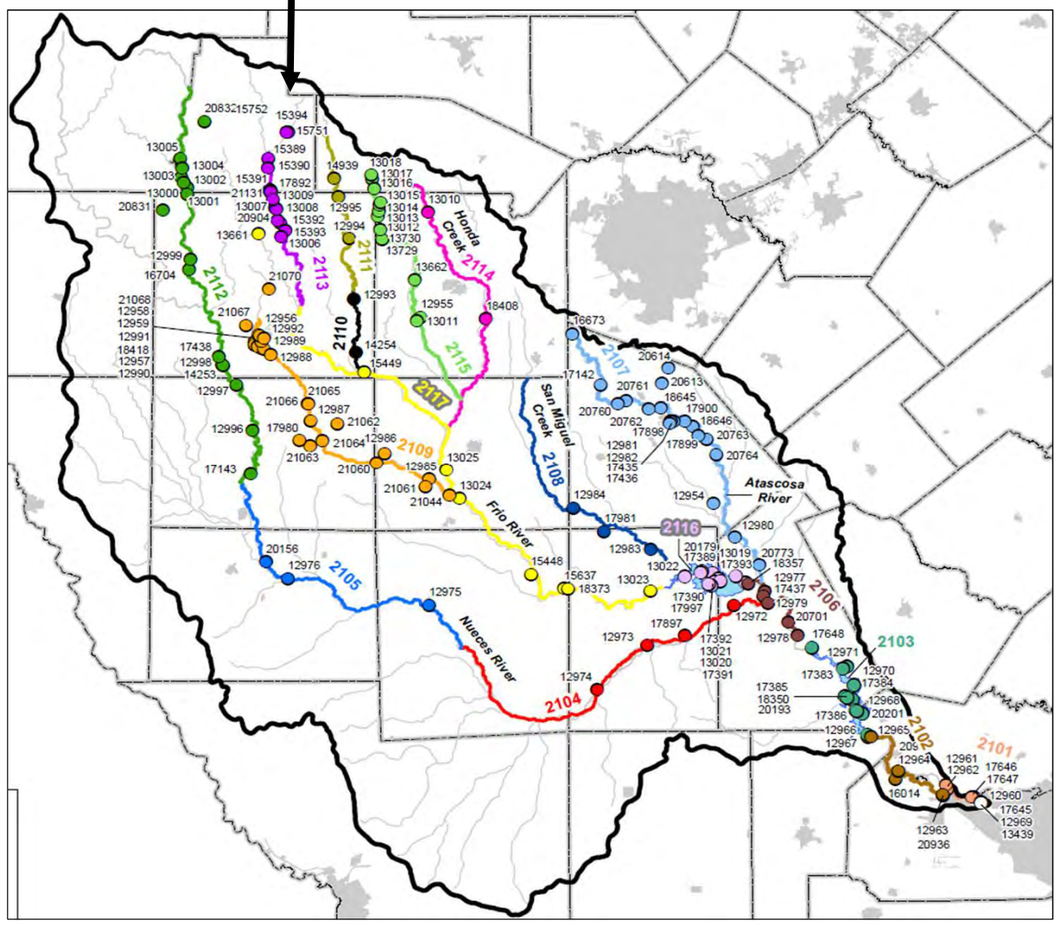




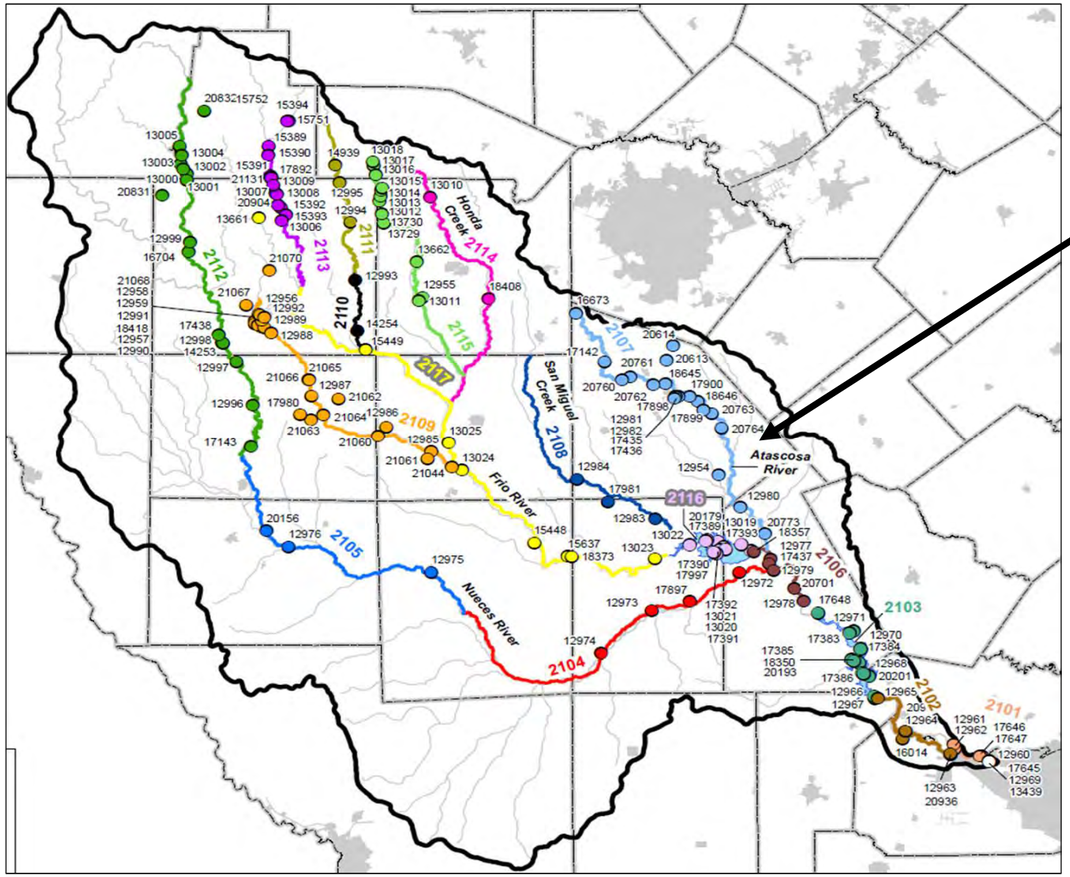
Basin 21: Nueces River

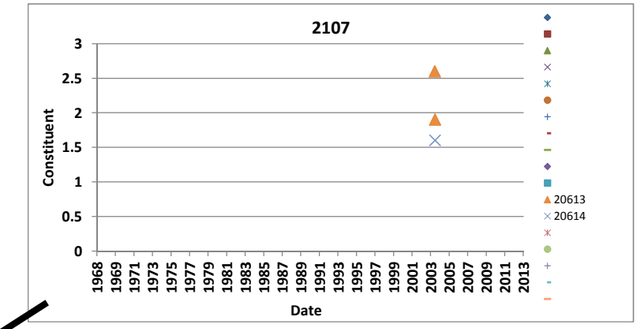
NITROGEN, TOTAL (MG/L AS N) vs Date





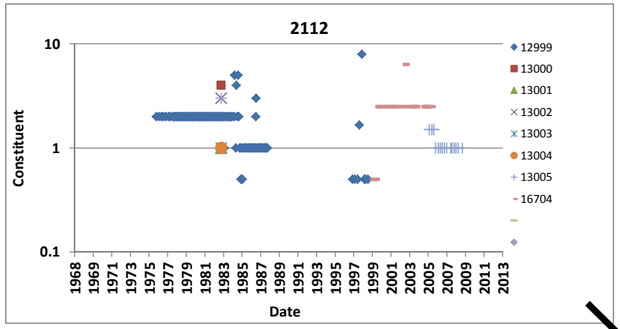
Basin 21: Nueces River
NITROGEN, TOTAL (MG/L AS N)vs Date

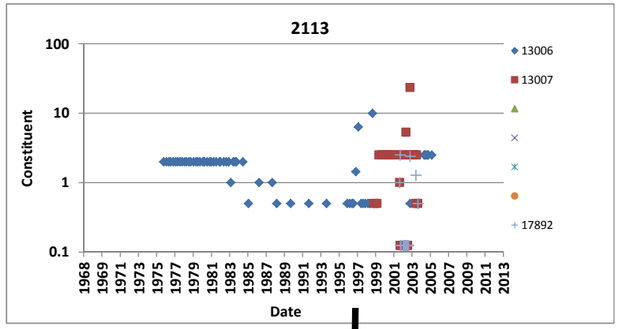


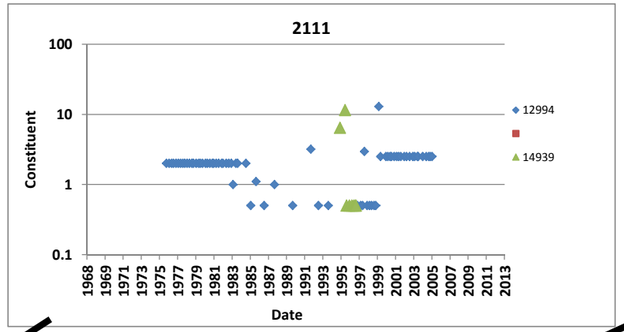


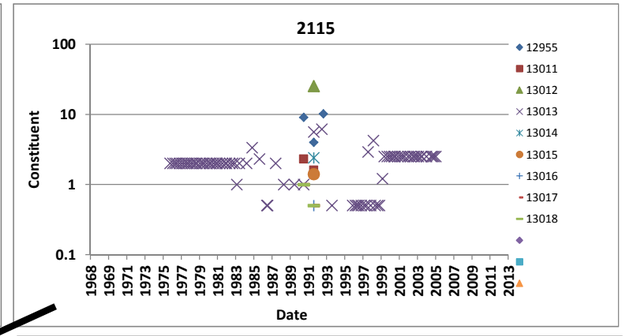
Basin 21: Nueces River

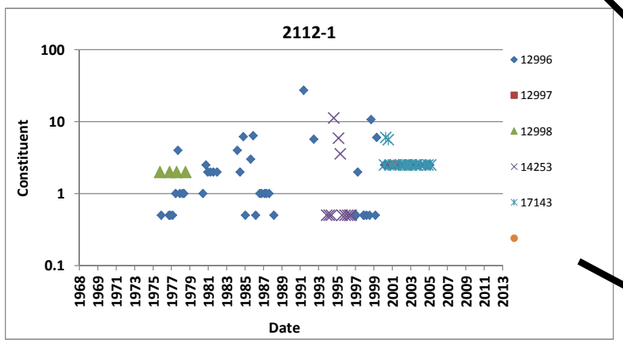
PHEOPHYTIN-A UG/L SPECTROPHOTOMETRIC ACID. METH. vs Date

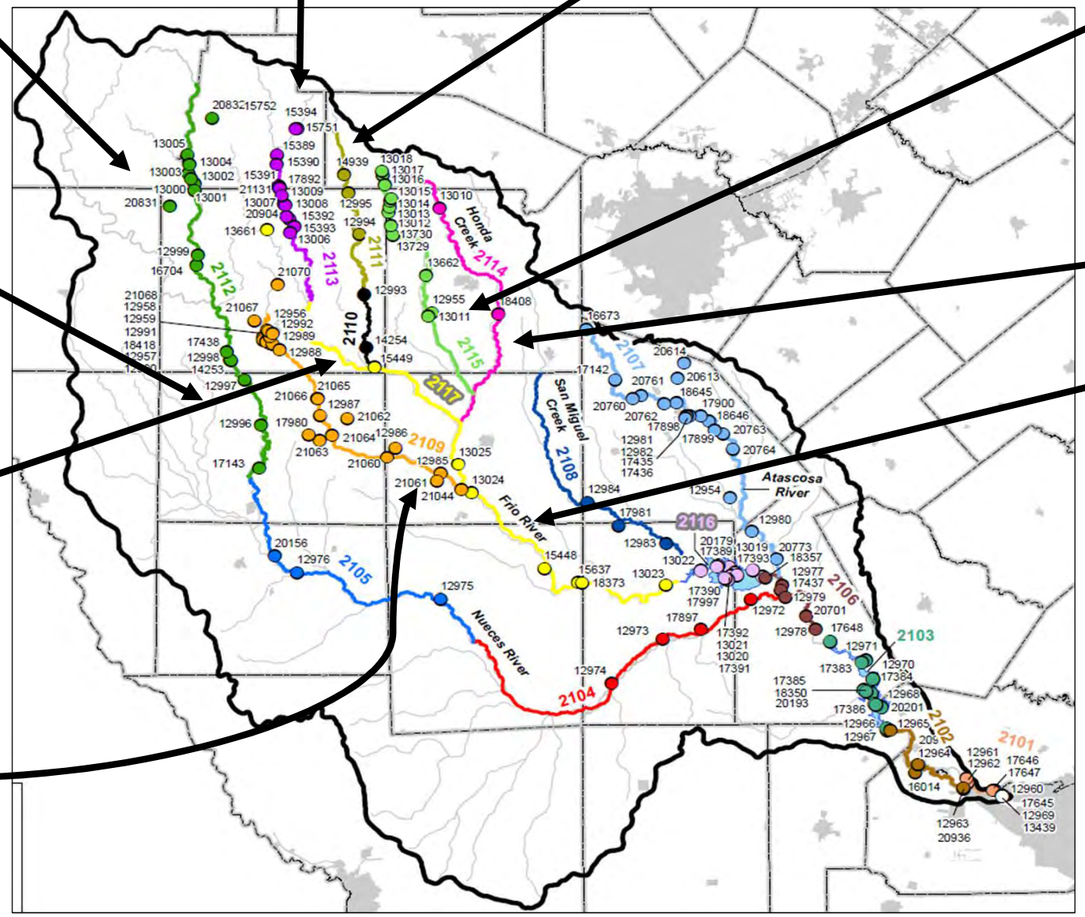


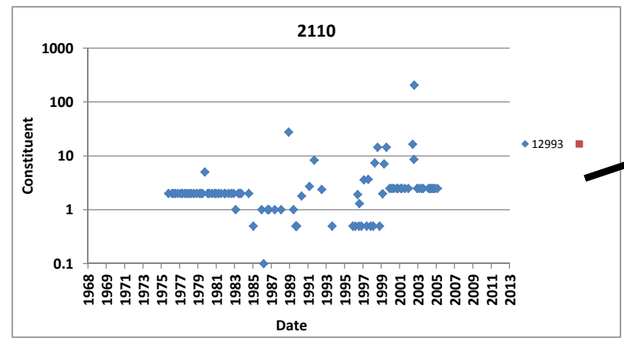


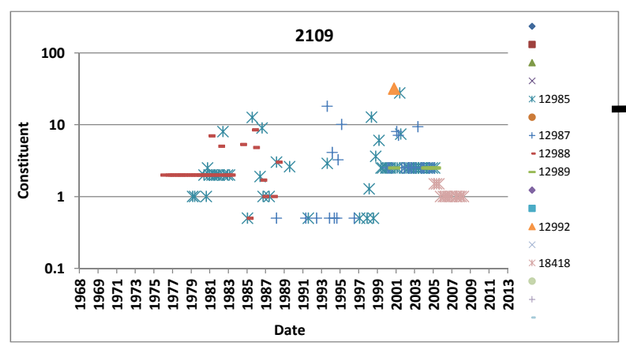


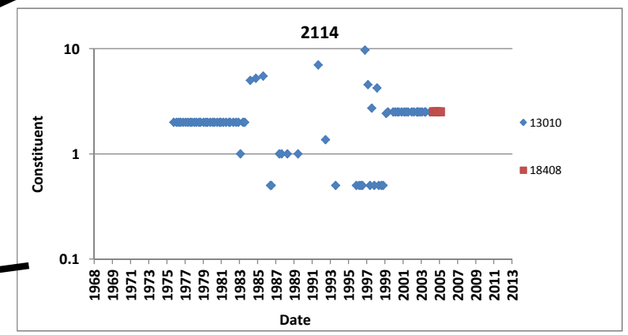


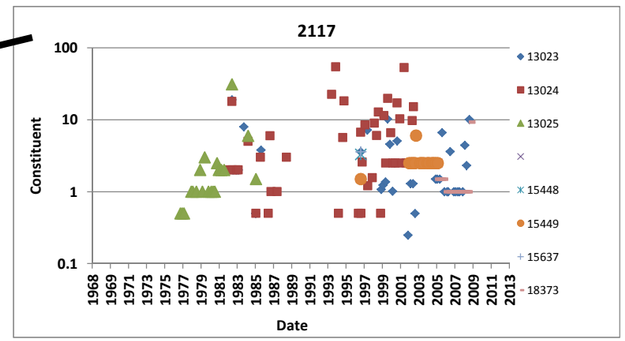






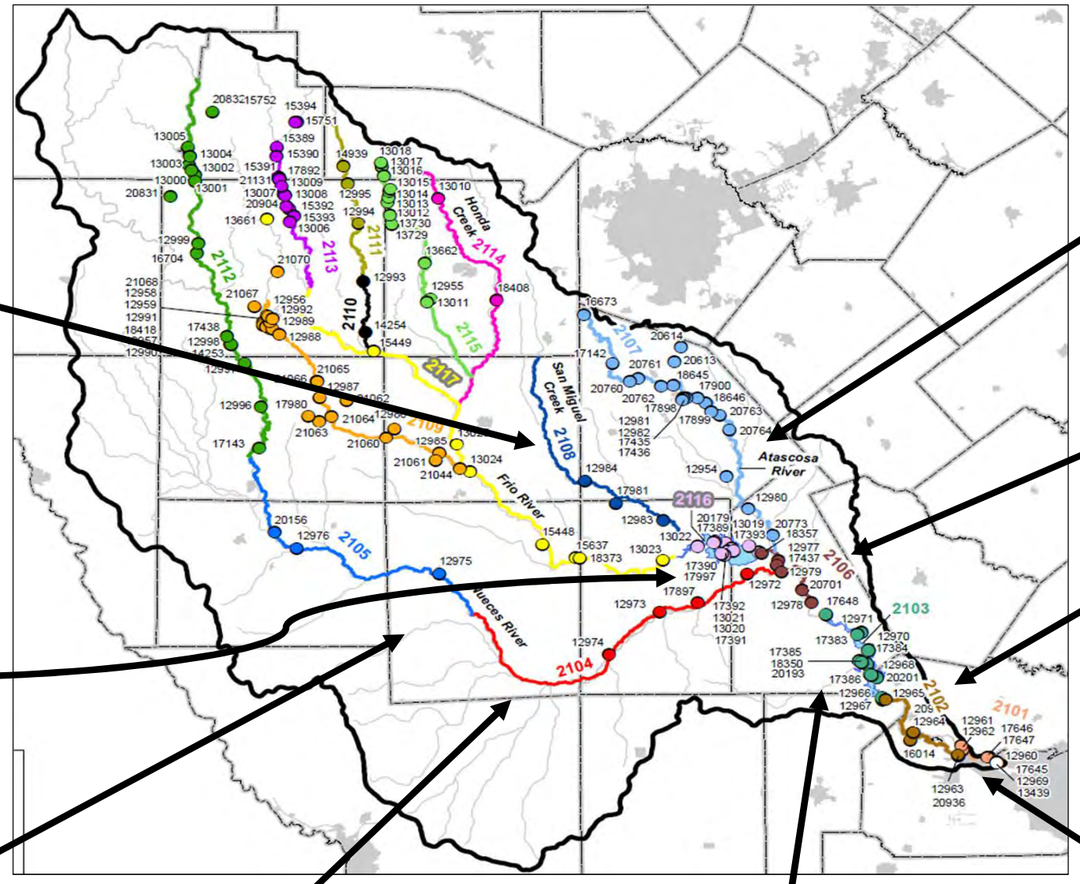


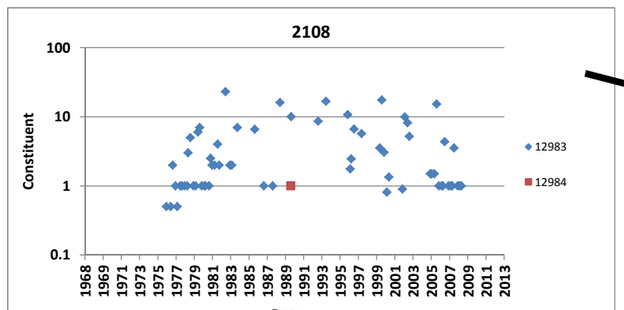


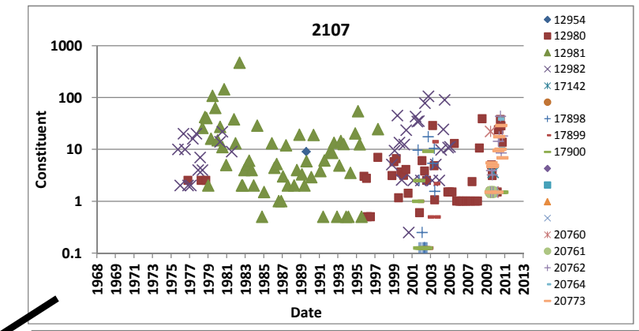


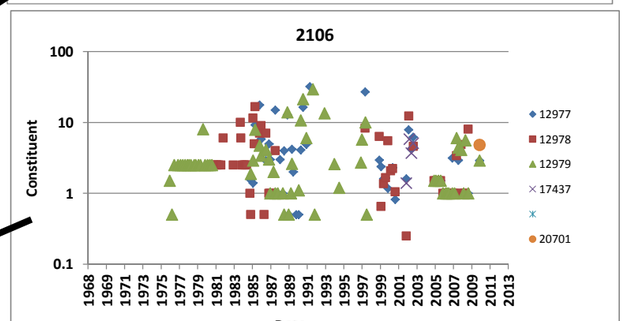
Basin 21: Nueces River

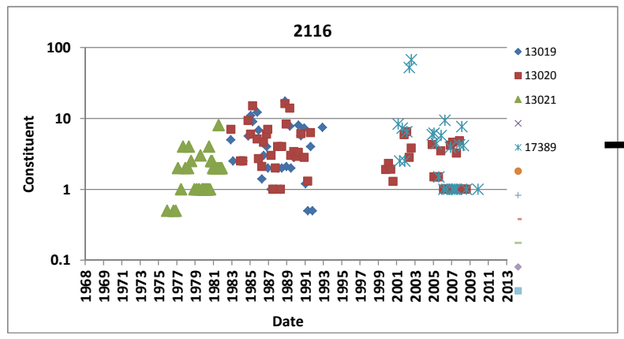
PHEOPHYTIN-A UG/L SPECTROPHOTOMETRIC ACID. METH. vs Date

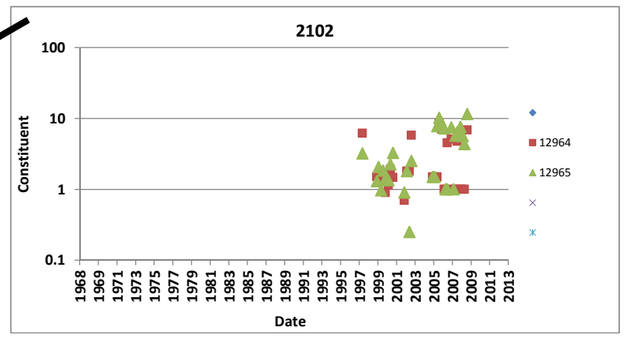


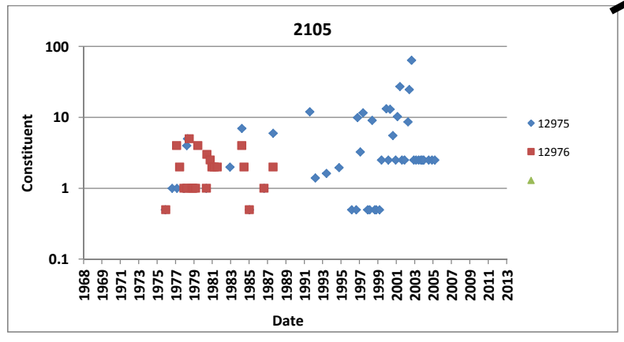


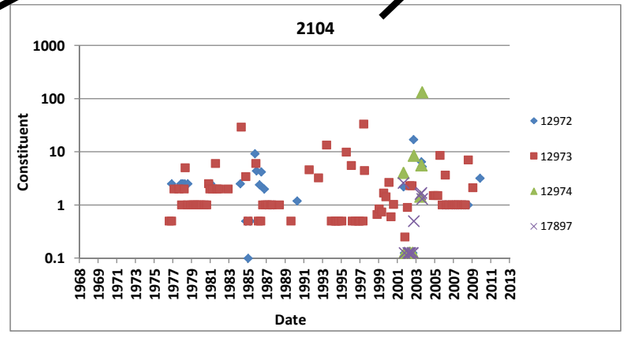


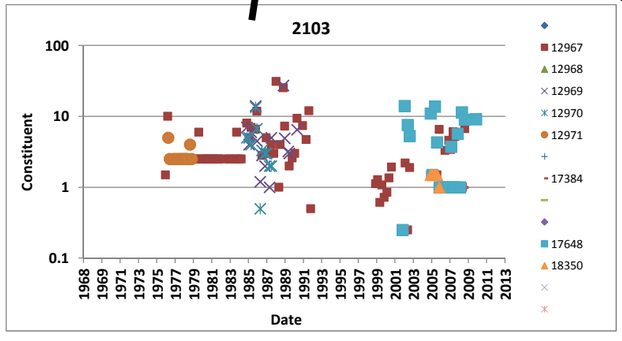


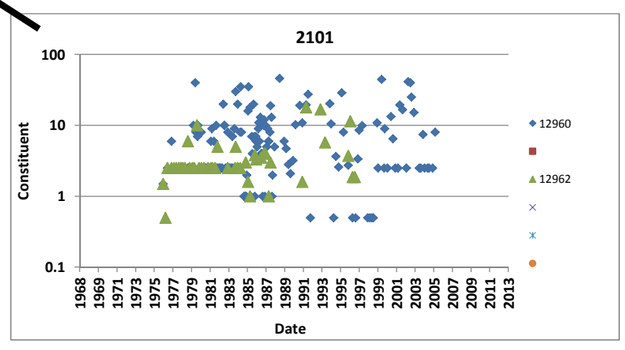




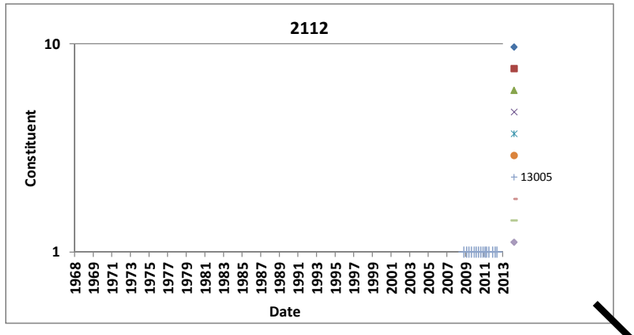


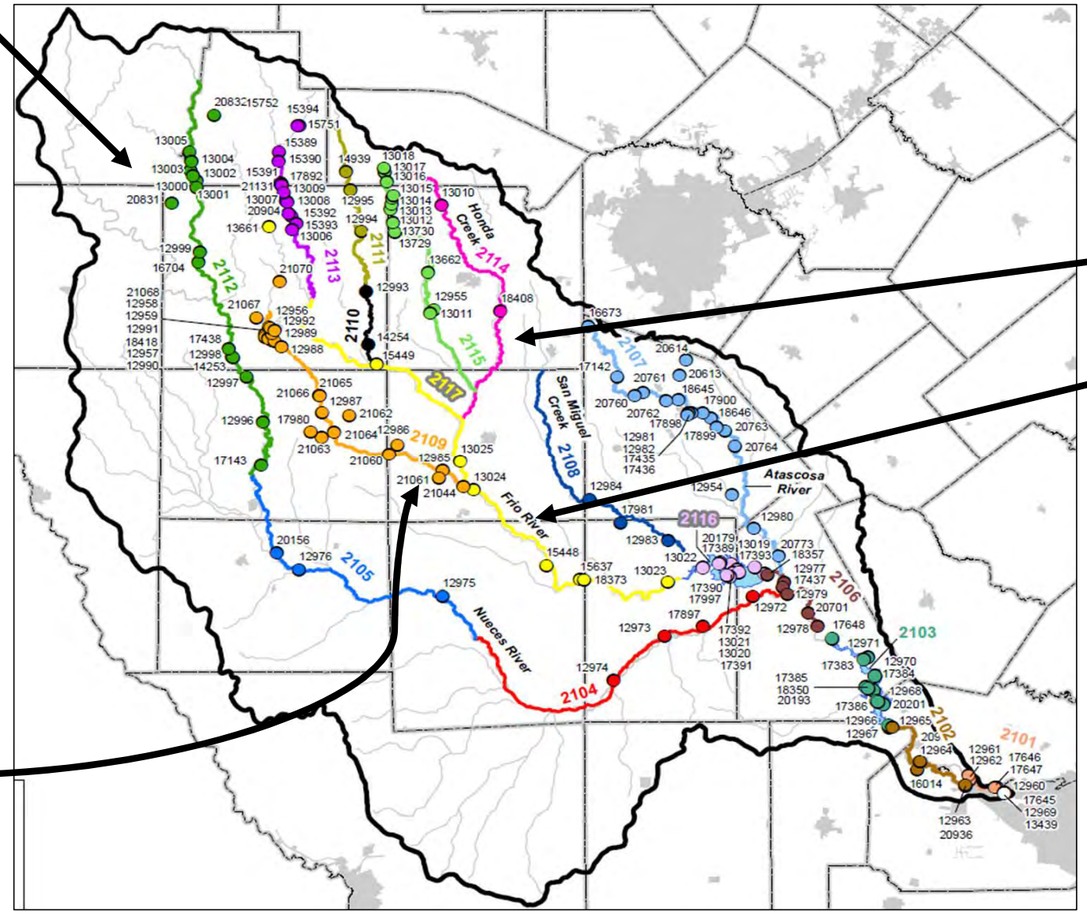


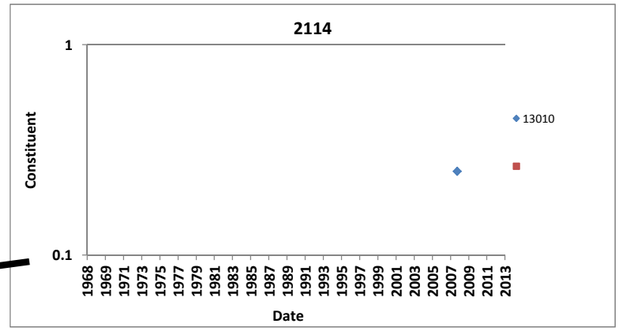


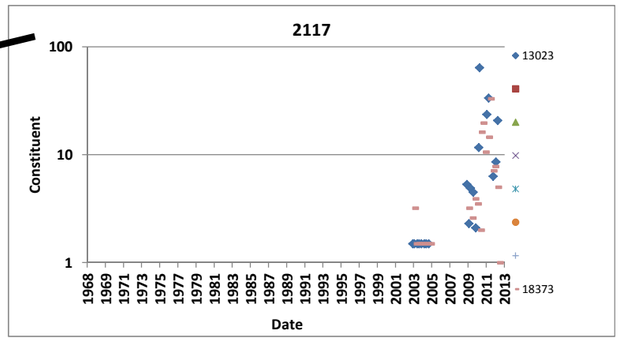


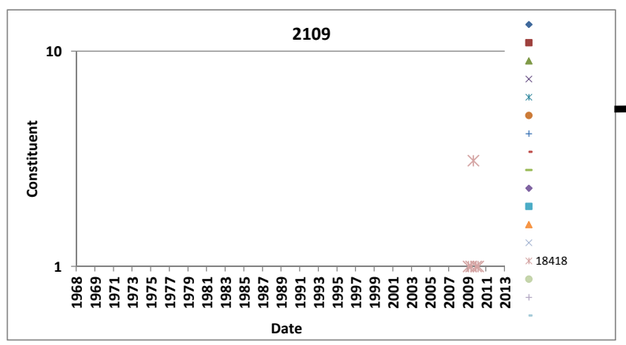
Basin 21: Nueces River
PHEOPHYTIN-A UG/L FLUOROMETRIC METHOD vs Date



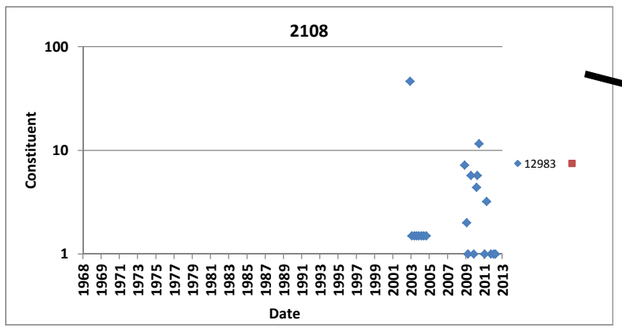


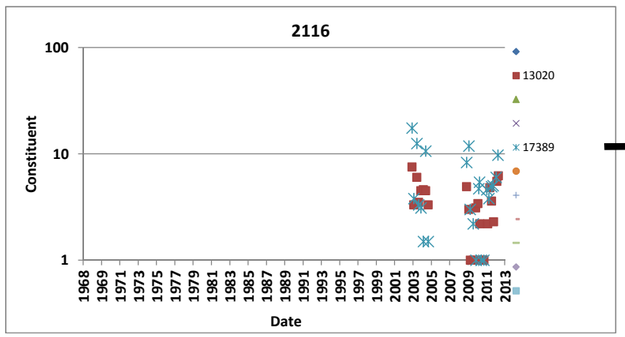


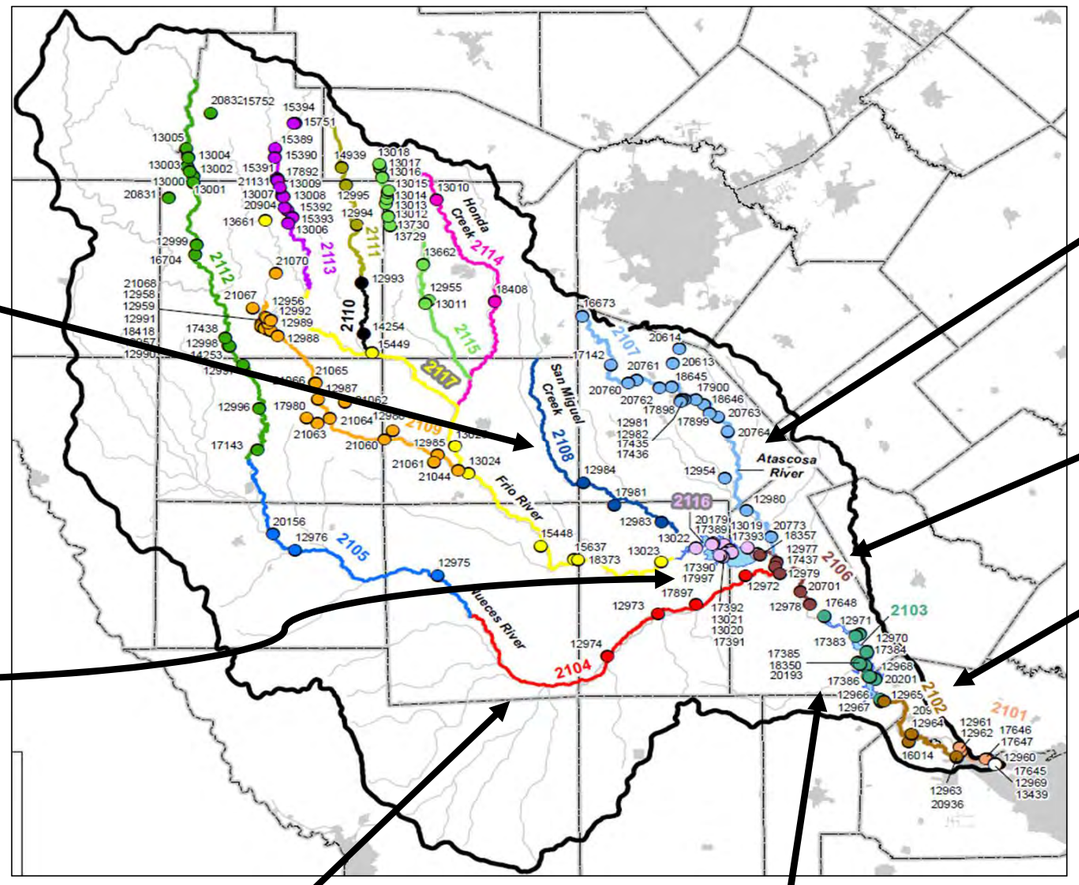


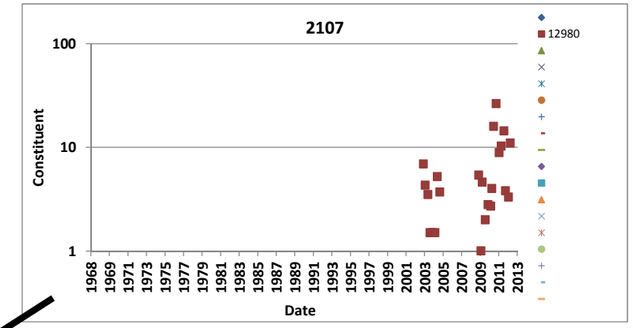


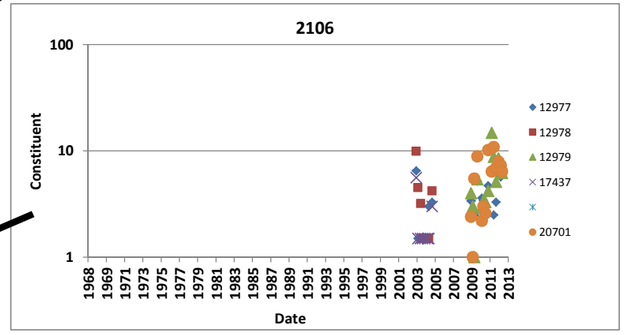
Basin 21: Nueces River
PHEOPHYTIN-A UG/L FLUOROMETRIC METHOD vs Date

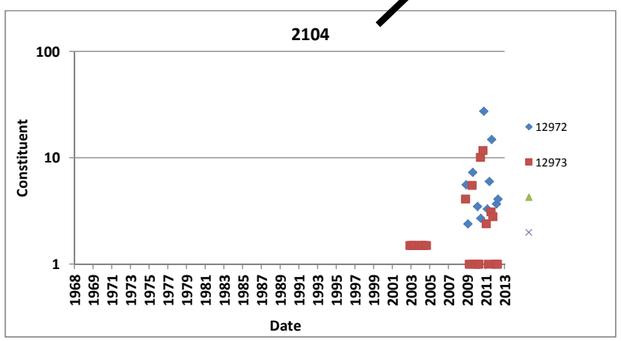


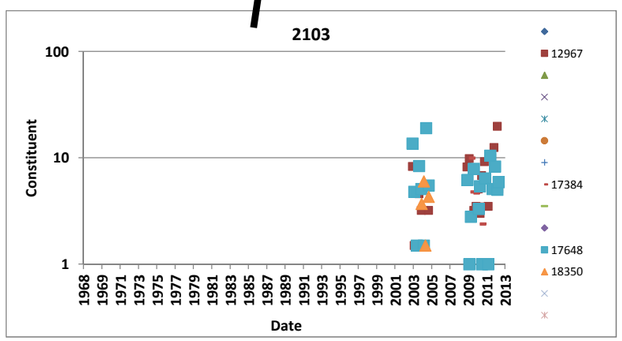




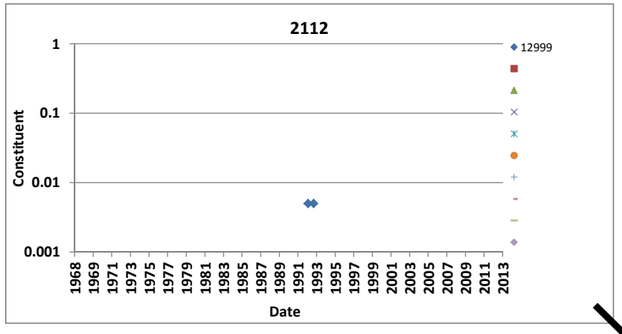


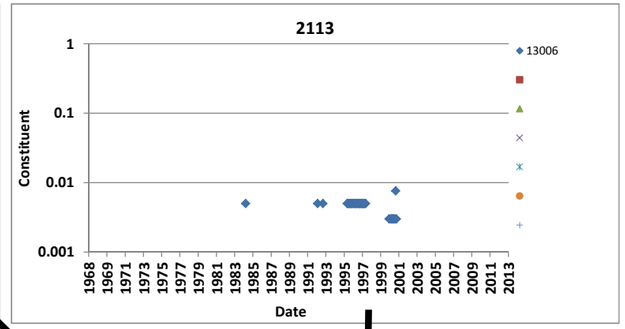


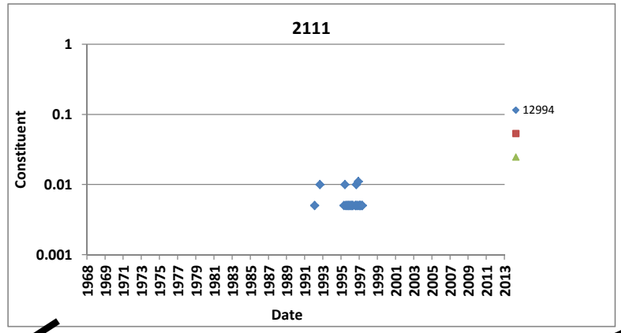


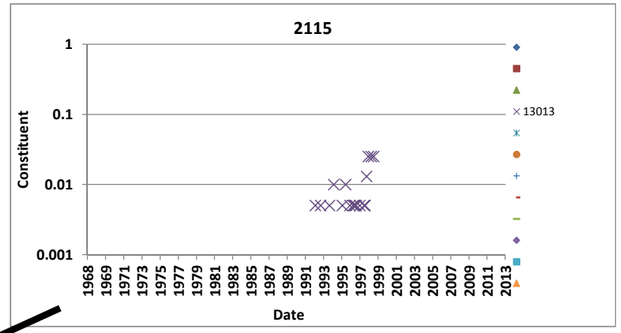


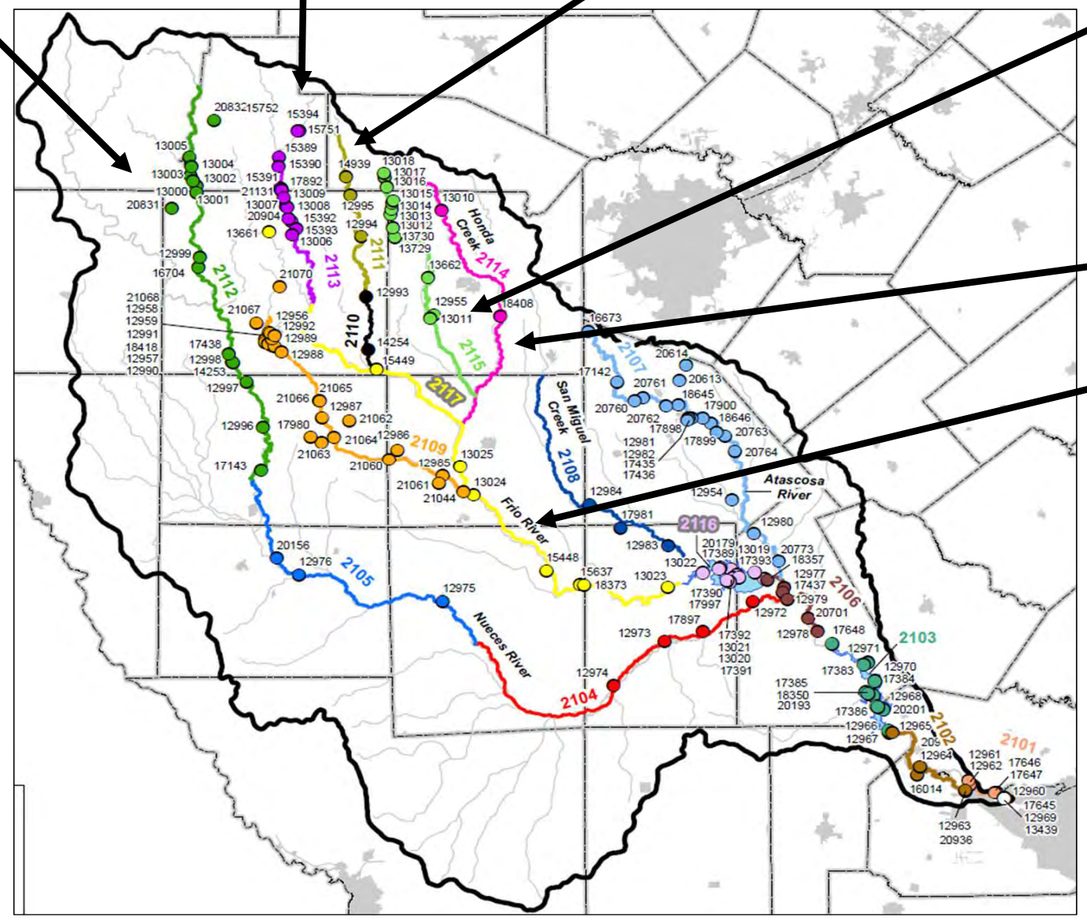
Basin 21: Nueces River
PHOSPHORUS, DISSOLVED (MG/L AS P) vs Date

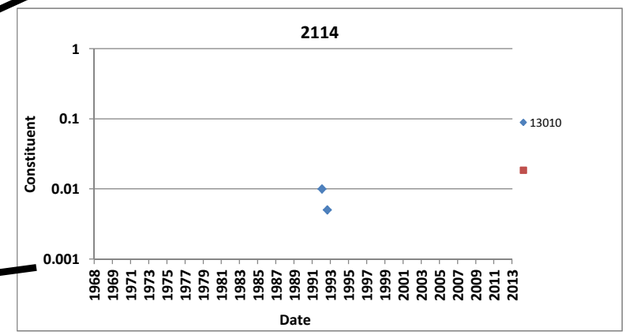


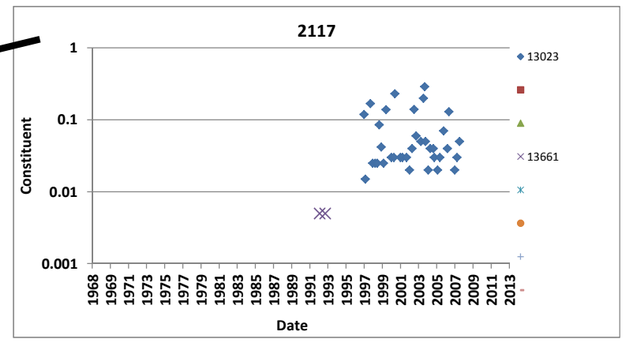




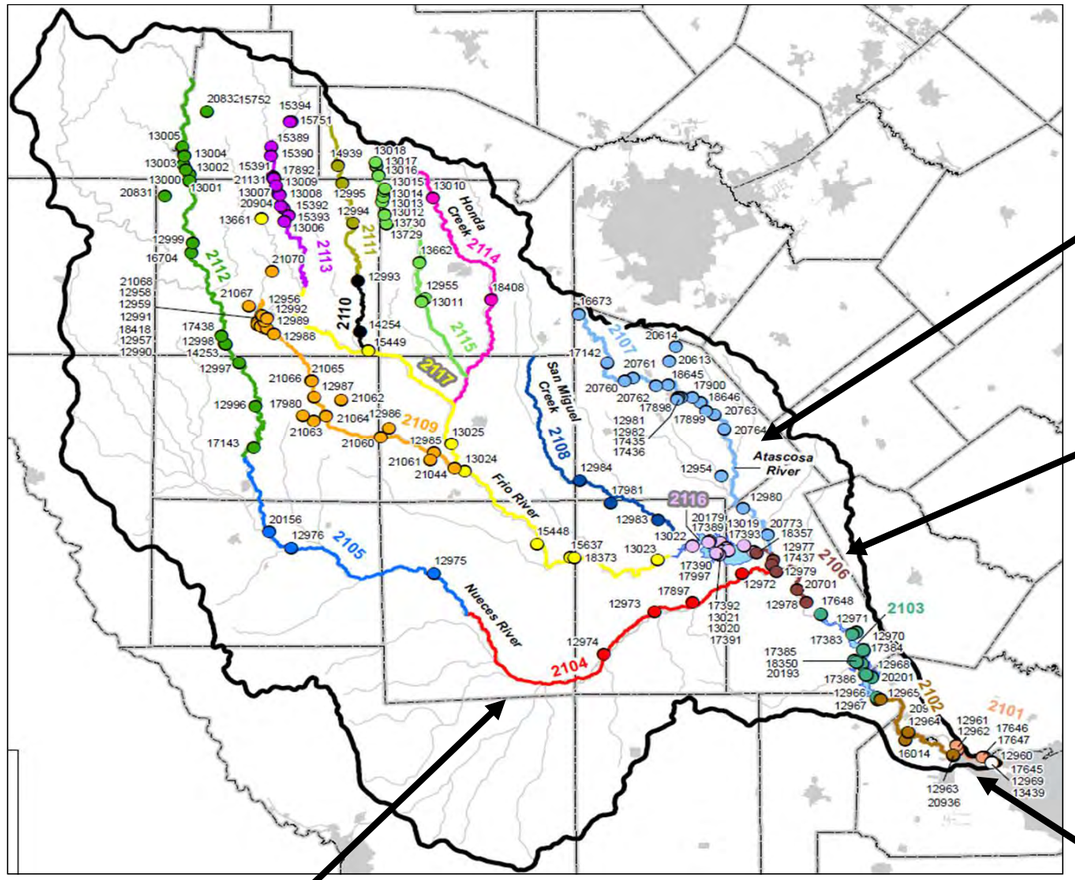


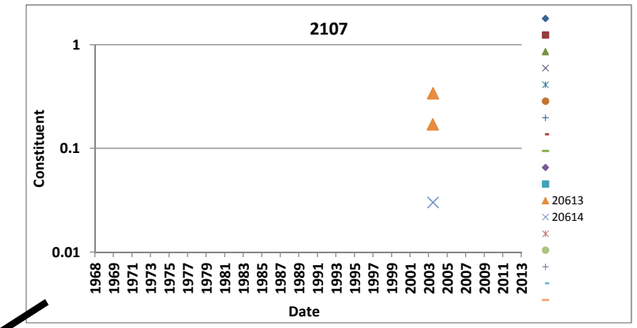


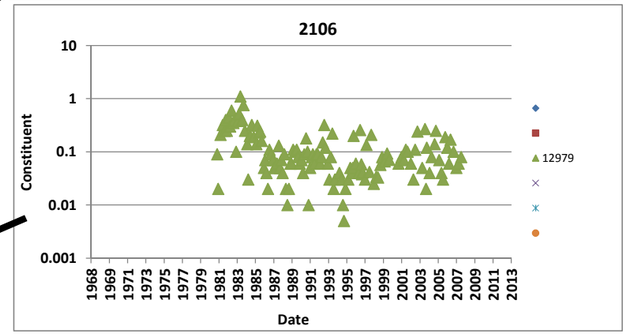


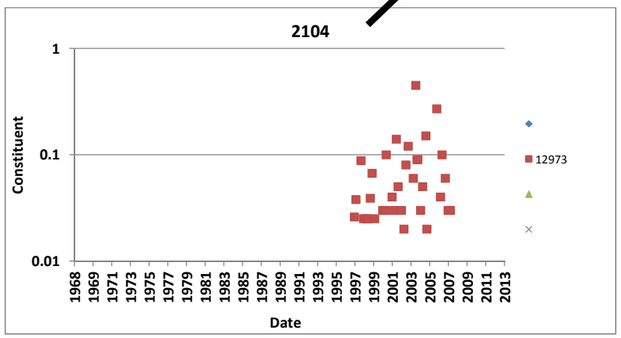


Basin 21: Nueces River
PHOSPHORUS, DISSOLVED (MG/L AS P) vs Date

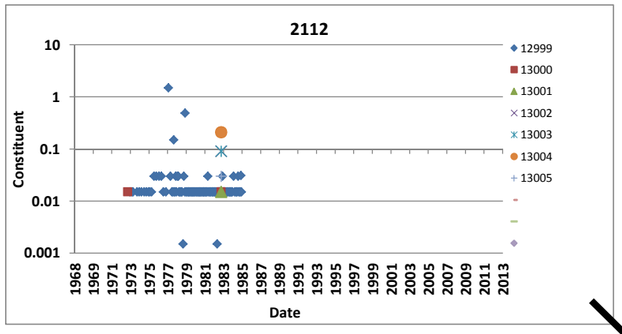


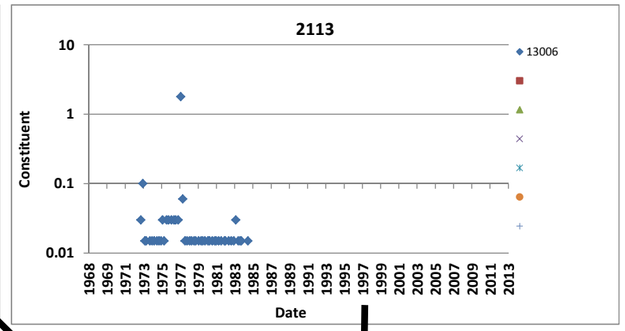


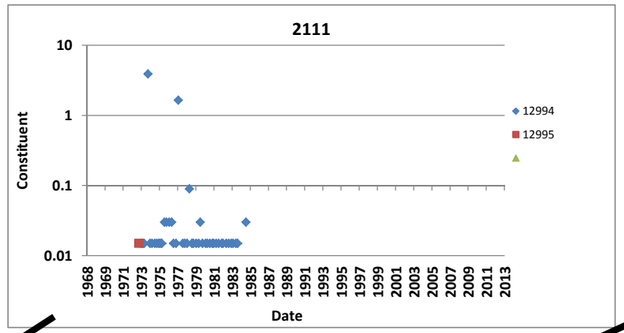


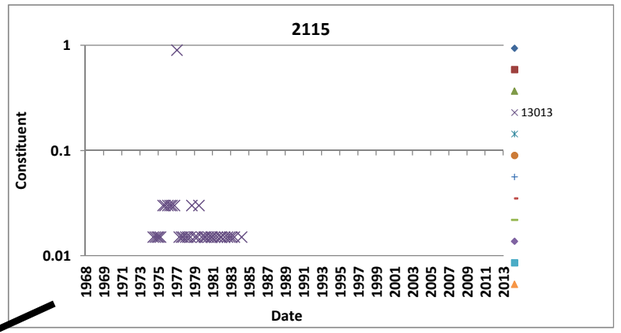


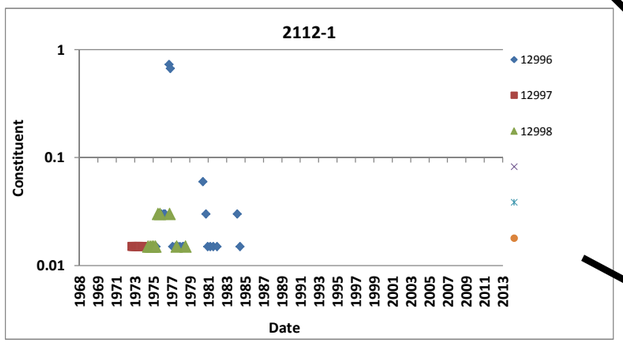
Basin 21: Nueces River
PHOSPHATE, ORTHO (MG/L AS PO4) vs Date

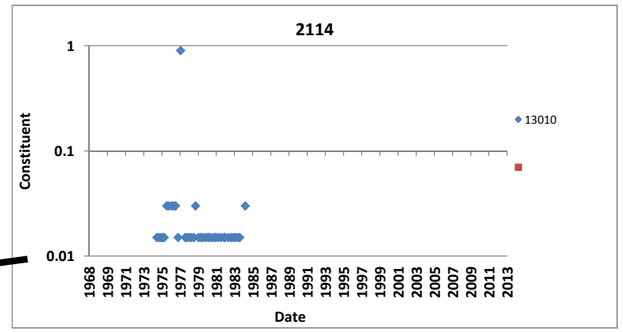


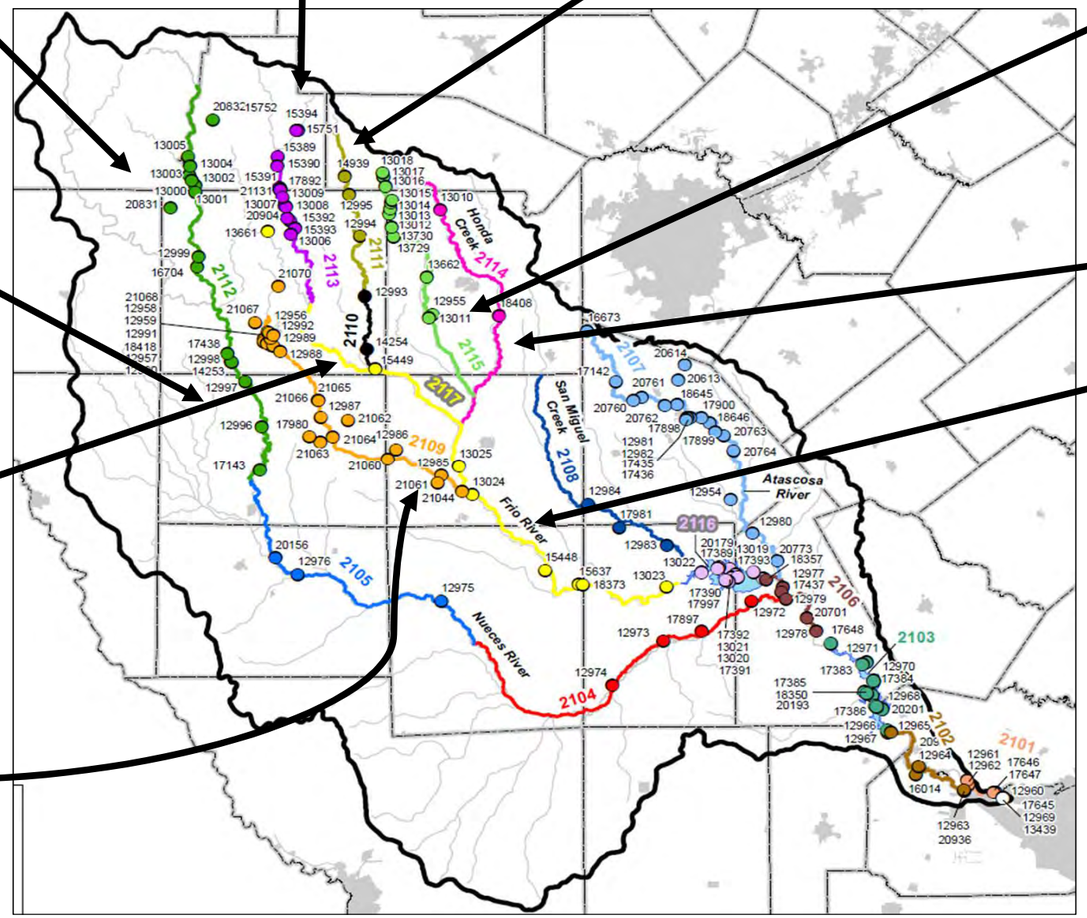


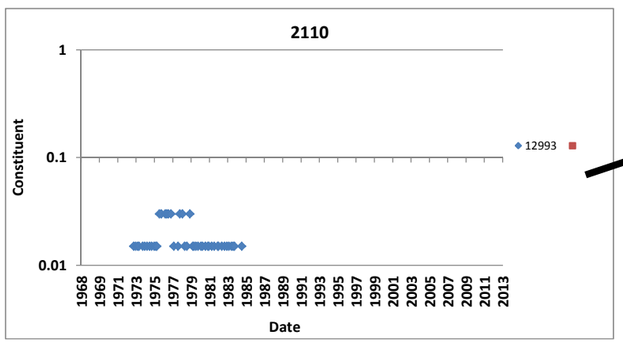


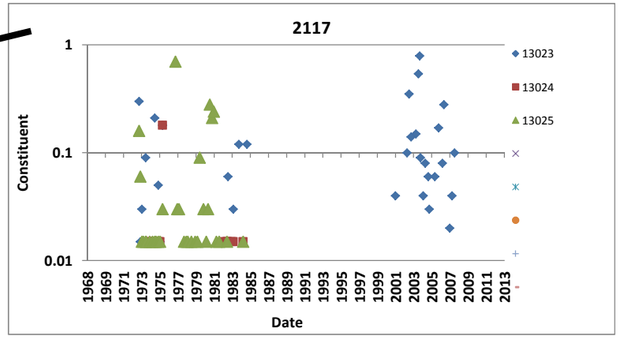


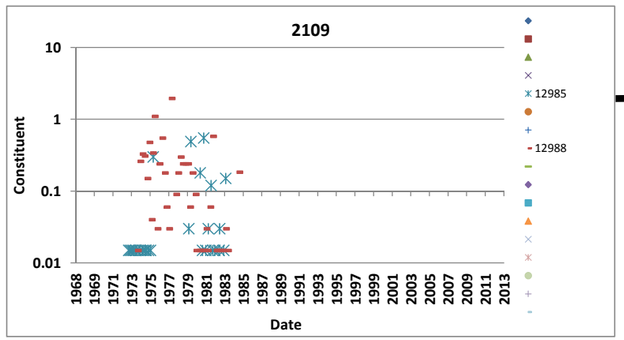




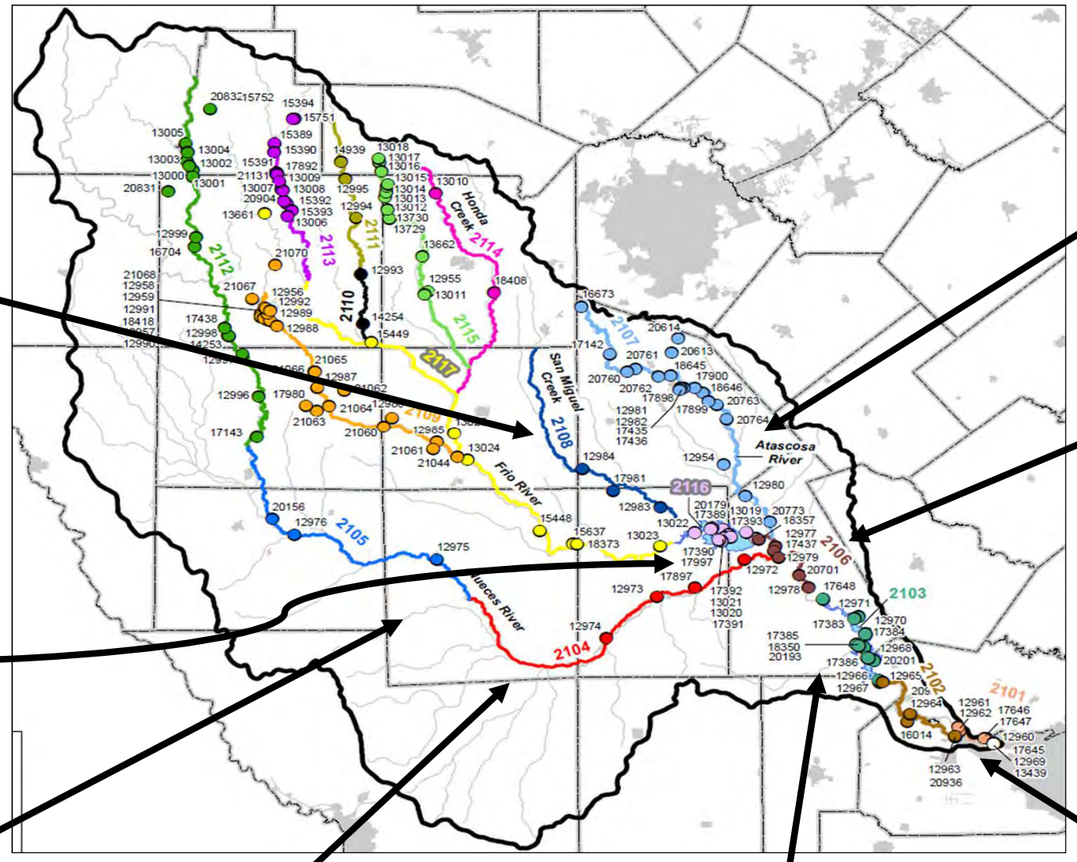


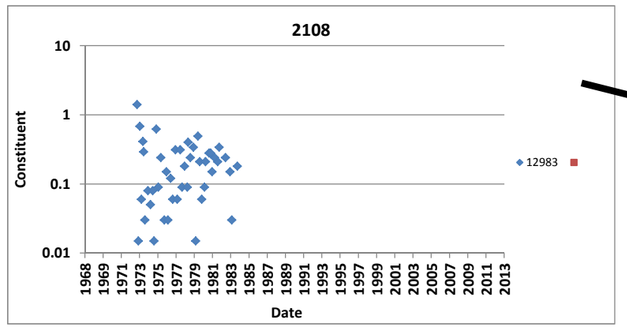


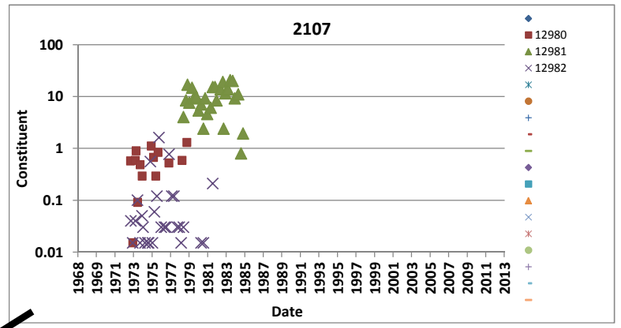


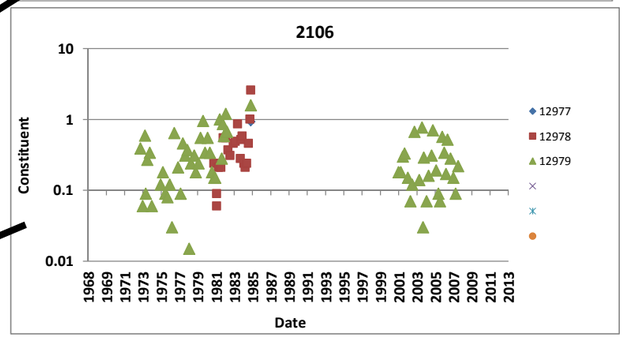


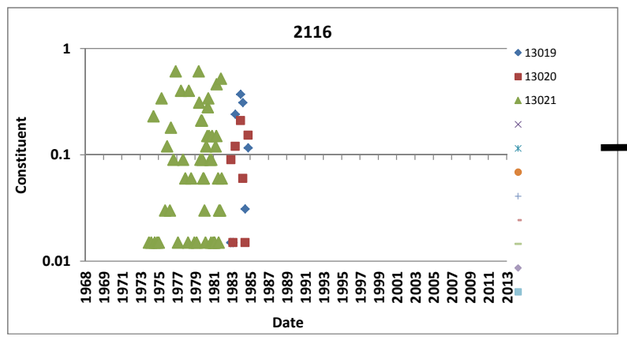
Basin 21: Nueces River
PHOSPHATE, ORTHO (MG/L AS PO4) vs Date

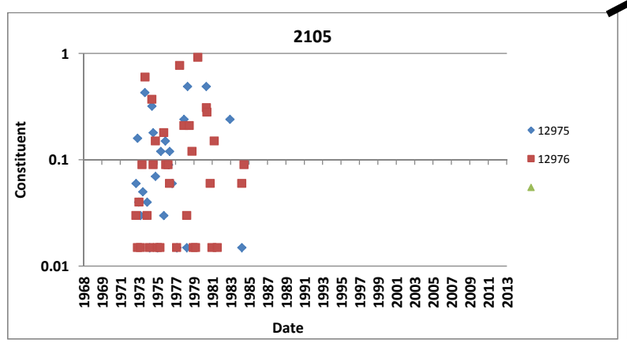


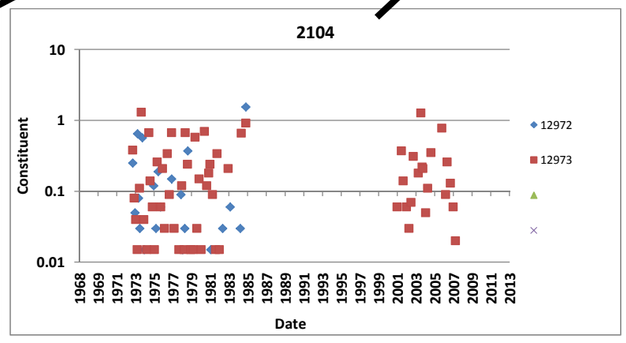


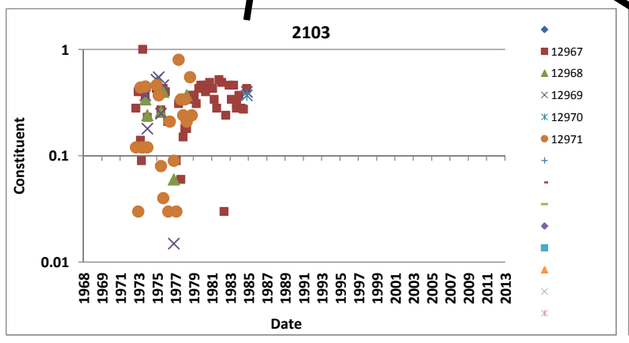


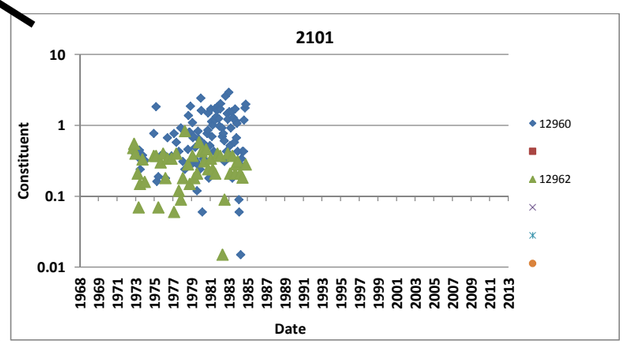






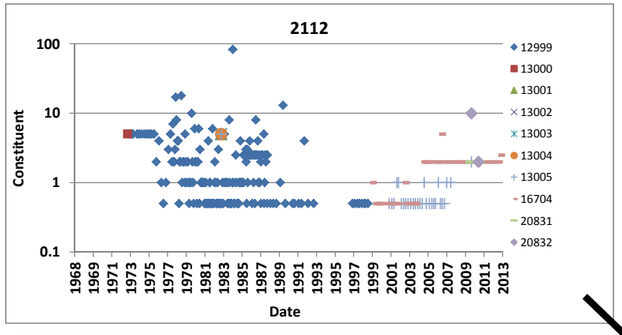


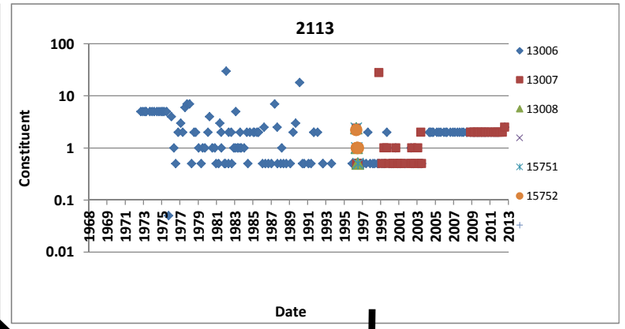


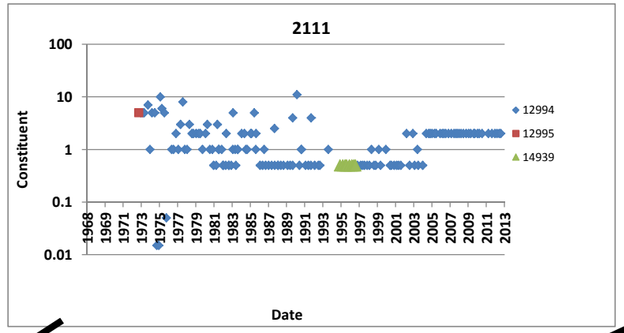


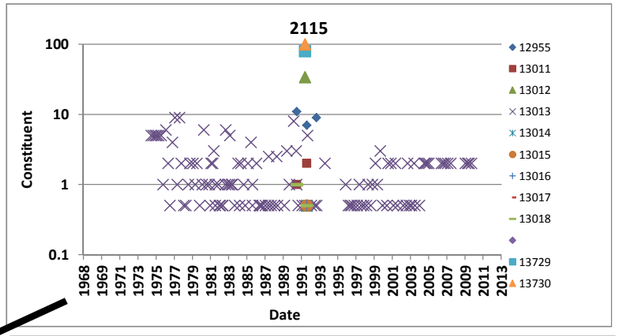
Basin 21: Nueces River

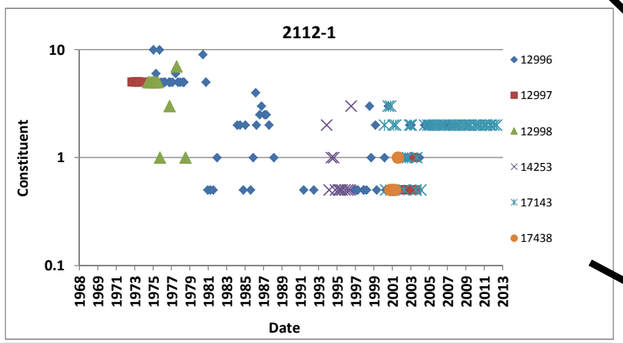
RESIDUE, VOLATILE NONFILTRABLE (MG/L) vs Date

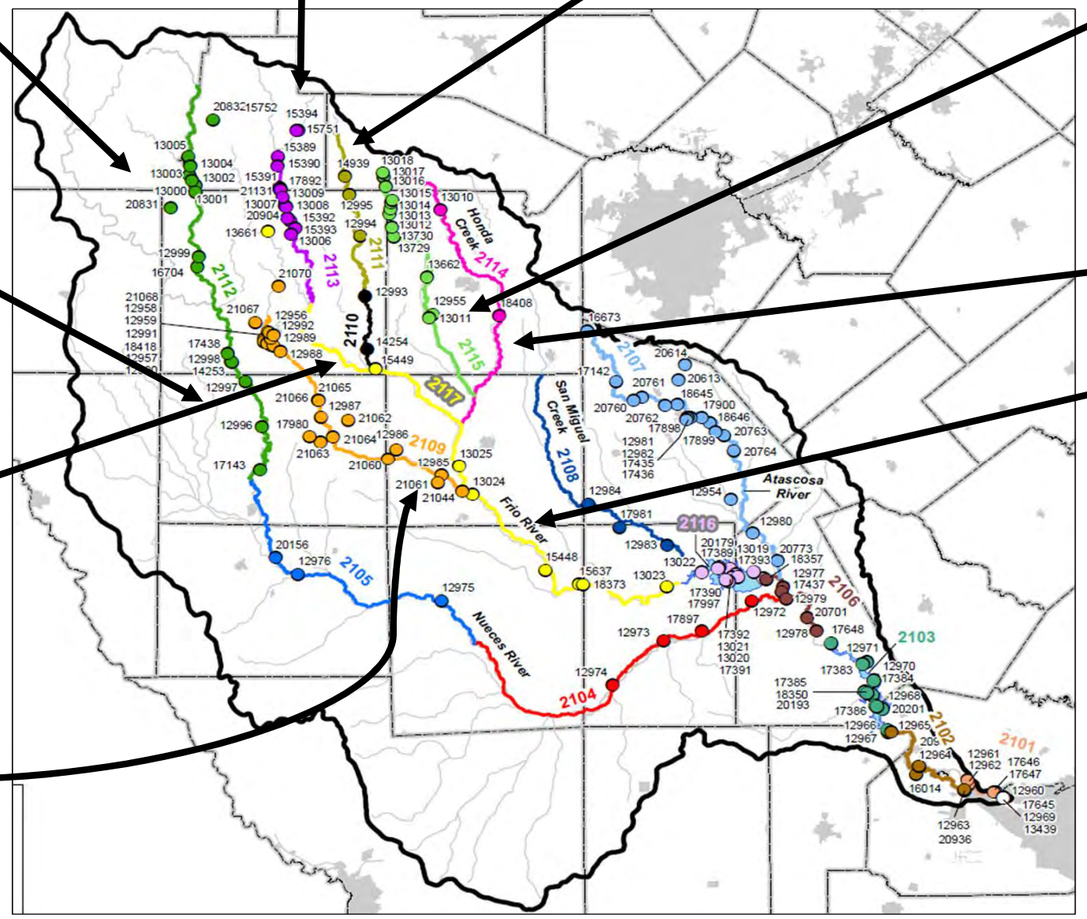


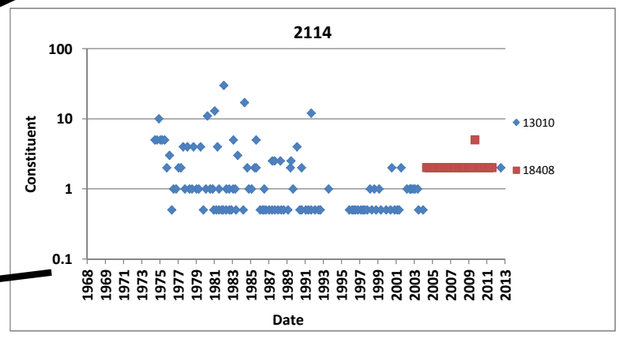


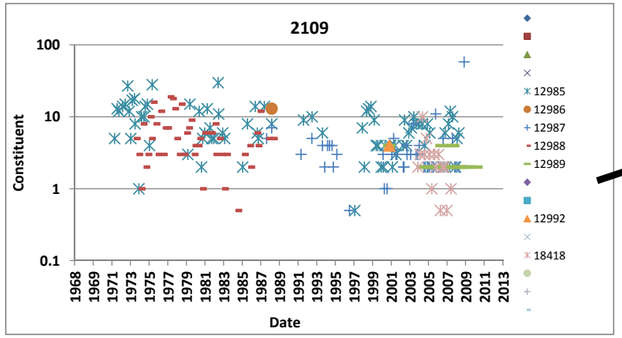


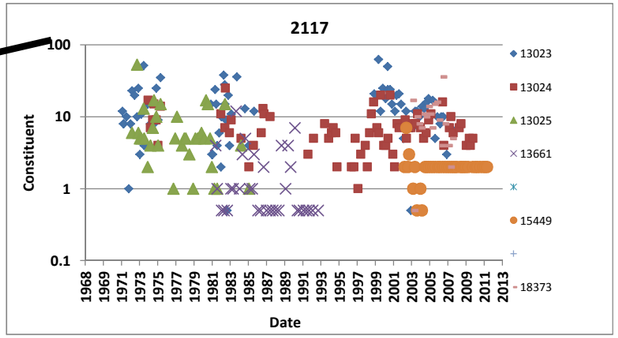


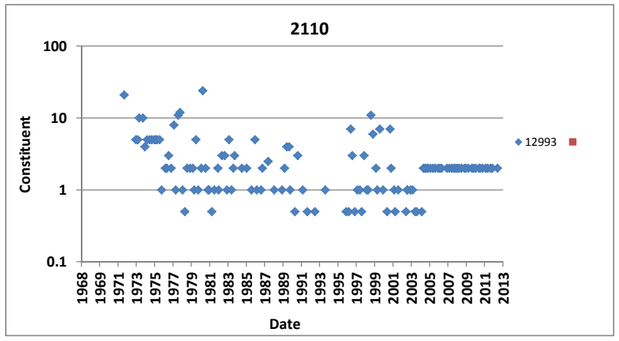




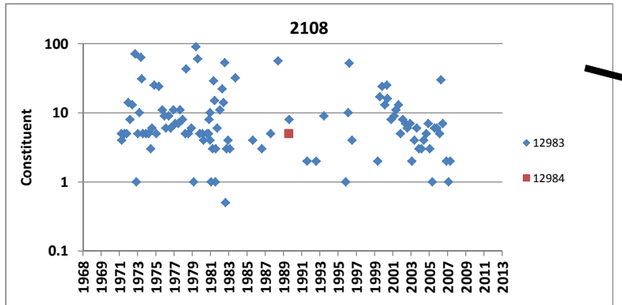


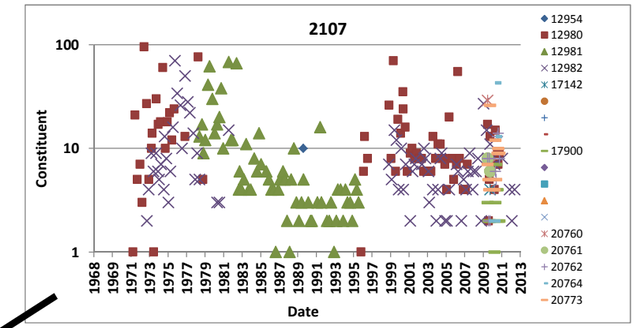


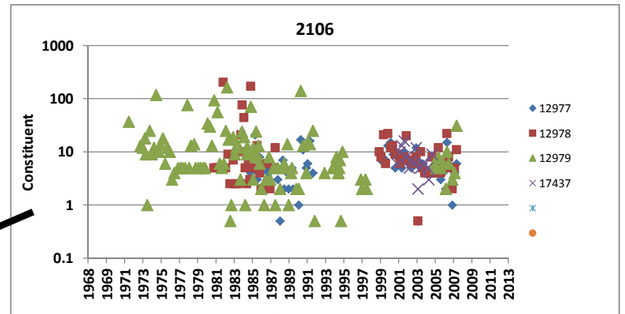


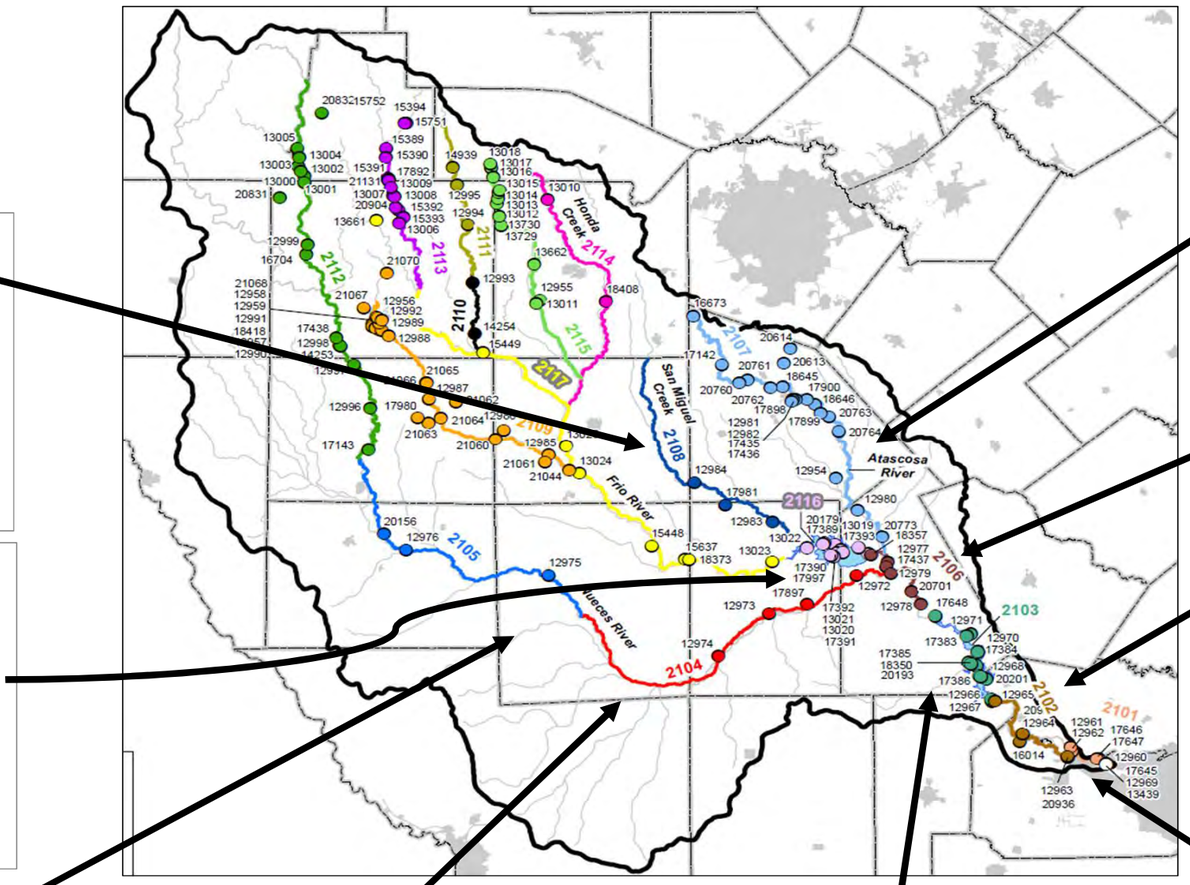


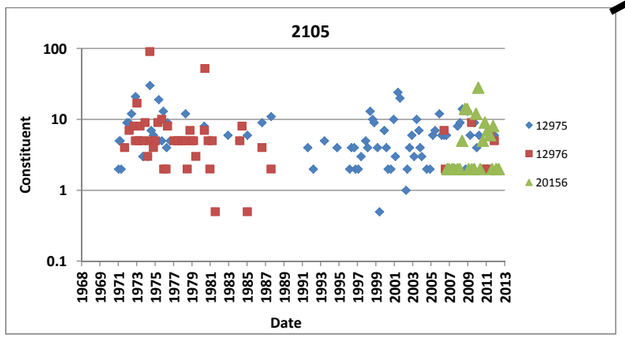
Basin 21: Nueces River
RESIDUE, VOLATILE NONFILTRABLE (MG/L) vs Date

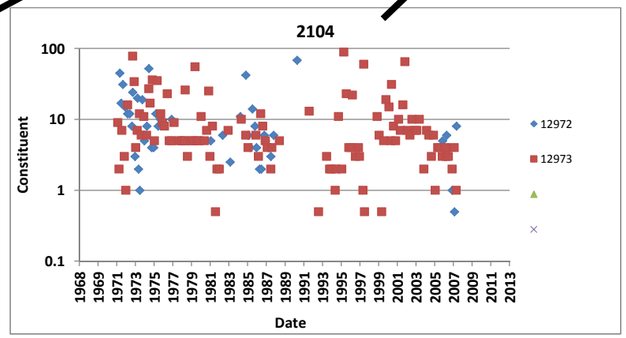


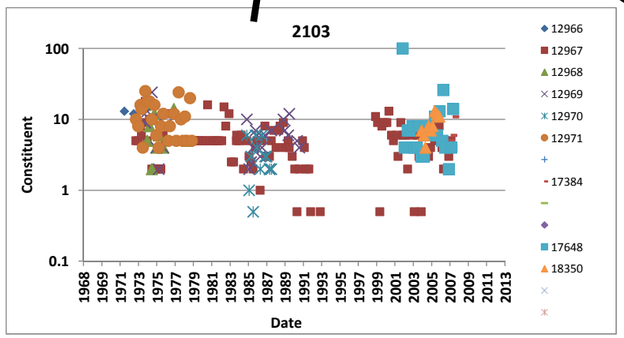


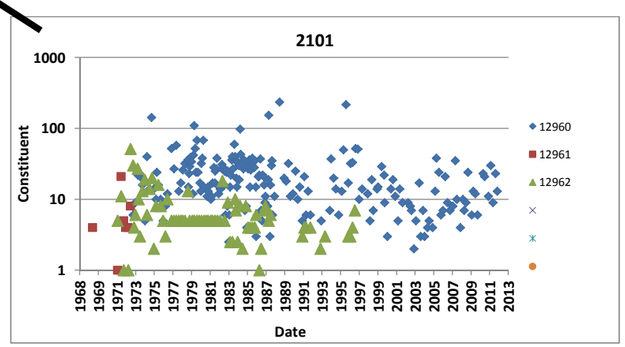






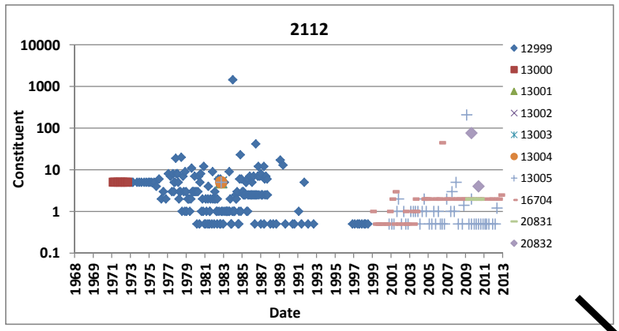


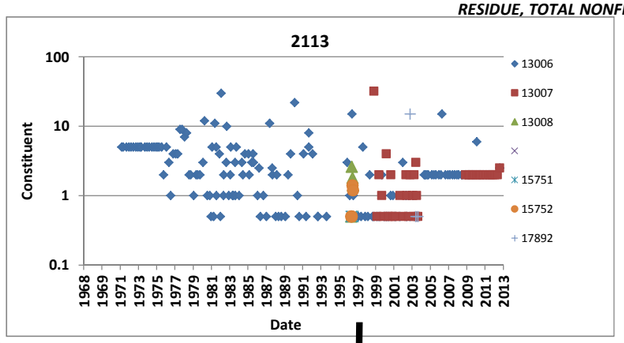


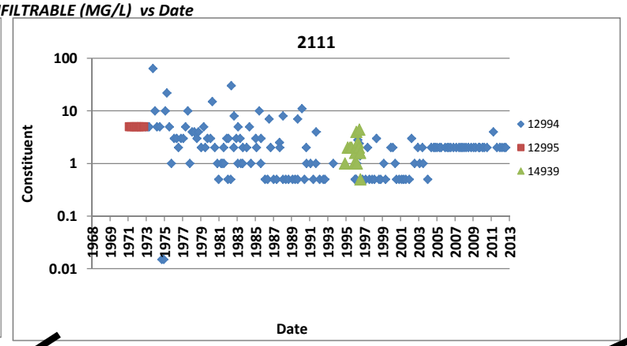


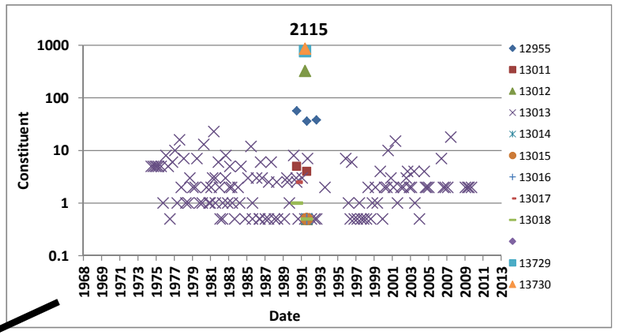
Basin 21: Nueces River

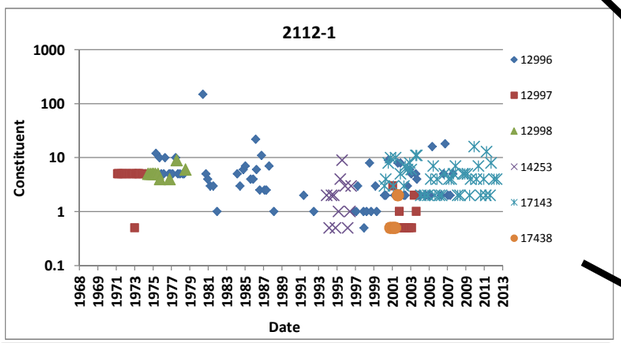
RESIDUE, TOTAL NONFILTRABLE (MG/L) vs Date

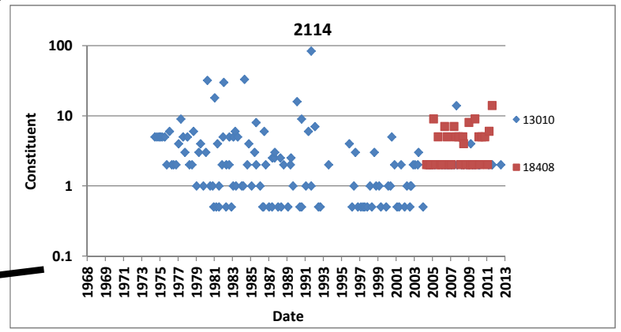


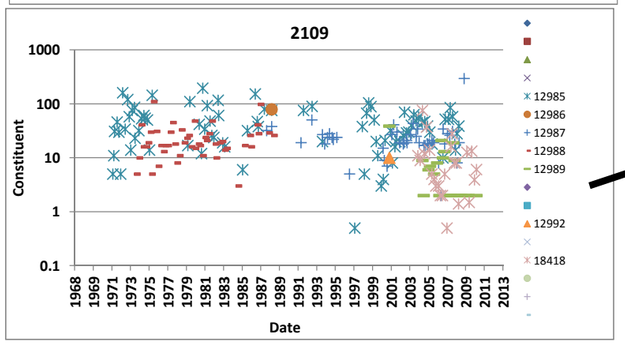


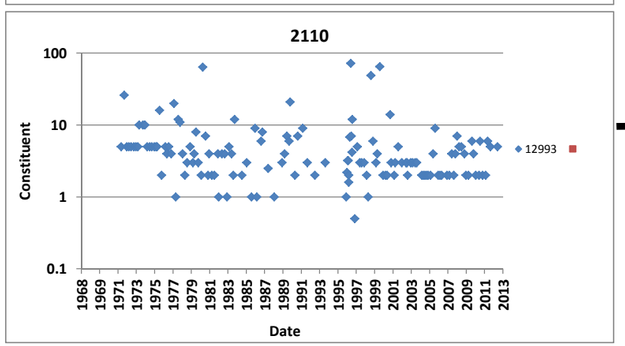


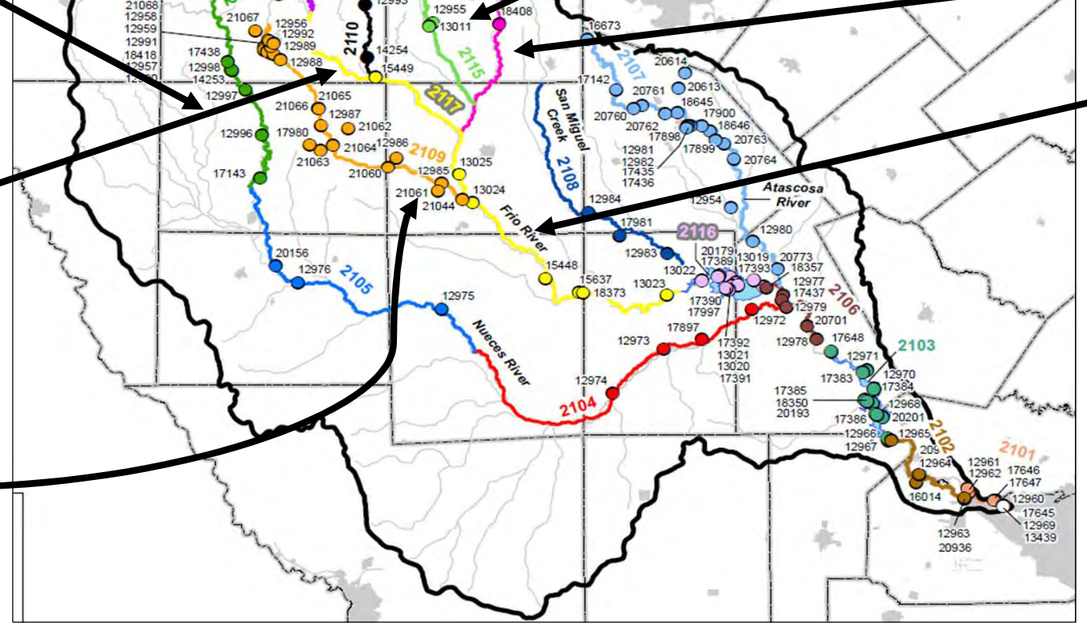


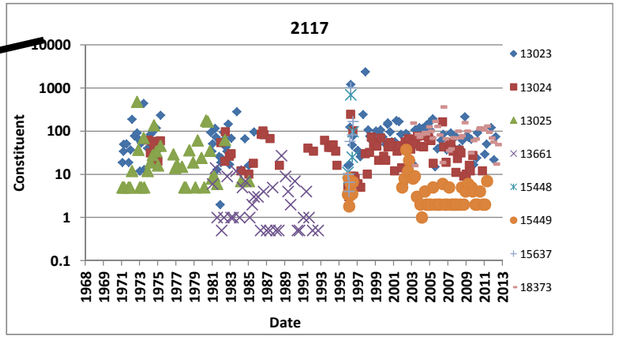




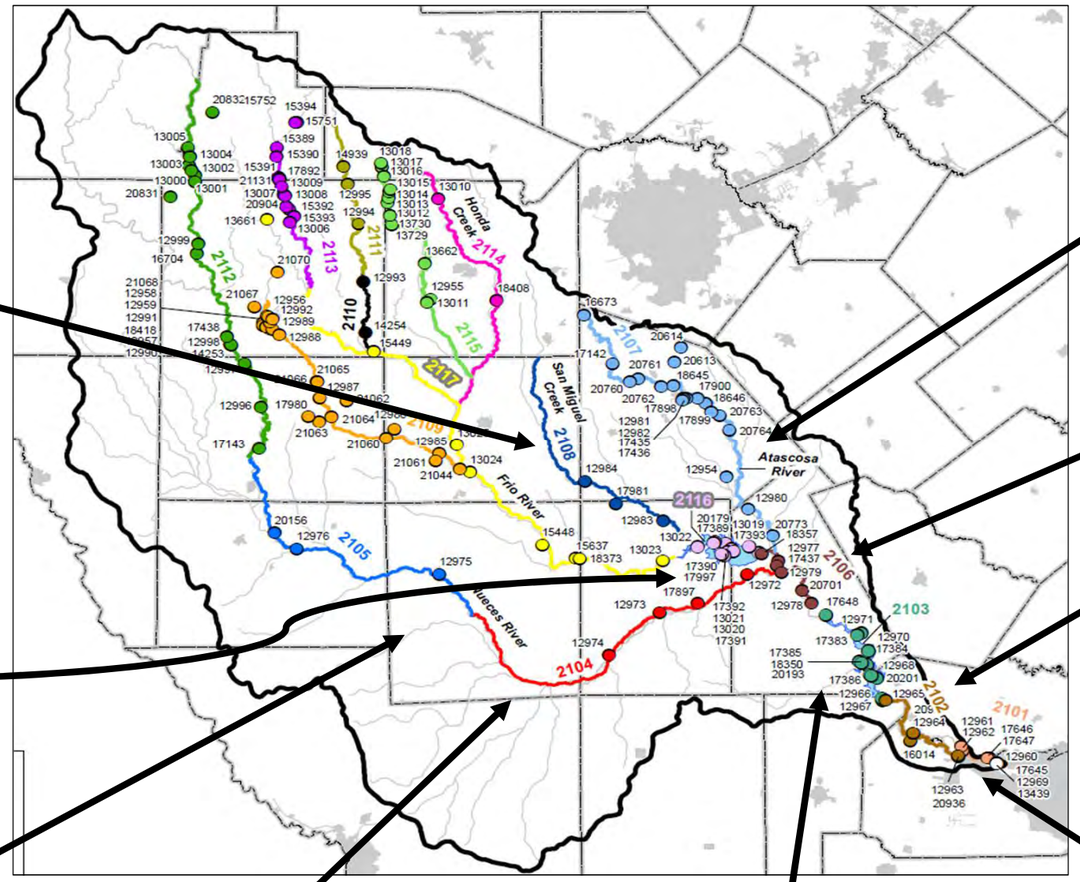


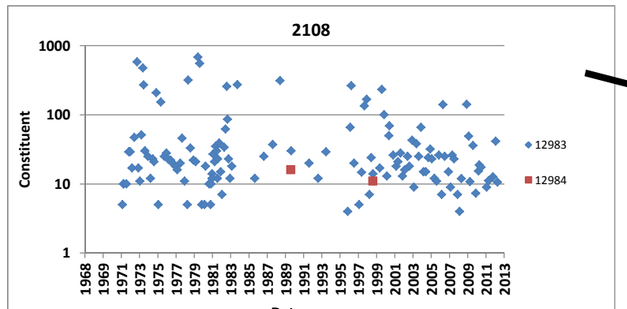


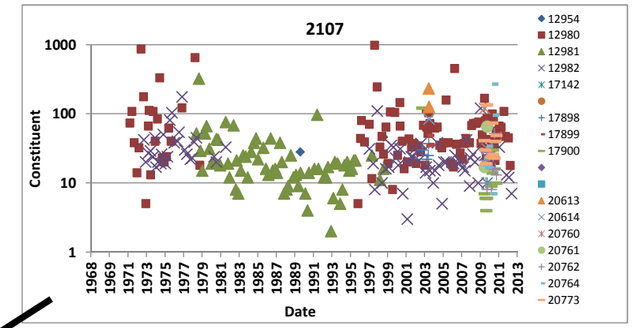


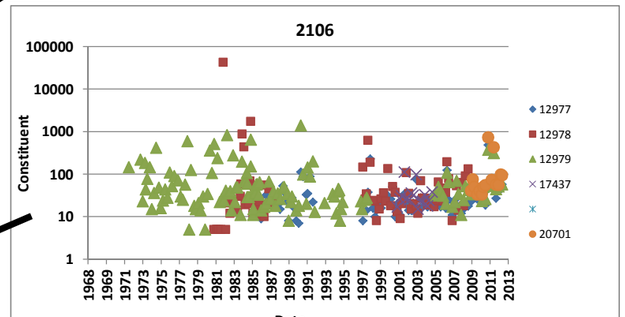


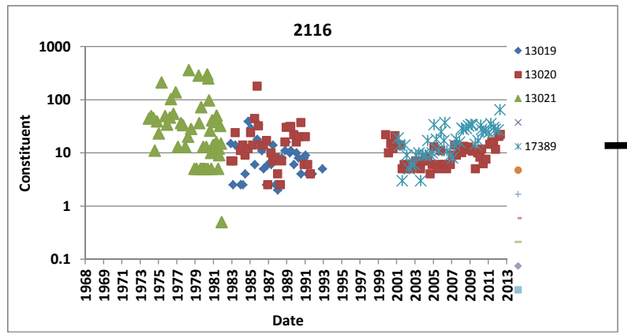
Basin 21: Nueces River
RESIDUE, TOTAL NONFILTRABLE (MG/L) vs Date

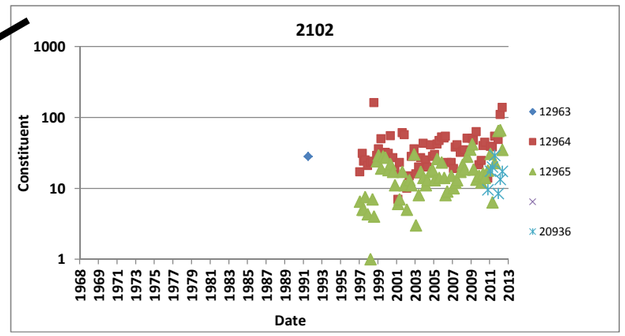


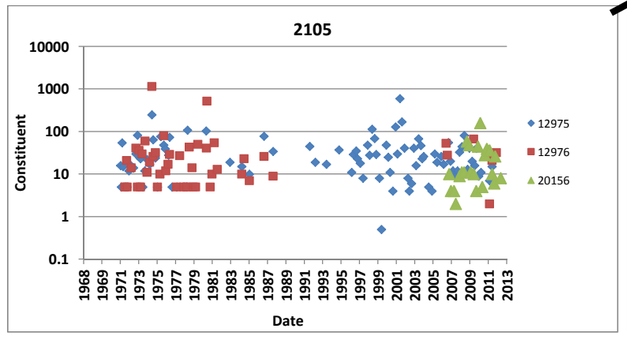


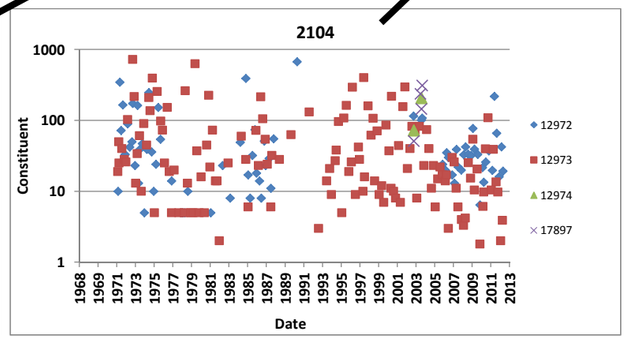


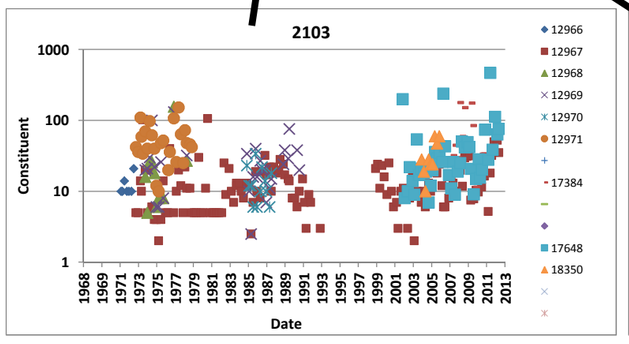


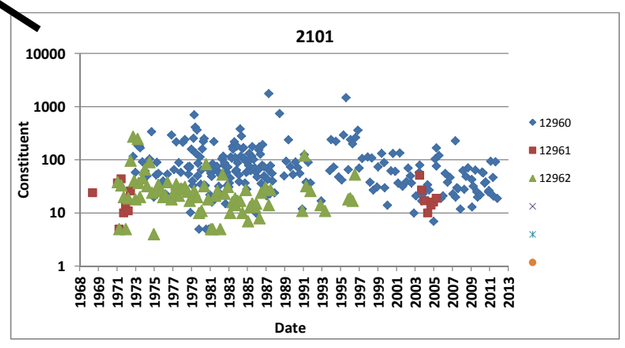




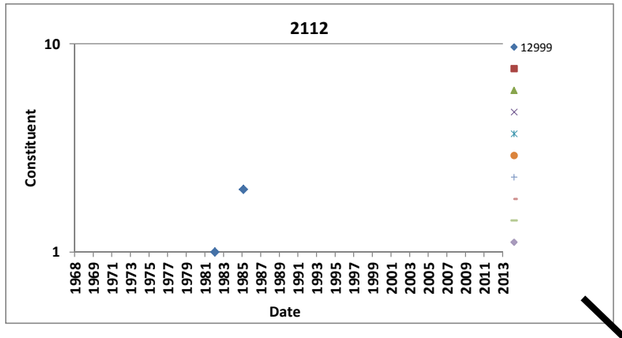


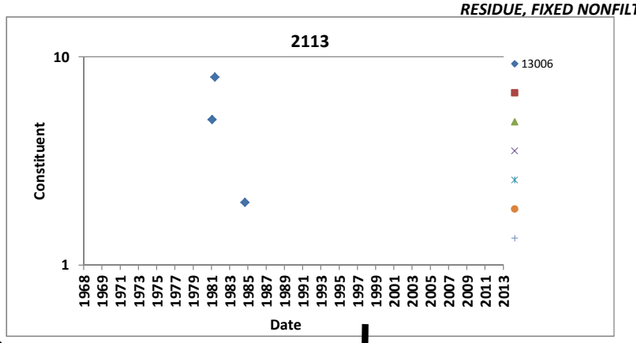


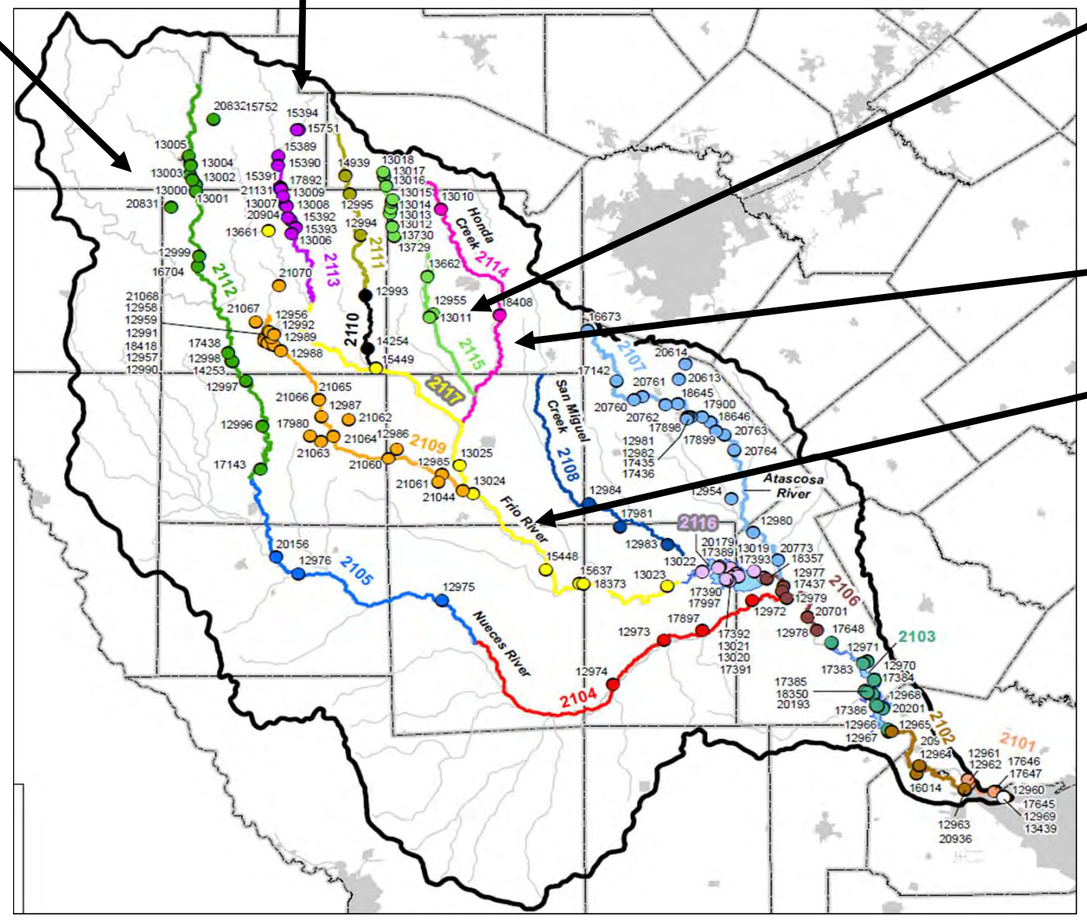


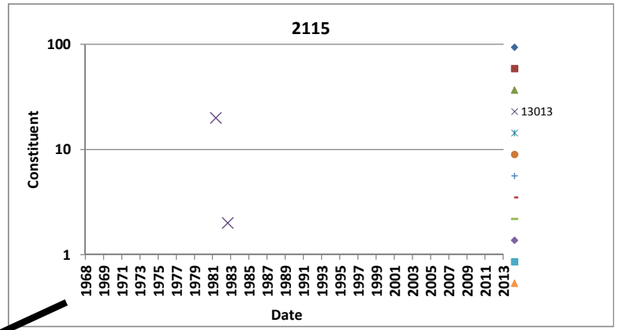


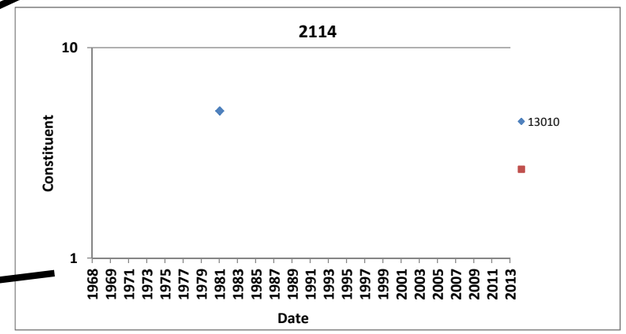
Basin 21: Nueces River
RESIDUE, FIXED NONFILTRABLE (MG/L) vs Date

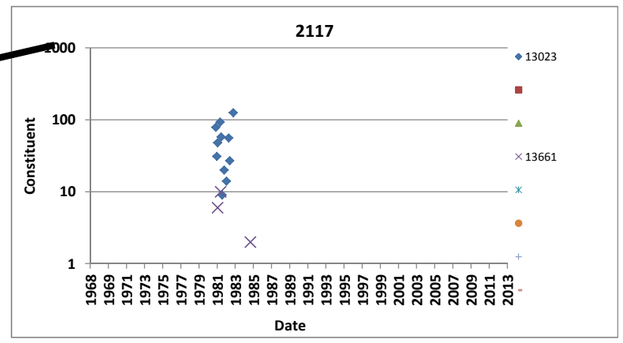




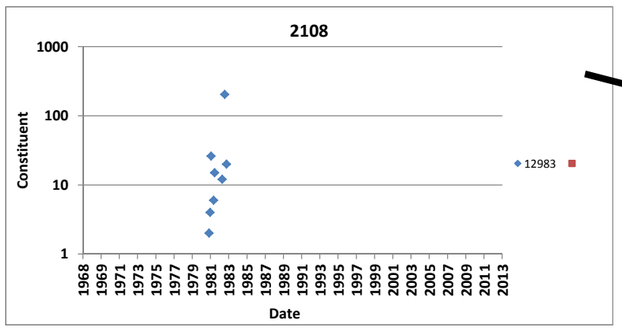


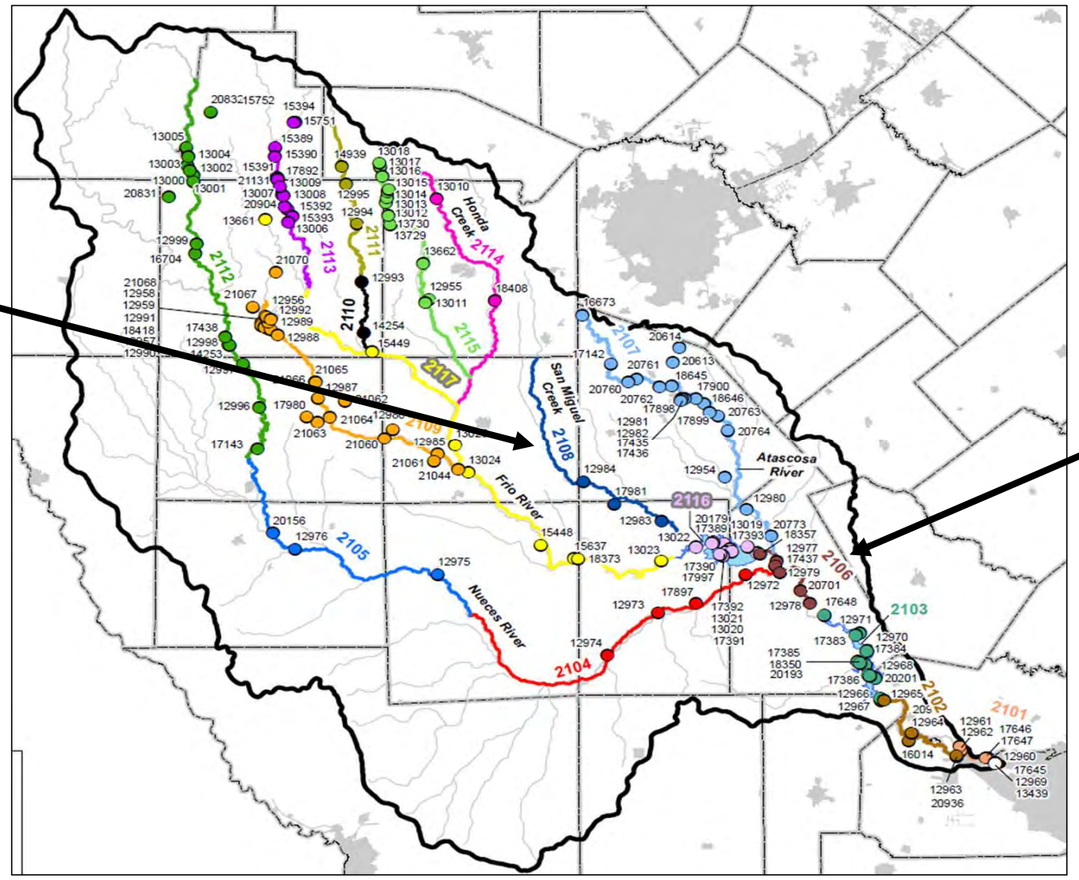


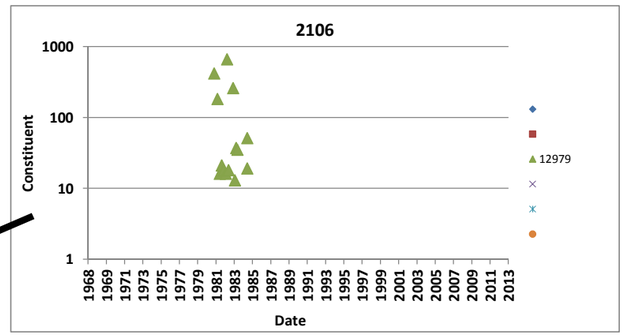




Basin 21: Nueces River
RESIDUE, FIXED NONFILTRABLE (MG/L) vs Date

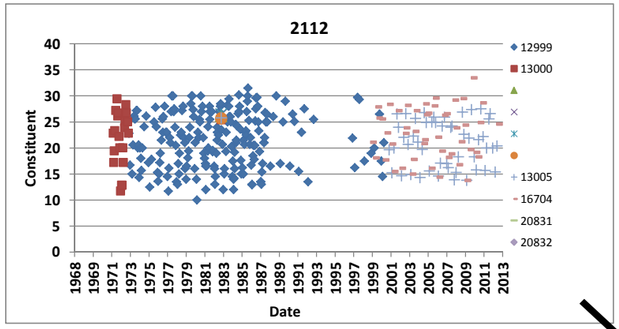


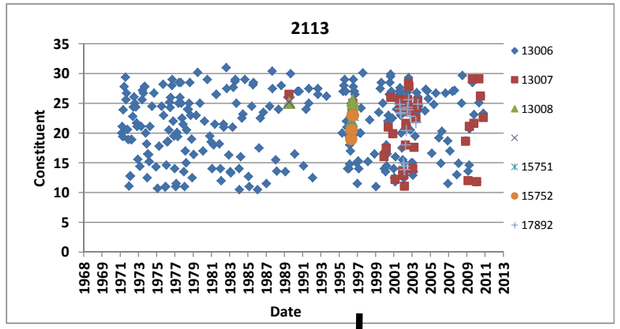


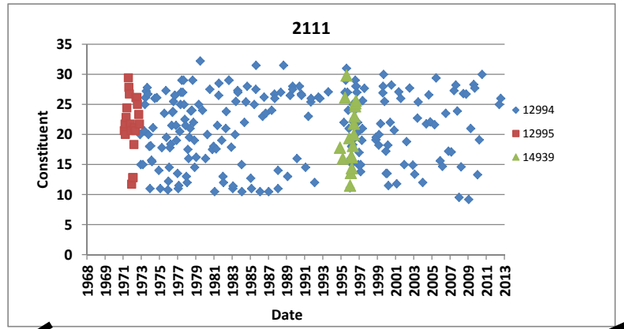


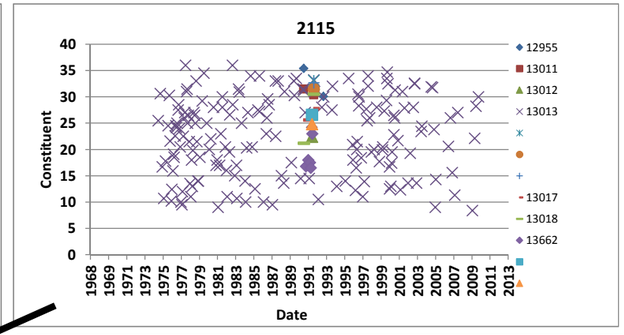
Basin 21: Nueces River

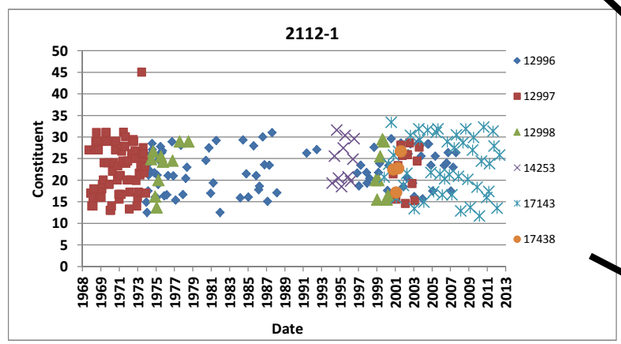
TEMPERATURE, WATER (DEGREES CENTIGRADE) vs Date

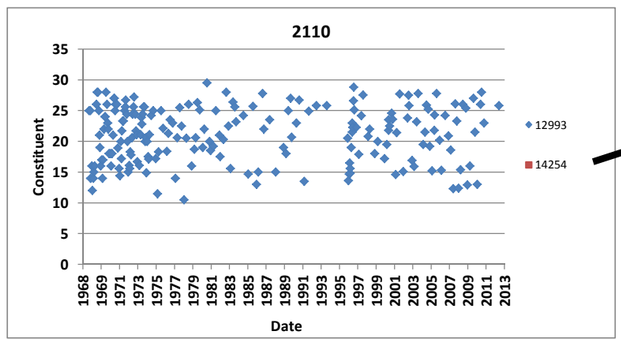


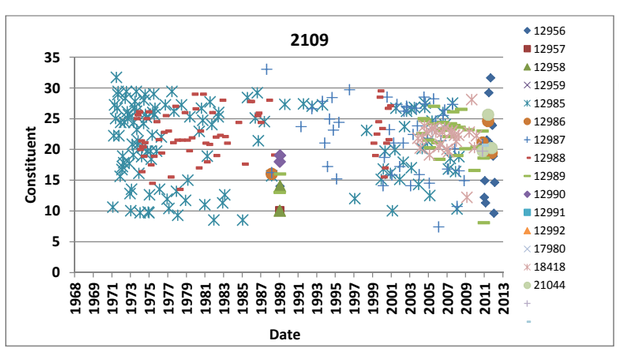


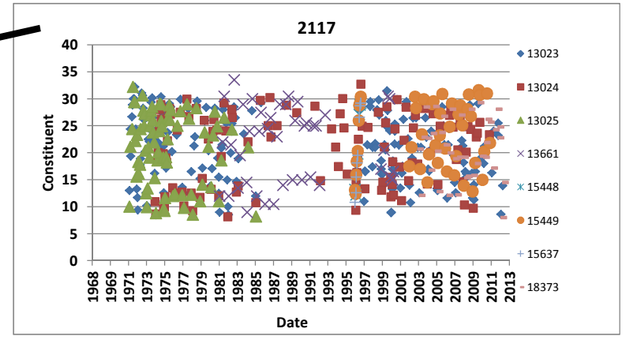


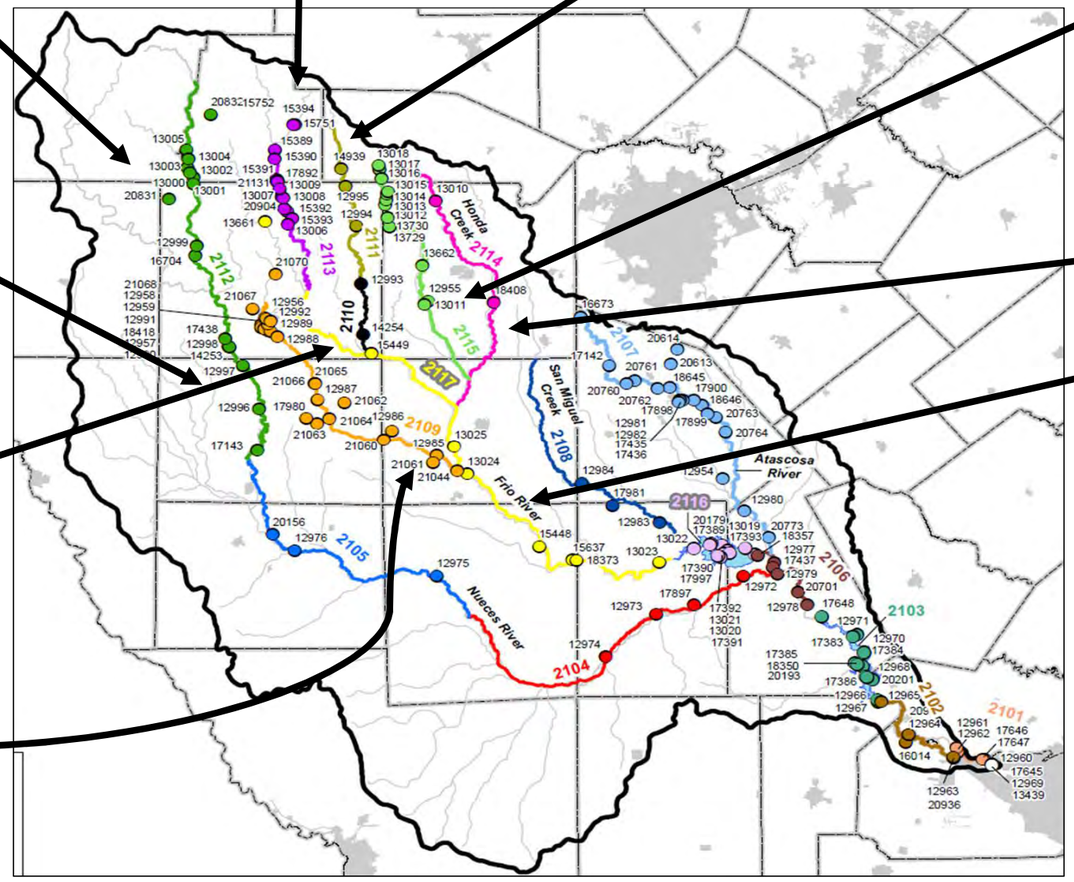




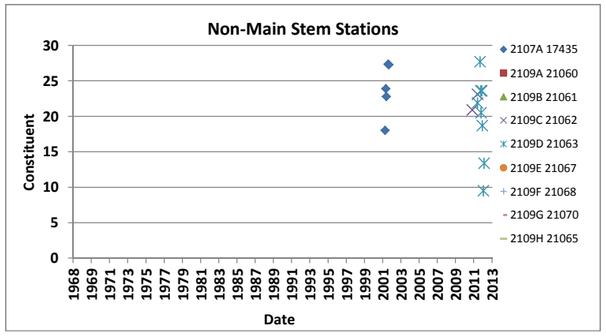


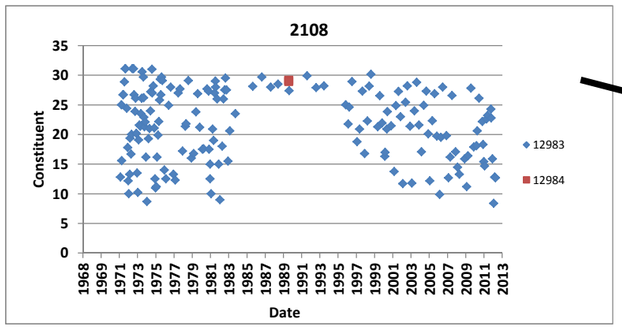


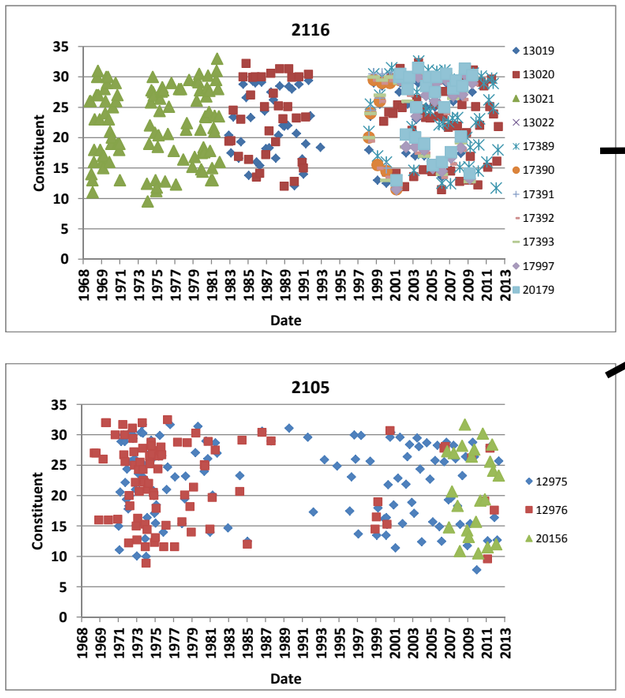


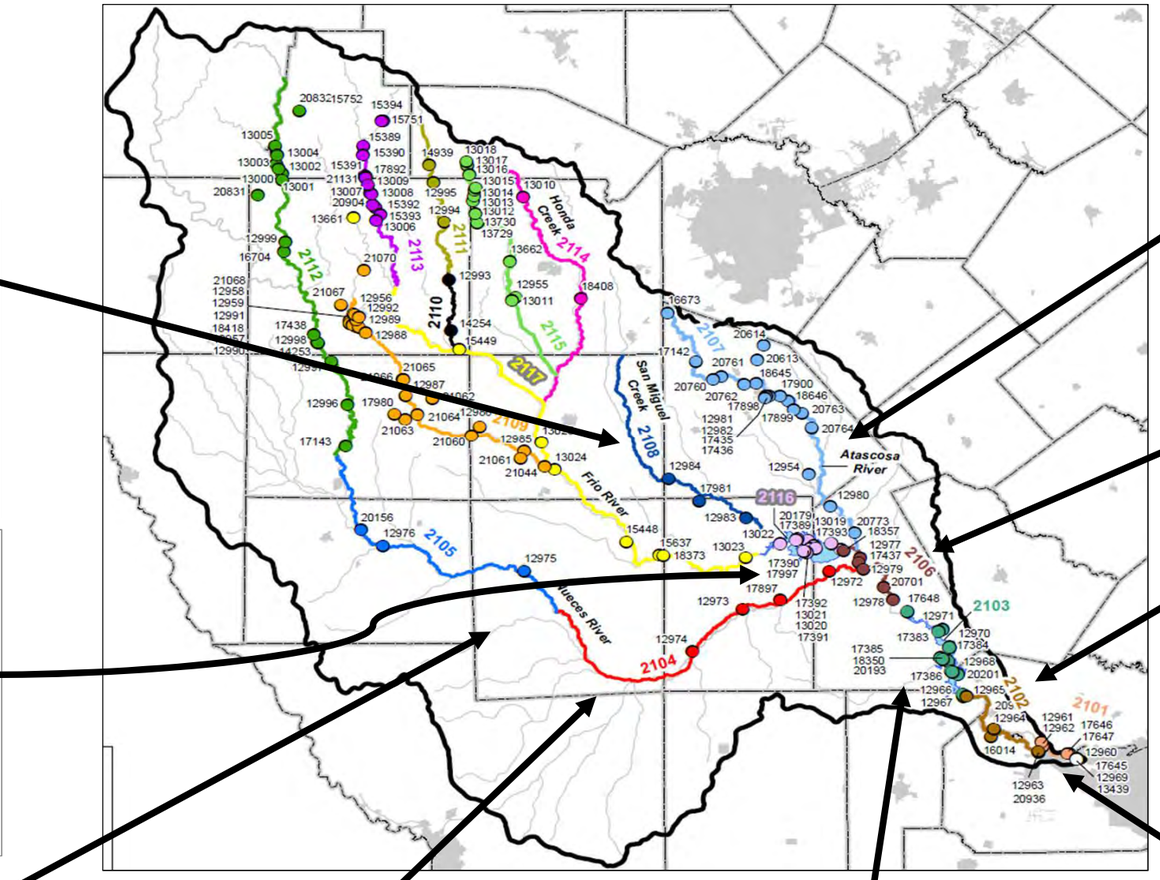


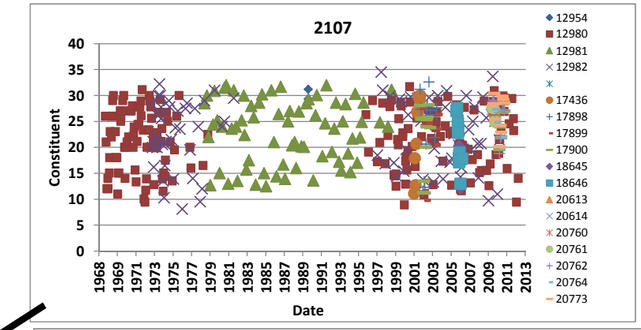
Basin 21: Nueces River
TEMPERATURE, WATER (DEGREES CENTIGRADE) vs Date

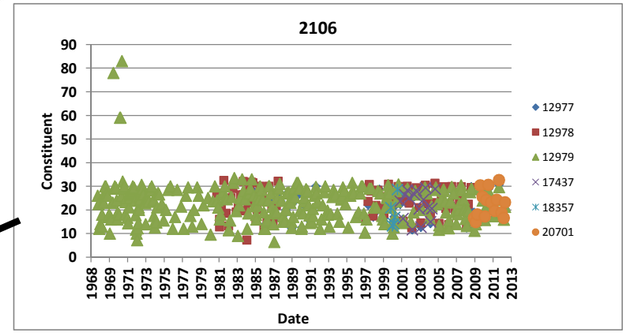


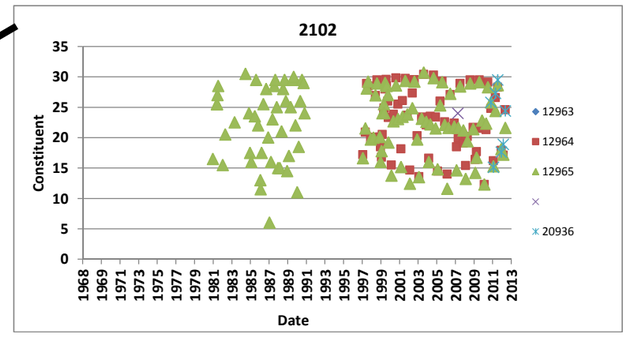


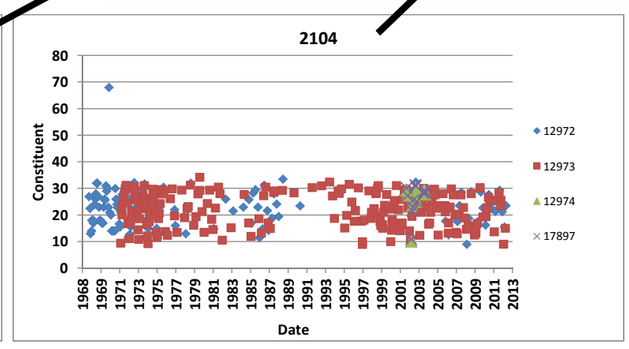


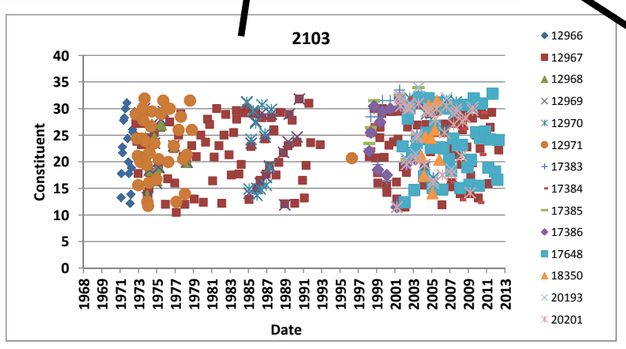


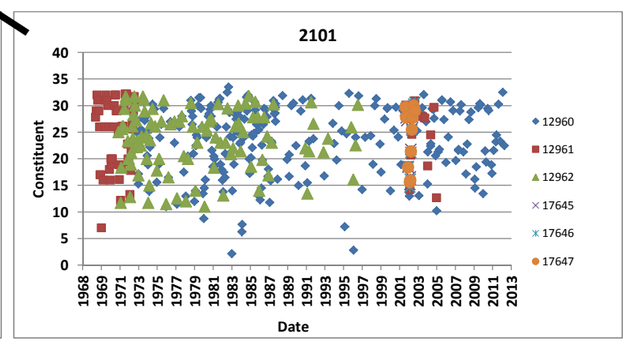






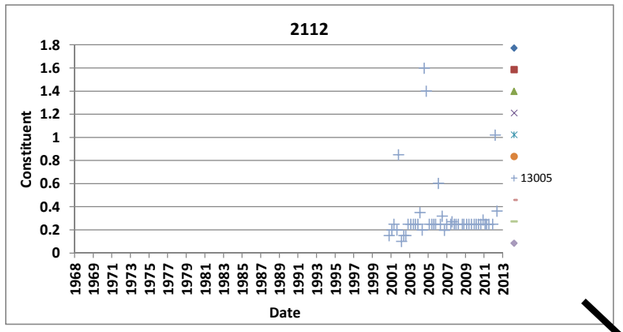


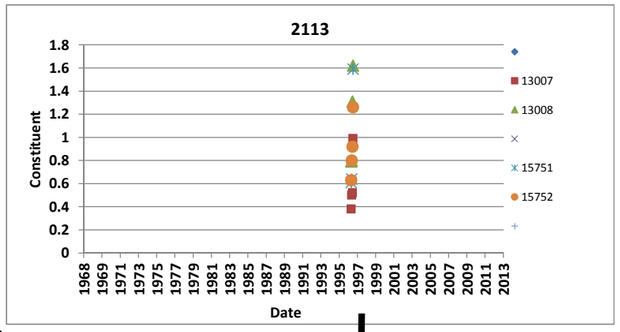


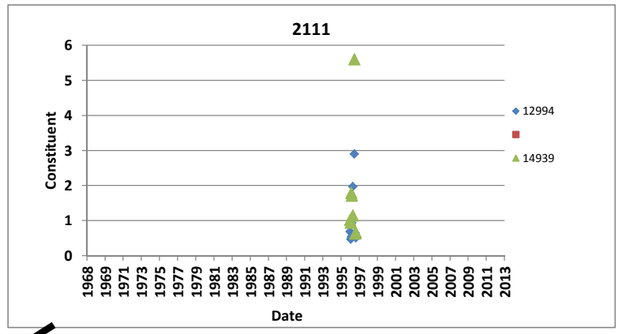


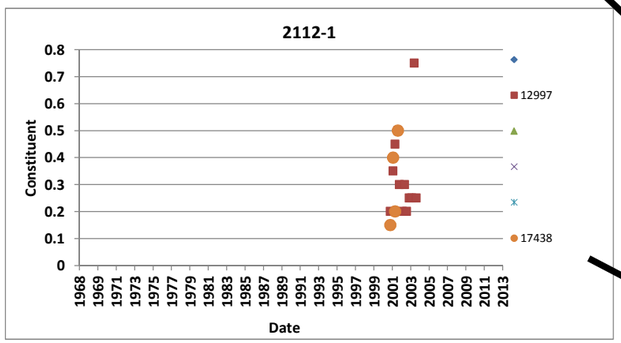
Basin 21: Nueces River

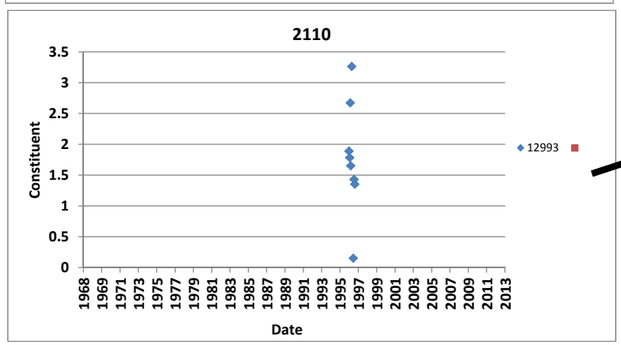
TURBIDITY,LAB NEPHELOMETRIC TURBIDITY UNITS, NTU vs Date

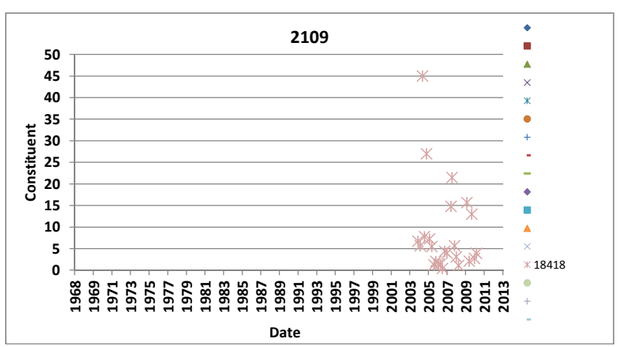


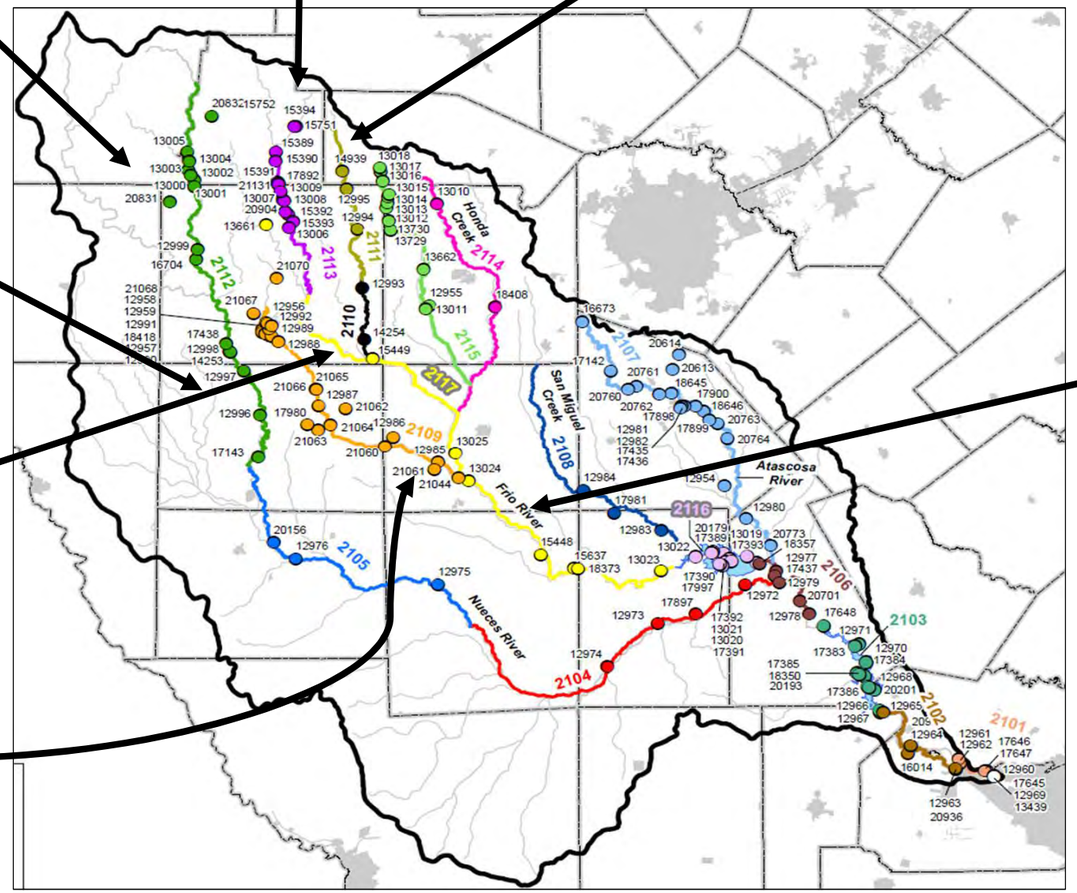


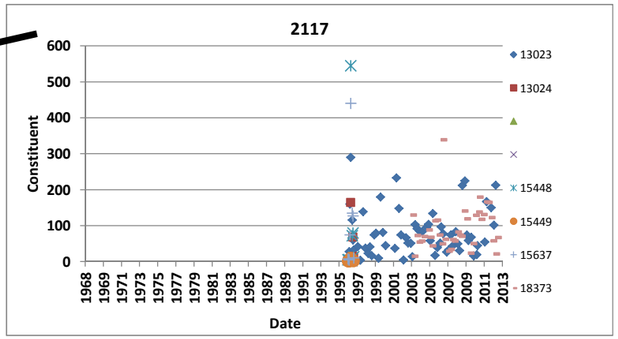






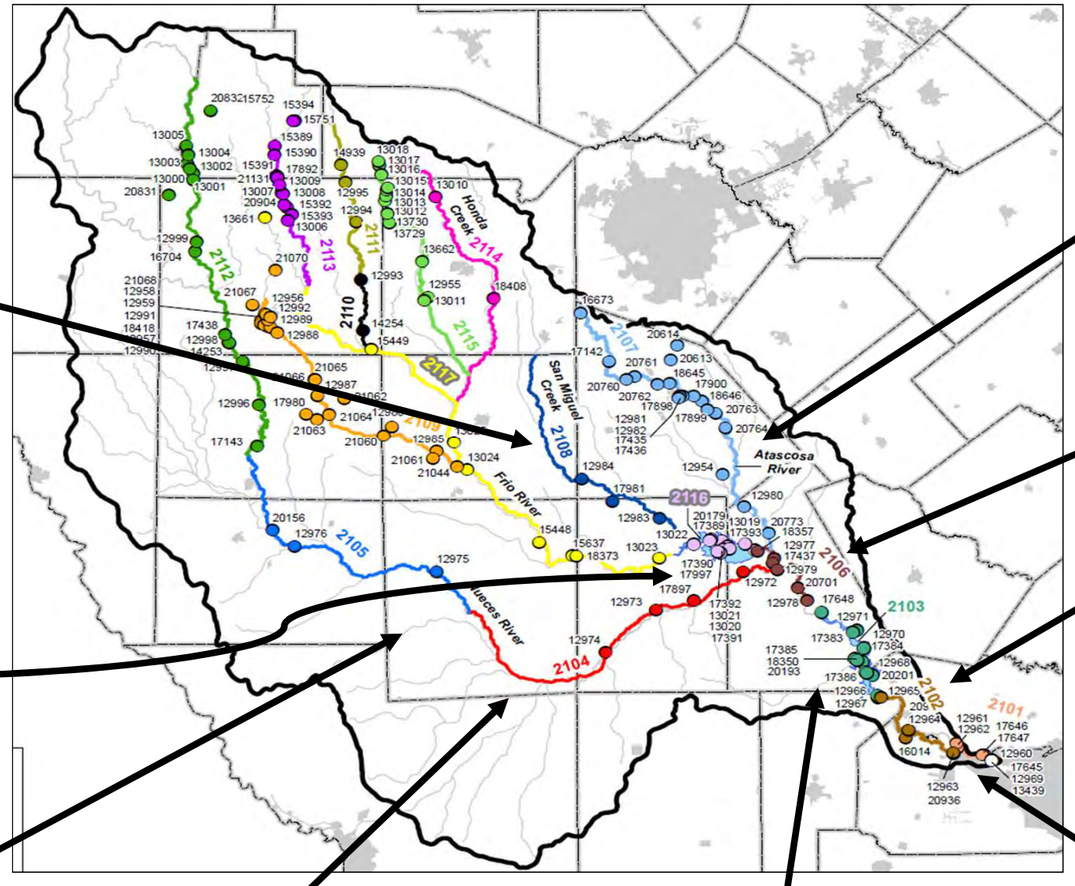


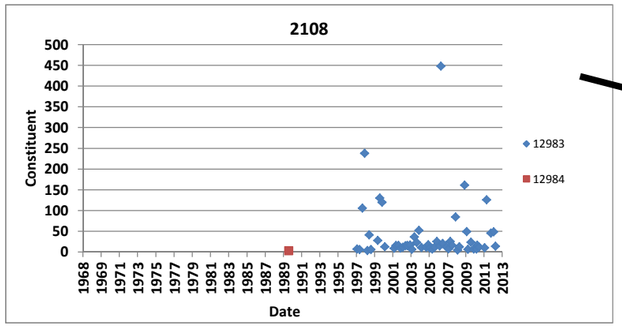


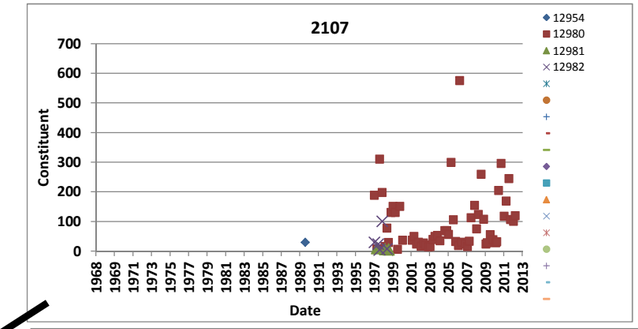


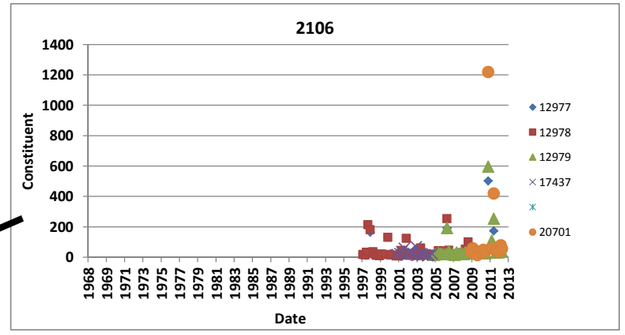
Basin 21: Nueces River

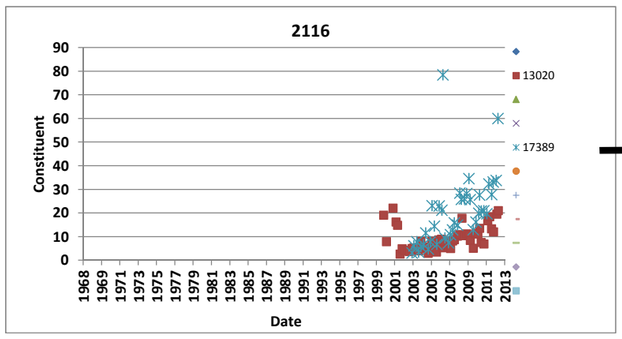
TURBIDITY,LAB NEPHELOMETRIC TURBIDITY UNITS, NTU vs Date

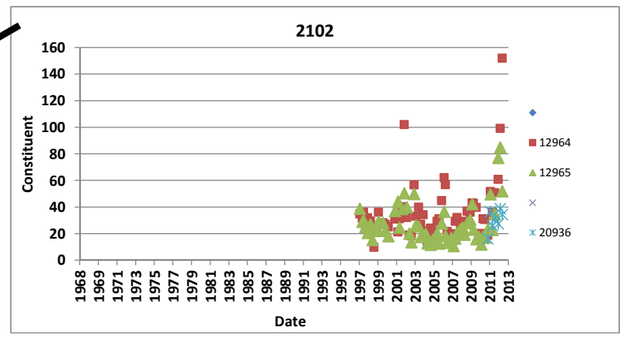


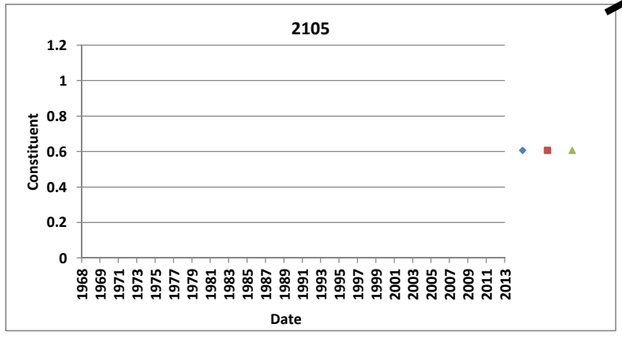


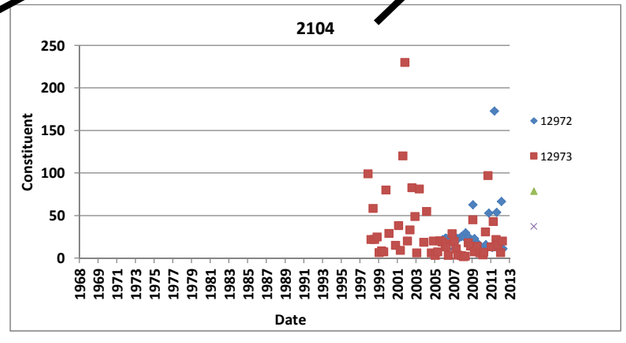


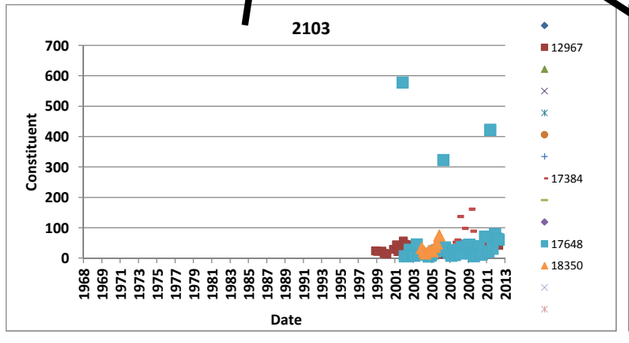


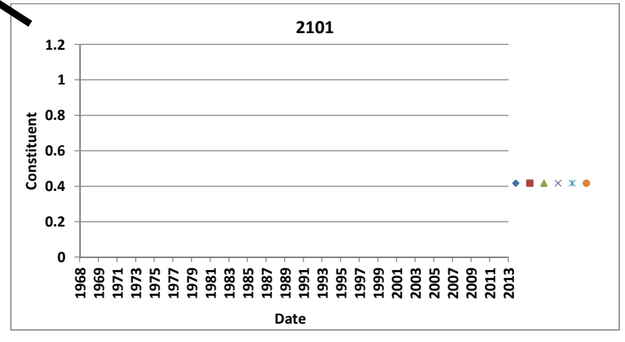




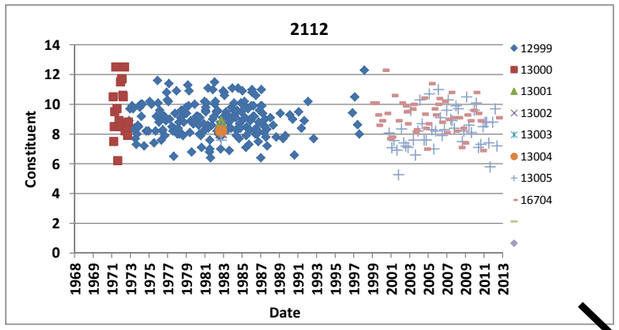


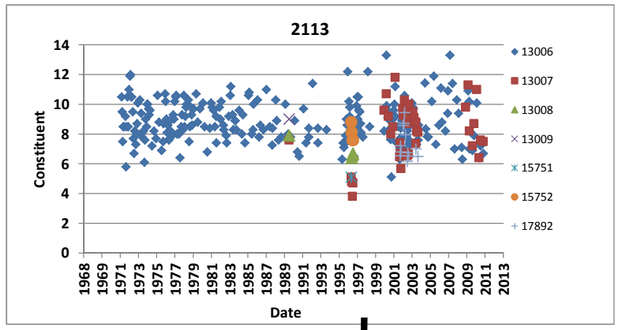


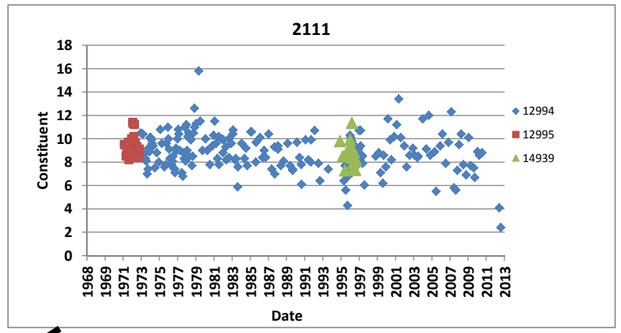


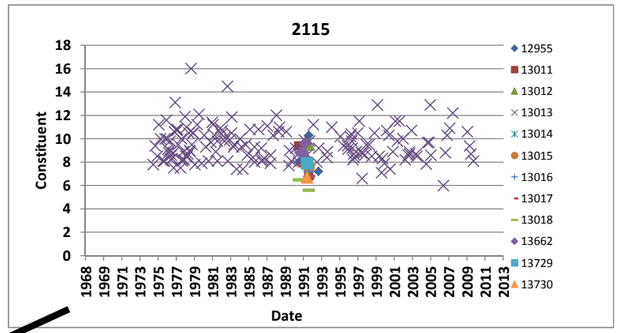


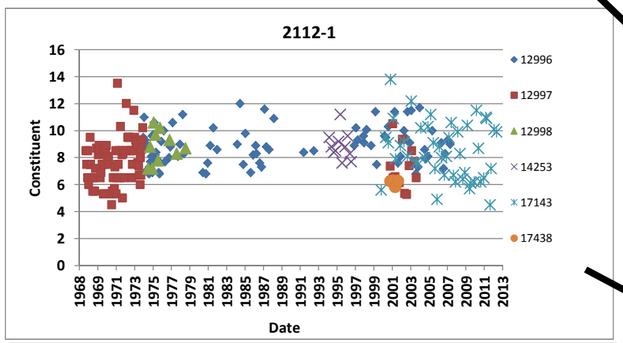
Basin 21: Nueces River
OXYGEN, DISSOLVED (MG/L) vs Date

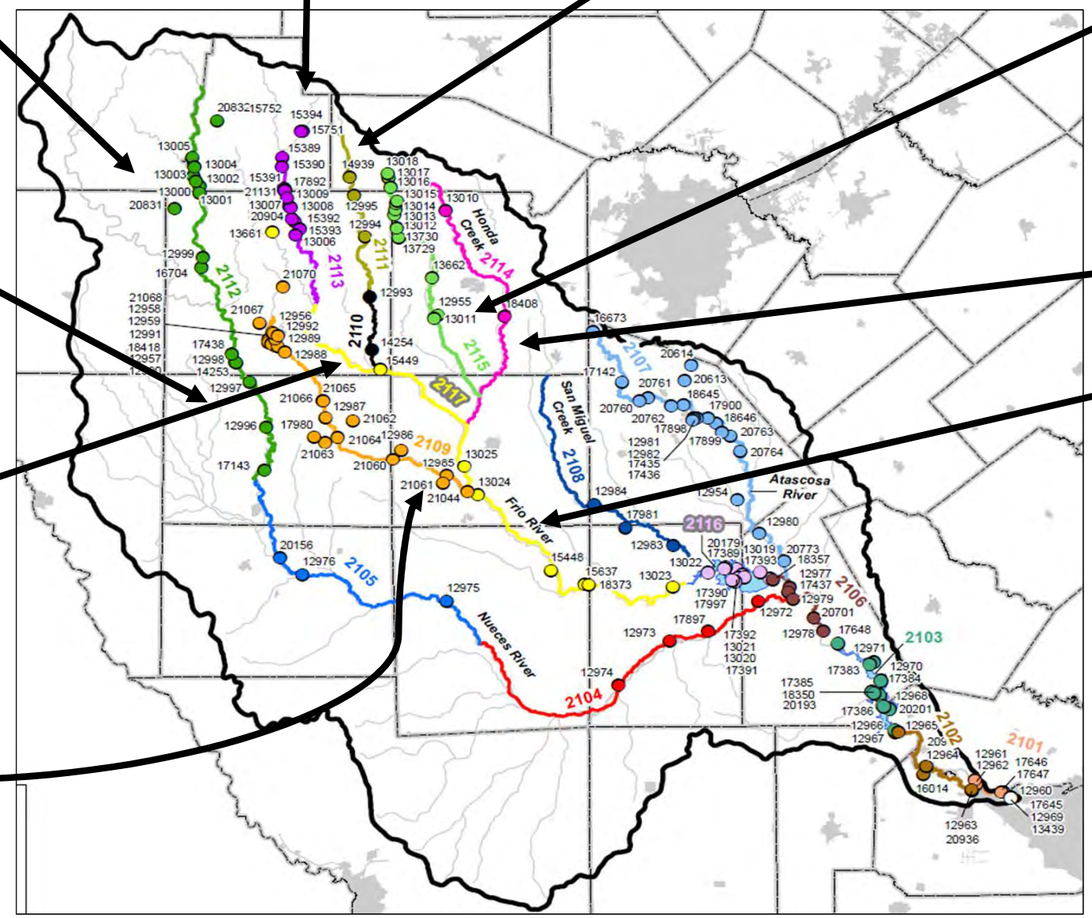


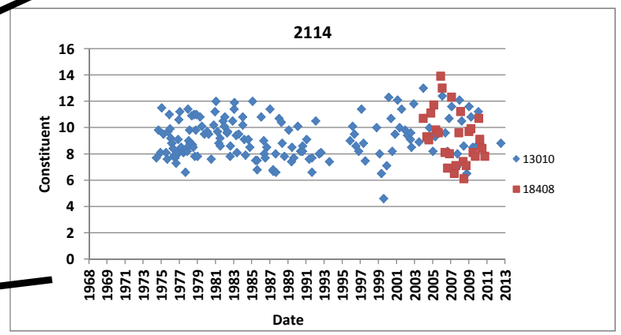


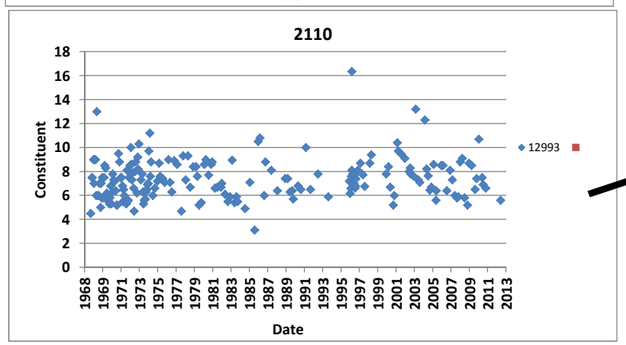


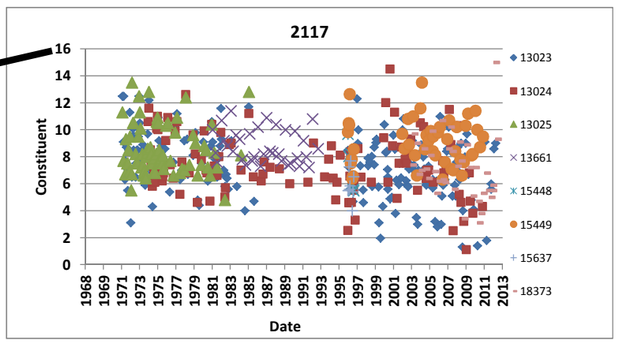


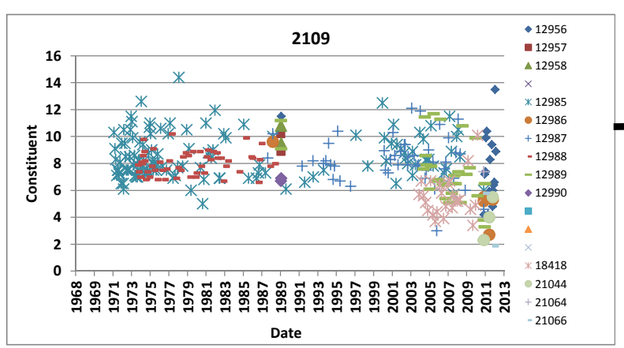




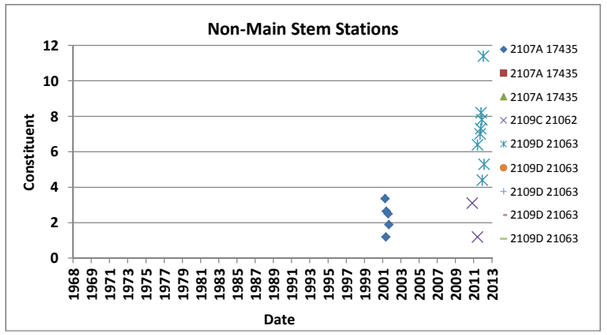


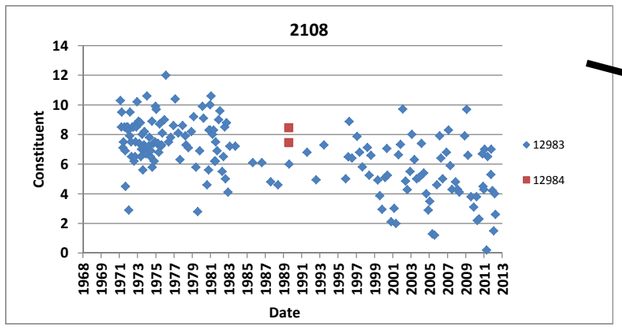


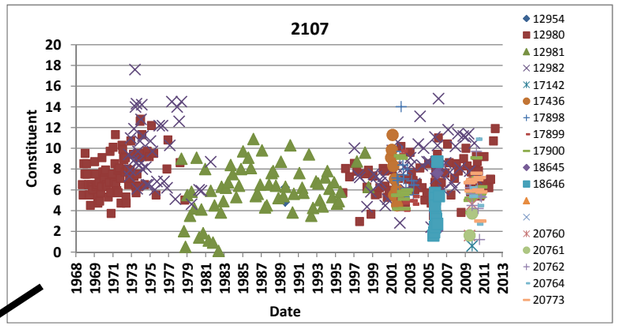


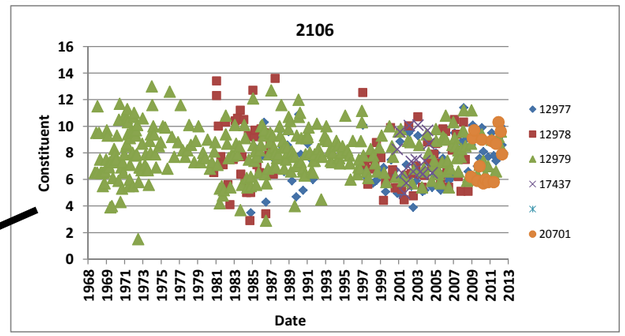


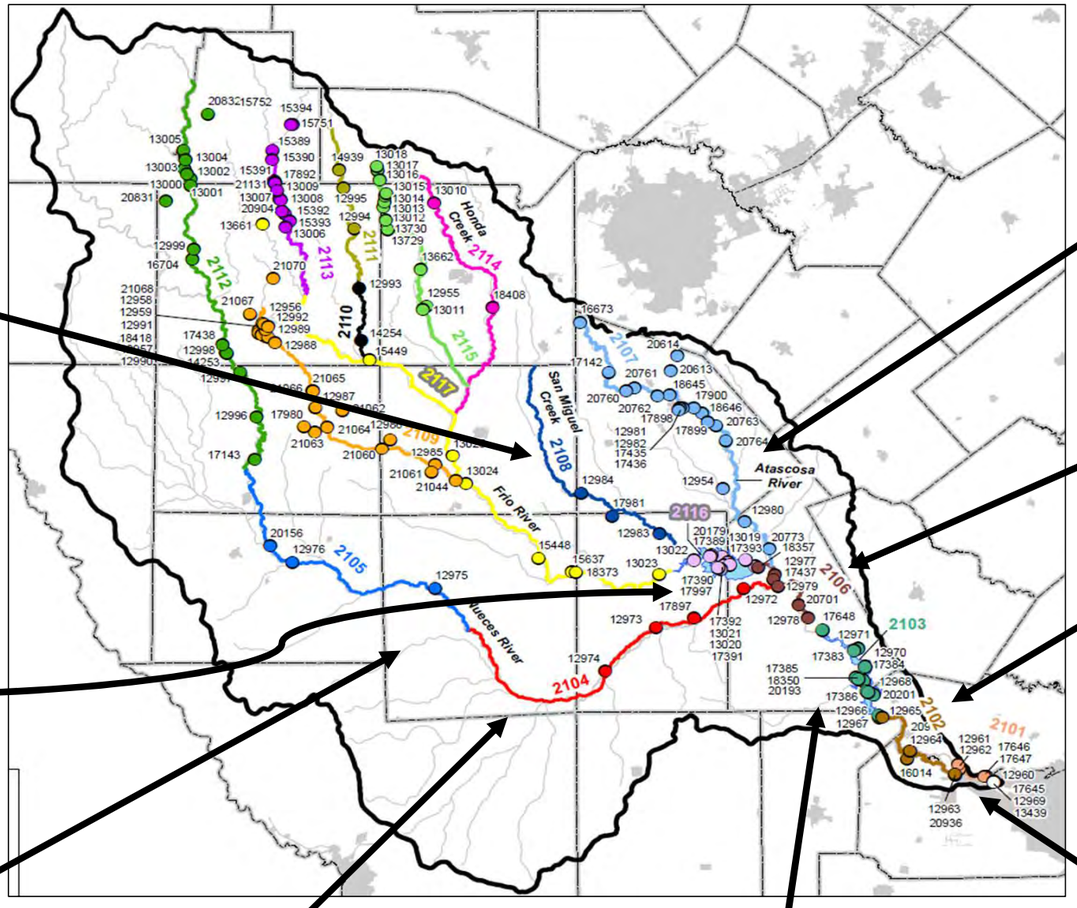
Basin 21: Nueces River
OXYGEN, DISSOLVED (MG/L) vs Date

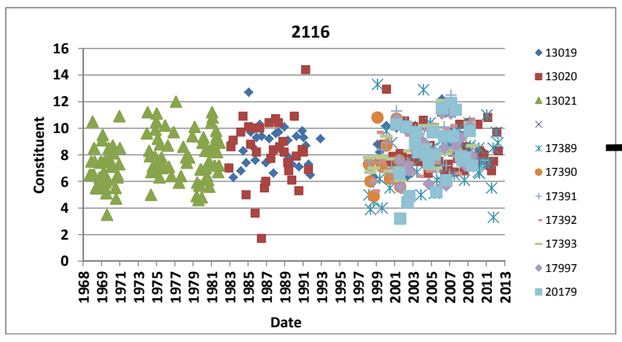


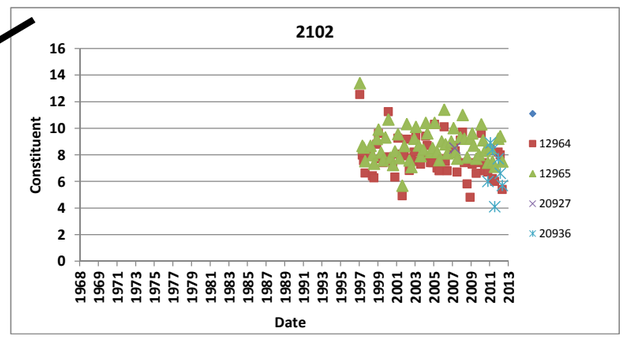


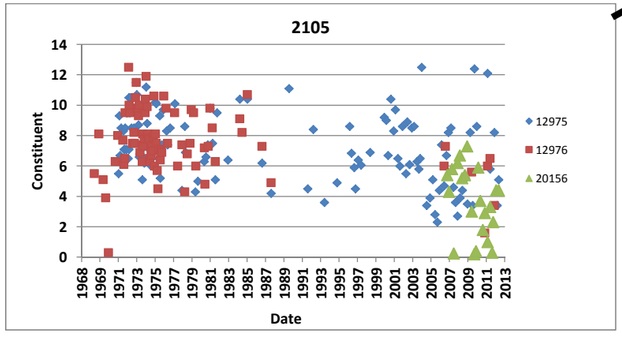


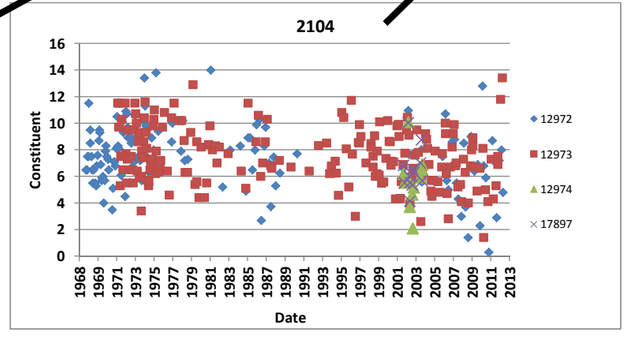


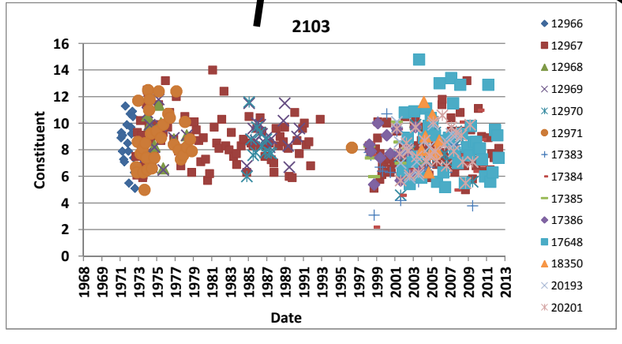


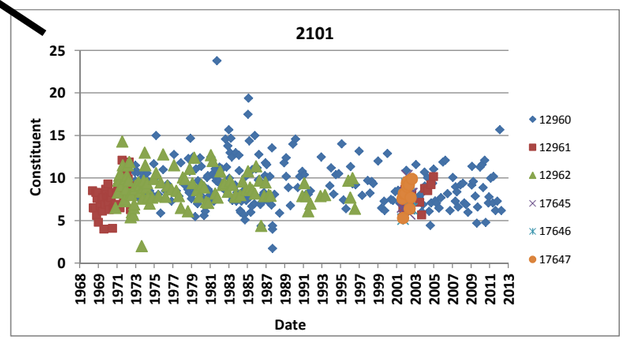




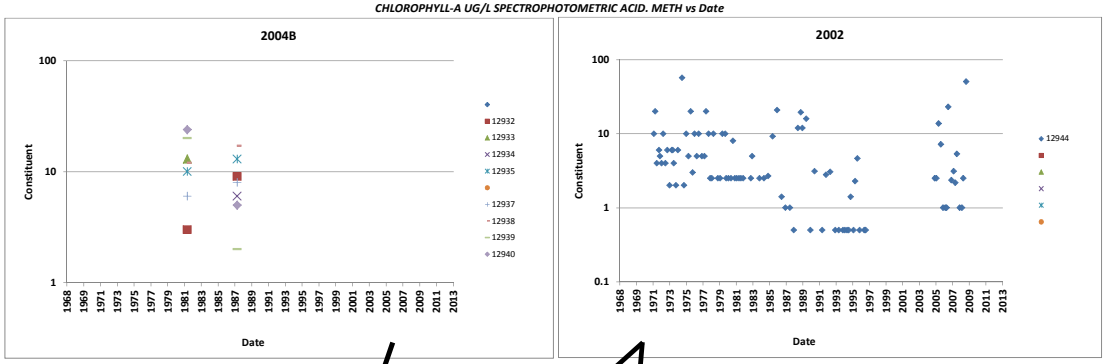


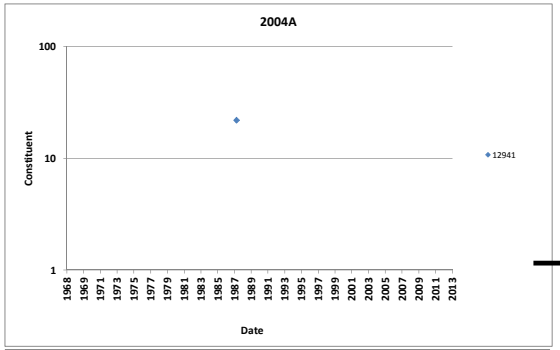


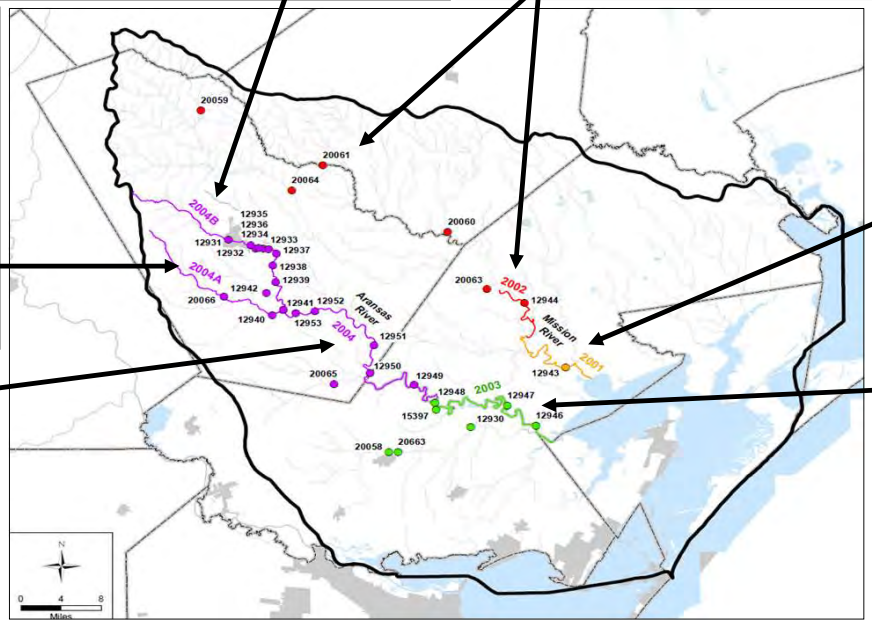


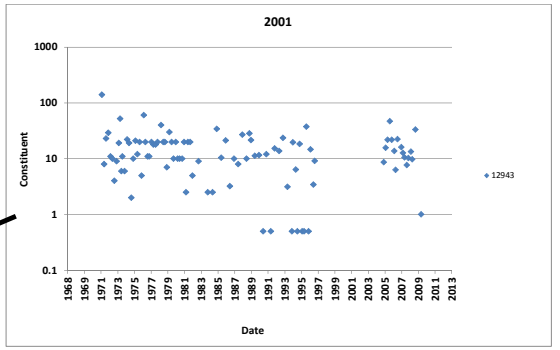


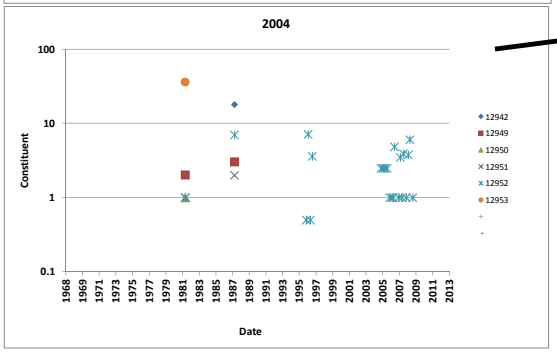
Basin 20: San Antonio-Nueces Coastal
CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH vs Date

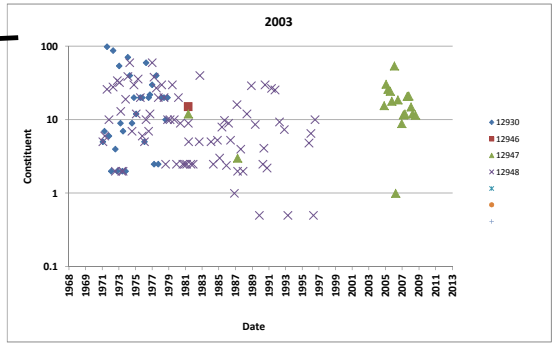




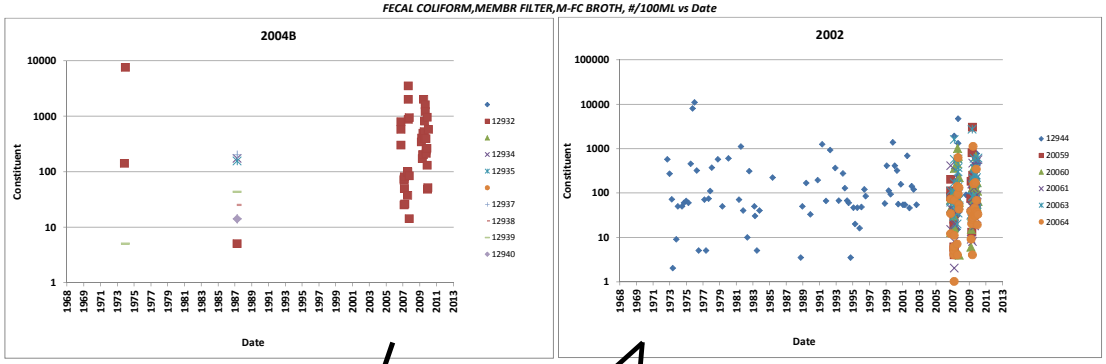


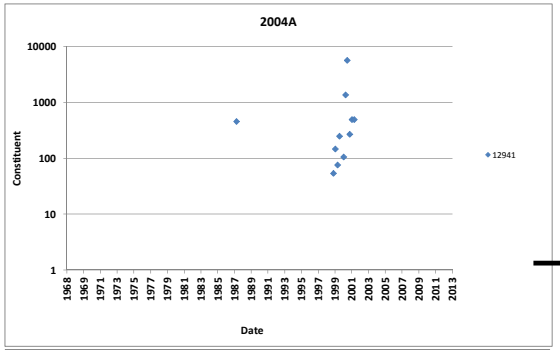


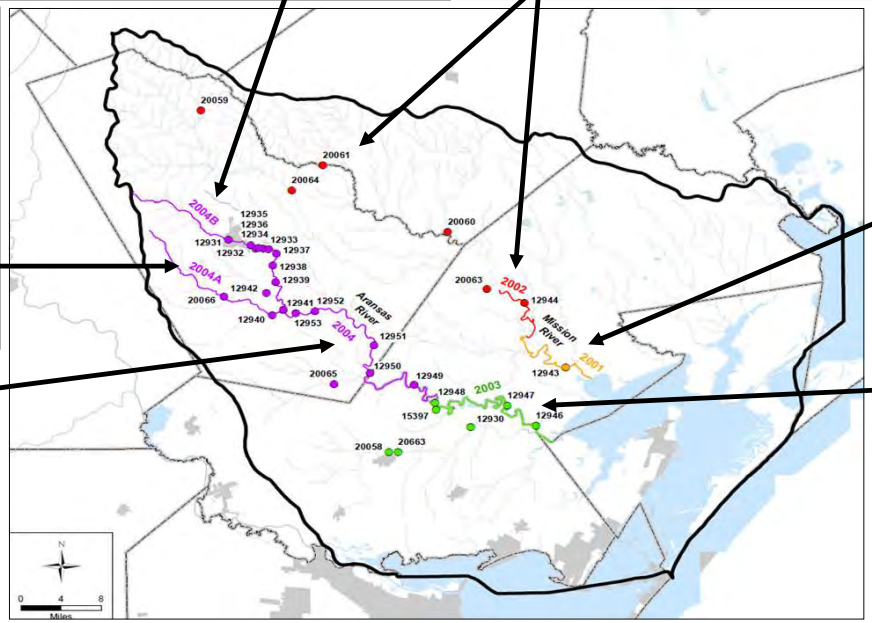


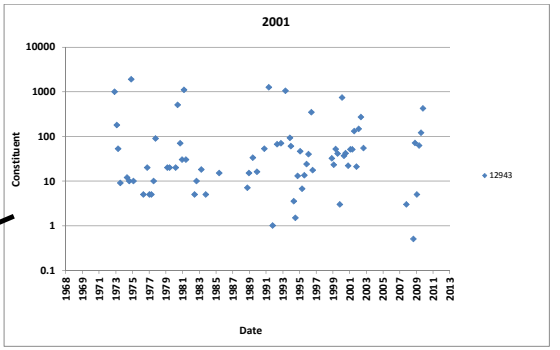


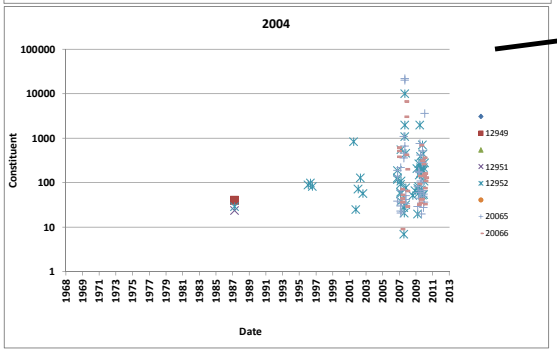
Basin 20: San Antonio-Nueces Coastal
FECAL COLIFORM,MEMBR FILTER,M-FC BROTH, #/100ML vs Date

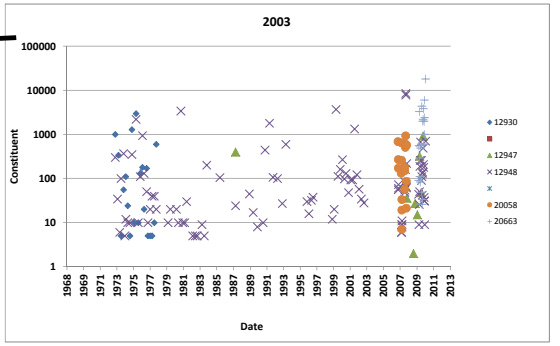




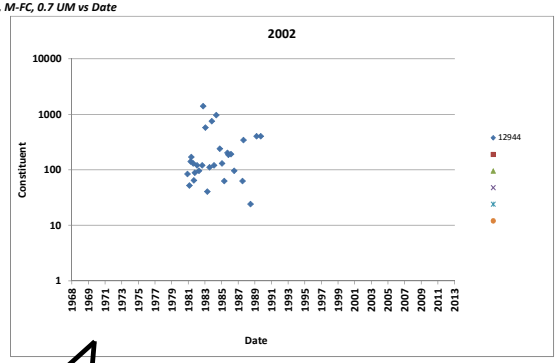


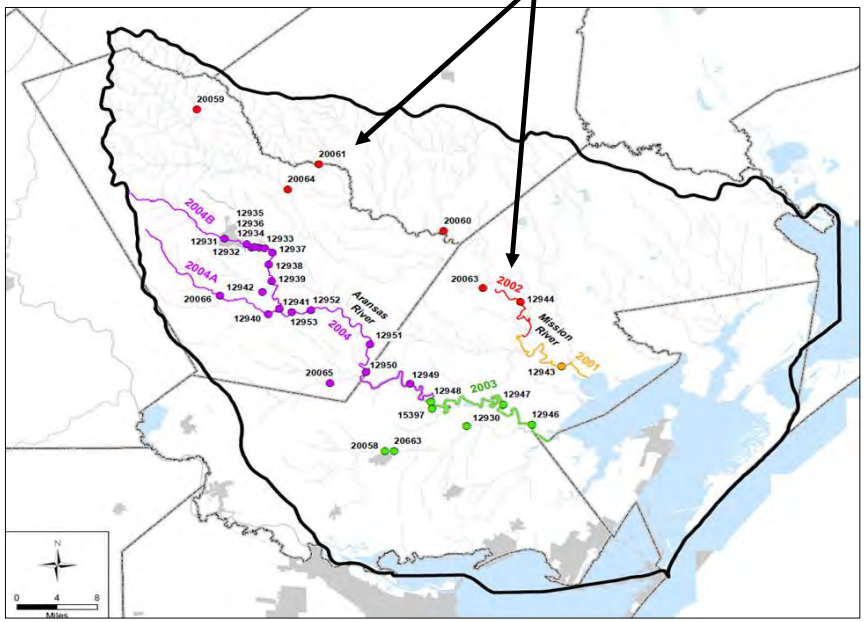




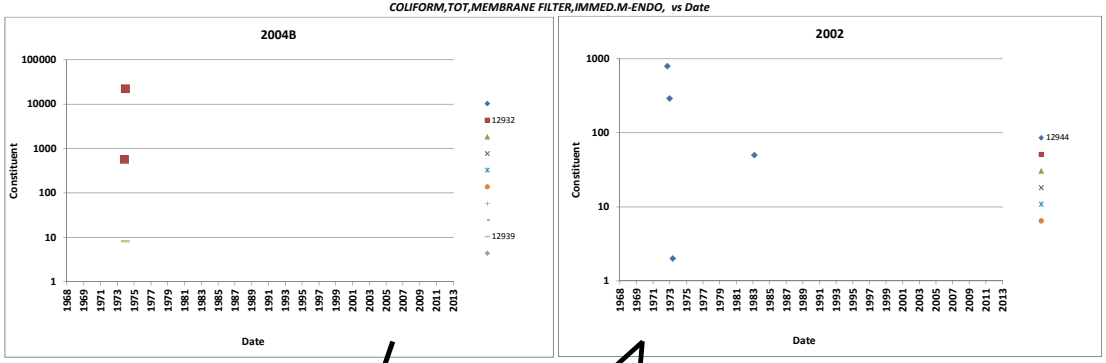


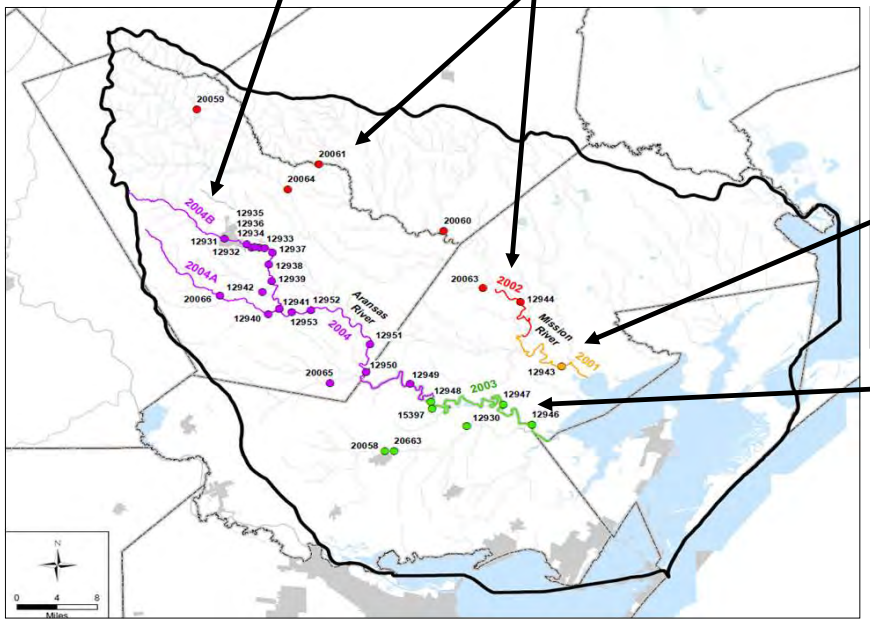
Basin 20: San Antonio-Nueces Coastal
FECAL COLIFORM, MF, M-FC, 0.7 UM vs Date

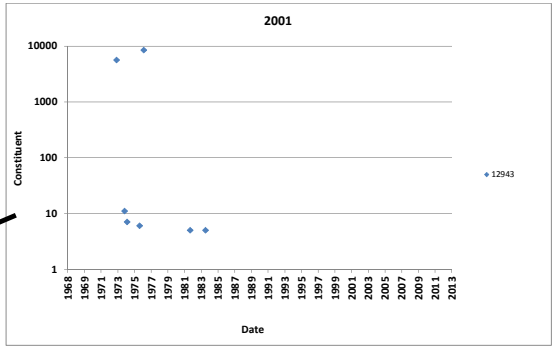


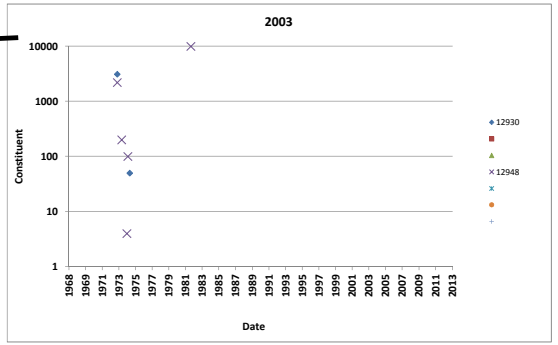


Basin 20: San Antonio-Nueces Coastal
COLIFORM,TOT,MEMBRANE FILTER,IMMED.M-ENDO, vs Date

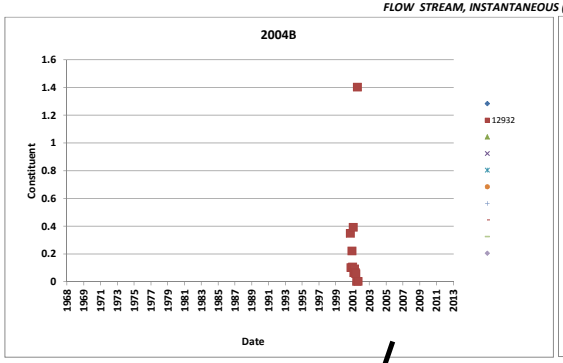


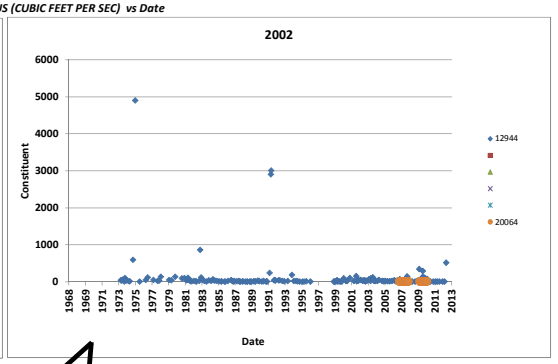


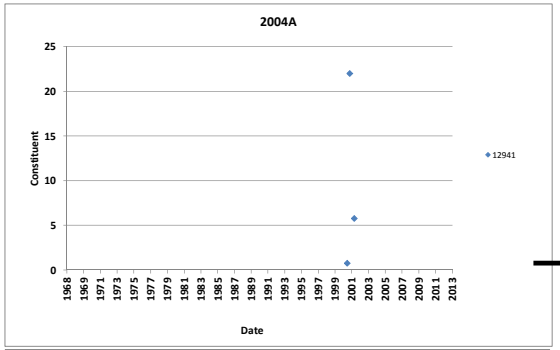


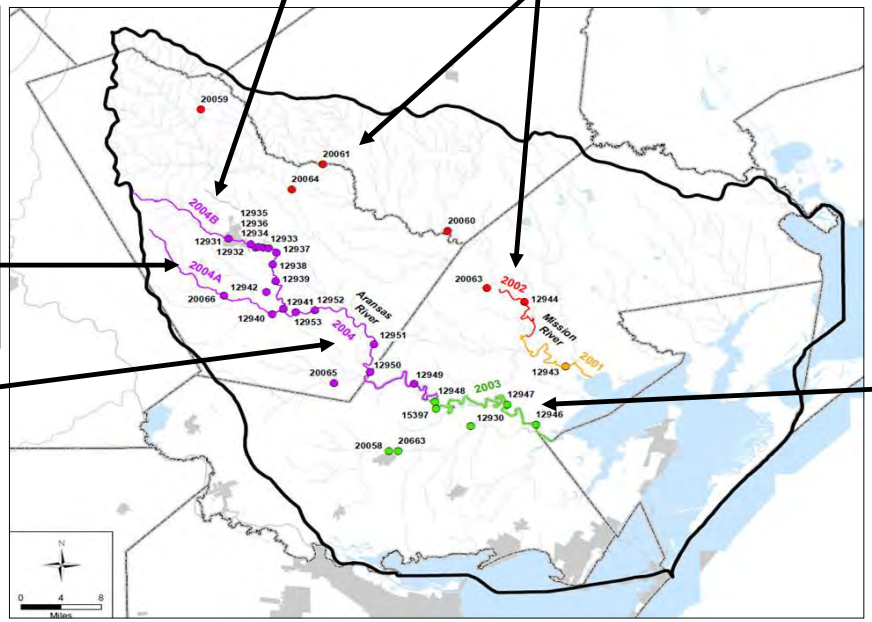


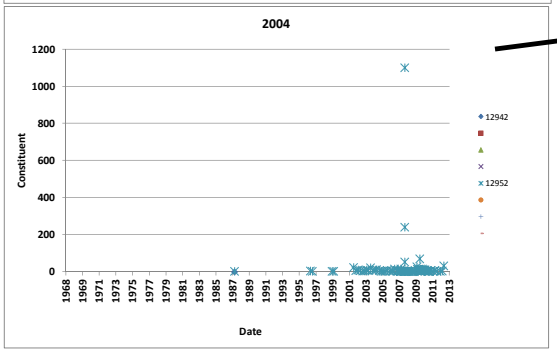
Basin 20: San Antonio-Nueces Coastal
FLOW STREAM, INSTANTANEOUS (CUBIC FEET PER SEC) vs Date

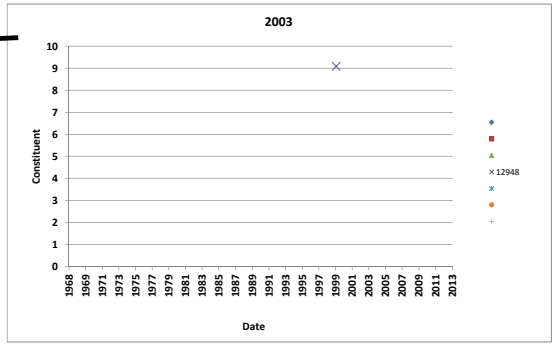




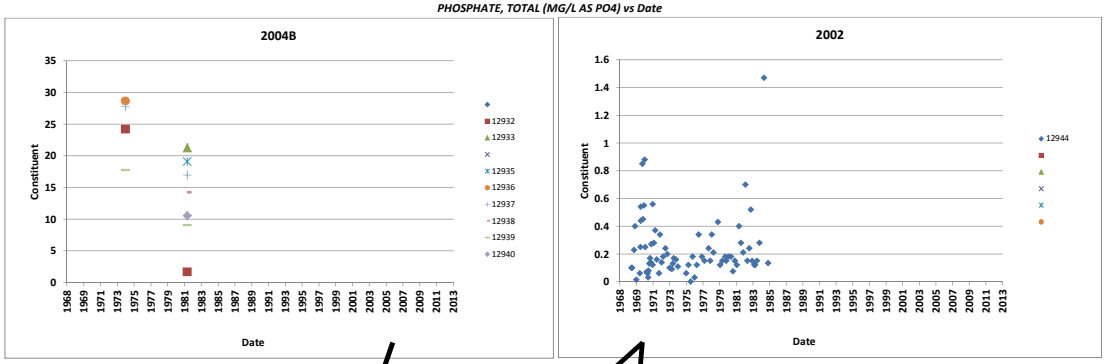


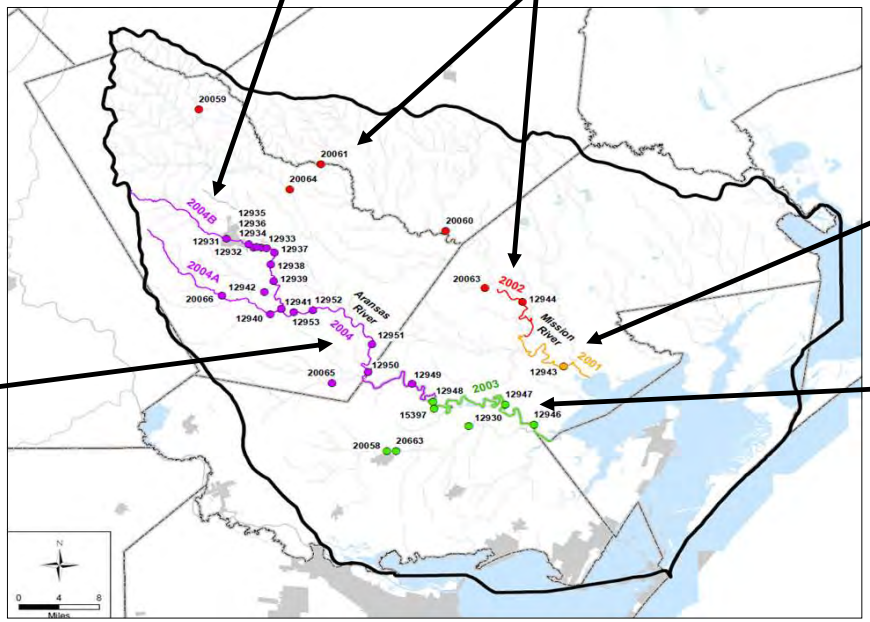


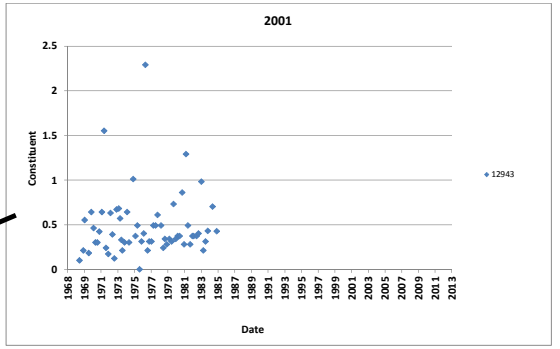


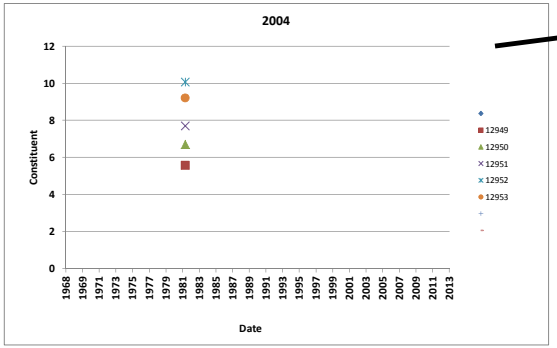


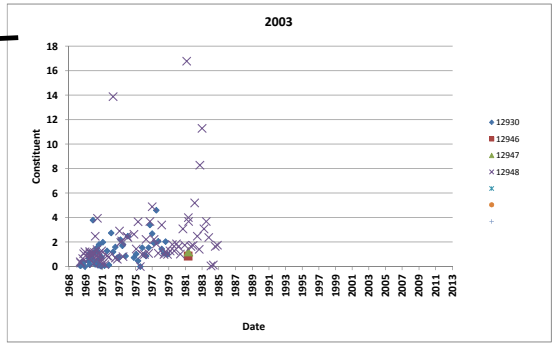
Basin 20: San Antonio-Nueces Coastal
PHOSPHATE, TOTAL (MG/L AS PO4) vs Date



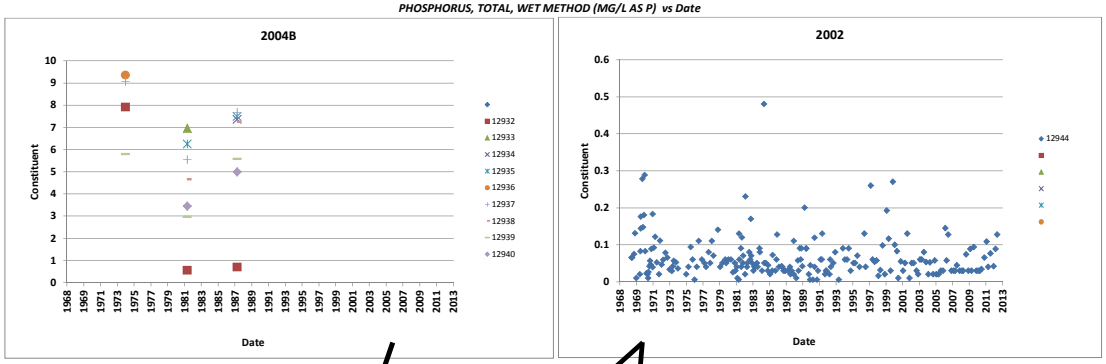


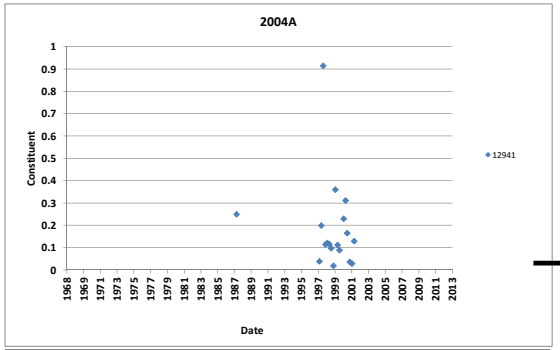


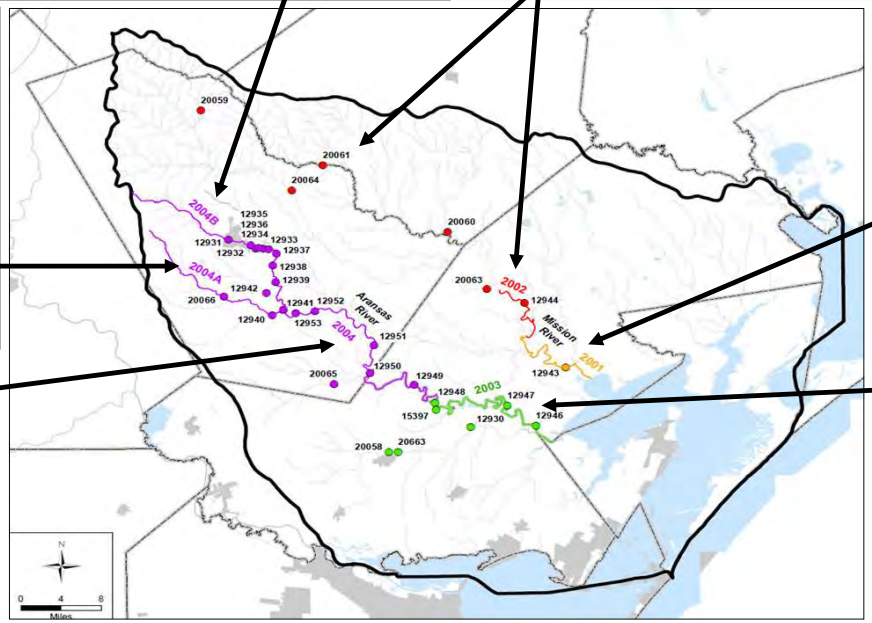


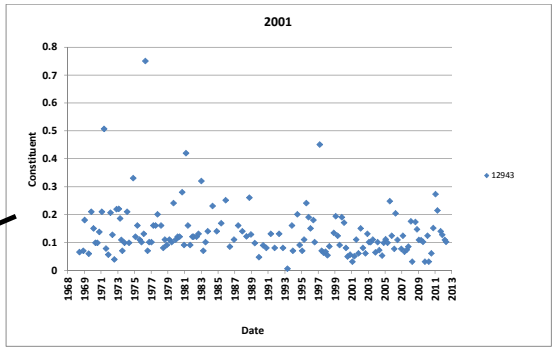


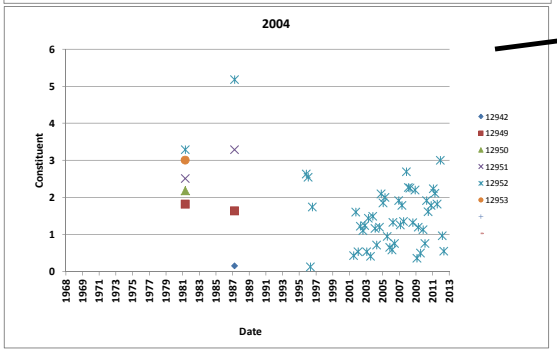
Basin 20: San Antonio-Nueces Coastal
PHOSPHORUS, TOTAL, WET METHOD (MG/L AS P) vs Date

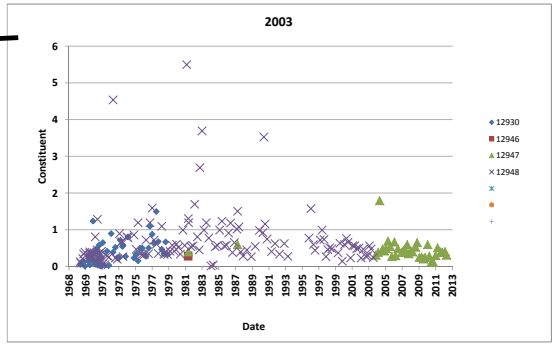




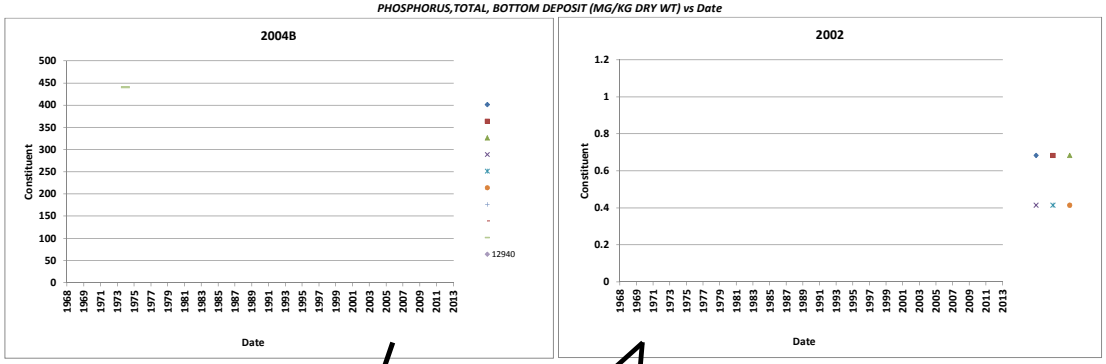


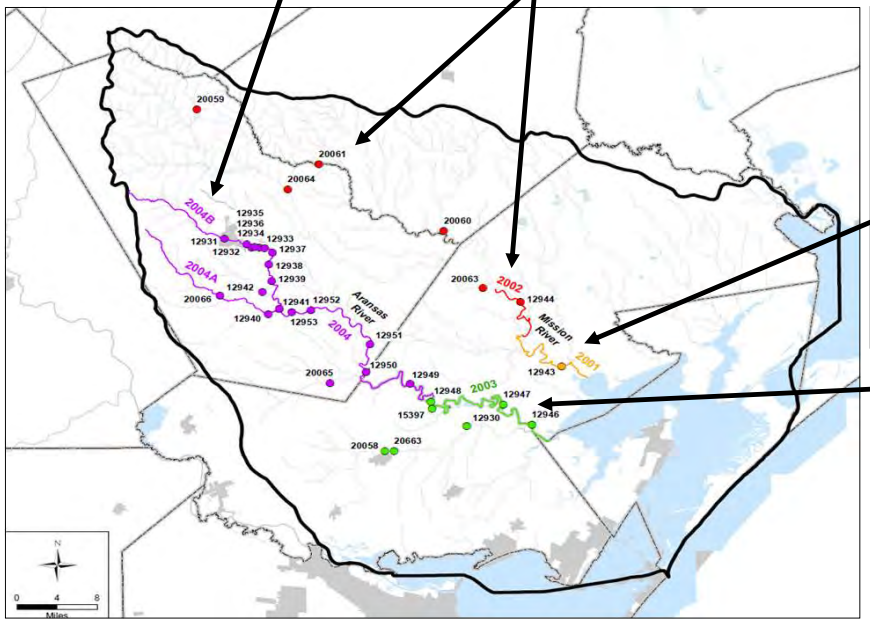


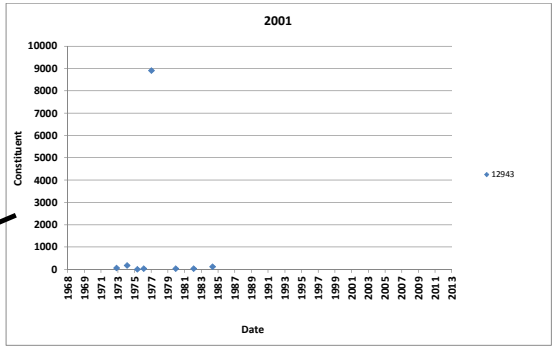


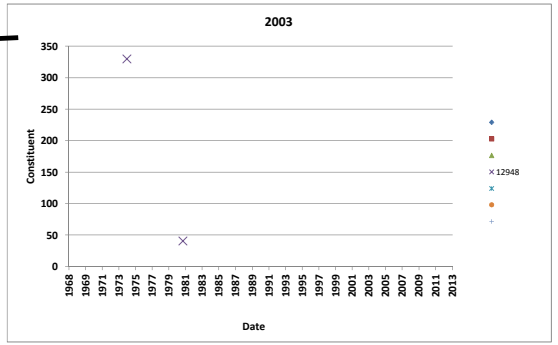


Basin 20: San Antonio-Nueces Coastal
PHOSPHORUS,TOTAL, BOTTOM DEPOSIT (MG/KG DRY WT) vs Date

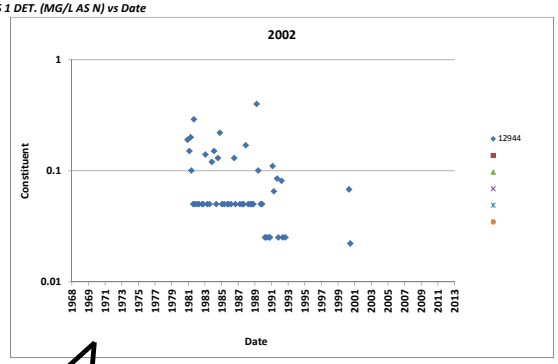


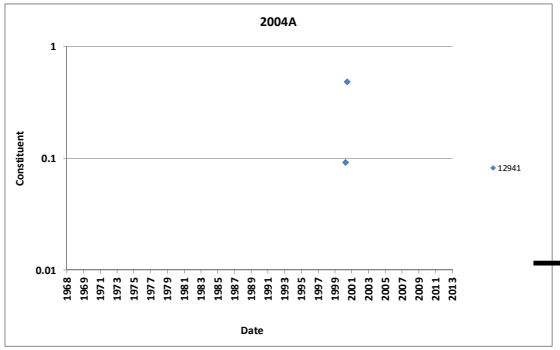


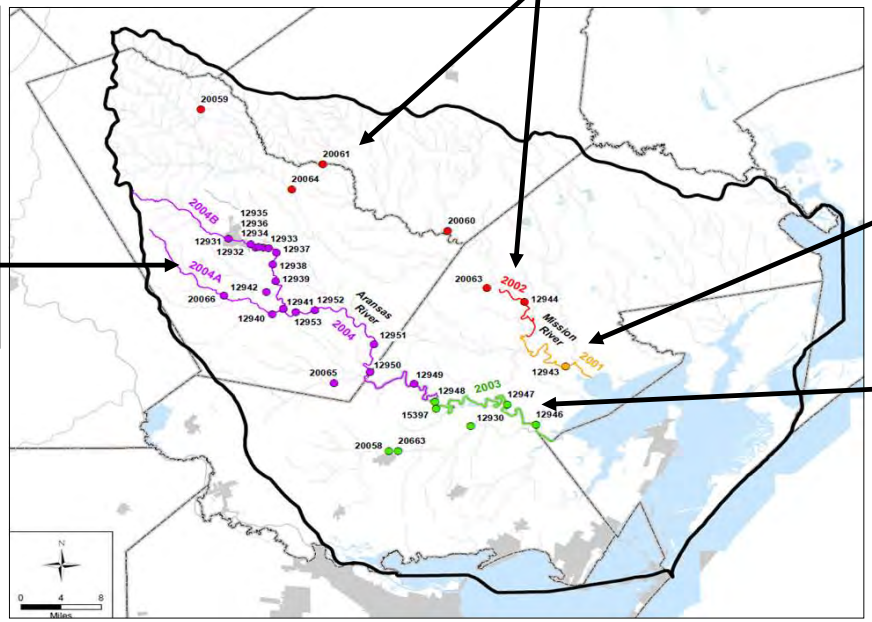


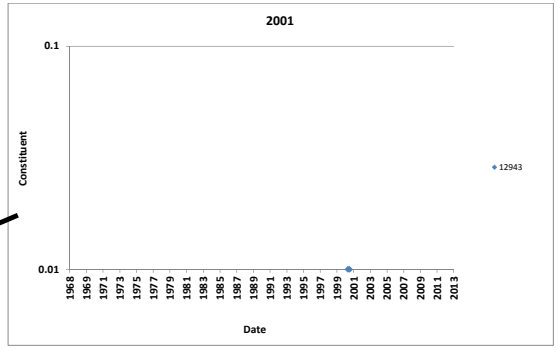


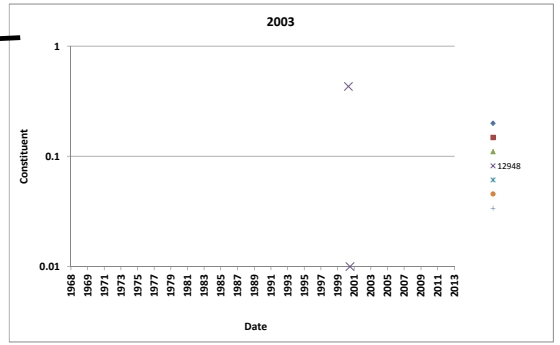
Basin 20: San Antonio-Nueces Coastal
NITRITE PLUS NITRATE, DISS 1 DET. (MG/L AS N) vs Date



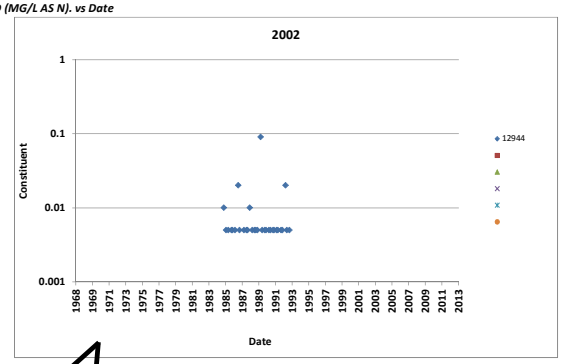


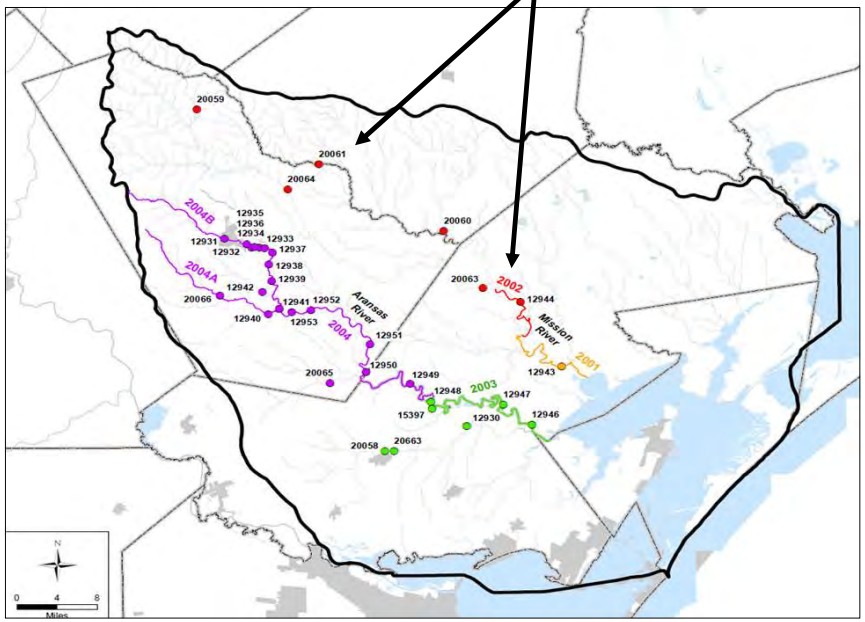




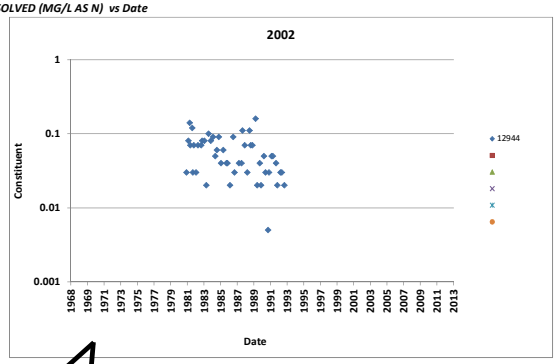


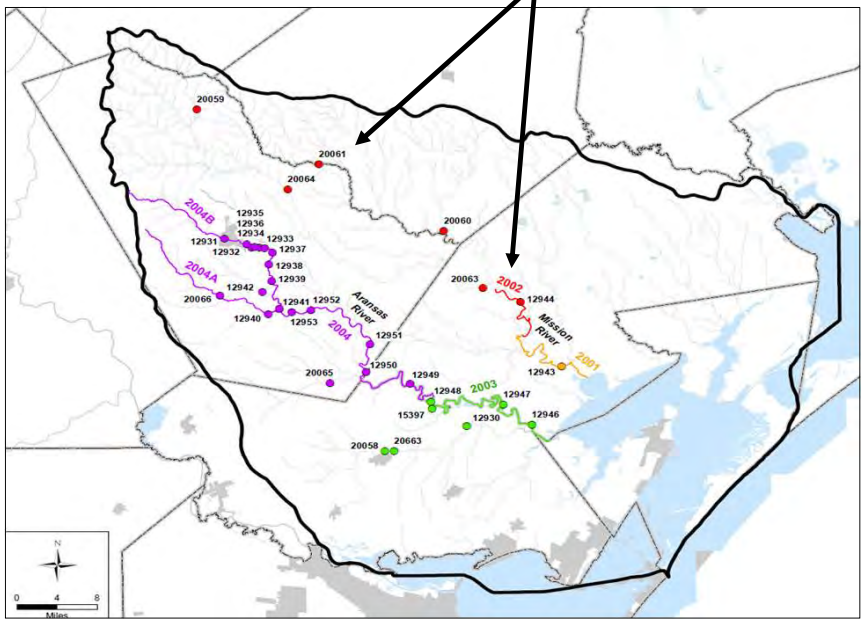
Basin 20: San Antonio-Nueces Coastal
NITRITE, DISSOLVED (MG/L AS N). vs Date



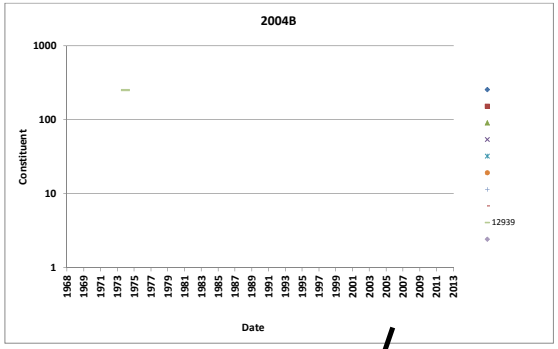


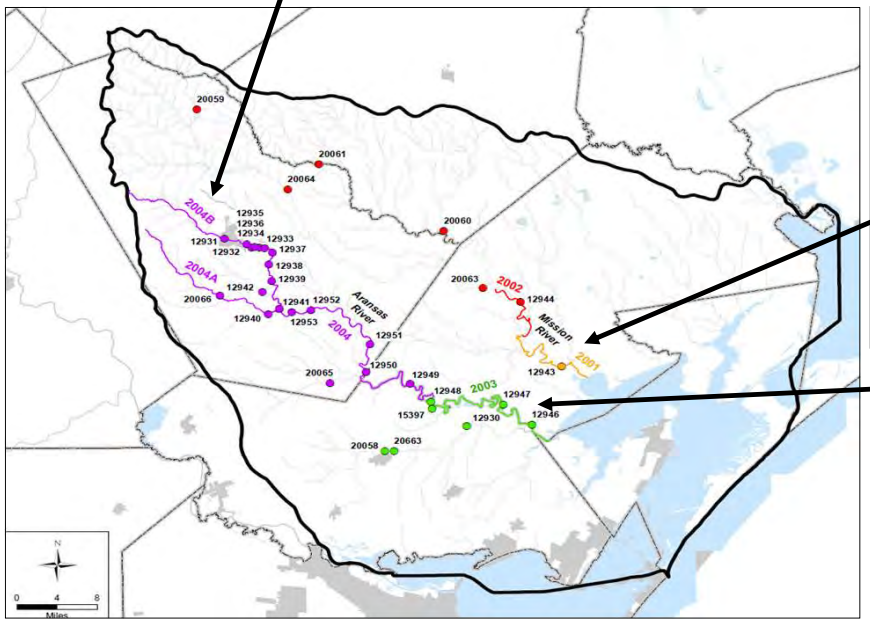
Basin 20: San Antonio-Nueces Coastal
NITROGEN, AMMONIA, DISSOLVED (MG/L AS N) vs Date

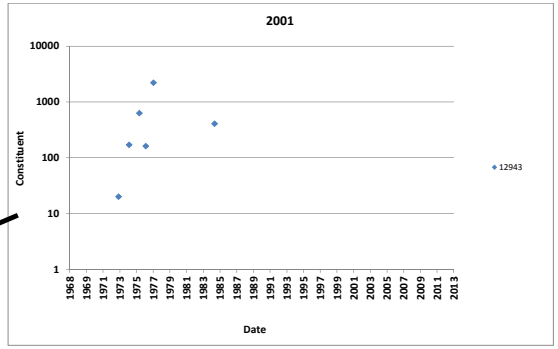


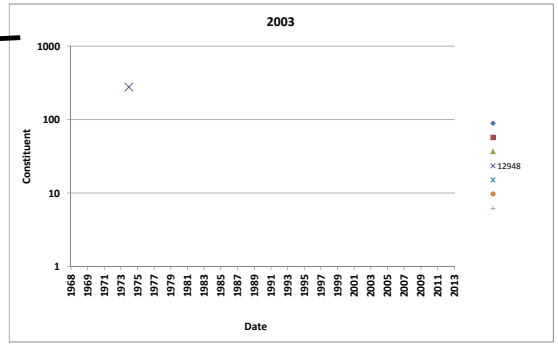


Basin 20: San Antonio-Nueces Coastal
NITROGEN,ORG. KJEL, BOT. DEPOS (MG/KG-N DRY WT) vs Date

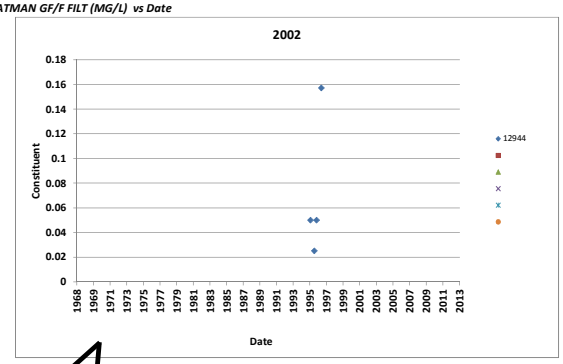


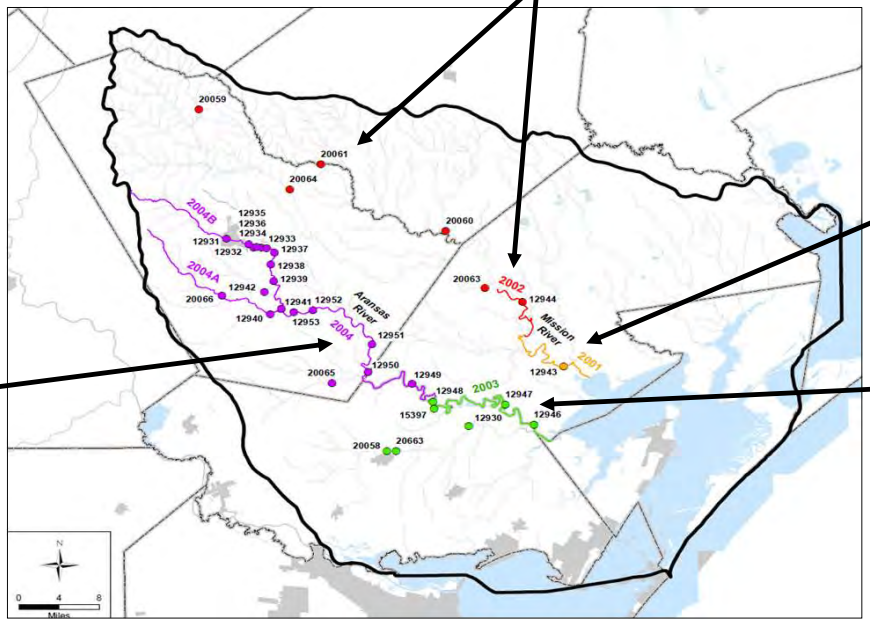


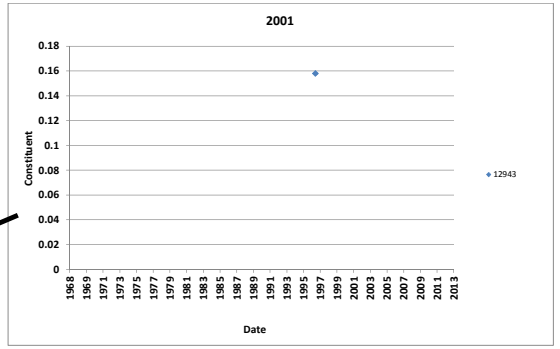


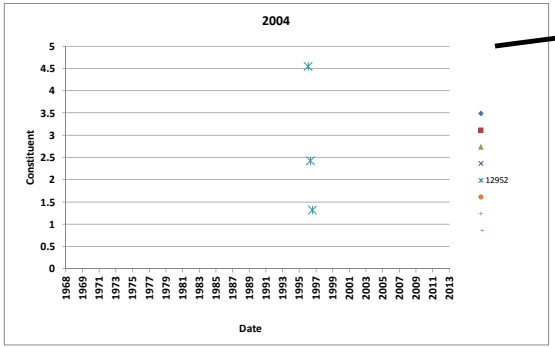


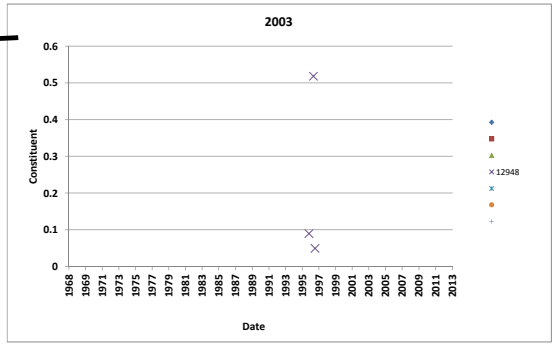
Basin 20: San Antonio-Nueces Coastal
NO2 PLUS NO3-N, TOTAL, WHATMAN GF/F FILT (MG/L) vs Date



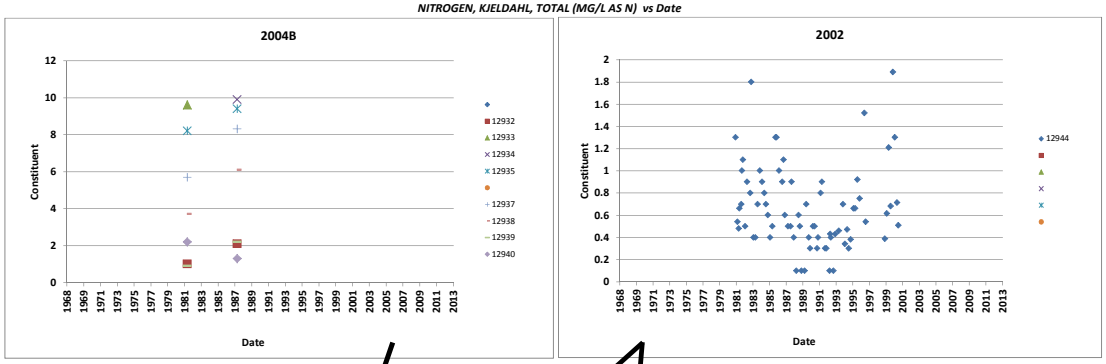


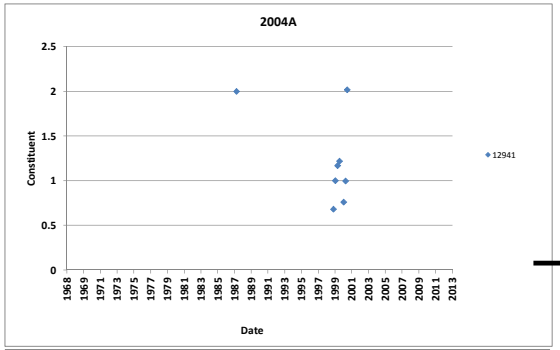


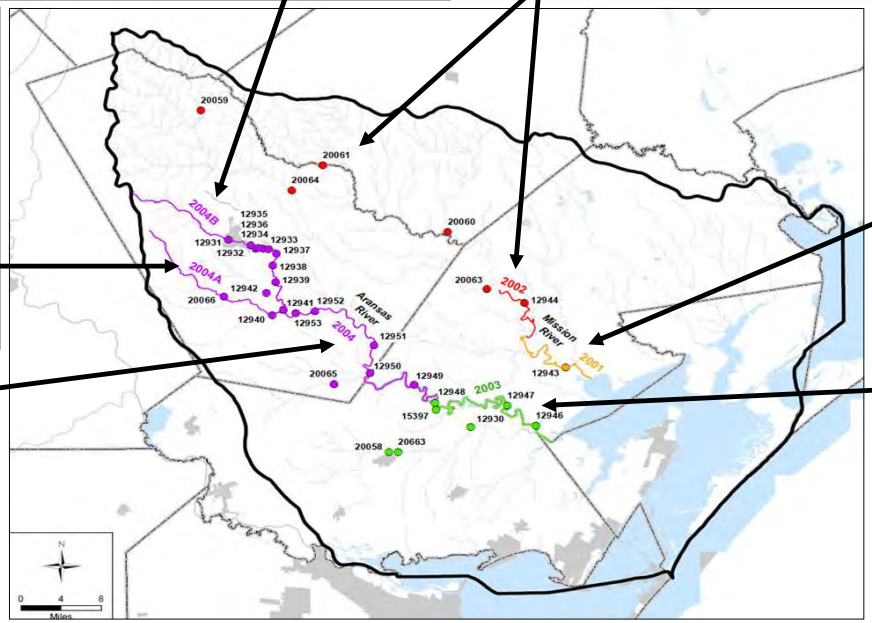


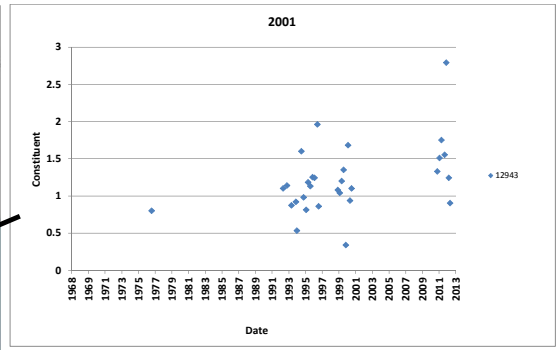


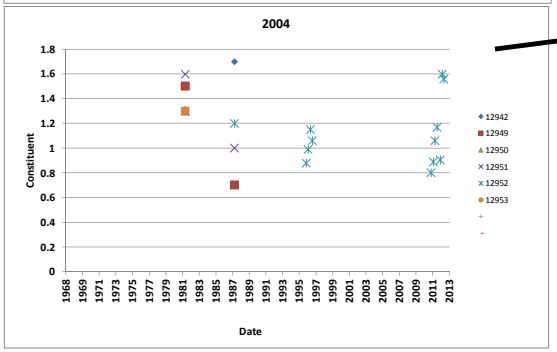
Basin 20: San Antonio-Nueces Coastal
NITROGEN, KJELDAHL, TOTAL (MG/L AS N) vs Date

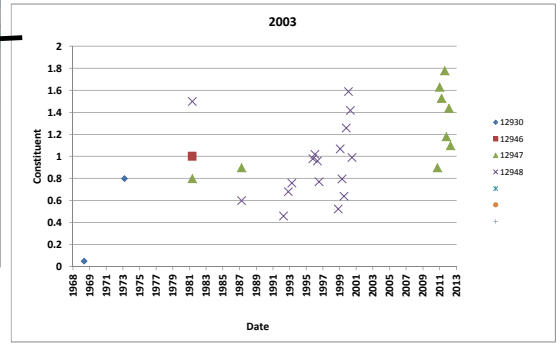




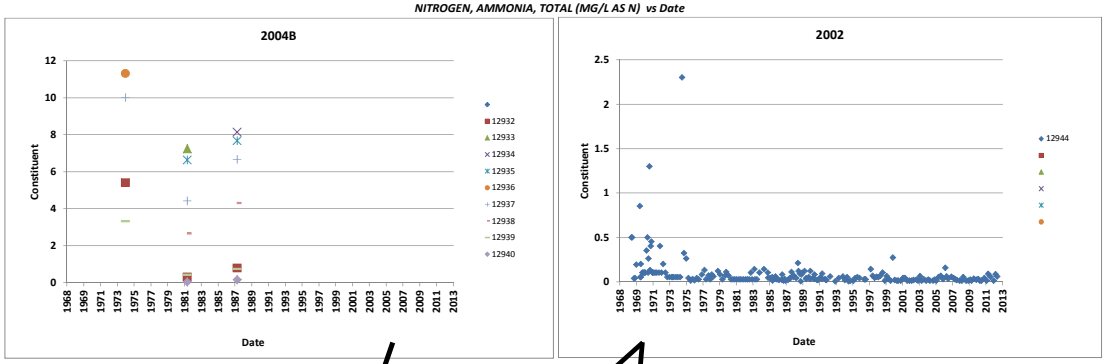


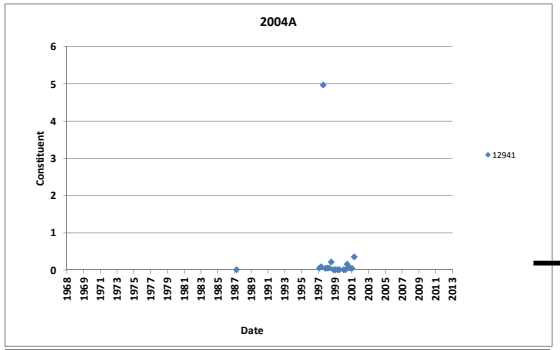


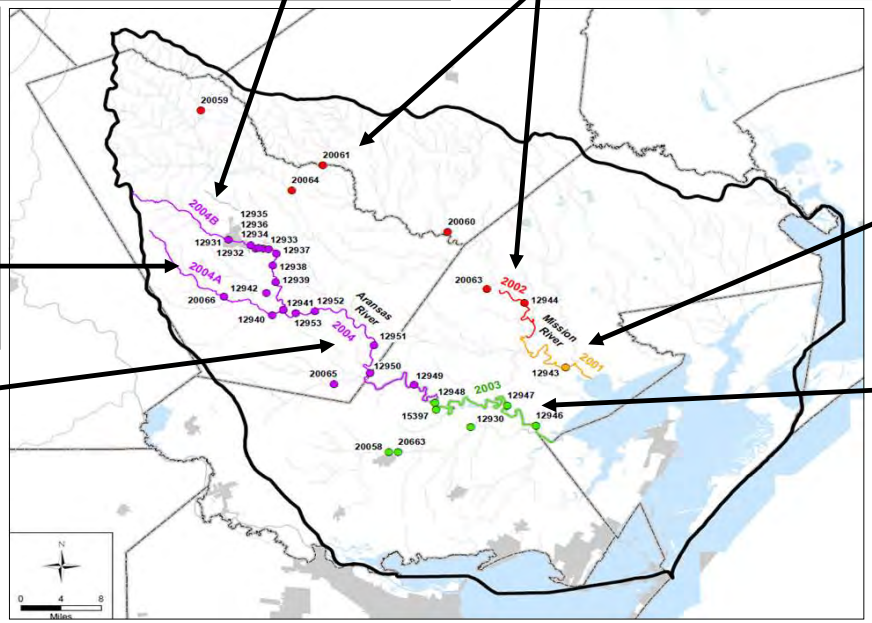


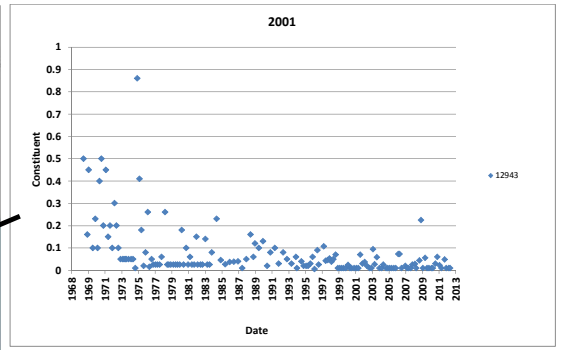


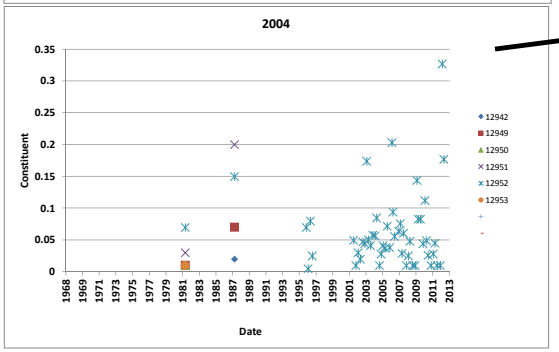
Basin 20: San Antonio-Nueces Coastal
NITROGEN, AMMONIA, TOTAL (MG/L AS N) vs Date

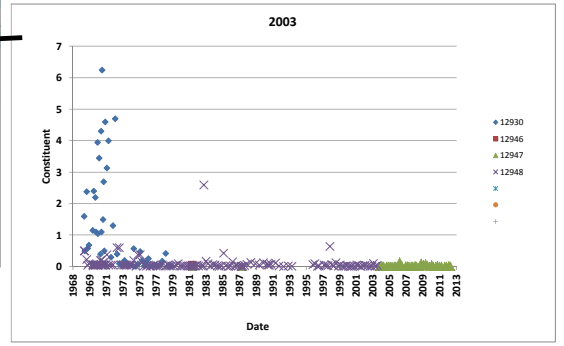




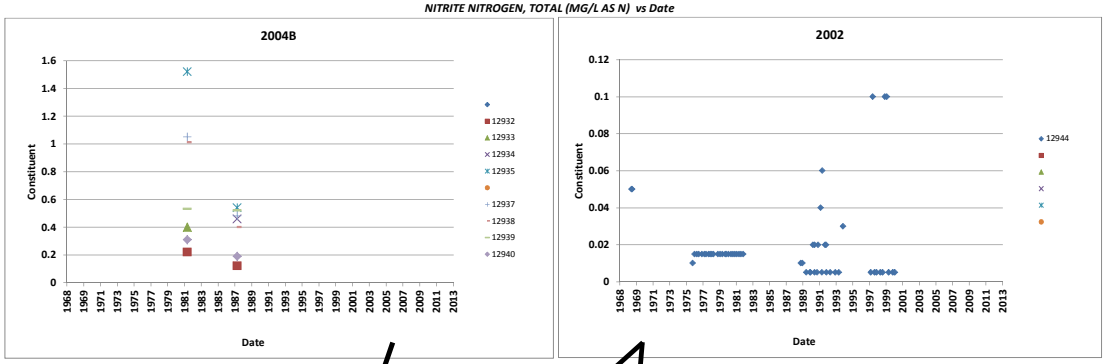


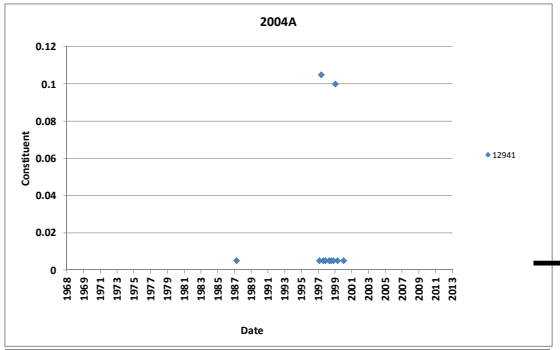


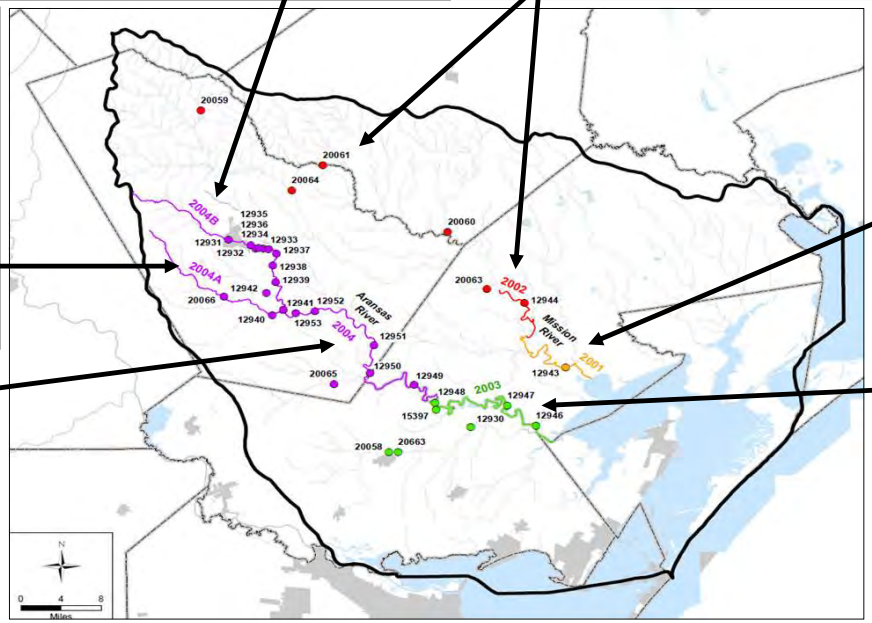


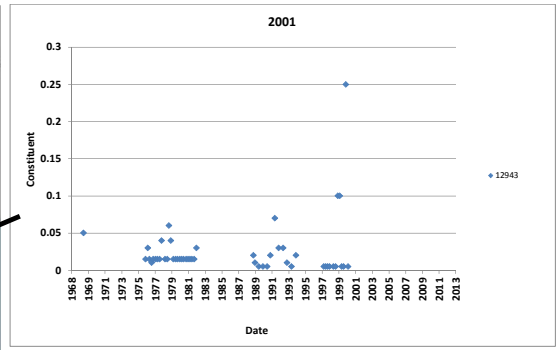


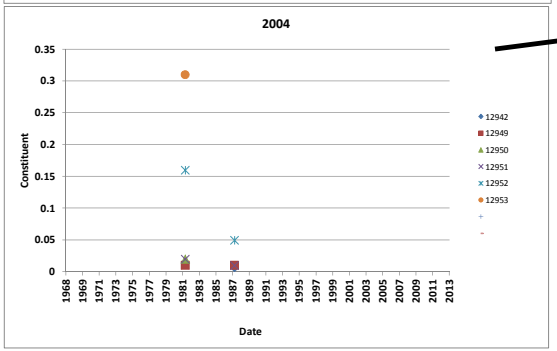
Basin 20: San Antonio-Nueces Coastal
NITRITE NITROGEN, TOTAL (MG/L AS N) vs Date

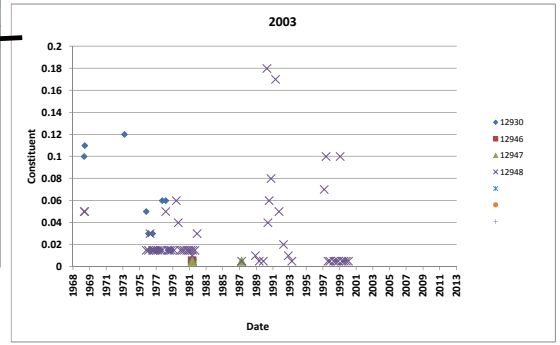




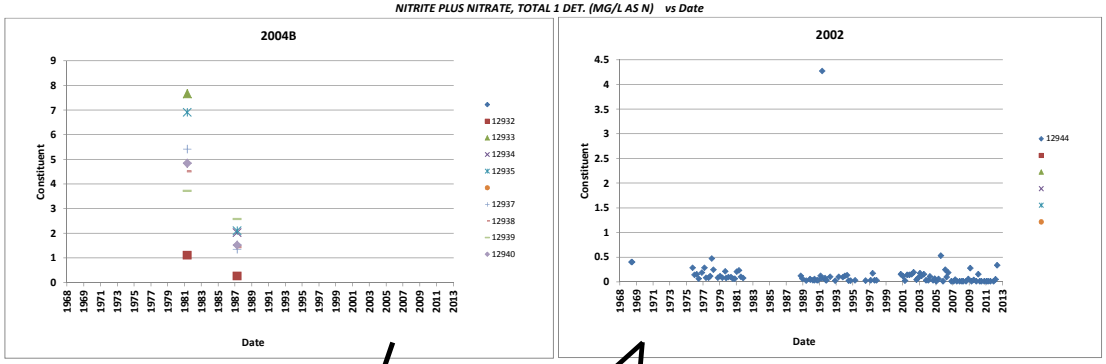


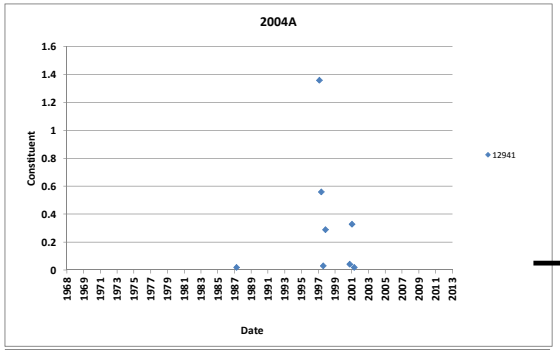


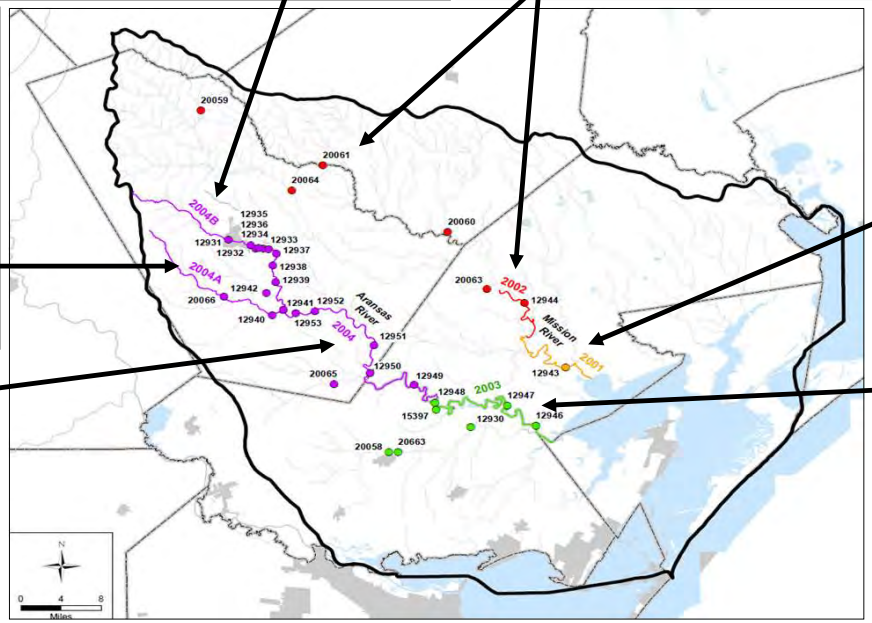


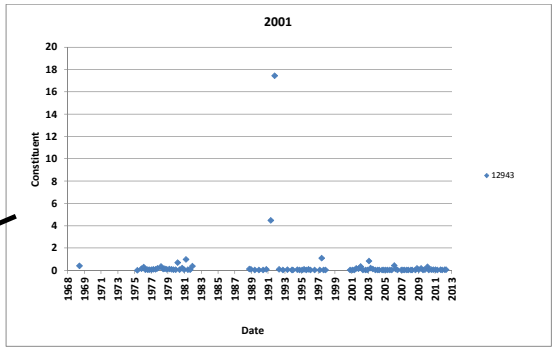


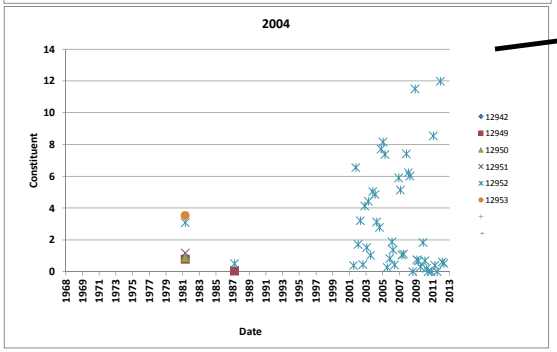
Basin 20: San Antonio-Nueces Coastal
NITRITE PLUS NITRATE, TOTAL 1 DET. (MG/L AS N) vs Date

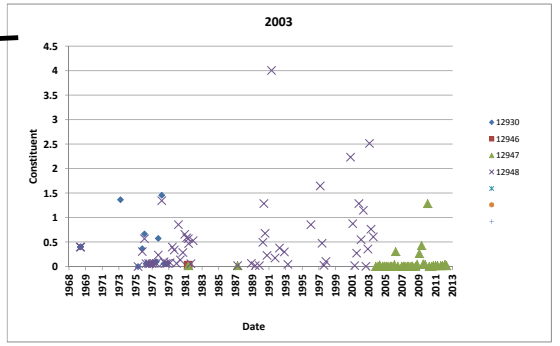




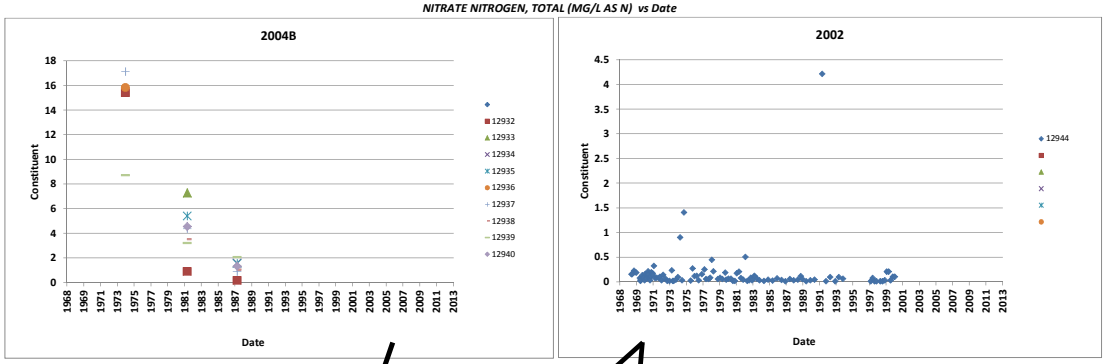


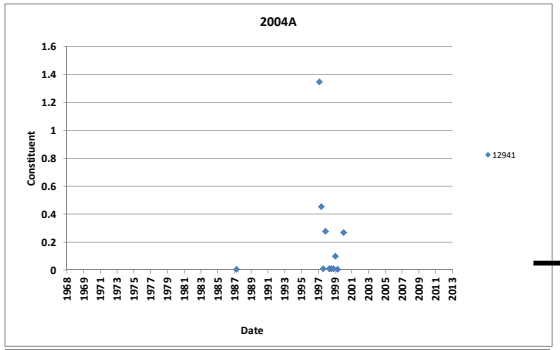


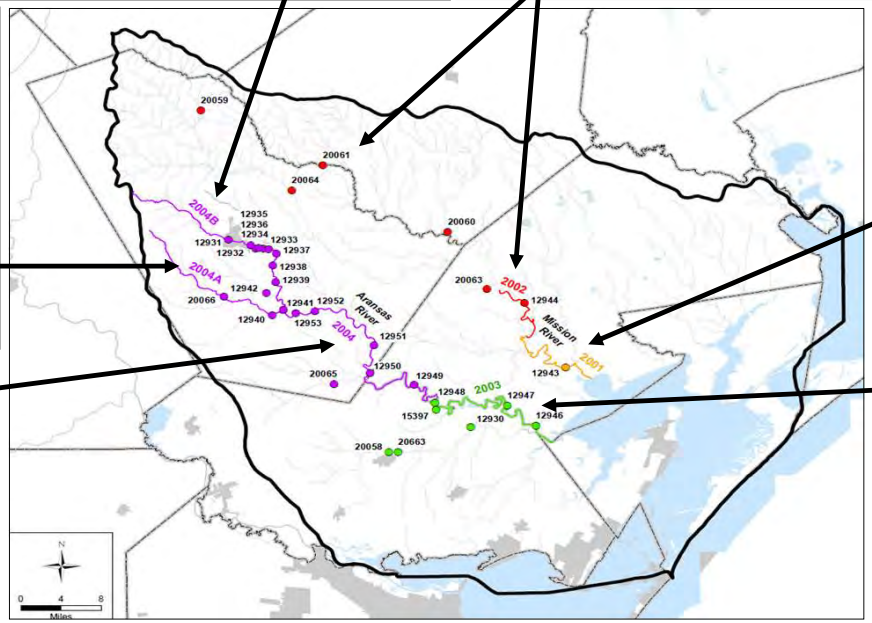


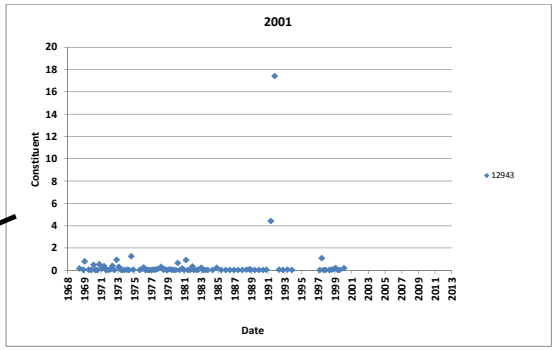


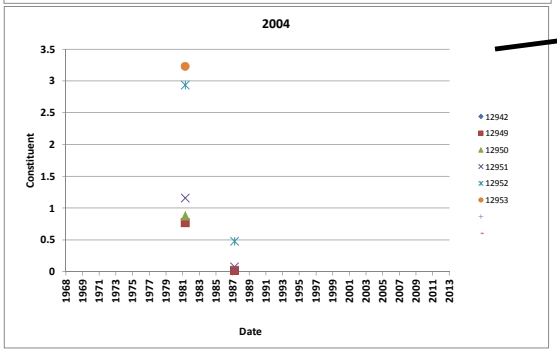
Basin 20: San Antonio-Nueces Coastal
NITRATE NITROGEN, TOTAL (MG/L AS N) vs Date

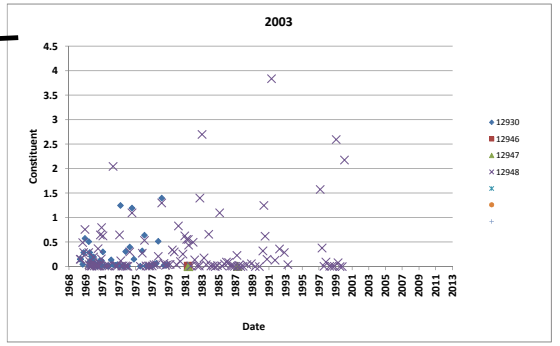




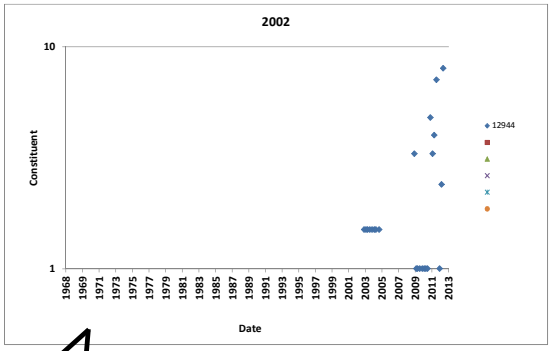


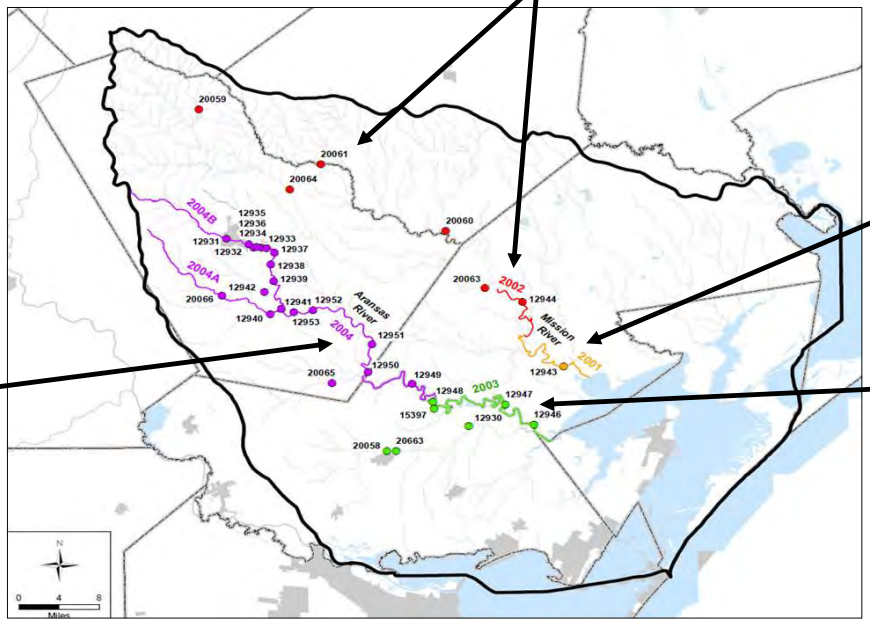


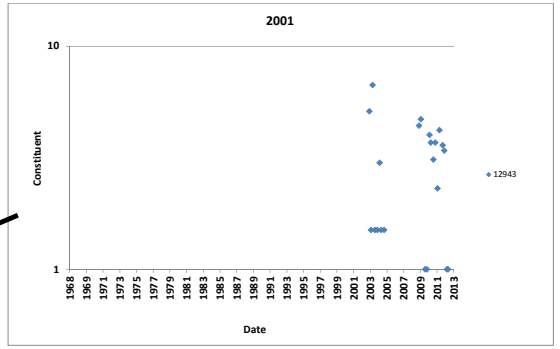


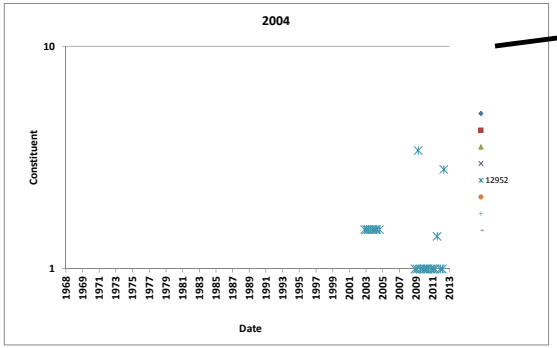


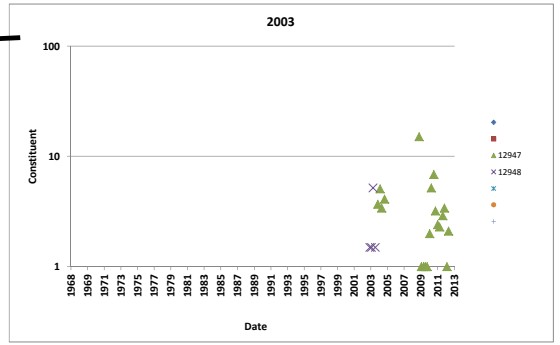
Basin 20: San Antonio-Nueces Coastal
PHEOPHYTIN-A UG/L FLUOROMETRIC METHOD vs Date



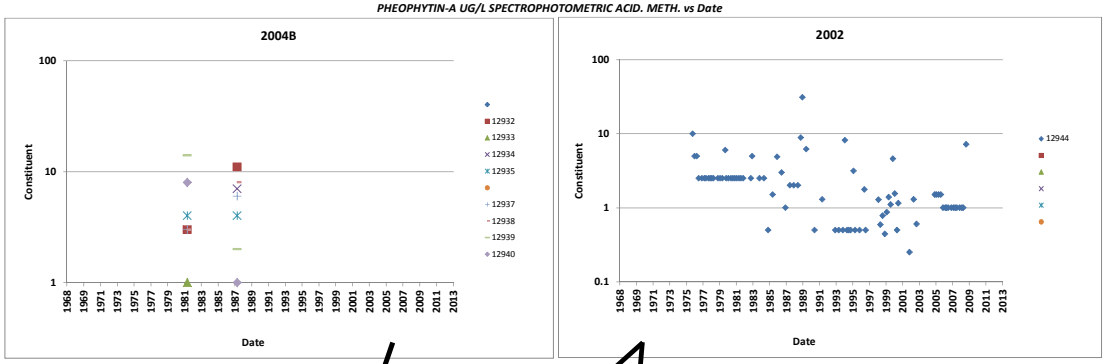


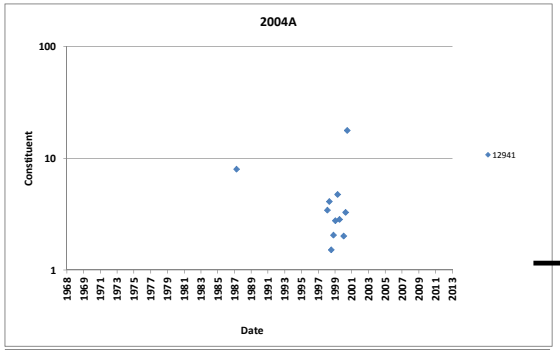


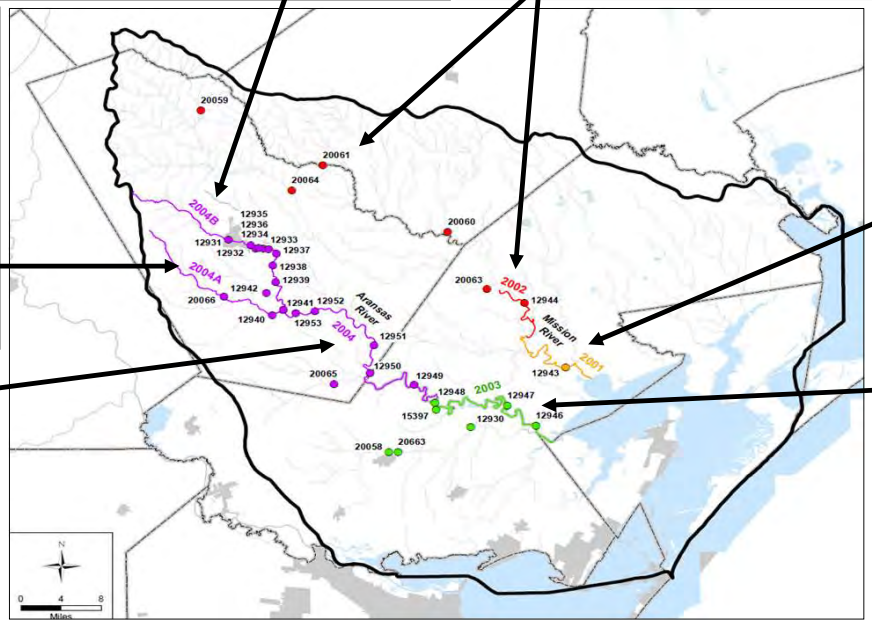


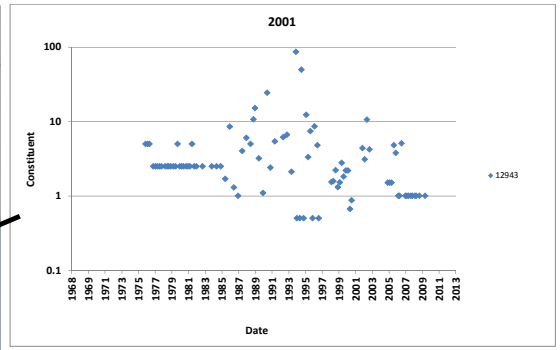


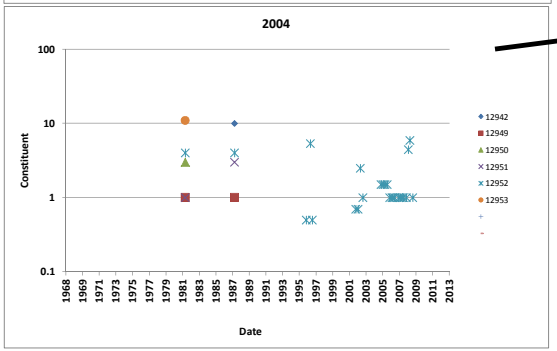
Basin 20: San Antonio-Nueces Coastal
PHEOPHYTIN-A UG/L SPECTROPHOTOMETRIC ACID. METH. vs Date

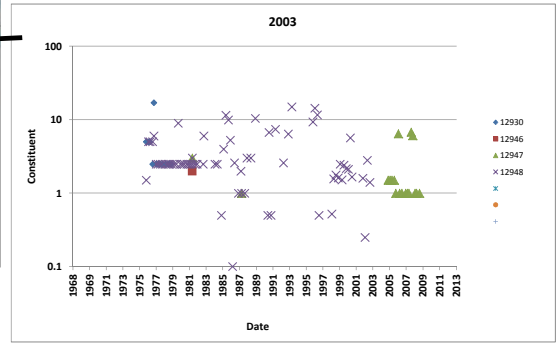




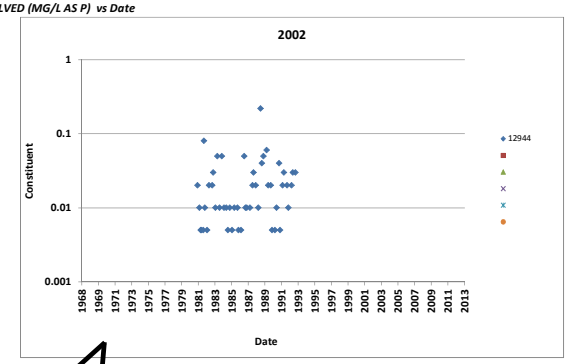


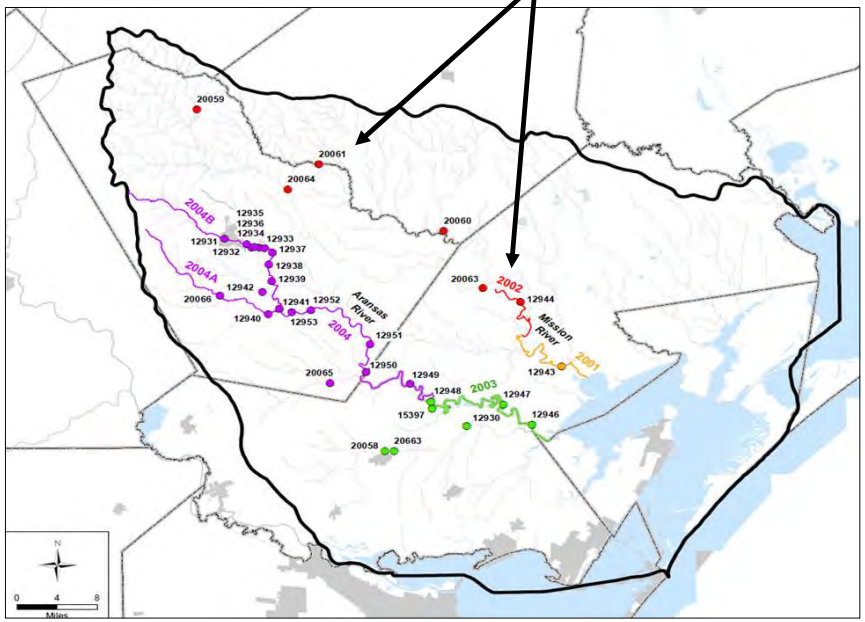




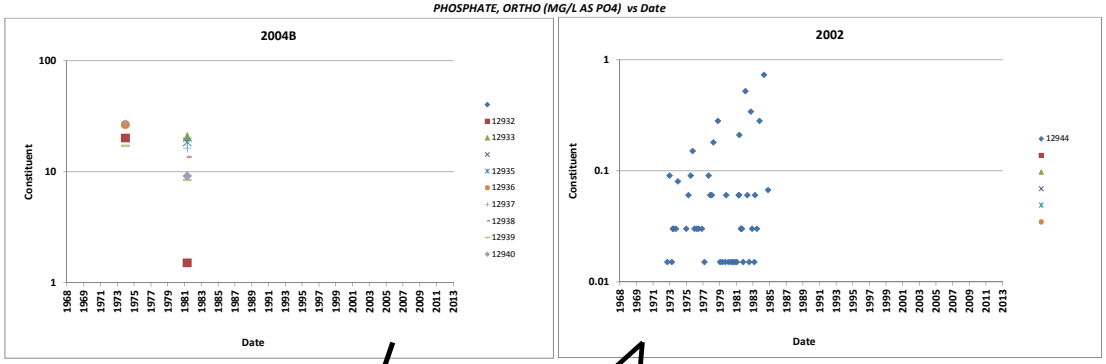


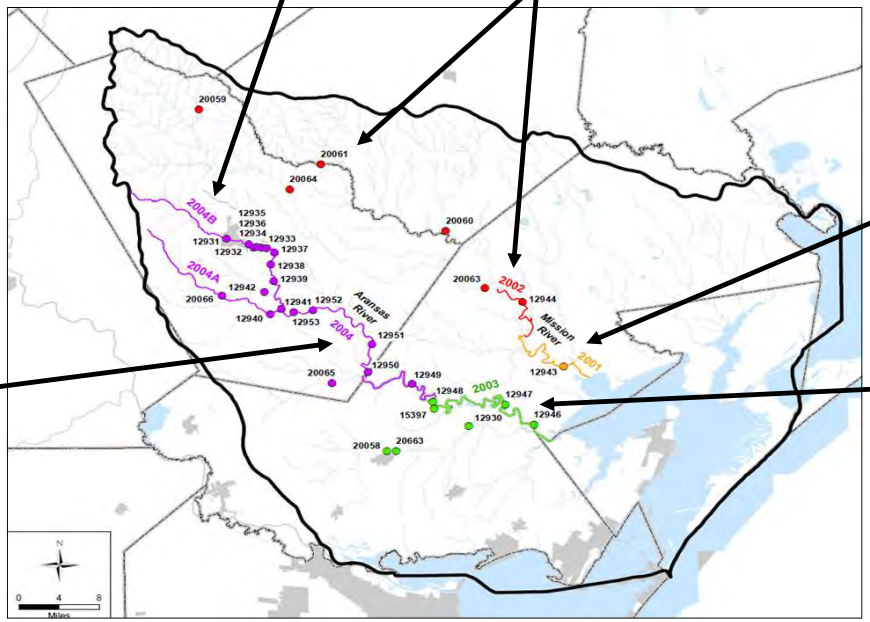
Basin 20: San Antonio-Nueces Coastal
PHOSPHORUS, DISSOLVED (MG/L AS P) vs Date

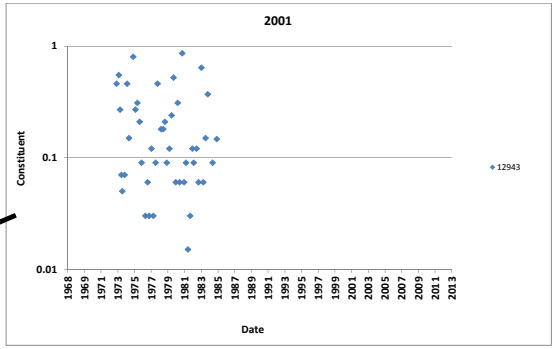


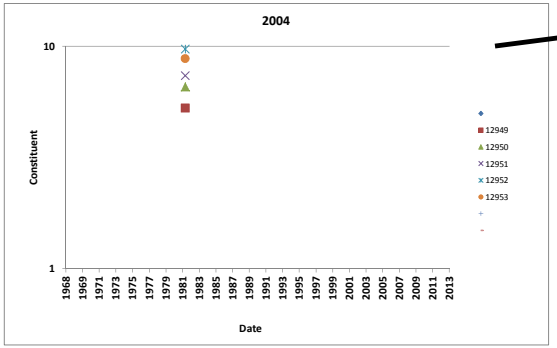


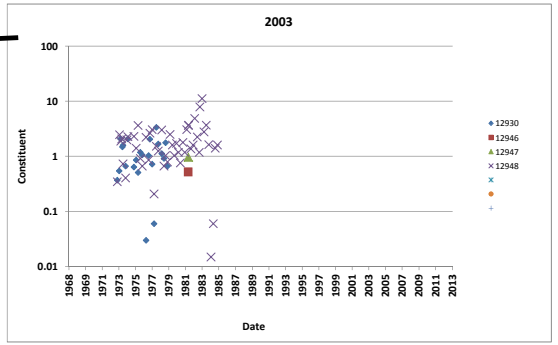
Basin 20: San Antonio-Nueces Coastal
PHOSPHATE, ORTHO (MG/L AS PO4) vs Date



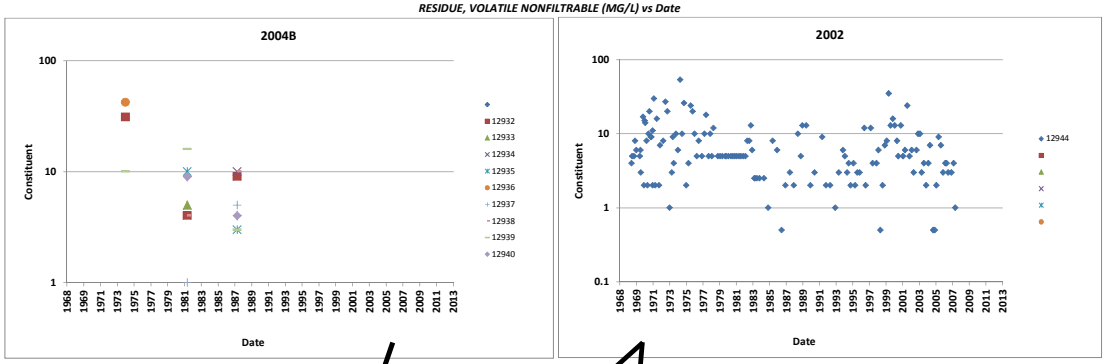


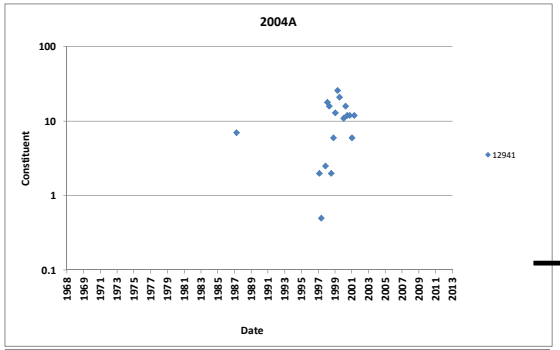


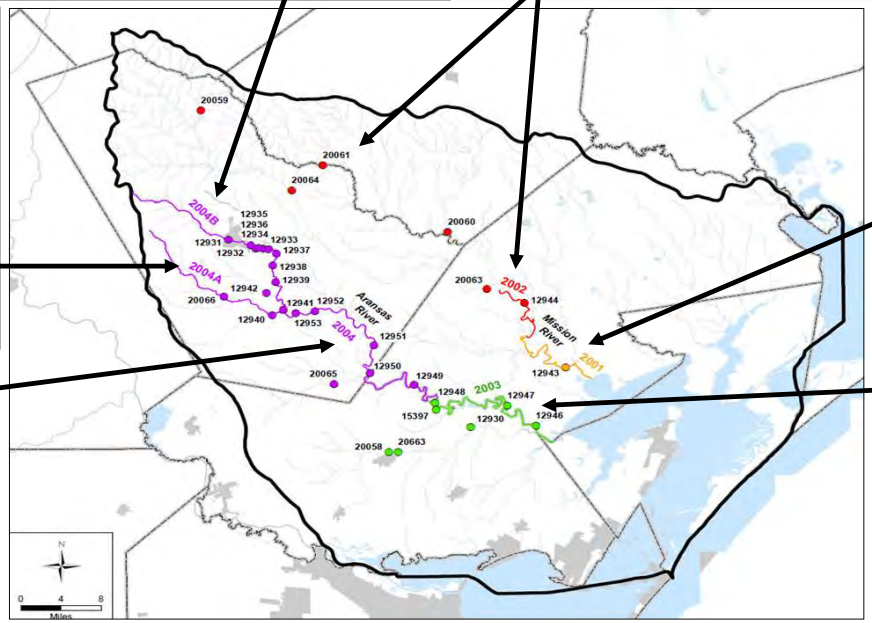


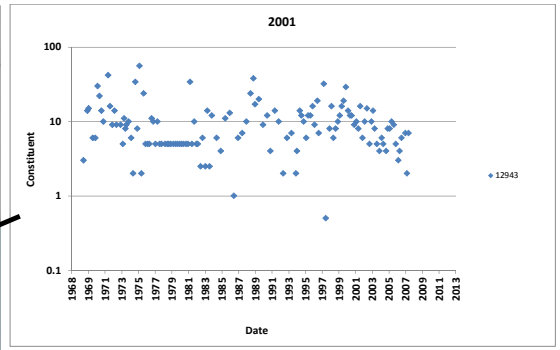


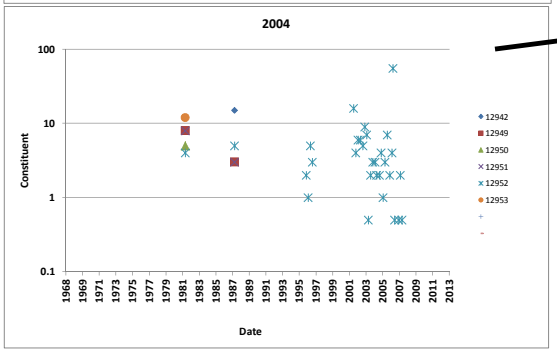
Basin 20: San Antonio-Nueces Coastal
RESIDUE, VOLATILE NONFILTRABLE (MG/L) vs Date

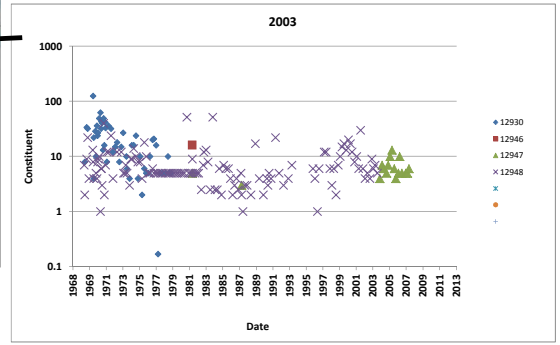




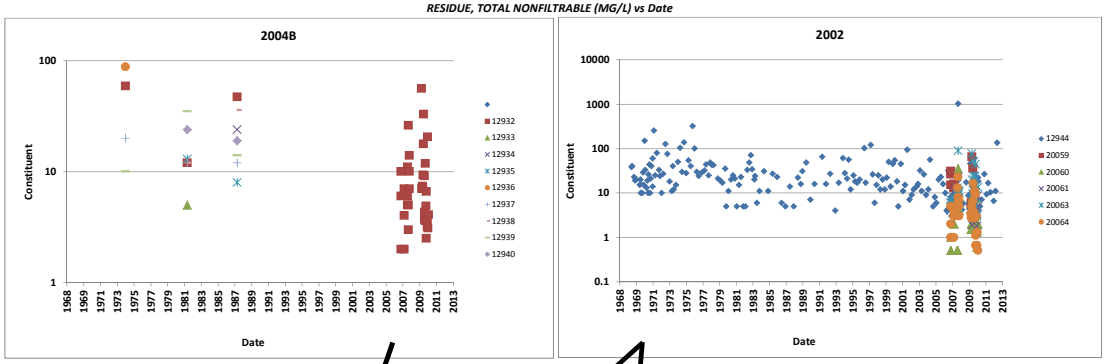


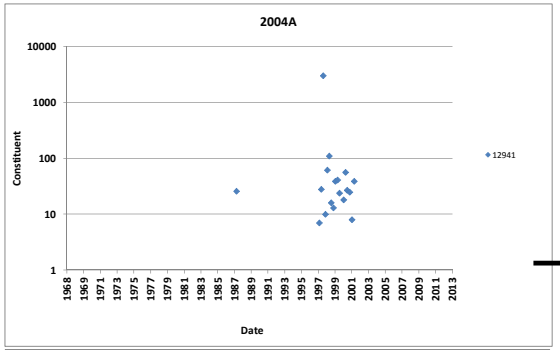


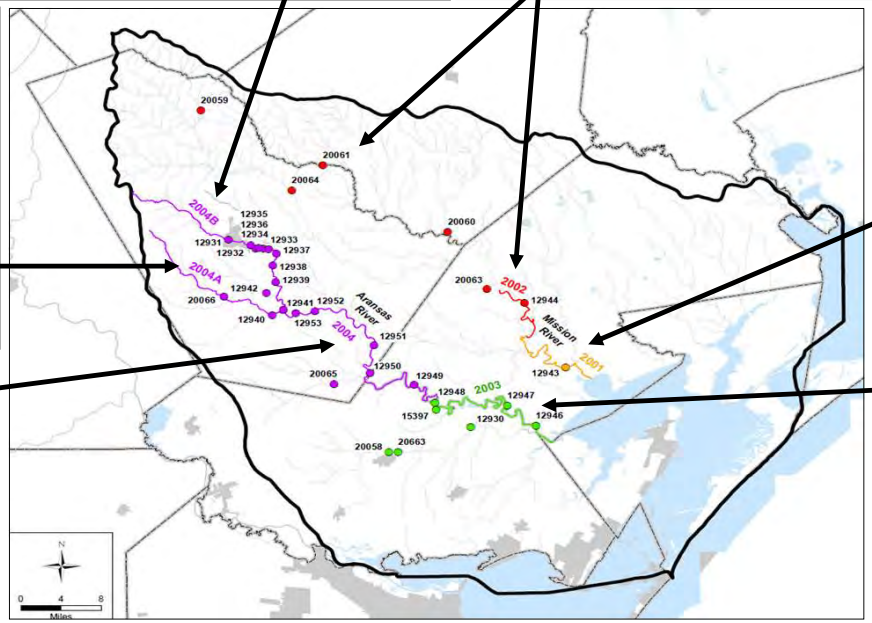


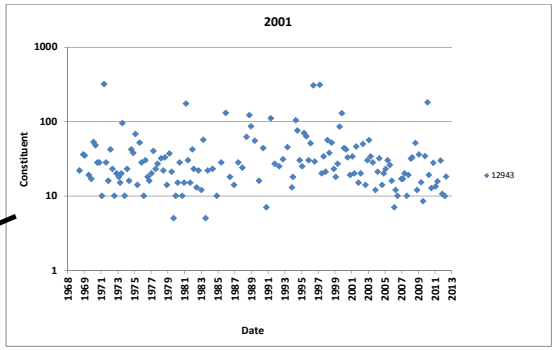


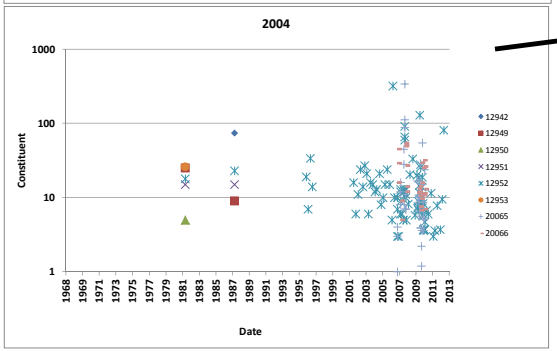
Basin 20: San Antonio-Nueces Coastal
RESIDUE, TOTAL NONFILTRABLE (MG/L) vs Date

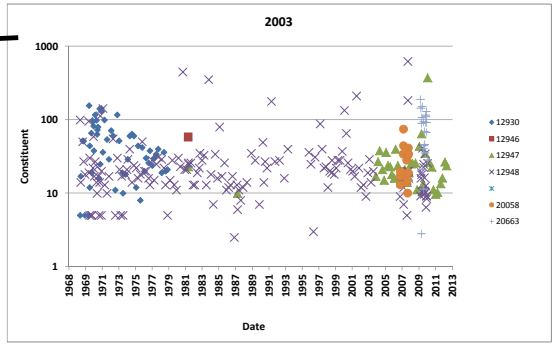




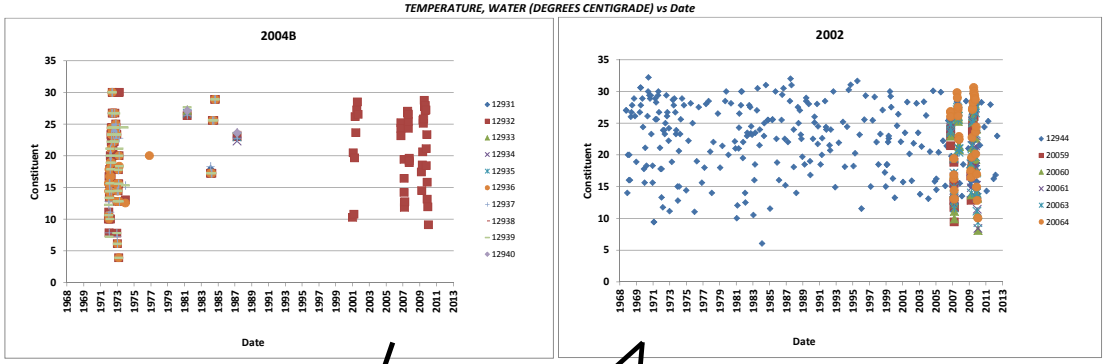


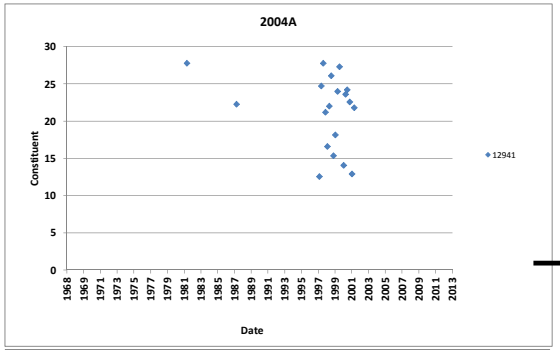


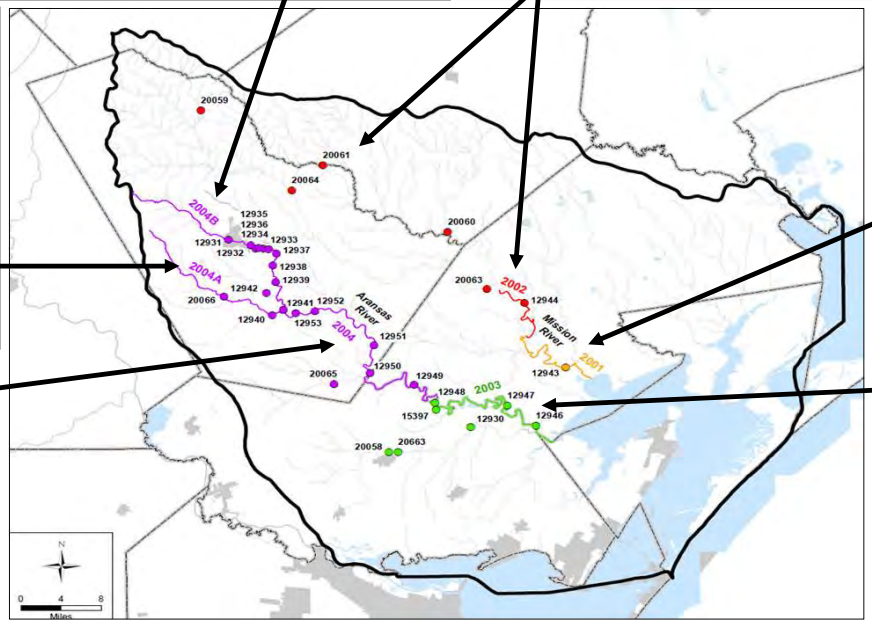


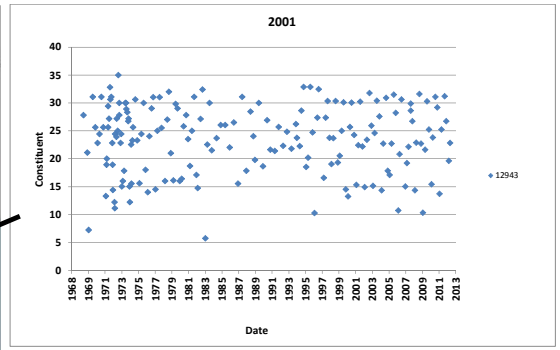


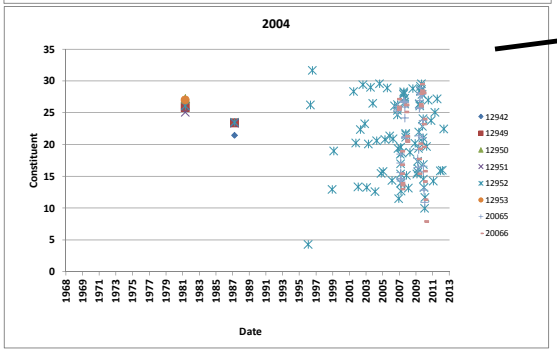
Basin 20: San Antonio-Nueces Coastal
TEMPERATURE, WATER (DEGREES CENTIGRADE) vs Date

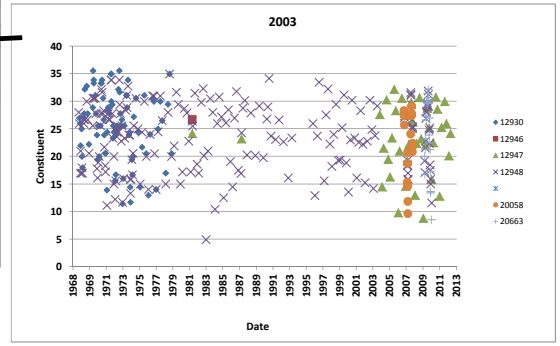




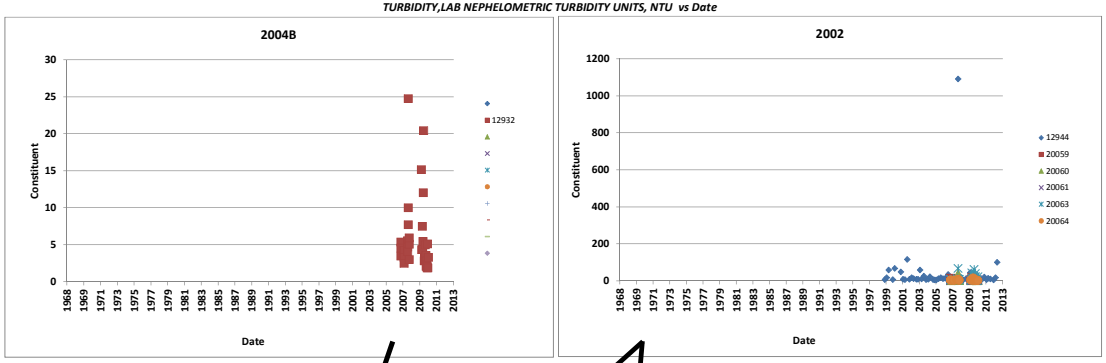


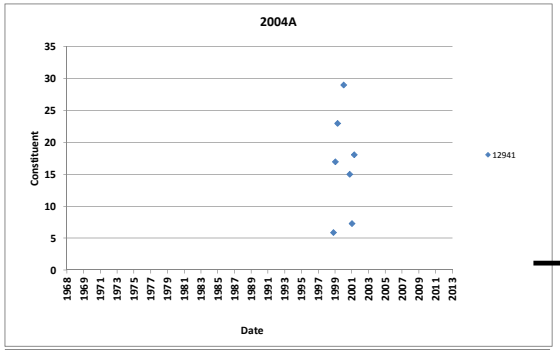


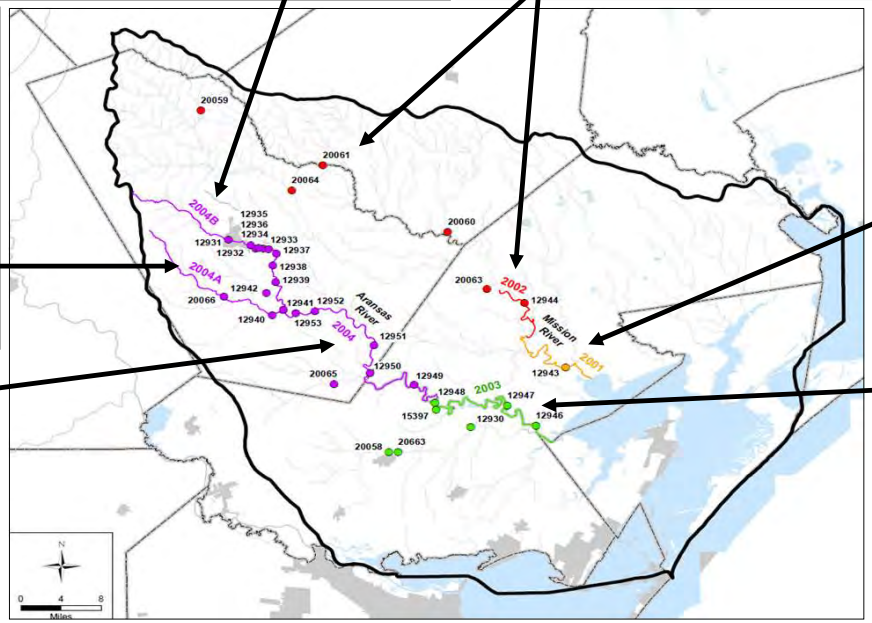


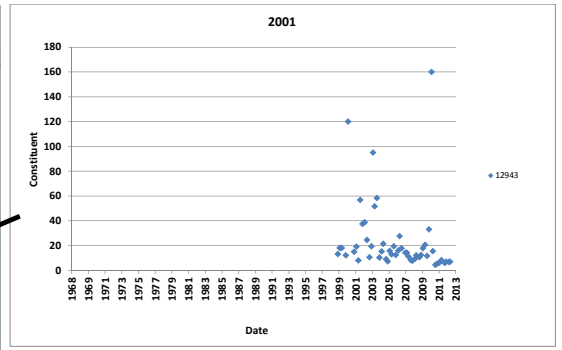


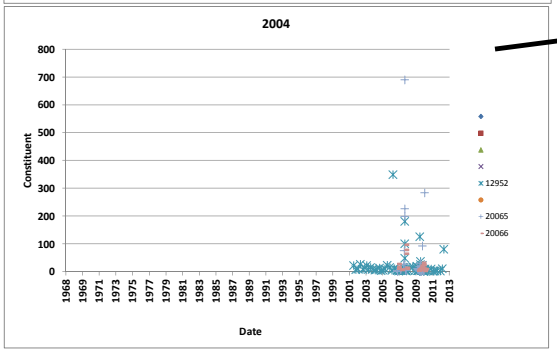
Basin 20: San Antonio-Nueces Coastal
TURBIDITY,LAB NEPHELOMETRIC TURBIDITY UNITS, NTU vs Date

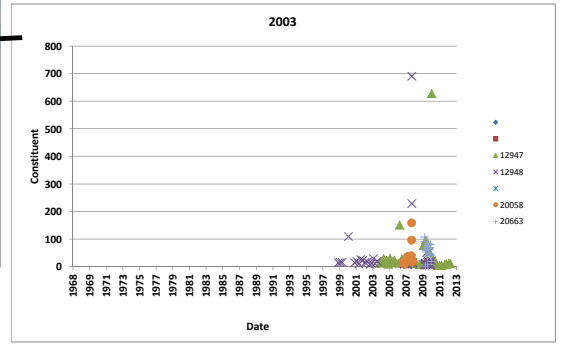




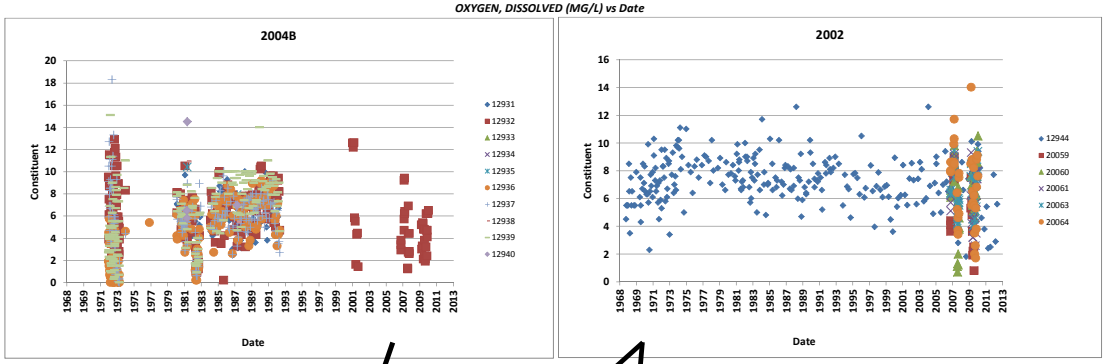


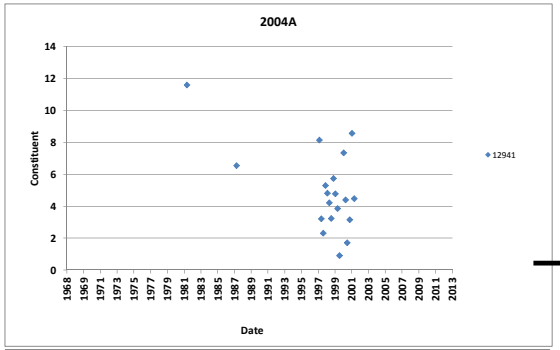


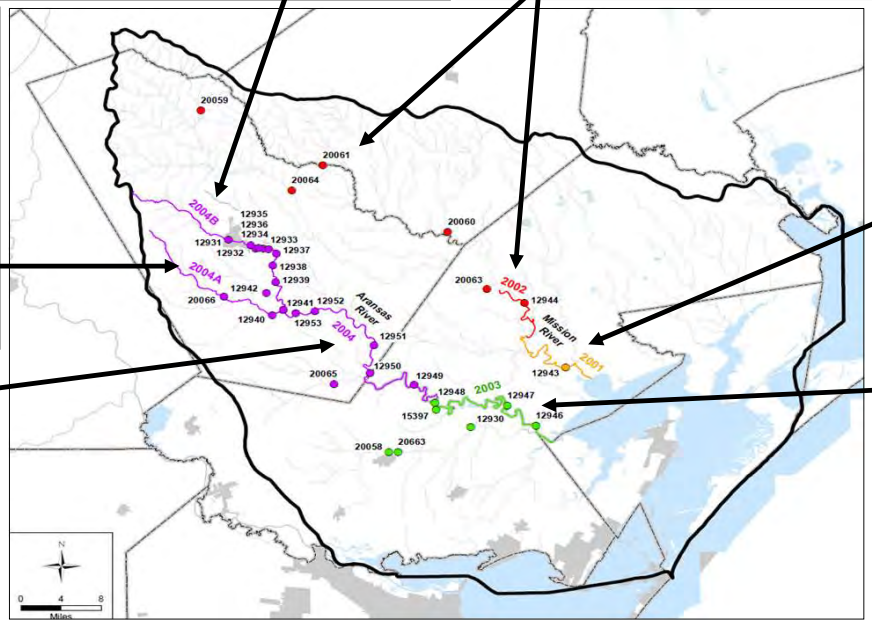


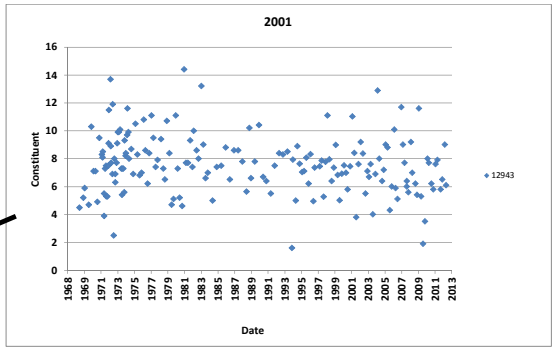


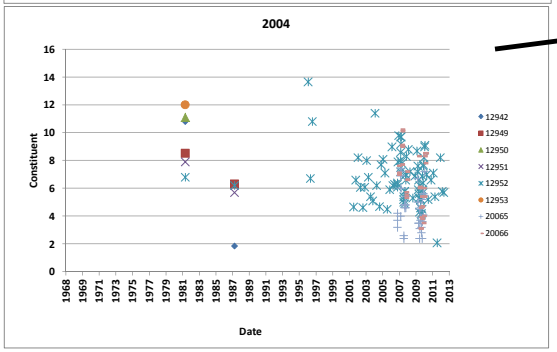
Basin 20: San Antonio-Nueces Coastal
OXYGEN, DISSOLVED (MG/L) vs Date

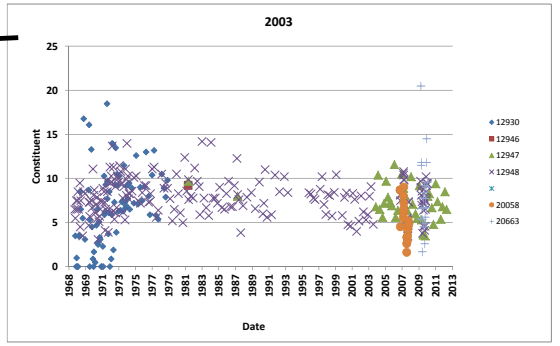




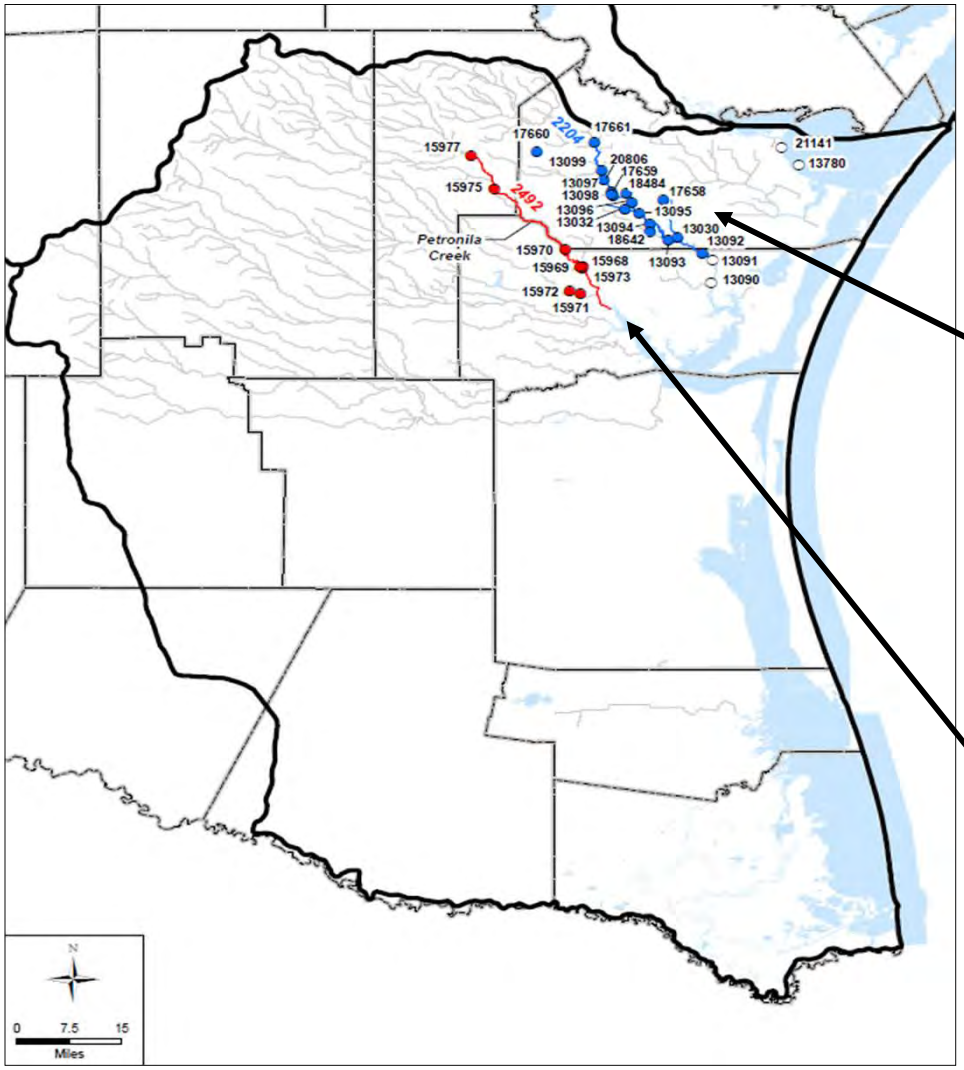


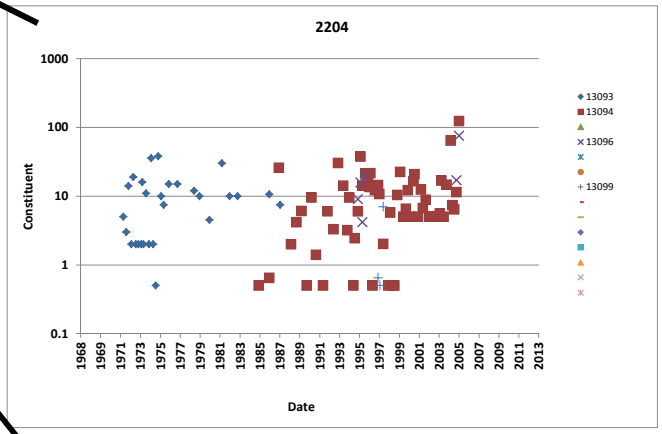


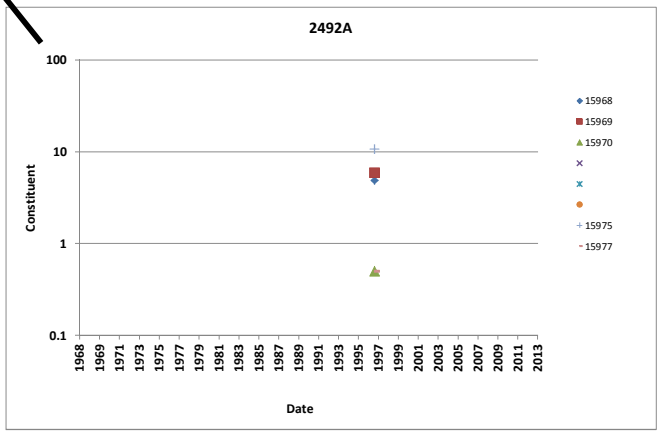




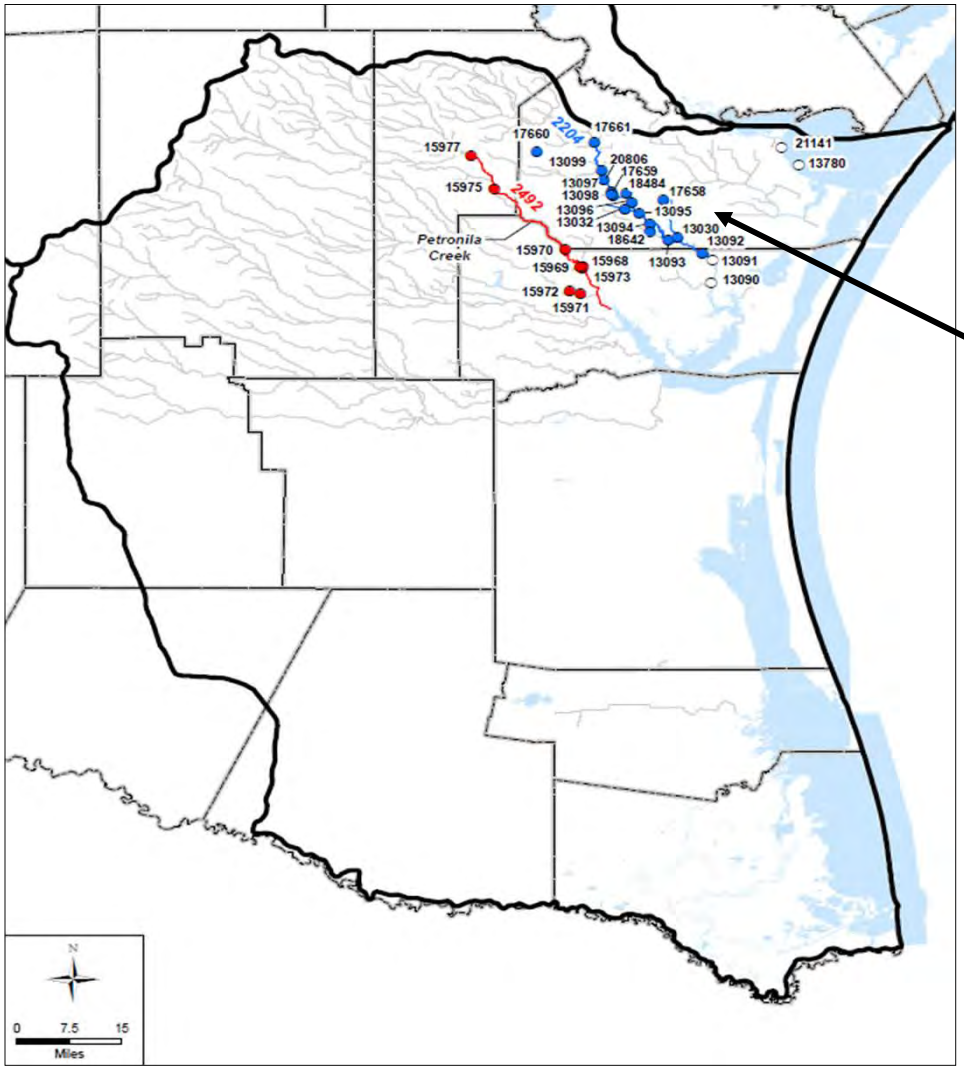
Basin 22: Nueces - Rio Grande Coastal
CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH vs Date

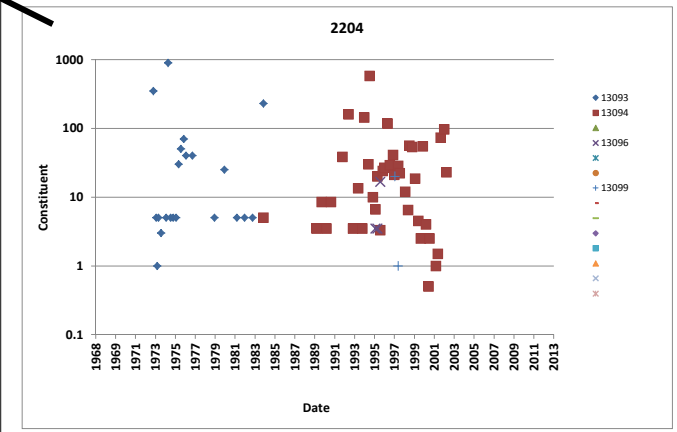




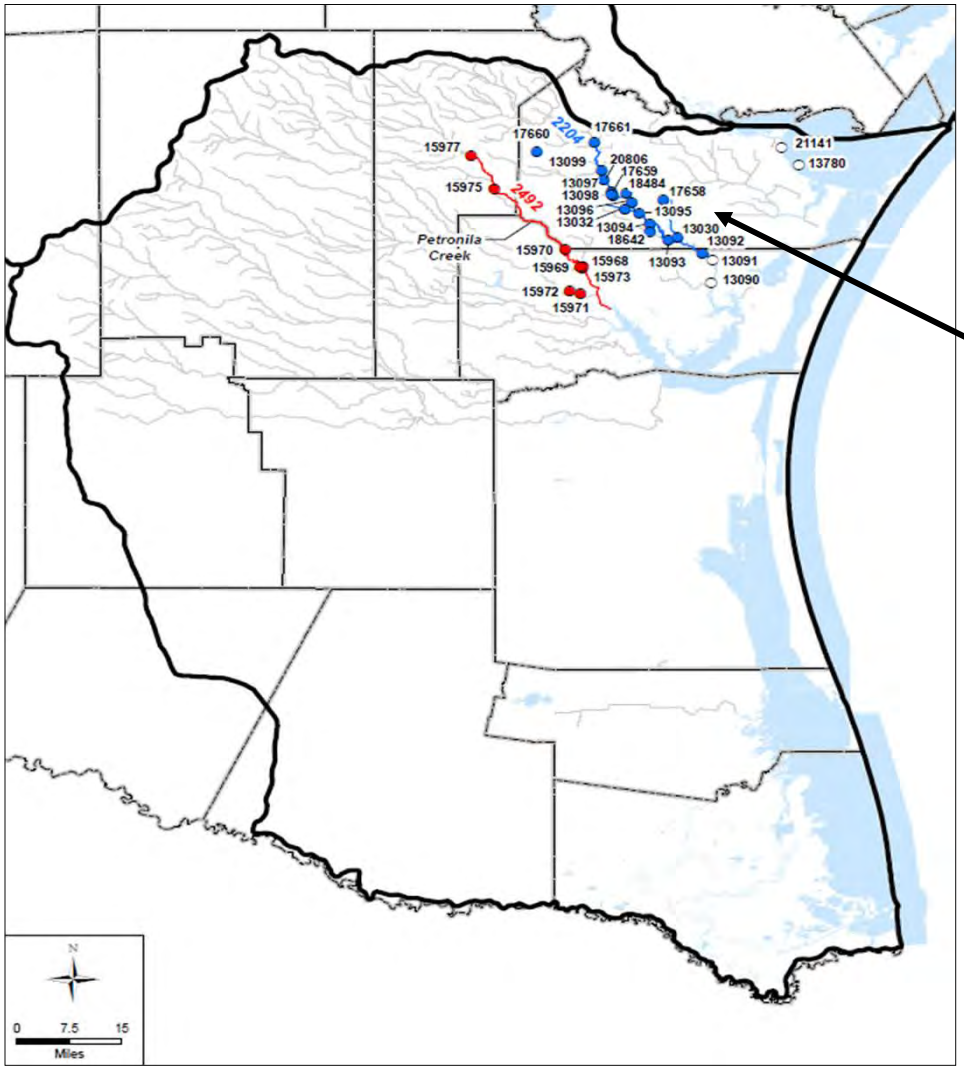


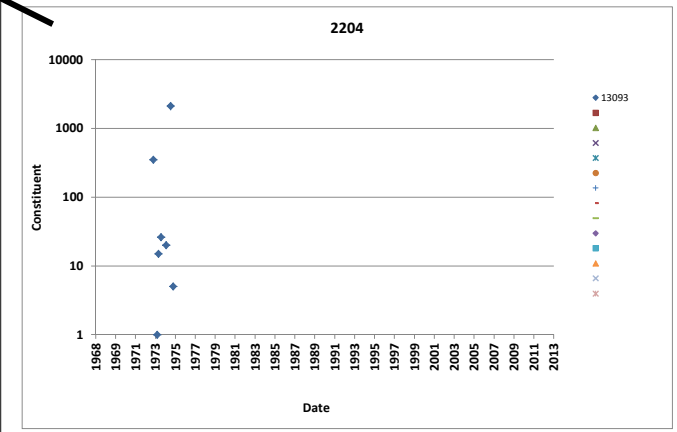
Basin 22: Nueces - Rio Grande Coastal
FECAL COLIFORM,MEMBR FILTER,M-FC BROTH, #/100ML vs Date



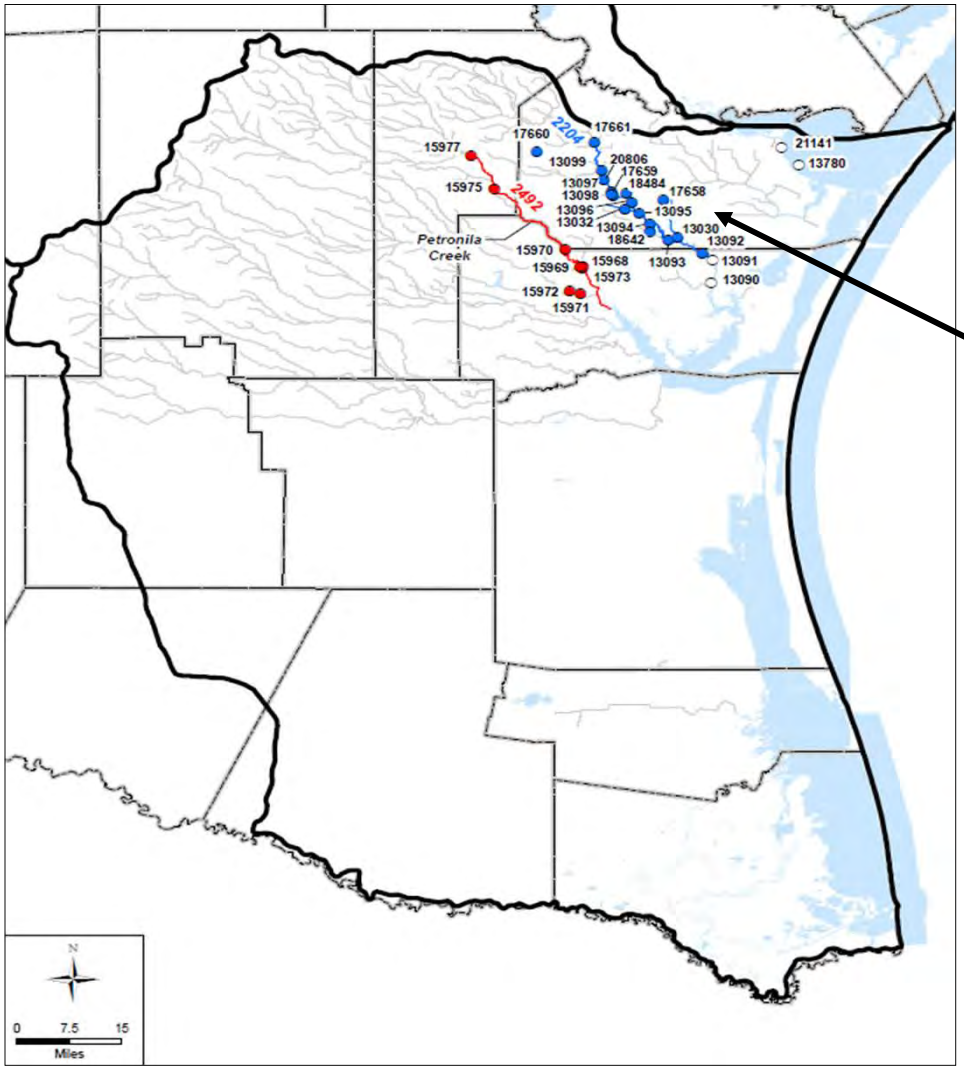


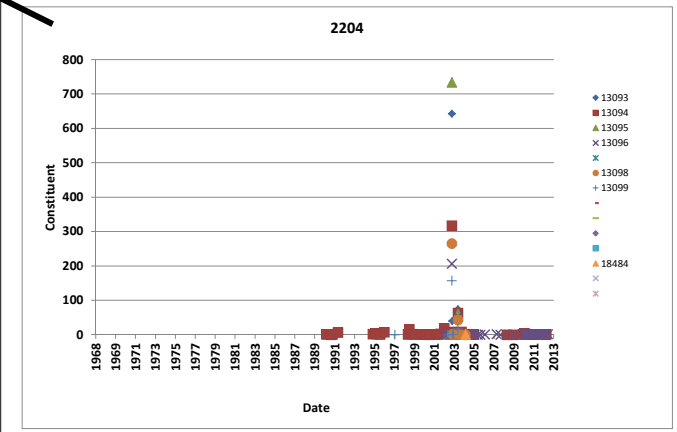
Basin 22: Nueces - Rio Grande Coastal
COLIFORM,TOT,MEMBRANE FILTER,IMMED.M-ENDO vs Date



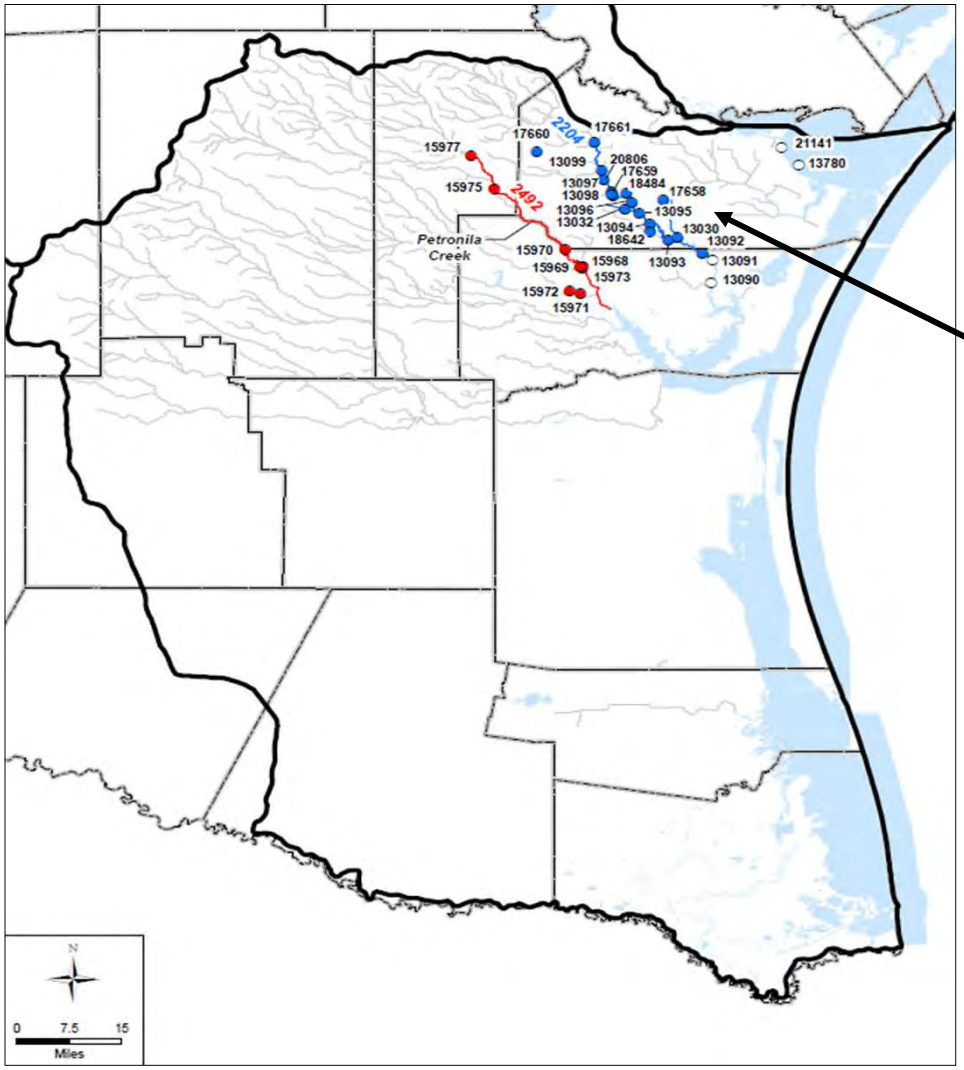


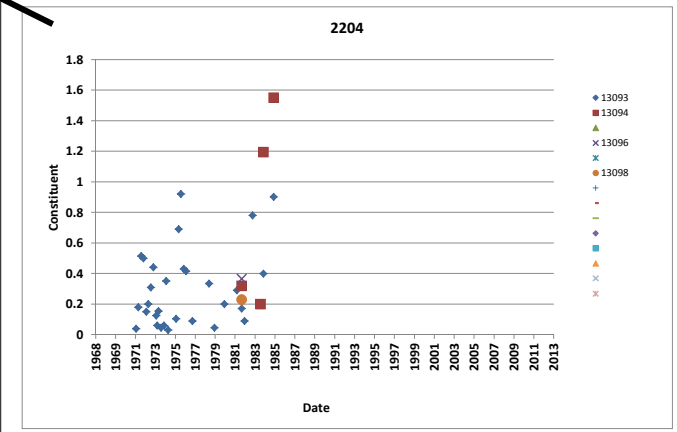
Basin 22: Nueces - Rio Grande Coastal
FLOW STREAM, INSTANTANEOUS (CUBIC FEET PER SEC) vs Date



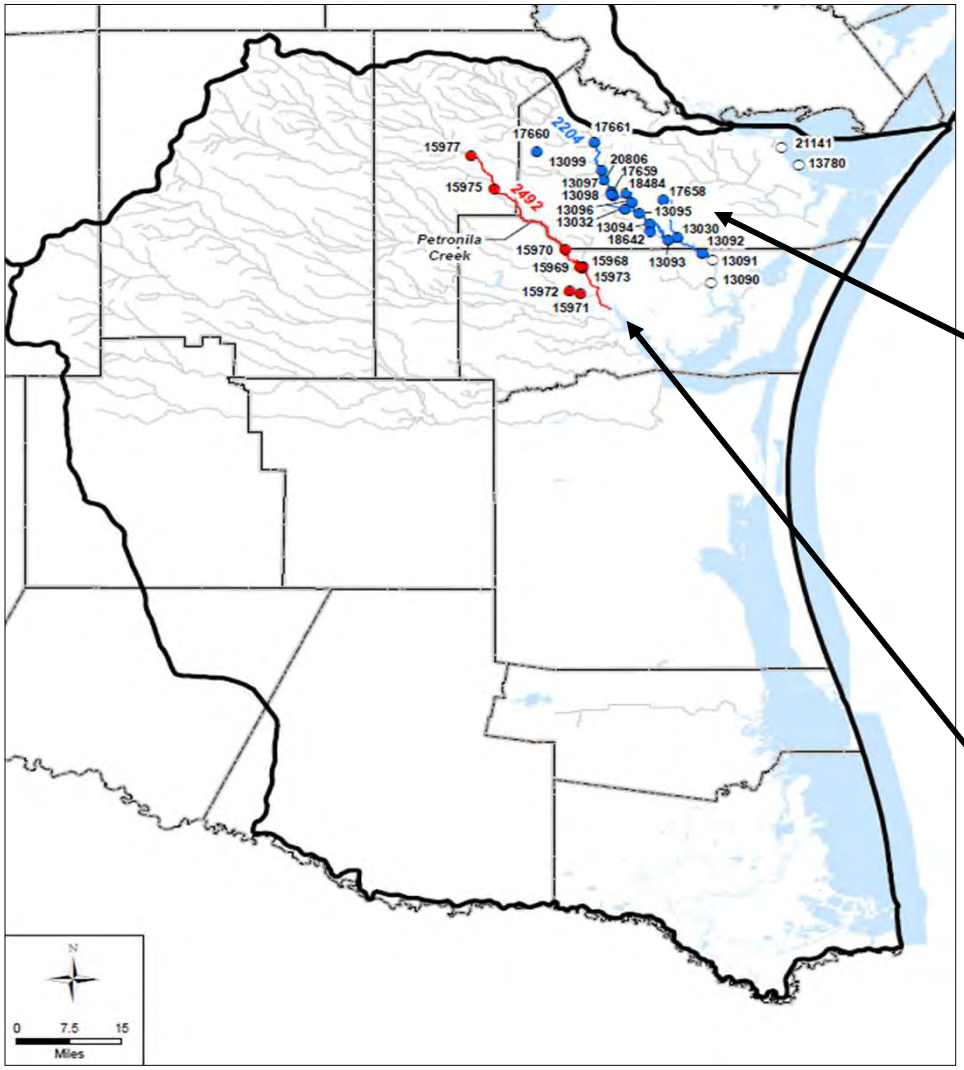


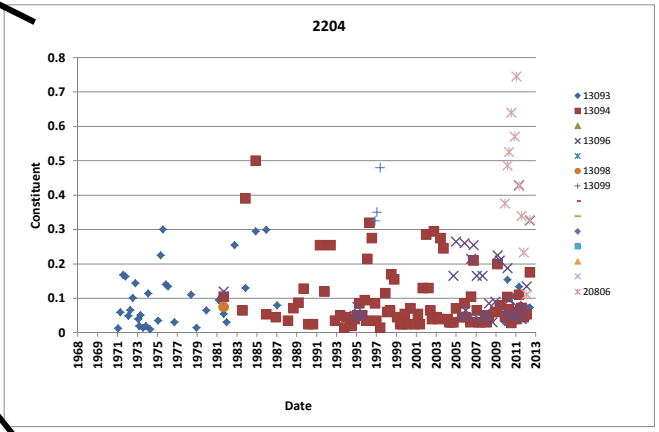
Basin 22: Nueces - Rio Grande Coastal
PHOSPHATE, TOTAL (MG/L AS PO4) vs Date

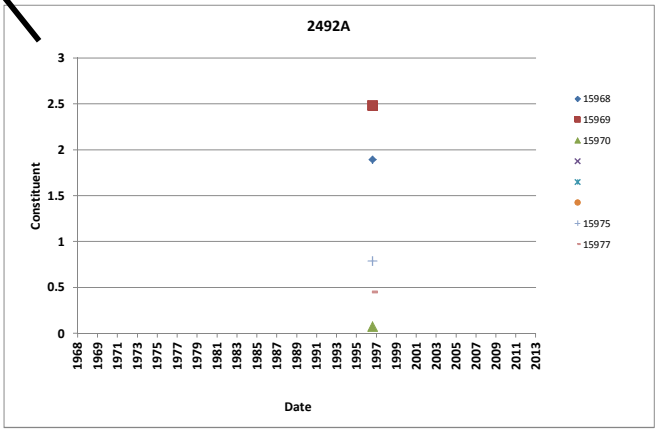




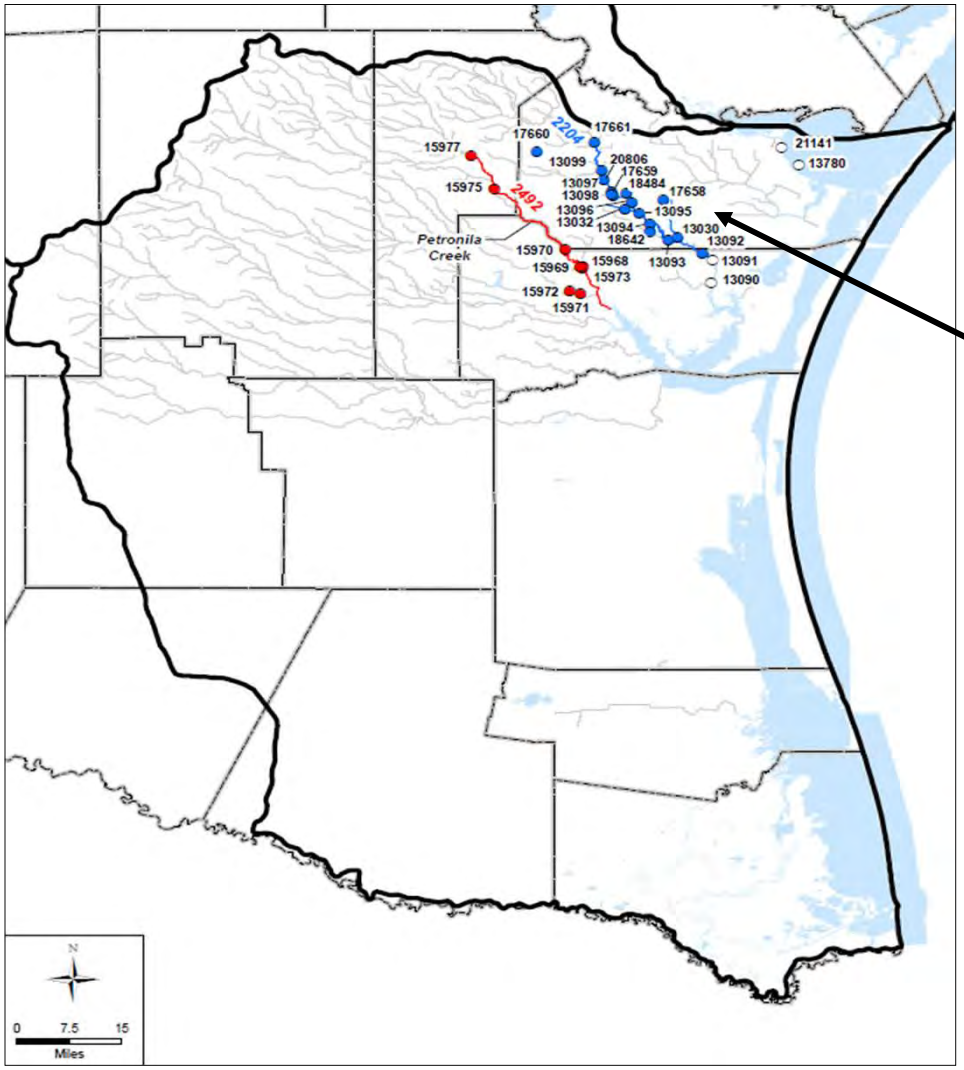
Basin 22: Nueces - Rio Grande Coastal
PHOSPHORUS, TOTAL, WET METHOD (MG/L AS P) vs Date

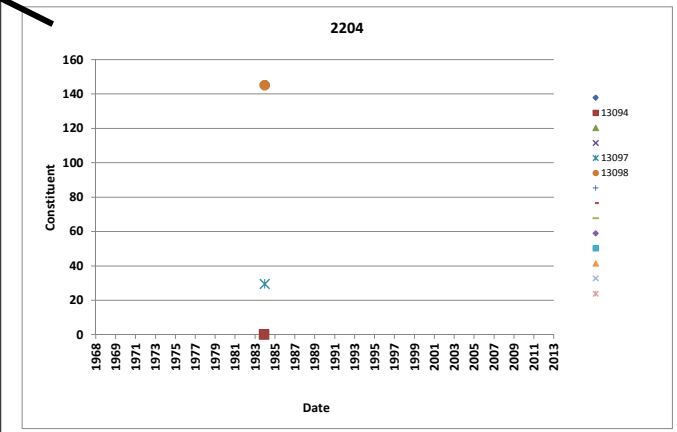




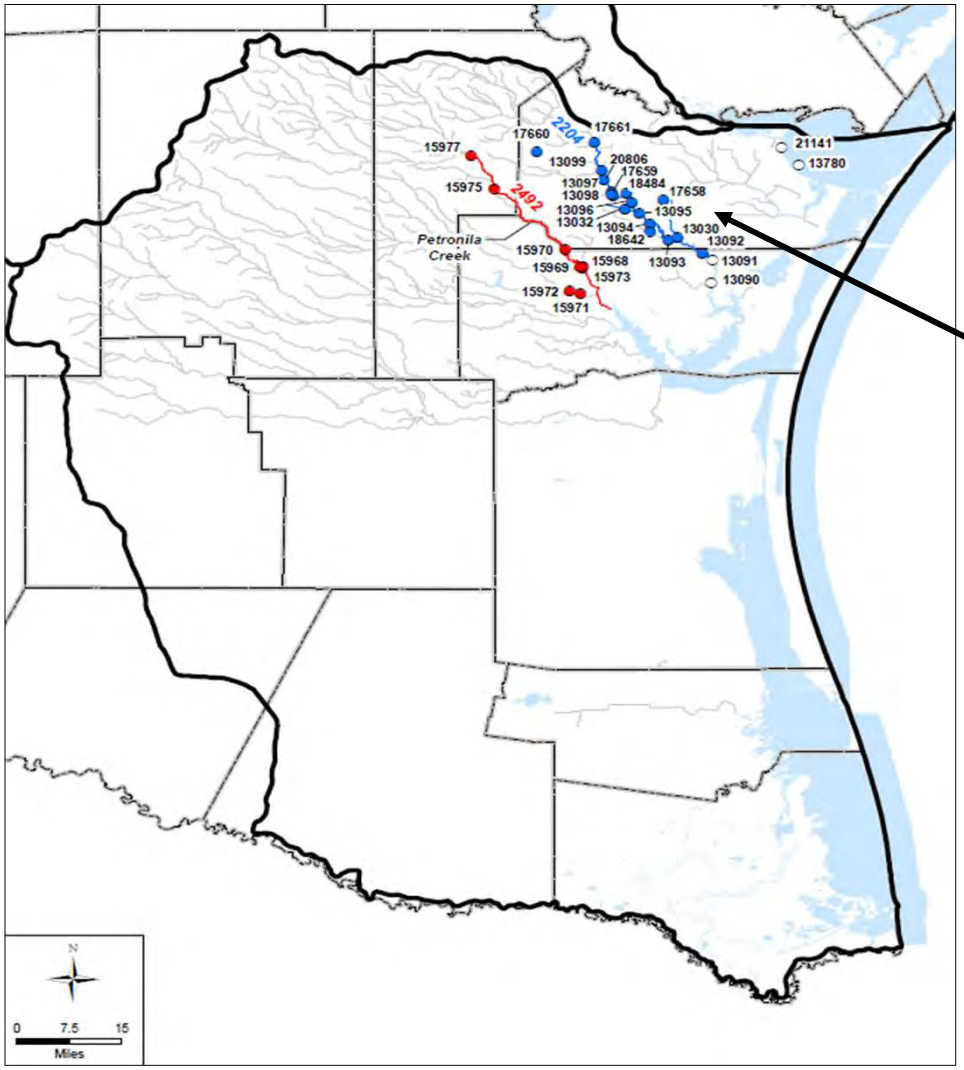


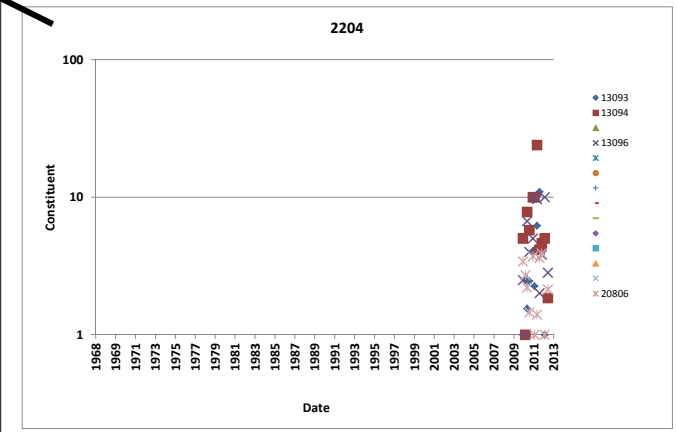
Basin 22: Nueces - Rio Grande Coastal
PHOSPHORUS,TOTAL, BOTTOM DEPOSIT (MG/KG DRY WT) vs Date



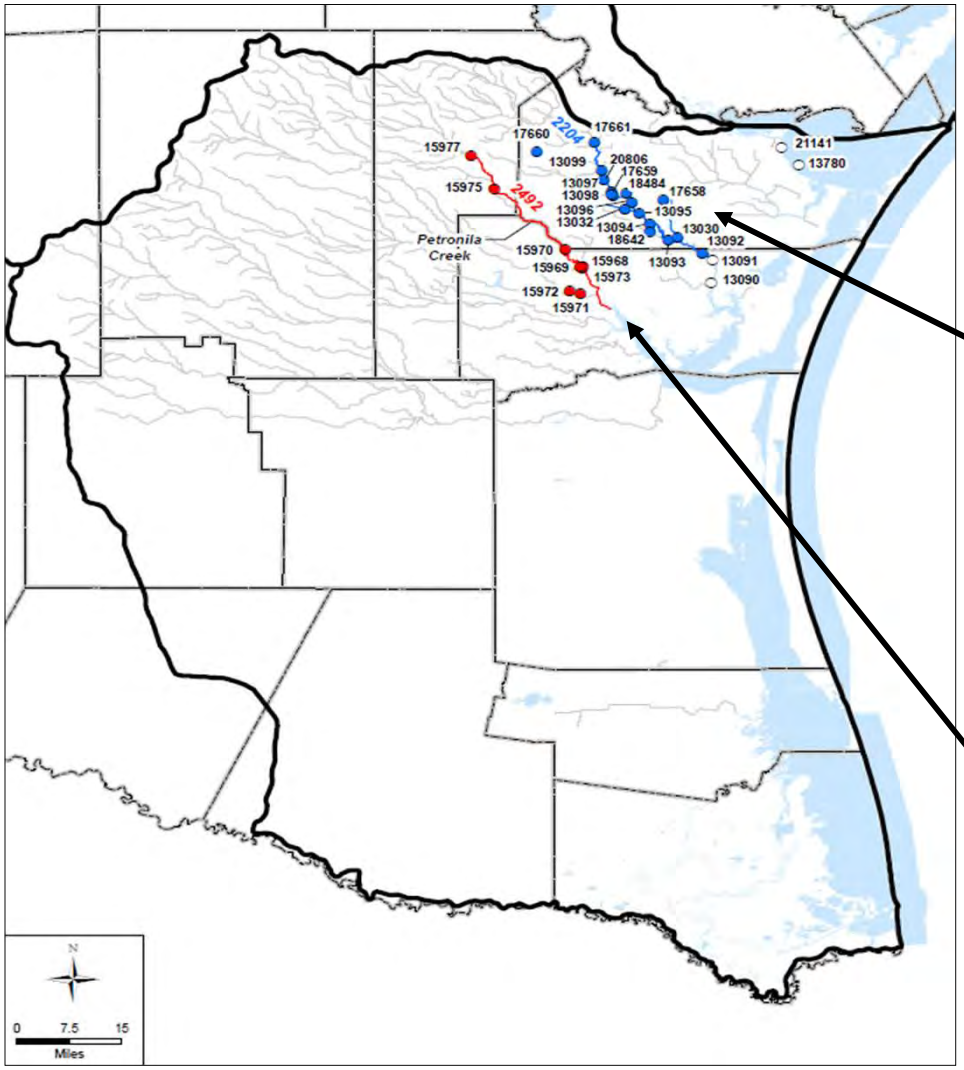


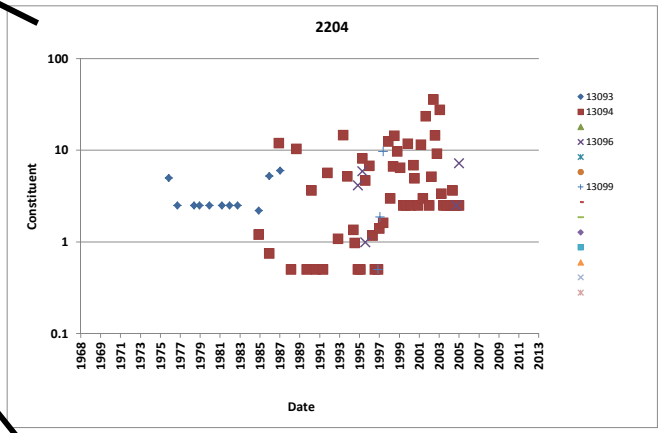
Basin 22: Nueces - Rio Grande Coastal
PHEOPHYTIN-A UG/L FLUOROMETRIC METHOD vs Date

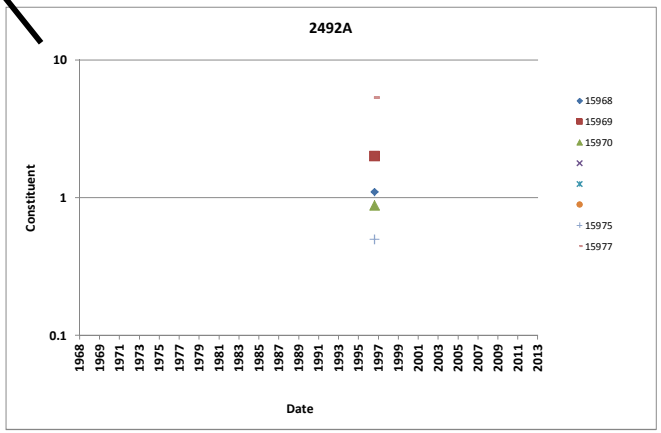




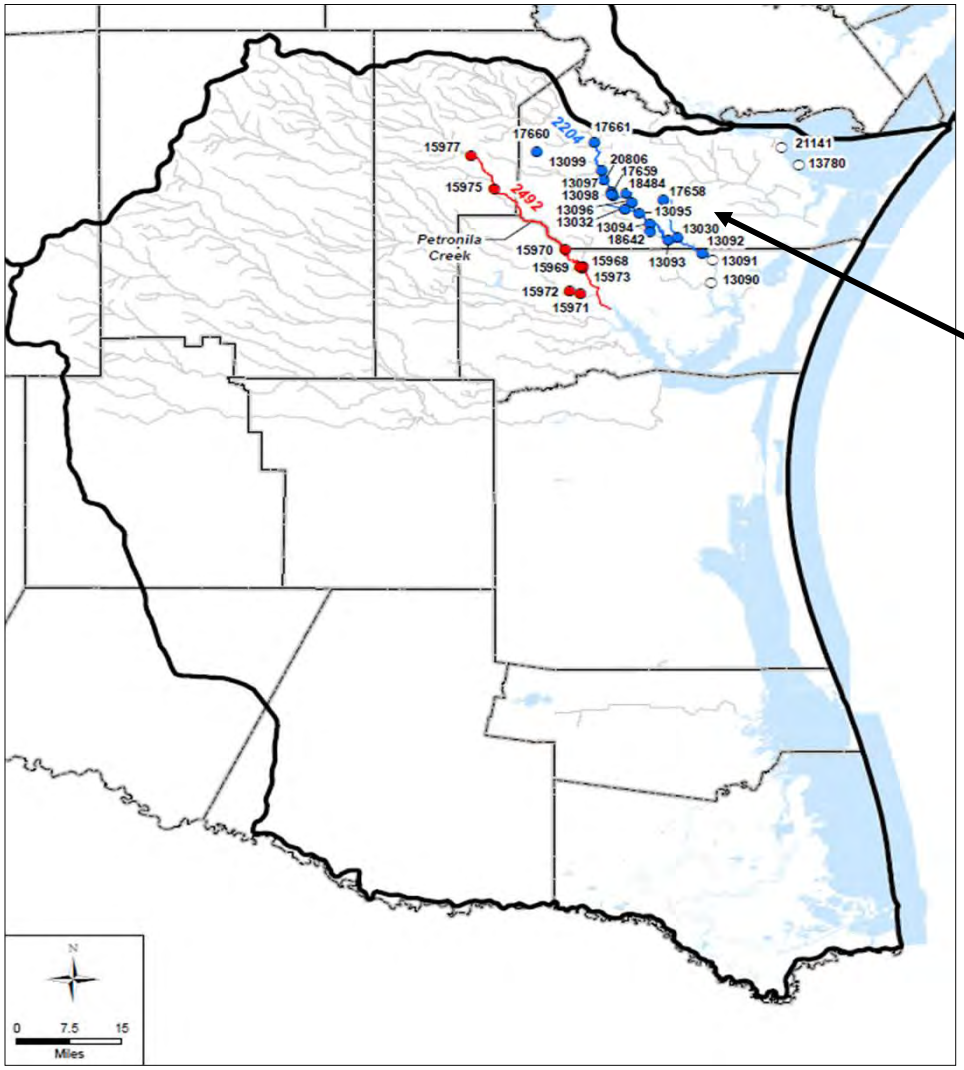
Basin 22: Nueces - Rio Grande Coastal
PHEOPHYTIN-A UG/L SPECTROPHOTOMETRIC ACID. METH. vs Date

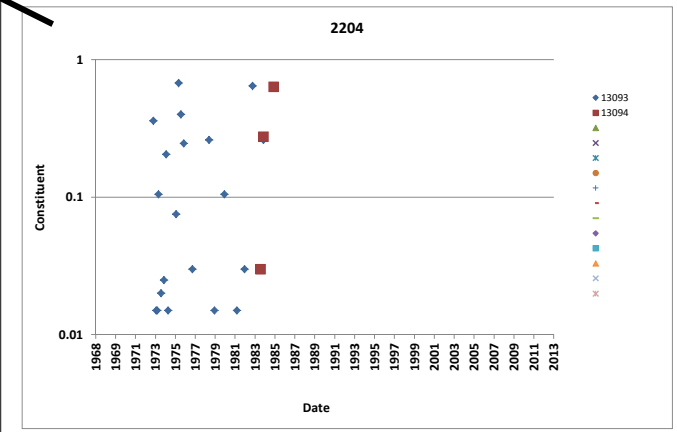




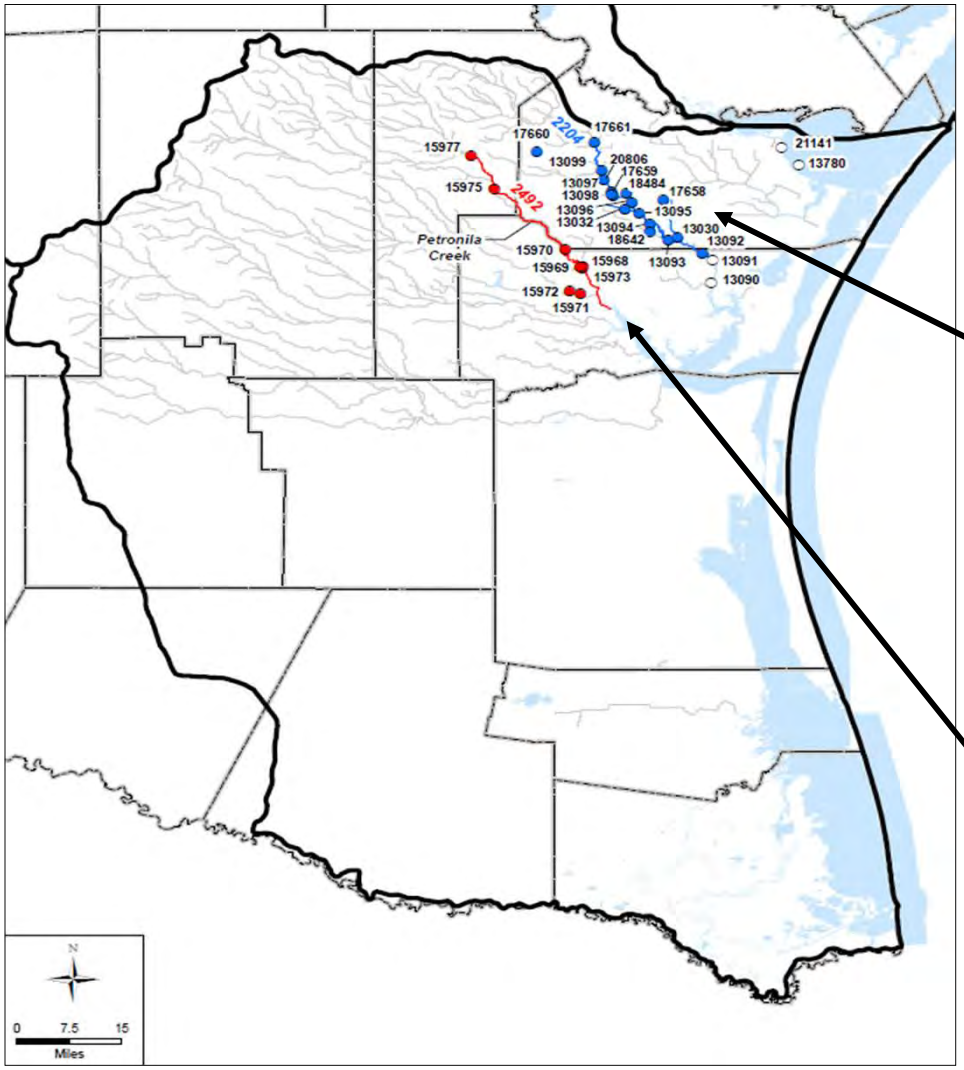


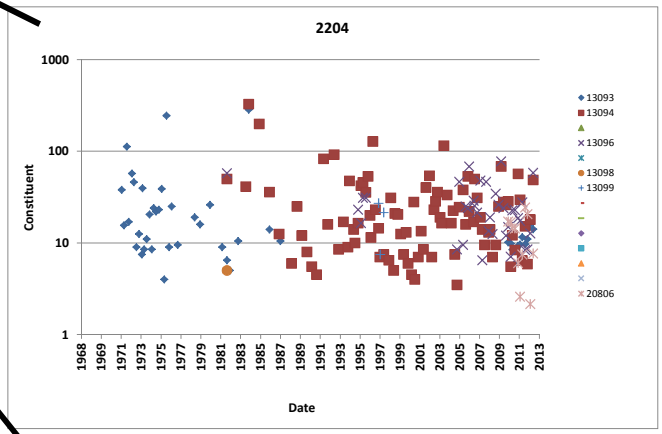
Basin 22: Nueces - Rio Grande Coastal
PHOSPHATE, ORTHO (MG/L AS PO4) vs Date

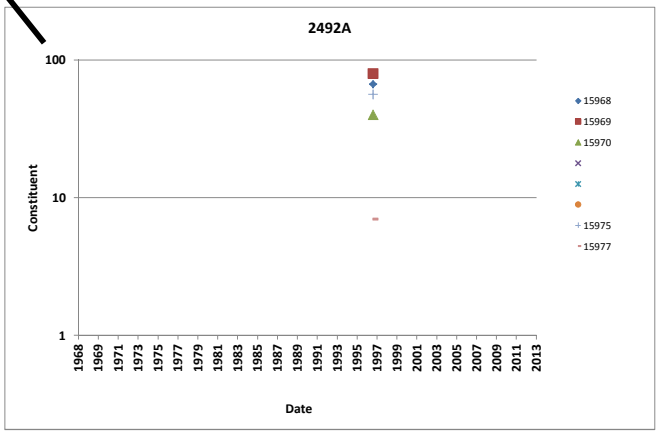




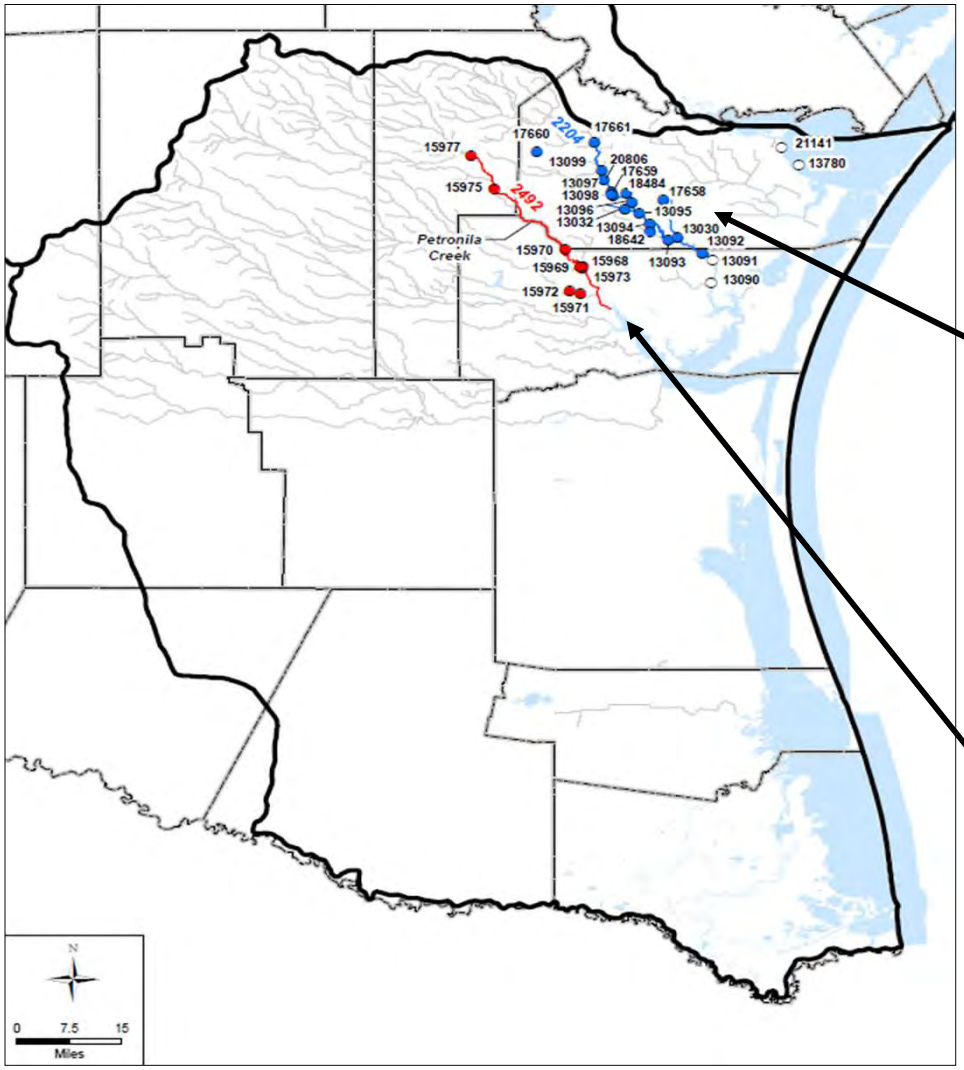
Basin 22: Nueces - Rio Grande Coastal
RESIDUE, TOTAL NONFILTRABLE (MG/L) vs Date

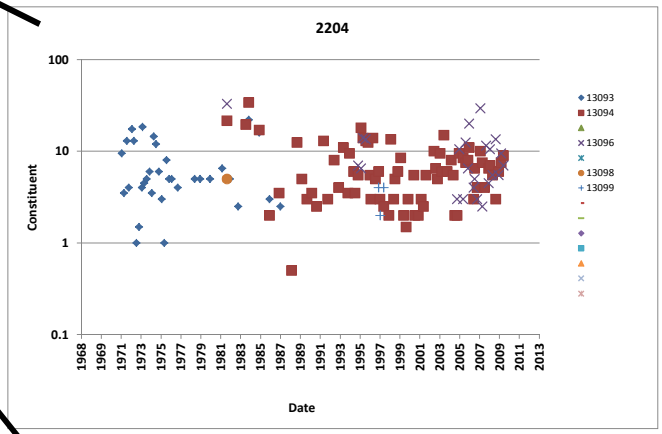


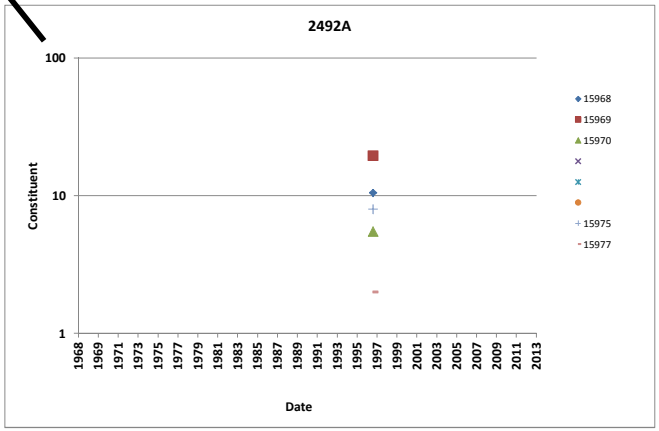




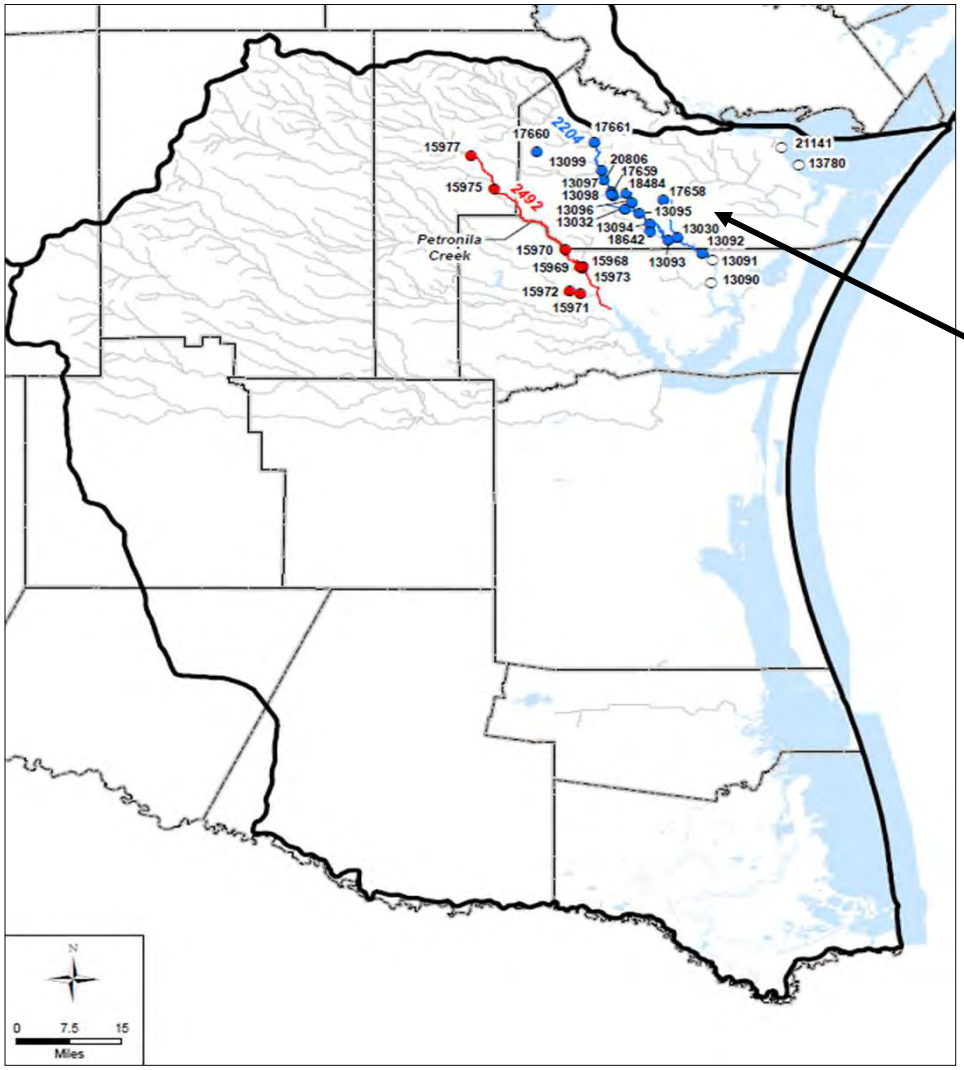
Basin 22: Nueces - Rio Grande Coastal
RESIDUE, VOLATILE NONFILTRABLE (MG/L) vs Date

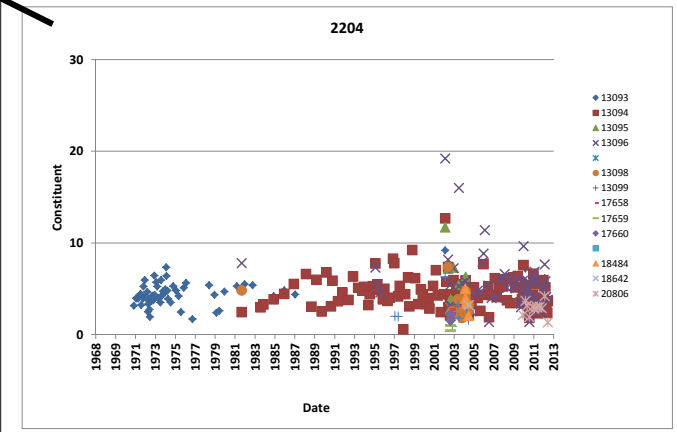




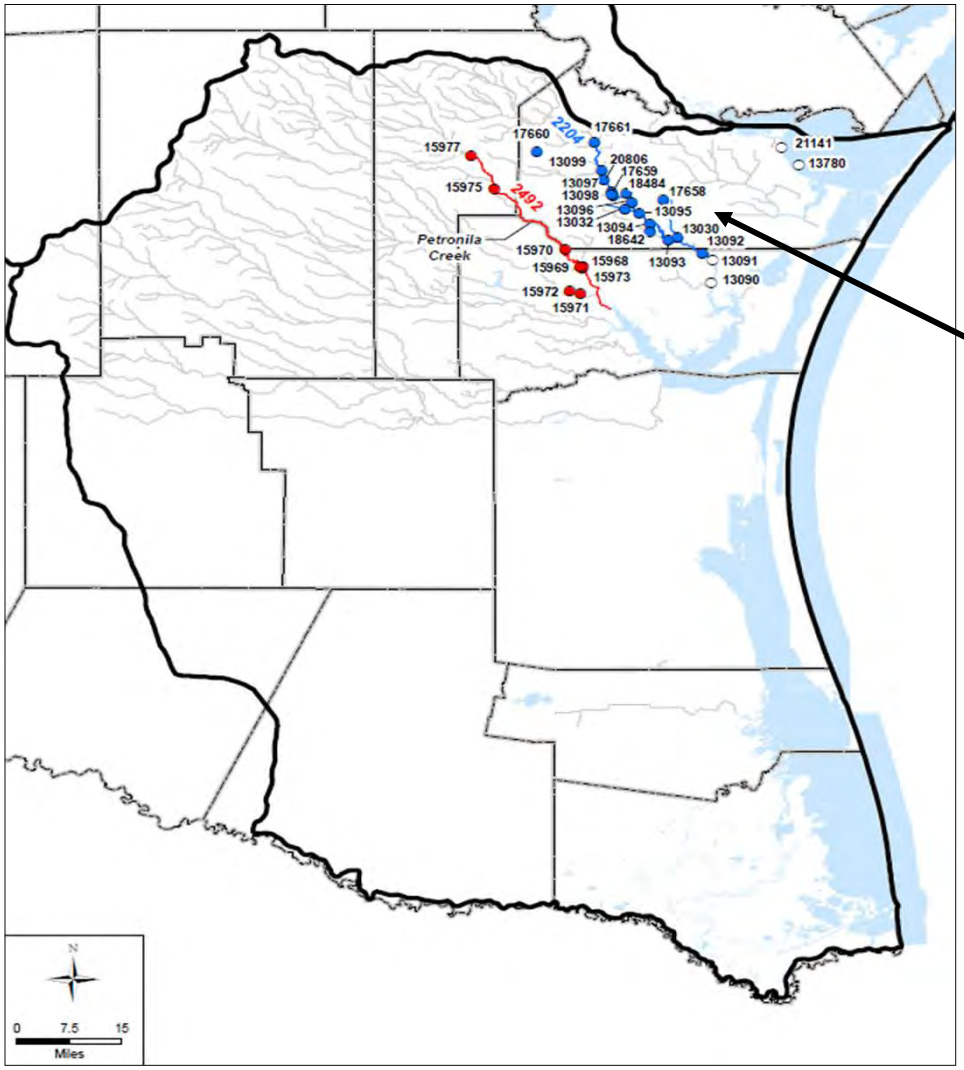


Basin 22: Nueces - Rio Grande Coastal
OXYGEN, DISSOLVED (MG/L) vs Date

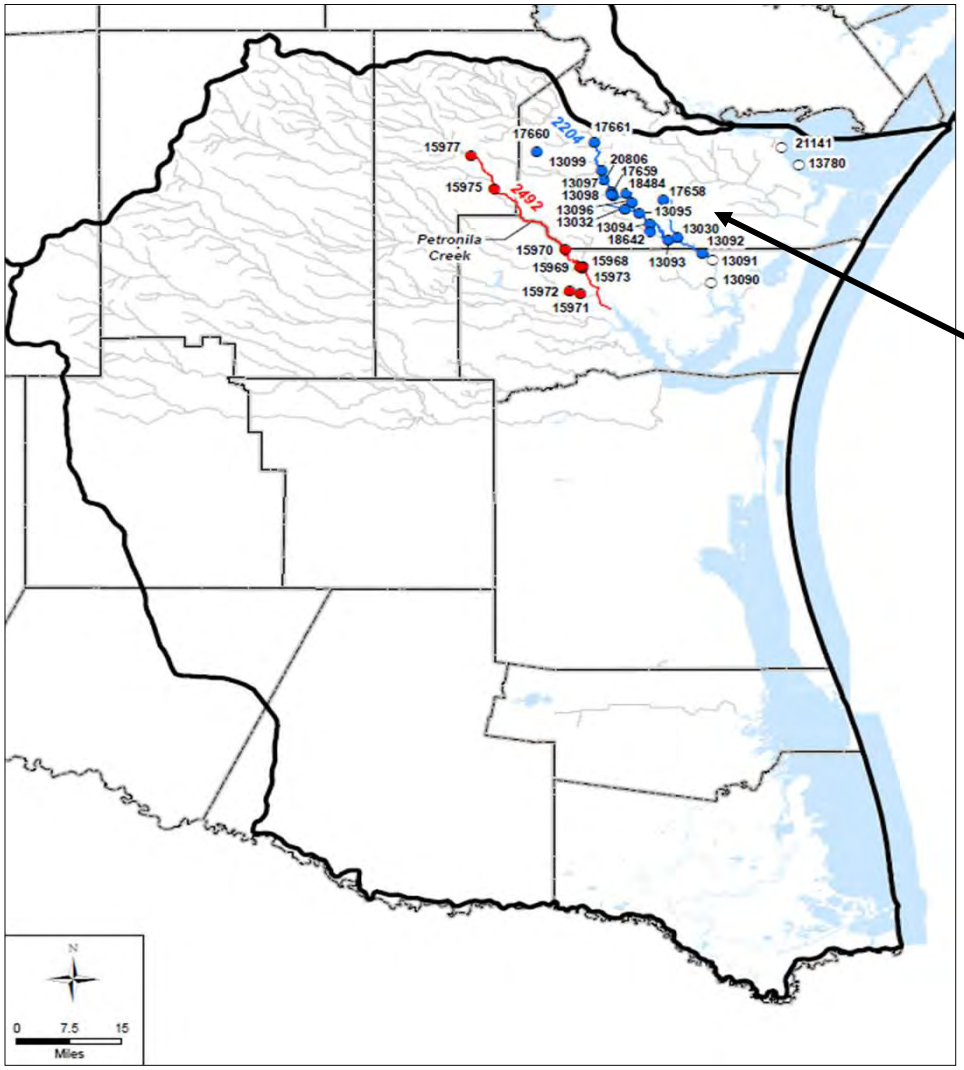


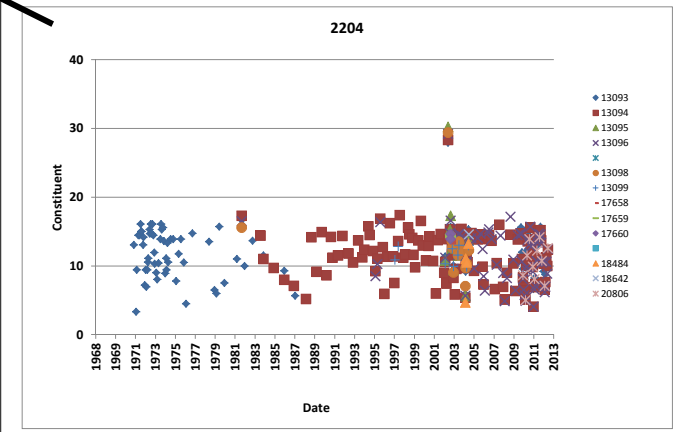


Basin 22: Nueces - Rio Grande Coastal
TURBIDITY,LAB NEPHELOMETRIC TURBIDITY UNITS, NTU vs Date



Basin 22: Nueces - Rio Grande Coastal
TEMPERATURE, WATER (DEGREES CENTIGRADE) vs Date



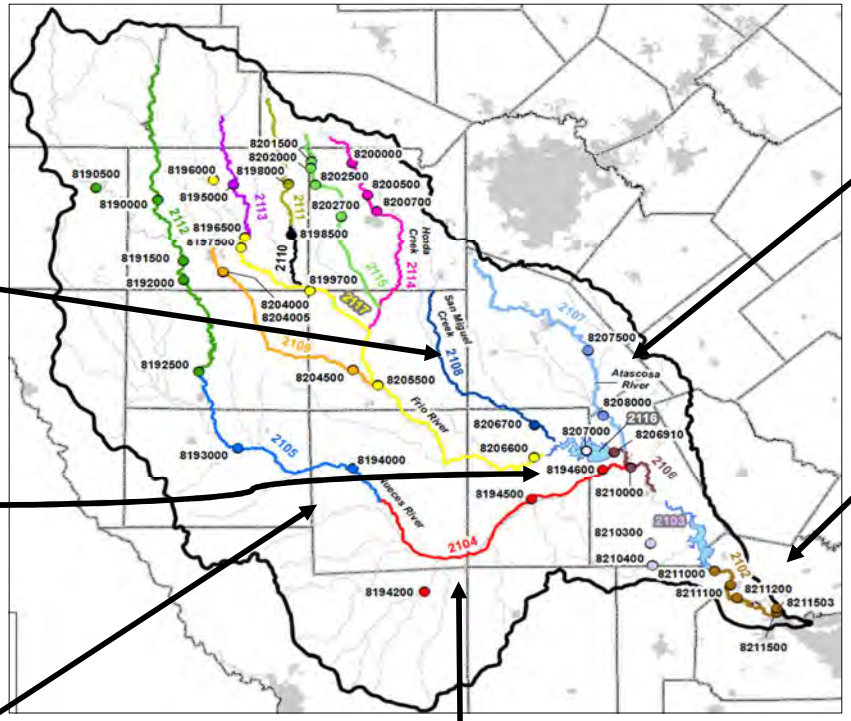


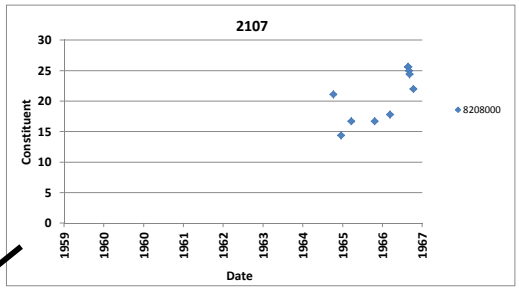
Appendix C. Graphical summary of USGS nutrient data available before 1968

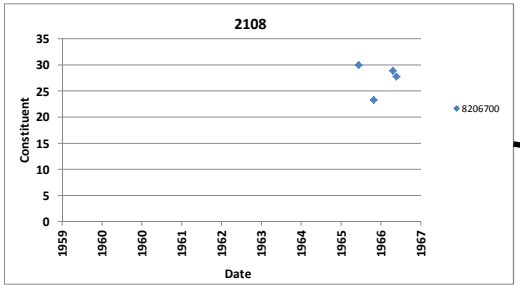
Count of Pre-1968 USGS Data

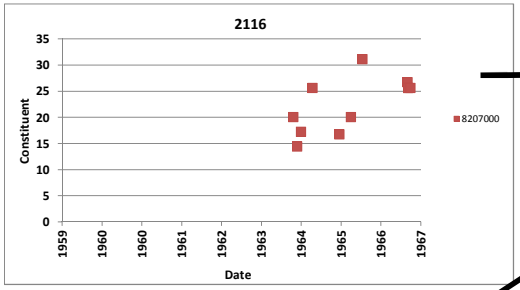
		Values		
site no	Site Name	Count of Temperature, water, degrees Celsius	Count of Nitrate, water, filtered, milligrams per liter as nitrogen	Count of Phosphate, water, unfiltered, milligrams per liter
8189300	Medio Ck nr Beeville, TX	6	12	
8189500	Mission Rv at Refugio, TX		14	
8189700	Aransas Rv nr Skidmore, TX	21	38	
8189800	Chiltipin Ck at Sinton, TX		2	
8190000	Nueces Rv at Laguna, TX	8	10	
8192000	Nueces Rv bl Uvalde, TX	8	23	
8193000	Nueces Rv nr Asherton, TX	4	9	
8194000	Nueces Rv at Cotulla, TX	6	17	
8194200	San Casimiro Ck nr Freer, TX	5	11	
8194500	Nueces Rv nr Tilden, TX	5	5	
8194600	Nueces Rv at Simmons, TX	5	12	
8195000	Frio Rv at Concan, TX	9	14	
8196000	Dry Frio Rv nr Reagan Wells, TX	9	8	
8198000	Sabinal Rv nr Sabinal, TX	8	11	
8200000	Hondo Ck nr Tarpley, TX	5	6	
8205500	Frio Rv nr Derby, TX	8	15	
8206700	San Miguel Ck nr Tilden, TX	4	7	
8207000	Frio Rv at Calliham, TX	11	34	
8208000	Atascosa Rv at Whitsett, TX	10	21	
8210000	Nueces Rv nr Three Rivers, TX		1	
8211000	Nueces Rv nr Mathis, TX		105	24
8211100	Nueces Rv bl Mathis, TX		1	
8211200	Nueces Rv at Bluntzer, TX	1	1	
8211800	San Diego Ck at Alice, TX	4	13	
8211900	San Fernando Ck at Alice, TX		1	
8212000	San Fernando Ck nr Alice, TX		9	
8212400	Los Olmos Ck nr Falfurrias, TX	1	2	
Grand Total		**138**	**402**	**24**

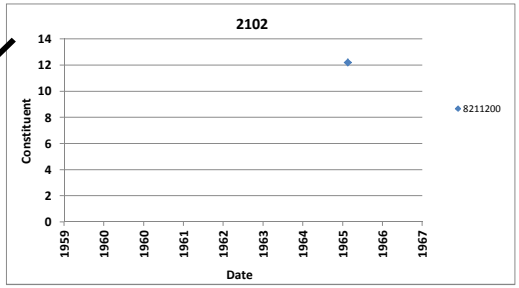
Basin 21: Nueces River Basin
Pre-1968 USGS Data
Max of Temperature, water, degrees Celsius

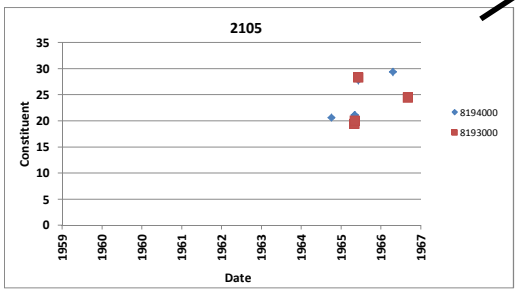


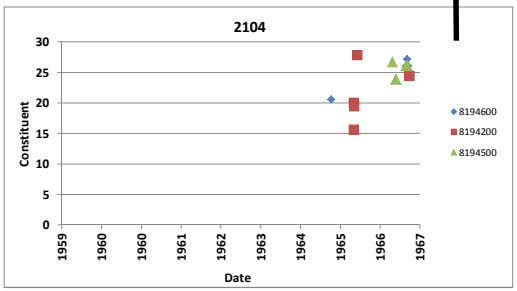




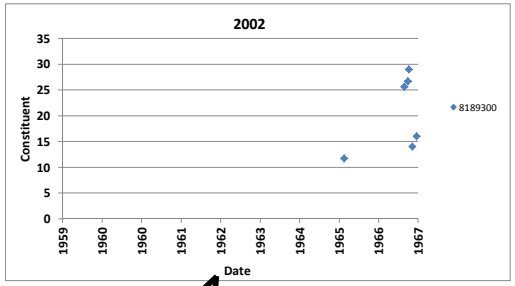


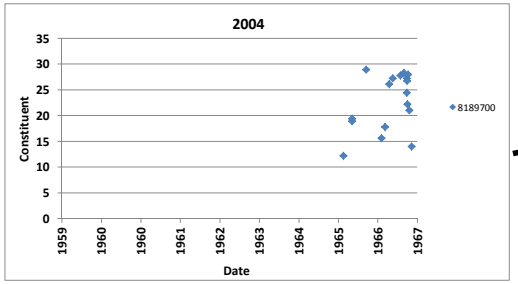


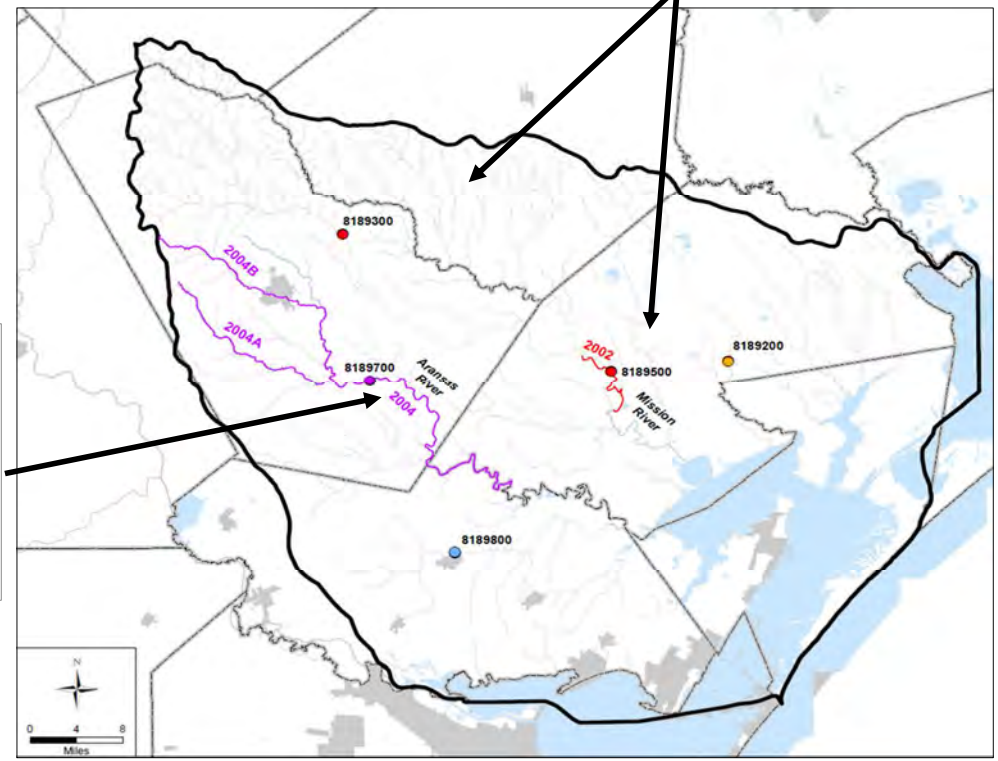




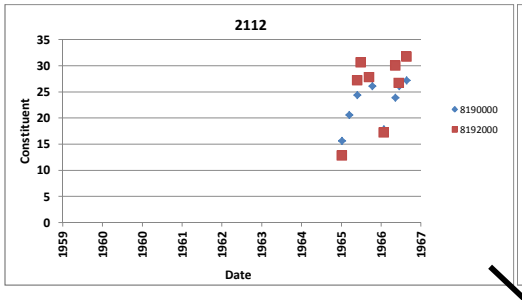
Basin 20: San Antonio-Nueces Coastal
Pre-1968 USGS Data
Max of Temperature, water, degrees Celsius

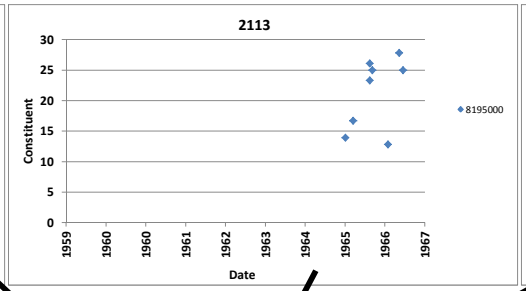


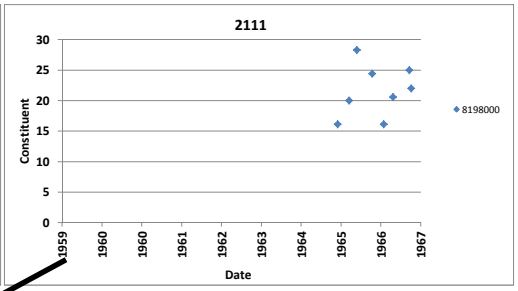


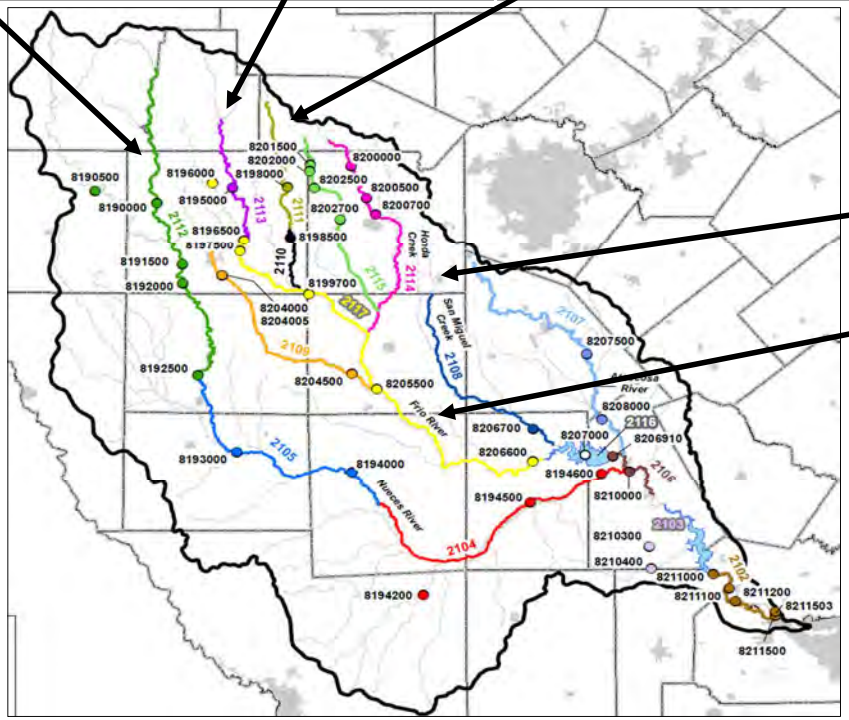


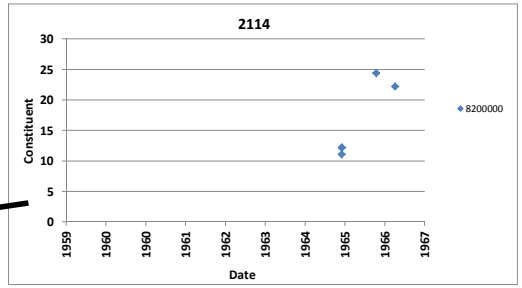
Basin 21: Nueces River Basin
Pre-1968 USGS Data
Max of Temperature, water, degrees Celsius

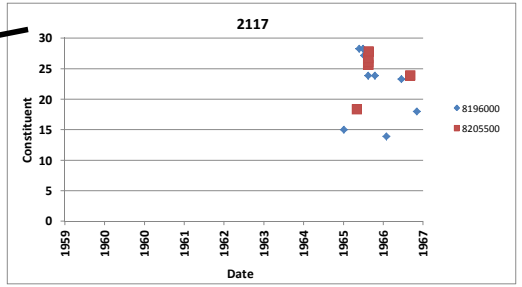




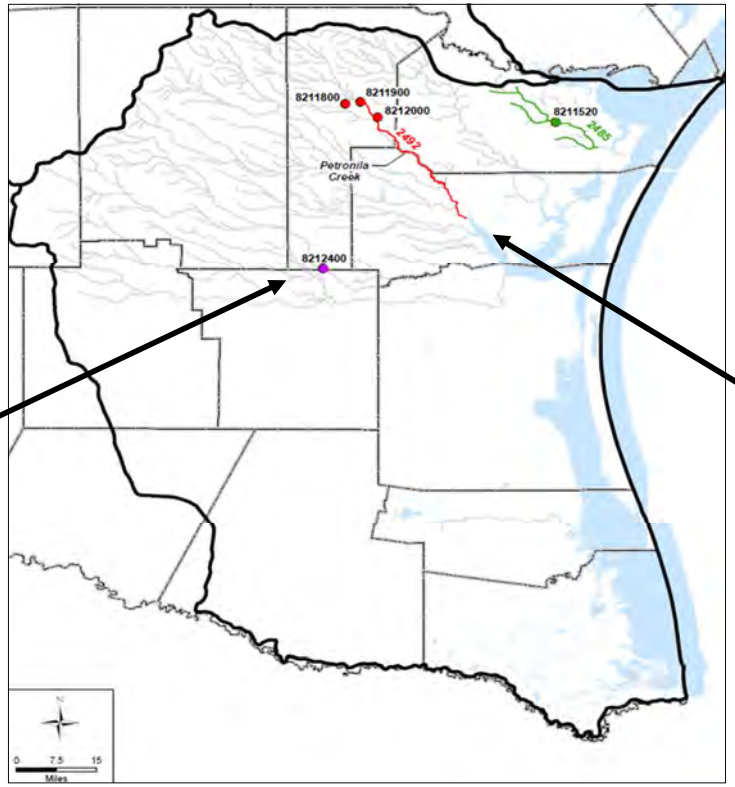


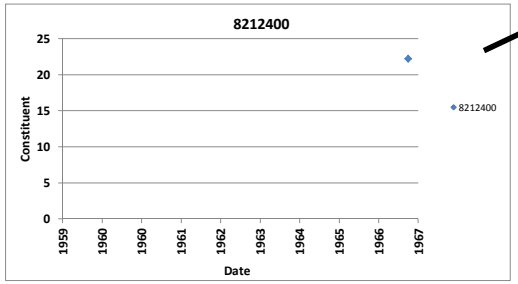


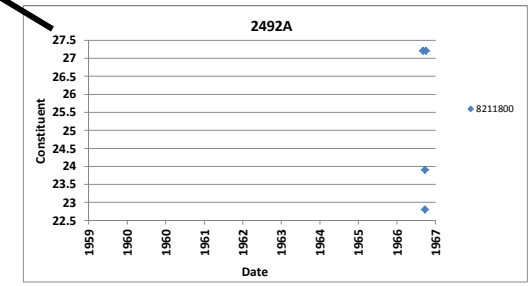




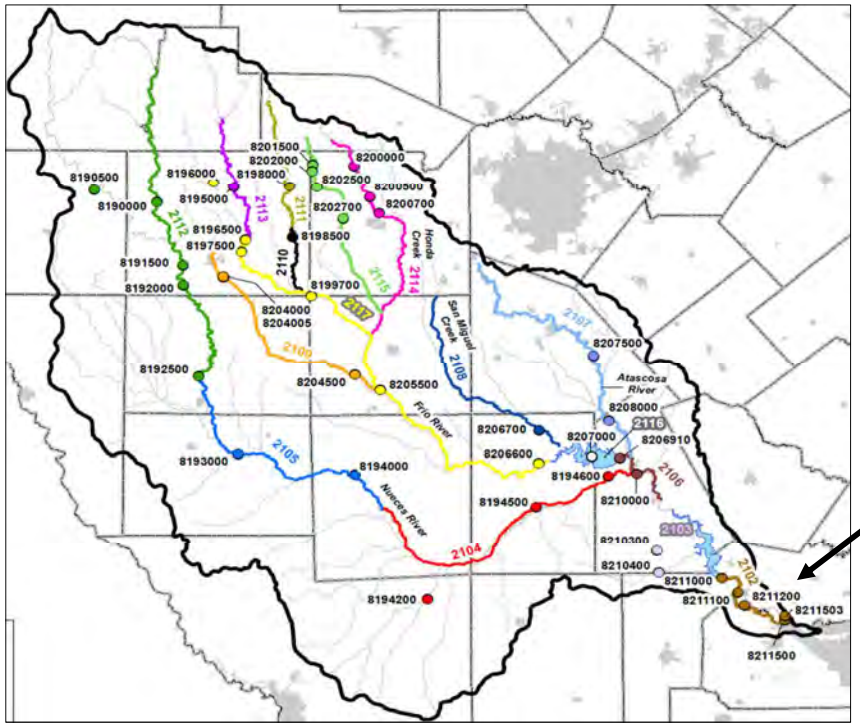
Basin 22: Nueces - Rio Grande Coastal
Pre-1968 USGS Data
Max of Temperature, water, degrees Celsius

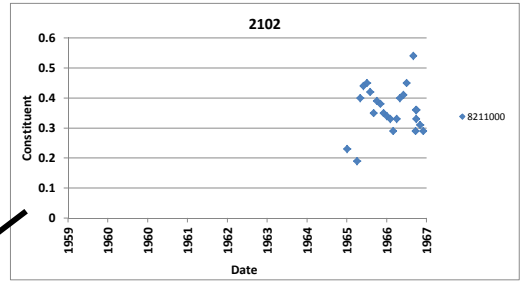




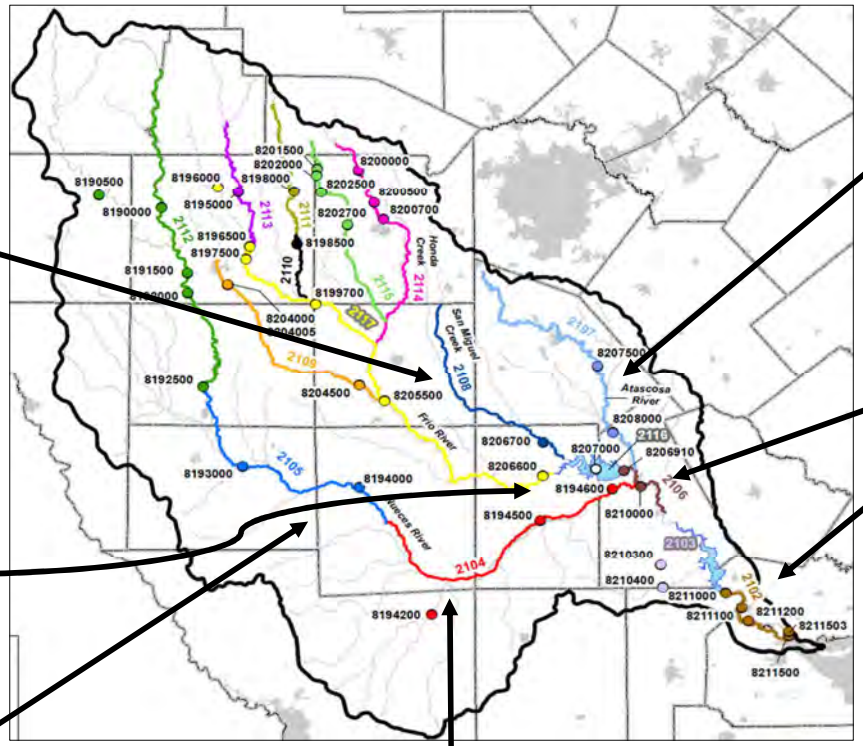


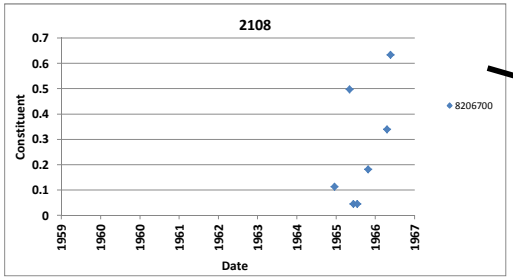
Basin 21: Nueces River Basin
Pre-1968 USGS Data
Phosphate, water, unfiltered, milligrams per liter

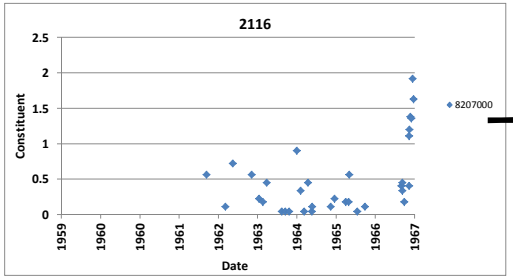


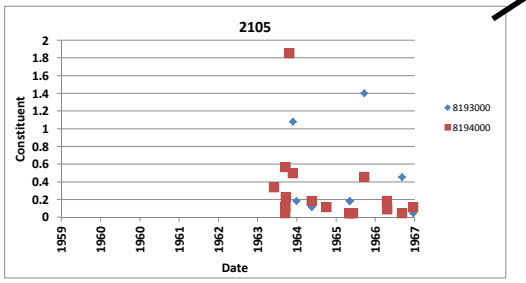


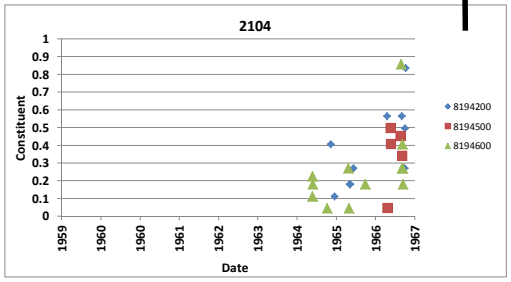
Basin 21: Nueces River Basin
Pre-1968 USGS Data
Nitrate, water, filtered, milligrams per liter as nitrogen

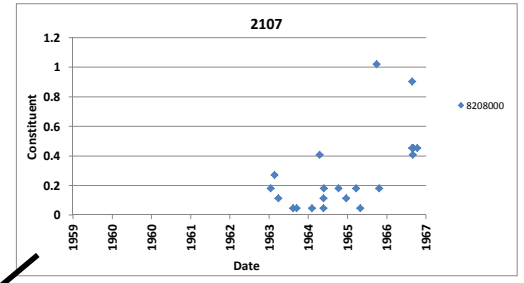


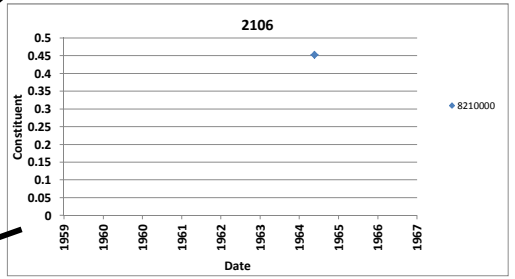


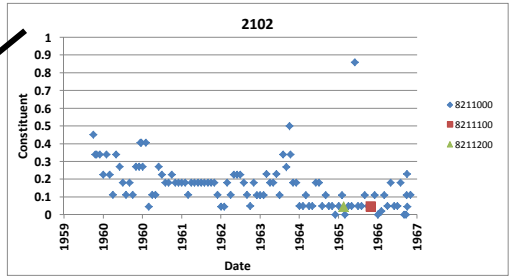




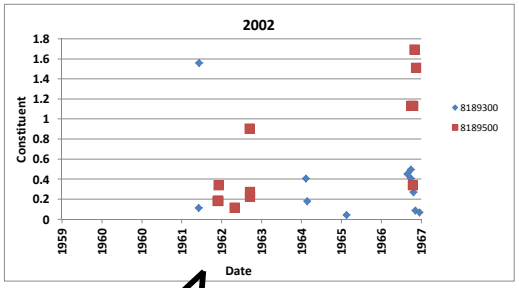


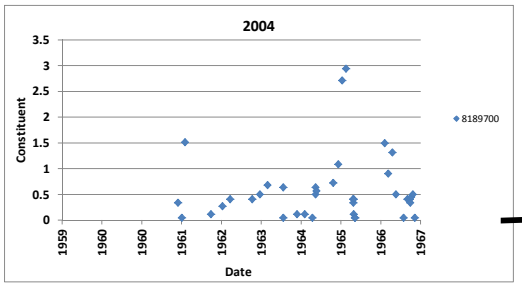


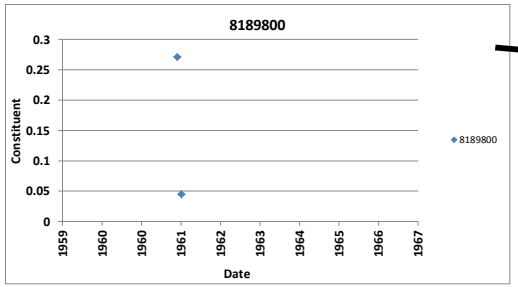


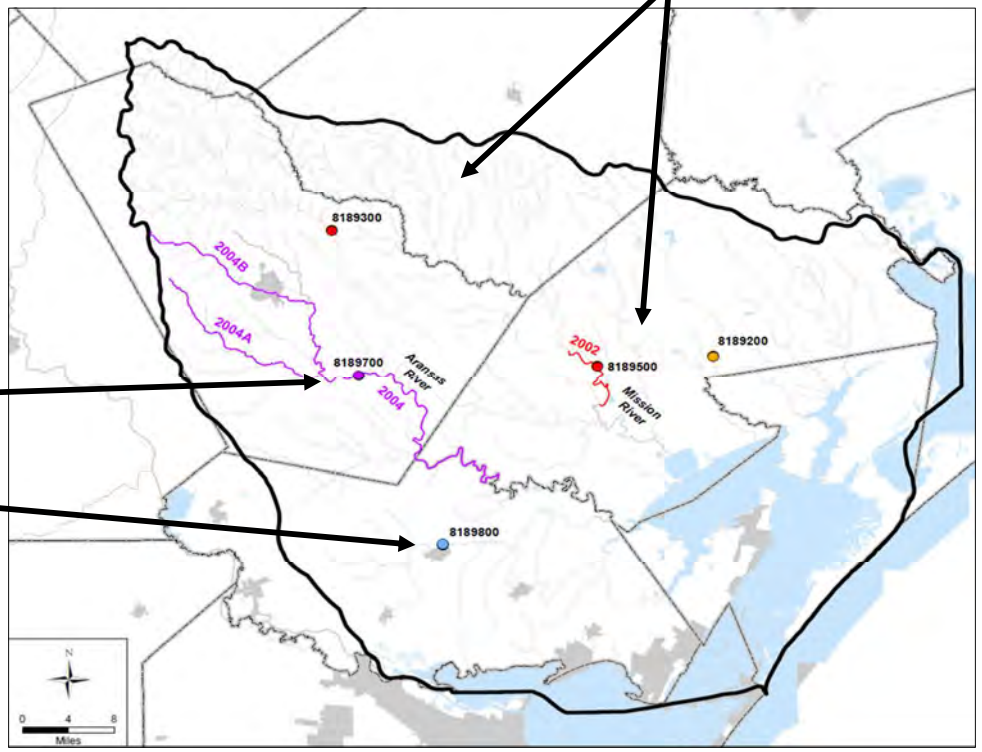


Basin 20: San Antonio-Nueces Coastal
Pre-1968 USGS Data
Nitrate, water, filtered, milligrams per liter as nitrogen

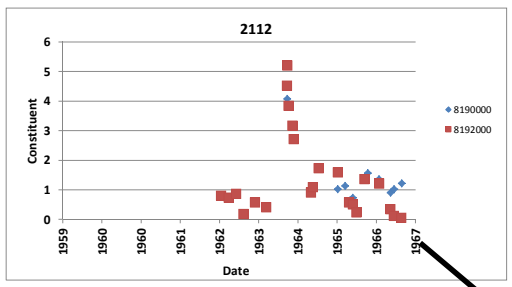


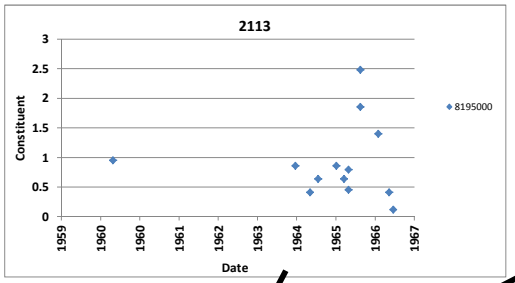


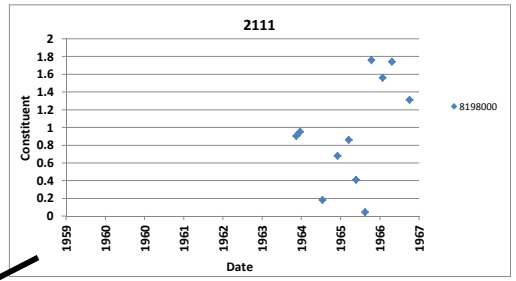


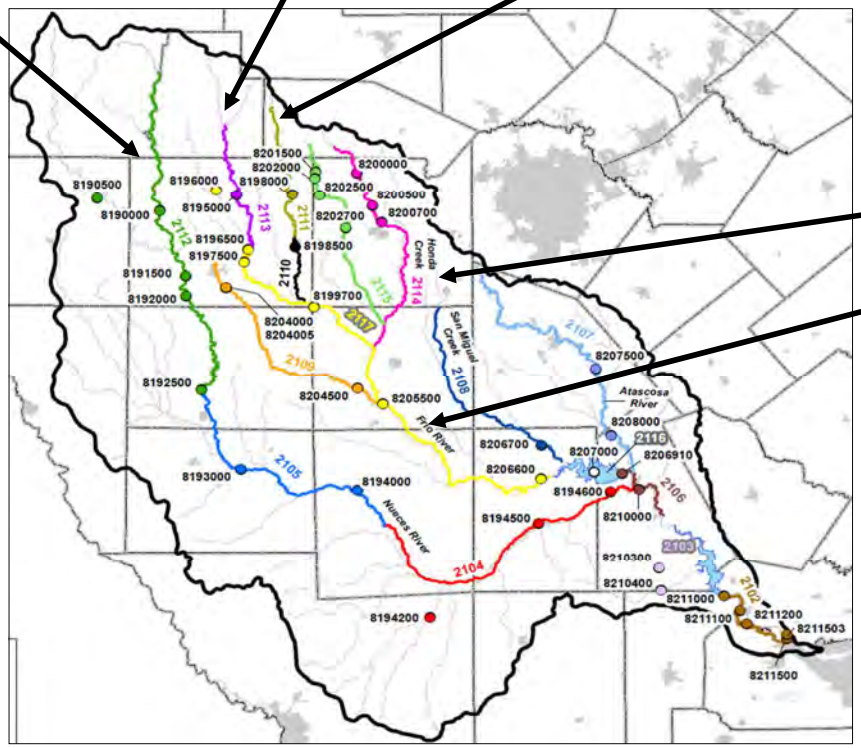


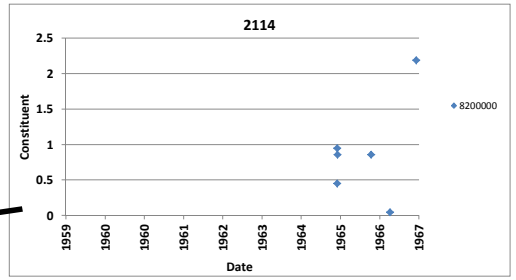
Basin 21: Nueces River Basin
Pre-1968 USGS Data
Nitrate, water, filtered, milligrams per liter as nitrogen

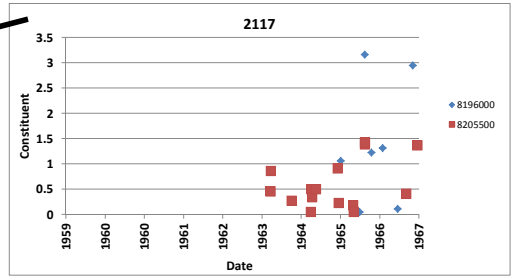




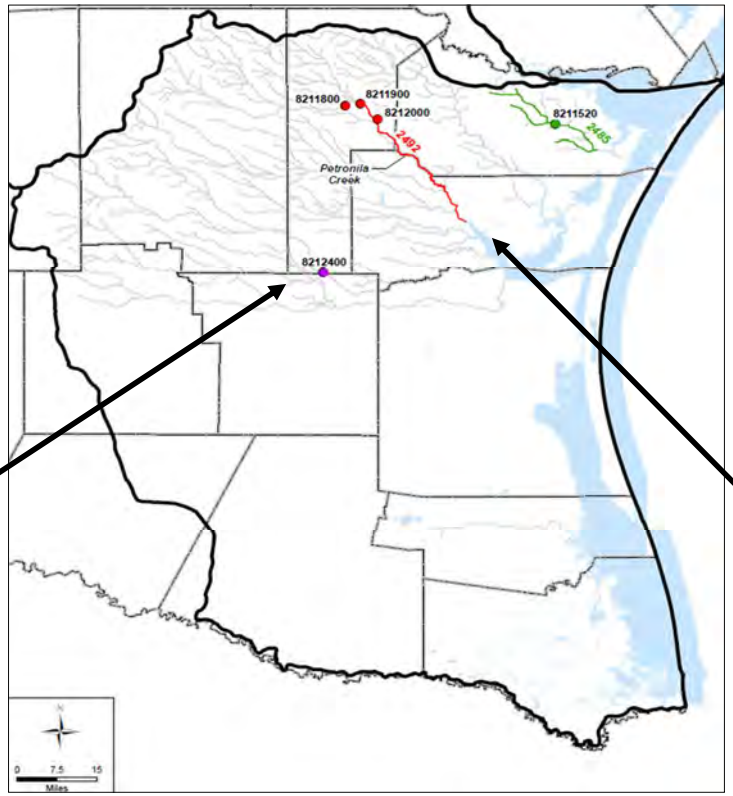


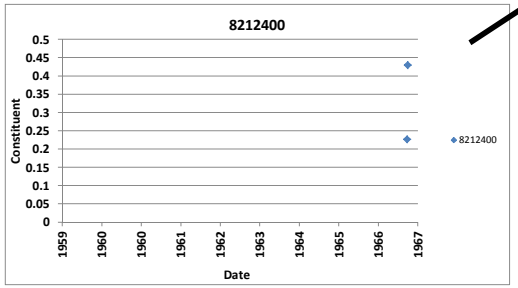


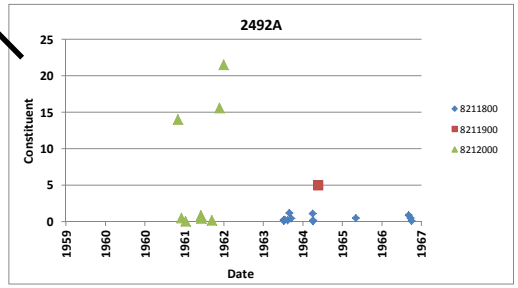




Basin 22: Nueces - Rio Grande Coastal
Pre-1968 USGS Data
Nitrate, water, filtered, milligrams per liter as nitrogen







Appendix D. Summary of outlier analyses

Maxima Outlier Analysis
Nueces Watershed
January 2015

Note: 12960 : Most downstream point in watershed. Appears in several of these tables and figures.

Chlorophyll a (CHLA)

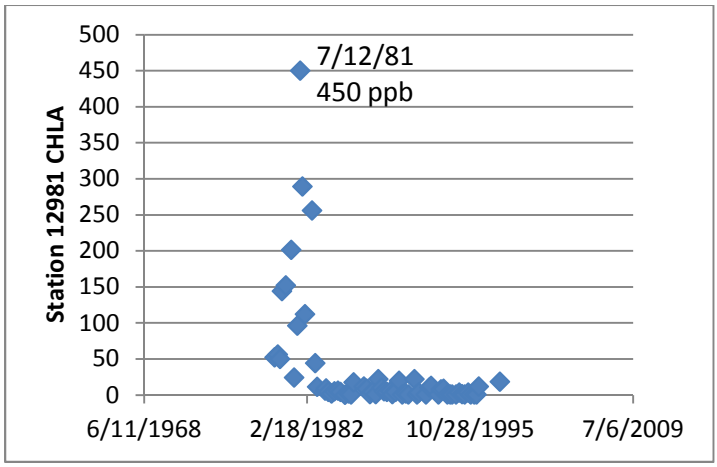
STATIONS WITH N = 40+			
	CHLA	CHLA	CHLA
Station	min	max	count
12999	0.50	4	146
13013	0.50	5	86
13010	0.50	5	88
12994	0.50	6	86
12988	0.05	8	49
13006	0.13	10	112
12996	0.50	19	69
13021	1.00	24	50
12993	0.50	26	109
12962	0.50	30	69
12972	0.13	31	62
12977	0.50	34	46
12979	0.50	36	89
12985	0.50	37	75
13020	2.00	38	46
12983	0.50	42	79
12973	0.05	46	97
12982	0.50	48	51
13023	0.50	62	49
12978	0.50	70	45
12967	0.50	73	88
12976	1.00	80	40
12980	0.50	111	56
13024	0.50	120	64
12975	0.50	199	73
12981	0.05	450	63
12960	0.50	488	190

12975: 7/14/72 outlier at 199 ppb

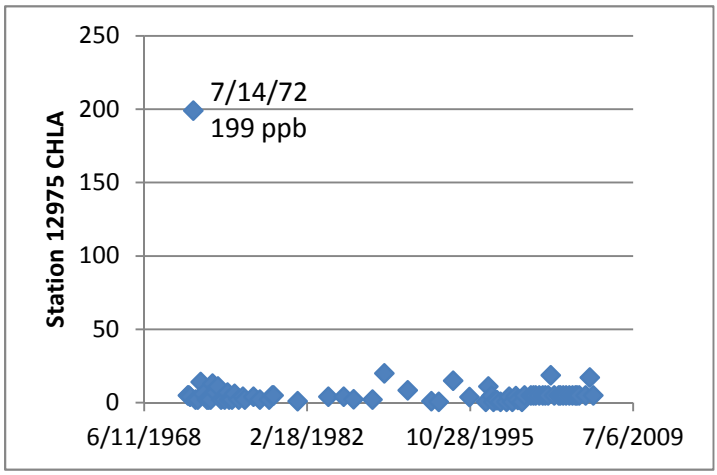
13024: 8/15/01 outlier at 120 ppb

12980: 7/12/11 outlier at 111 ppb

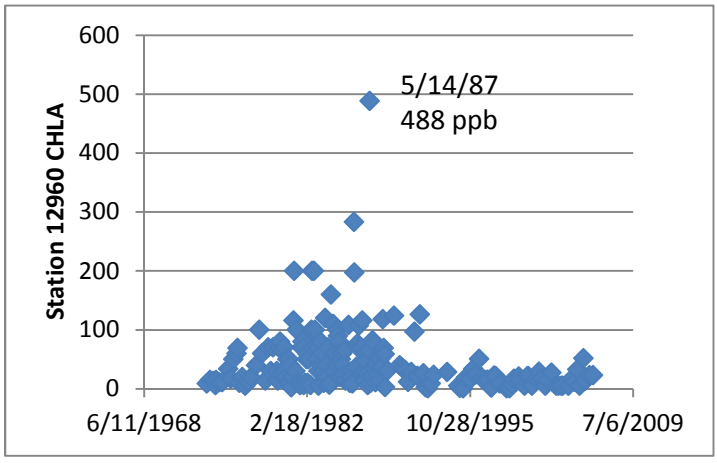
12976: 6/17/85 outlier at 80 ppb



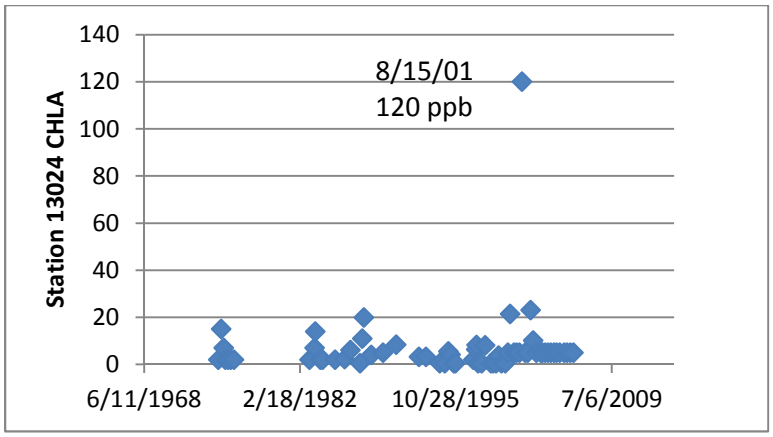
not outlier, near WWTP



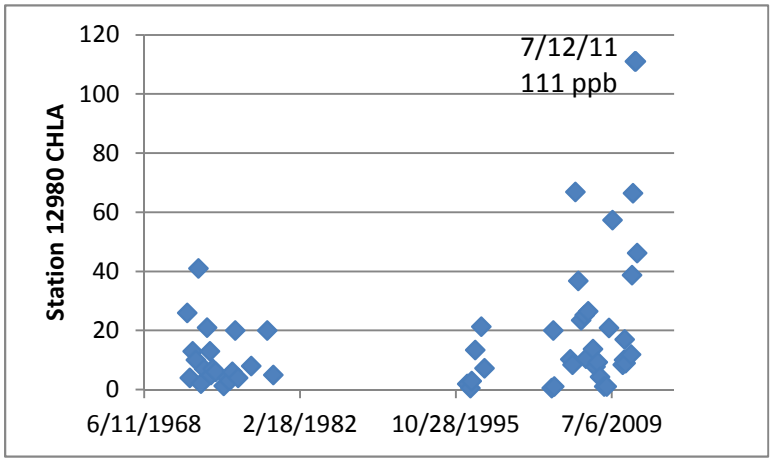
outlier



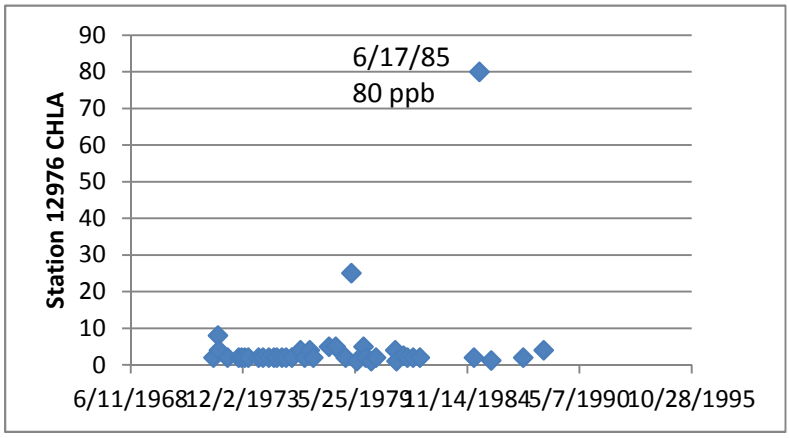
not outlier; 1.6" rain in 8 days before 5/14/87. Note most downstream point on Nueces.



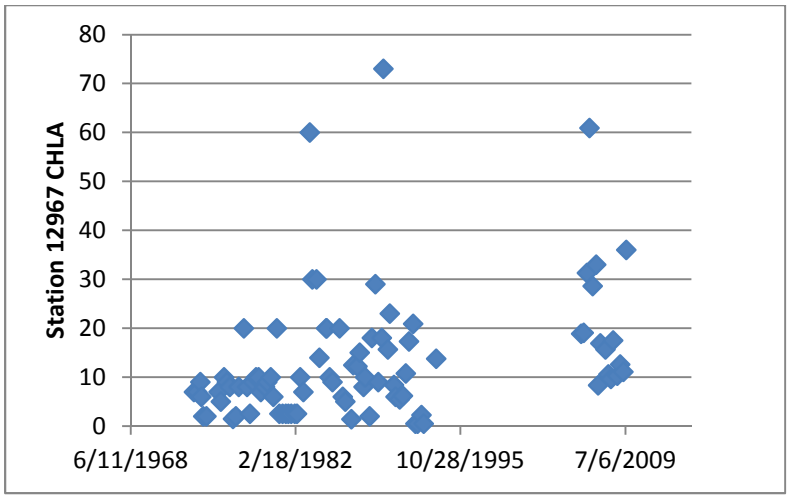
Outlier



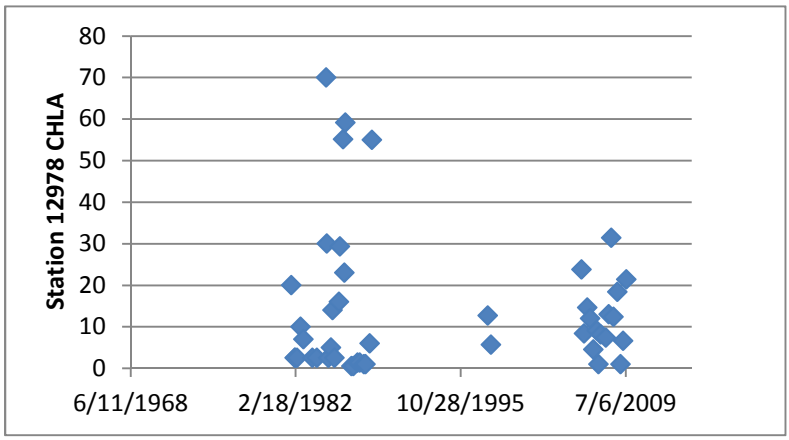
Outlier



Outlier



Not outlier

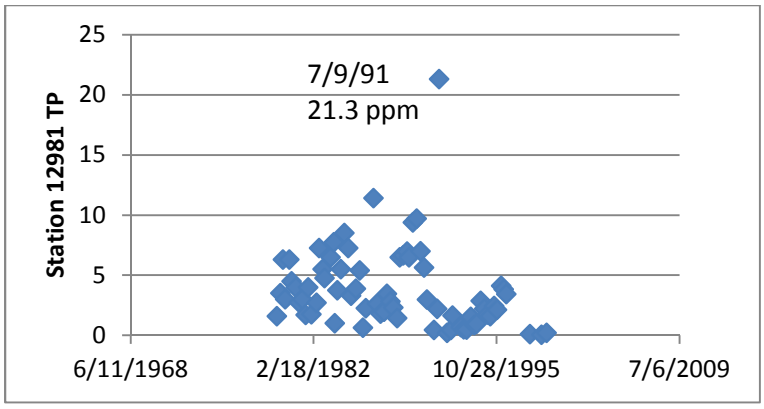


Not outlier

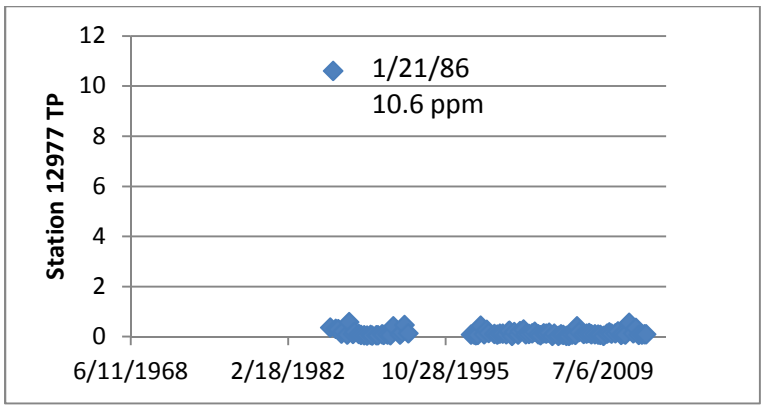
TP

STATIONS WITH N = 40+			
	TP	TP	TP
Station	min	max	count
17143	0.010	0.050	43
13007	0.005	0.100	43
16704	0.005	0.100	50
17389	0.020	0.209	46
13005	0.001	0.400	49
12996	0.005	0.400	76
13024	0.005	0.440	84
12964	0.020	0.516	63
13021	0.005	0.520	53
12965	0.041	0.530	63
12993	0.005	0.530	139
12987	0.025	0.560	46
15449	0.005	0.560	46
12999	0.001	0.560	180
13006	0.002	0.600	217
12988	0.005	0.660	48
13013	0.005	0.680	129
12975	0.010	0.710	95
17648	0.020	0.723	43
12962	0.040	0.840	76
12985	0.005	0.850	84
12967	0.020	0.930	130
12976	0.010	0.948	47
12973	0.010	1.013	139
12982	0.016	1.240	77
12980	0.023	1.240	100
12994	0.005	1.275	176
12979	0.030	1.300	179
12978	0.020	1.350	79
13020	0.010	2.080	85
12960	0.020	2.090	216
12972	0.005	2.410	78
13010	0.005	3.460	141
12983	0.020	8.020	133
13023	0.005	9.990	110
12977	0.020	10.600	90
12981	0.060	21.300	69

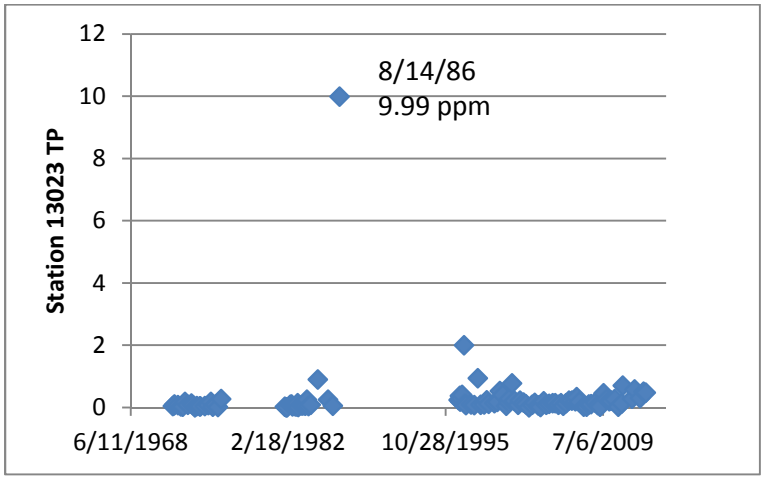
12972, 12960, – not an outlier



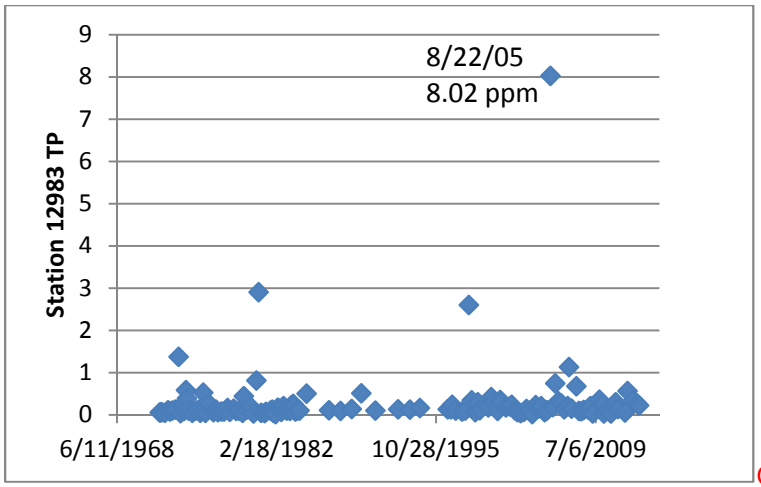
Not an outlier; Large rains three days prior to 7/9/91.



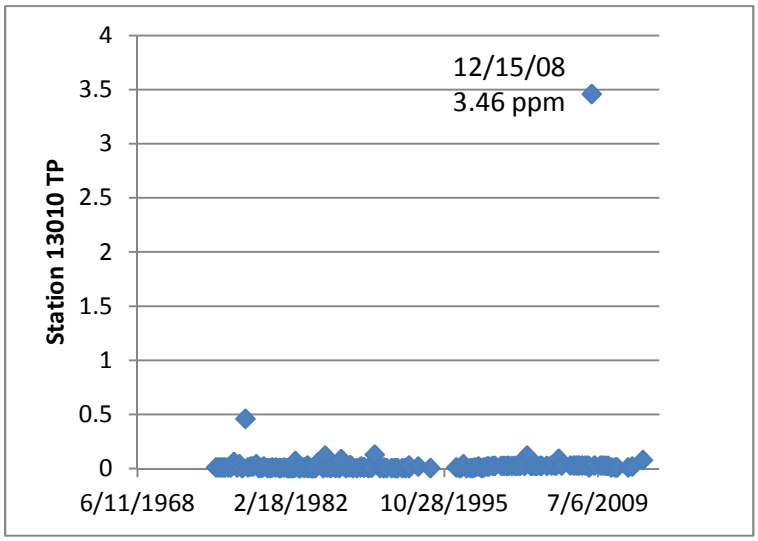
Outlier: Near Three Rivers, no big rainfall



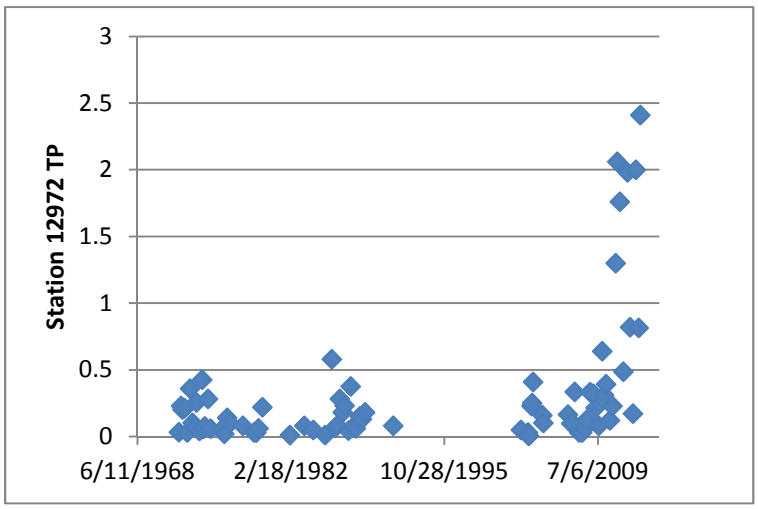
Not an outlier; Large rains one week and then two days prior to high point.



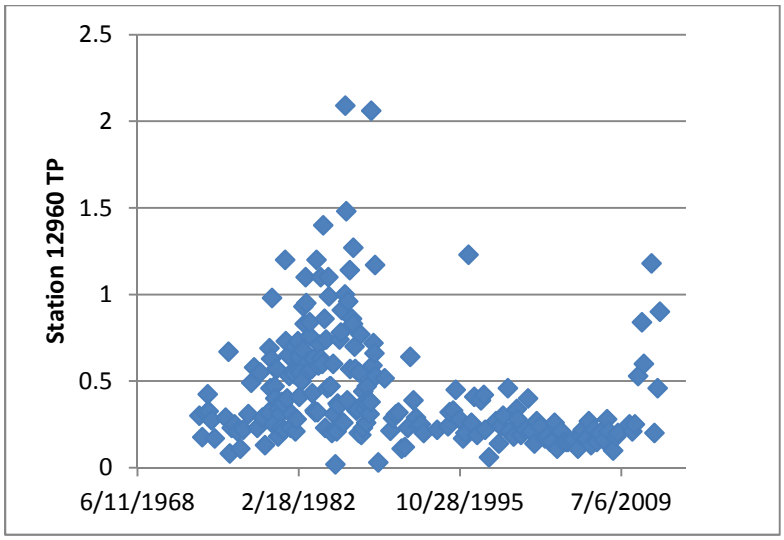
Outlier; no rain



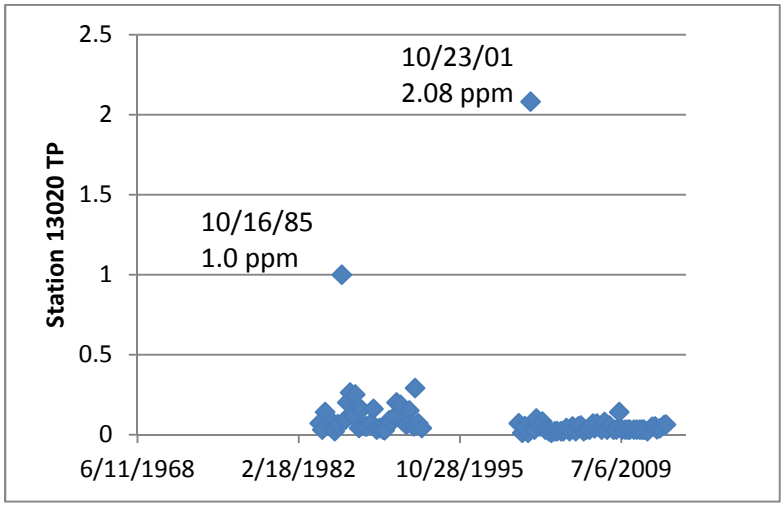
Outlier; no rain



Not an outlier



Not an outlier



10/16/85 not outlier, rain event;

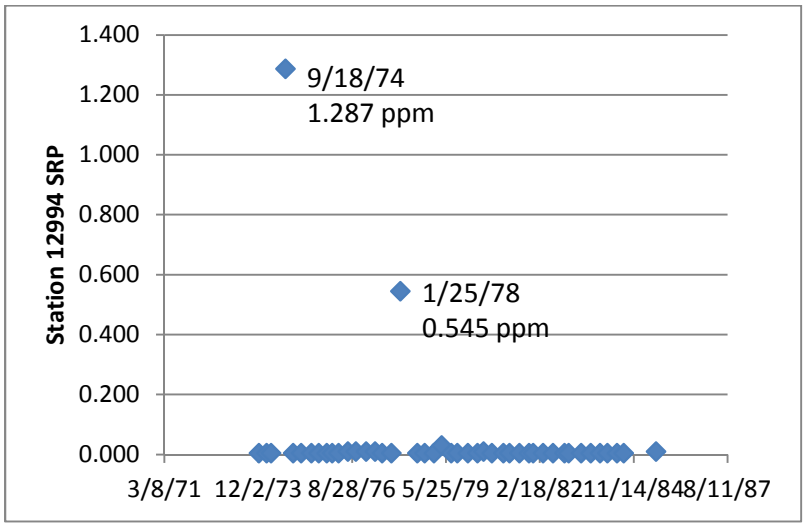
10/23/01 is outlier, no rain

SRP

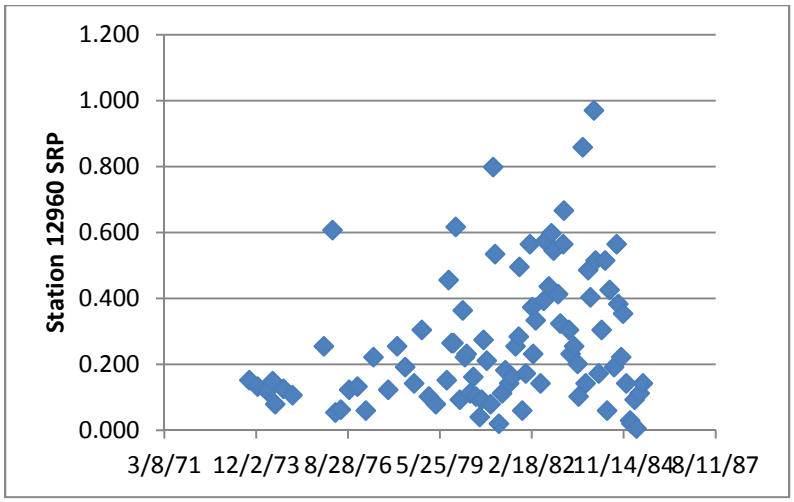
STATIONS WITH N = 40+			
	SRP	SRP	SRP
Station	Min	max	Count
12993	0.005	0.010	46
13021	0.005	0.201	53
12962	0.005	0.274	48
12967	0.010	0.330	47
12973	0.005	0.429	62
12983	0.005	0.462	44
12999	0.000	0.495	108
12979	0.005	0.524	66
13006	0.005	0.594	47
12988	0.005	0.647	40
12960	0.005	0.970	97
12994	0.005	1.287	44

12960 – not an outlier

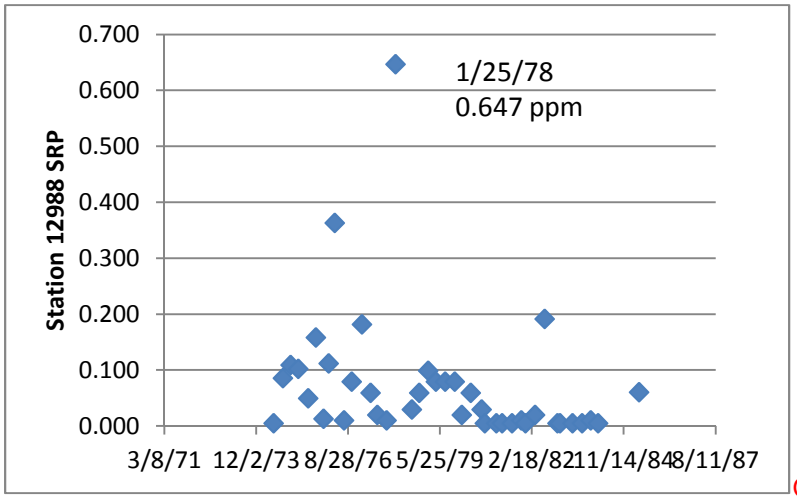
1/25/78 – Three outliers. 13006, 12994, 12988 – No significant rainfall before event. Sample analysis error or contamination?



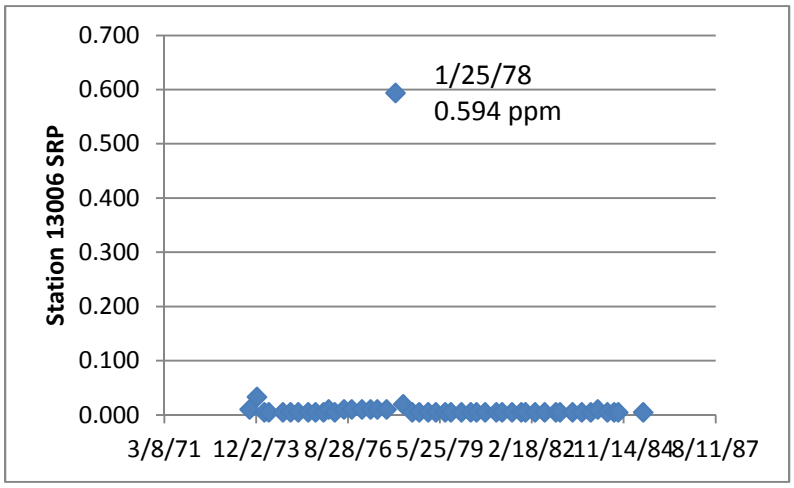
Outlier on 1/25/78; 9/18/74 – doesn't look to be outlier. Some small rains before and elevated TP on same day.



not an outlier



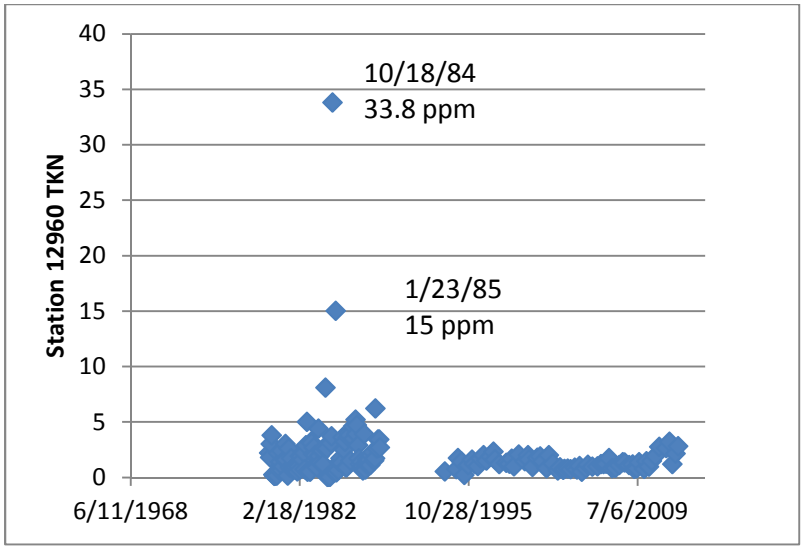
Outlier



Outlier

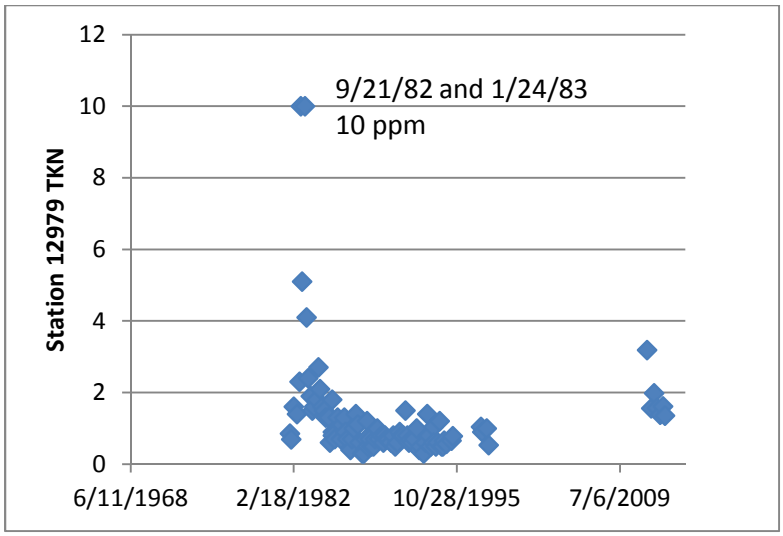
TKN

STATIONS WITH N = 40+			
	TKN	TKN	TKN
Station	min	max	Count
15449	0.019	0.55	45
16704	0.050	0.57	48
13007	0.025	0.59	47
17143	0.100	0.83	44
13013	0.025	1.30	78
12987	0.190	1.33	41
12993	0.025	1.43	69
13010	0.050	1.54	89
13024	0.050	1.85	63
13006	0.025	1.90	155
12994	0.025	2.10	119
12967	0.190	2.11	40
12982	0.010	2.24	48
13023	0.195	2.59	40
12975	0.100	3.07	56
12999	0.010	4.00	157
12979	0.300	10.00	96
12960	0.050	33.80	175



Not outlier: Large rains (>1") before 10/18/84 measurement.

1/23/85: total of 1.2" of rain in the 10 days before. (outlier or not?)

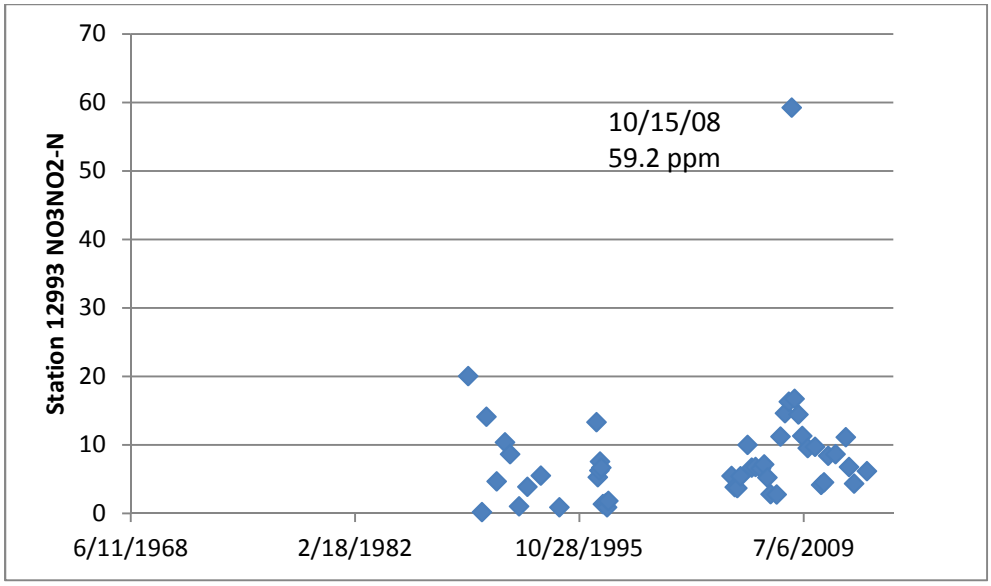


9/21/82 and 1/24/83: Rains only up to .3" three to four day before each of these high points. Seem to be outliers.

Also had high NH3-N on 1/24/83

NO3NO2-N

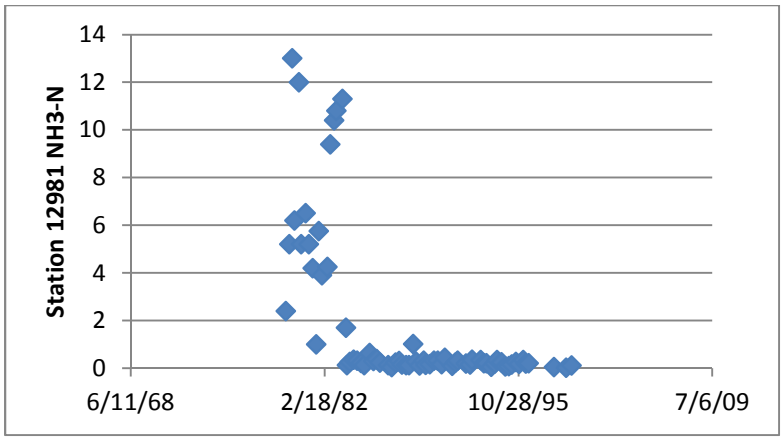
STATIONS WITH N = 40+			
	NOx-N	NOx-N	NOx-N
Station	Min	max	Count
12967	0.010	0.660	85
17648	0.010	1.050	43
13013	0.020	1.300	49
13020	0.010	1.300	60
12994	0.020	1.300	79
12973	0.010	1.430	60
13005	0.070	1.640	42
12980	0.010	1.790	66
12960	0.005	2.270	176
13006	0.050	2.400	69
12983	0.010	2.600	66
12978	0.010	2.950	44
12977	0.010	2.960	65
12965	0.010	3.010	52
12964	0.010	3.030	52
12999	0.122	3.301	150
13010	0.020	3.870	62
12979	0.010	4.030	133
13023	0.010	7.620	67
12993	0.170	59.200	48



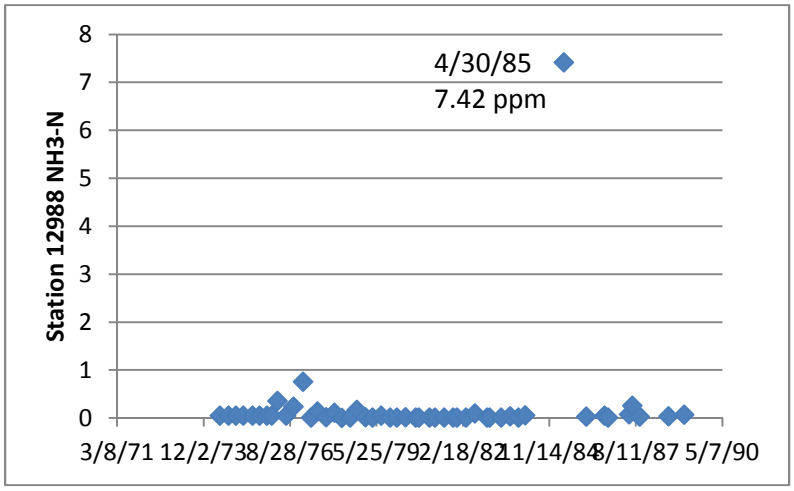
Rained 0.85" on 10/15/08. Not an outlier?

NH3-N

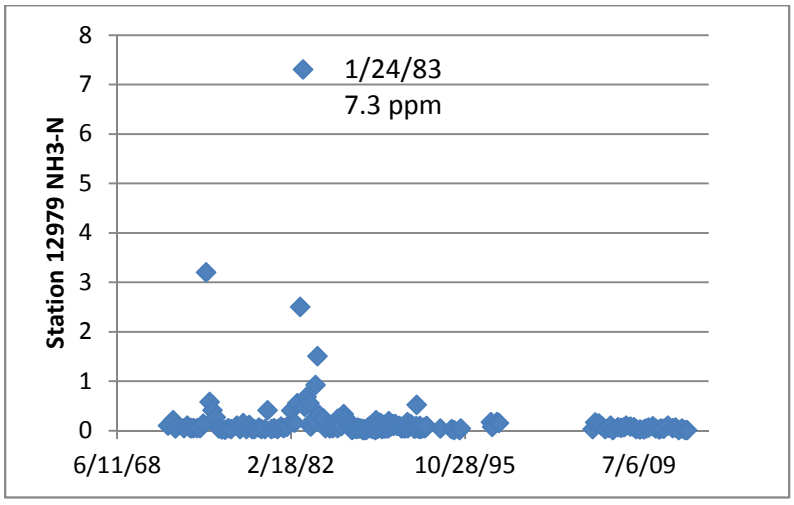
STATIONS WITH N = 40+			
	NH3-3	NH3-3	NH3-3
Station	Min	Max	Count
16704	0.025	0.060	54
17143	0.025	0.100	44
17389	0.010	0.120	46
17648	0.010	0.127	43
12964	0.010	0.140	63
12965	0.010	0.149	63
12985	0.005	0.160	83
12987	0.005	0.190	46
13024	0.005	0.200	88
15449	0.010	0.260	46
13021	0.005	0.280	53
12962	0.005	0.300	79
12978	0.010	0.330	81
13025	0.010	0.400	40
12993	0.005	0.400	141
12967	0.005	0.420	133
13013	0.005	0.430	126
12999	0.005	0.440	181
12996	0.010	0.470	76
12994	0.005	0.470	154
13005	0.010	0.500	48
12983	0.005	0.500	133
13006	0.005	0.500	169
12973	0.005	0.525	139
13007	0.010	0.530	50
13010	0.005	0.560	143
12976	0.010	0.602	48
12982	0.010	0.670	80
12977	0.010	0.750	92
13020	0.005	0.760	85
13023	0.005	0.808	111
12960	0.005	1.800	223
12980	0.005	1.900	102
12975	0.005	1.960	96
12972	0.000	2.500	82
12979	0.000	7.300	171
12988	0.005	7.420	49
12981	0.024	13.000	69



not outlier

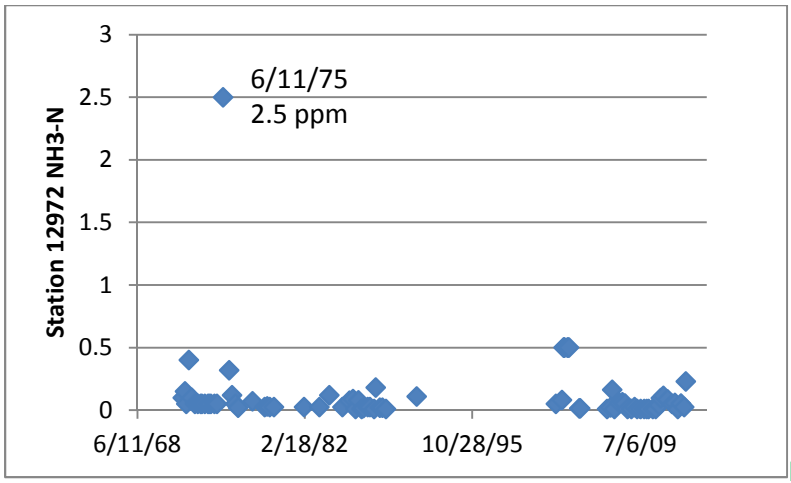


Only minor rain before 4/30. Outlier.

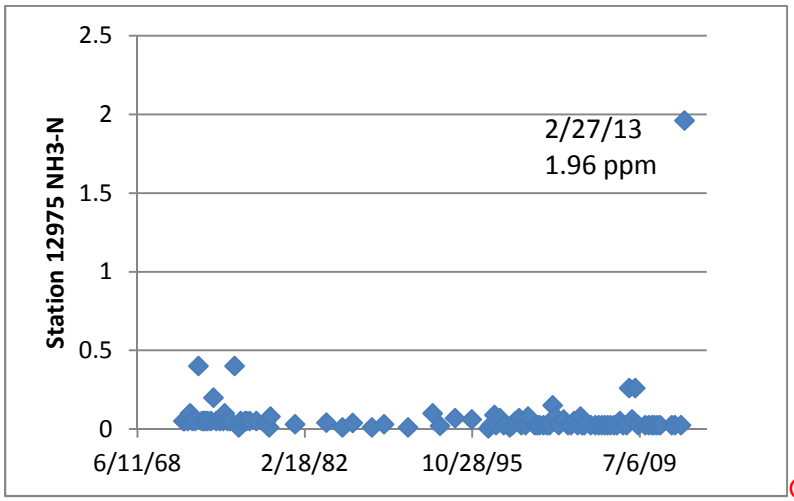


Also had high TKN on 1/24/83

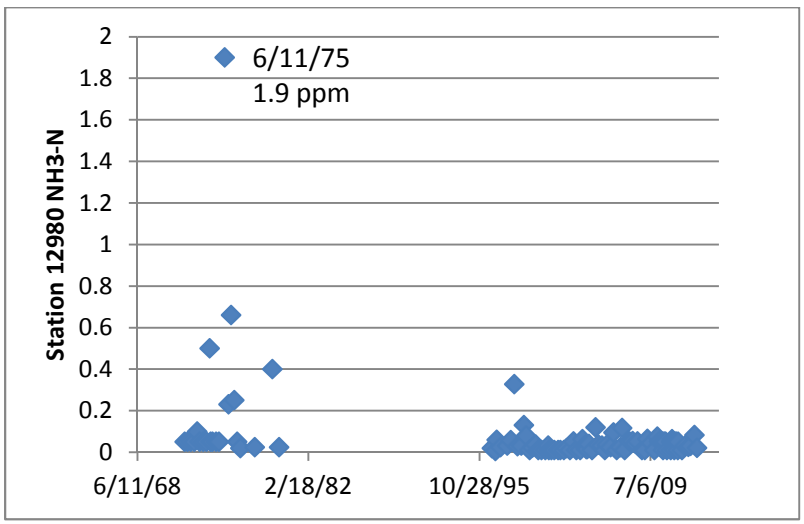
Outlier or not?



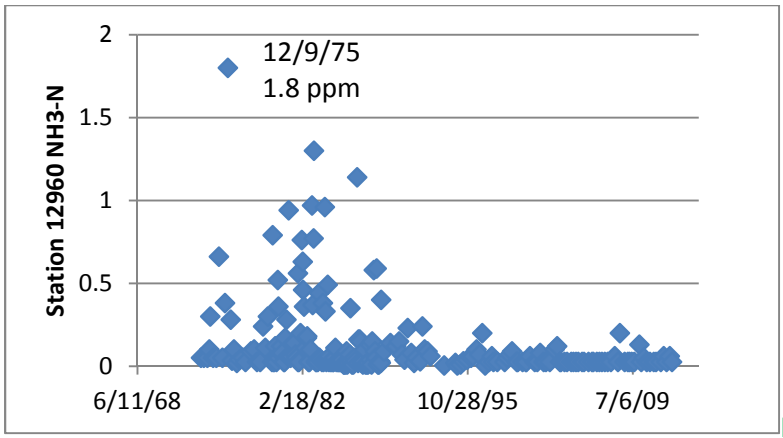
Not an outlier. 1" rain day before



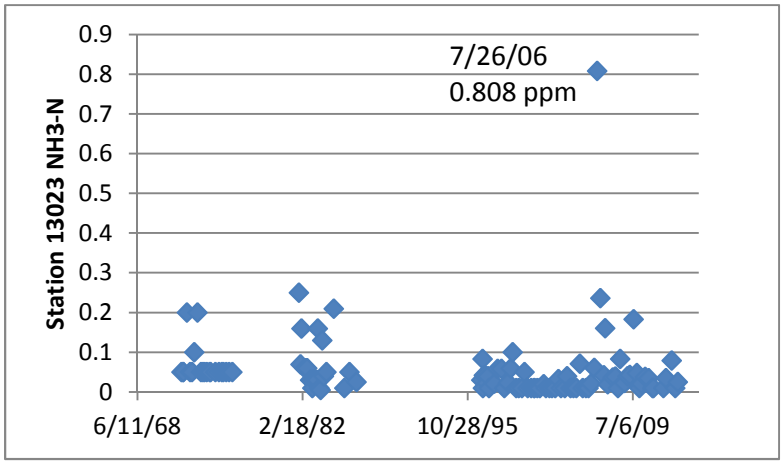
Outlier. No rain, no other reason to be so high.



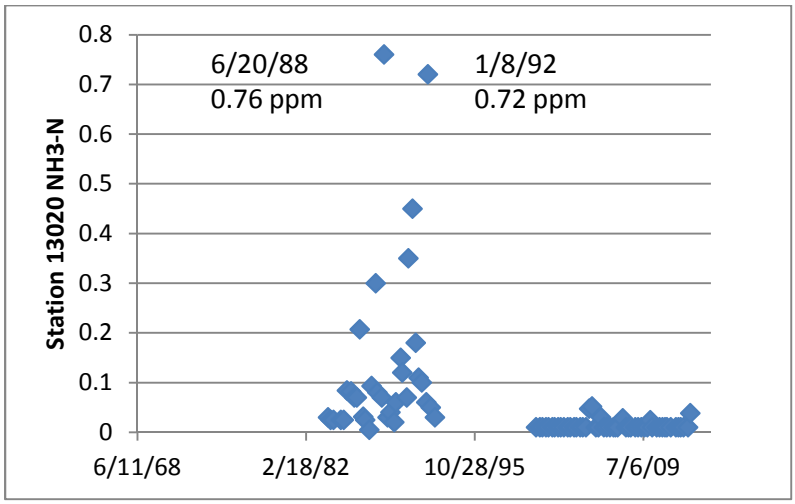
Not an outlier. 1" rain day before



Not outlier



Not outlier. 3" rain in 3 days before 7/26.



Not outlier

Potential Issues with Detection Limits

SRP

Of the 42 stations reporting SRP data, 31 had a reported minimum value of 0.005 ppm.

Station 12999 had one reported value of 0 on 8/22/79, which should be removed. All other minimum values for this station were 0.005 ppm.

TP

A total of 108 stations reported values for TP. The minimum reported value for 33 stations was 0.005 ppm. There were 5 stations that reported values less than 0.005 ppm: Station 12999 (0.001), Station 12997 (0.001), Station 13005 (0.001), Station 17438 (0.001), and Station 13006 (0.002).

Station 12999 had a reported value of 0.0005 ppm on 8/22/79. Upon removal of this point, the lowest reported value was 0.005 ppm.

Station 12997 had reported TP samples from 1972 to 1974 (range: 0.010 to 0.049 ppm), and from 2001 to 2004 (range: 0.001 to 0.300 ppm; see below).

10/16/2001	0.001
1/16/2002	0.025
1/28/2002	0.001
4/15/2002	0.019
8/12/2002	0.300
10/8/2002	0.010
2/4/2003	0.001
5/6/2003	0.002
7/24/2003	0.004
10/28/2003	0.002
2/10/2004	0.001
5/19/2004	0.001
8/10/2004	0.009

Station 13055 reported values from 2001 to 2005 that were often below the 0.005 minimum value reported for most stations (below). However, from 2006 to 2013 the minimum reported value was 0.01 ppm.

10/16/2001	0.001
1/28/2002	0.001
5/7/2002	0.001
8/12/2002	0.1
10/8/2002	0.4
2/4/2003	0.004
5/6/2003	0.003
7/24/2003	0.004
10/28/2003	0.002
2/10/2004	0.001
5/19/2004	0.001
8/10/2004	0.012
11/9/2004	0.001
2/3/2005	0.001
5/3/2005	0.001
7/19/2005	0.001
10/10/2005	0.001

Station 17438 only had 4 reported TP values, all between 2001 and 2002 (below):

10/16/2001	0.001
1/28/2002	0.001
4/15/2002	0.022
8/12/2002	0.2

Station 13006: November 2000 to September 2004 data is suspect (below):

11/30/2000	0.002	2/11/2003	0.002
1/30/2001	0.002	4/8/2003	0.020
2/21/2001	0.025	4/24/2003	0.025
3/6/2001	0.002	5/1/2003	0.005
5/2/2001	0.002	5/19/2003	0.002
5/22/2001	0.025	5/28/2003	0.100
7/17/2001	0.002	6/11/2003	0.005
8/15/2001	0.002	6/18/2003	0.003
10/23/2001	0.002	8/6/2003	0.025
11/19/2001	0.025	8/12/2003	0.003
12/18/2001	0.002	9/9/2003	0.002
1/15/2002	0.002	10/7/2003	0.005
2/13/2002	0.025	10/15/2003	0.002
2/21/2002	0.002	11/20/2003	0.002
4/17/2002	0.002	12/10/2003	0.002
6/27/2002	0.004	1/14/2004	0.002
7/30/2002	0.002	1/22/2004	0.025
8/15/2002	0.050	2/10/2004	0.004
8/22/2002	0.025	3/10/2004	0.025
8/29/2002	0.002	4/21/2004	0.004
9/24/2002	0.002	5/19/2004	0.025
10/15/2002	0.002	5/25/2004	0.005
11/14/2002	0.002	6/8/2004	0.006
12/11/2002	0.025	6/24/2004	0.025
12/18/2002	0.002	8/11/2004	0.005
1/14/2003	0.003	8/17/2004	0.002
1/30/2003	0.005	9/8/2004	0.002

In summary, Stations 12997, 13005, and 13006 had suspicious TP values in the early 2000s. These stations are on the upper portions of the Nueces and Frio Rivers.

CHLA

Of the 89 stations reporting CHLA values, 33 reported a minimum value of 0.5 ppm. Several stations, however, reported minimum values of either 0.05 or 0.13 ppm (below):

Station	min	count
12973	0.05	97
12981	0.05	63
12988	0.05	49
12972	0.13	62
12974	0.13	12
13006	0.13	112
13007	0.13	33
17892	0.13	15
17897	0.13	12
17898	0.13	15
17899	0.13	16
17900	0.13	22

Station 12973: 4/23/85 value of 0.05 ppm removed; minimum value becomes 0.5 ppm.

Station 12981: 4/23/85 value of 0.05 ppm removed; minimum value becomes 0.5 ppm.

Station 12988: 4/30/85 value of 0.05 ppm removed; minimum value becomes 0.5 ppm.

Station 12972:

10/6/2002	0.125
2/27/2003	0.125
4/8/2003	0.125
5/1/2003	0.125
5/14/2003	0.125
8/6/2003	0.125
8/26/2003	0.125

Station 12974:

10/6/2002	0.125
2/27/2003	0.125
4/8/2003	0.125
5/1/2003	0.125
5/14/2003	0.125
8/6/2003	0.125
8/26/2003	0.125

Station 13006:

9/6/2002	0.125
9/17/2002	0.125
10/6/2002	0.125
1/8/2003	0.125
1/30/2003	0.125
2/27/2003	0.125
4/8/2003	0.125
5/1/2003	0.125
6/11/2003	0.125
7/9/2003	0.125

Station 13007:

9/6/2002	0.125
9/17/2002	0.125
10/6/2002	0.125
1/8/2003	0.125
1/30/2003	0.125
2/27/2003	0.125
4/8/2003	0.125
5/1/2003	0.125
6/11/2003	0.125
7/9/2003	0.125

Station 17892:

9/17/2002	0.125
10/6/2002	0.125
1/8/2003	0.125
1/30/2003	0.125
2/27/2003	0.125
4/8/2003	0.125
5/1/2003	0.125
6/11/2003	0.125
7/9/2003	0.125
8/6/2003	0.125

Station 17897:

10/6/2002	0.125
2/27/2003	0.125
4/8/2003	0.125
5/1/2003	0.125
5/14/2003	0.125
8/6/2003	0.125
8/26/2003	0.125

Station 17898, 17899, and 17900:

Enddate	CHLA 17898	CHLA 17899	CHLA 17900
8/21/2002	1	1	1
10/1/2002	0.125	1	0.125
10/8/2002	5	5	5
12/11/2002	0.125	0.125	0.125
1/30/2003	0.28	0.125	0.125
2/27/2003	0.125	0.125	0.125
4/8/2003	0.125	0.125	0.125
5/1/2003	0.125	0.125	0.125
5/14/2003	0.125	0.125	0.125
6/12/2003	0.125	0.125	0.125
8/6/2003	0.125	0.125	0.125
8/26/2003		0.125	

In summary, three stations reporting minimum values of 0.05 ppm CHLA were likely data entry errors and likely were 0.5 ppm. There were 9 stations reporting a minimum value of 0.125 ppm during the 2002 to 2003 period. Reported minimum values for these stations were at or above 0.5 ppm for the remaining data period of record for those stations. It may be the case that one-quarter dilutions were performed on these samples, because then the minimum value would be 0.5 ppm.

TKN

The majority of the 83 stations reporting TKN values reported minimum values of 0.025 ppm or greater. However, two stations reported minimum values of 0.010 (12982 and 12999) and one station reported a minimum value of 0.019 (15449).

Station 12982: after removal of the 1/21/98 data point of 0.010 ppm TKN, the minimum reported value becomes 0.23 ppm.

Station 12999: upon removal of the data points below, the minimum reported value becomes 0.025 ppm.

3/12/1985	0.01
5/15/1985	0.01
7/22/1985	0.01
1/29/1985	0.02

Station 15449: upon removal of the 6/9/97 data point of 0.010 ppm TKN, the minimum reported value becomes 0.025 ppm.

NO3NO2-N

The majority of the 98 stations reporting NO3NO2-N values reported minimum values of 0.010 ppm or greater. However, one station reported a minimum value of 0.002 (13021) and two stations reported a minimum value of 0.005 (12960 and 12962).

Station 13021: upon removal of the data points below, the minimum reported value becomes 0.010 ppm.

8/13/1982	0.002
12/9/1980	0.005
1/7/1981	0.005

Station 12960: upon removal of the data points below, the minimum reported value becomes 0.010 ppm.

1/22/1986	0.005
7/22/1985	0.005
8/12/1985	0.005
9/20/1985	0.005
5/7/1986	0.005
6/17/1986	0.005
7/2/1986	0.005
9/24/1986	0.005
4/8/1997	0.005

Station 12962: upon removal of the data point from 4/21/88 (0.005), the minimum reported value becomes 0.030 ppm.

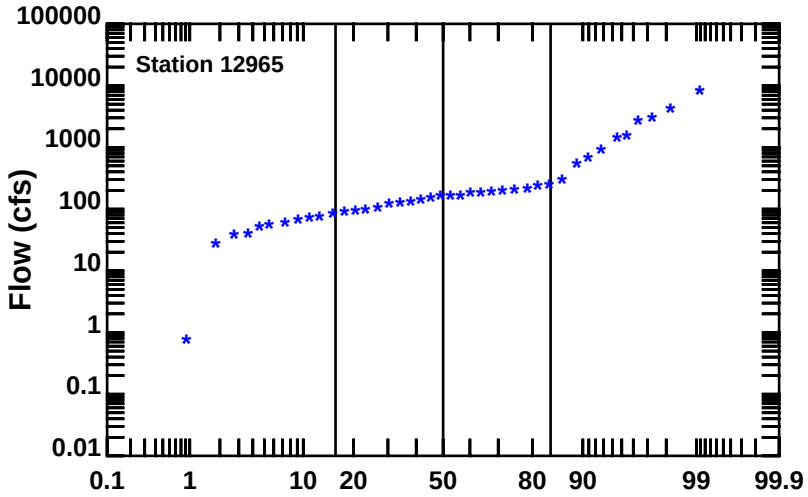
NH3-N

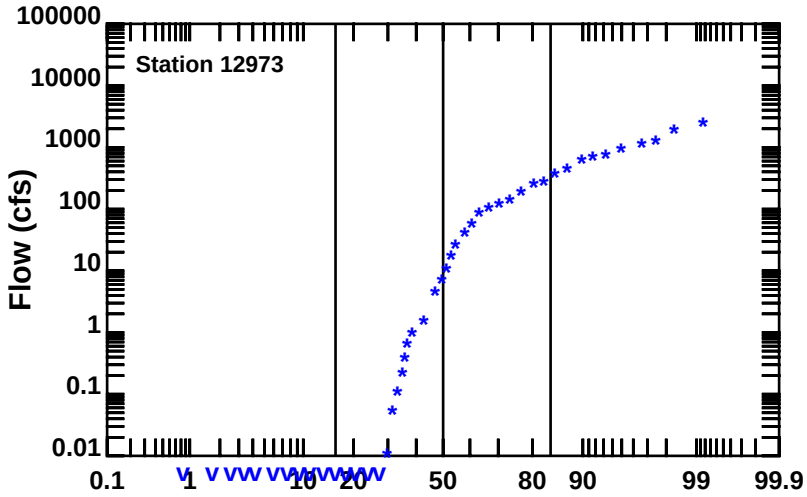
The majority of the 104 stations reporting NH3-N values reported minimum values of 0.005 ppm. However, three stations reported minimum values of 0 (12971, 12972, and 12979).

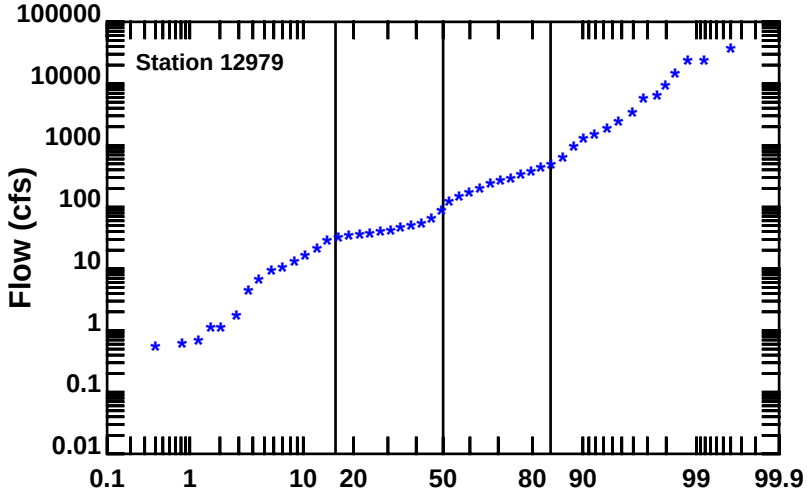
Station 12971: Upon removal of the 0 value reported on 9/25/75, the minimum reported value becomes 0.005 ppm.

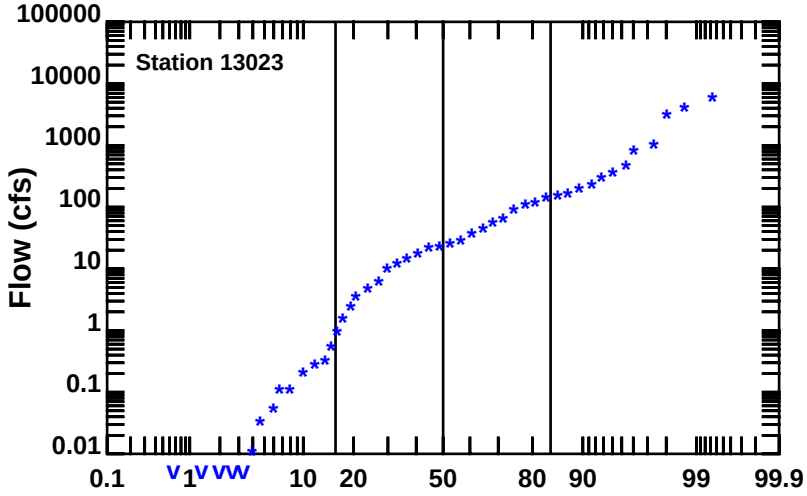
Station 12972: Upon removal of the 0 values reported on 3/19/75 and 9/25/75, the minimum reported value becomes 0.005 ppm.

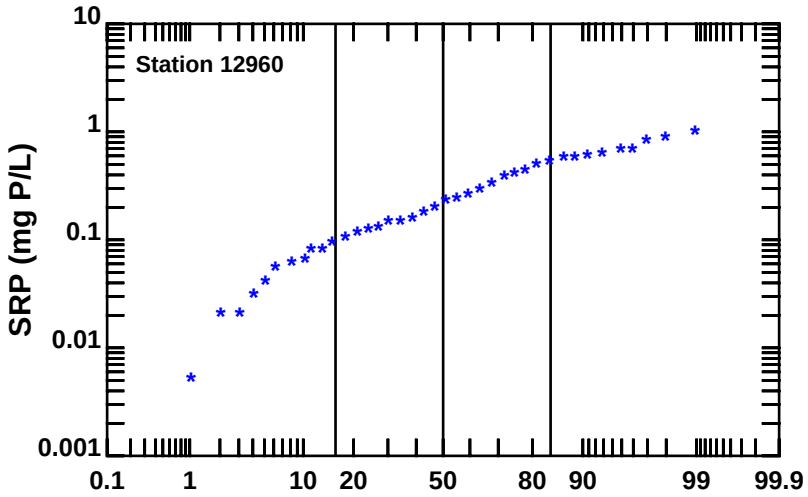
Station 12979: Upon removal of the 0 value reported on 1/14/72, the minimum reported value becomes 0.005 ppm.

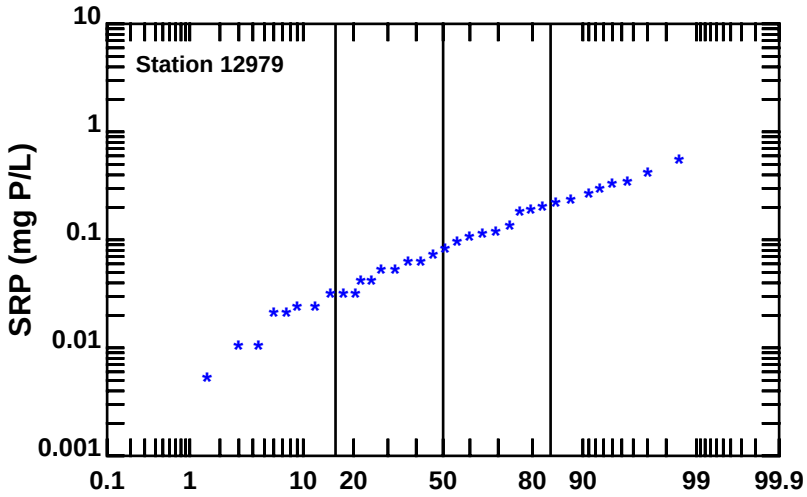

Station 12965
Flow (cfs)
100000
10000
1000
100
10
1
0.1
0.01
0.1
1
10
20
50
80
90
99
99.9

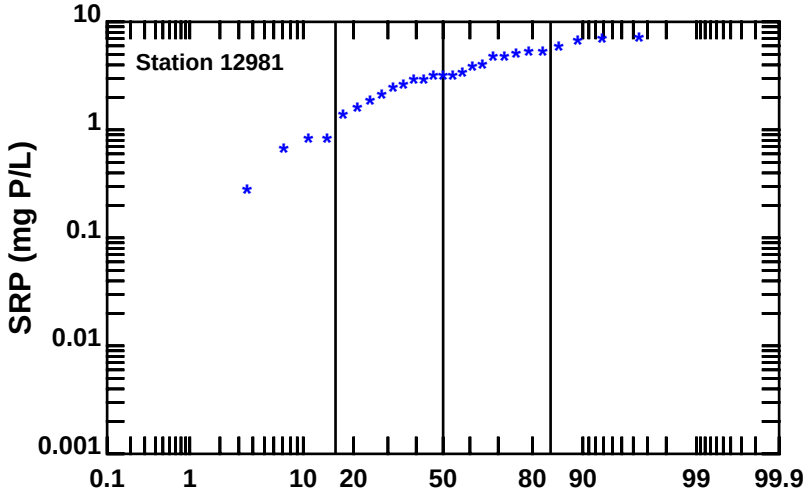

Station 12973
Flow (cfs)
100000
10000
1000
100
10
1
0.1
0.01
0.1
1
10
20
50
80
90
99
99.9

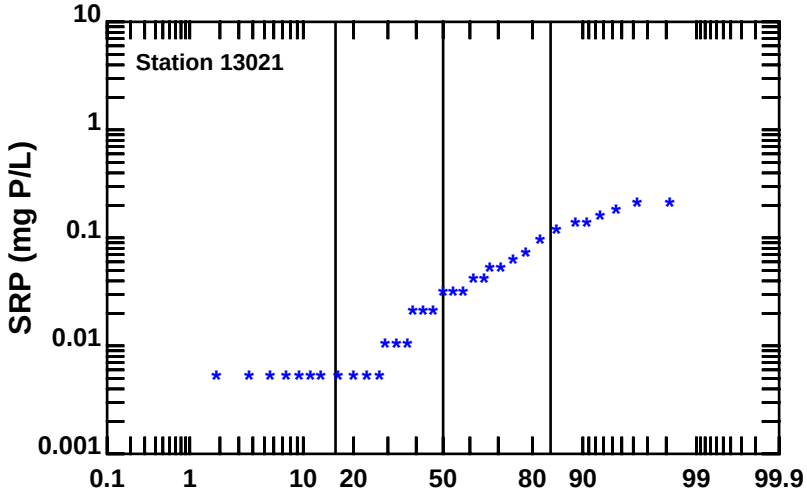

Station 12979
Flow (cfs)
100000
10000
1000
100
10
1
0.1
0.01
0.1
1
10
20
50
80
90
99
99.9

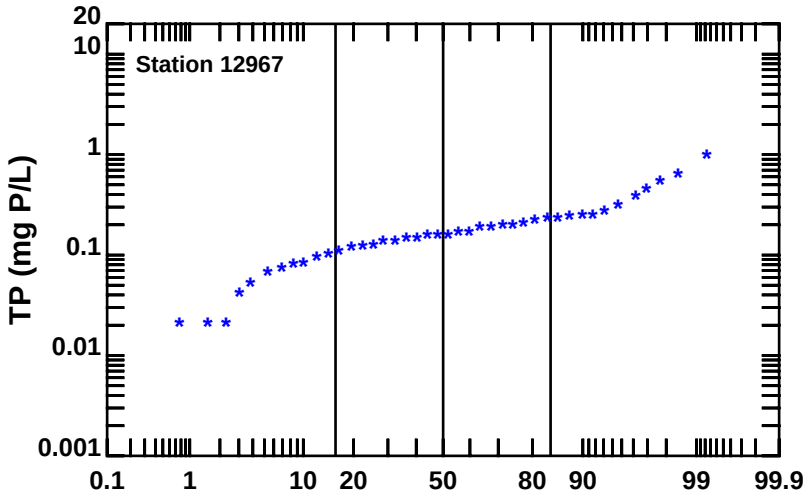

Station 13023
Flow (cfs)
100000
10000
1000
100
10
1
0.1
0.01
0.1
1
10
20
50
80
90
99
99.9

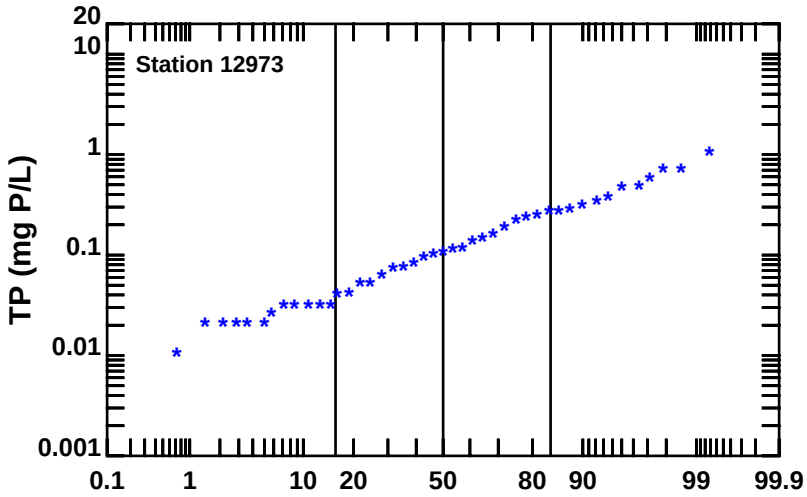

Station 12960
SRP (mg P/L)
10
1
0.1
0.01
0.001
0.1
1
10
20
50
80
90
99
99.9

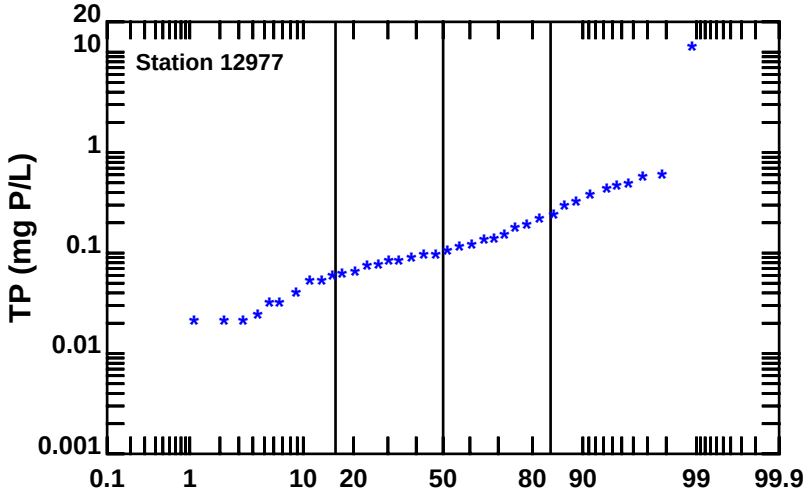

Station 12979
SRP (mg P/L)
10
1
0.1
0.01
0.001
0.1
1
10
20
50
80
90
99
99.9

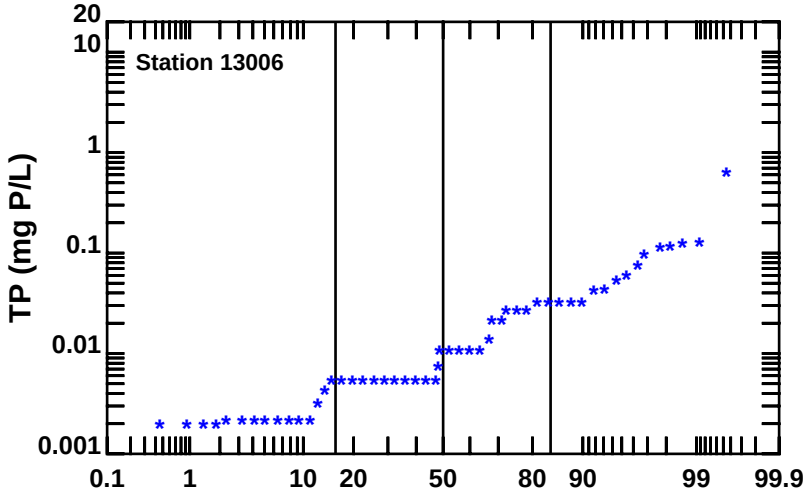

Station 12981
SRP (mg P/L)
10
1
0.1
0.01
0.001
0.1
1
10
20
50
80
90
99
99.9

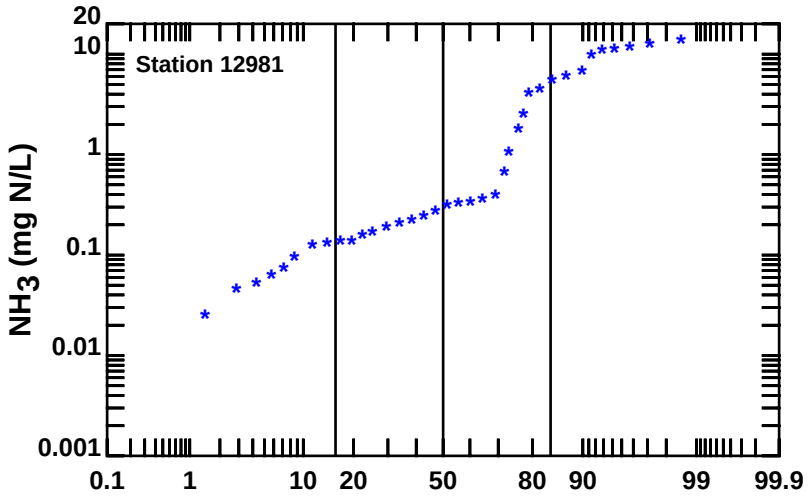

Station 13021
SRP (mg P/L)
10
1
0.1
0.01
0.001
0.1
1
10
20
50
80
90
99
99.9

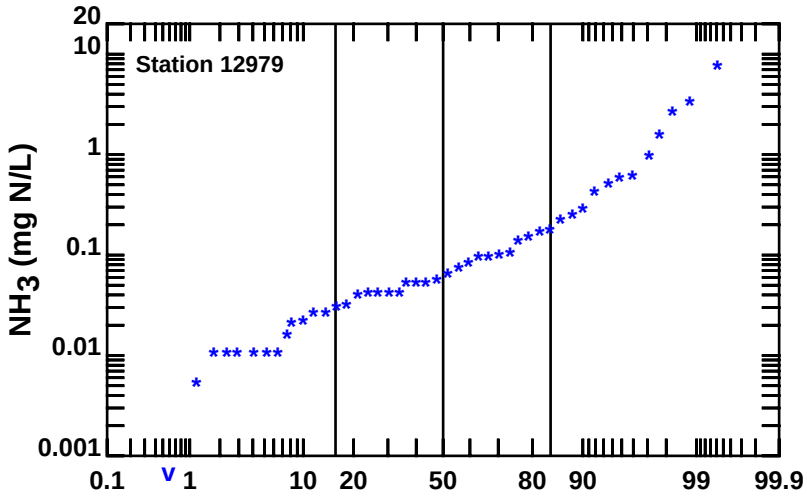

Station 12967
TP (mg P/L)
20
10
1
0.1
0.01
0.001
0.1
1
10
20
50
80
90
99
99.9

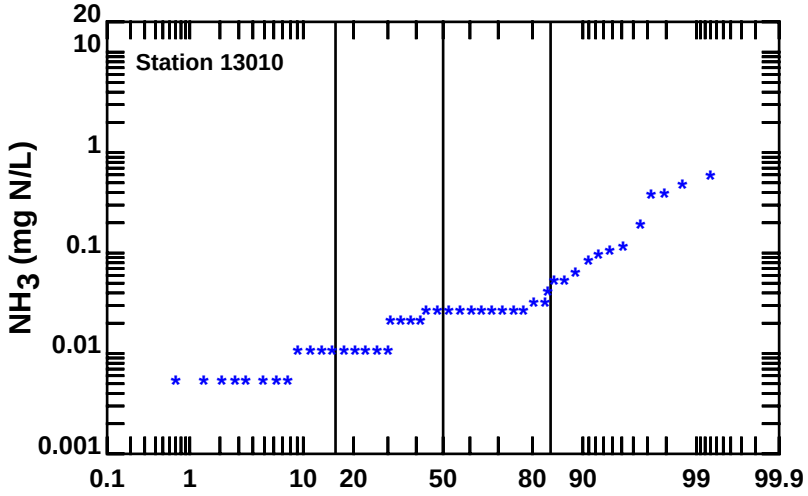

Station 12973
TP (mg P/L)
20
10
1
0.1
0.01
0.001
0.1
1
10
20
50
80
90
99
99.9

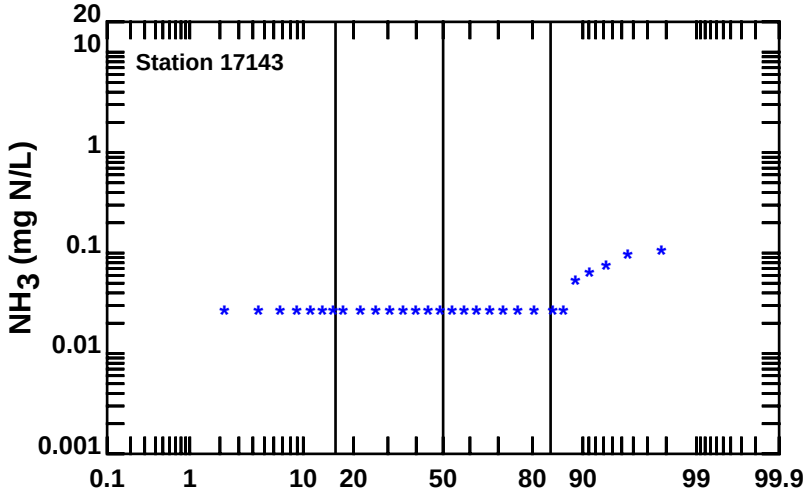

Station 12977
TP (mg P/L)
20
10
1
0.1
0.01
0.001
0.1
1
10
20
50
80
90
99
99.9

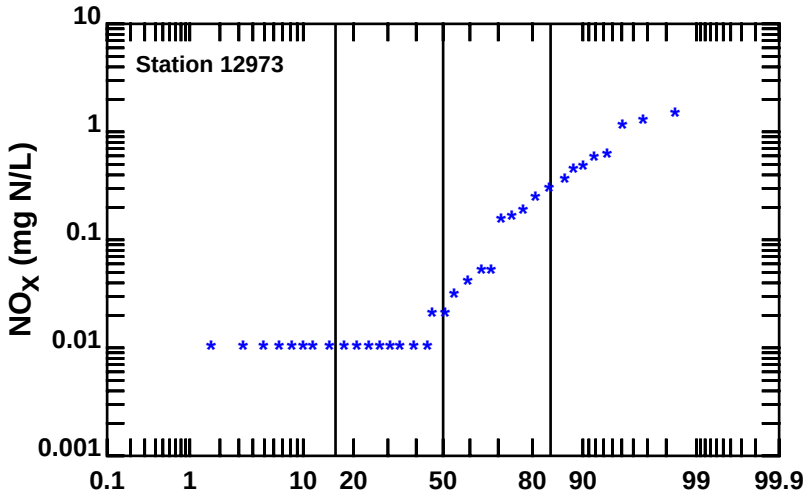

Station 13006
TP (mg P/L)
20
10
1
0.1
0.01
0.001
0.1
1
10
20
50
80
90
99
99.9

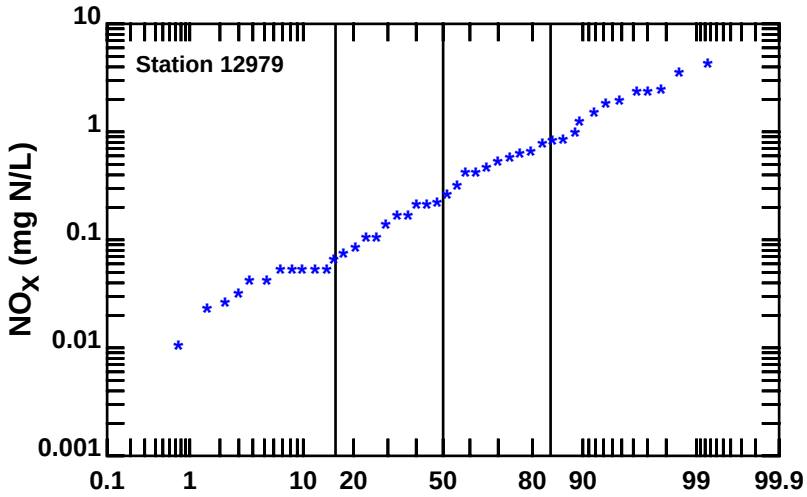

Station 12981
NH3 (mg N/L)
20
10
1
0.1
0.01
0.001
0.1
1
10
20
50
80
90
99
99.9

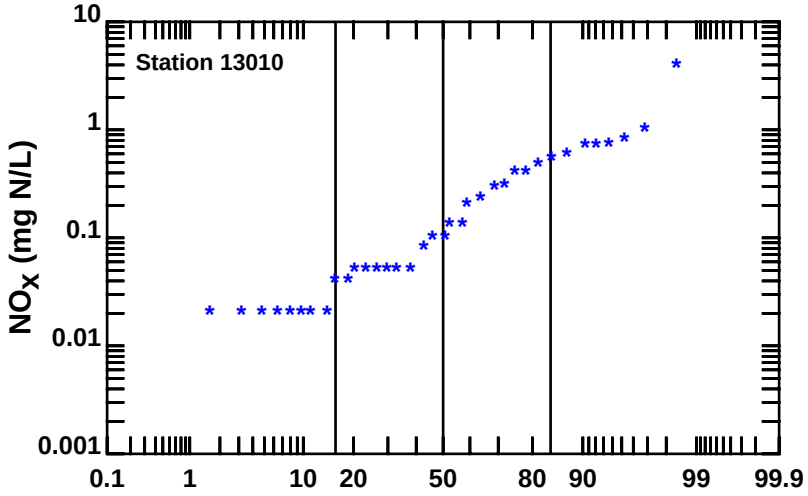

Station 12979
NH3 (mg N/L)
20
10
1
0.1
0.01
0.001
0.1
1
10
20
50
80
90
99
99.9

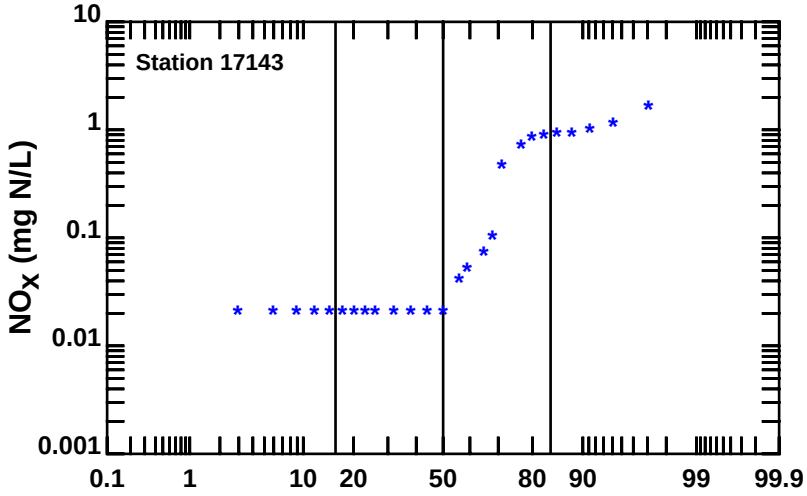

Station 13010
NH3 (mg N/L)
20
10
1
0.1
0.01
0.001
0.1
1
10
20
50
80
90
99
99.9

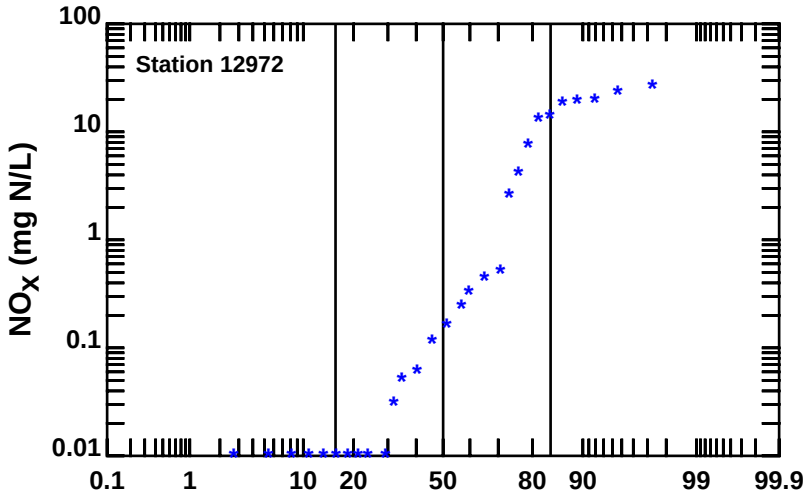

Station 17143
NH3 (mg N/L)
20
10
1
0.1
0.01
0.001
0.1
1
10
20
50
80
90
99
99.9

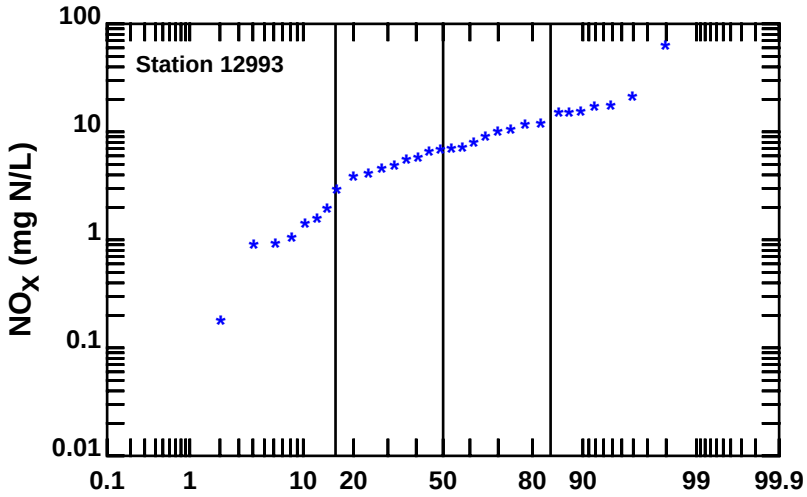

Station 12973
NOX (mg N/L)
10
1
0.1
0.01
0.001
0.1
1
10
20
50
80
90
99
99.9

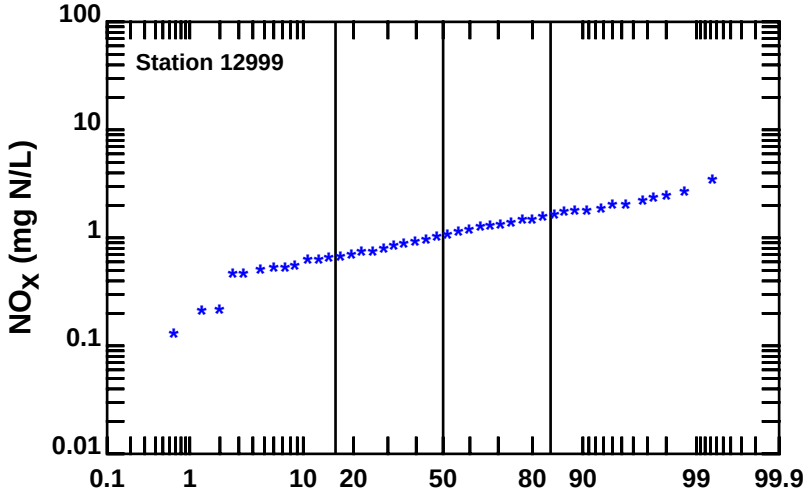

Station 12979
NOX (mg N/L)
10
1
0.1
0.01
0.001
0.1
1
10
20
50
80
90
99
99.9

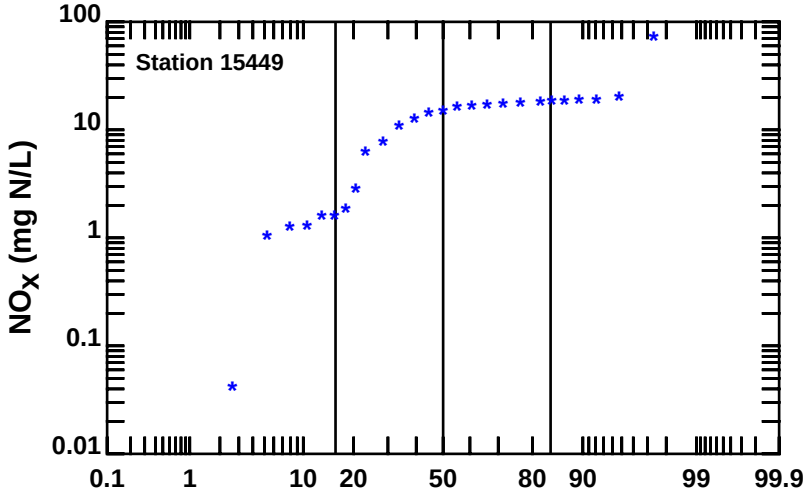

Station 13010
NOX (mg N/L)
10
1
0.1
0.01
0.001
0.1
1
10
20
50
80
90
99
99.9

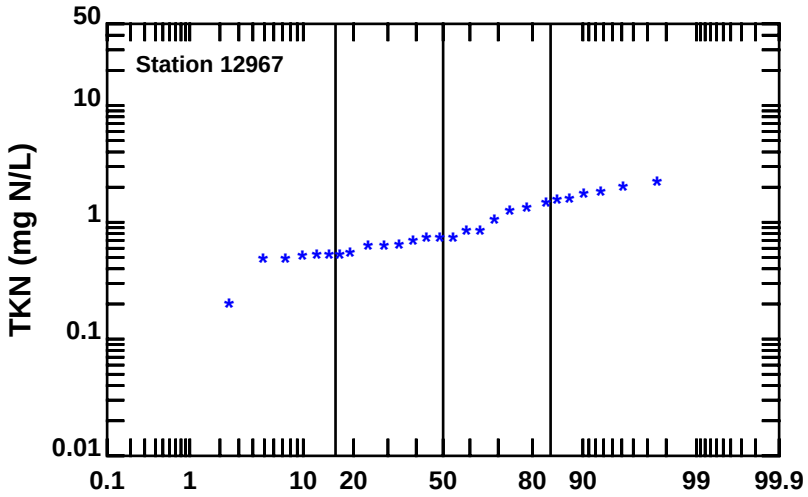

Station 17143
NOX (mg N/L)
10
1
0.1
0.01
0.001
0.1
1
10
20
50
80
90
99
99.9

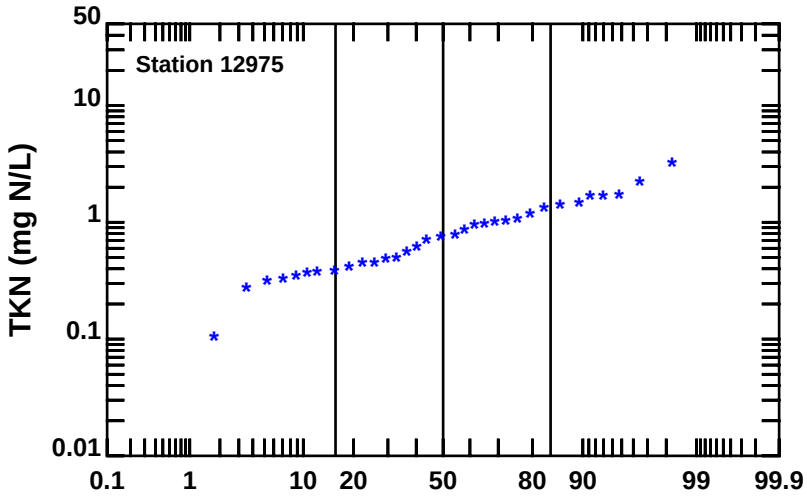

Station 12972
NOX (mg N/L)
100
10
1
0.1
0.01
0.1
1
10
20
50
80
90
99
99.9

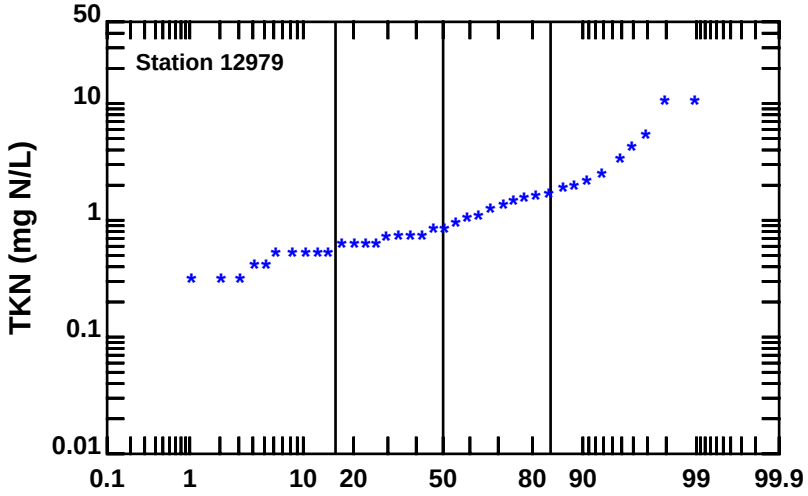

Station 12993
NOX (mg N/L)
100
10
1
0.1
0.01
0.1
1
10
20
50
80
90
99
99.9

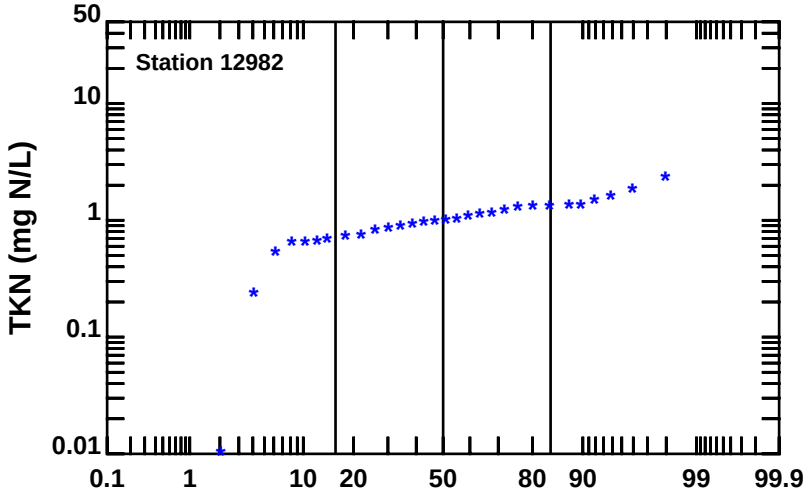

Station 12999
NOX (mg N/L)
100
10
1
0.1
0.01
0.1
1
10
20
50
80
90
99
99.9

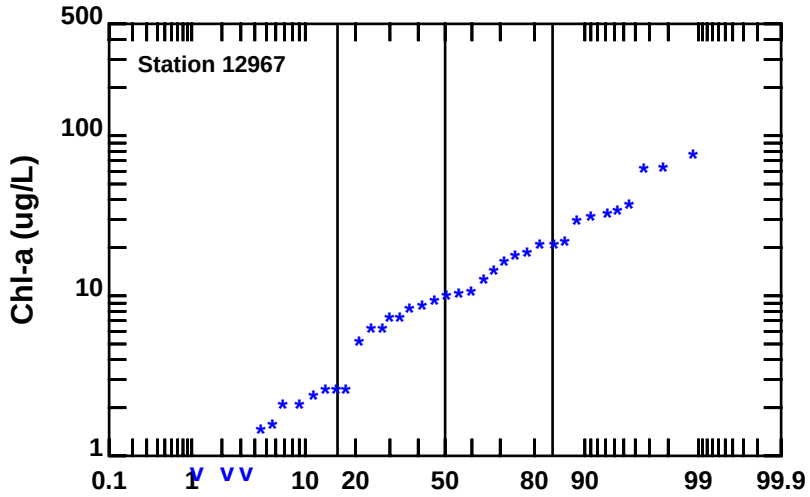

Station 15449
NOX (mg N/L)
100
10
1
0.1
0.01
0.1
1
10
20
50
80
90
99
99.9

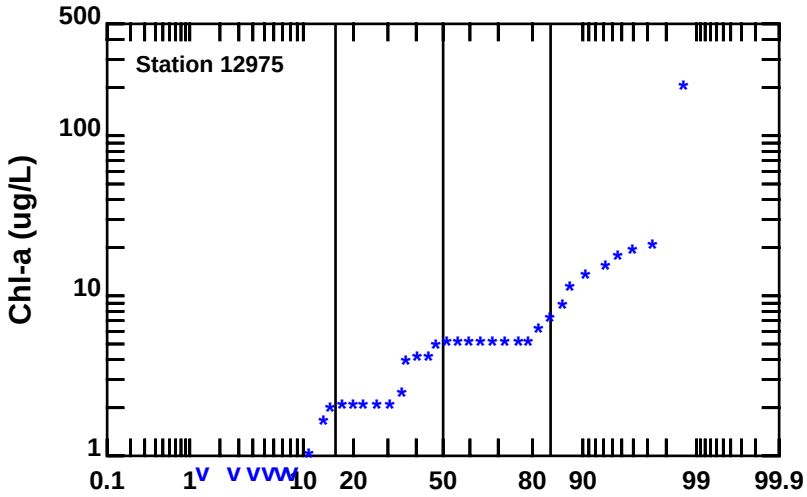

Station 12967
TKN (mg N/L)
50
10
1
0.1
0.01
0.1
1
10
20
50
80
90
99
99.9

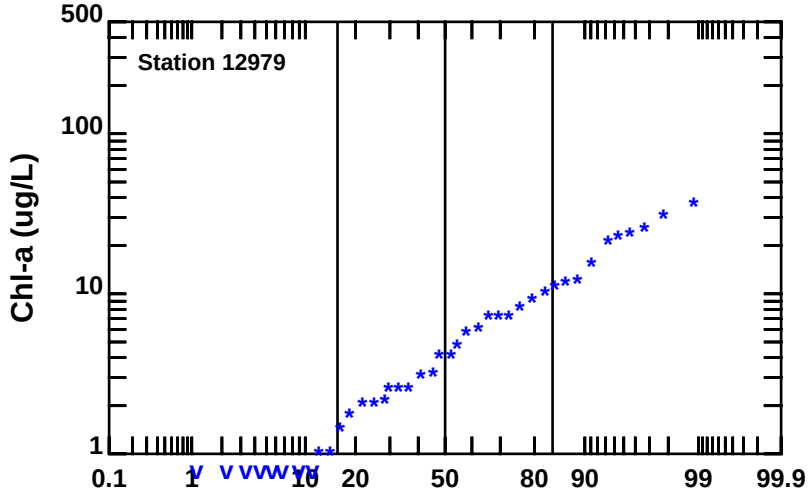

Station 12975
TKN (mg N/L)
50
10
1
0.1
0.01
0.1
1
10
20
50
80
90
99
99.9

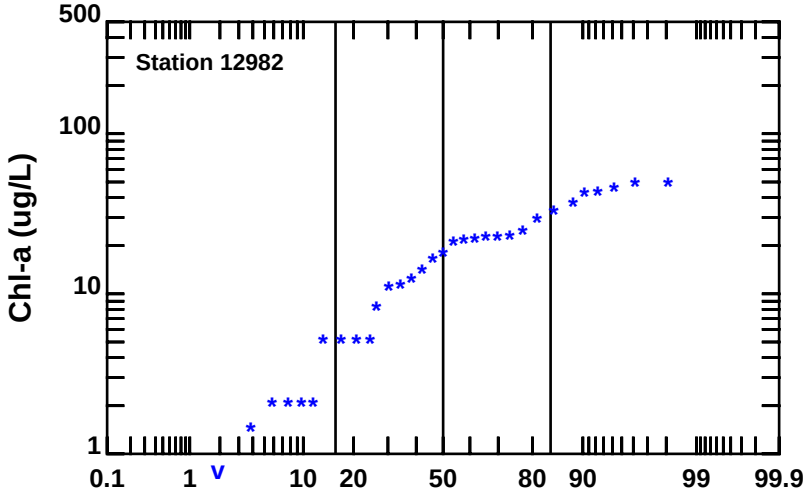

Station 12979
TKN (mg N/L)
50
10
1
0.1
0.01
0.1
1
10
20
50
80
90
99
99.9


Station 12982
TKN (mg N/L)
50
10
1
0.1
0.01
0.1
1
10
20
50
80
90
99
99.9


Station 12967
Chl-a (ug/L)
500
100
10
1
0.1
1
10
20
50
80
90
99
99.9


Station 12975
Chl-a (ug/L)
500
100
10
1
0.1
1
10
20
50
80
90
99
99.9


Station 12979
Chl-a (ug/L)
500
100
10
1
0.1
1
10
20
50
80
90
99
99.9


Station 12982
Chl-a (ug/L)
500
100
10
1
0.1
1
10
20
50
80
90
99
99.9

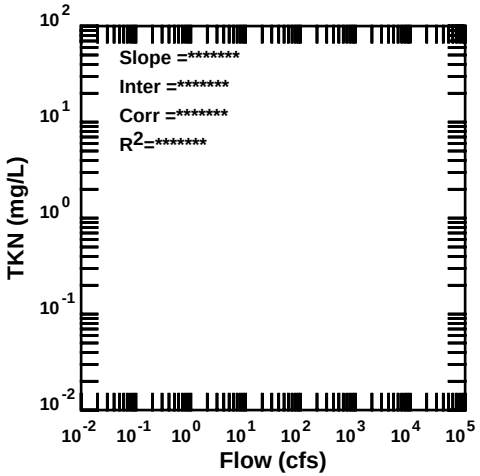
Appendix E. Nueces Basin regression analysis figures.

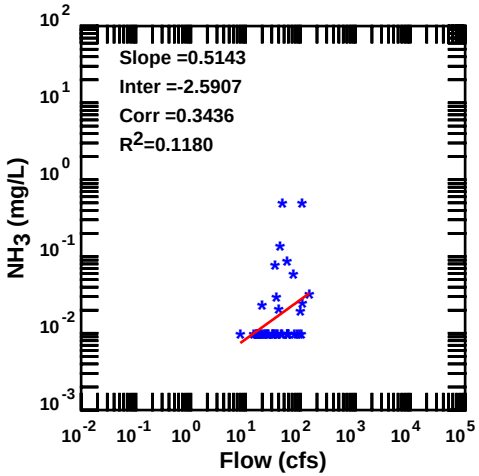
The appendix is organized into the following sections:

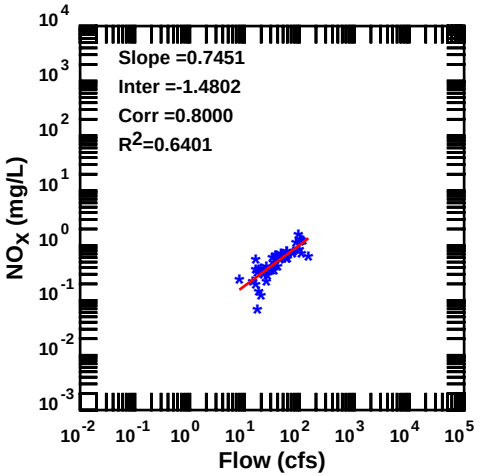
1. Instantaneous flow vs. constituent concentration regressions
    a. x-axis shows flow (cfs); y-axis shows constituent concentration (µg/L for chl-a, mg/L for all other constituents)
2. Linear regression analysis: observed and estimated constituent concentrations
    a. x-axis shows time (yrs); y-axis shows constituent concentration (µg/L for chl-a, mg/L for all other constituents)
3. LOADEST analysis: observed and estimated constituent concentrations
    a. x-axis shows time (yrs); y-axis shows constituent concentration (µg/L for chl-a, mg/L for all other constituents)
4. Linear regression analysis: observed and estimated constituent load
    a. x-axis shows time (yrs); y-axis shows load (kg/day)
5. LOADEST analysis: observed and estimated constituent load
    a. x-axis shows time (yrs); y-axis shows load (kg/day)
6. Linear regression analysis: observed vs. estimated concentrations
    a. x-axis shows estimated constituent concentration (µg/L for chl-a, mg/L for all other constituents); y-axis shows observed constituent concentration (µg/L for chl-a, mg/L for all other constituents)
7. LOADEST analysis: observed vs. estimated concentrations
    a. x-axis shows estimated constituent concentration (µg/L for chl-a, mg/L for all other constituents); y-axis shows observed constituent concentration (µg/L for chl-a, mg/L for all other constituents)
8. Linear regression analysis: observed vs. estimated loads
    a. x-axis shows estimated constituent load (kg/day); y-axis shows observed constituent load (kg/day)
9. LOADEST analysis: observed vs. estimated loads
    a. x-axis shows estimated constituent load (kg/day); y-axis shows observed constituent load (kg/day)
10. Linear regression analysis: observed and estimated constituent concentrations
    a. x-axis shows flow (cfs); y-axis shows constituent concentration (µg/L for chl-a, mg/L for all other constituents)
11. Linear regression analysis: Time series of estimated and observed constituent concentration
    a. x-axis shows time (yrs); y-axis shows constituent concentration (µg/L for chl-a, mg/L for all other constituents)
12. LOADEST analysis: Time series of estimated and observed constituent concentration
    a. x-axis shows time (yrs); y-axis shows constituent concentration (µg/L for chl-a, mg/L for all other constituents)
13. Mission-Aransas (Basin ID 20) linear regression analysis: observed and estimated constituent concentrations

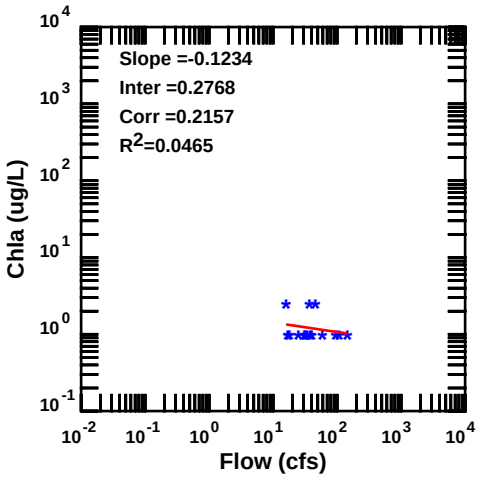
    a. x-axis shows time (yrs); y-axis shows constituent concentration (µg/L for chl-a, mg/L for all other constituents)

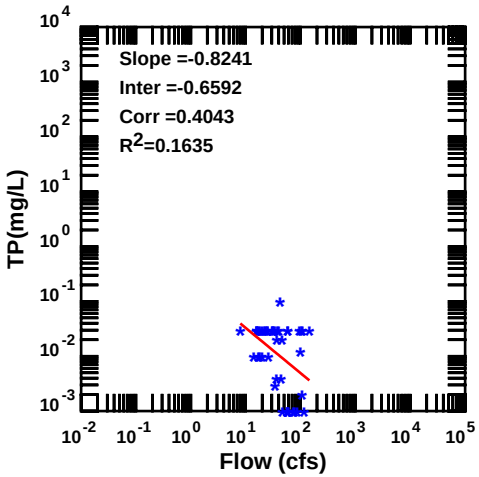
14. Mission-Aransas (Basin ID 20) LOADEST analysis: observed and estimated constituent concentrations
    a. x-axis shows time (yrs); y-axis shows constituent concentration (µg/L for chl-a, mg/L for all other constituents)
15. Mission-Aransas (Basin ID 20) linear regression analysis: observed and estimated constituent load
    a. x-axis shows time (yrs); y-axis shows load (kg/day)
16. Mission-Aransas (Basin ID 20) LOADEST analysis: observed and estimated constituent load
    a. x-axis shows time (yrs); y-axis shows load (kg/day)

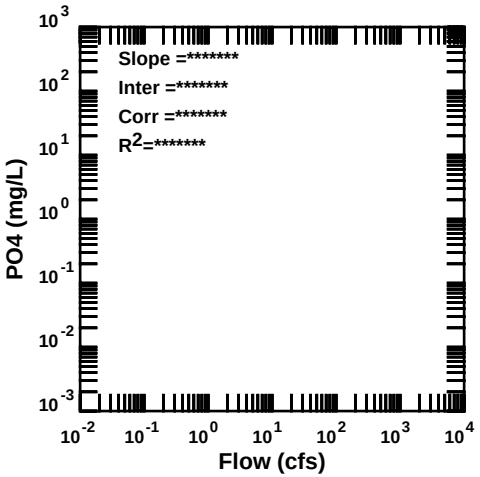






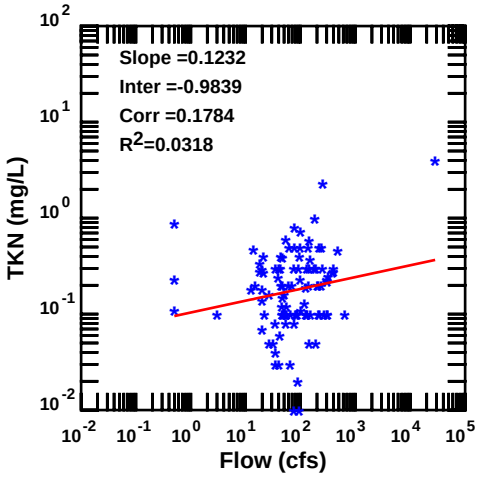


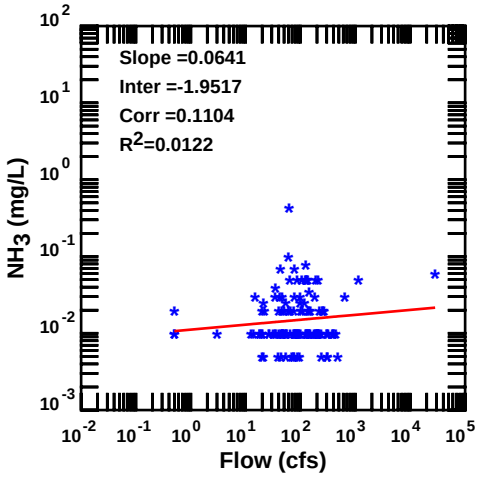


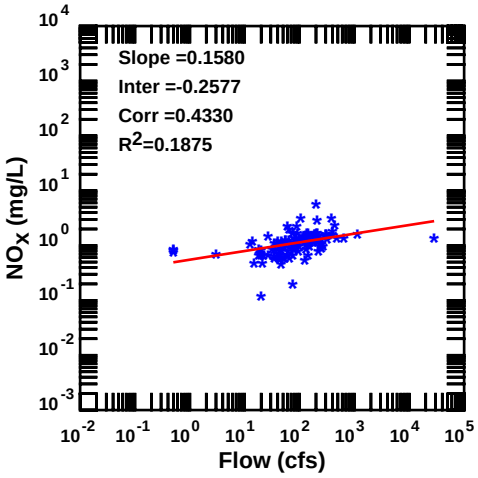


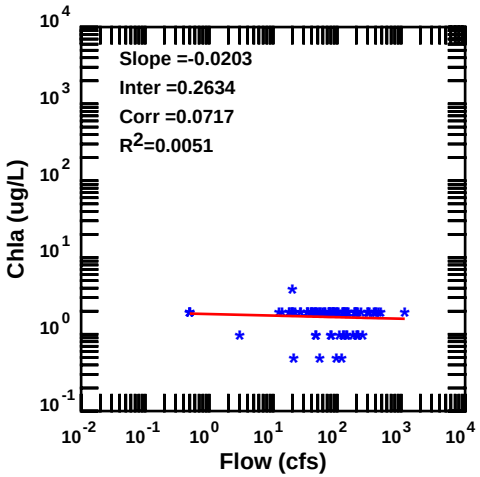
Regression analysis, Station 13005

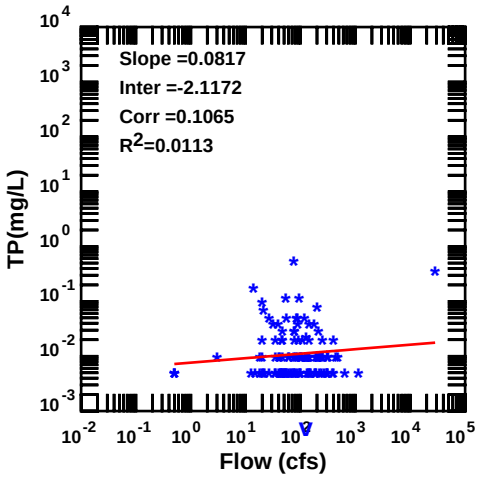
Nueces Tributaries, Texas (1970-2014)

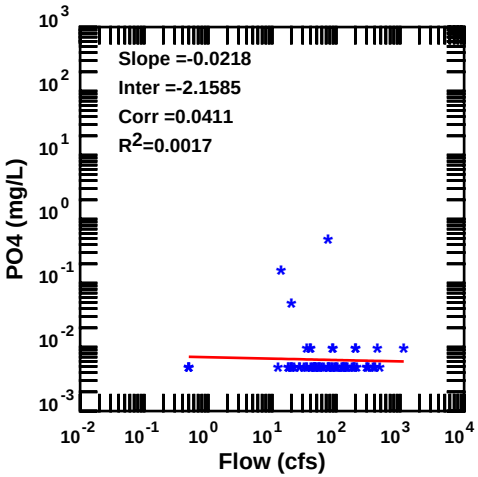






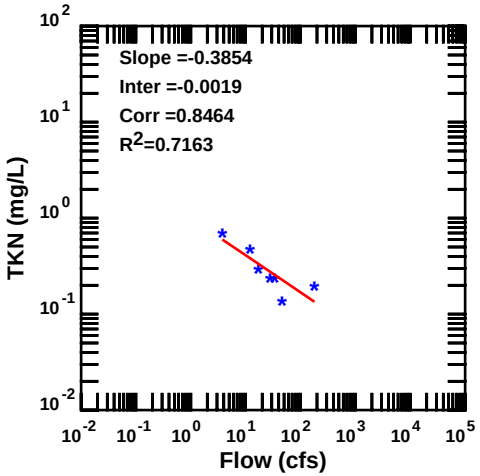


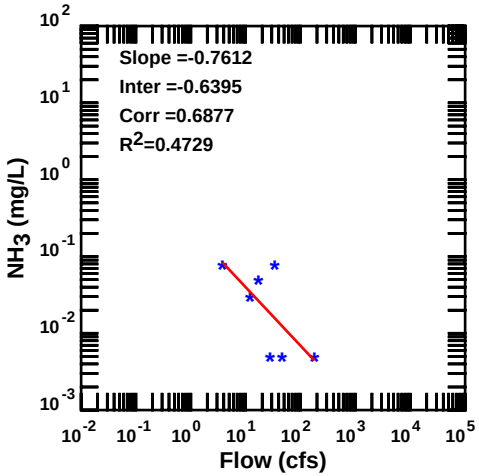


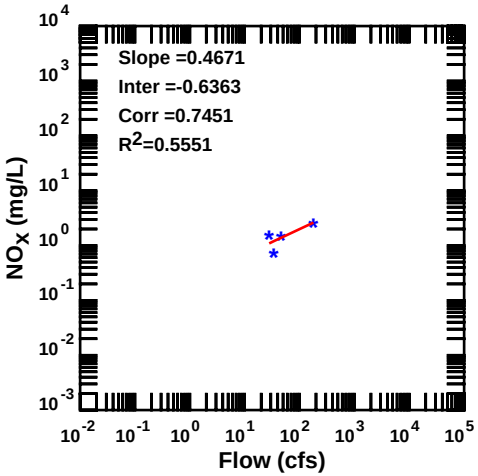


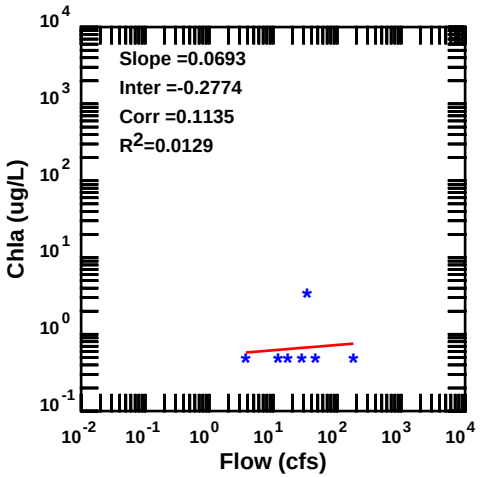
Regression analysis, Station 12999

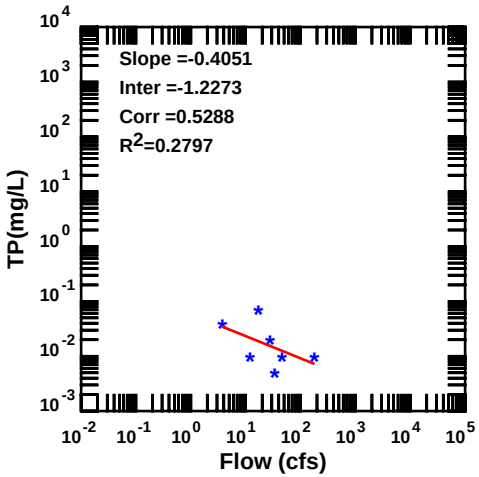
Nueces Tributaries, Texas (1970-2014)





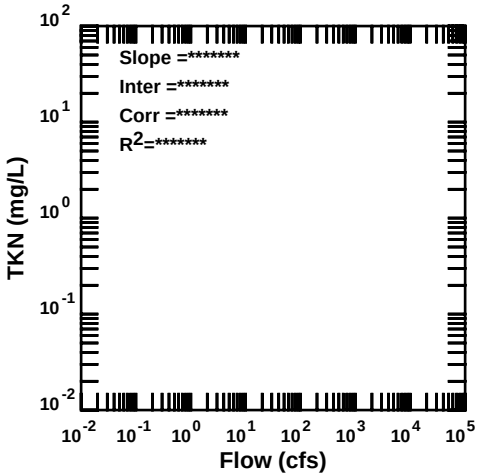


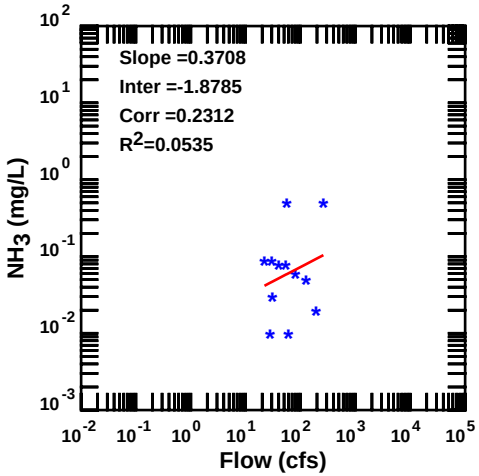


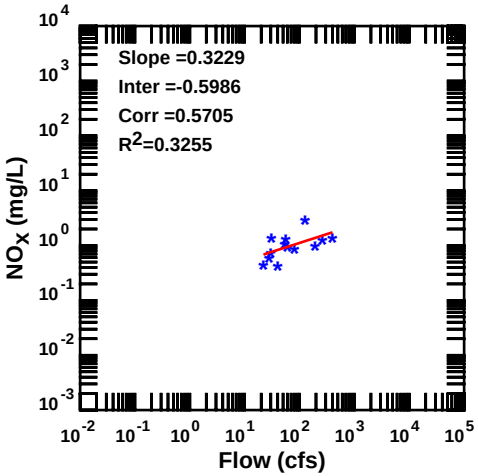


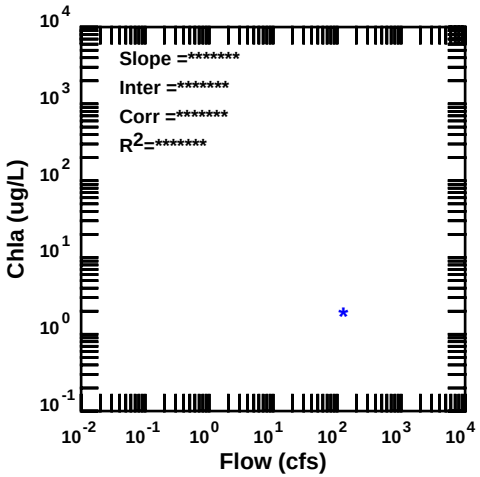
Regression analysis, Station 14253

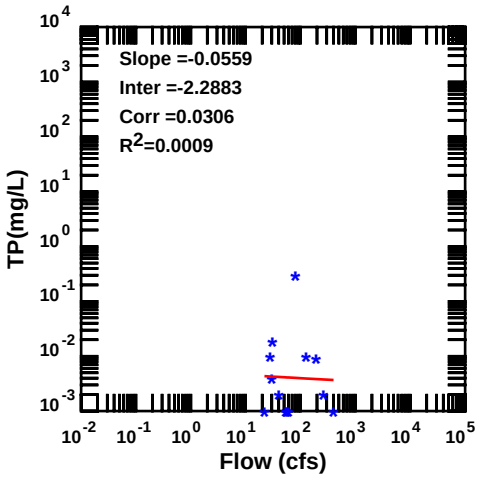
Nueces Tributaries, Texas (1970-2014)

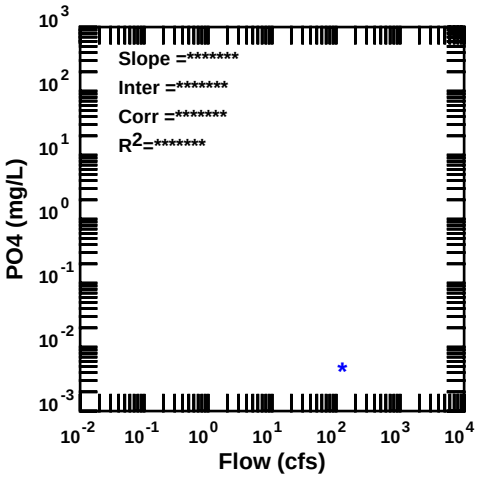






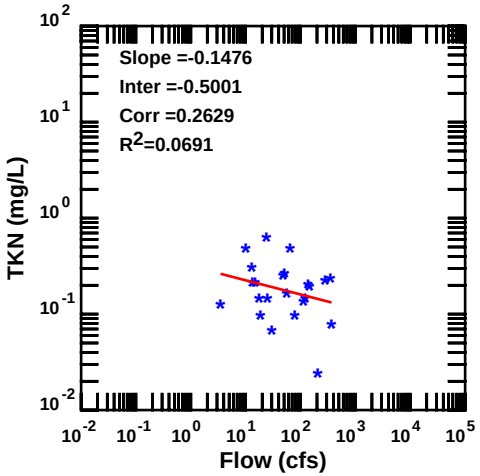


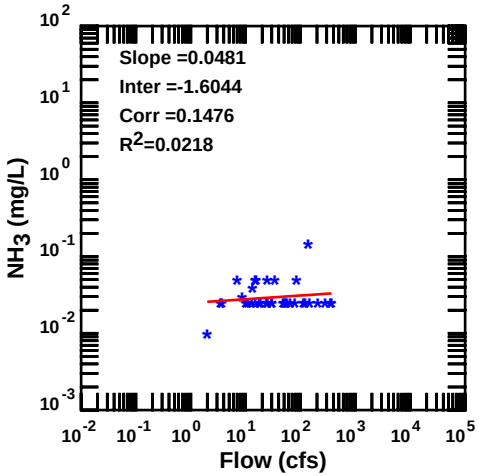


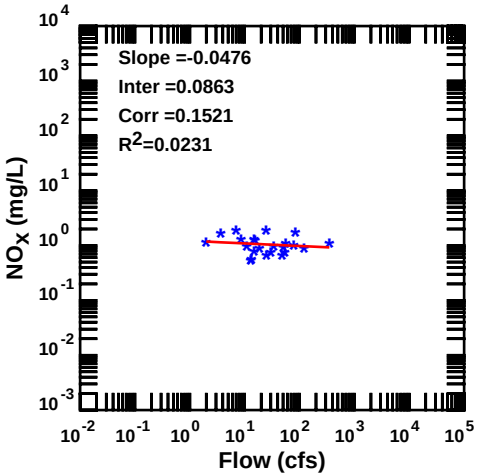


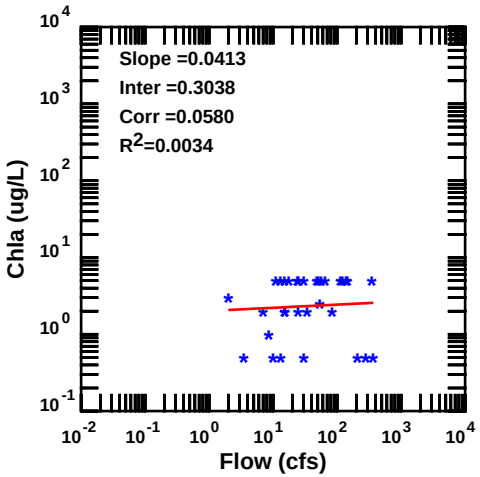
Regression analysis, Station 12997

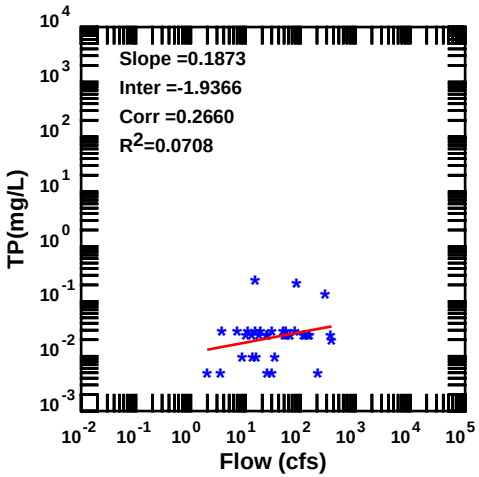
Nueces Tributaries, Texas (1970-2014)

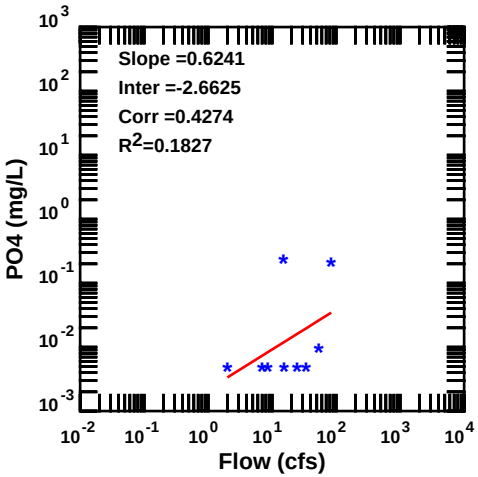






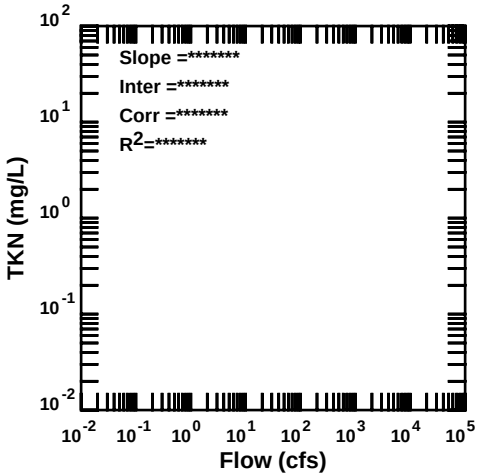


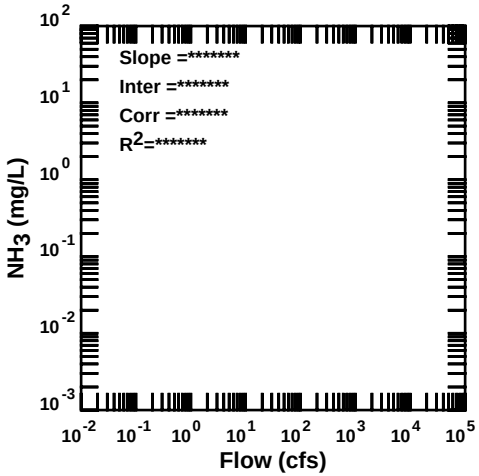


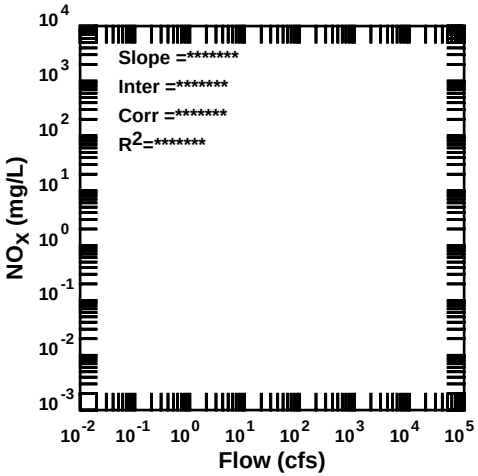


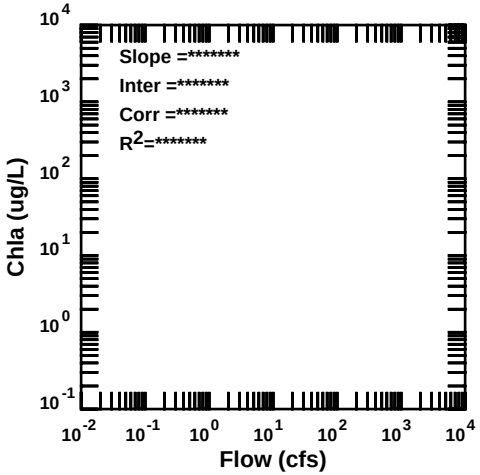
Regression analysis, Station 12996

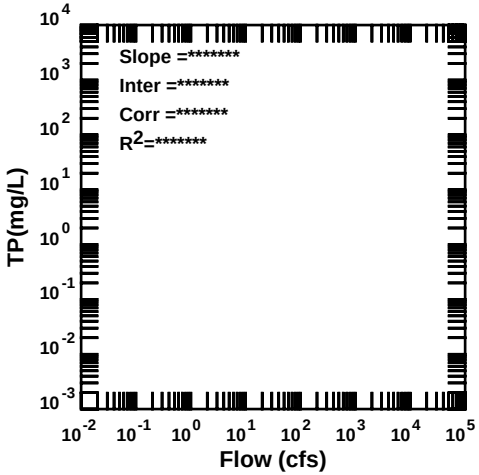
Nueces Tributaries, Texas (1970-2014)





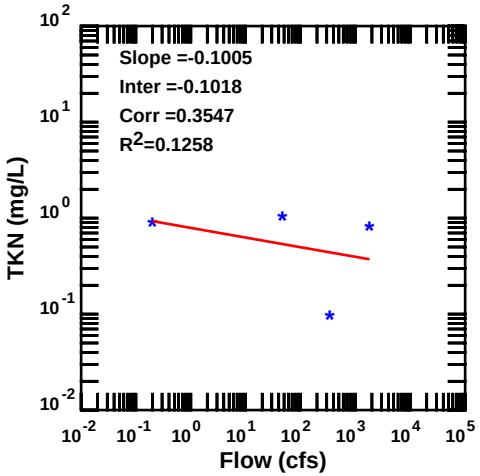


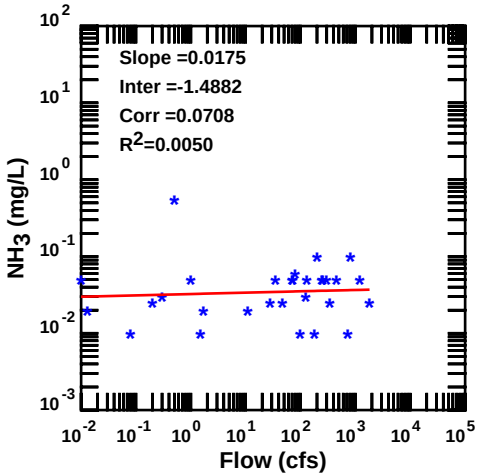


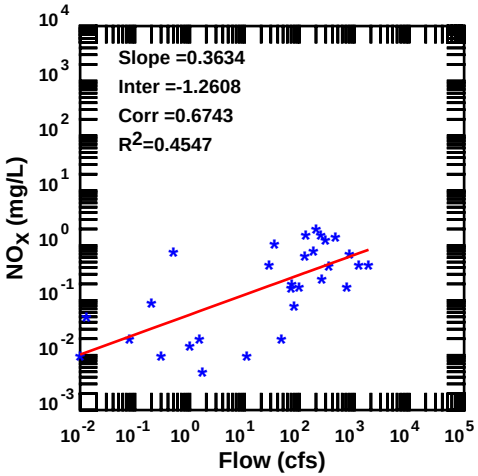


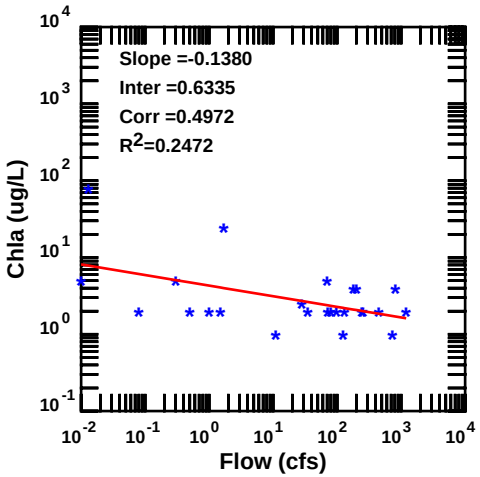
Regression analysis, Station 17143

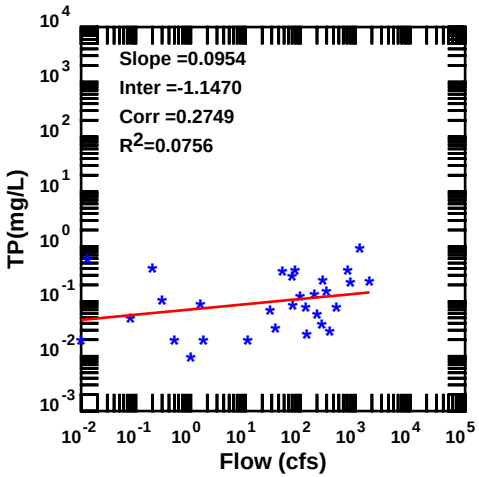
Nueces Tributaries, Texas (1970-2014)

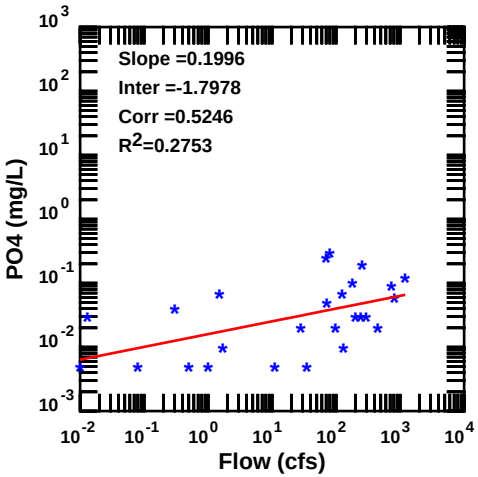






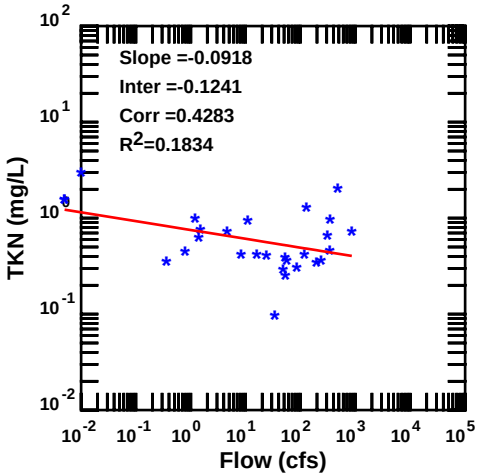


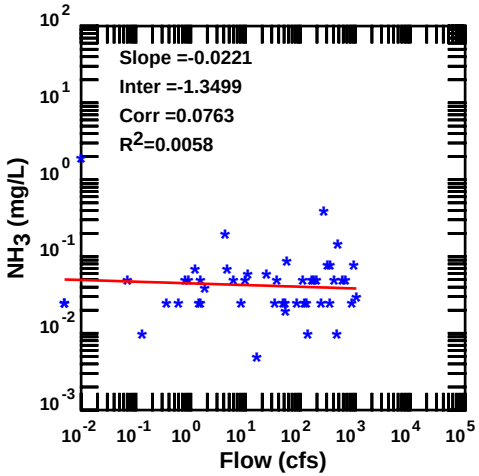


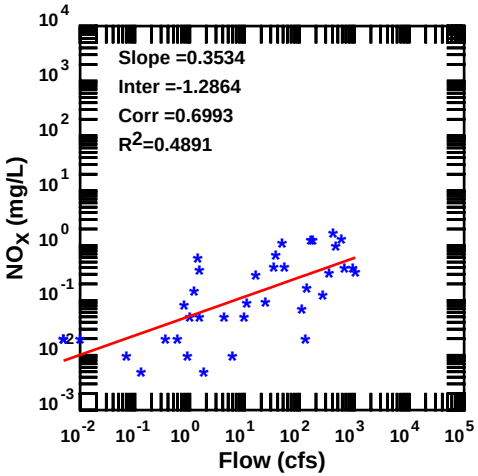


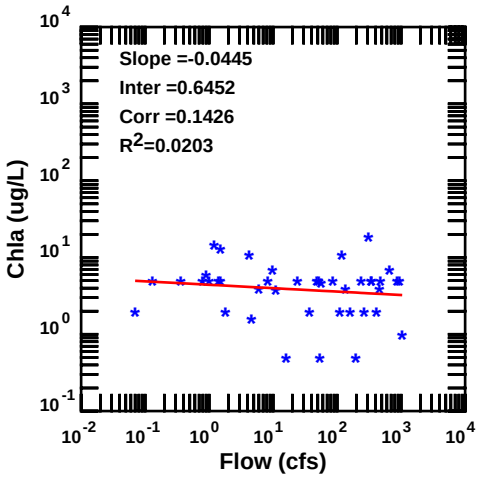
Regression analysis, Station 12976

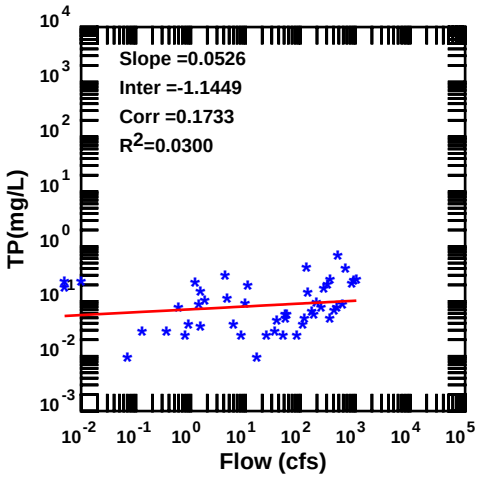
Nueces Tributaries, Texas (1970-2014)

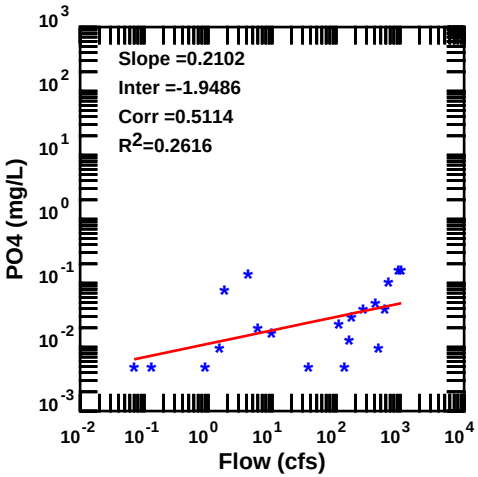






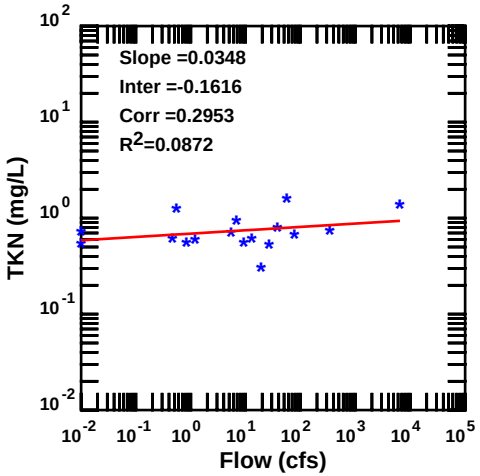


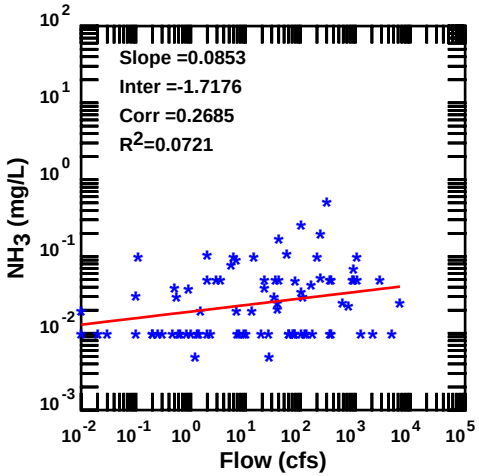


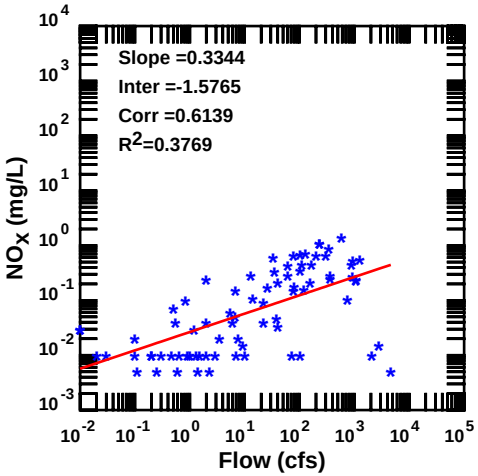


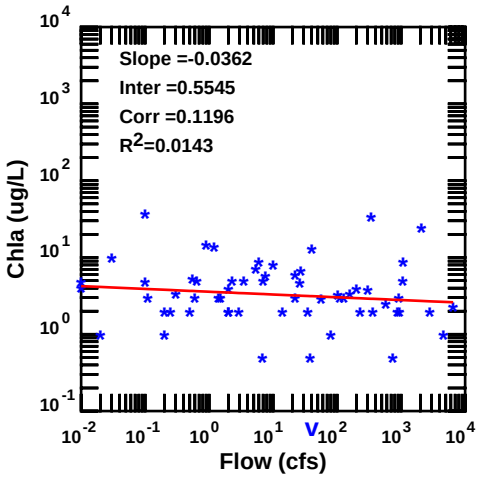
Regression analysis, Station 12975

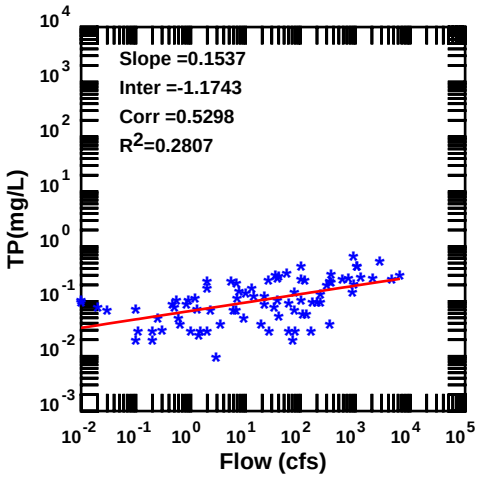
Nueces Tributaries, Texas (1970-2014)

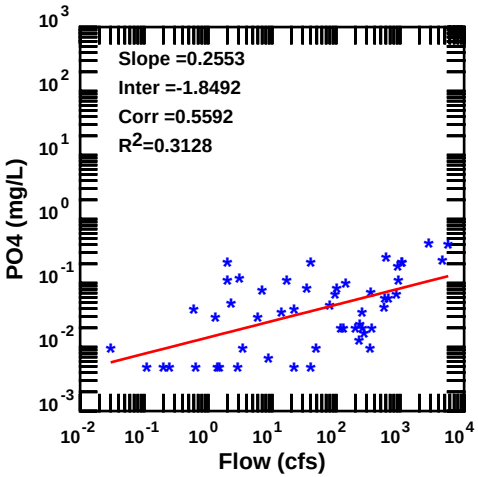






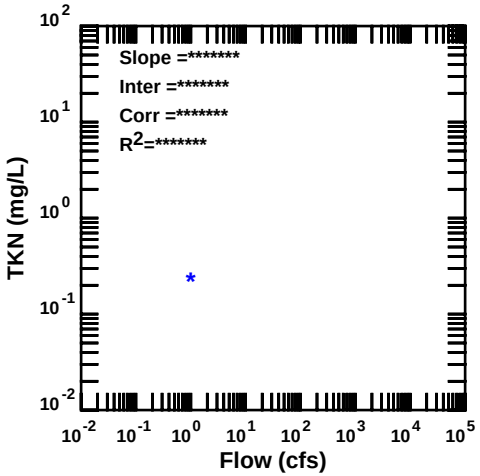


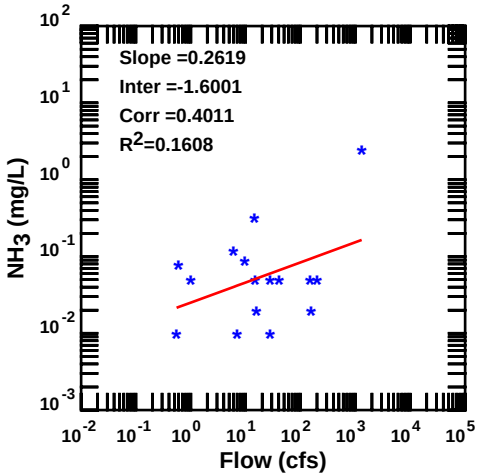


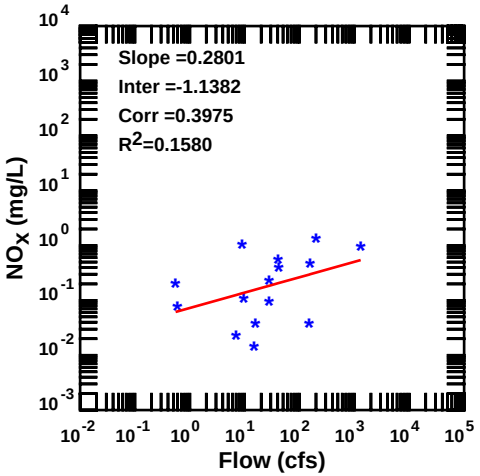


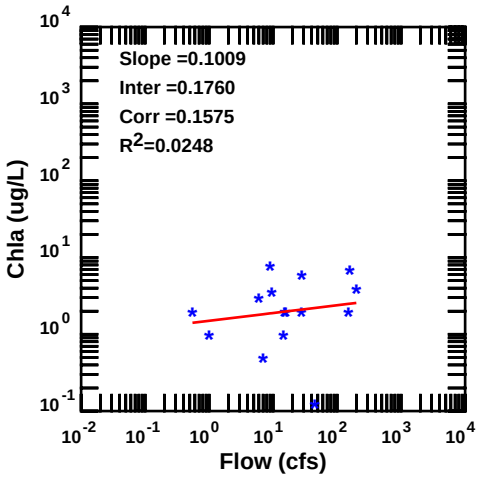
Regression analysis, Station 12973

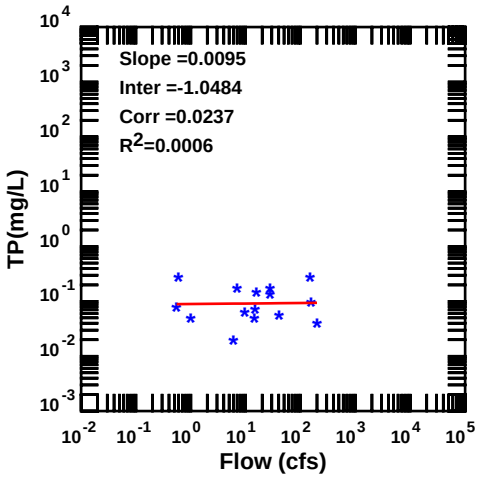
Nueces Tributaries, Texas (1970-2014)

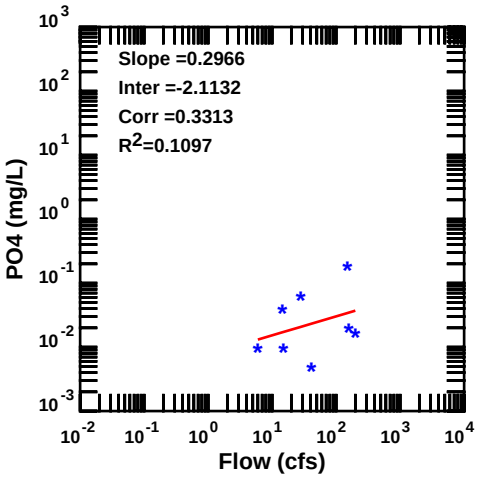






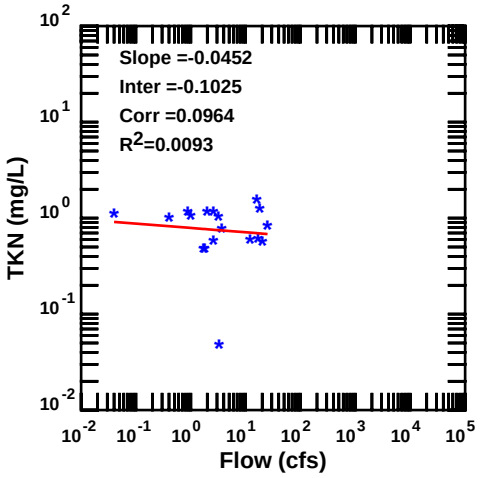


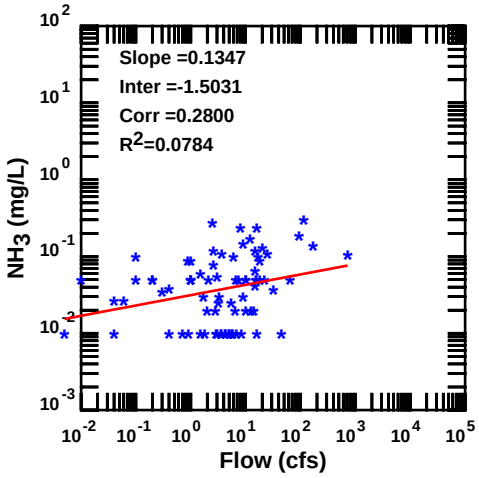


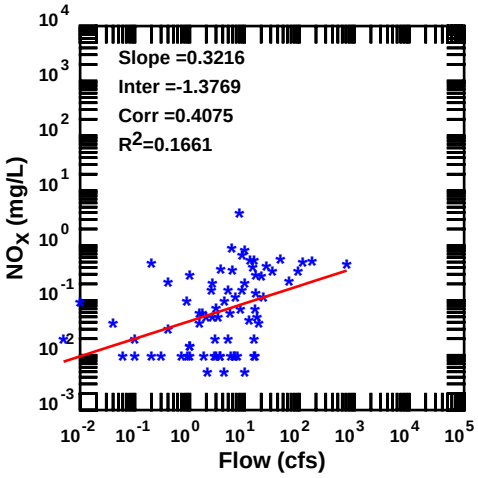


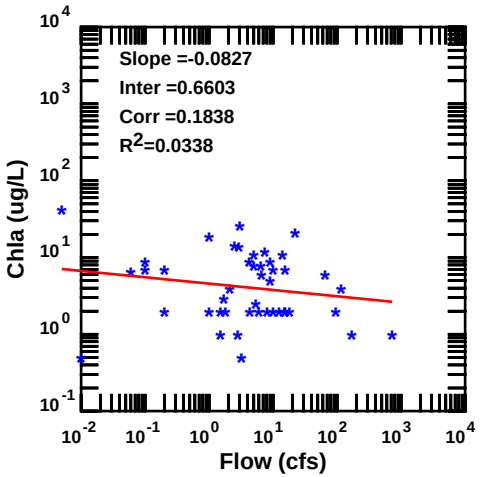
Regression analysis, Station 12972

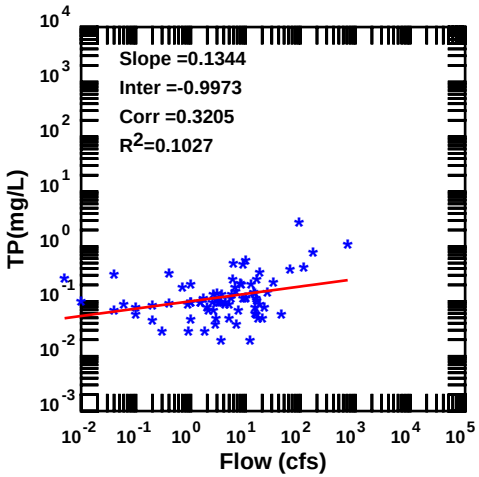
Nueces Tributaries, Texas (1970-2014)

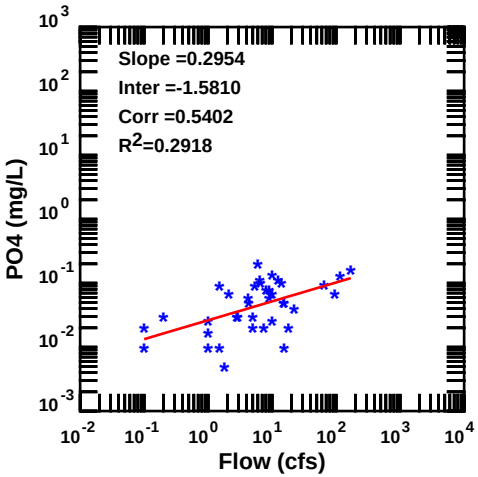






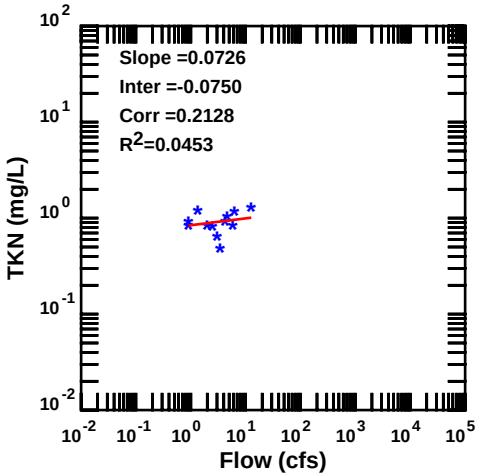


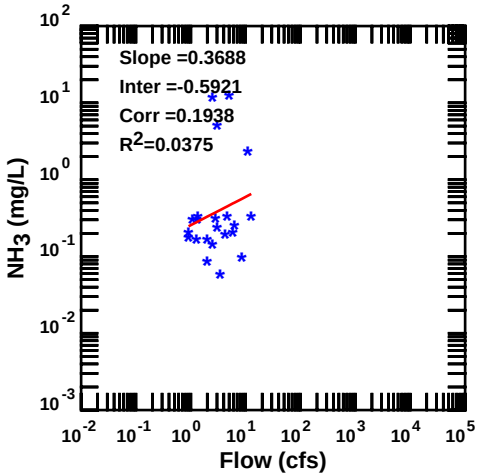


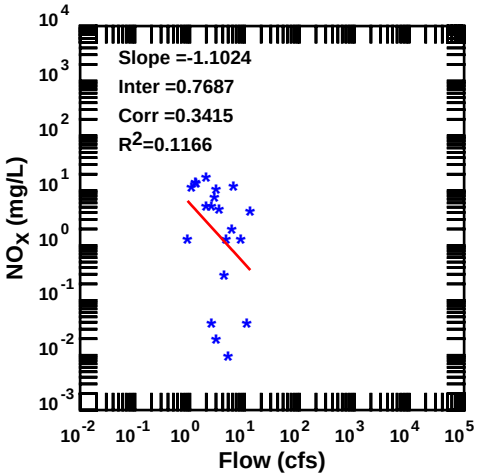


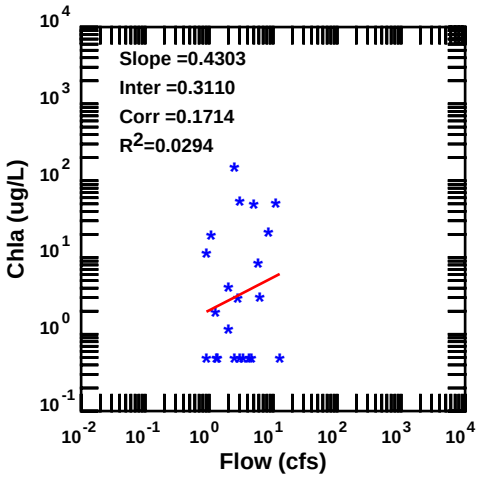
Regression analysis, Station 12983

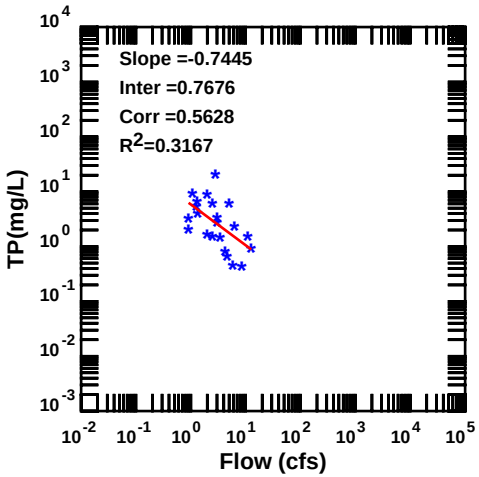
Nueces Tributaries, Texas (1970-2014)

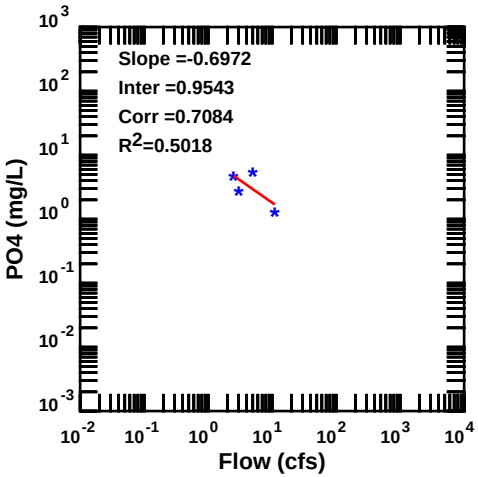






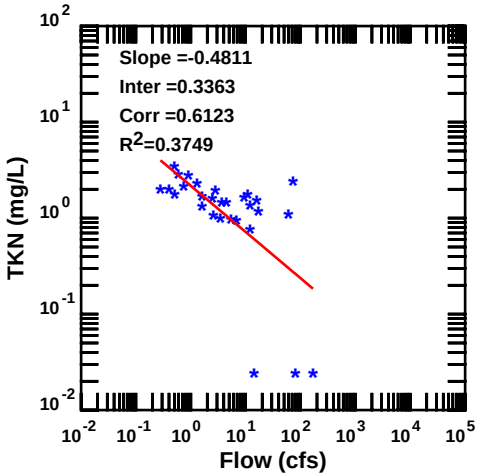


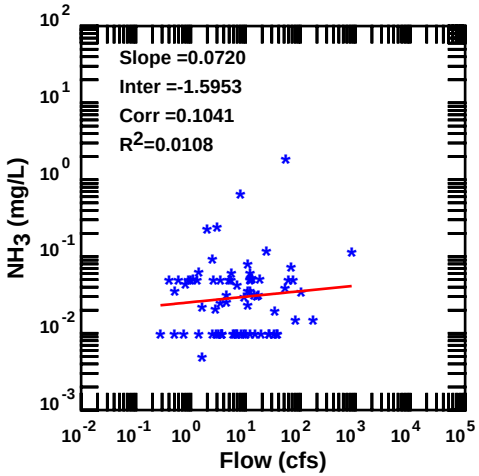


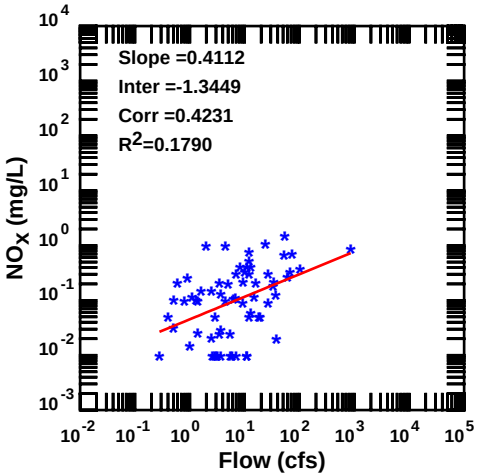


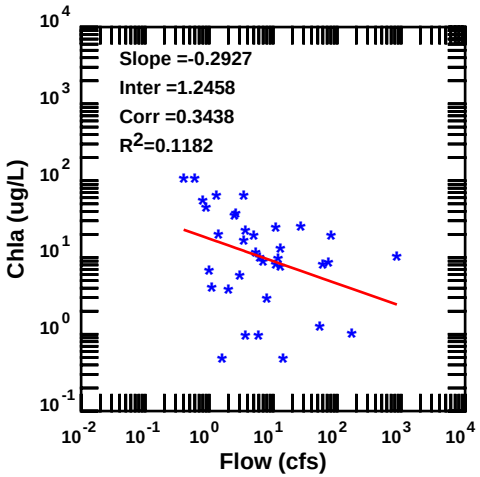
Regression analysis, Station 12981

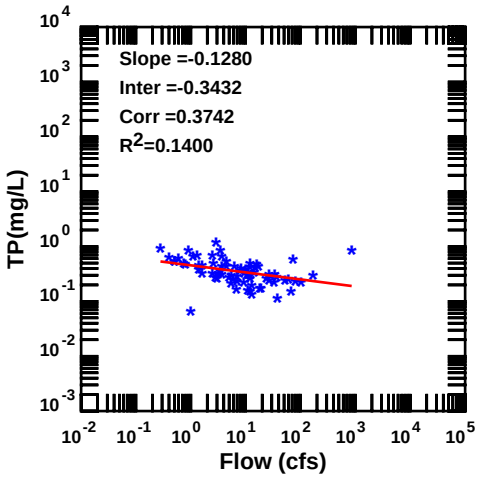
Nueces Tributaries, Texas (1970-2014)

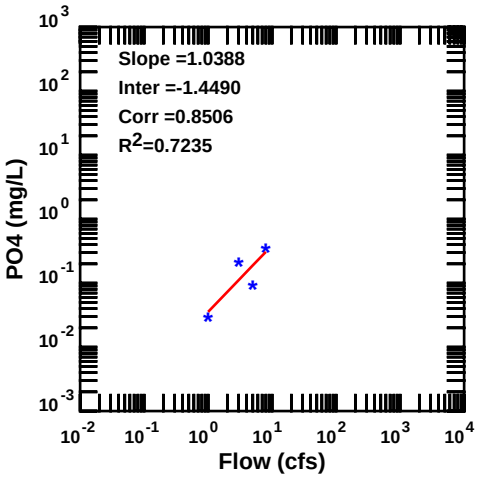






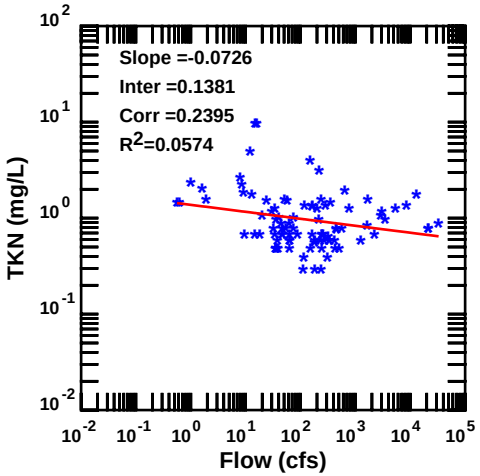


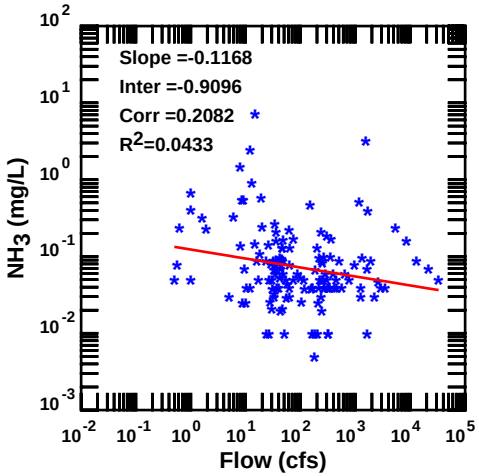


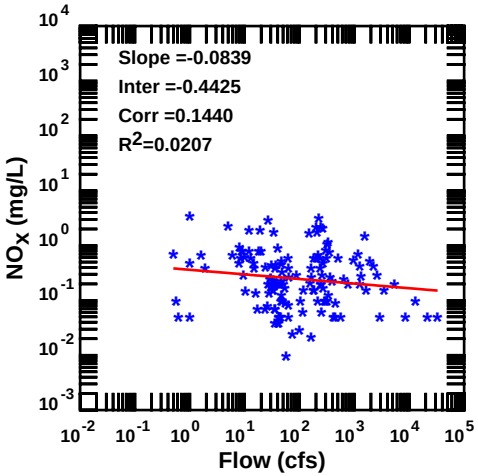


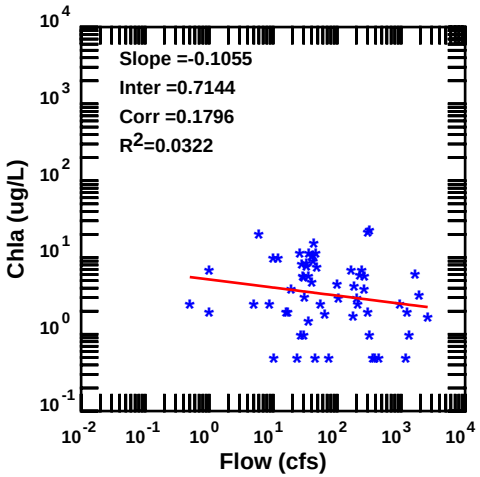
Regression analysis, Station 12980

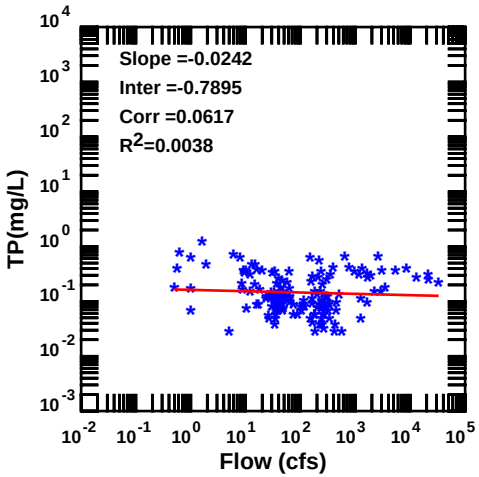
Nueces Tributaries, Texas (1970-2014)

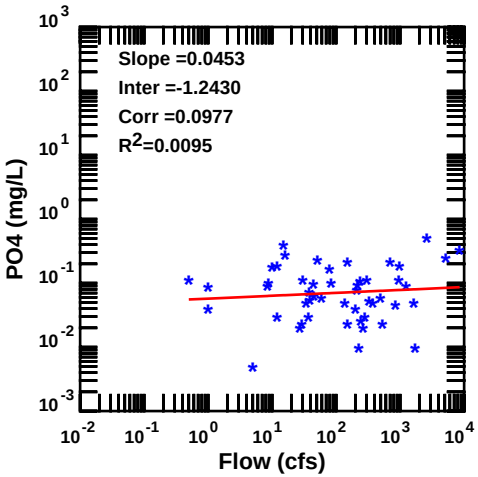






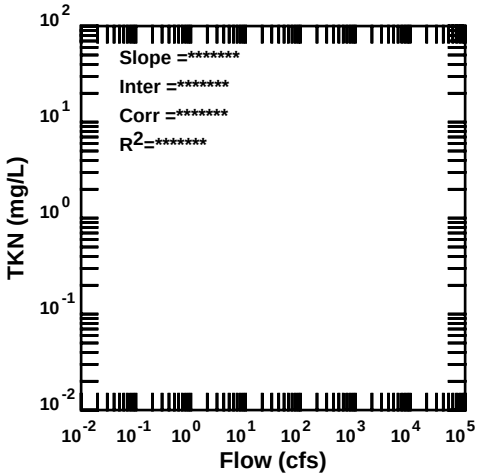


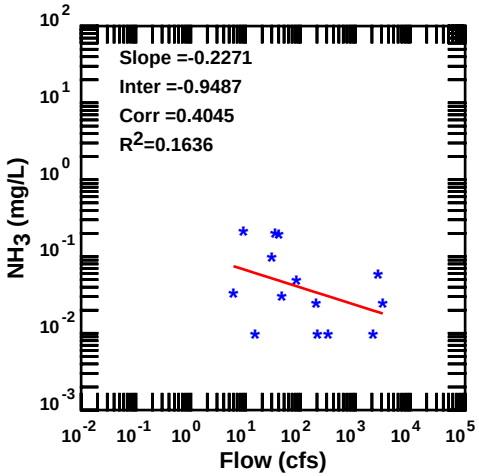


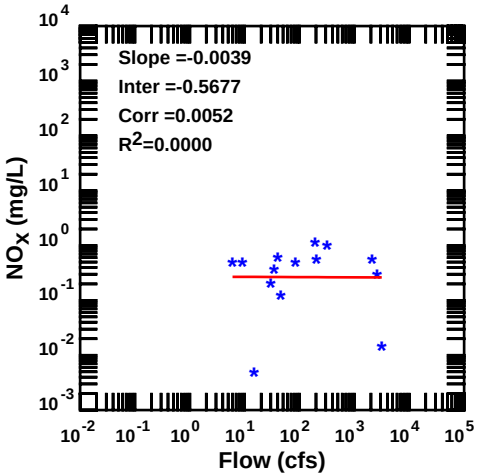


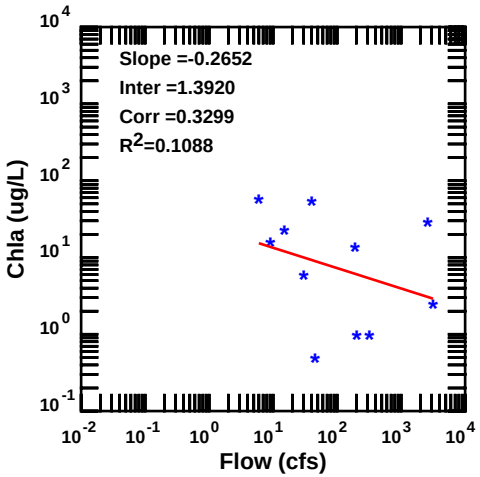
Regression analysis, Station 12979

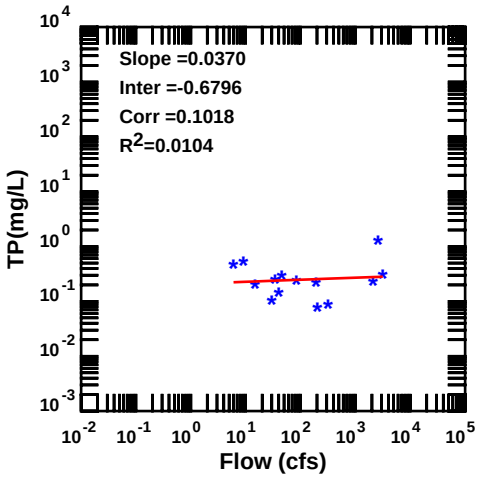
Nueces Tributaries, Texas (1970-2014)

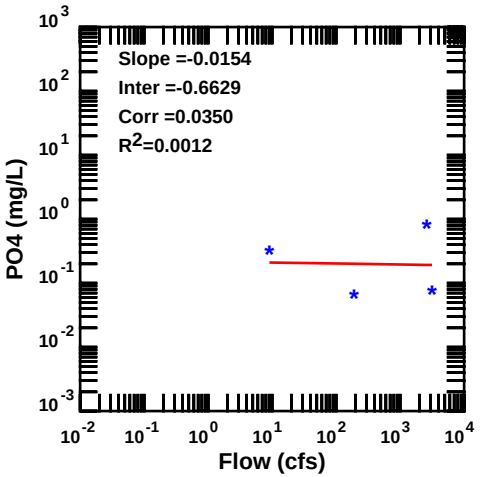






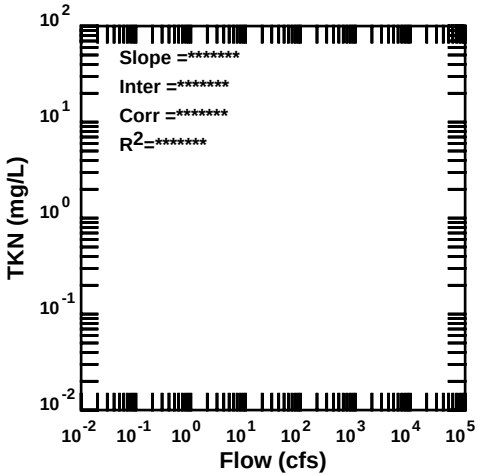


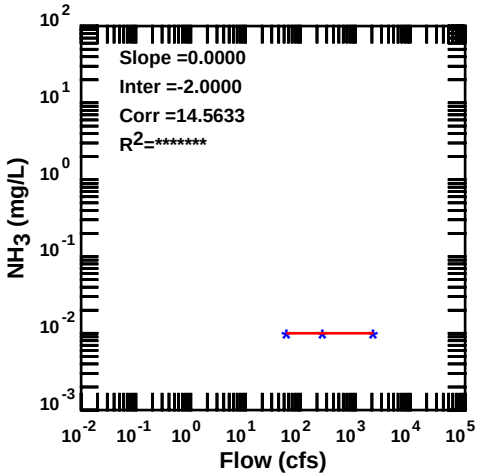


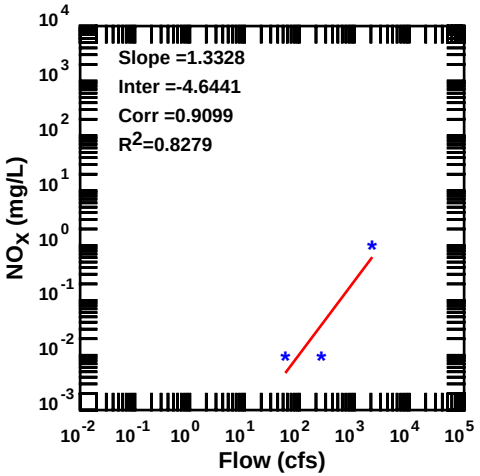


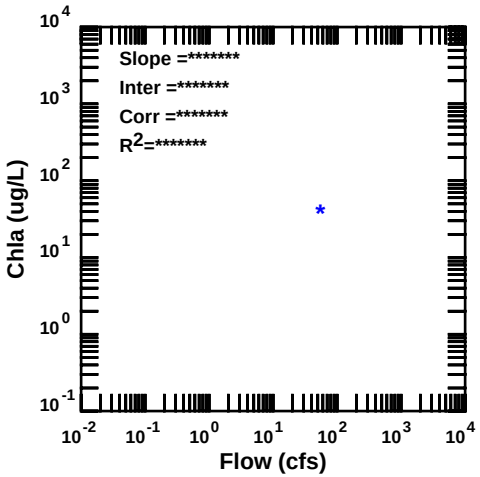
Regression analysis, Station 12978

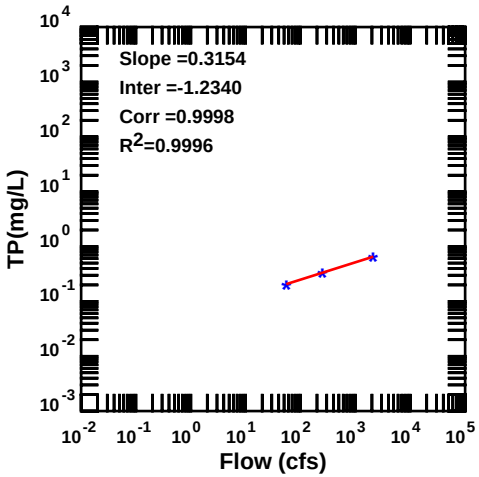
Nueces Tributaries, Texas (1970-2014)





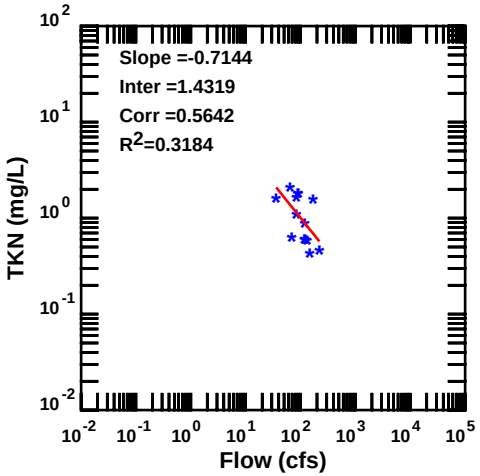


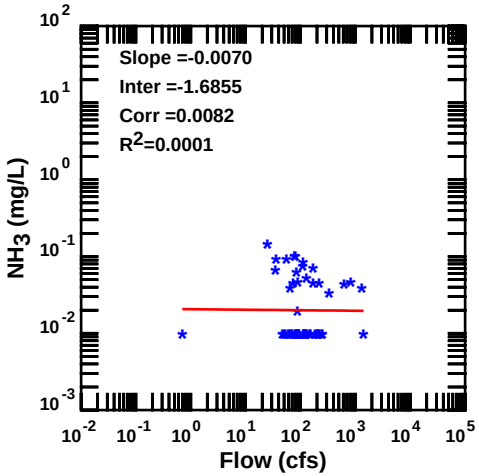


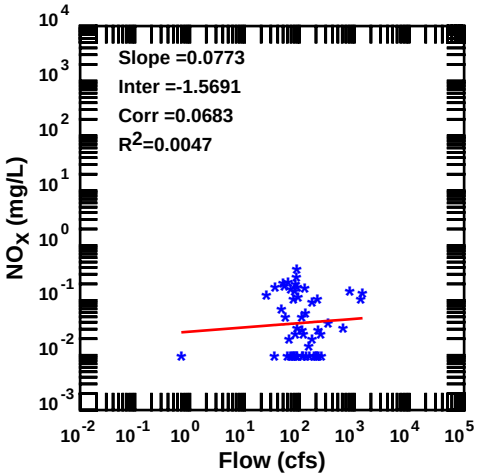


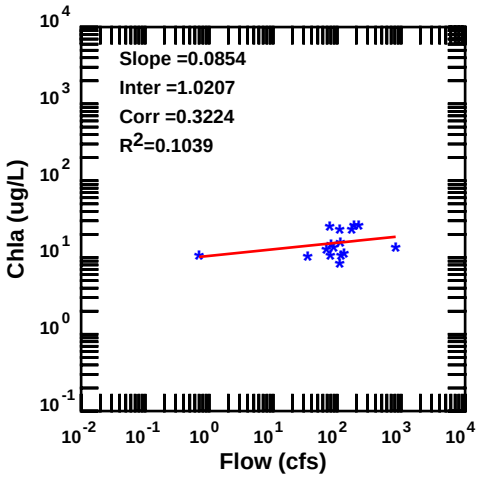
Regression analysis, Station 17648

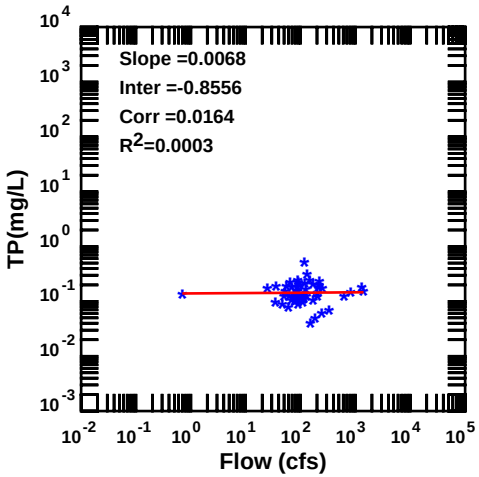
Nueces Tributaries, Texas (1970-2014)





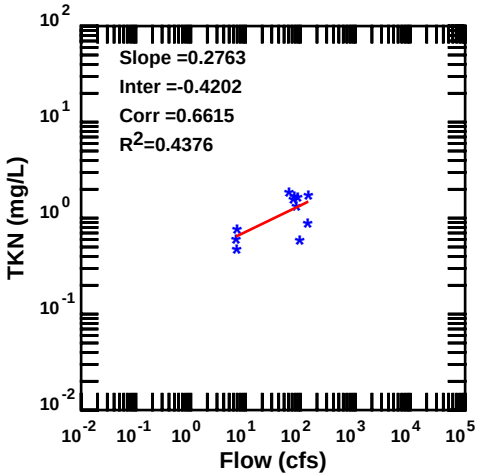


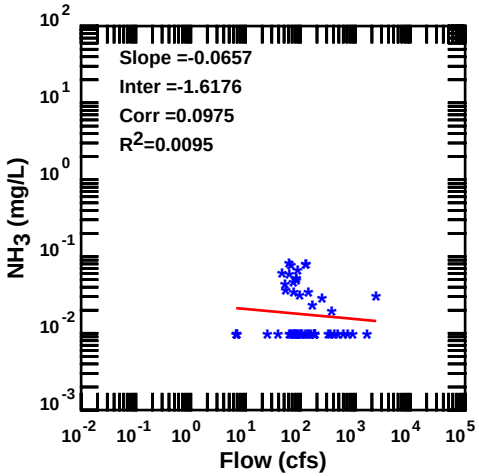


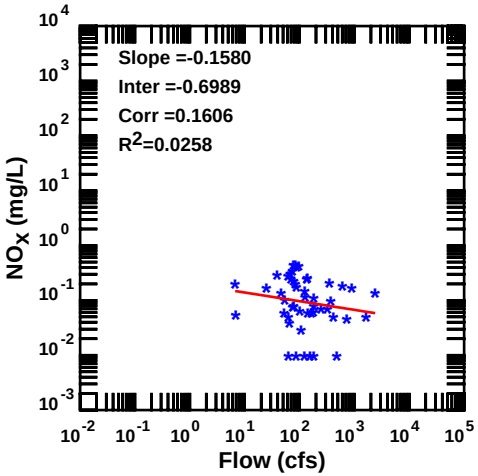


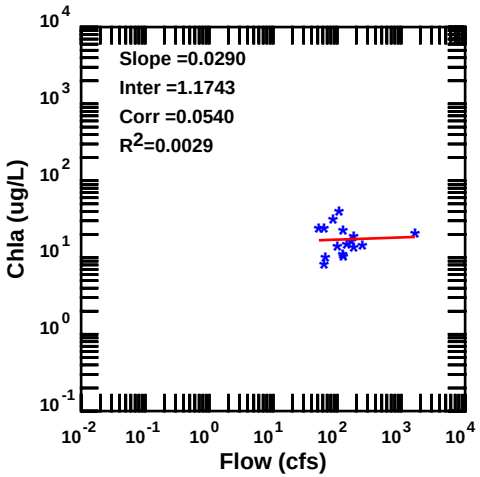
Regression analysis, Station 12965

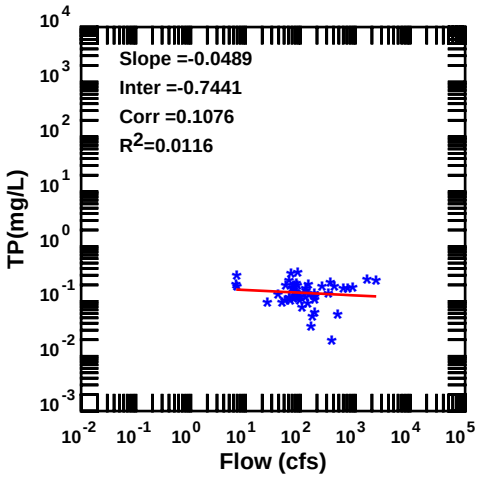
Nueces Tributaries, Texas (1970-2014)





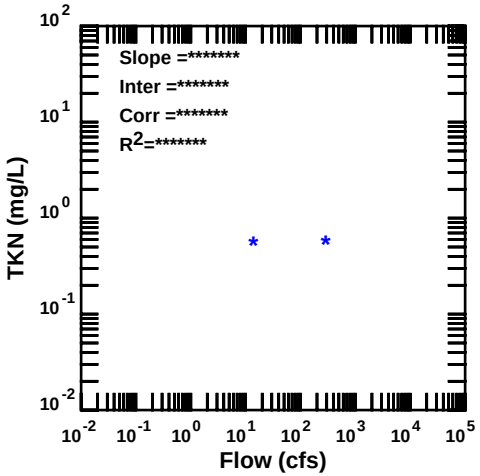


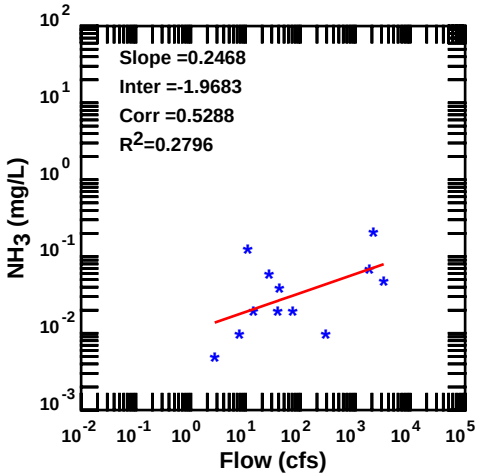


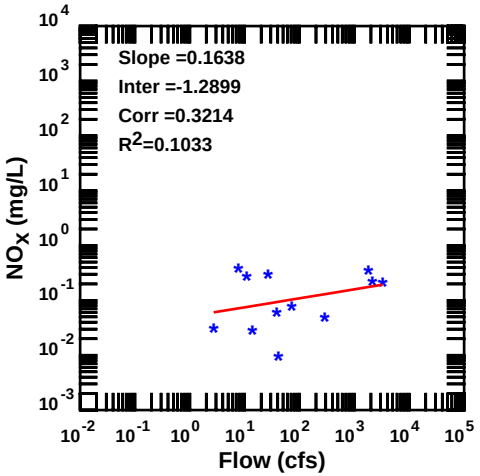


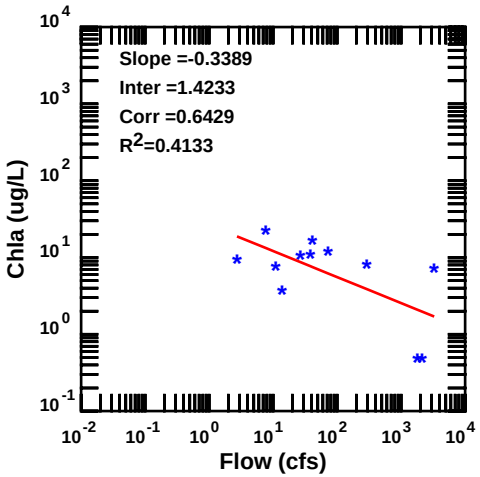
Regression analysis, Station 12964

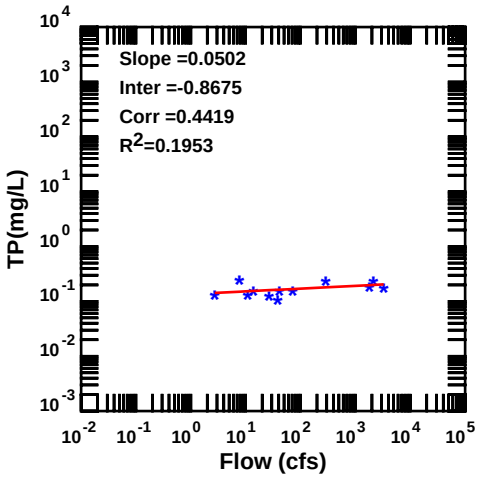
Nueces Tributaries, Texas (1970-2014)

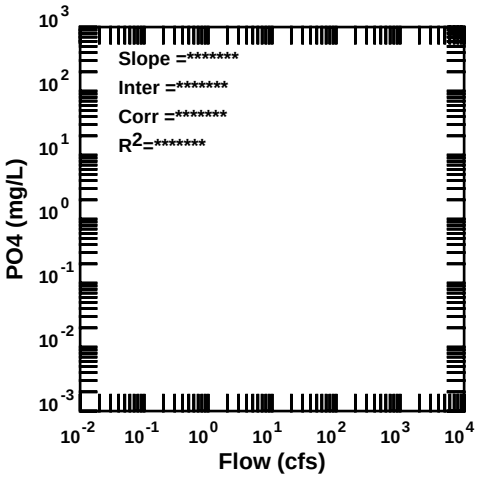






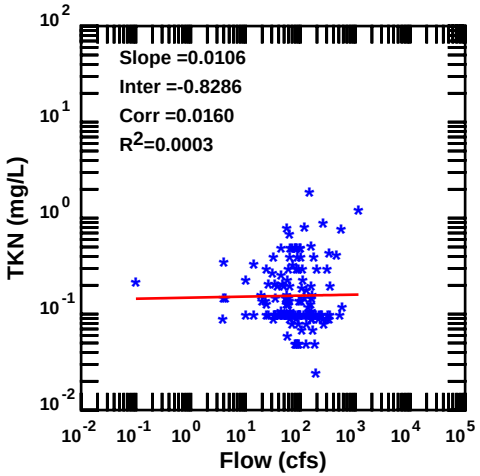


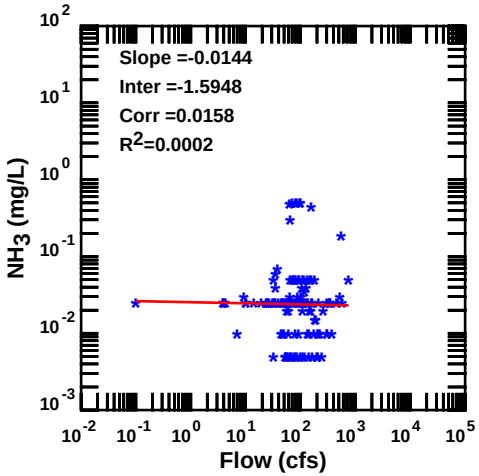


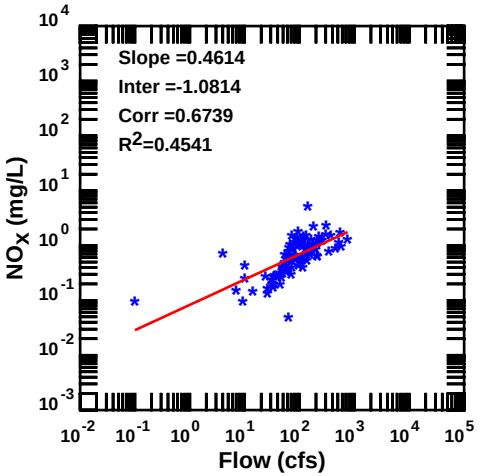


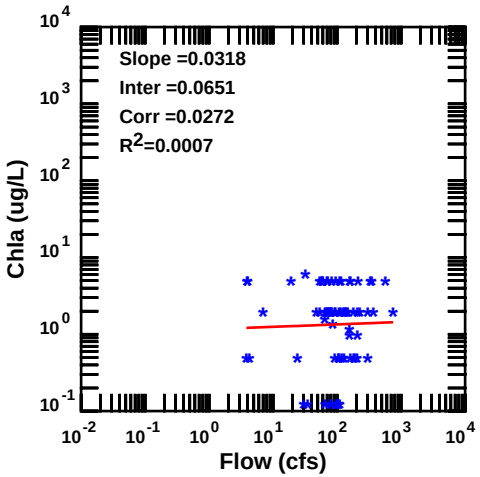
Regression analysis, Station 12962

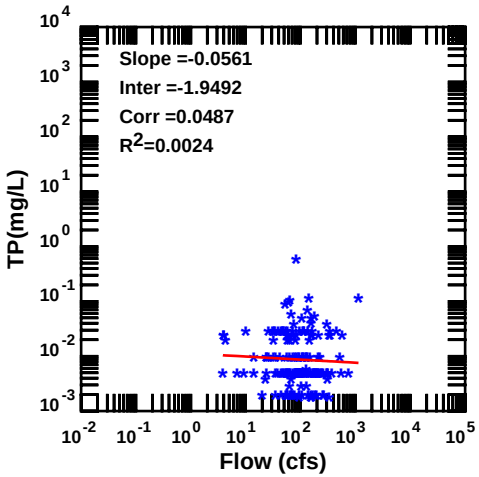
Nueces Tributaries, Texas (1970-2014)

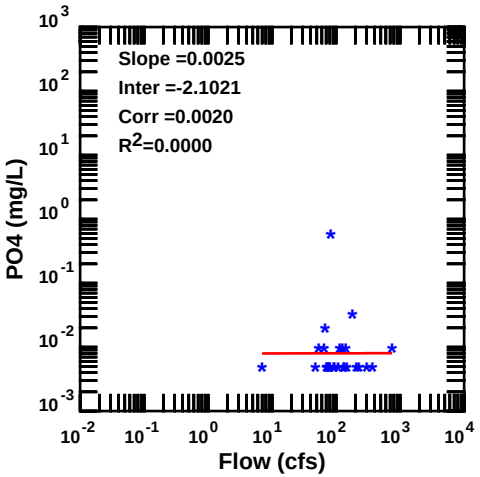






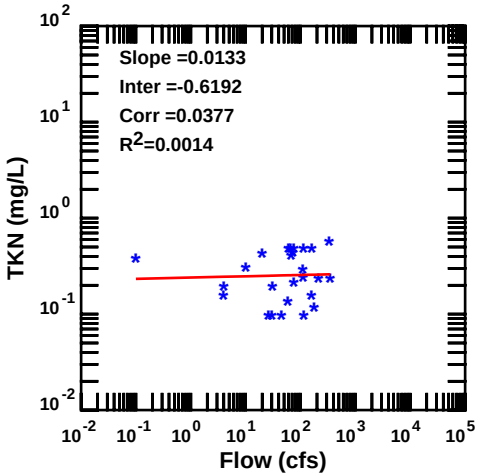


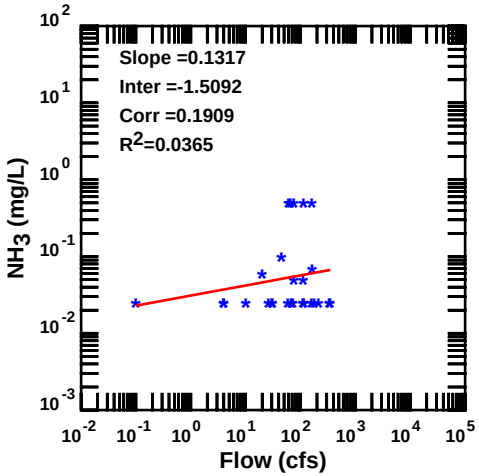


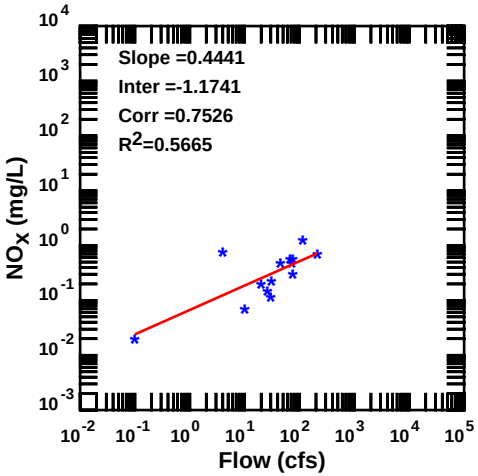


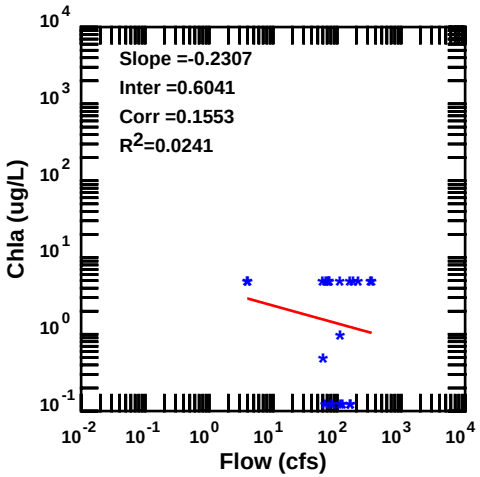
Regression analysis, Station 13006

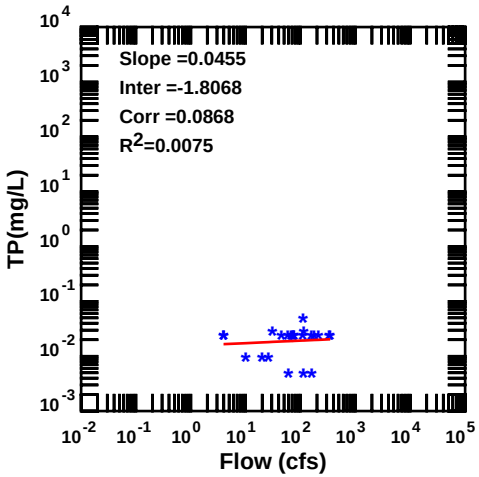
Nueces Tributaries, Texas (1970-2014)





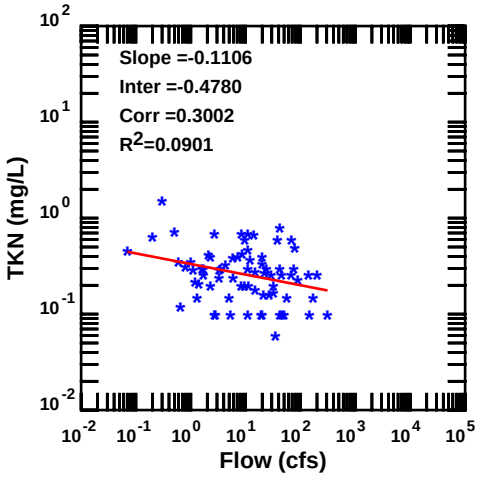


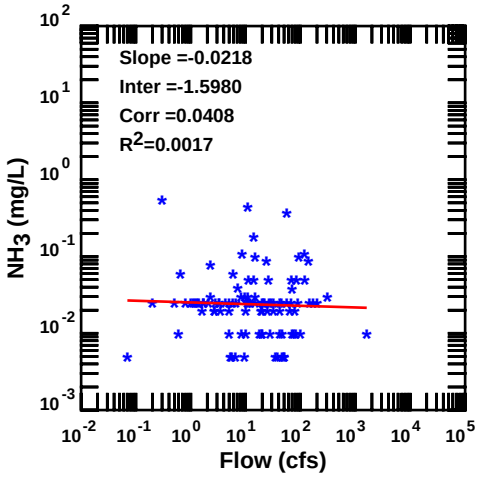


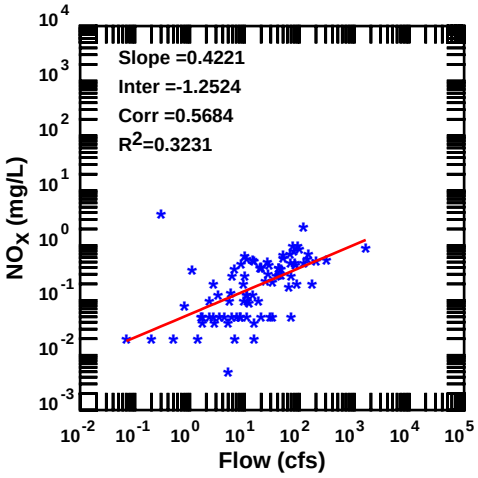


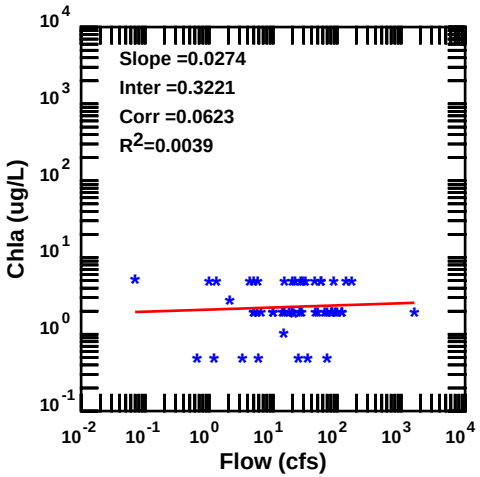
Regression analysis, Station 13007

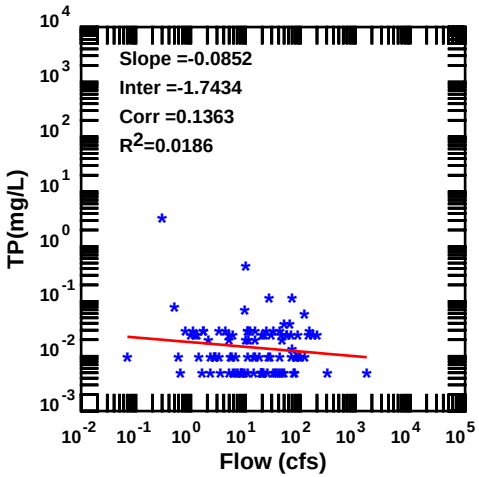
Nueces Tributaries, Texas (1970-2014)

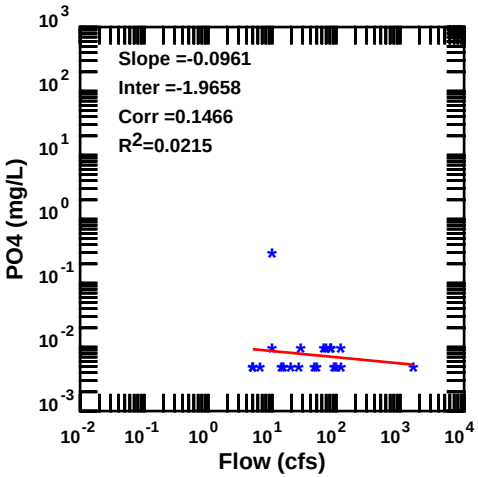






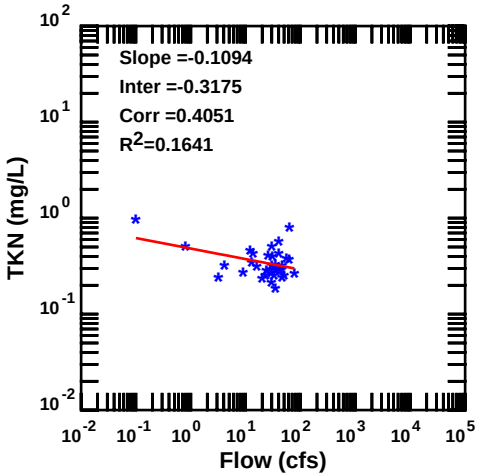


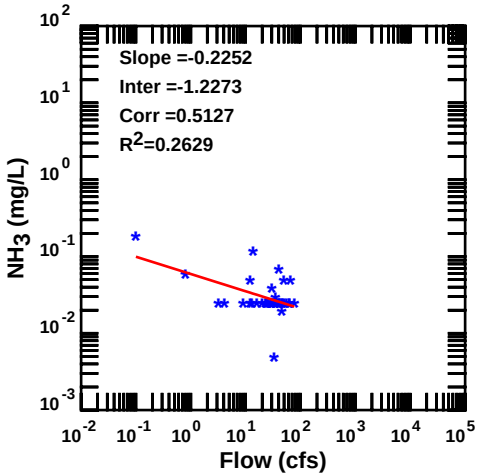


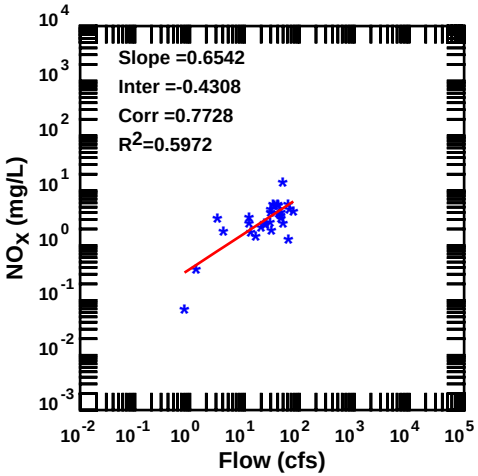


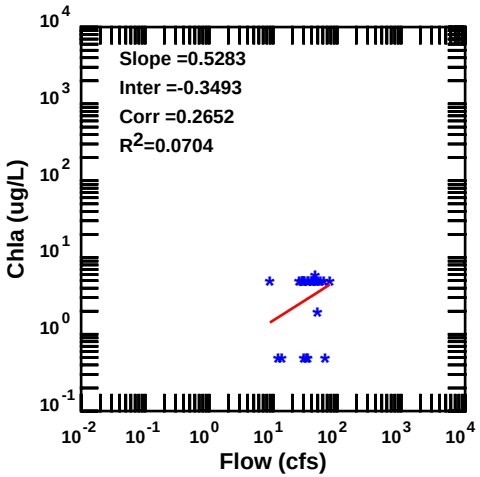
Regression analysis, Station 13010

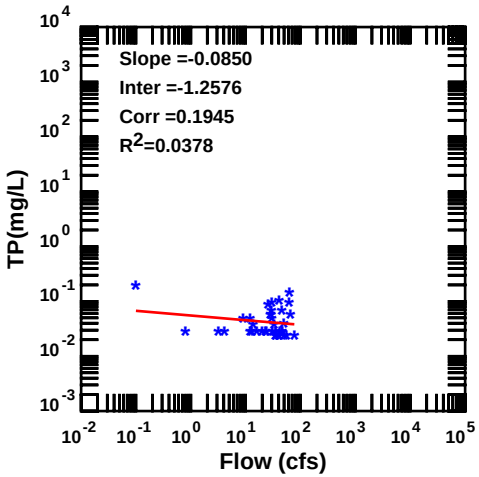
Nueces Tributaries, Texas (1970-2014)





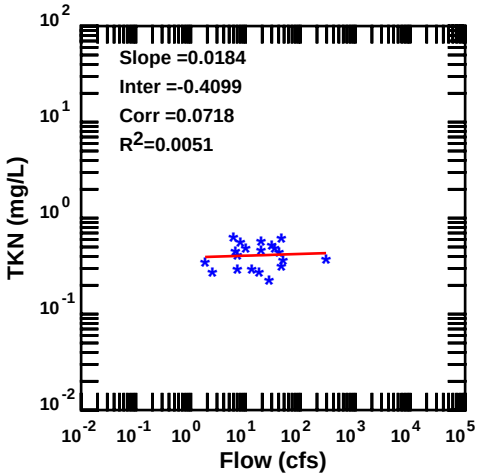


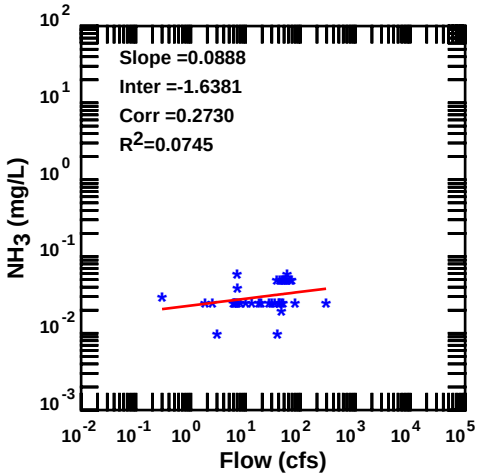


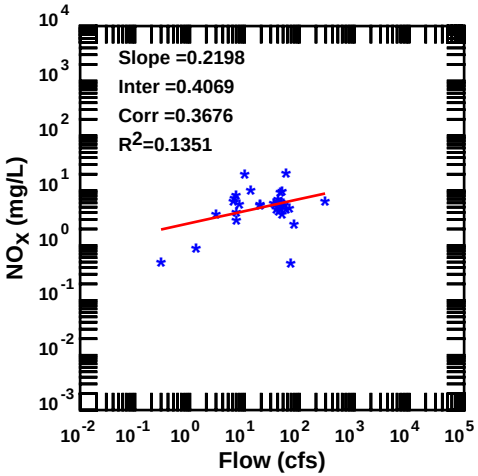


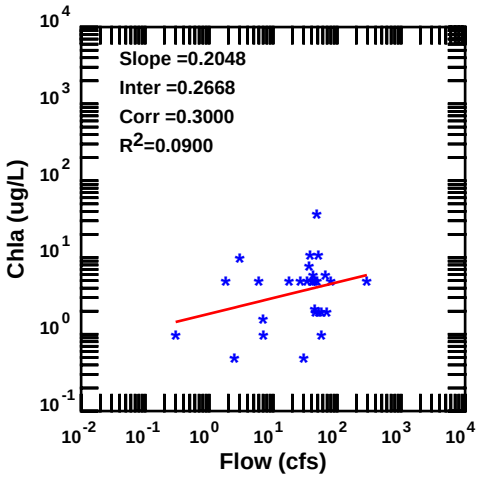
Regression analysis, Station 12987

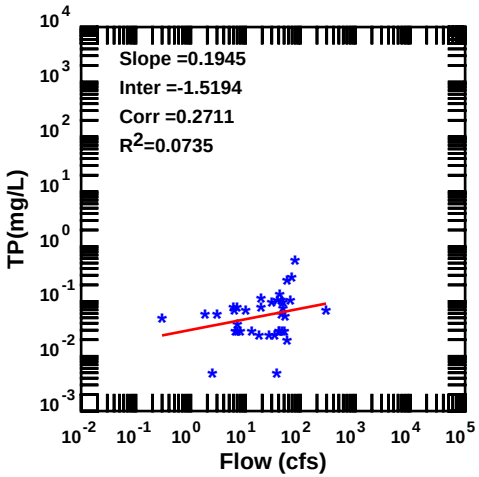
Nueces Tributaries, Texas (1970-2014)

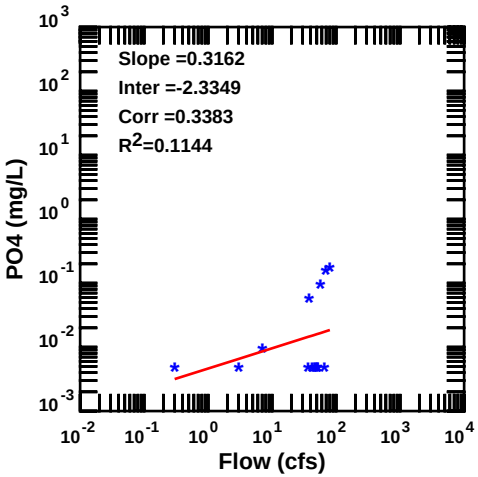






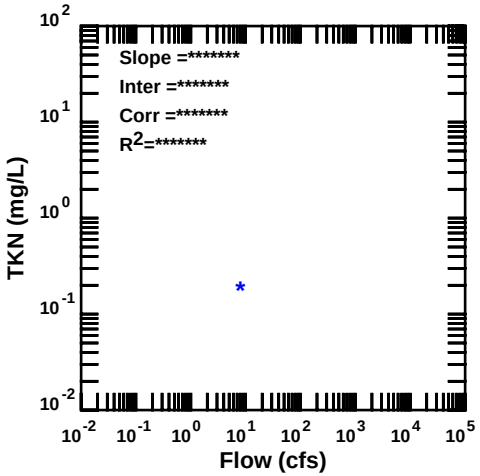


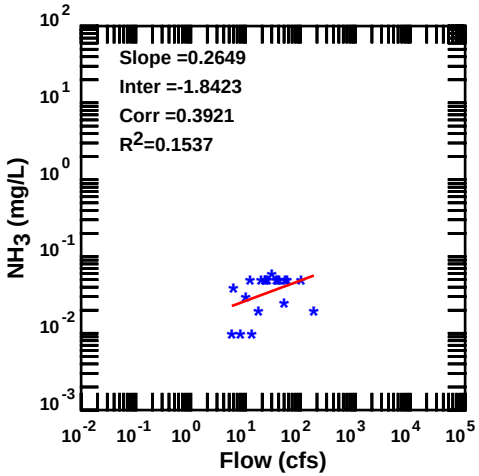


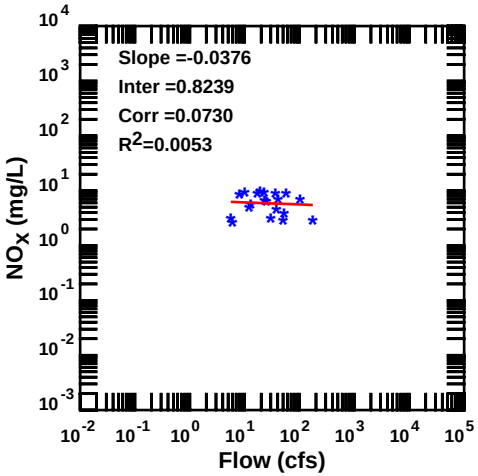


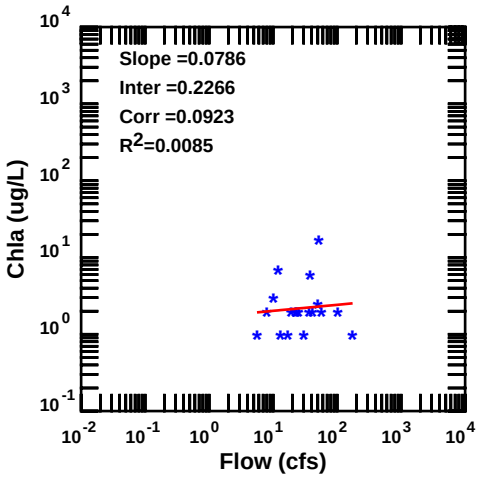
Regression analysis, Station 12985

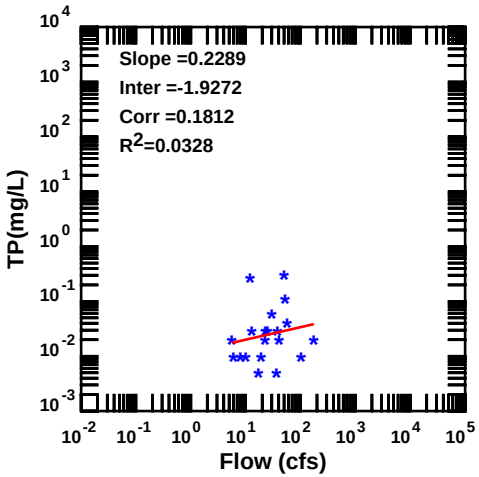
Nueces Tributaries, Texas (1970-2014)

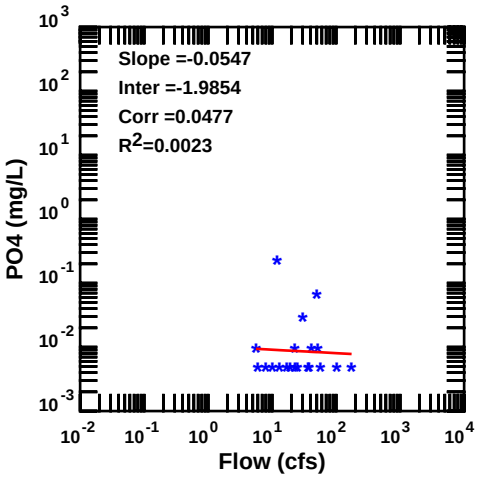






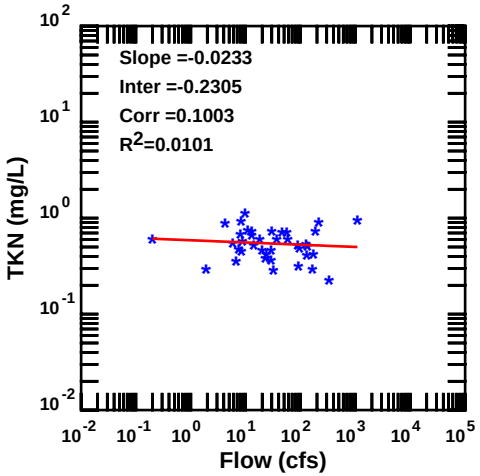


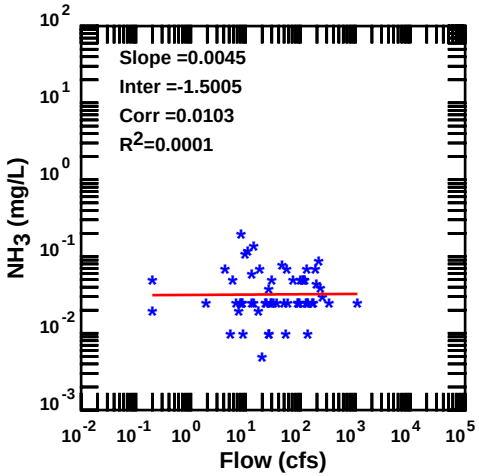


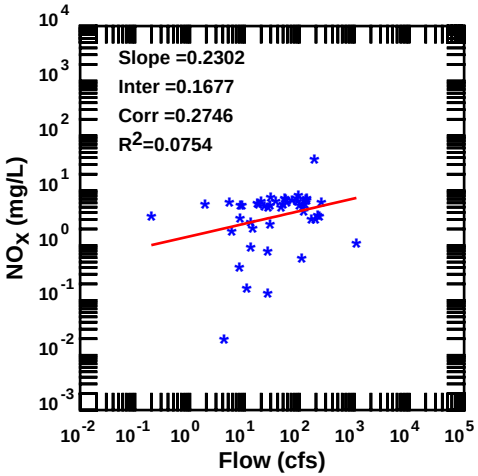


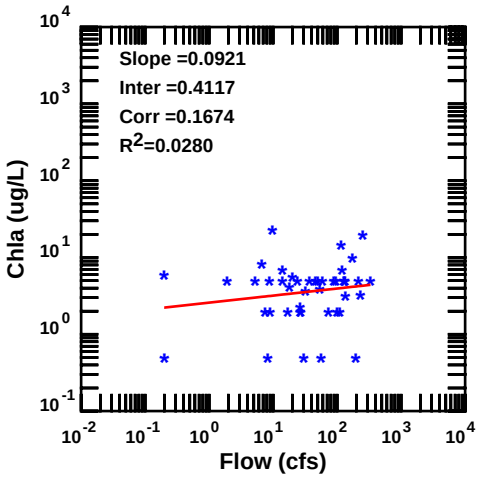
Regression analysis, Station 13025

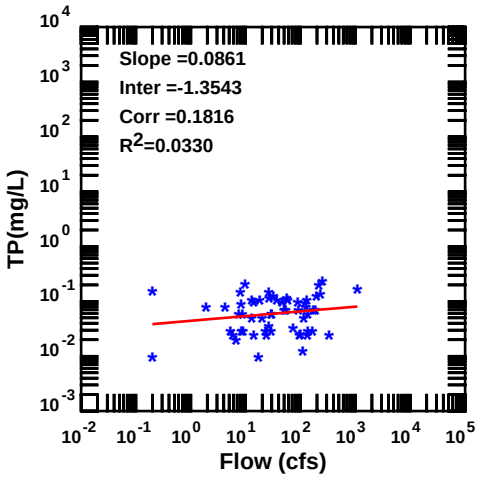
Nueces Tributaries, Texas (1970-2014)

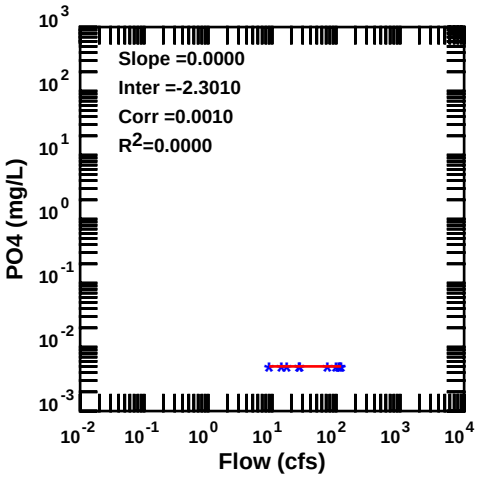






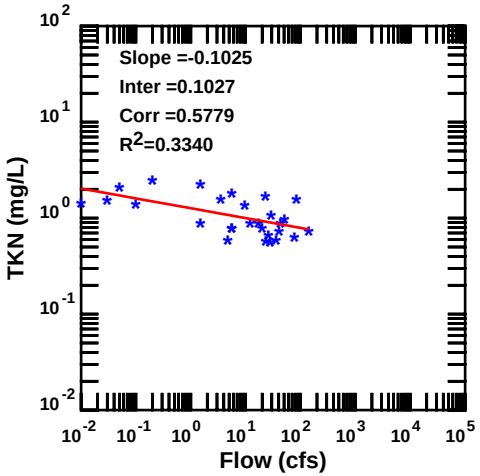


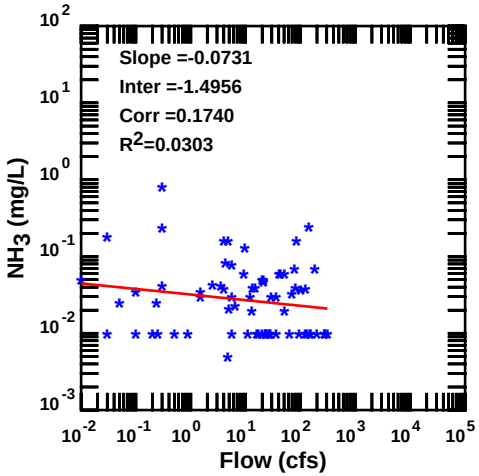


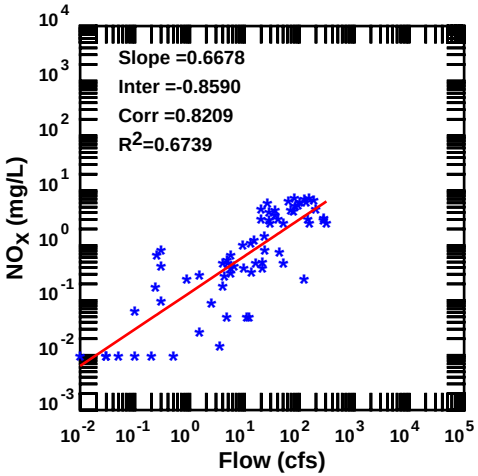


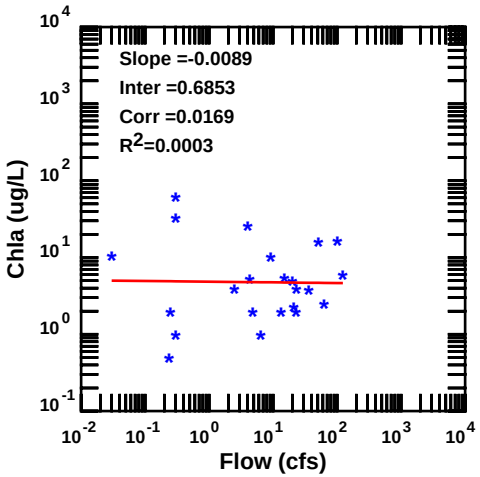
Regression analysis, Station 13024

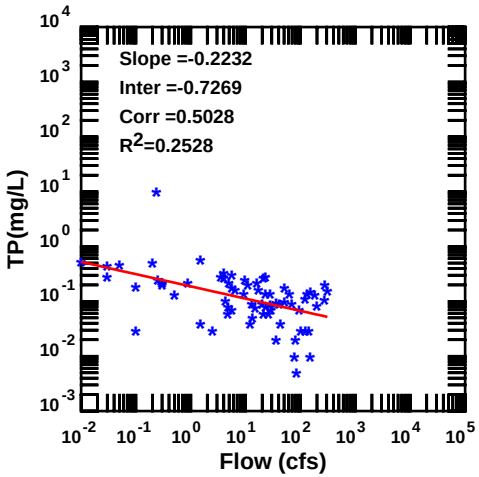
Nueces Tributaries, Texas (1970-2014)

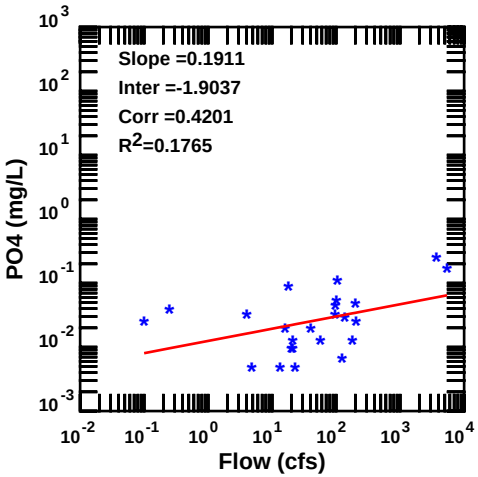






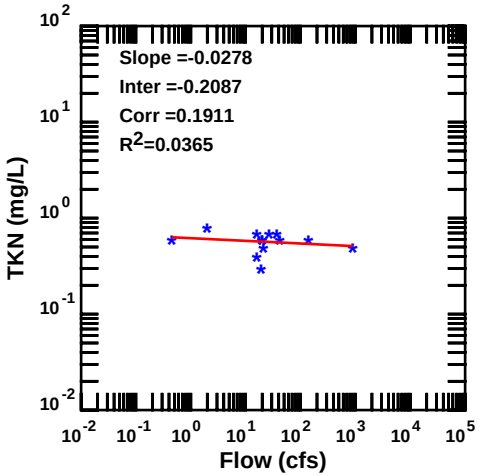


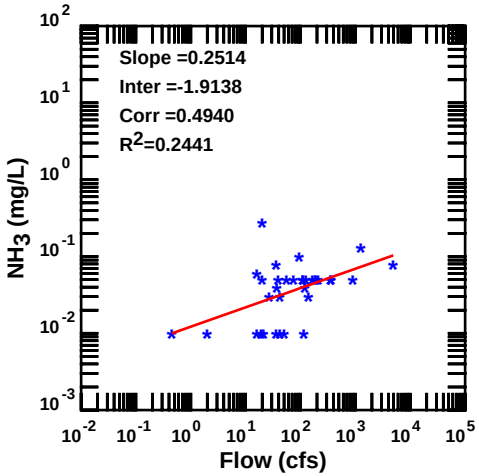


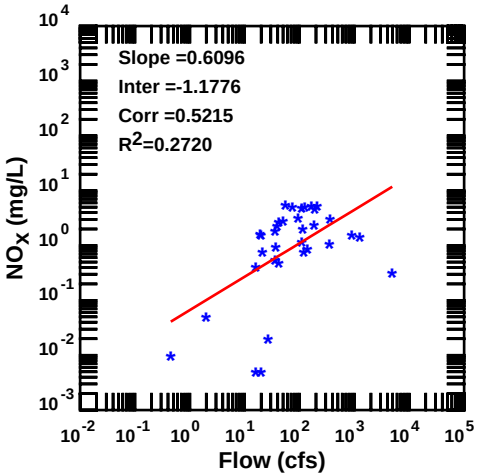


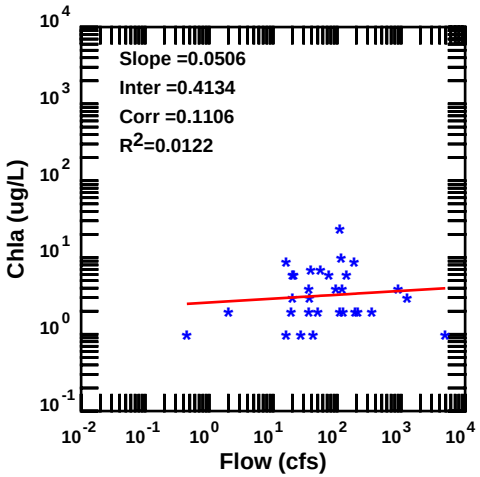
Regression analysis, Station 13023

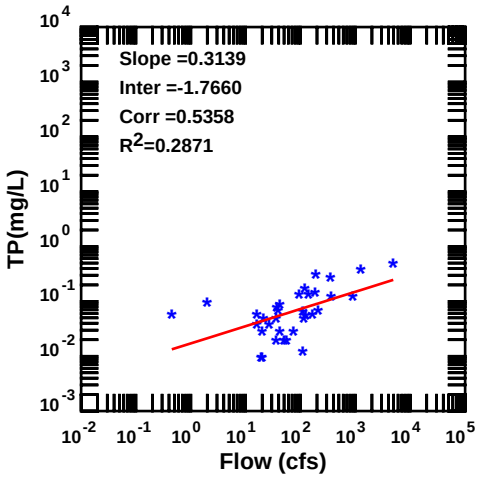
Nueces Tributaries, Texas (1970-2014)

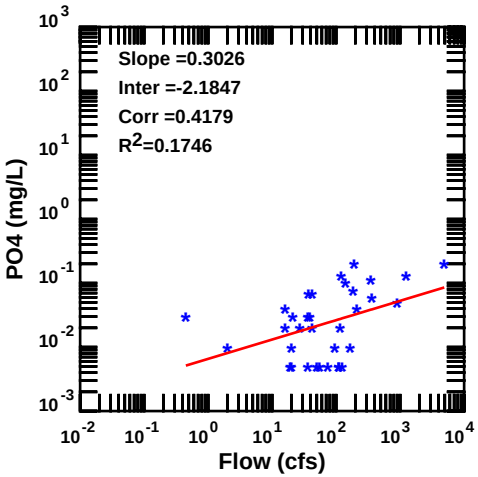






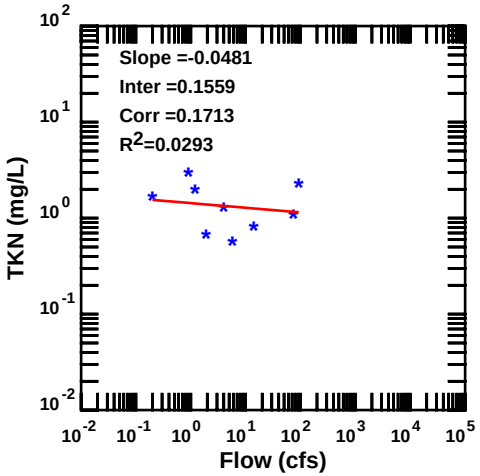


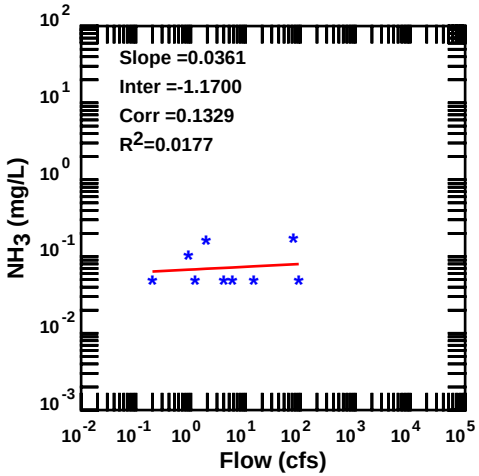


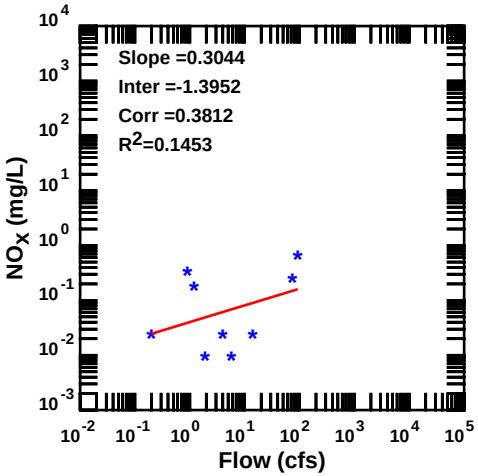


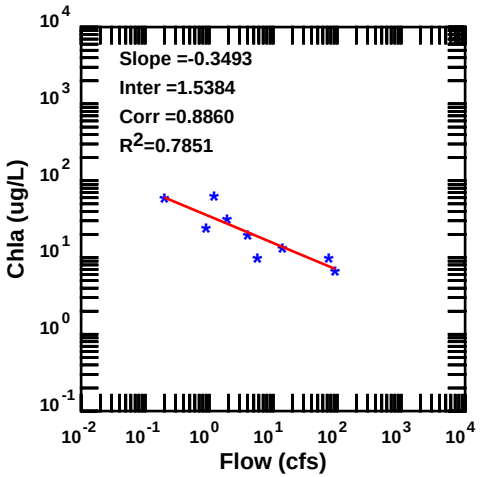
Regression analysis, Station 13021

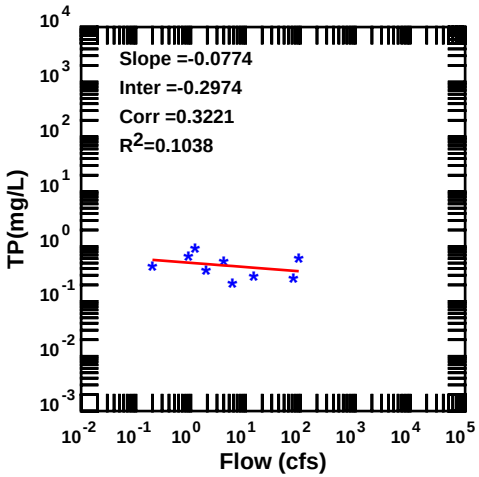
Nueces Tributaries, Texas (1970-2014)





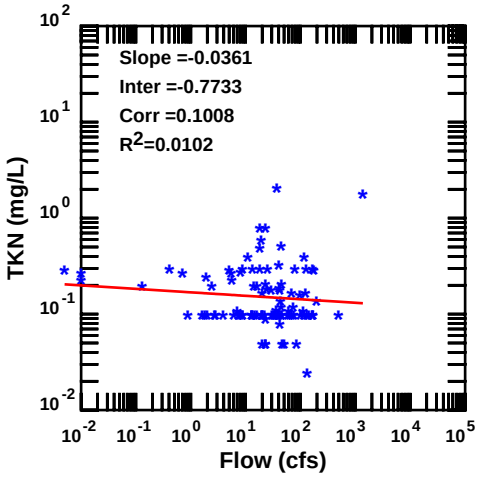


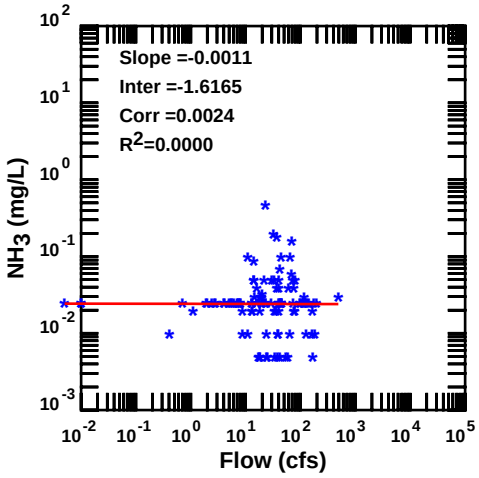


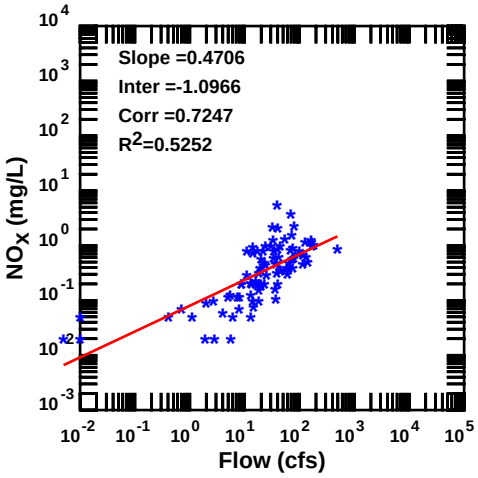


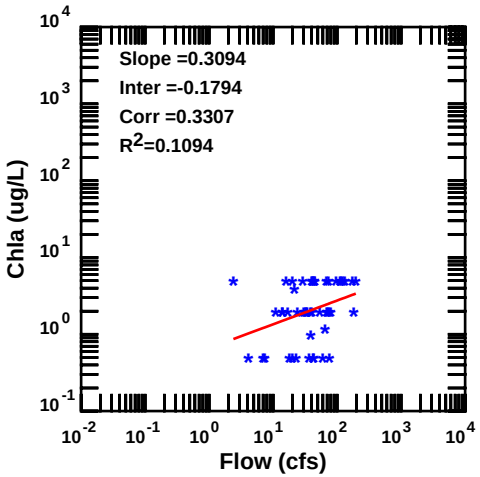
Regression analysis, Station 20773

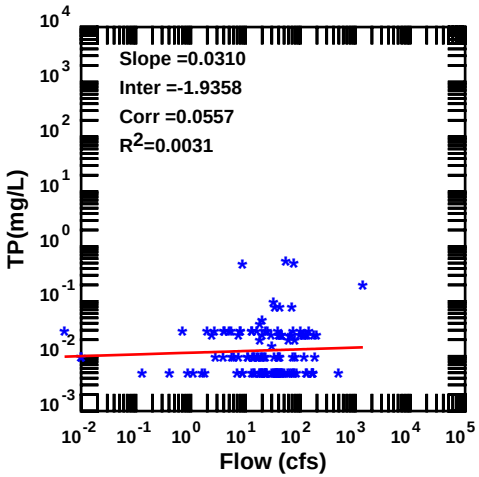
Nueces Tributaries, Texas (1970-2014)

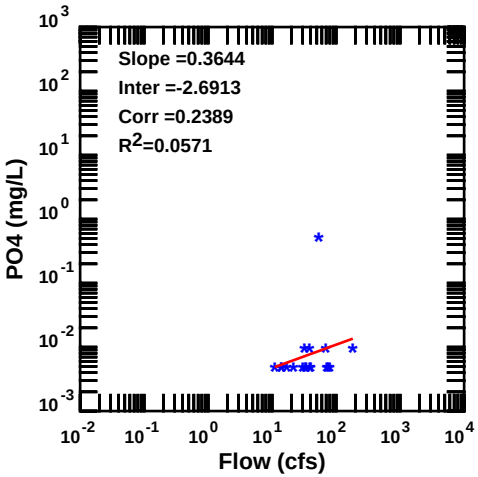






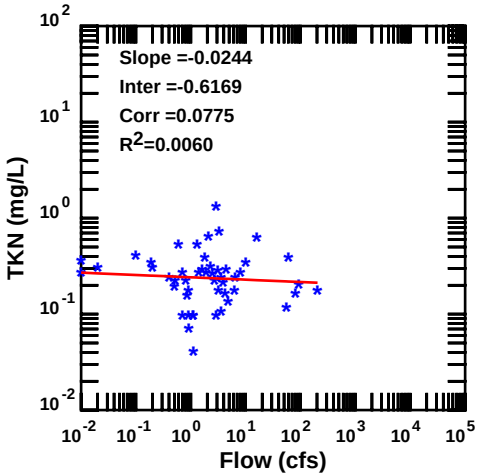


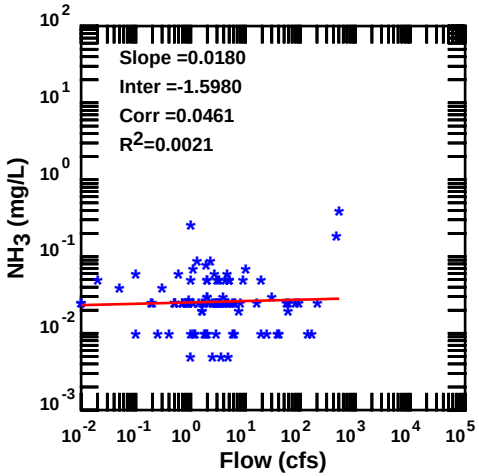


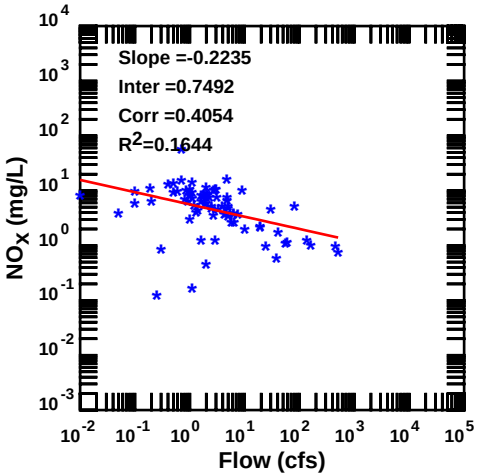


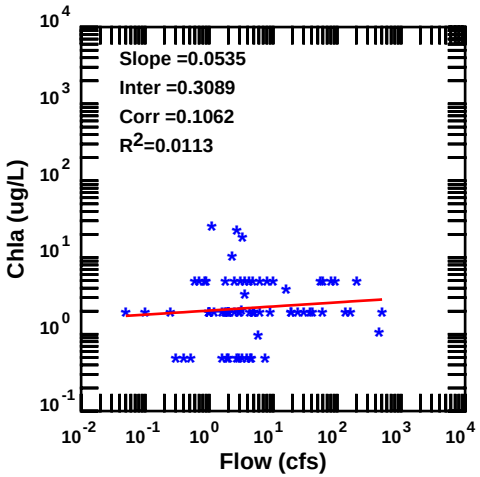
Regression analysis, Station 12994

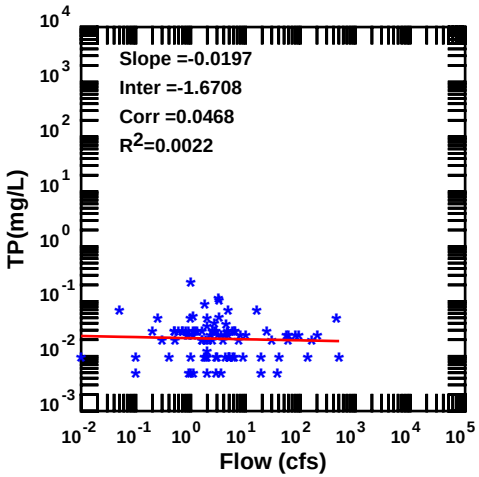
Nueces Tributaries, Texas (1970-2014)

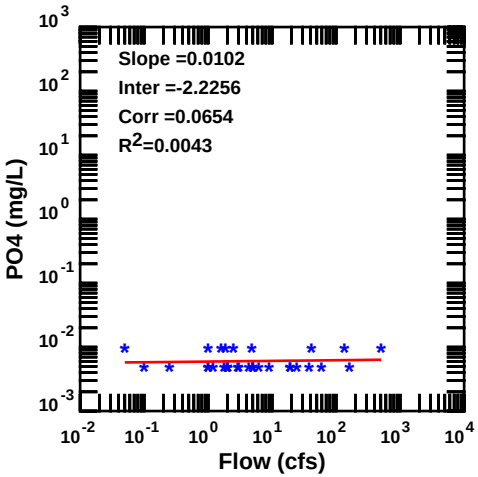






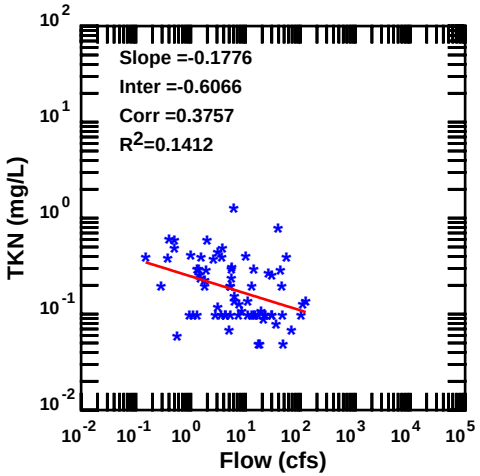


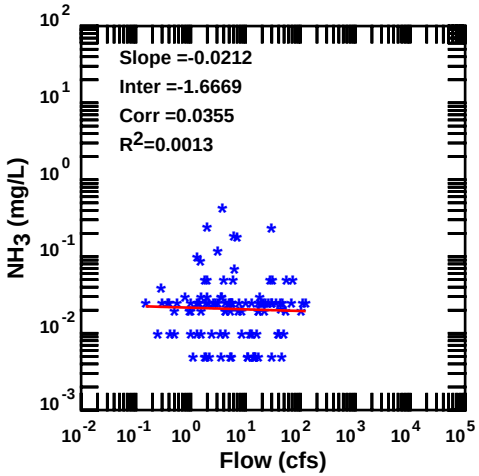


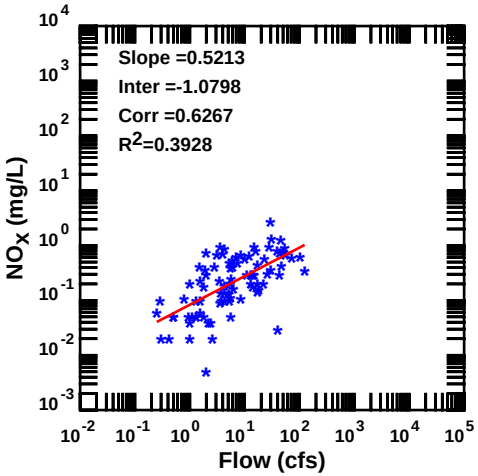


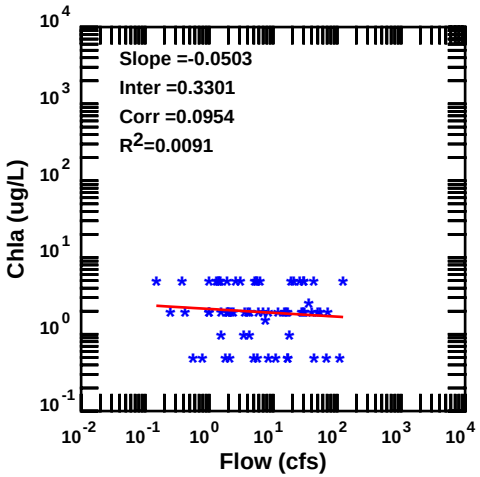
Regression analysis, Station 12993

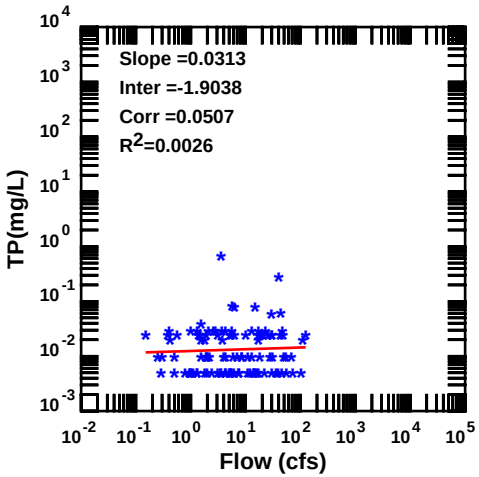
Nueces Tributaries, Texas (1970-2014)

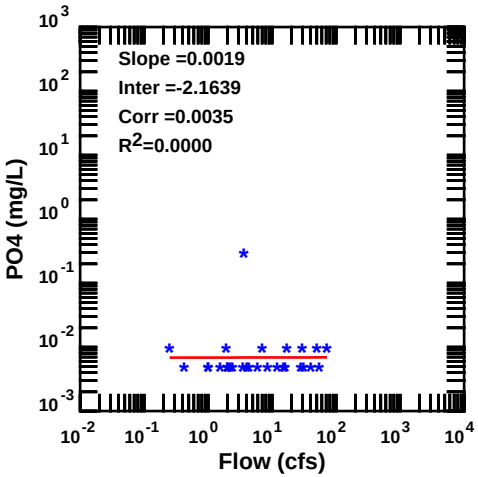






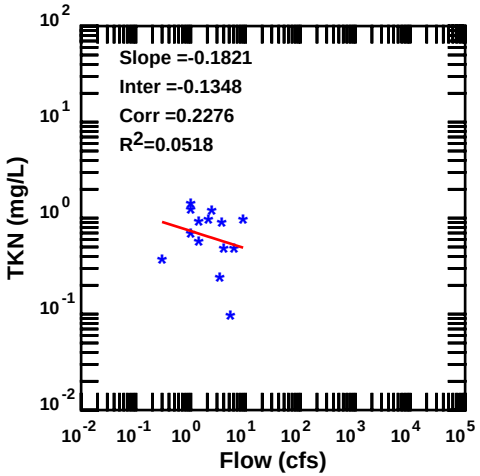


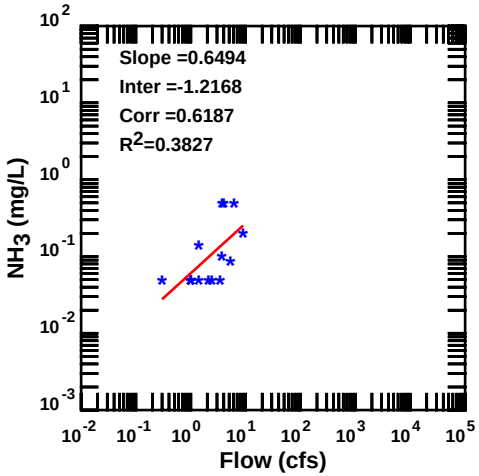


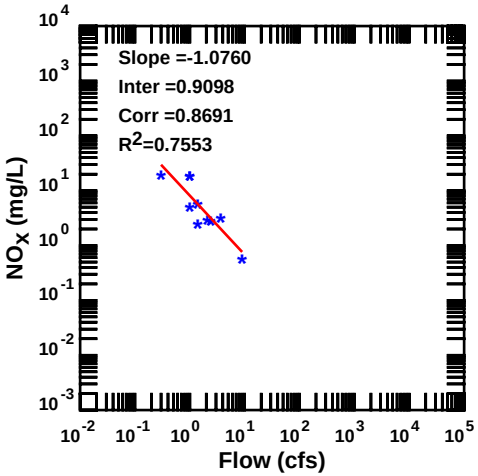


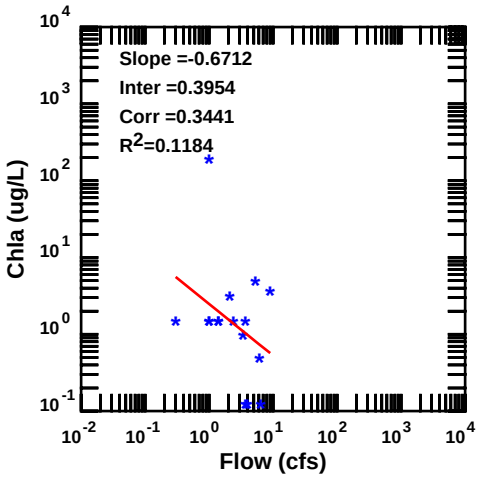
Regression analysis, Station 13013

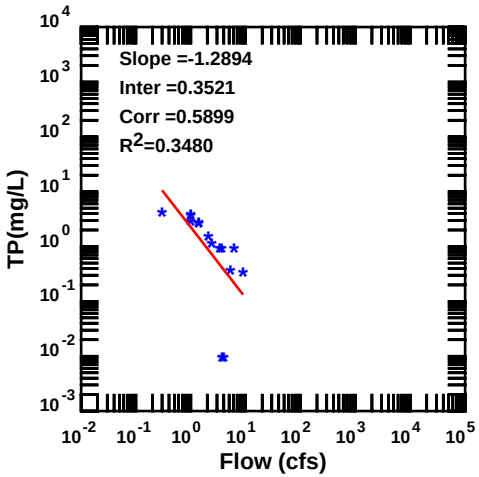
Nueces Tributaries, Texas (1970-2014)





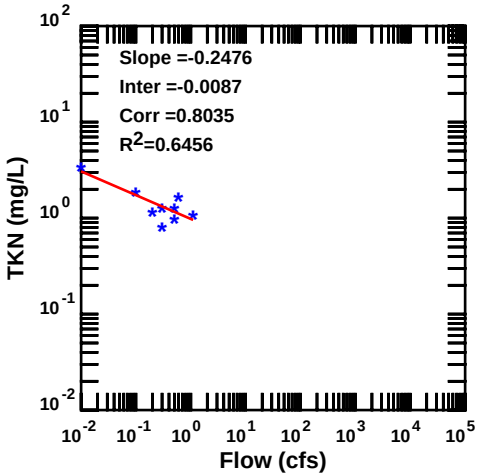


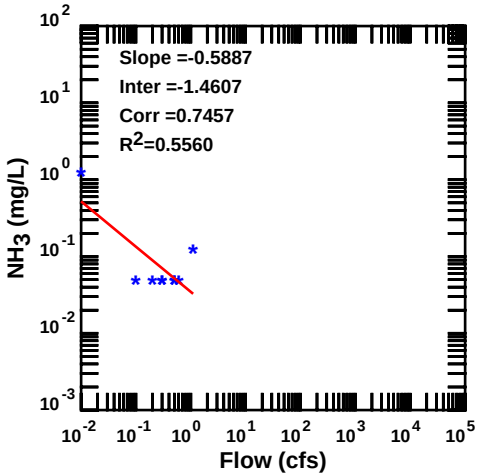


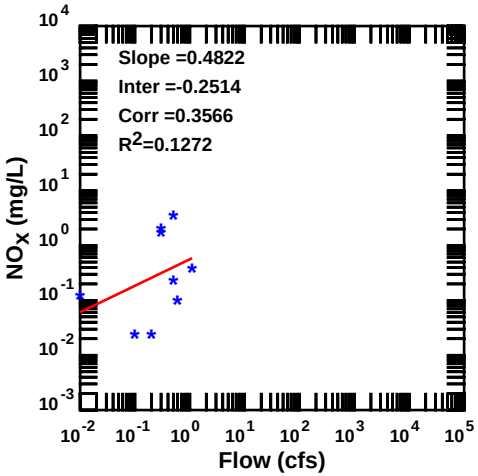


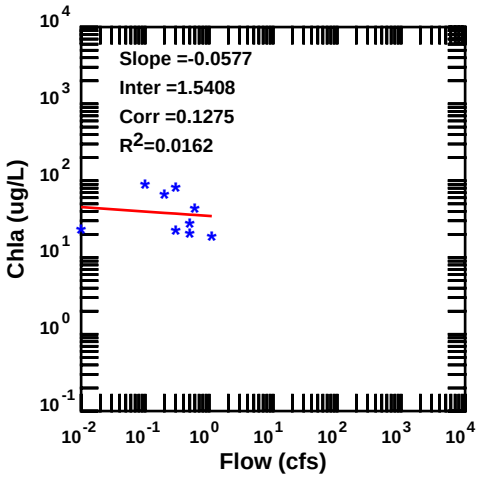
Regression analysis, Station 17900

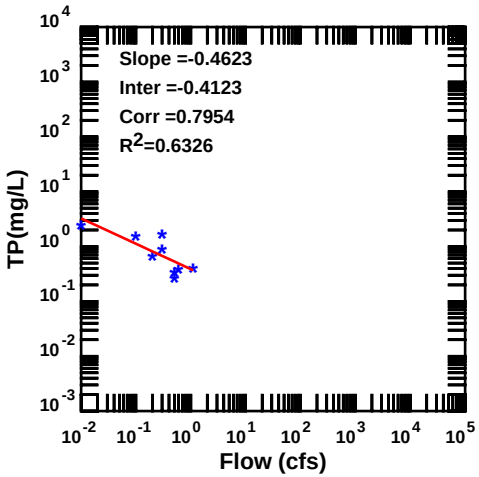
Nueces Tributaries, Texas (1970-2014)





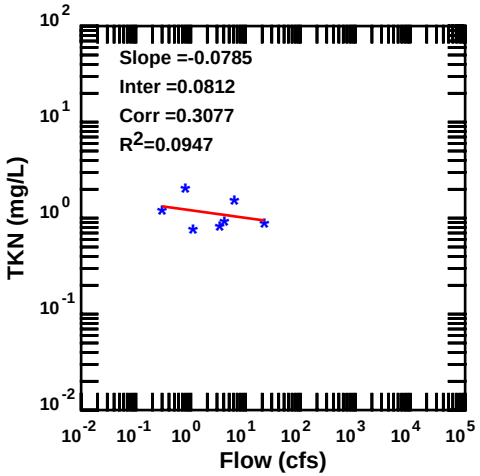


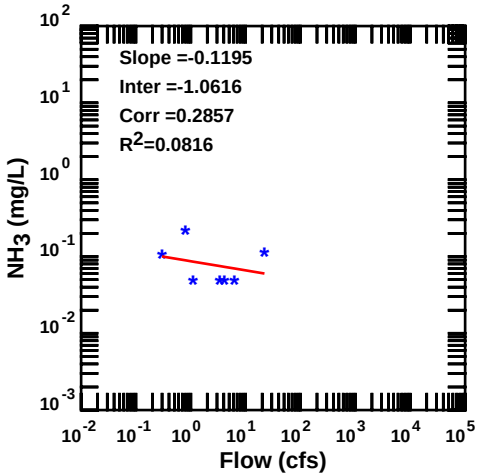


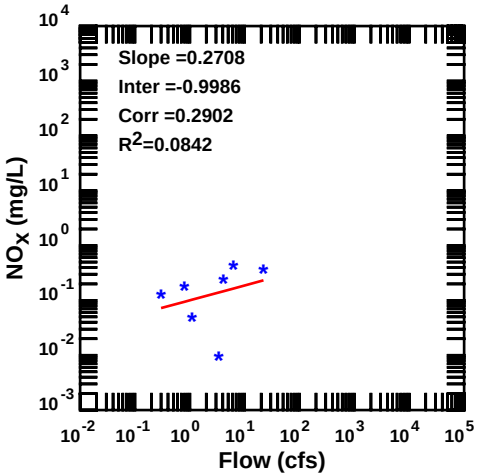


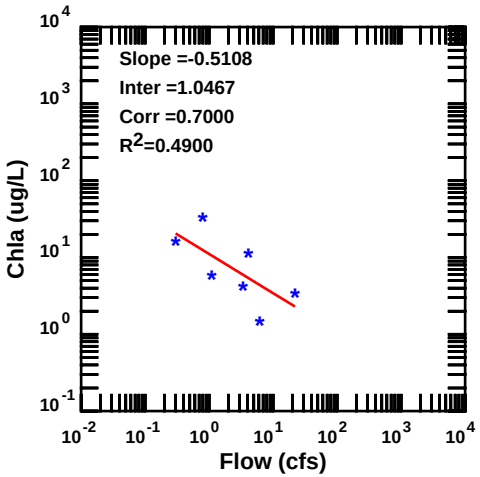
Regression analysis, Station 20762

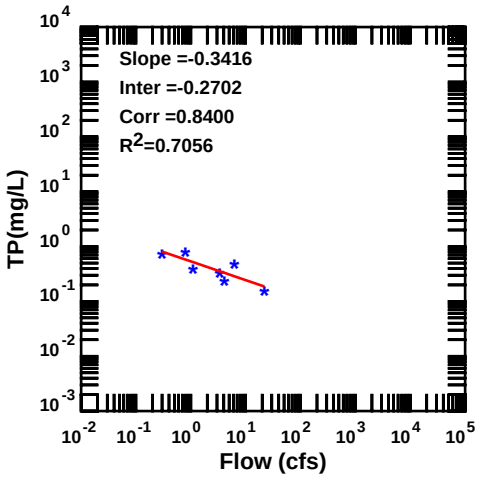
Nueces Tributaries, Texas (1970-2014)





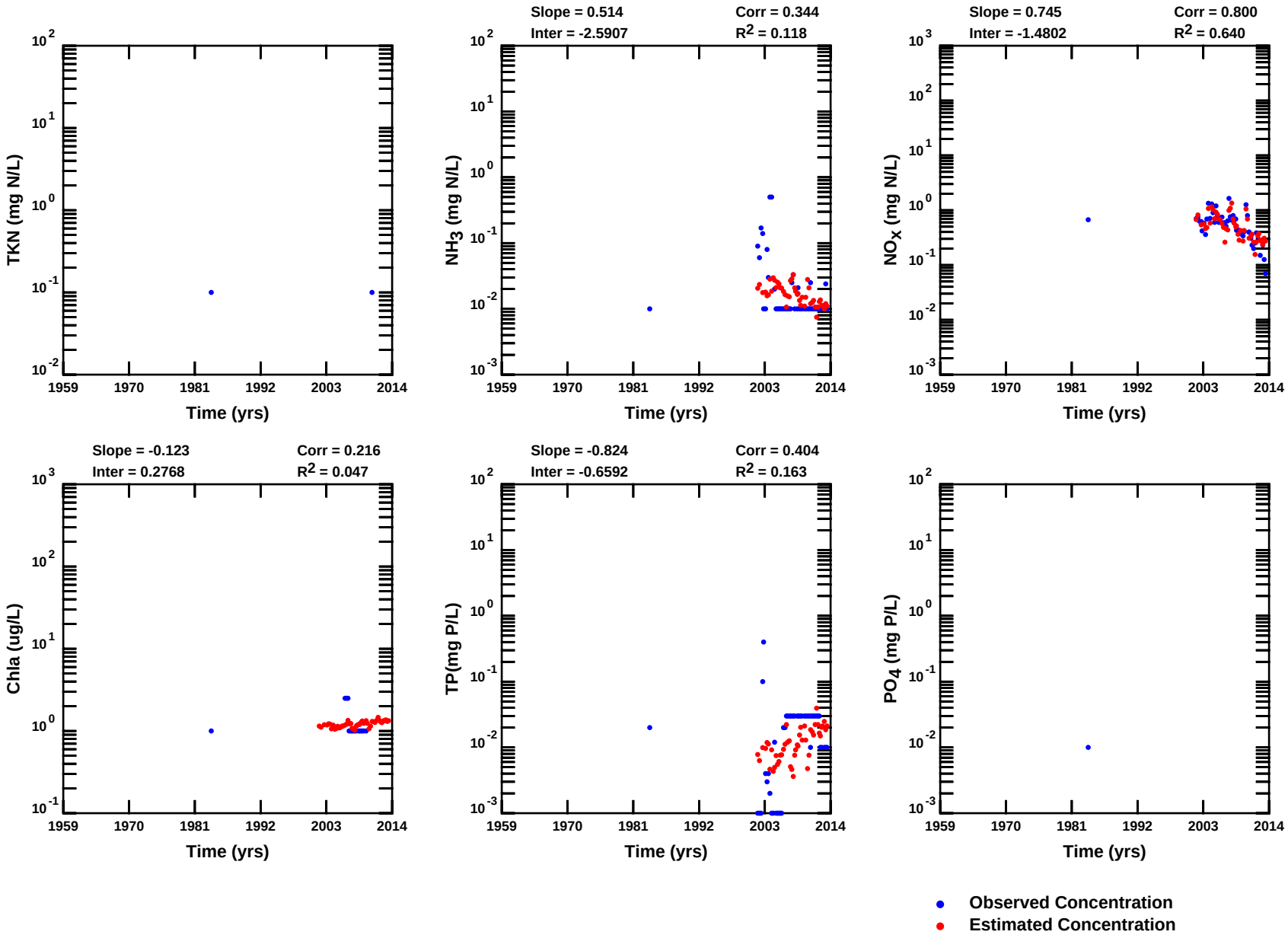




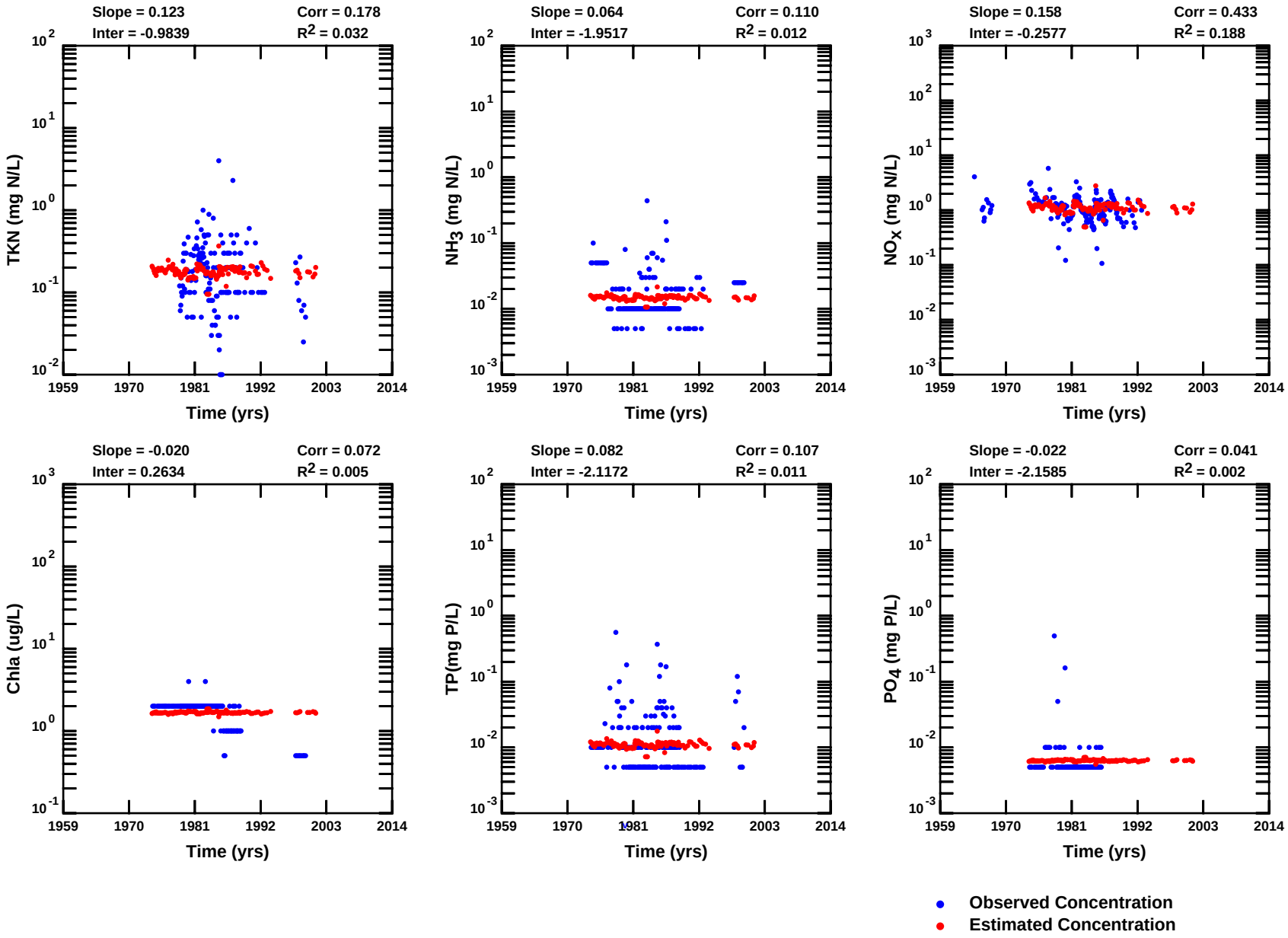


Regression analysis, Station 20764

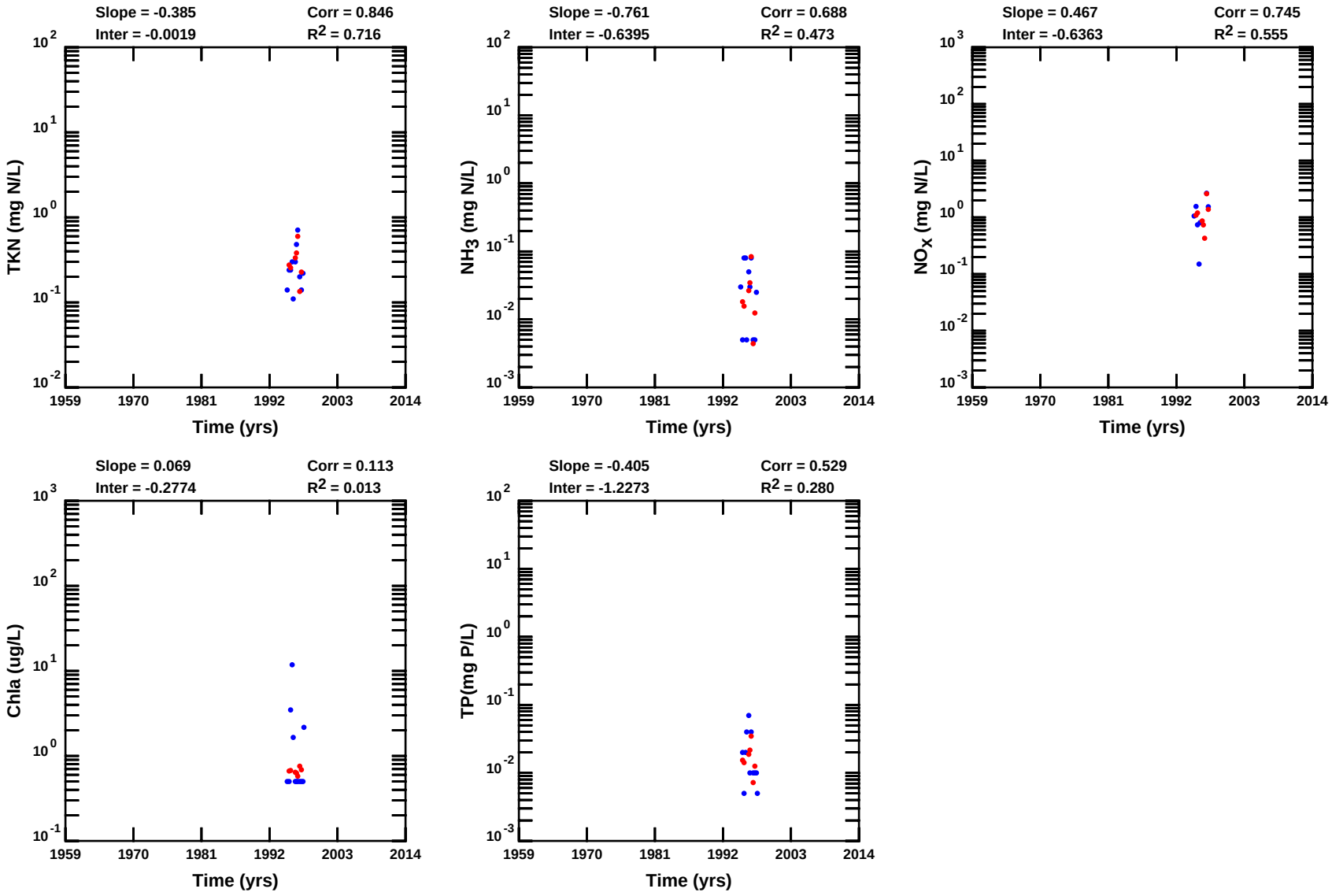
Nueces Tributaries, Texas (1970-2014)



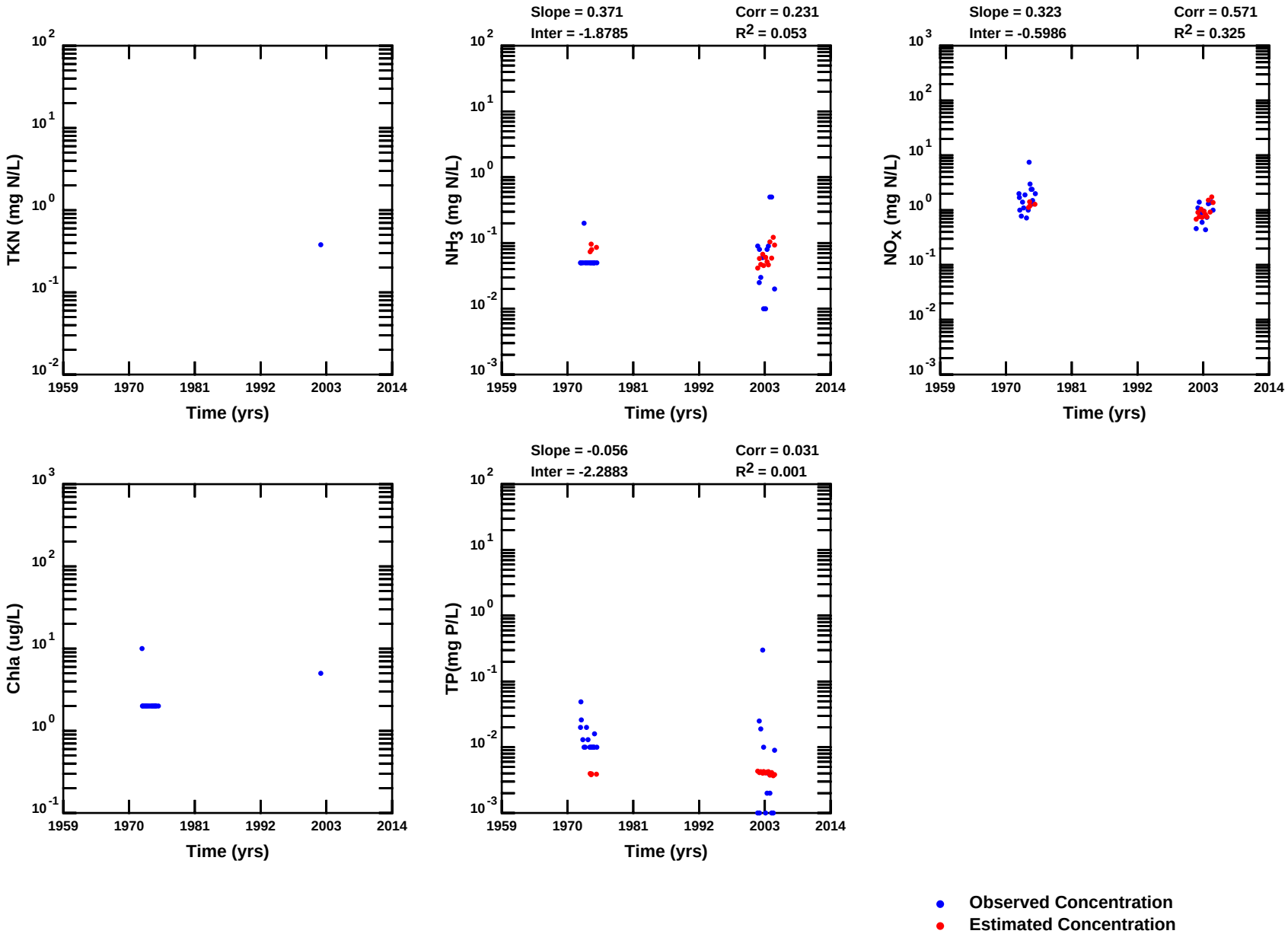
Nutrient Distributions, Station 13005
Nueces Tributaries, Texas (1959-2014)



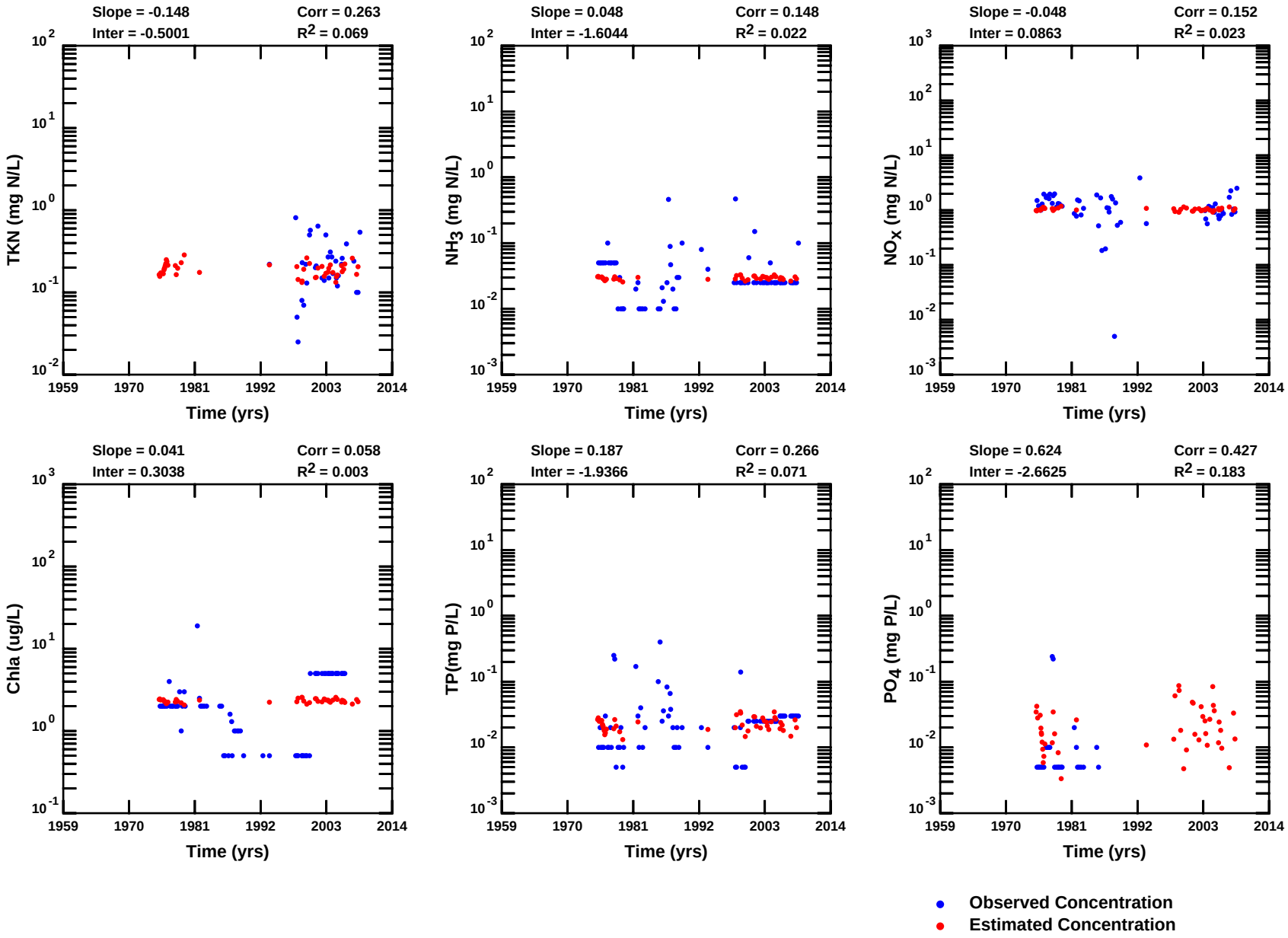
Nutrient Distributions, Station 12999
Nueces Tributaries, Texas (1959-2014)



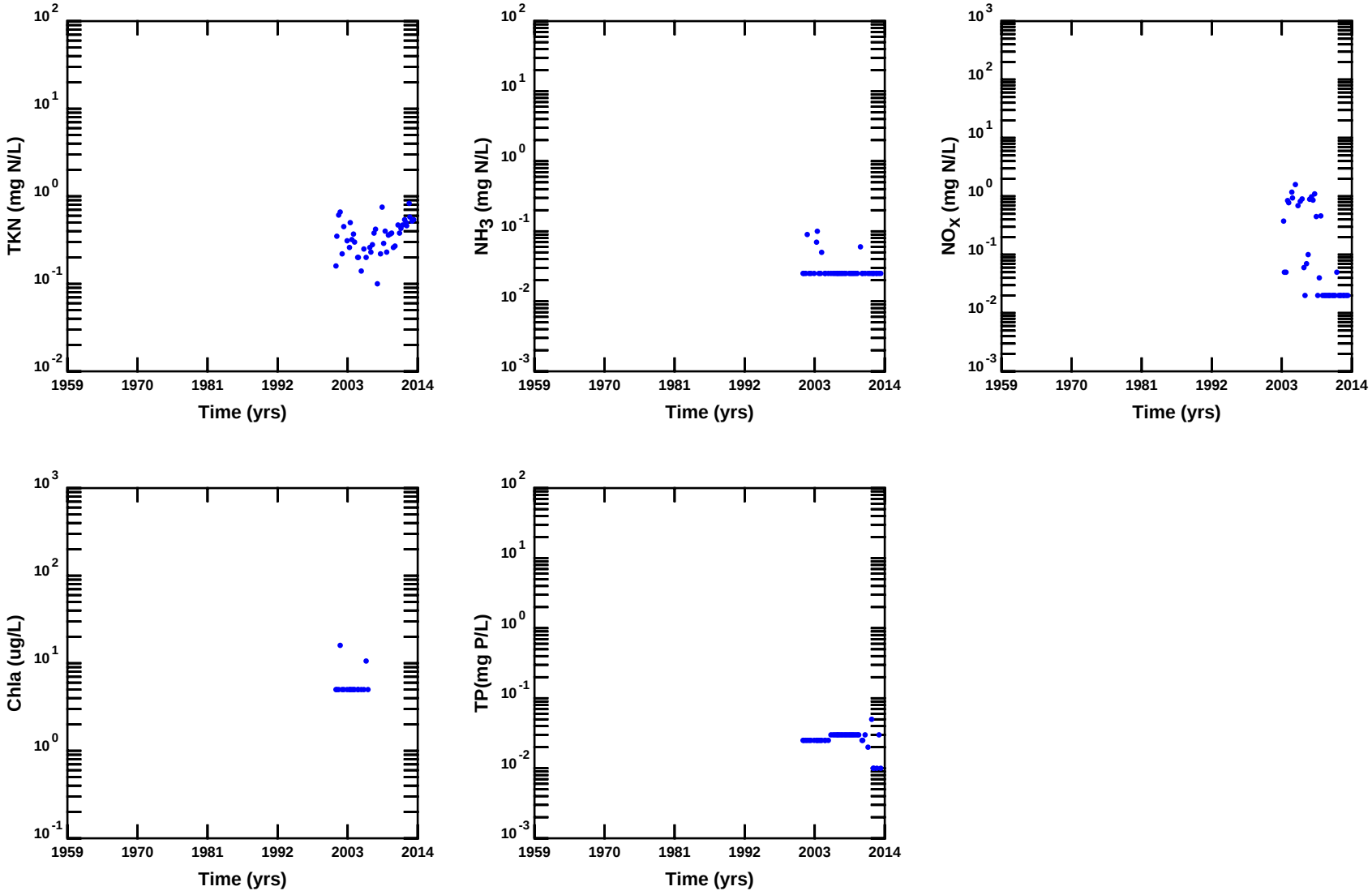
Nutrient Distributions, Station 14253
Nueces Tributaries, Texas (1959-2014)



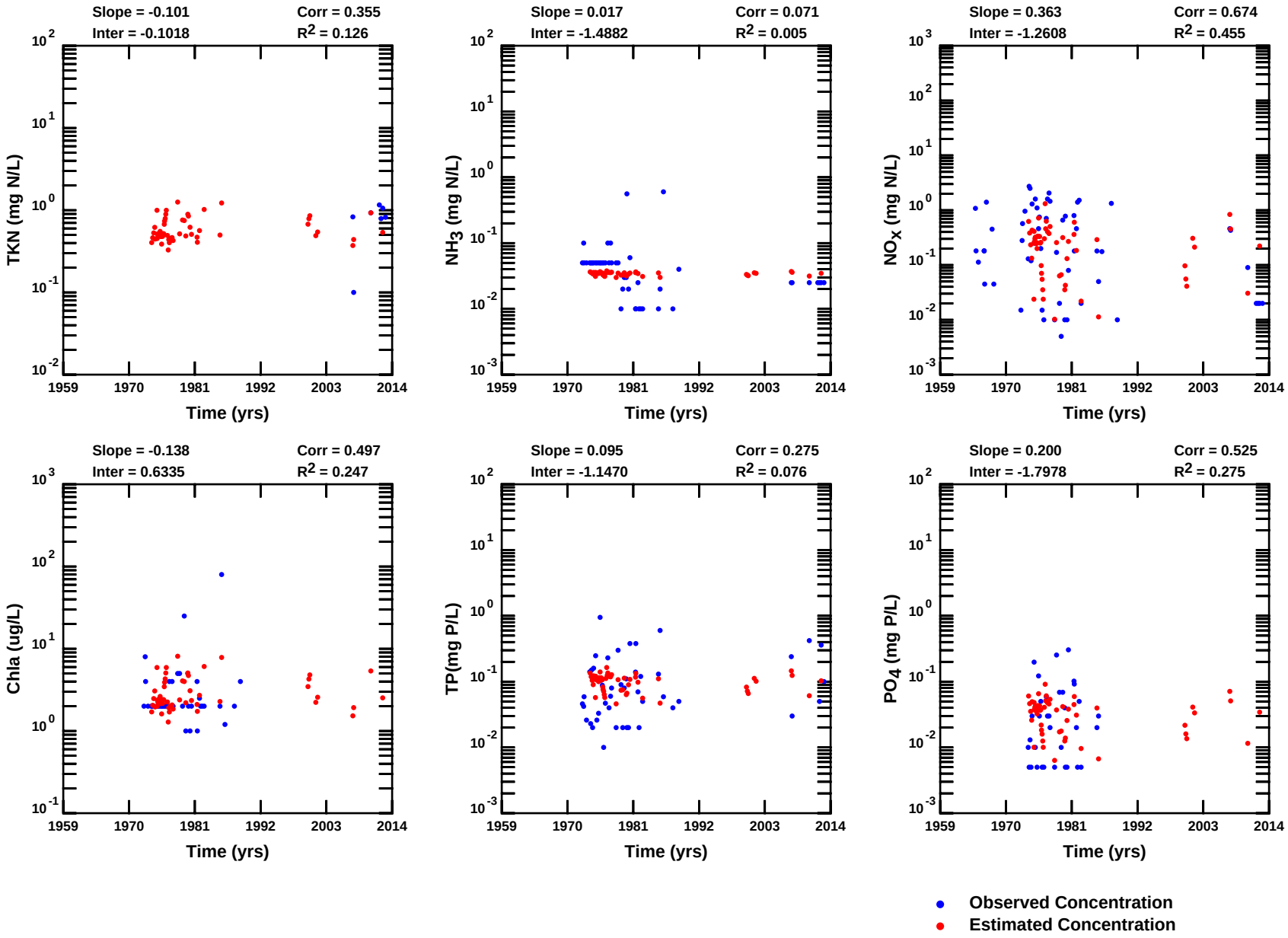
Nutrient Distributions, Station 12997
Nueces Tributaries, Texas (1959-2014)



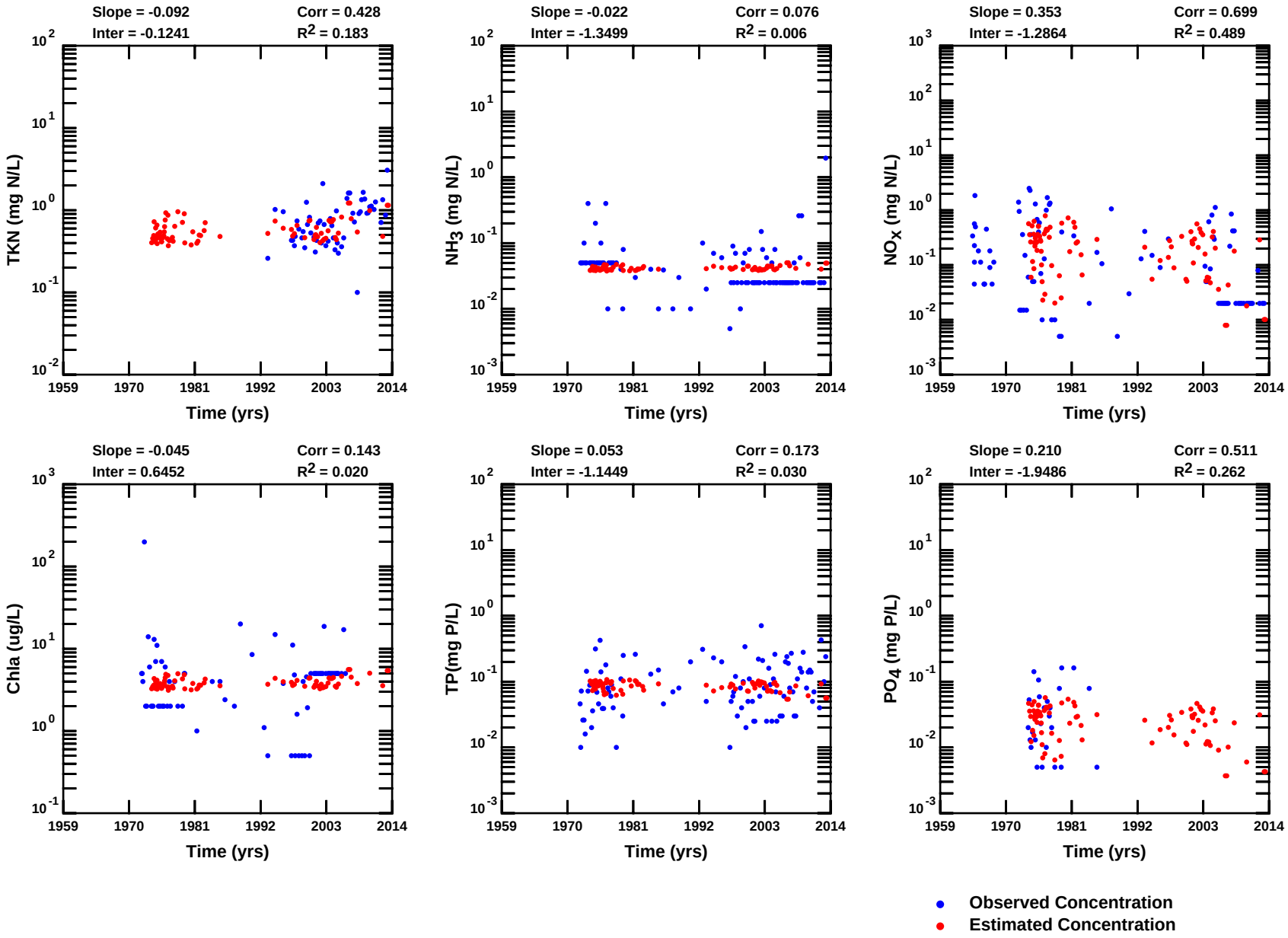
Nutrient Distributions, Station 12996
Nueces Tributaries, Texas (1959-2014)



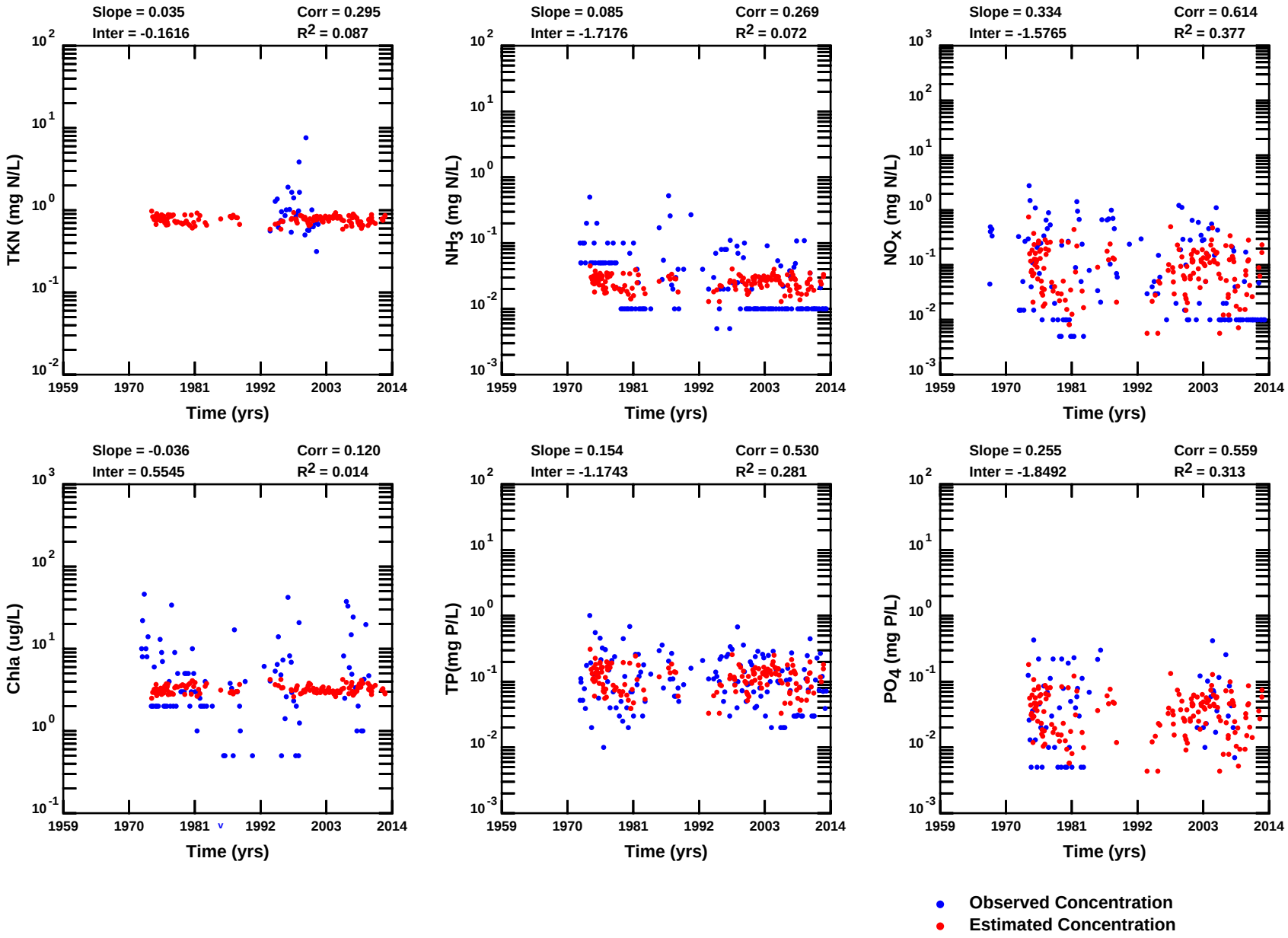
Nutrient Distributions, Station 17143
Nueces Tributaries, Texas (1959-2014)



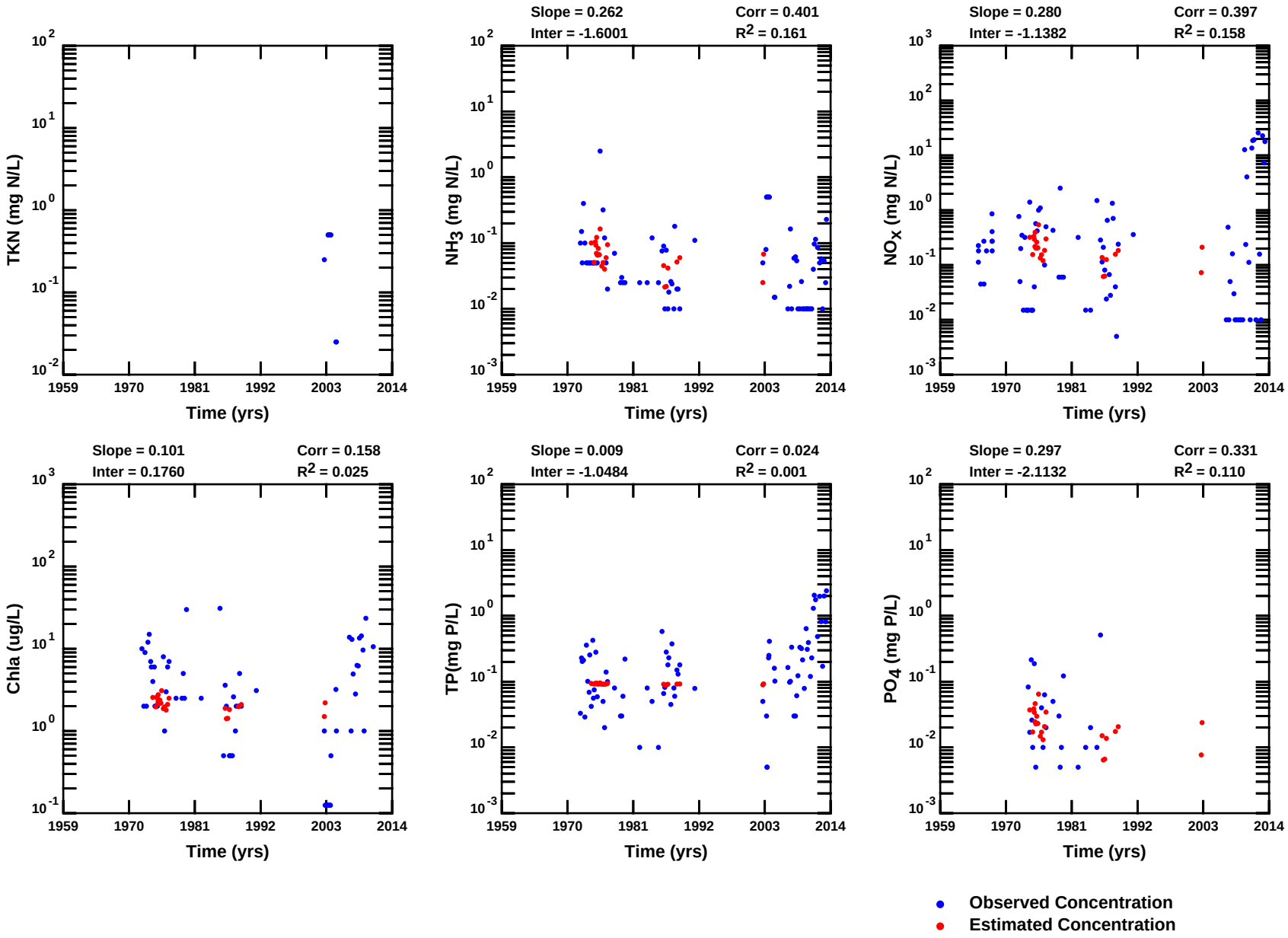
Nutrient Distributions, Station 12976
Nueces Tributaries, Texas (1959-2014)



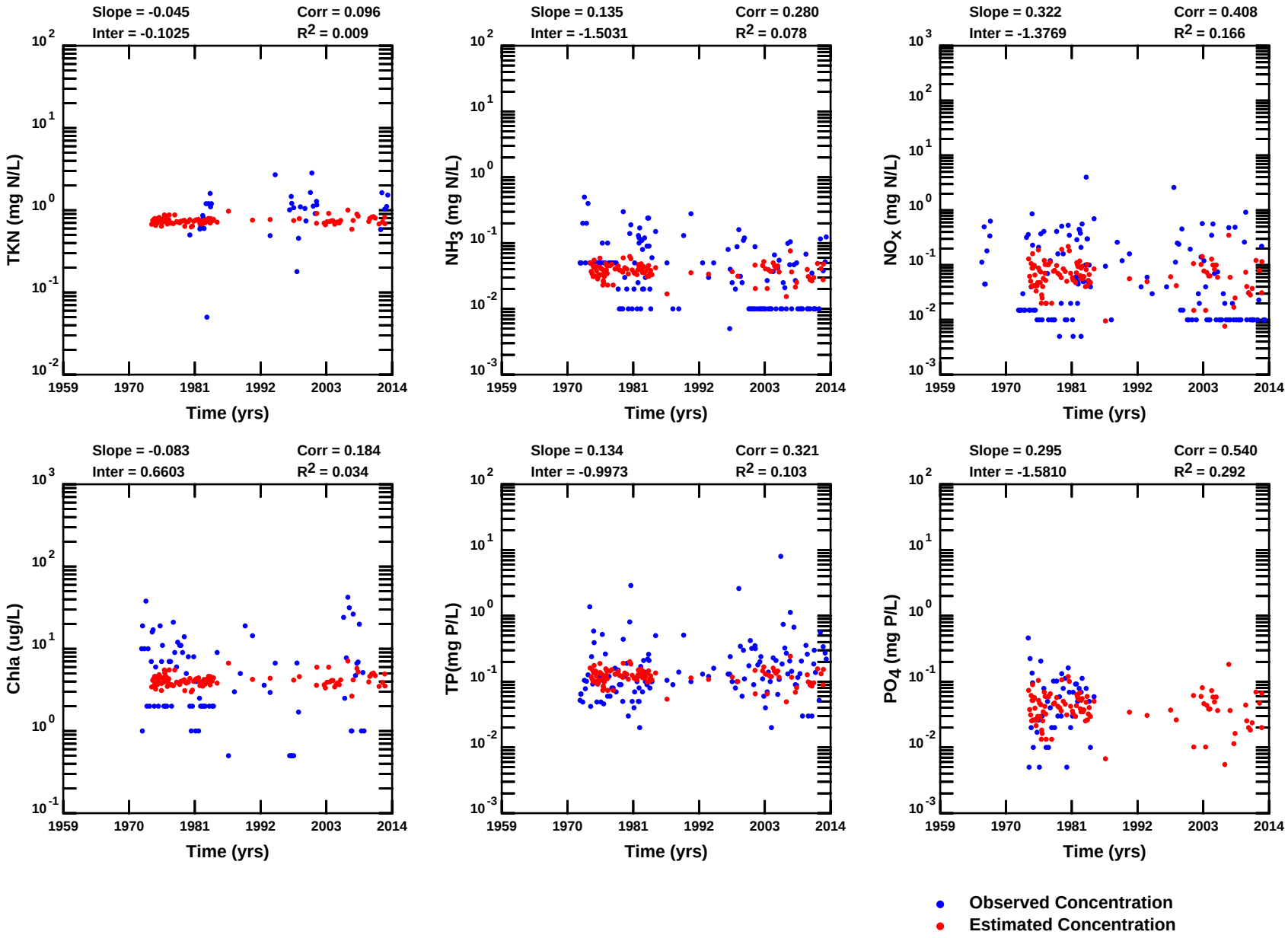
Nutrient Distributions, Station 12975
Nueces Tributaries, Texas (1959-2014)



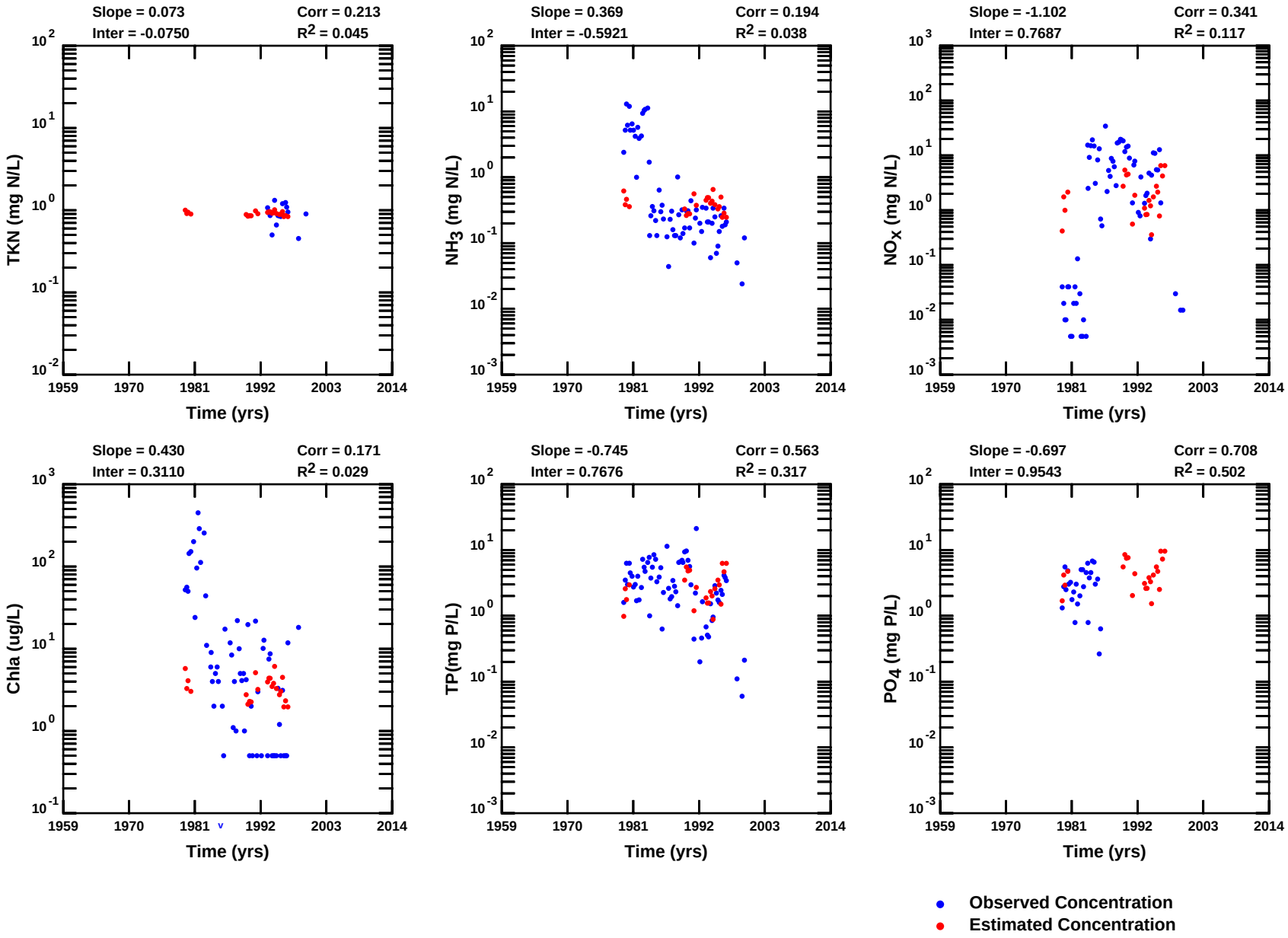
Nutrient Distributions, Station 12973
Nueces Tributaries, Texas (1959-2014)



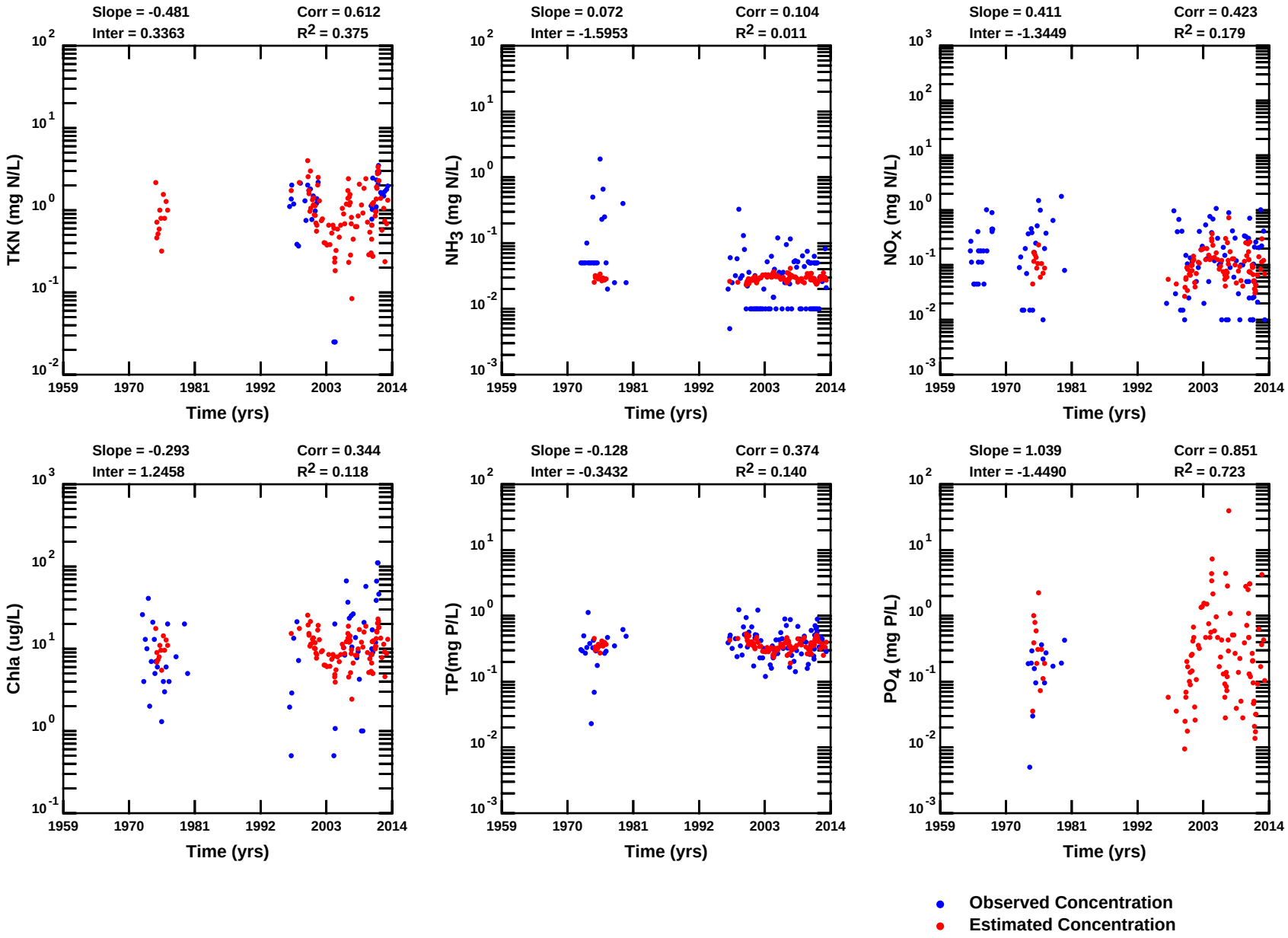
Nutrient Distributions, Station 12972
Nueces Tributaries, Texas (1959-2014)



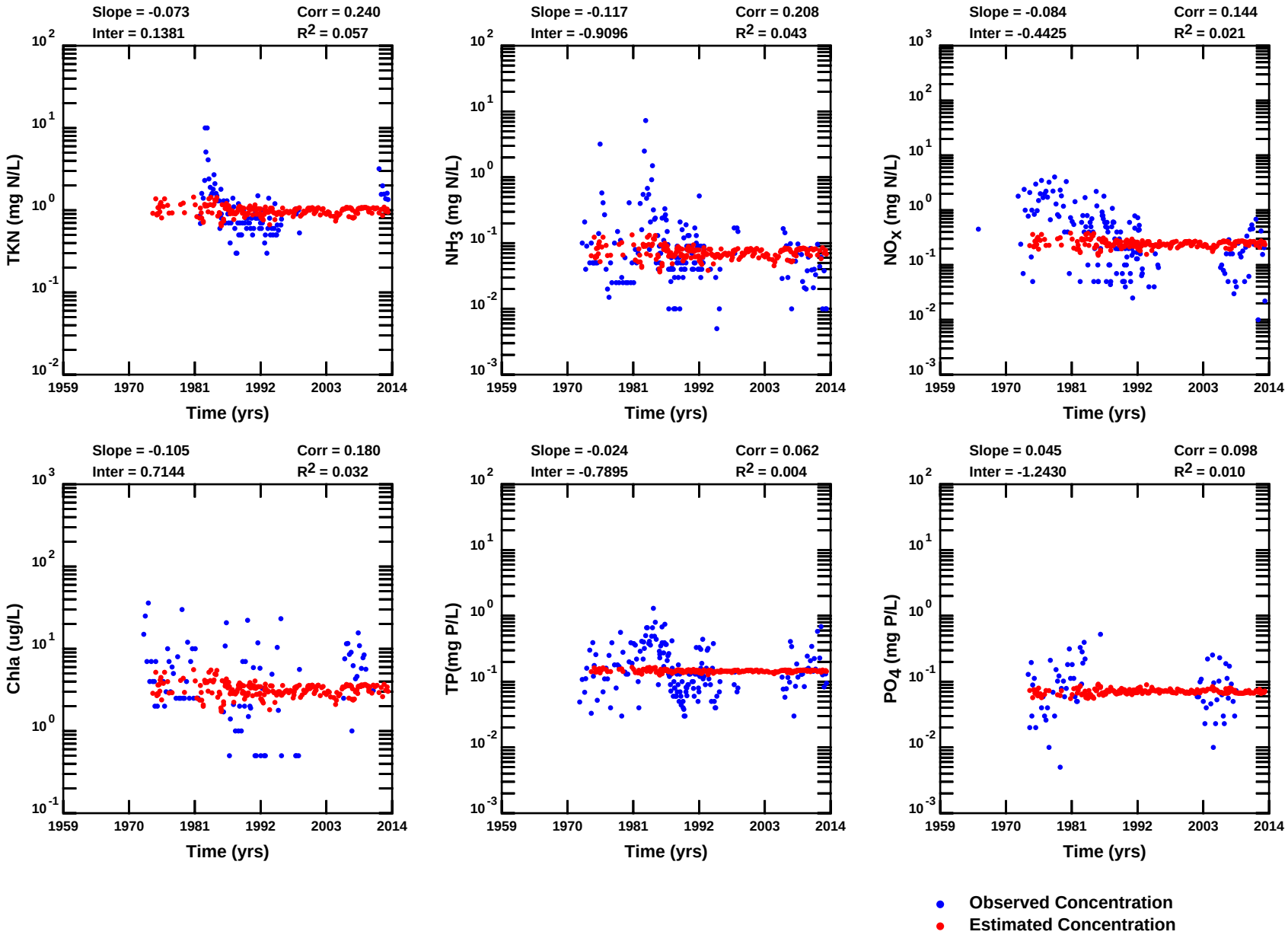
Nutrient Distributions, Station 12983
Nueces Tributaries, Texas (1959-2014)



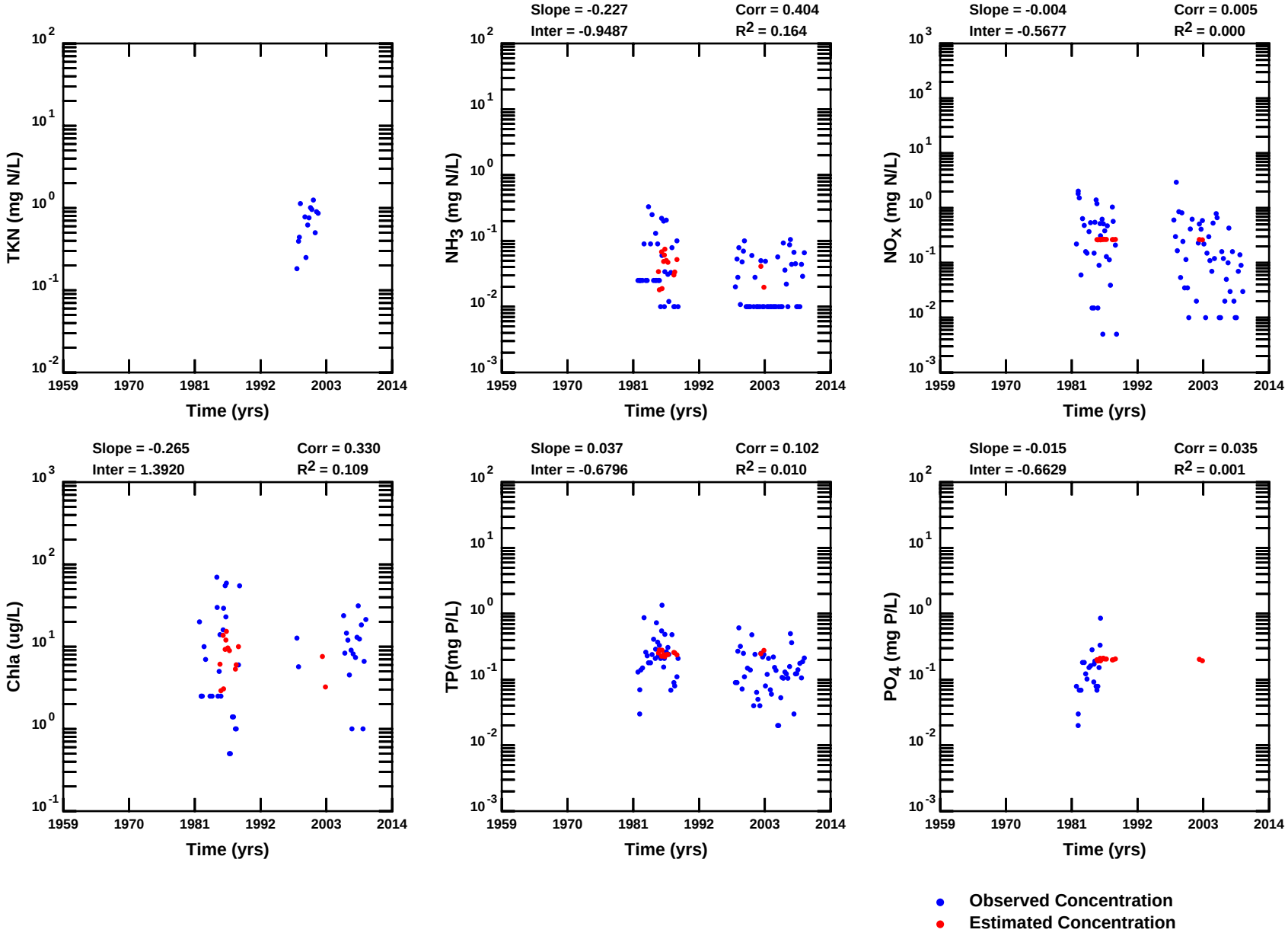
Nutrient Distributions, Station 12981
Nueces Tributaries, Texas (1959-2014)



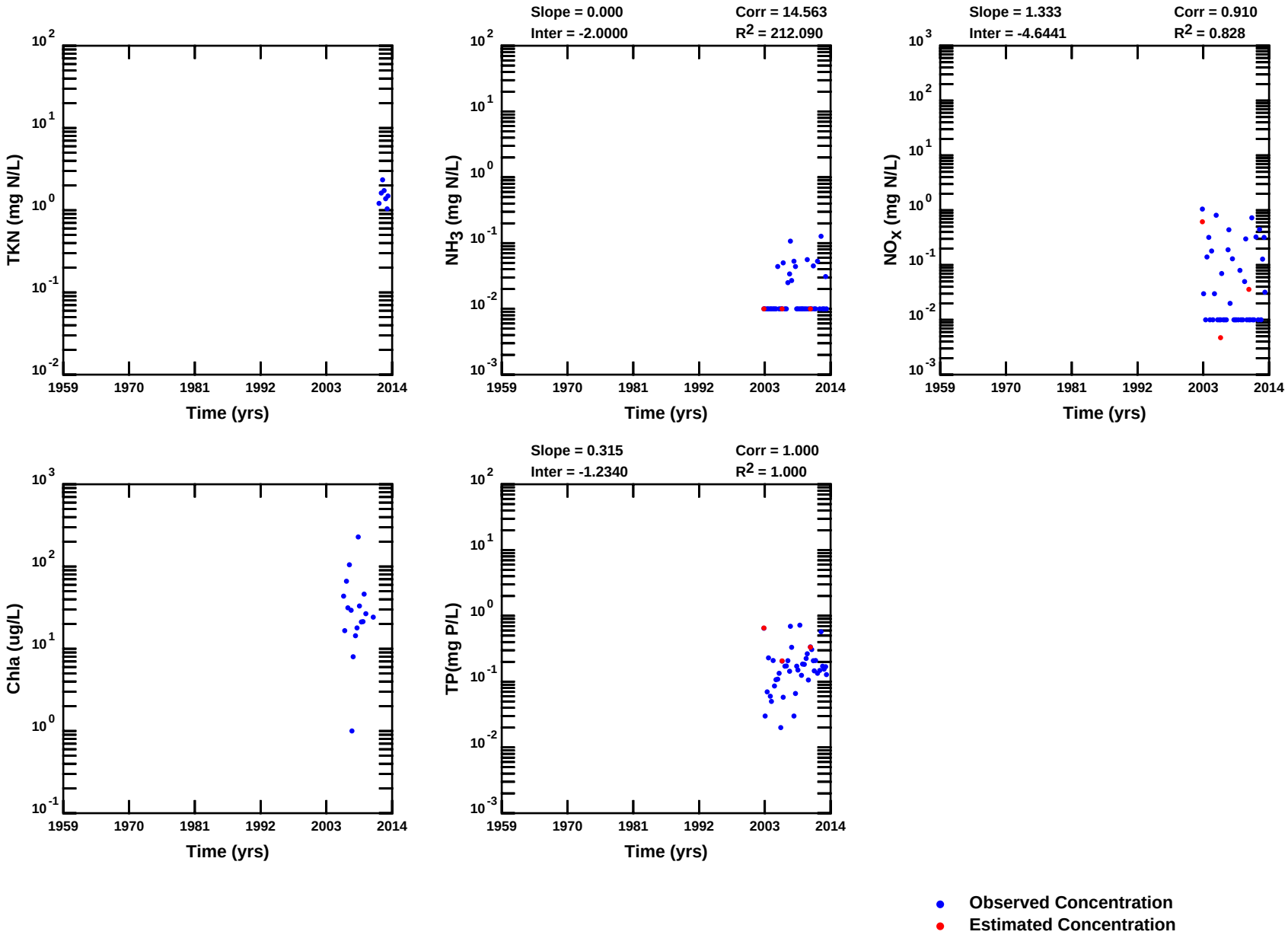
Nutrient Distributions, Station 12980
Nueces Tributaries, Texas (1959-2014)



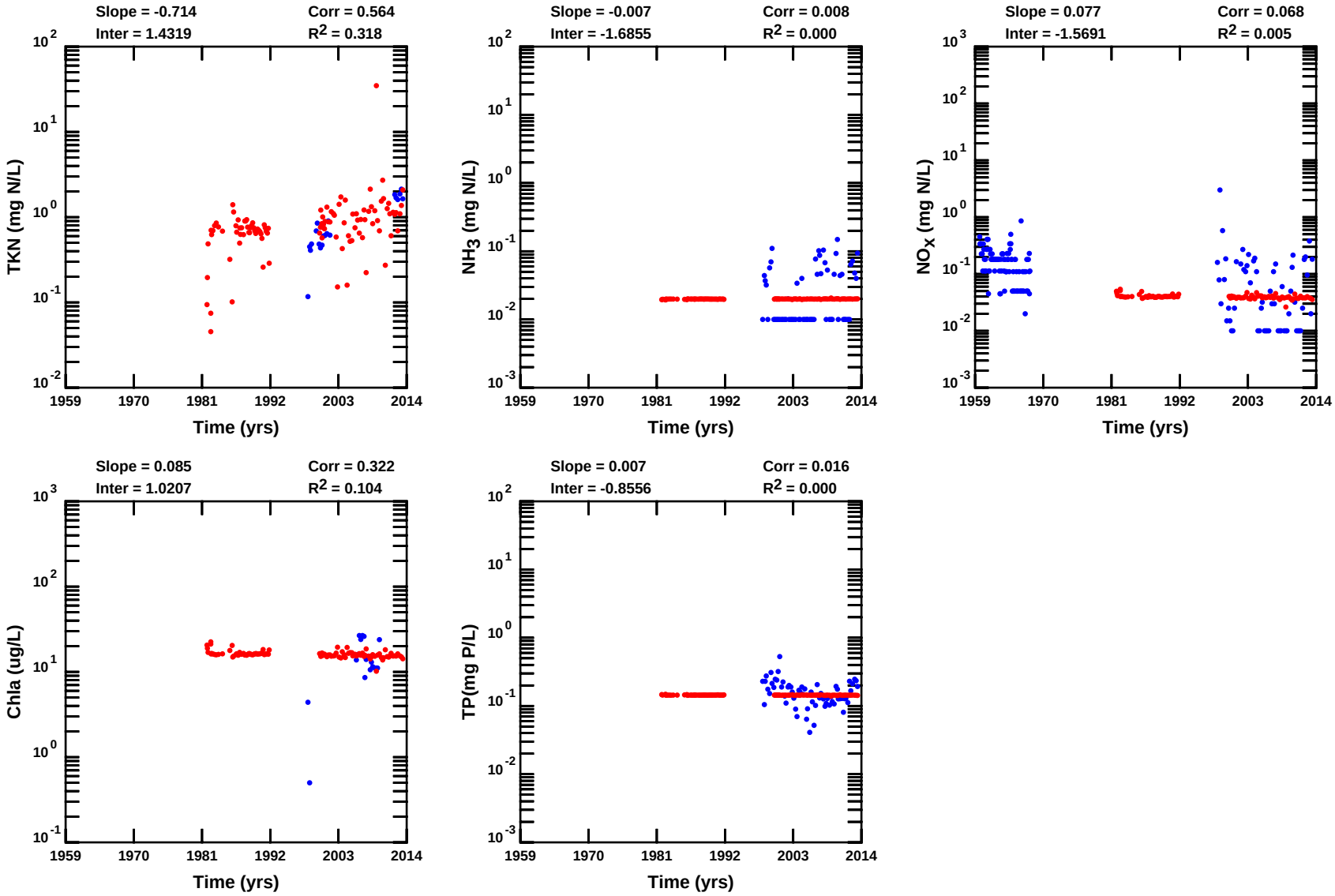
Nutrient Distributions, Station 12979
Nueces Tributaries, Texas (1959-2014)



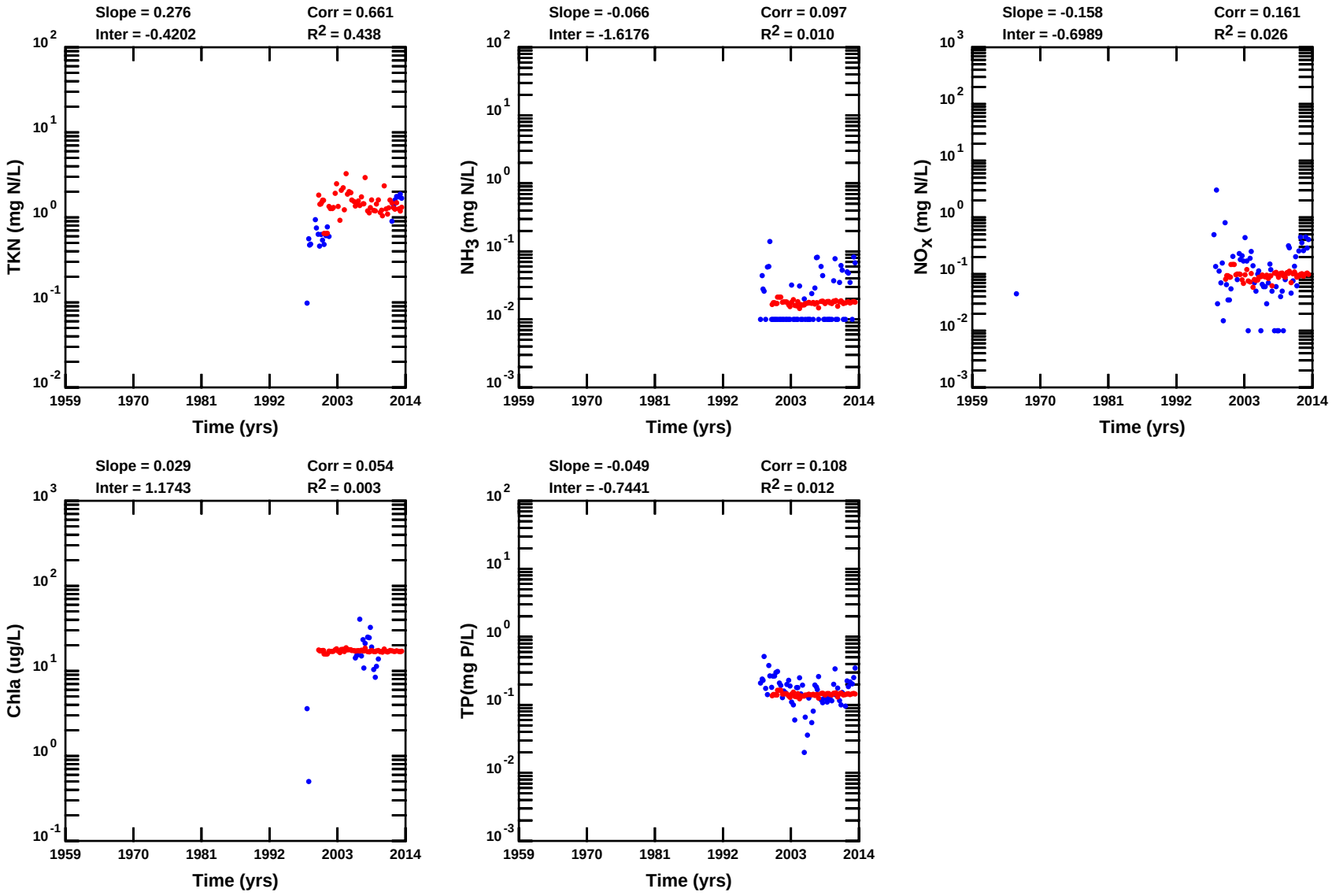
Nutrient Distributions, Station 12978
Nueces Tributaries, Texas (1959-2014)



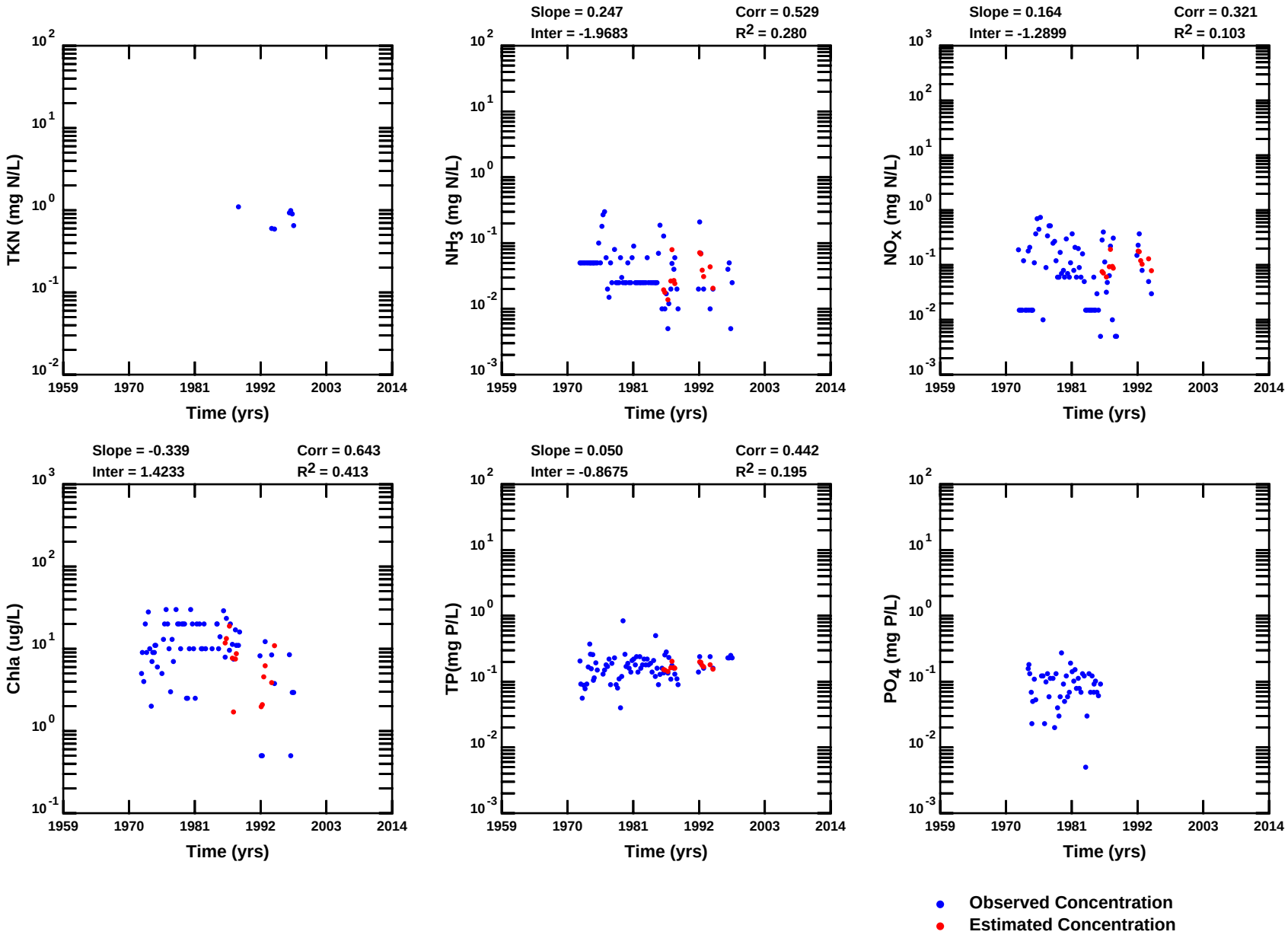
Nutrient Distributions, Station 17648
Nueces Tributaries, Texas (1959-2014)



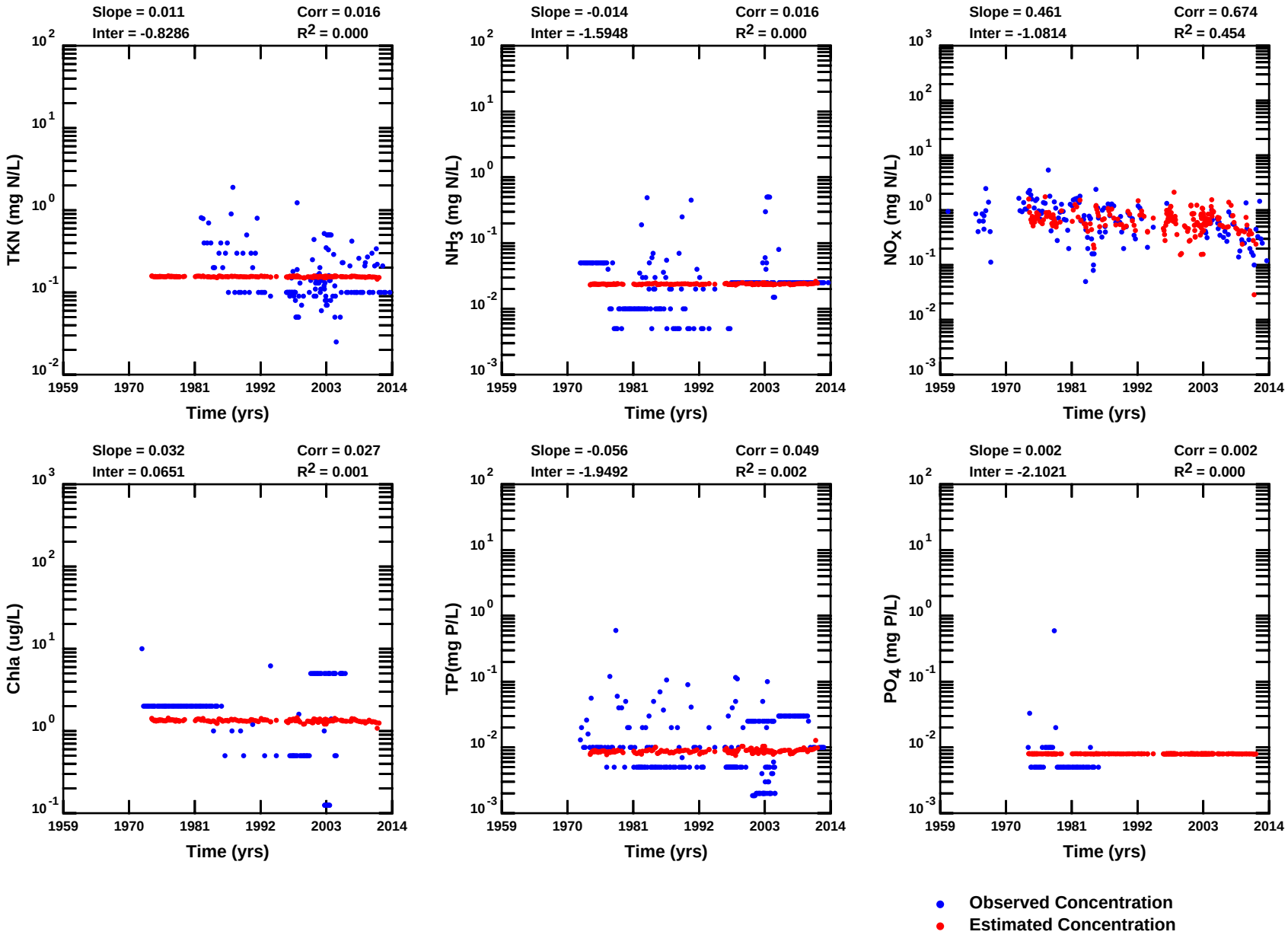
Nutrient Distributions, Station 12965
Nueces Tributaries, Texas (1959-2014)



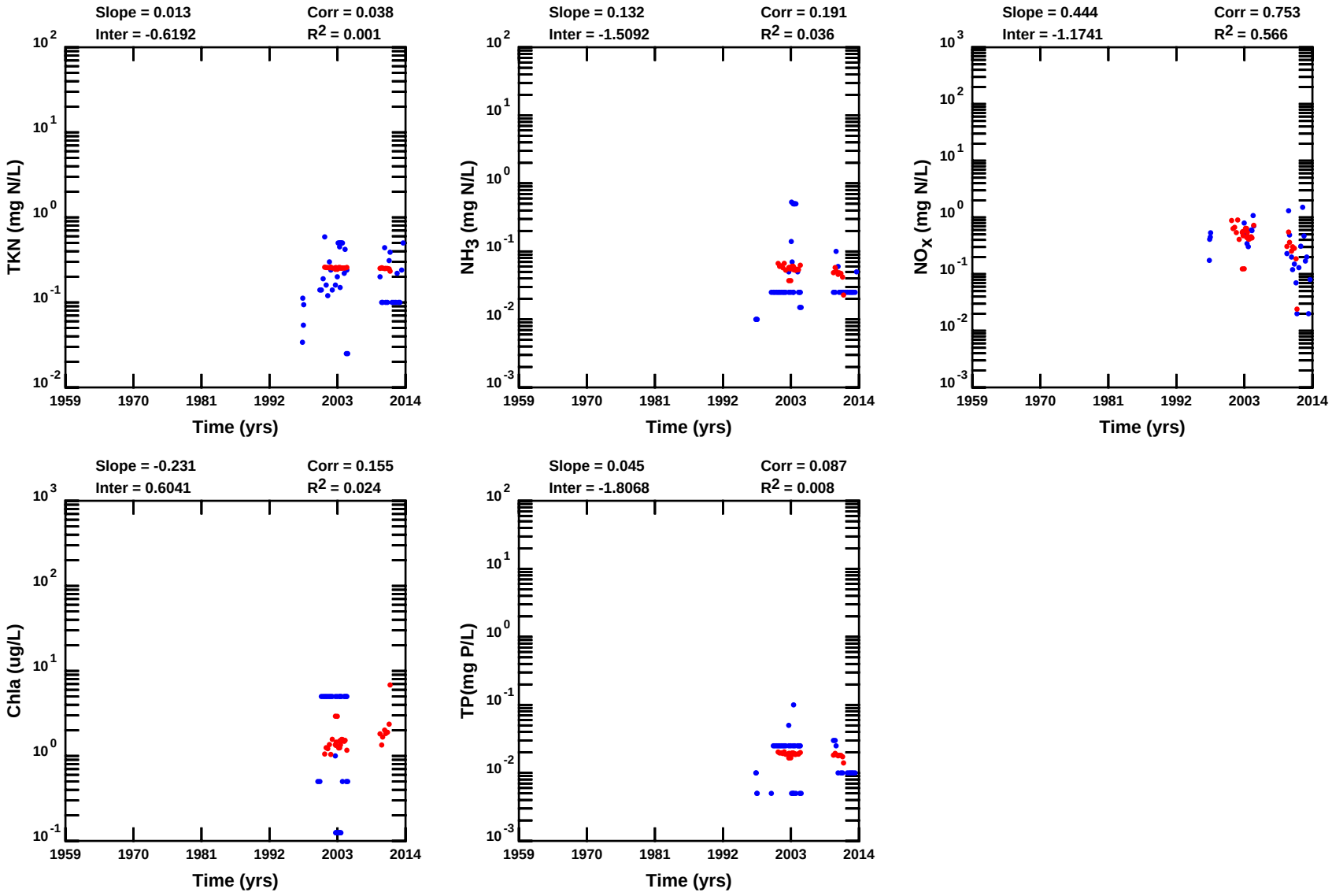
Nutrient Distributions, Station 12964
Nueces Tributaries, Texas (1959-2014)



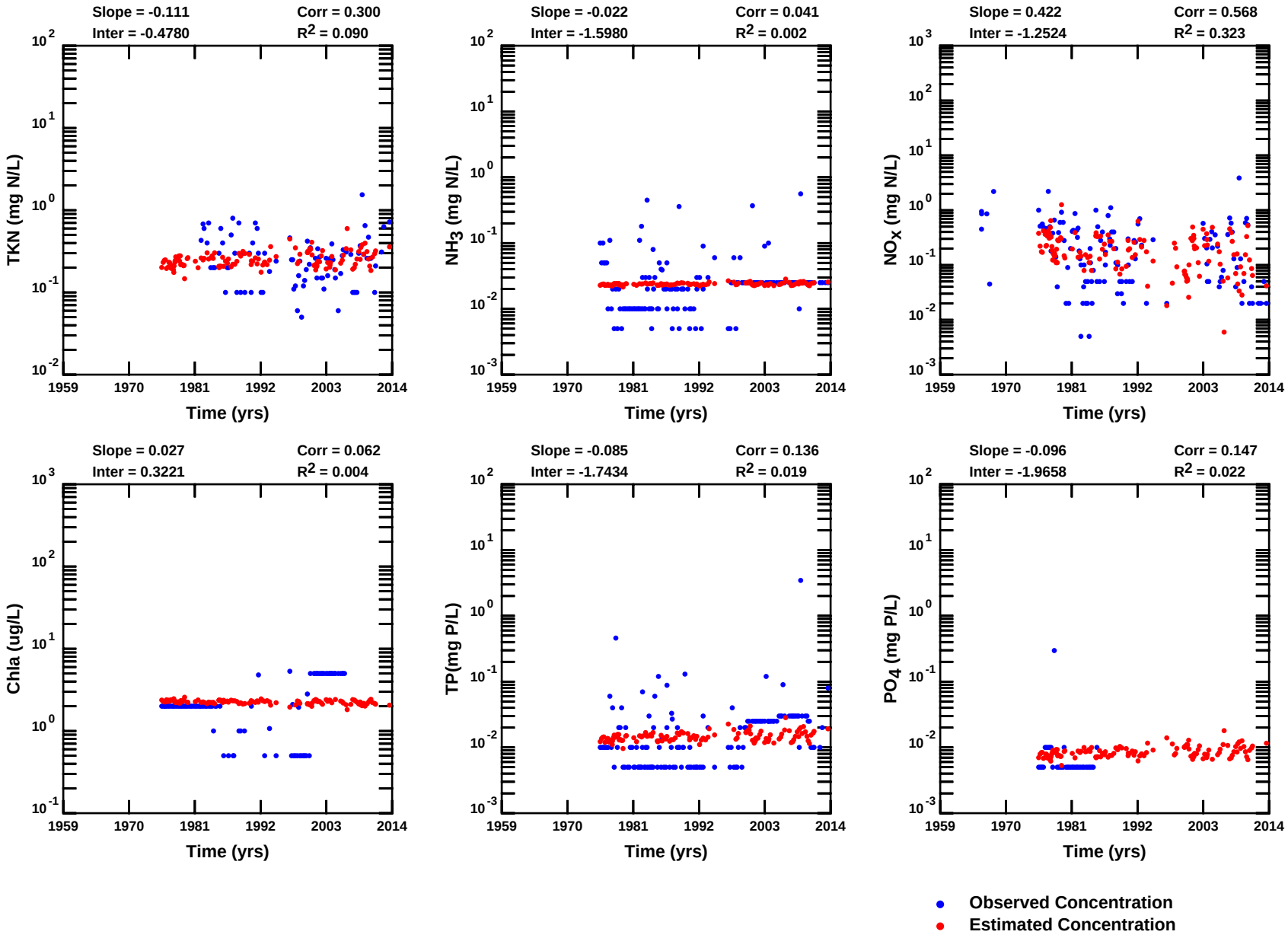
Nutrient Distributions, Station 12962
Nueces Tributaries, Texas (1959-2014)



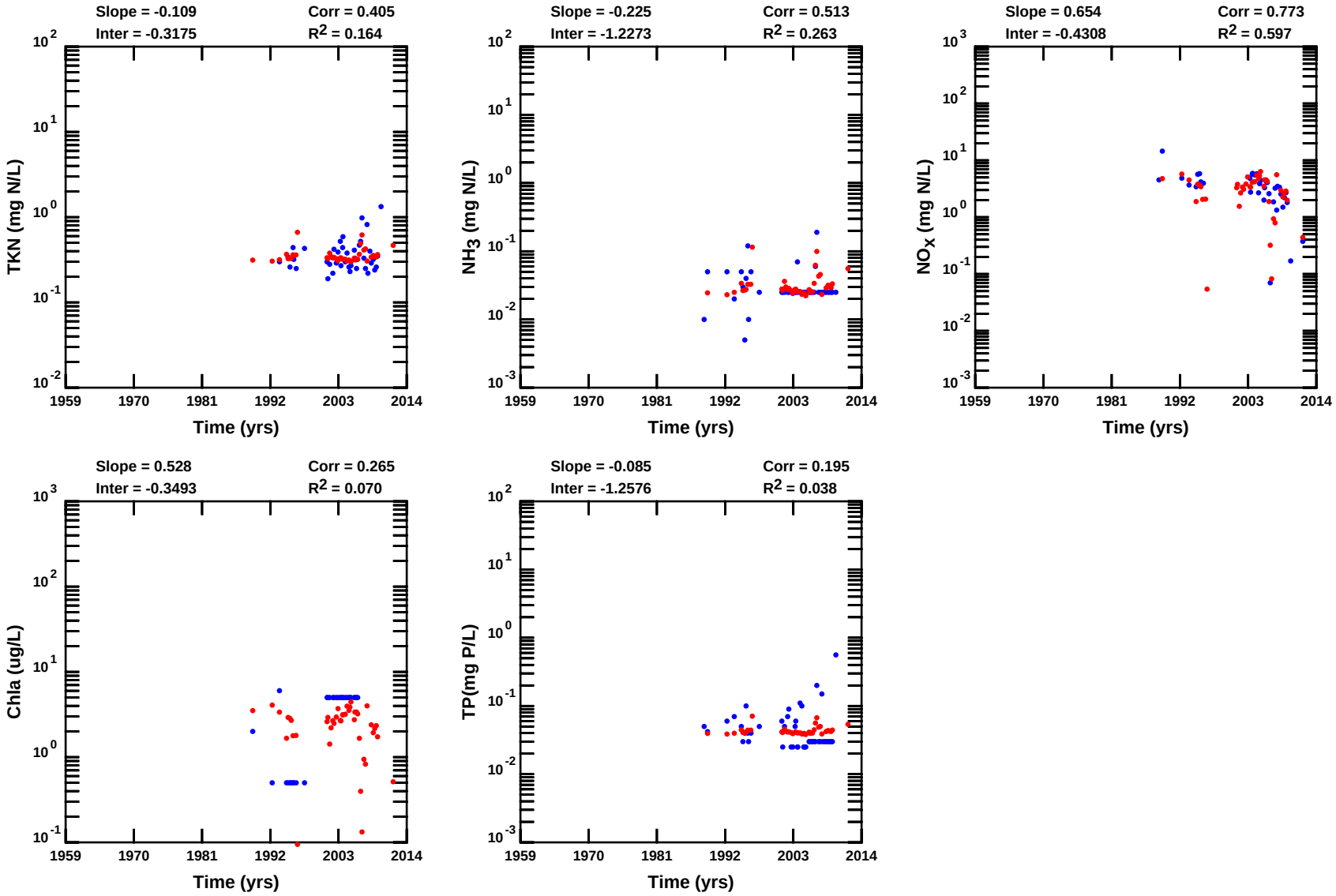
Nutrient Distributions, Station 13006
Nueces Tributaries, Texas (1959-2014)



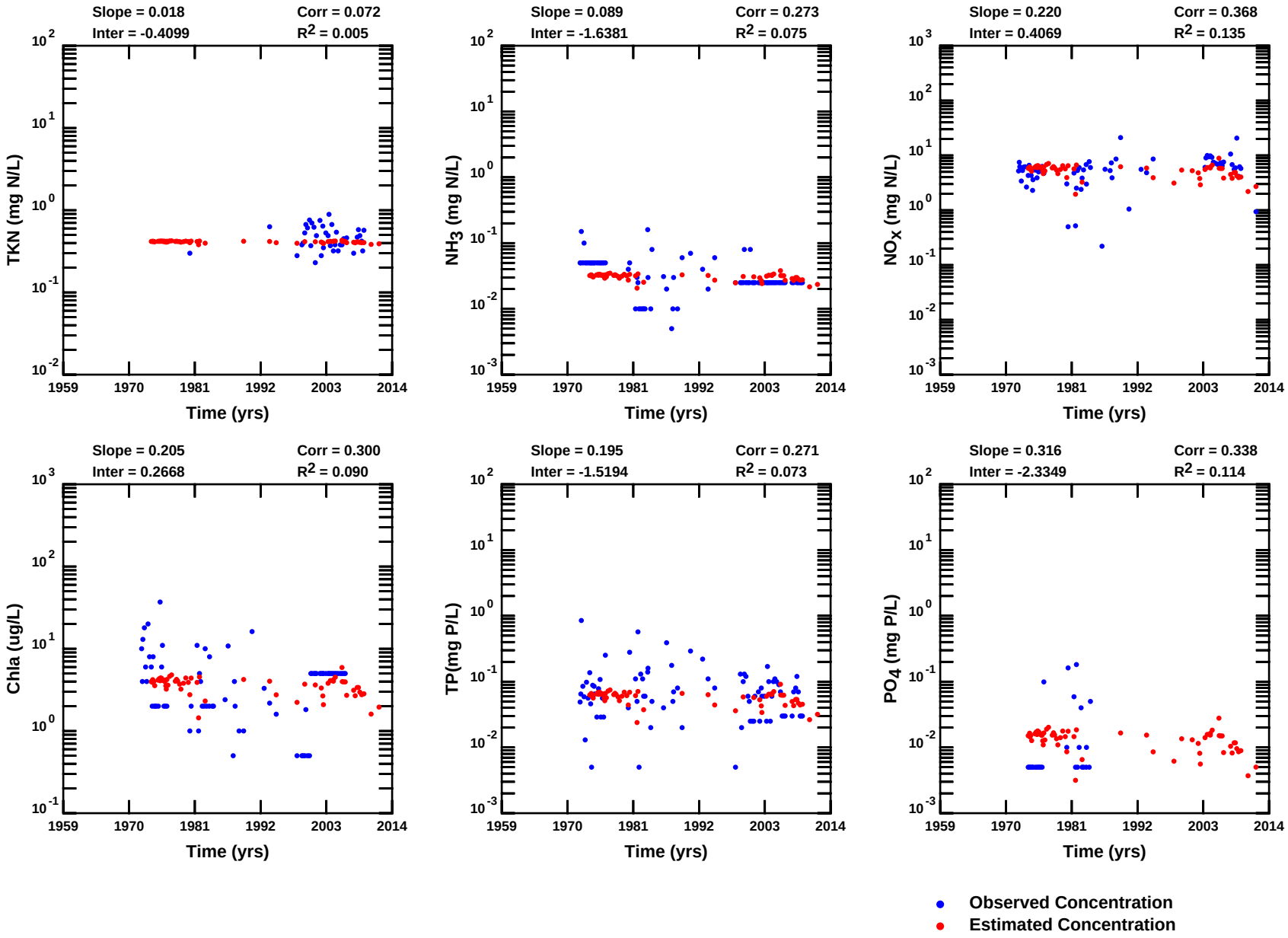
Nutrient Distributions, Station 13007
Nueces Tributaries, Texas (1959-2014)



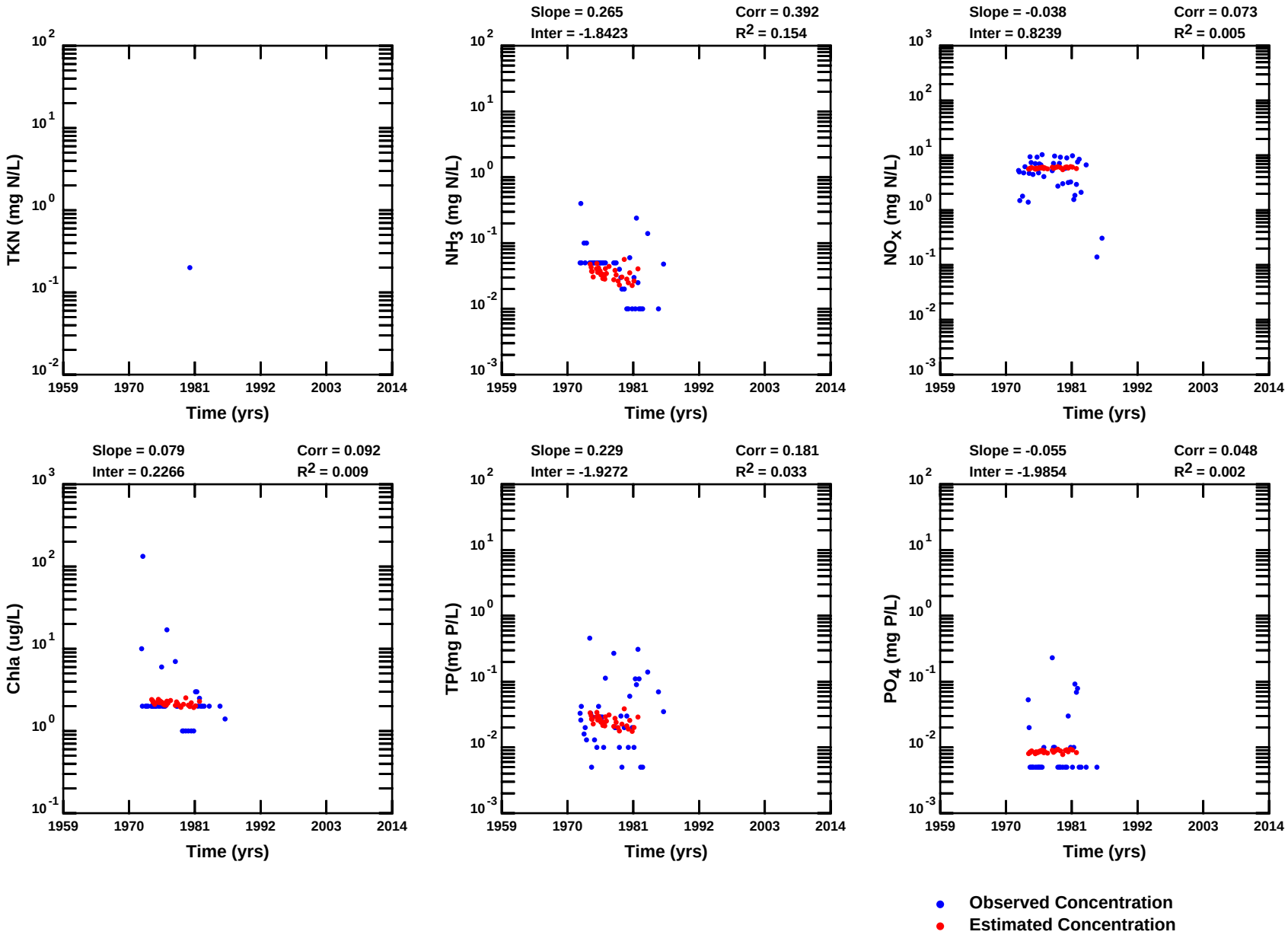
Nutrient Distributions, Station 13010
Nueces Tributaries, Texas (1959-2014)



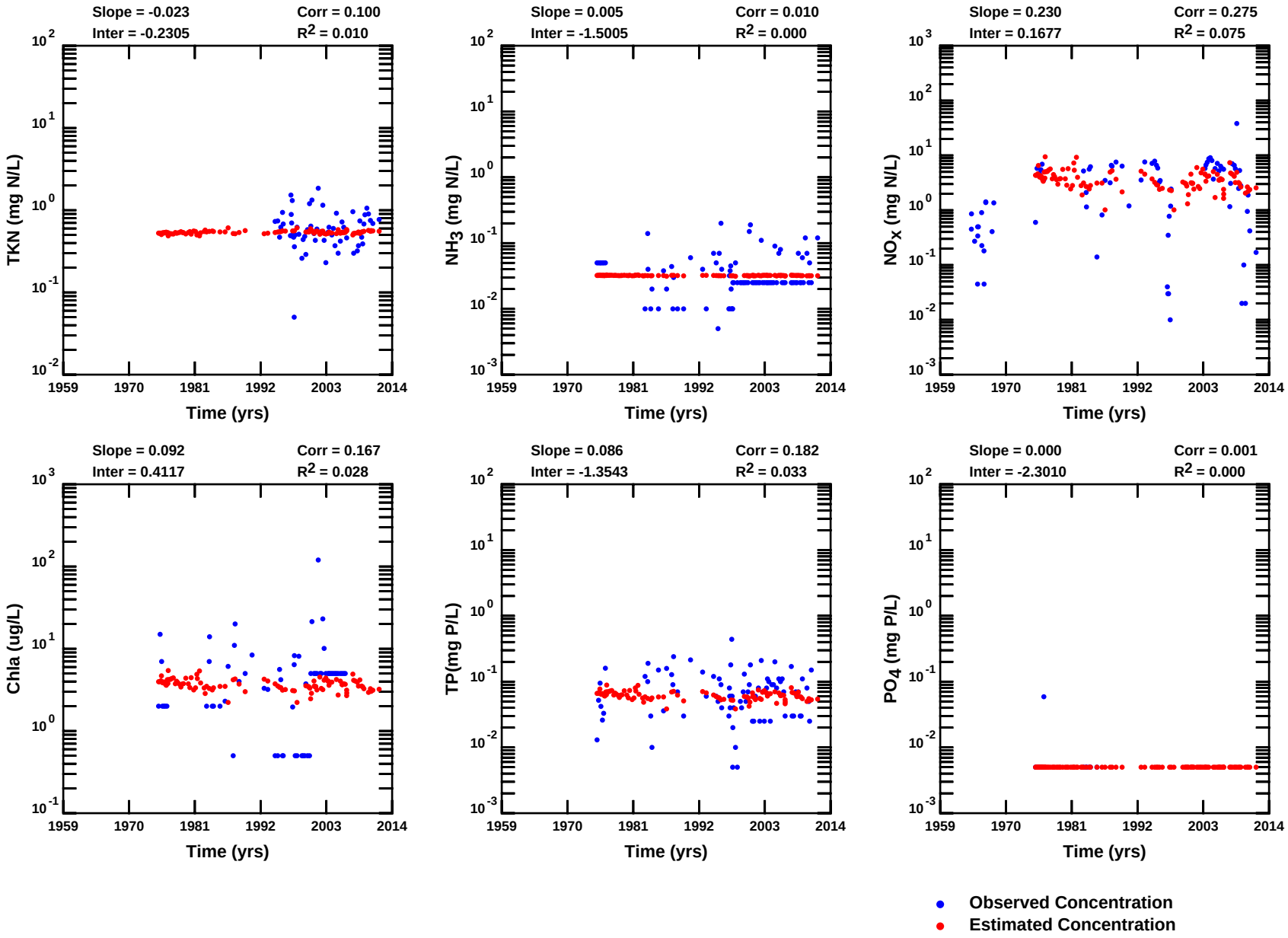
Nutrient Distributions, Station 12987
Nueces Tributaries, Texas (1959-2014)



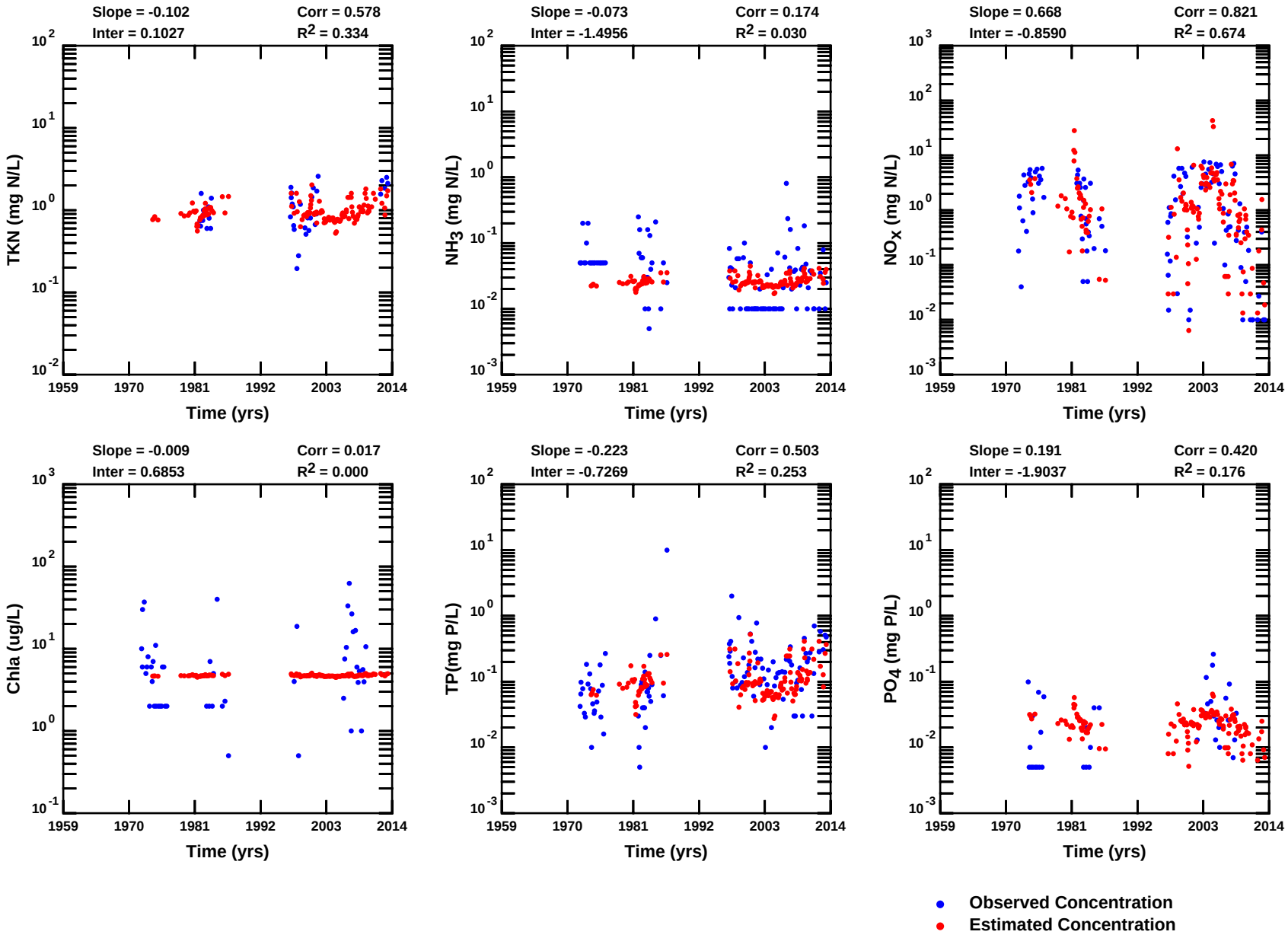
Nutrient Distributions, Station 12985
Nueces Tributaries, Texas (1959-2014)



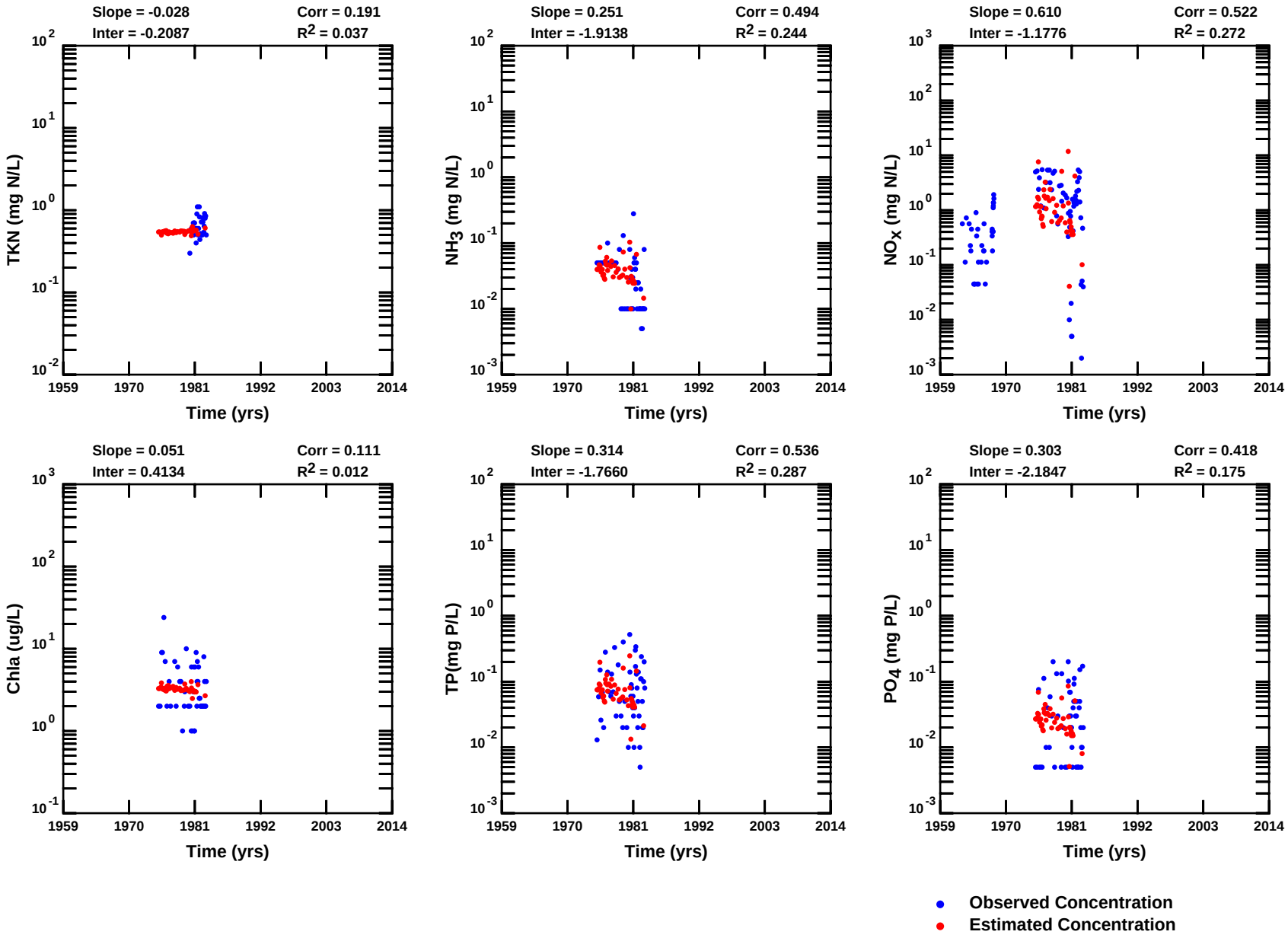
Nutrient Distributions, Station 13025
Nueces Tributaries, Texas (1959-2014)



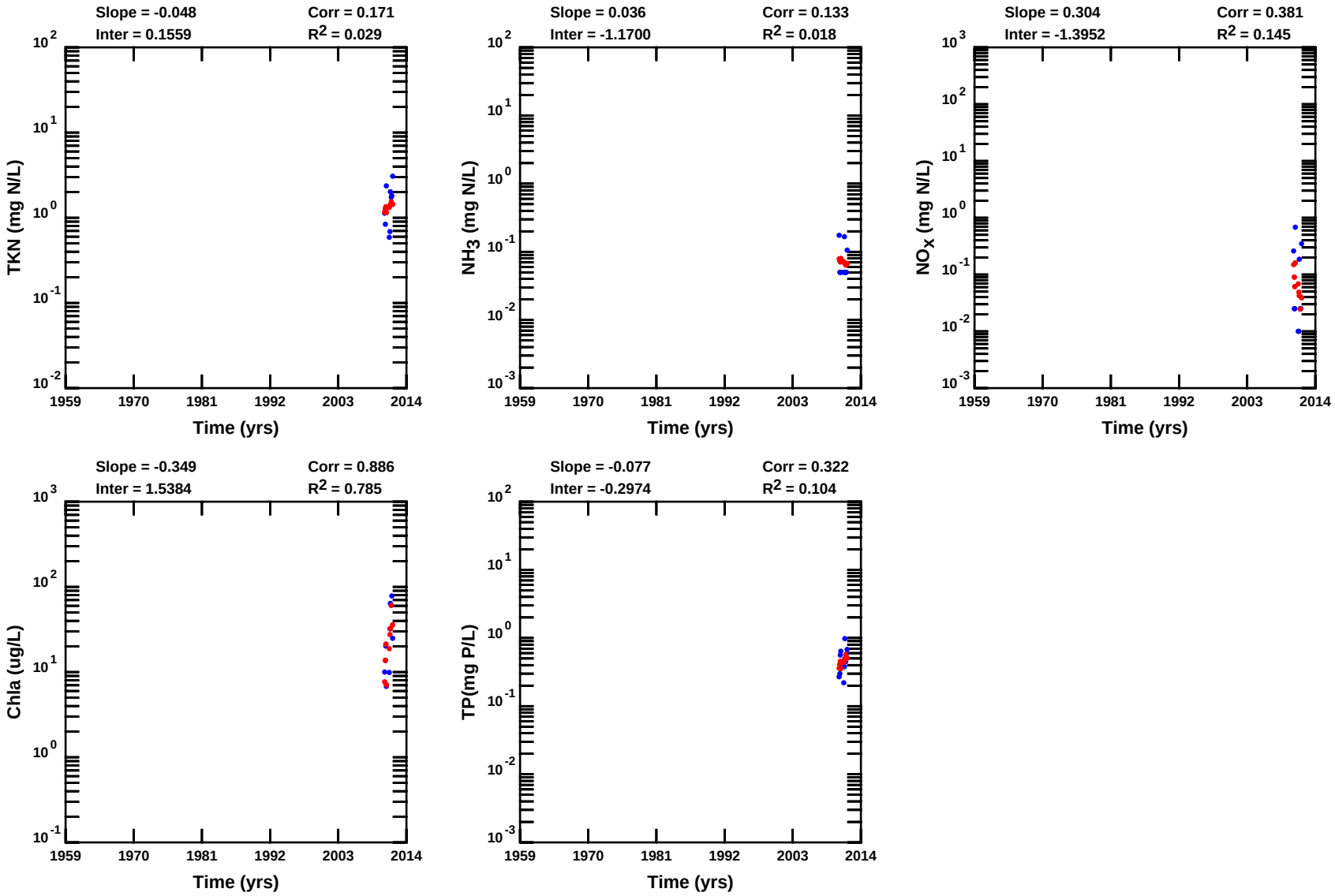
Nutrient Distributions, Station 13024
Nueces Tributaries, Texas (1959-2014)



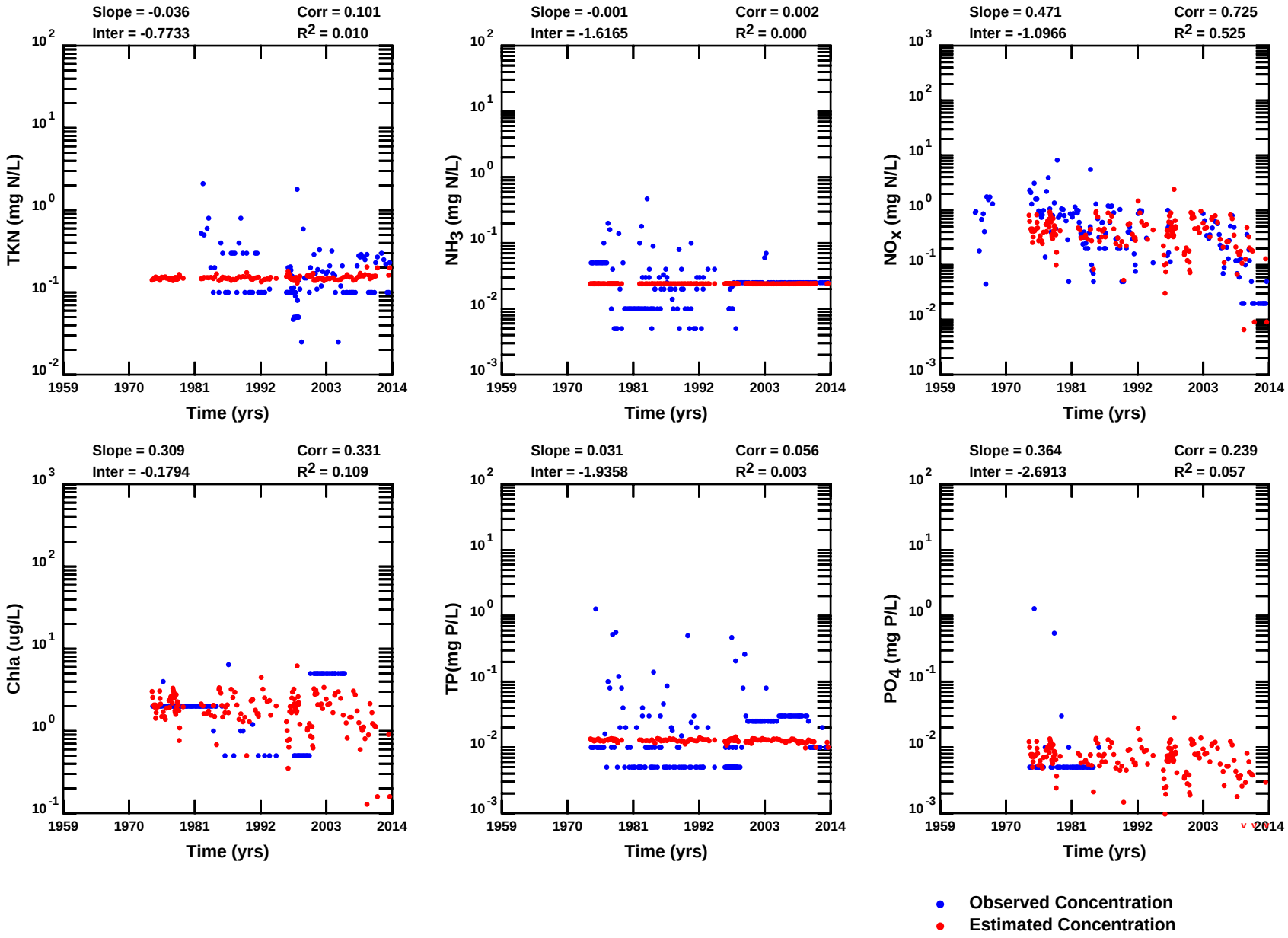
Nutrient Distributions, Station 13023
Nueces Tributaries, Texas (1959-2014)



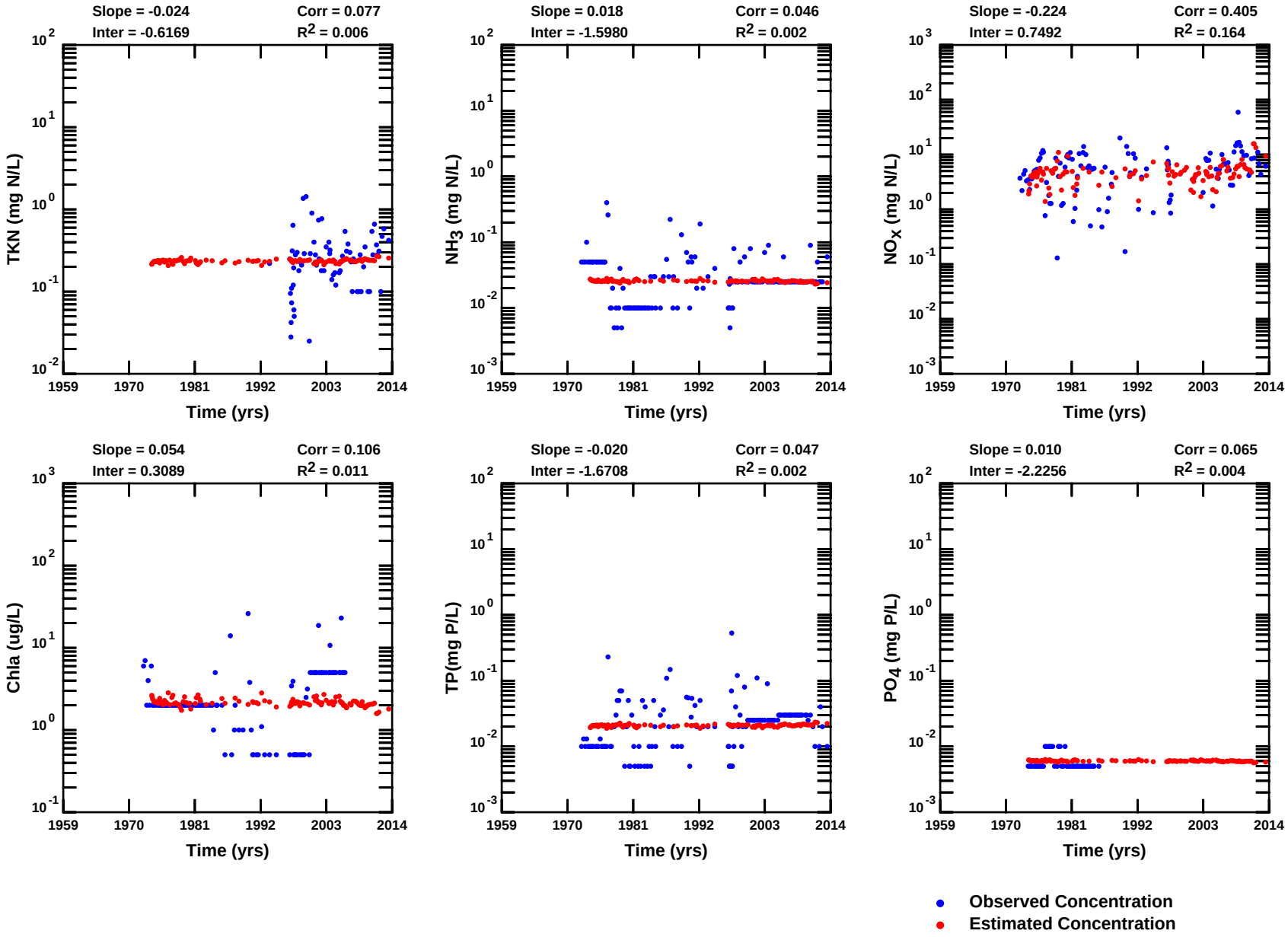
Nutrient Distributions, Station 13021
Nueces Tributaries, Texas (1959-2014)



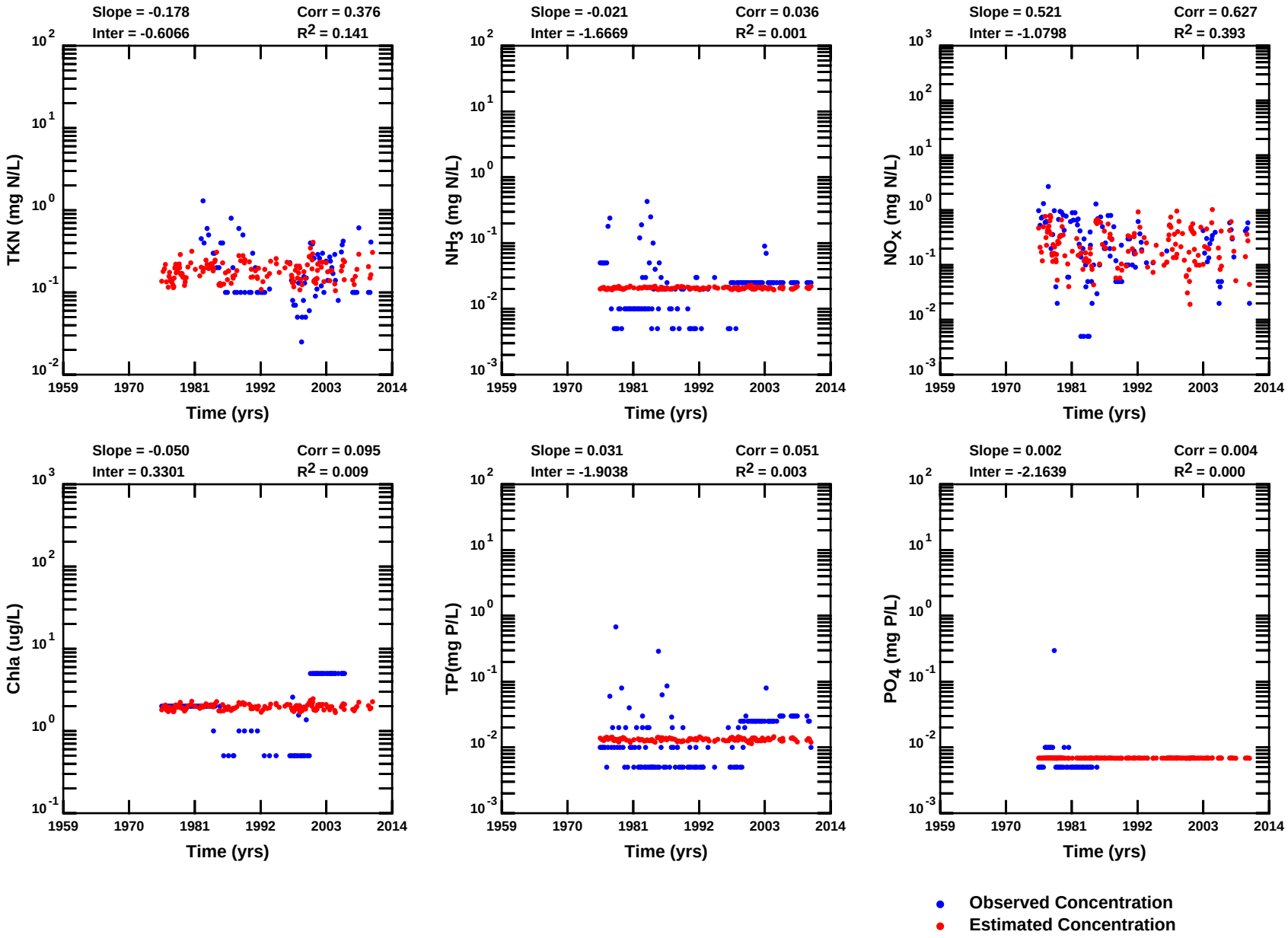
Nutrient Distributions, Station 20773
Nueces Tributaries, Texas (1959-2014)



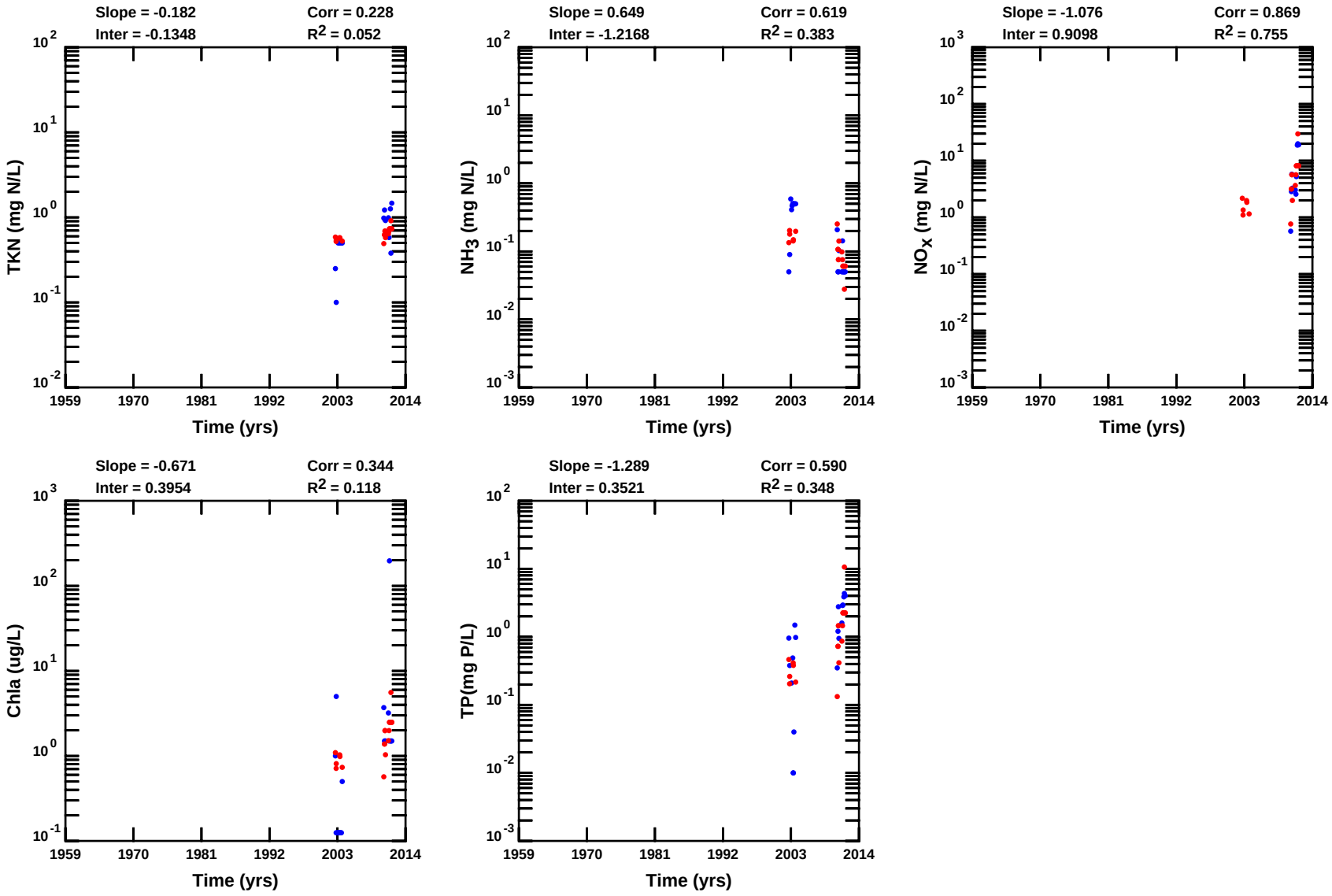
Nutrient Distributions, Station 12994
Nueces Tributaries, Texas (1959-2014)



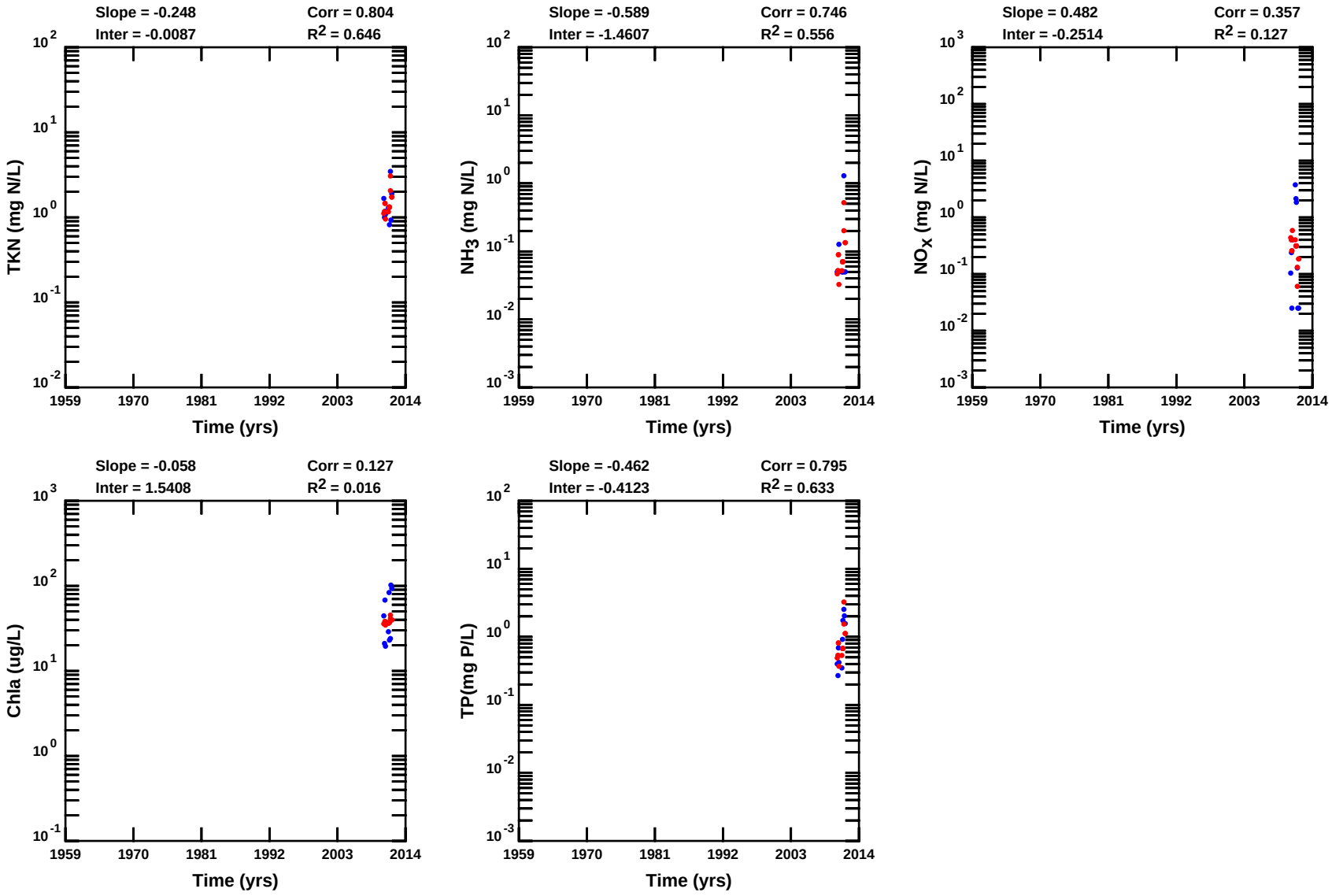
Nutrient Distributions, Station 12993
Nueces Tributaries, Texas (1959-2014)



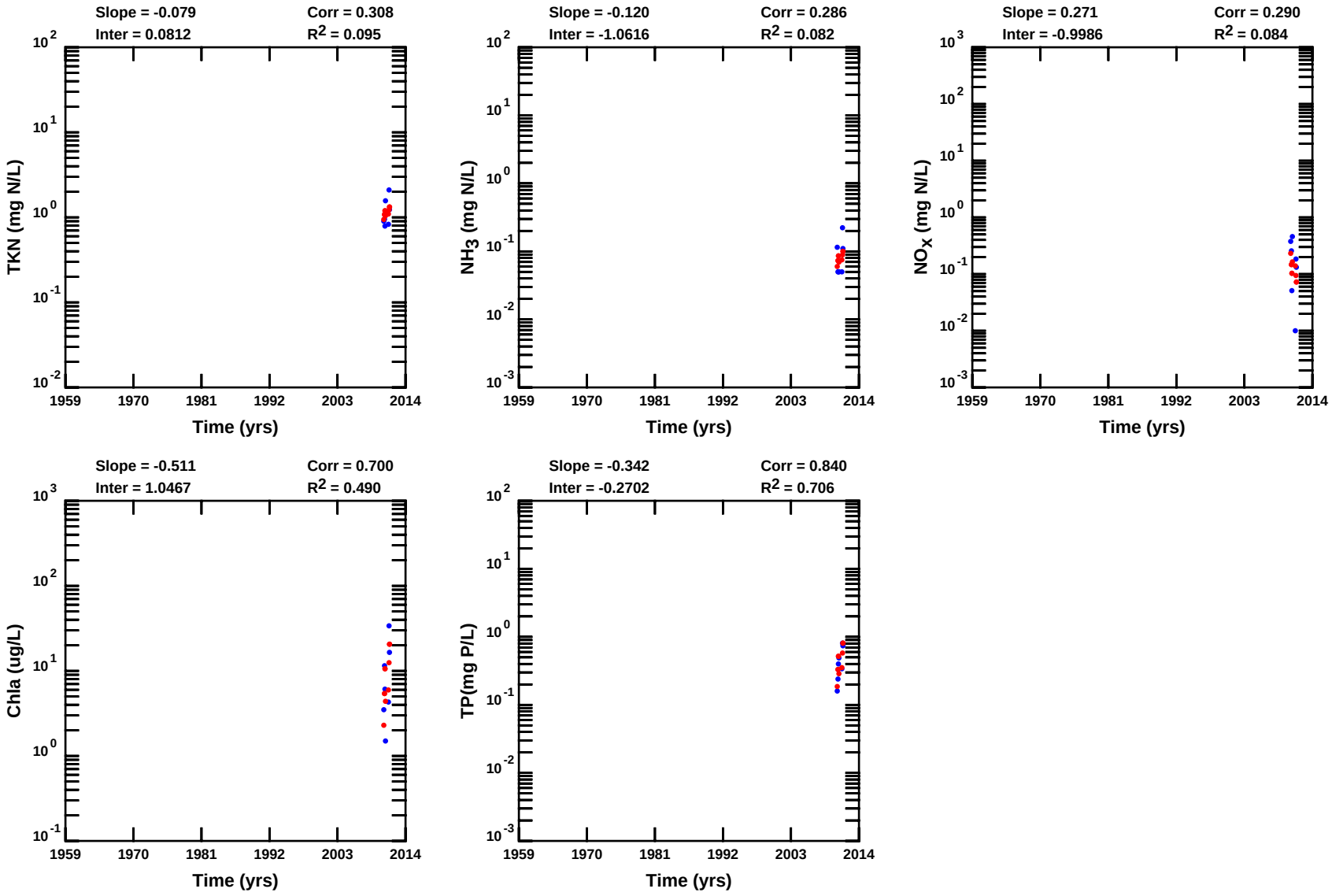
Nutrient Distributions, Station 13013
Nueces Tributaries, Texas (1959-2014)



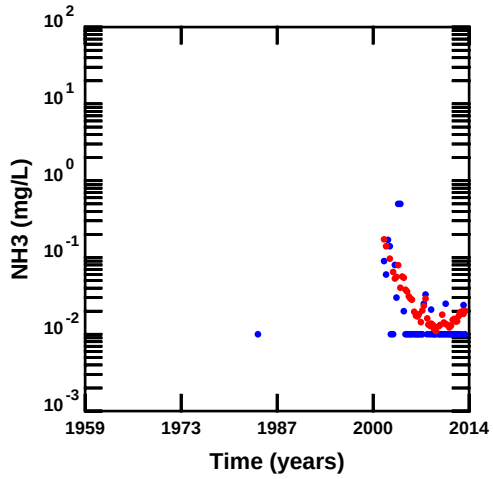
Nutrient Distributions, Station 17900
Nueces Tributaries, Texas (1959-2014)

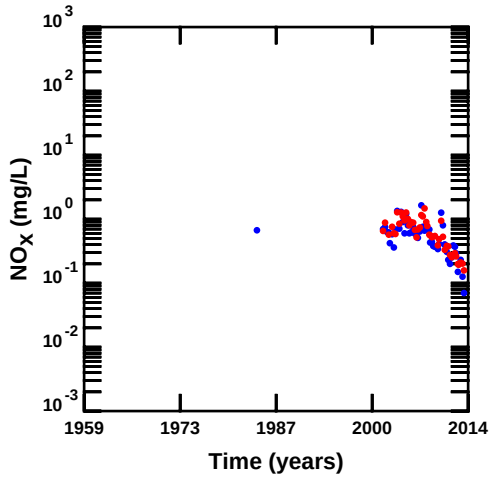


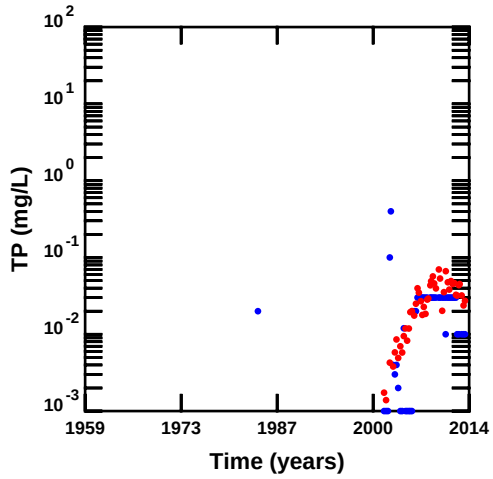
Nutrient Distributions, Station 20762
Nueces Tributaries, Texas (1959-2014)



Nutrient Distributions, Station 20764
Nueces Tributaries, Texas (1959-2014)

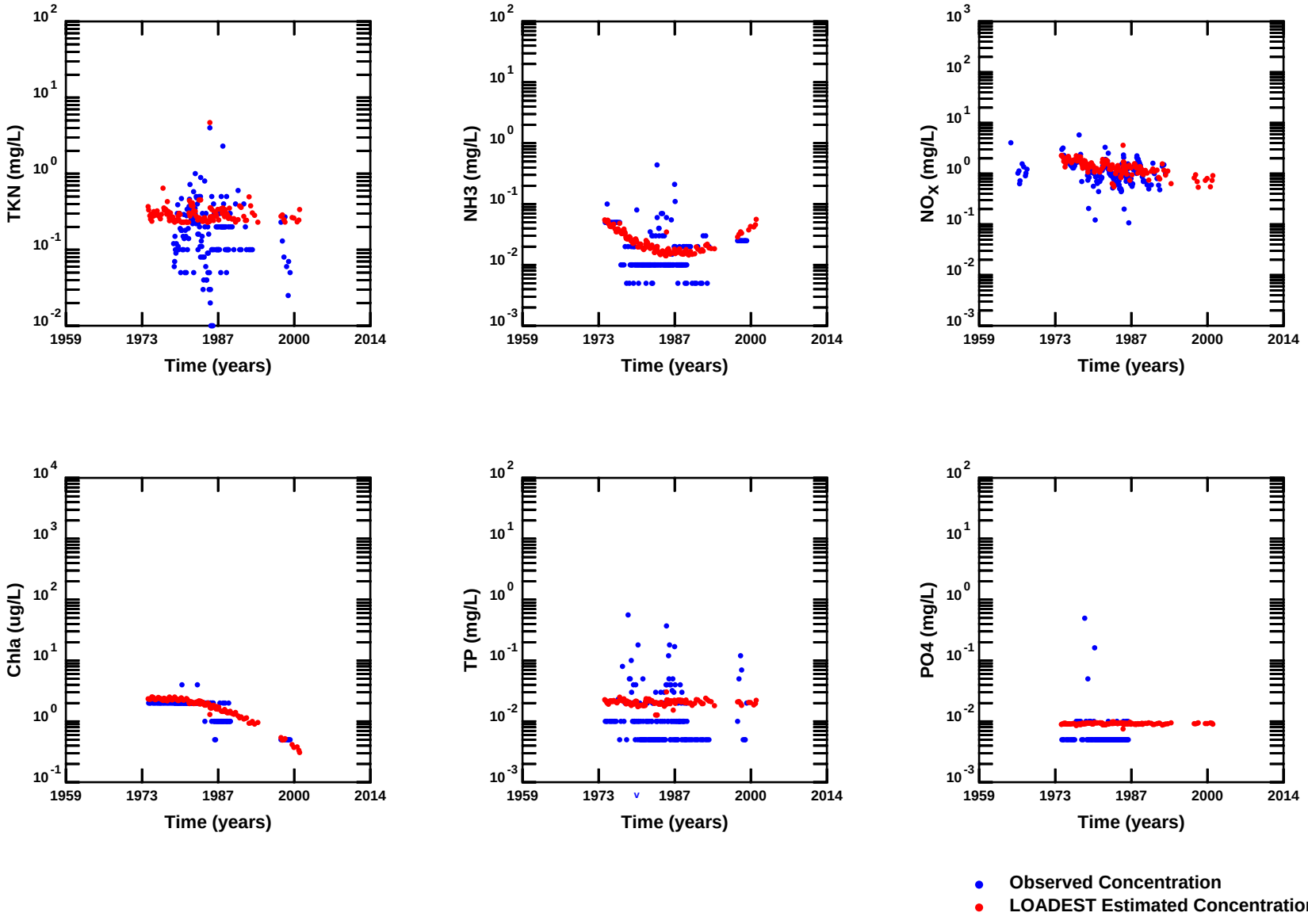




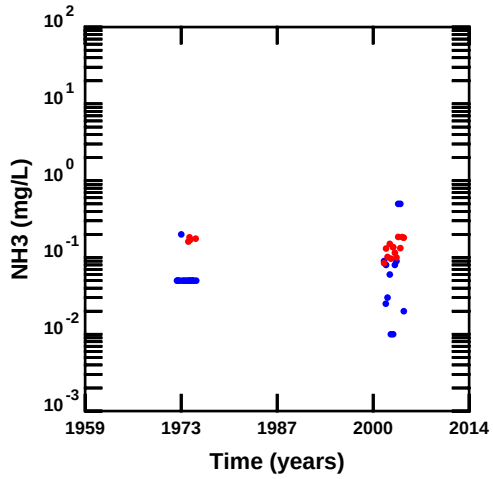


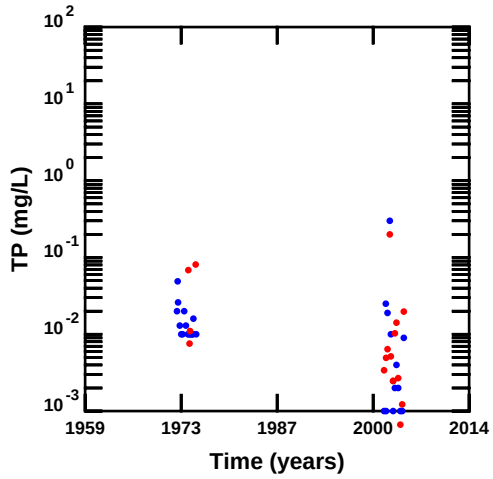
Observed Concentration
LOADEST Estimated Concentration

Observed Data vs. LOADEST Estimated Concentration, Station 13005
Nueces Tributaries, Texas (1959-2014)



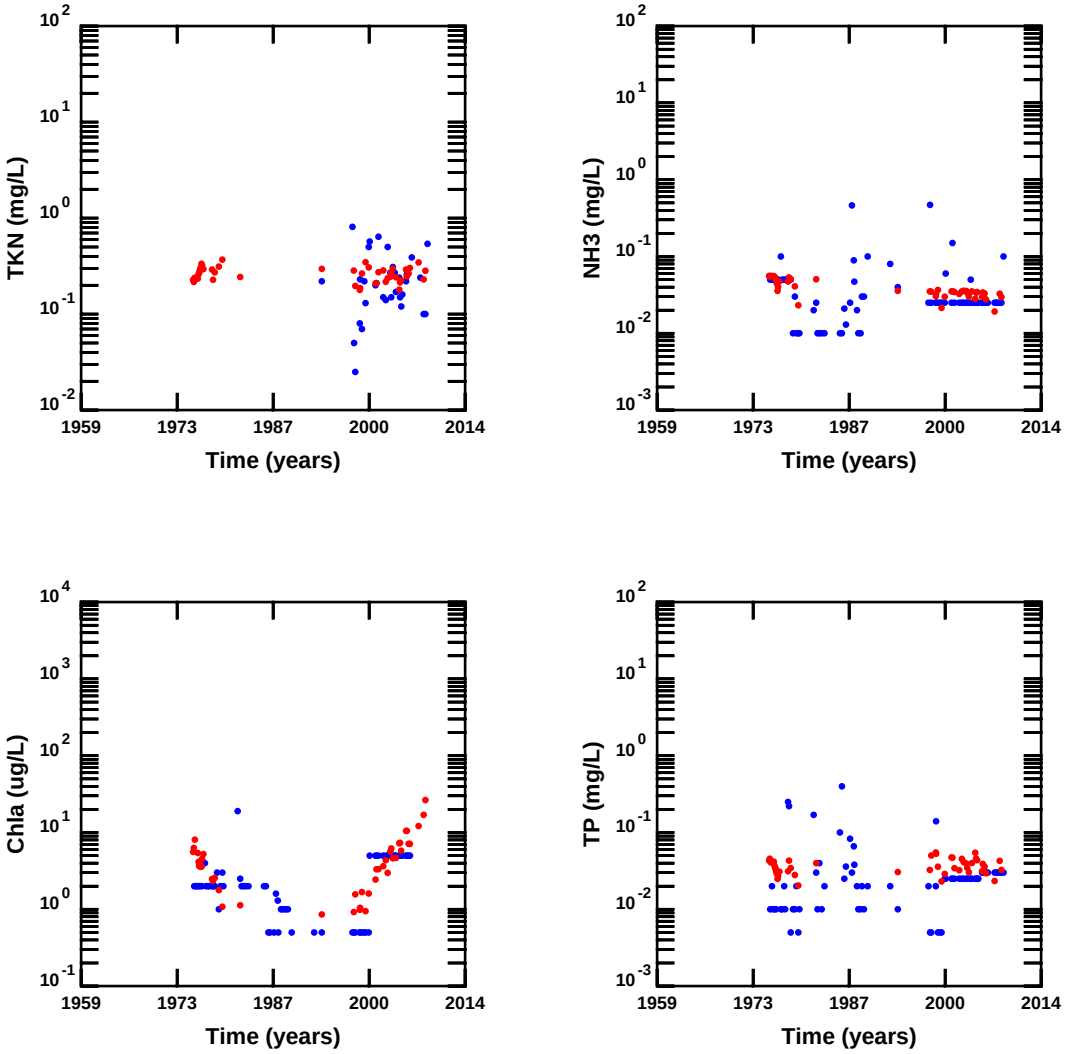
Observed Data vs. LOADEST Estimated Concentration, Station 12999
Nueces Tributaries, Texas (1959-2014)



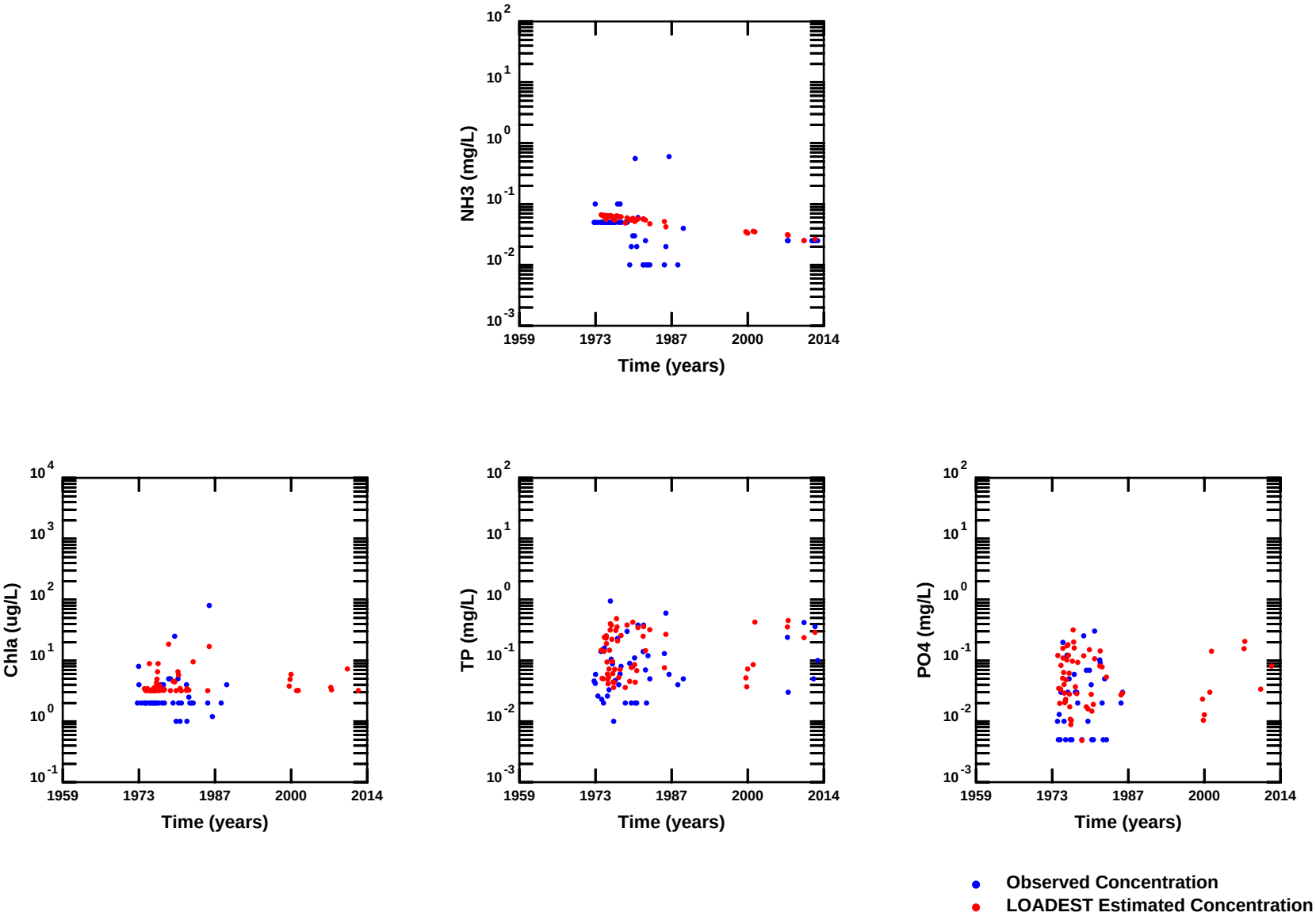


Observed Concentration
LOADEST Estimated Concentration

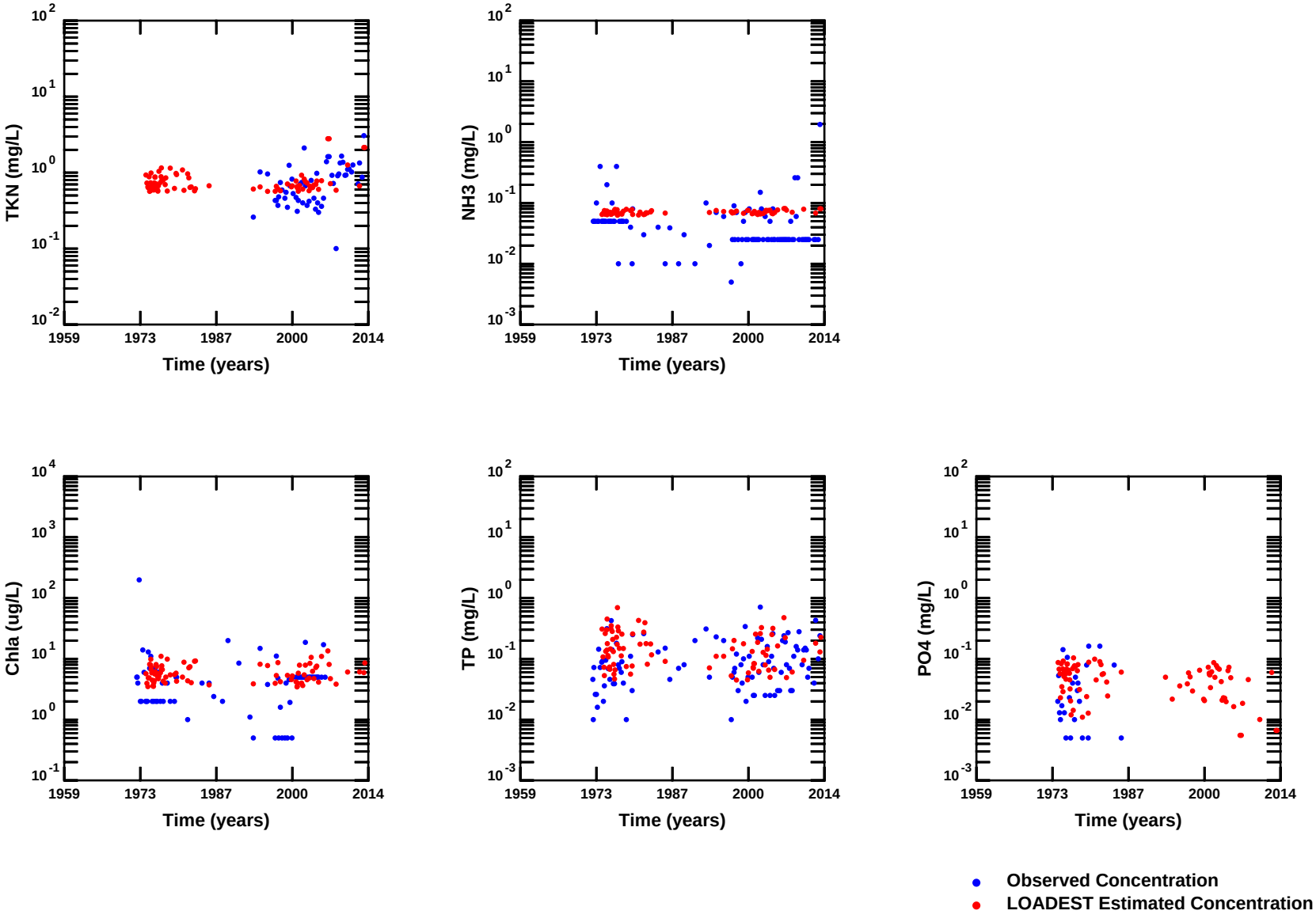
Observed Data vs. LOADEST Estimated Concentration, Station 12997
Nueces Tributaries, Texas (1959-2014)



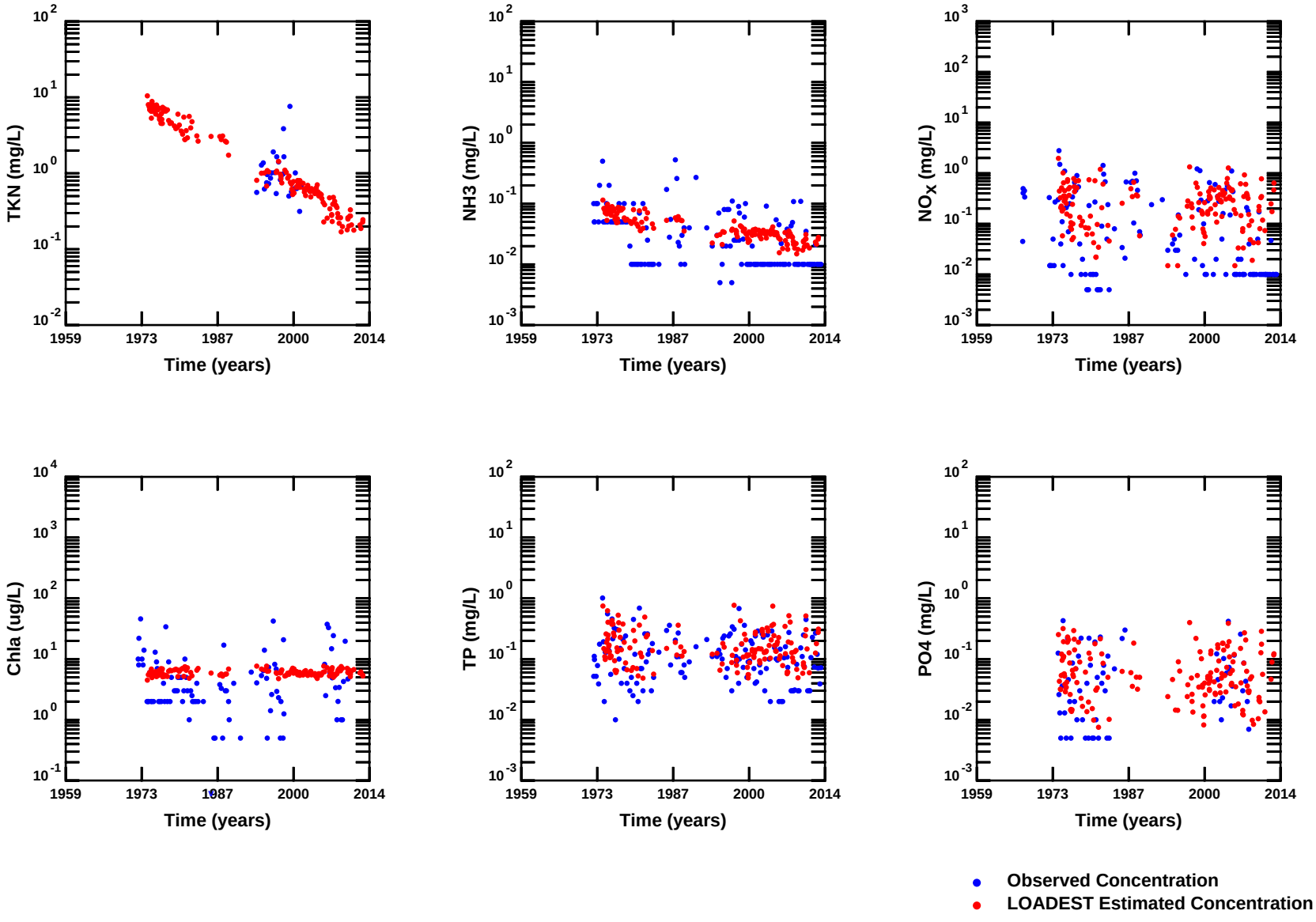
Observed Data vs. LOADEST Estimated Concentration, Station 12996
Nueces Tributaries, Texas (1959-2014)



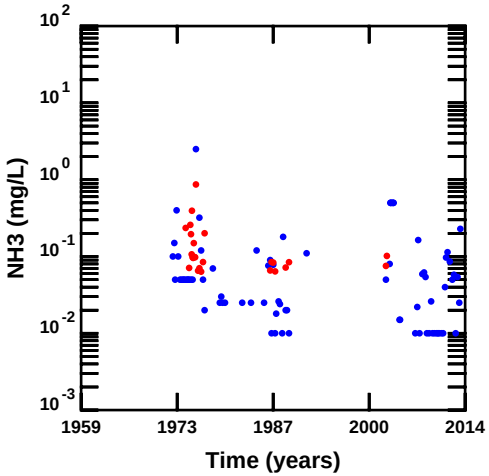
Observed Data vs. LOADEST Estimated Concentration, Station 12976
Nueces Tributaries, Texas (1959-2014)

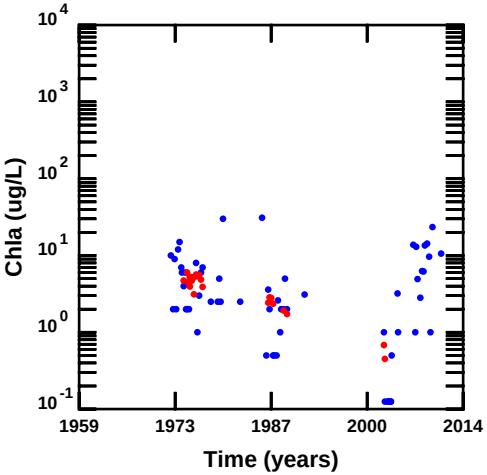


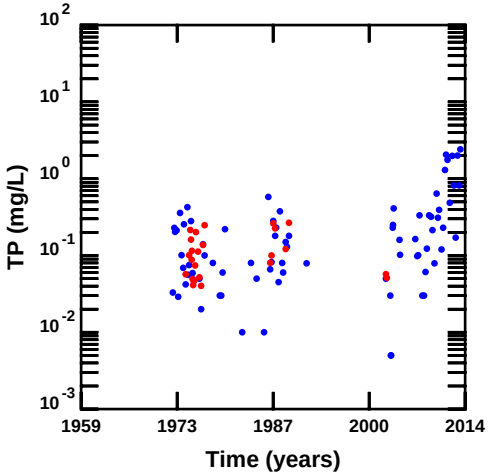
Observed Data vs. LOADEST Estimated Concentration, Station 12975
Nueces Tributaries, Texas (1959-2014)



Observed Data vs. LOADEST Estimated Concentration, Station 12973
Nueces Tributaries, Texas (1959-2014)

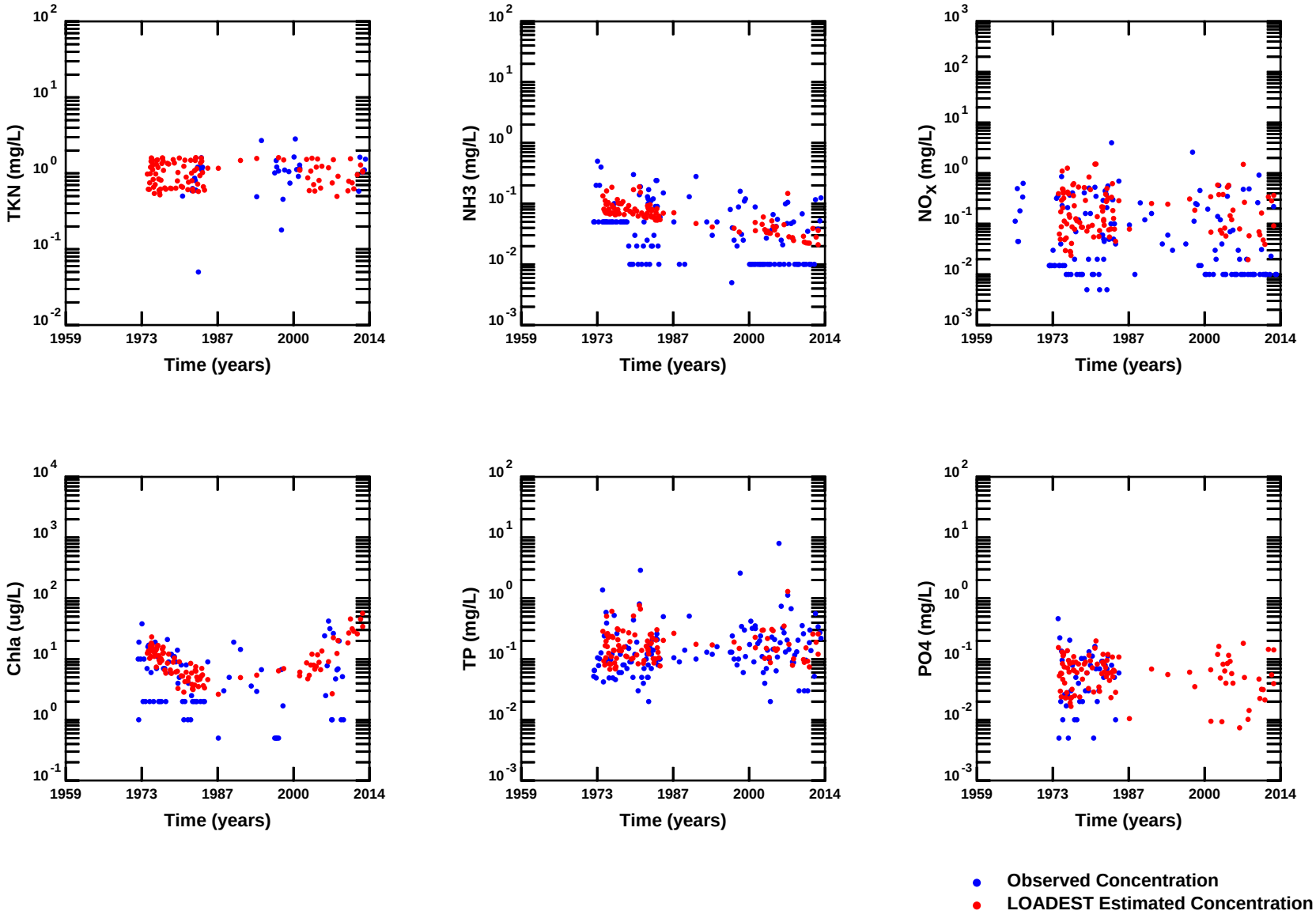




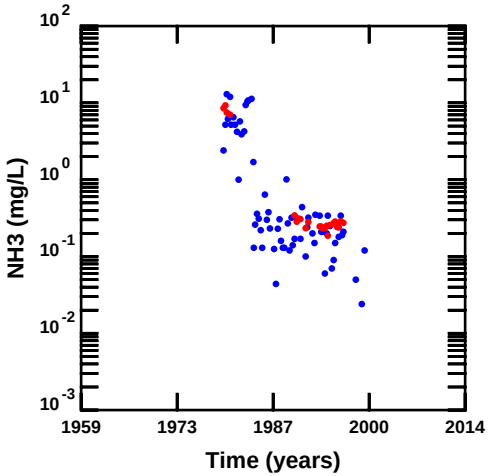


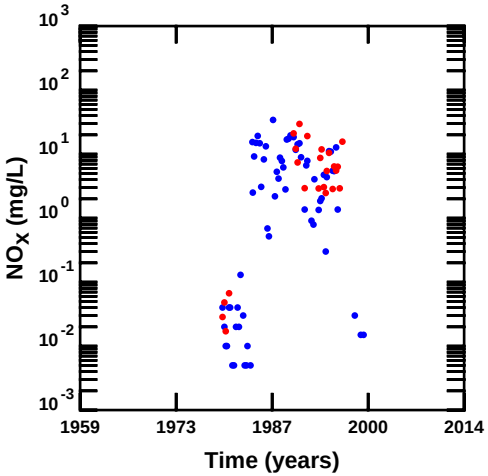
Observed Concentration
LOADEST Estimated Concentration

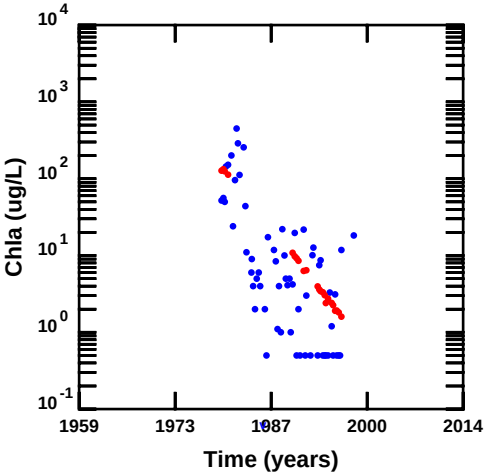
Observed Data vs. LOADEST Estimated Concentration, Station 12972
Nueces Tributaries, Texas (1959-2014)

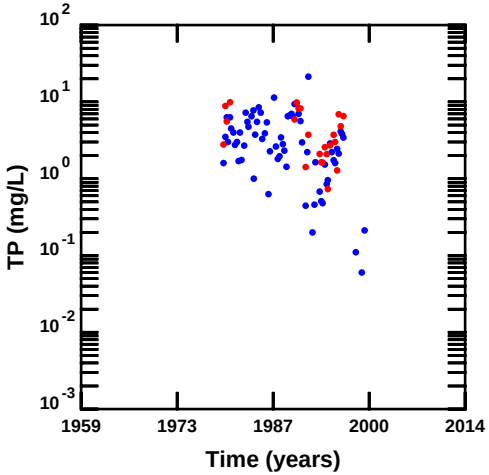


Observed Data vs. LOADEST Estimated Concentration, Station 12983
Nueces Tributaries, Texas (1959-2014)



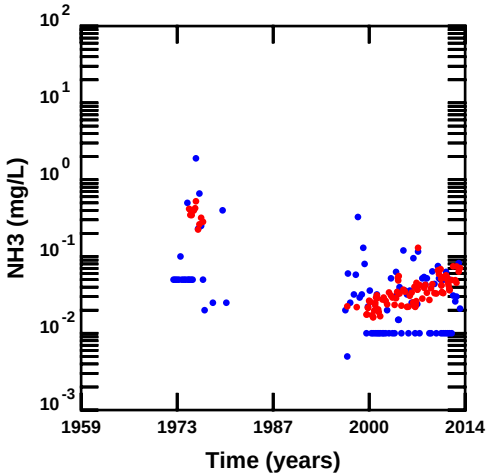


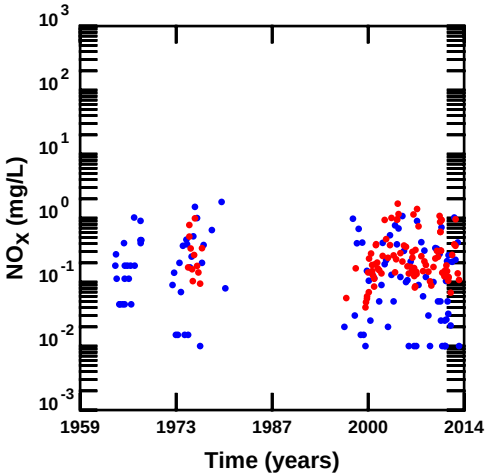


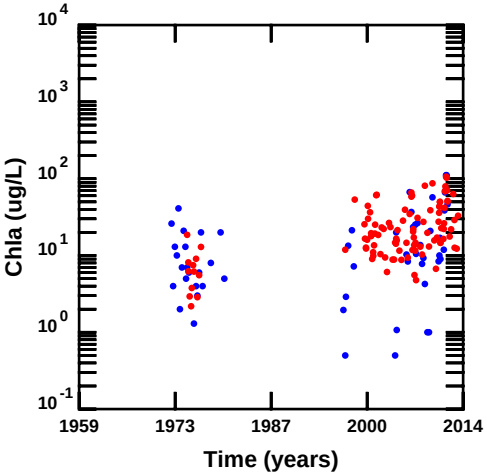


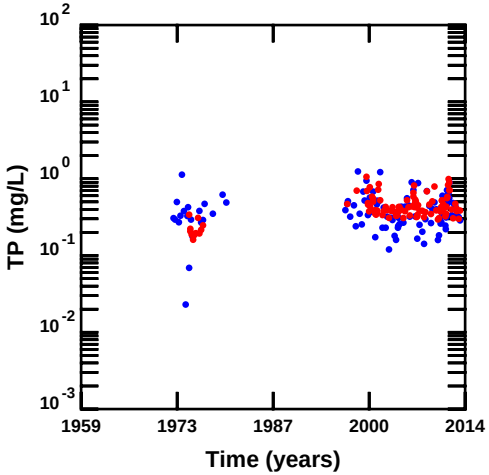
Observed Concentration
LOADEST Estimated Concentration

Observed Data vs. LOADEST Estimated Concentration, Station 12981
Nueces Tributaries, Texas (1959-2014)



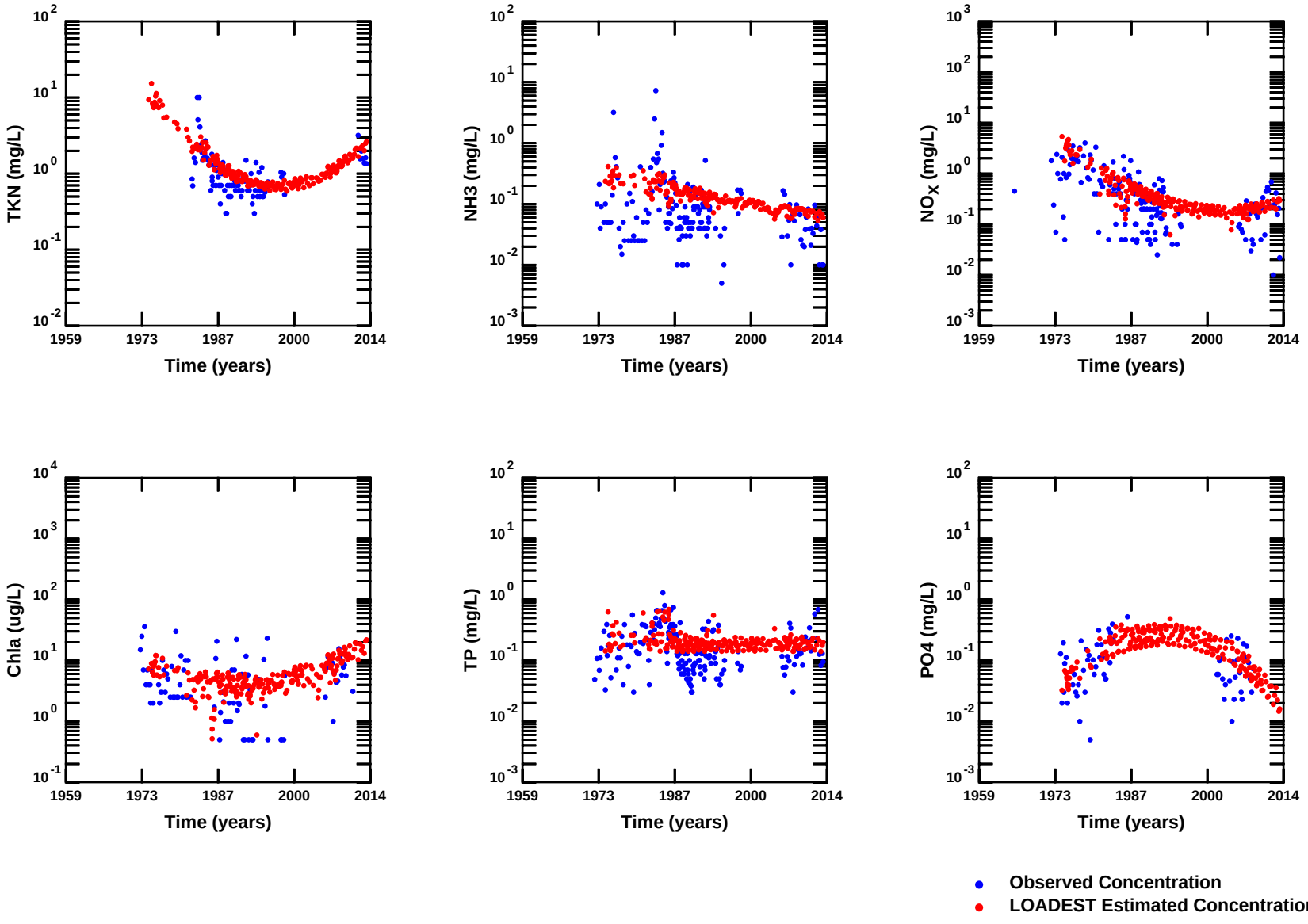




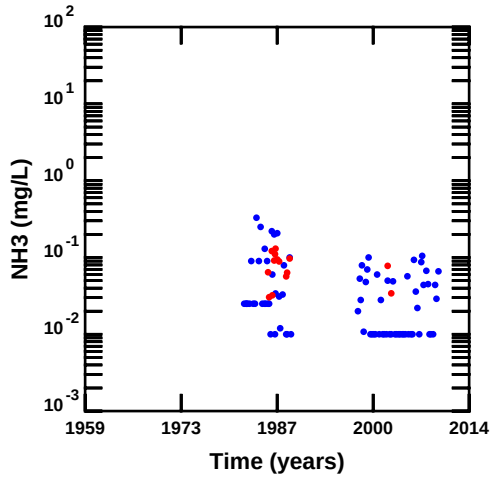


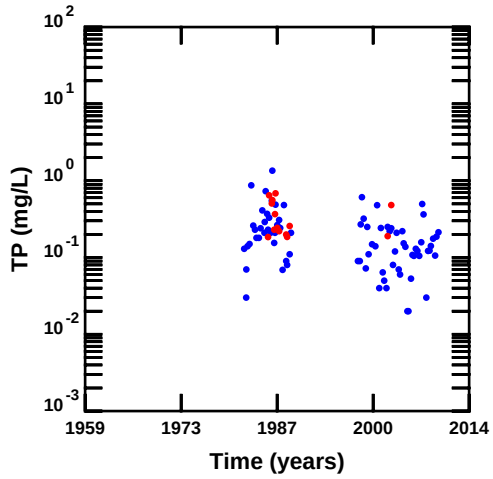
Observed Concentration
LOADEST Estimated Concentration

Observed Data vs. LOADEST Estimated Concentration, Station 12980
Nueces Tributaries, Texas (1959-2014)



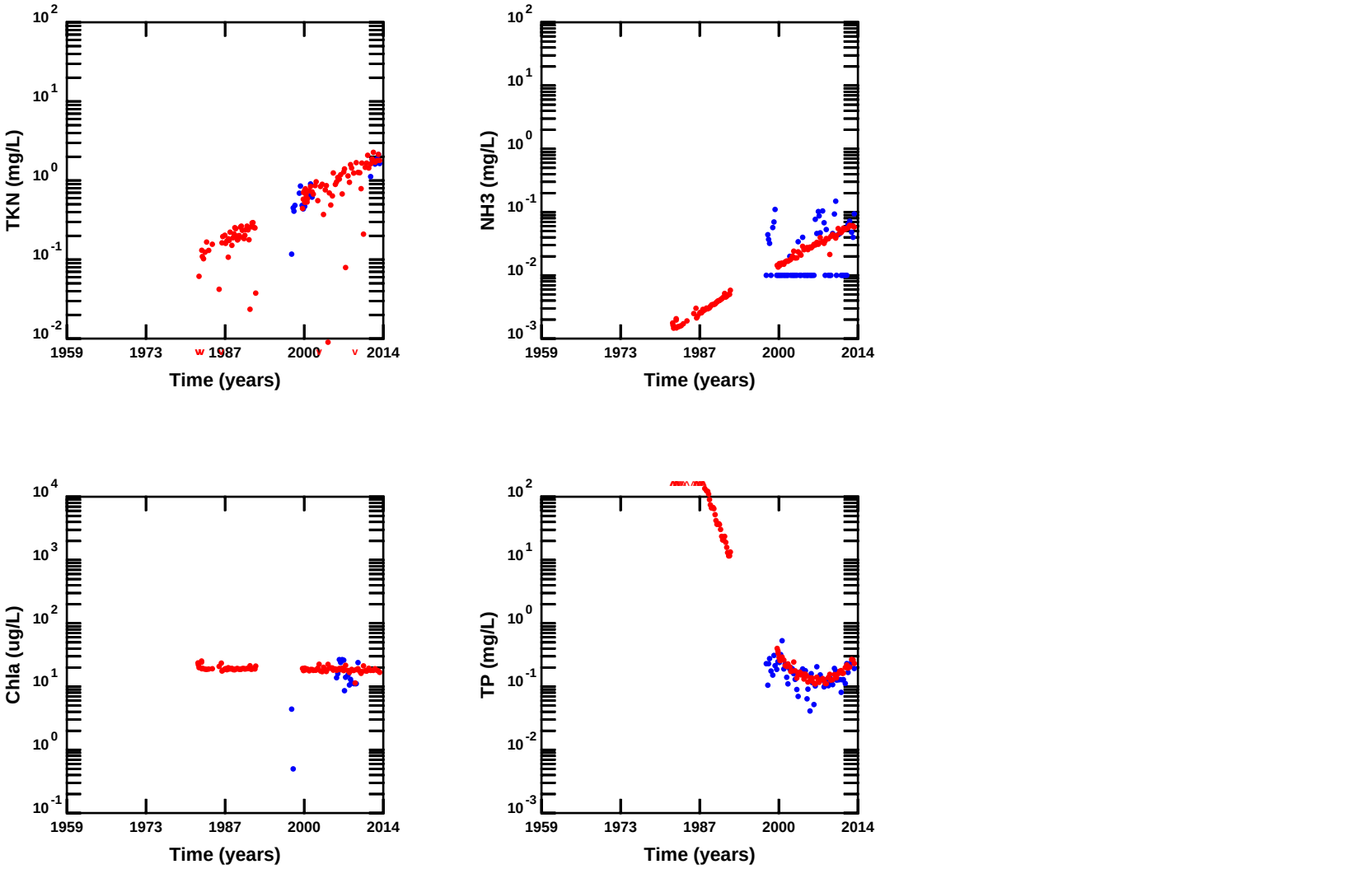
Observed Data vs. LOADEST Estimated Concentration, Station 12979
Nueces Tributaries, Texas (1959-2014)



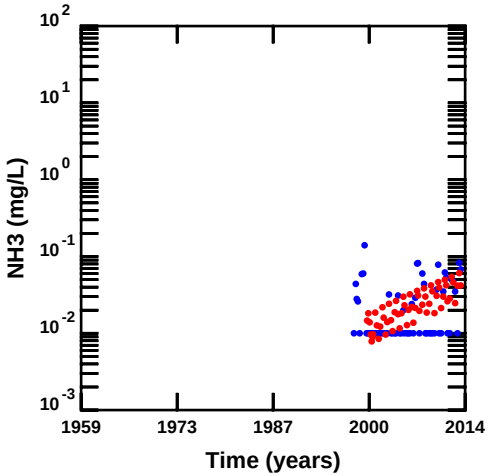


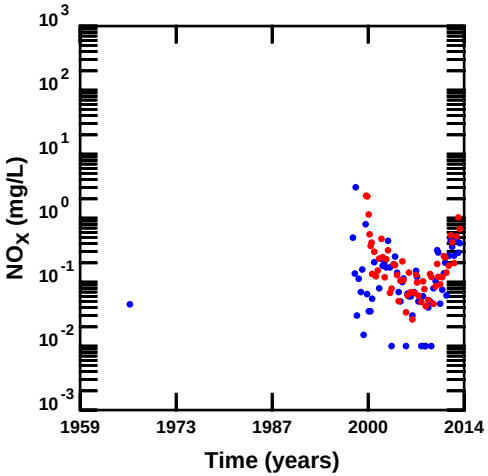
Observed Concentration
LOADEST Estimated Concentration

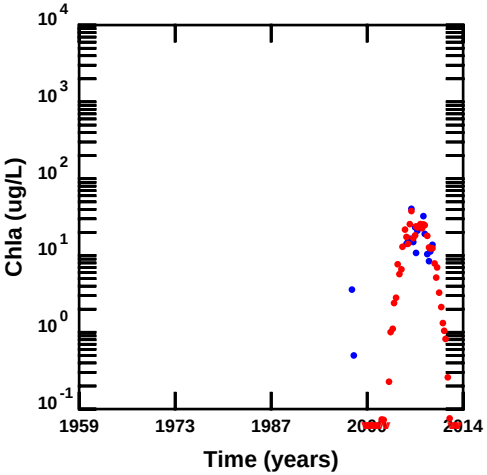
Observed Data vs. LOADEST Estimated Concentration, Station 12978
Nueces Tributaries, Texas (1959-2014)

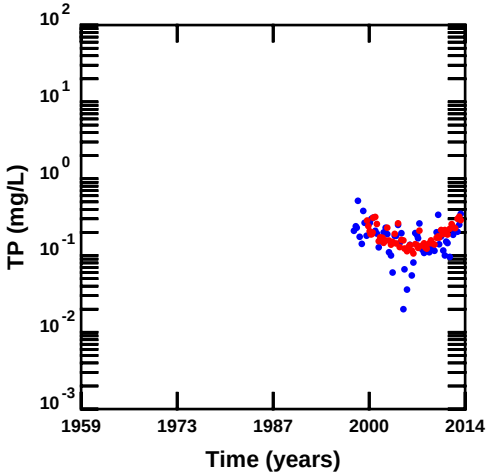


Observed Data vs. LOADEST Estimated Concentration, Station 12965
Nueces Tributaries, Texas (1959-2014)



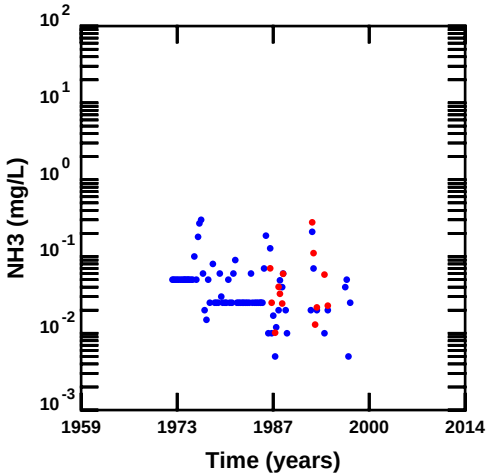


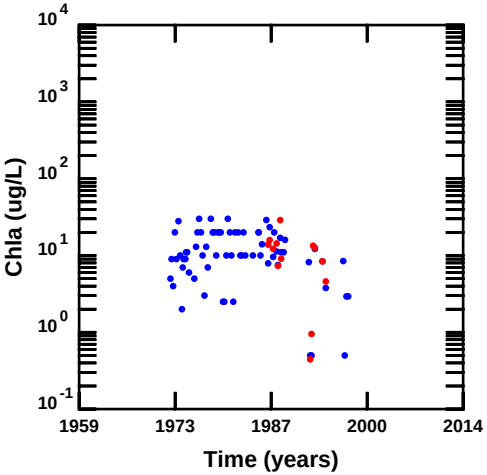


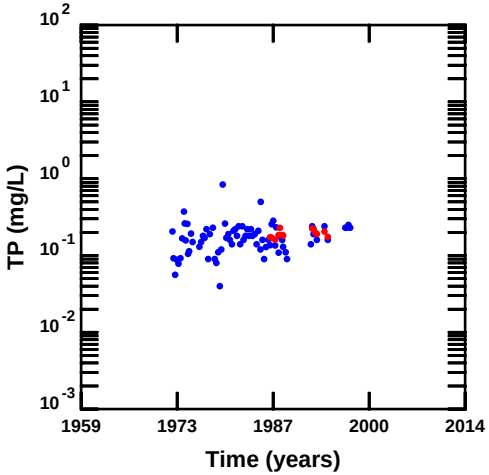


Observed Concentration
LOADEST Estimated Concentration

Observed Data vs. LOADEST Estimated Concentration, Station 12964
Nueces Tributaries, Texas (1959-2014)

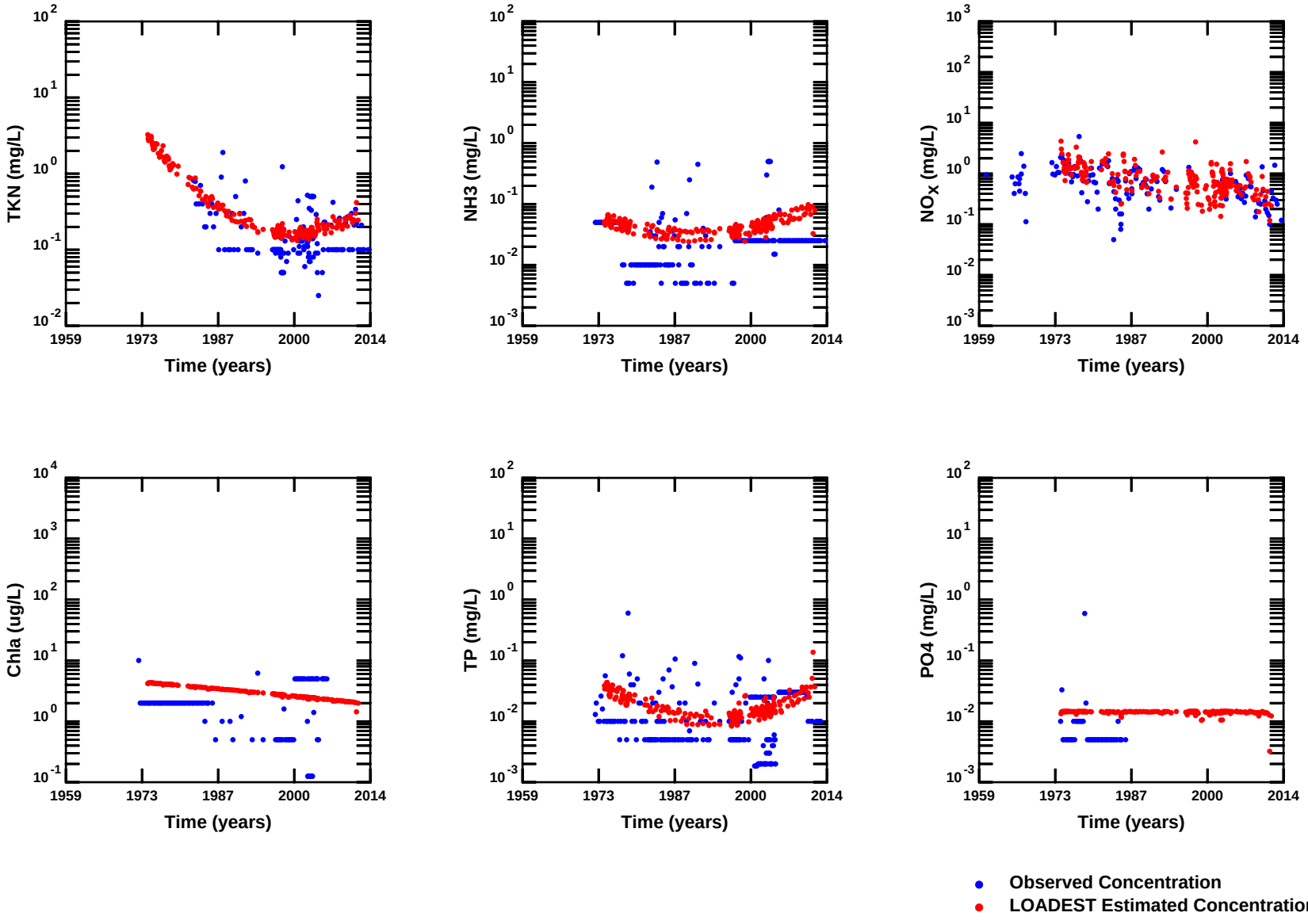




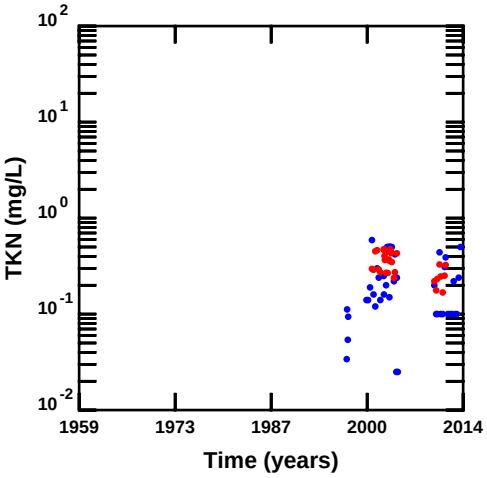


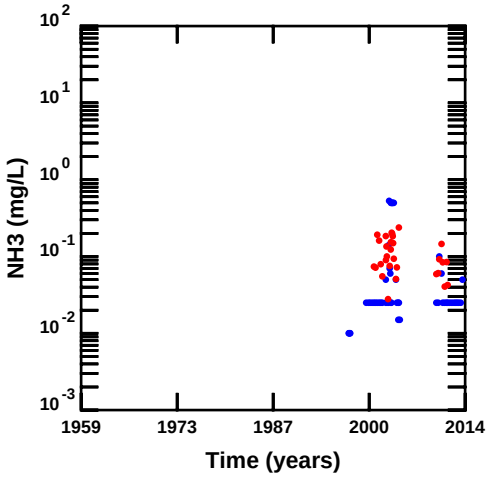
Observed Concentration
LOADEST Estimated Concentration

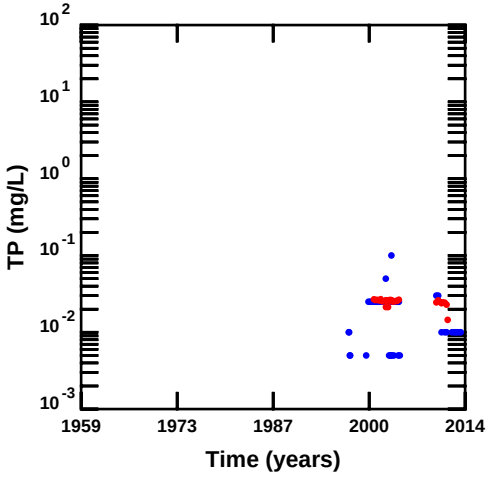
Observed Data vs. LOADEST Estimated Concentration, Station 12962
Nueces Tributaries, Texas (1959-2014)



Observed Data vs. LOADEST Estimated Concentration, Station 13006
Nueces Tributaries, Texas (1959-2014)

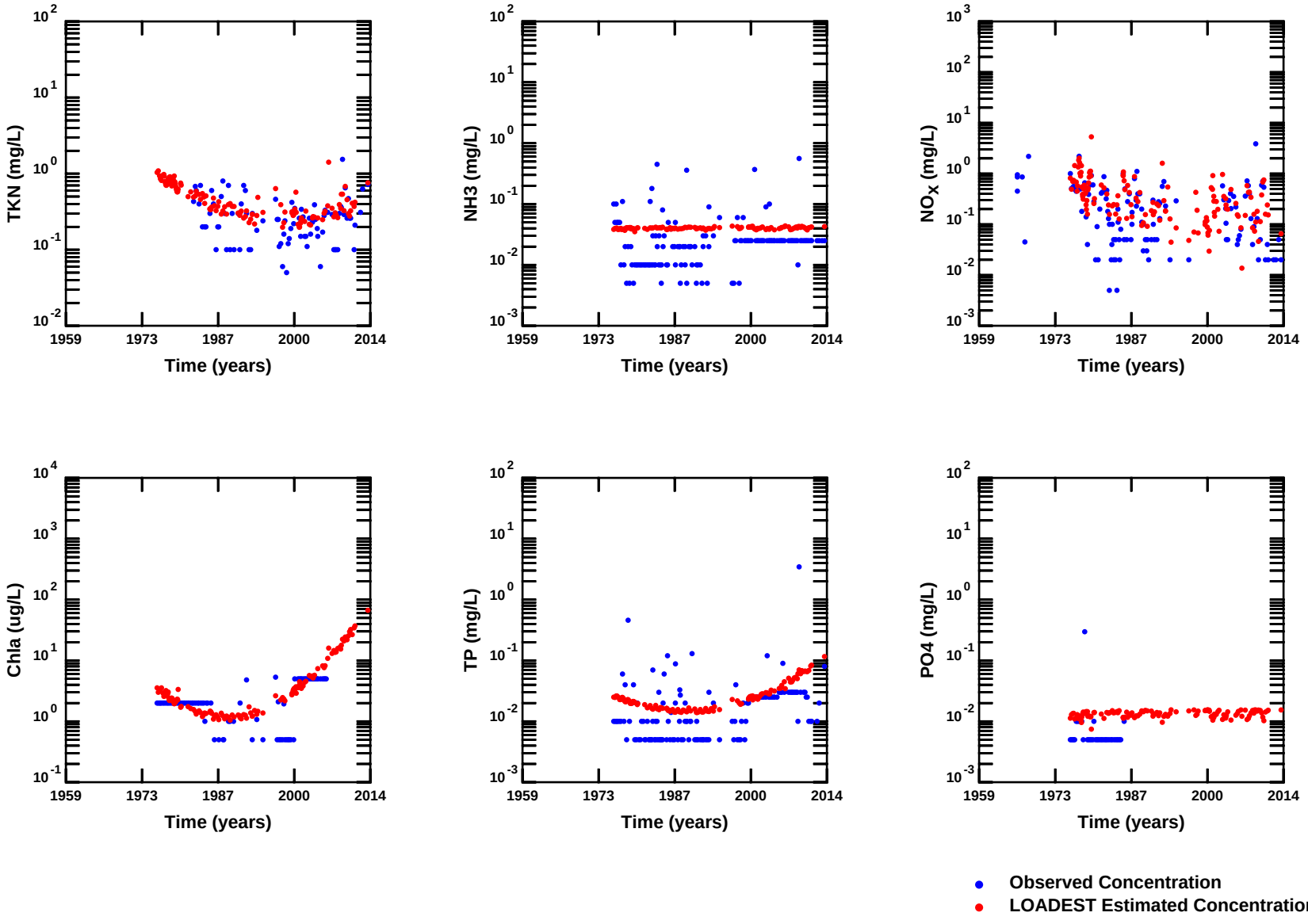




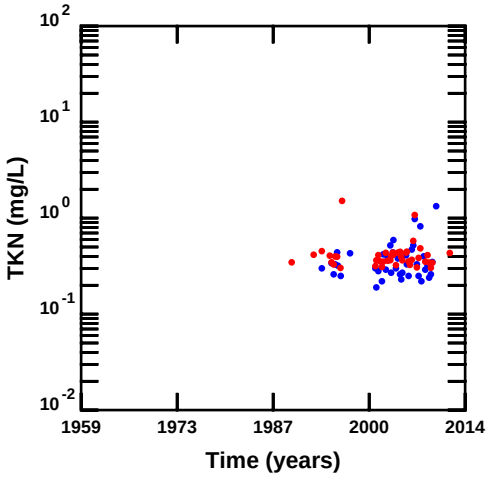


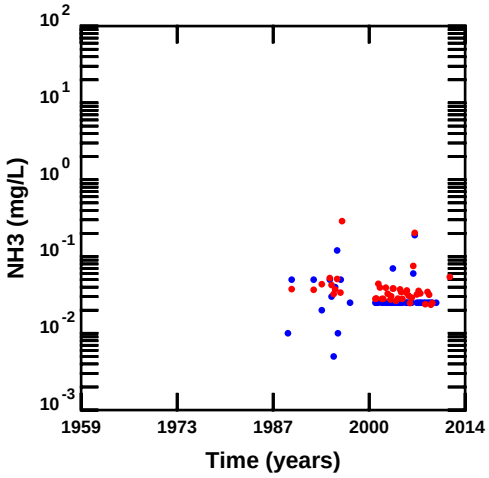
Observed Concentration
LOADEST Estimated Concentration

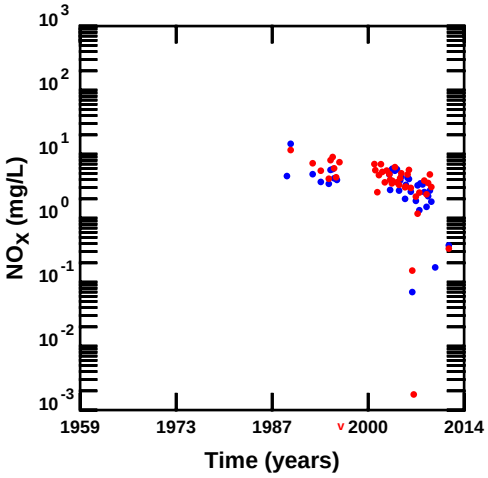
Observed Data vs. LOADEST Estimated Concentration, Station 13007
Nueces Tributaries, Texas (1959-2014)

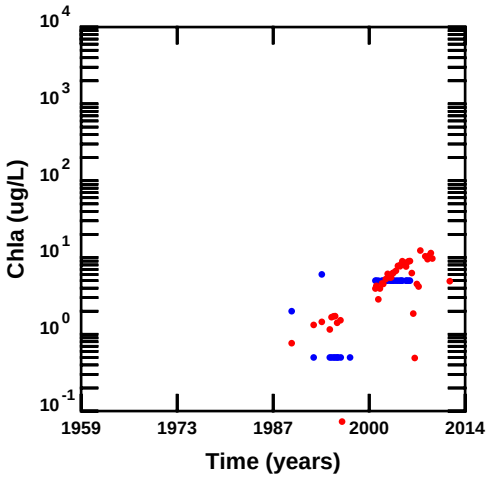


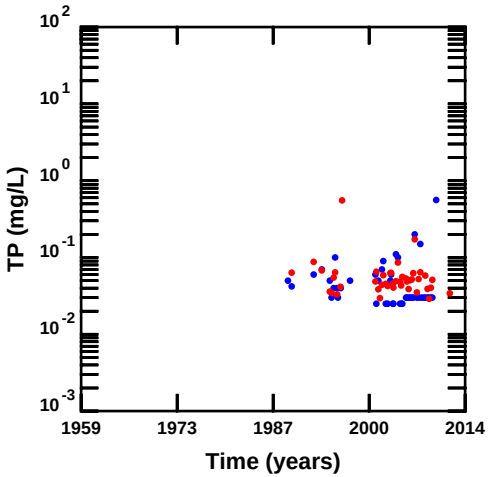
Observed Data vs. LOADEST Estimated Concentration, Station 13010
Nueces Tributaries, Texas (1959-2014)





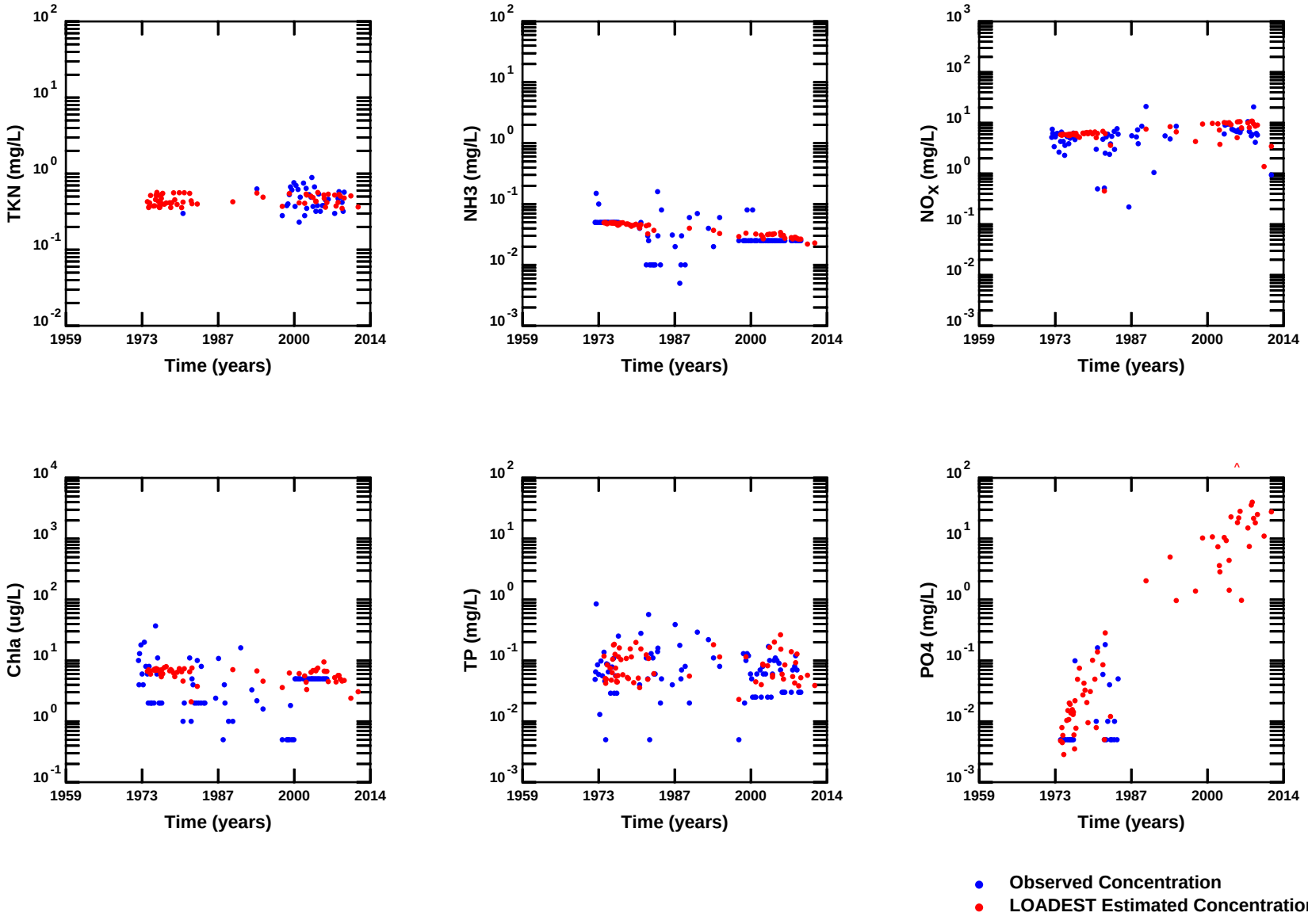




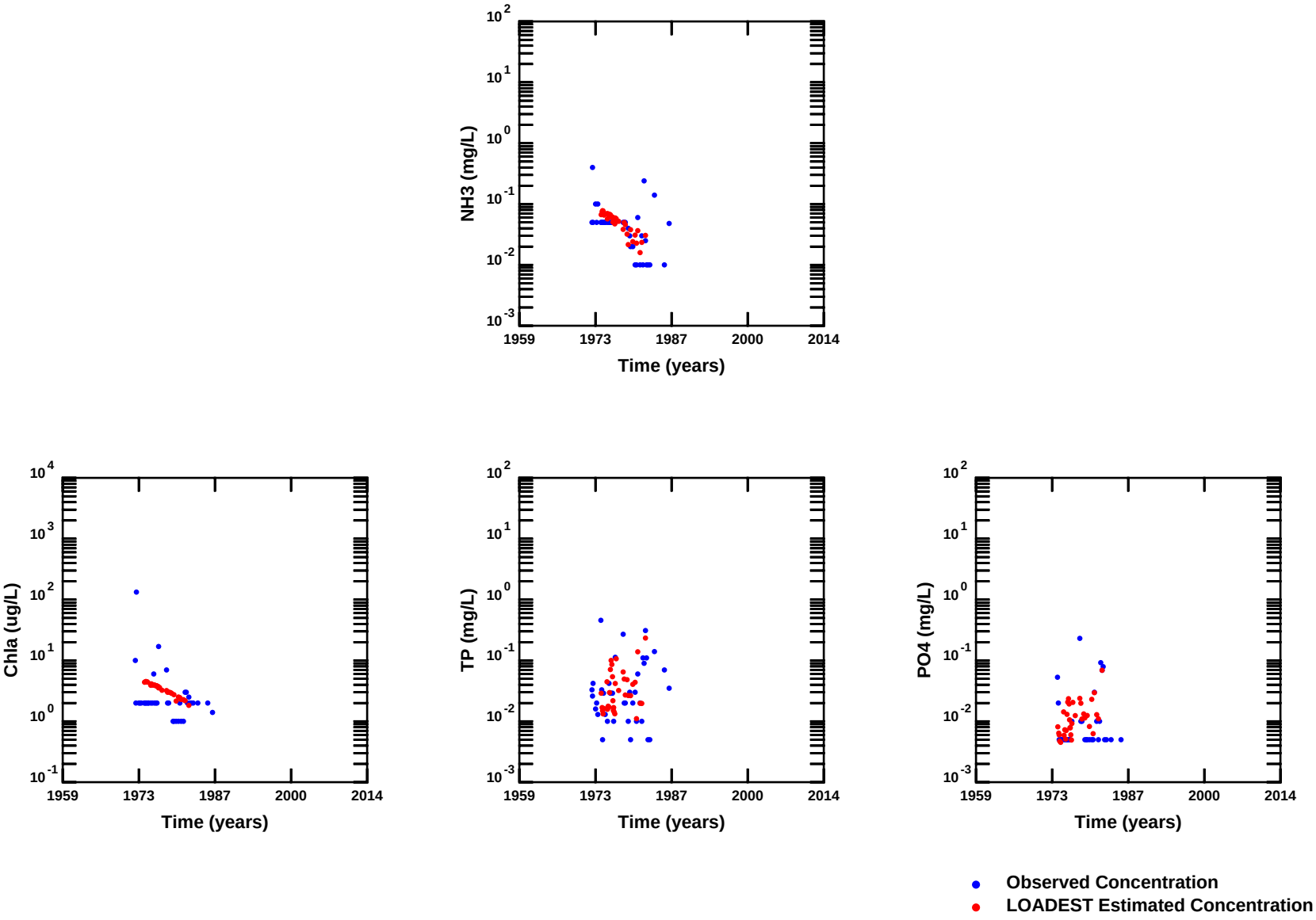


Observed Concentration
LOADEST Estimated Concentration

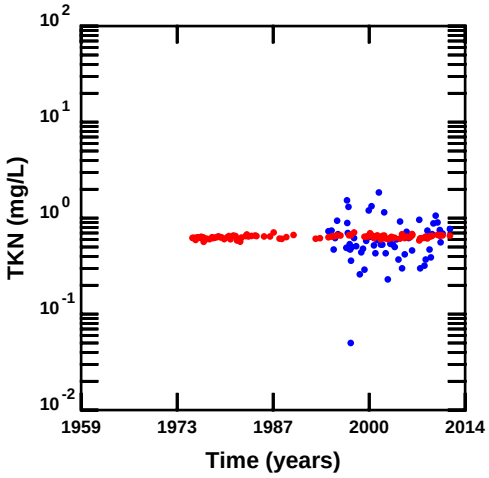
Observed Data vs. LOADEST Estimated Concentration, Station 12987
Nueces Tributaries, Texas (1959-2014)

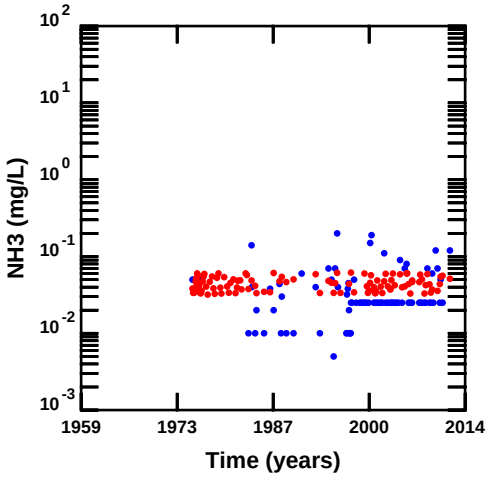


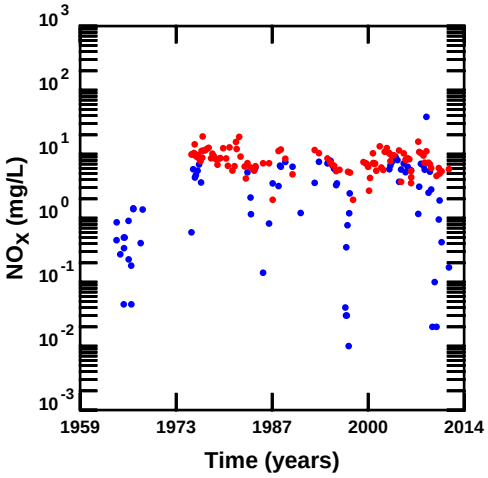
Observed Data vs. LOADEST Estimated Concentration, Station 12985
Nueces Tributaries, Texas (1959-2014)

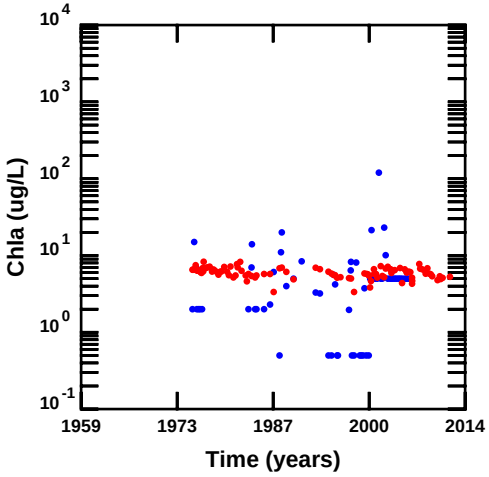


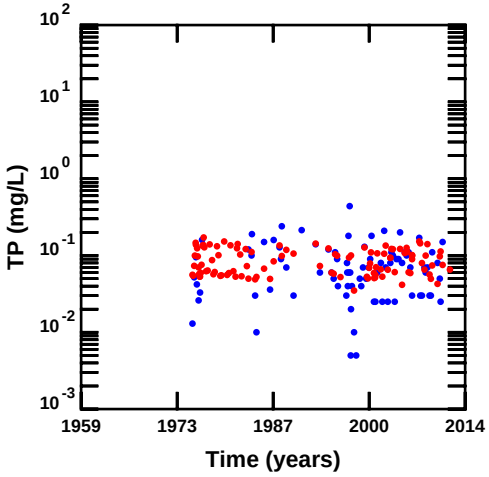
Observed Data vs. LOADEST Estimated Concentration, Station 13025
Nueces Tributaries, Texas (1959-2014)





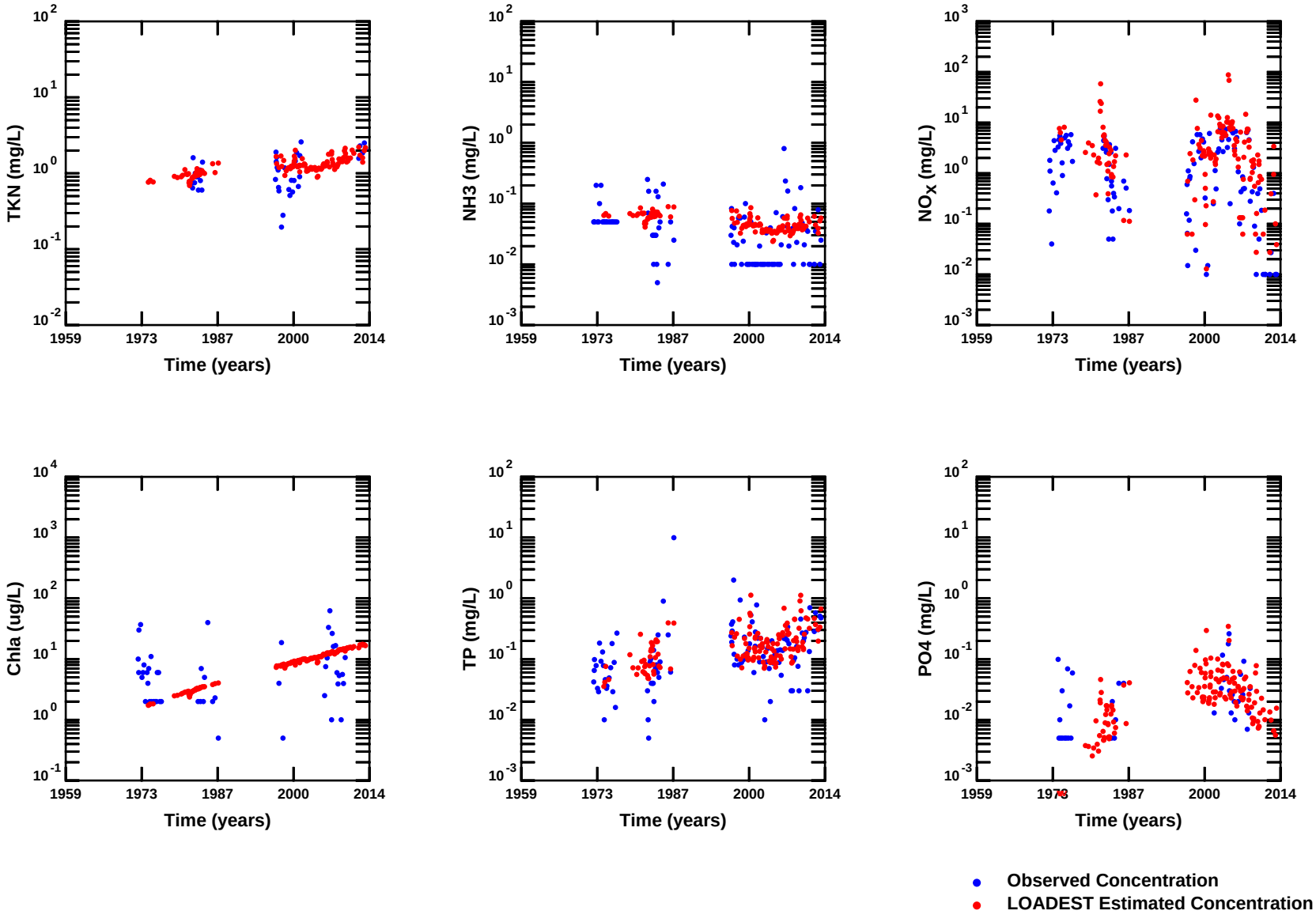




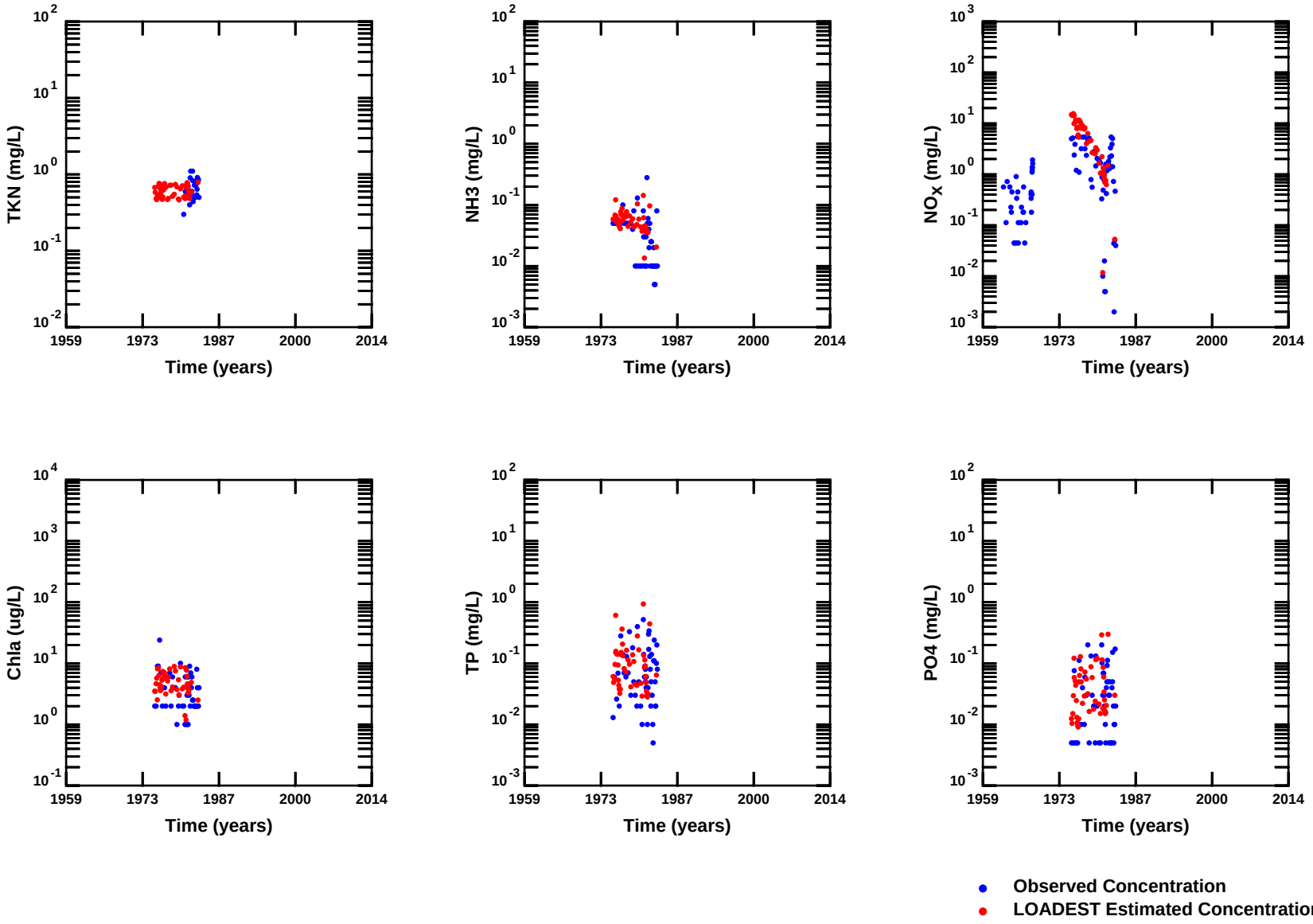


Observed Concentration
LOADEST Estimated Concentration

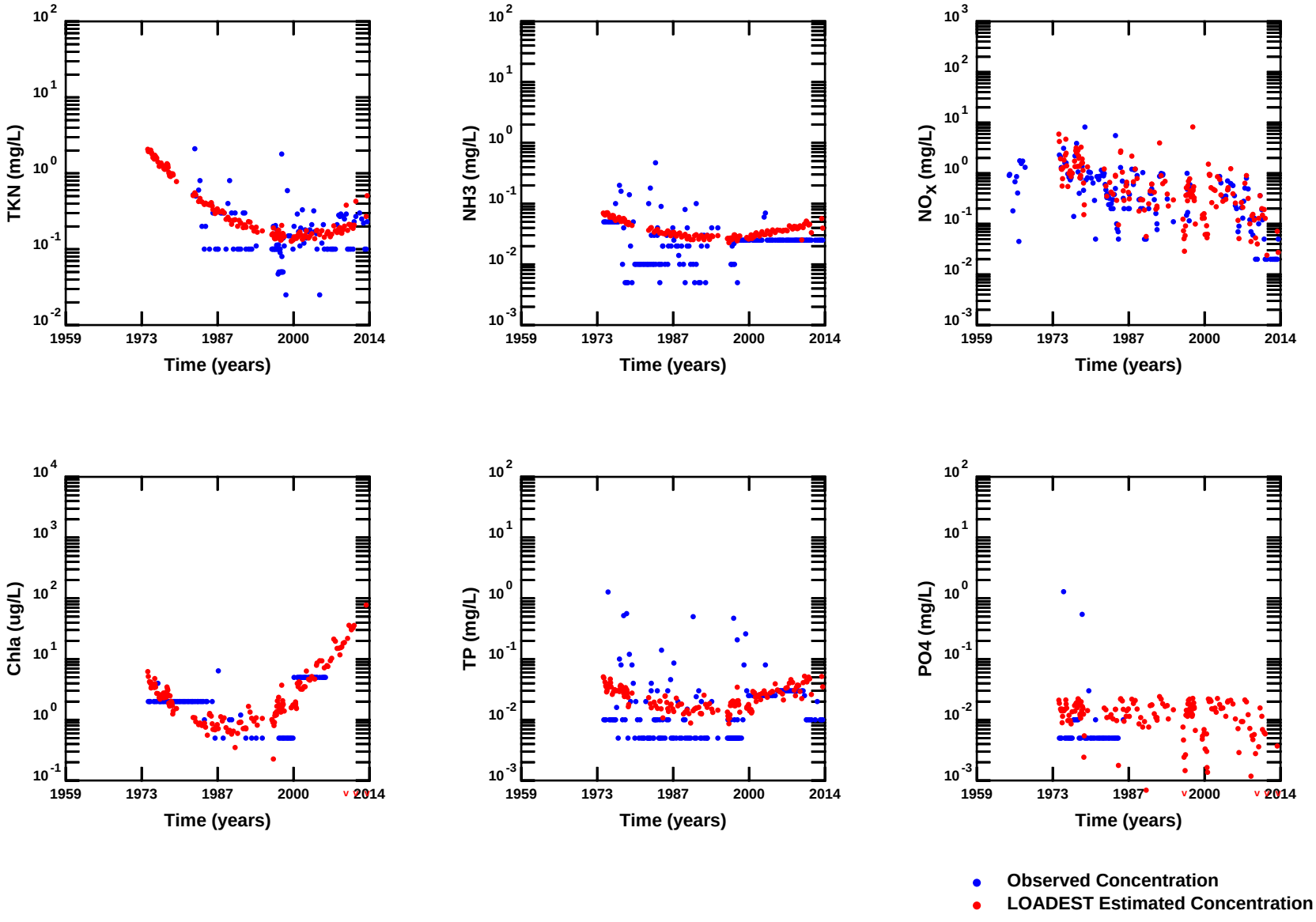
Observed Data vs. LOADEST Estimated Concentration, Station 13024
Nueces Tributaries, Texas (1959-2014)



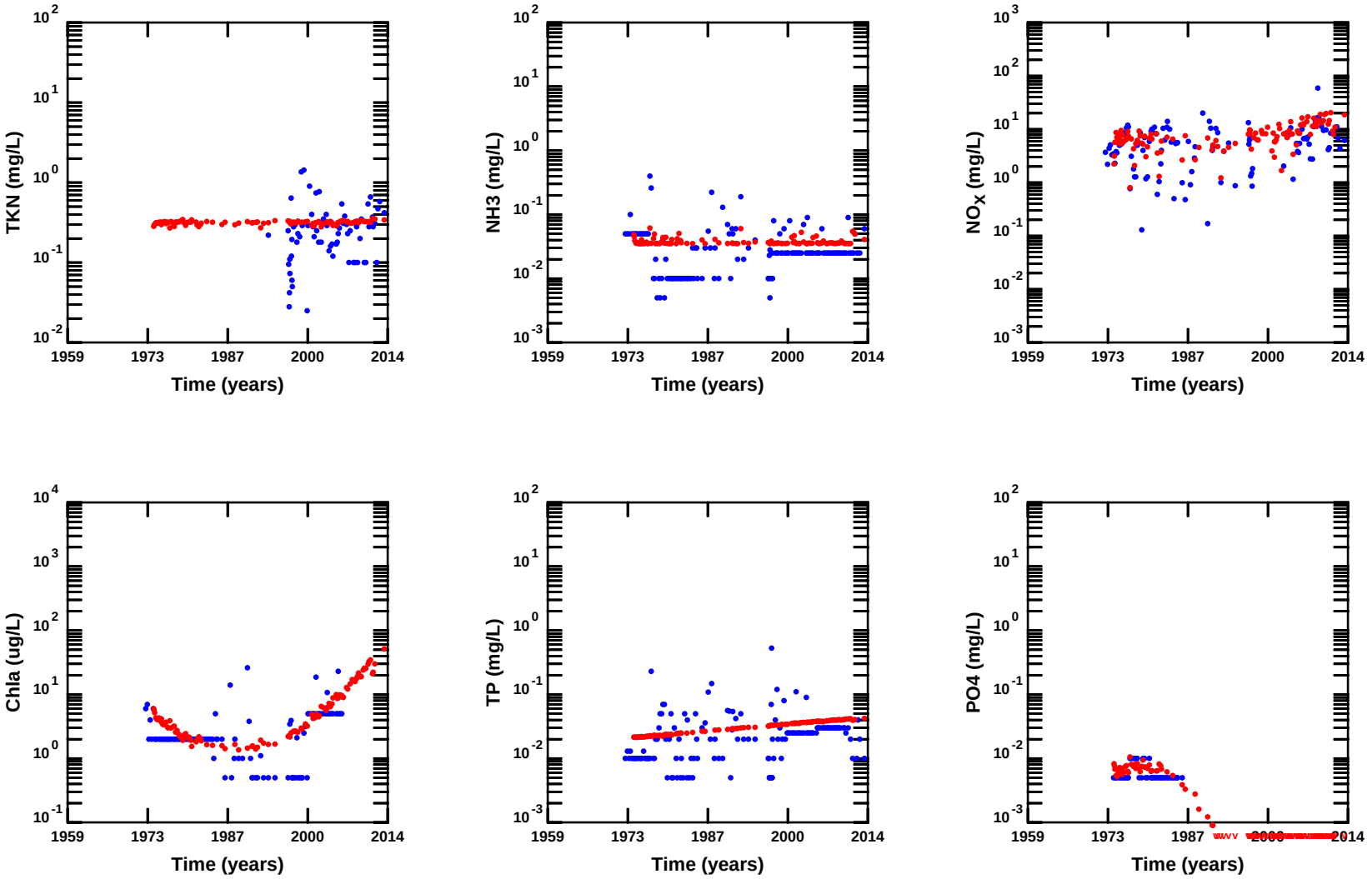
Observed Data vs. LOADEST Estimated Concentration, Station 13023
Nueces Tributaries, Texas (1959-2014)



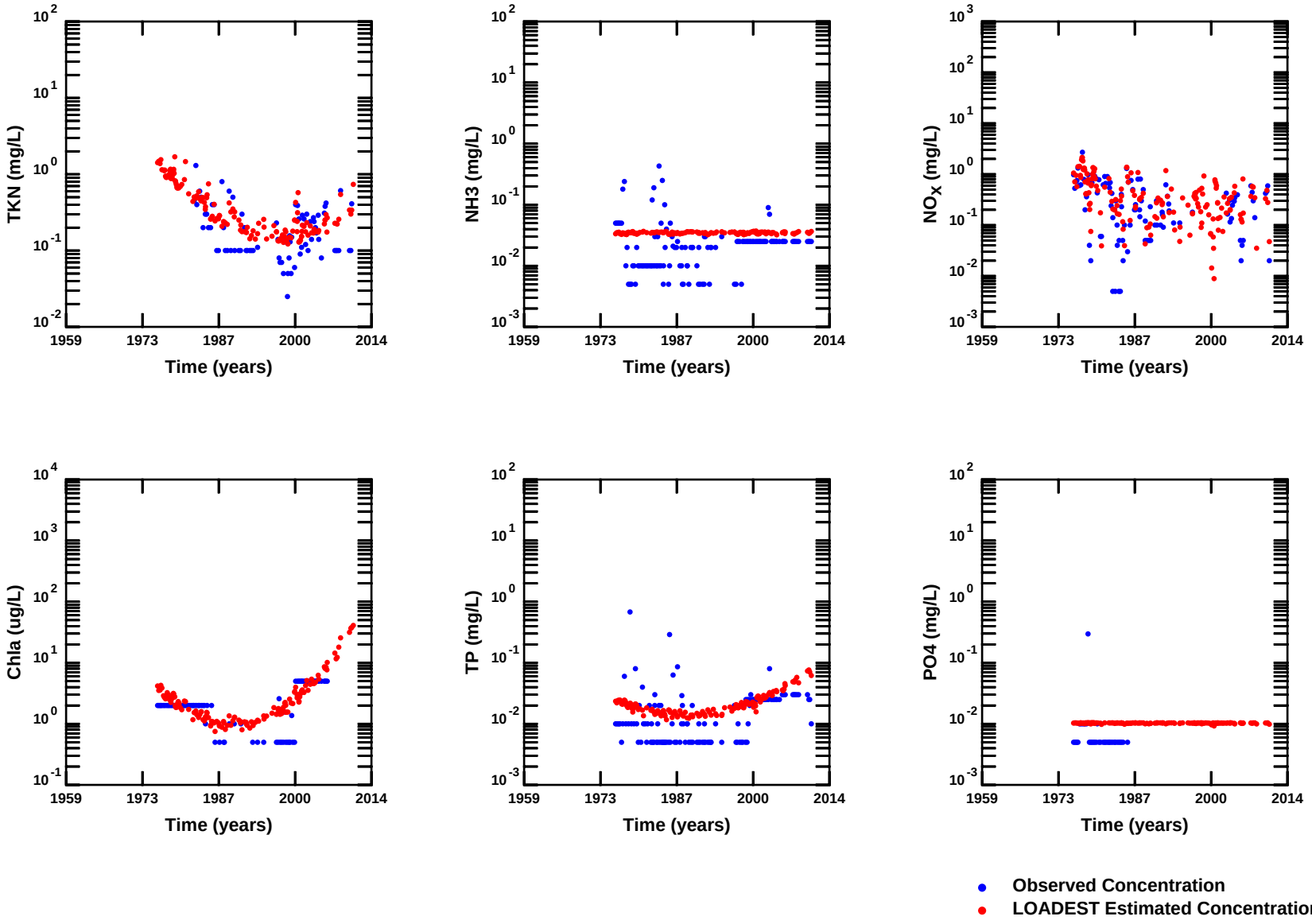
Observed Data vs. LOADEST Estimated Concentration, Station 13021
Nueces Tributaries, Texas (1959-2014)



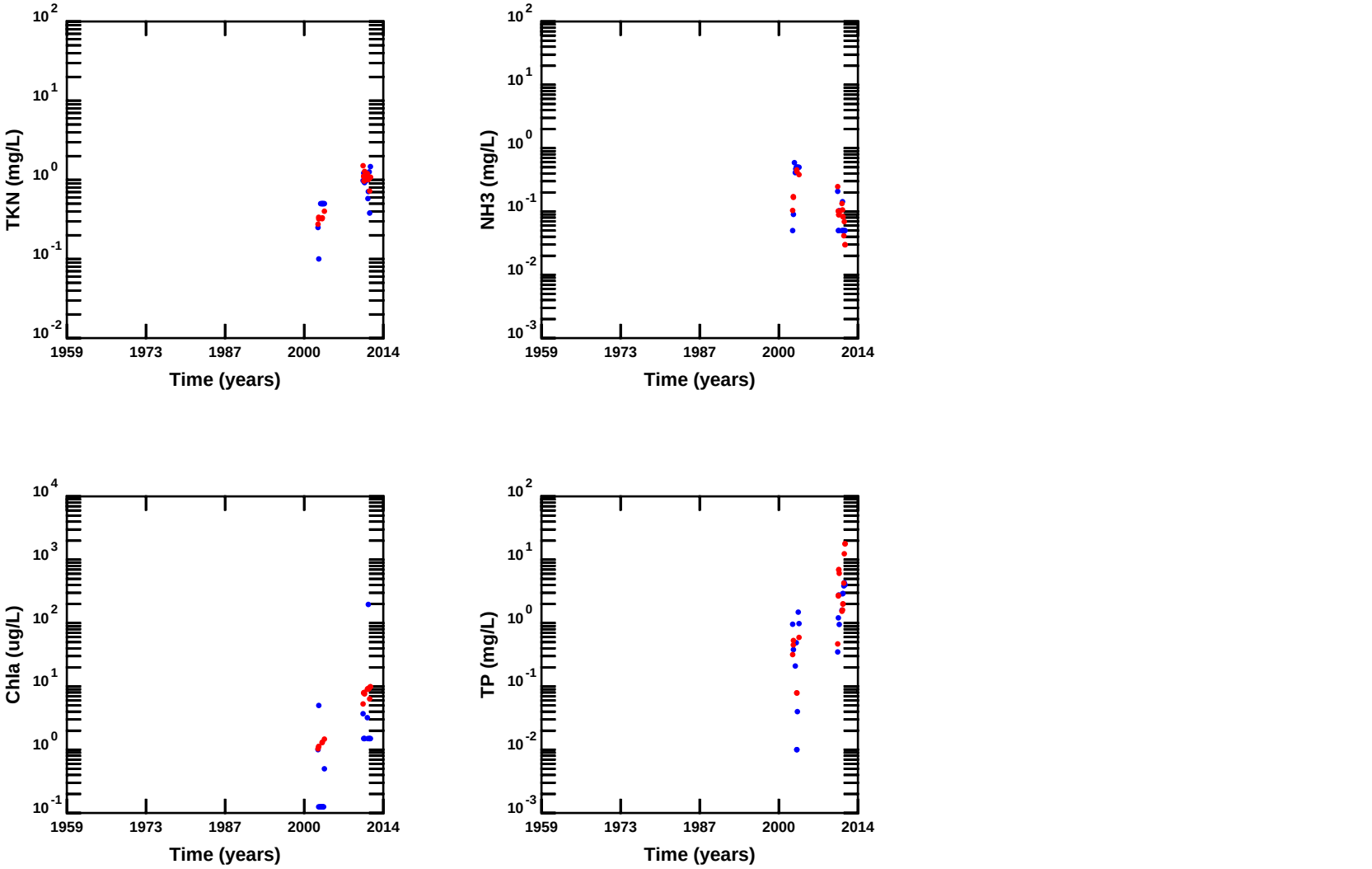
Observed Data vs. LOADEST Estimated Concentration, Station 12994
Nueces Tributaries, Texas (1959-2014)



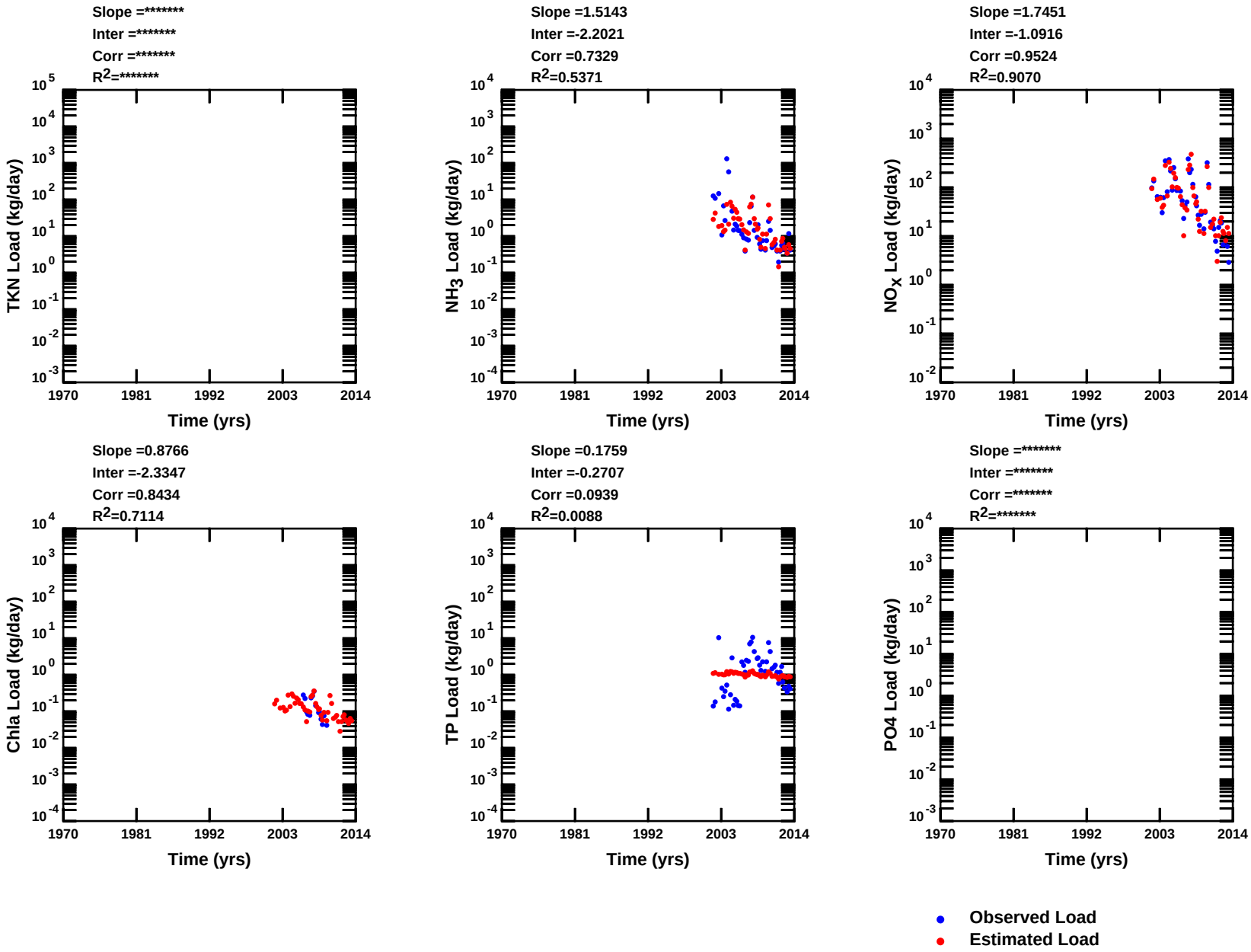
Observed Data vs. LOADEST Estimated Concentration, Station 12993
Nueces Tributaries, Texas (1959-2014)



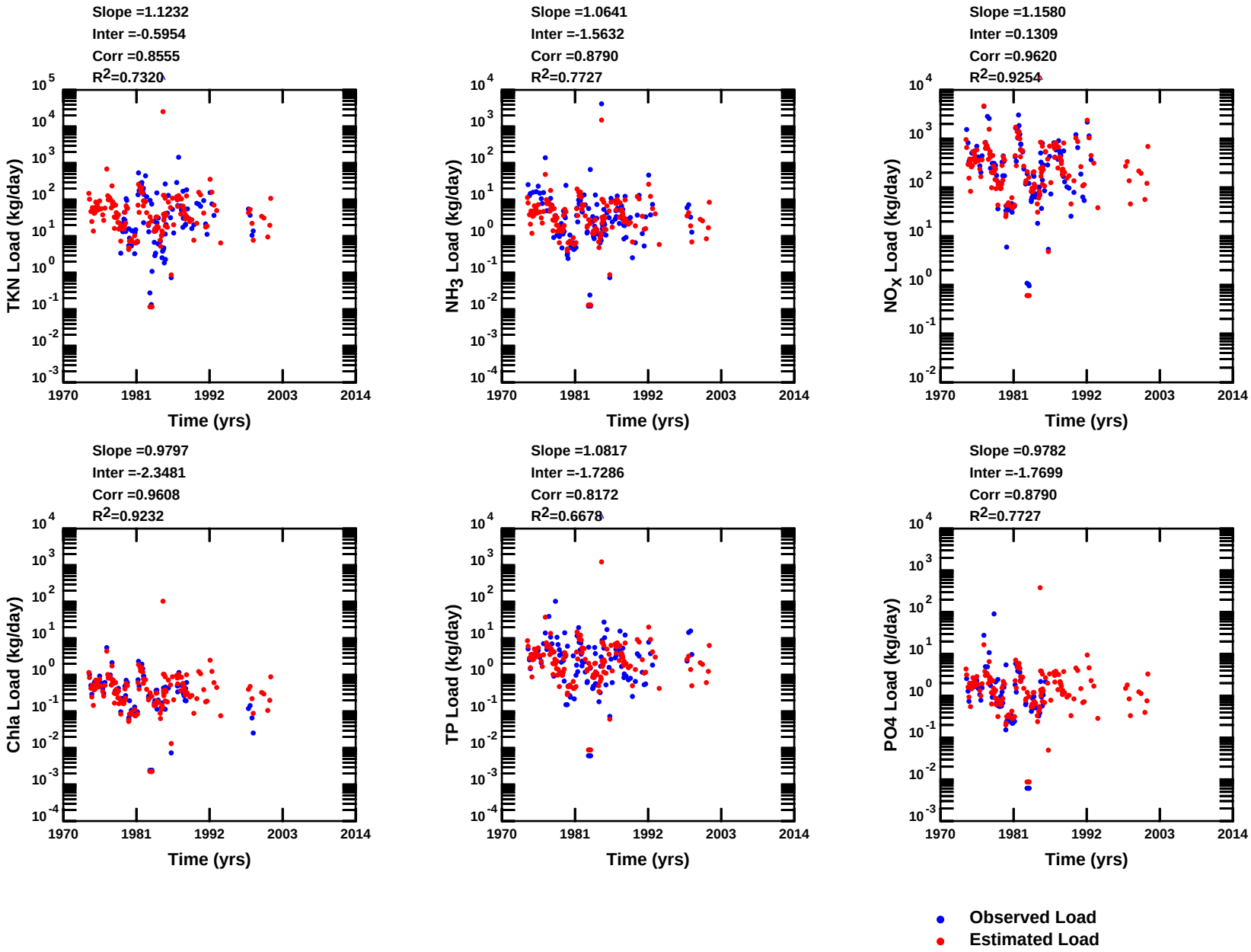
Observed Data vs. LOADEST Estimated Concentration, Station 13013
Nueces Tributaries, Texas (1959-2014)



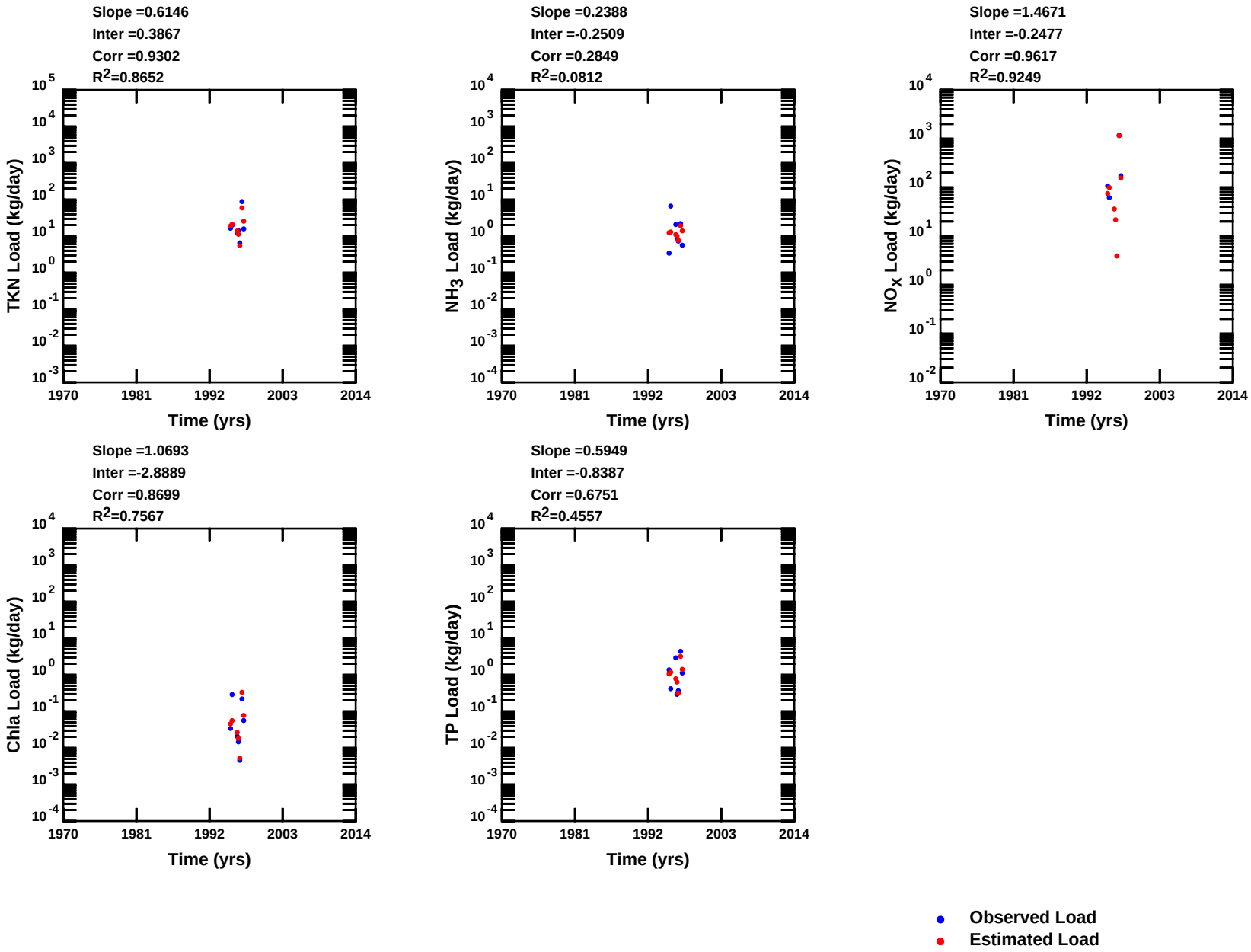
Observed Data vs. LOADEST Estimated Concentration, Station 17900
Nueces Tributaries, Texas (1959-2014)



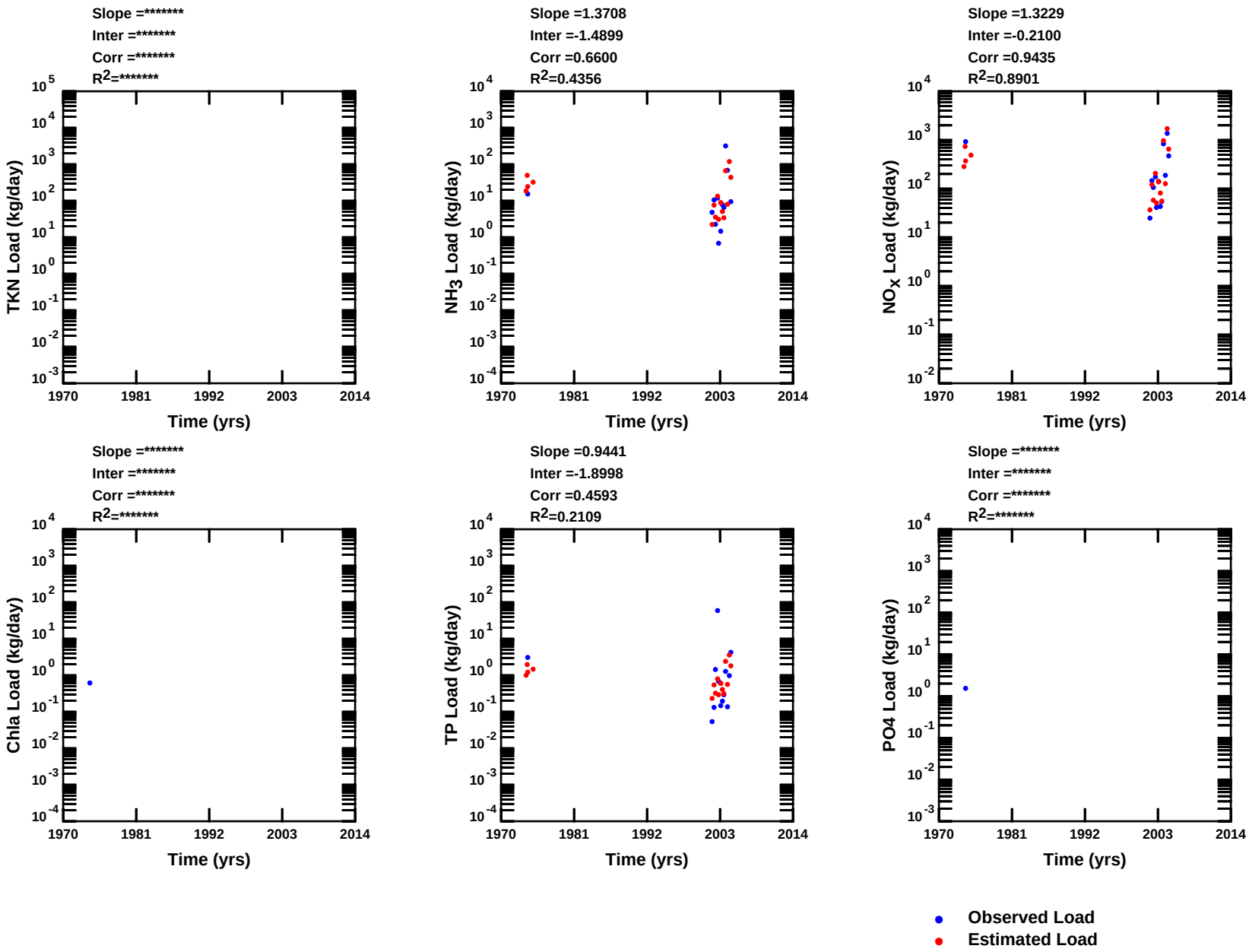
Nutrient Load Distribution, Station 13005
Nueces Tributaries, Texas (1970-2014)



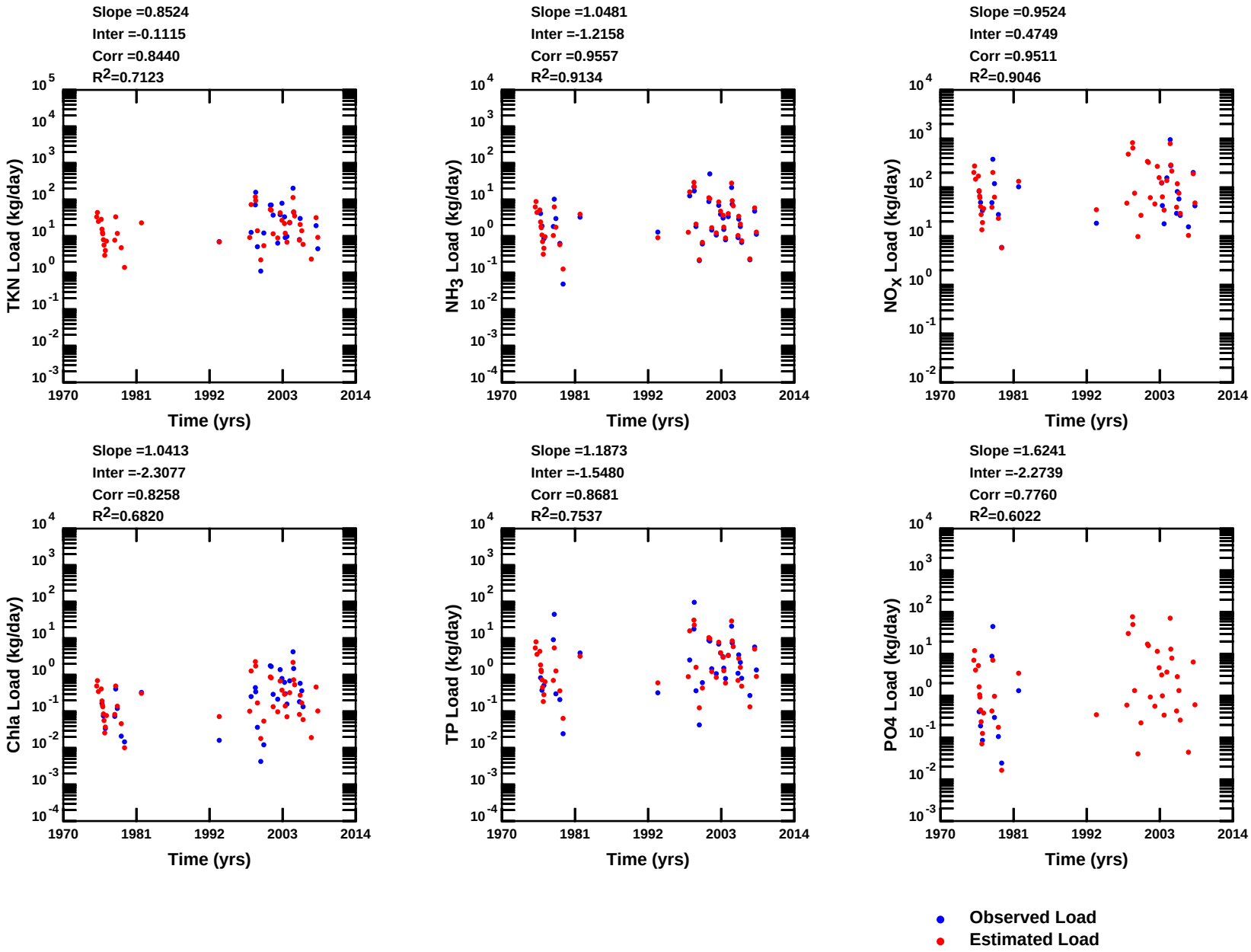
Nutrient Load Distribution, Station 12999
Nueces Tributaries, Texas (1970-2014)



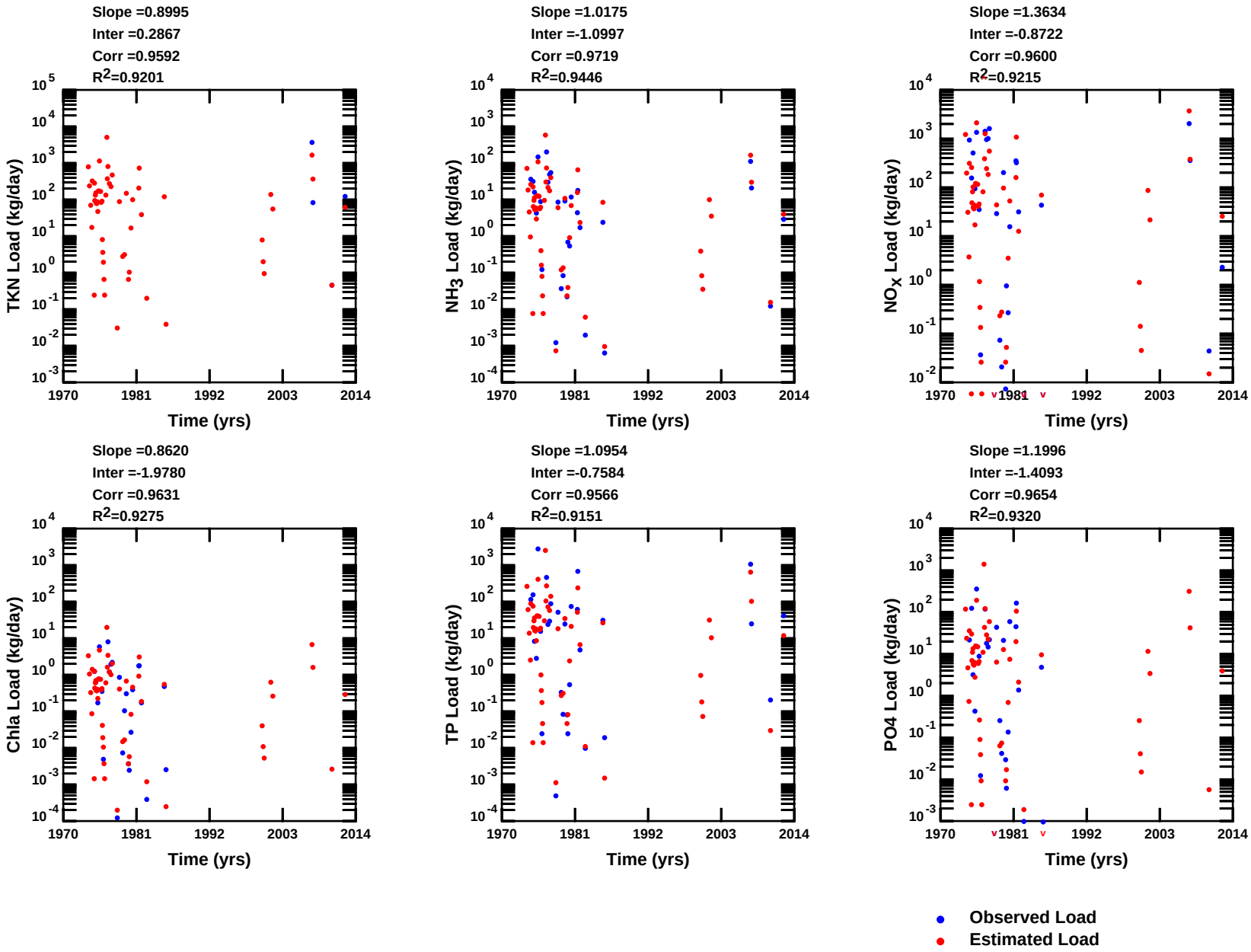
Nutrient Load Distribution, Station 14253
Nueces Tributaries, Texas (1970-2014)



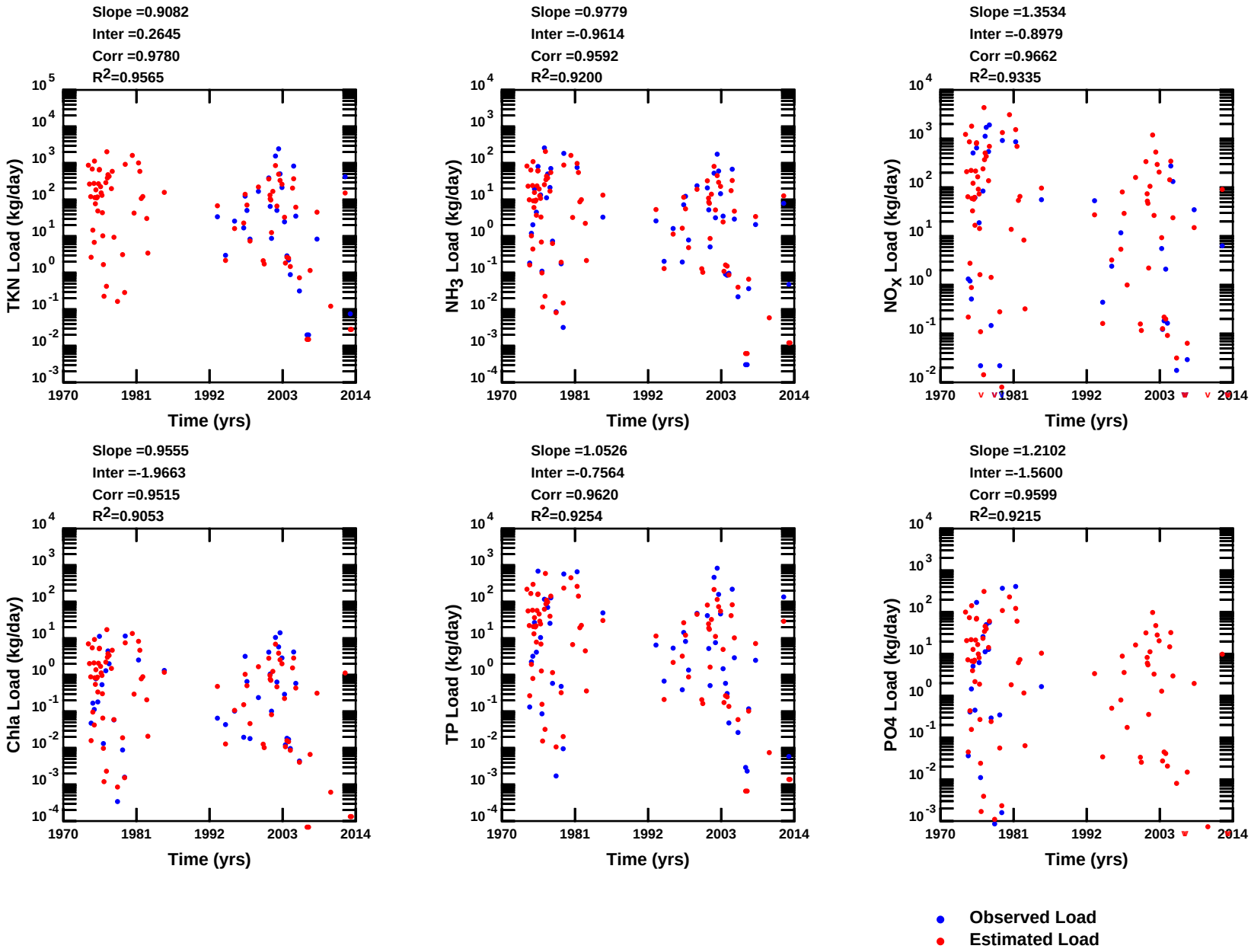
Nutrient Load Distribution, Station 12997
Nueces Tributaries, Texas (1970-2014)



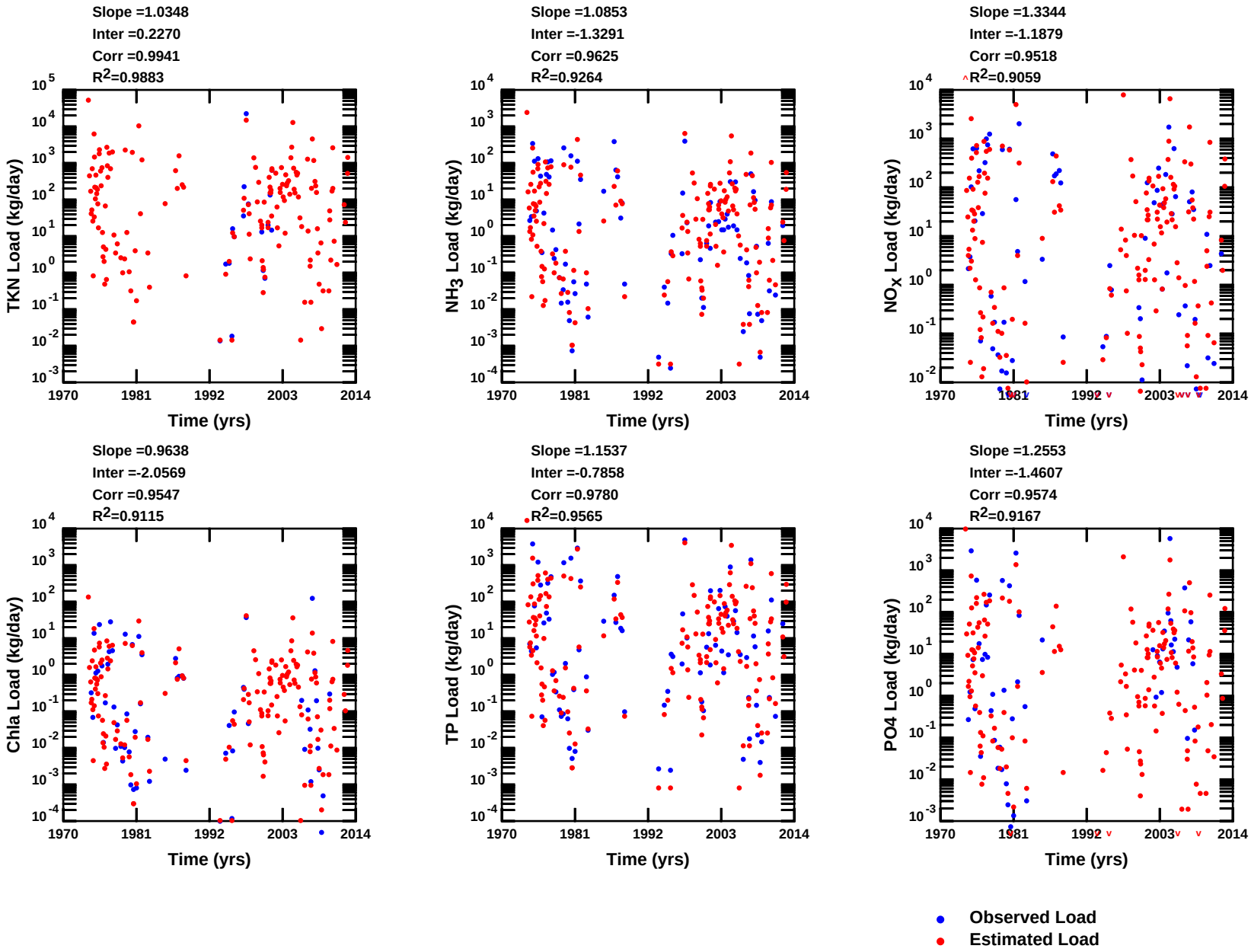
Nutrient Load Distribution, Station 12996
Nueces Tributaries, Texas (1970-2014)



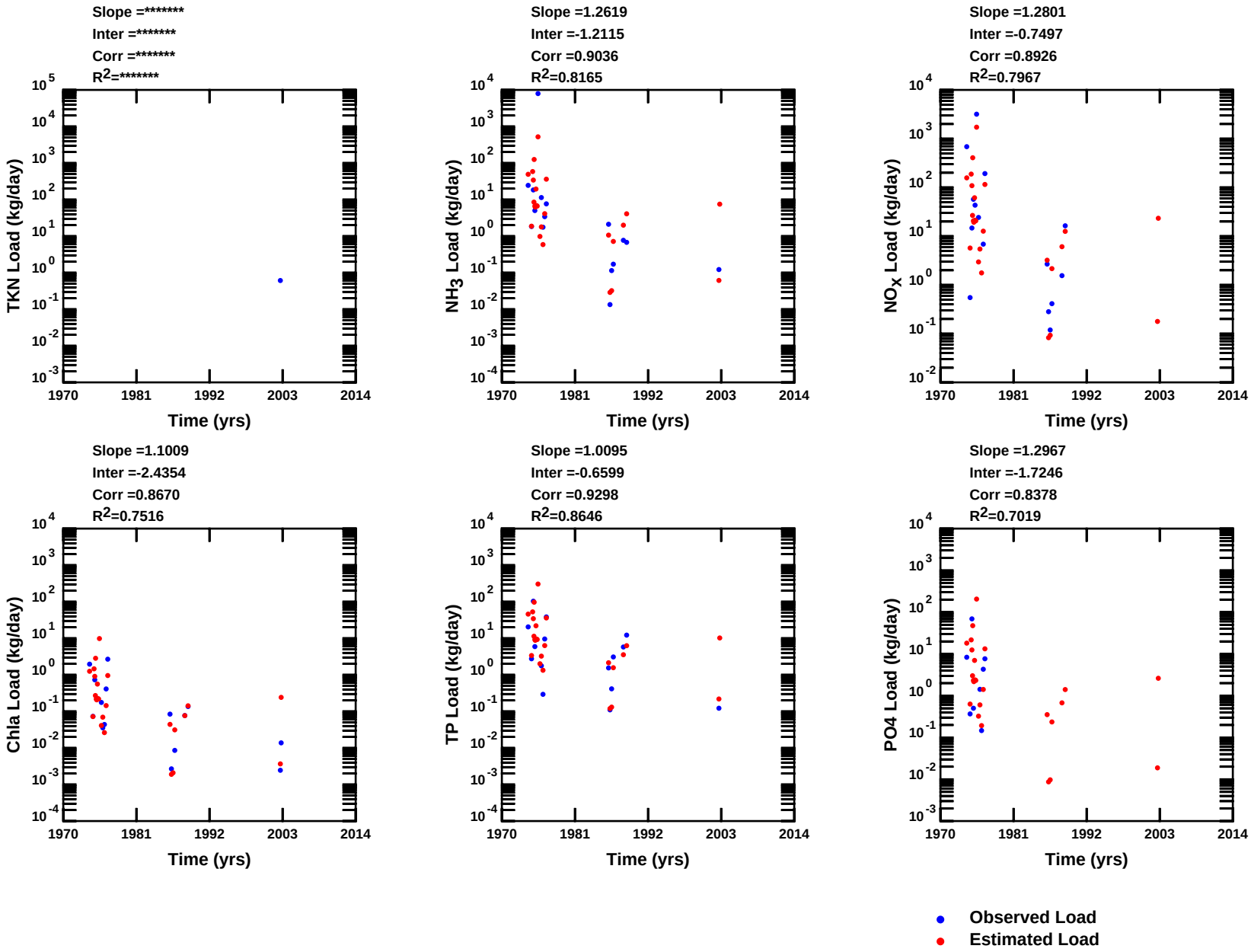
Nutrient Load Distribution, Station 12976
Nueces Tributaries, Texas (1970-2014)



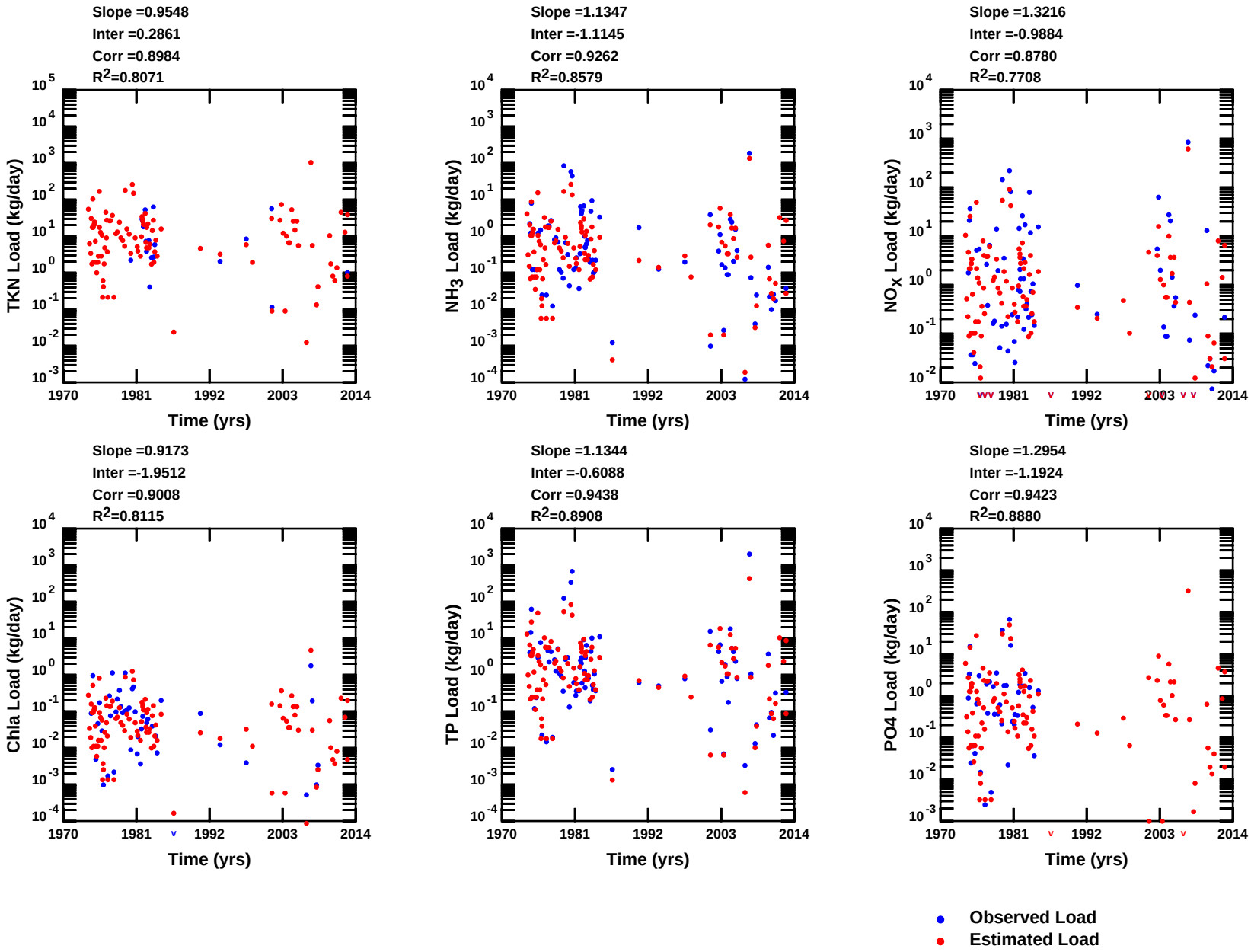
Nutrient Load Distribution, Station 12975
Nueces Tributaries, Texas (1970-2014)



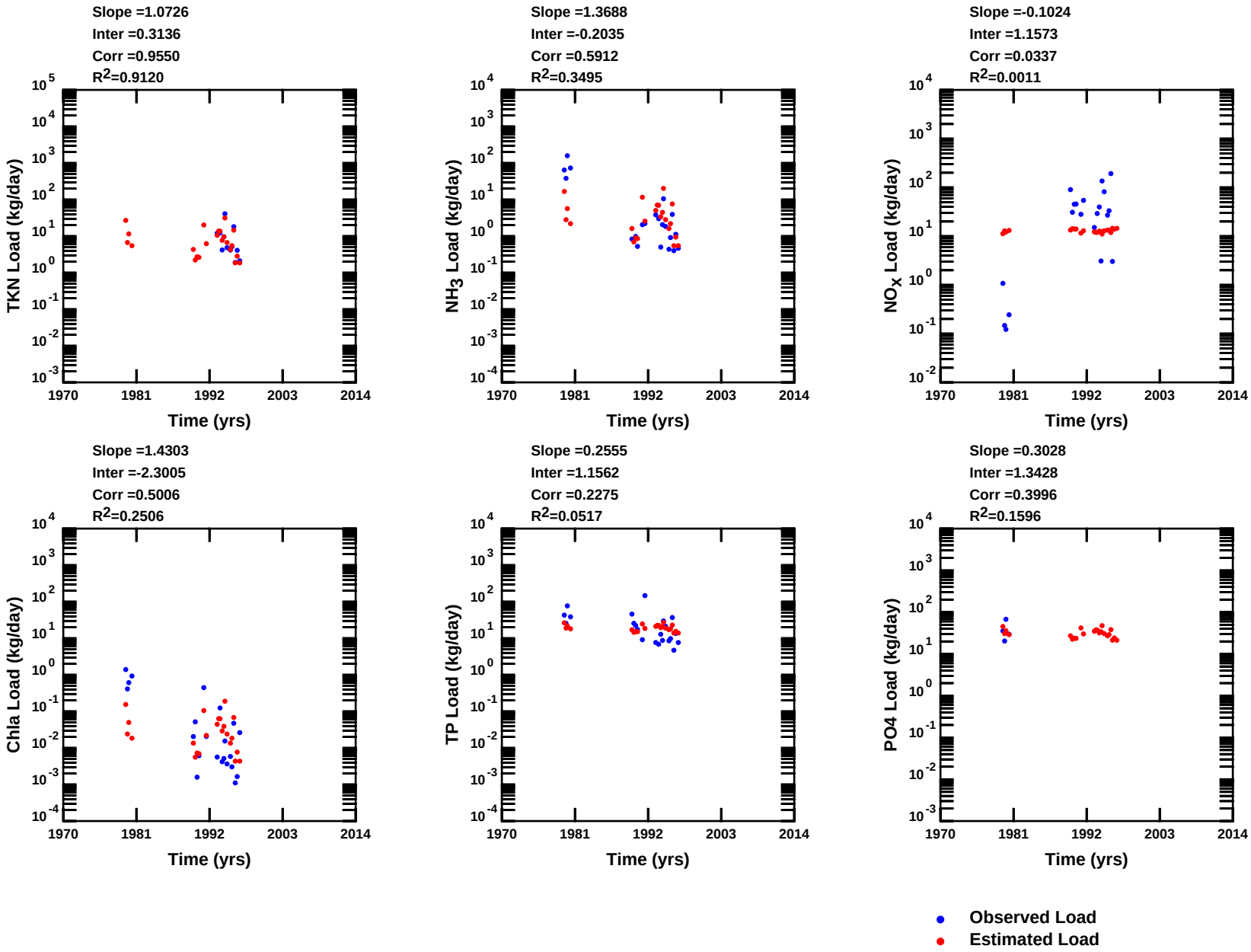
Nutrient Load Distribution, Station 12973
Nueces Tributaries, Texas (1970-2014)



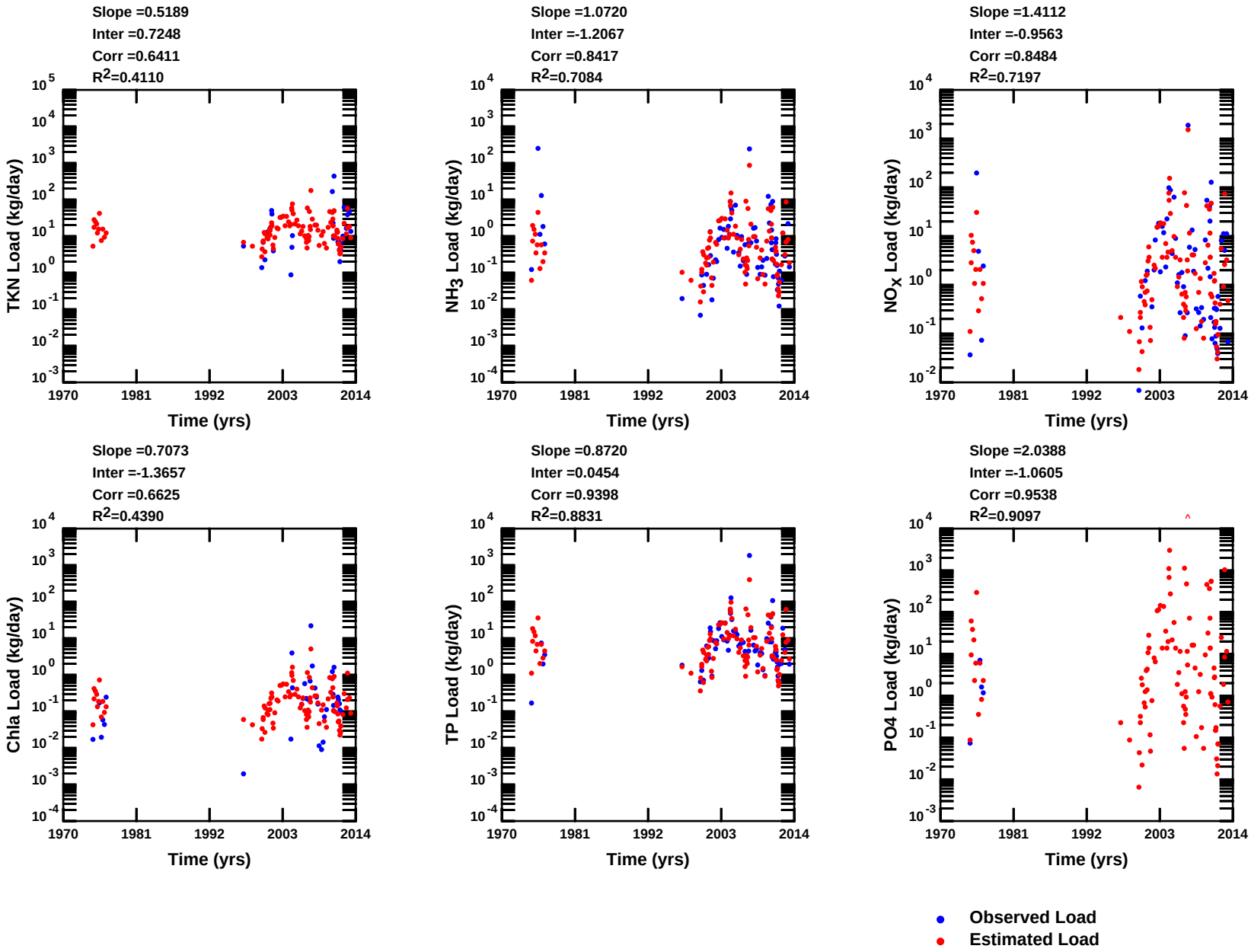
Nutrient Load Distribution, Station 12972
Nueces Tributaries, Texas (1970-2014)



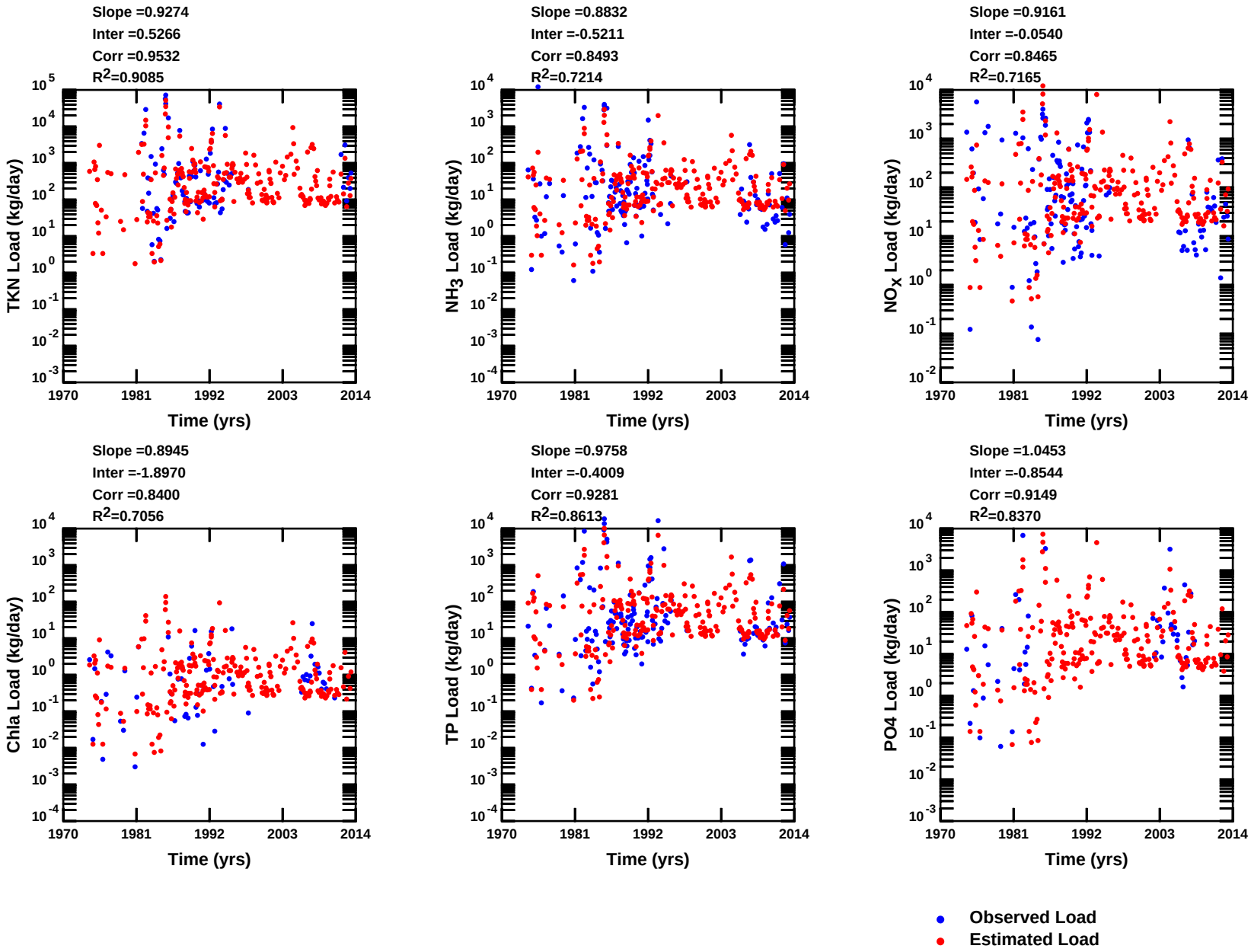
Nutrient Load Distribution, Station 12983
Nueces Tributaries, Texas (1970-2014)



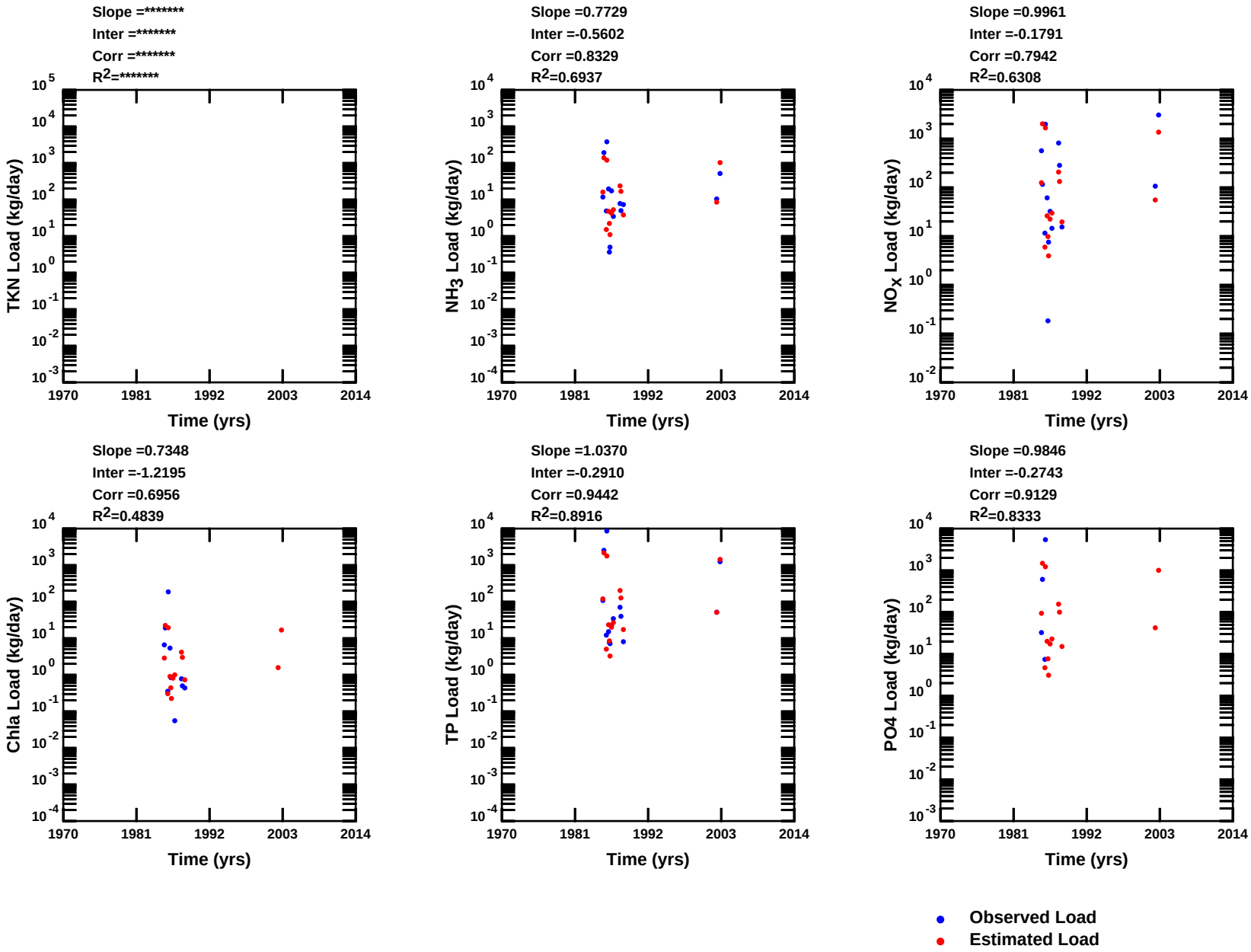
Nutrient Load Distribution, Station 12981
Nueces Tributaries, Texas (1970-2014)



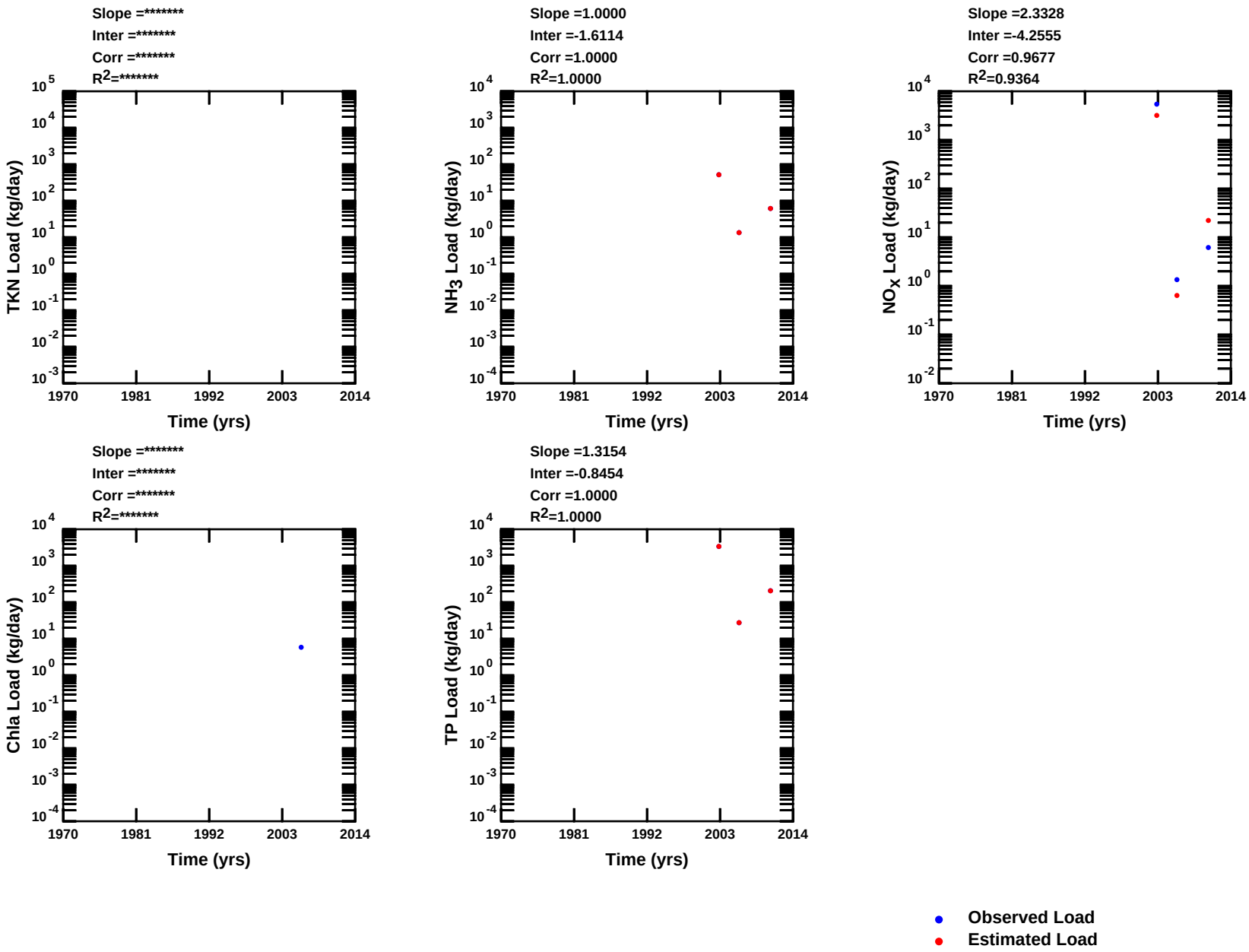
Nutrient Load Distribution, Station 12980
Nueces Tributaries, Texas (1970-2014)



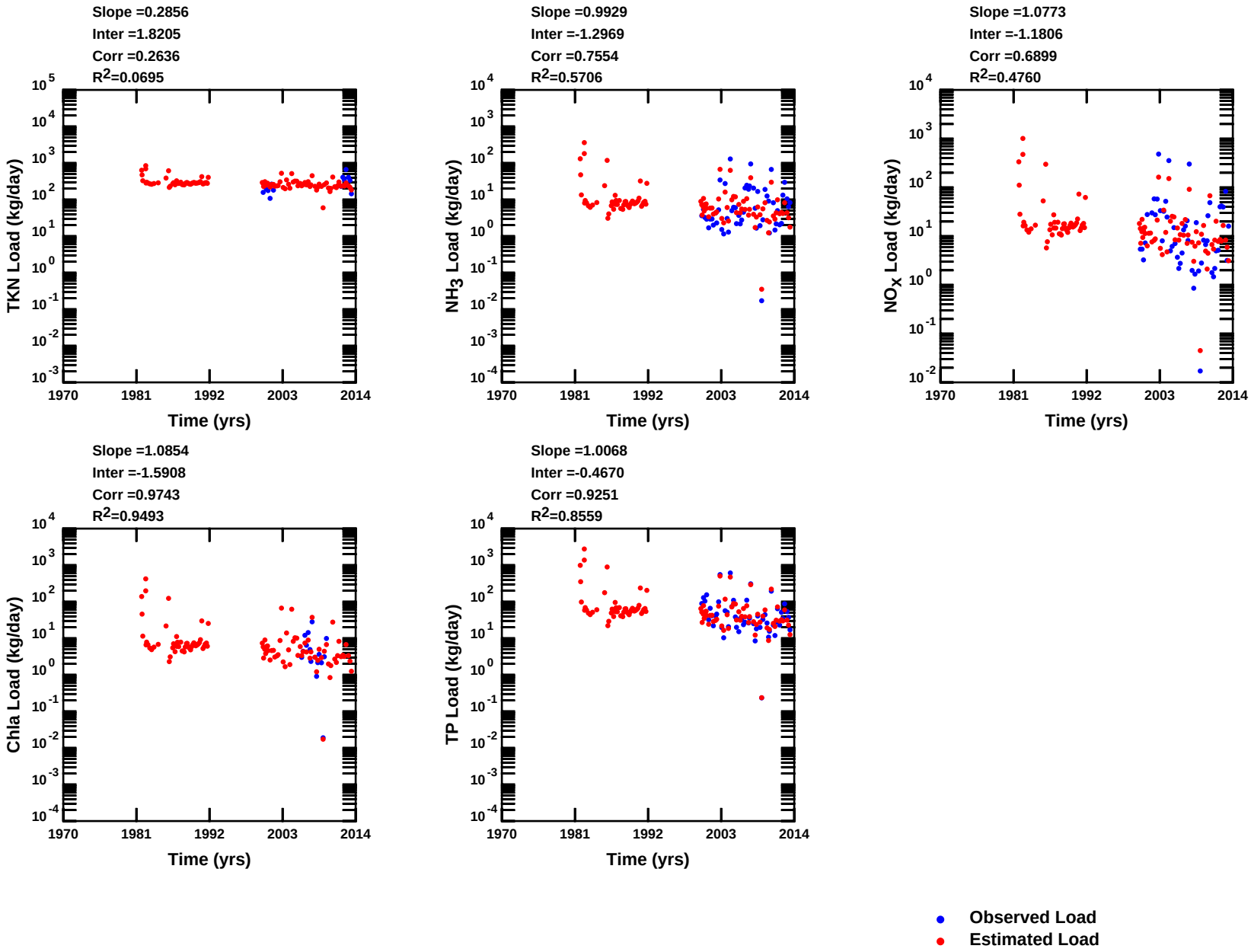
Nutrient Load Distribution, Station 12979
Nueces Tributaries, Texas (1970-2014)



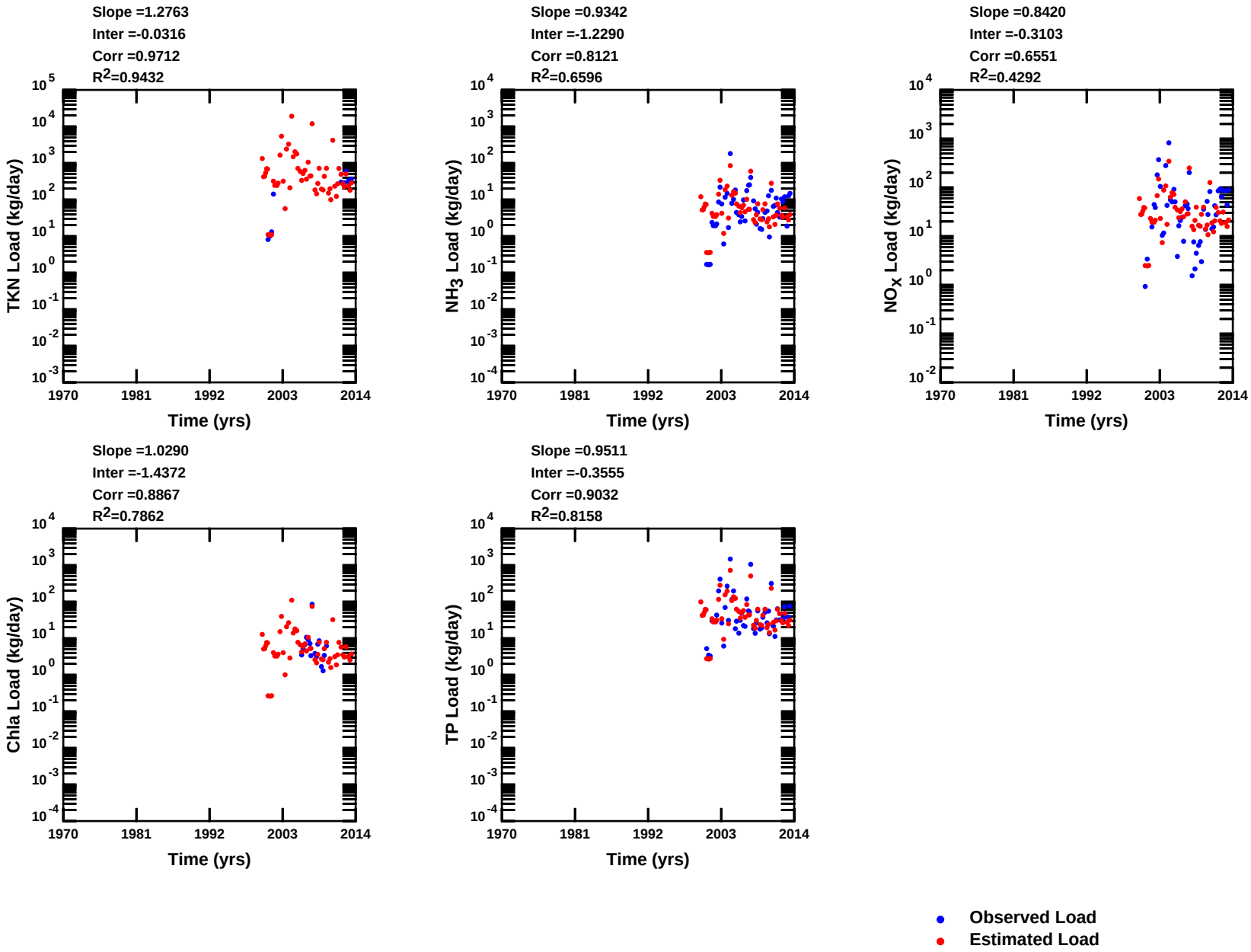
Nutrient Load Distribution, Station 12978
Nueces Tributaries, Texas (1970-2014)



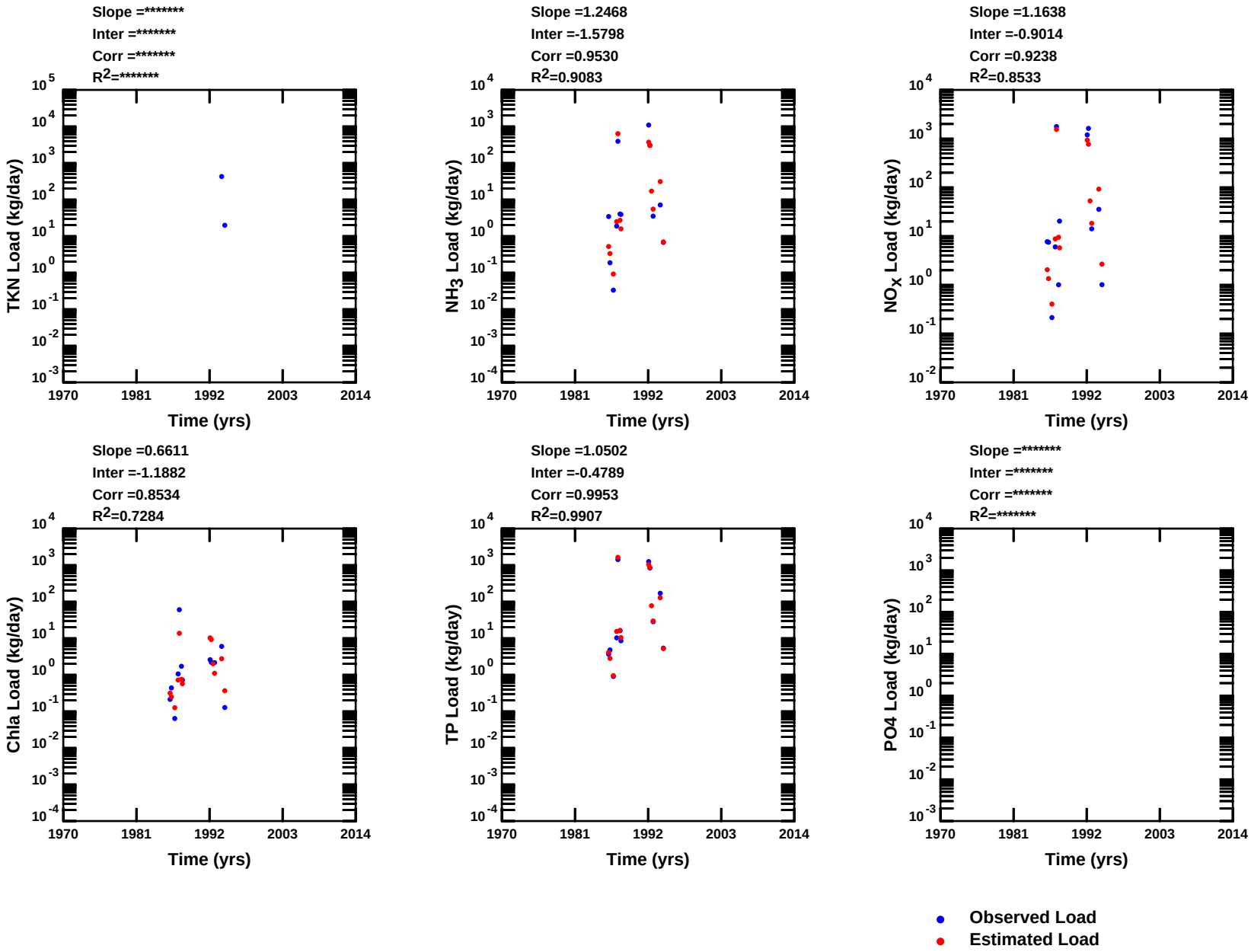
Nutrient Load Distribution, Station 17648
Nueces Tributaries, Texas (1970-2014)



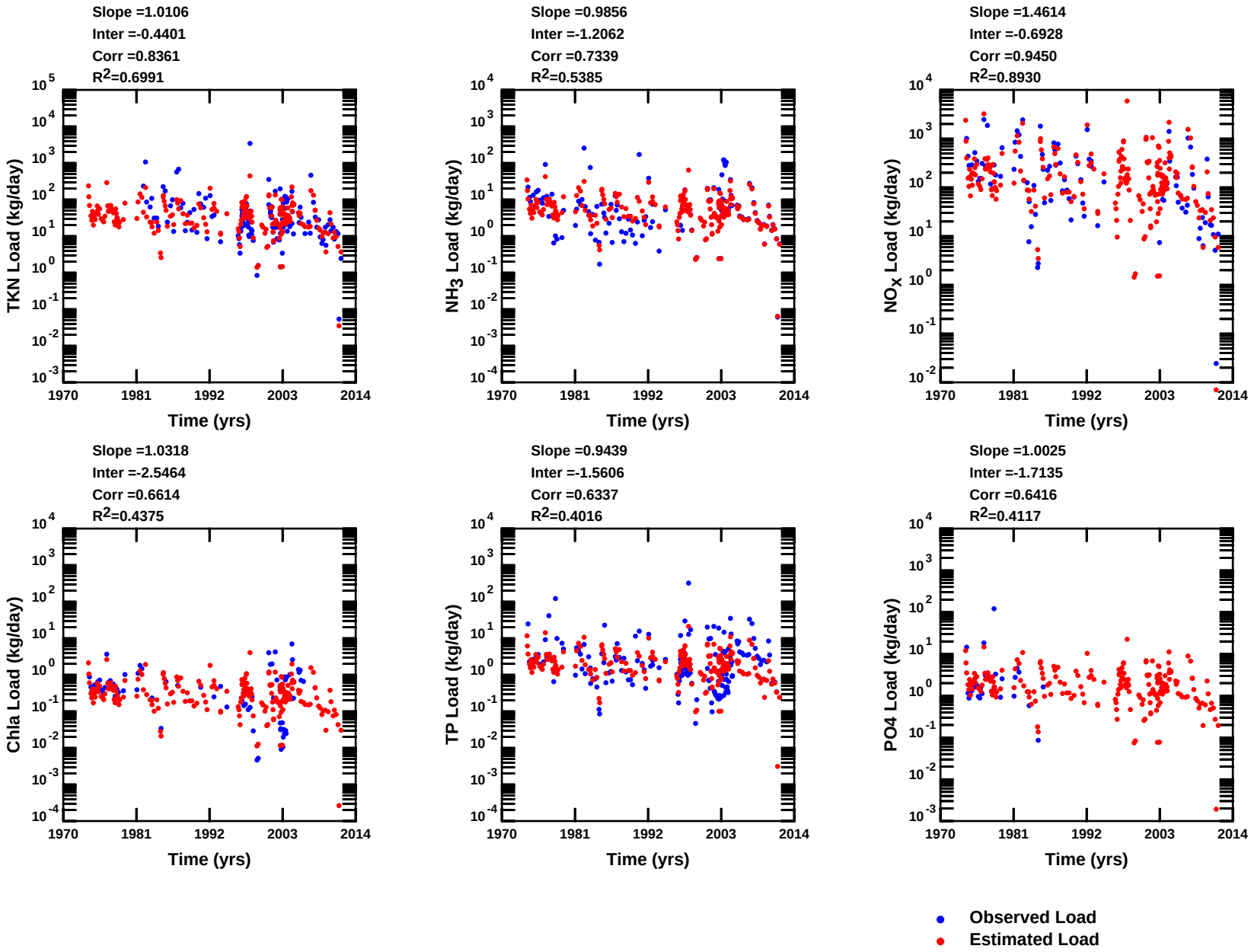
Nutrient Load Distribution, Station 12965
Nueces Tributaries, Texas (1970-2014)



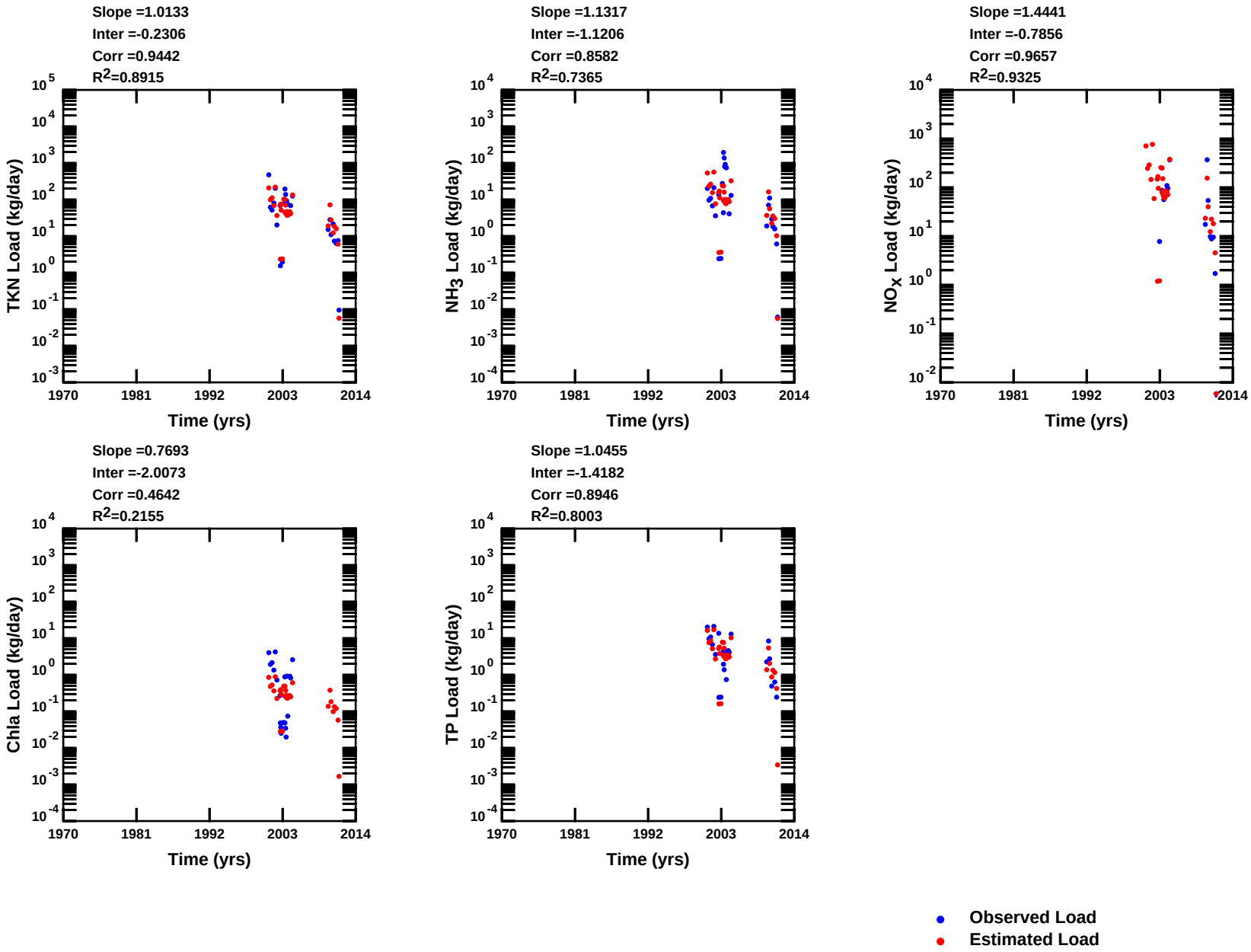
Nutrient Load Distribution, Station 12964
Nueces Tributaries, Texas (1970-2014)



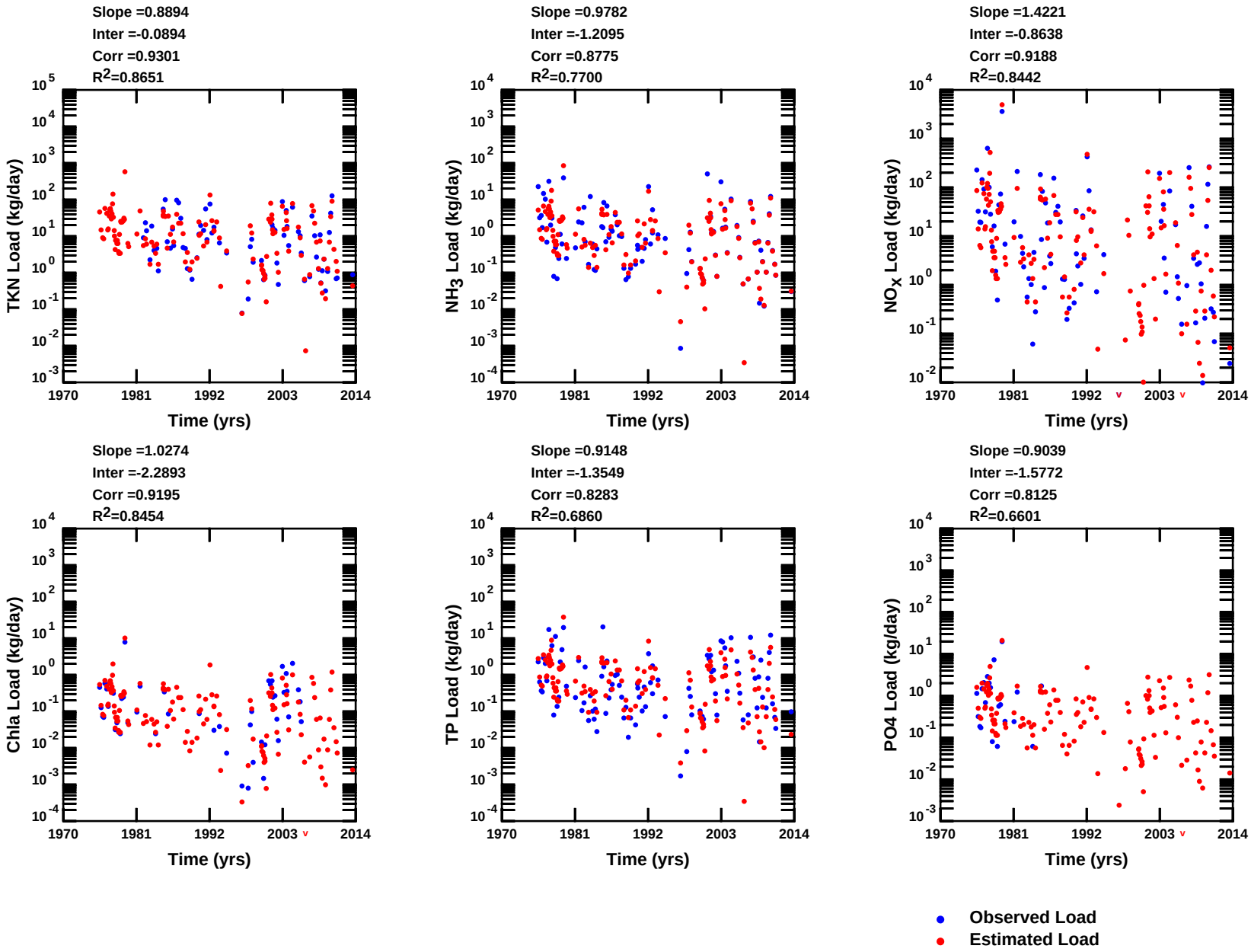
Nutrient Load Distribution, Station 12962
Nueces Tributaries, Texas (1970-2014)



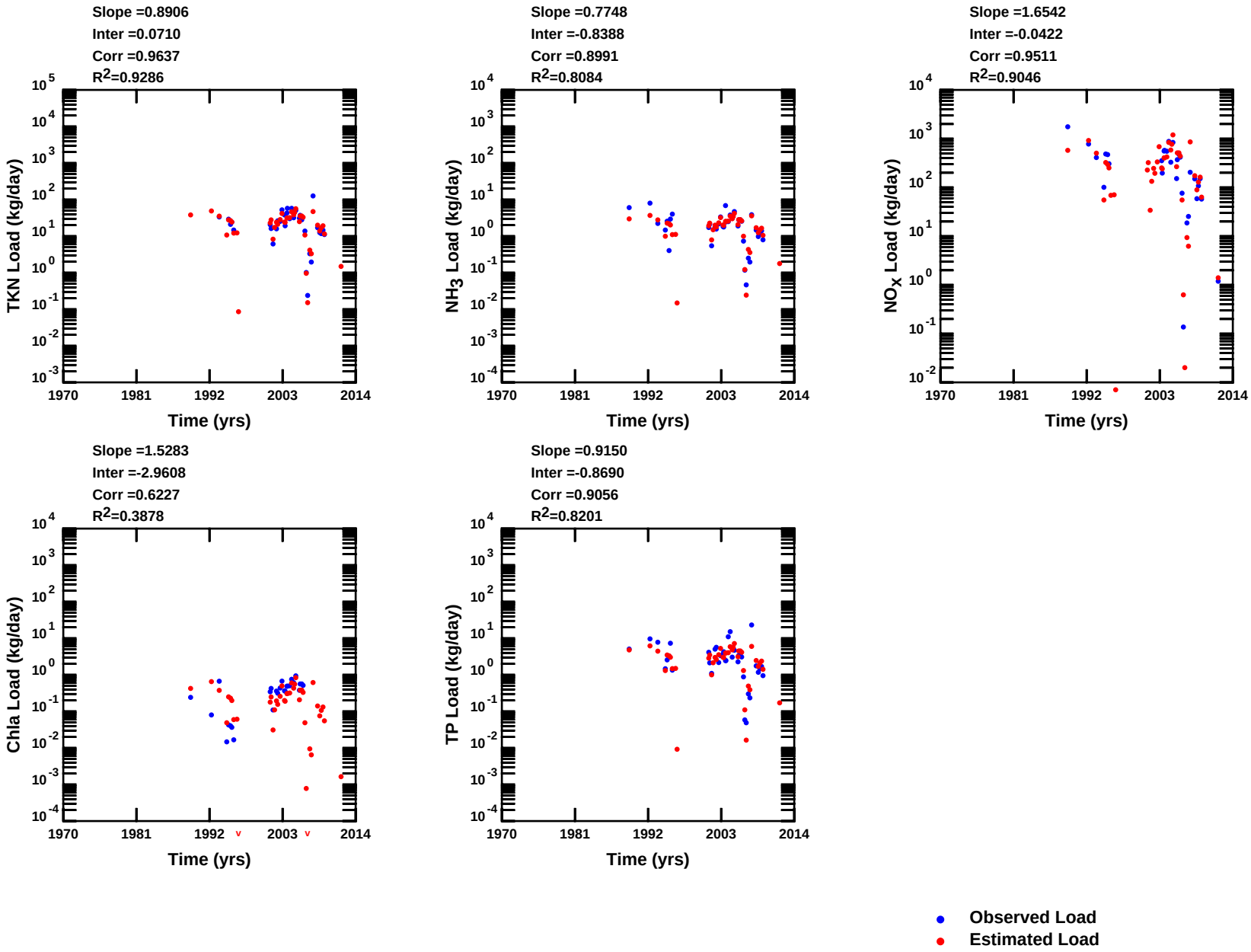
Nutrient Load Distribution, Station 13006
Nueces Tributaries, Texas (1970-2014)



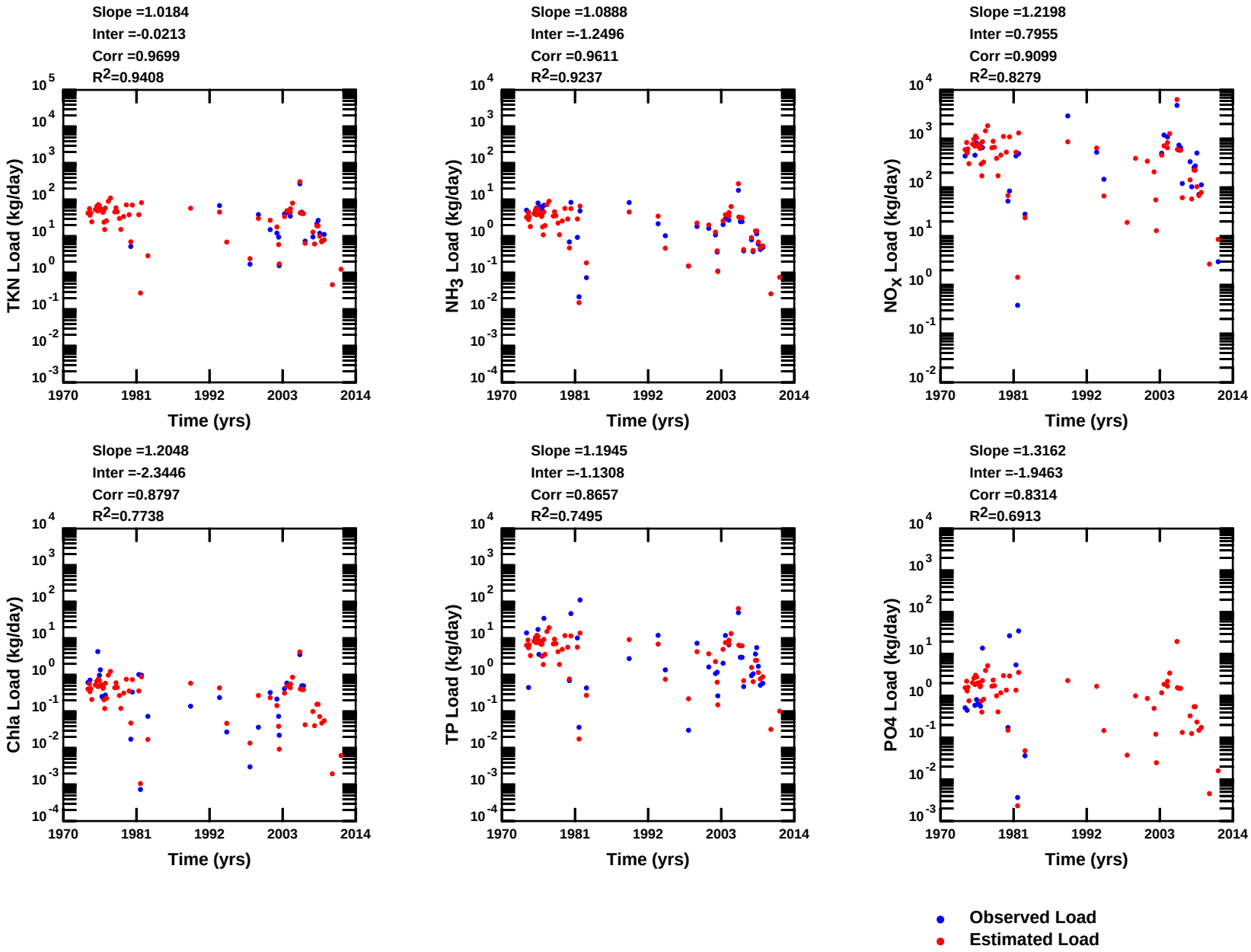
Nutrient Load Distribution, Station 13007
Nueces Tributaries, Texas (1970-2014)



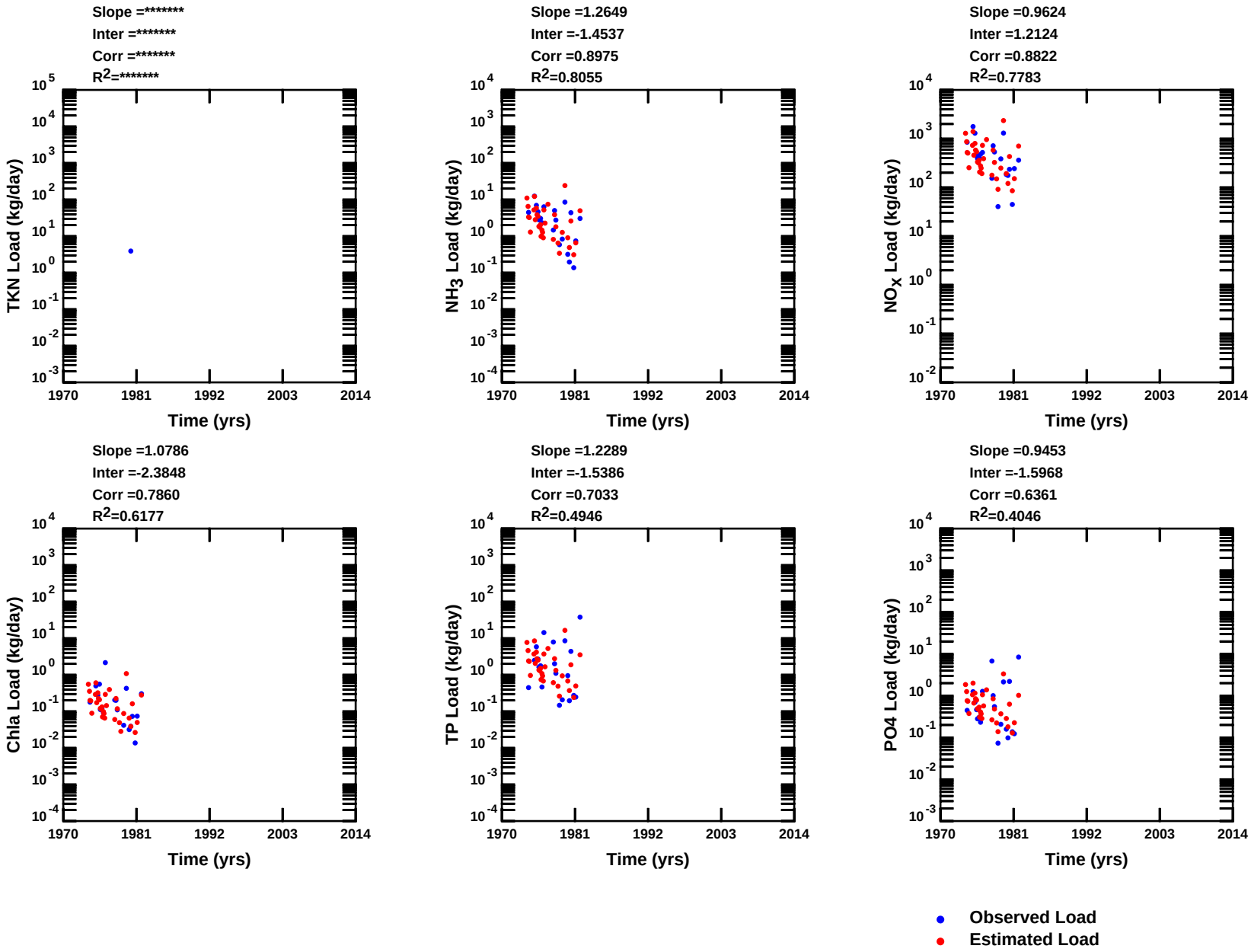
Nutrient Load Distribution, Station 13010
Nueces Tributaries, Texas (1970-2014)



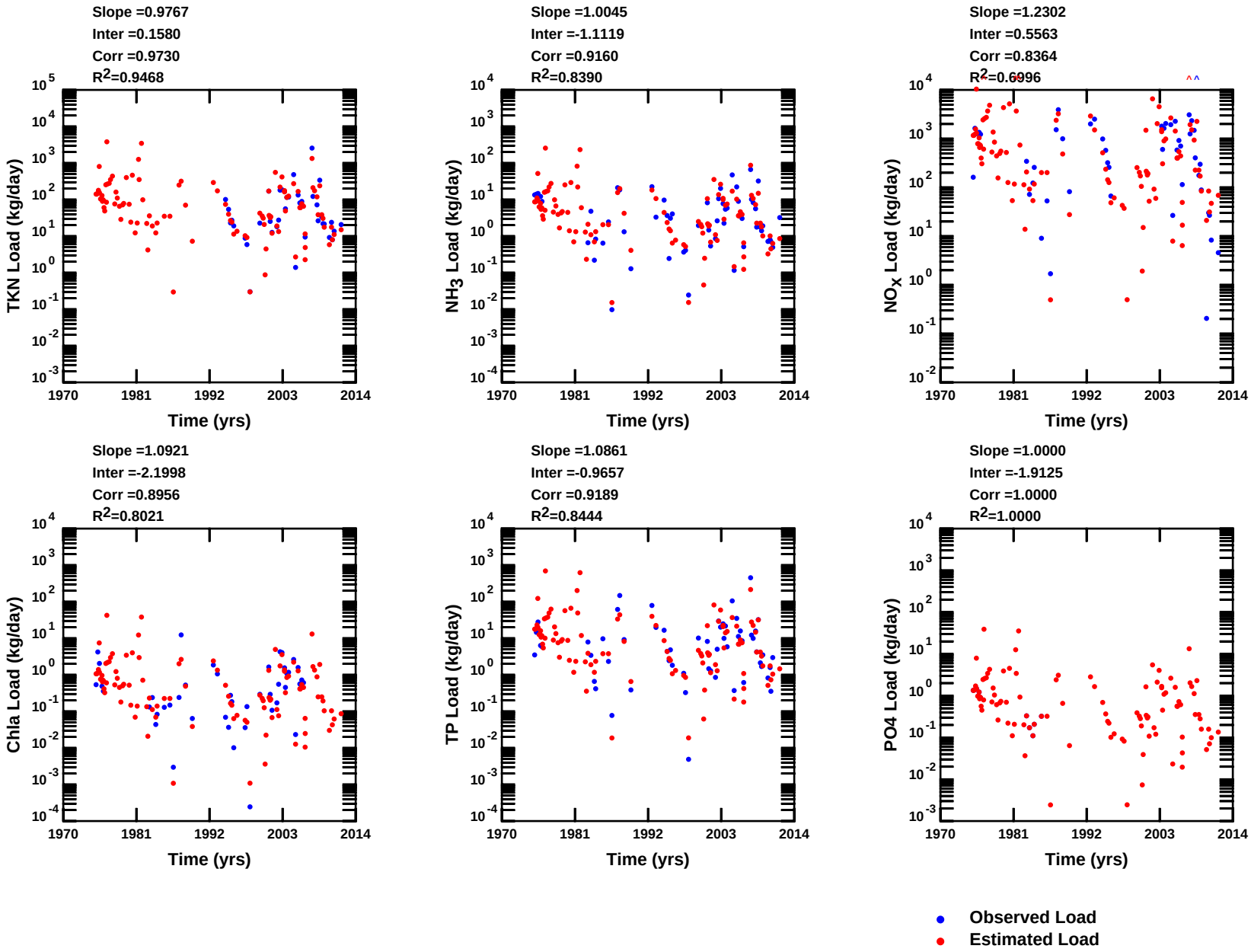
Nutrient Load Distribution, Station 12987
Nueces Tributaries, Texas (1970-2014)



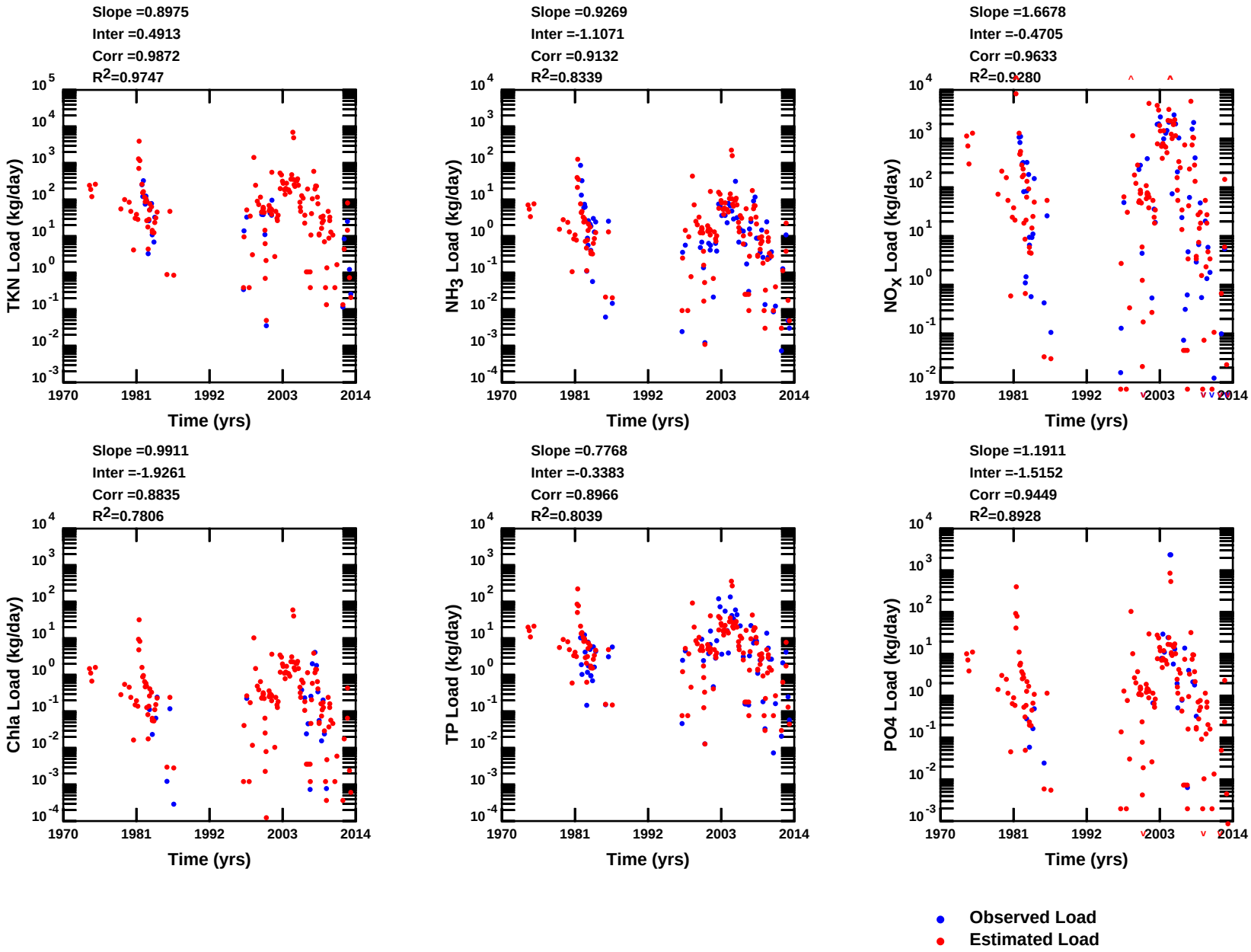
Nutrient Load Distribution, Station 12985
Nueces Tributaries, Texas (1970-2014)



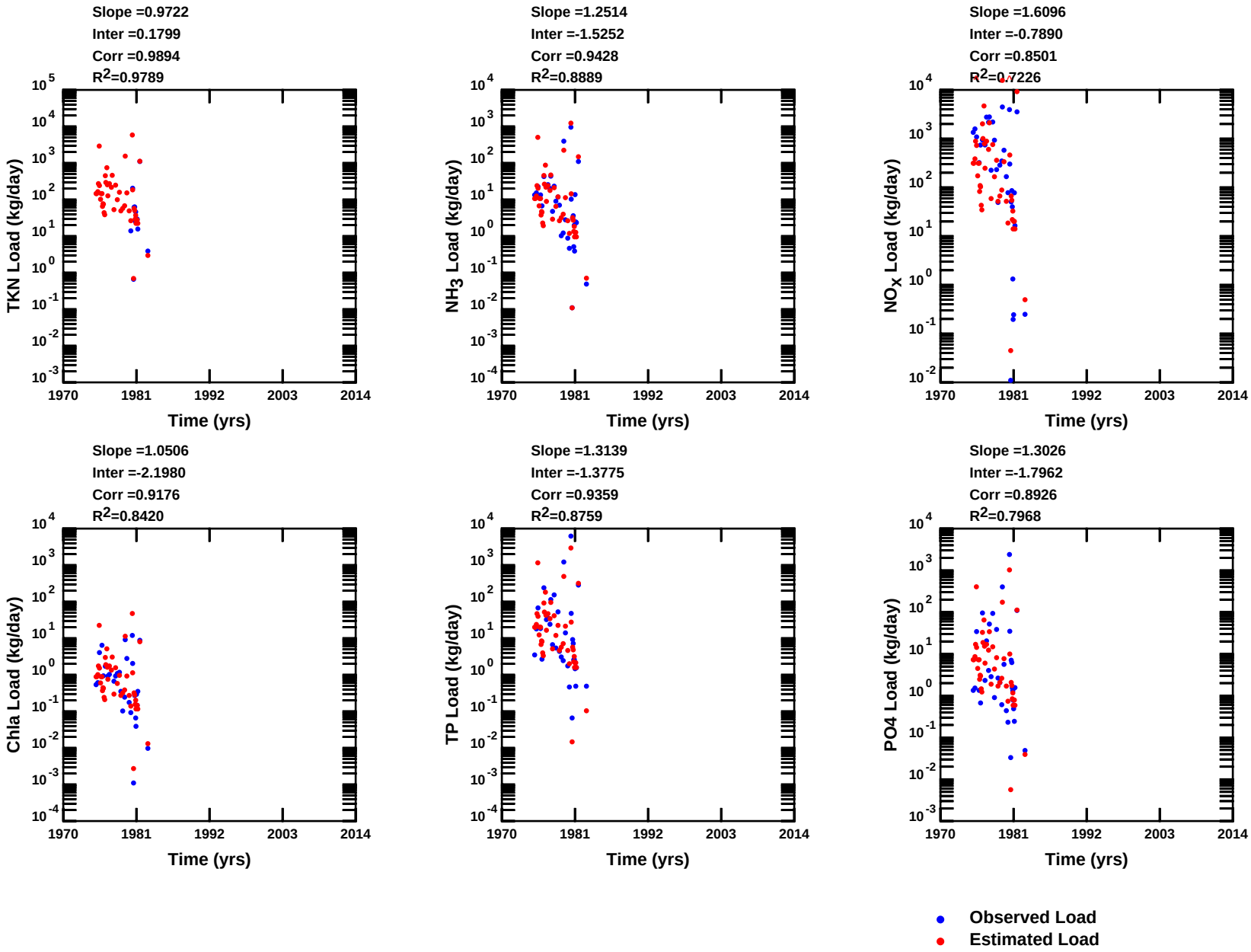
Nutrient Load Distribution, Station 13025
Nueces Tributaries, Texas (1970-2014)



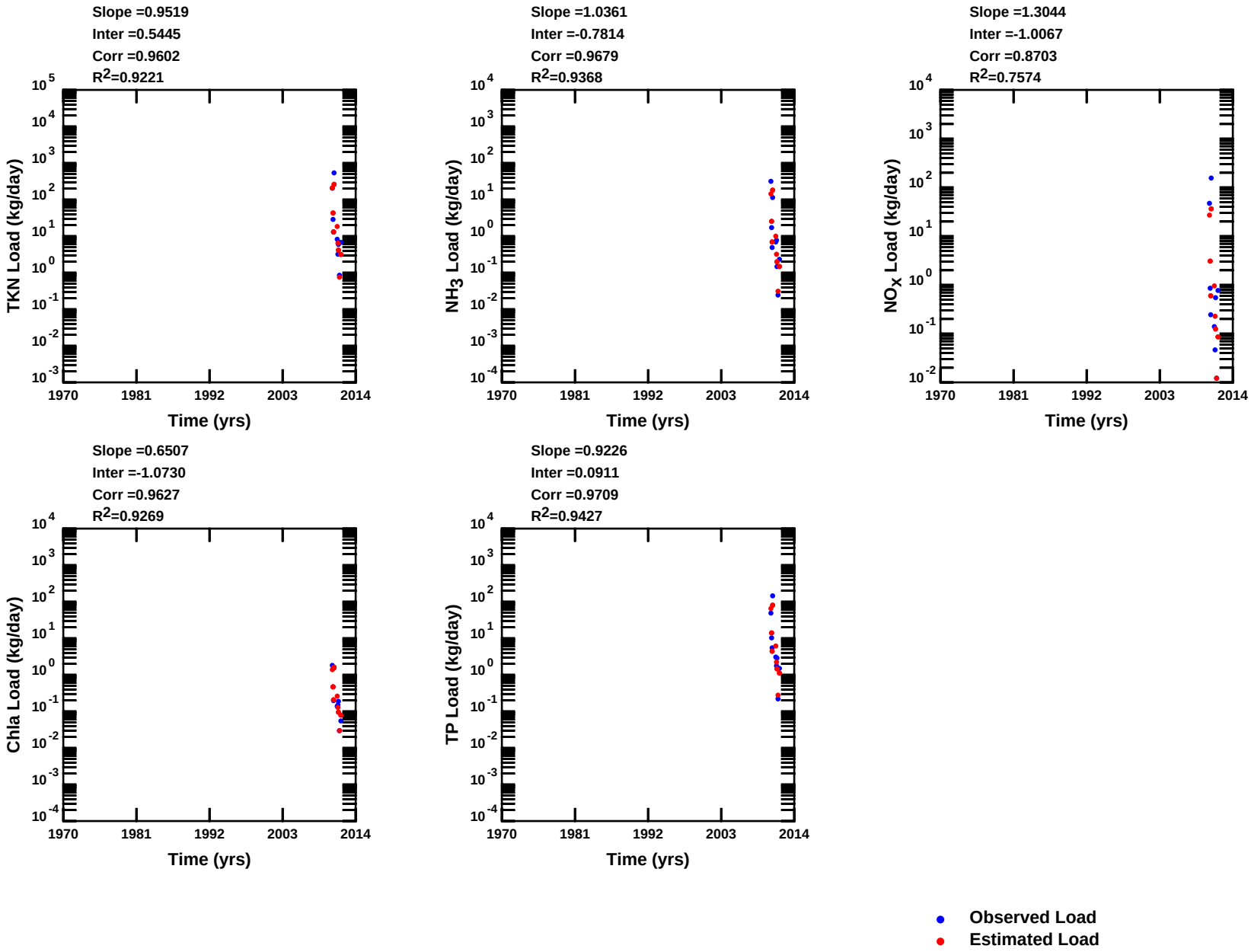
Nutrient Load Distribution, Station 13024
Nueces Tributaries, Texas (1970-2014)



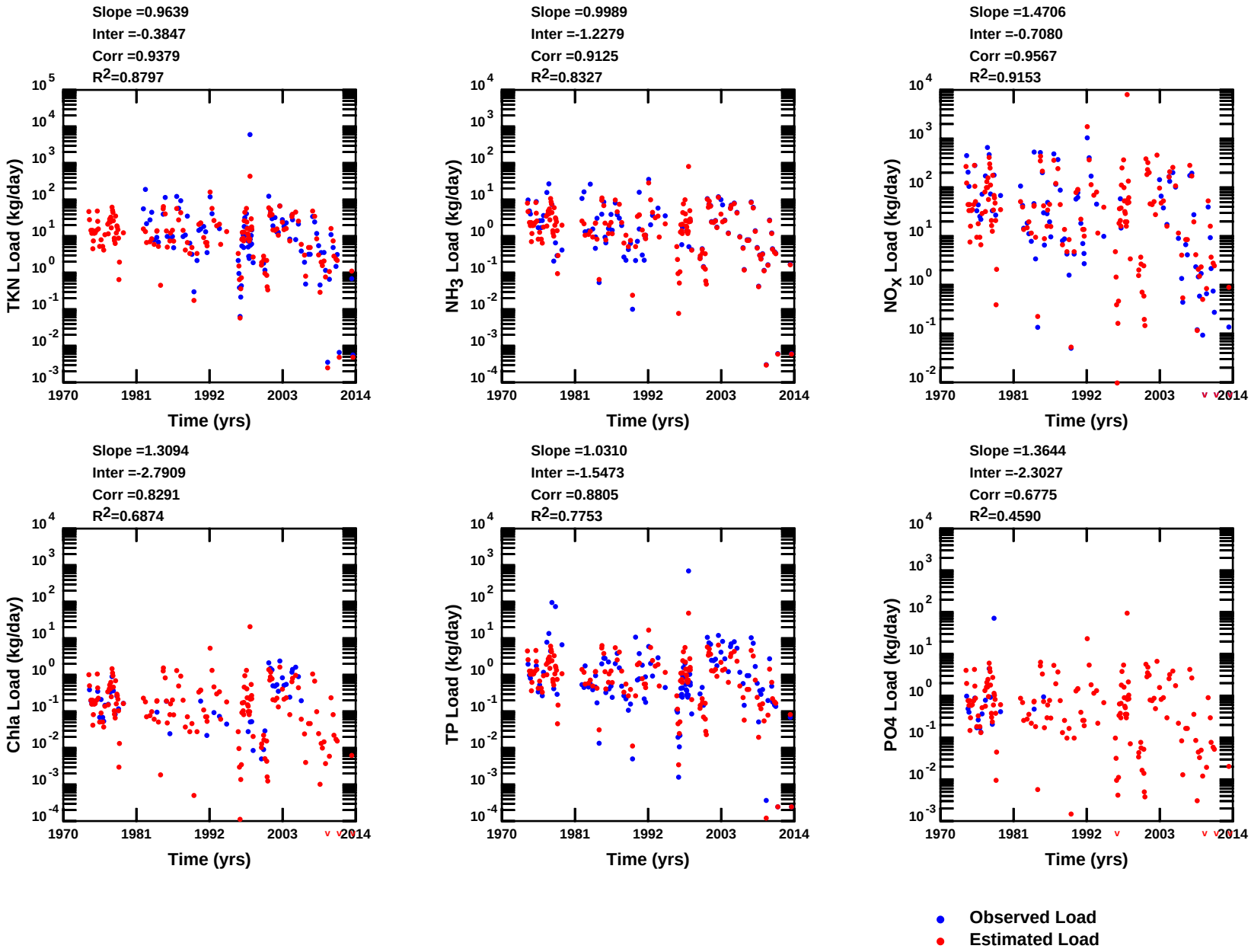
Nutrient Load Distribution, Station 13023
Nueces Tributaries, Texas (1970-2014)



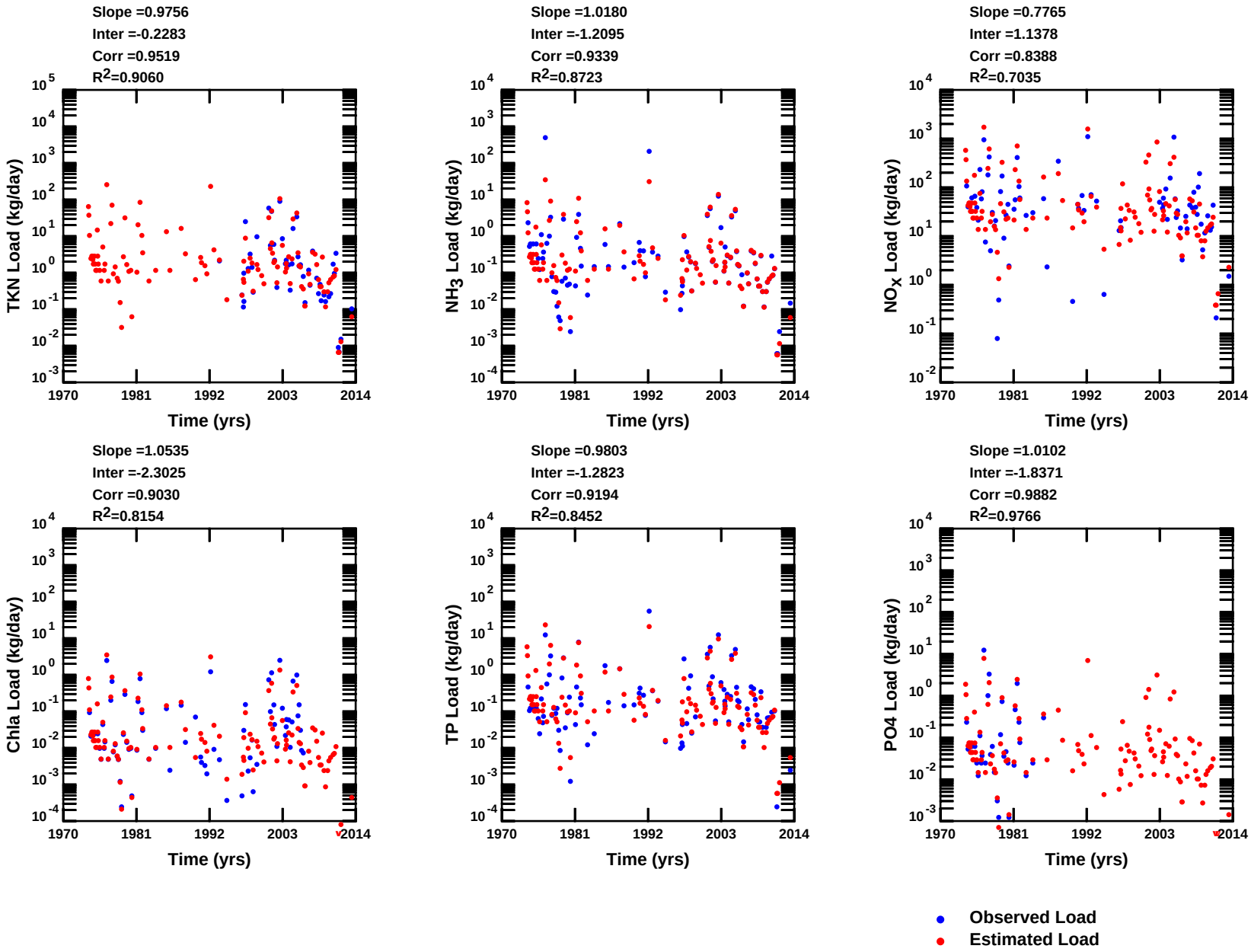
Nutrient Load Distribution, Station 13021
Nueces Tributaries, Texas (1970-2014)



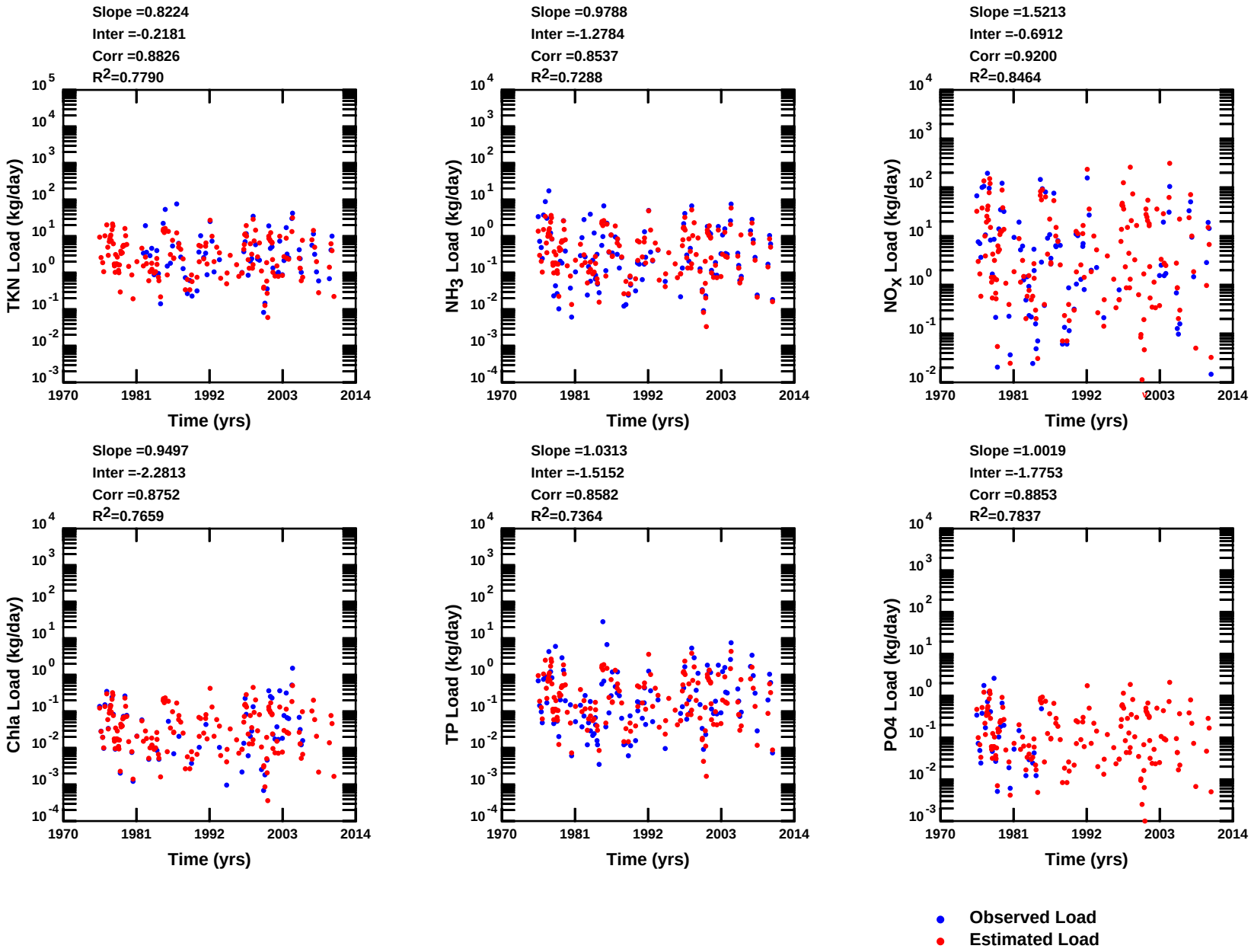
Nutrient Load Distribution, Station 20773
Nueces Tributaries, Texas (1970-2014)



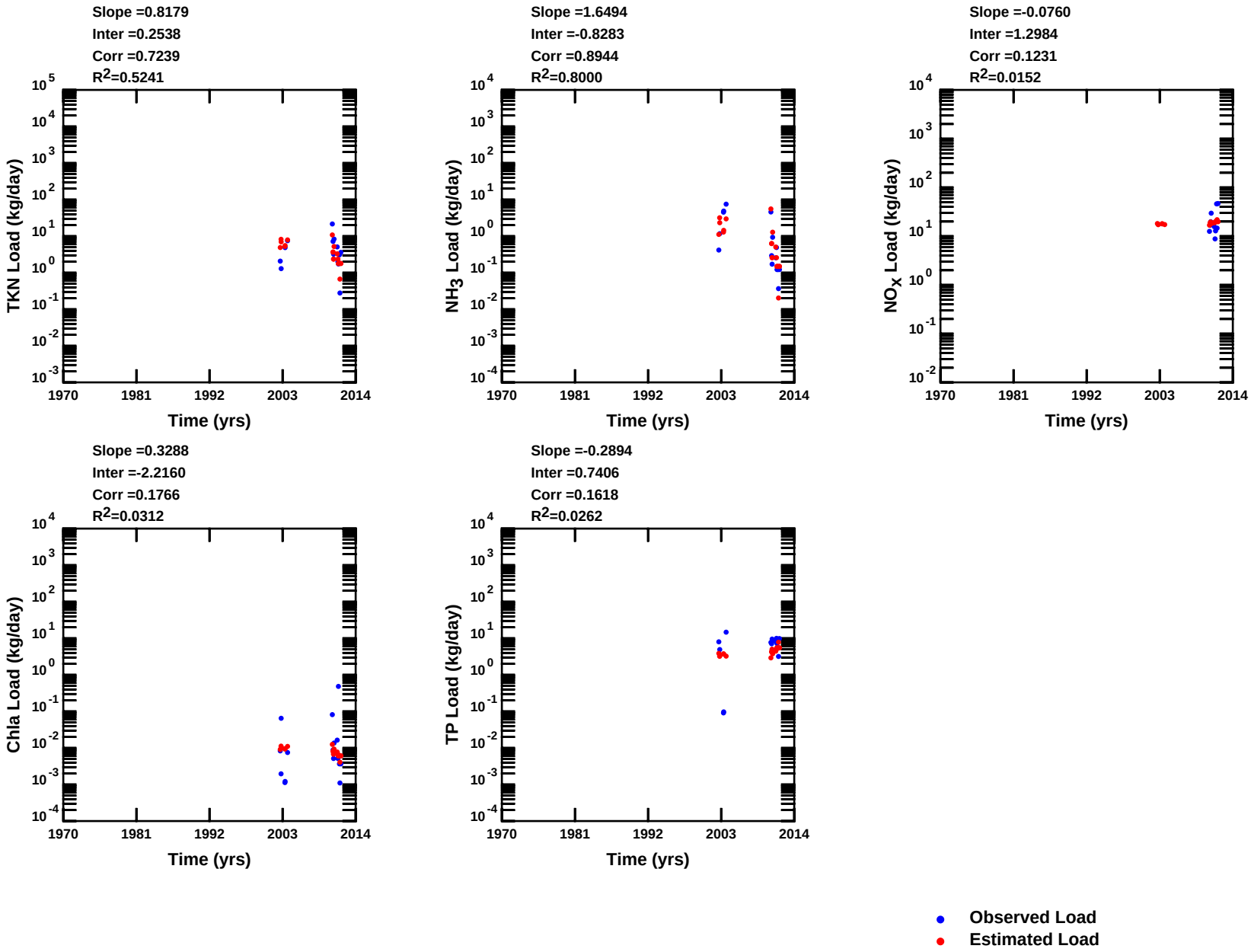
Nutrient Load Distribution, Station 12994
Nueces Tributaries, Texas (1970-2014)



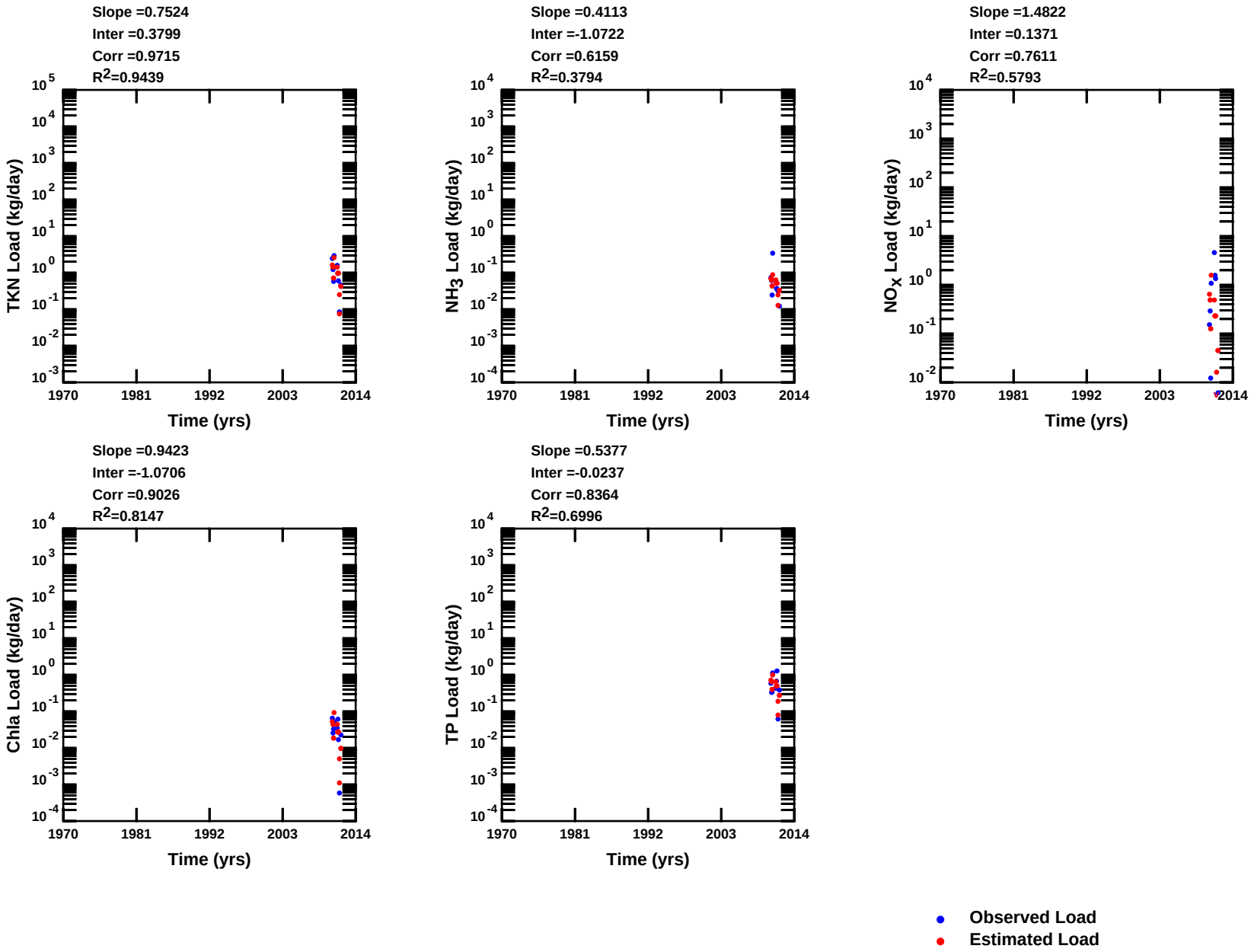
Nutrient Load Distribution, Station 12993
Nueces Tributaries, Texas (1970-2014)



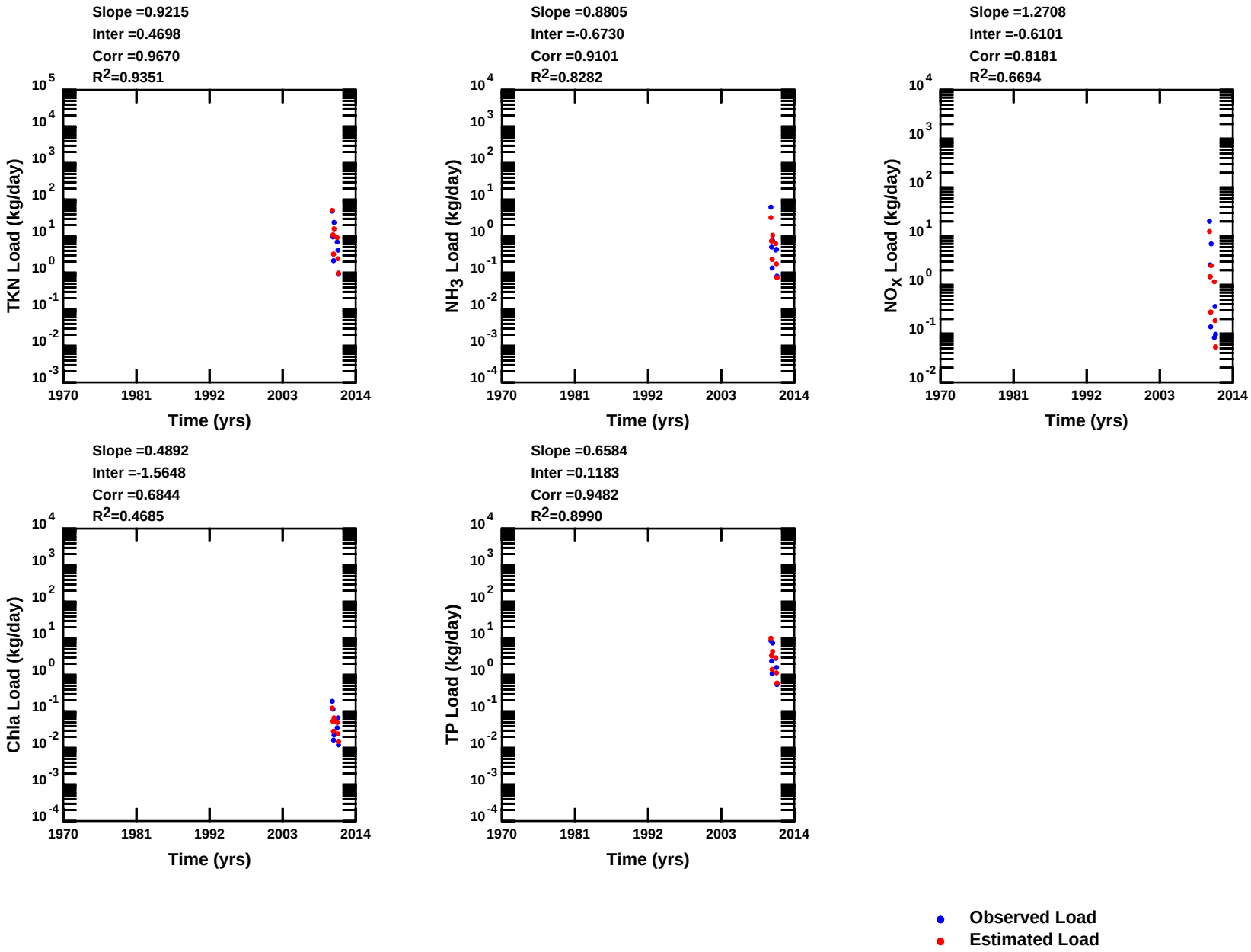
Nutrient Load Distribution, Station 13013
Nueces Tributaries, Texas (1970-2014)



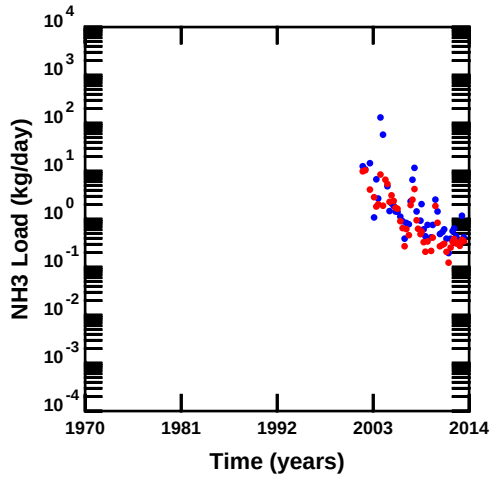
Nutrient Load Distribution, Station 17900
Nueces Tributaries, Texas (1970-2014)

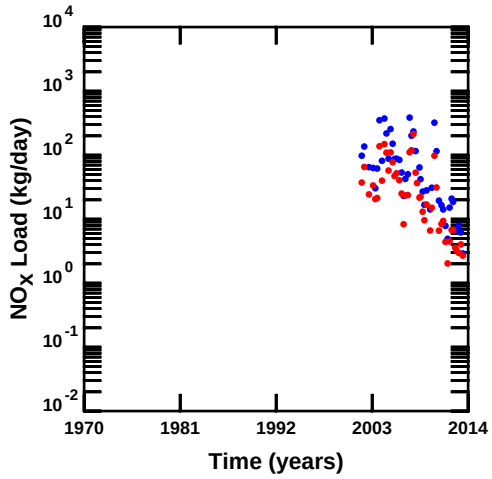


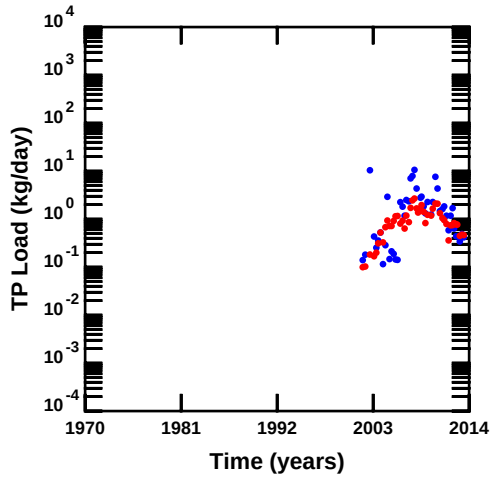
Nutrient Load Distribution, Station 20762
Nueces Tributaries, Texas (1970-2014)



Nutrient Load Distribution, Station 20764
Nueces Tributaries, Texas (1970-2014)

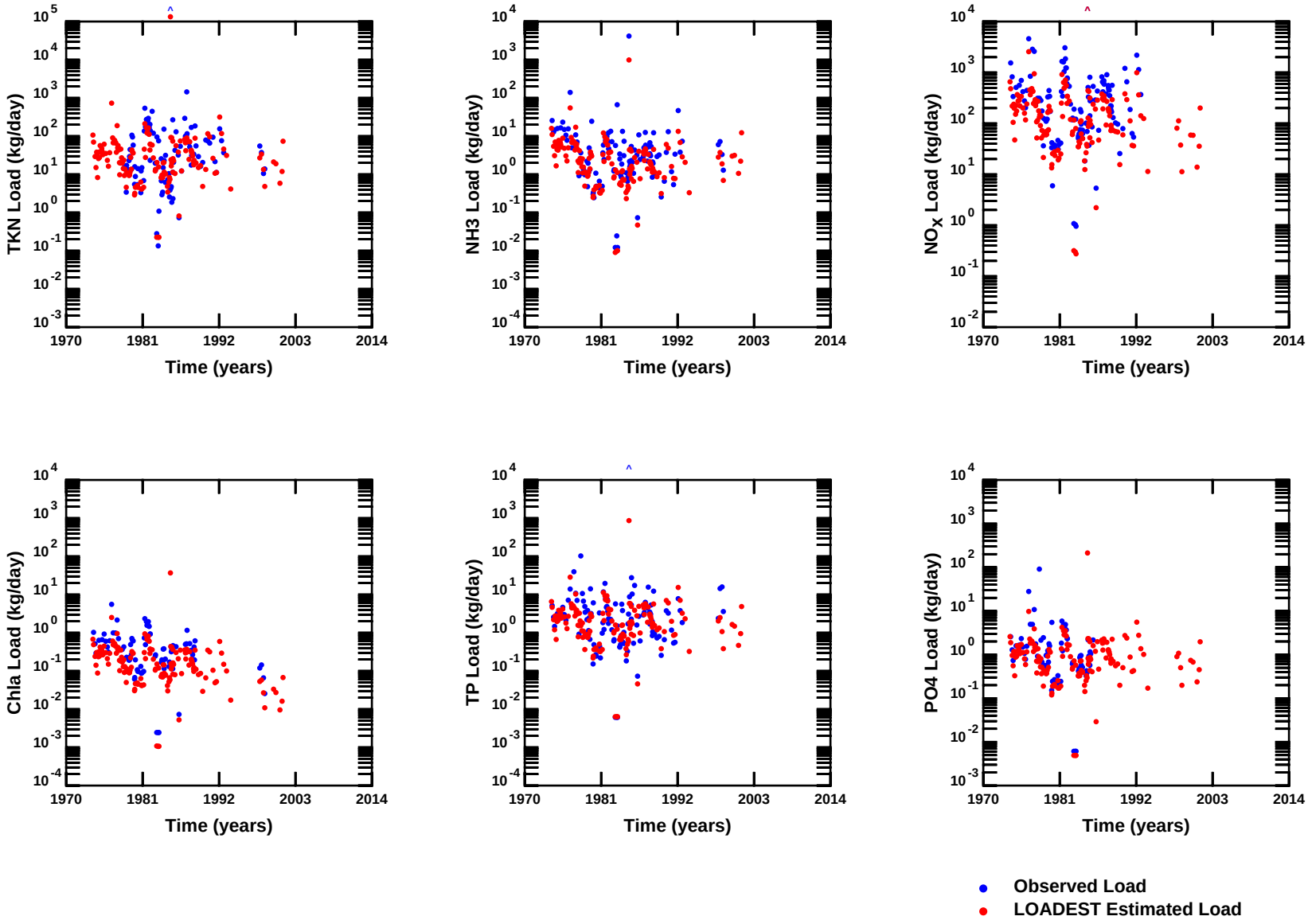




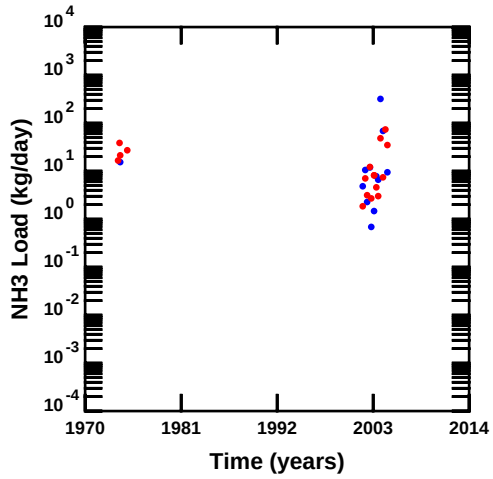


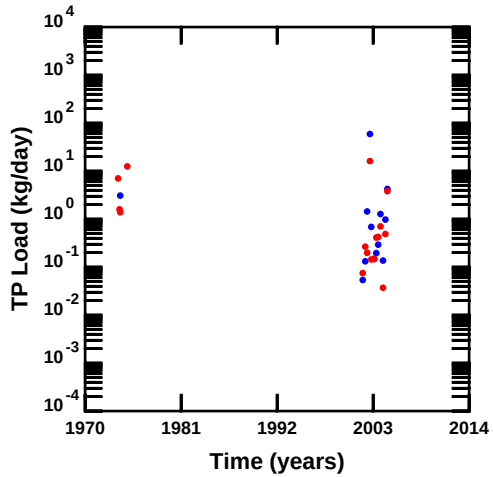
Observed Load
LOADEST Estimated Load

Observed Load vs. LOADEST Estimated Load, Station 13005
Nueces Tributaries, Texas (1970-2014)



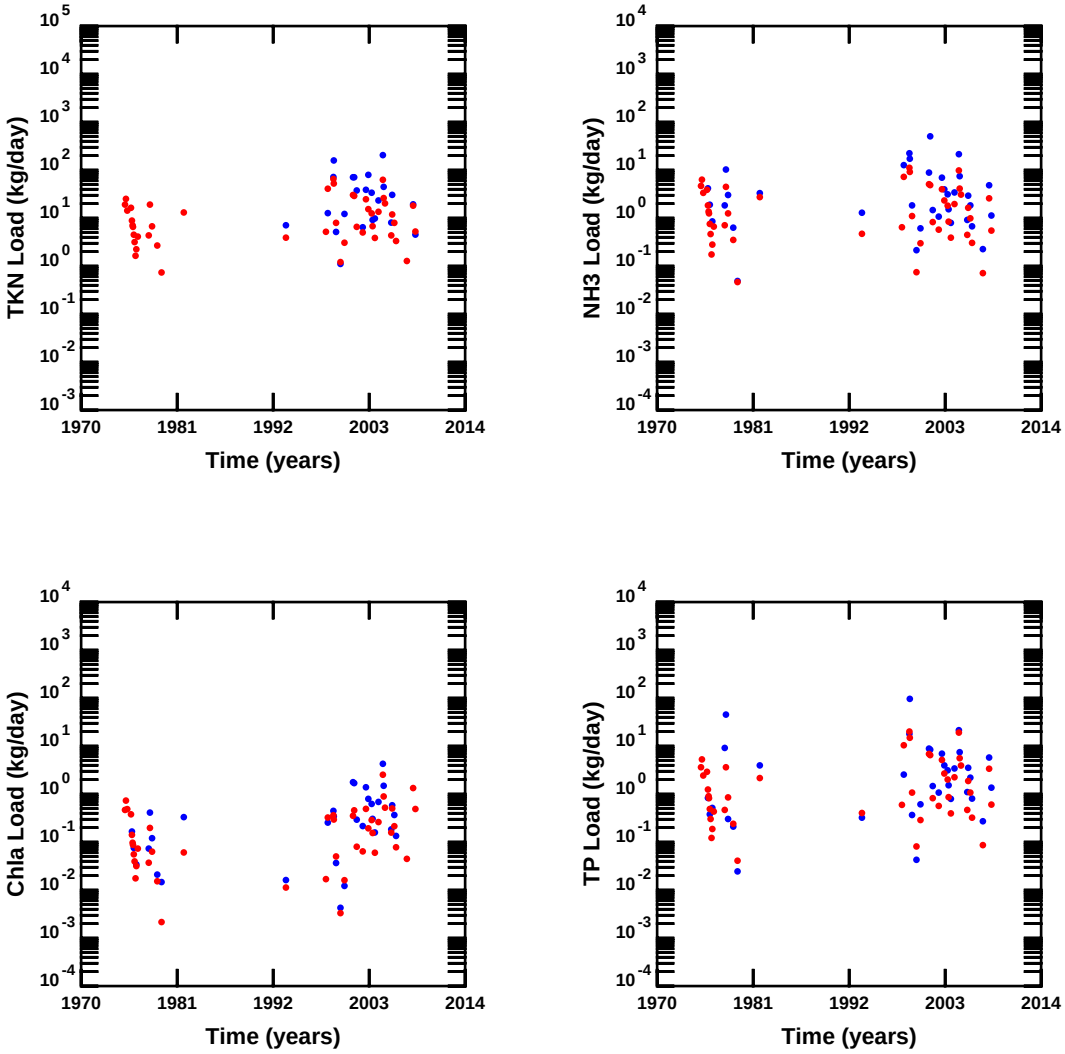
Observed Load vs. LOADEST Estimated Load, Station 12999
Nueces Tributaries, Texas (1970-2014)



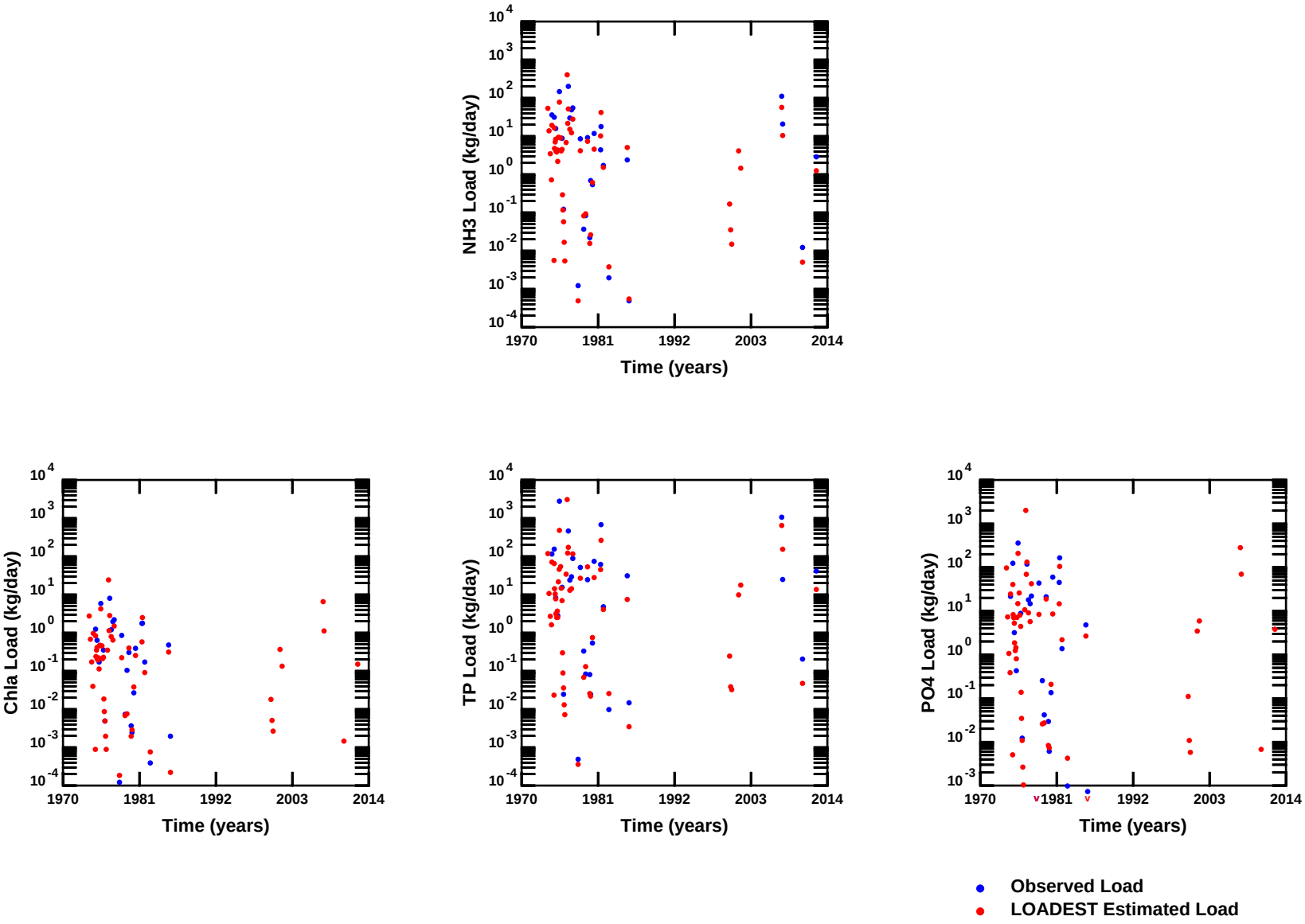


Observed Load
LOADEST Estimated Load

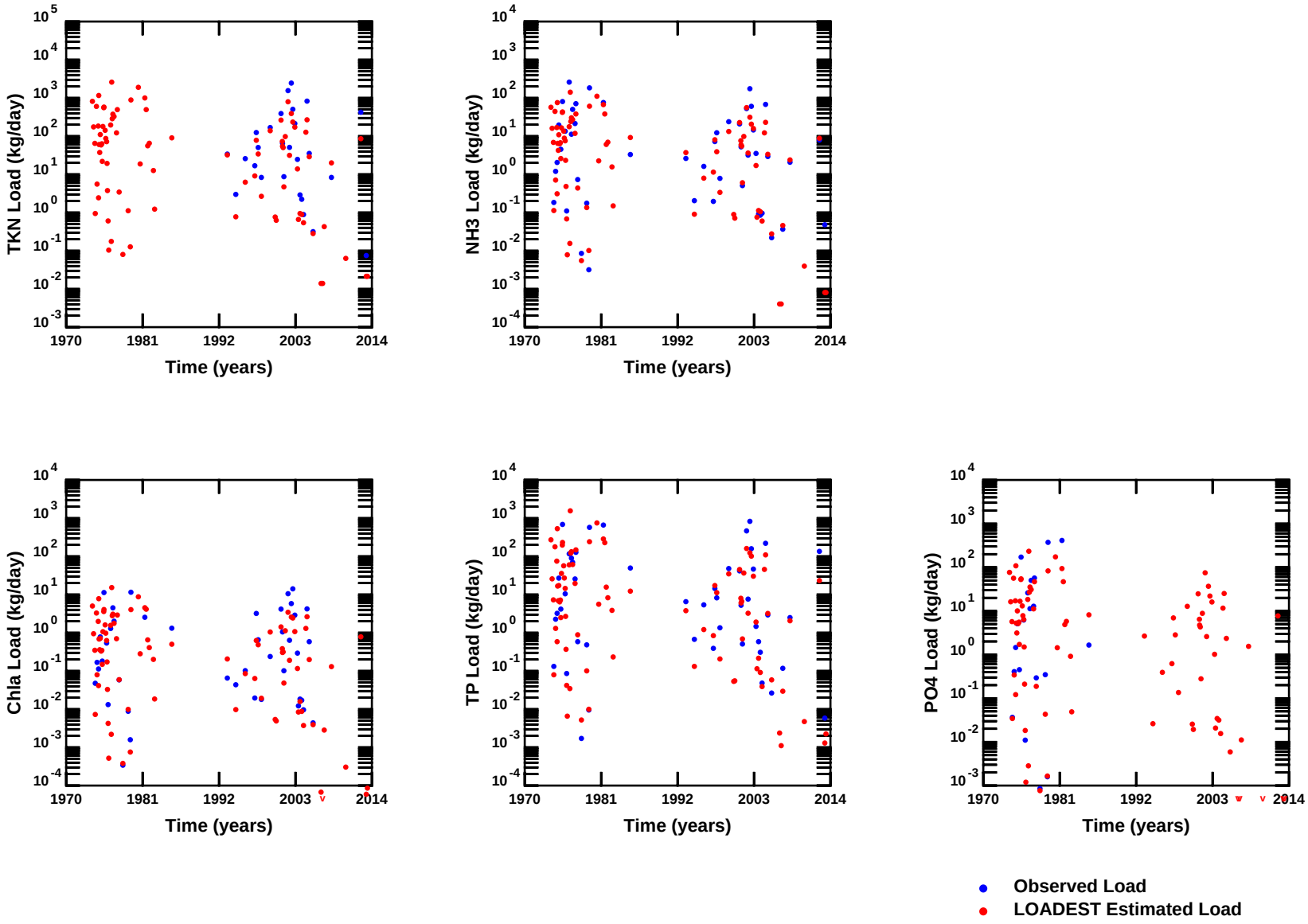
Observed Load vs. LOADEST Estimated Load, Station 12997
Nueces Tributaries, Texas (1970-2014)



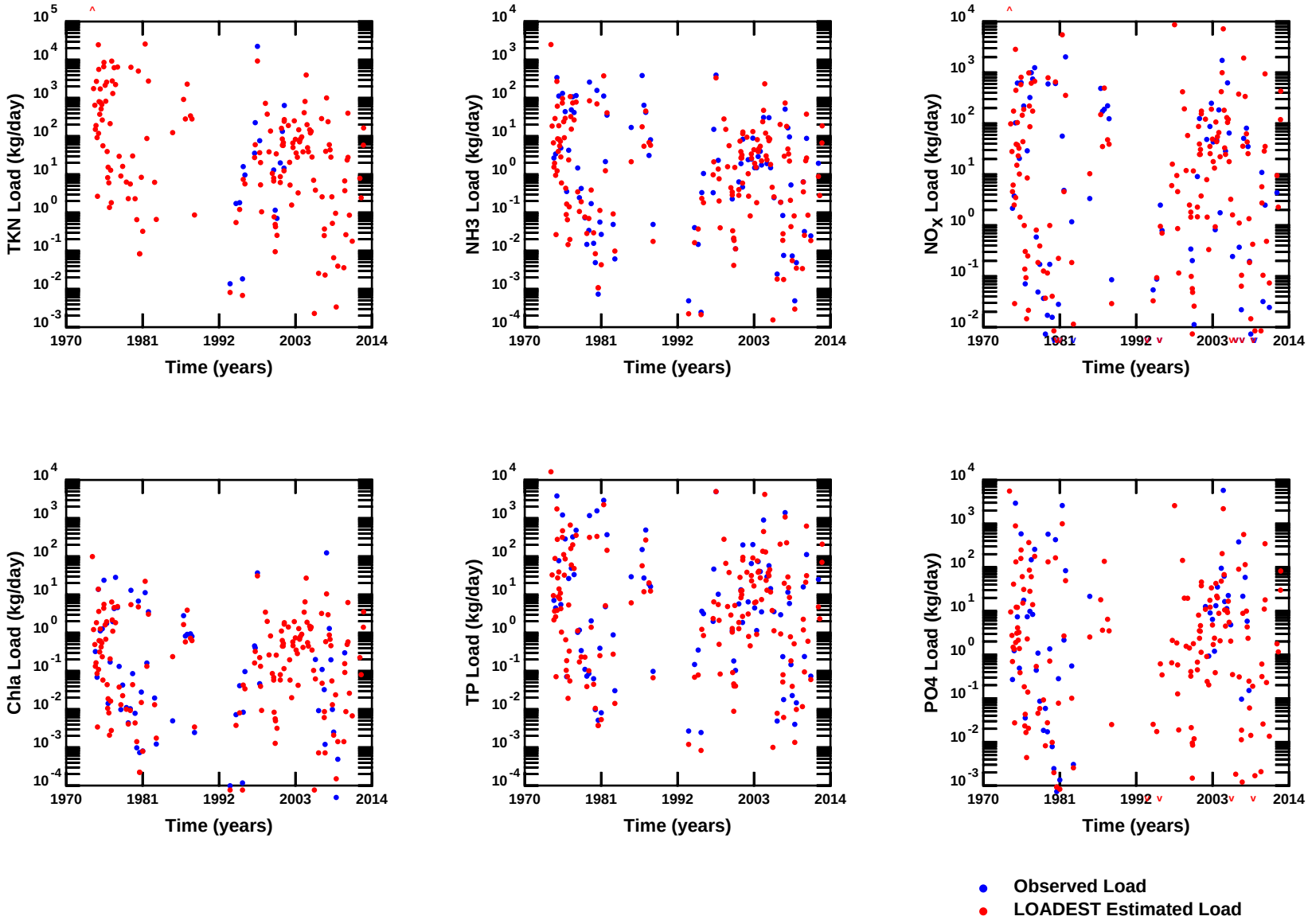
Observed Load vs. LOADEST Estimated Load, Station 12996
Nueces Tributaries, Texas (1970-2014)



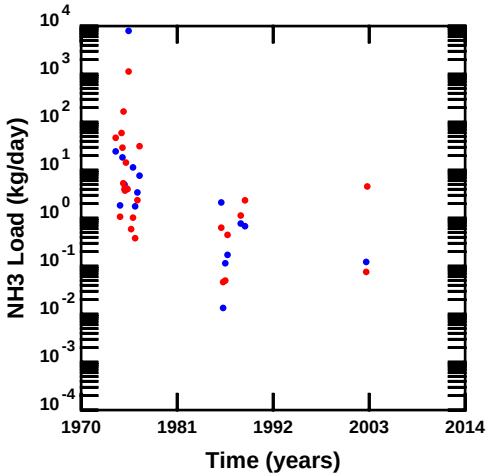
Observed Load vs. LOADEST Estimated Load, Station 12976
Nueces Tributaries, Texas (1970-2014)

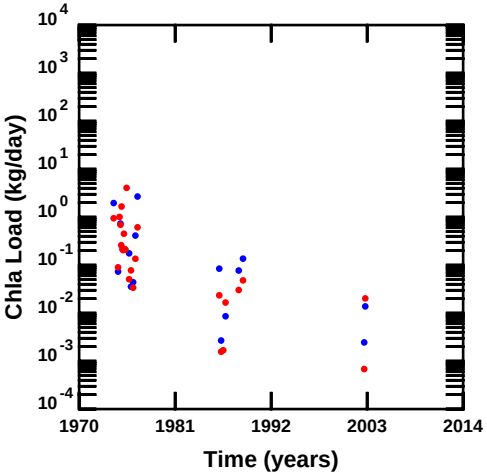


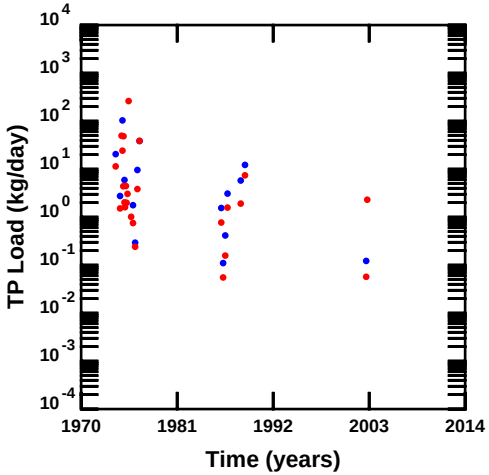
Observed Load vs. LOADEST Estimated Load, Station 12975
Nueces Tributaries, Texas (1970-2014)



Observed Load vs. LOADEST Estimated Load, Station 12973
Nueces Tributaries, Texas (1970-2014)

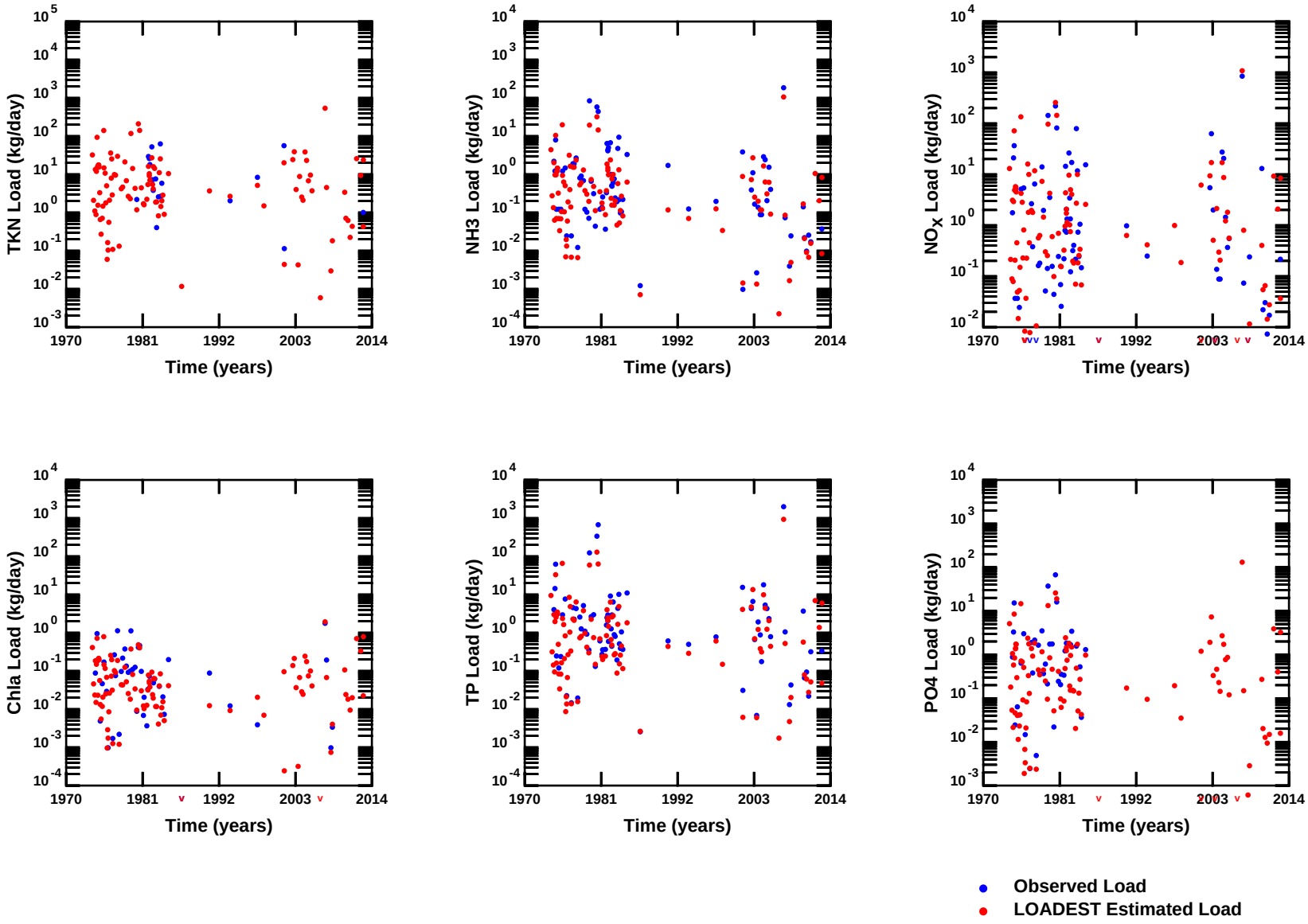




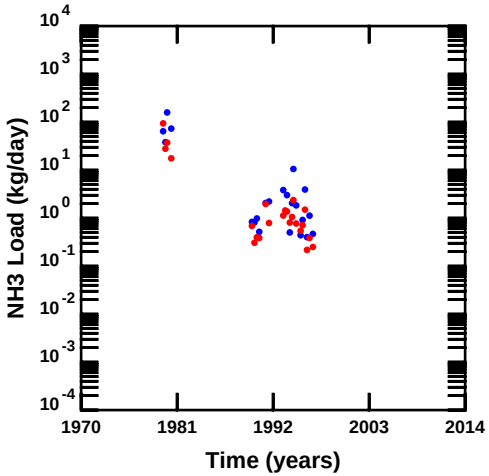


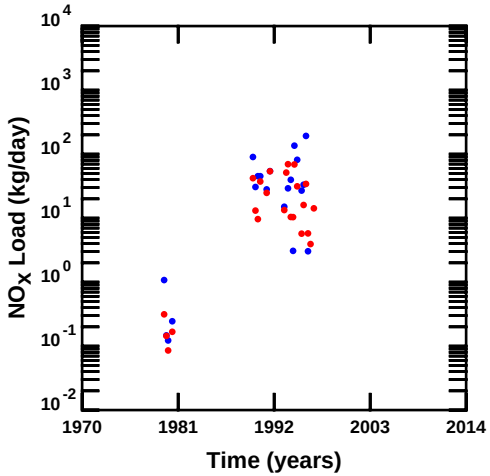
Observed Load
LOADEST Estimated Load

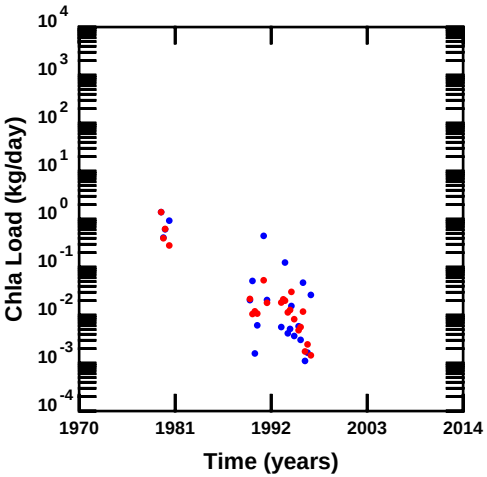
Observed Load vs. LOADEST Estimated Load, Station 12972
Nueces Tributaries, Texas (1970-2014)

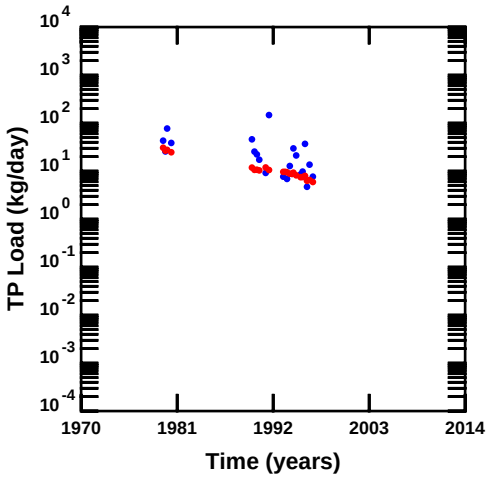


Observed Load vs. LOADEST Estimated Load, Station 12983
Nueces Tributaries, Texas (1970-2014)



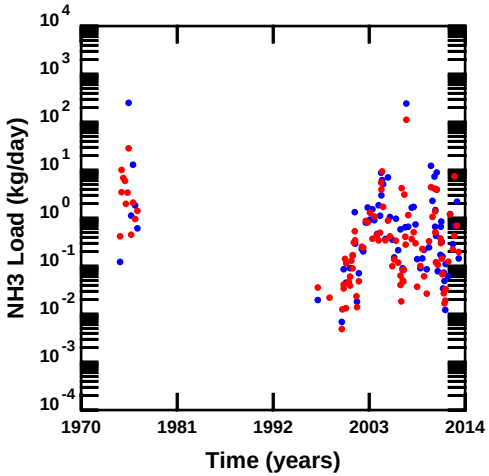


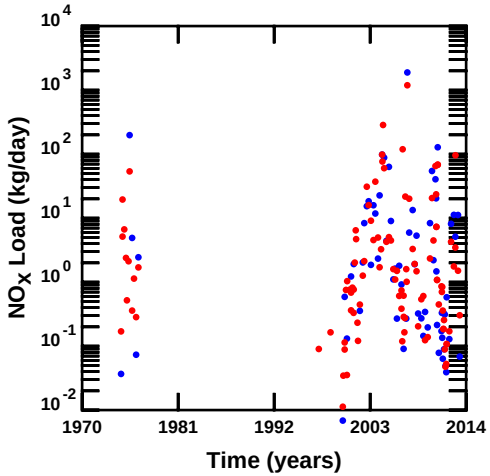


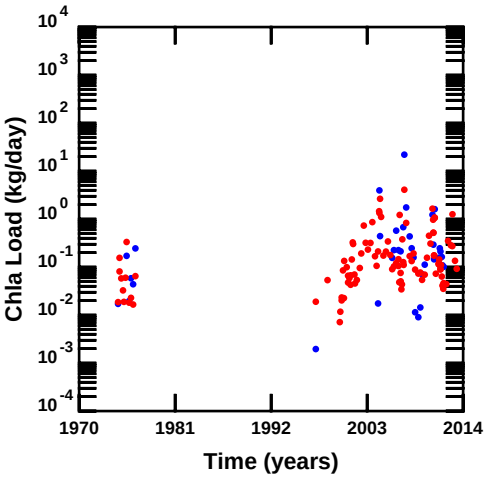


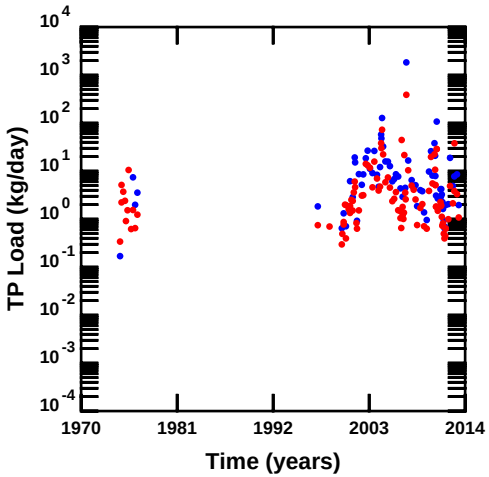
Observed Load
LOADEST Estimated Load

Observed Load vs. LOADEST Estimated Load, Station 12981
Nueces Tributaries, Texas (1970-2014)



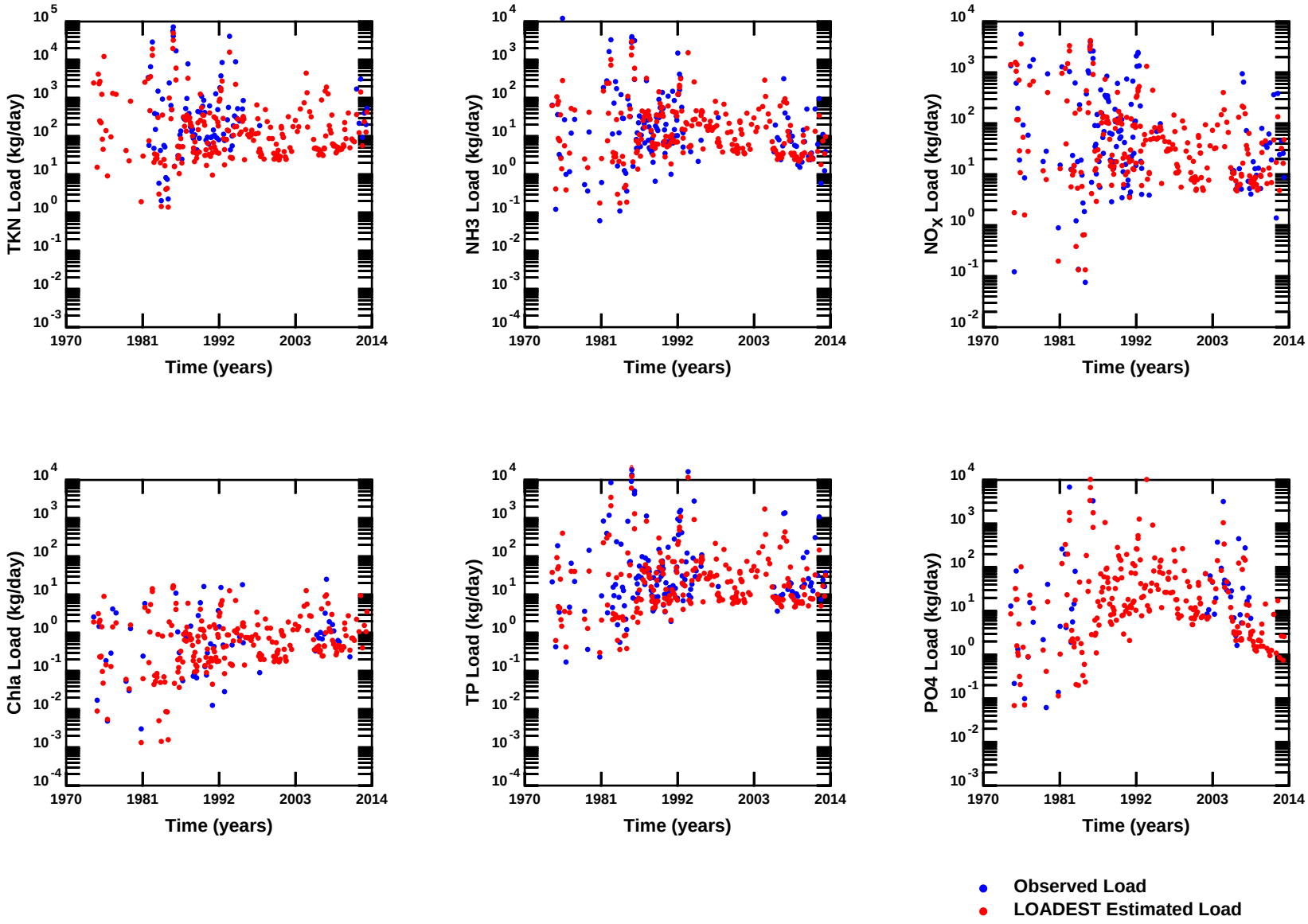




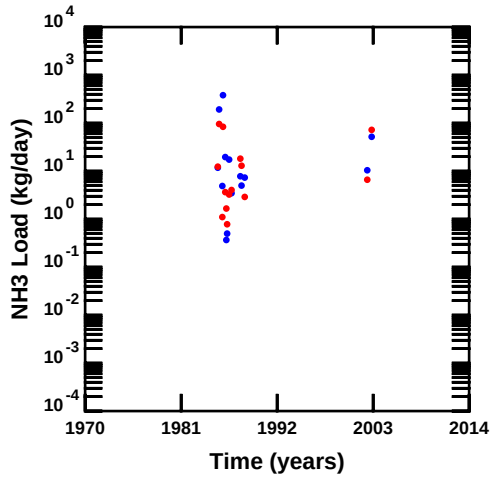


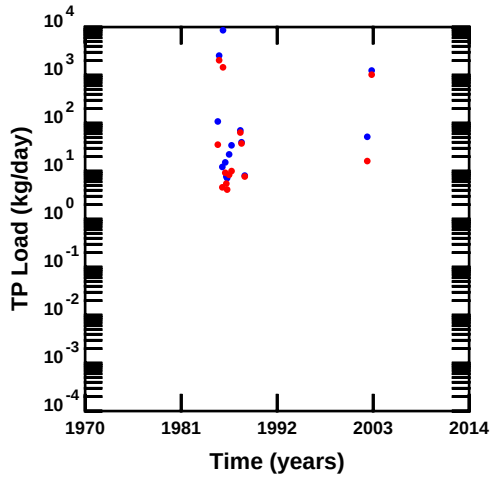
Observed Load
LOADEST Estimated Load

Observed Load vs. LOADEST Estimated Load, Station 12980
Nueces Tributaries, Texas (1970-2014)



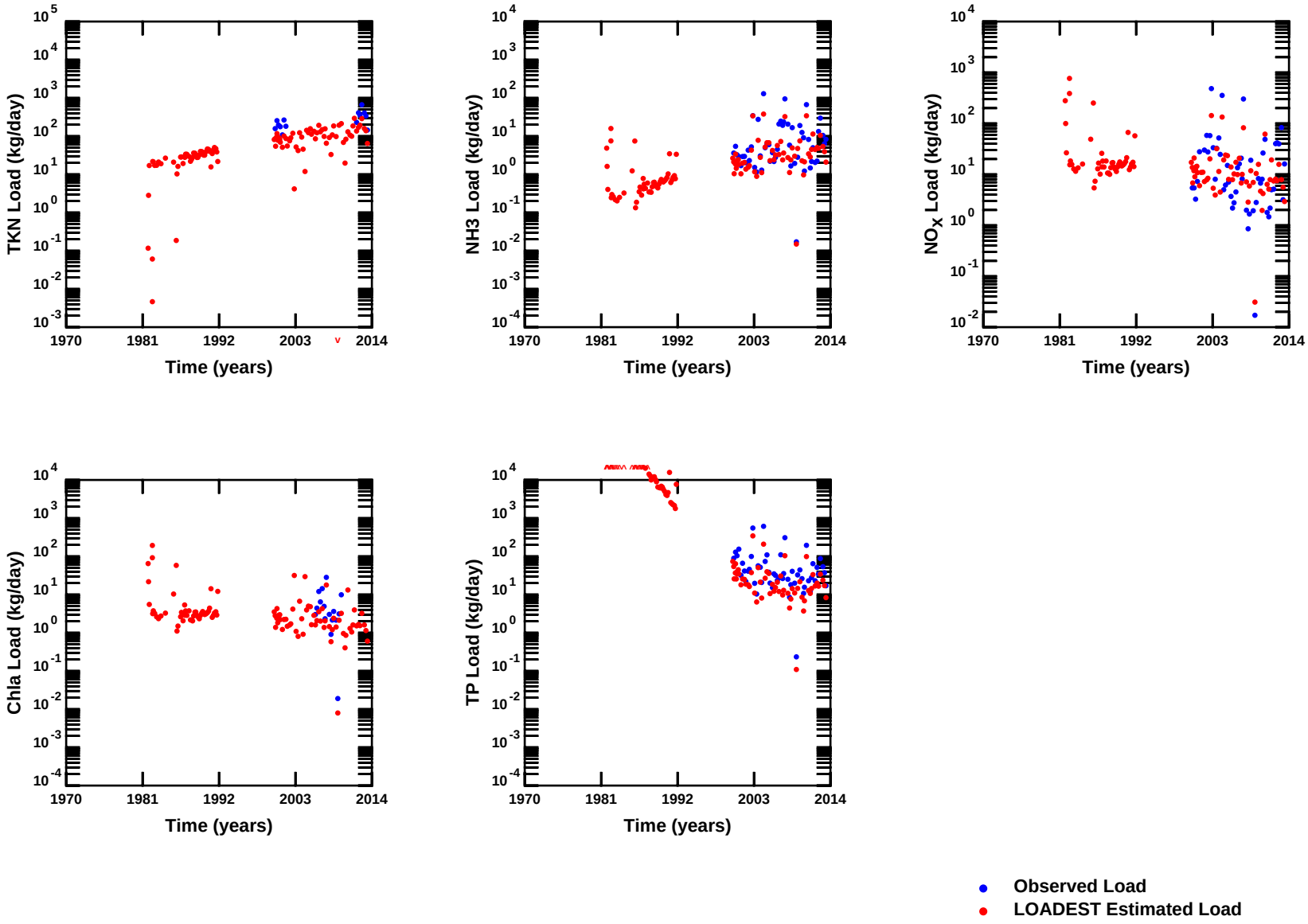
Observed Load vs. LOADEST Estimated Load, Station 12979
Nueces Tributaries, Texas (1970-2014)



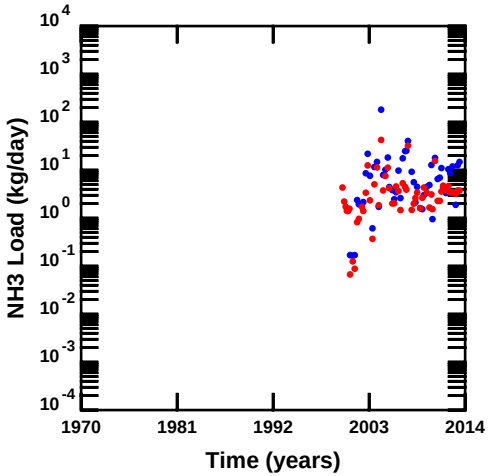


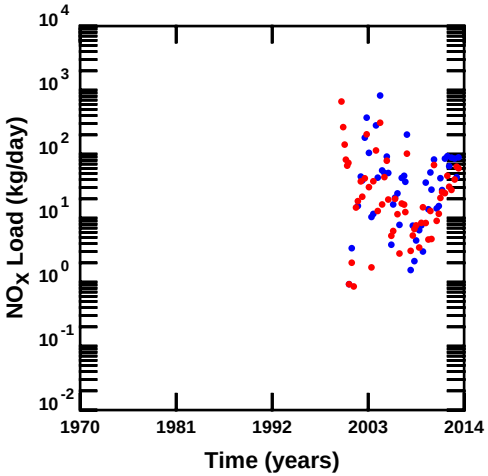
Observed Load
LOADEST Estimated Load

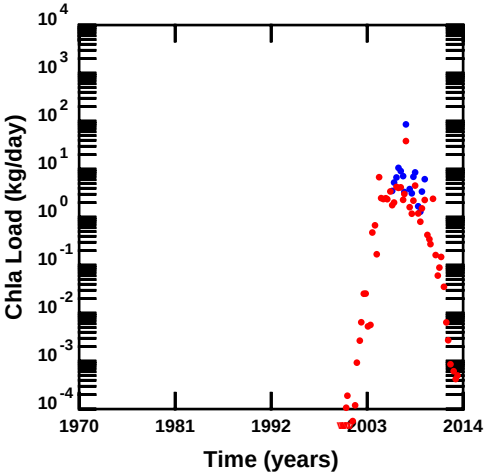
Observed Load vs. LOADEST Estimated Load, Station 12978
Nueces Tributaries, Texas (1970-2014)

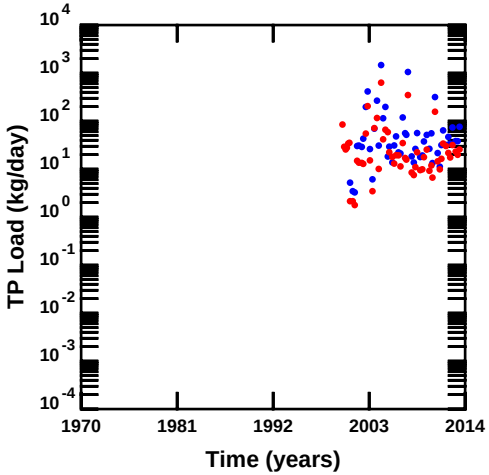


Observed Load vs. LOADEST Estimated Load, Station 12965
Nueces Tributaries, Texas (1970-2014)



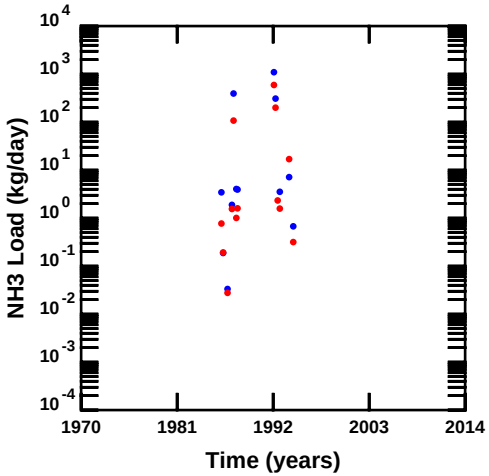


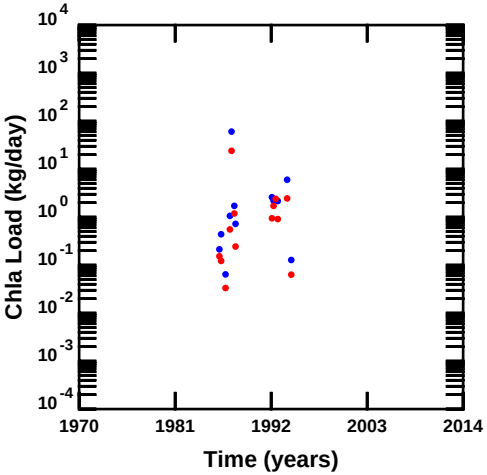


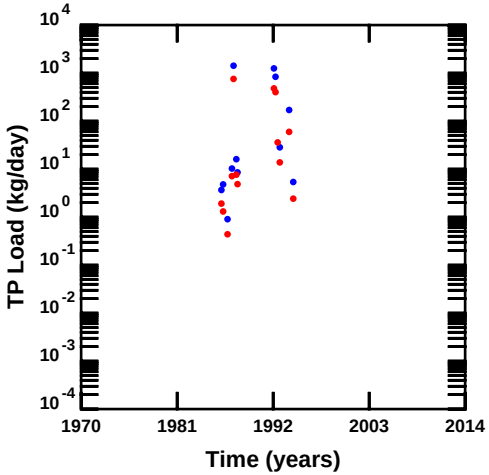


Observed Load
LOADEST Estimated Load

Observed Load vs. LOADEST Estimated Load, Station 12964
Nueces Tributaries, Texas (1970-2014)

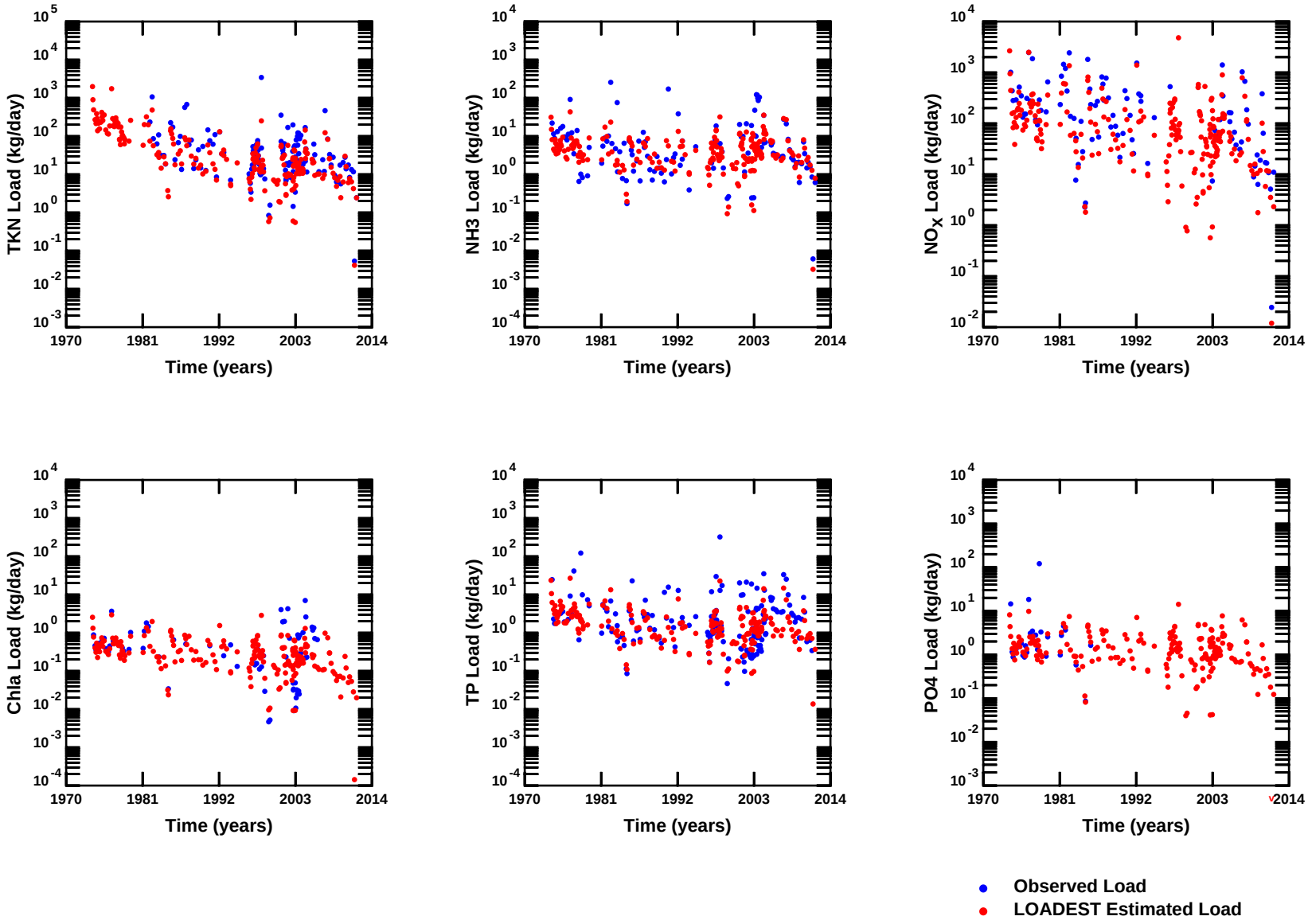




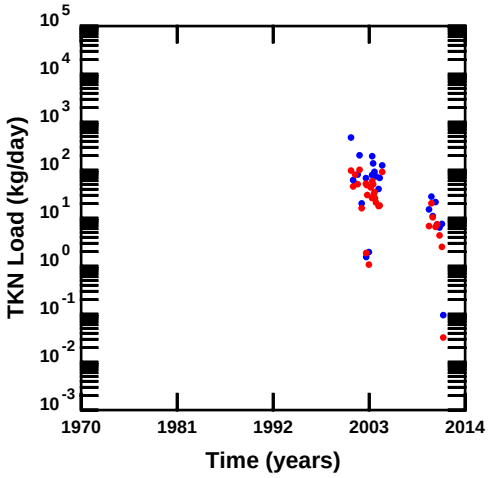


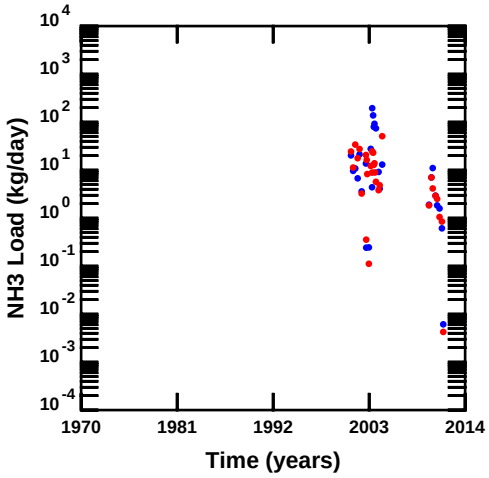
Observed Load
LOADEST Estimated Load

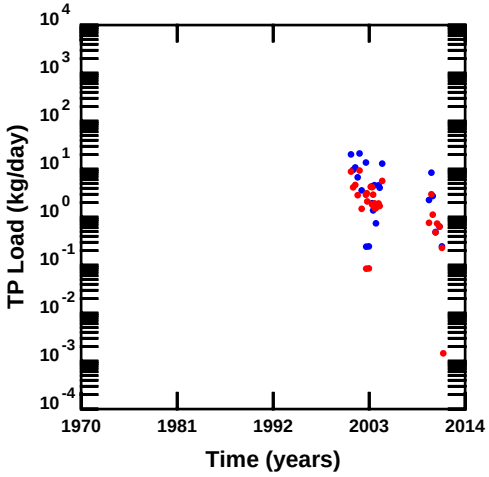
Observed Load vs. LOADEST Estimated Load, Station 12962
Nueces Tributaries, Texas (1970-2014)



Observed Load vs. LOADEST Estimated Load, Station 13006
Nueces Tributaries, Texas (1970-2014)

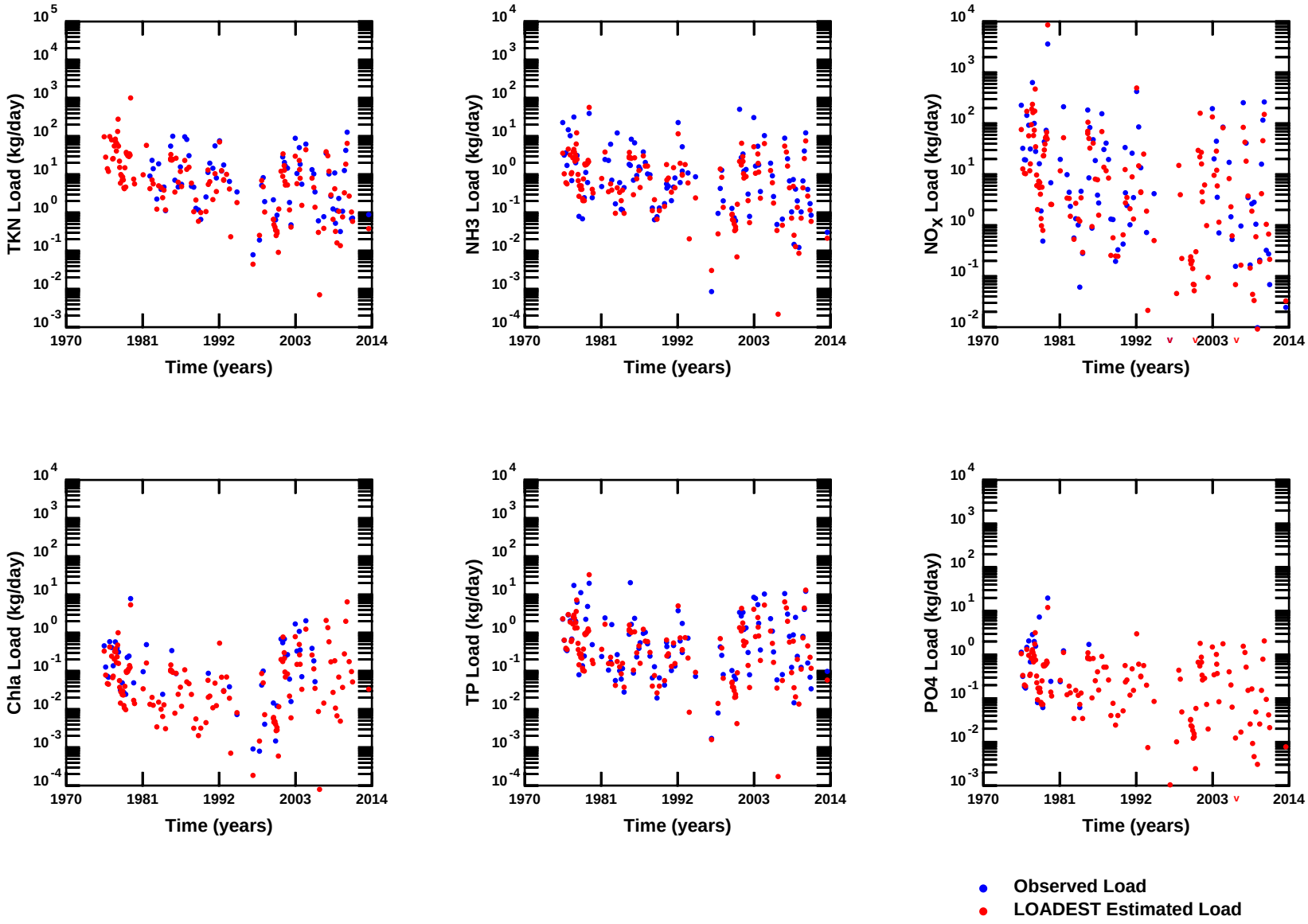




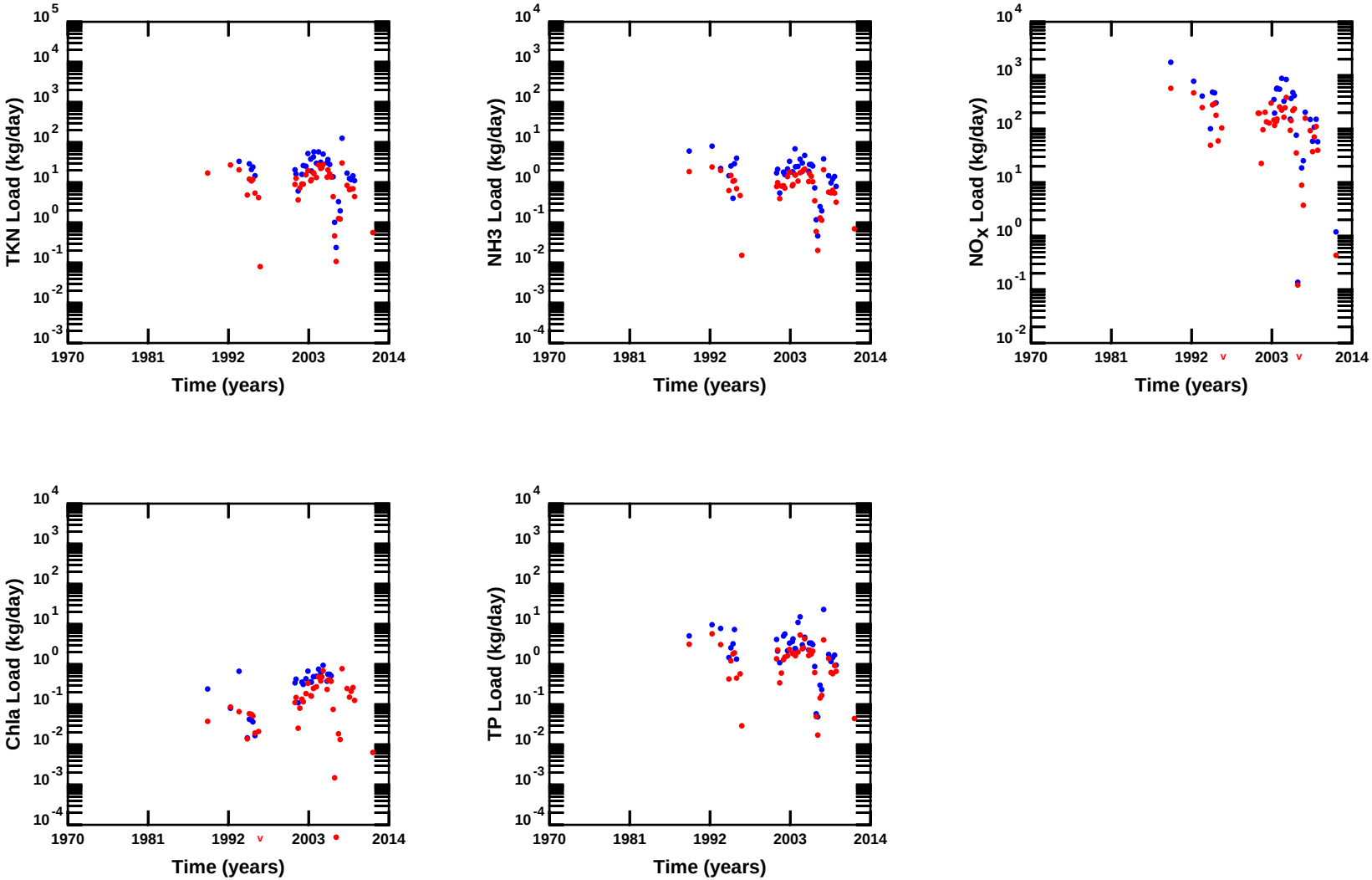


Observed Load
LOADEST Estimated Load

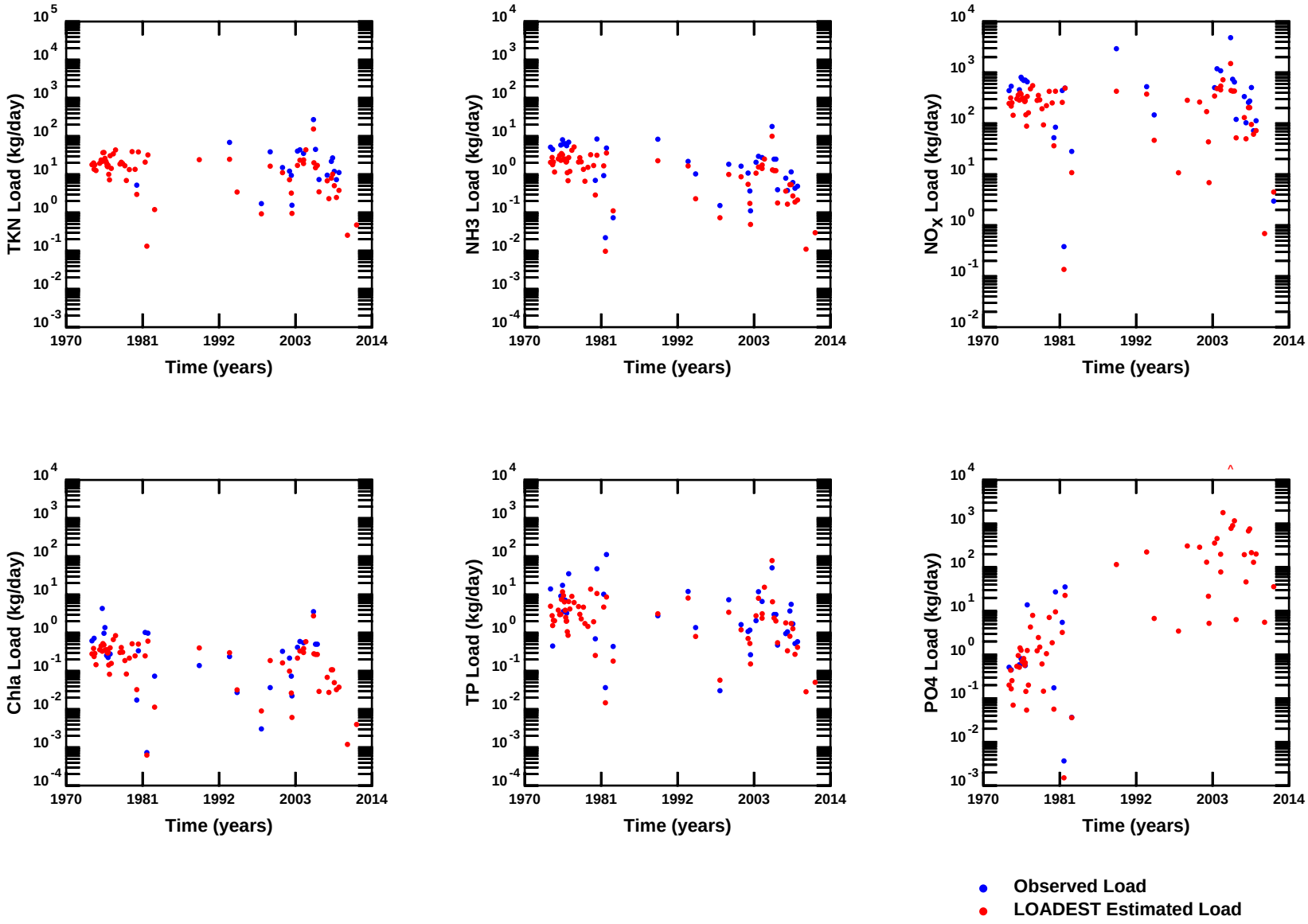
Observed Load vs. LOADEST Estimated Load, Station 13007
Nueces Tributaries, Texas (1970-2014)



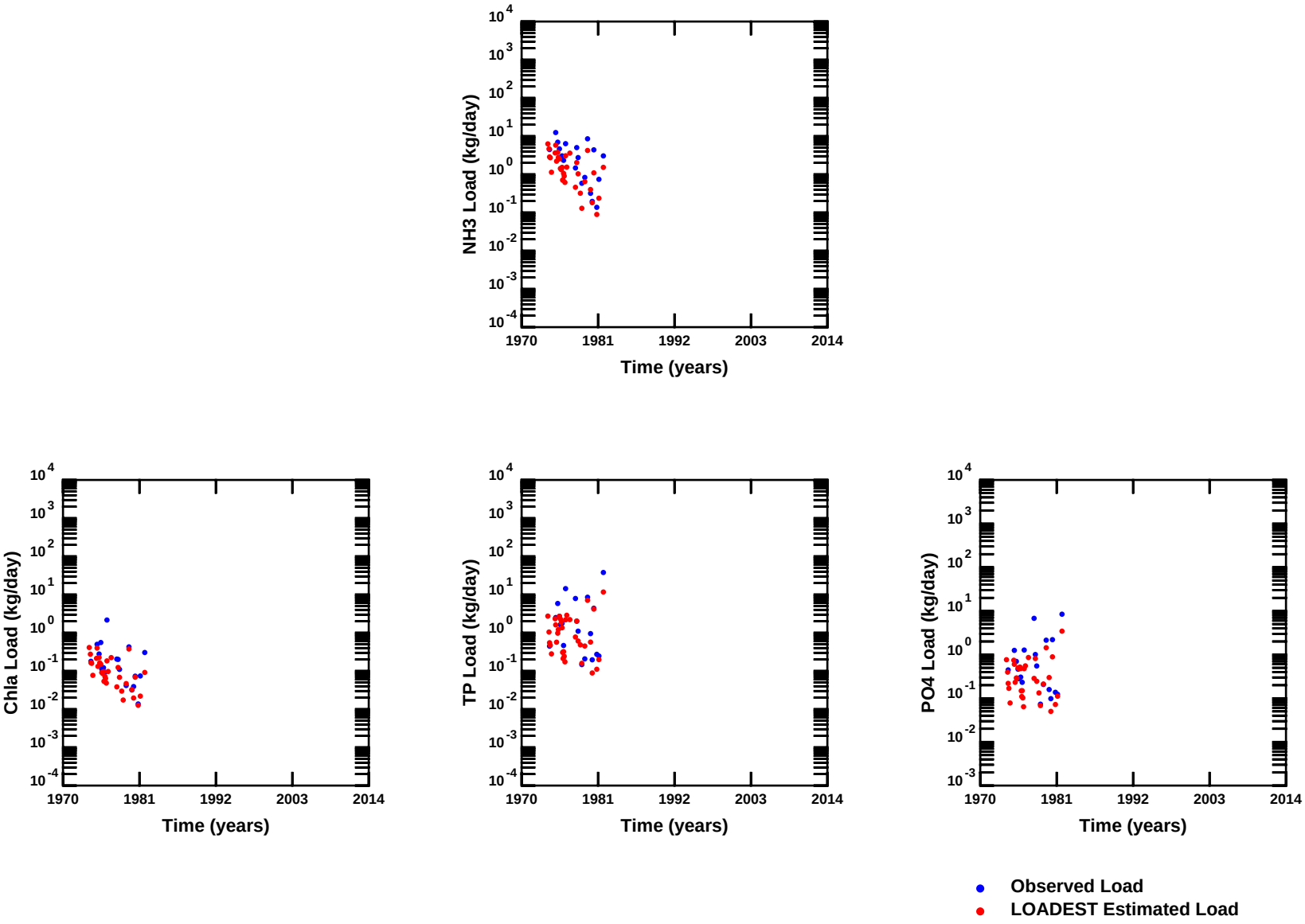
Observed Load vs. LOADEST Estimated Load, Station 13010
Nueces Tributaries, Texas (1970-2014)



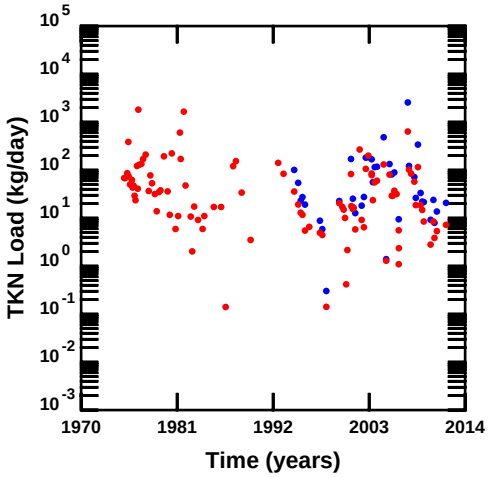
Observed Load vs. LOADEST Estimated Load, Station 12987
Nueces Tributaries, Texas (1970-2014)

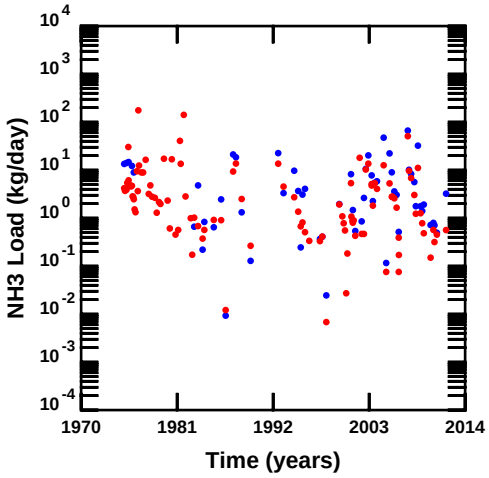


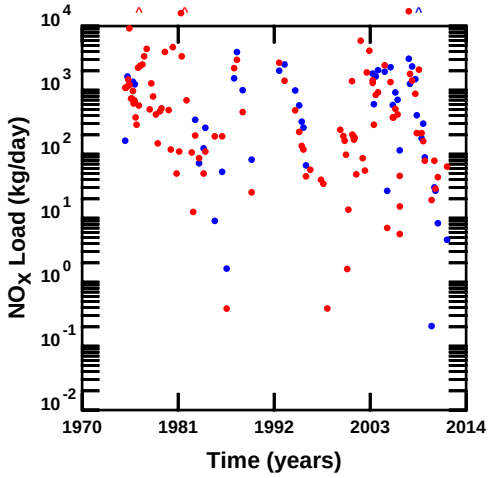
Observed Load vs. LOADEST Estimated Load, Station 12985
Nueces Tributaries, Texas (1970-2014)

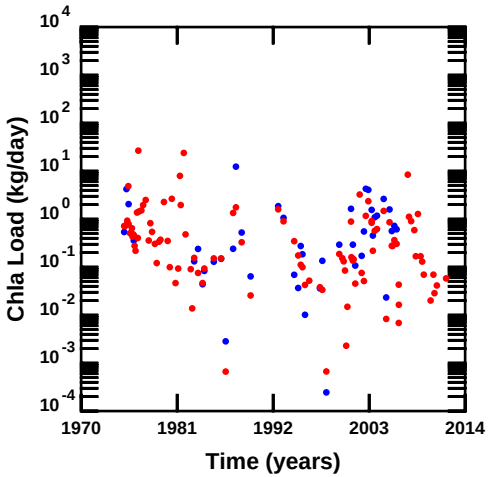


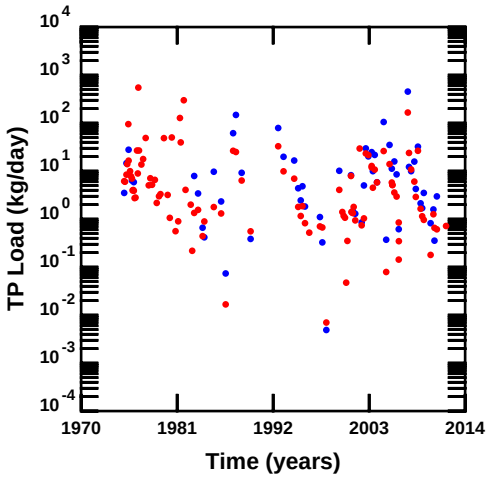
Observed Load vs. LOADEST Estimated Load, Station 13025
Nueces Tributaries, Texas (1970-2014)



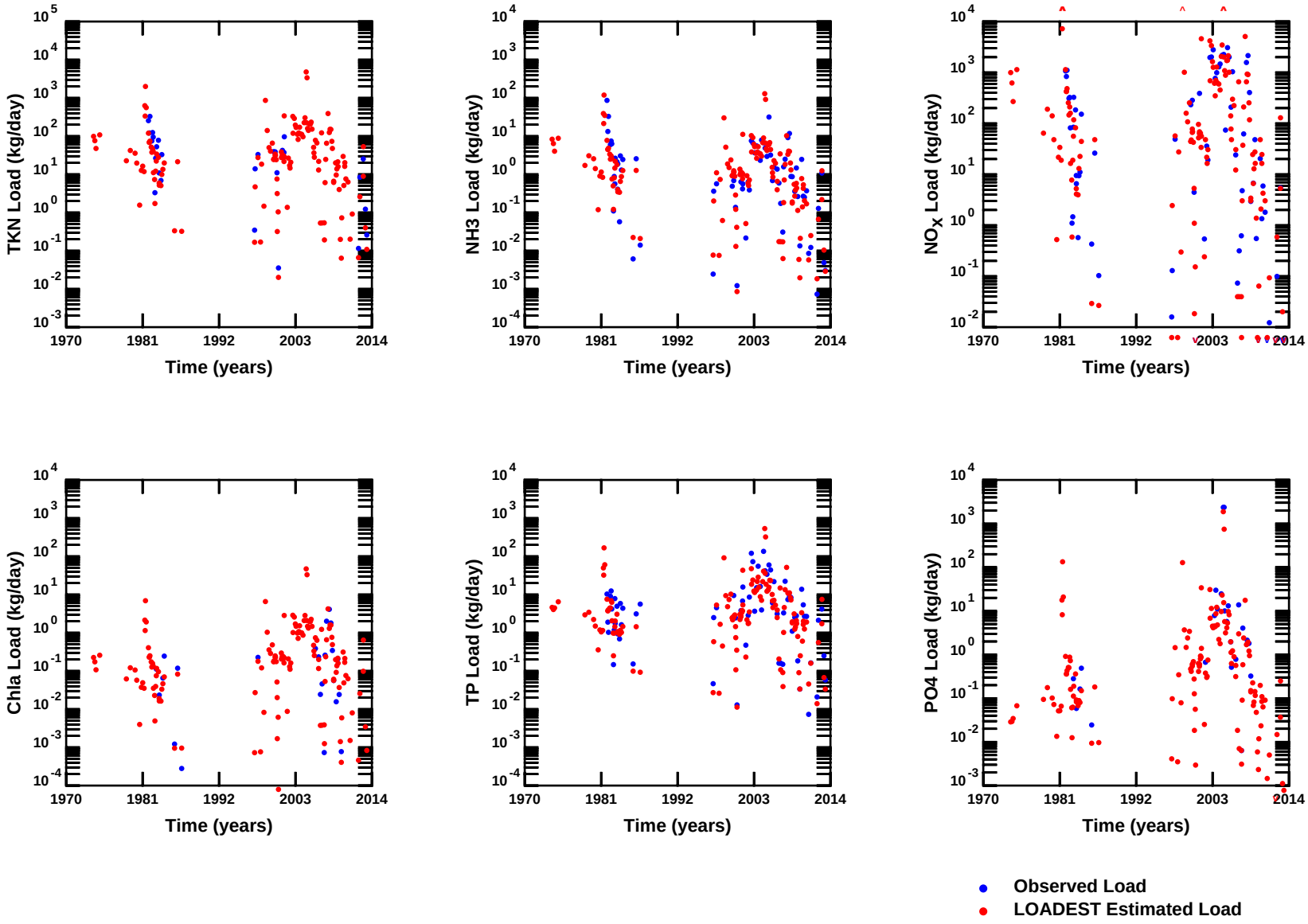




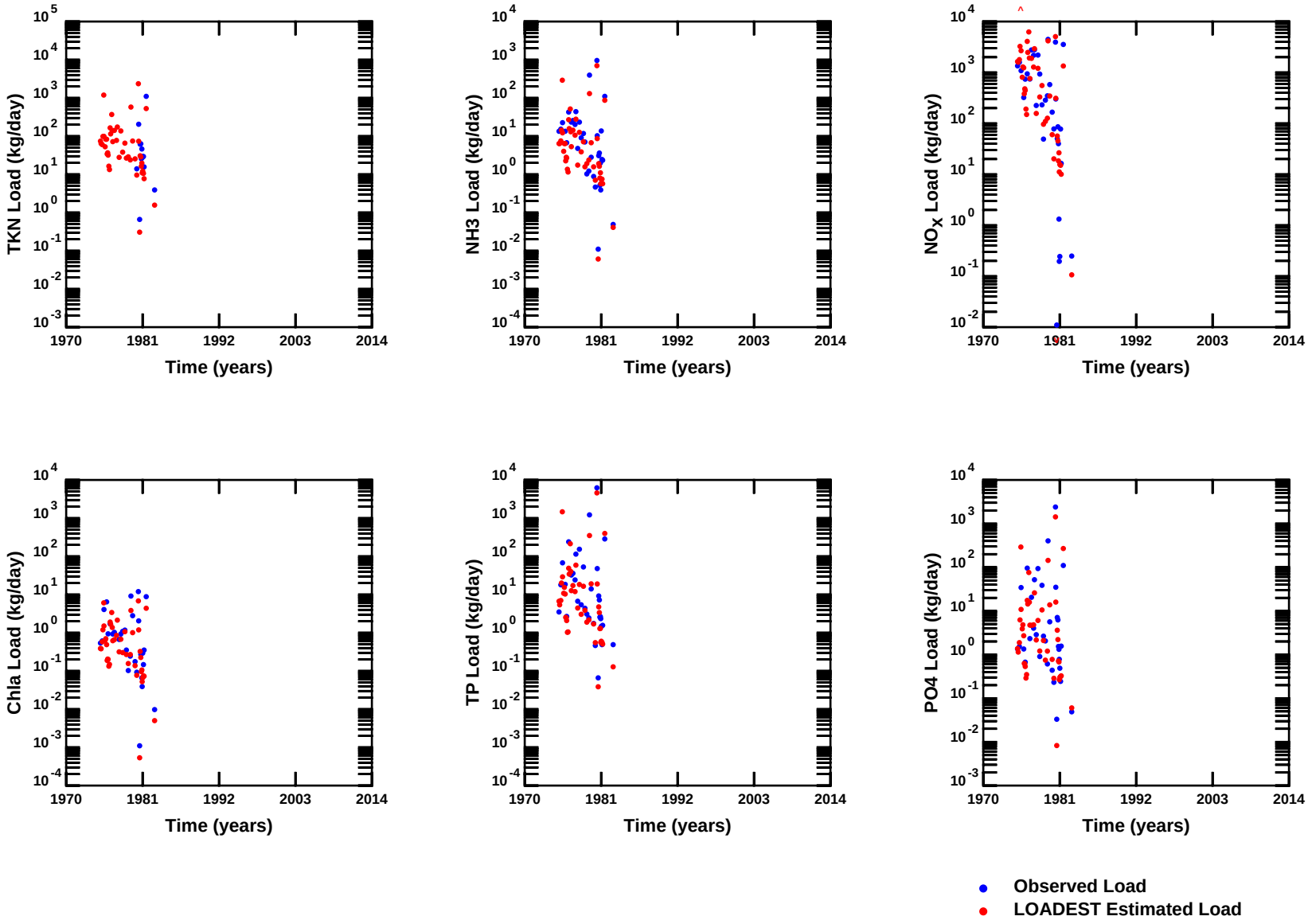




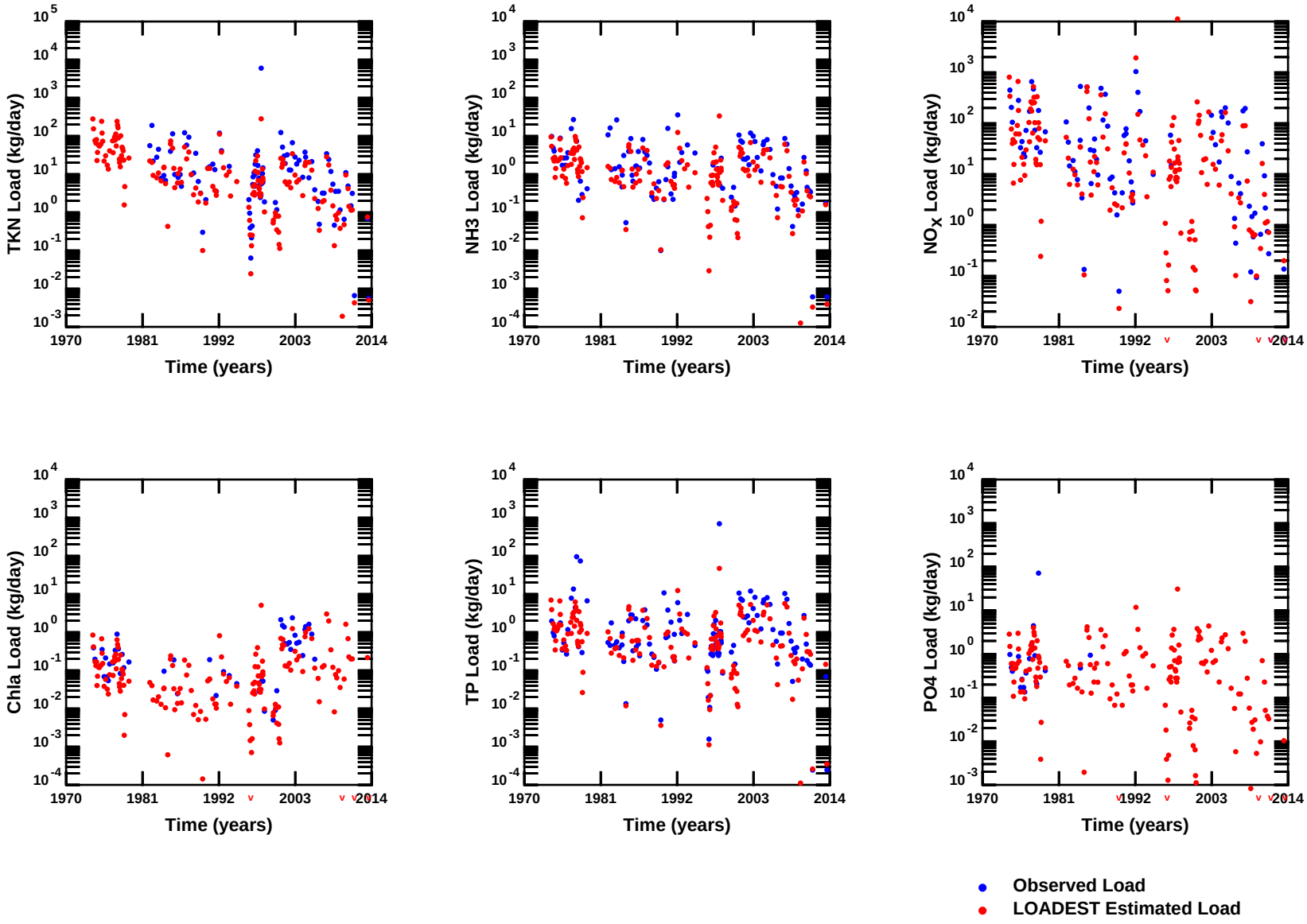
Observed Load vs. LOADEST Estimated Load, Station 13024
Nueces Tributaries, Texas (1970-2014)



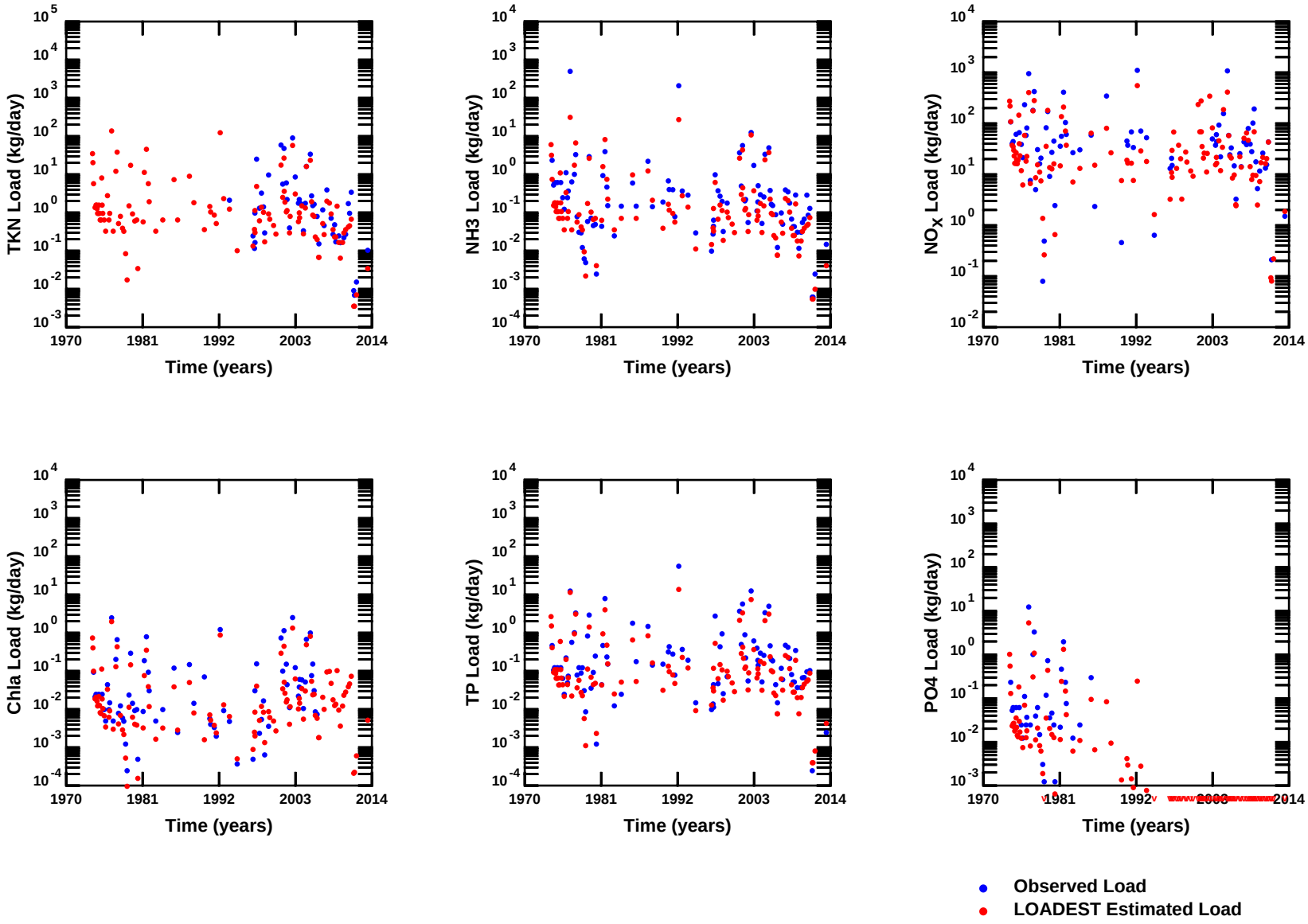
Observed Load vs. LOADEST Estimated Load, Station 13023
Nueces Tributaries, Texas (1970-2014)



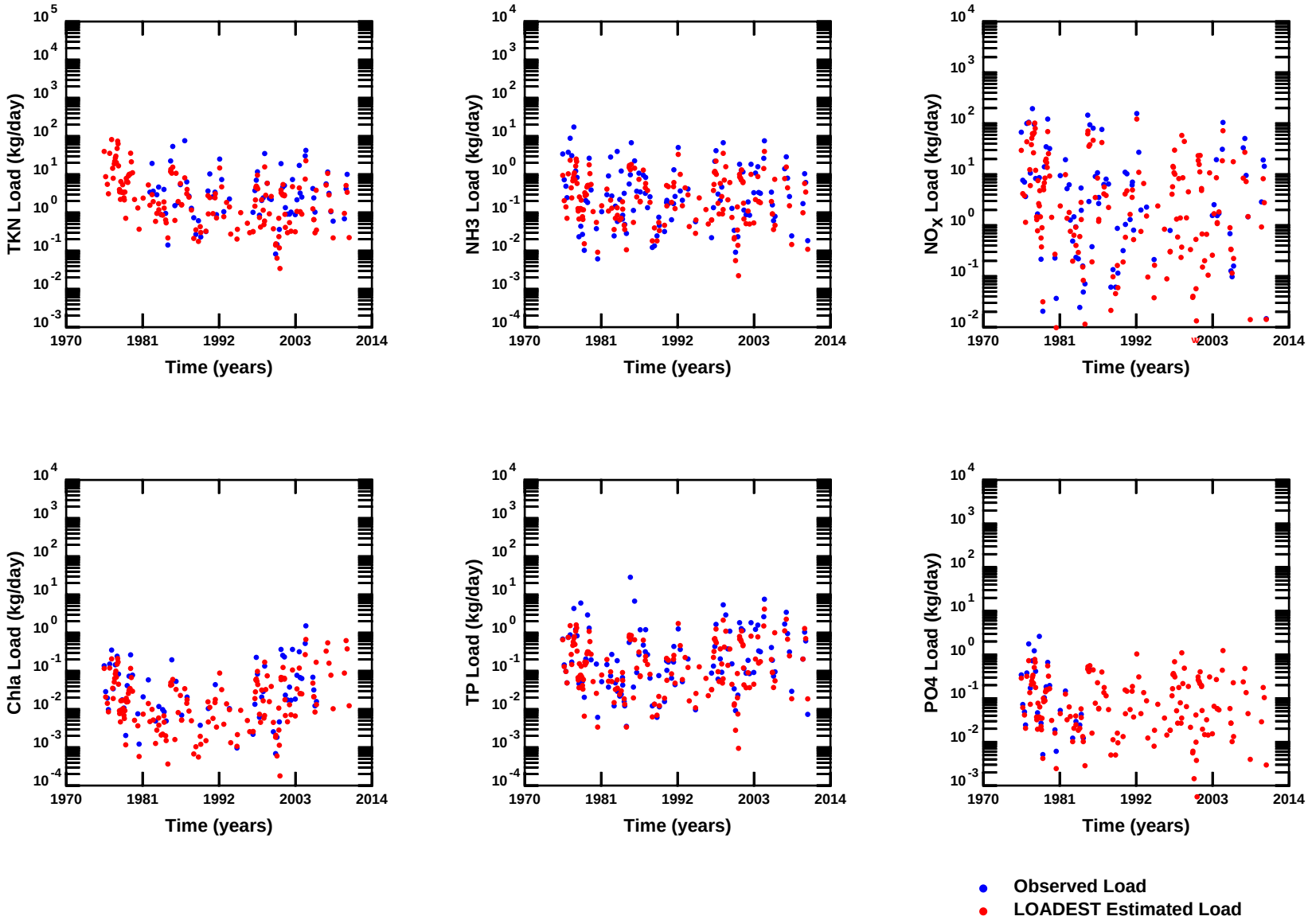
Observed Load vs. LOADEST Estimated Load, Station 13021
Nueces Tributaries, Texas (1970-2014)



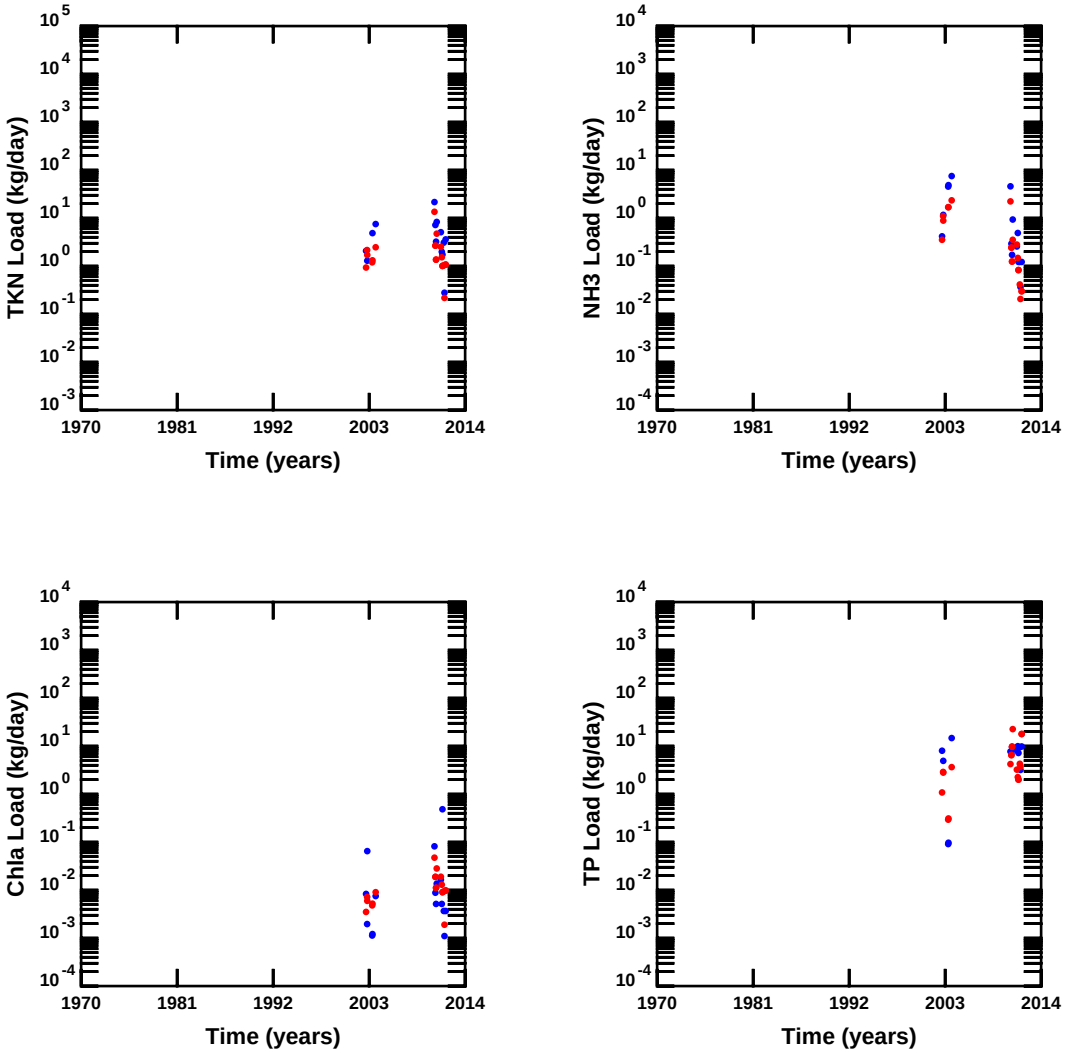
Observed Load vs. LOADEST Estimated Load, Station 12994
Nueces Tributaries, Texas (1970-2014)



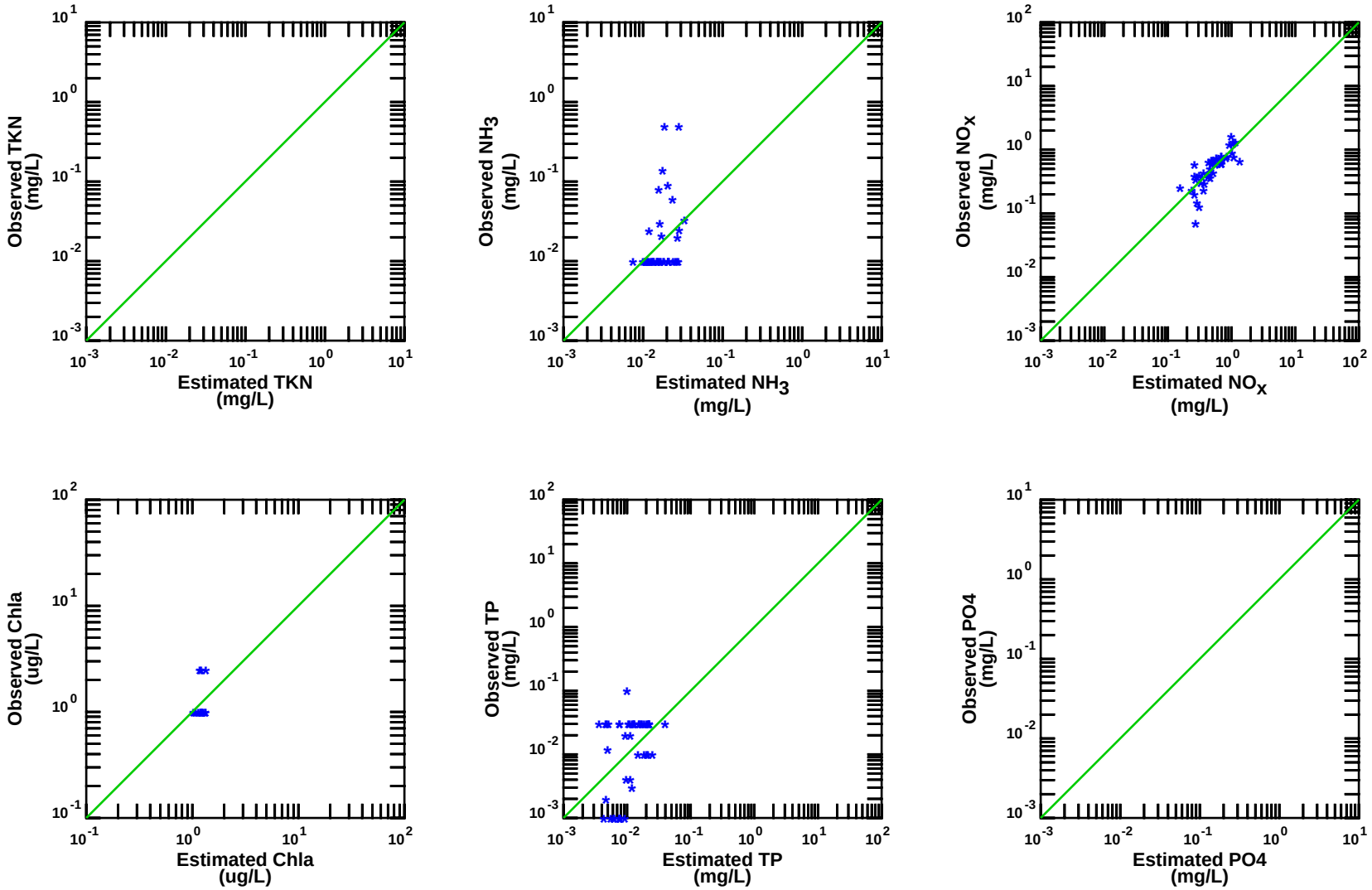
Observed Load vs. LOADEST Estimated Load, Station 12993
Nueces Tributaries, Texas (1970-2014)



Observed Load vs. LOADEST Estimated Load, Station 13013
Nueces Tributaries, Texas (1970-2014)

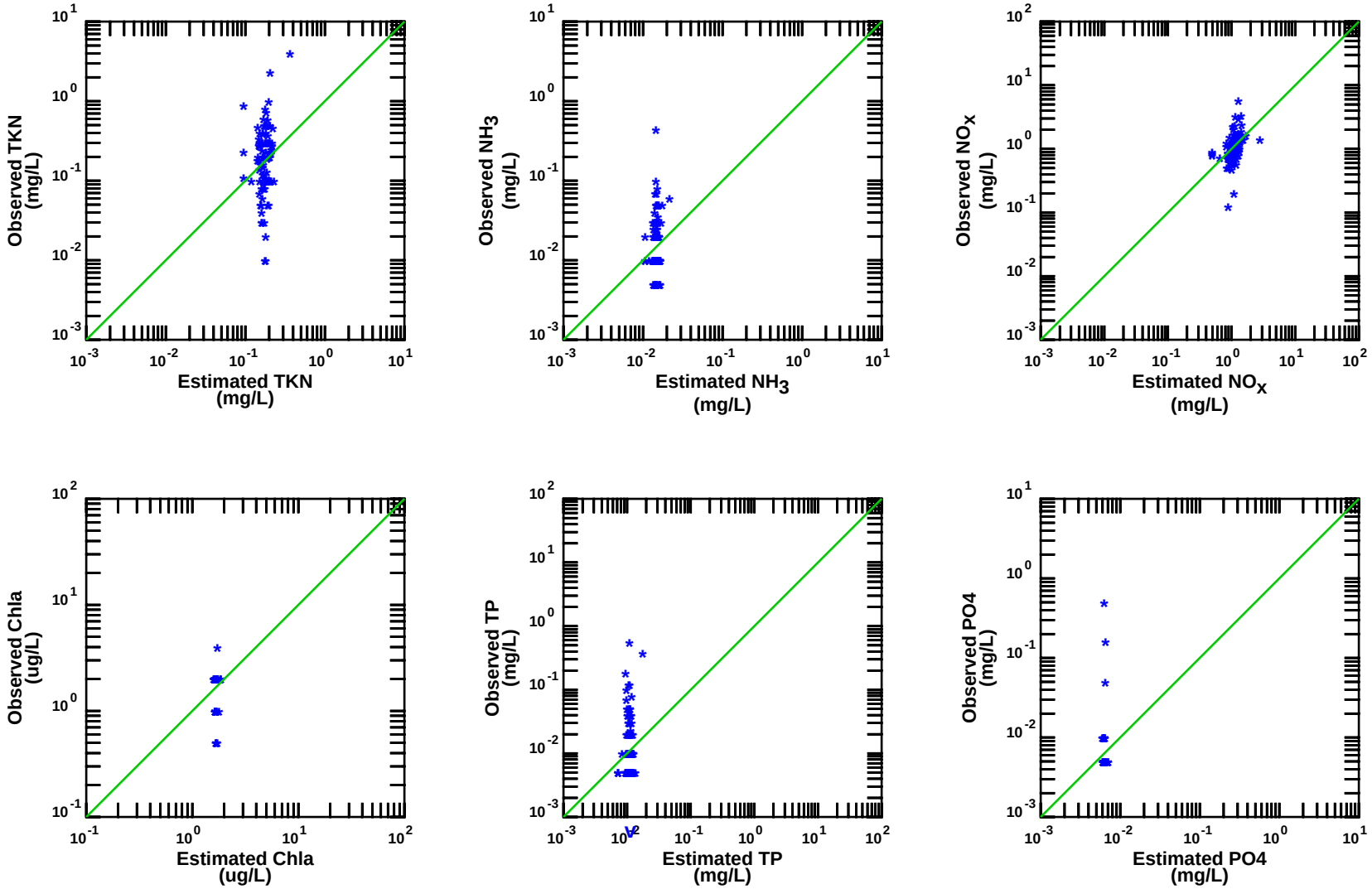


Observed Load vs. LOADEST Estimated Load, Station 17900
Nueces Tributaries, Texas (1970-2014)



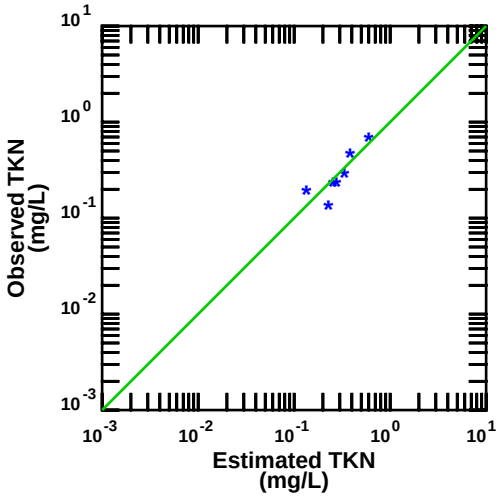
Observed Data vs. Estimated Data, Station 13005

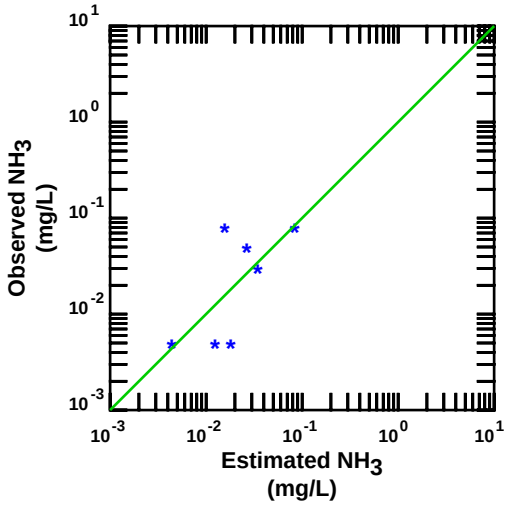
Nueces Tributaries, Texas (1970-2014)

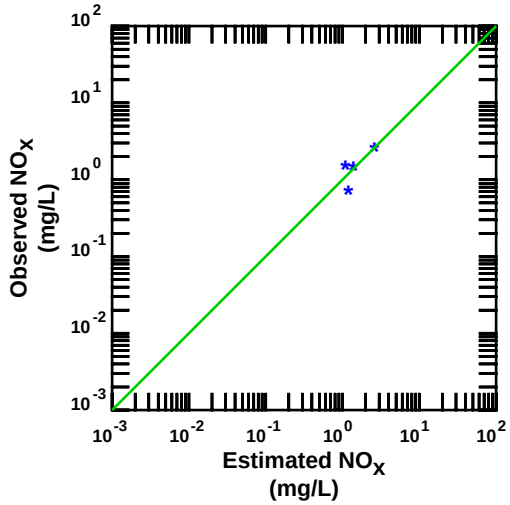


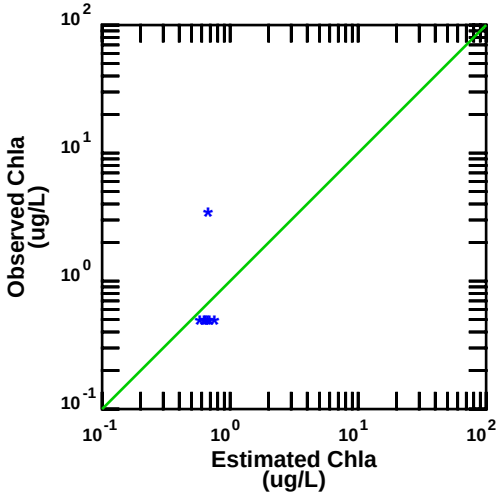
Observed Data vs. Estimated Data, Station 12999

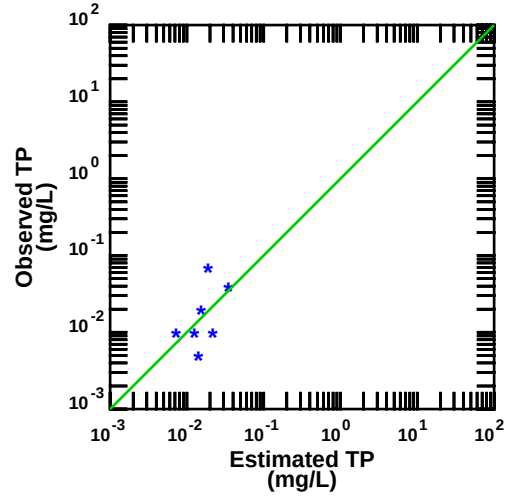
Nueces Tributaries, Texas (1970-2014)





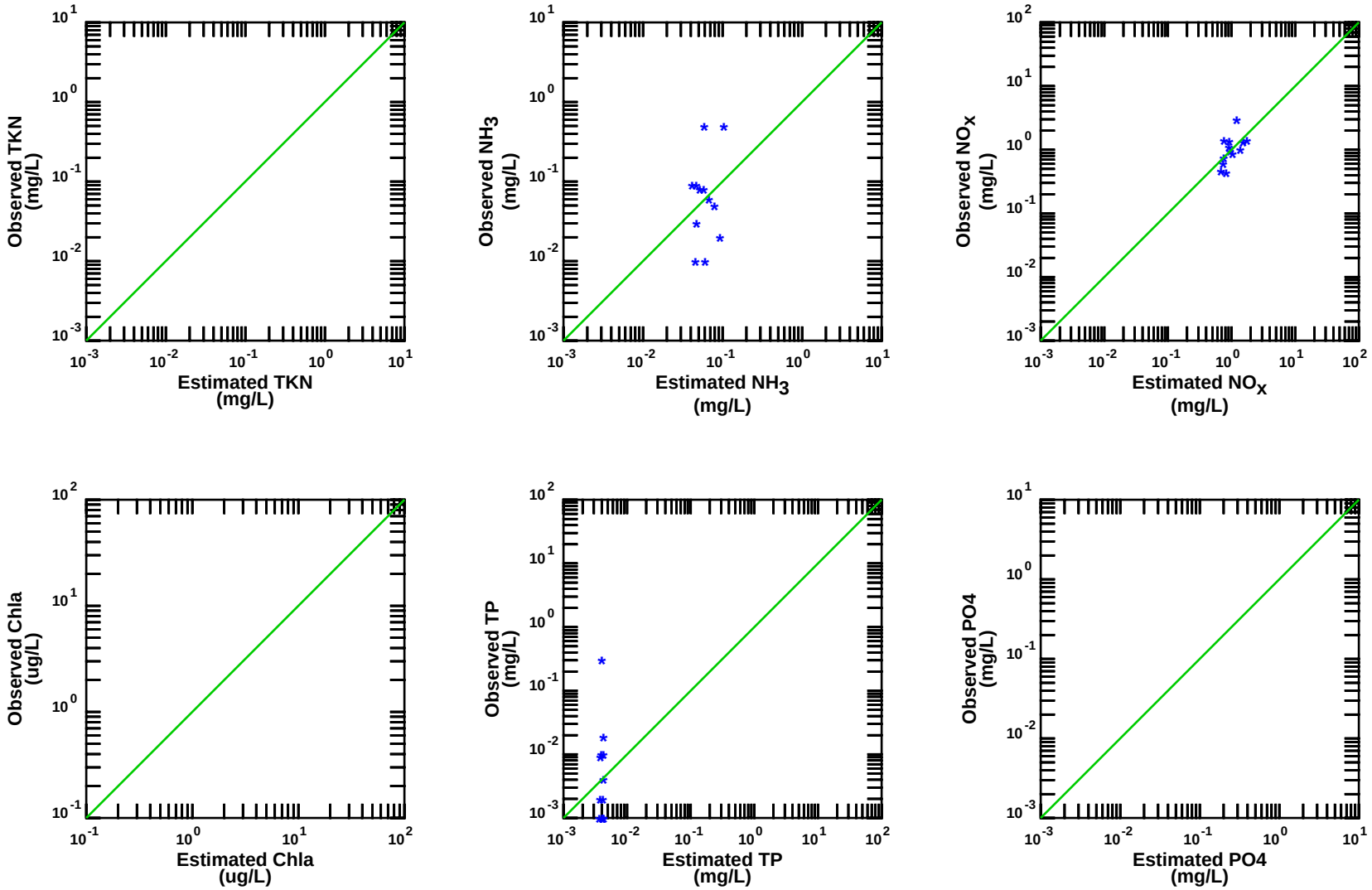






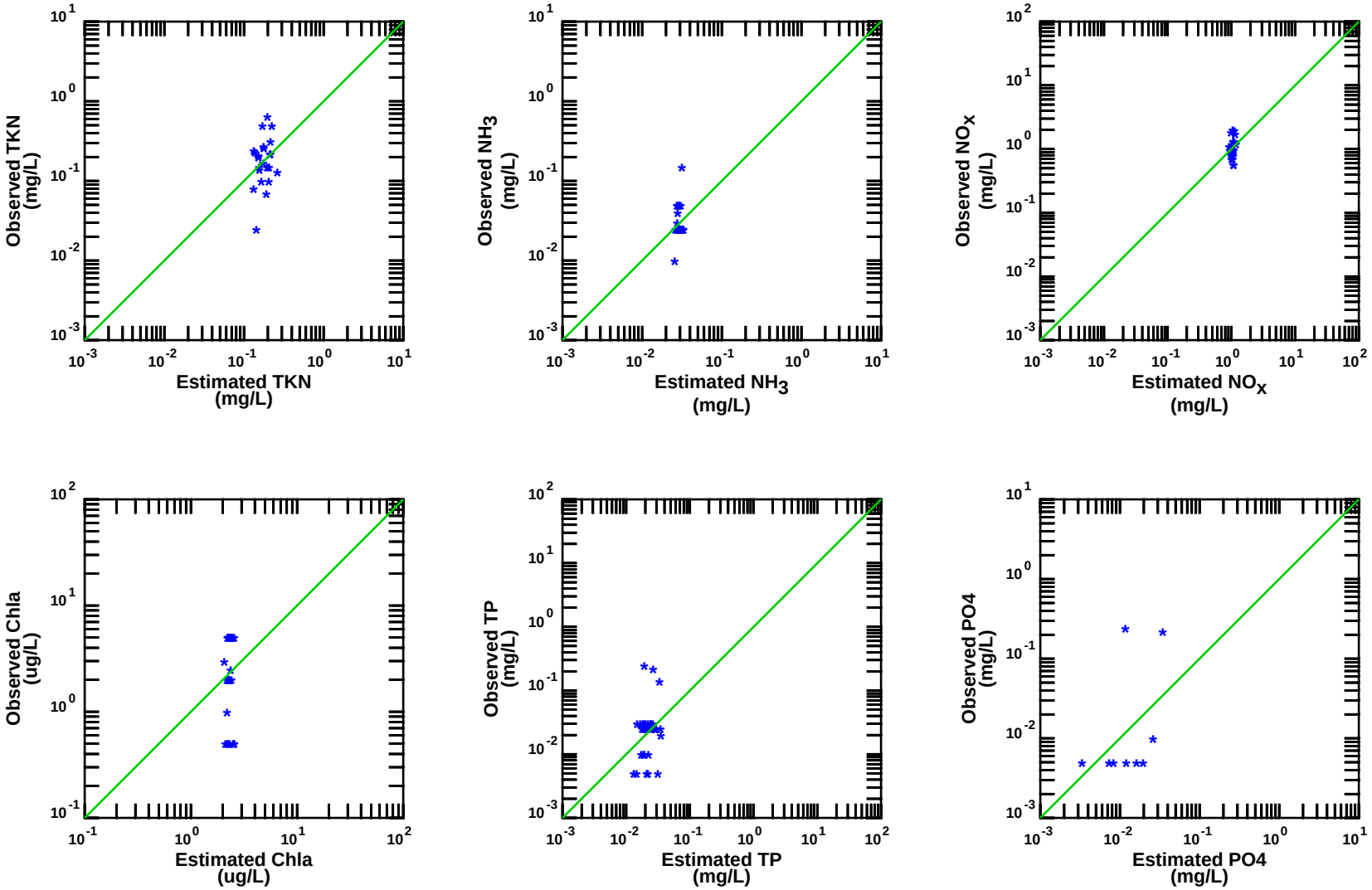
Observed Data vs. Estimated Data, Station 14253

Nueces Tributaries, Texas (1970-2014)



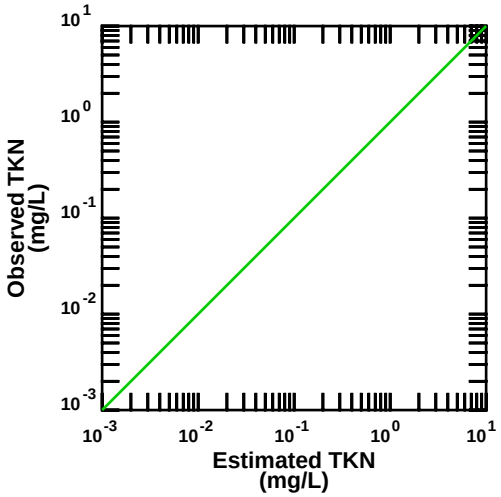
Observed Data vs. Estimated Data, Station 12997

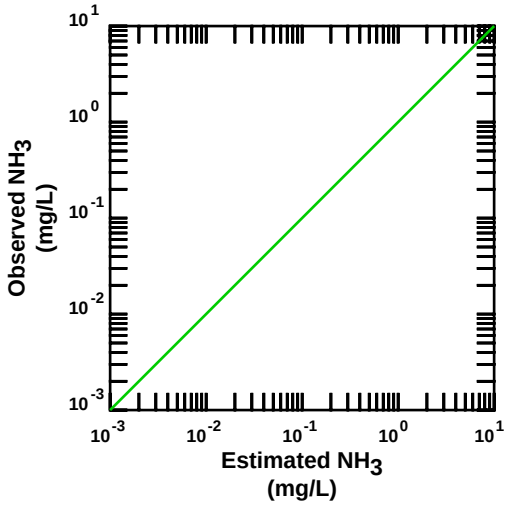
Nueces Tributaries, Texas (1970-2014)

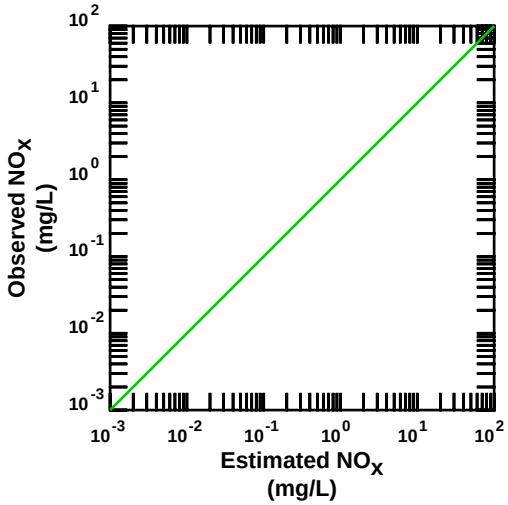


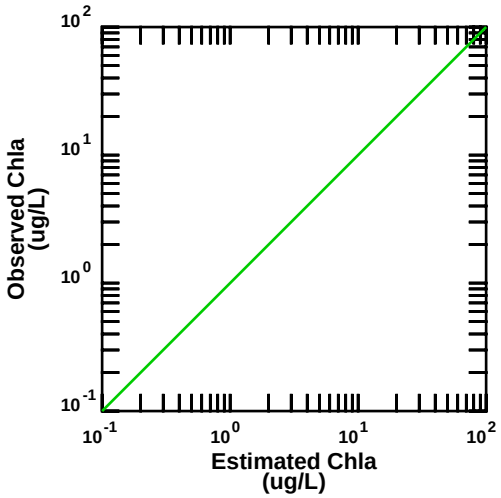
Observed Data vs. Estimated Data, Station 12996

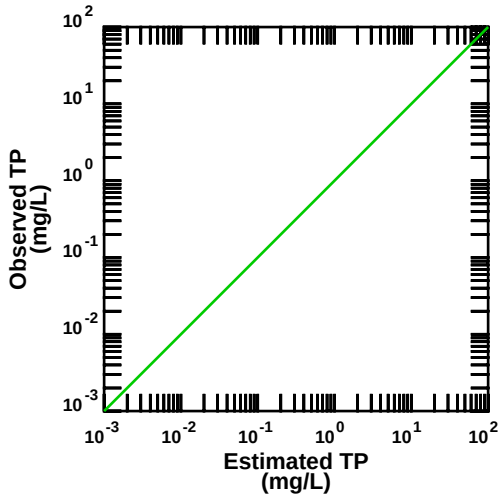
Nueces Tributaries, Texas (1970-2014)





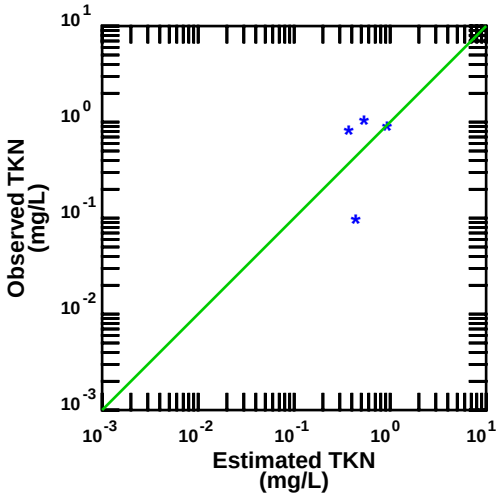


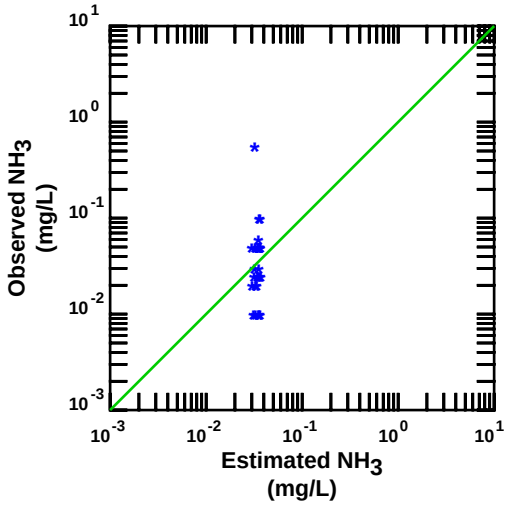


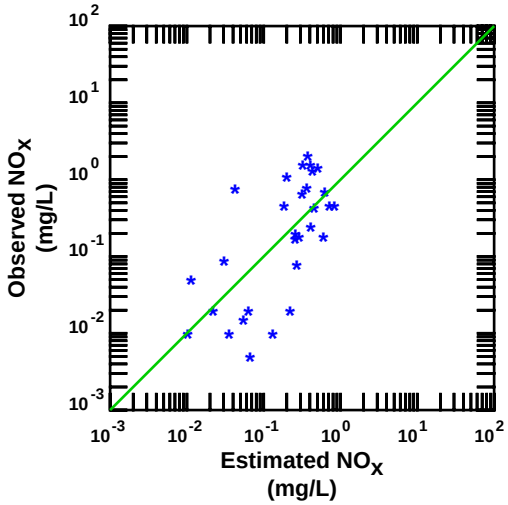


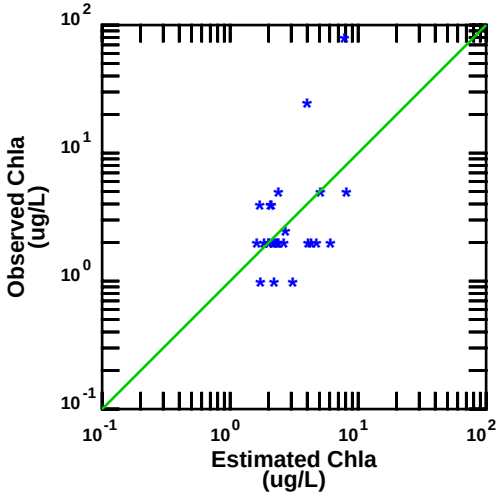
Observed Data vs. Estimated Data, Station 17143

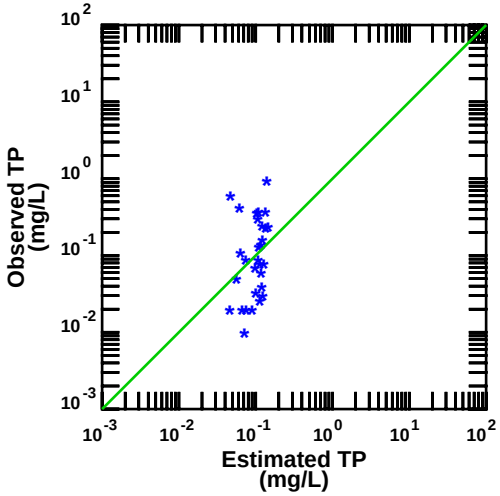
Nueces Tributaries, Texas (1970-2014)

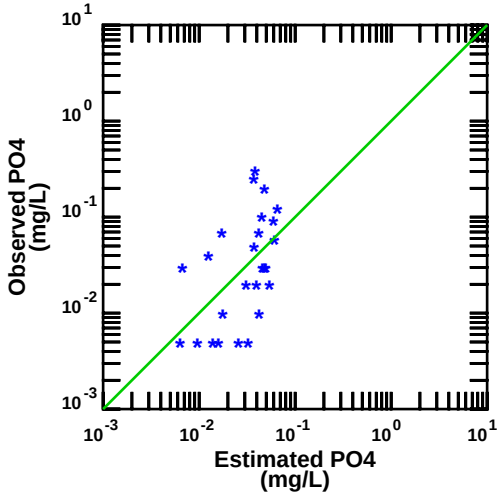






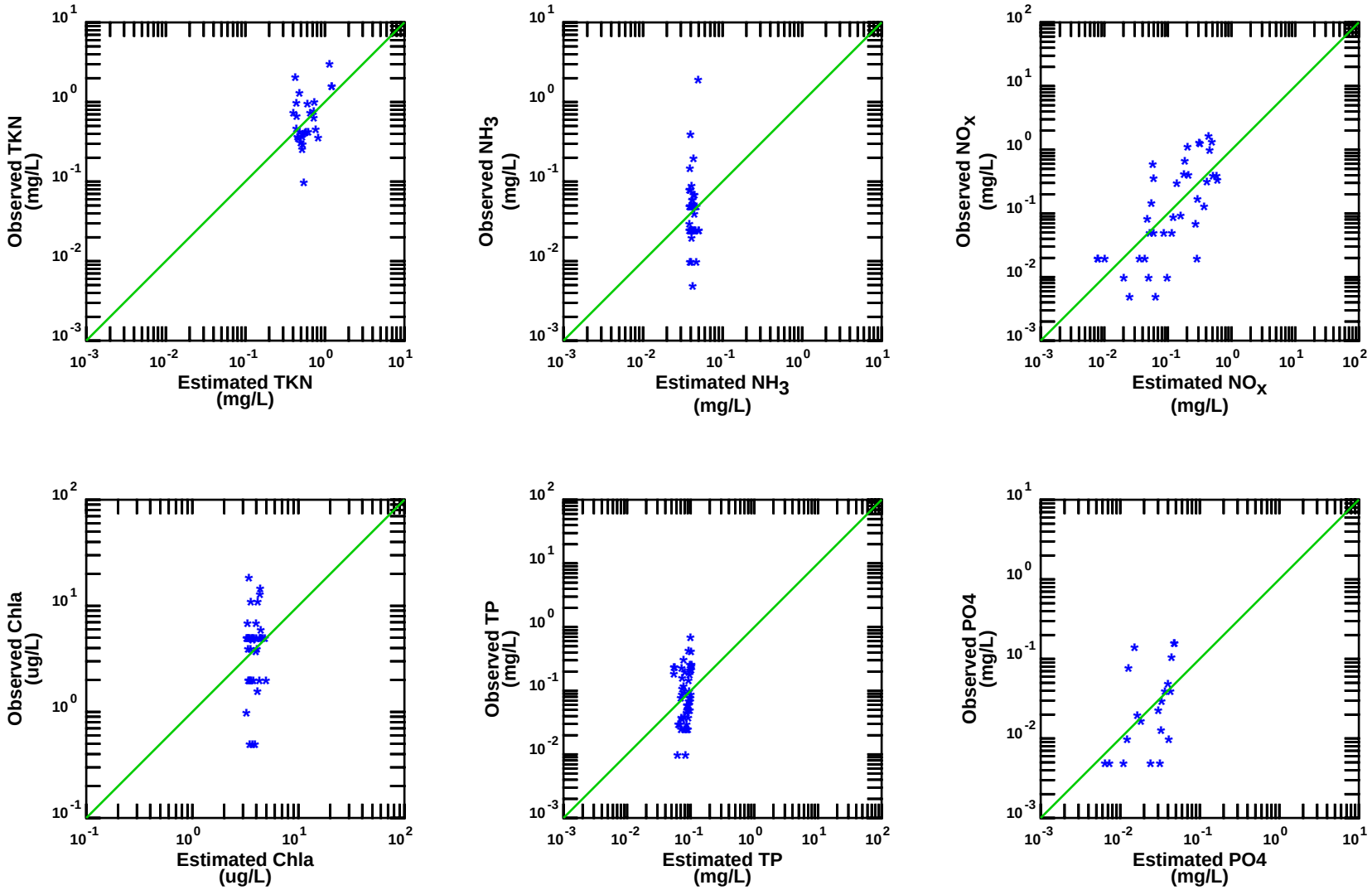






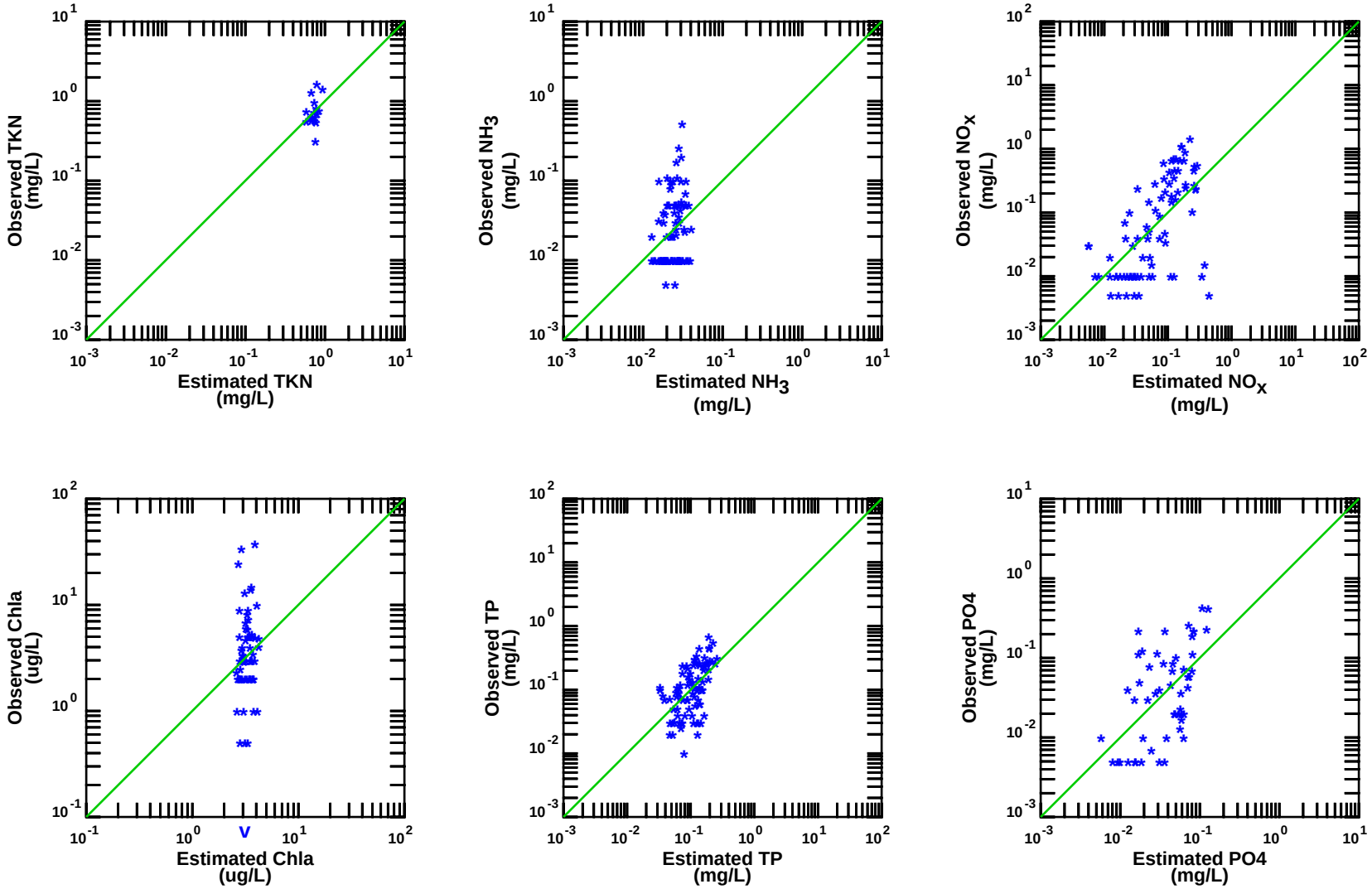
Observed Data vs. Estimated Data, Station 12976

Nueces Tributaries, Texas (1970-2014)



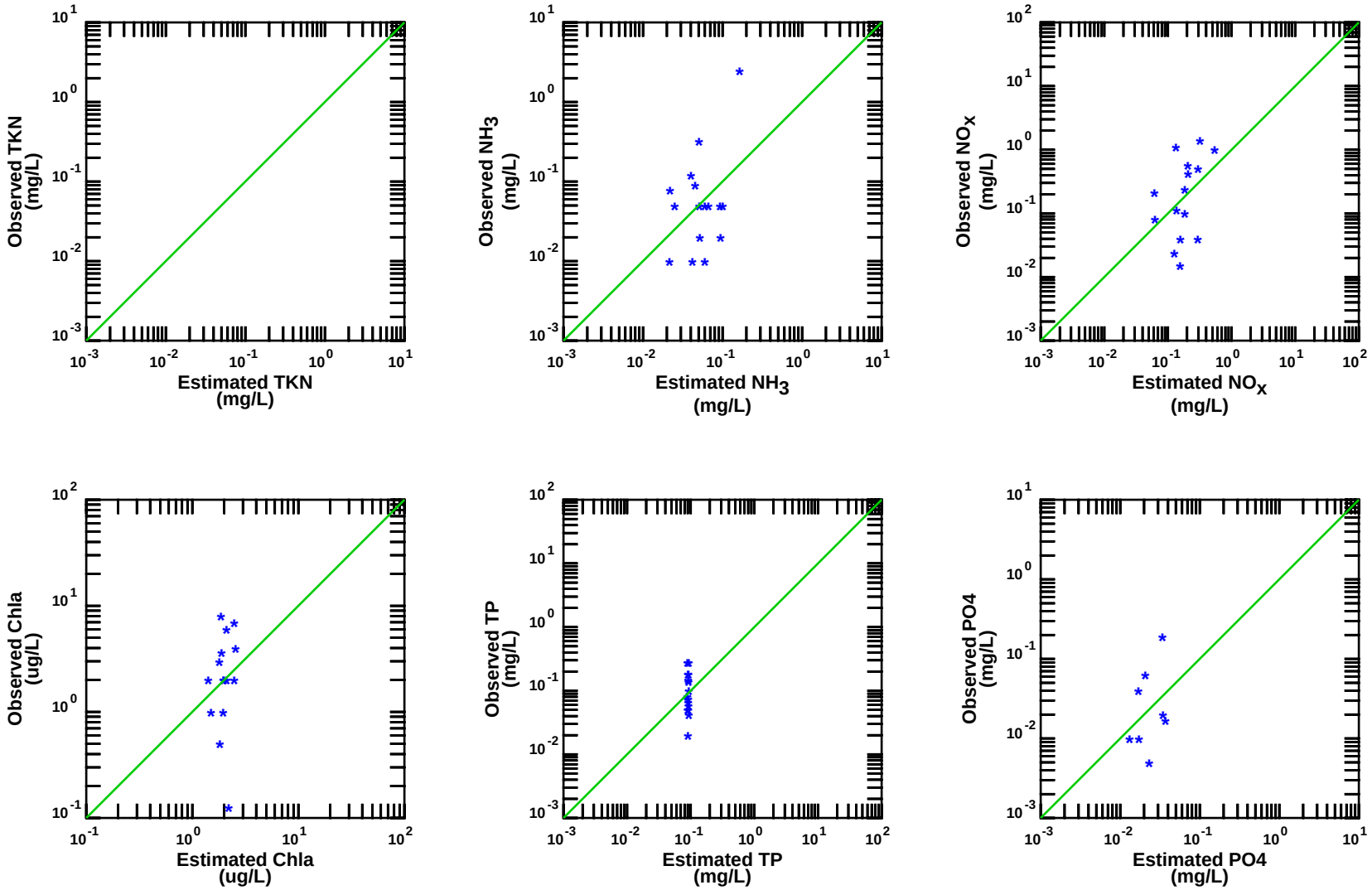
Observed Data vs. Estimated Data, Station 12975

Nueces Tributaries, Texas (1970-2014)



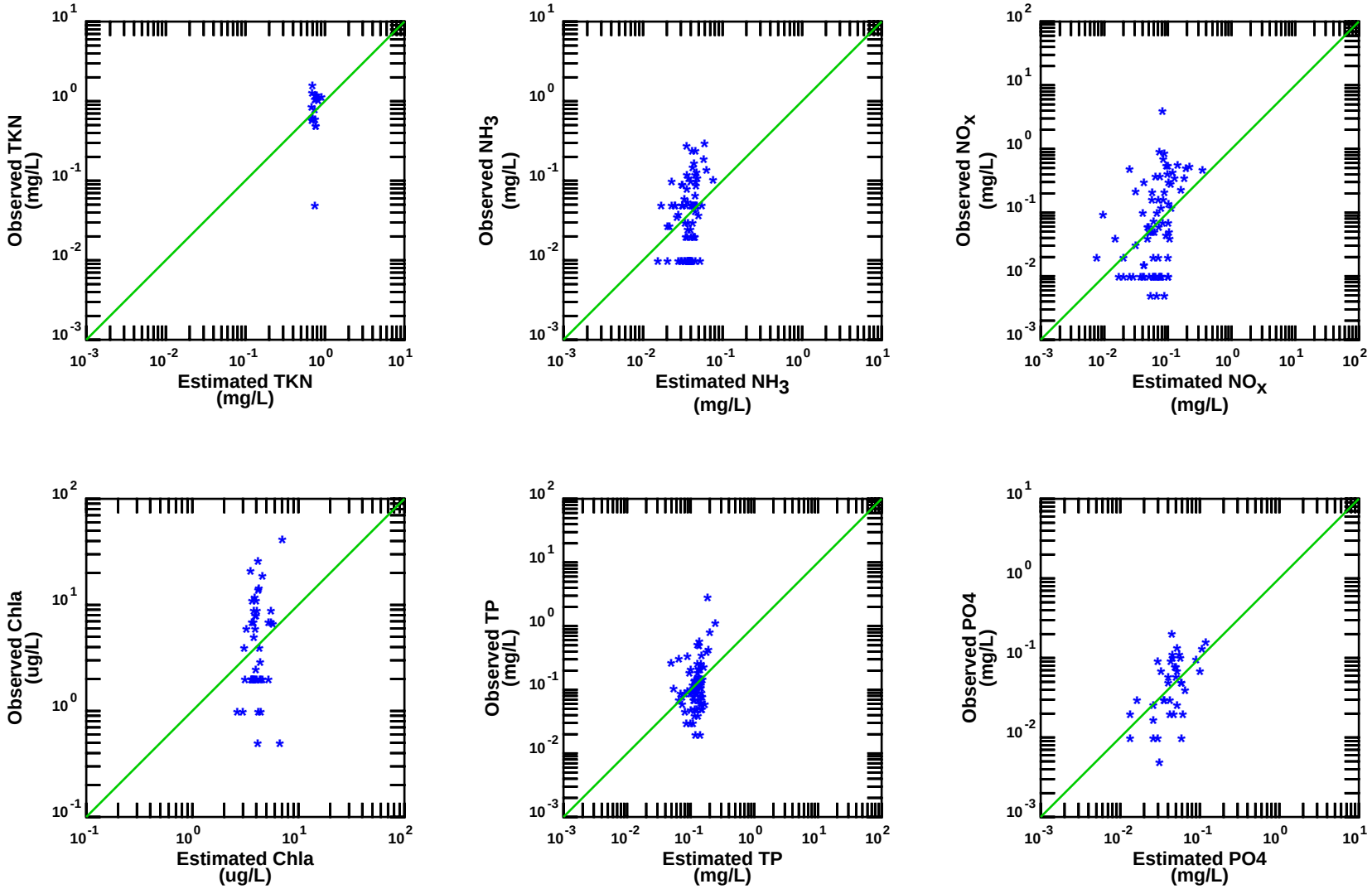
Observed Data vs. Estimated Data, Station 12973

Nueces Tributaries, Texas (1970-2014)



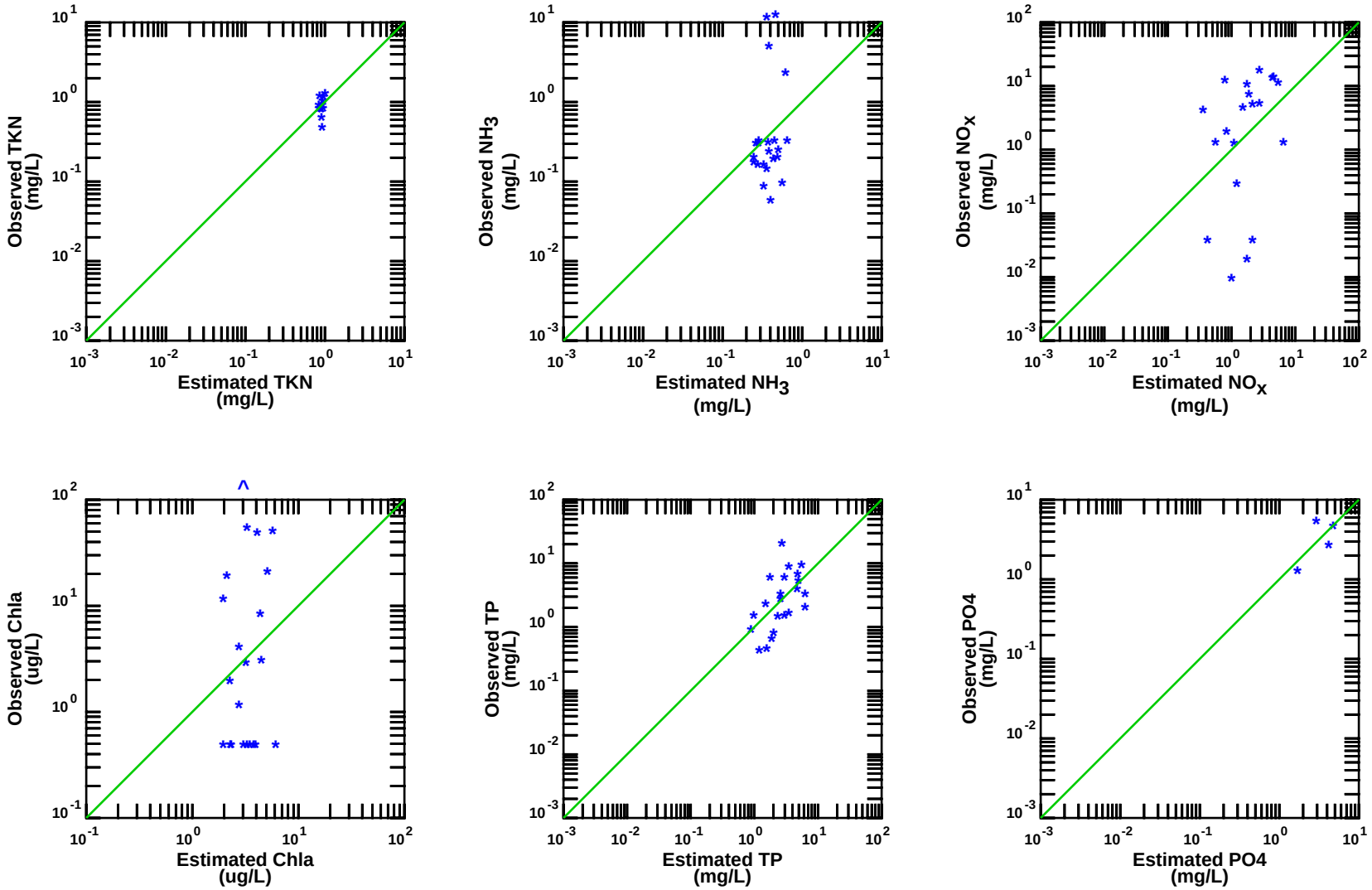
Observed Data vs. Estimated Data, Station 12972

Nueces Tributaries, Texas (1970-2014)



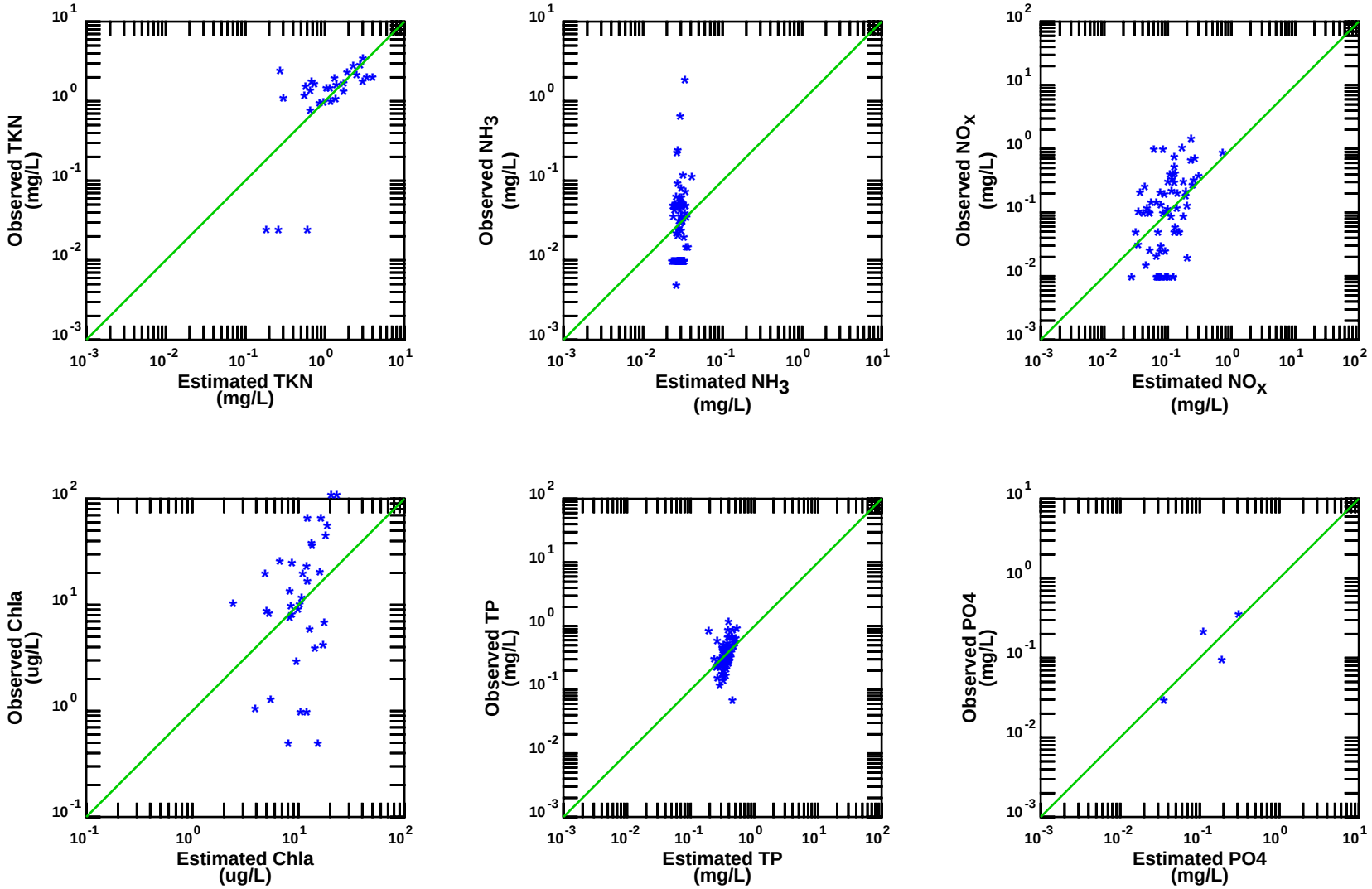
Observed Data vs. Estimated Data, Station 12983

Nueces Tributaries, Texas (1970-2014)



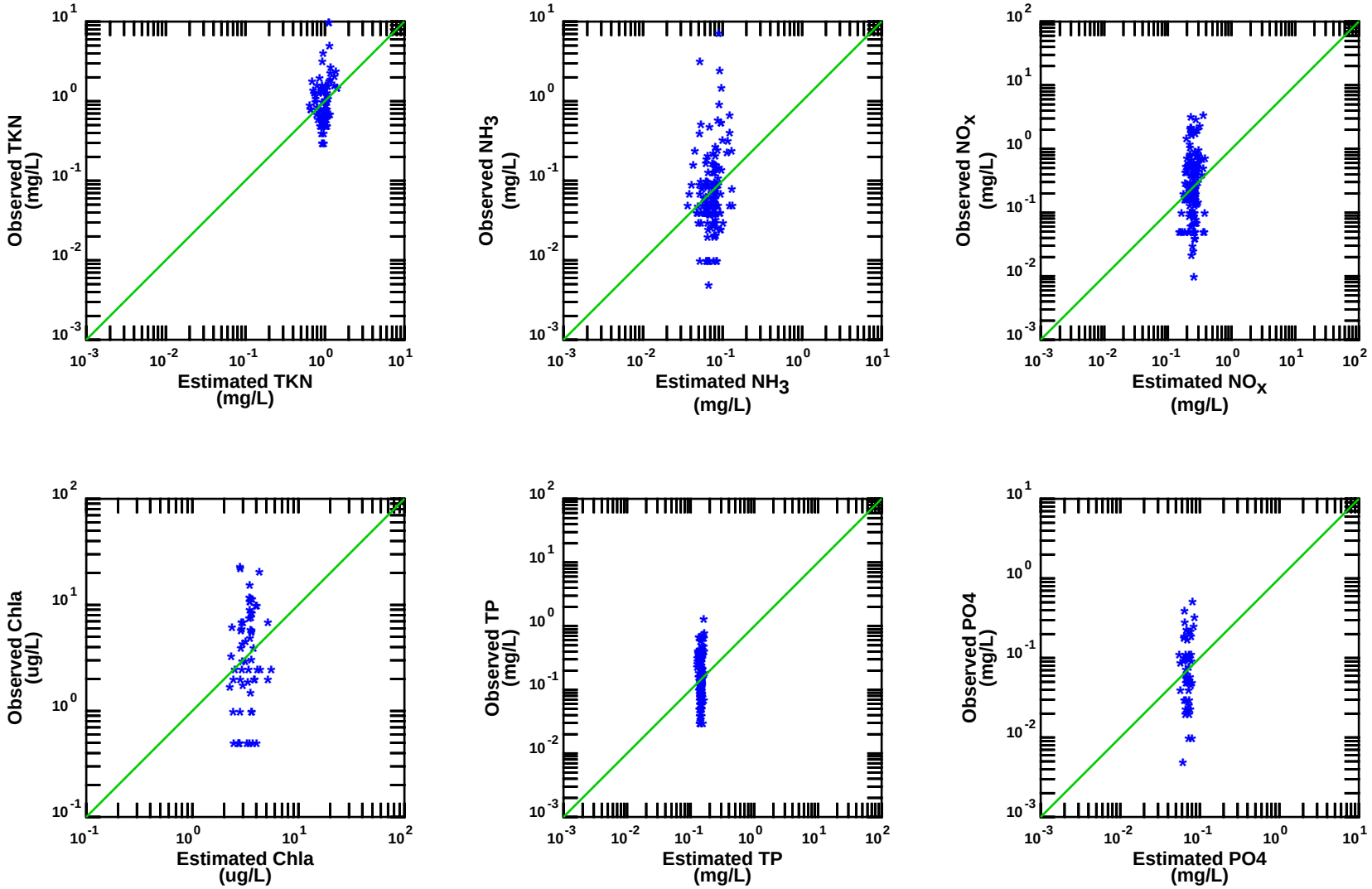
Observed Data vs. Estimated Data, Station 12981

Nueces Tributaries, Texas (1970-2014)



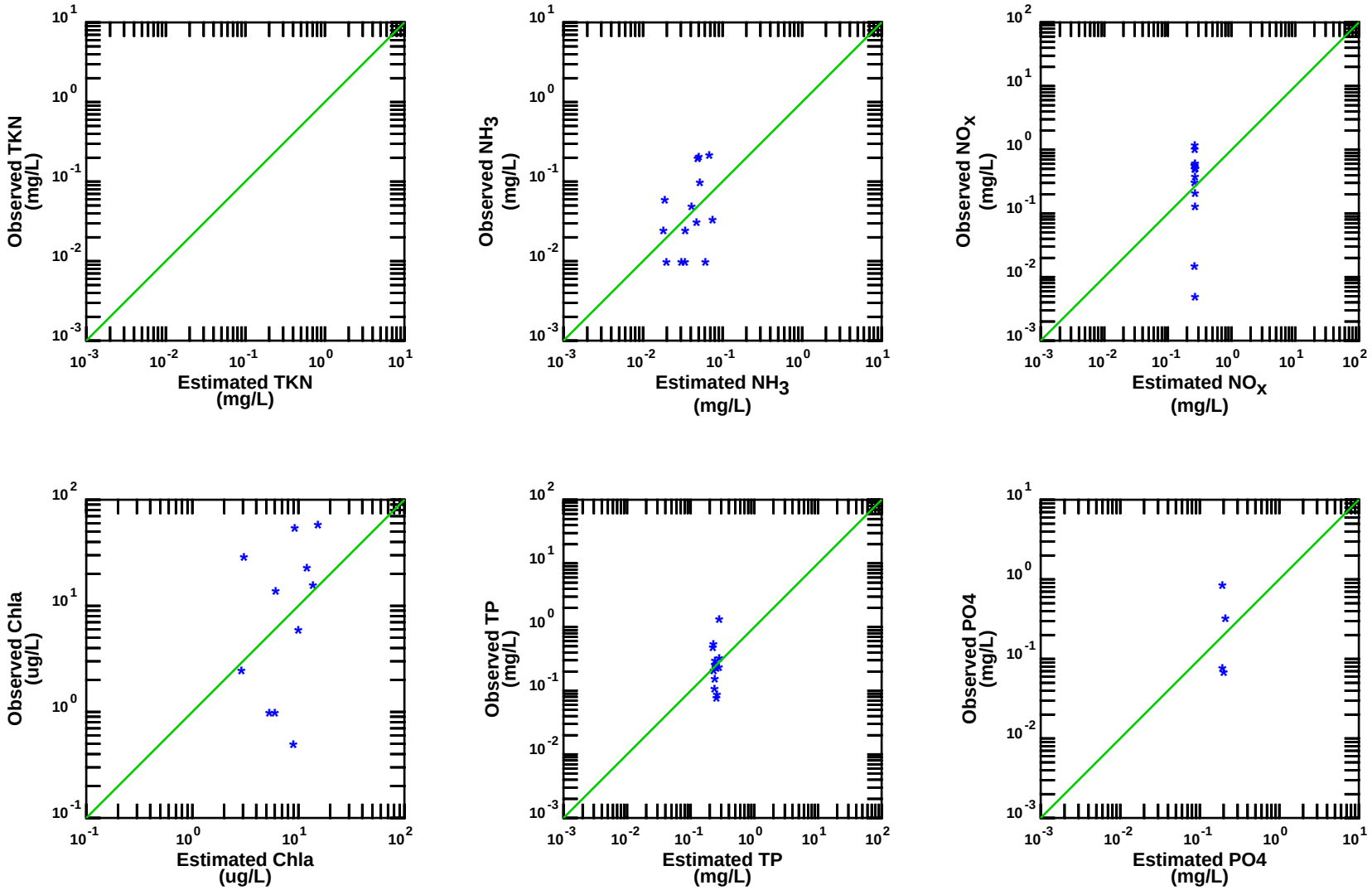
Observed Data vs. Estimated Data, Station 12980

Nueces Tributaries, Texas (1970-2014)



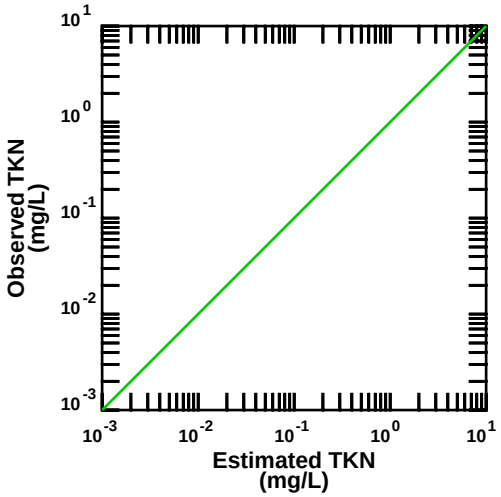
Observed Data vs. Estimated Data, Station 12979

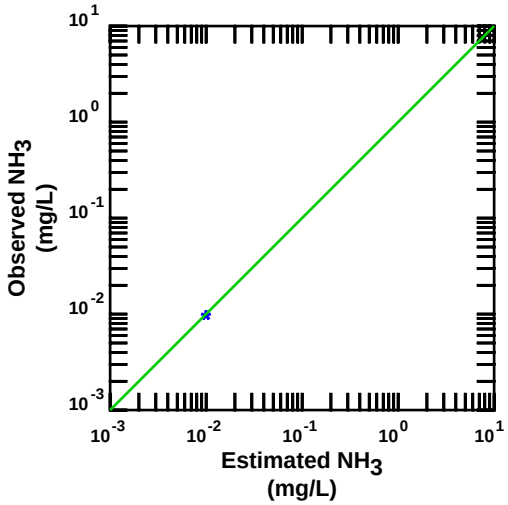
Nueces Tributaries, Texas (1970-2014)

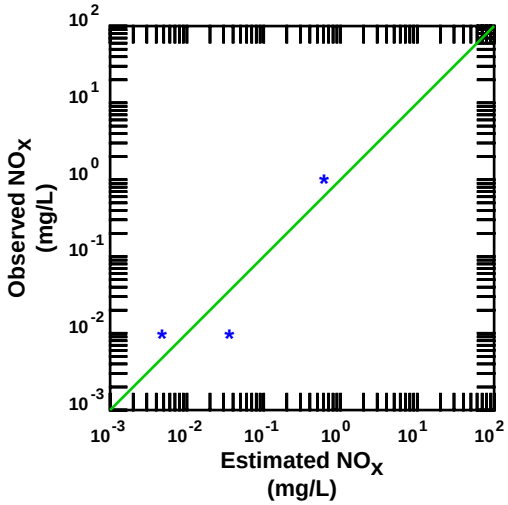


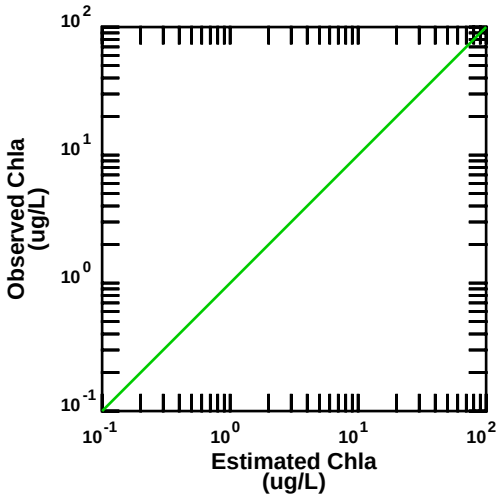
Observed Data vs. Estimated Data, Station 12978

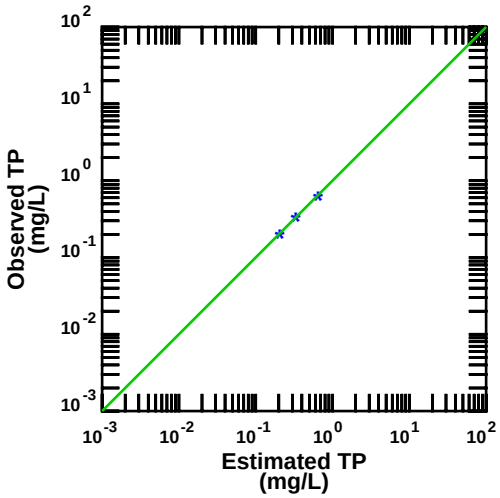
Nueces Tributaries, Texas (1970-2014)





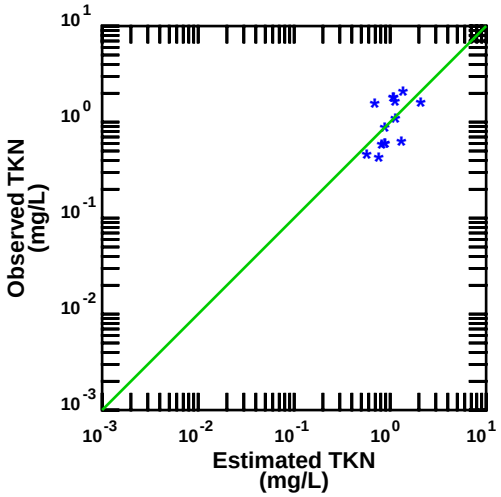


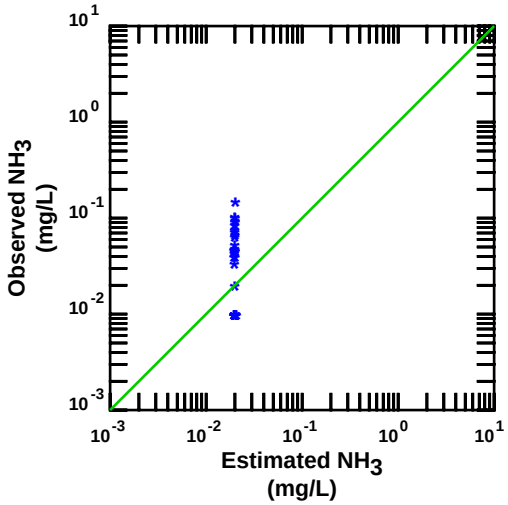


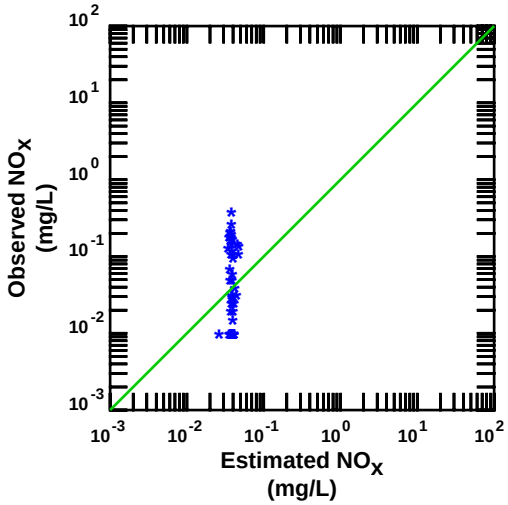


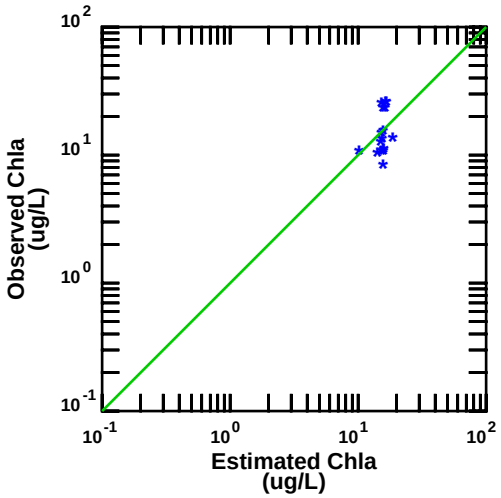
Observed Data vs. Estimated Data, Station 17648

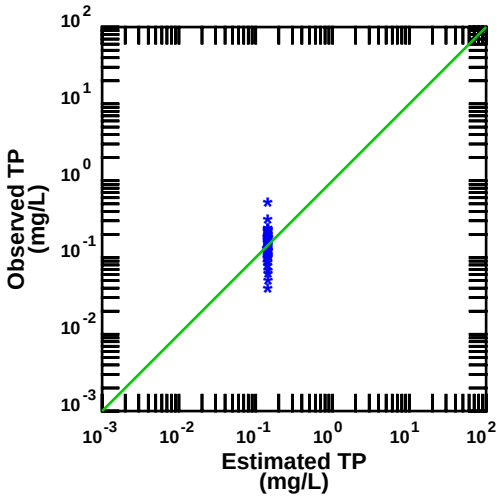
Nueces Tributaries, Texas (1970-2014)





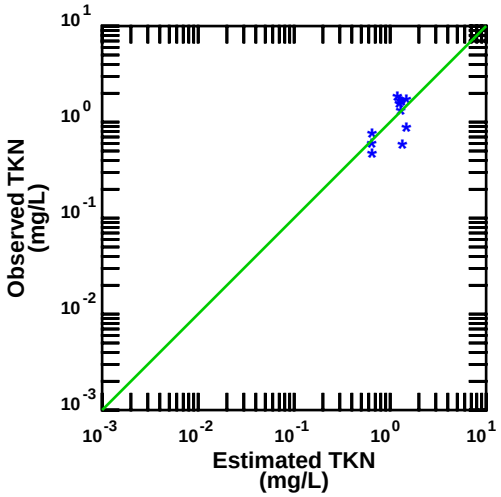


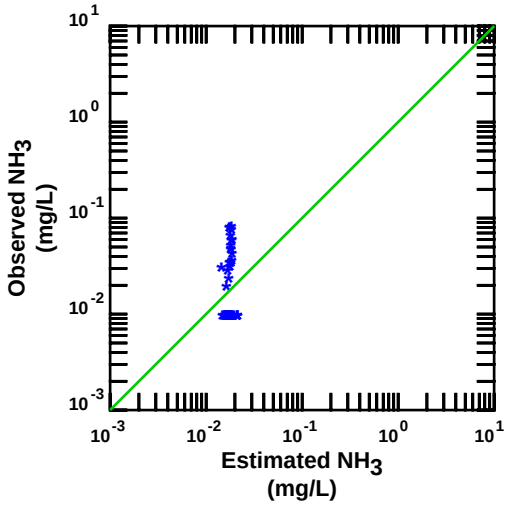


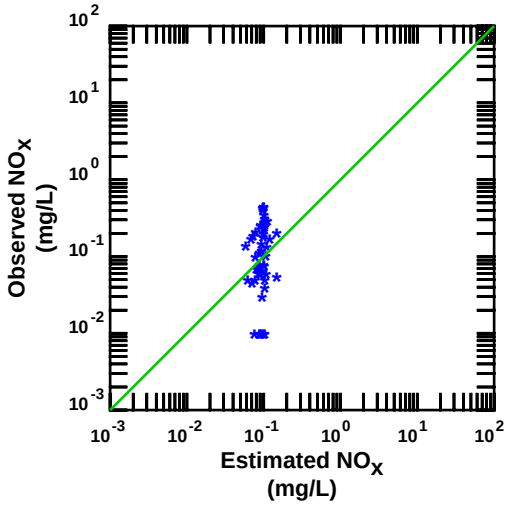


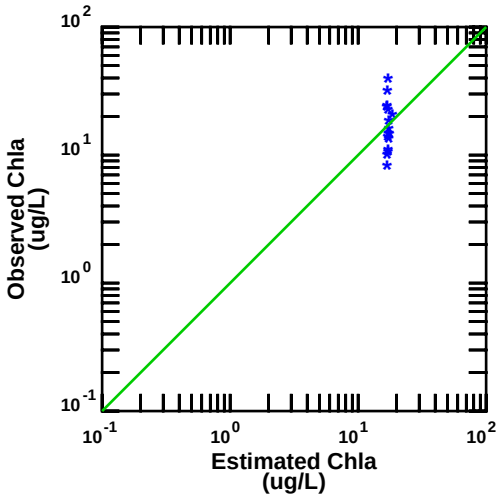
Observed Data vs. Estimated Data, Station 12965

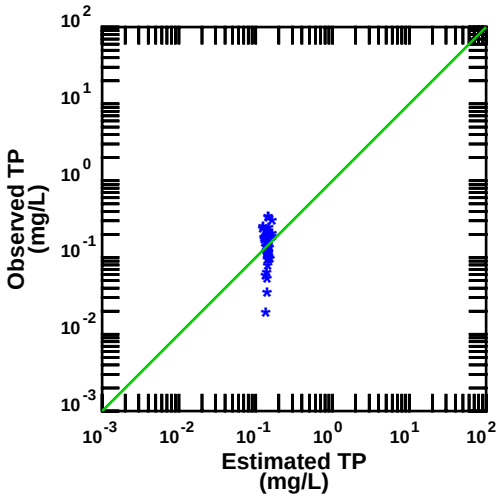
Nueces Tributaries, Texas (1970-2014)





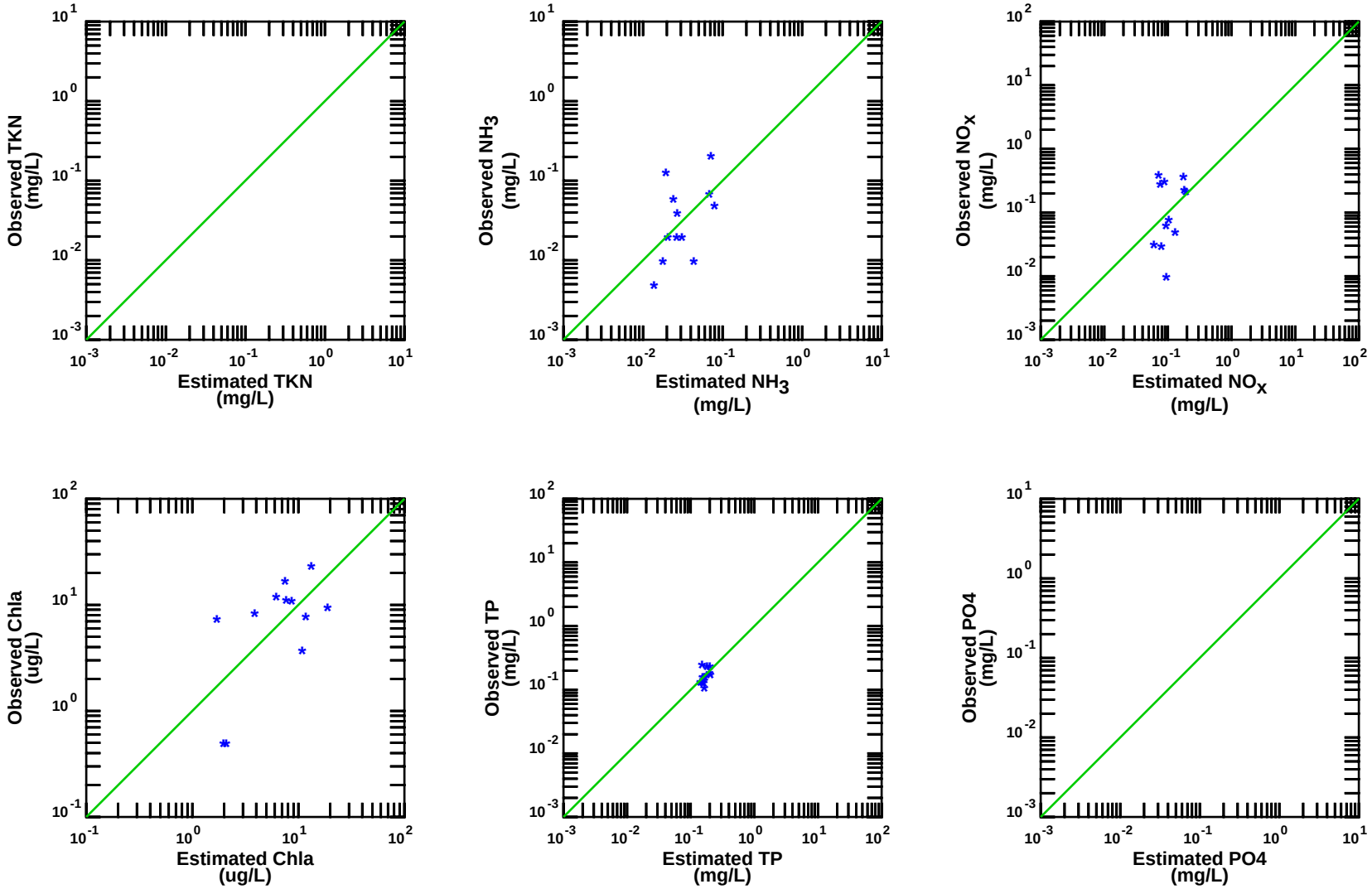






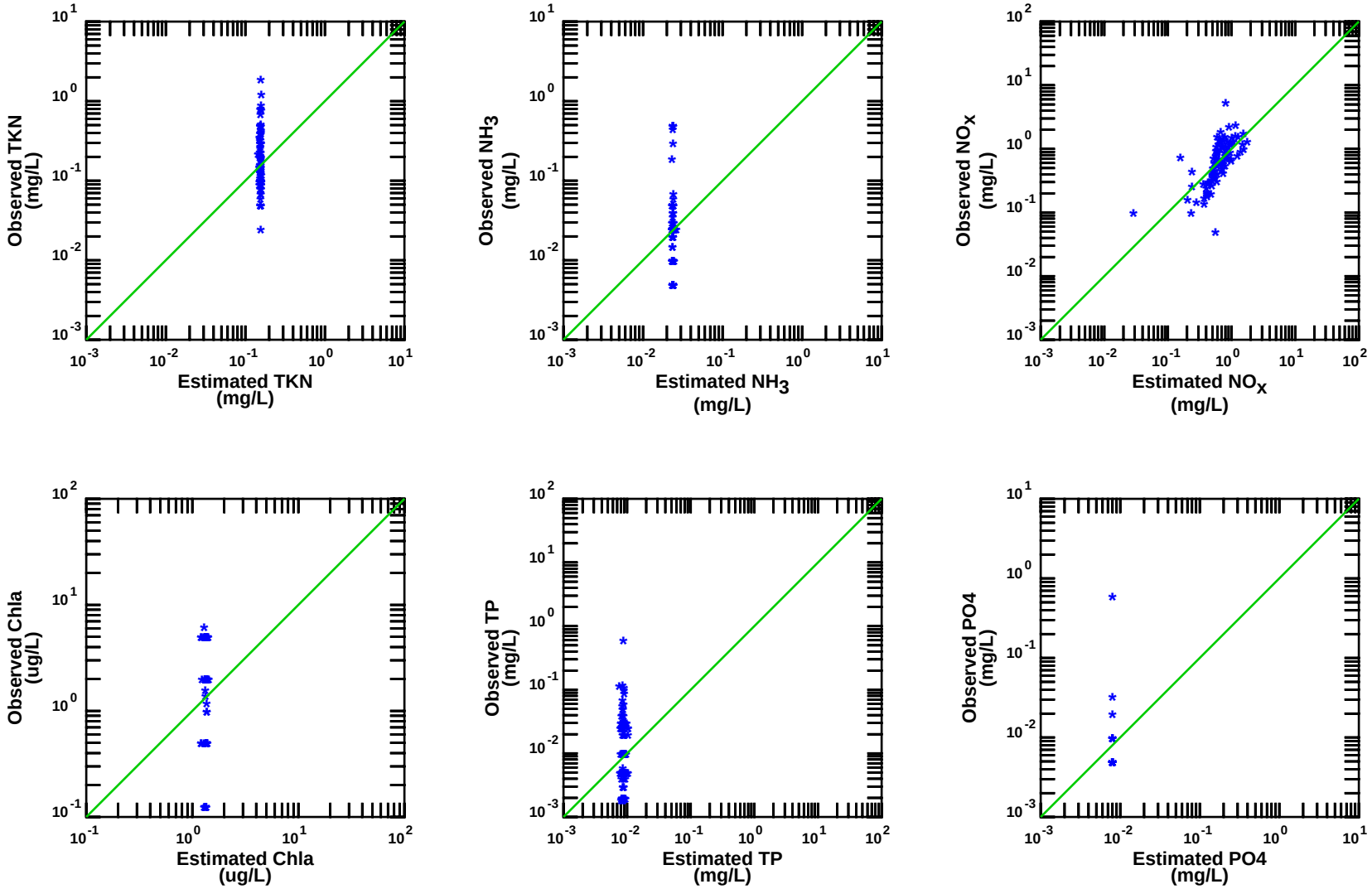
Observed Data vs. Estimated Data, Station 12964

Nueces Tributaries, Texas (1970-2014)



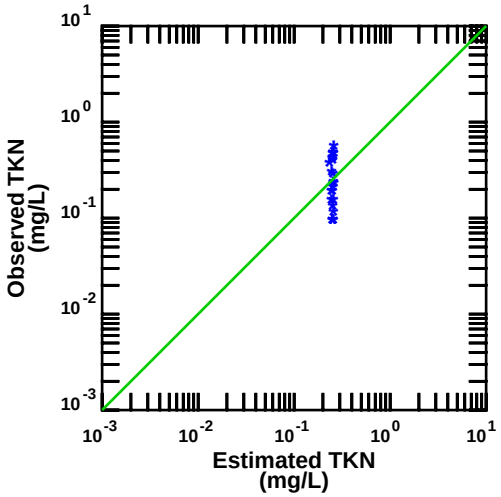
Observed Data vs. Estimated Data, Station 12962

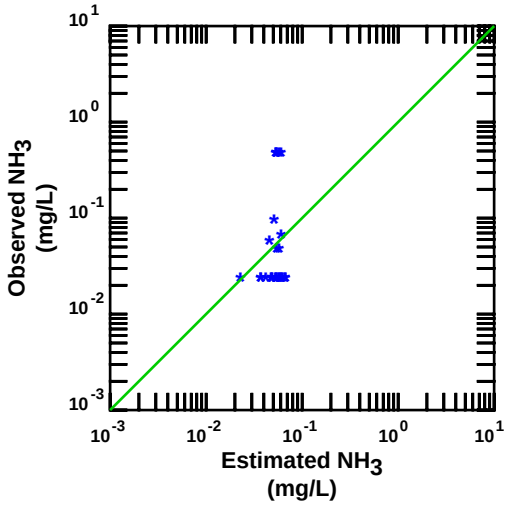
Nueces Tributaries, Texas (1970-2014)

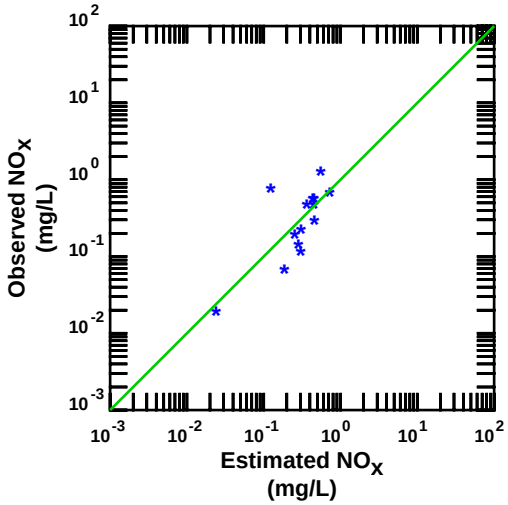


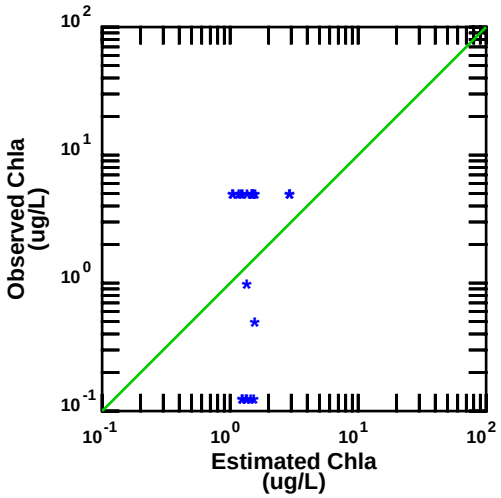
Observed Data vs. Estimated Data, Station 13006

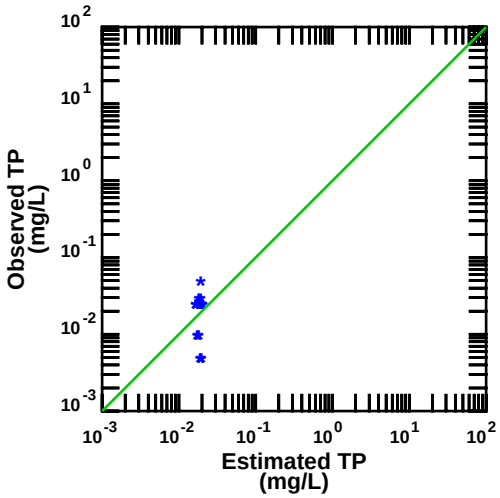
Nueces Tributaries, Texas (1970-2014)





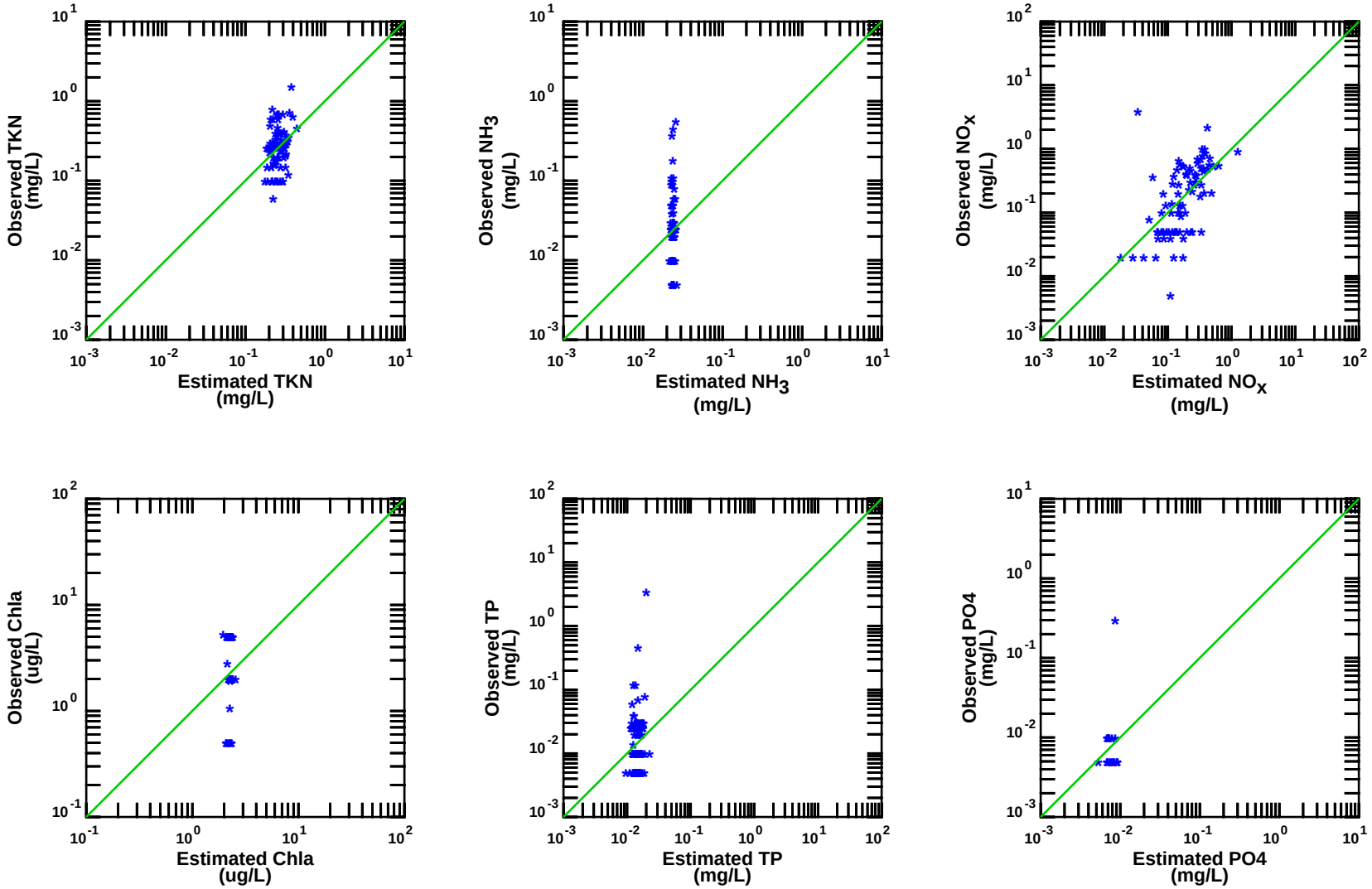






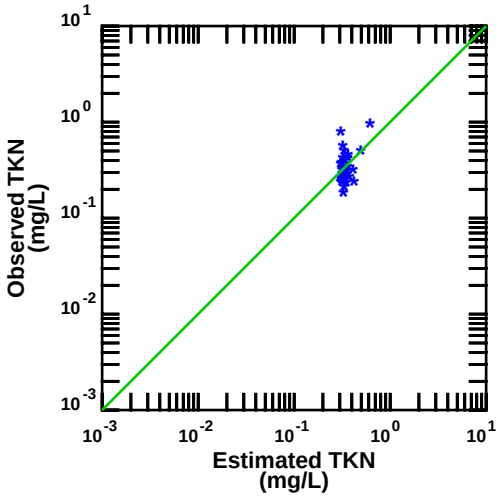
Observed Data vs. Estimated Data, Station 13007

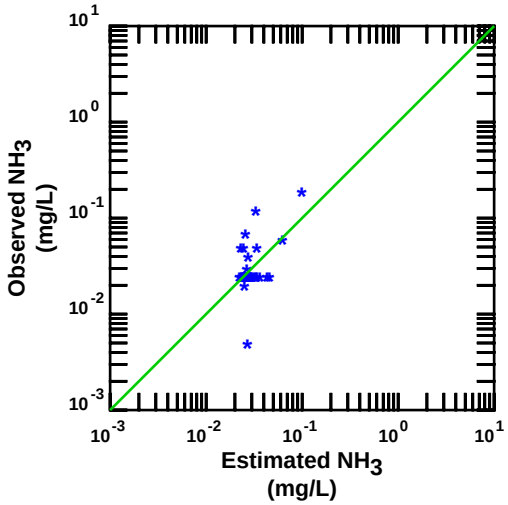
Nueces Tributaries, Texas (1970-2014)

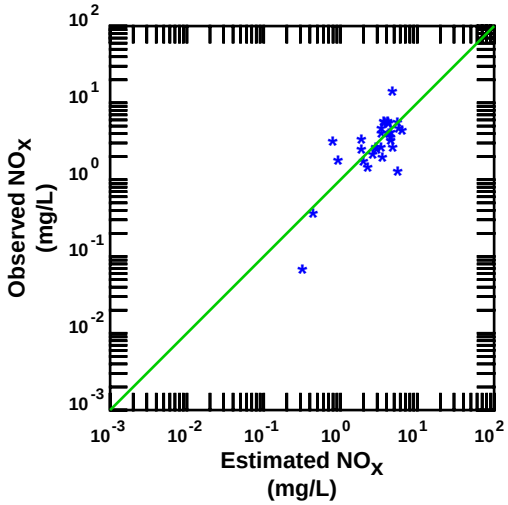


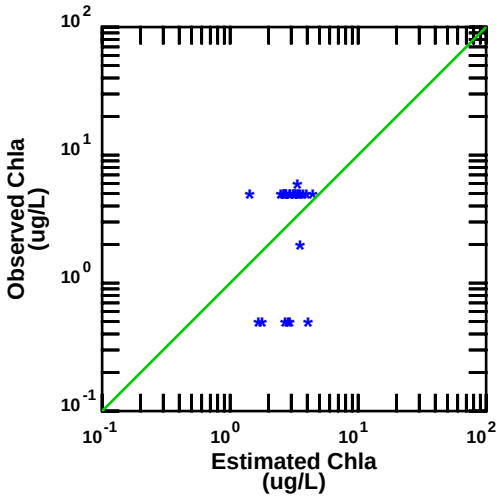
Observed Data vs. Estimated Data, Station 13010

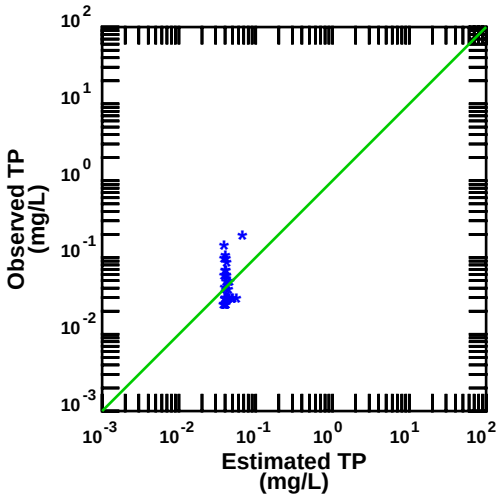
Nueces Tributaries, Texas (1970-2014)





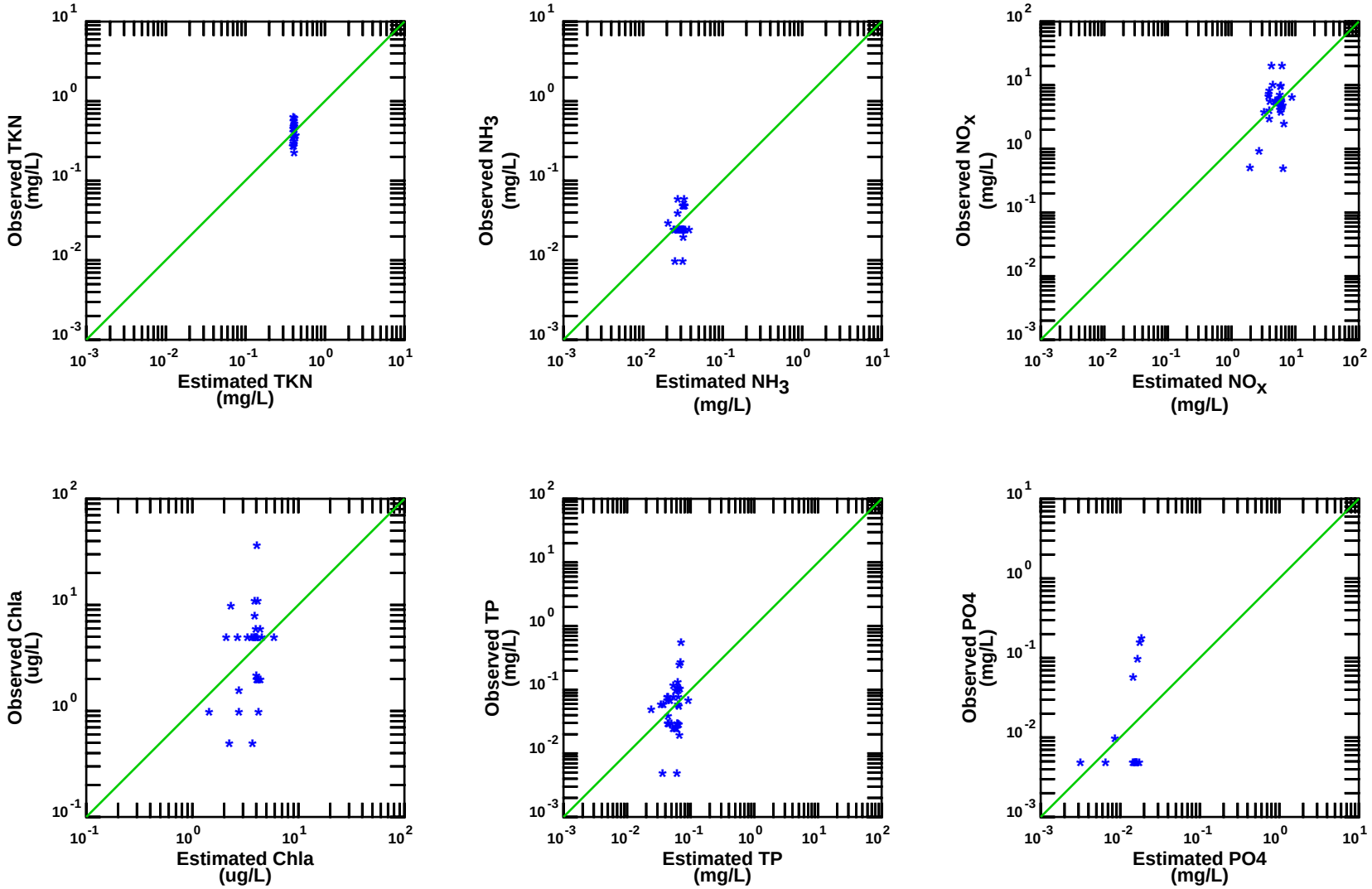






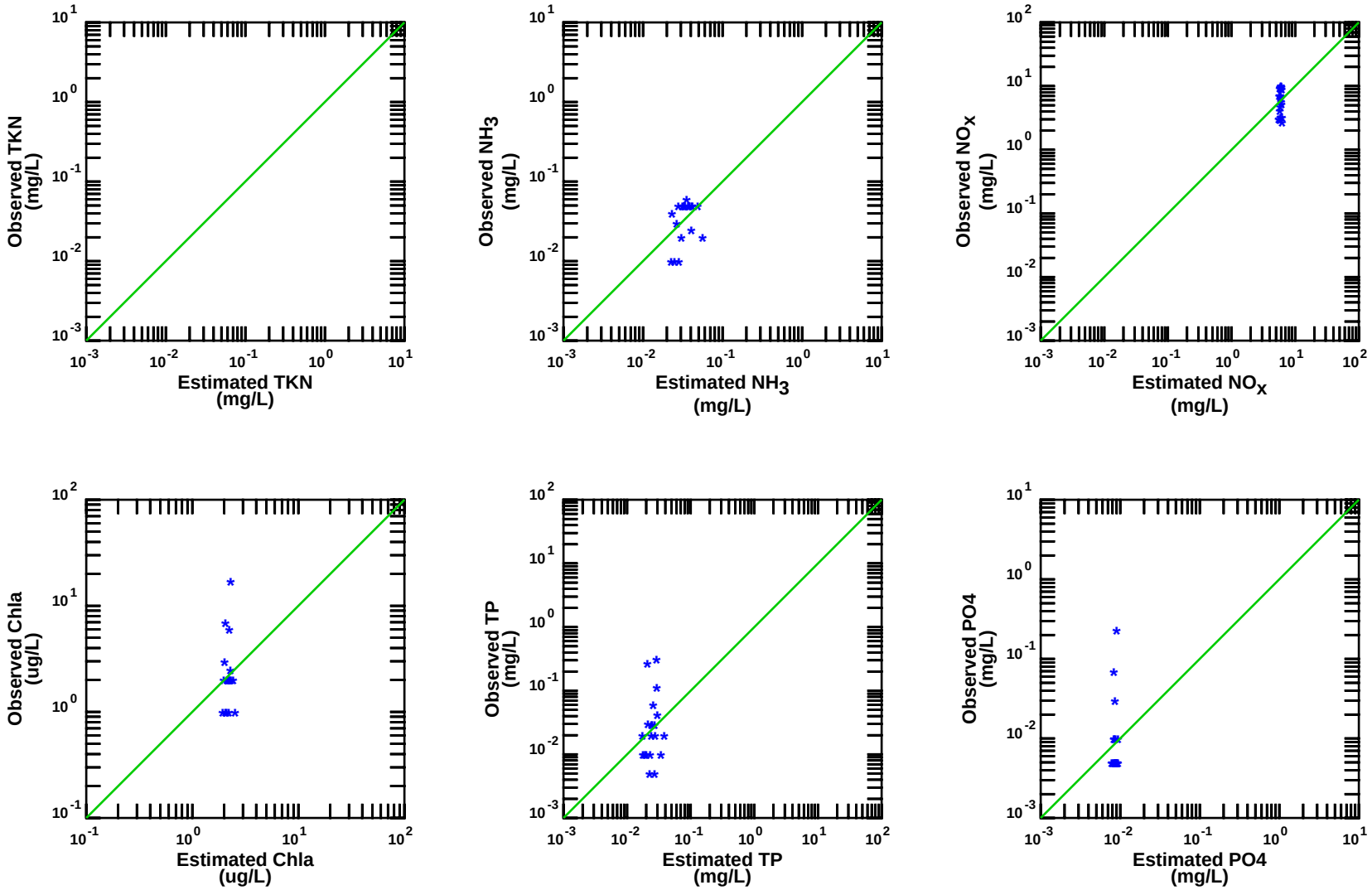
Observed Data vs. Estimated Data, Station 12987

Nueces Tributaries, Texas (1970-2014)



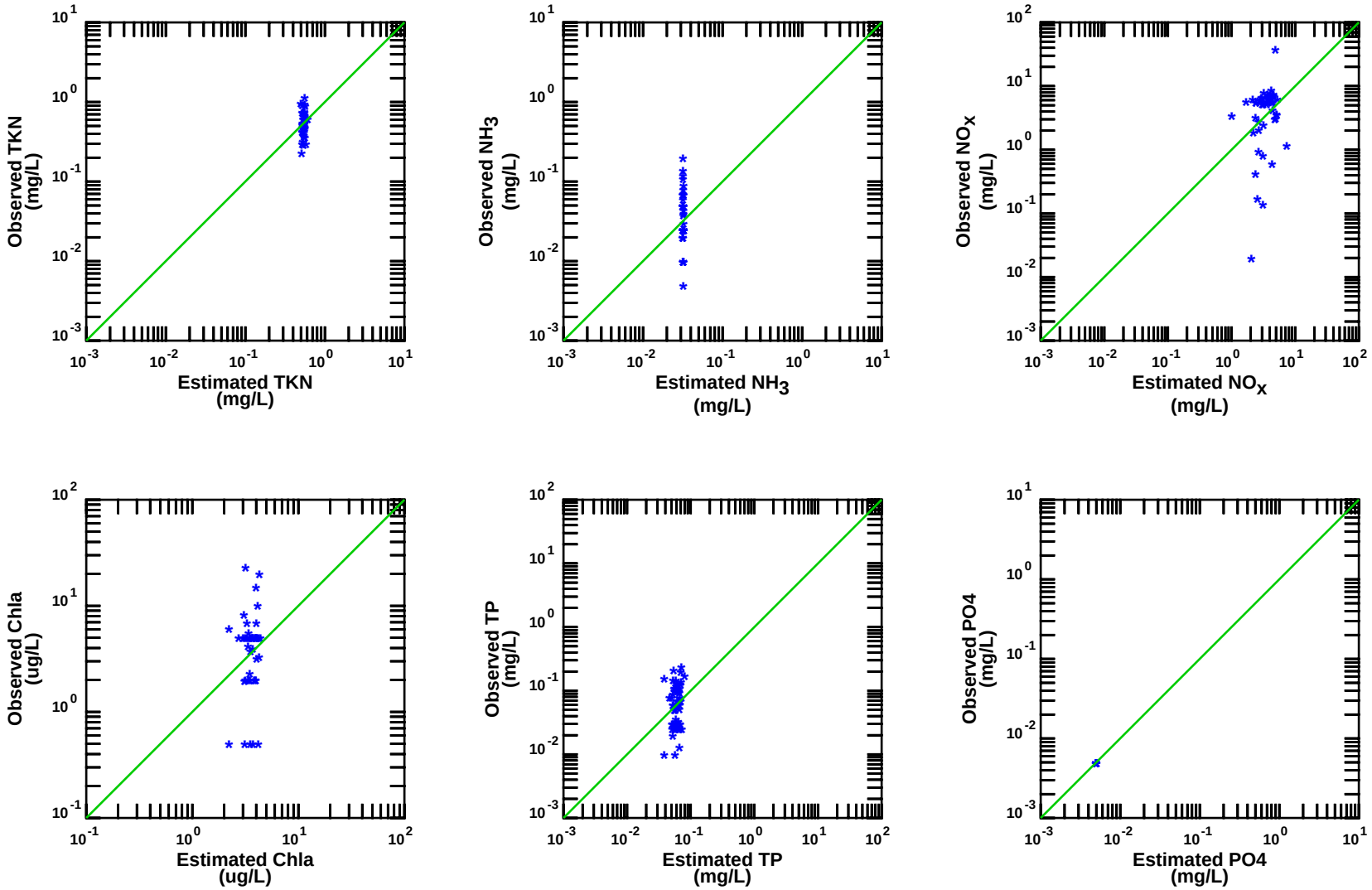
Observed Data vs. Estimated Data, Station 12985

Nueces Tributaries, Texas (1970-2014)



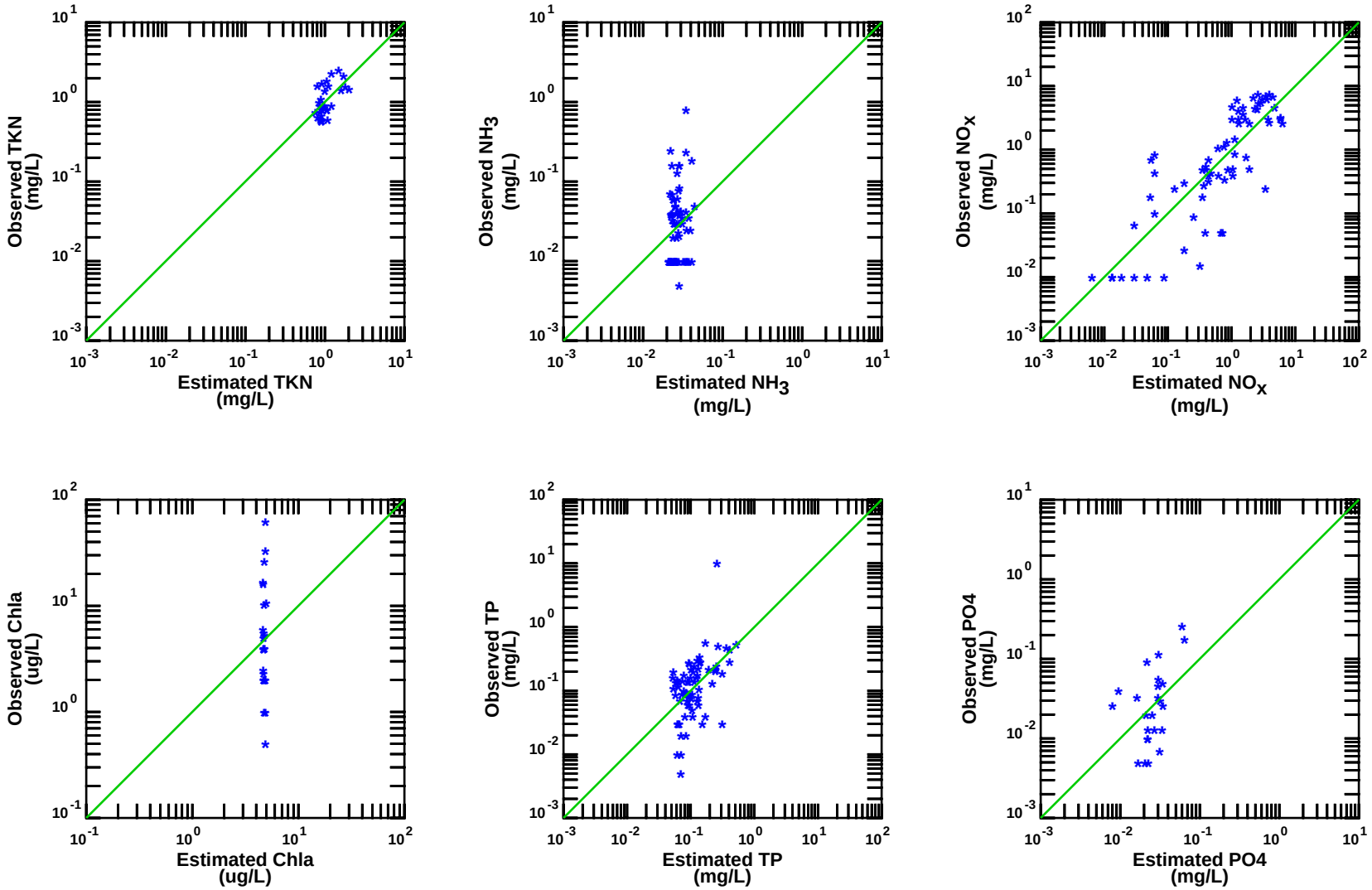
Observed Data vs. Estimated Data, Station 13025

Nueces Tributaries, Texas (1970-2014)



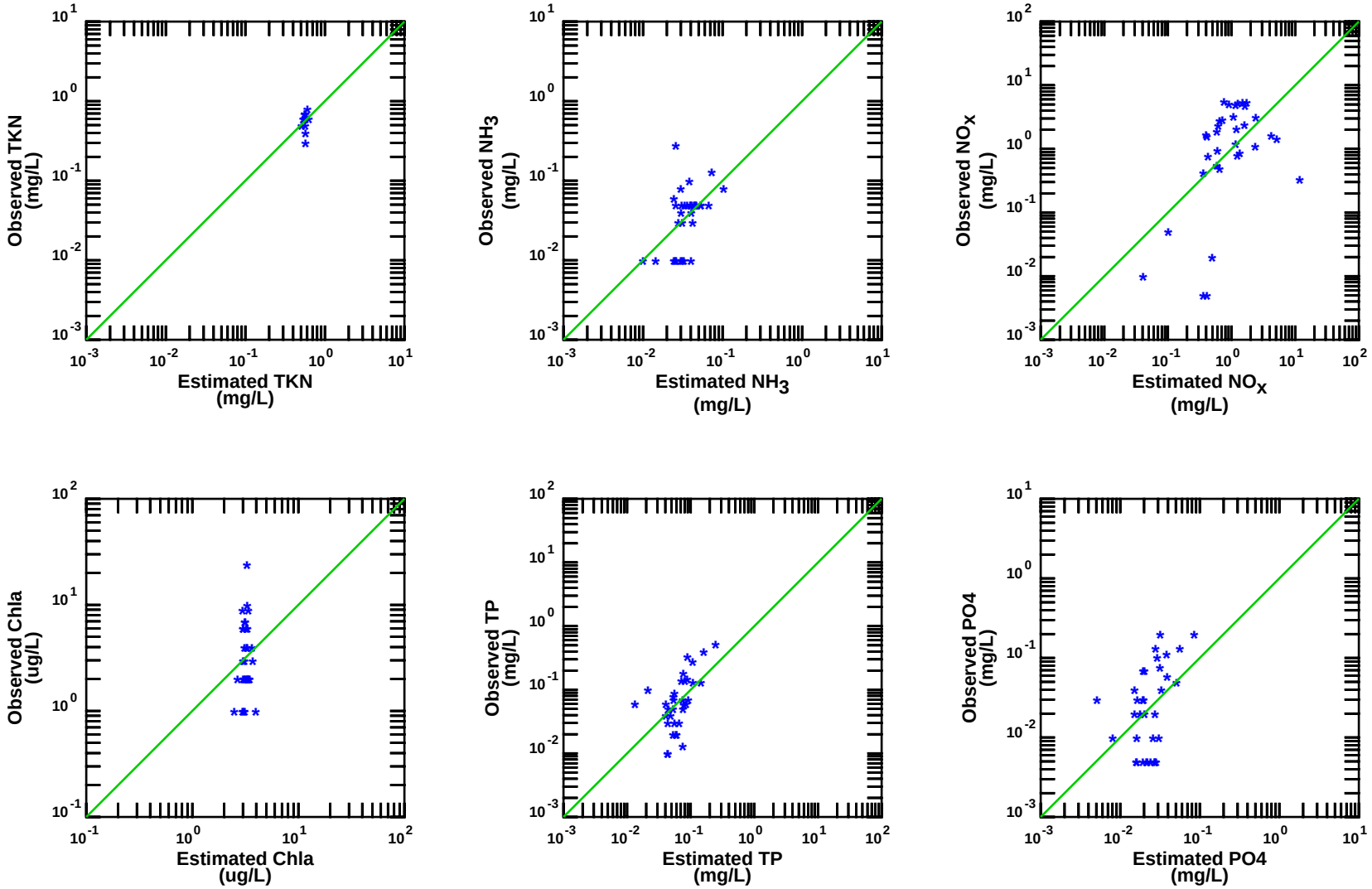
Observed Data vs. Estimated Data, Station 13024

Nueces Tributaries, Texas (1970-2014)



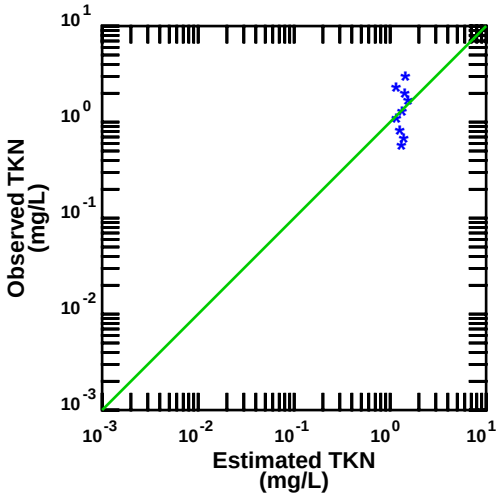
Observed Data vs. Estimated Data, Station 13023

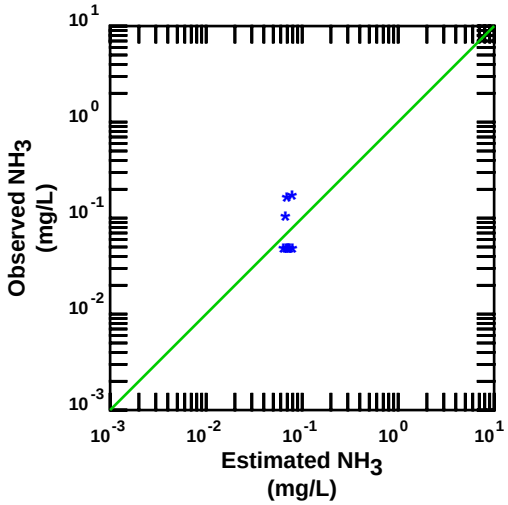
Nueces Tributaries, Texas (1970-2014)

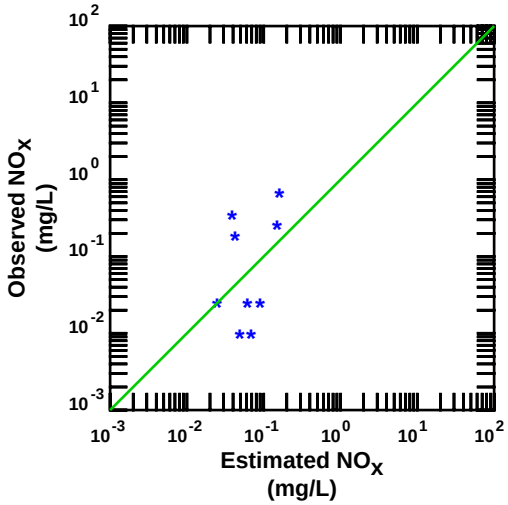


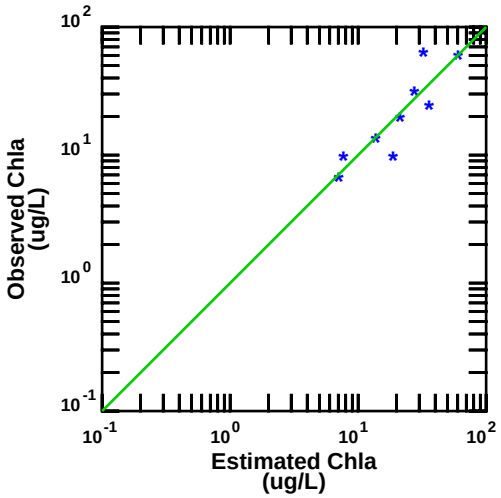
Observed Data vs. Estimated Data, Station 13021

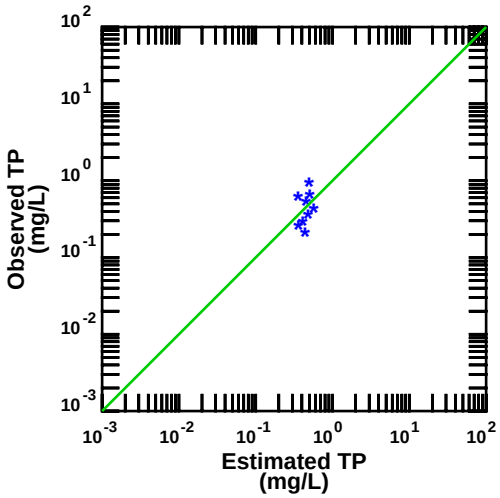
Nueces Tributaries, Texas (1970-2014)





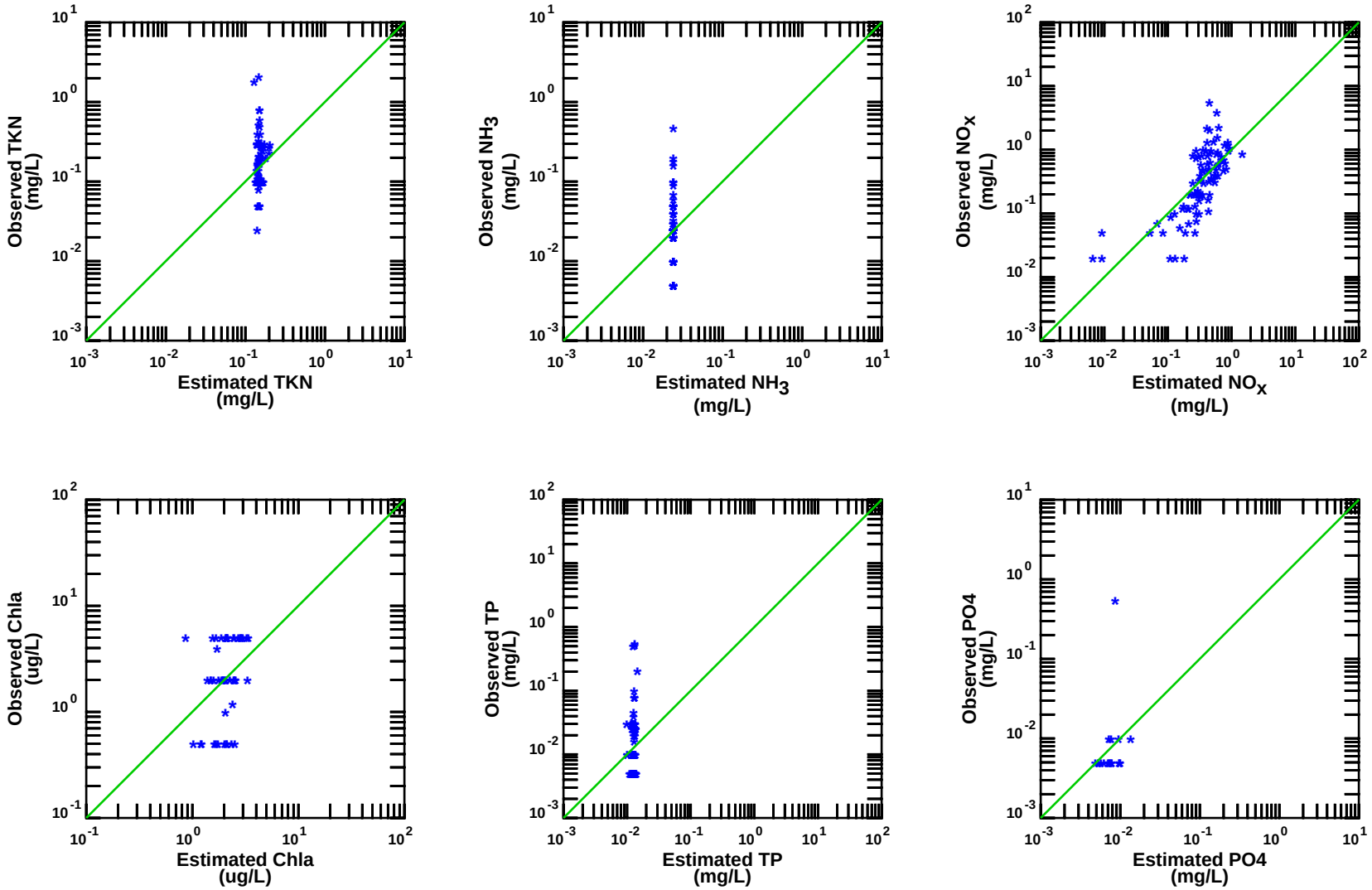






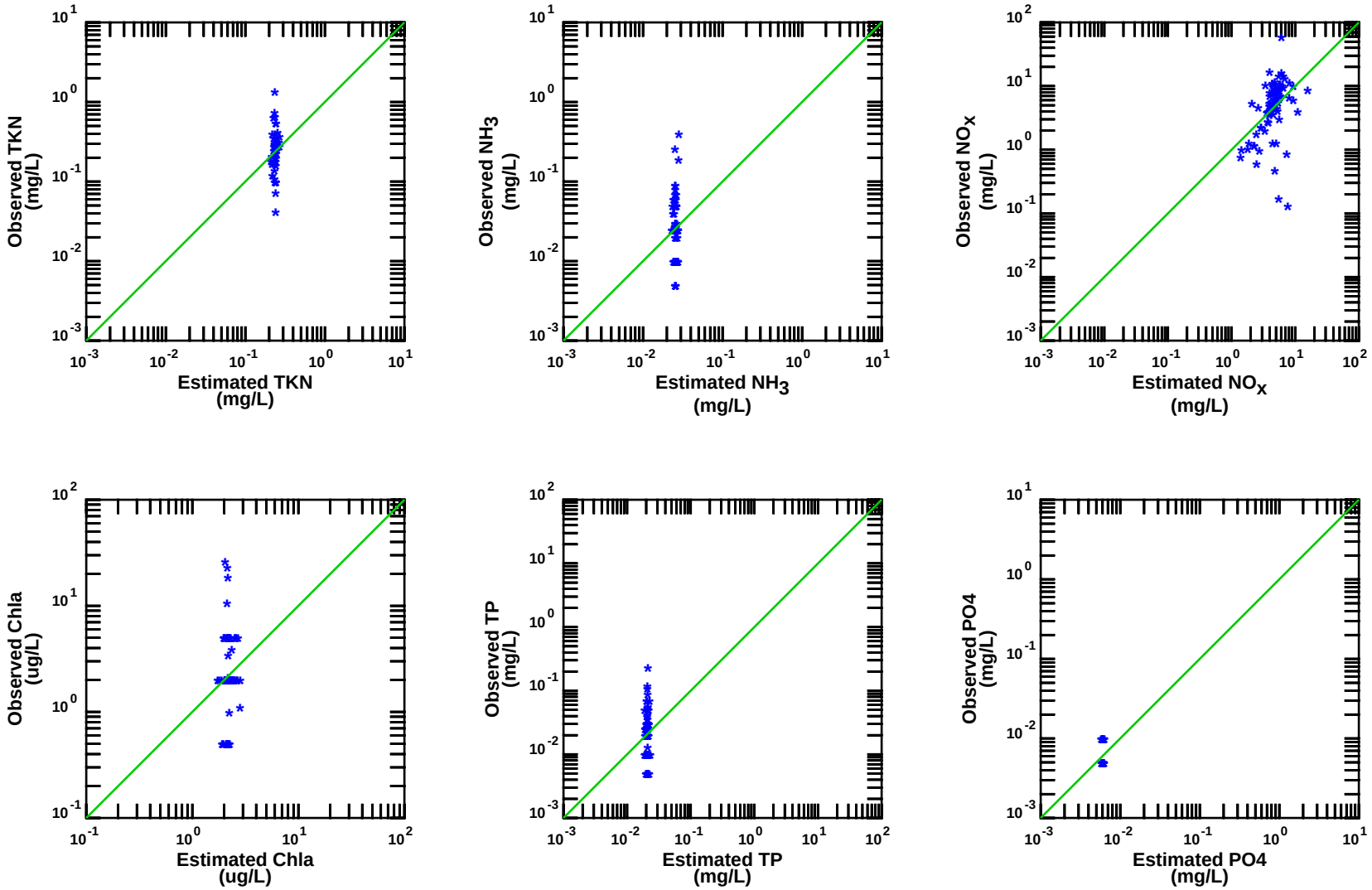
Observed Data vs. Estimated Data, Station 20773

Nueces Tributaries, Texas (1970-2014)



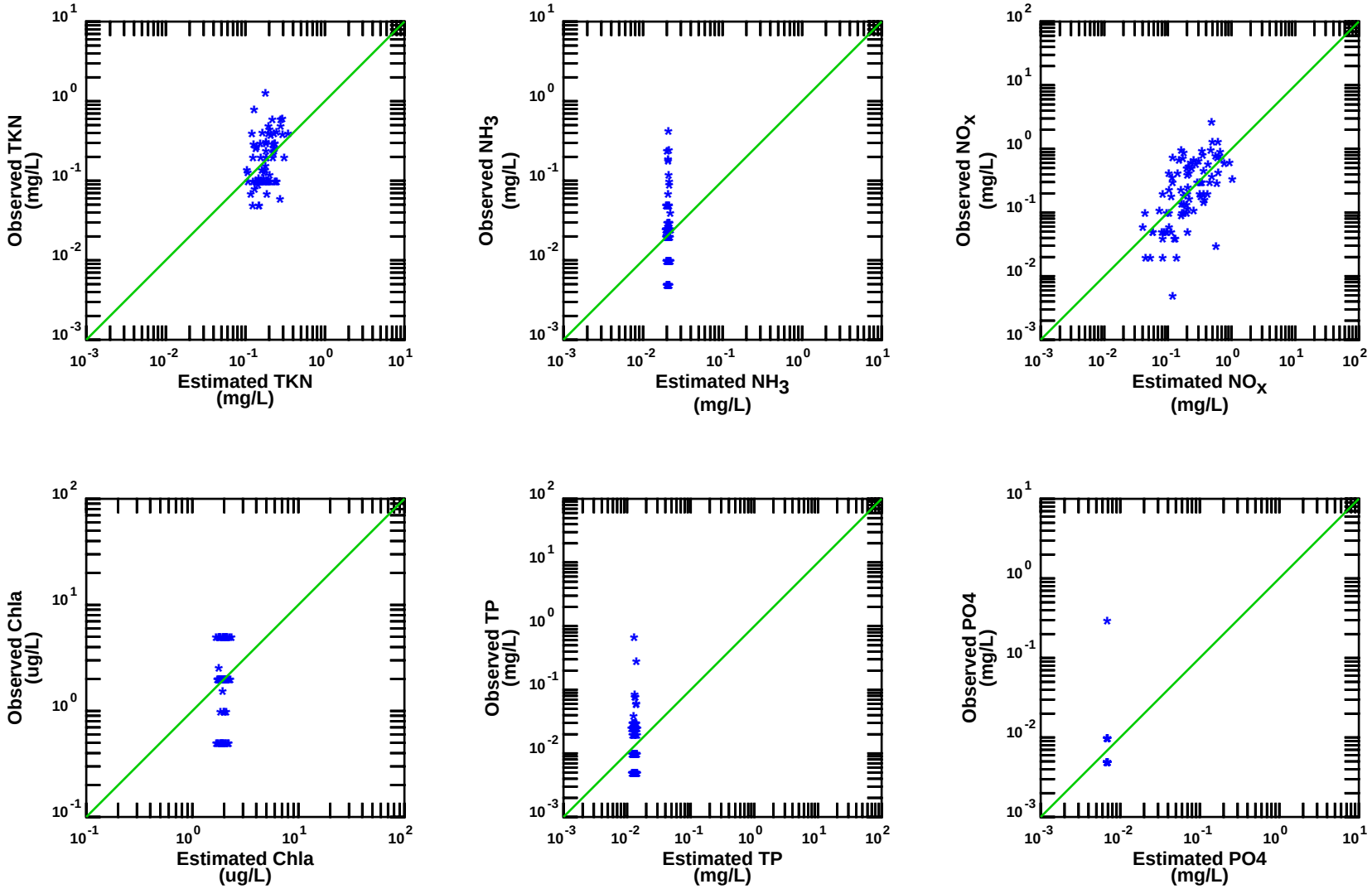
Observed Data vs. Estimated Data, Station 12994

Nueces Tributaries, Texas (1970-2014)



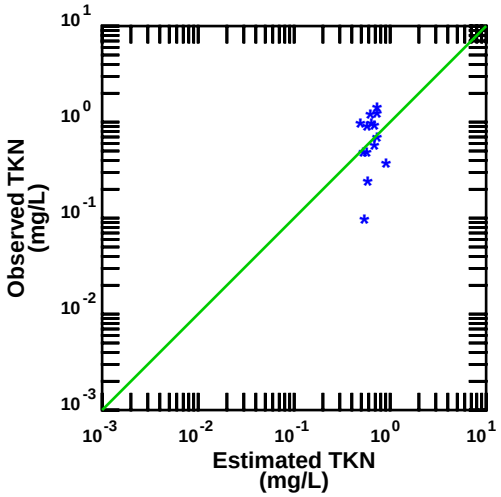
Observed Data vs. Estimated Data, Station 12993

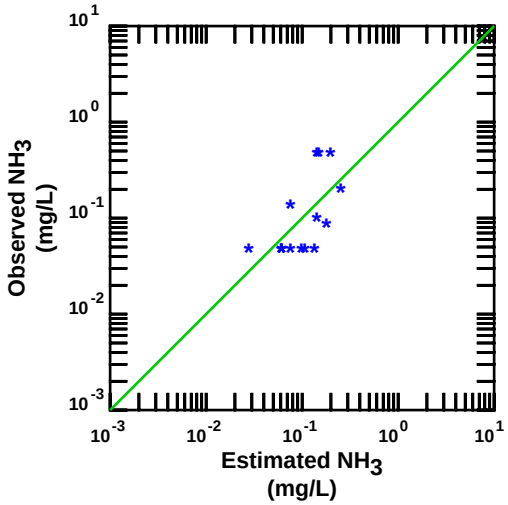
Nueces Tributaries, Texas (1970-2014)

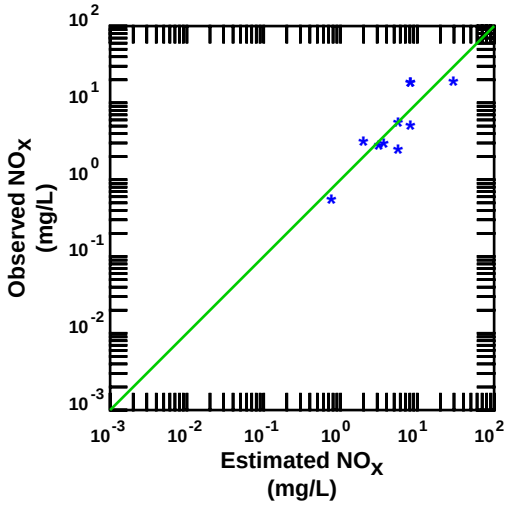


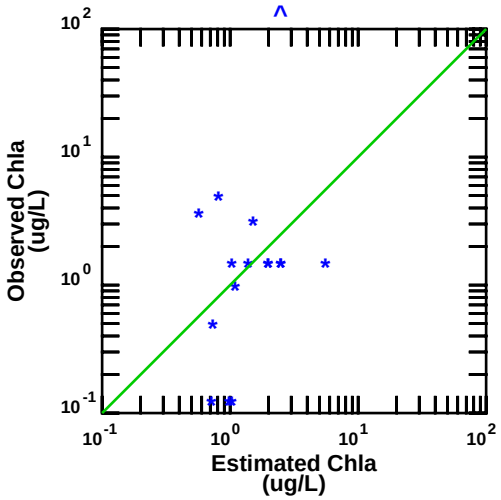
Observed Data vs. Estimated Data, Station 13013

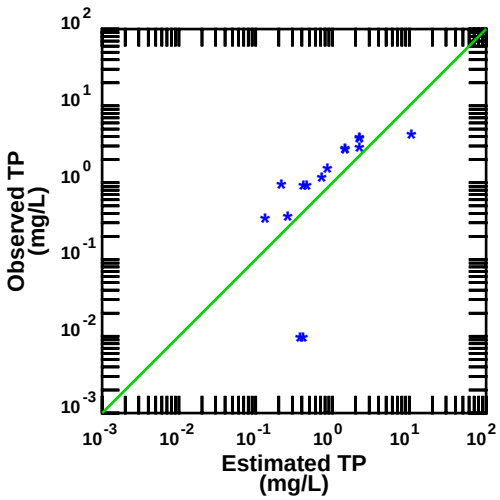
Nueces Tributaries, Texas (1970-2014)





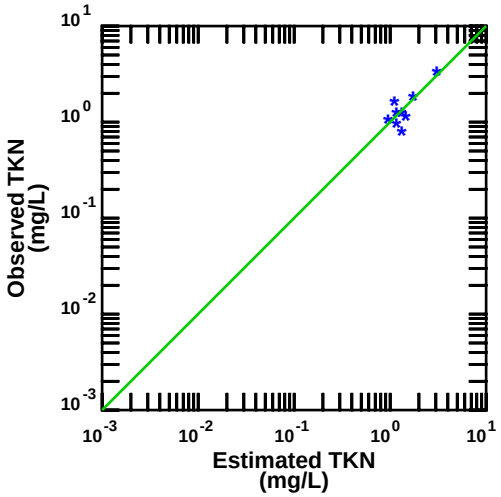


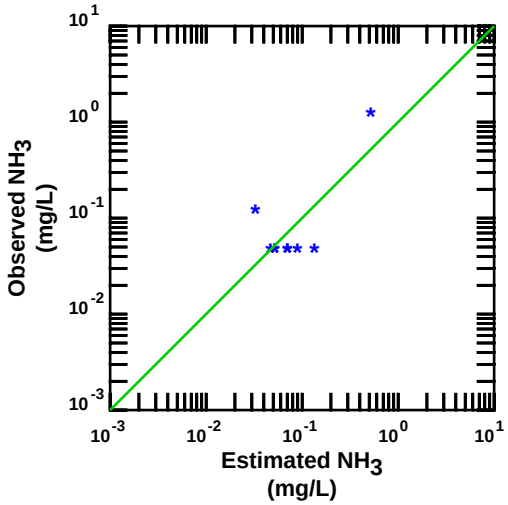


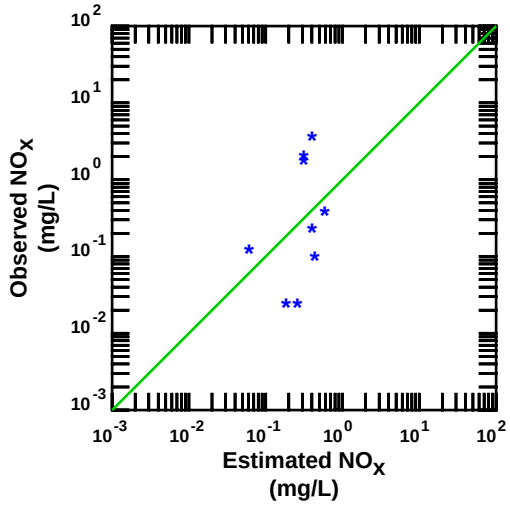


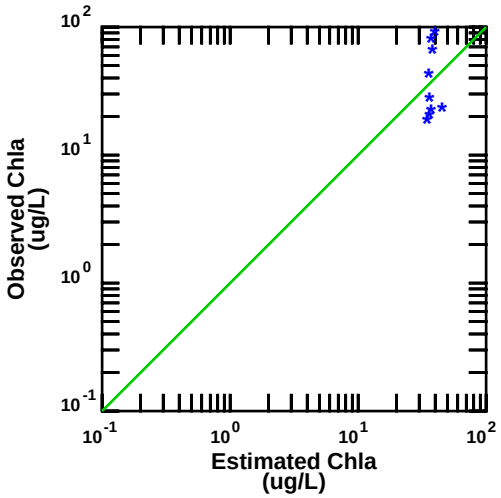
Observed Data vs. Estimated Data, Station 17900

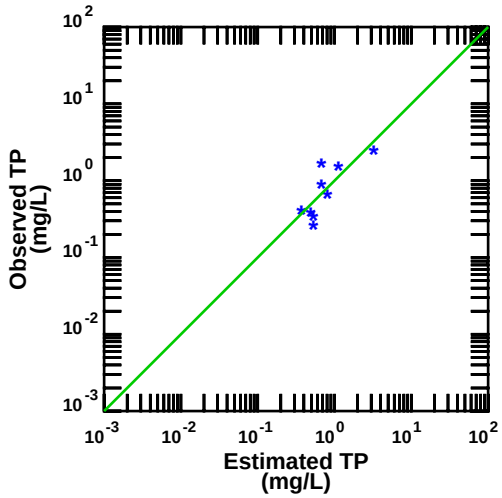
Nueces Tributaries, Texas (1970-2014)





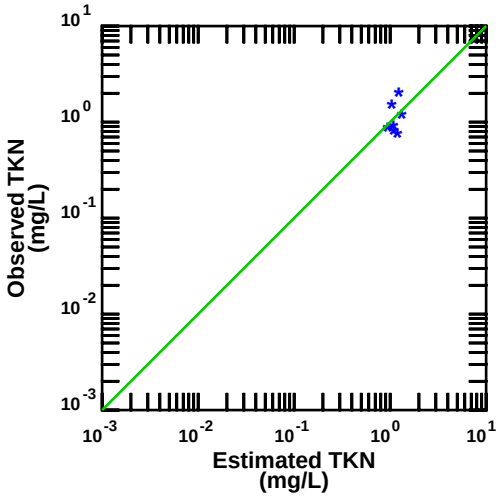


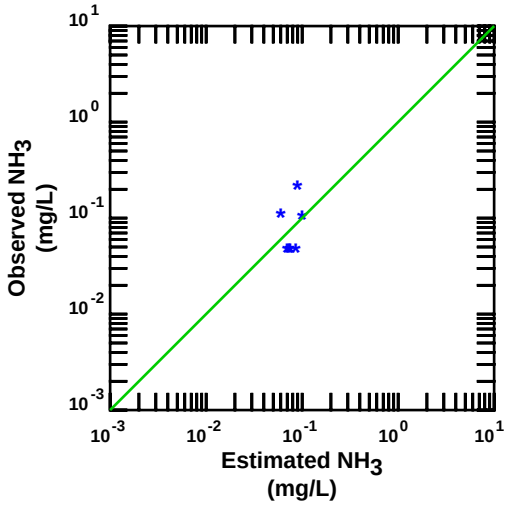


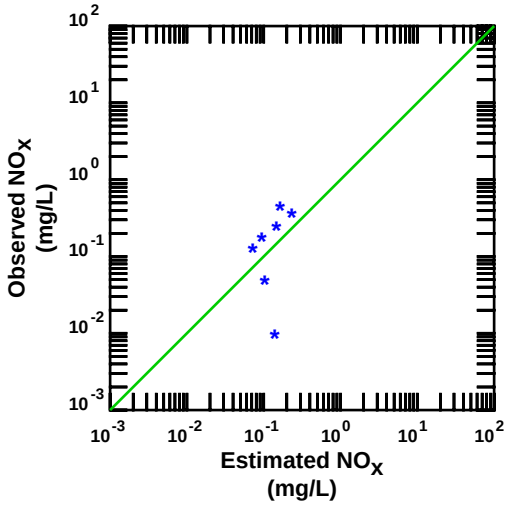


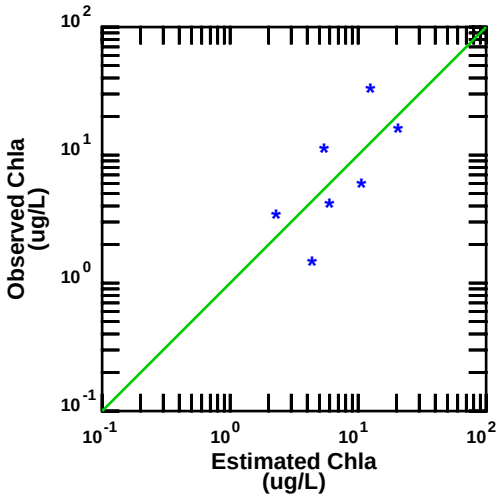
Observed Data vs. Estimated Data, Station 20762

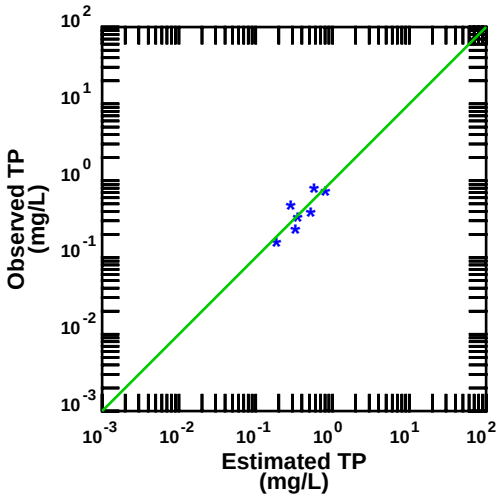
Nueces Tributaries, Texas (1970-2014)





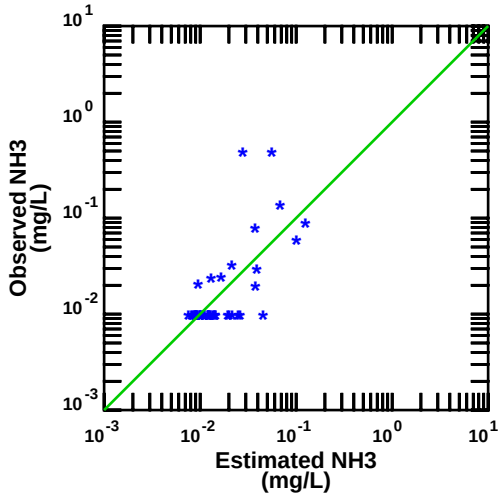


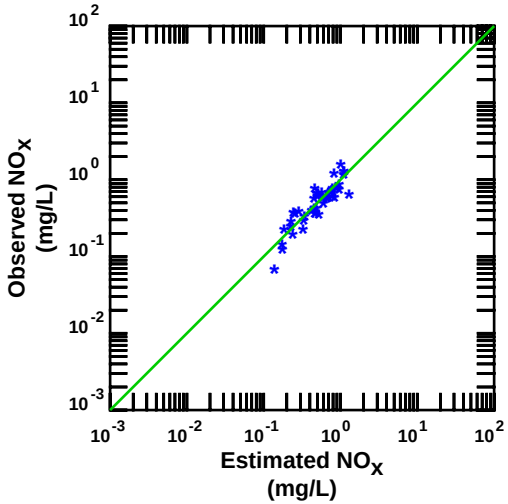


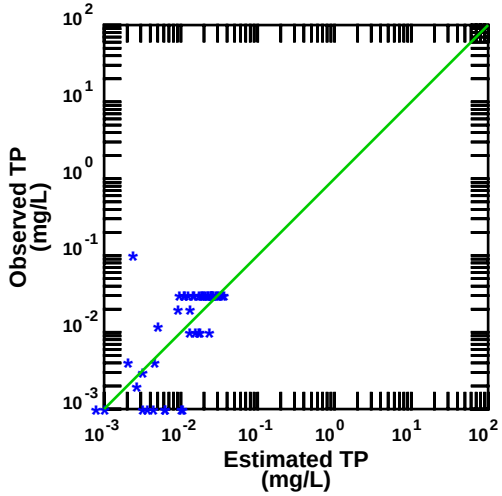


Observed Data vs. Estimated Data, Station 20764

Nueces Tributaries, Texas (1970-2014)

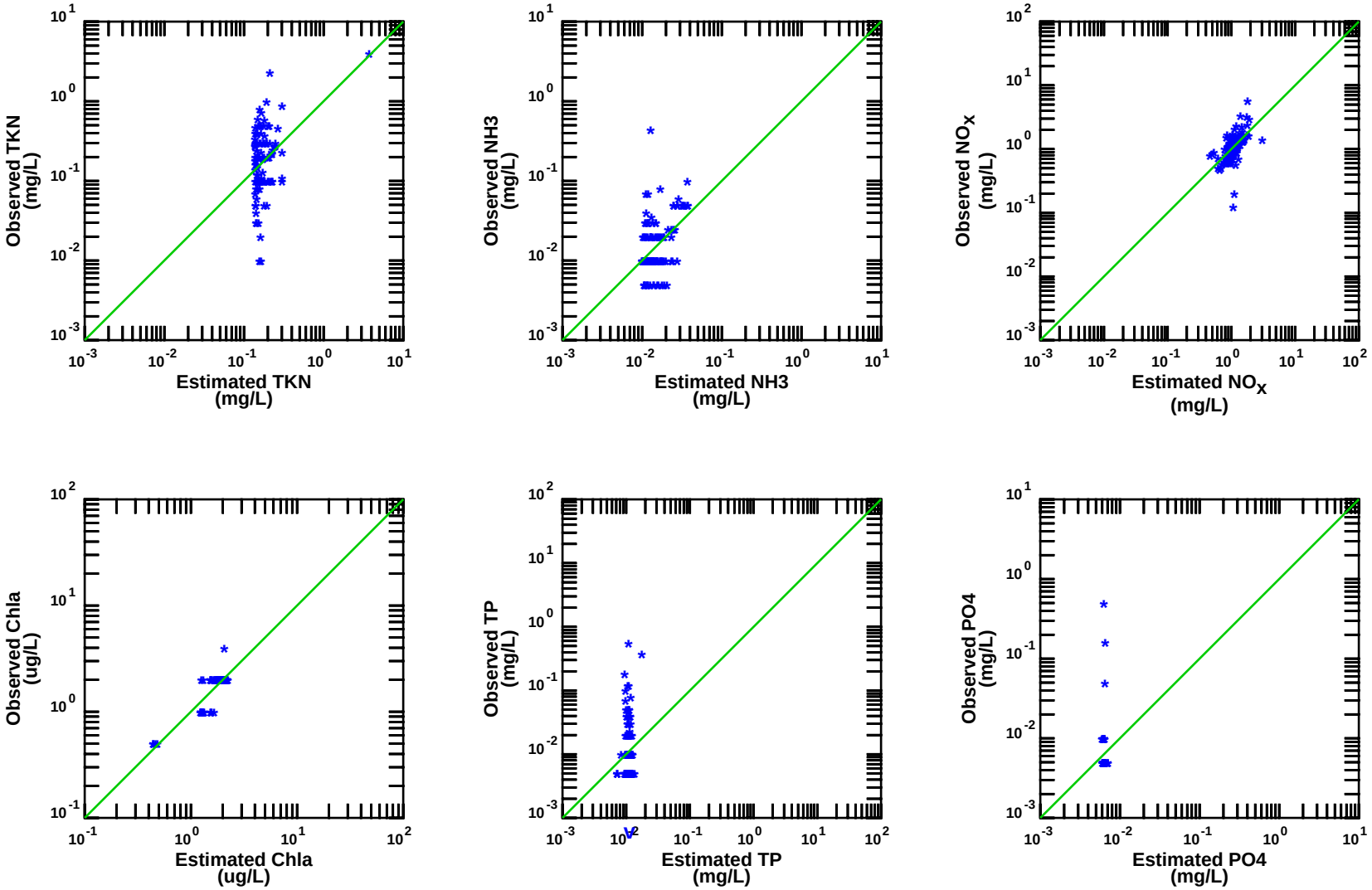






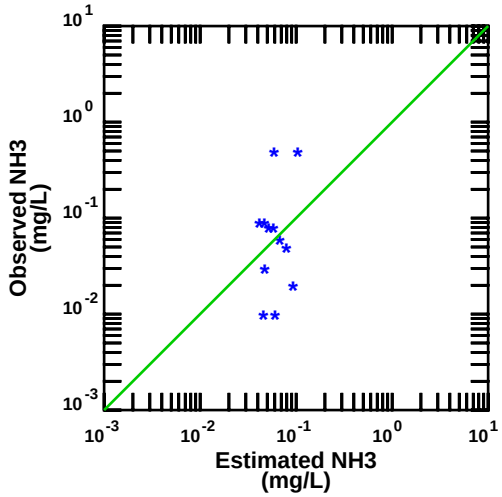
Observed Data vs. LOADEST Estimated Concentration, Station 13005

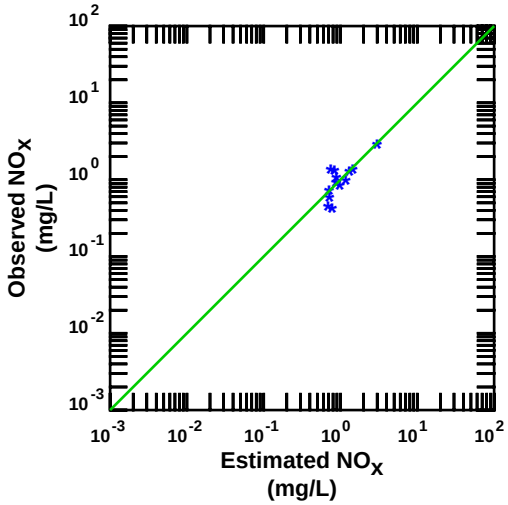
Nueces Tributaries, Texas (1970-2014)

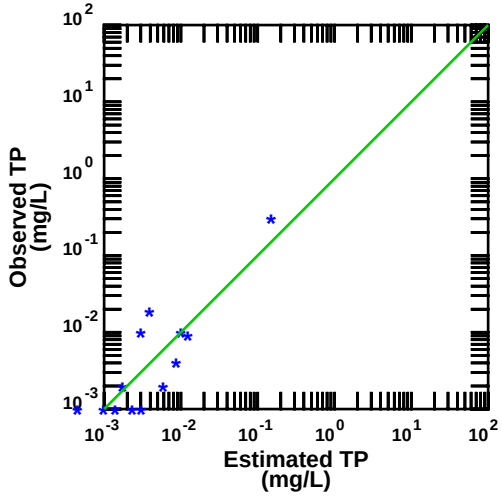


Observed Data vs. LOADEST Estimated Concentration, Station 12999

Nueces Tributaries, Texas (1970-2014)

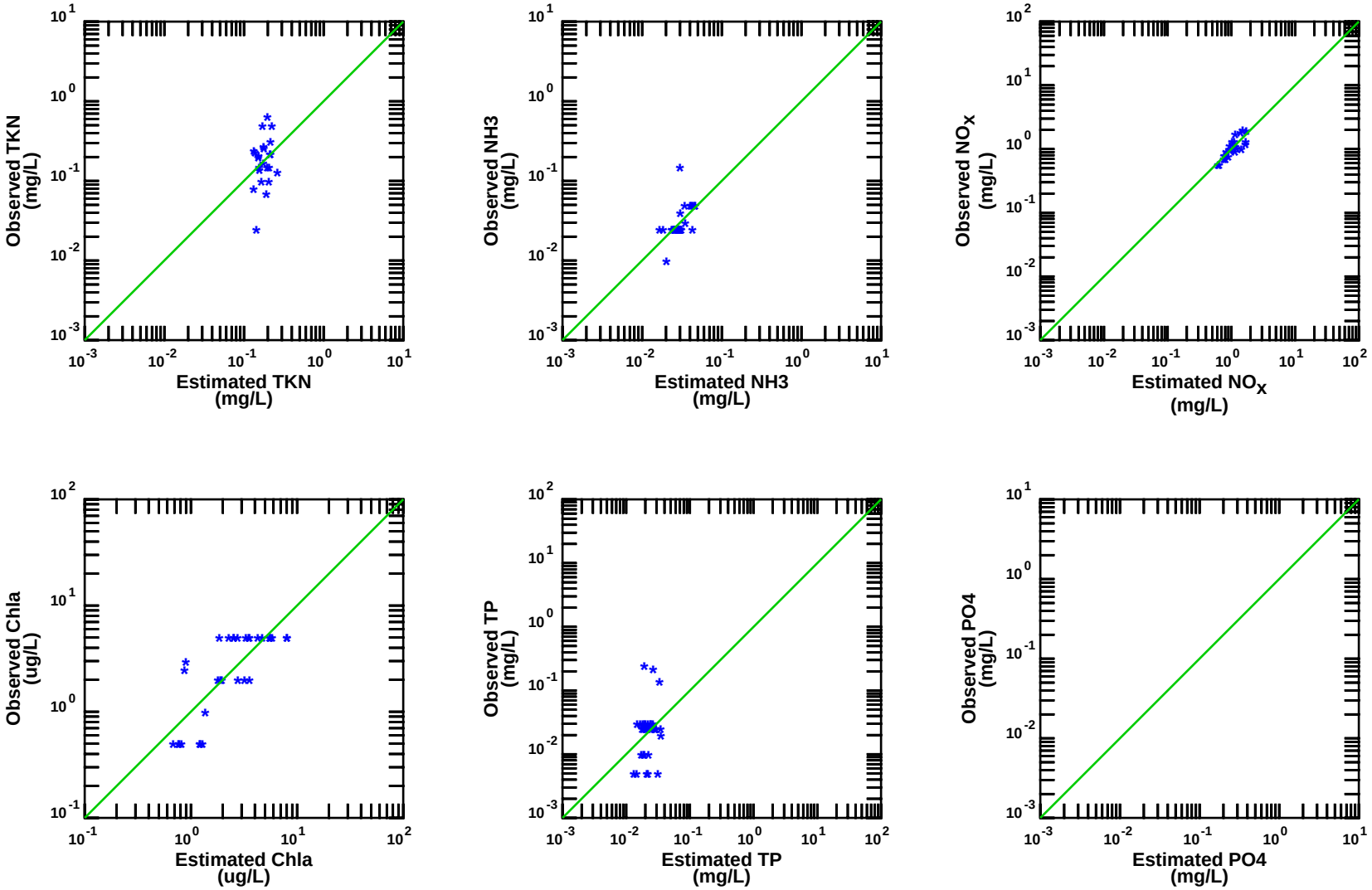






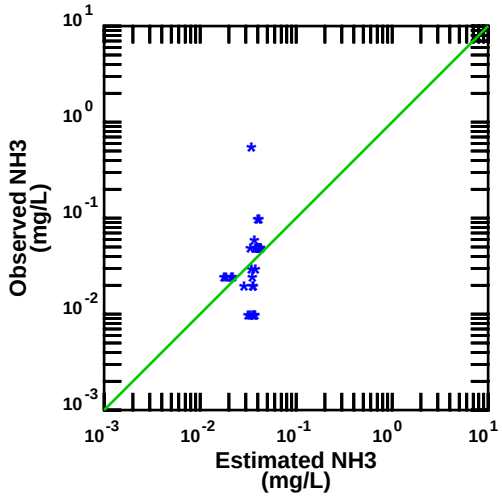
Observed Data vs. LOADEST Estimated Concentration, Station 12997

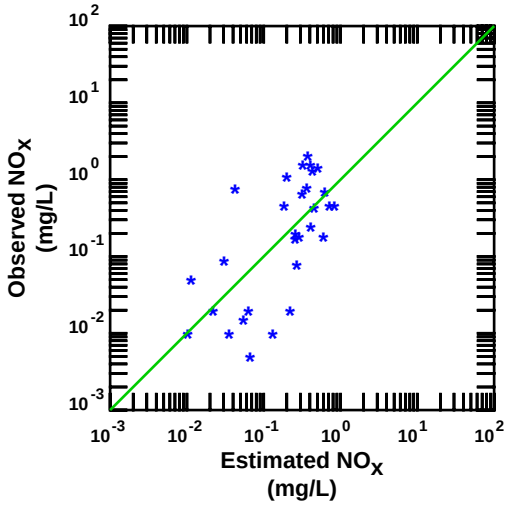
Nueces Tributaries, Texas (1970-2014)

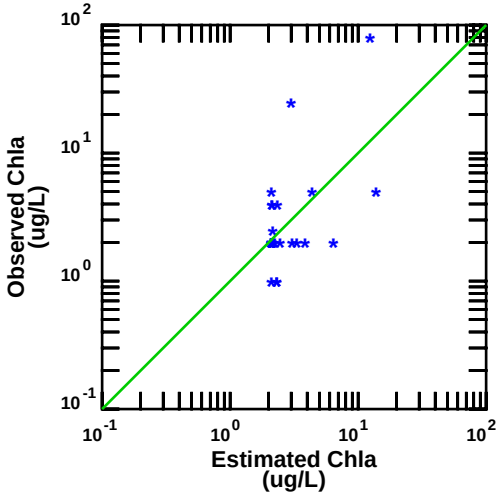


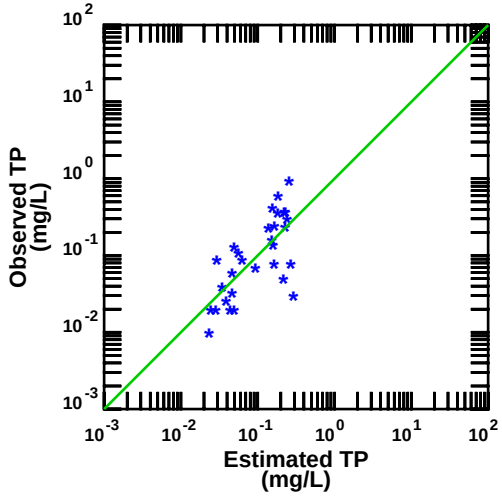
Observed Data vs. LOADEST Estimated Concentration, Station 12996

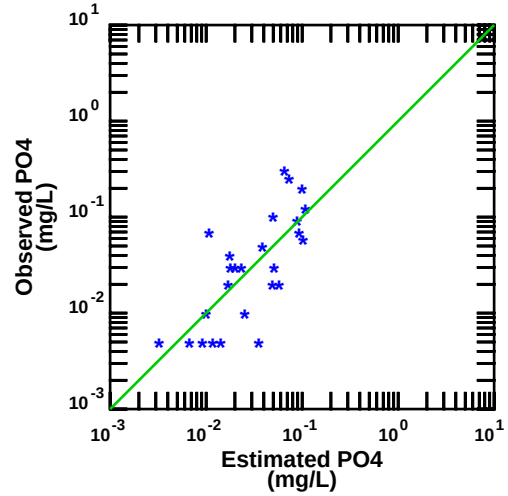
Nueces Tributaries, Texas (1970-2014)





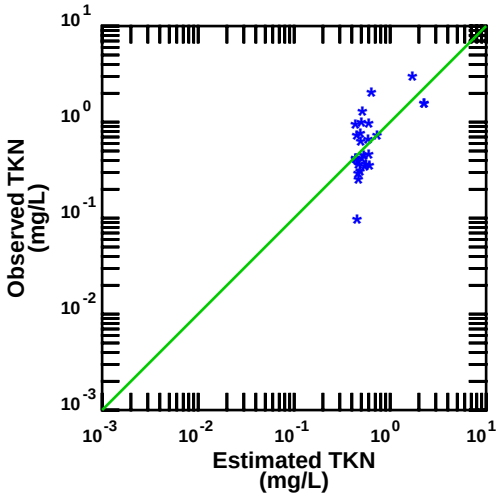


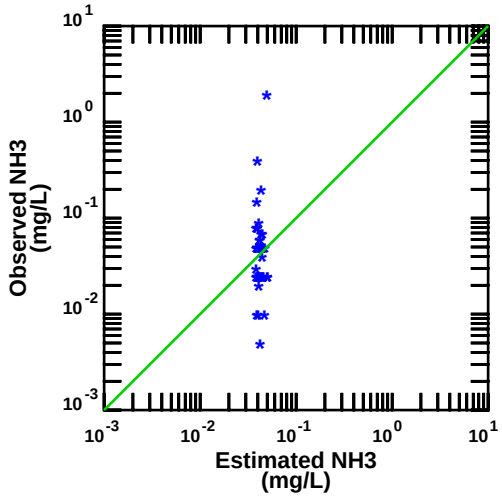


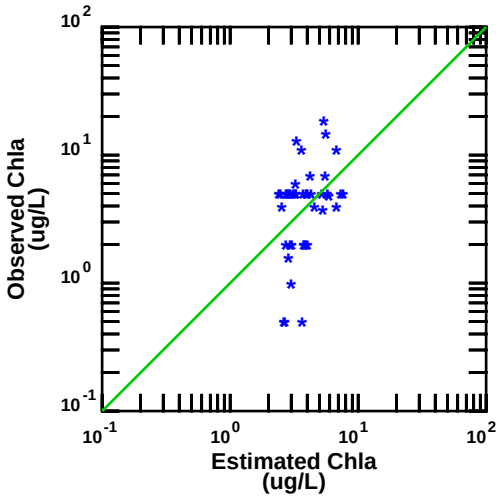


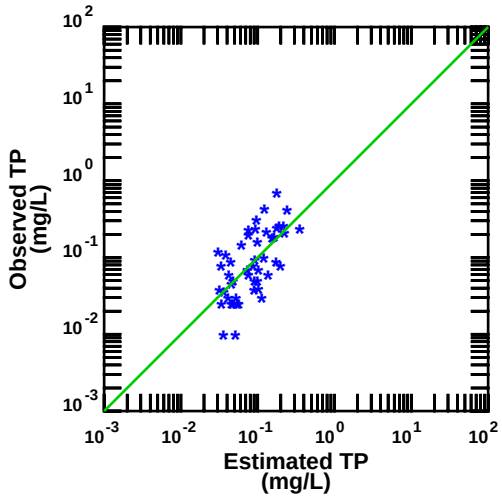
Observed Data vs. LOADEST Estimated Concentration, Station 12976

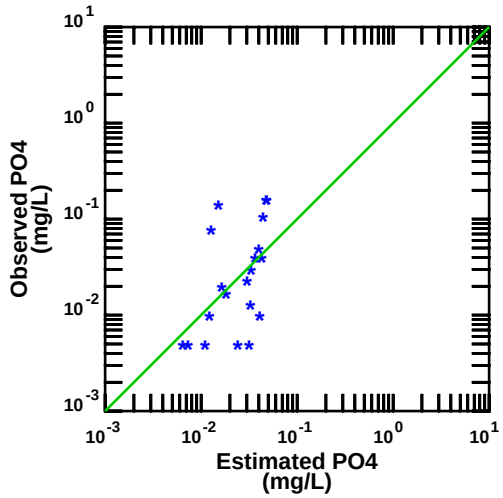
Nueces Tributaries, Texas (1970-2014)





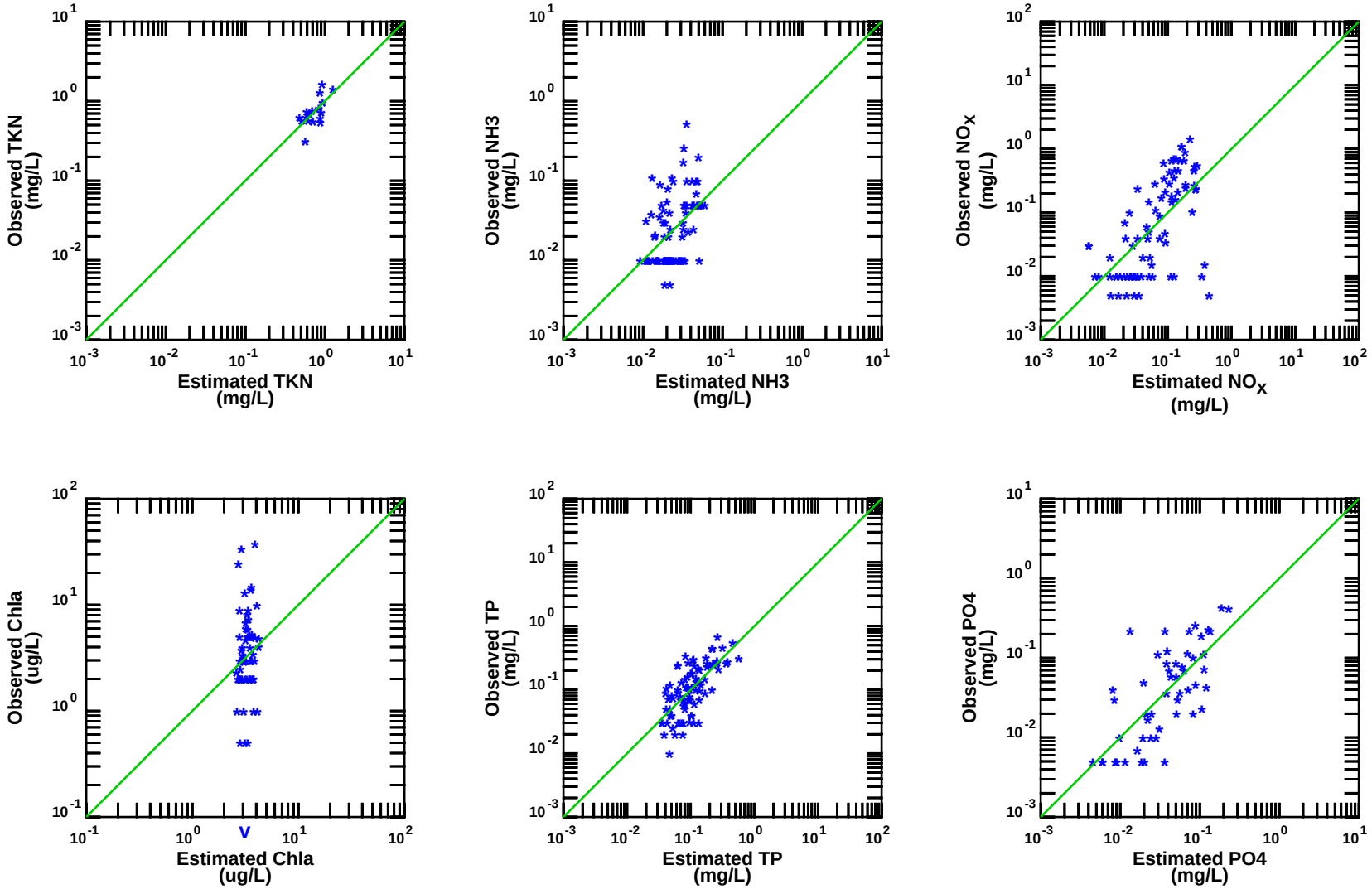






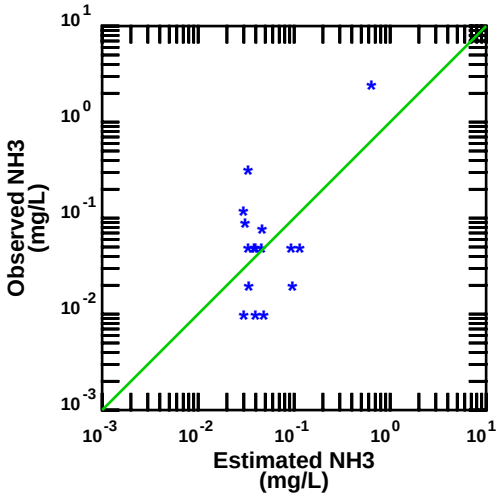
Observed Data vs. LOADEST Estimated Concentration, Station 12975

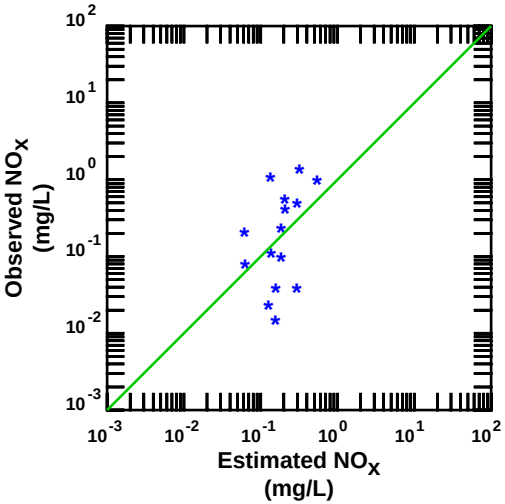
Nueces Tributaries, Texas (1970-2014)

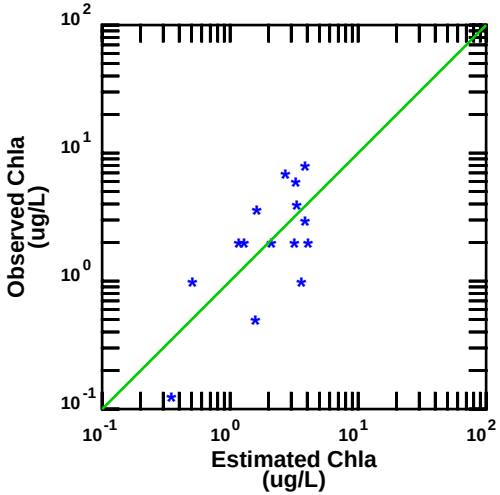


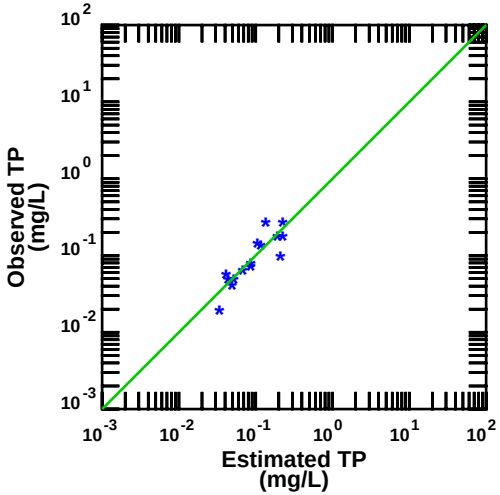
Observed Data vs. LOADEST Estimated Concentration, Station 12973

Nueces Tributaries, Texas (1970-2014)



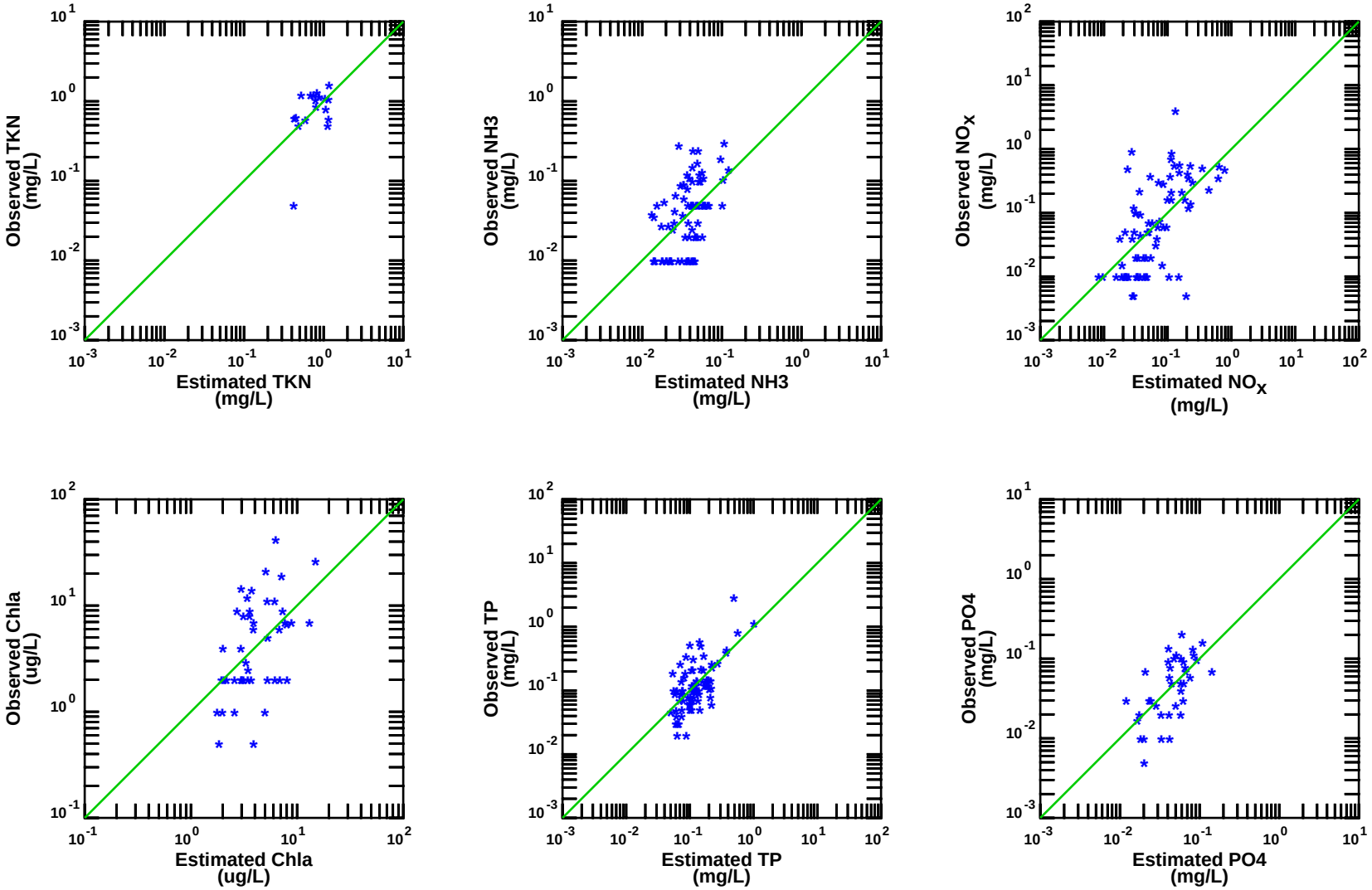






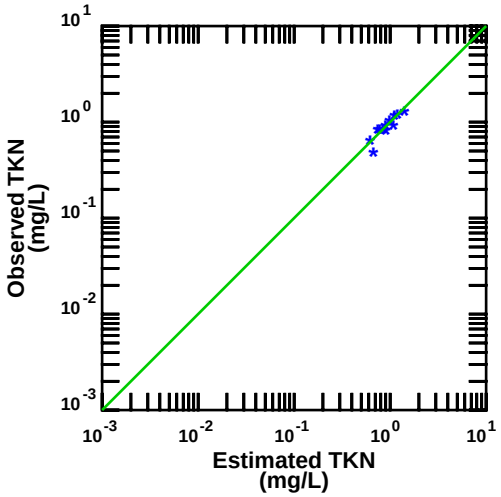
Observed Data vs. LOADEST Estimated Concentration, Station 12972

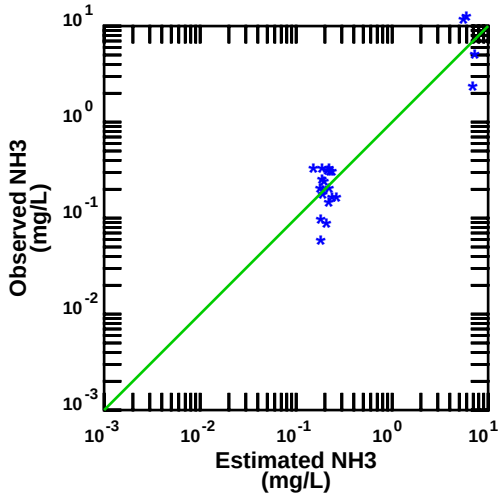
Nueces Tributaries, Texas (1970-2014)

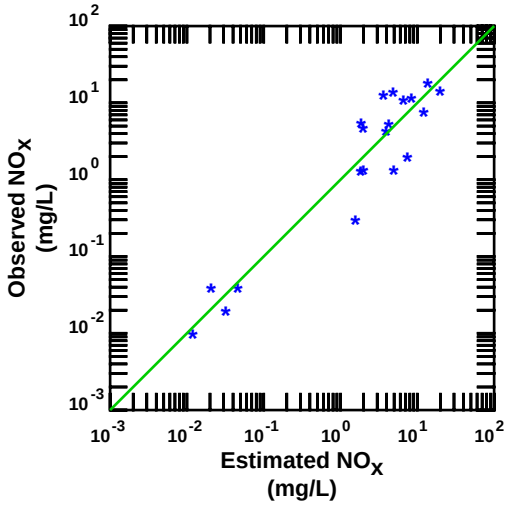


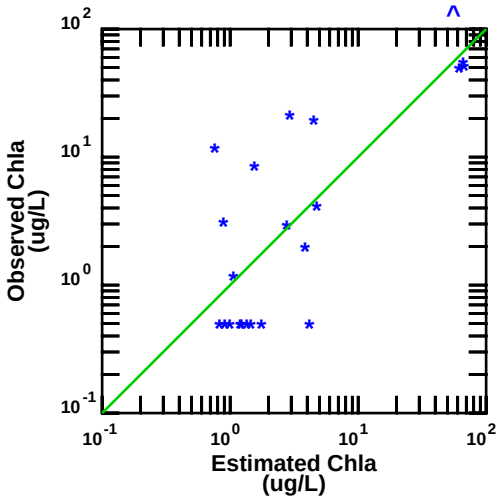
Observed Data vs. LOADEST Estimated Concentration, Station 12983

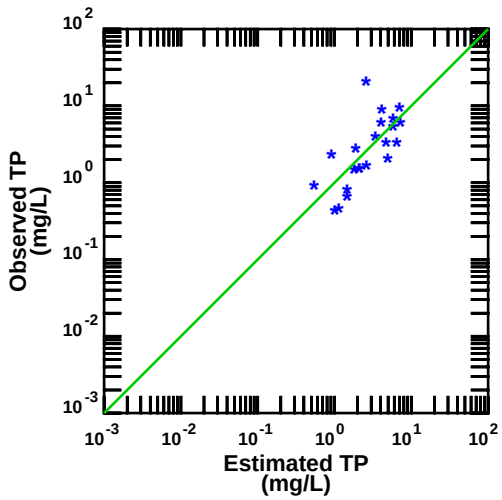
Nueces Tributaries, Texas (1970-2014)





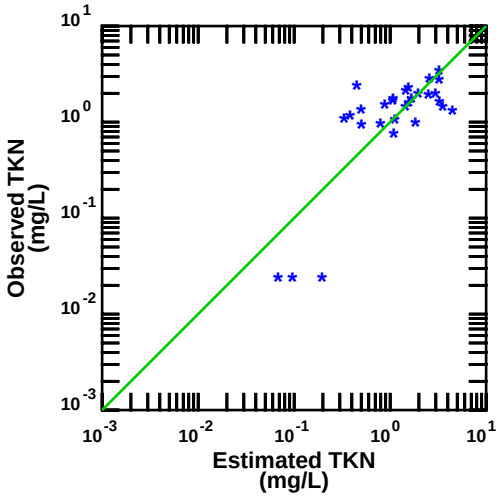


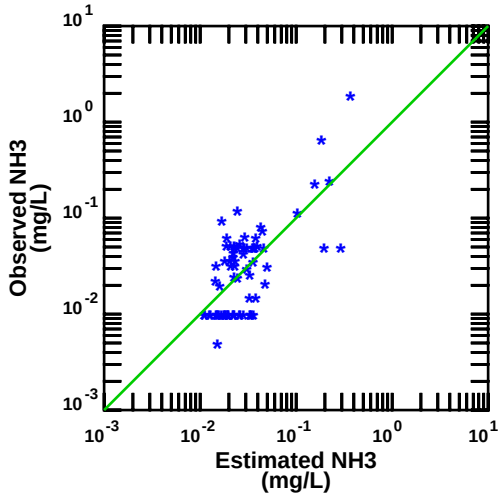


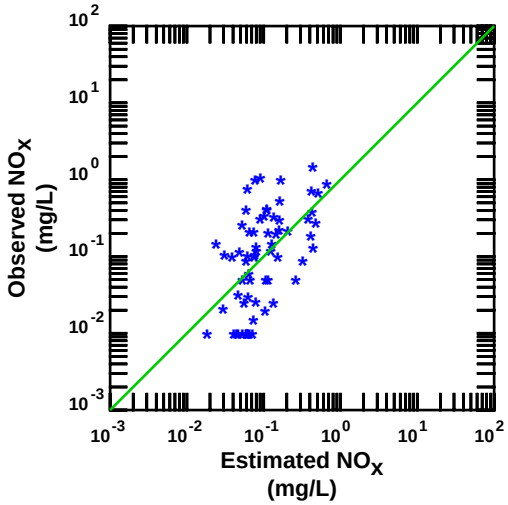


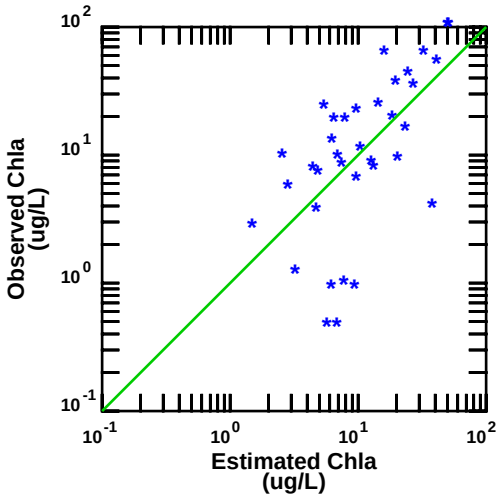
Observed Data vs. LOADEST Estimated Concentration, Station 12981

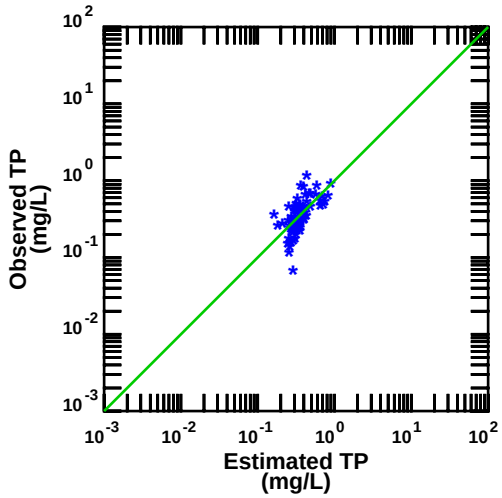
Nueces Tributaries, Texas (1970-2014)





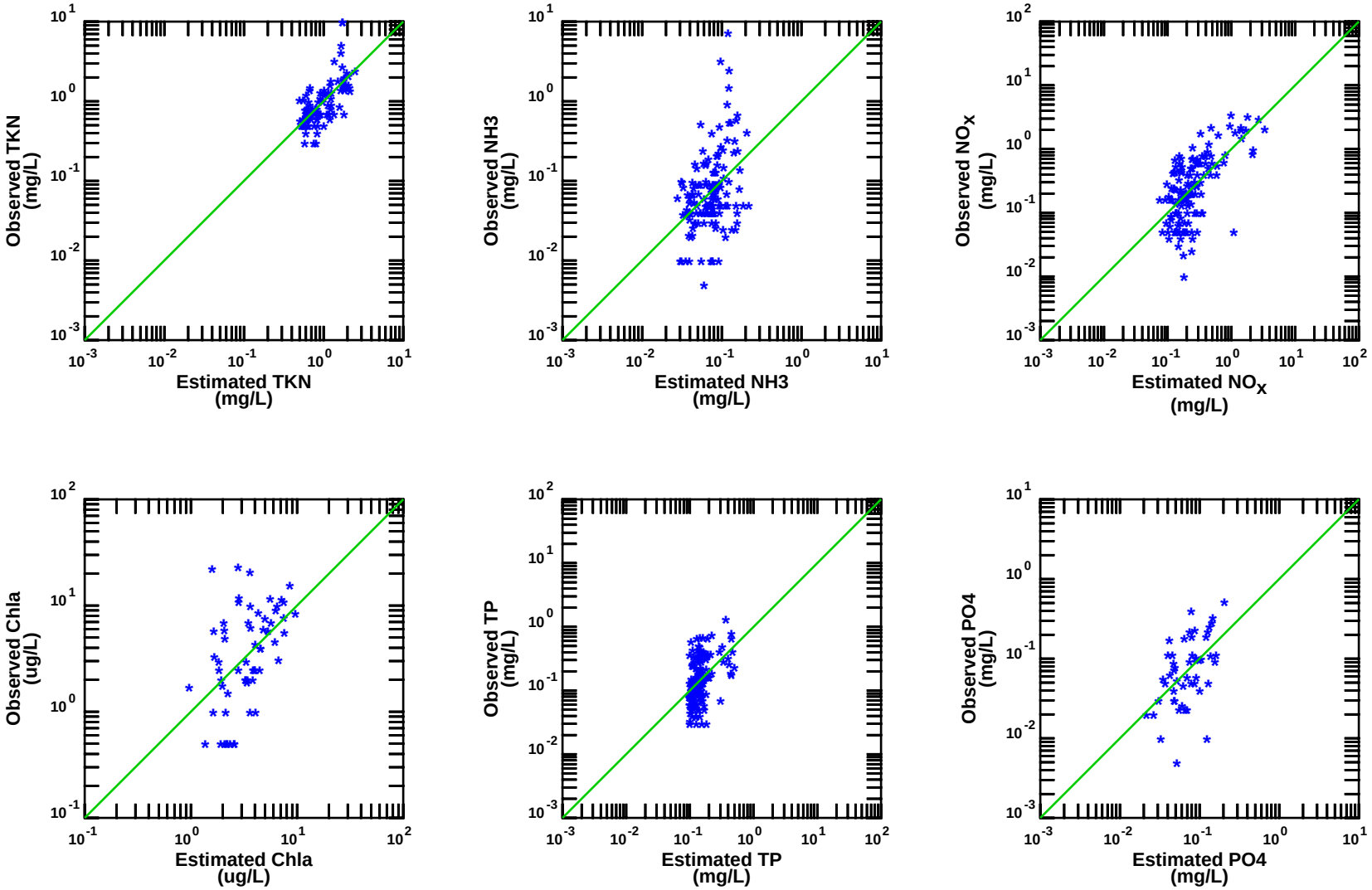






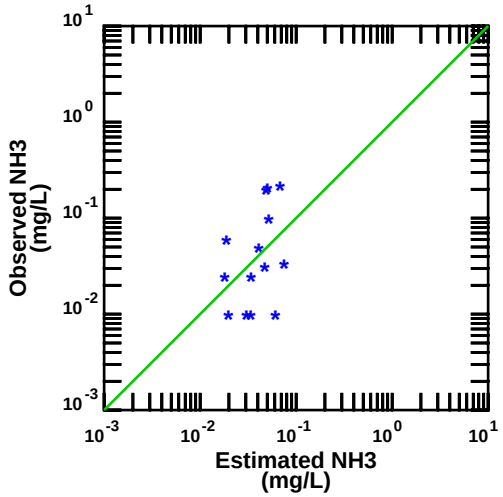
Observed Data vs. LOADEST Estimated Concentration, Station 12980

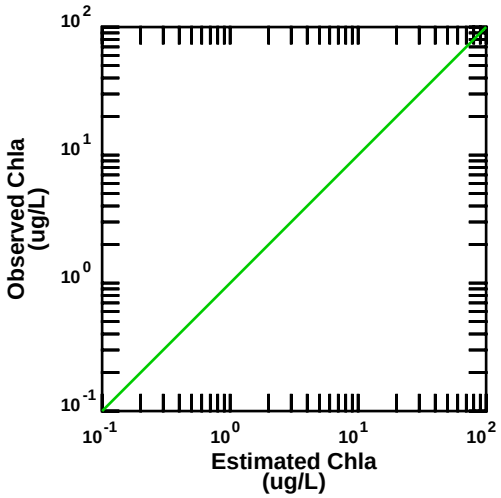
Nueces Tributaries, Texas (1970-2014)

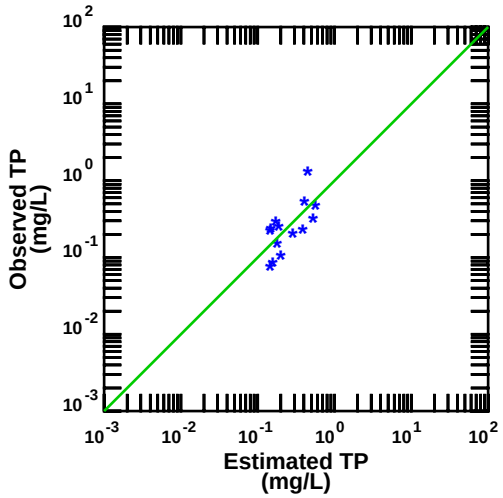


Observed Data vs. LOADEST Estimated Concentration, Station 12979

Nueces Tributaries, Texas (1970-2014)

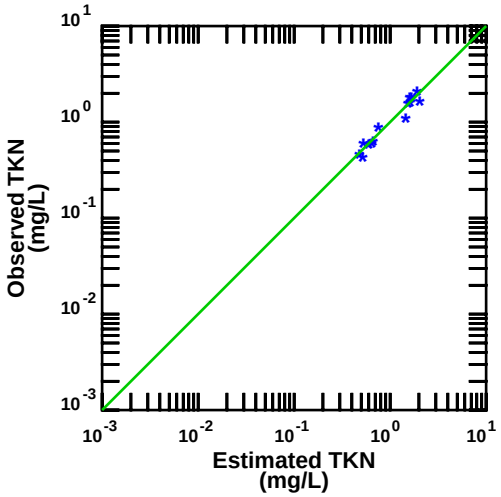


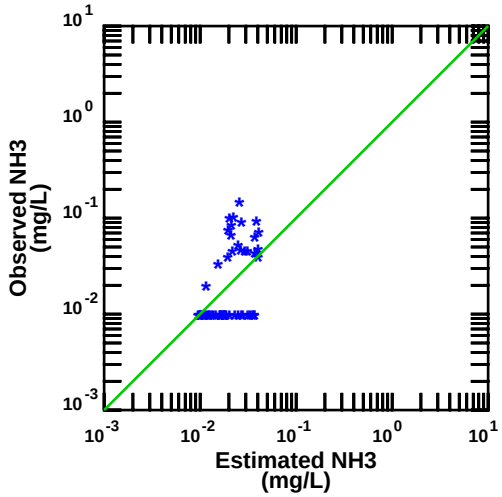


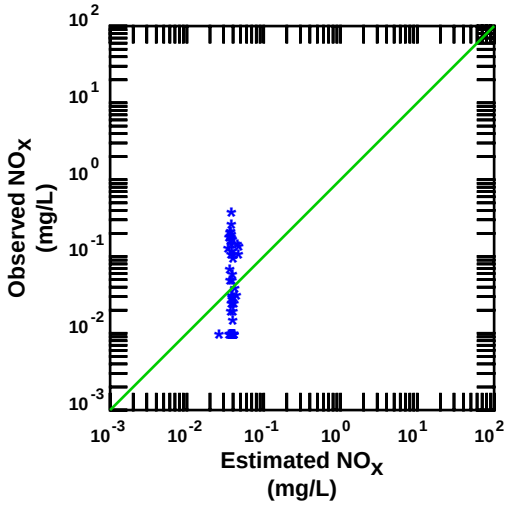


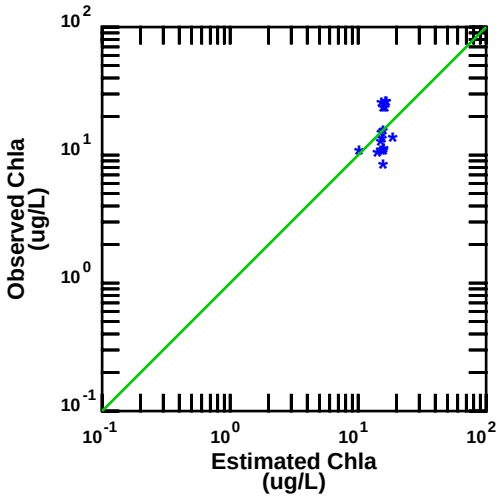
Observed Data vs. LOADEST Estimated Concentration, Station 12978

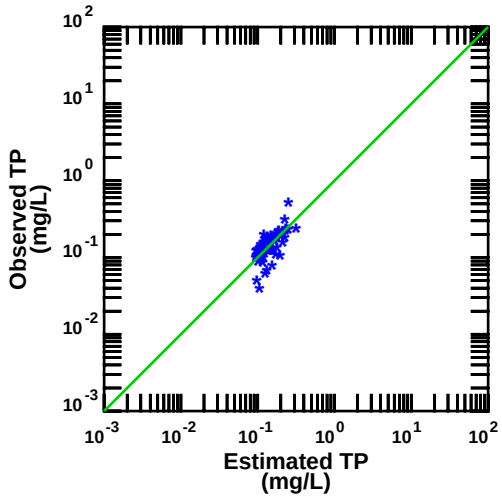
Nueces Tributaries, Texas (1970-2014)





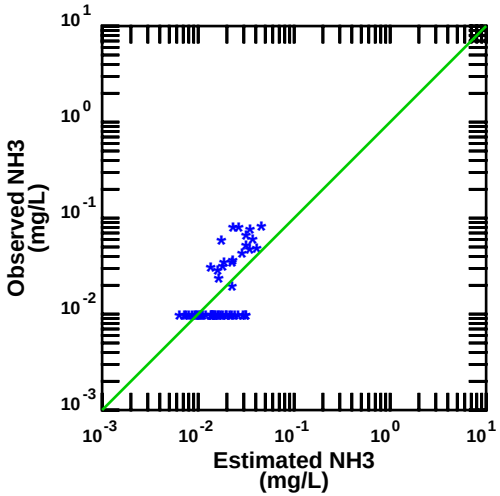


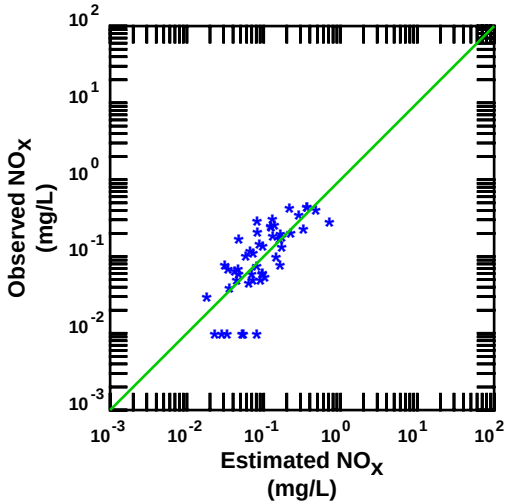


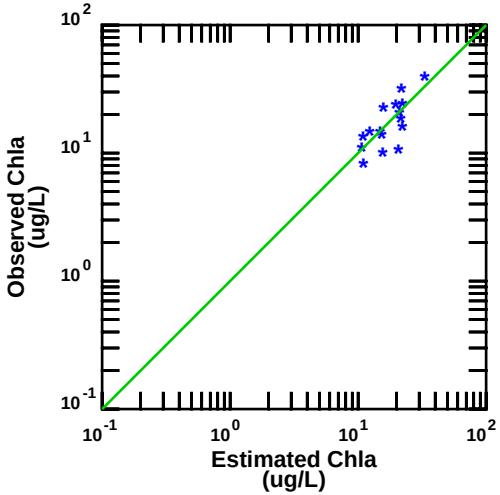


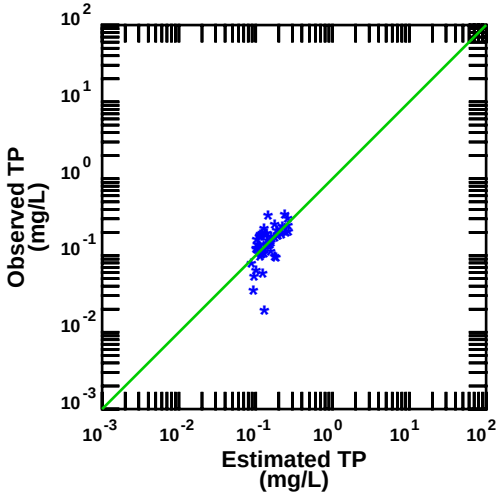
Observed Data vs. LOADEST Estimated Concentration, Station 12965

Nueces Tributaries, Texas (1970-2014)



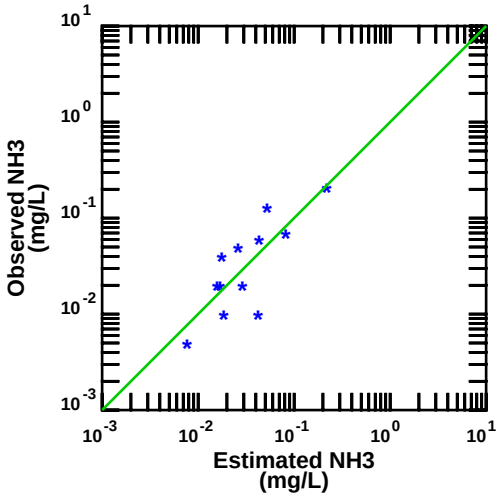


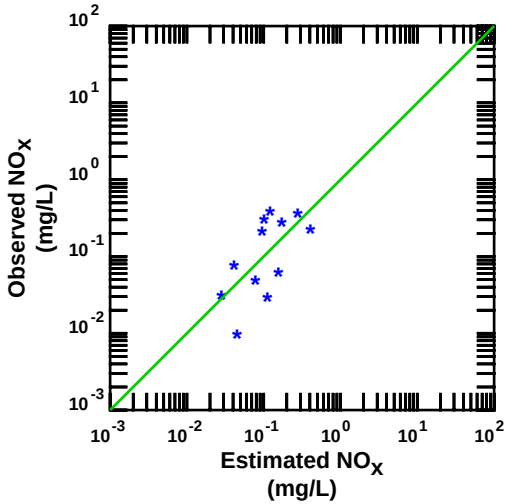


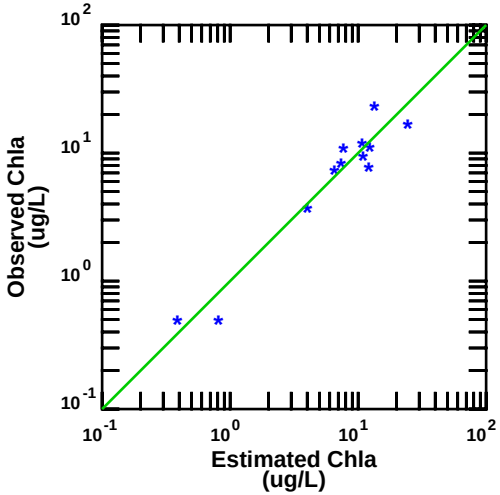


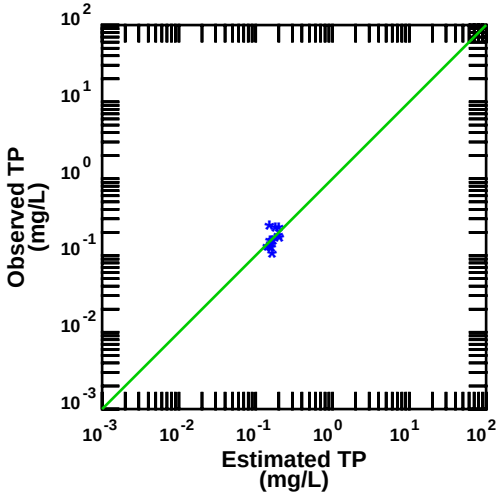
Observed Data vs. LOADEST Estimated Concentration, Station 12964

Nueces Tributaries, Texas (1970-2014)



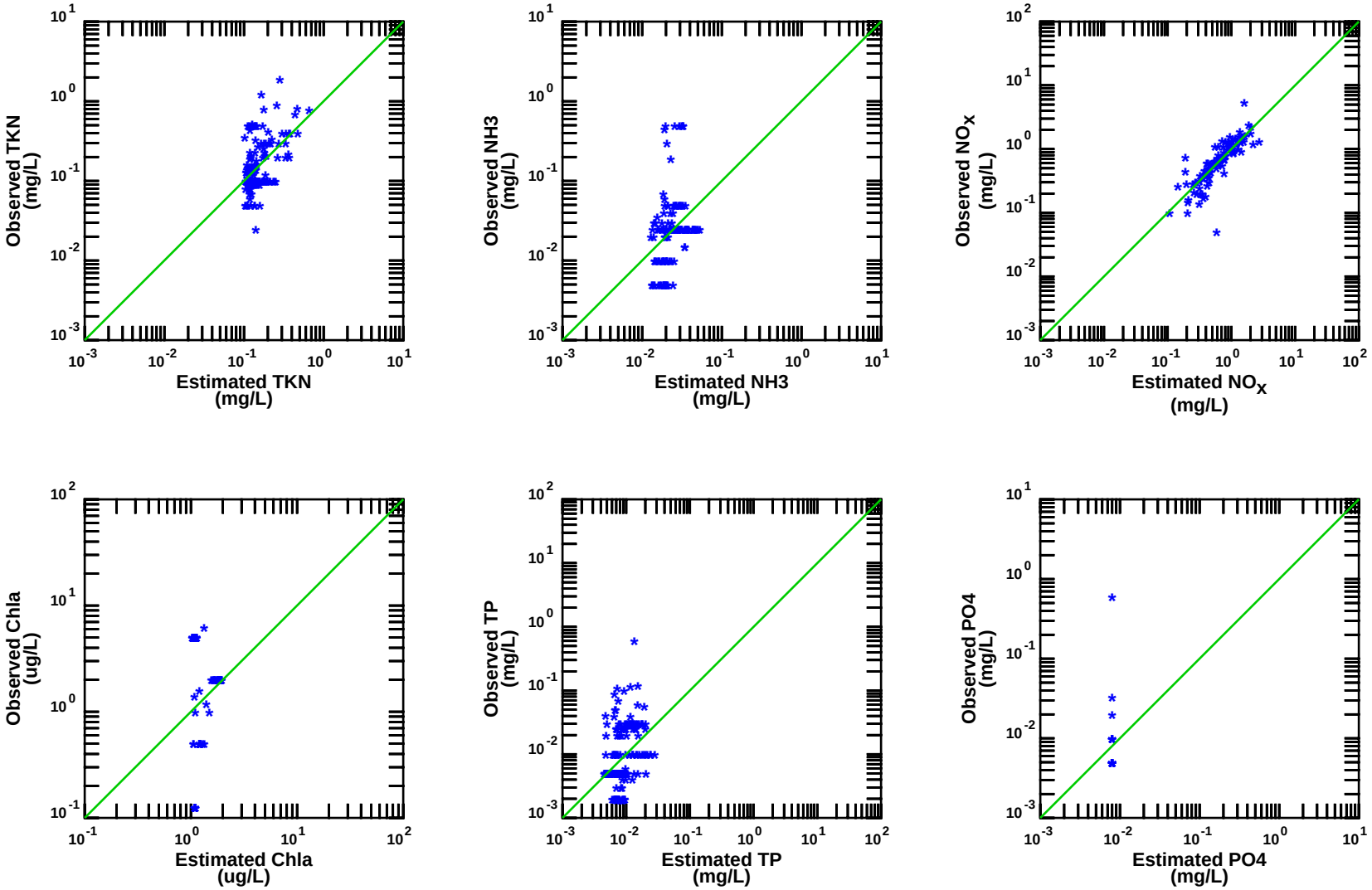






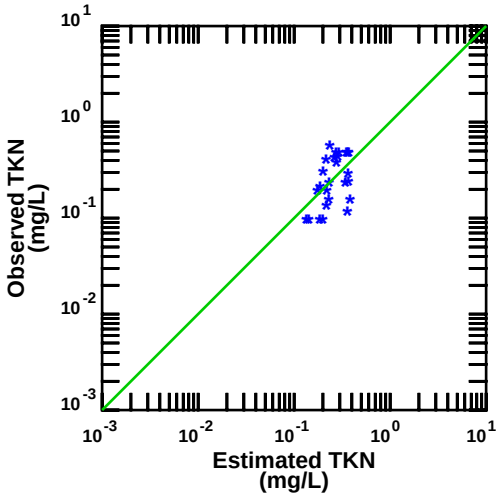
Observed Data vs. LOADEST Estimated Concentration, Station 12962

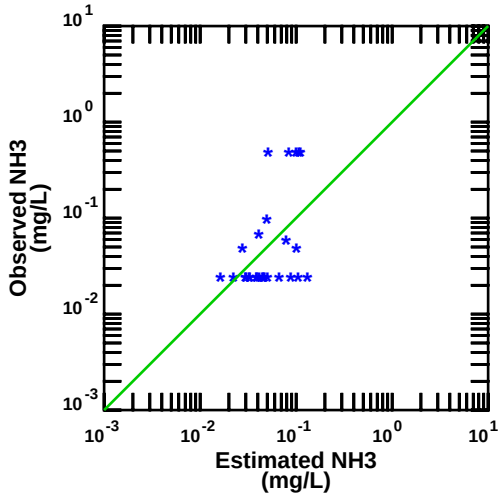
Nueces Tributaries, Texas (1970-2014)

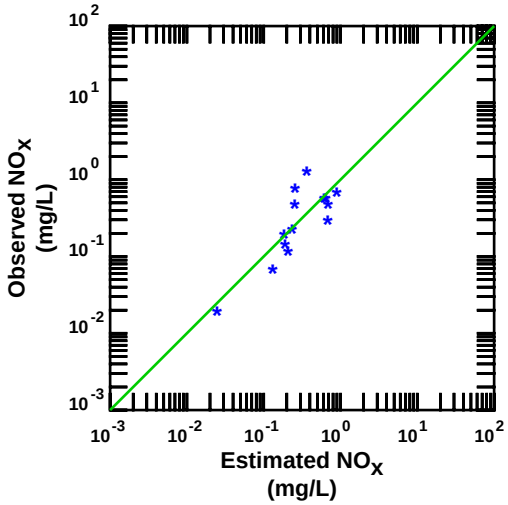


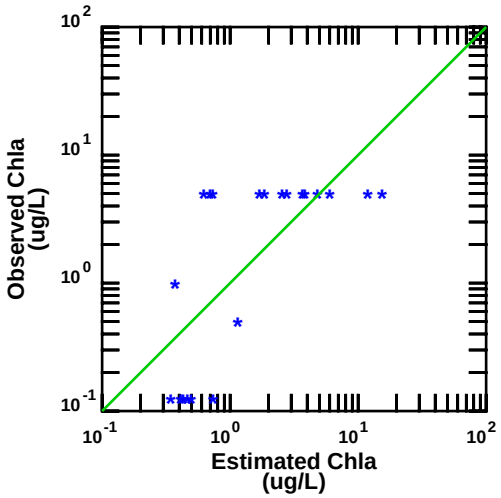
Observed Data vs. LOADEST Estimated Concentration, Station 13006

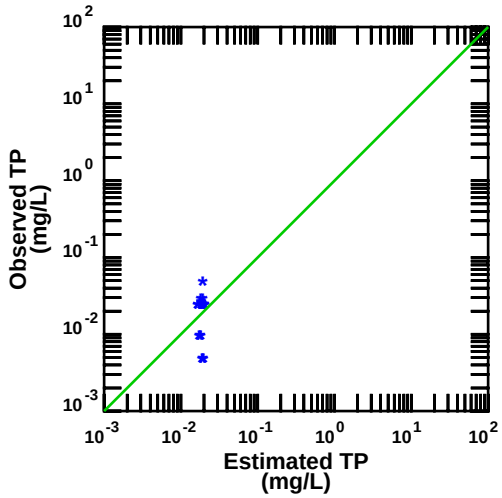
Nueces Tributaries, Texas (1970-2014)





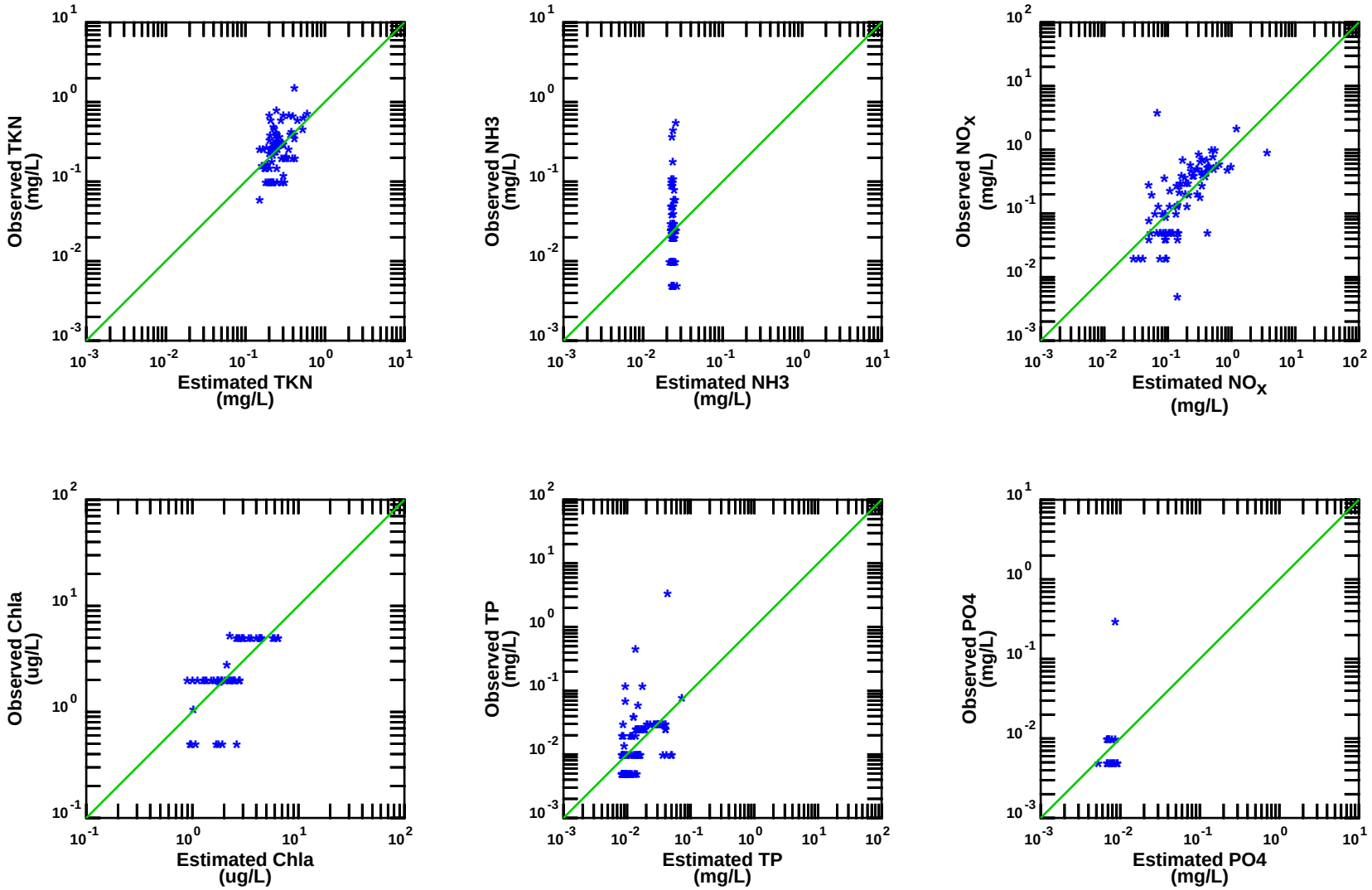






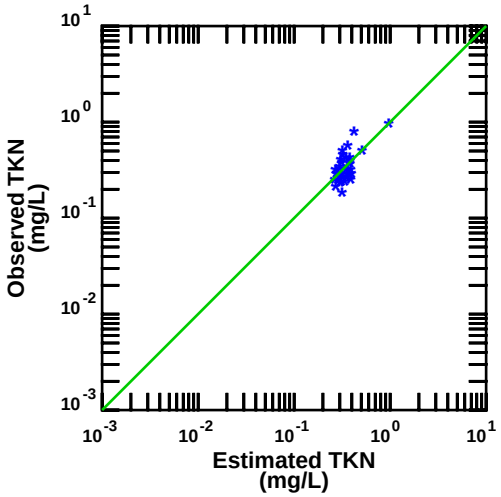
Observed Data vs. LOADEST Estimated Concentration, Station 13007

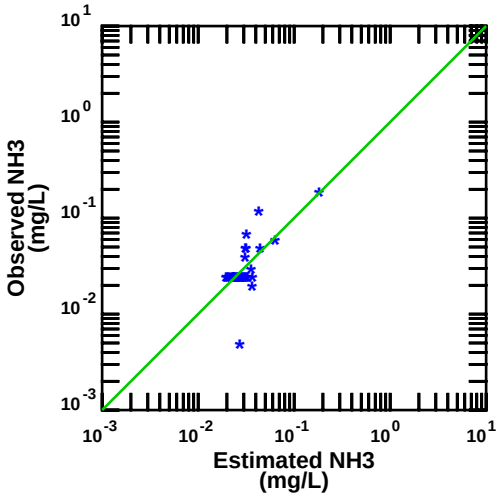
Nueces Tributaries, Texas (1970-2014)

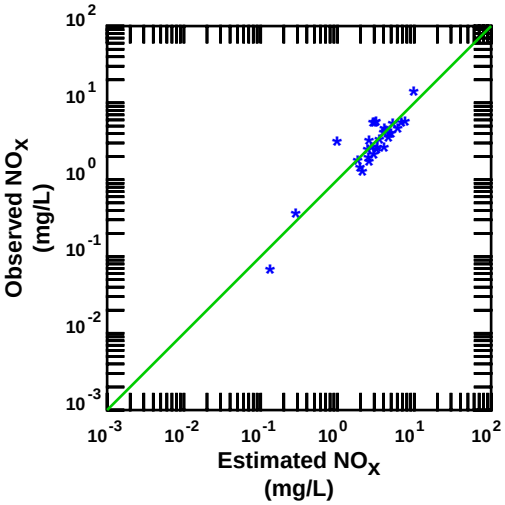


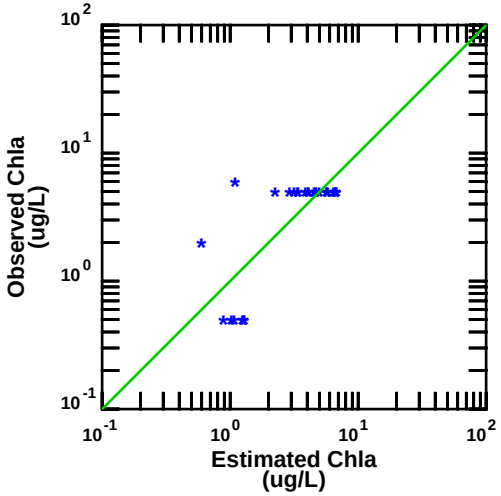
Observed Data vs. LOADEST Estimated Concentration, Station 13010

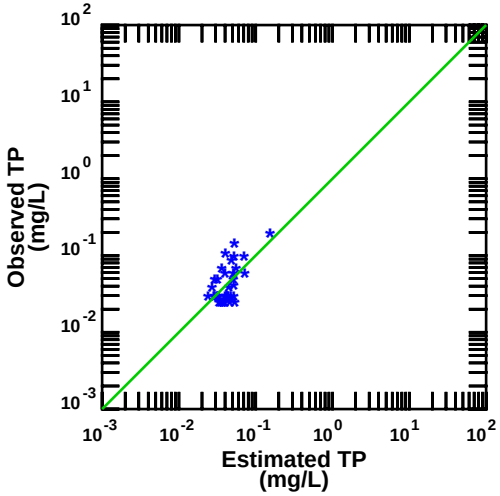
Nueces Tributaries, Texas (1970-2014)





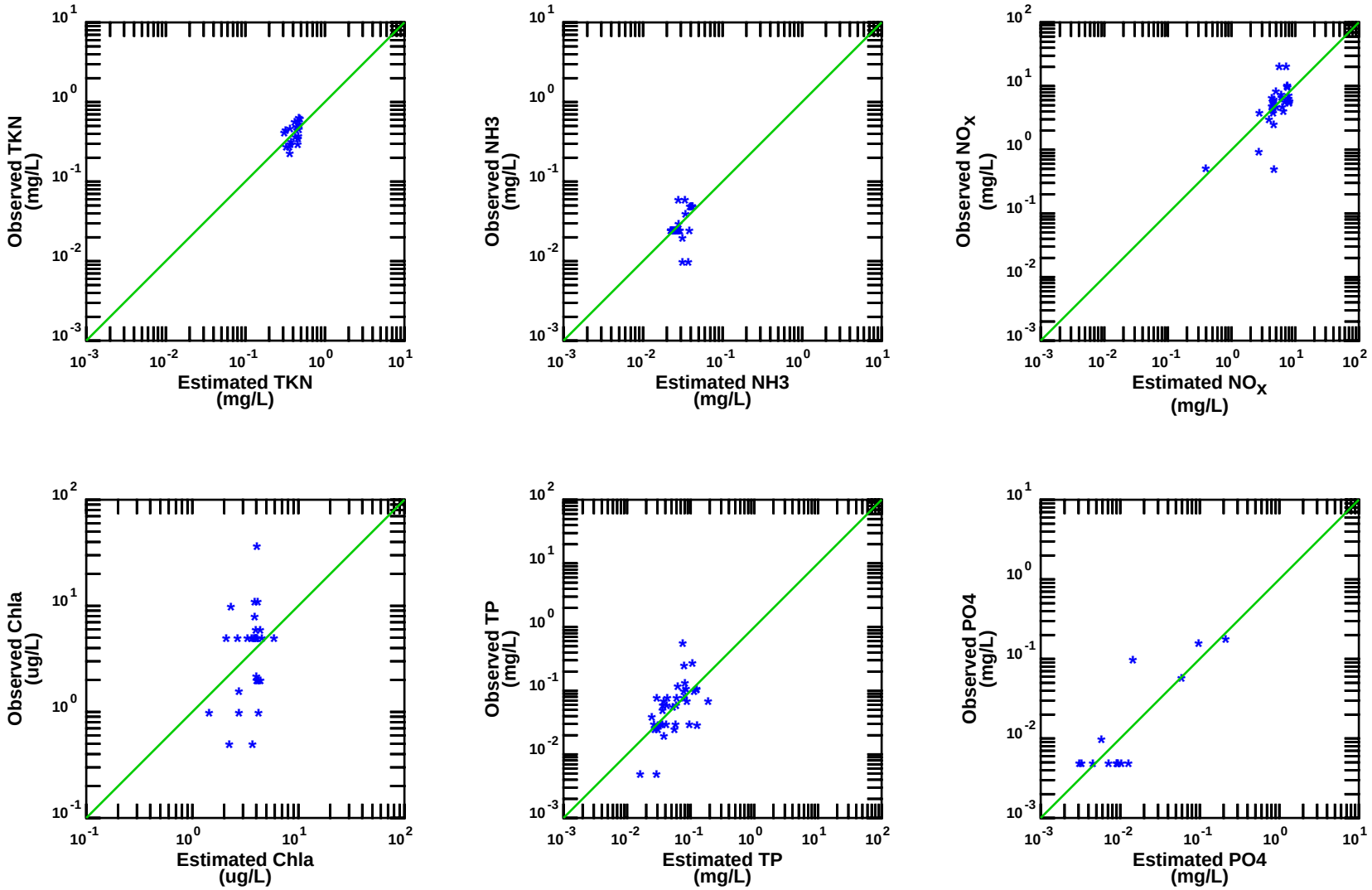






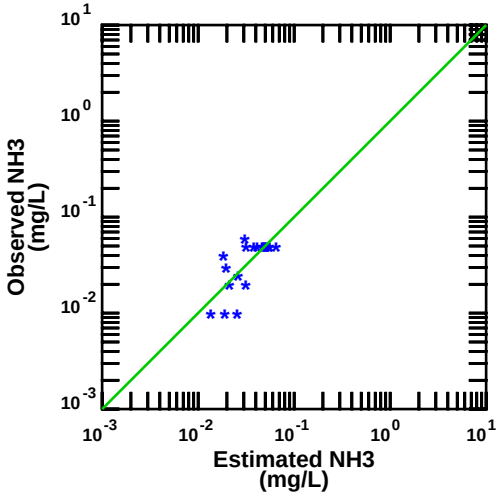
Observed Data vs. LOADEST Estimated Concentration, Station 12987

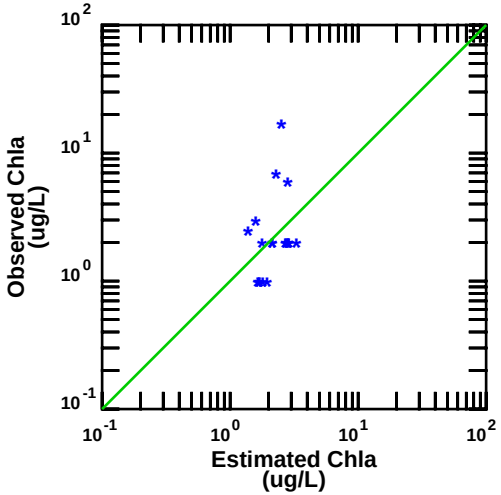
Nueces Tributaries, Texas (1970-2014)

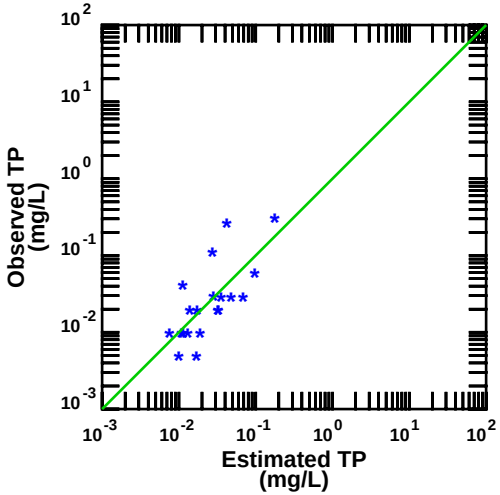


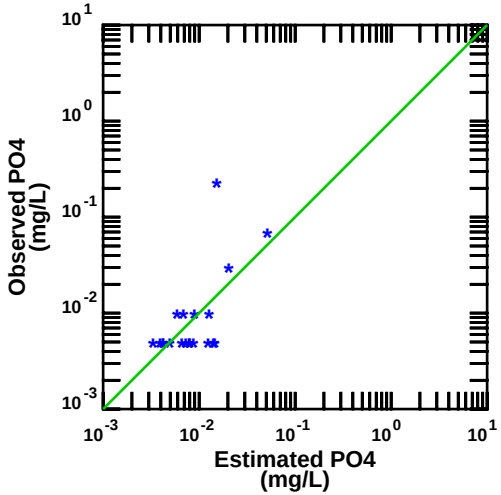
Observed Data vs. LOADEST Estimated Concentration, Station 12985

Nueces Tributaries, Texas (1970-2014)



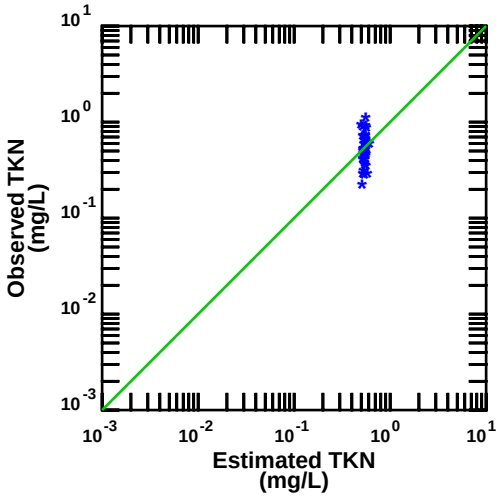


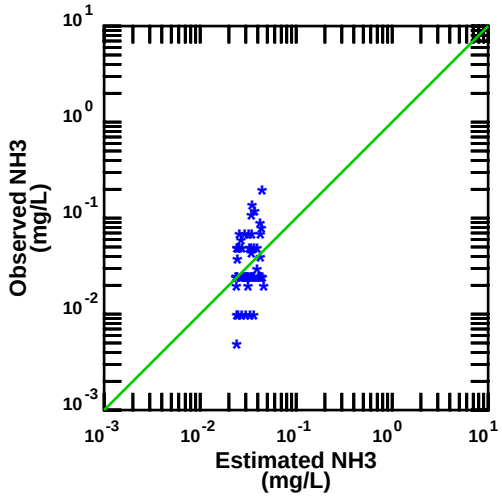


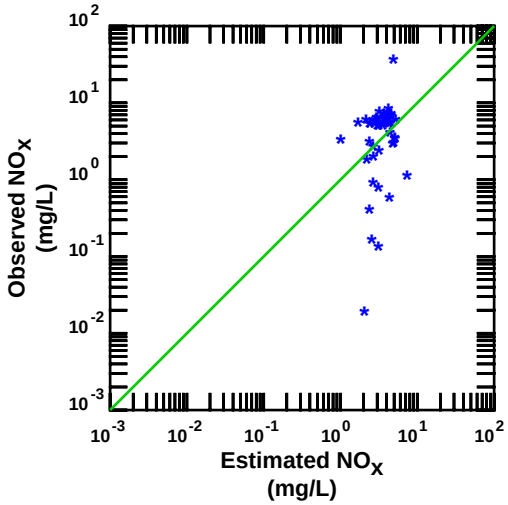


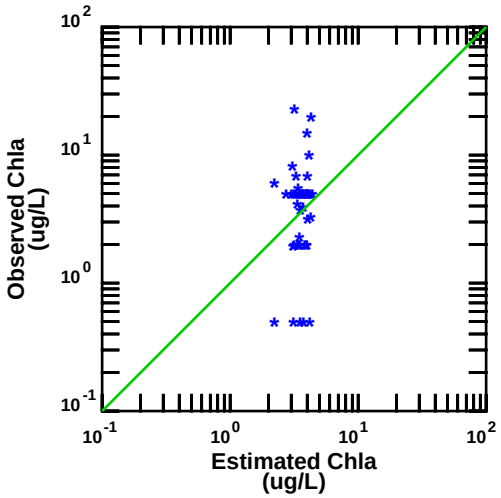
Observed Data vs. LOADEST Estimated Concentration, Station 13025

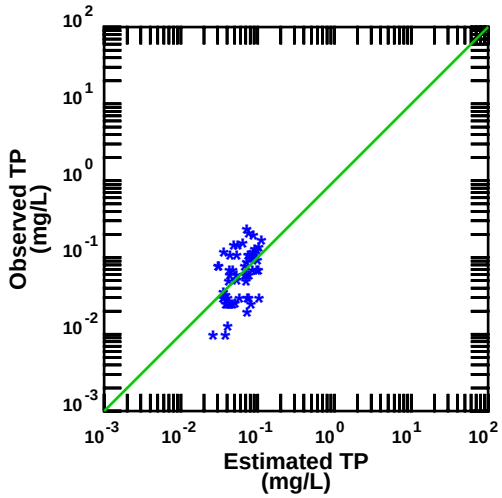
Nueces Tributaries, Texas (1970-2014)





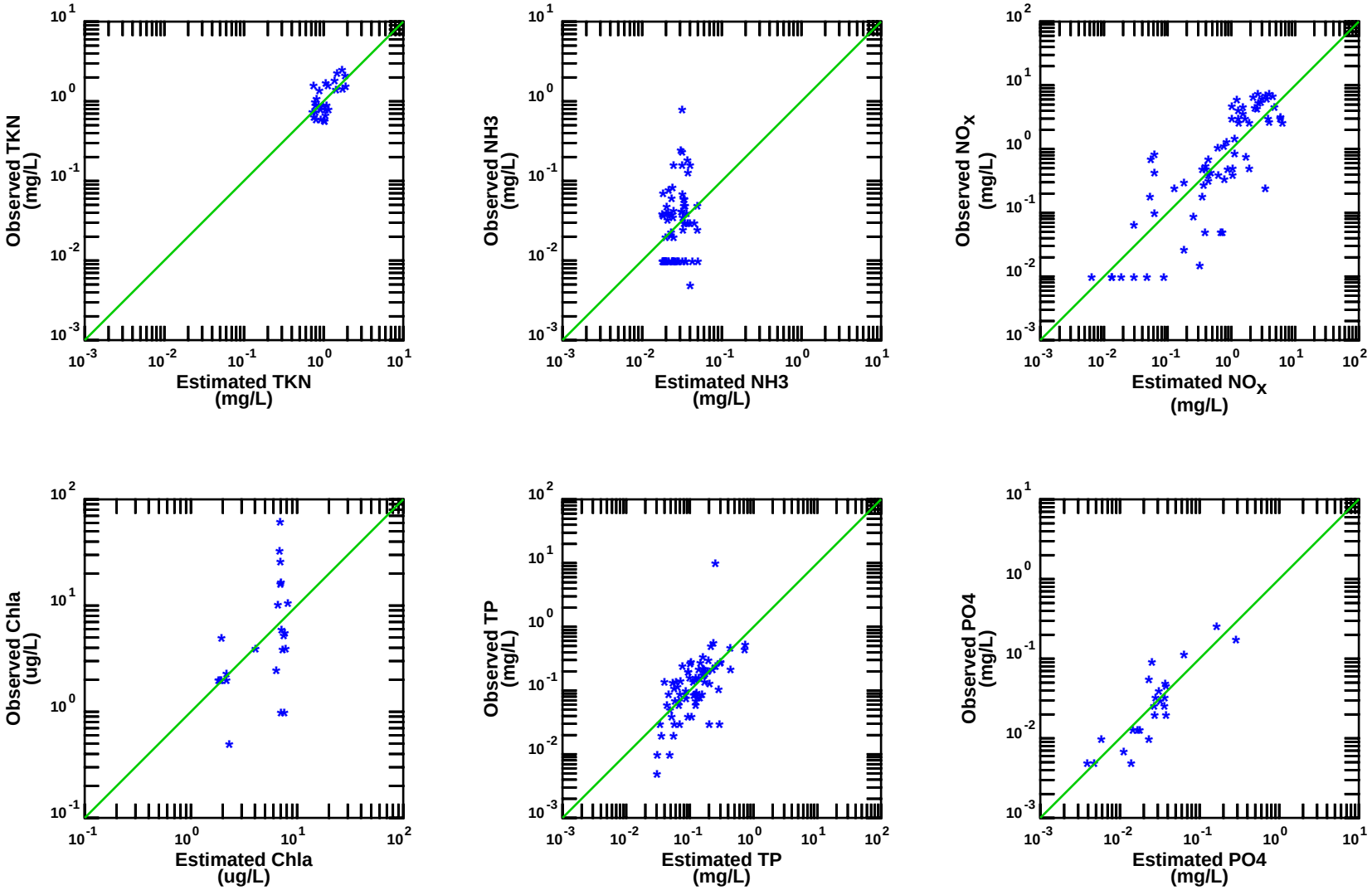






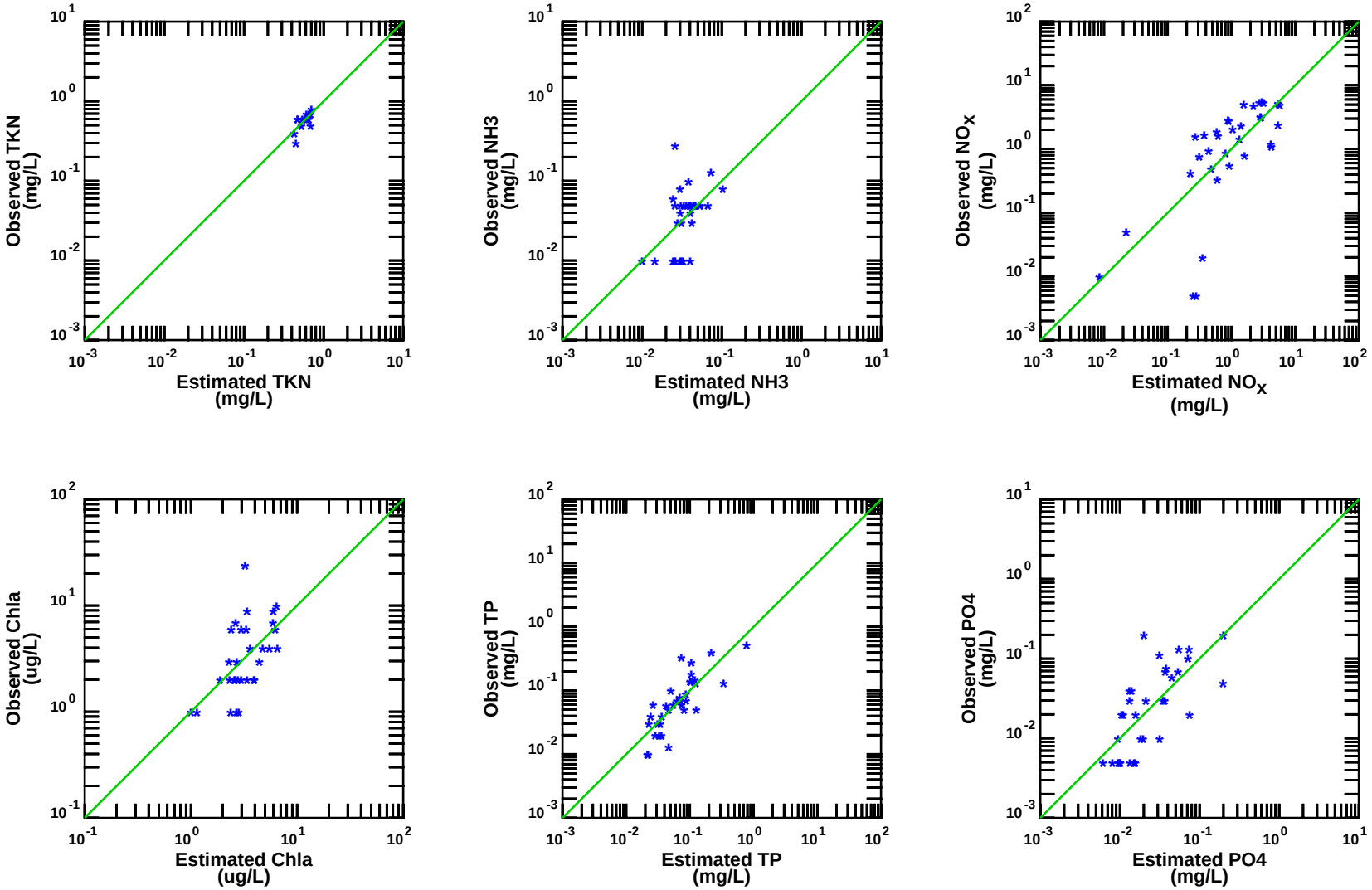
Observed Data vs. LOADEST Estimated Concentration, Station 13024

Nueces Tributaries, Texas (1970-2014)



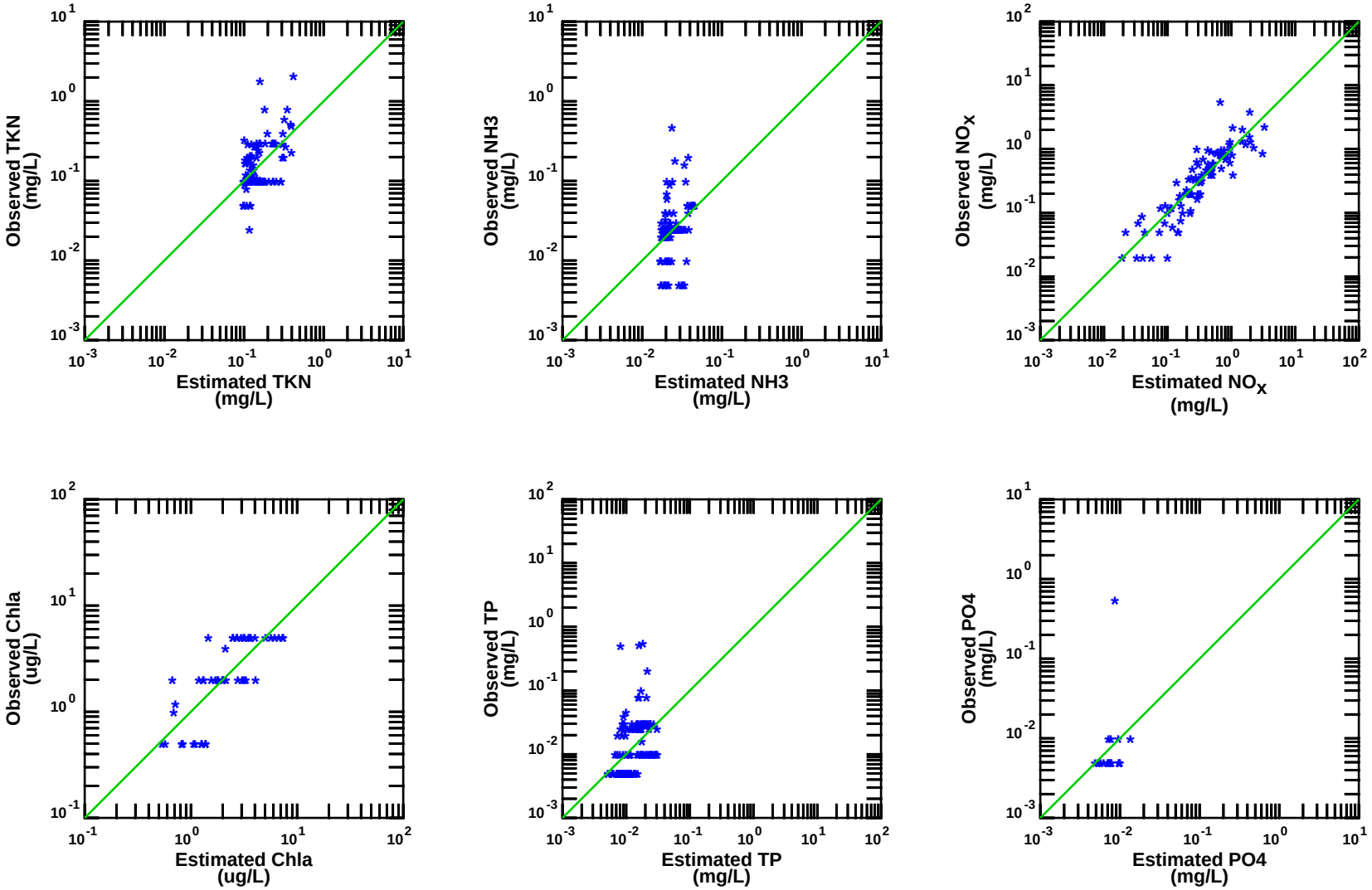
Observed Data vs. LOADEST Estimated Concentration, Station 13023

Nueces Tributaries, Texas (1970-2014)



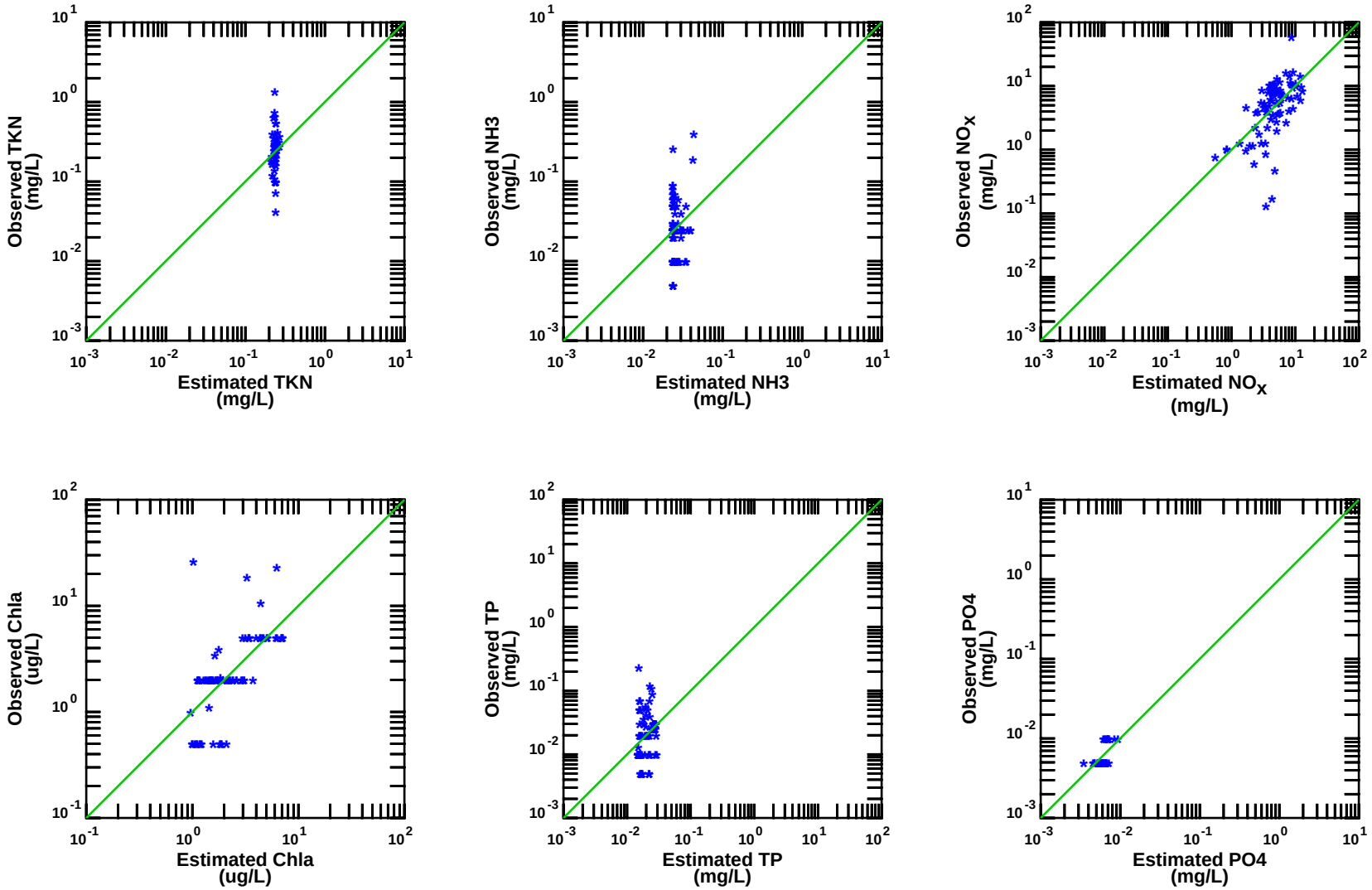
Observed Data vs. LOADEST Estimated Concentration, Station 13021

Nueces Tributaries, Texas (1970-2014)



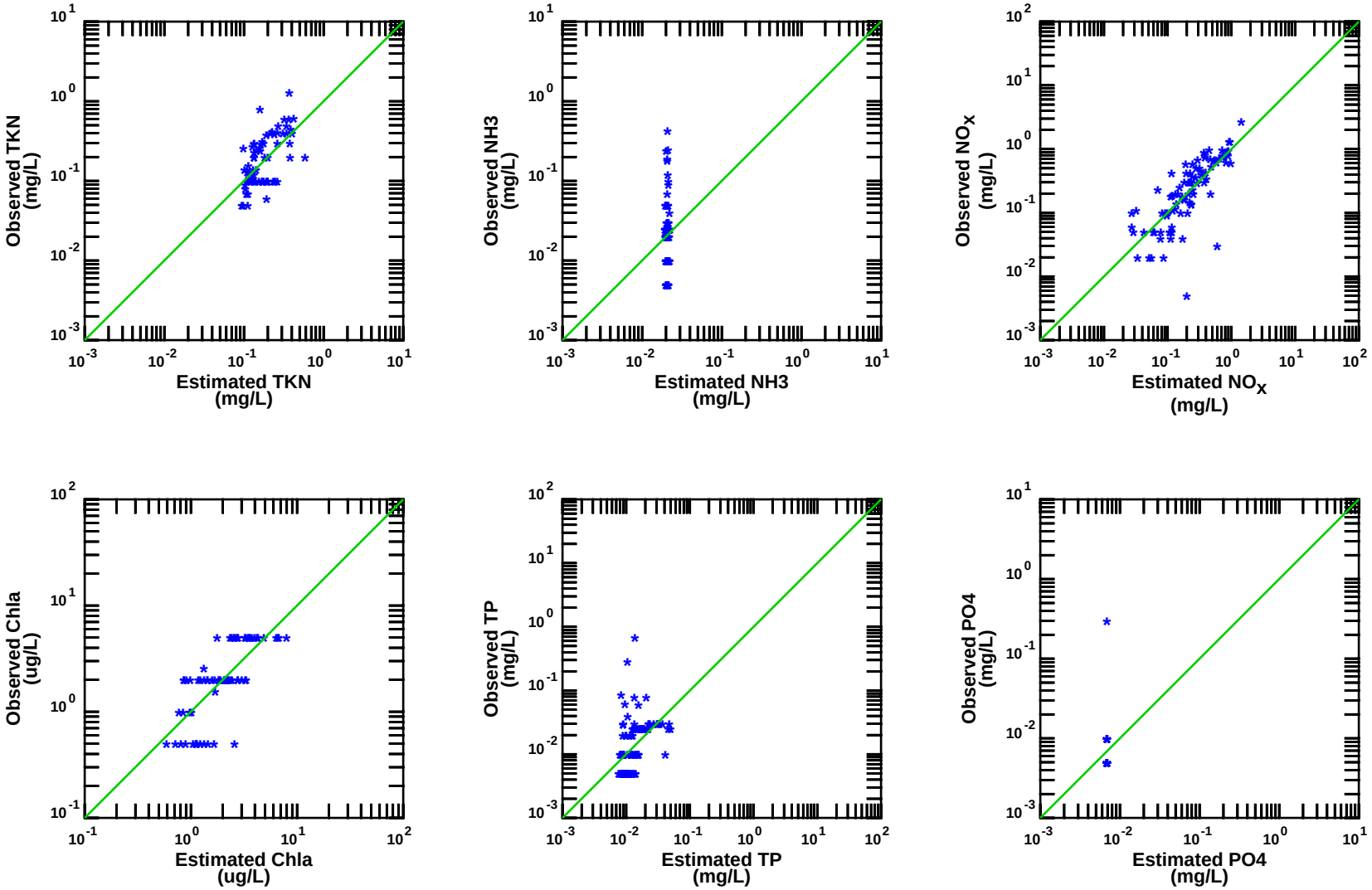
Observed Data vs. LOADEST Estimated Concentration, Station 12994

Nueces Tributaries, Texas (1970-2014)



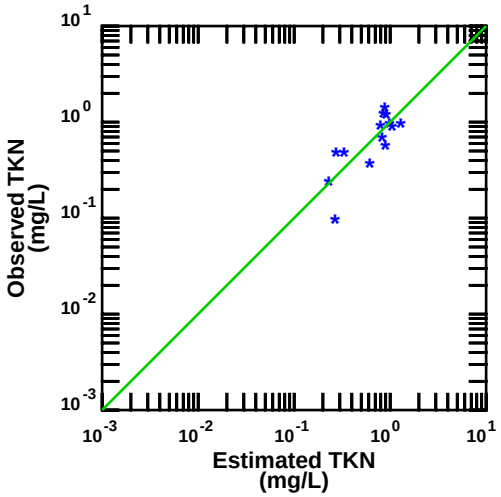
Observed Data vs. LOADEST Estimated Concentration, Station 12993

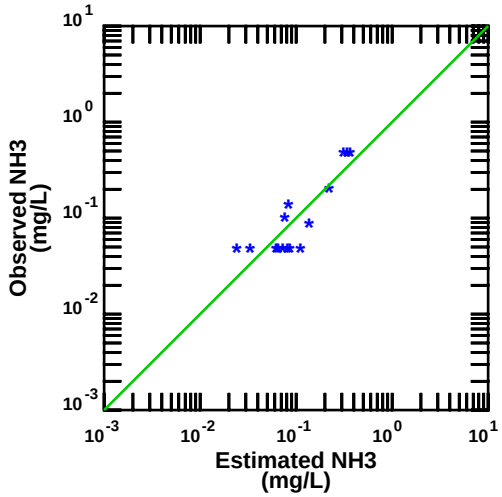
Nueces Tributaries, Texas (1970-2014)

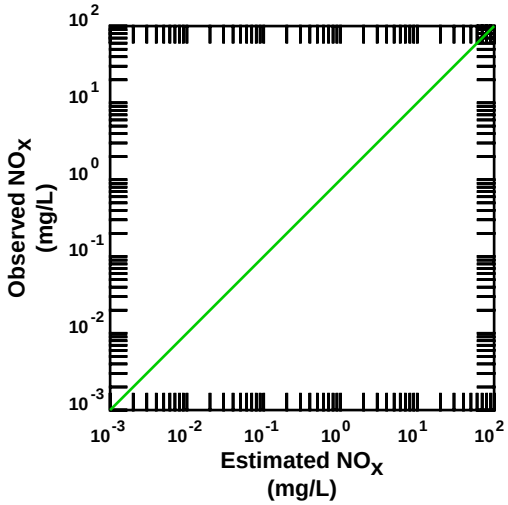


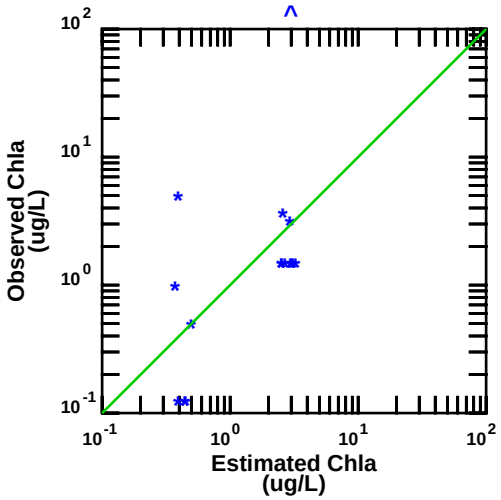
Observed Data vs. LOADEST Estimated Concentration, Station 13013

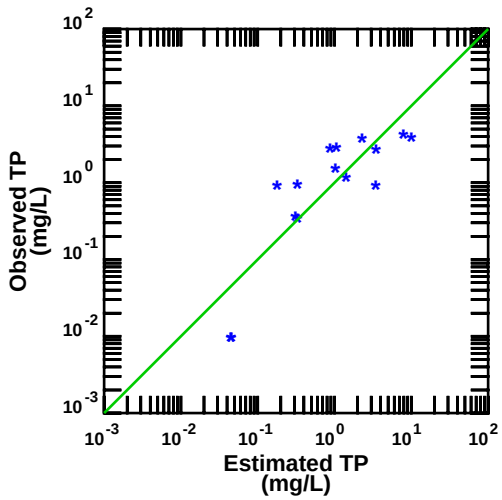
Nueces Tributaries, Texas (1970-2014)





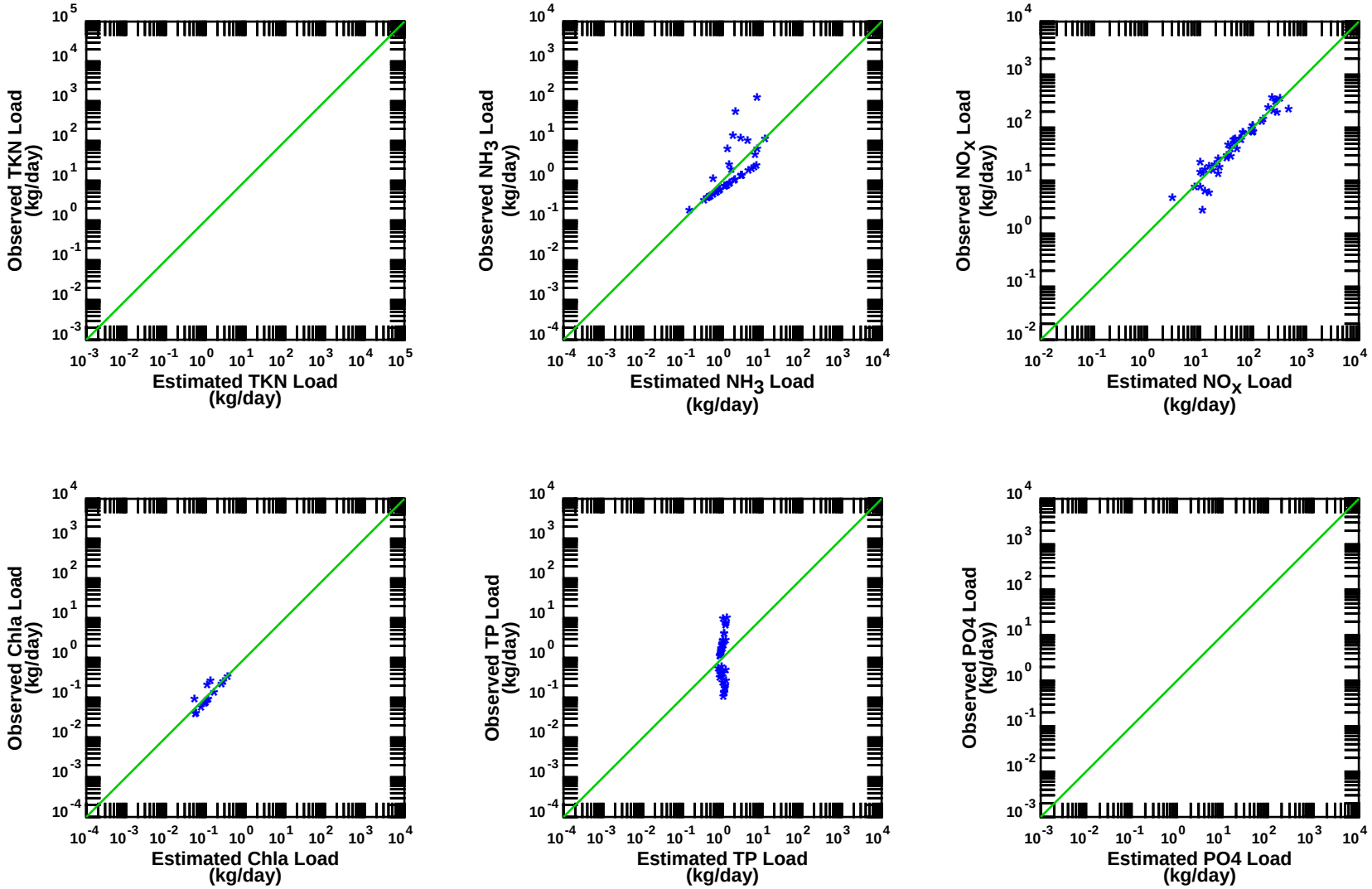






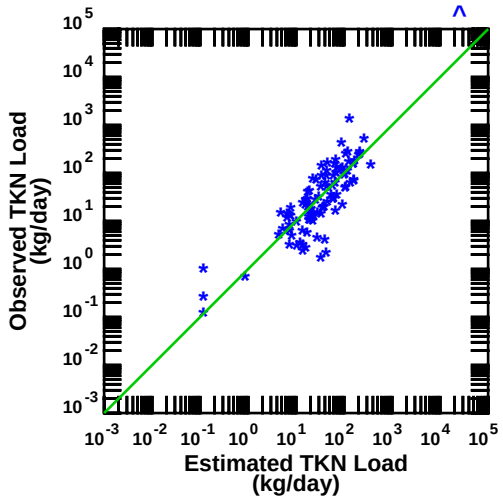
Observed Data vs. LOADEST Estimated Concentration, Station 17900

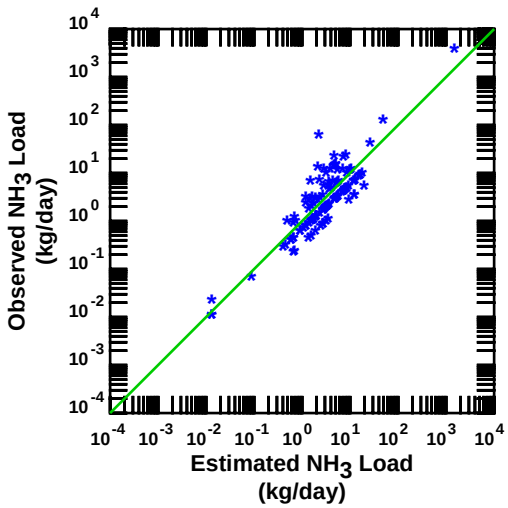
Nueces Tributaries, Texas (1970-2014)

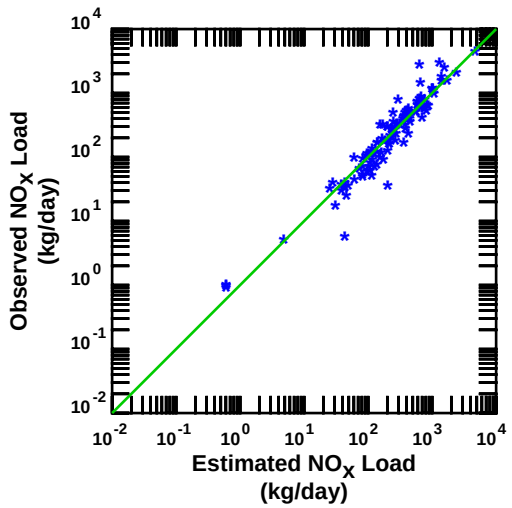


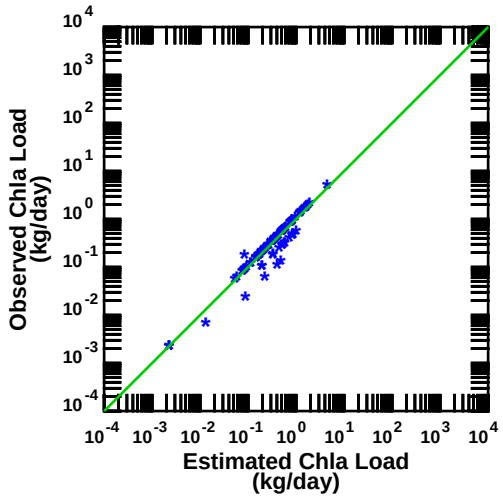
Observed Loads vs. Estimated Load, Station 13005

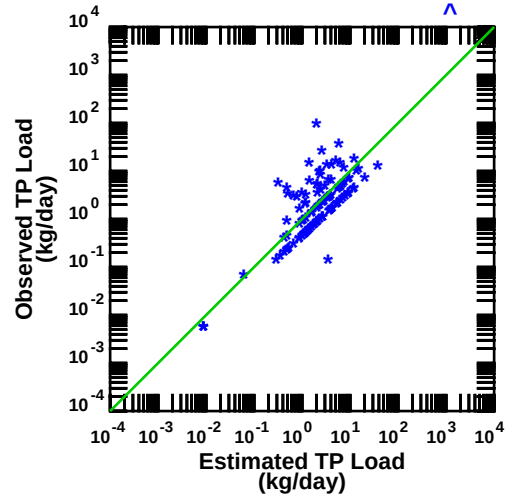
Nueces Tributaries, Texas (1970-2014)

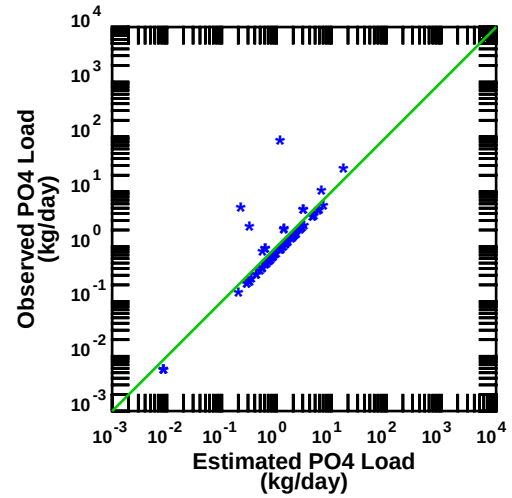






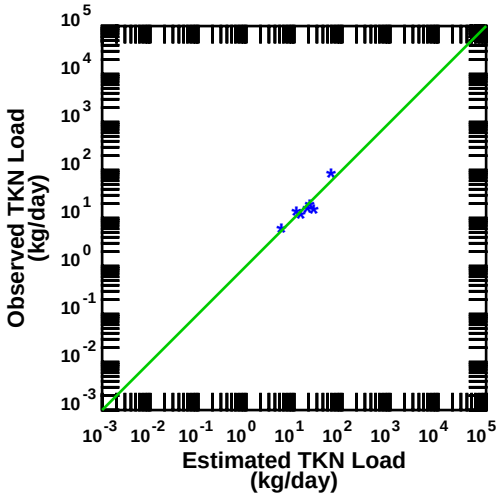


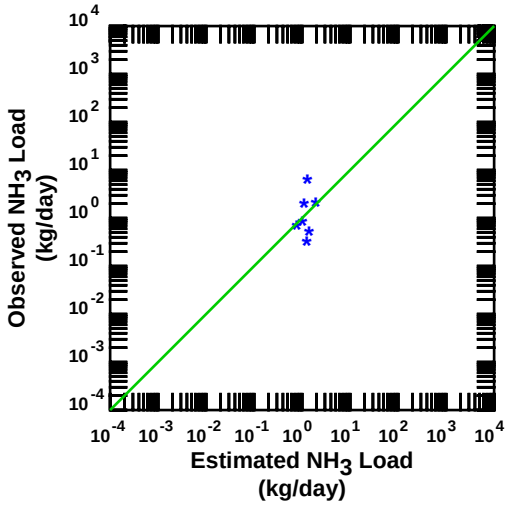


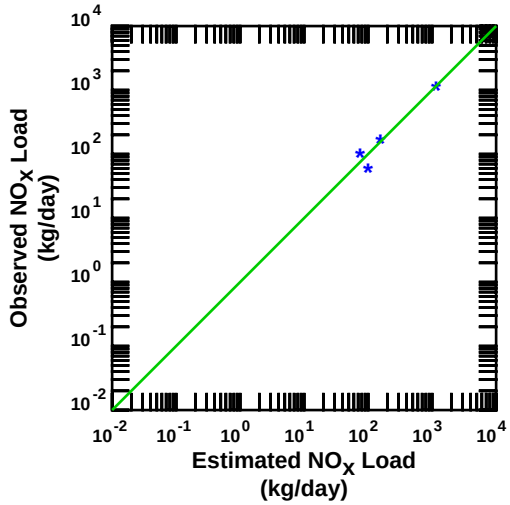


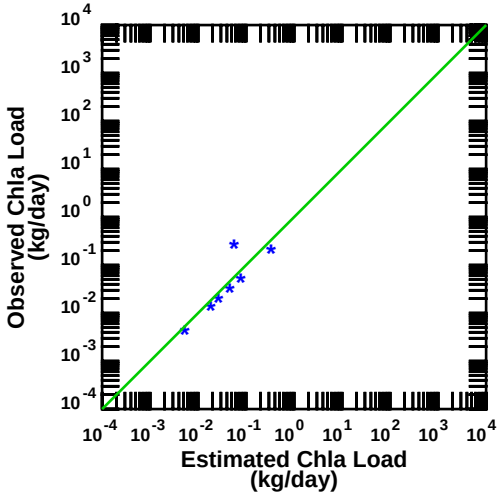
Observed Loads vs. Estimated Load, Station 12999

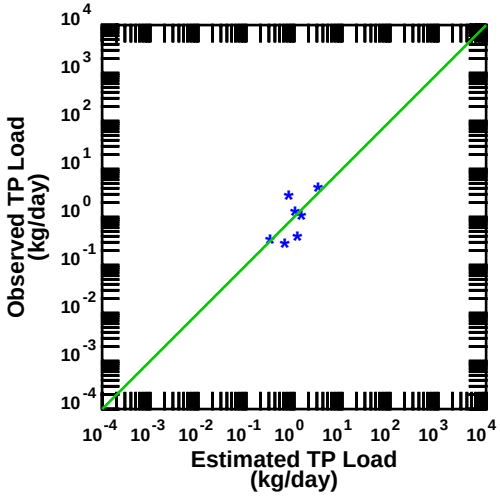
Nueces Tributaries, Texas (1970-2014)





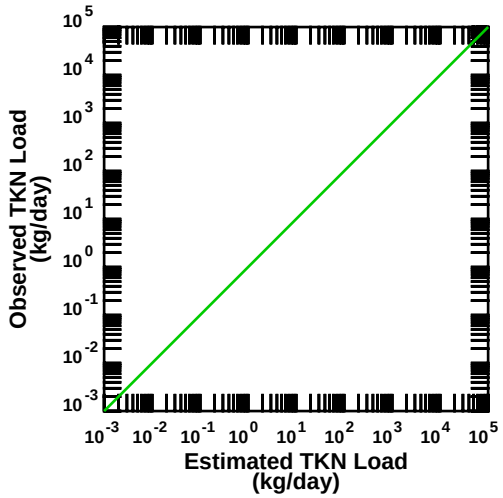


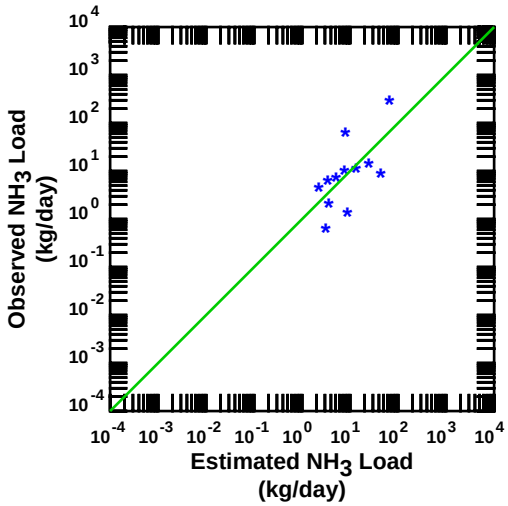


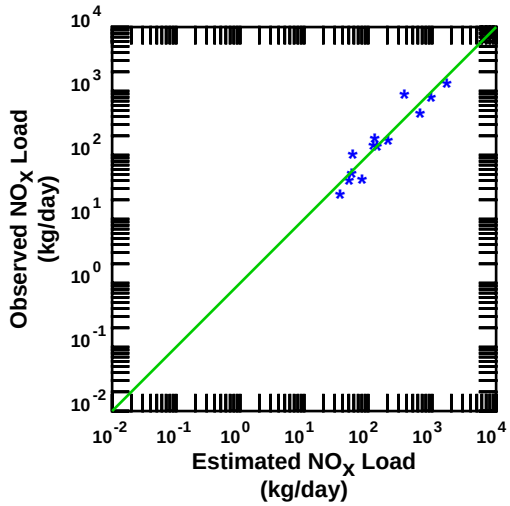


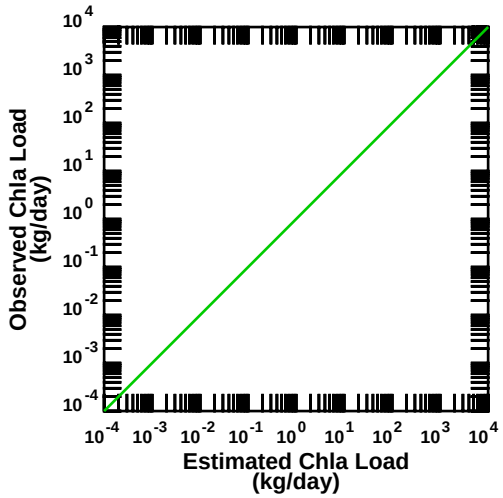
Observed Loads vs. Estimated Load, Station 14253

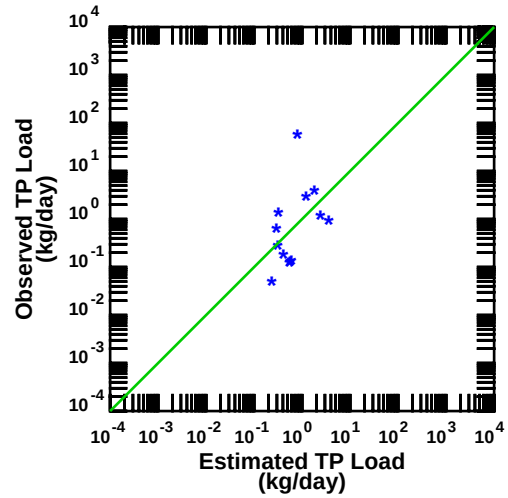
Nueces Tributaries, Texas (1970-2014)

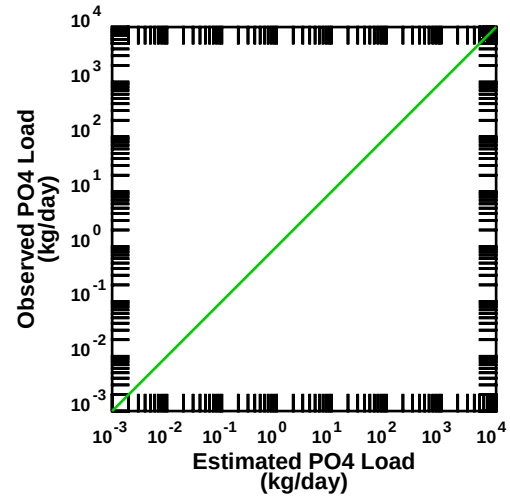






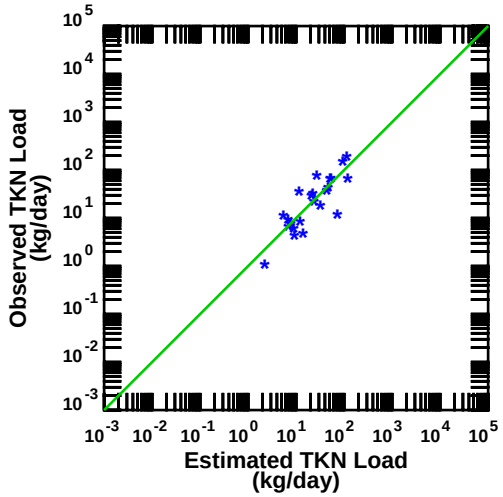


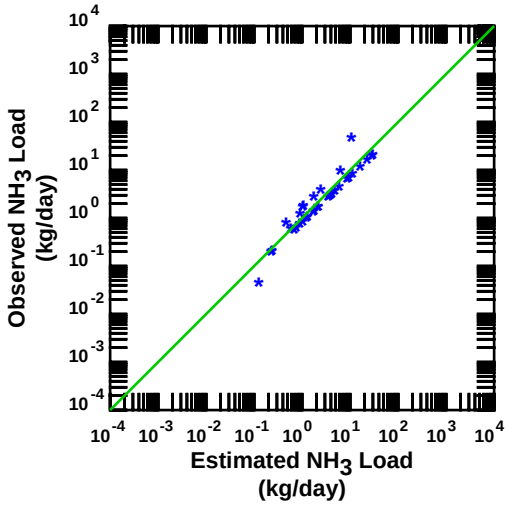


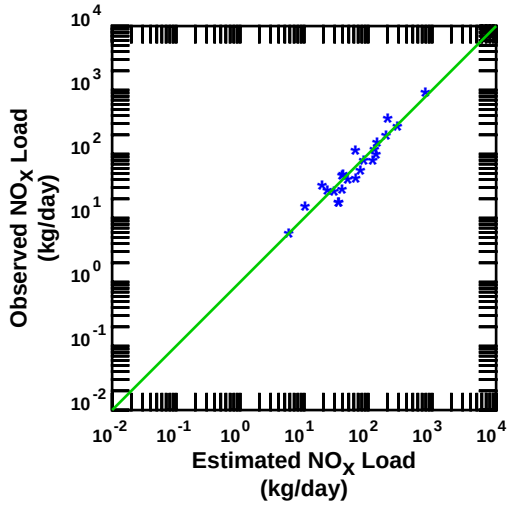


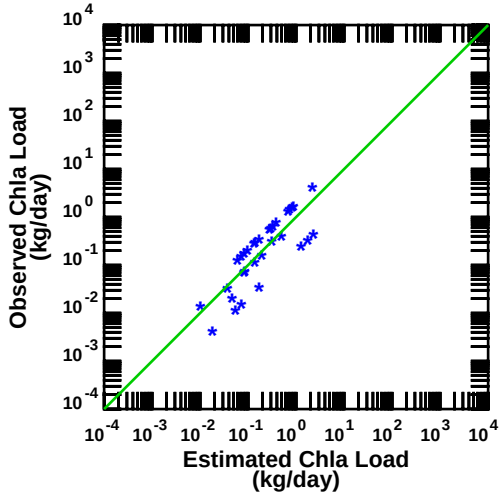
Observed Loads vs. Estimated Load, Station 12997

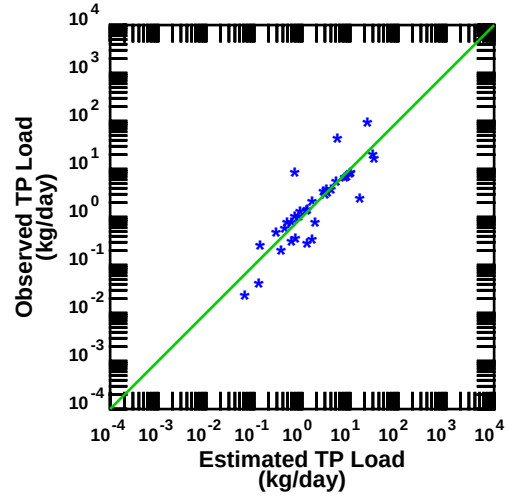
Nueces Tributaries, Texas (1970-2014)

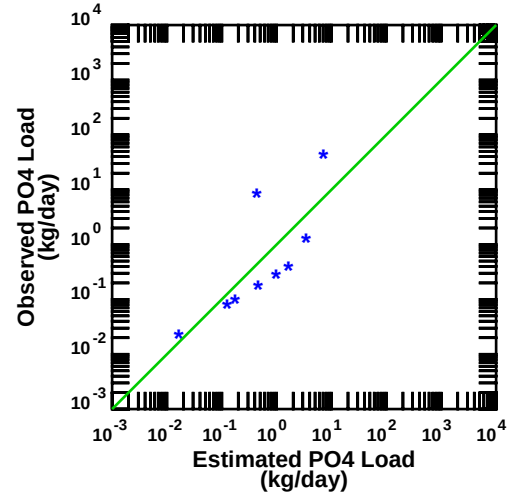






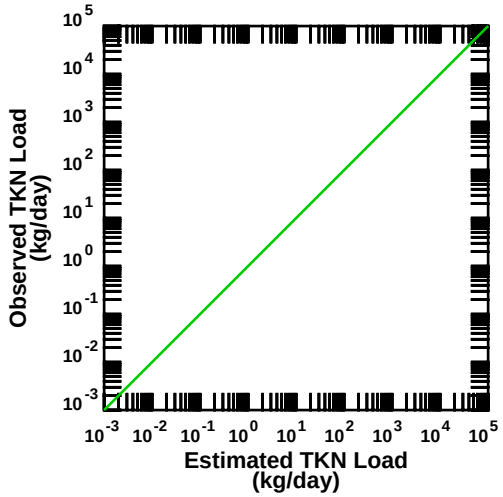


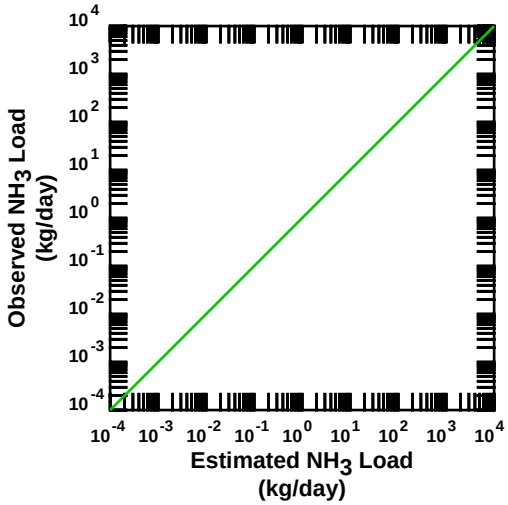


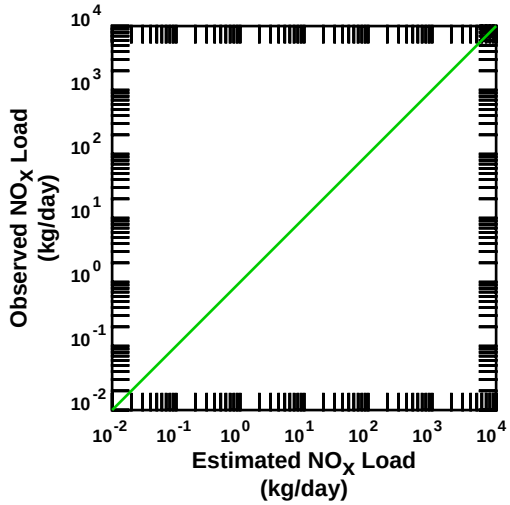


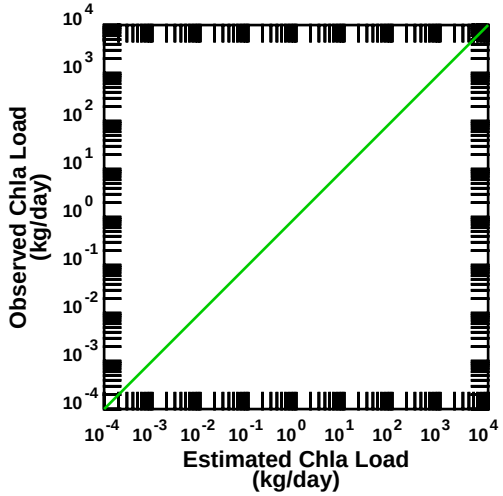
Observed Loads vs. Estimated Load, Station 12996

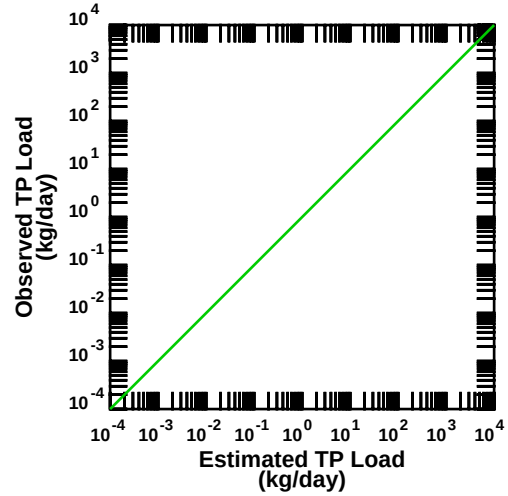
Nueces Tributaries, Texas (1970-2014)





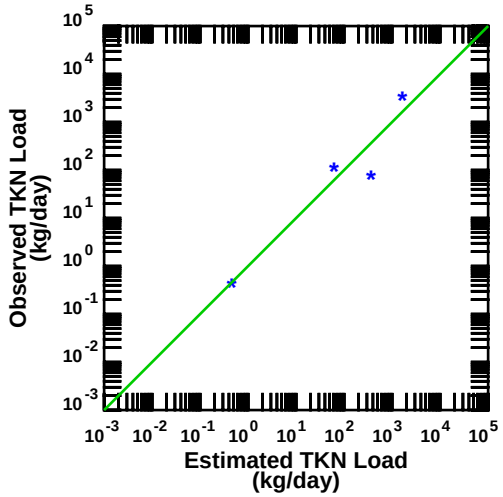


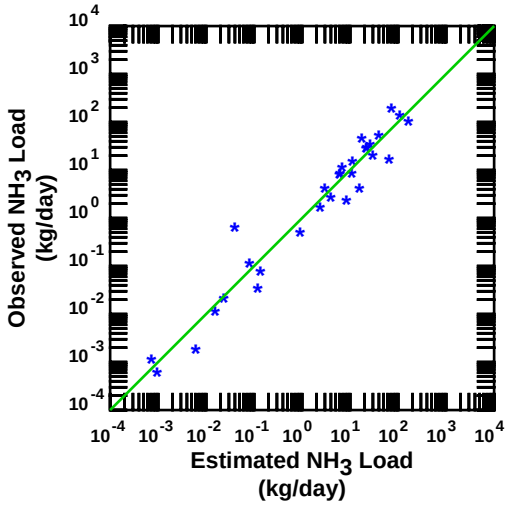


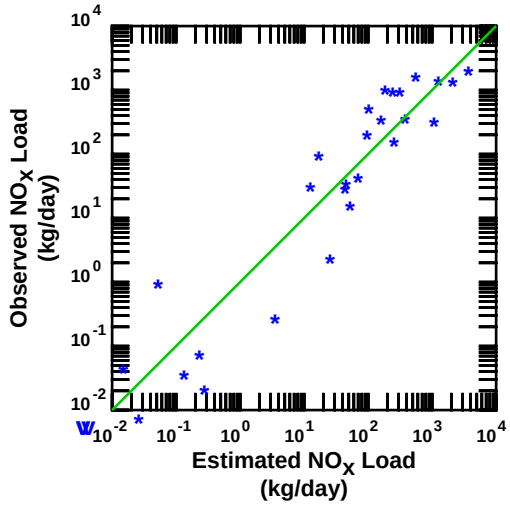


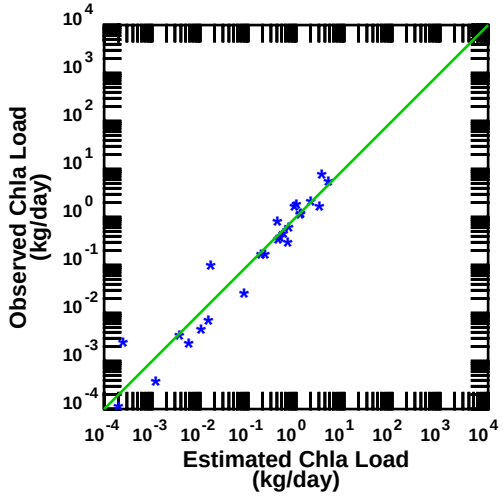
Observed Loads vs. Estimated Load, Station 17143

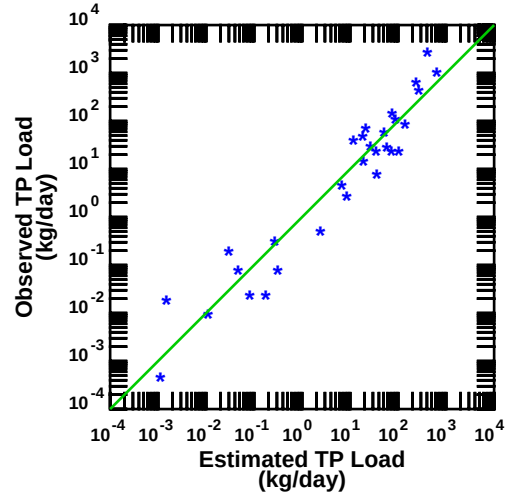
Nueces Tributaries, Texas (1970-2014)

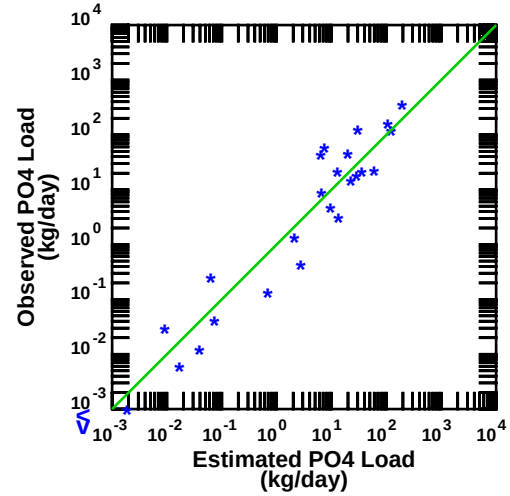






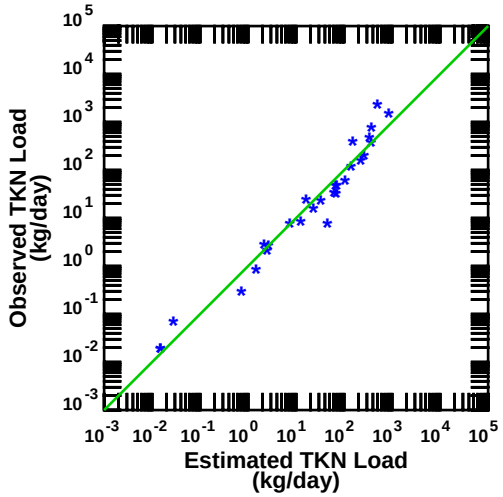


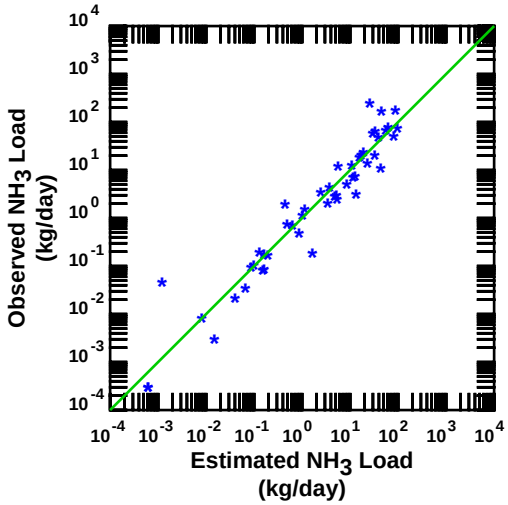


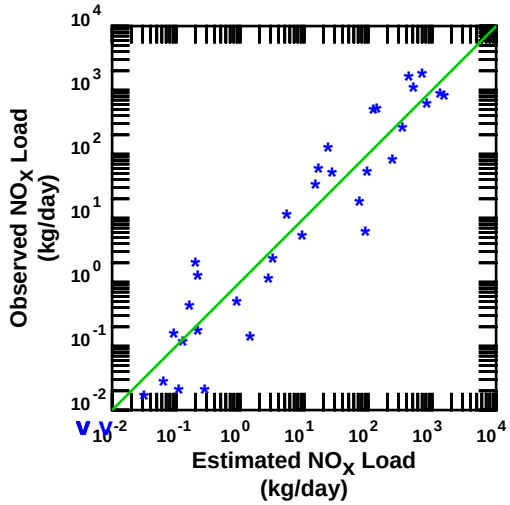


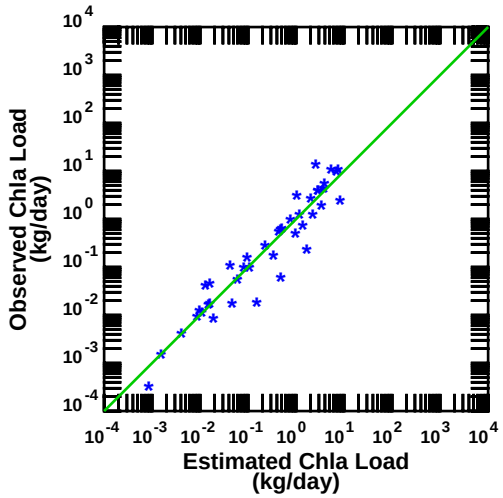
Observed Loads vs. Estimated Load, Station 12976

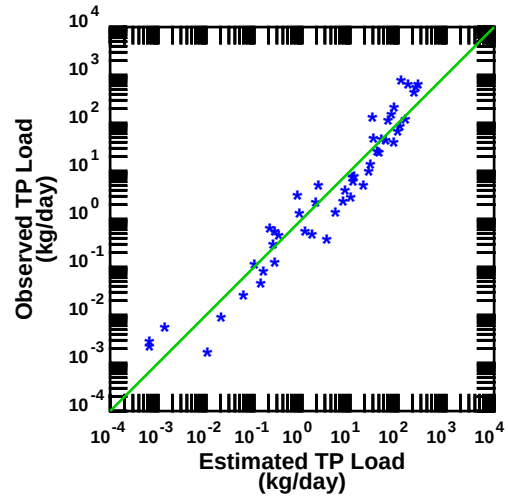
Nueces Tributaries, Texas (1970-2014)

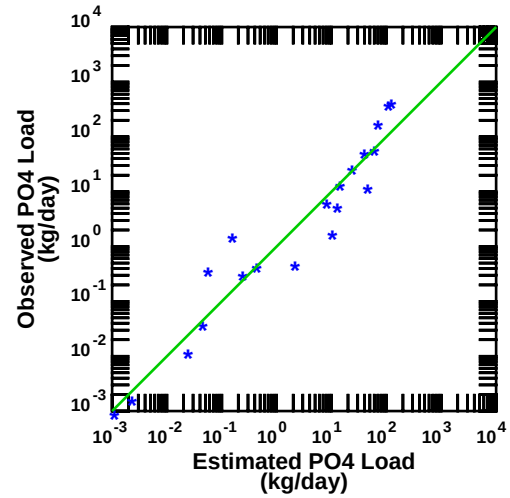






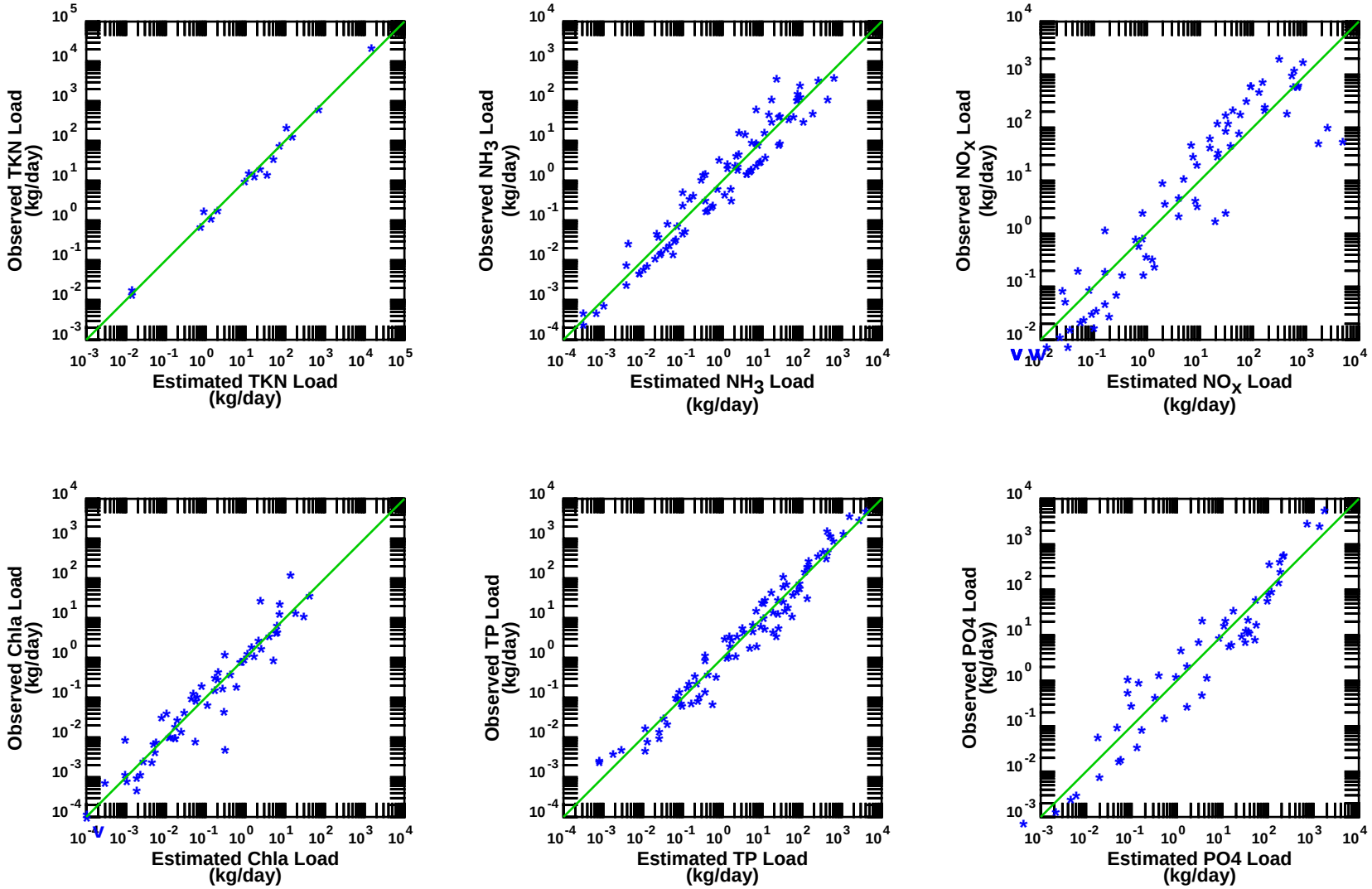






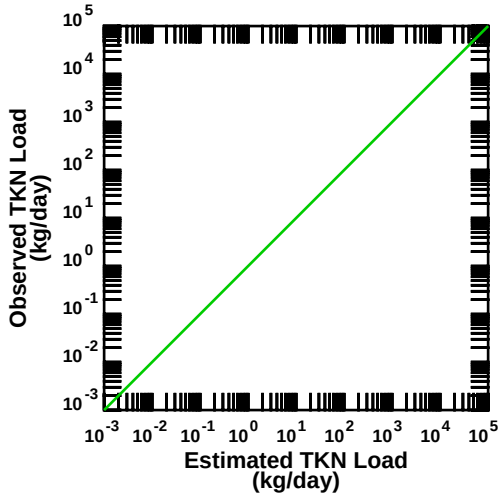
Observed Loads vs. Estimated Load, Station 12975

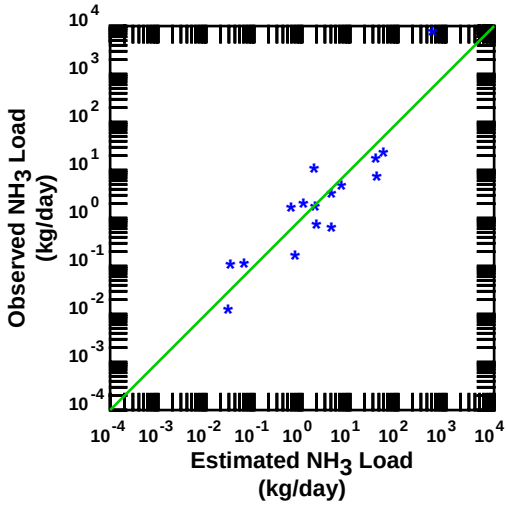
Nueces Tributaries, Texas (1970-2014)

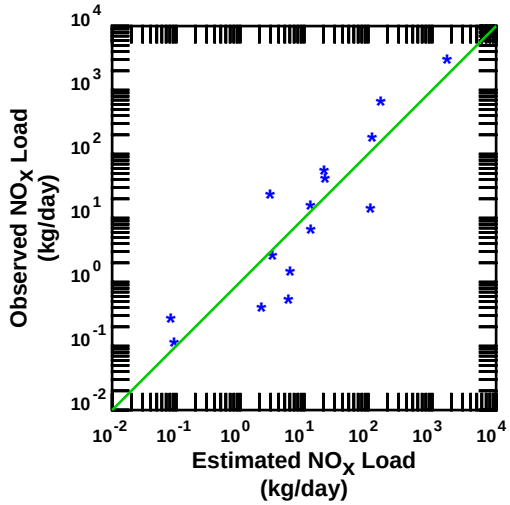


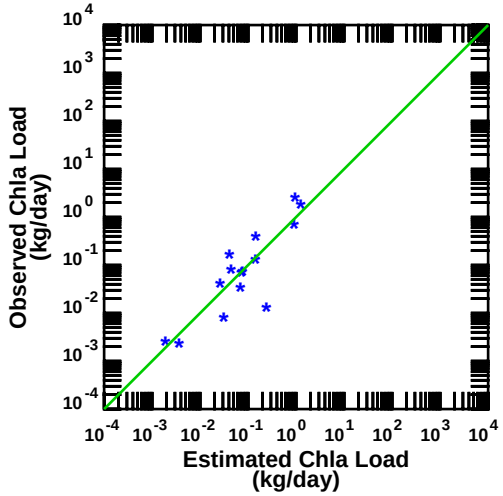
Observed Loads vs. Estimated Load, Station 12973

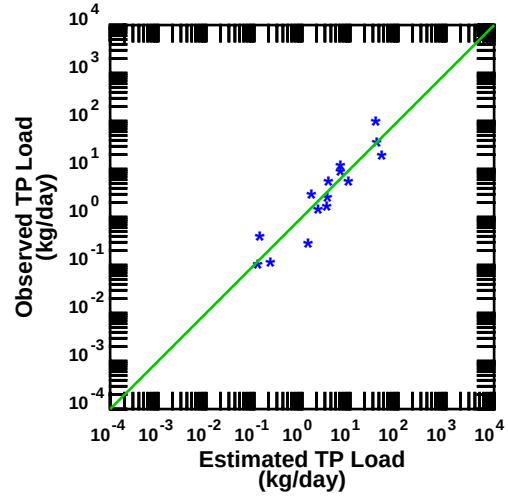
Nueces Tributaries, Texas (1970-2014)

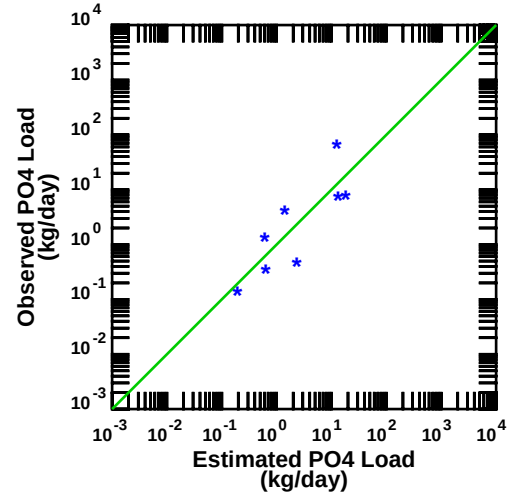






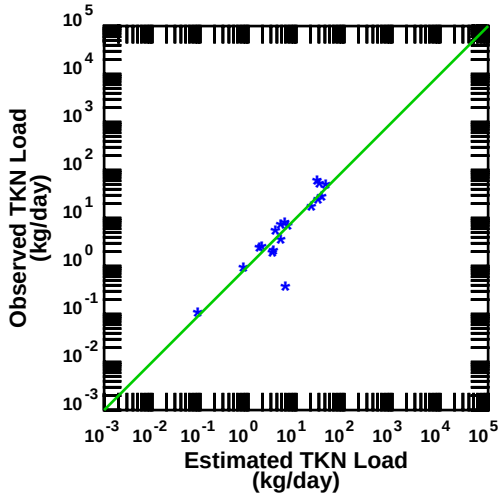


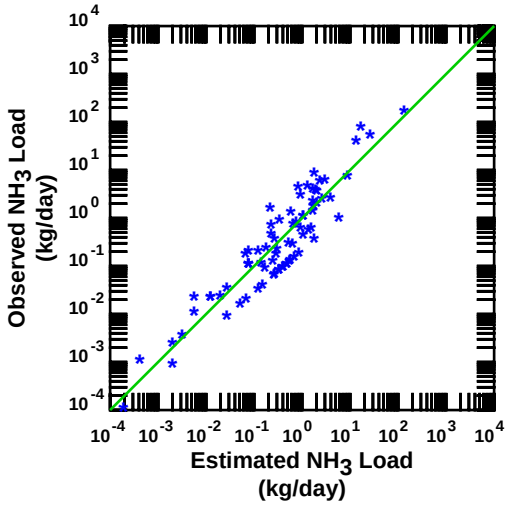


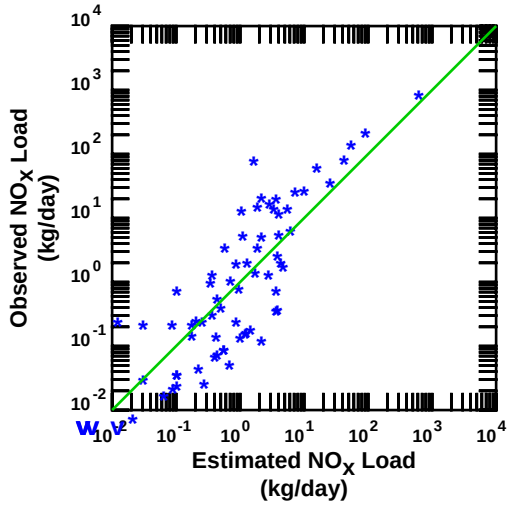


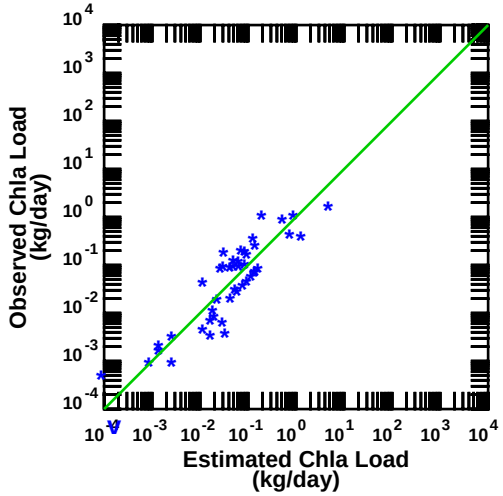
Observed Loads vs. Estimated Load, Station 12972

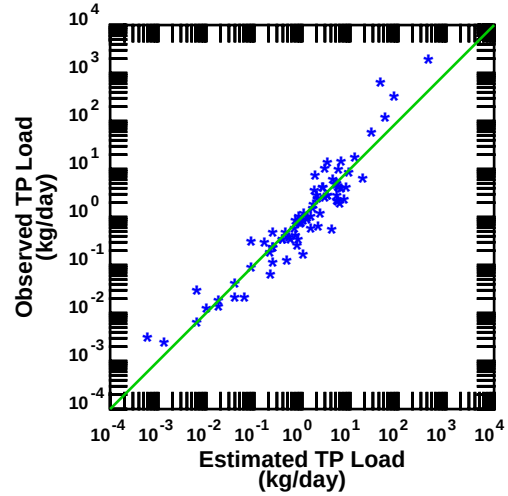
Nueces Tributaries, Texas (1970-2014)

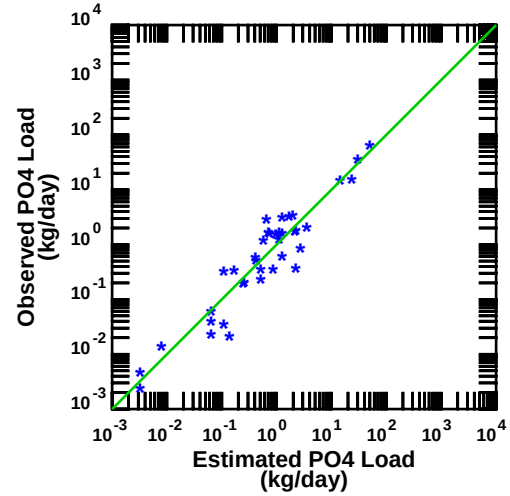






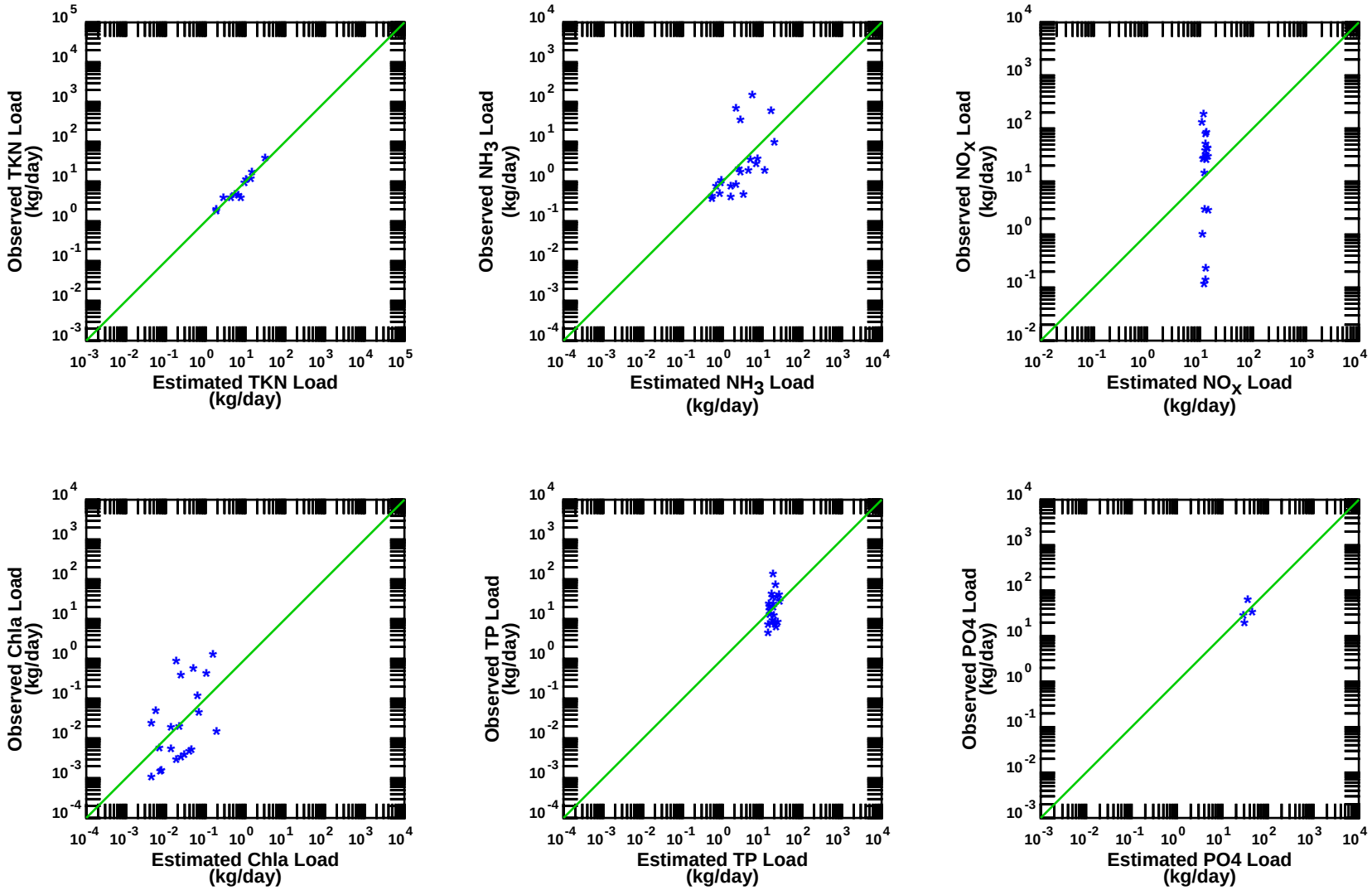






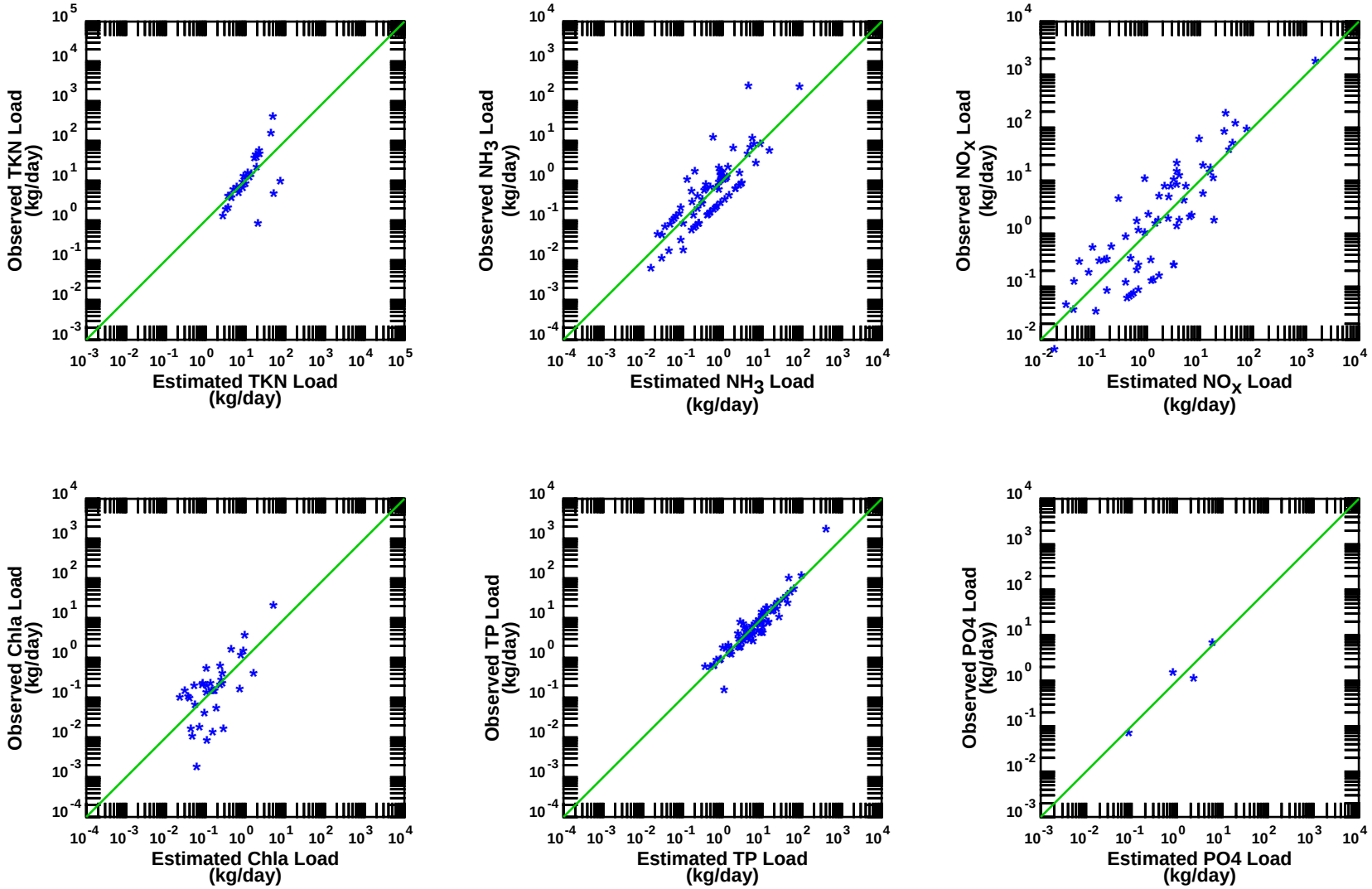
Observed Loads vs. Estimated Load, Station 12983

Nueces Tributaries, Texas (1970-2014)



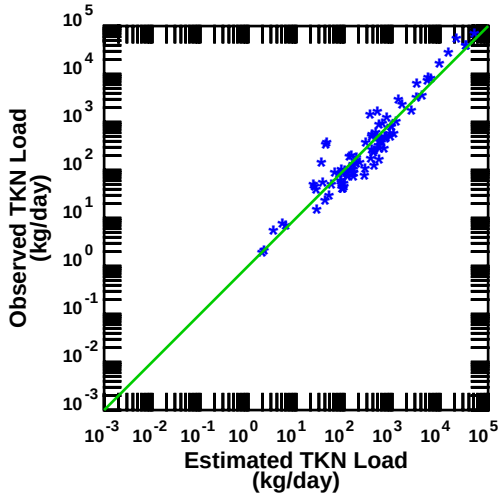
Observed Loads vs. Estimated Load, Station 12981

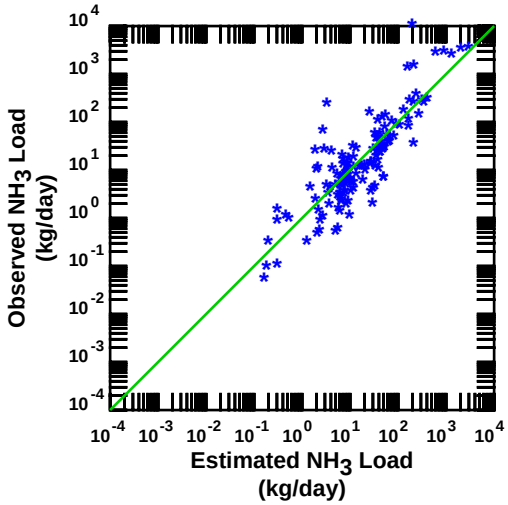
Nueces Tributaries, Texas (1970-2014)

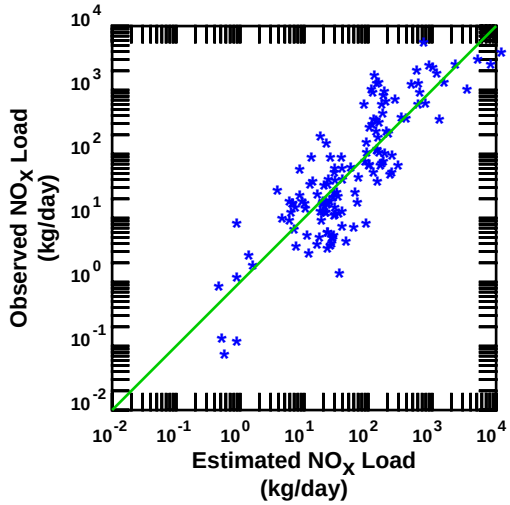


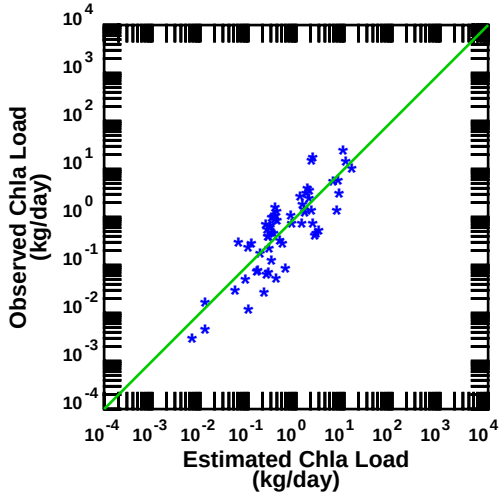
Observed Loads vs. Estimated Load, Station 12980

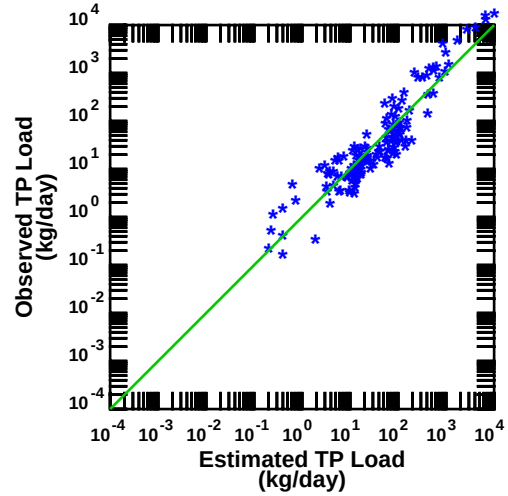
Nueces Tributaries, Texas (1970-2014)

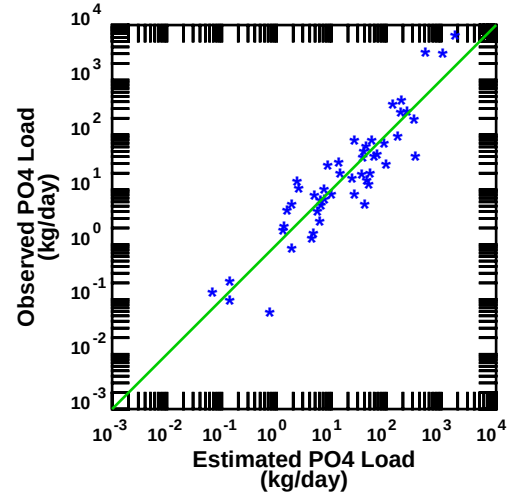






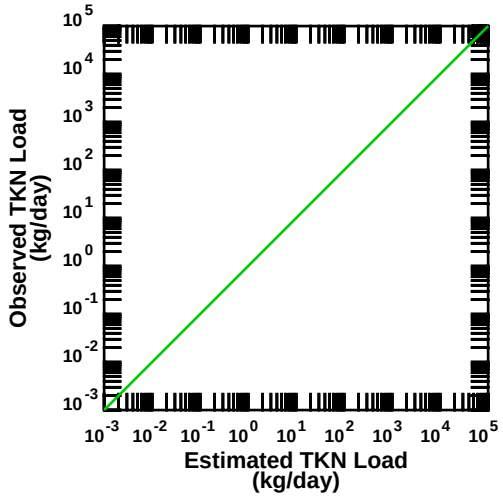


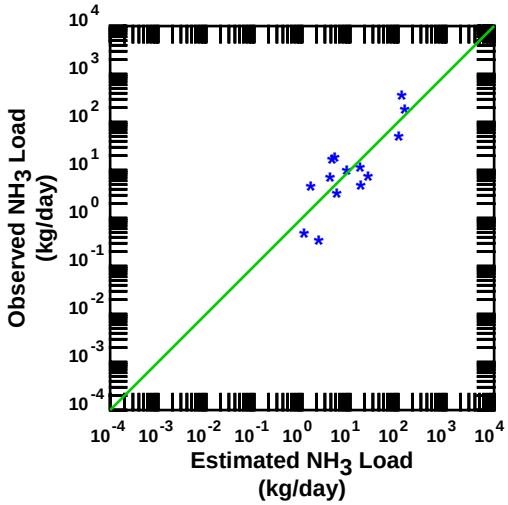


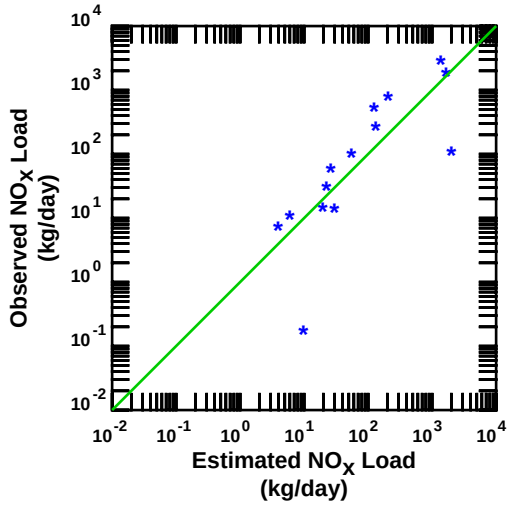


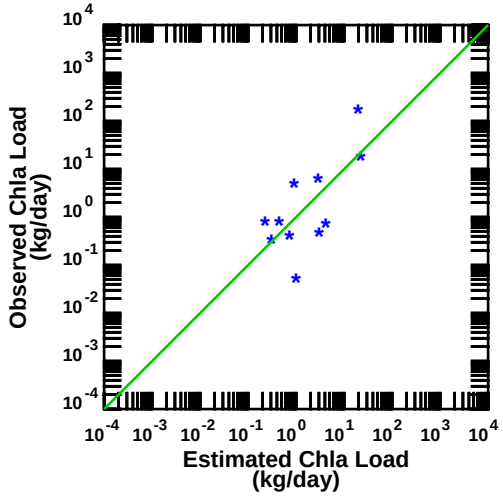
Observed Loads vs. Estimated Load, Station 12979

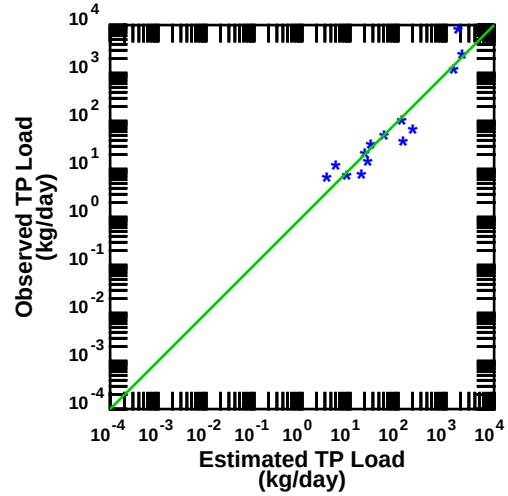
Nueces Tributaries, Texas (1970-2014)

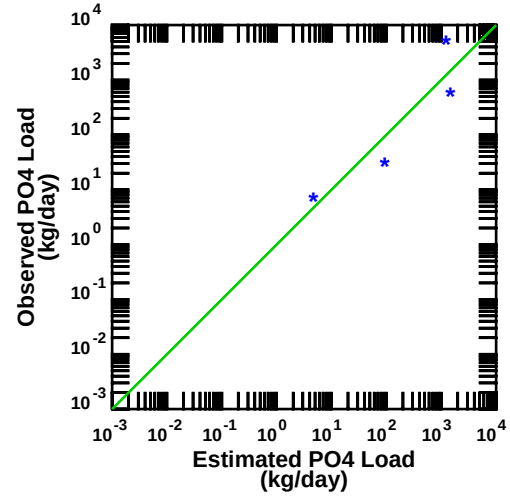






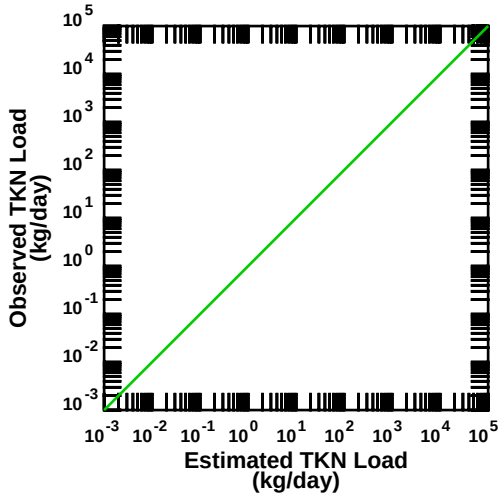


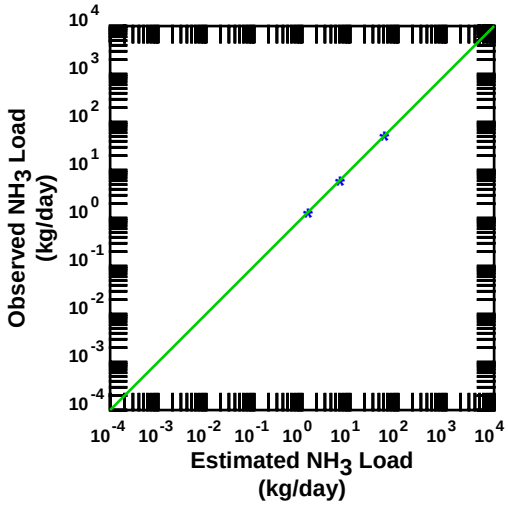


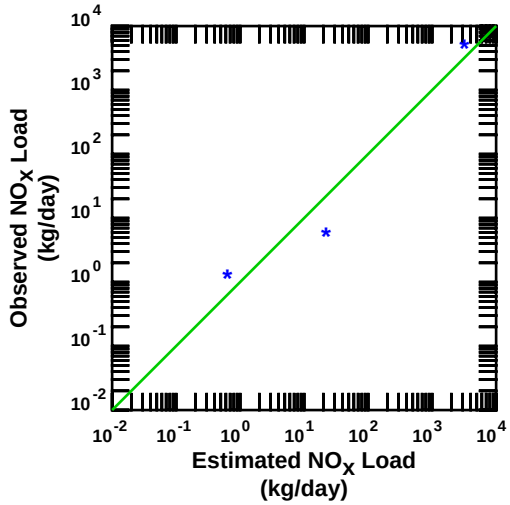


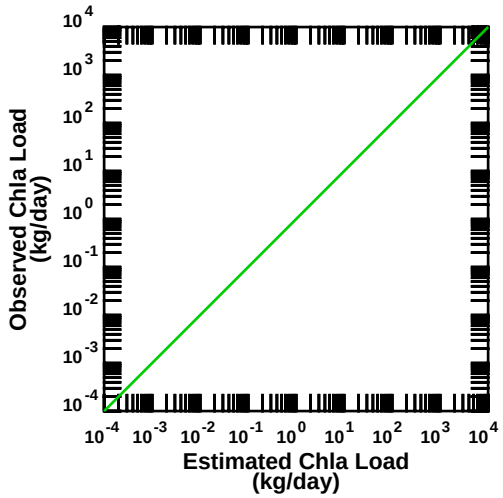
Observed Loads vs. Estimated Load, Station 12978

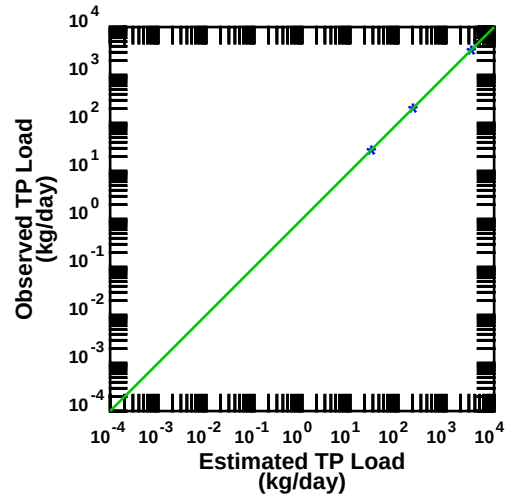
Nueces Tributaries, Texas (1970-2014)





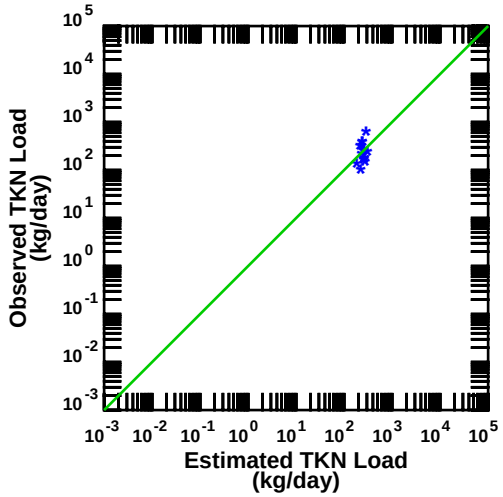


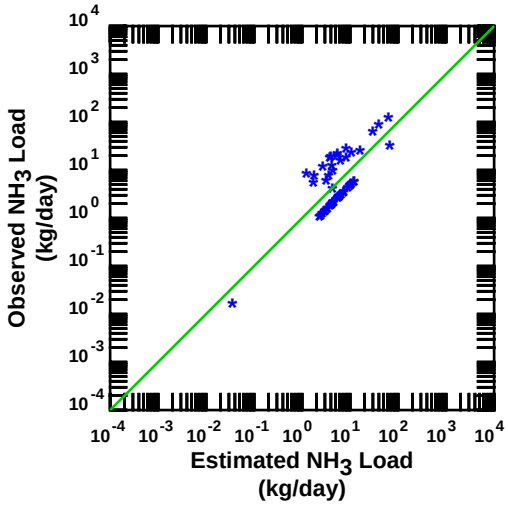


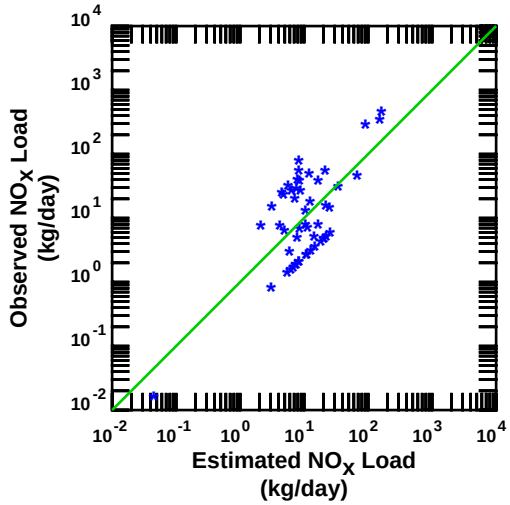


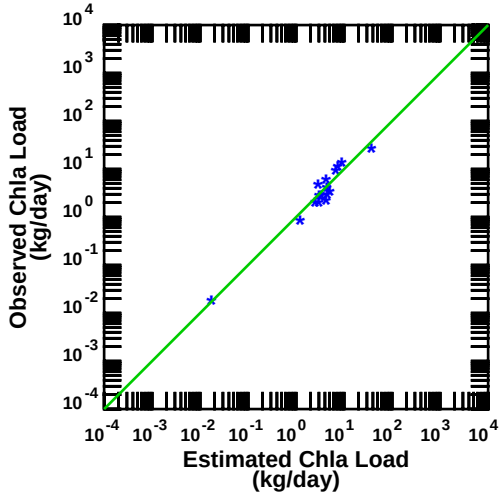
Observed Loads vs. Estimated Load, Station 17648

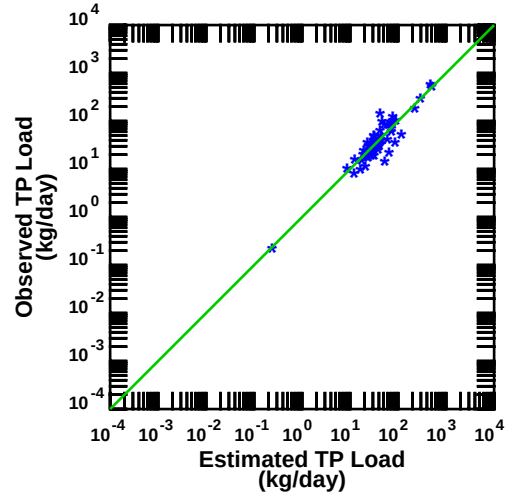
Nueces Tributaries, Texas (1970-2014)





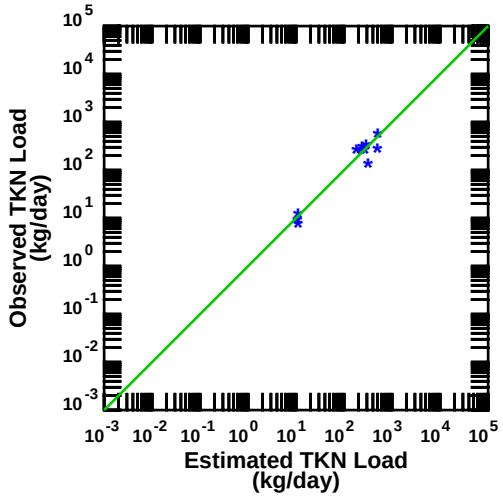


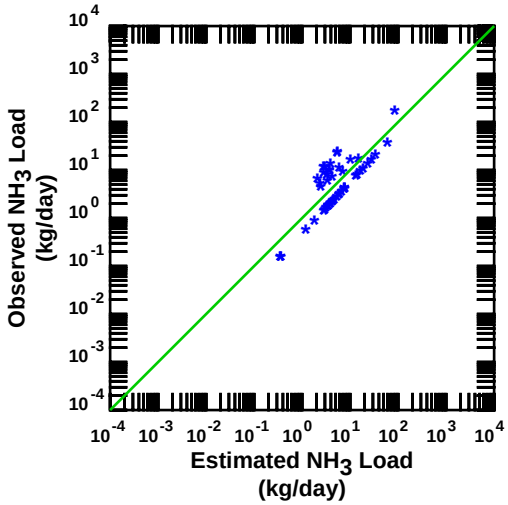


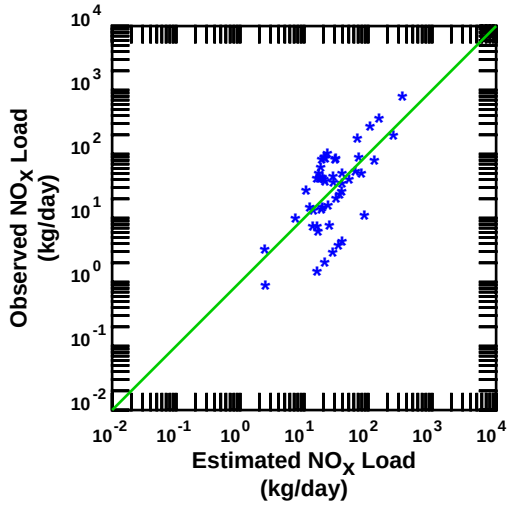


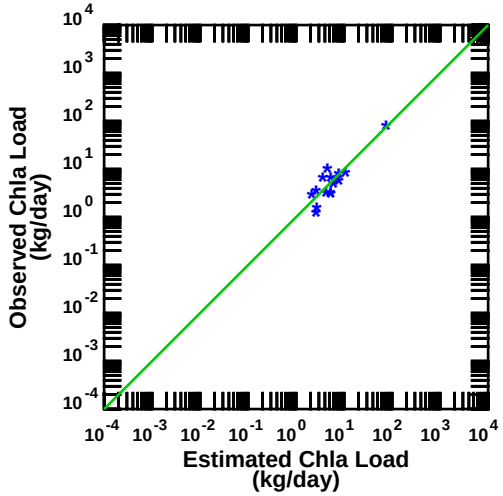
Observed Loads vs. Estimated Load, Station 12965

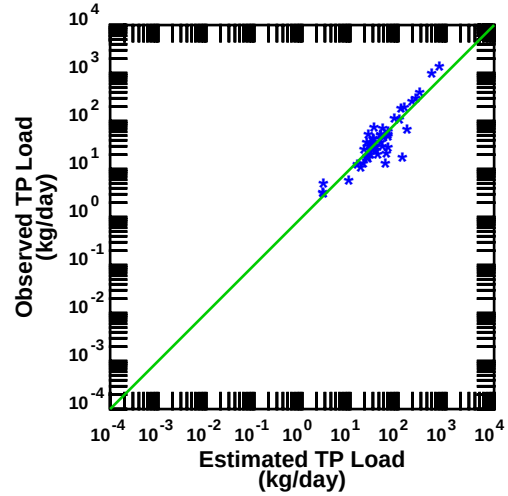
Nueces Tributaries, Texas (1970-2014)





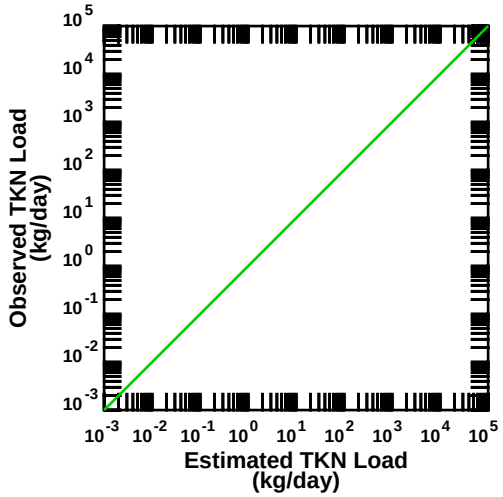


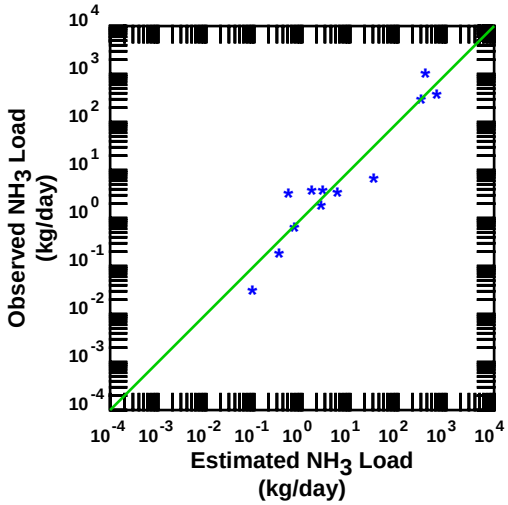


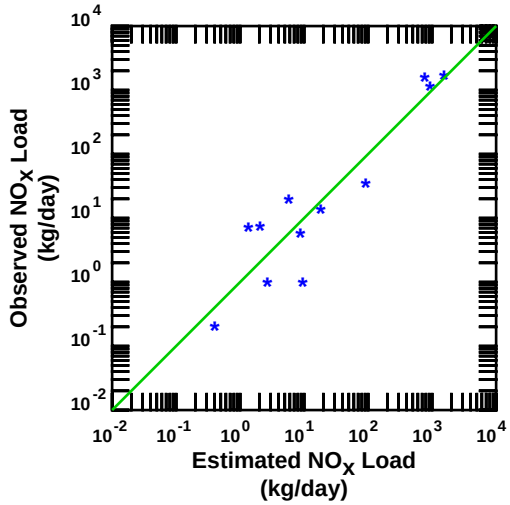


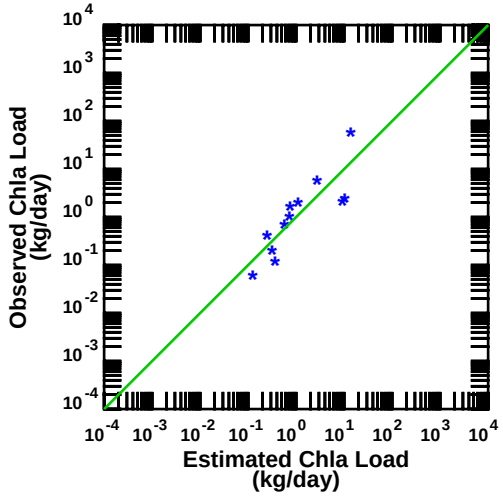
Observed Loads vs. Estimated Load, Station 12964

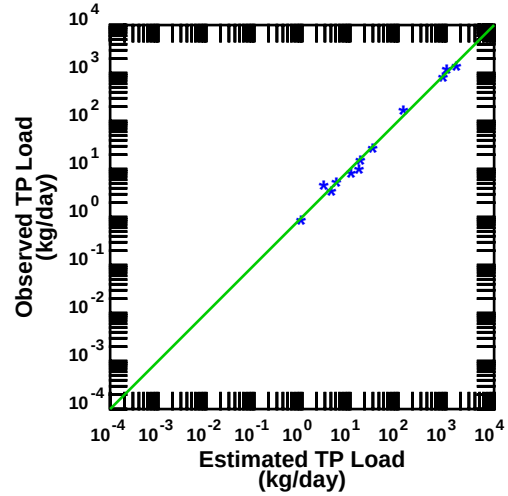
Nueces Tributaries, Texas (1970-2014)

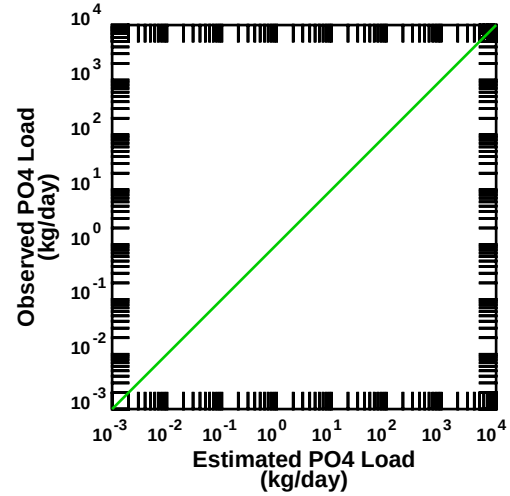






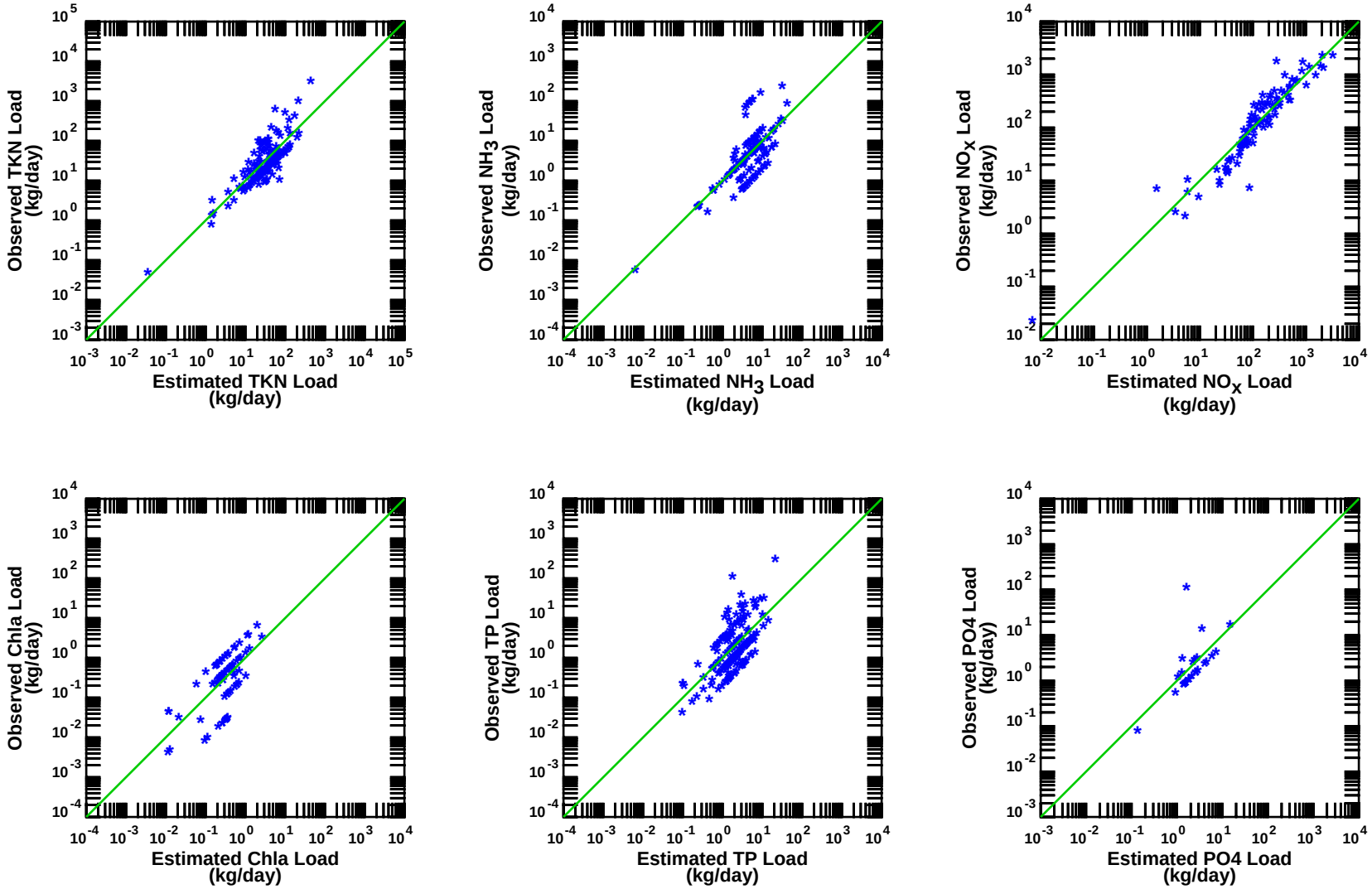






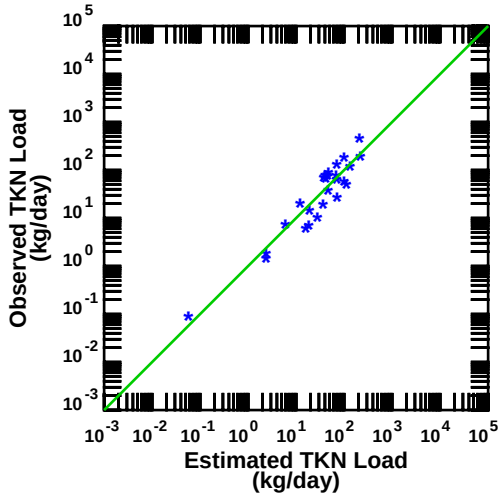
Observed Loads vs. Estimated Load, Station 12962

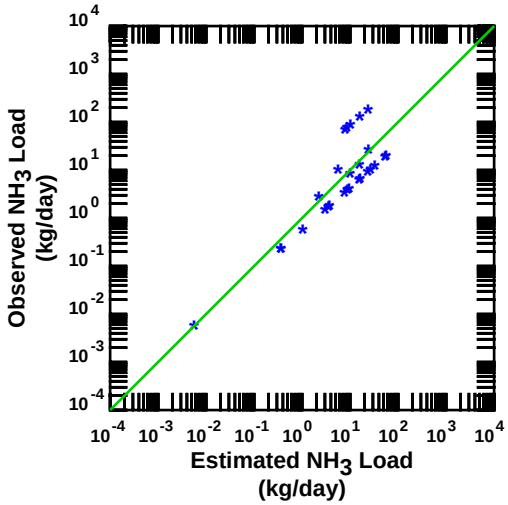
Nueces Tributaries, Texas (1970-2014)

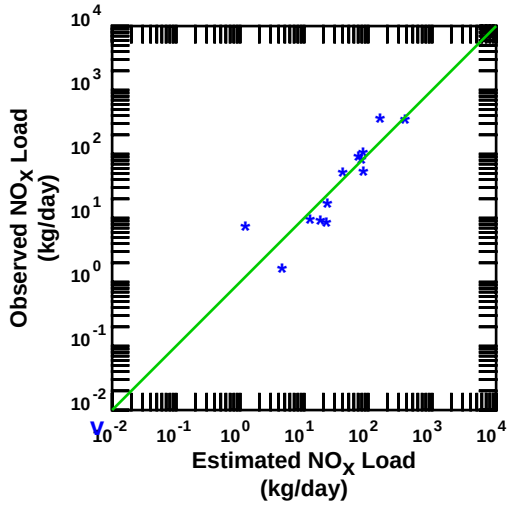


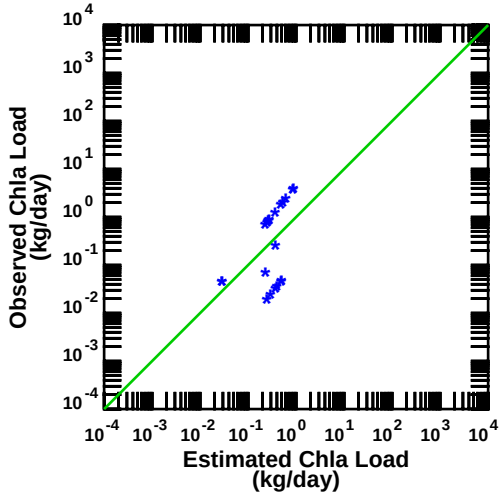
Observed Loads vs. Estimated Load, Station 13006

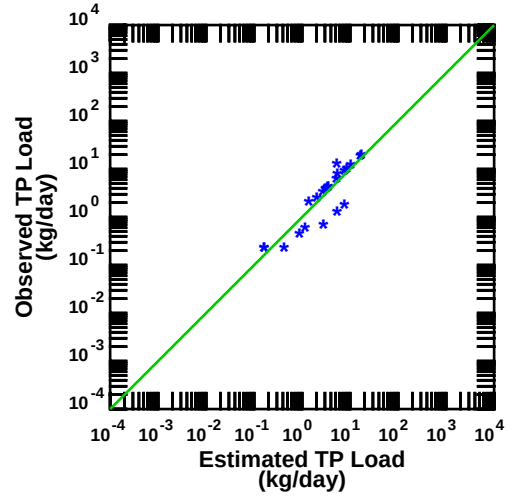
Nueces Tributaries, Texas (1970-2014)





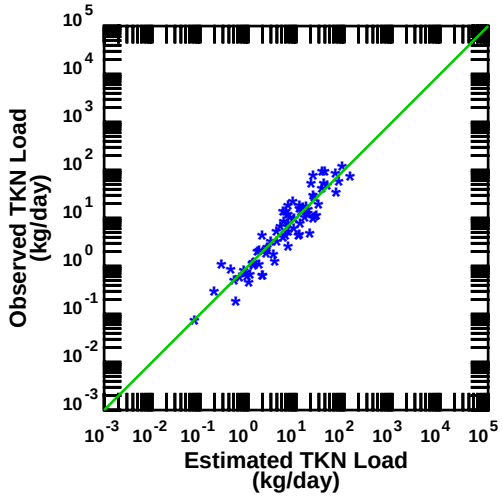


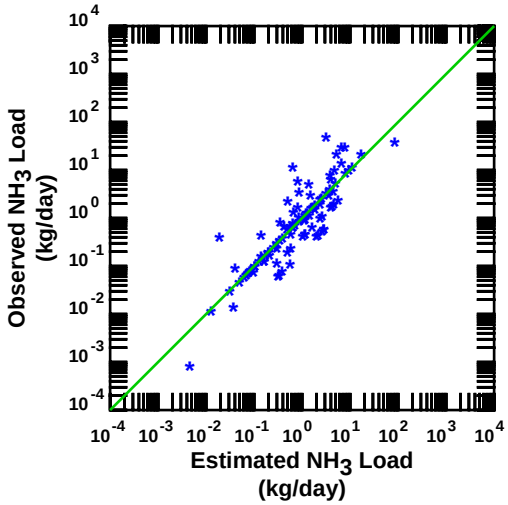


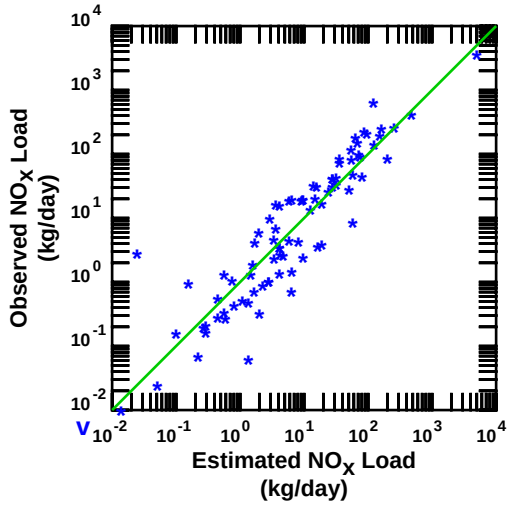


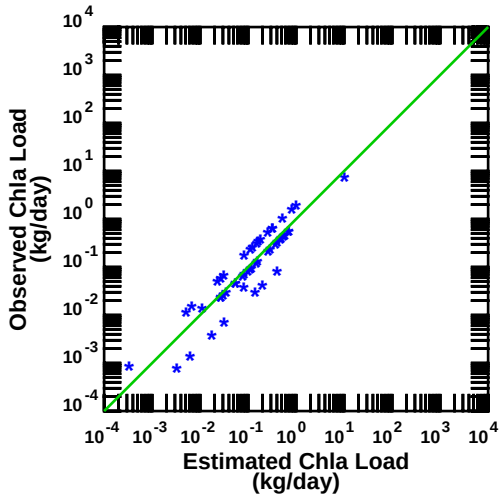
Observed Loads vs. Estimated Load, Station 13007

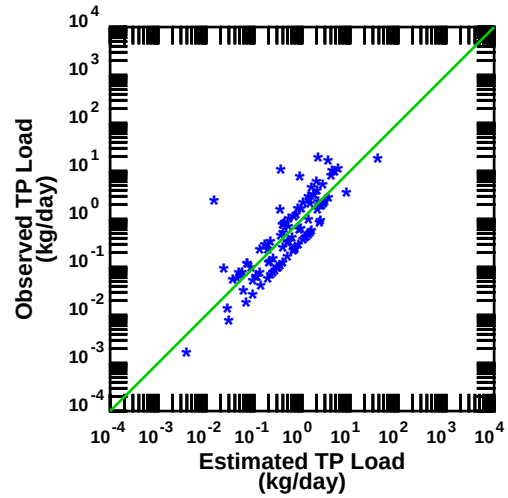
Nueces Tributaries, Texas (1970-2014)

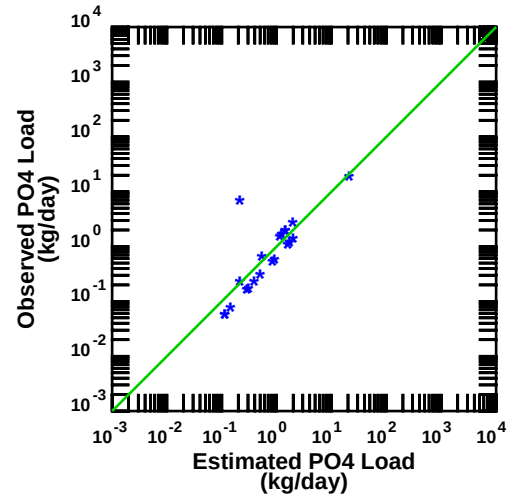






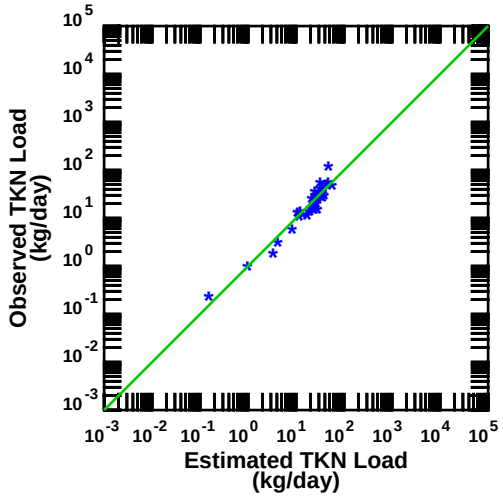


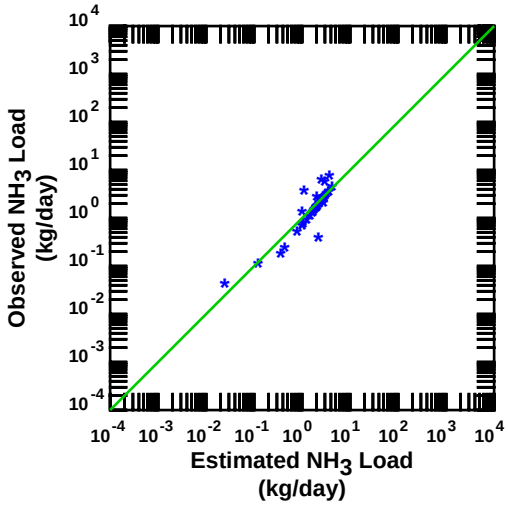


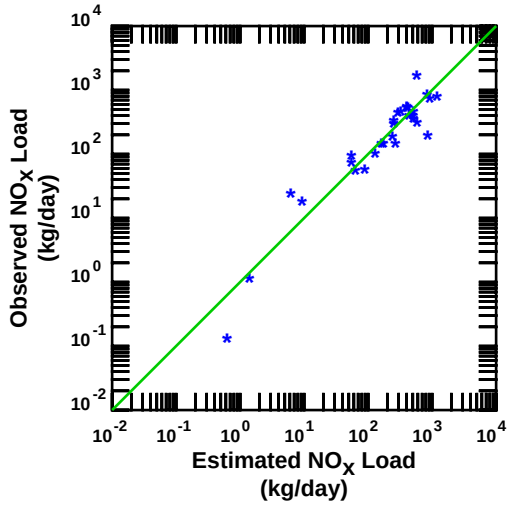


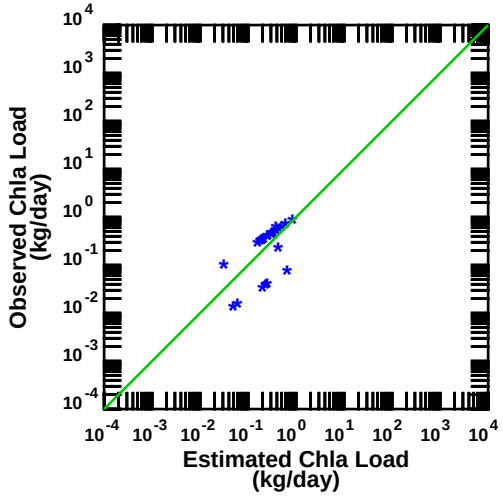
Observed Loads vs. Estimated Load, Station 13010

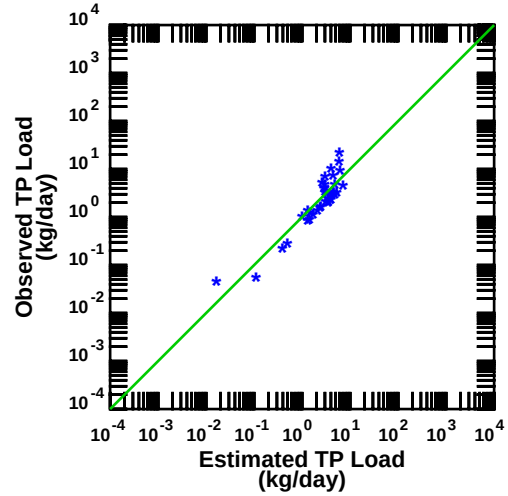
Nueces Tributaries, Texas (1970-2014)





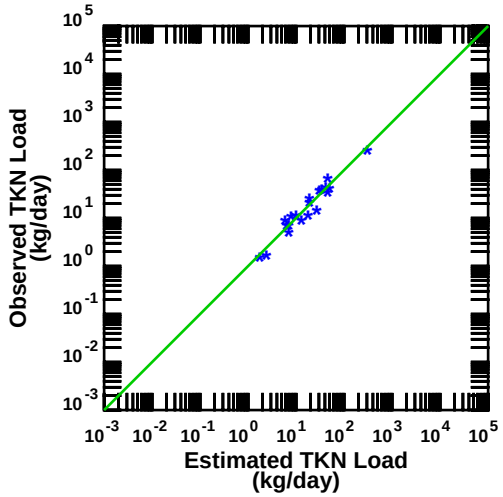


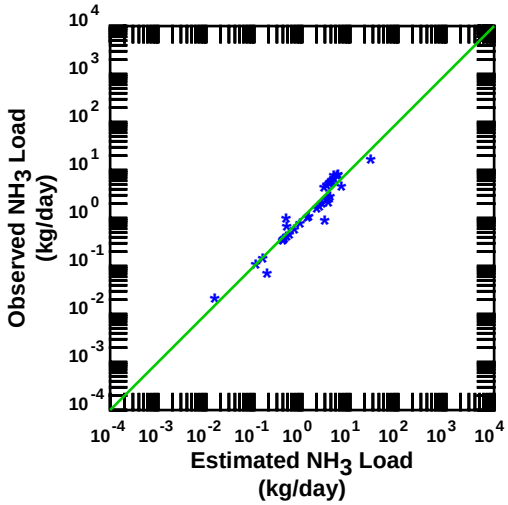


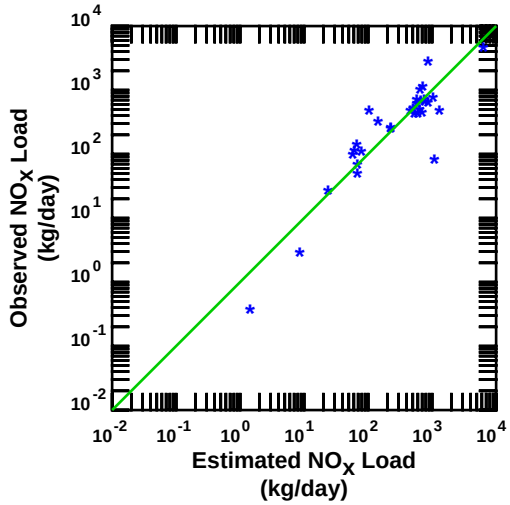


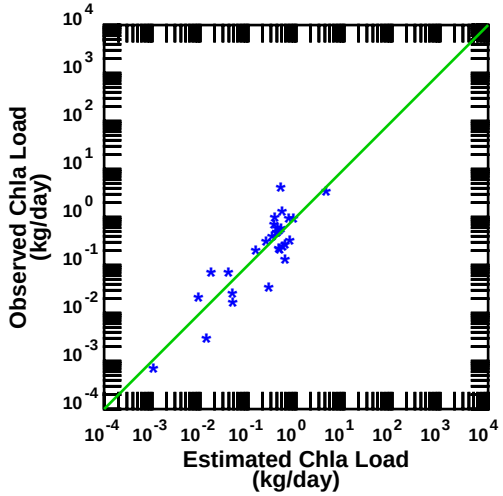
Observed Loads vs. Estimated Load, Station 12987

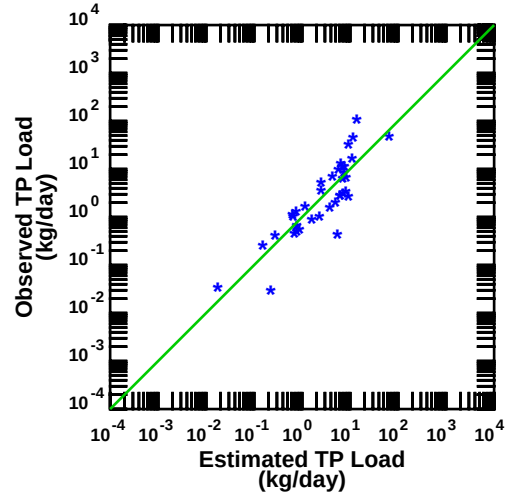
Nueces Tributaries, Texas (1970-2014)

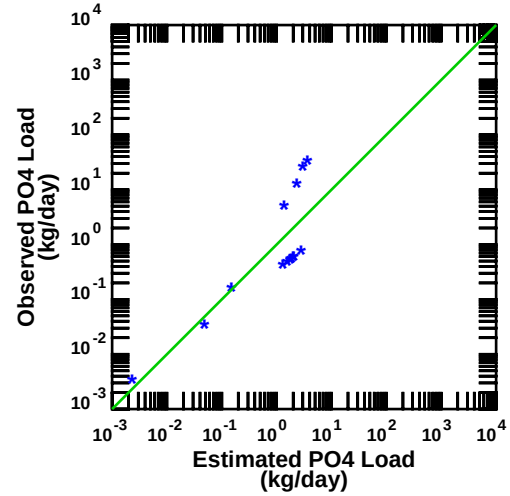






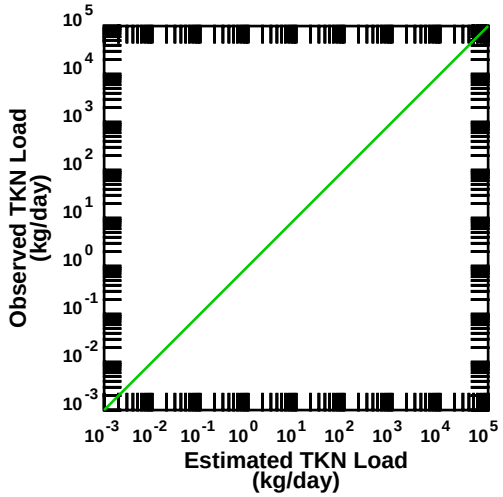


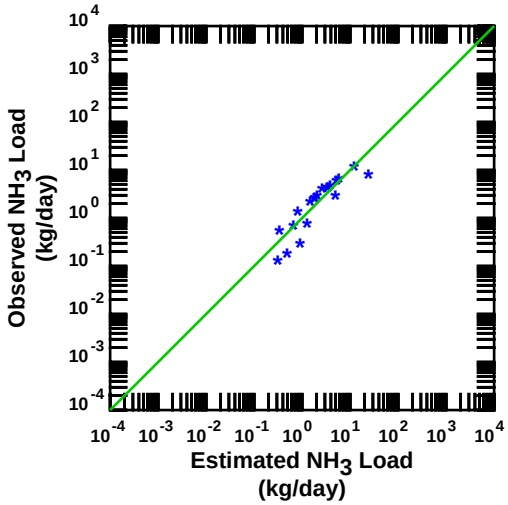


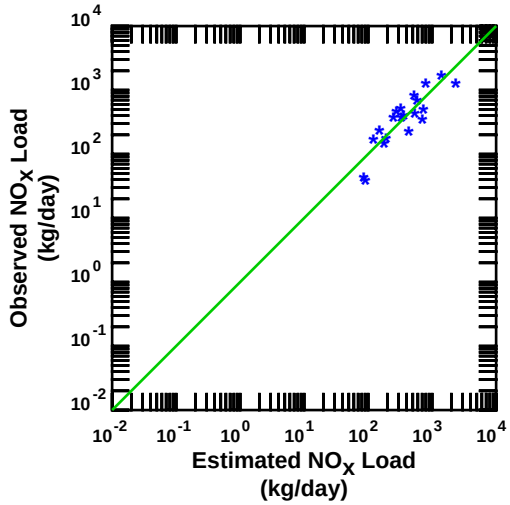


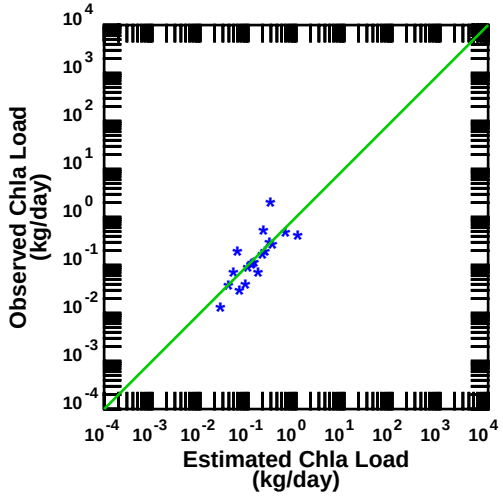
Observed Loads vs. Estimated Load, Station 12985

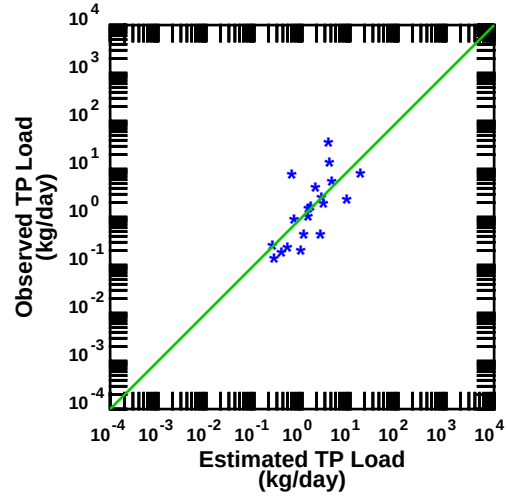
Nueces Tributaries, Texas (1970-2014)

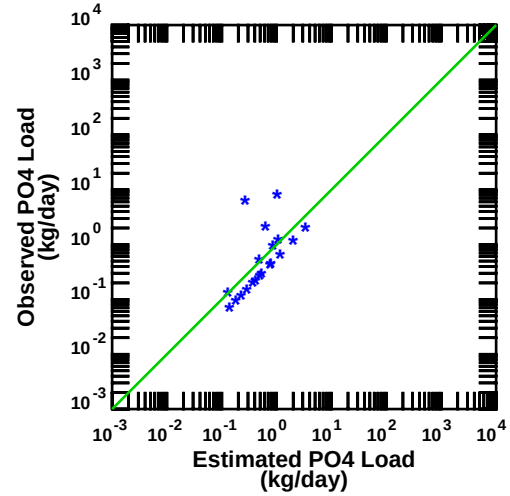






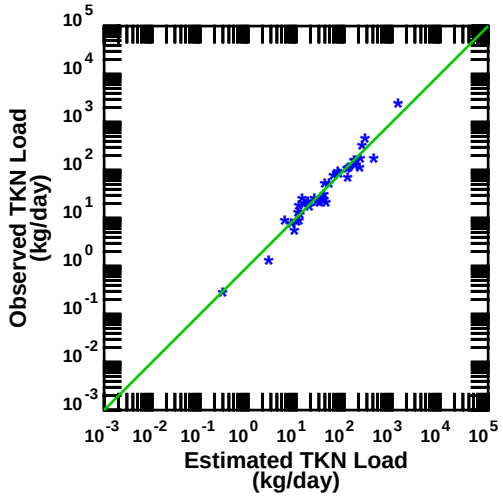


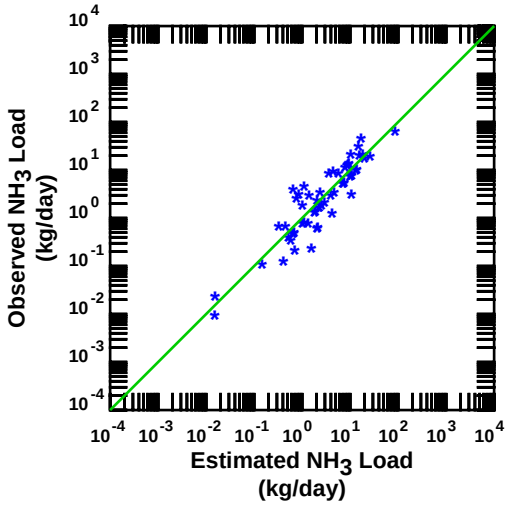


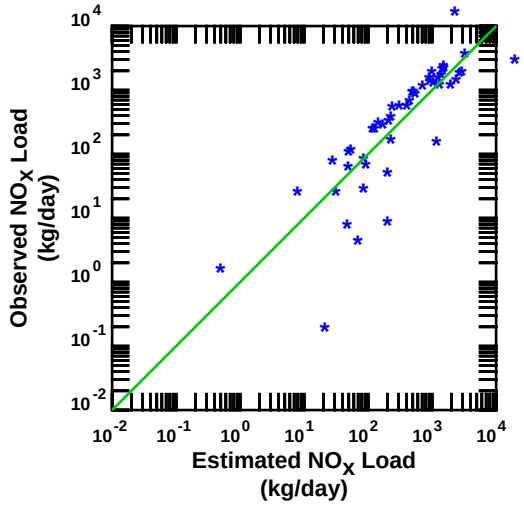


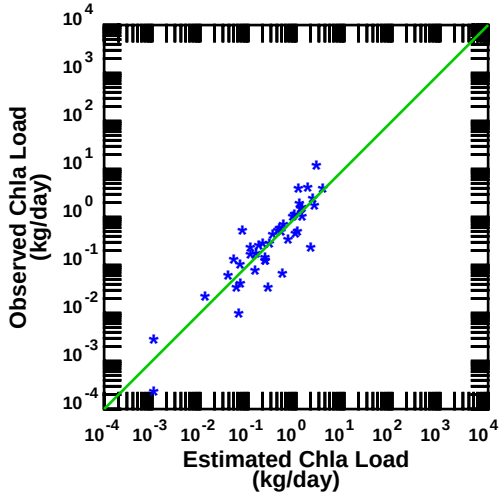
Observed Loads vs. Estimated Load, Station 13025

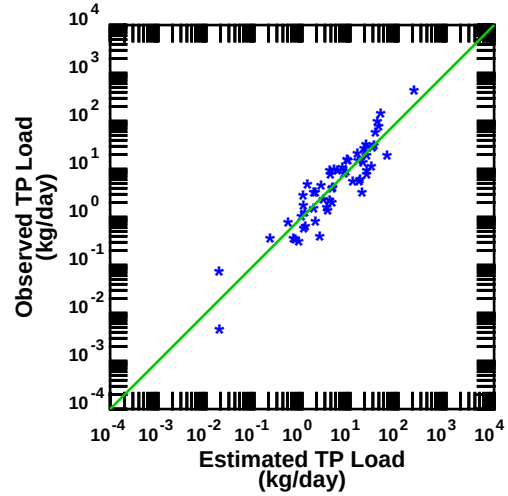
Nueces Tributaries, Texas (1970-2014)

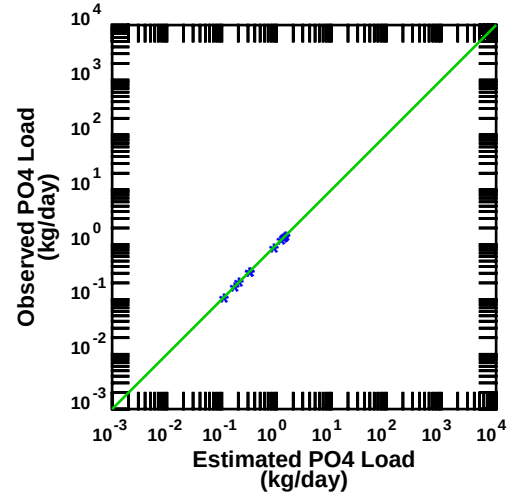






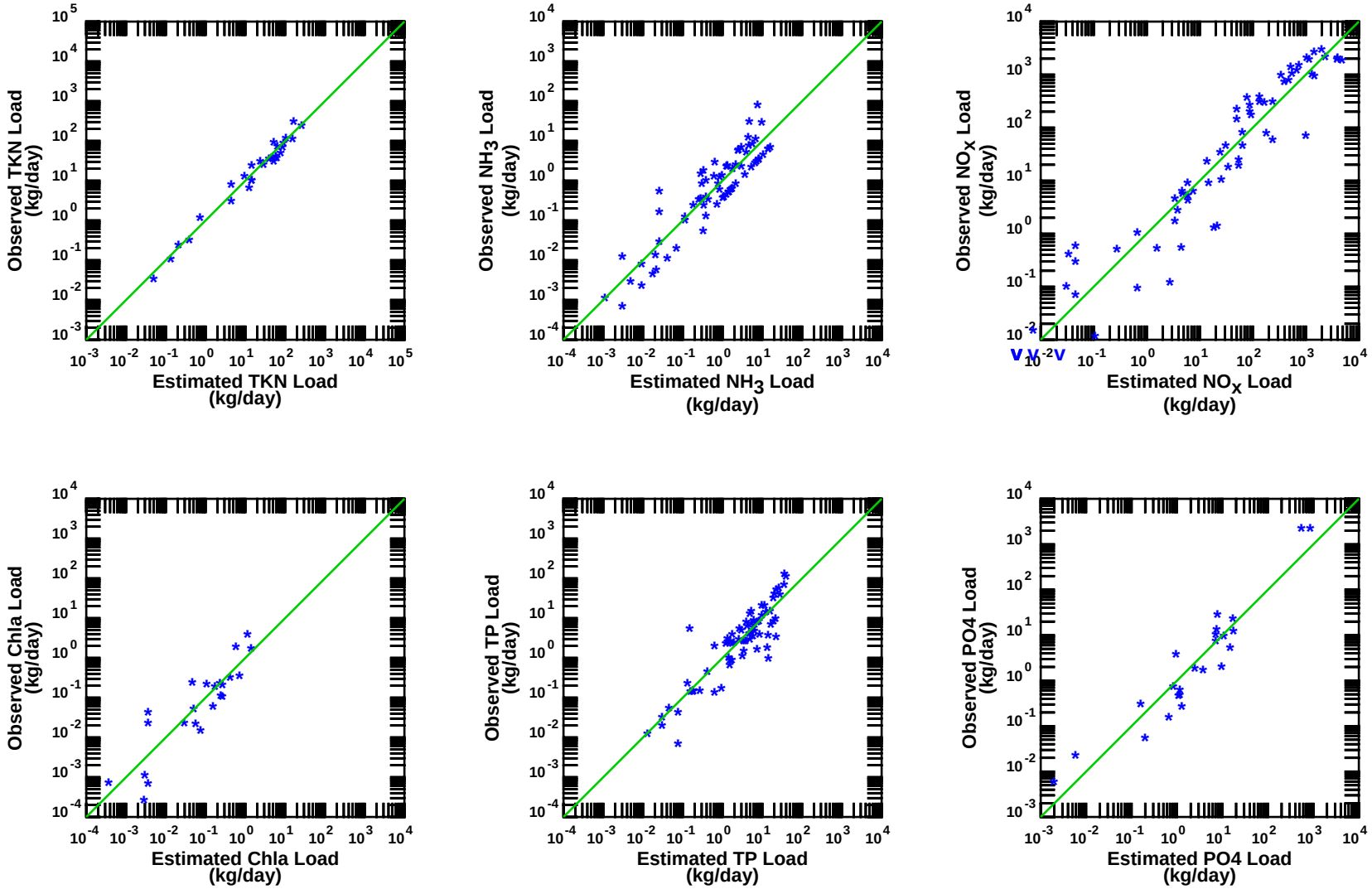






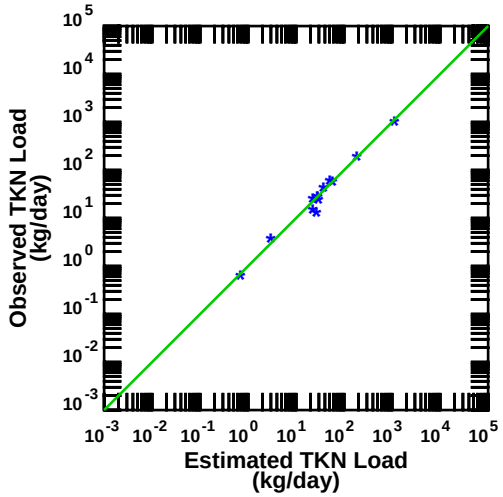
Observed Loads vs. Estimated Load, Station 13024

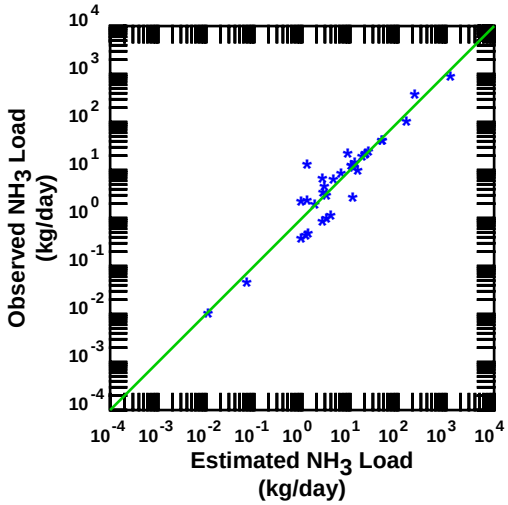
Nueces Tributaries, Texas (1970-2014)

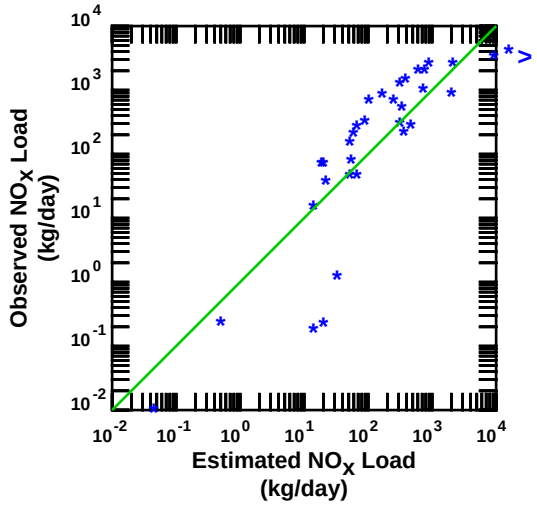


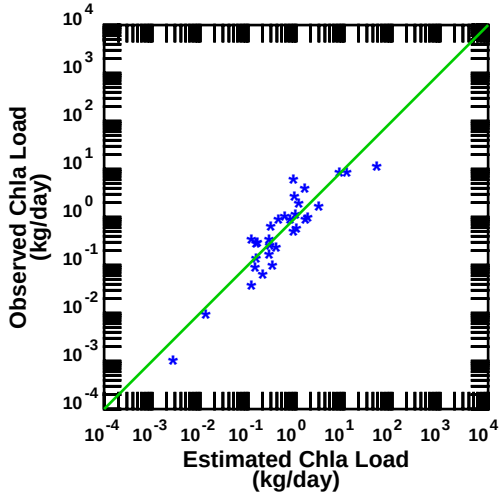
Observed Loads vs. Estimated Load, Station 13023

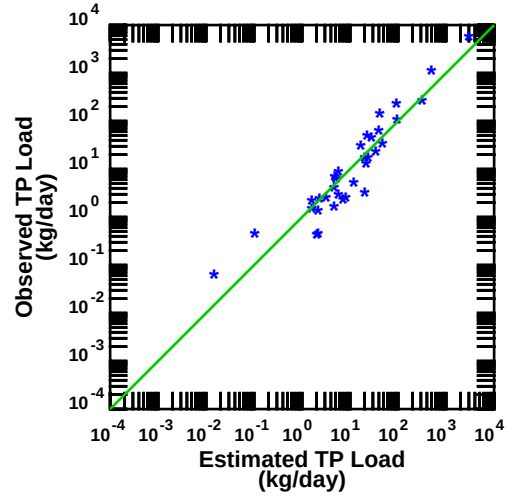
Nueces Tributaries, Texas (1970-2014)

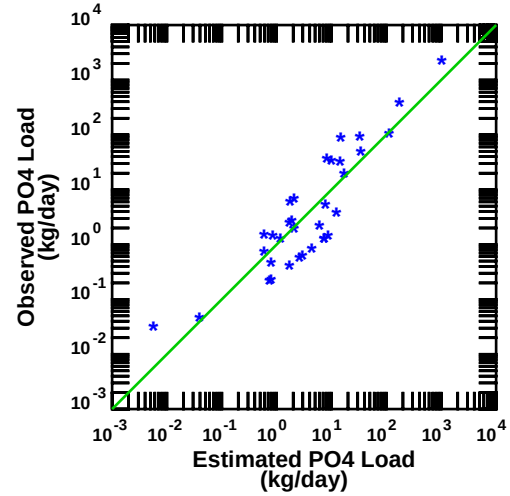






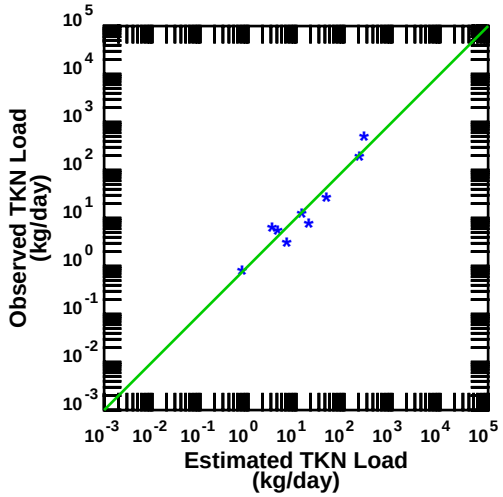


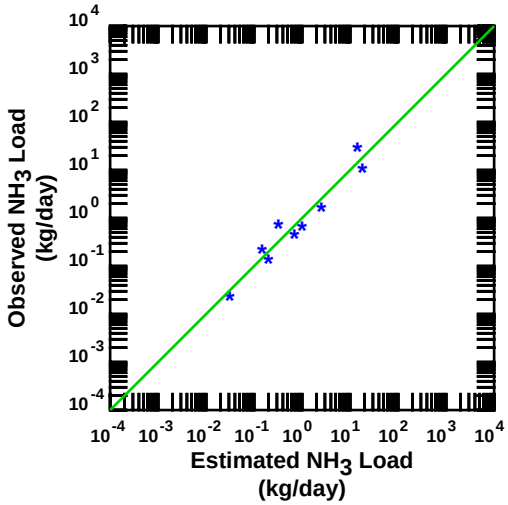


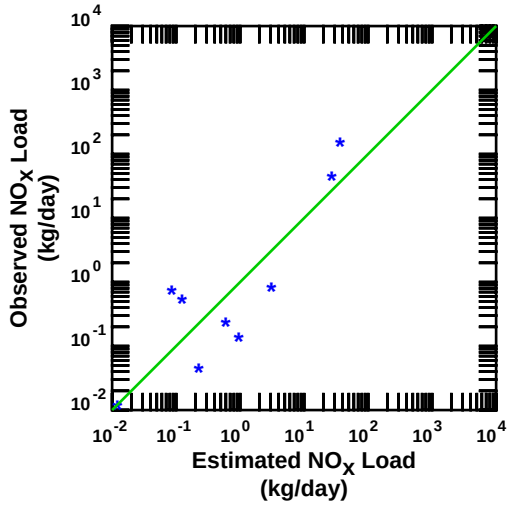


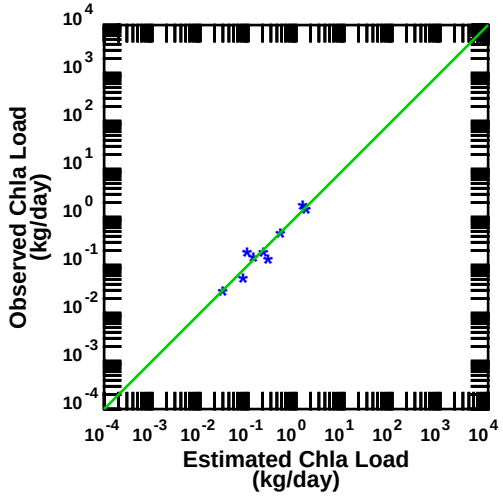
Observed Loads vs. Estimated Load, Station 13021

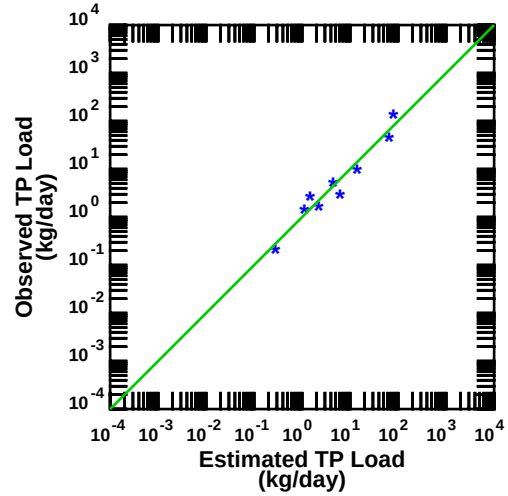
Nueces Tributaries, Texas (1970-2014)





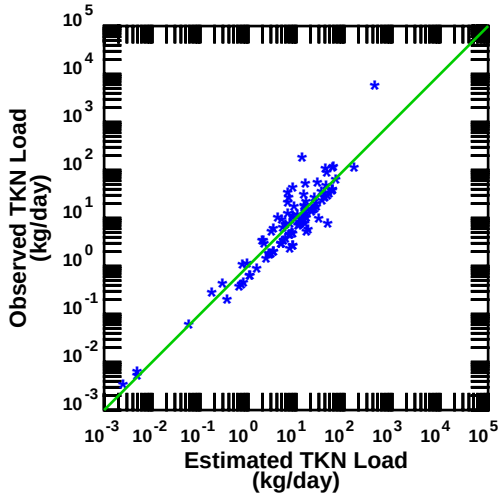


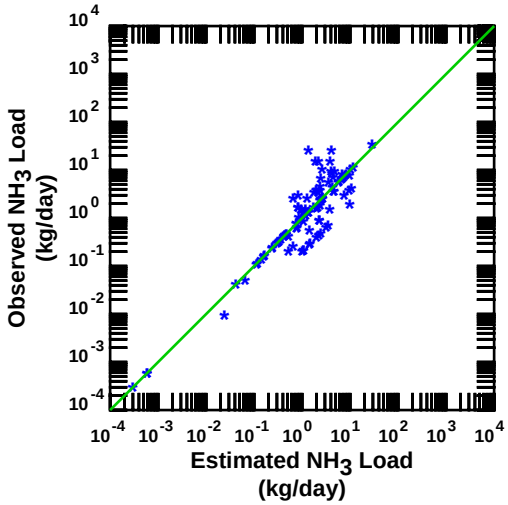


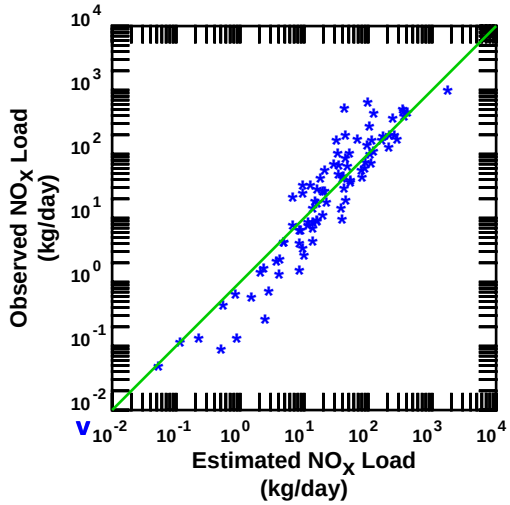


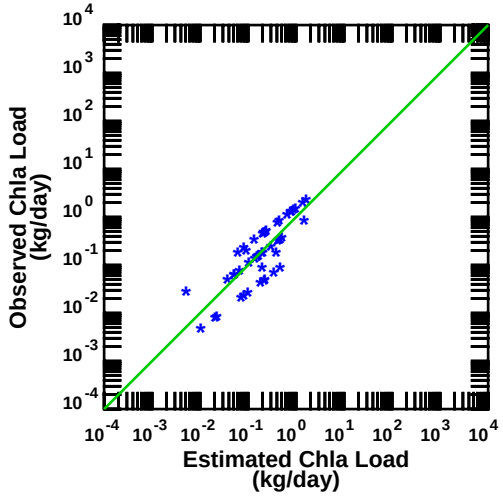
Observed Loads vs. Estimated Load, Station 20773

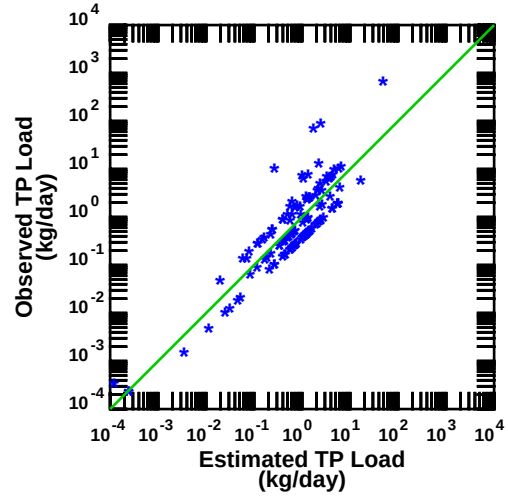
Nueces Tributaries, Texas (1970-2014)

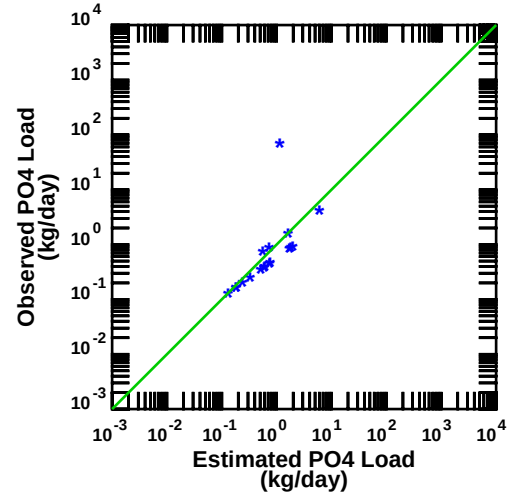






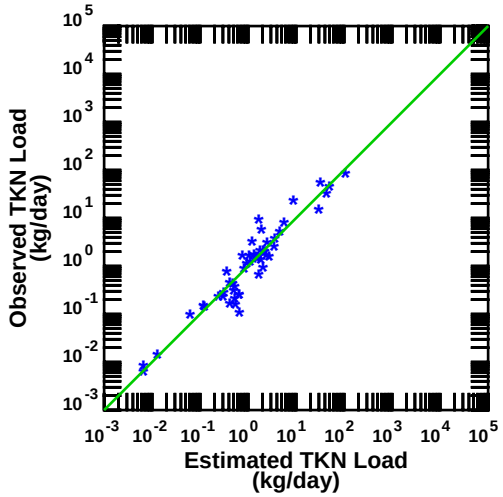


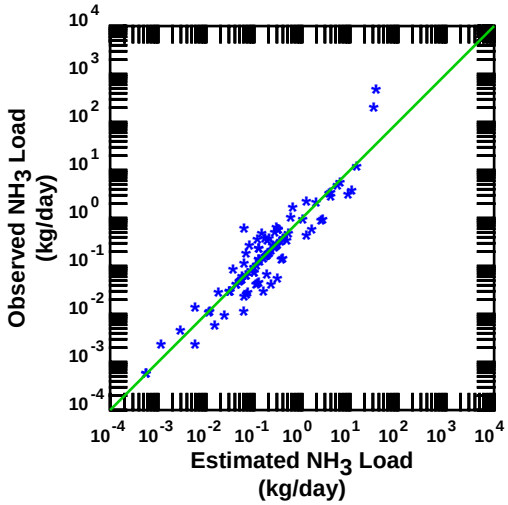


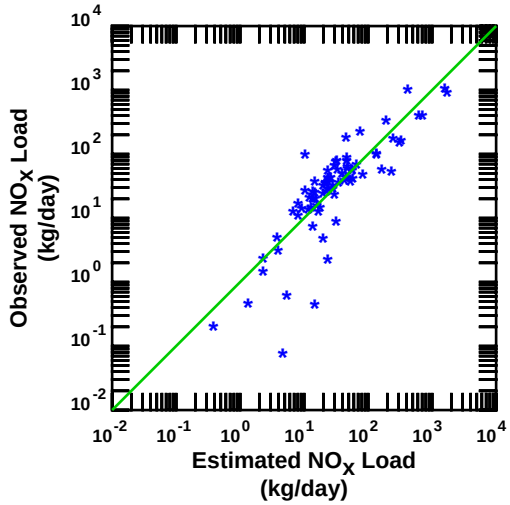


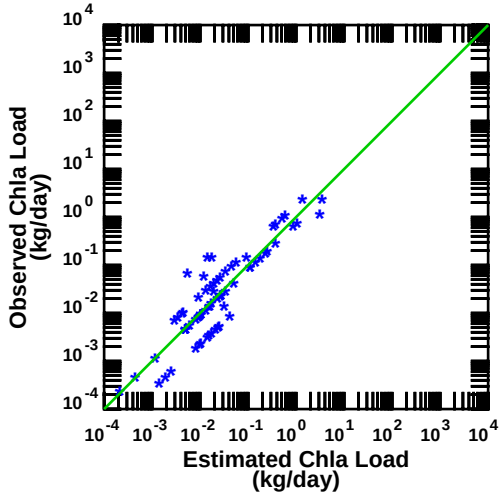
Observed Loads vs. Estimated Load, Station 12994

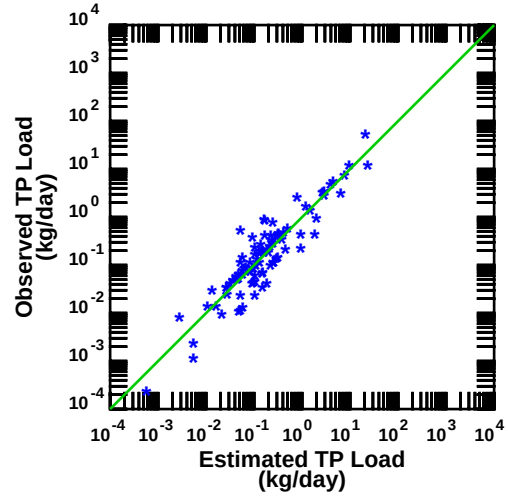
Nueces Tributaries, Texas (1970-2014)

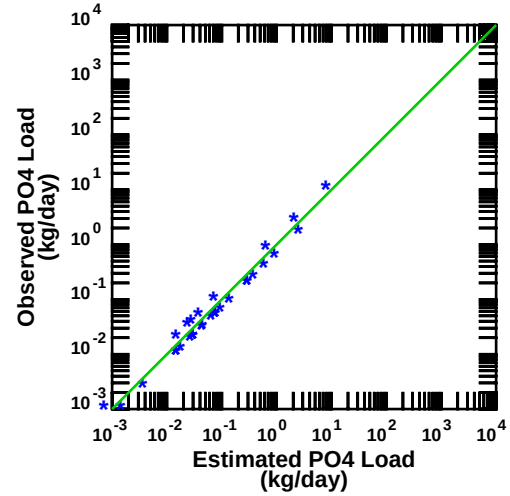






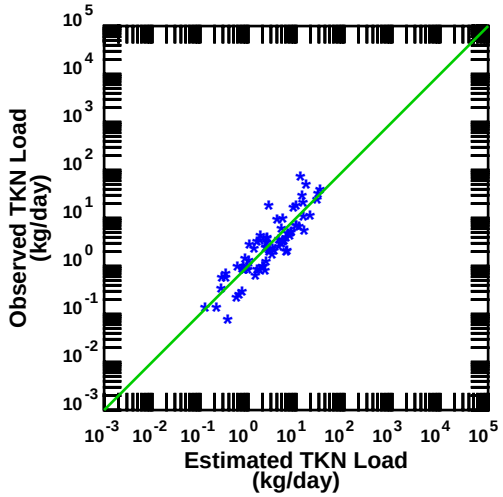


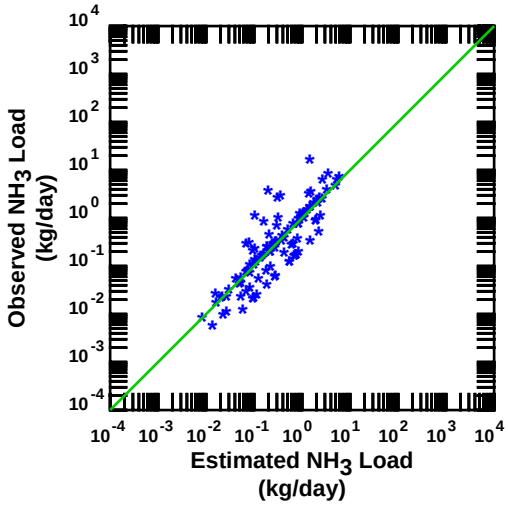


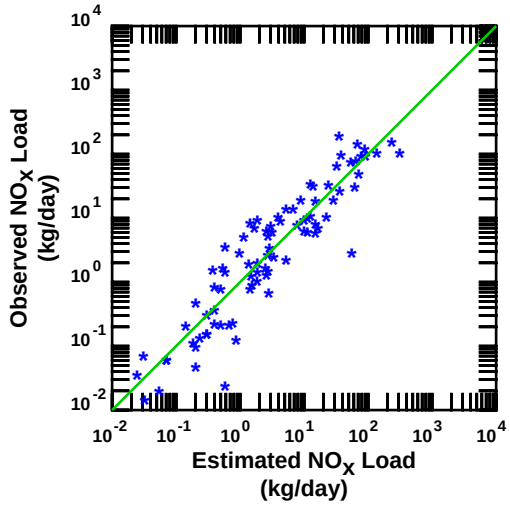


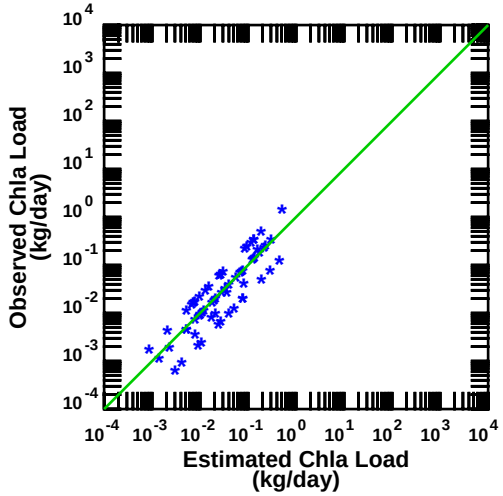
Observed Loads vs. Estimated Load, Station 12993

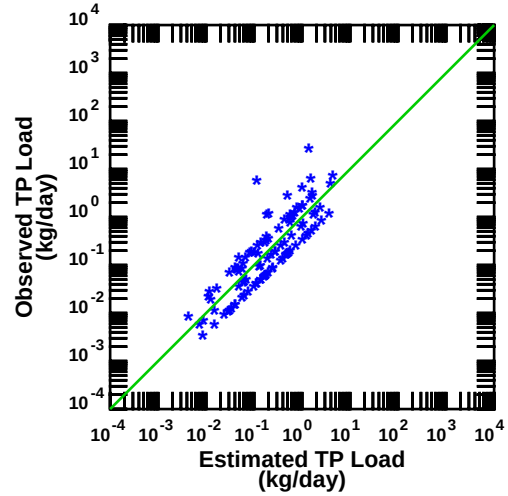
Nueces Tributaries, Texas (1970-2014)

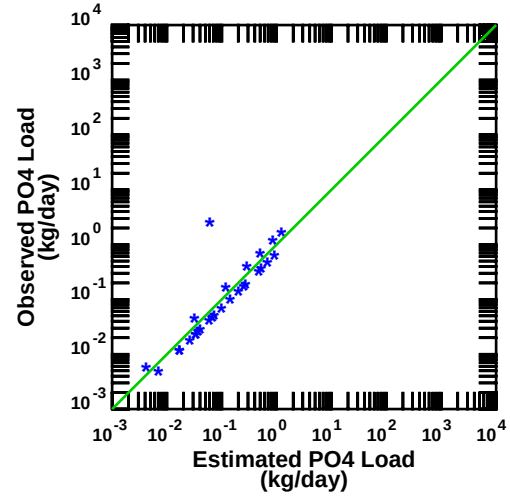






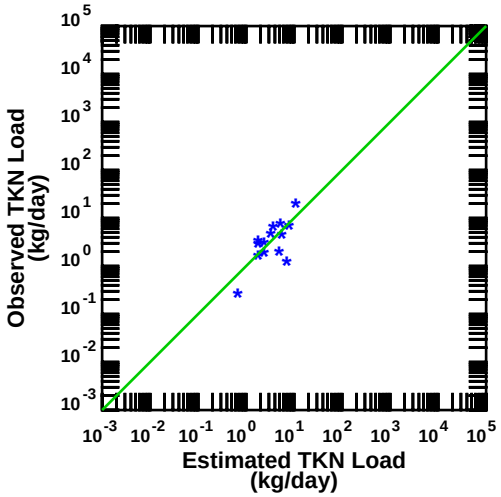


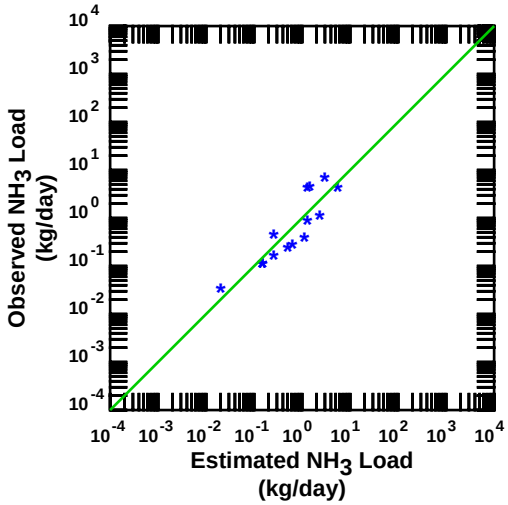


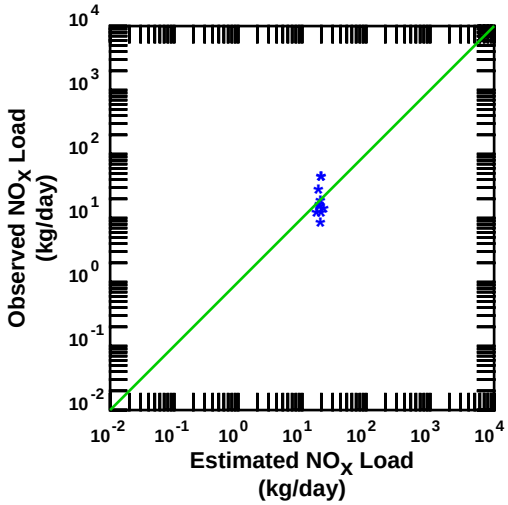


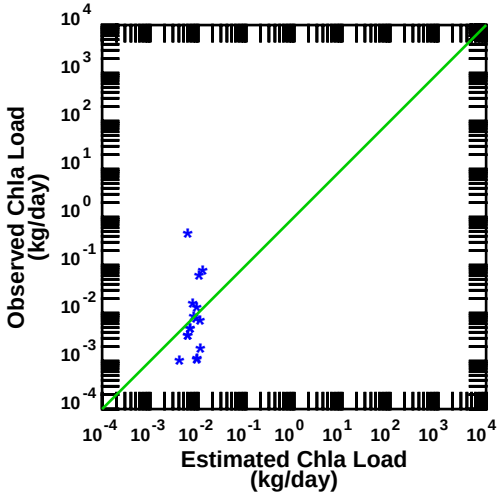
Observed Loads vs. Estimated Load, Station 13013

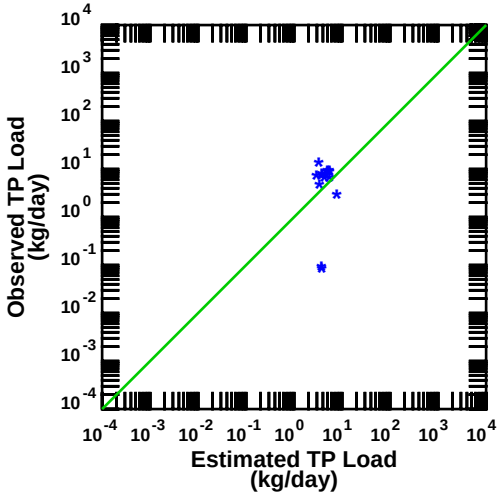
Nueces Tributaries, Texas (1970-2014)





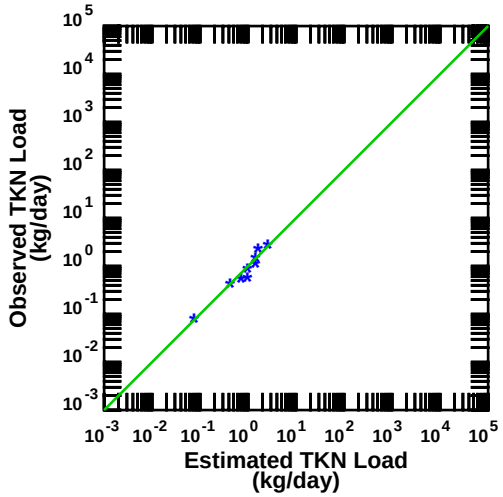


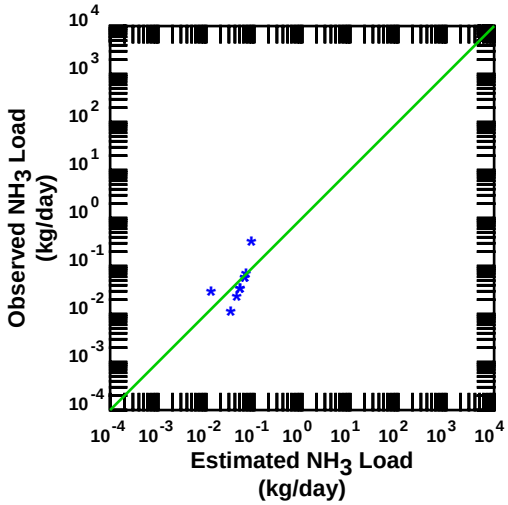


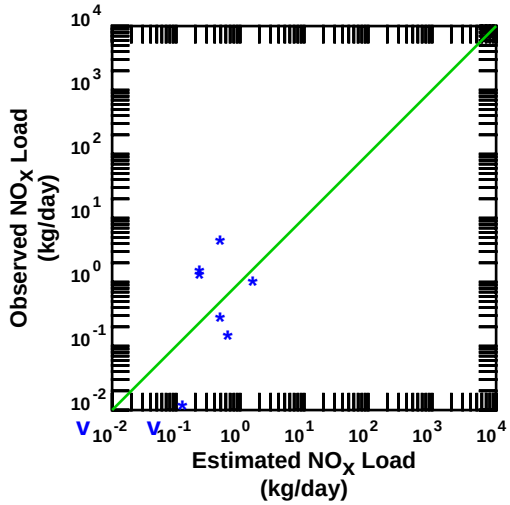


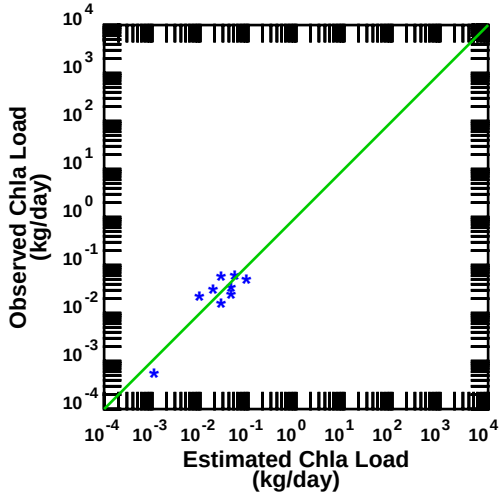
Observed Loads vs. Estimated Load, Station 17900

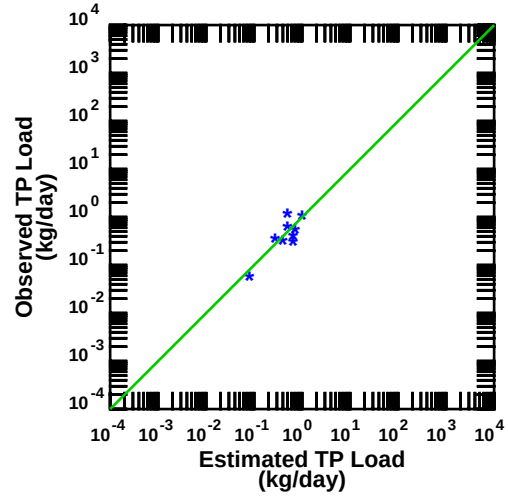
Nueces Tributaries, Texas (1970-2014)





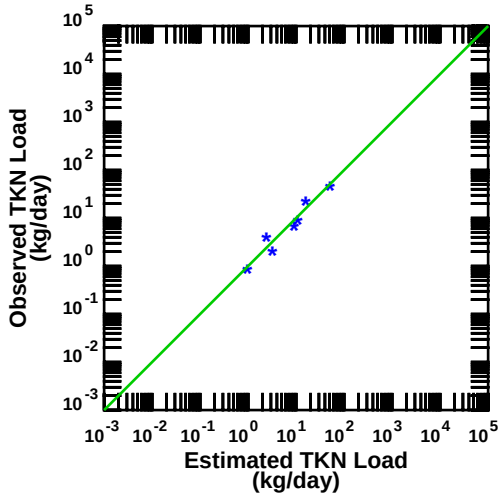


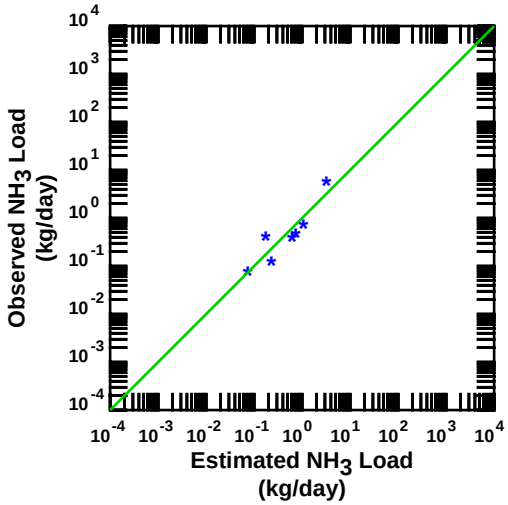


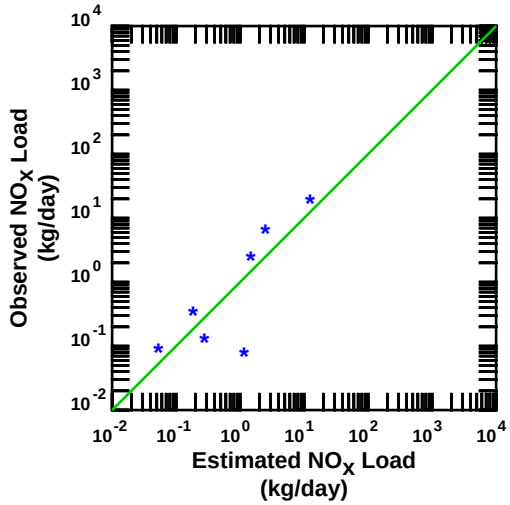


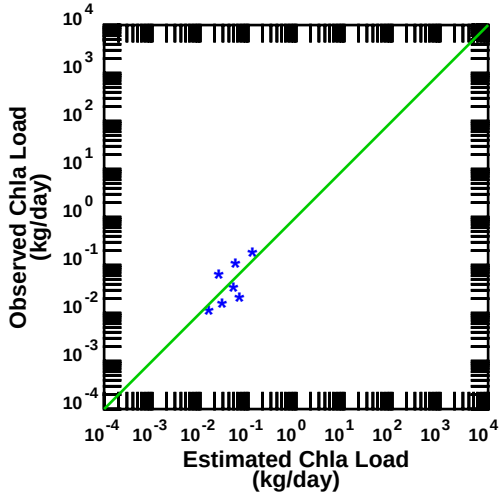
Observed Loads vs. Estimated Load, Station 20762

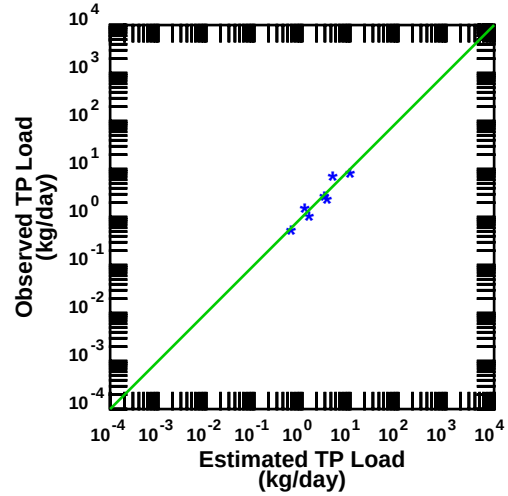
Nueces Tributaries, Texas (1970-2014)





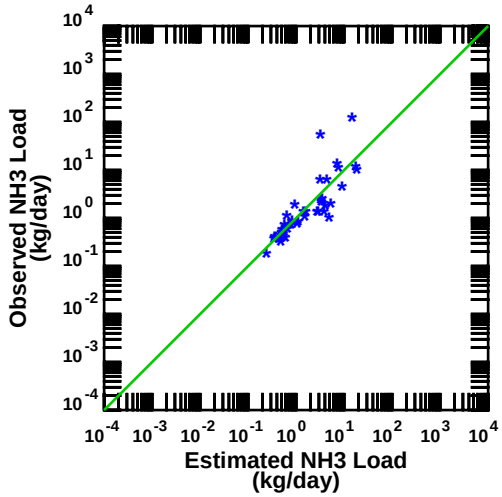


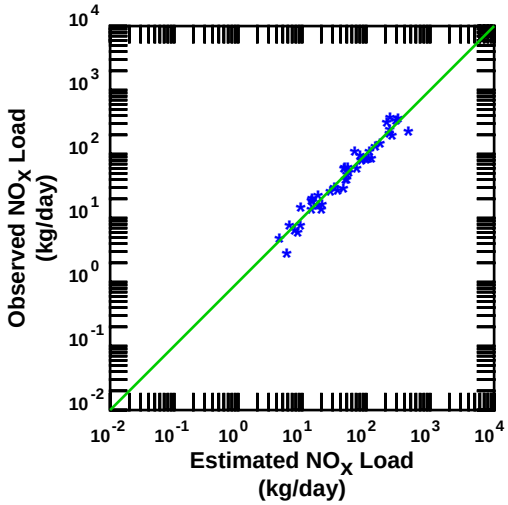


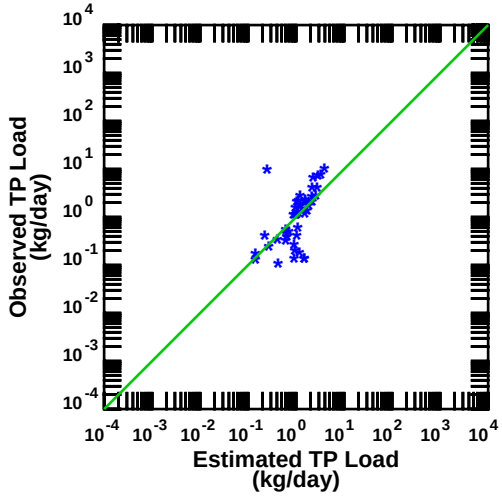


Observed Loads vs. Estimated Load, Station 20764

Nueces Tributaries, Texas (1970-2014)

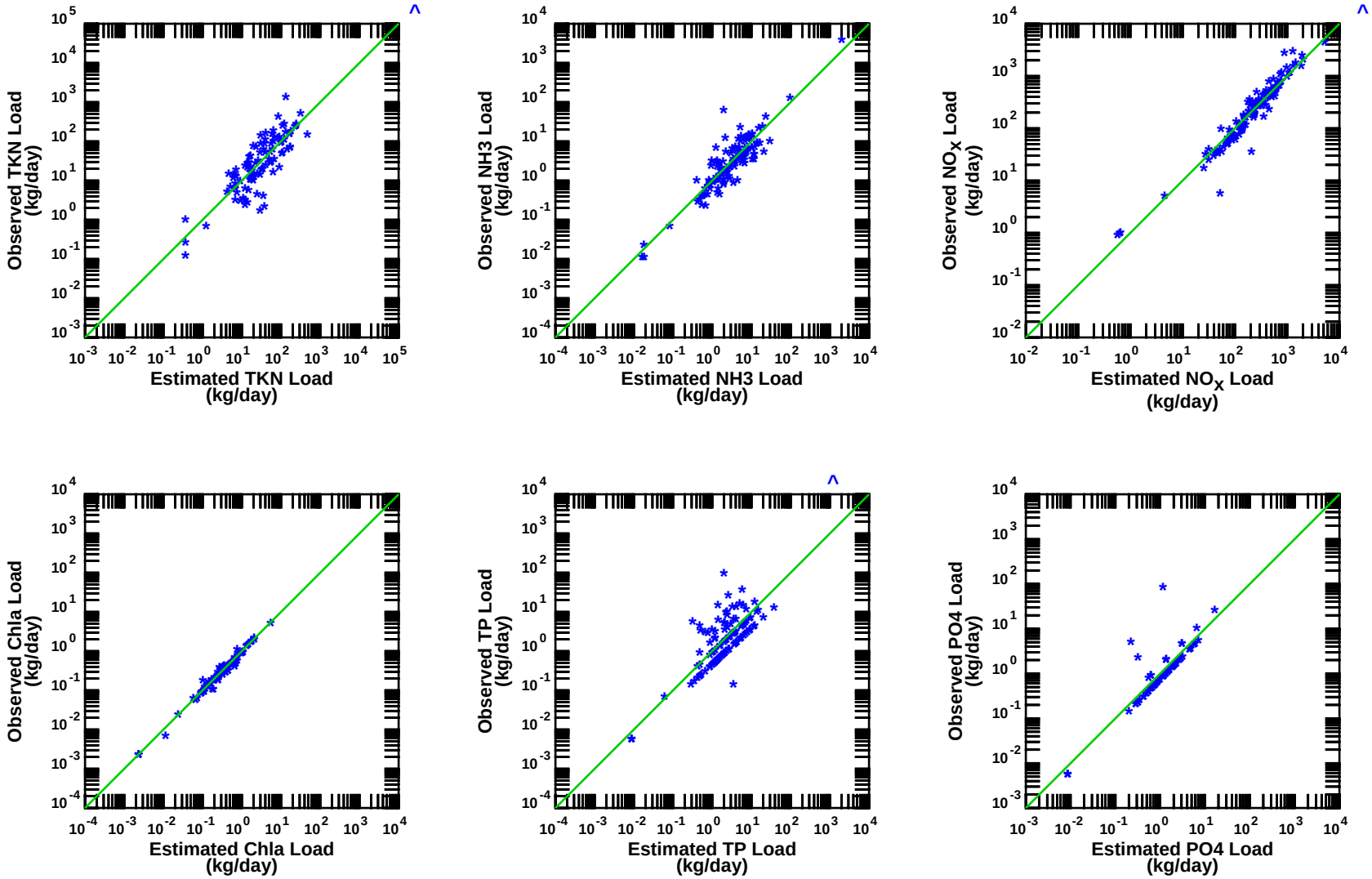






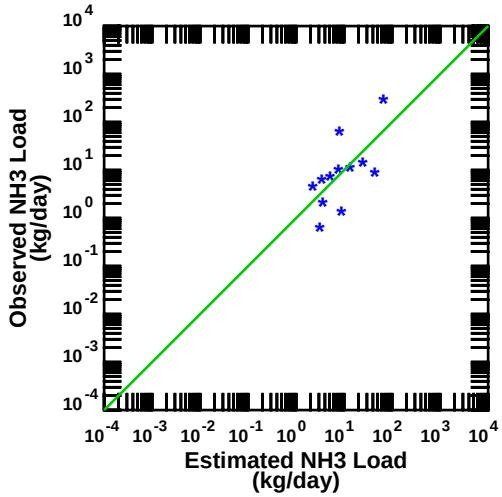
Observed Load vs. LOADEST Estimated Load, Station 13005

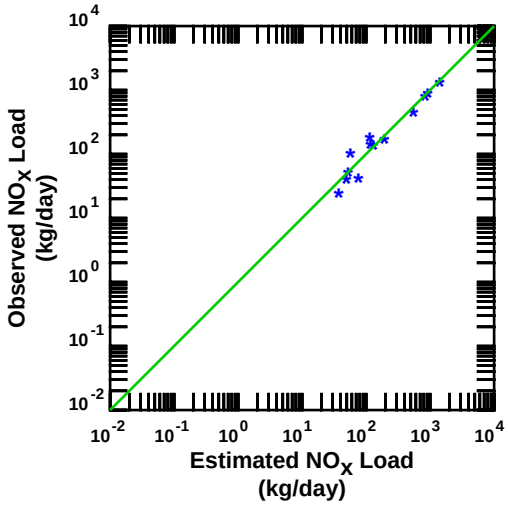
Nueces Tributaries, Texas (1970-2014)

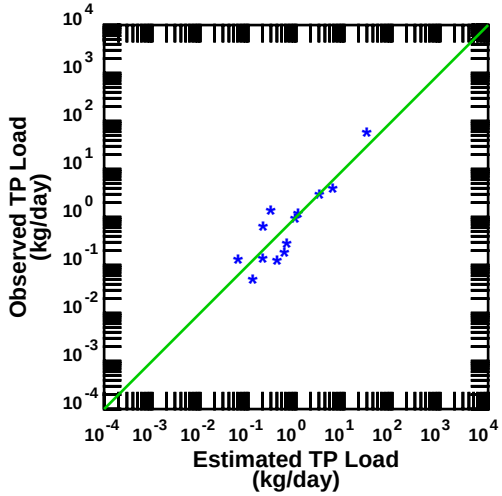


Observed Load vs. LOADEST Estimated Load, Station 12999

Nueces Tributaries, Texas (1970-2014)

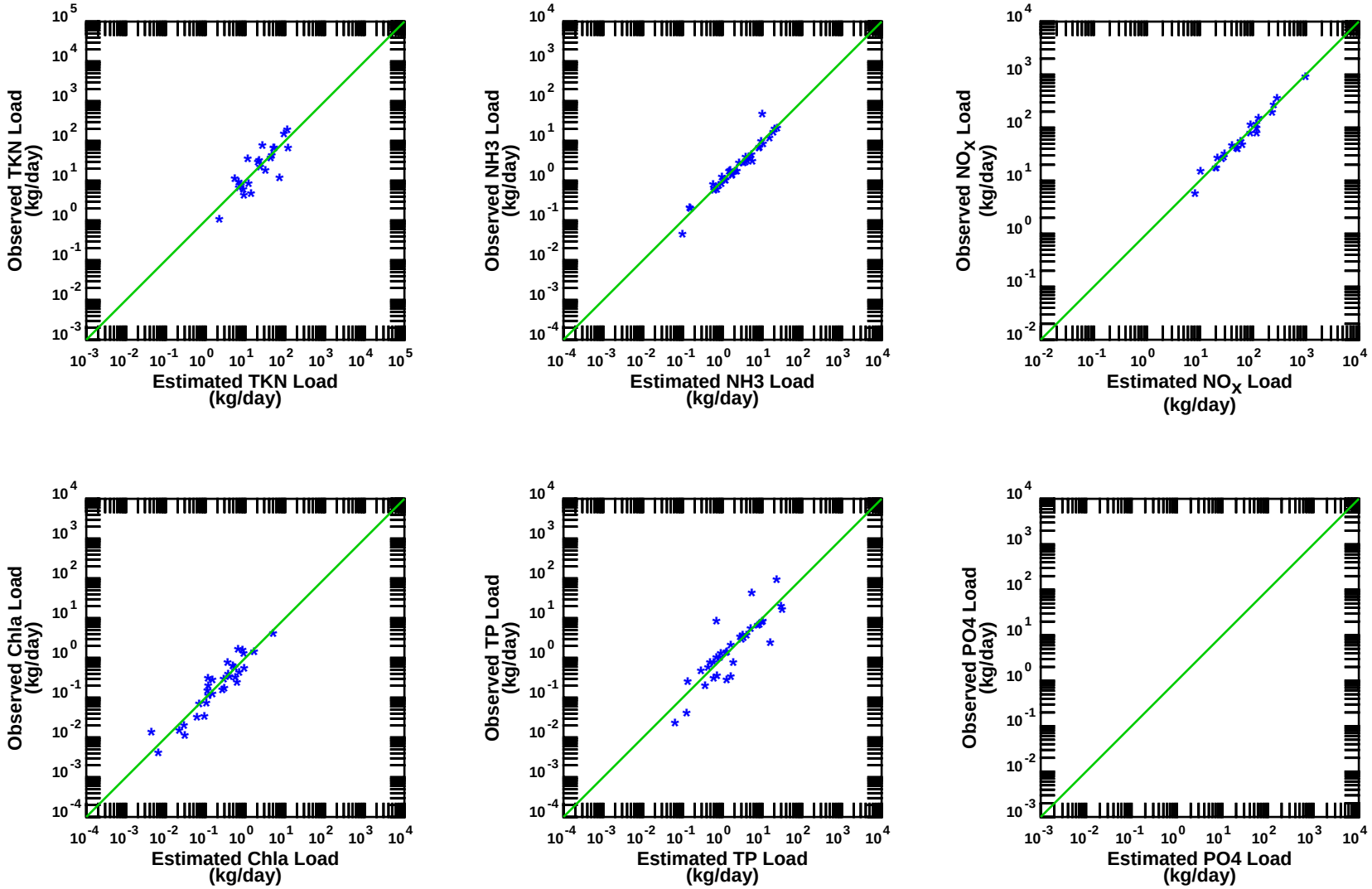






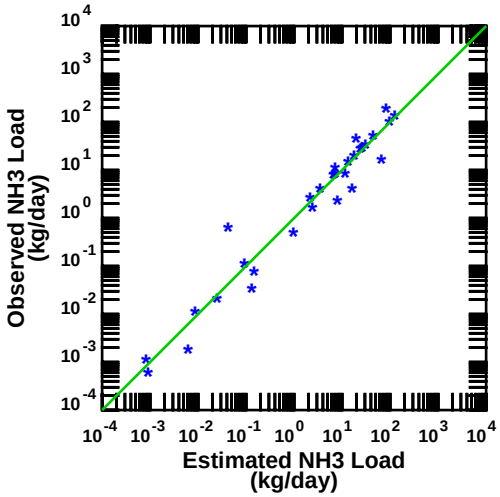
Observed Load vs. LOADEST Estimated Load, Station 12997

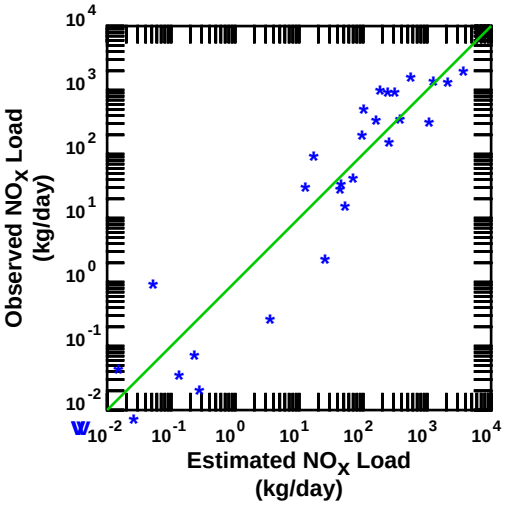
Nueces Tributaries, Texas (1970-2014)

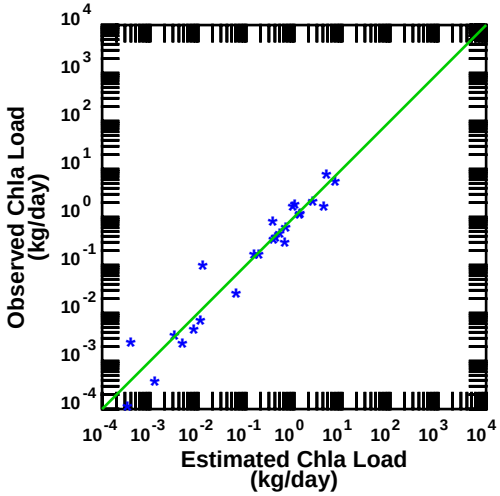


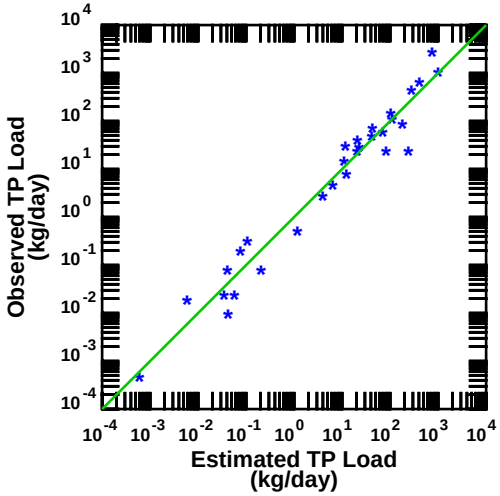
Observed Load vs. LOADEST Estimated Load, Station 12996

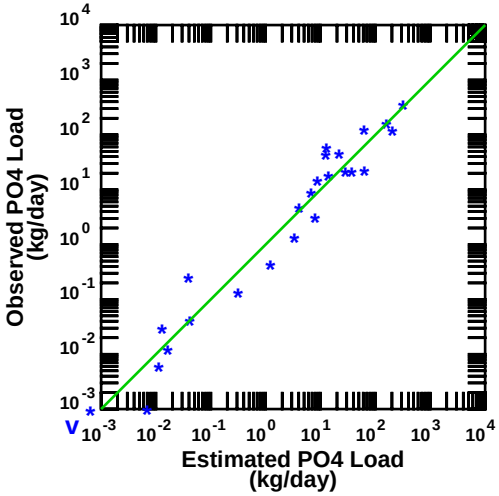
Nueces Tributaries, Texas (1970-2014)





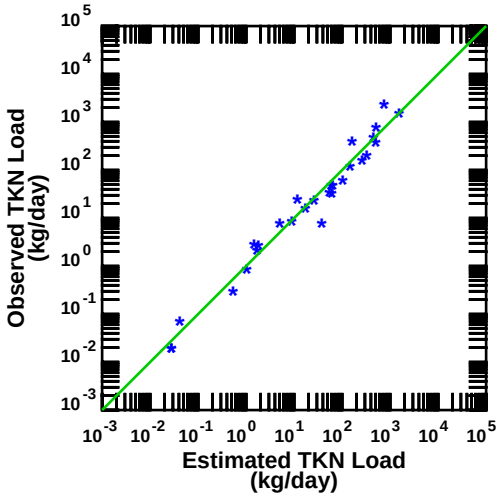


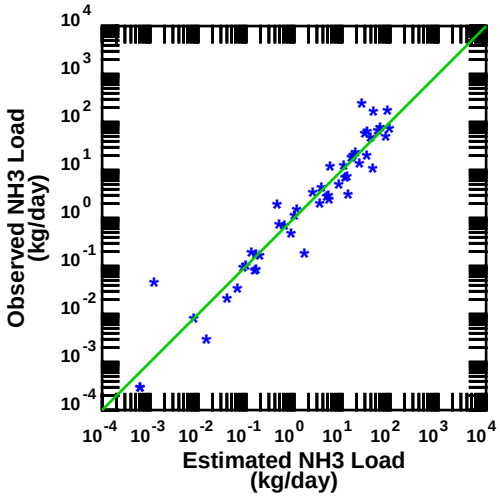


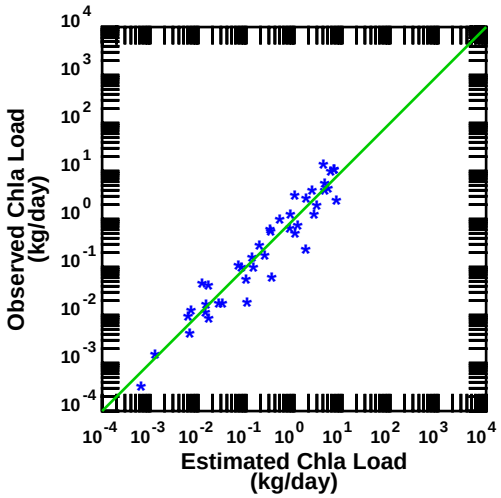


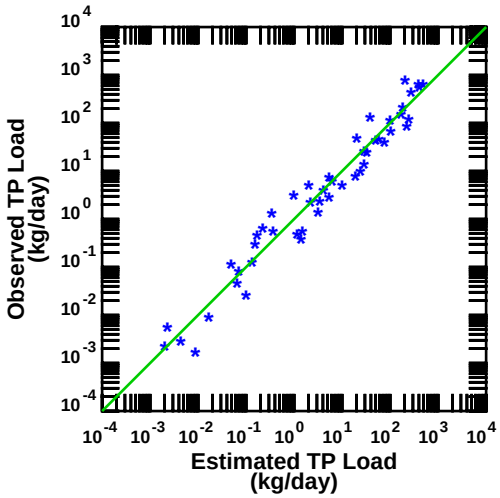
Observed Load vs. LOADEST Estimated Load, Station 12976

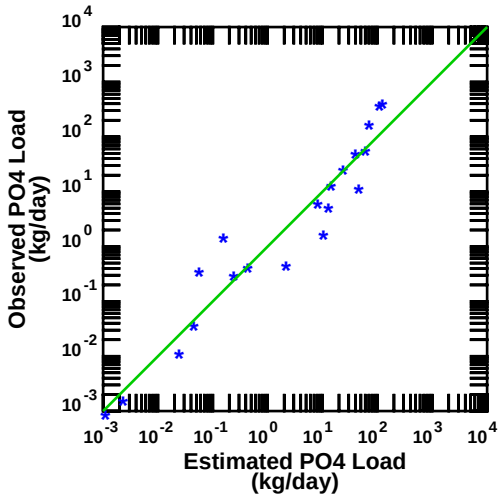
Nueces Tributaries, Texas (1970-2014)





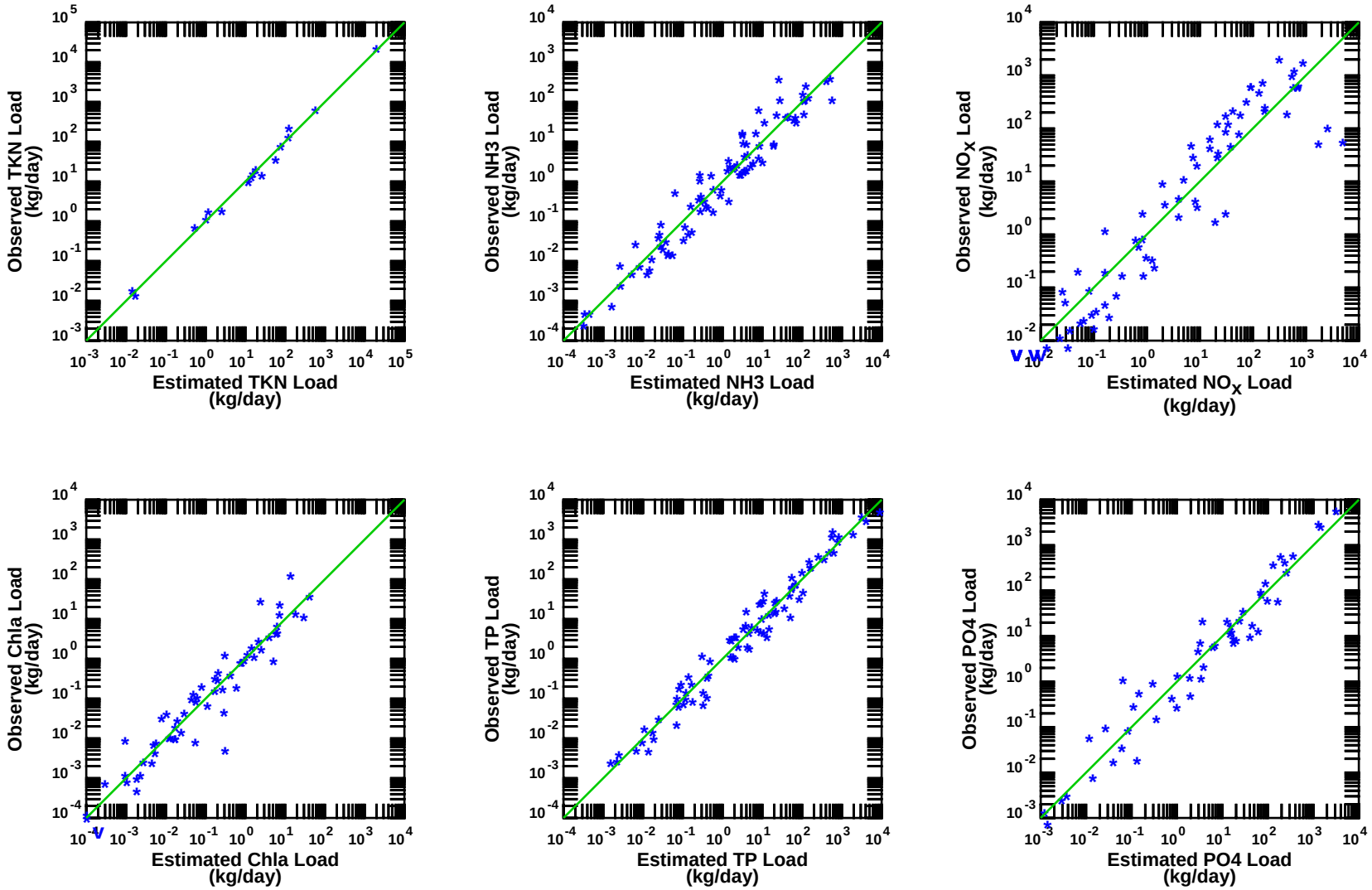






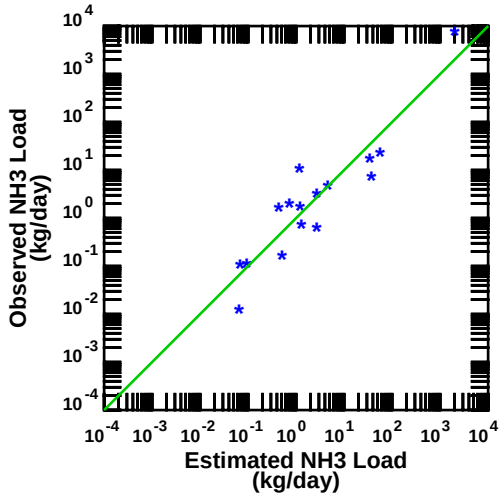
Observed Load vs. LOADEST Estimated Load, Station 12975

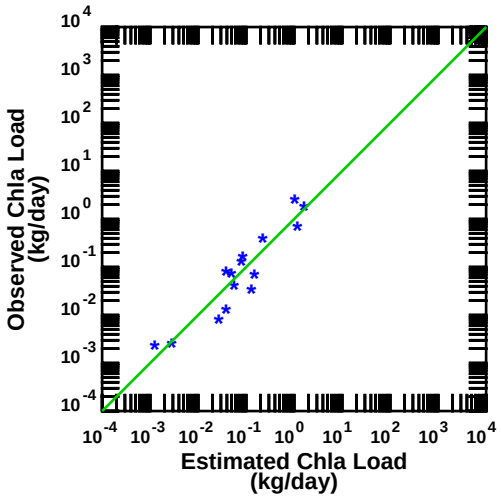
Nueces Tributaries, Texas (1970-2014)

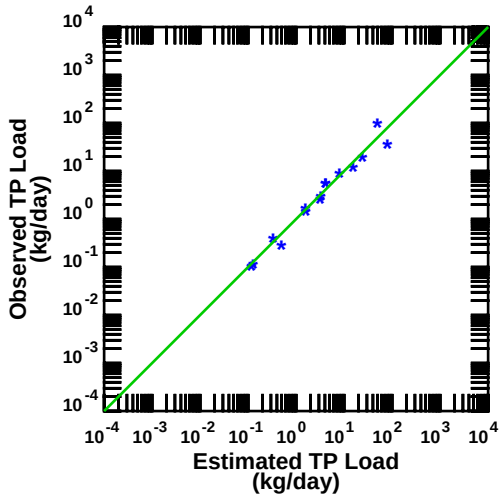


Observed Load vs. LOADEST Estimated Load, Station 12973

Nueces Tributaries, Texas (1970-2014)

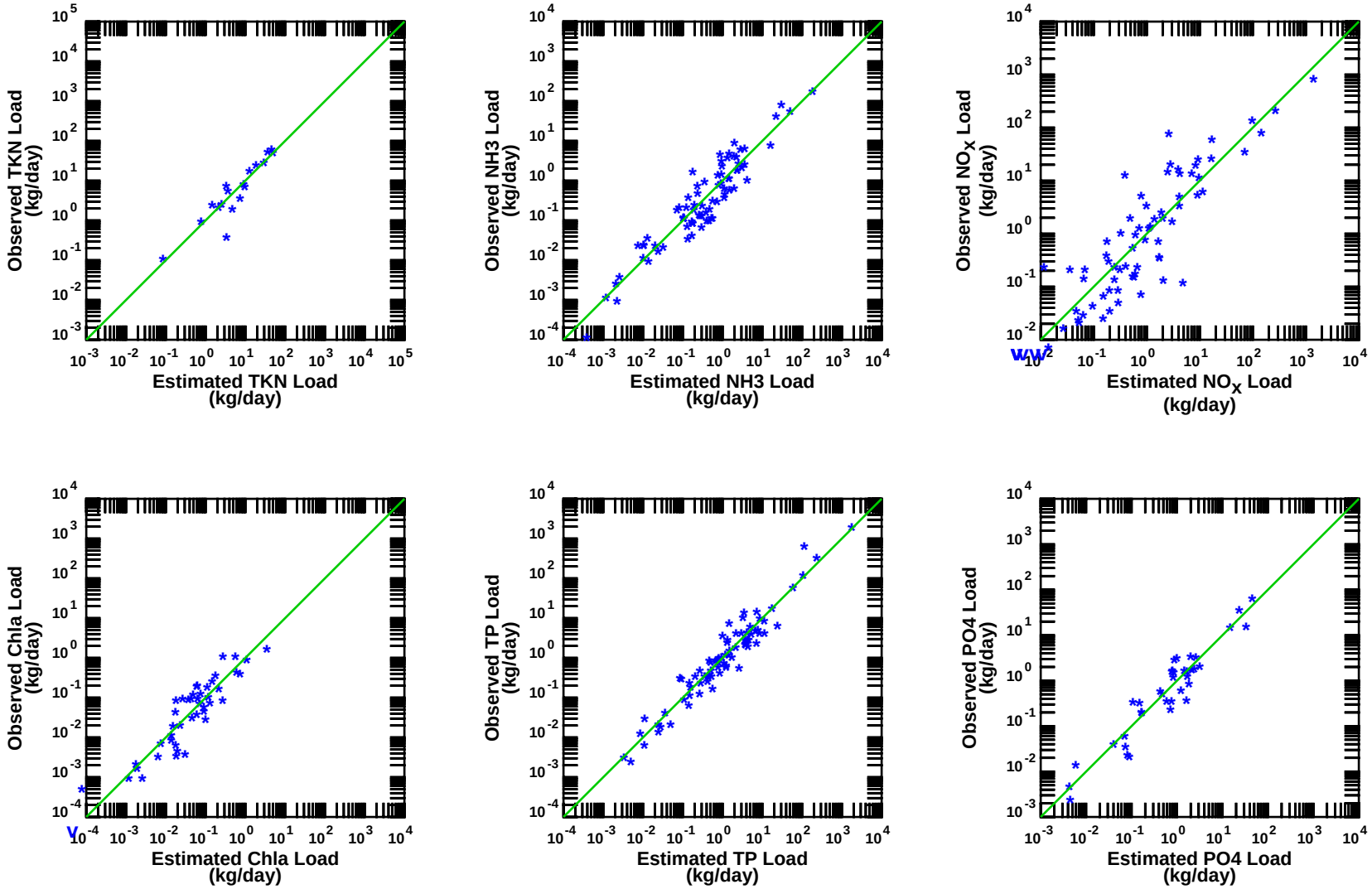






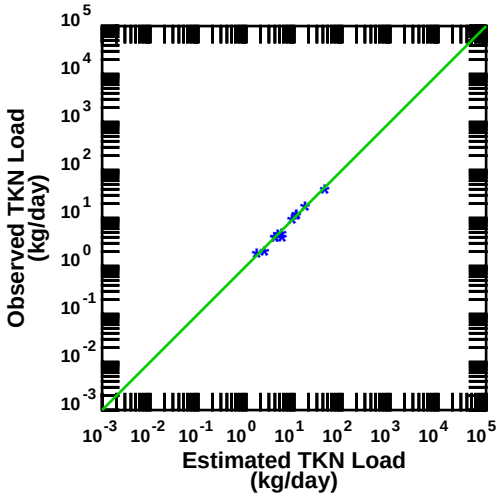
Observed Load vs. LOADEST Estimated Load, Station 12972

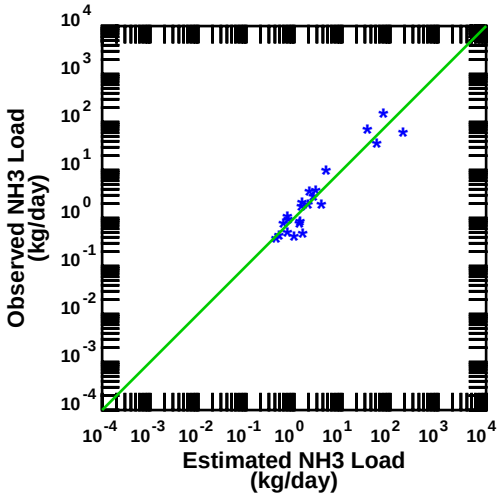
Nueces Tributaries, Texas (1970-2014)

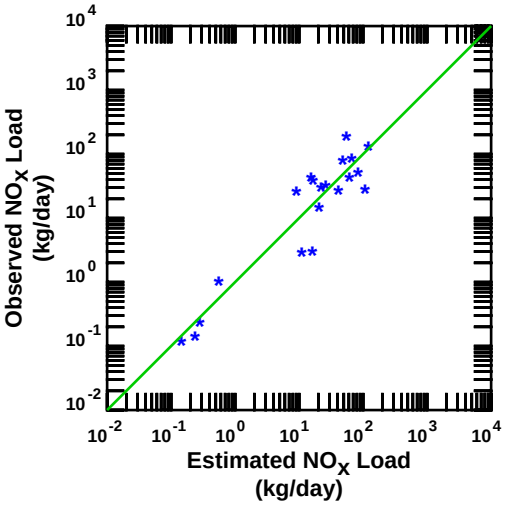


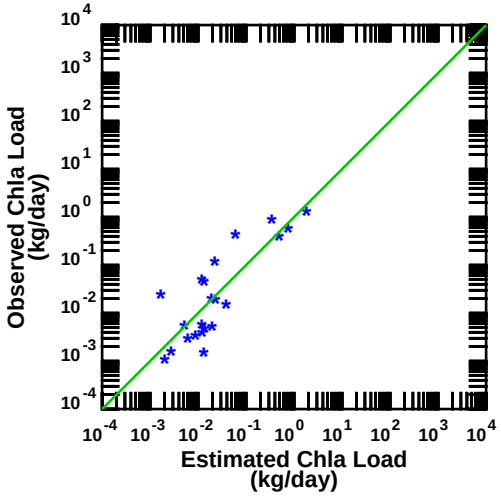
Observed Load vs. LOADEST Estimated Load, Station 12983

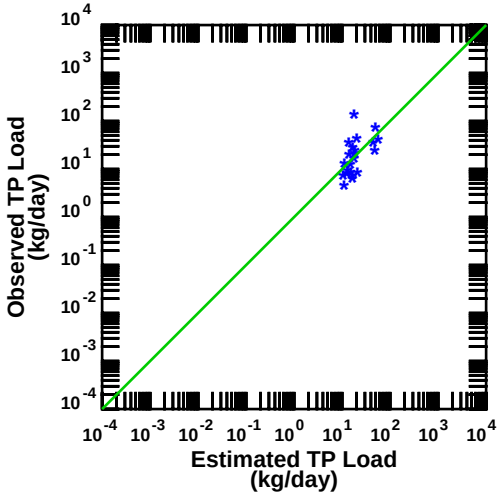
Nueces Tributaries, Texas (1970-2014)





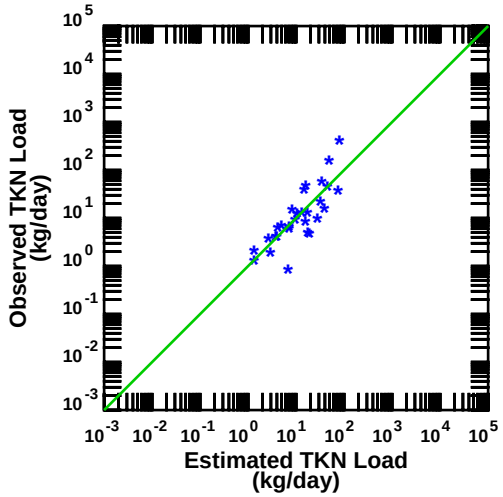


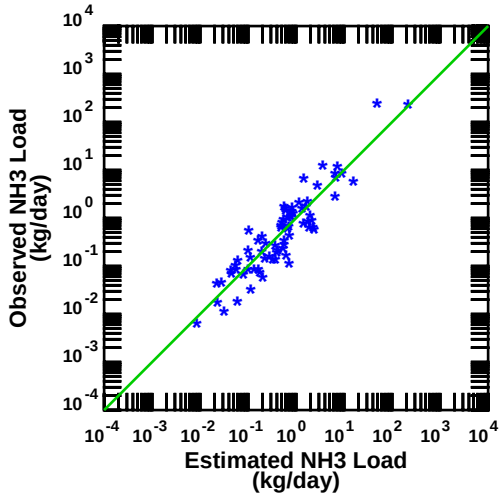


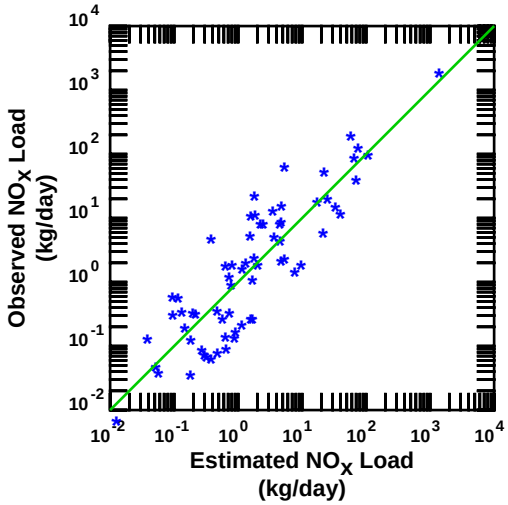


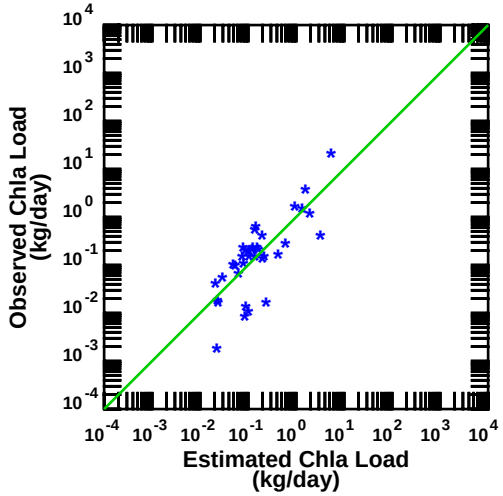
Observed Load vs. LOADEST Estimated Load, Station 12981

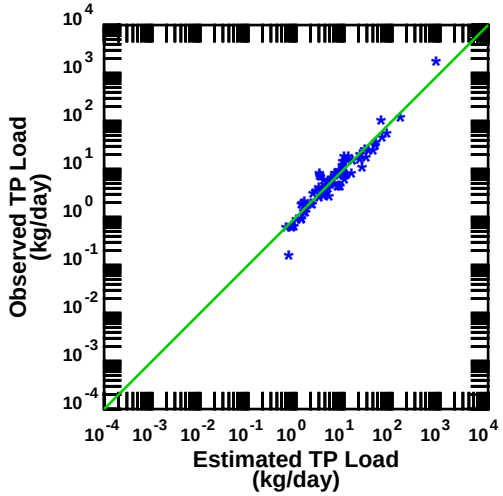
Nueces Tributaries, Texas (1970-2014)





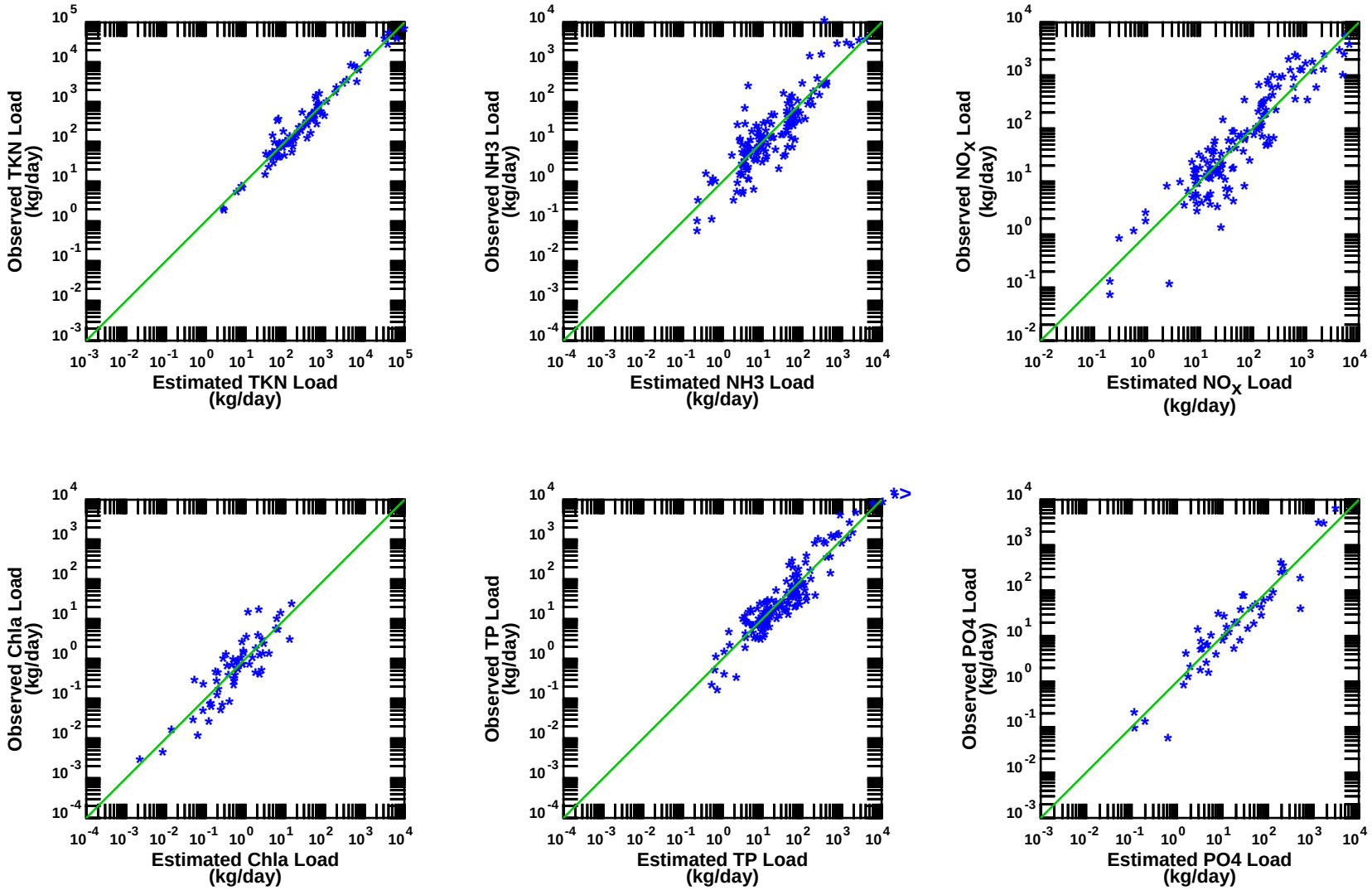






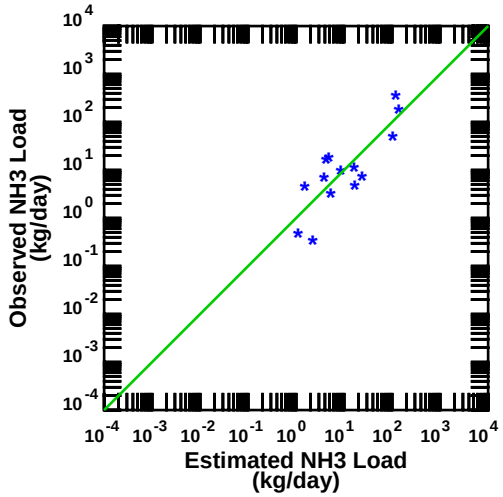
Observed Load vs. LOADEST Estimated Load, Station 12980

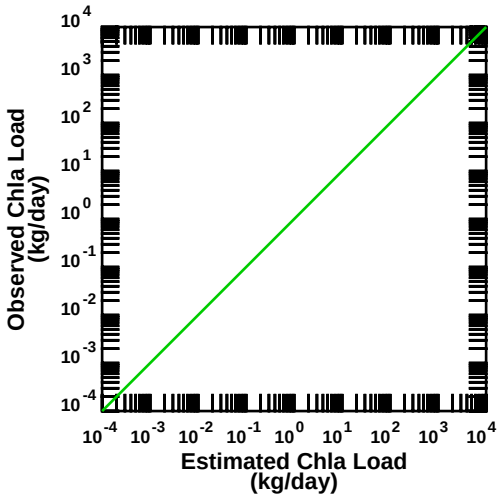
Nueces Tributaries, Texas (1970-2014)

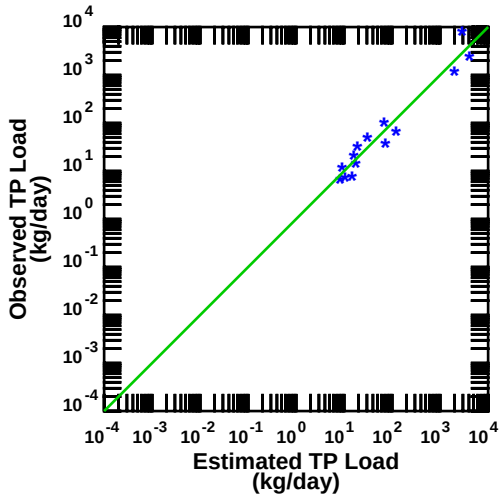


Observed Load vs. LOADEST Estimated Load, Station 12979

Nueces Tributaries, Texas (1970-2014)

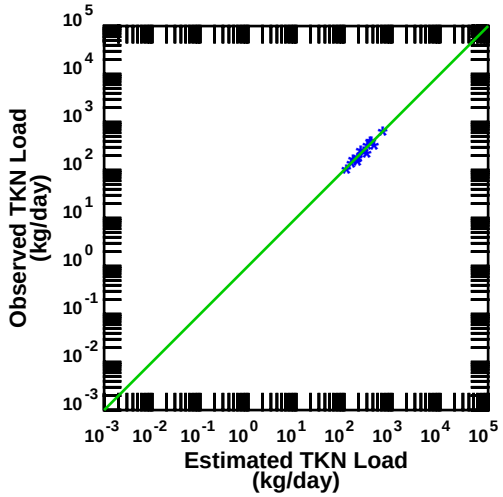


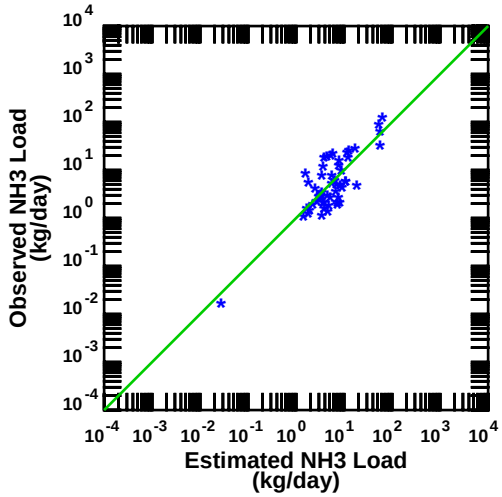


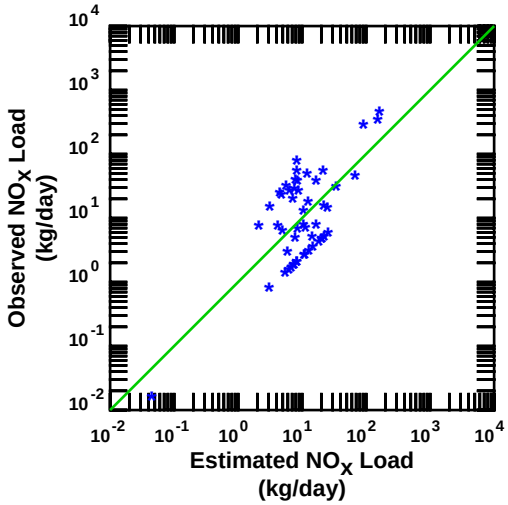


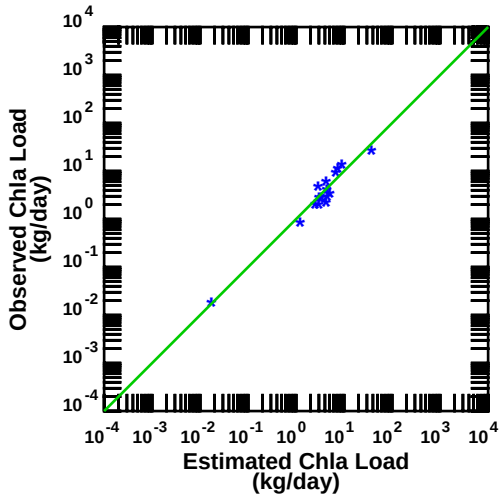
Observed Load vs. LOADEST Estimated Load, Station 12978

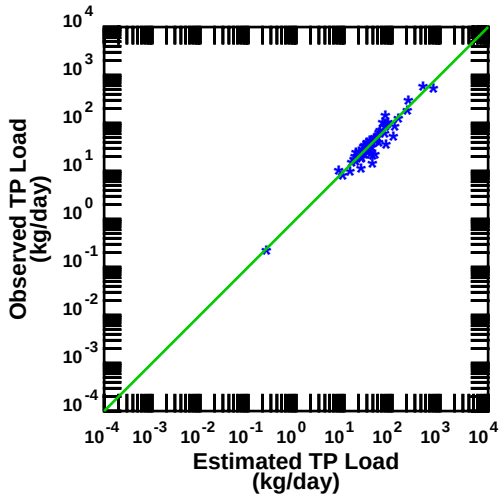
Nueces Tributaries, Texas (1970-2014)





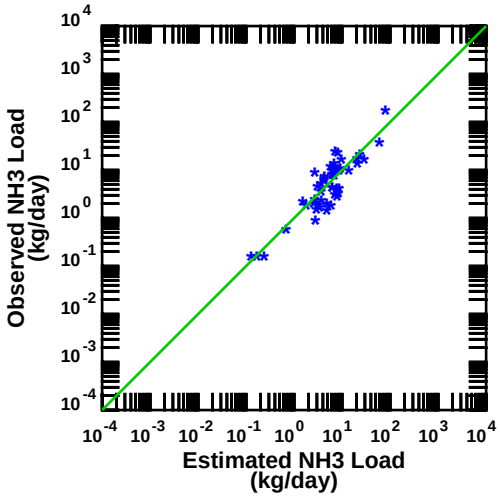


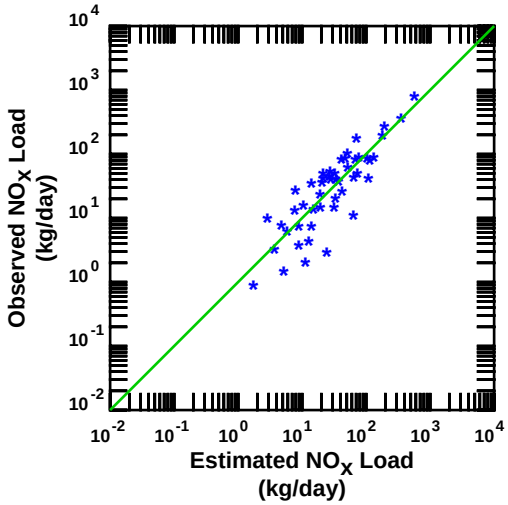


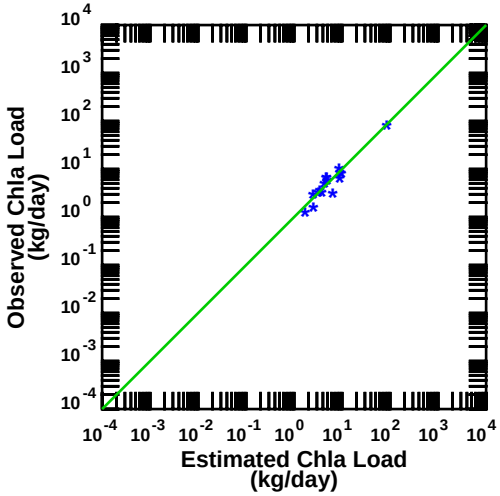


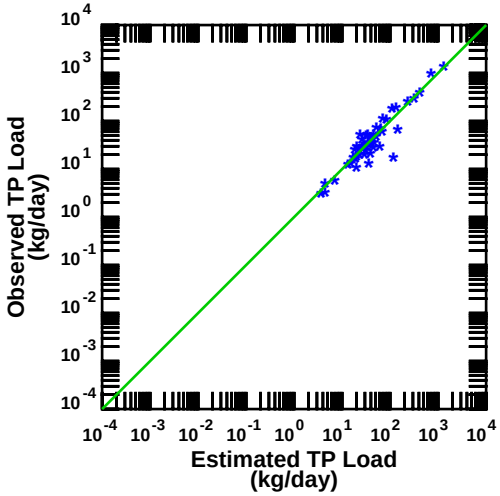
Observed Load vs. LOADEST Estimated Load, Station 12965

Nueces Tributaries, Texas (1970-2014)



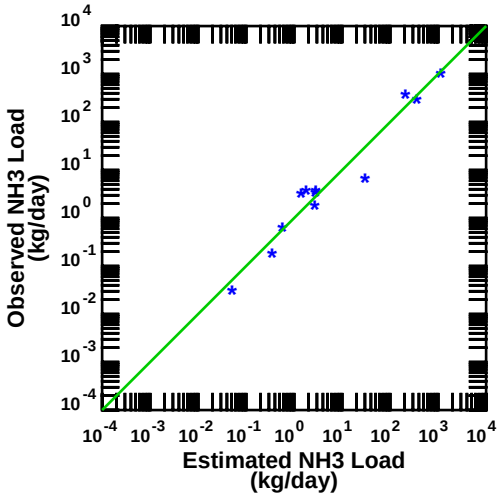


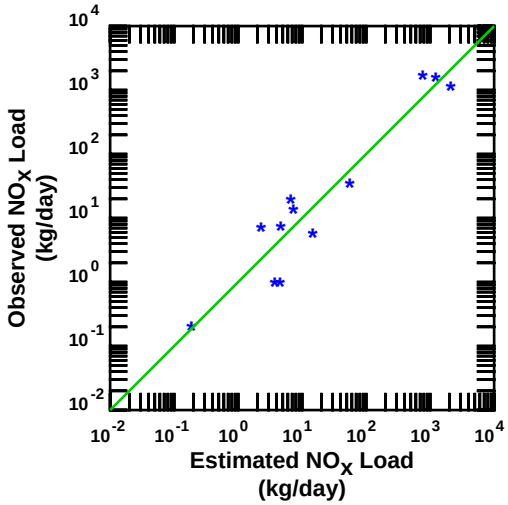


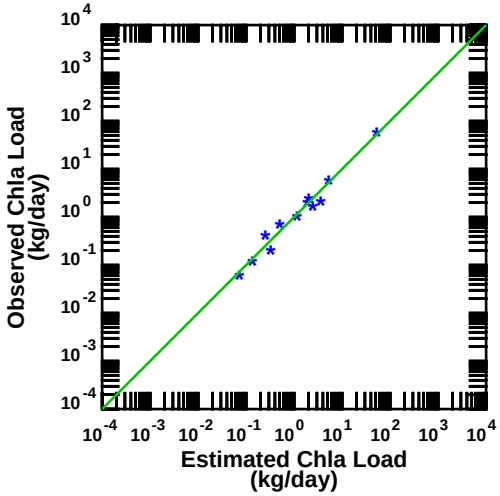


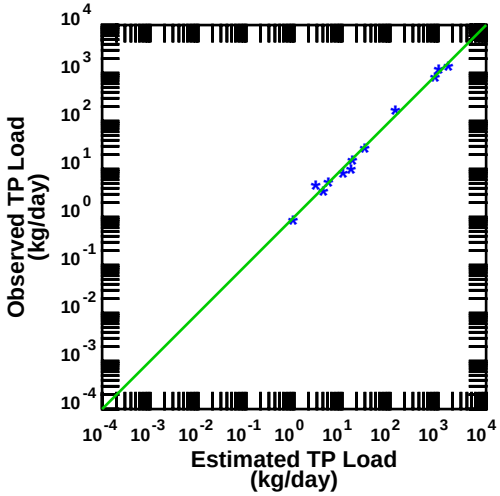
Observed Load vs. LOADEST Estimated Load, Station 12964

Nueces Tributaries, Texas (1970-2014)



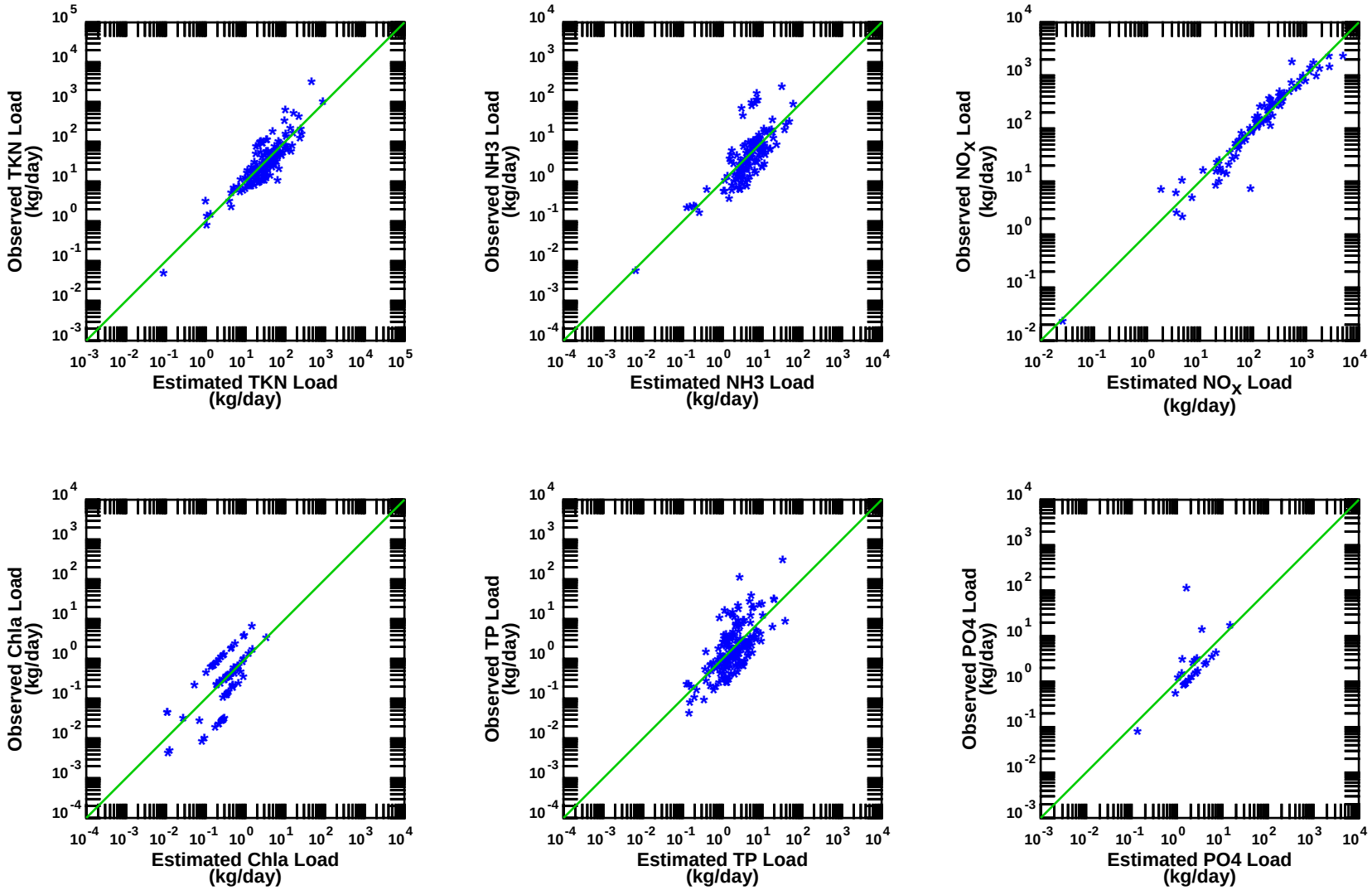






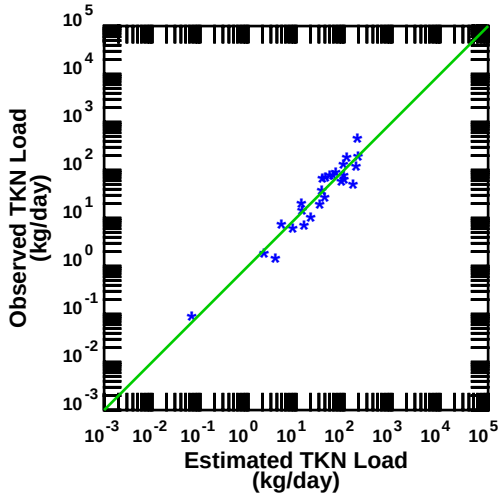
Observed Load vs. LOADEST Estimated Load, Station 12962

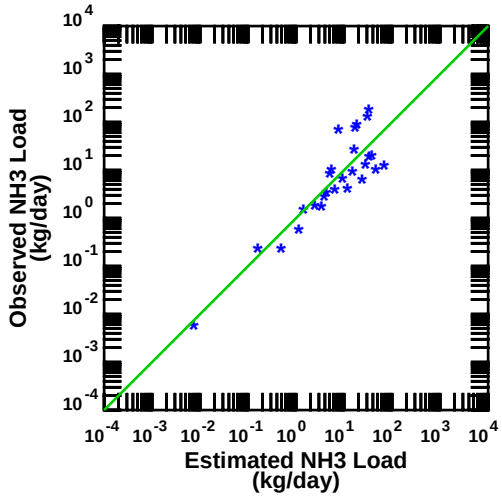
Nueces Tributaries, Texas (1970-2014)

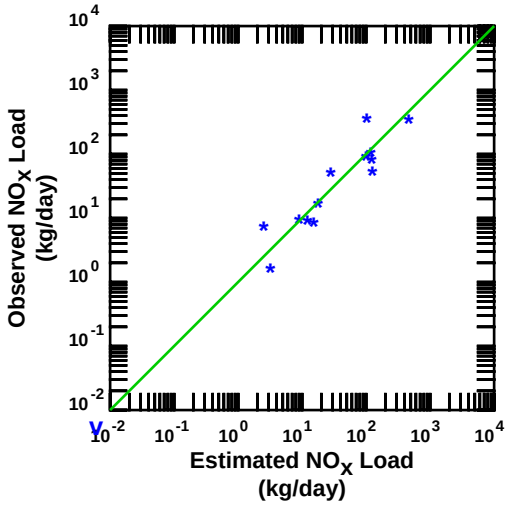


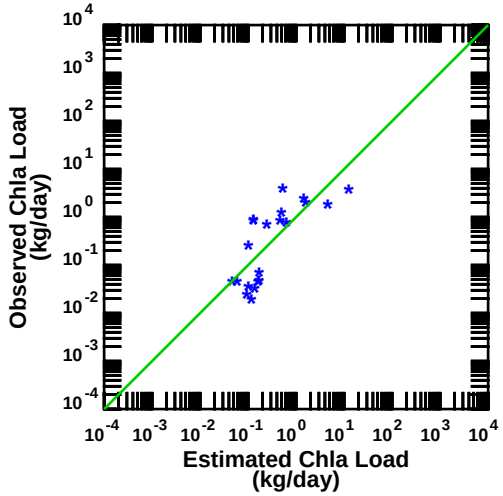
Observed Load vs. LOADEST Estimated Load, Station 13006

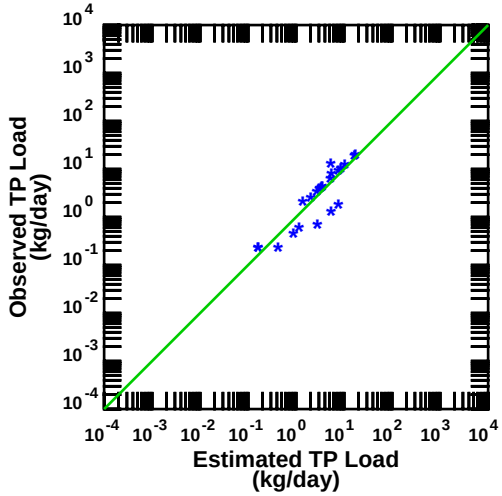
Nueces Tributaries, Texas (1970-2014)





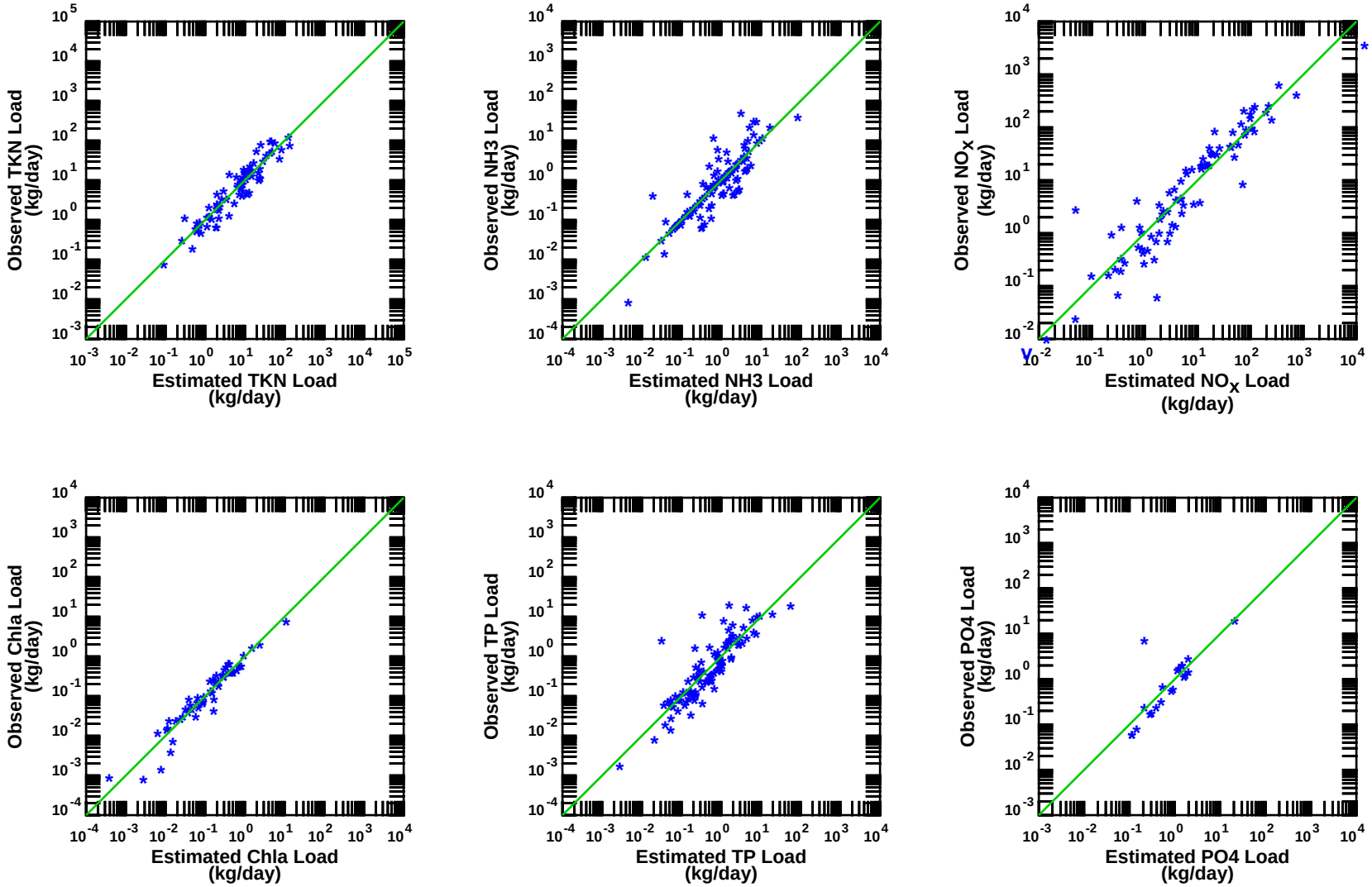






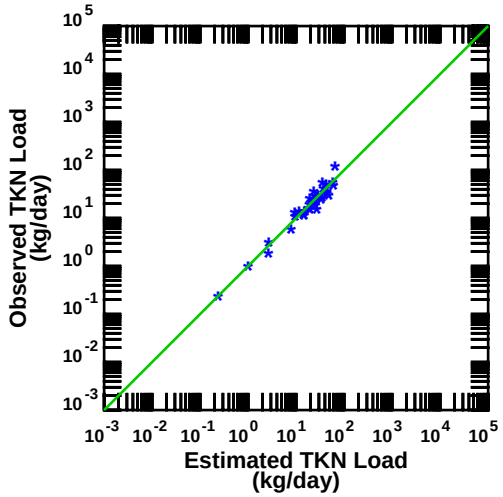
Observed Load vs. LOADEST Estimated Load, Station 13007

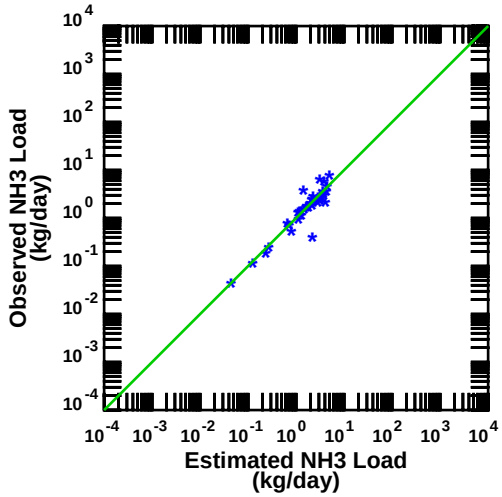
Nueces Tributaries, Texas (1970-2014)

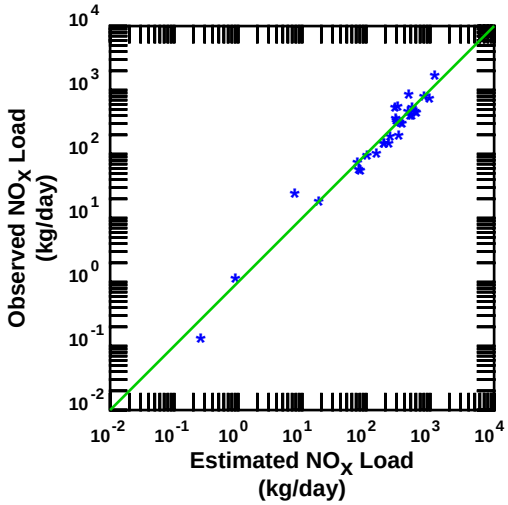


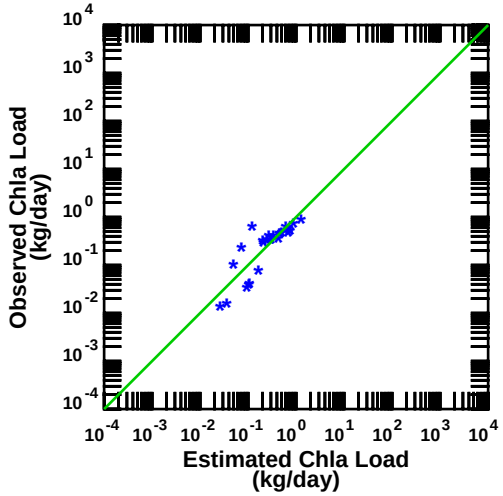
Observed Load vs. LOADEST Estimated Load, Station 13010

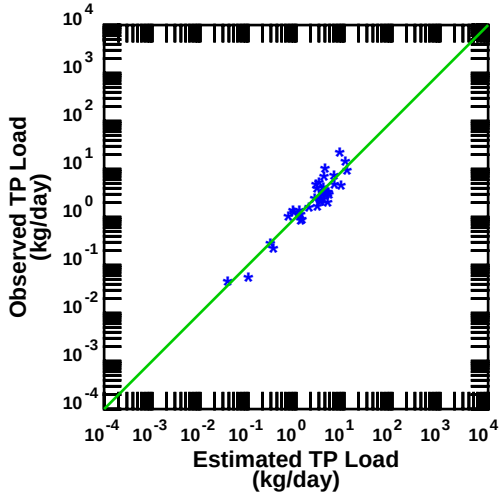
Nueces Tributaries, Texas (1970-2014)





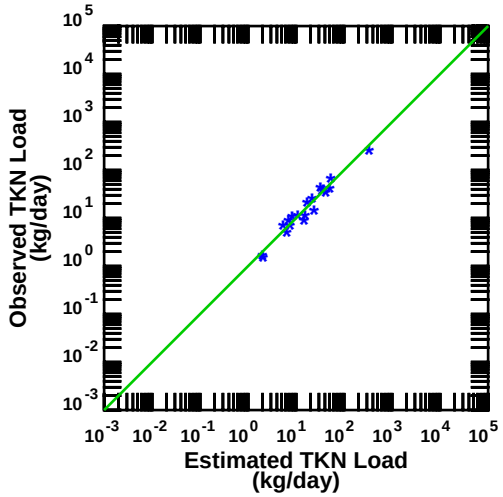


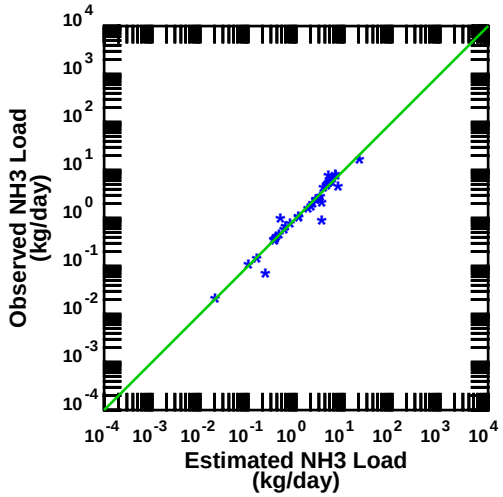


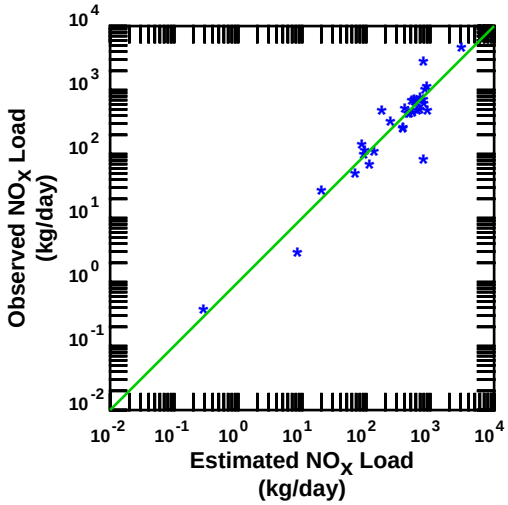


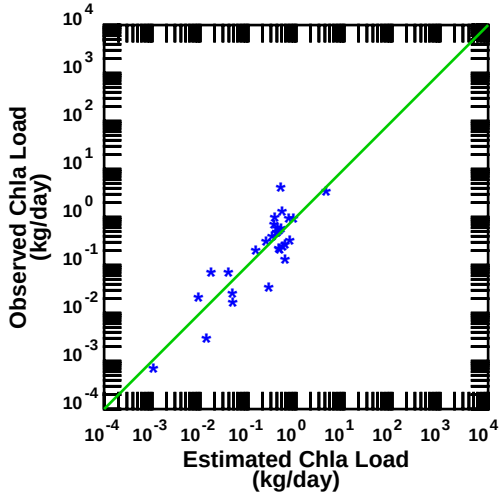
Observed Load vs. LOADEST Estimated Load, Station 12987

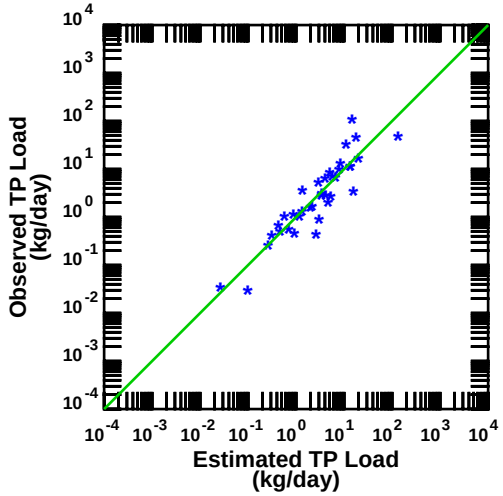
Nueces Tributaries, Texas (1970-2014)

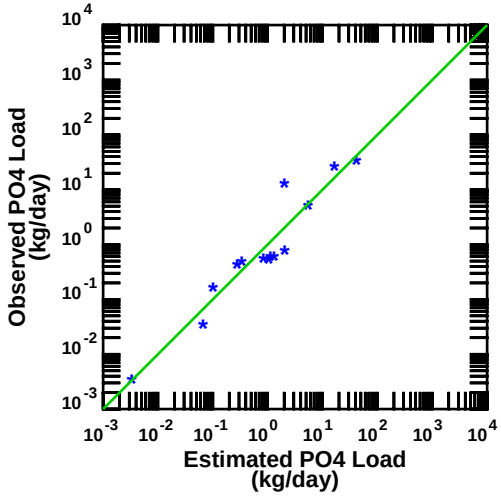






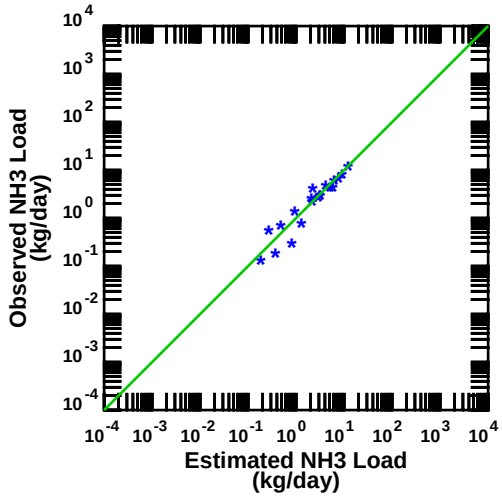


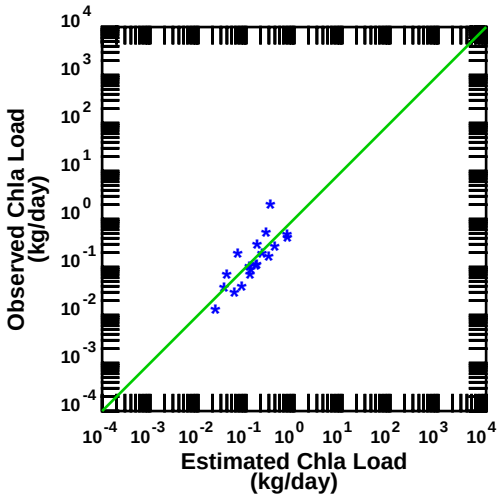


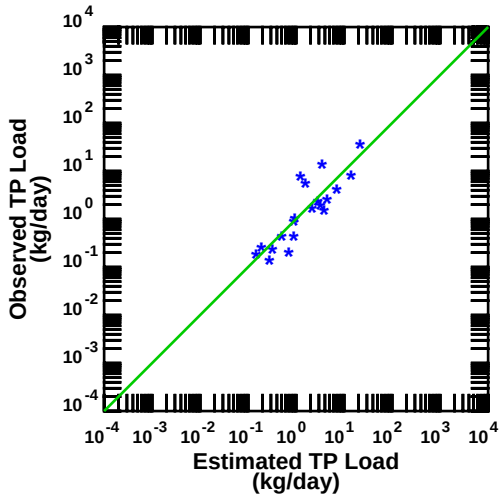


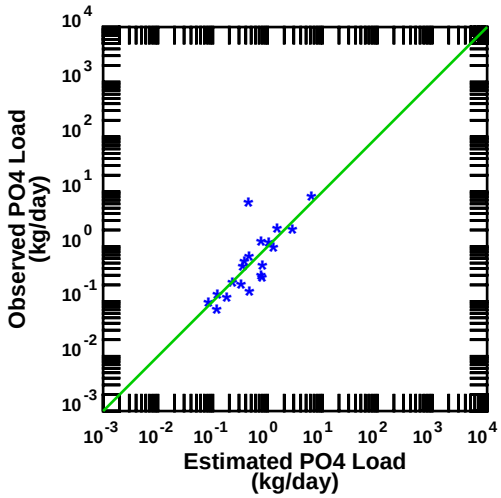
Observed Load vs. LOADEST Estimated Load, Station 12985

Nueces Tributaries, Texas (1970-2014)



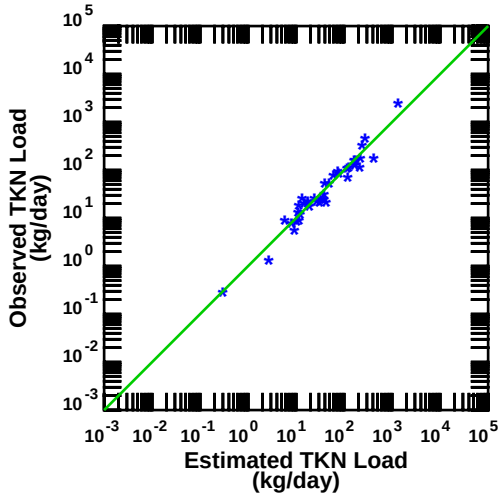


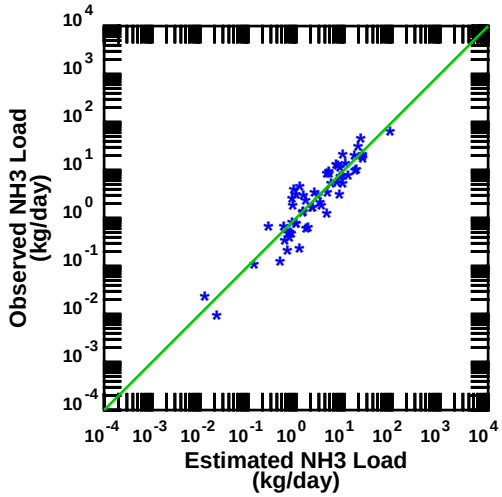


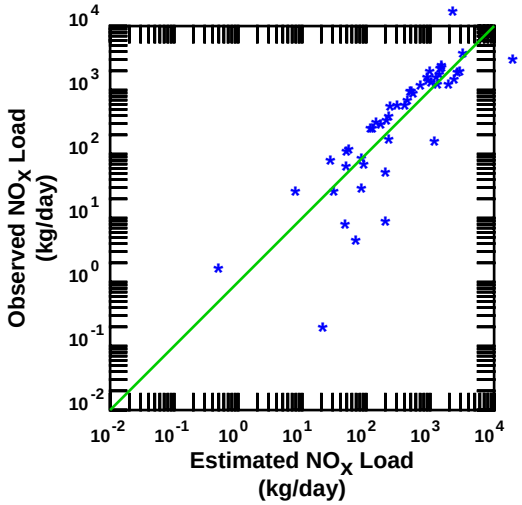


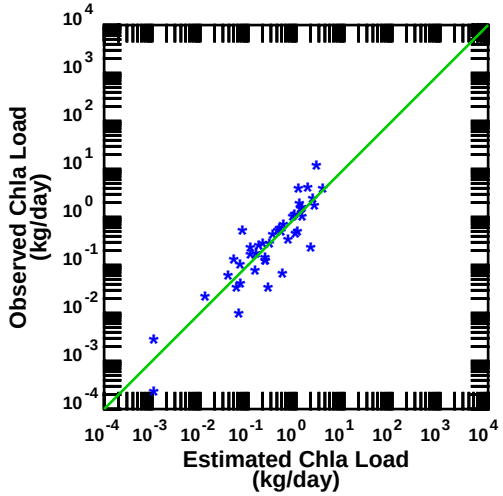
Observed Load vs. LOADEST Estimated Load, Station 13025

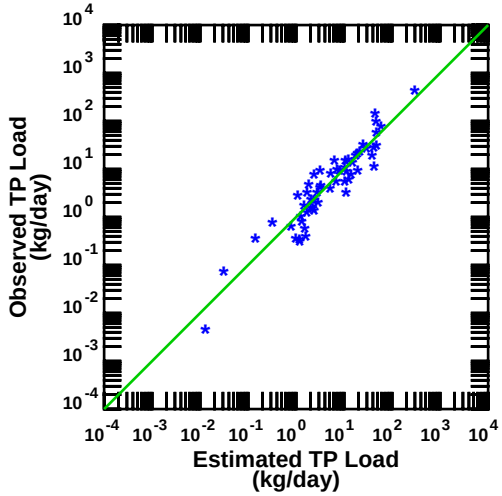
Nueces Tributaries, Texas (1970-2014)





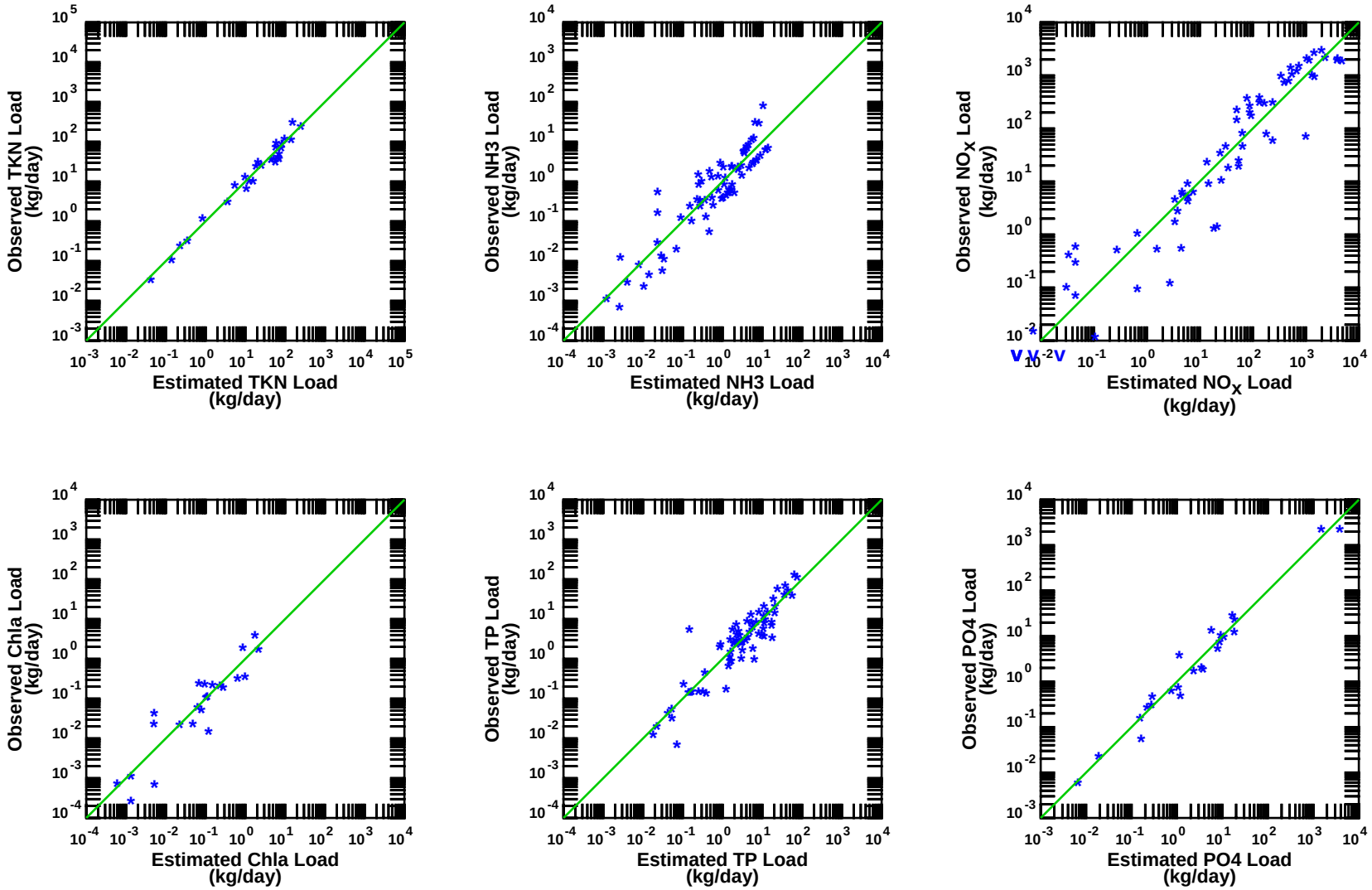






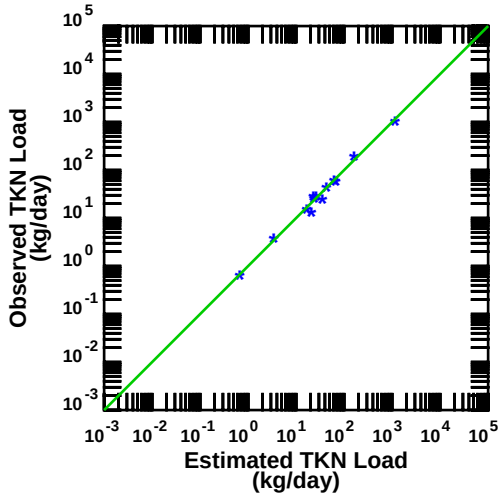
Observed Load vs. LOADEST Estimated Load, Station 13024

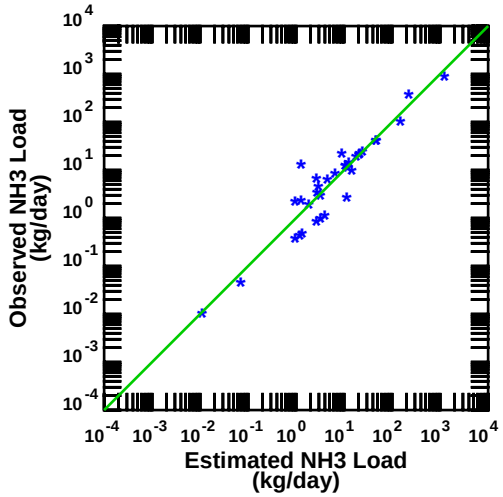
Nueces Tributaries, Texas (1970-2014)

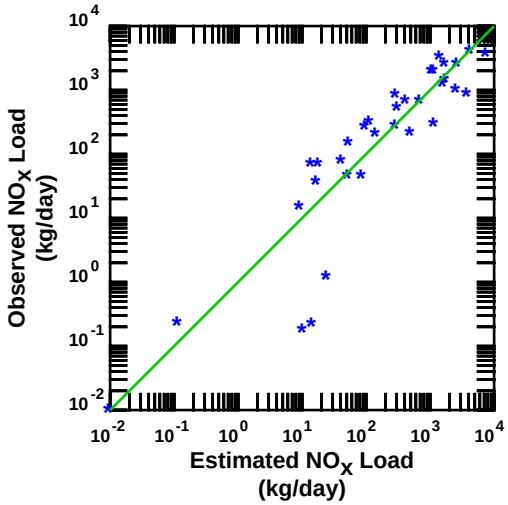


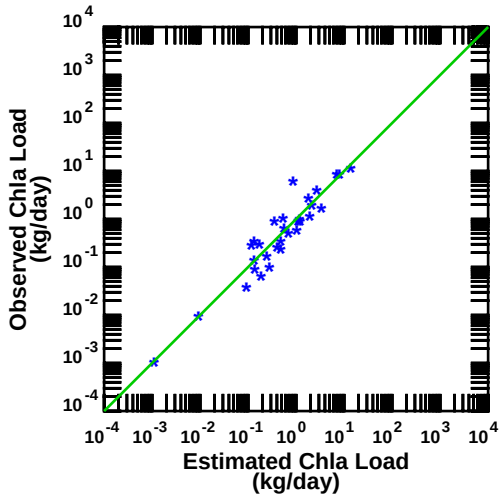
Observed Load vs. LOADEST Estimated Load, Station 13023

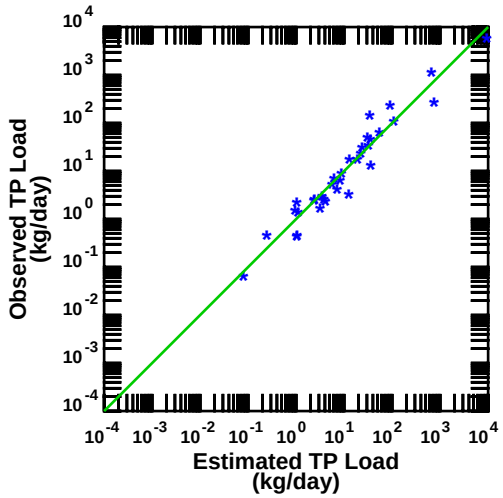
Nueces Tributaries, Texas (1970-2014)

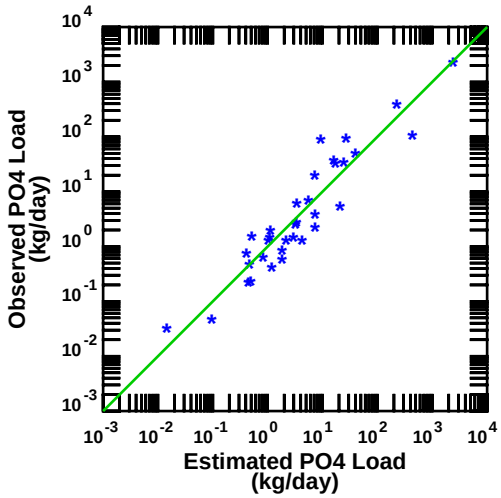






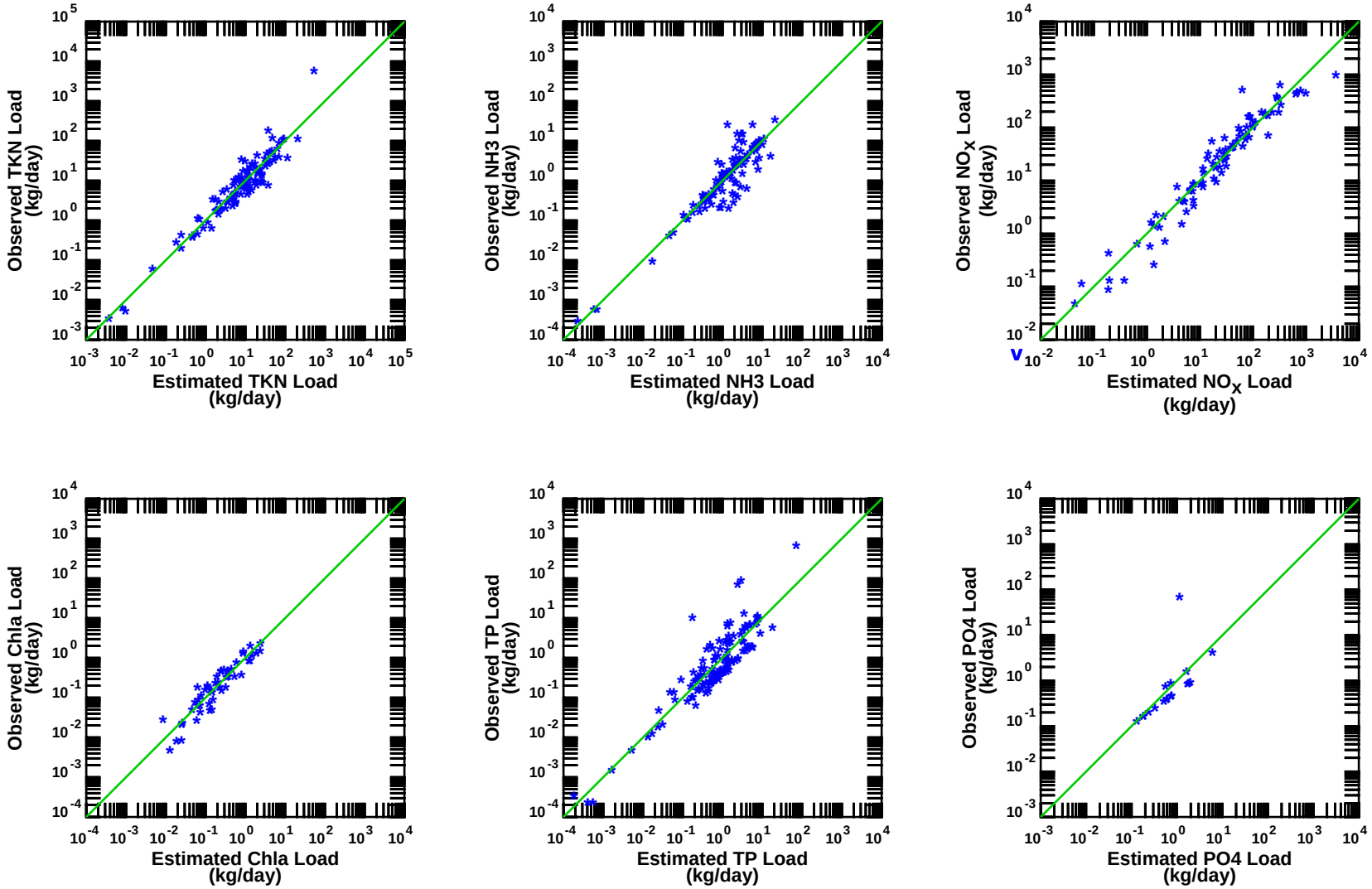






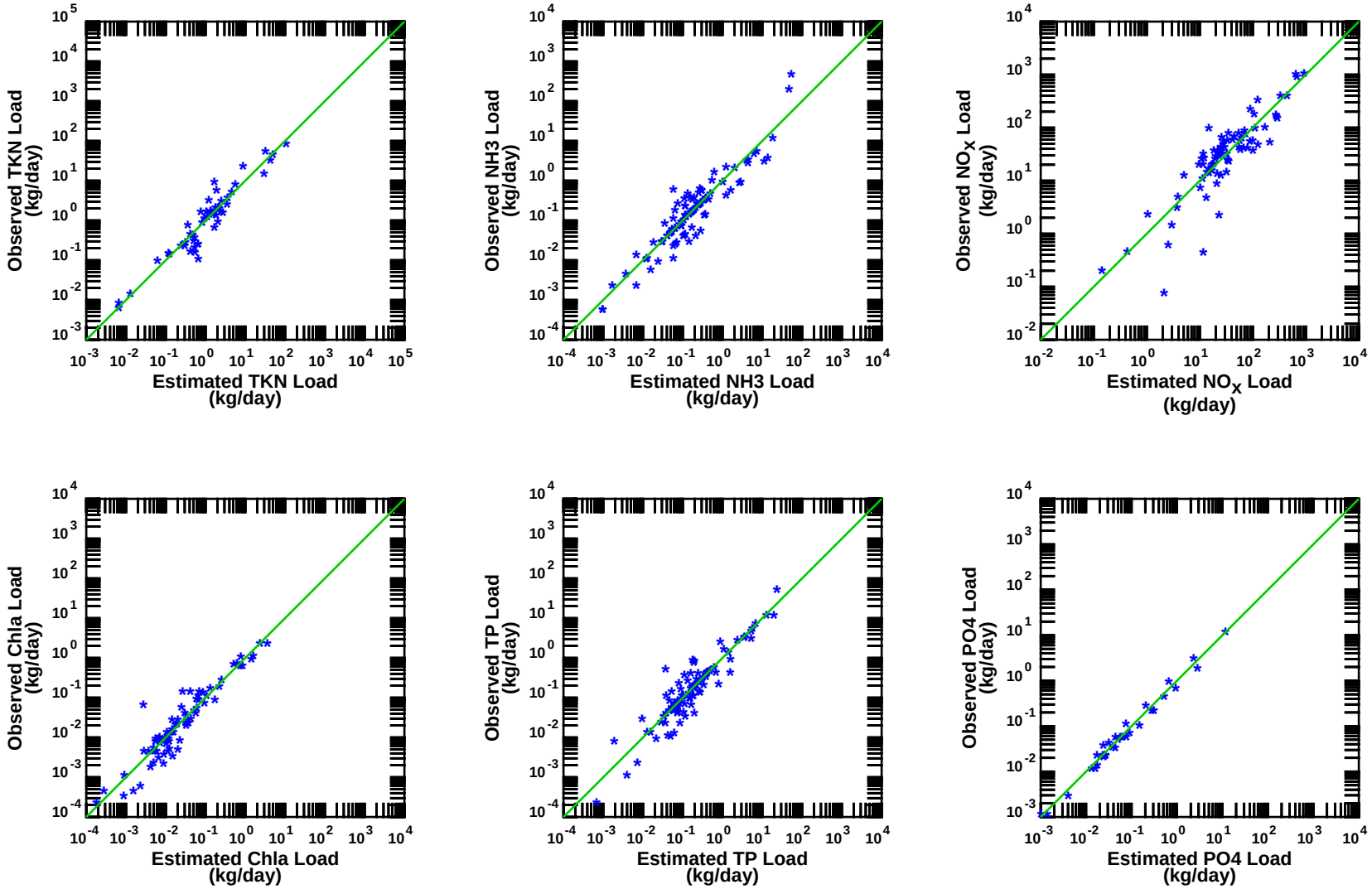
Observed Load vs. LOADEST Estimated Load, Station 13021

Nueces Tributaries, Texas (1970-2014)



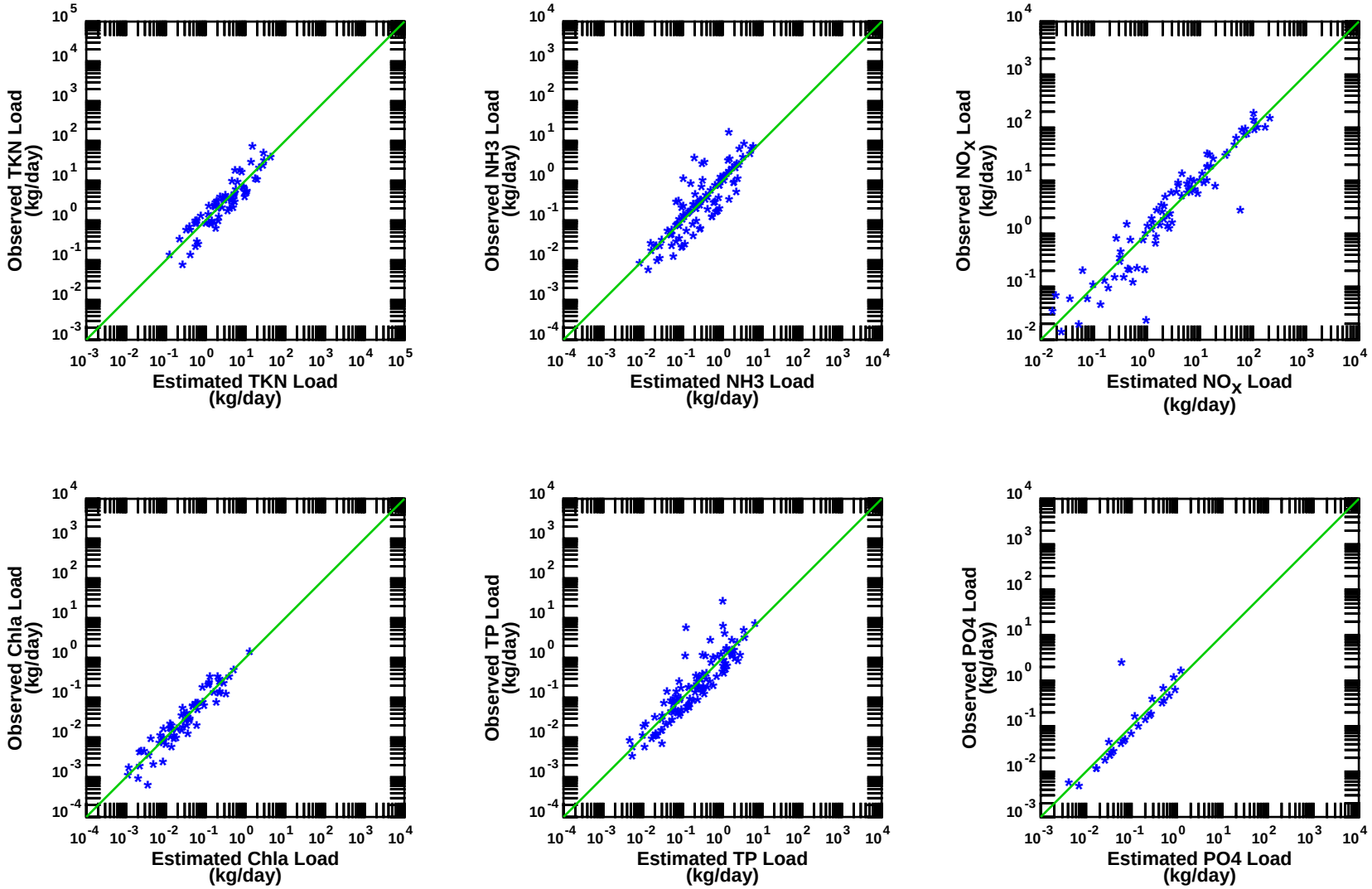
Observed Load vs. LOADEST Estimated Load, Station 12994

Nueces Tributaries, Texas (1970-2014)



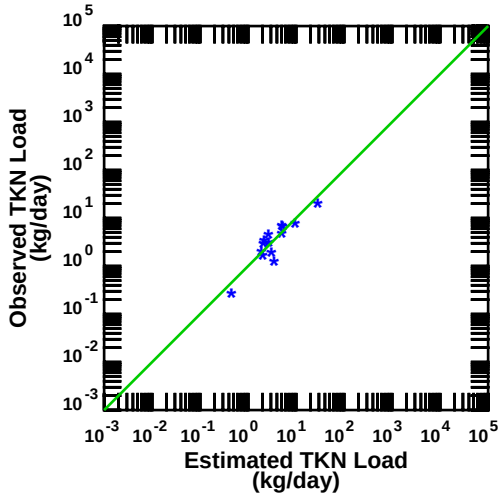
Observed Load vs. LOADEST Estimated Load, Station 12993

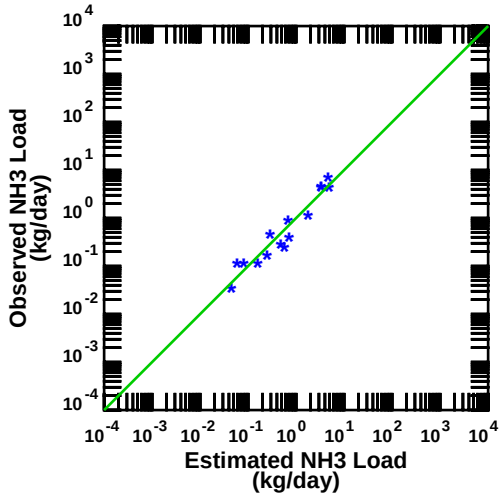
Nueces Tributaries, Texas (1970-2014)

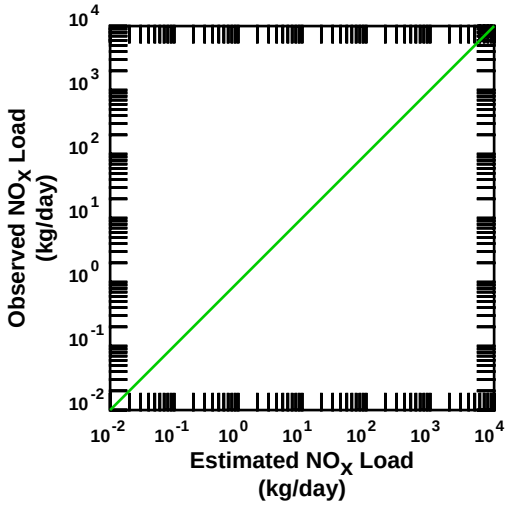


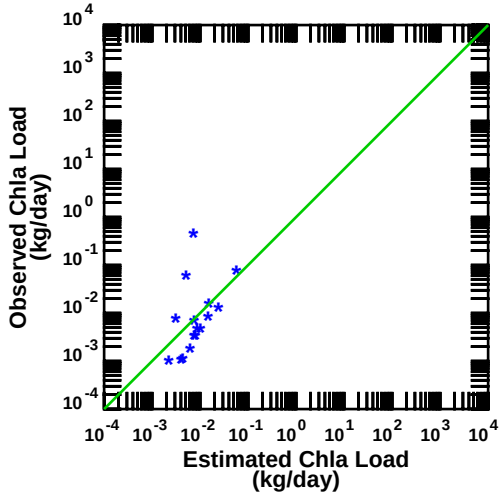
Observed Load vs. LOADEST Estimated Load, Station 13013

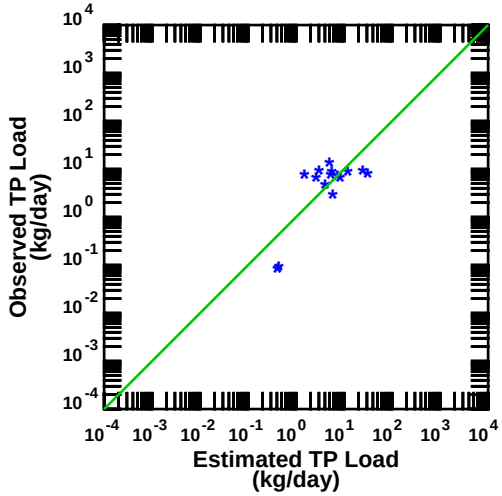
Nueces Tributaries, Texas (1970-2014)





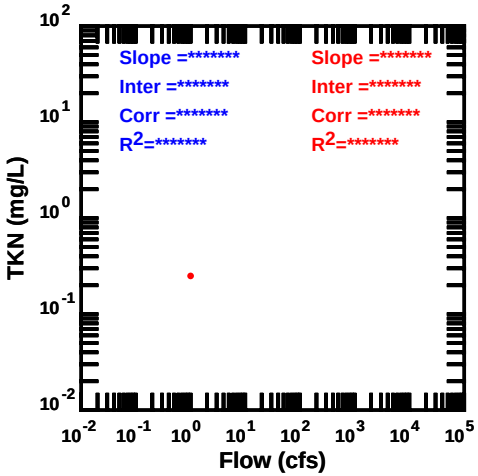


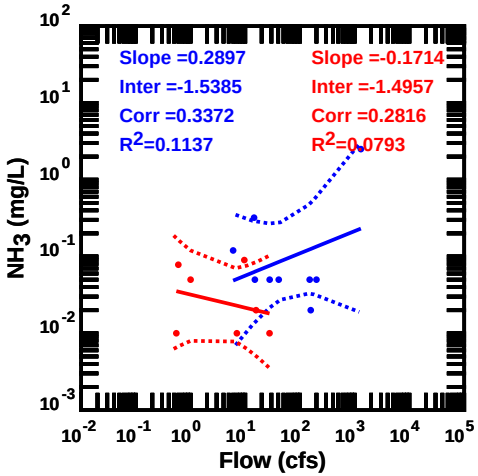


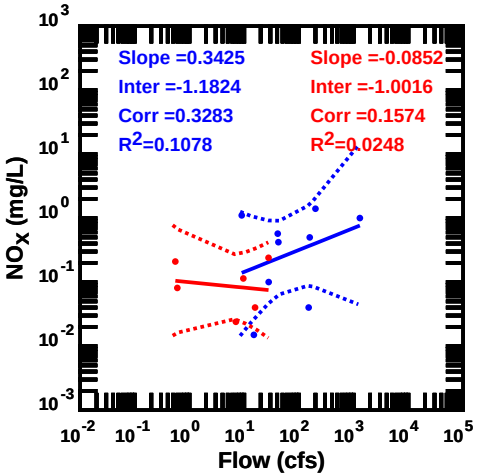


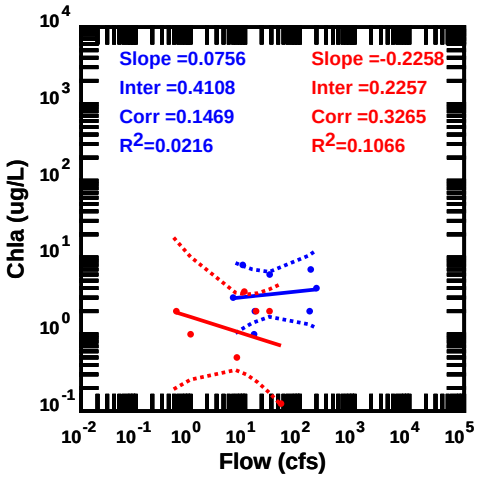
Observed Load vs. LOADEST Estimated Load, Station 17900

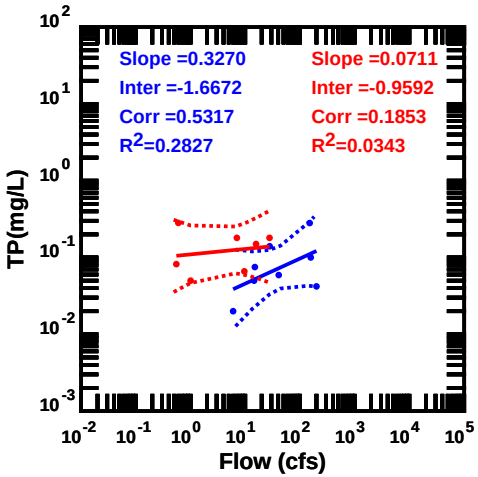
Nueces Tributaries, Texas (1970-2014)

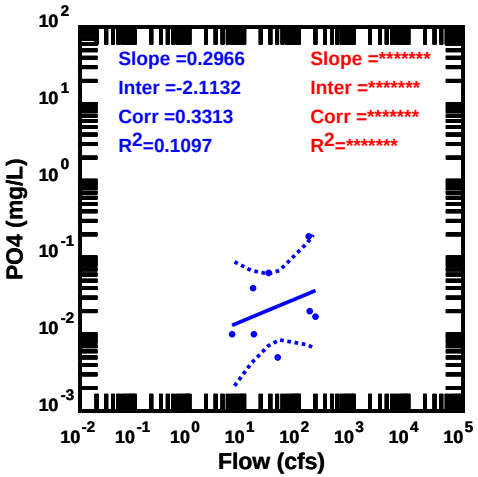












Regression analysis, Station 12972

Nueces Tributaries, Texas (1970-2014)

Before 1986

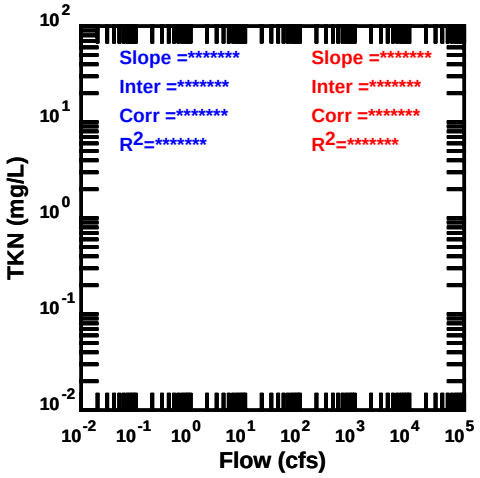
Observed Data

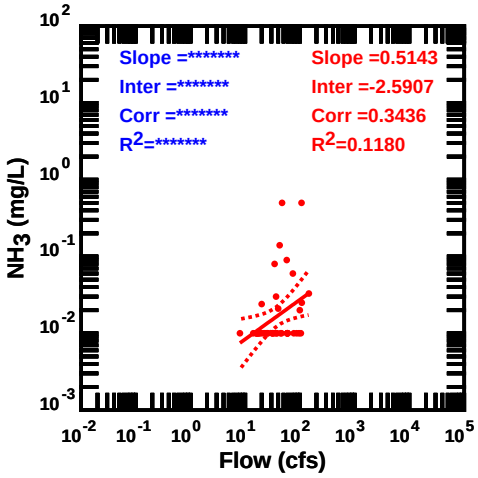
95% Confidence Interval

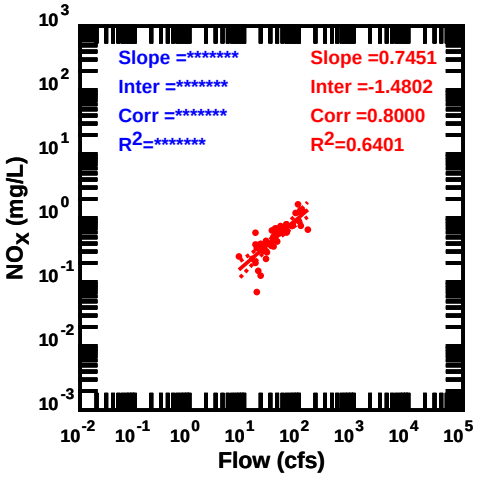
After 1986

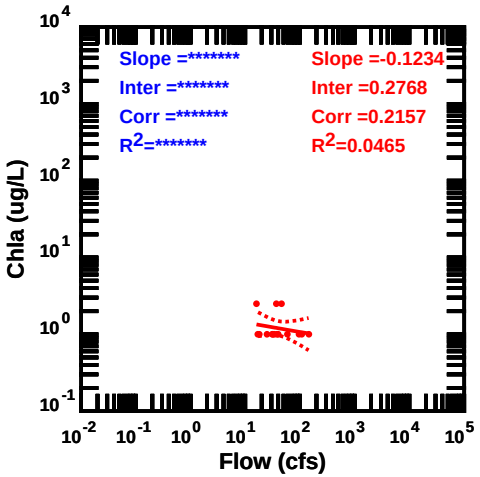
Observed Data

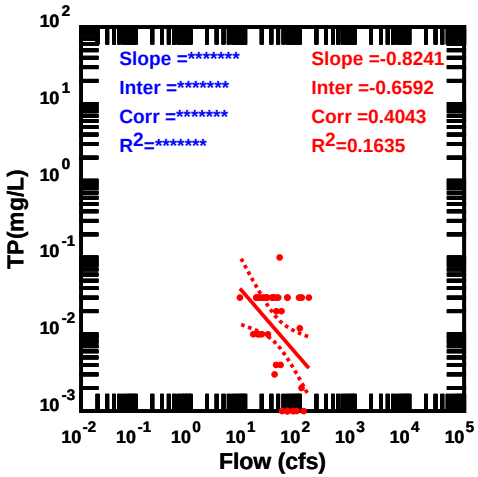
95% Confidence Interval

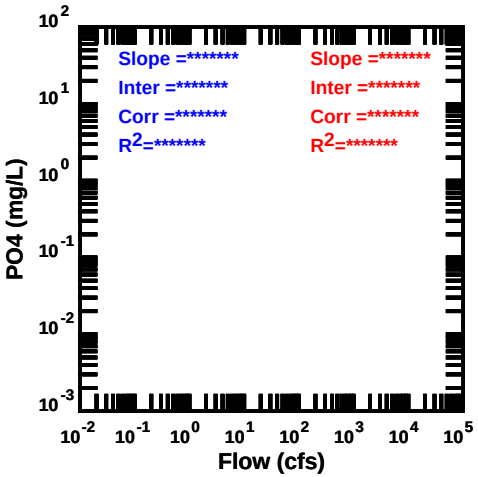












Regression analysis, Station 13005

Nueces Tributaries, Texas (1970-2014)

Before 1986

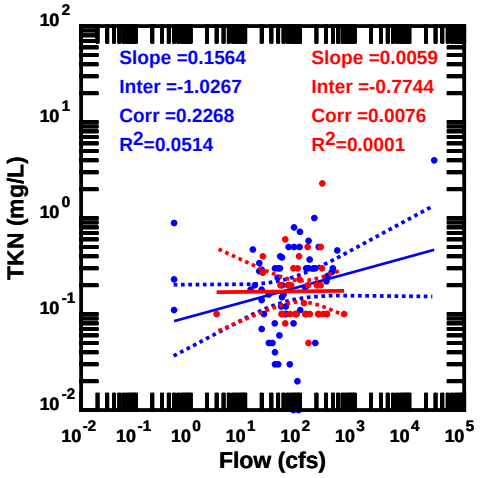
Observed Data

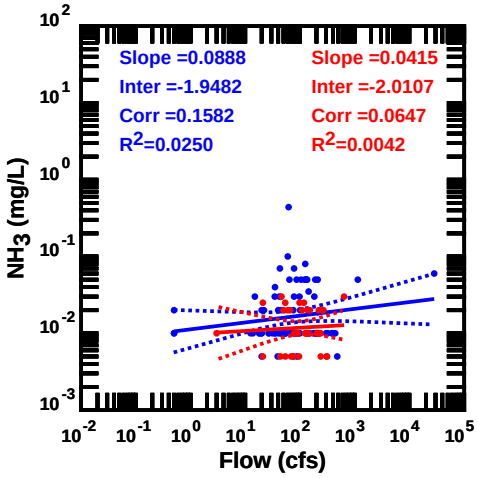
95% Confidence Interval

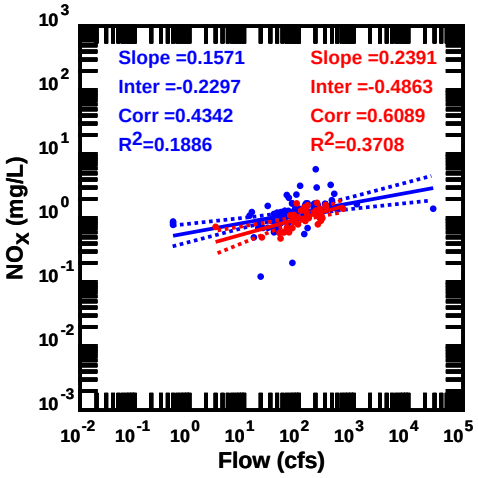
After 1986

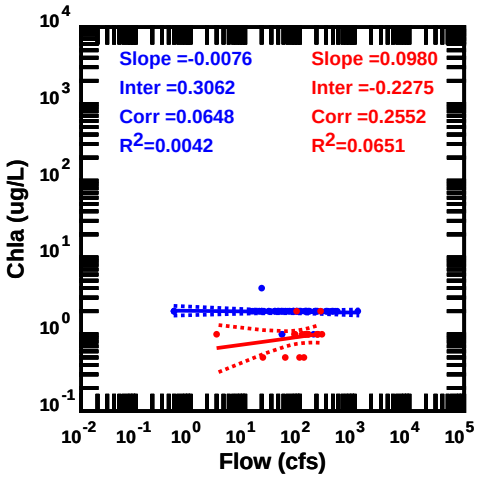
Observed Data

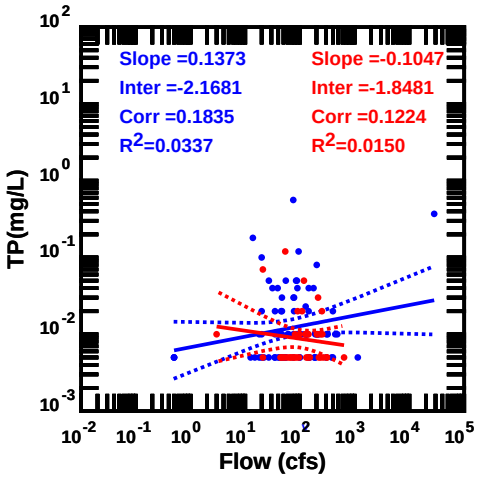
95% Confidence Interval

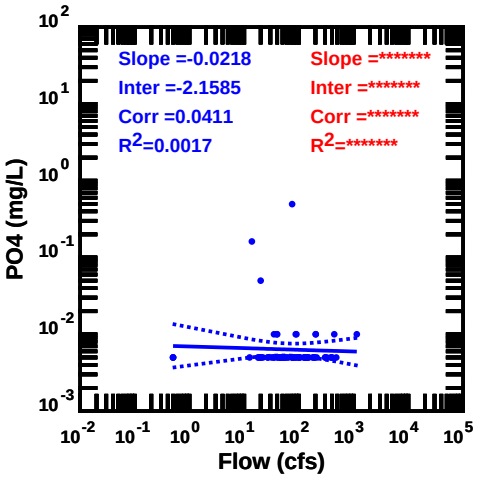












Regression analysis, Station 12999

Nueces Tributaries, Texas (1970-2014)

Before 1986

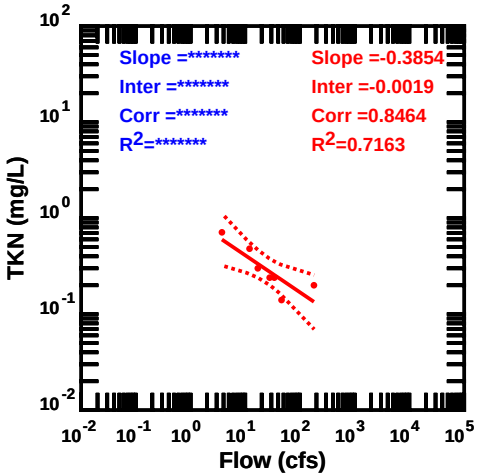
Observed Data

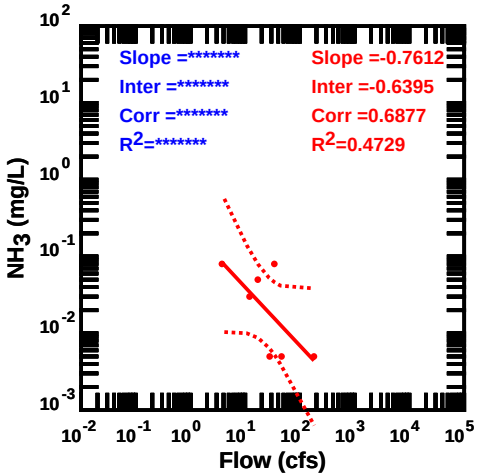
95% Confidence Interval

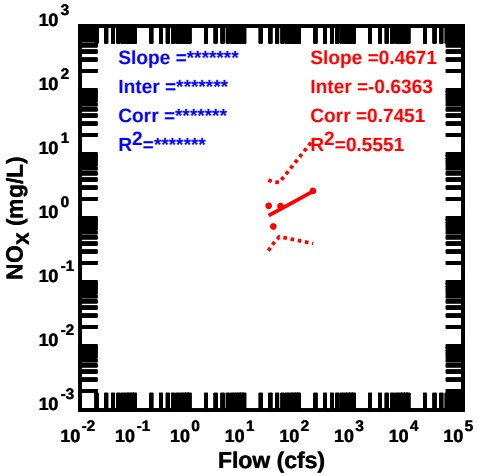
After 1986

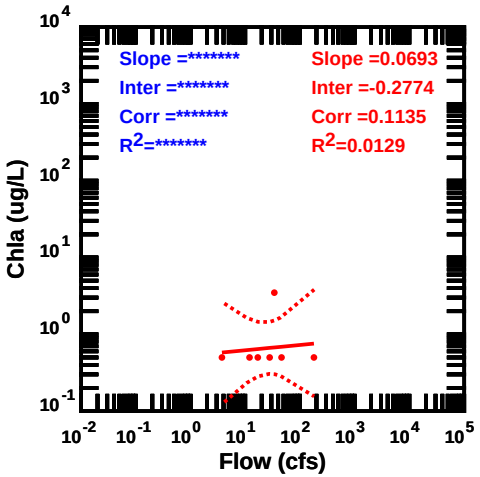
Observed Data

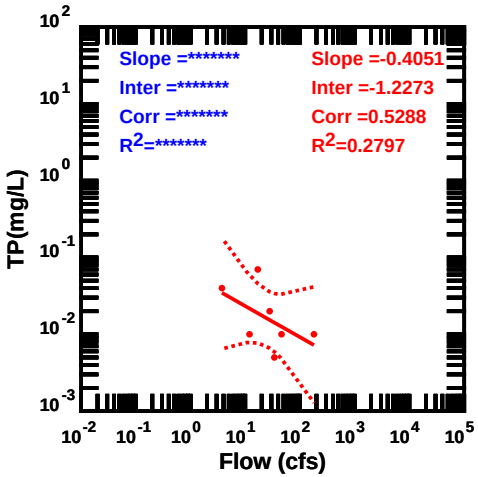
95% Confidence Interval











Regression analysis, Station 14253

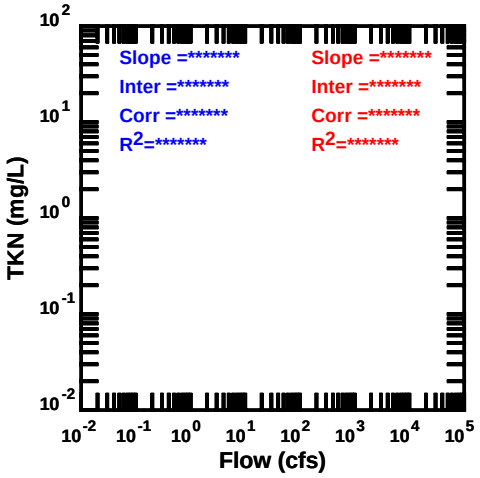
Nueces Tributaries, Texas (1970-2014)

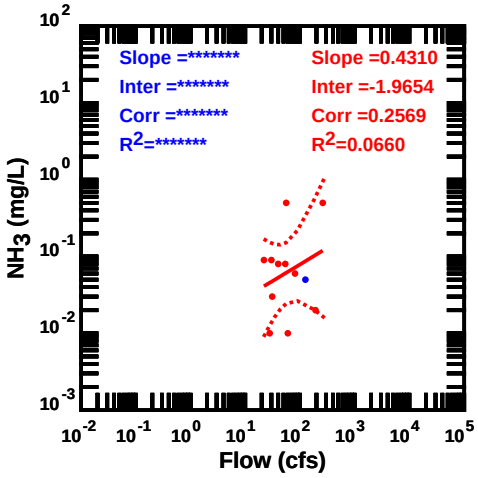
Before 1986

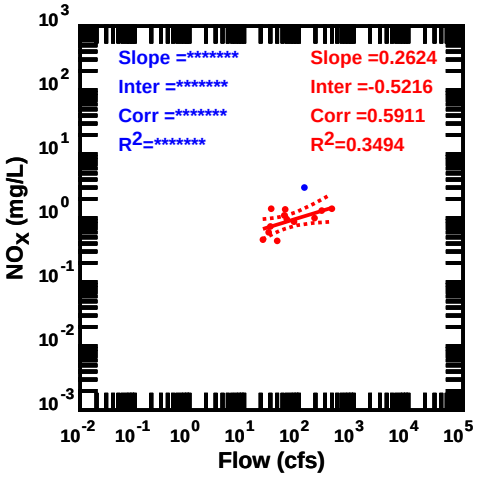
- Observed Data
- 95% Confidence Interval

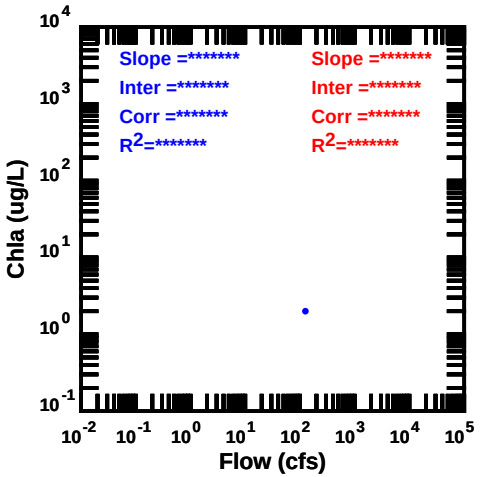
After 1986

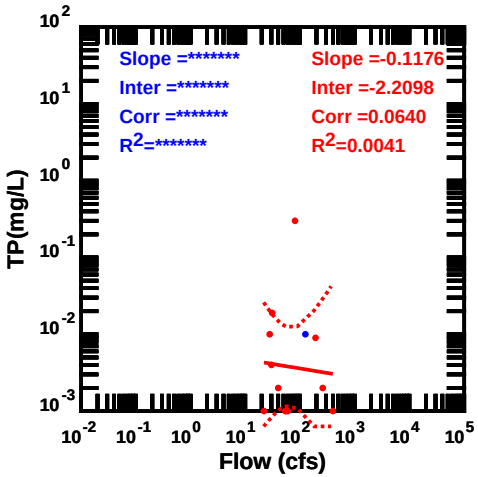
- Observed Data
- 95% Confidence Interval

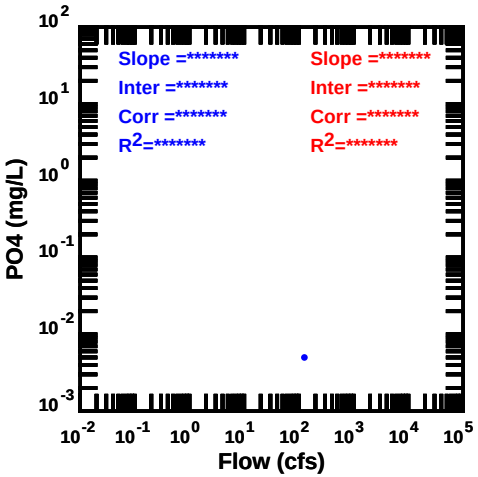












Regression analysis, Station 12997

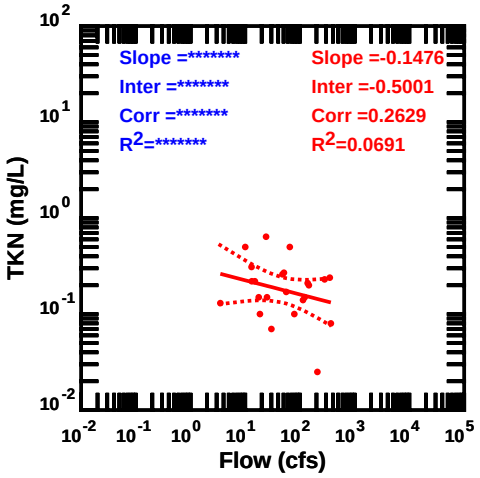
Nueces Tributaries, Texas (1970-2014)

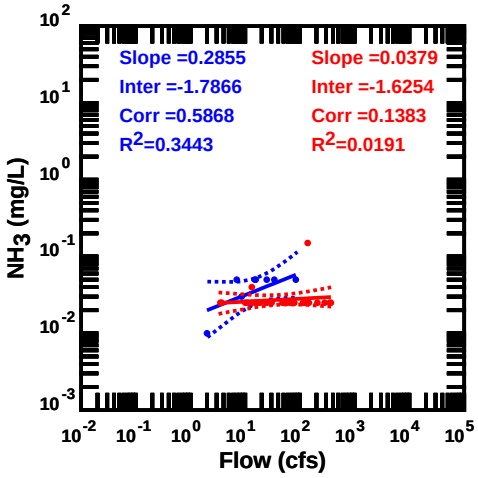
Before 1986

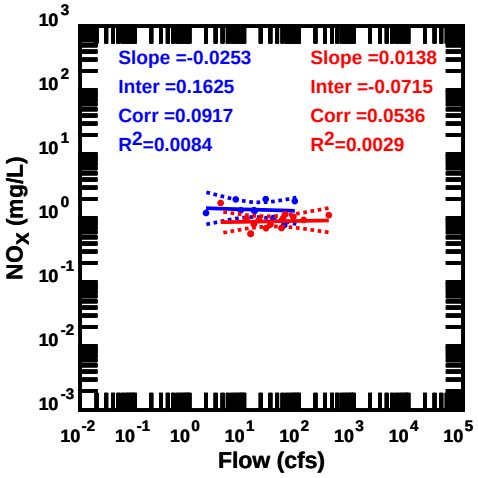
- **Observed Data**
- **95% Confidence Interval**

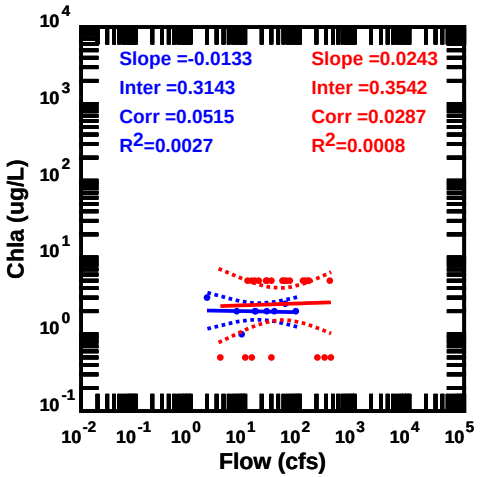
After 1986

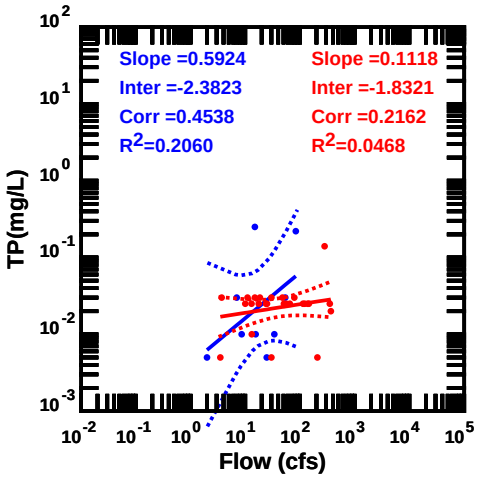
- **Observed Data**
- **95% Confidence Interval**

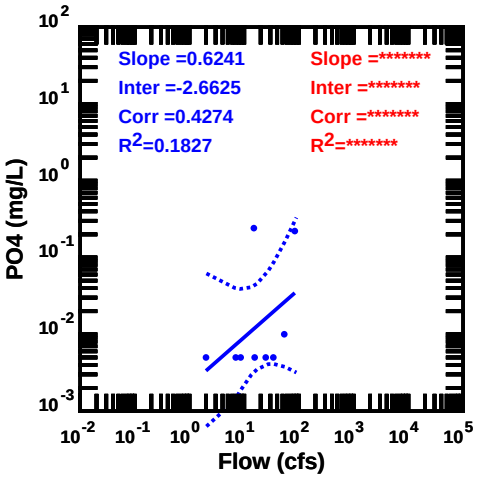












Regression analysis, Station 12996

Nueces Tributaries, Texas (1970-2014)

Before 1986

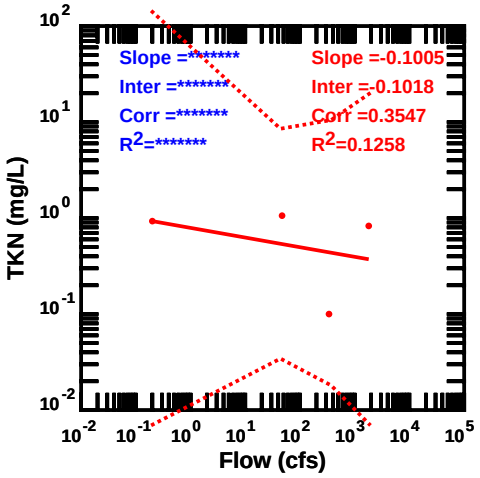
Observed Data

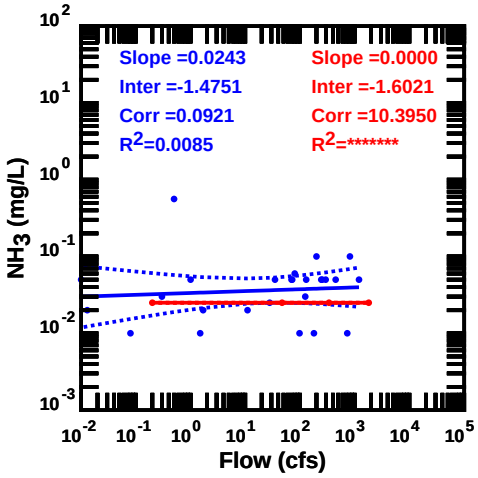
95% Confidence Interval

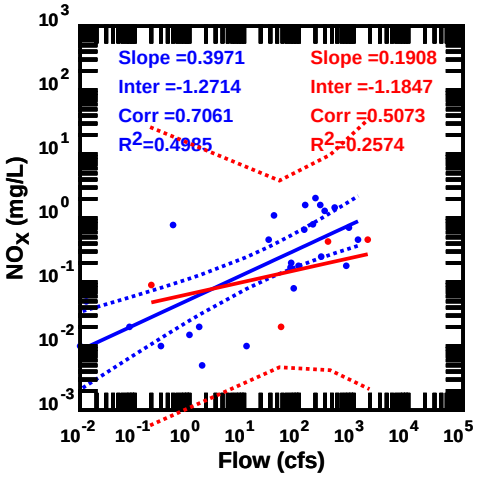
After 1986

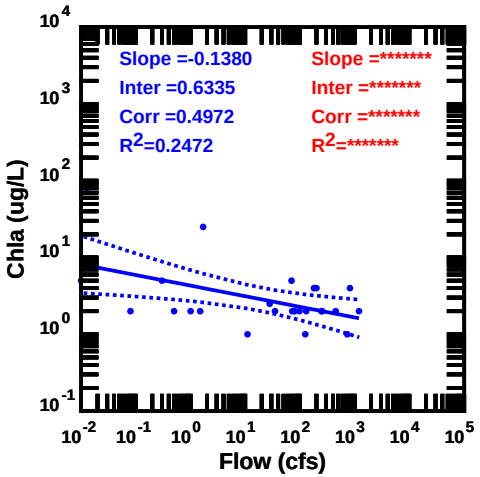
Observed Data

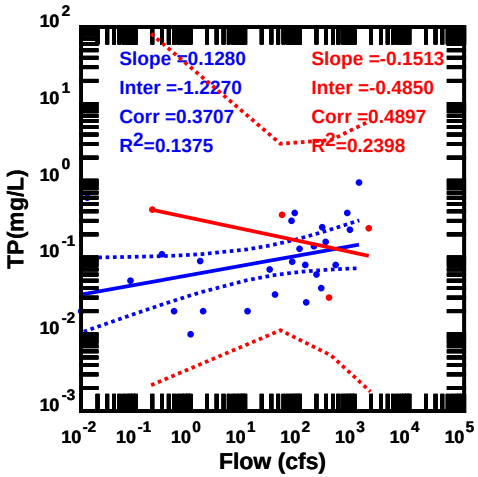
95% Confidence Interval

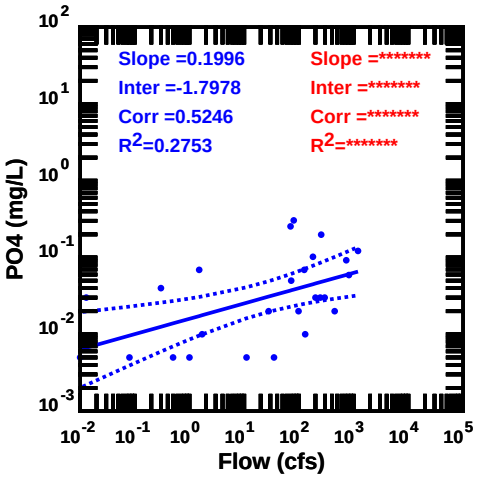










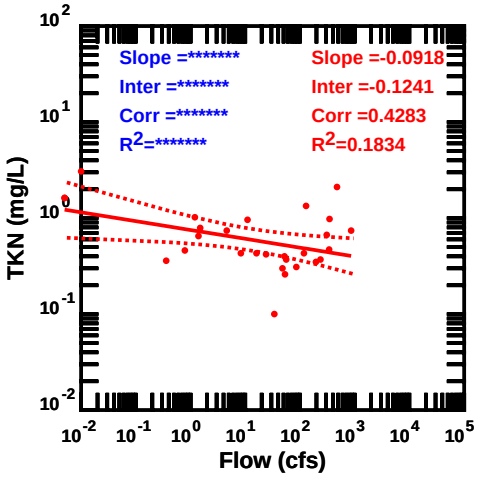


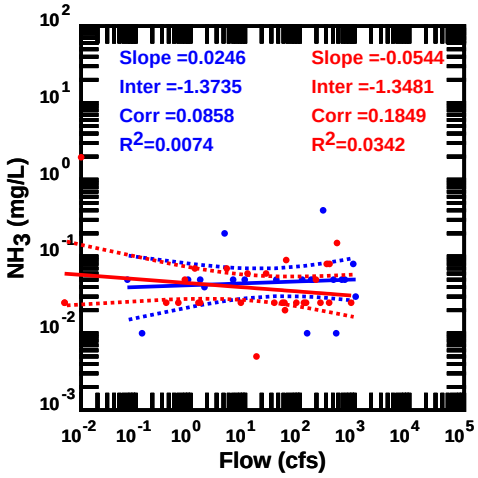
Regression analysis, Station 12976

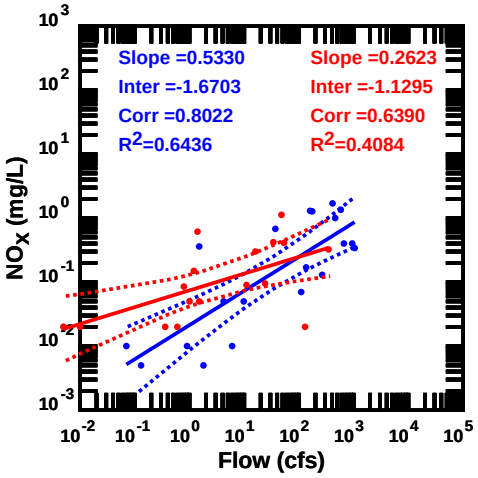
Nueces Tributaries, Texas (1970-2014)

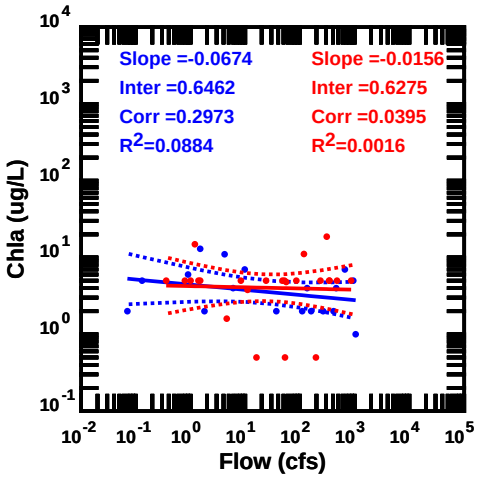
Before 1986
- **Observed Data**
- **95% Confidence Interval**

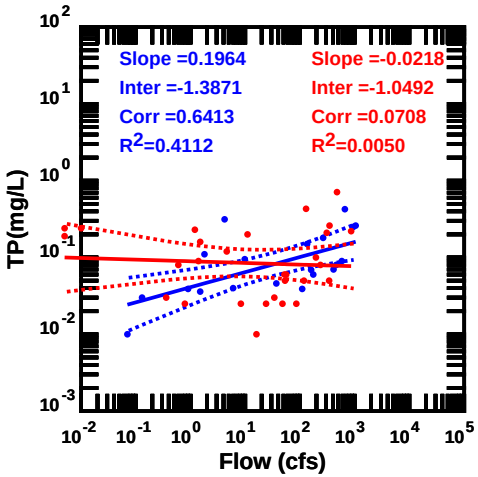
After 1986
- **Observed Data**
- **95% Confidence Interval**

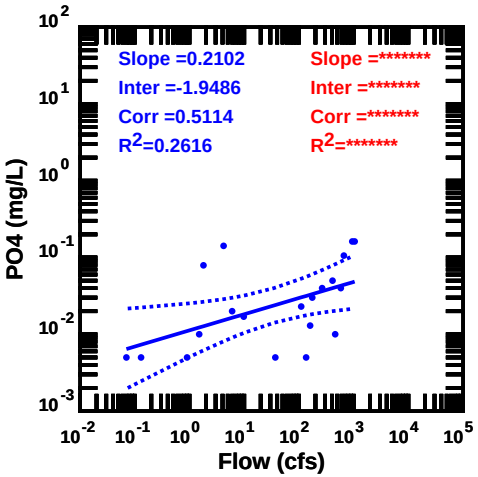












Regression analysis, Station 12975

Nueces Tributaries, Texas (1970-2014)

Before 1986

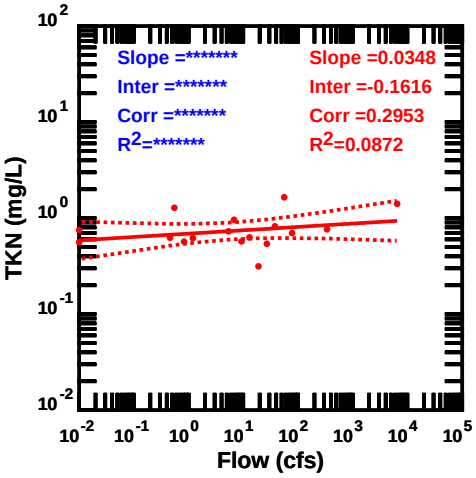
Observed Data

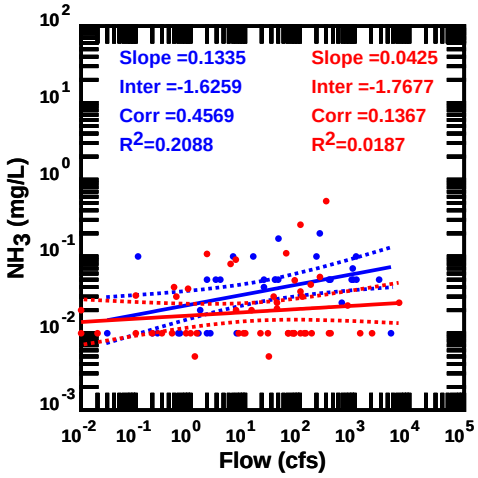
95% Confidence Interval

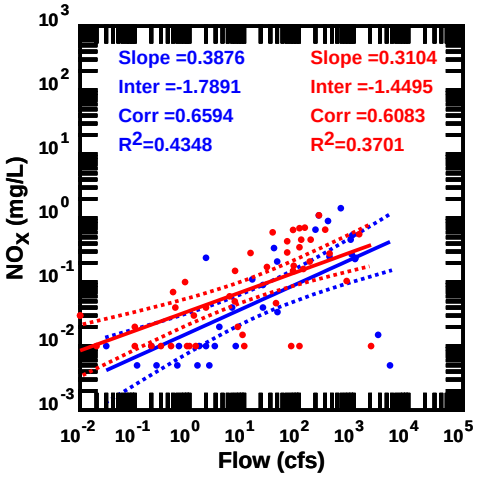
After 1986

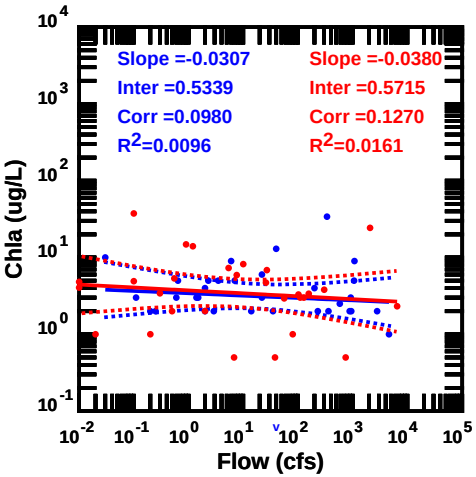
Observed Data

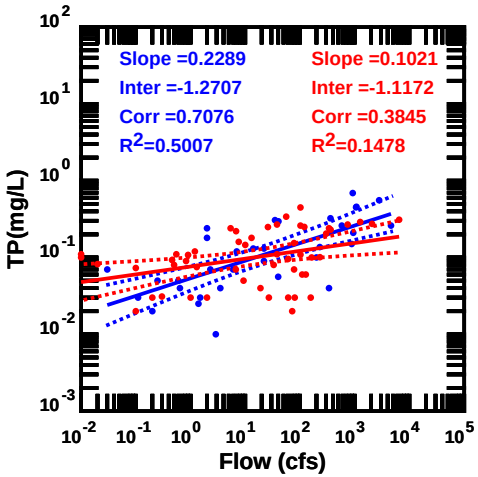
95% Confidence Interval

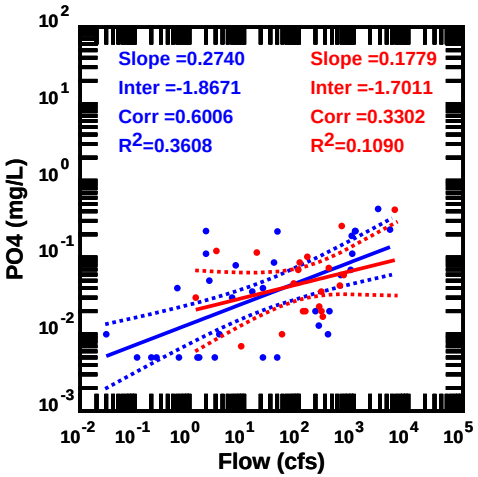










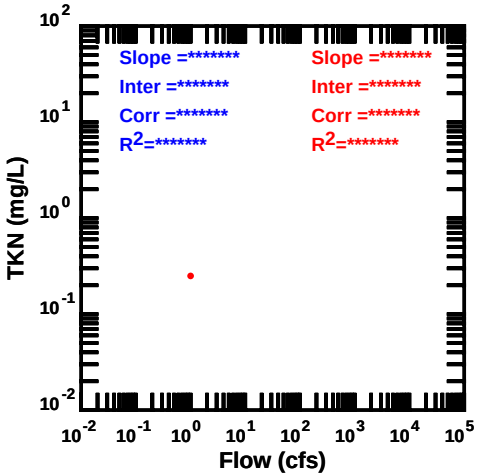


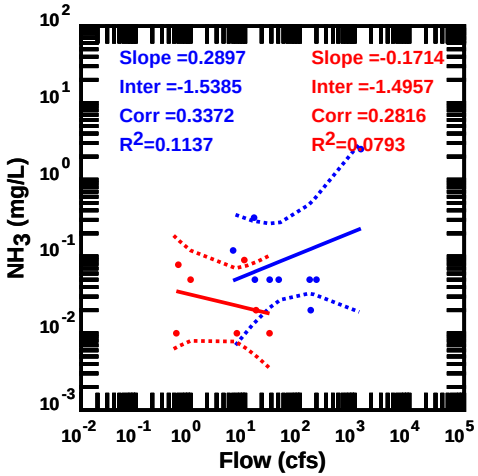
Regression analysis, Station 12973

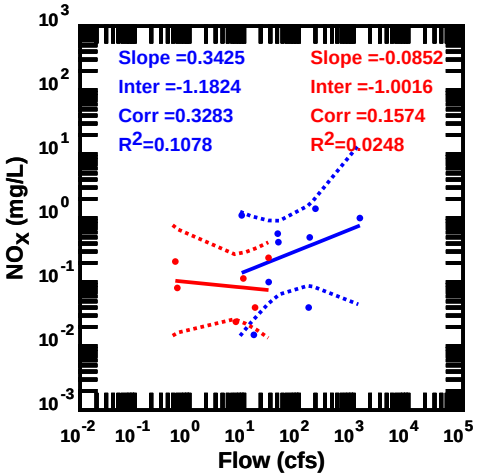
Nueces Tributaries, Texas (1970-2014)

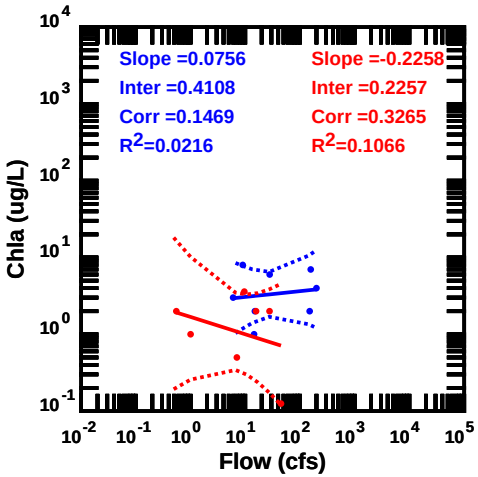
Before 1986
- **Observed Data**
- **95% Confidence Interval**

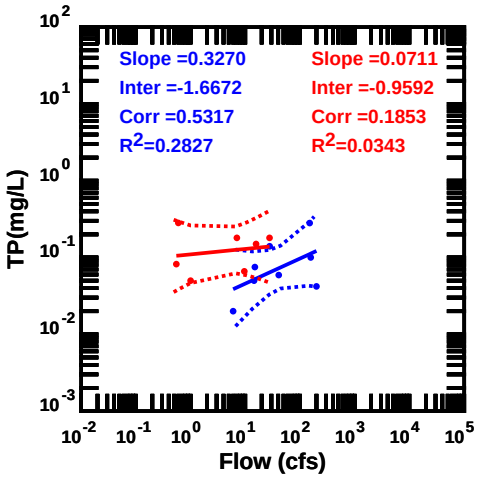
After 1986
- **Observed Data**
- **95% Confidence Interval**

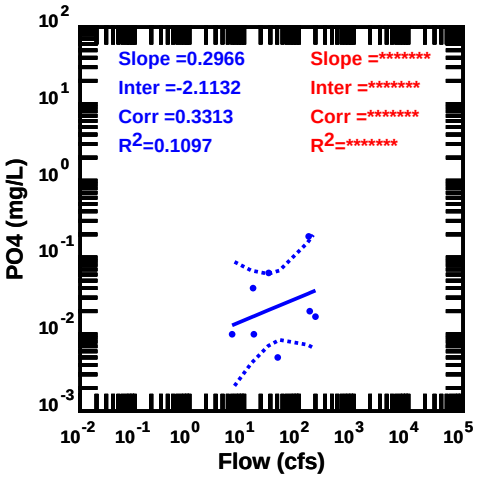












Regression analysis, Station 12972

Nueces Tributaries, Texas (1970-2014)

Before 1986

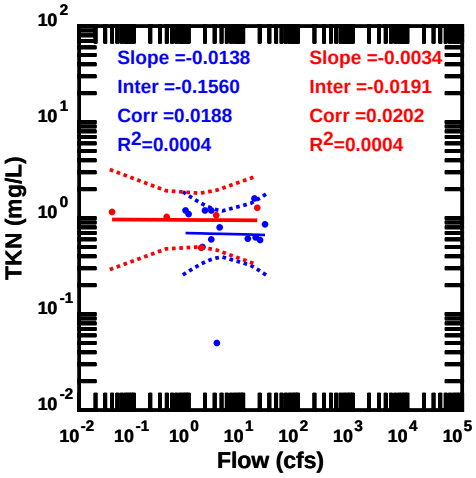
Observed Data

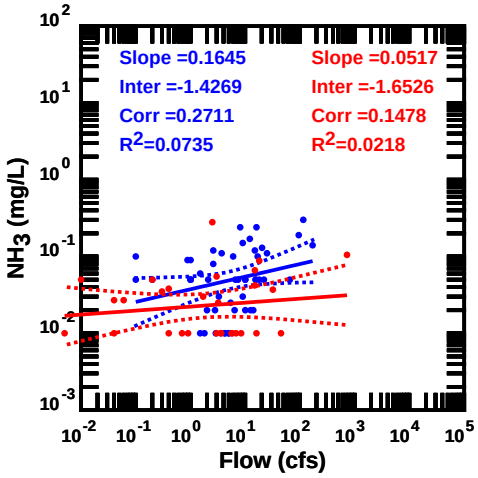
95% Confidence Interval

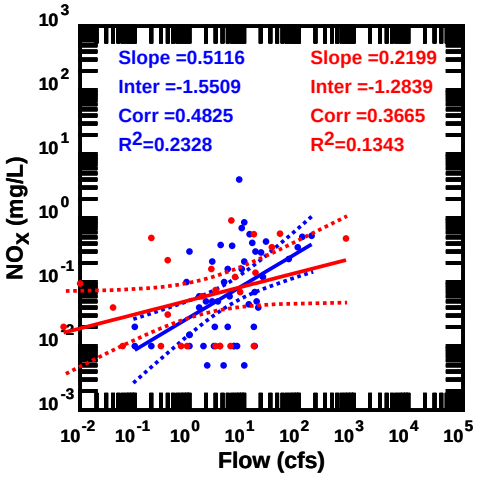
After 1986

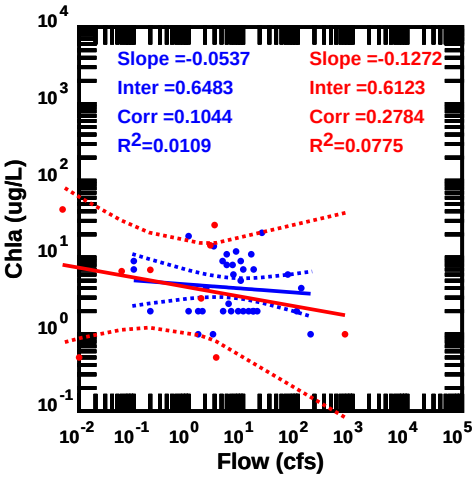
Observed Data

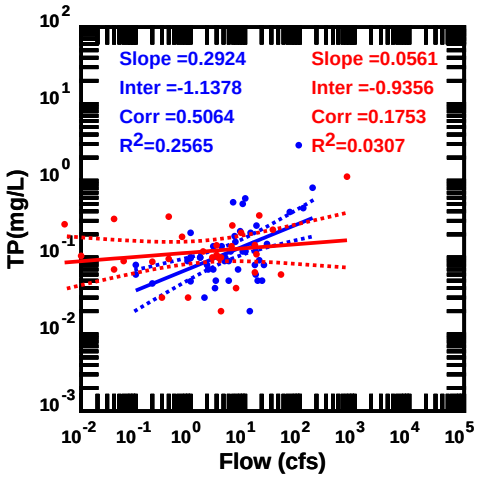
95% Confidence Interval

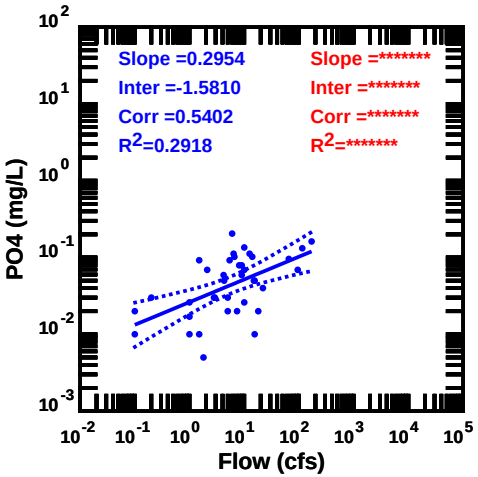












Regression analysis, Station 12983

Nueces Tributaries, Texas (1970-2014)

Before 1986

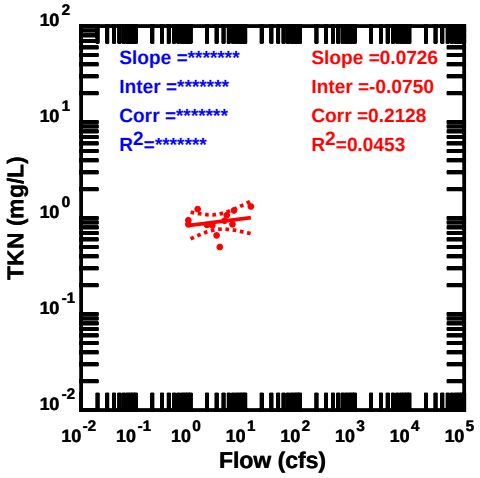
Observed Data

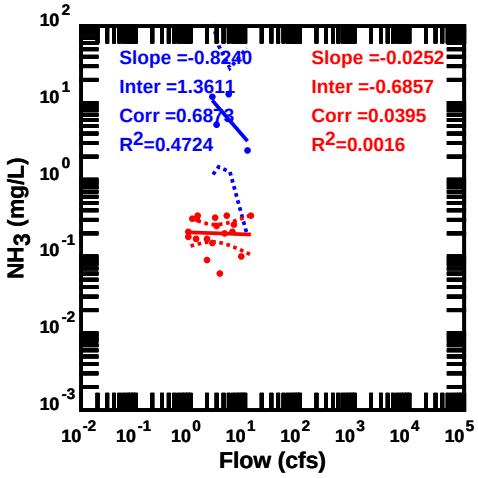
95% Confidence Interval

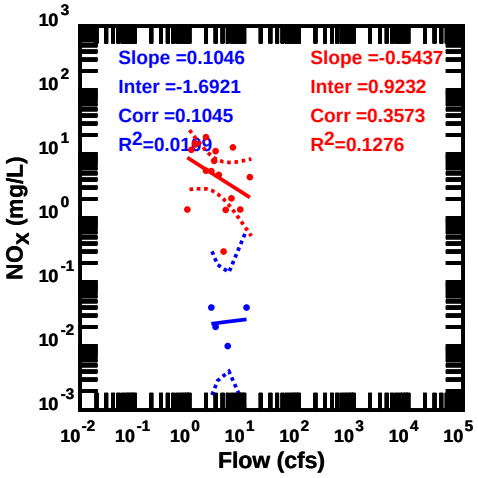
After 1986

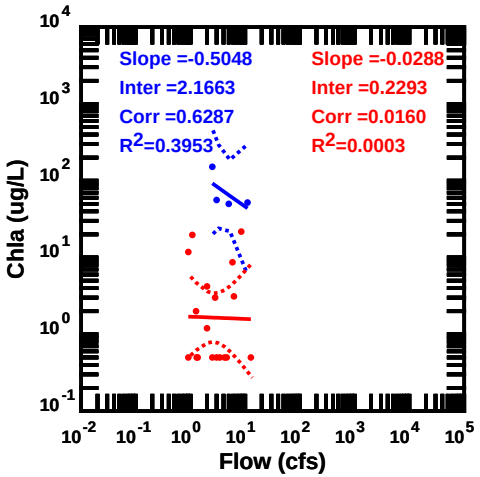
Observed Data

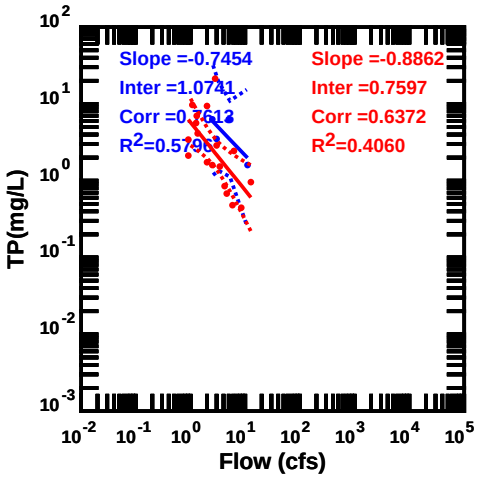
95% Confidence Interval

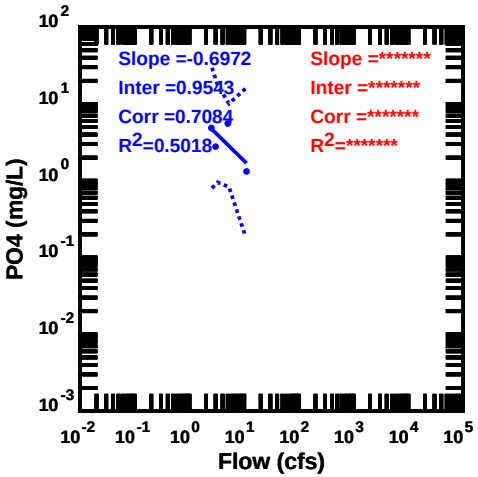












Regression analysis, Station 12981

Nueces Tributaries, Texas (1970-2014)

Before 1986

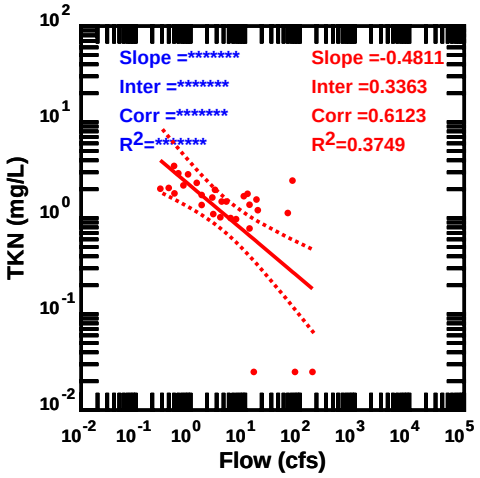
Observed Data

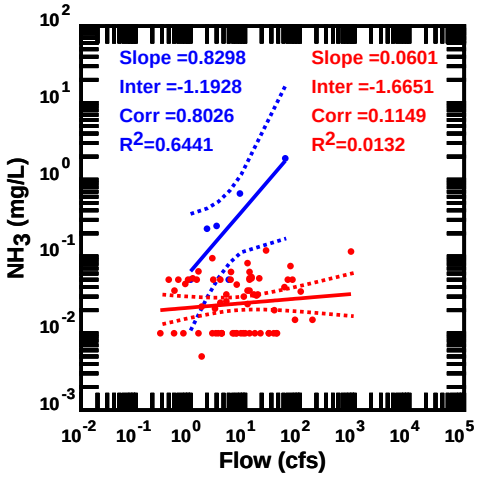
95% Confidence Interval

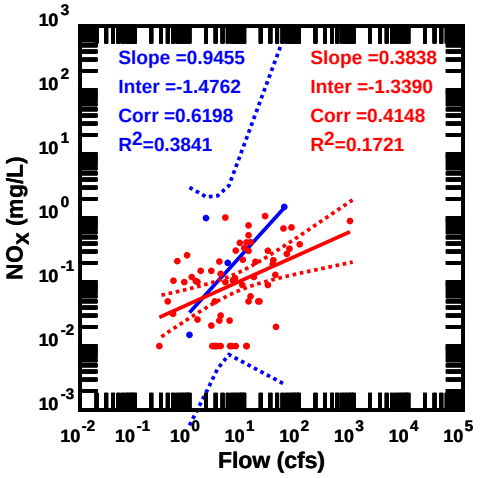
After 1986

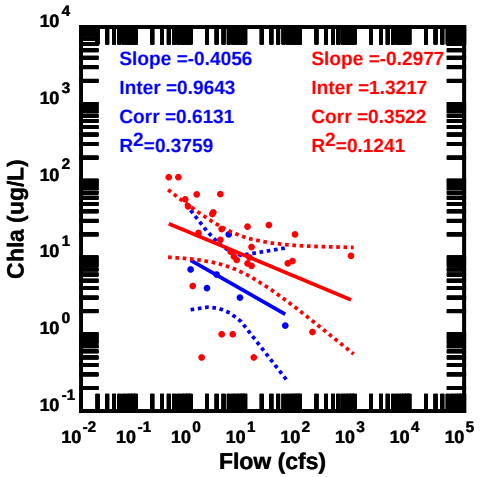
Observed Data

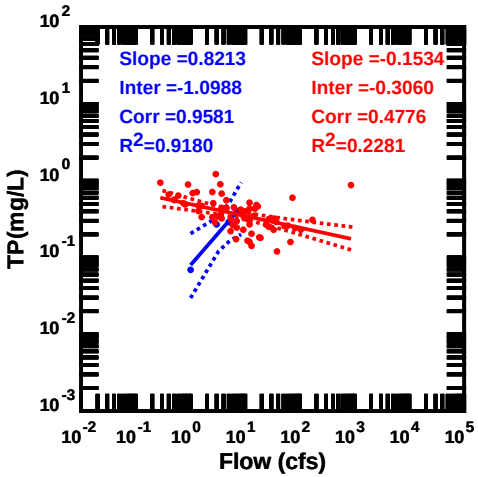
95% Confidence Interval

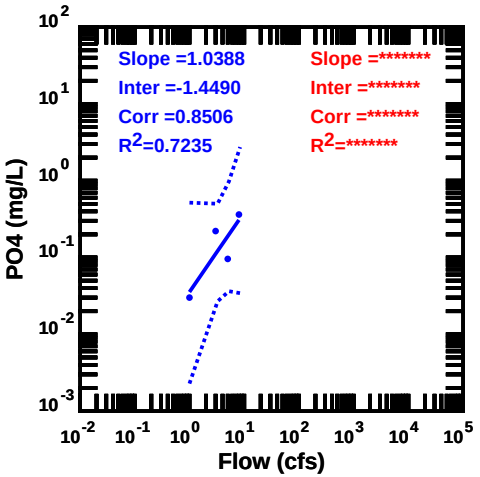












Regression analysis, Station 12980

Nueces Tributaries, Texas (1970-2014)

Before 1986

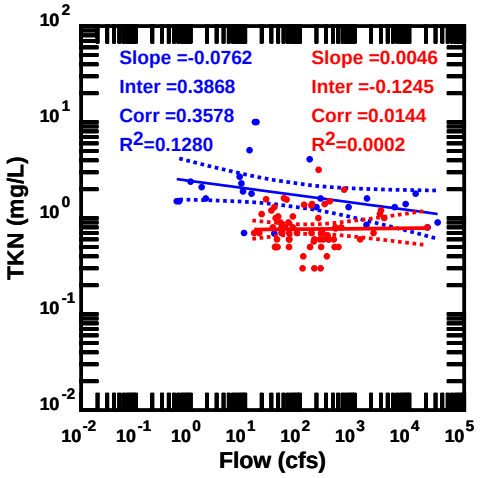
Observed Data

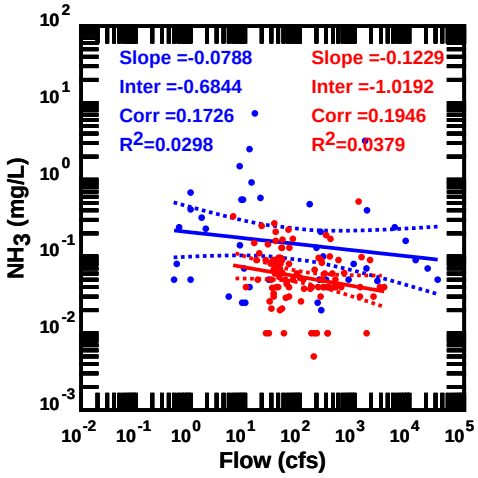
95% Confidence Interval

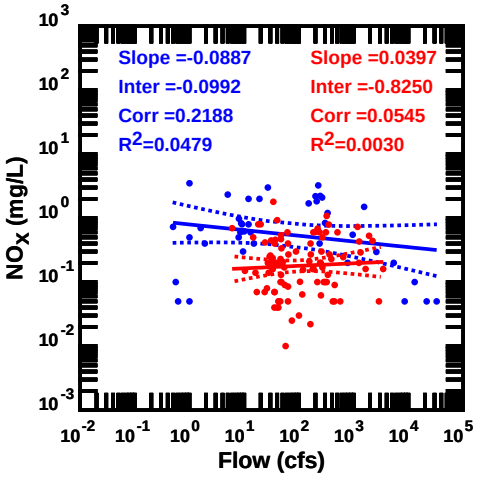
After 1986

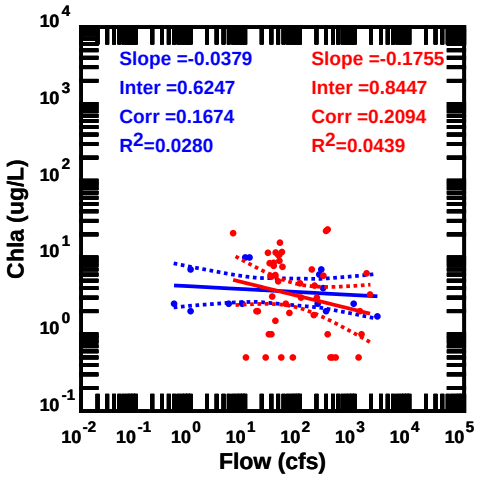
Observed Data

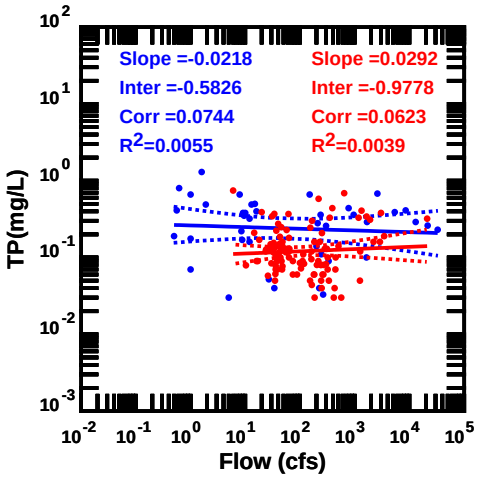
95% Confidence Interval

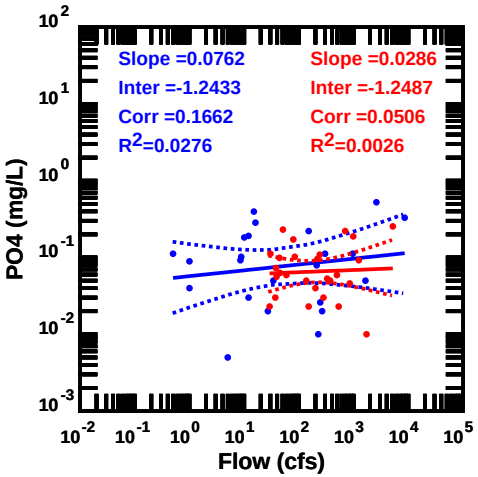












Regression analysis, Station 12979

Nueces Tributaries, Texas (1970-2014)

Before 1986

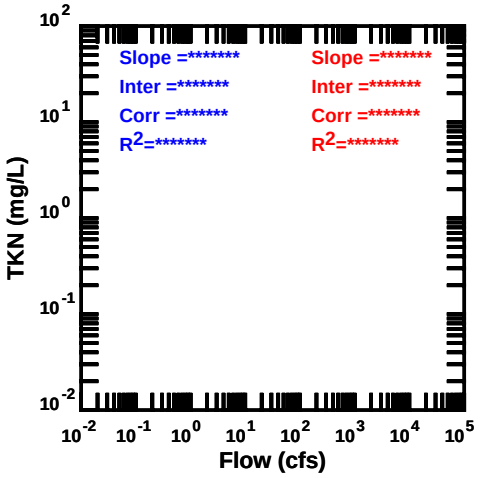
Observed Data

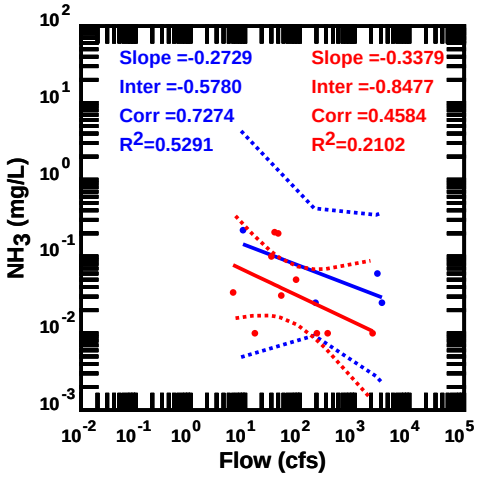
95% Confidence Interval

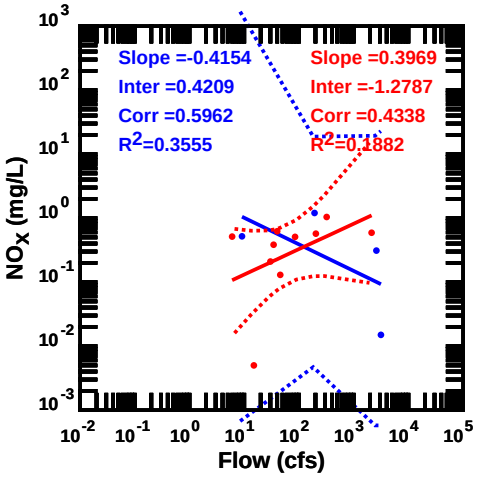
After 1986

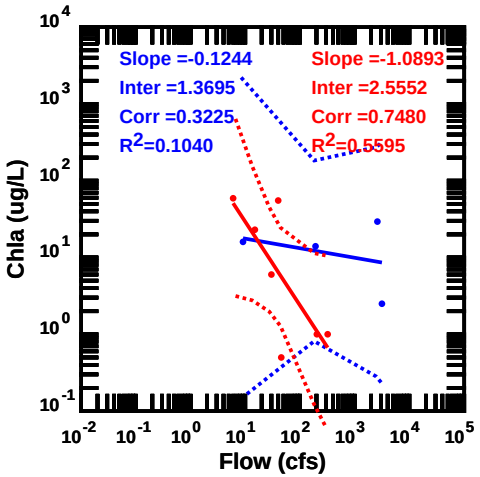
Observed Data

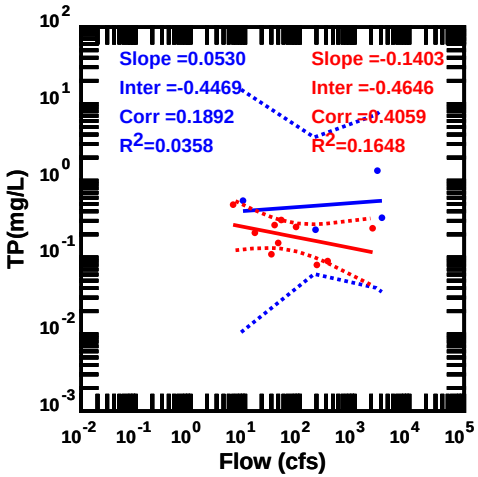
95% Confidence Interval

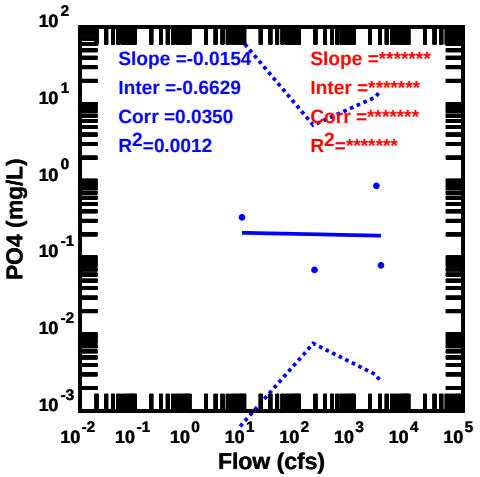












Regression analysis, Station 12978

Nueces Tributaries, Texas (1970-2014)

Before 1986

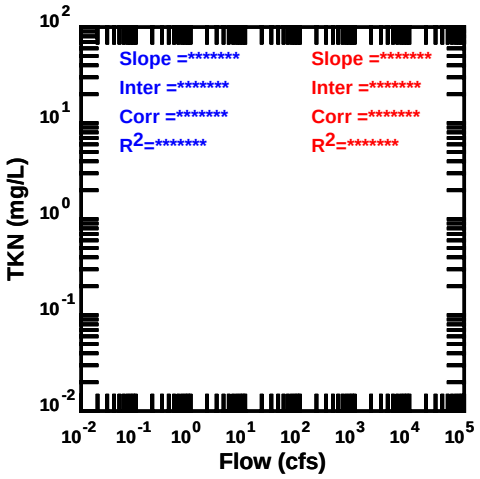
Observed Data

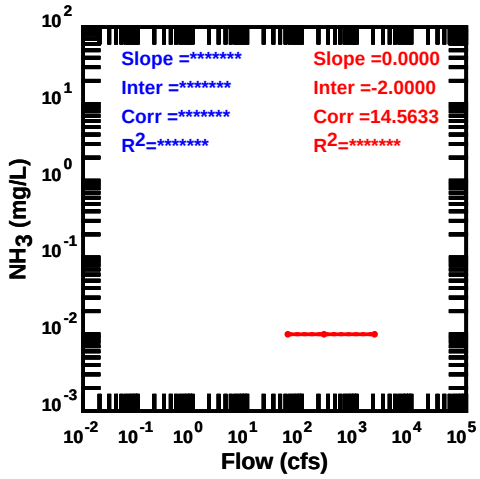
95% Confidence Interval

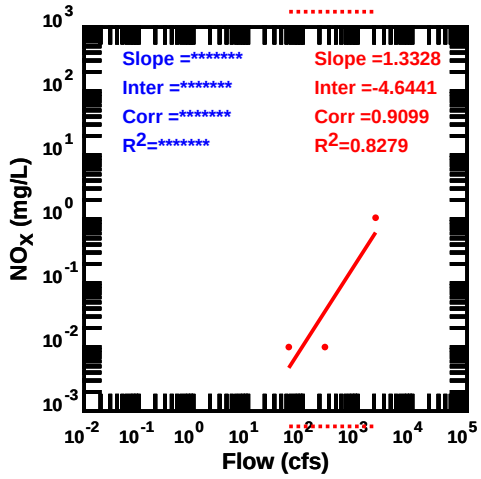
After 1986

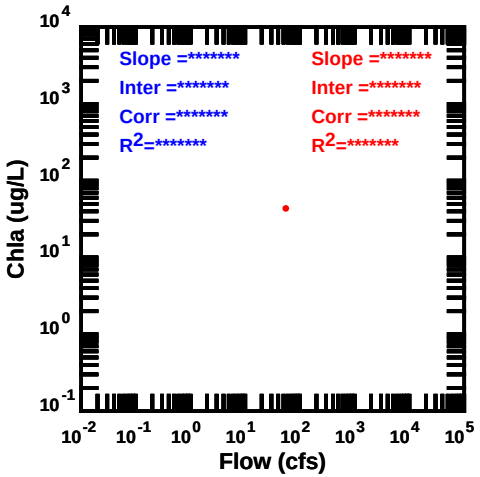
Observed Data

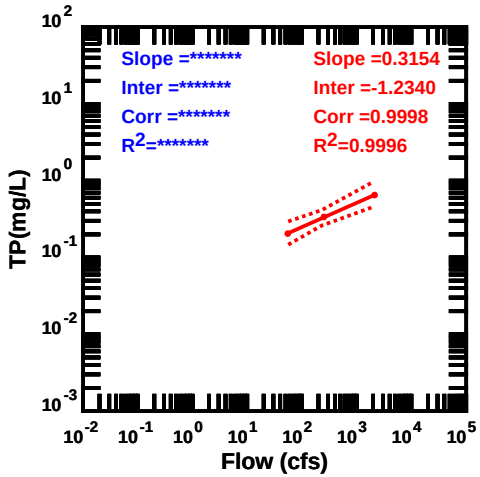
95% Confidence Interval











Regression analysis, Station 17648

Nueces Tributaries, Texas (1970-2014)

Before 1986

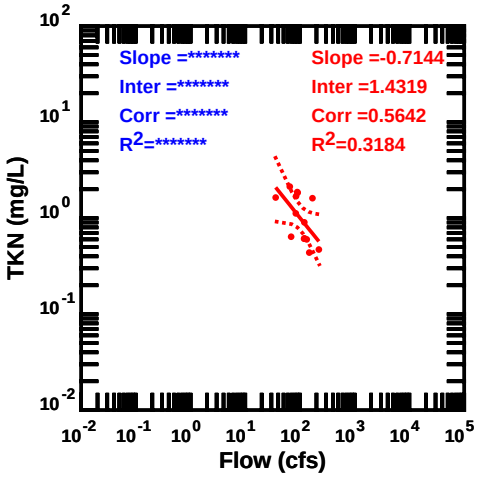
Observed Data

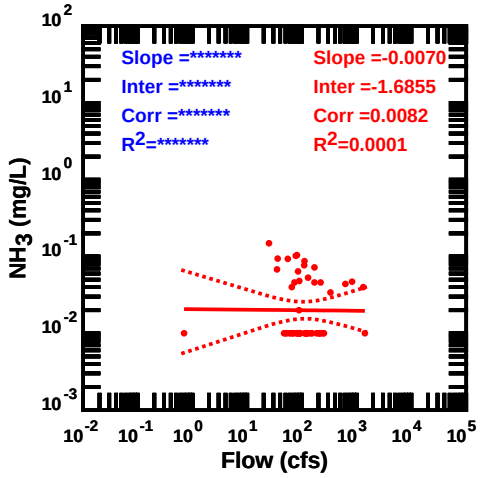
95% Confidence Interval

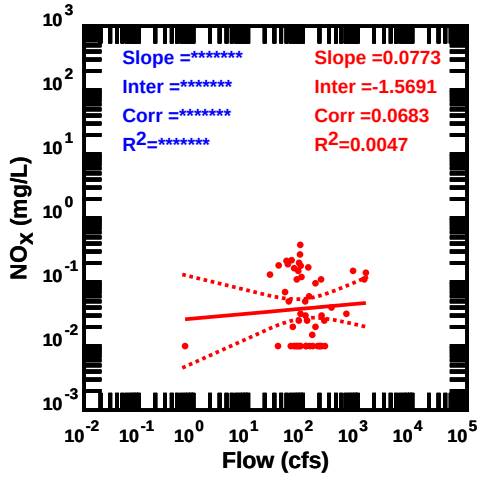
After 1986

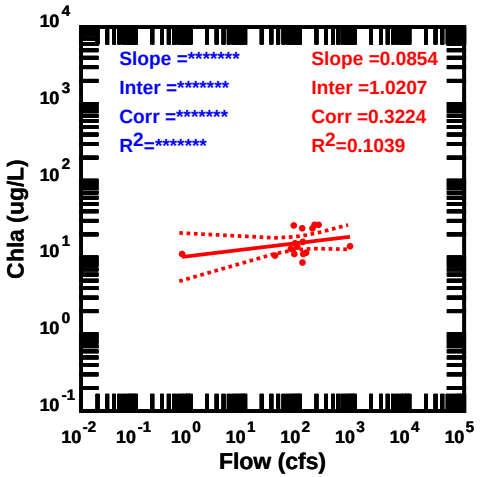
Observed Data

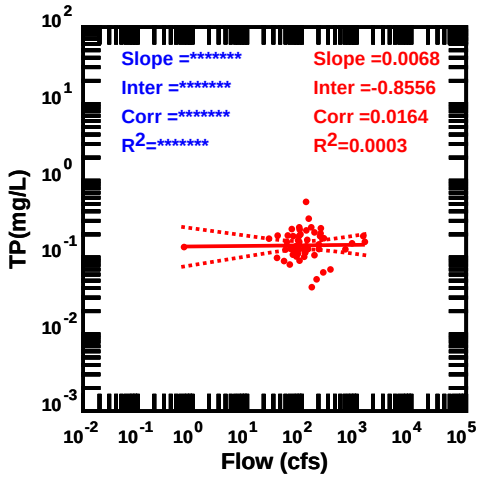
95% Confidence Interval











Regression analysis, Station 12965

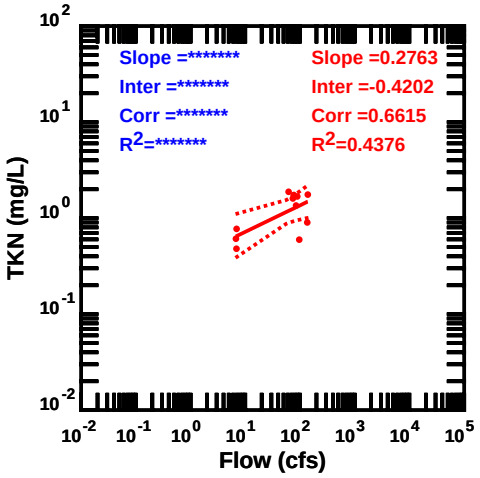
Nueces Tributaries, Texas (1970-2014)

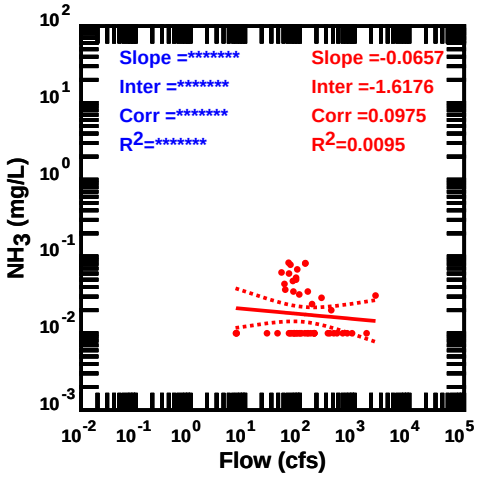
Before 1986

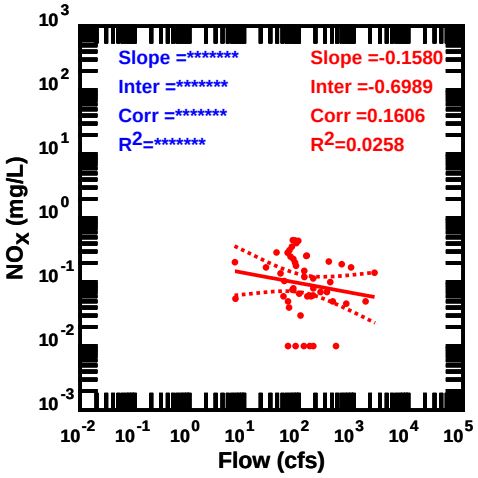
- **Observed Data**
- **95% Confidence Interval**

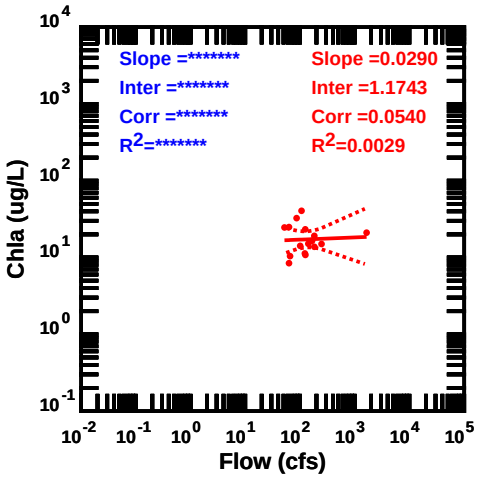
After 1986

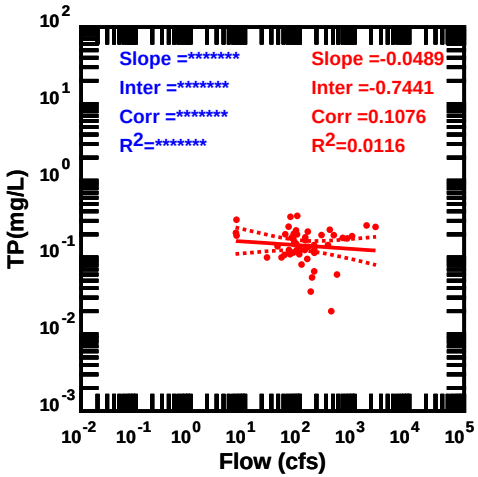
- **Observed Data**
- **95% Confidence Interval**











Regression analysis, Station 12964

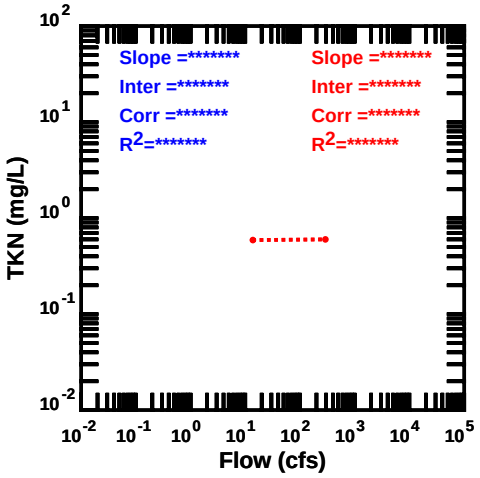
Nueces Tributaries, Texas (1970-2014)

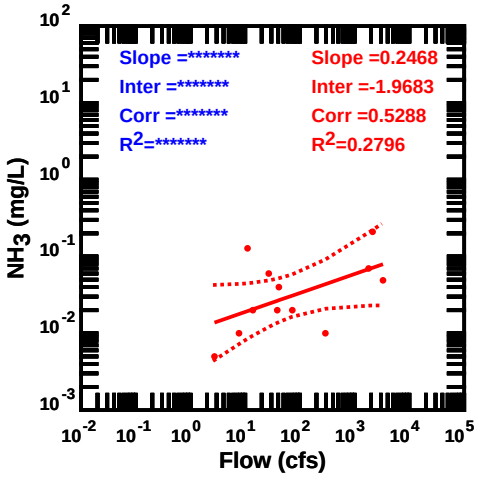
Before 1986

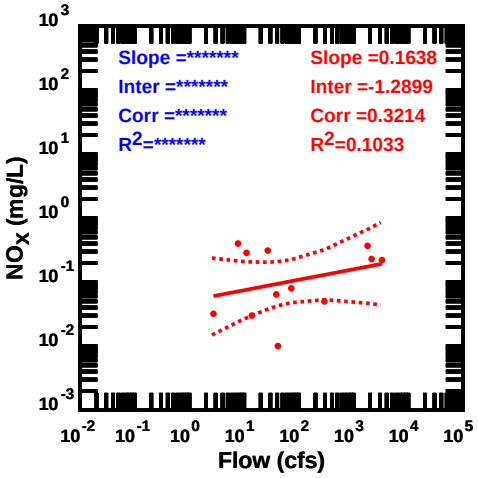
- **Observed Data**
- **95% Confidence Interval**

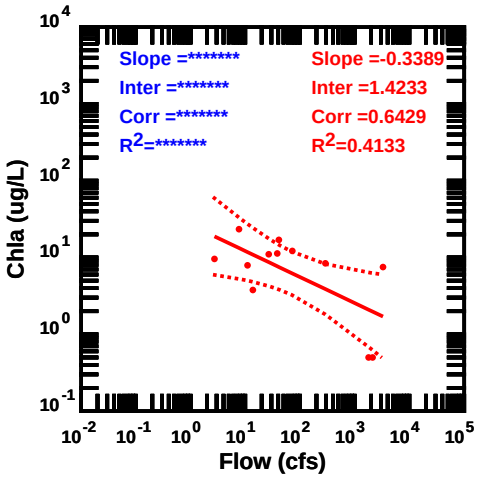
After 1986

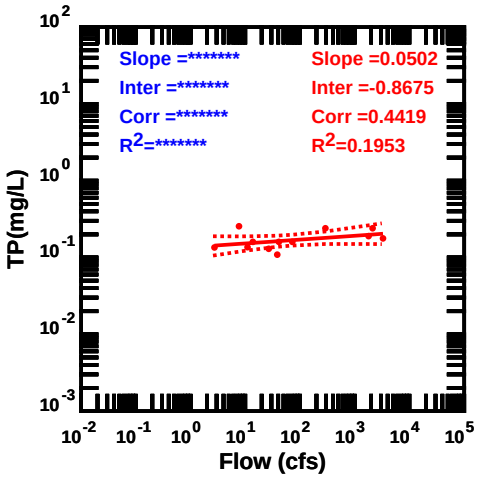
- **Observed Data**
- **95% Confidence Interval**

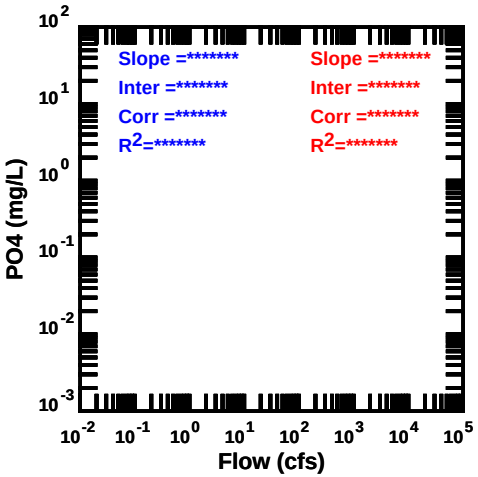












Regression analysis, Station 12962

Nueces Tributaries, Texas (1970-2014)

Before 1986

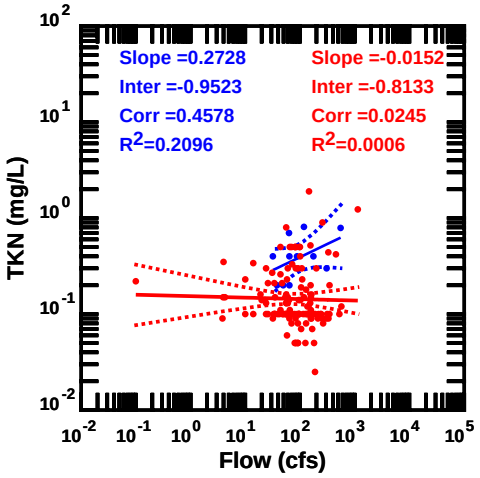
Observed Data

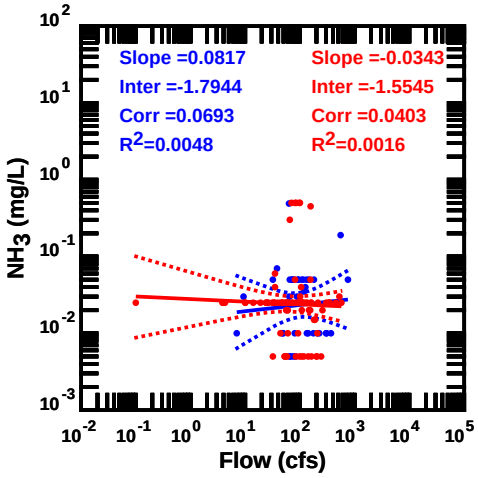
95% Confidence Interval

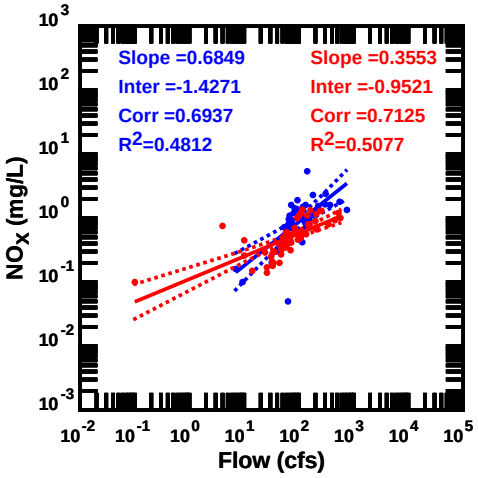
After 1986

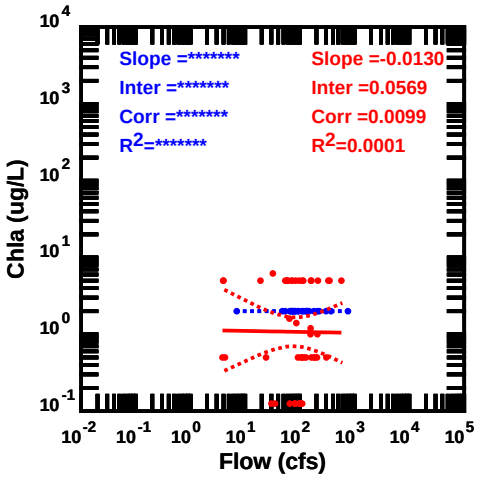
Observed Data

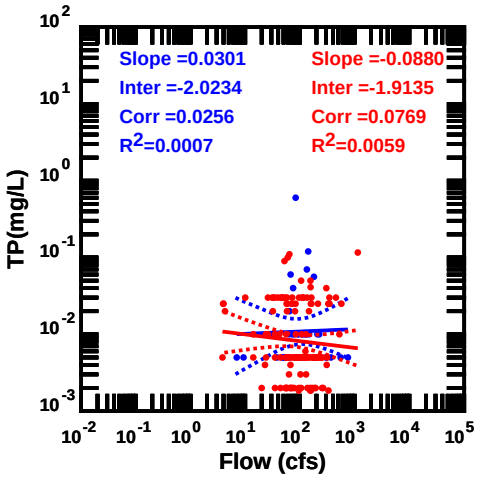
95% Confidence Interval

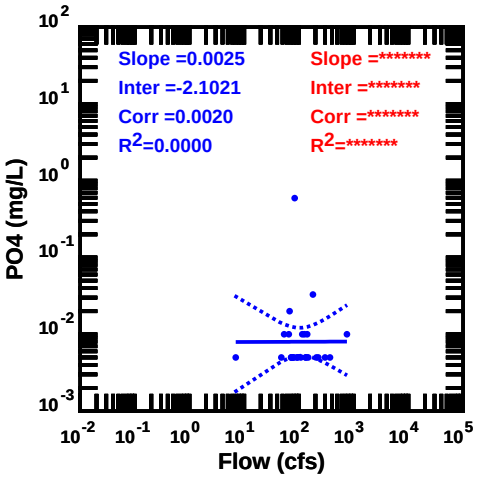












Regression analysis, Station 13006

Nueces Tributaries, Texas (1970-2014)

Before 1986

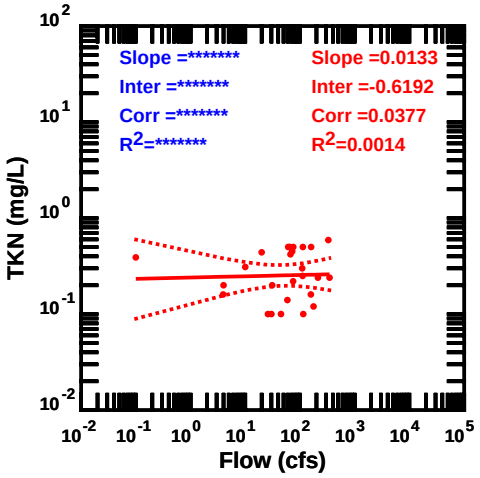
Observed Data

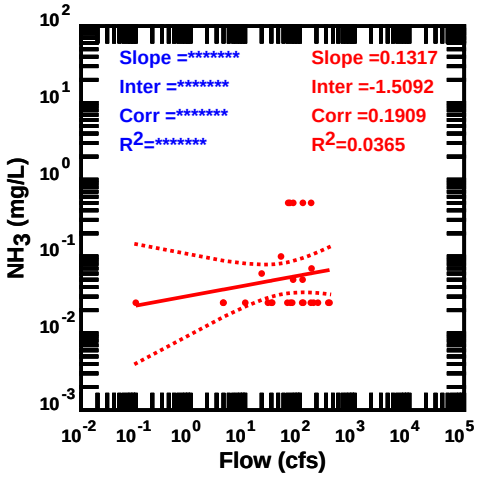
95% Confidence Interval

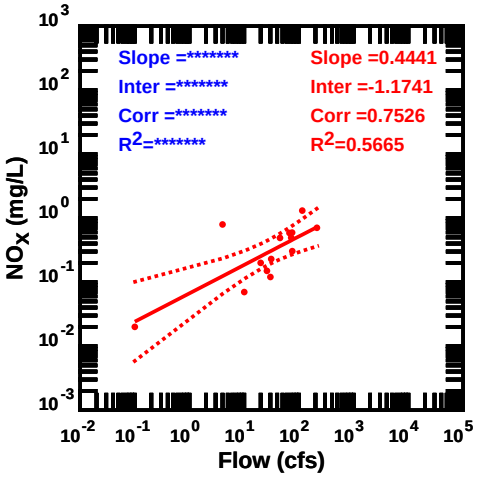
After 1986

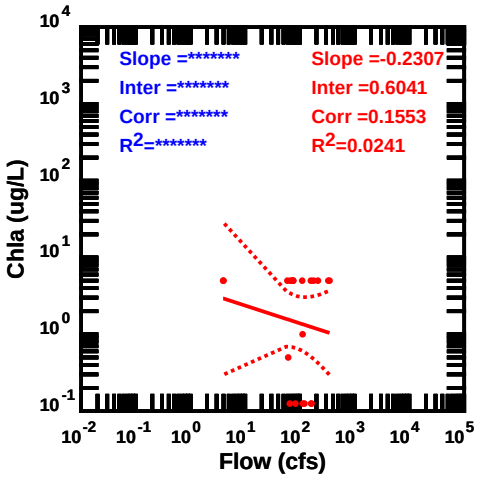
Observed Data

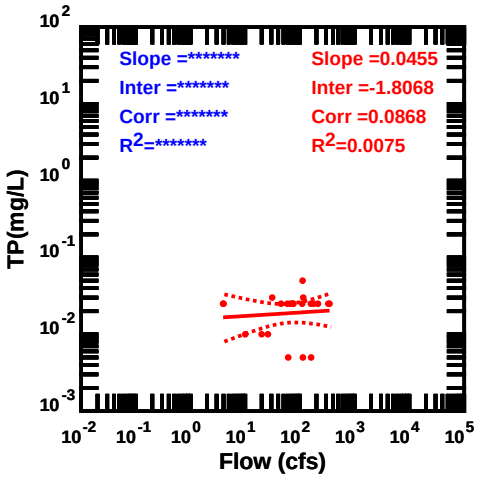
95% Confidence Interval











Regression analysis, Station 13007

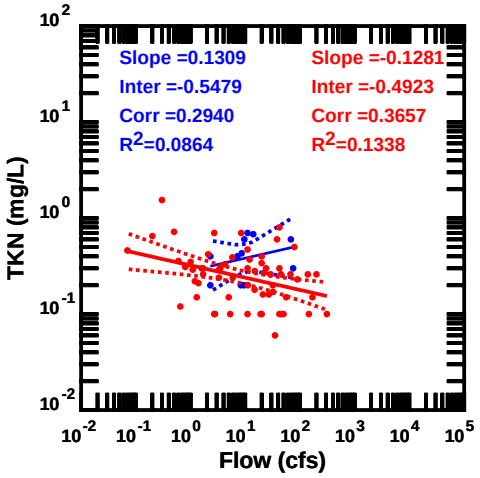
Nueces Tributaries, Texas (1970-2014)

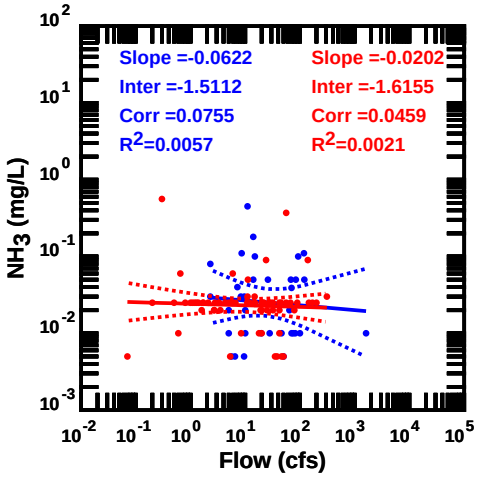
Before 1986

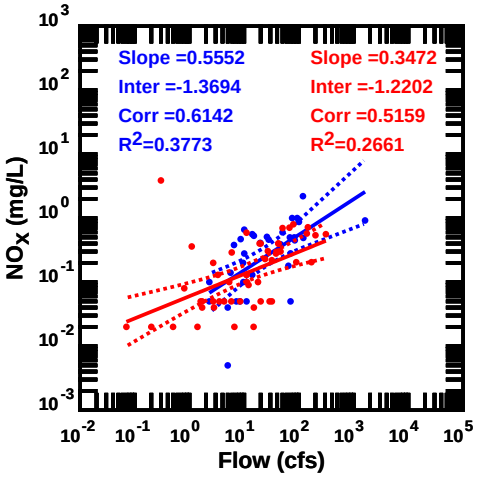
- **Observed Data**
- **95% Confidence Interval**

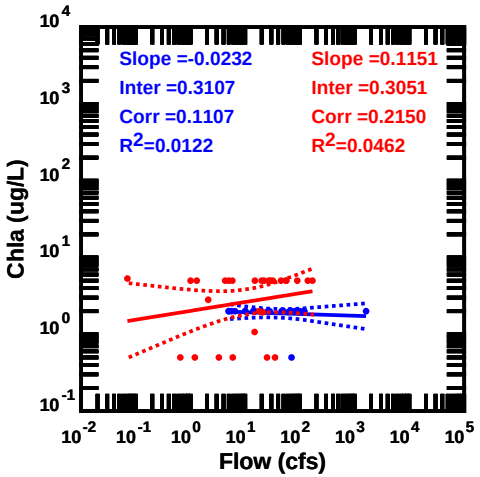
After 1986

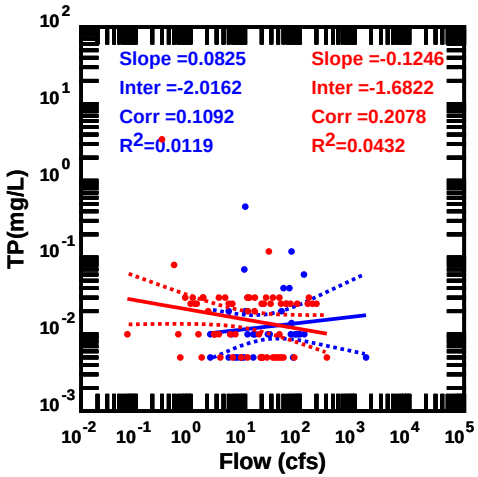
- **Observed Data**
- **95% Confidence Interval**

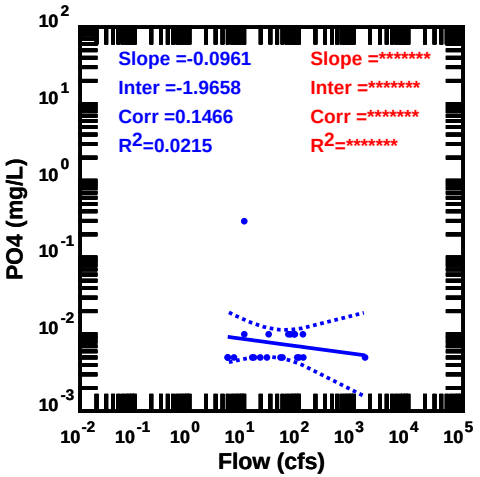










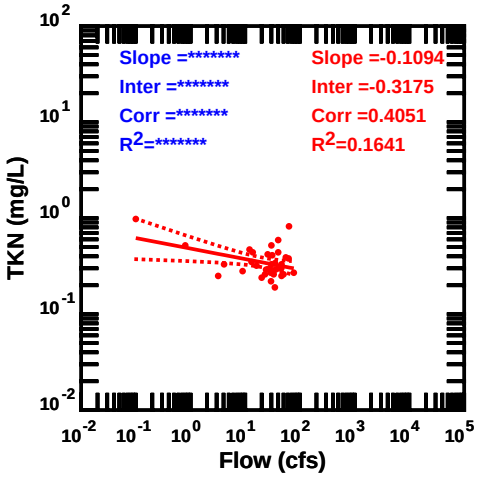


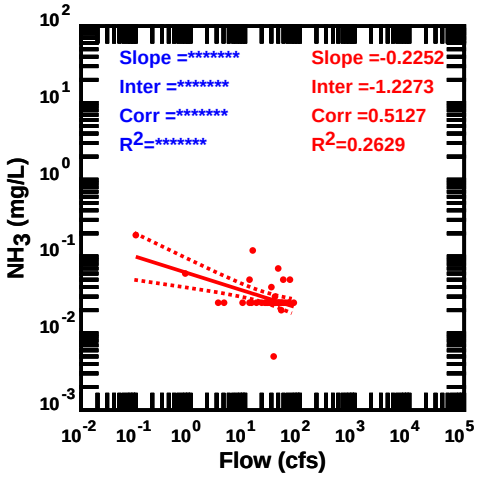
Regression analysis, Station 13010

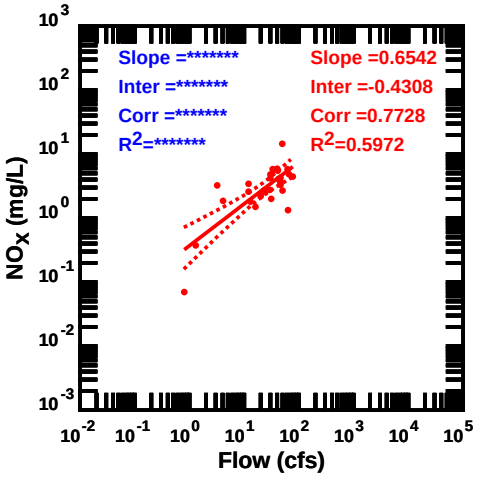
Nueces Tributaries, Texas (1970-2014)

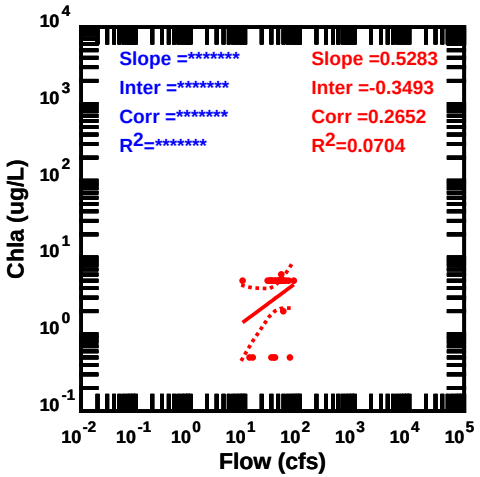
Before 1986
- **Observed Data**
- **95% Confidence Interval**

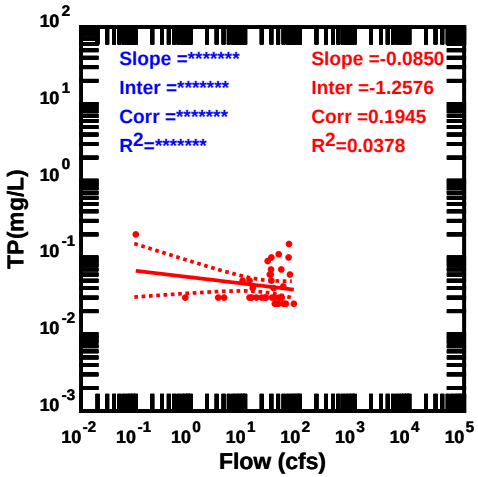
After 1986
- **Observed Data**
- **95% Confidence Interval**











Regression analysis, Station 12987

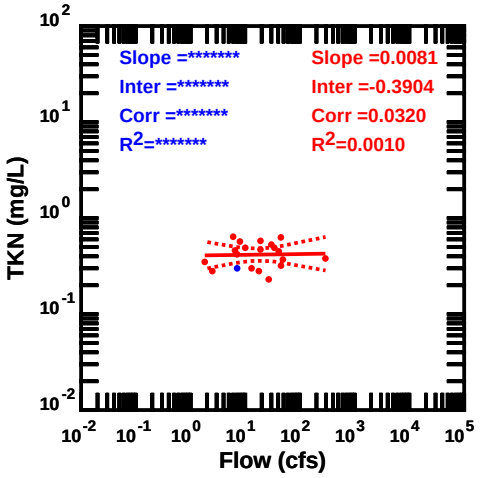
Nueces Tributaries, Texas (1970-2014)

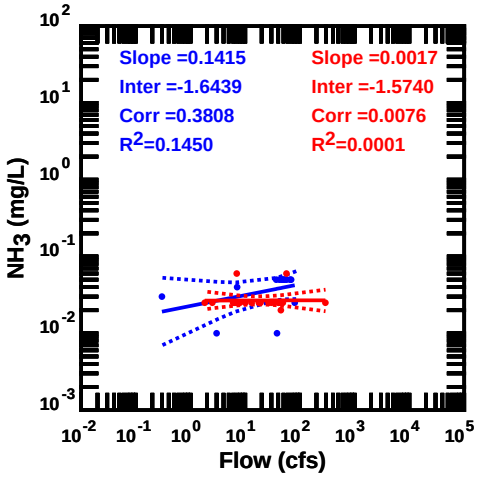
Before 1986

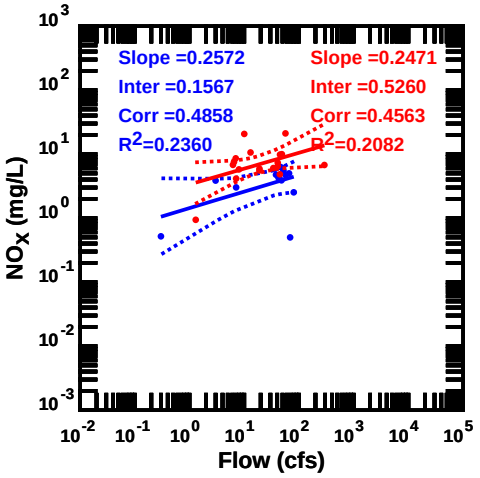
- **Observed Data**
- **95% Confidence Interval**

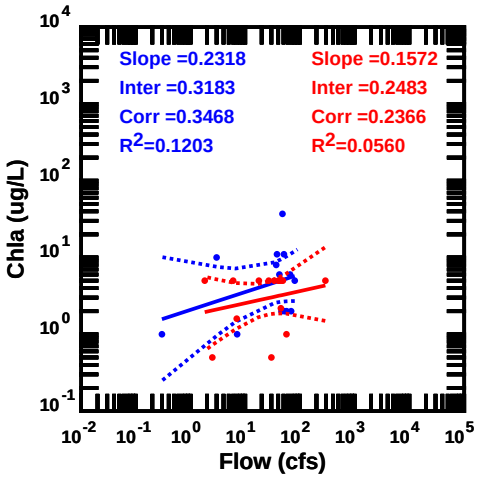
After 1986

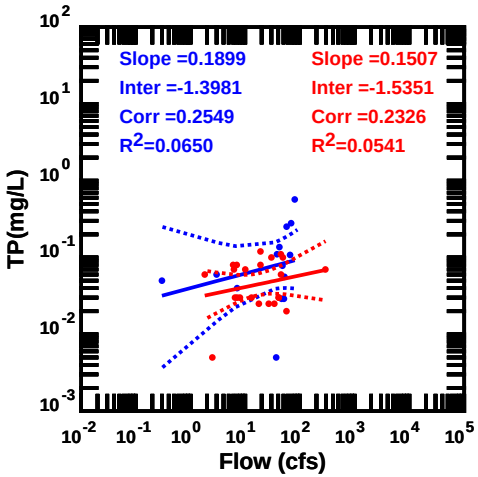
- **Observed Data**
- **95% Confidence Interval**

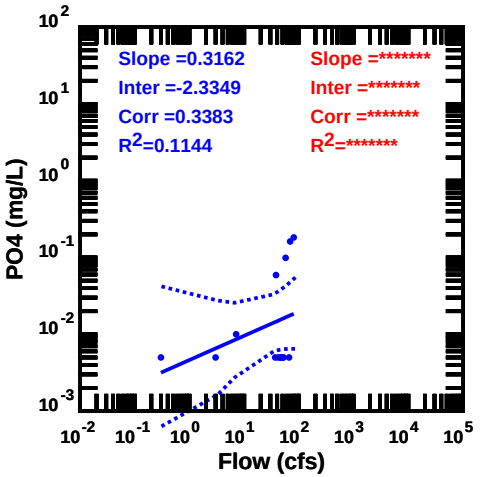












Regression analysis, Station 12985

Nueces Tributaries, Texas (1970-2014)

Before 1986

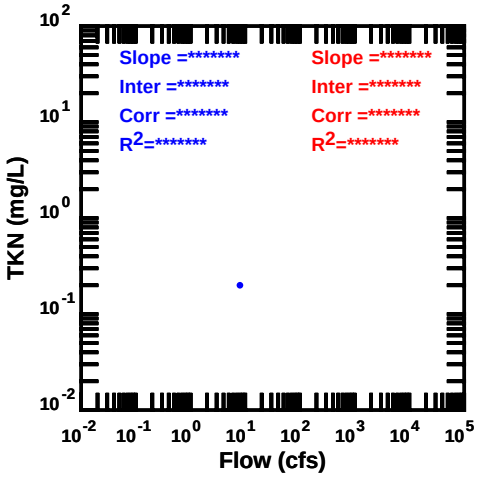
Observed Data

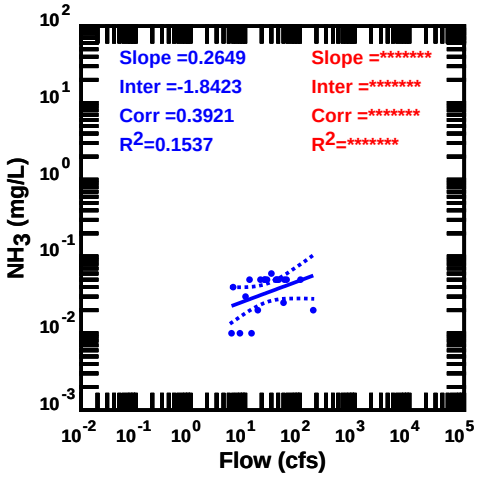
95% Confidence Interval

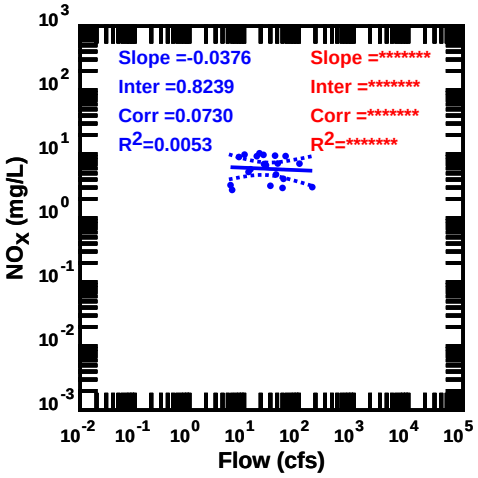
After 1986

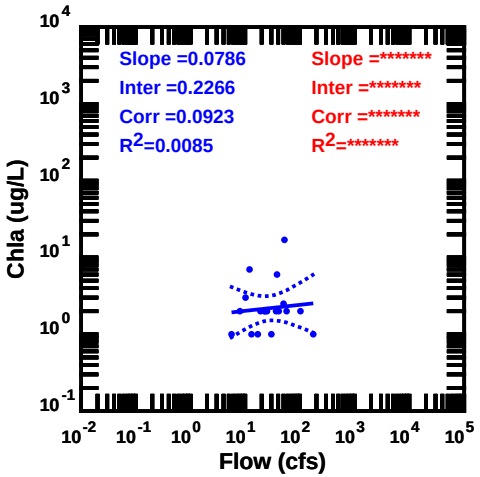
Observed Data

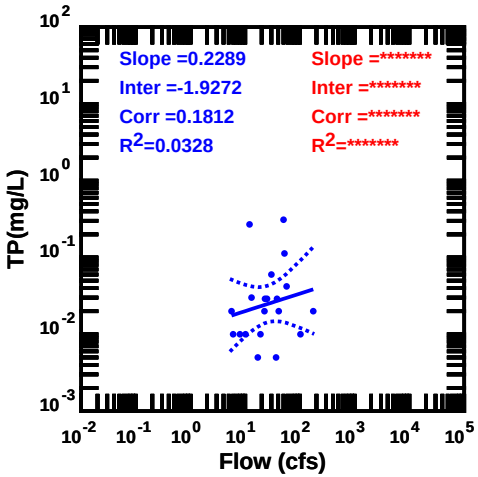
95% Confidence Interval

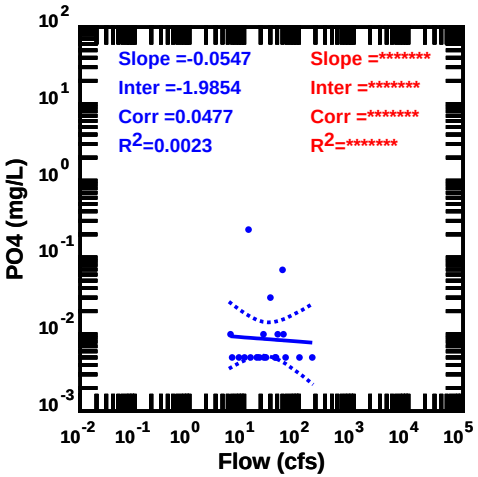












Regression analysis, Station 13025

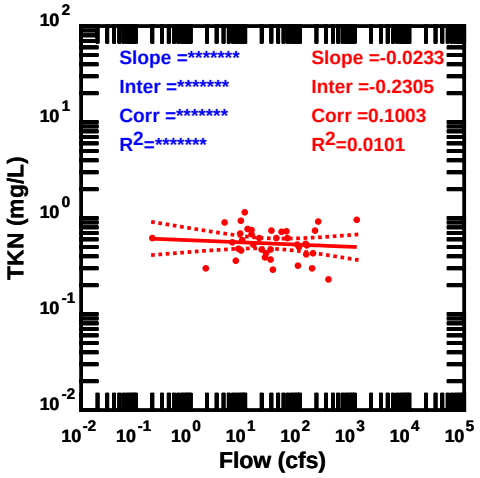
Nueces Tributaries, Texas (1970-2014)

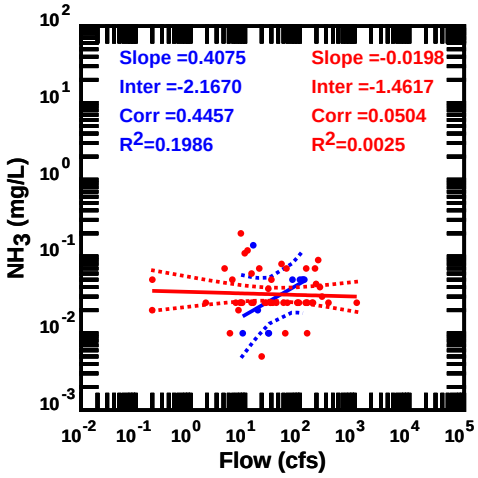
Before 1986

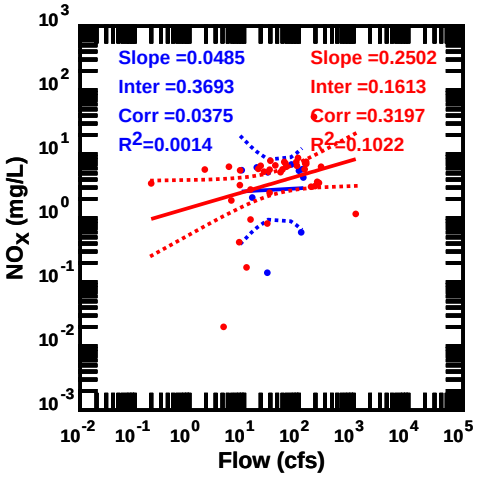
- **Observed Data**
- **95% Confidence Interval**

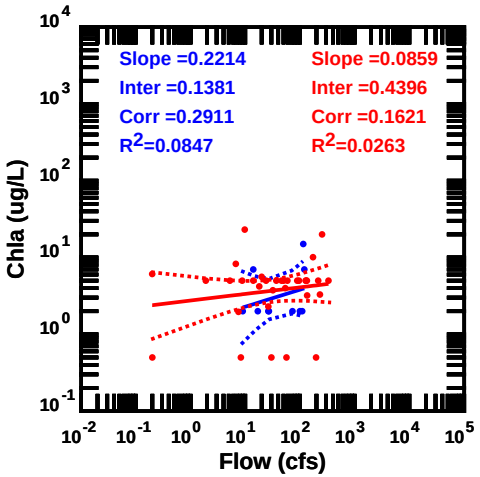
After 1986

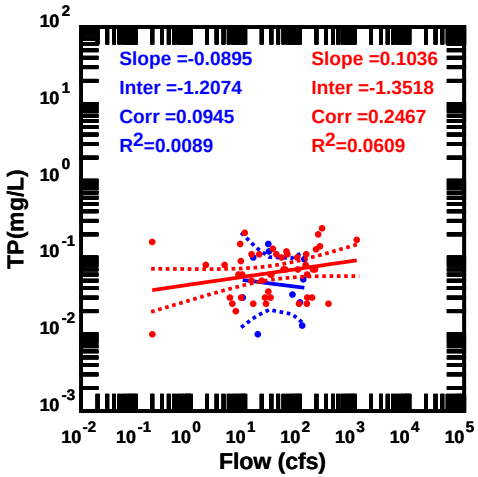
- **Observed Data**
- **95% Confidence Interval**

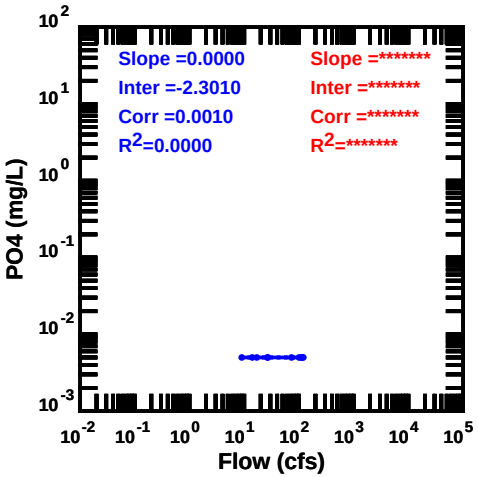












Regression analysis, Station 13024

Nueces Tributaries, Texas (1970-2014)

Before 1986

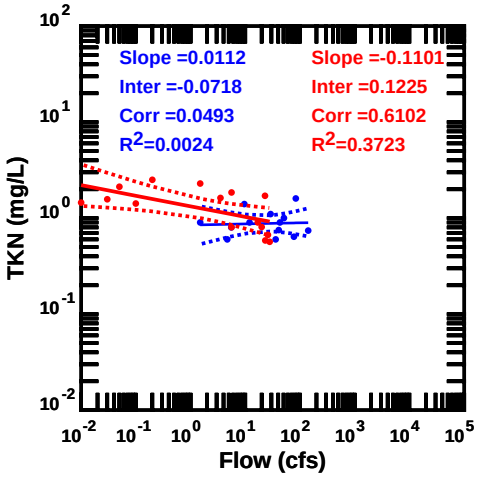
Observed Data

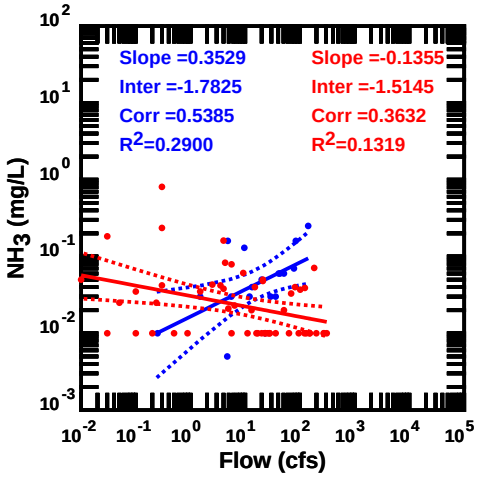
95% Confidence Interval

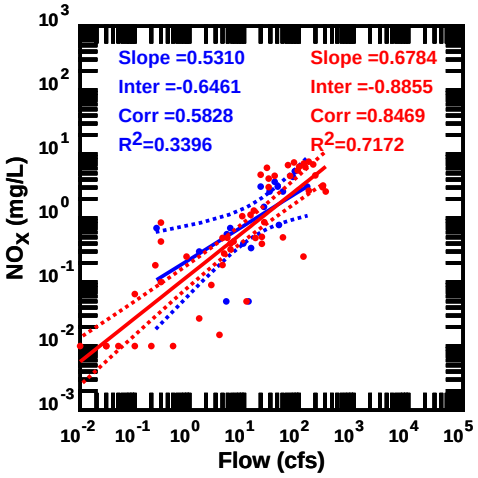
After 1986

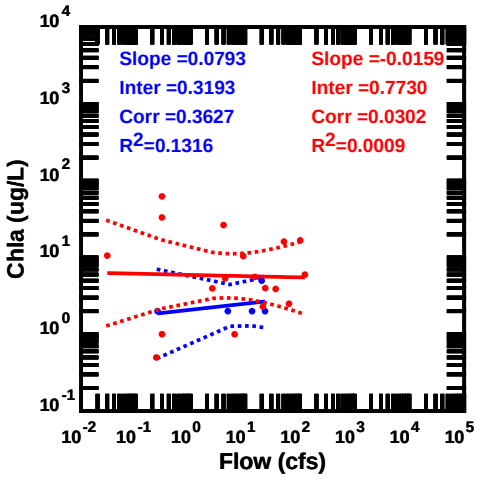
Observed Data

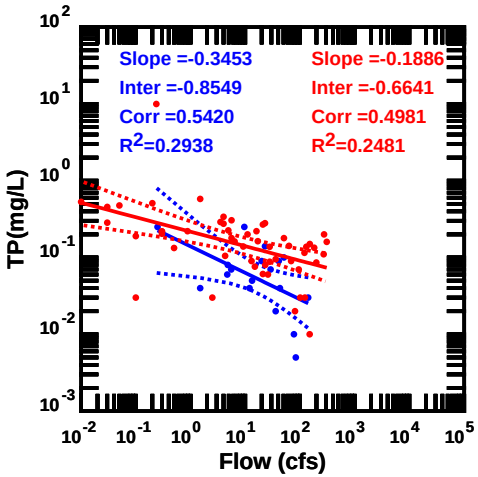
95% Confidence Interval

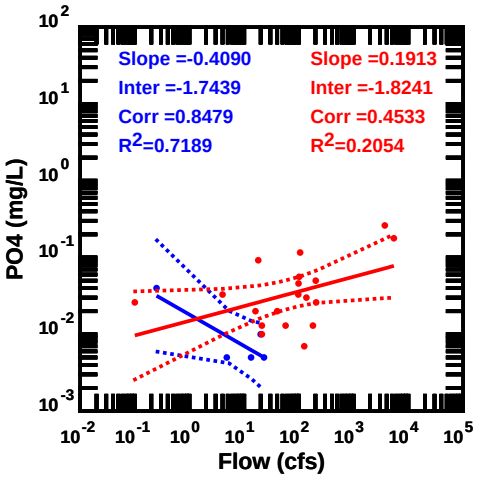












Regression analysis, Station 13023

Nueces Tributaries, Texas (1970-2014)

Before 1986

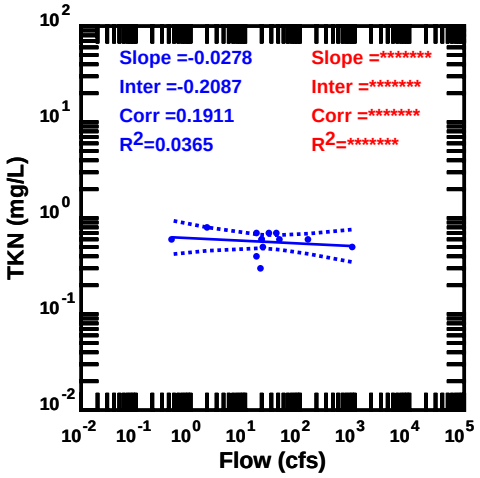
Observed Data

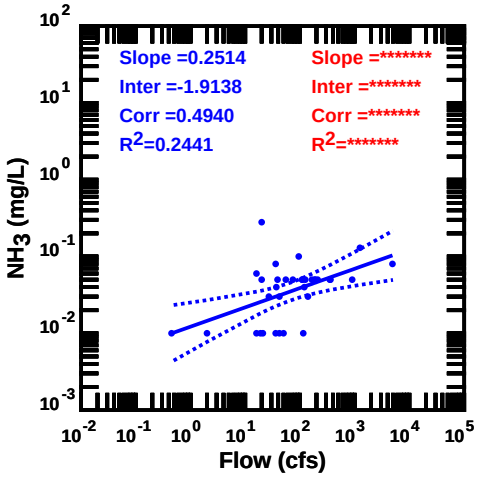
95% Confidence Interval

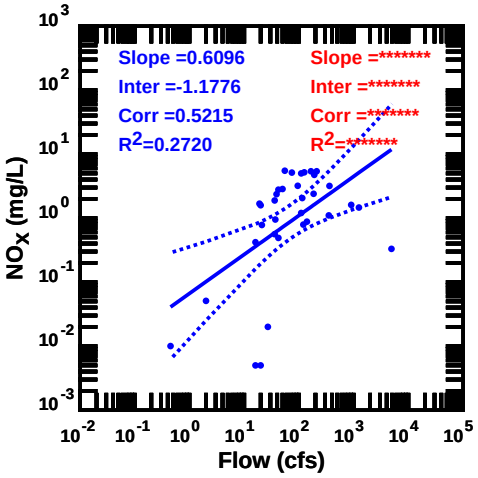
After 1986

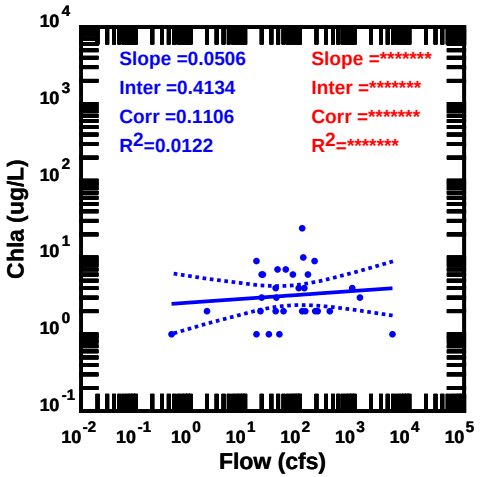
Observed Data

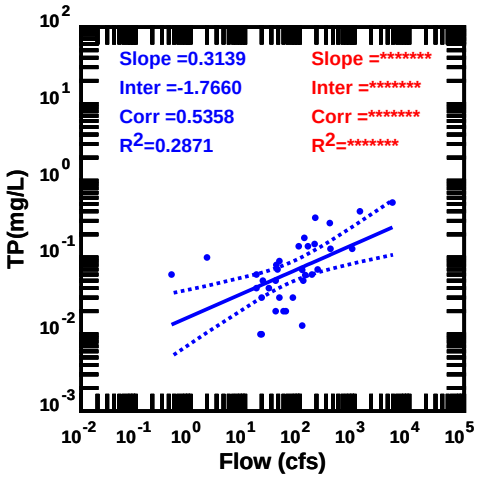
95% Confidence Interval

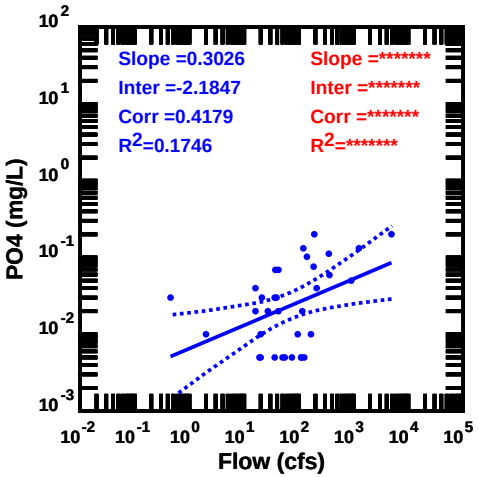












Regression analysis, Station 13021

Nueces Tributaries, Texas (1970-2014)

Before 1986

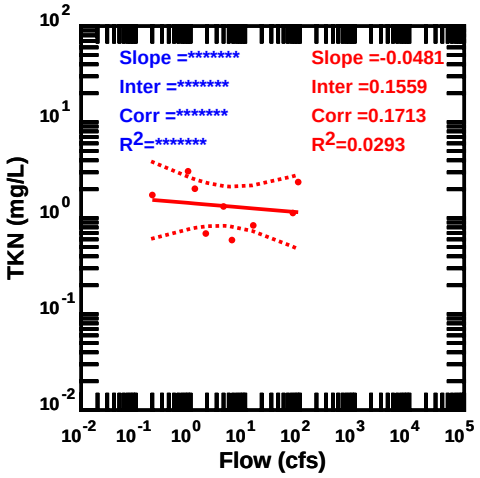
Observed Data

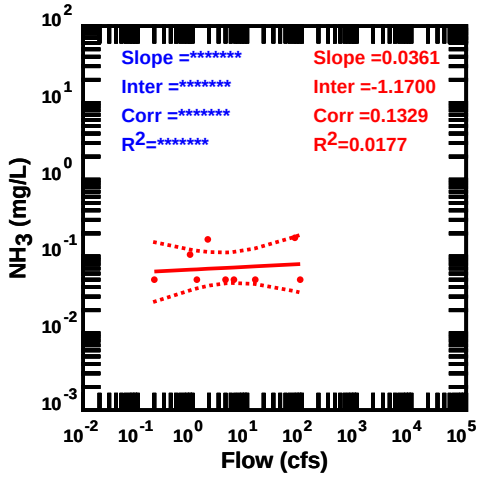
95% Confidence Interval

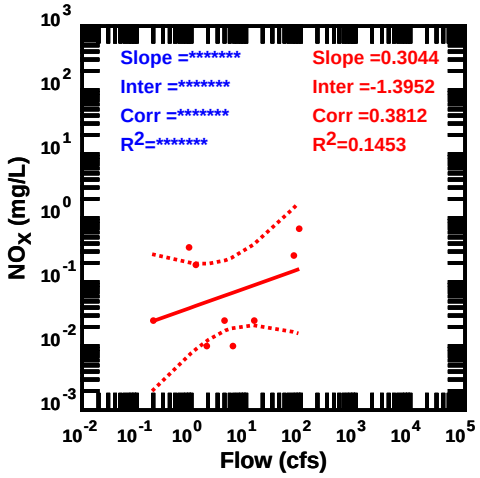
After 1986

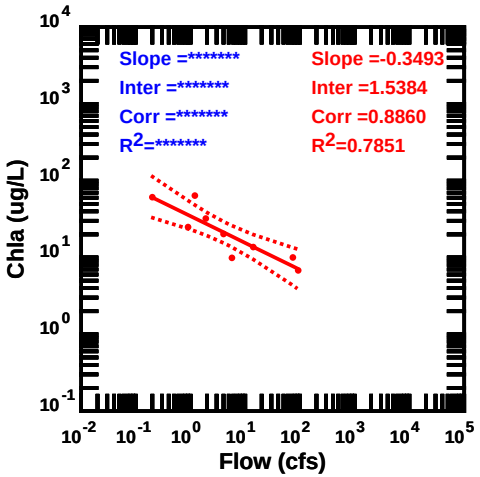
Observed Data

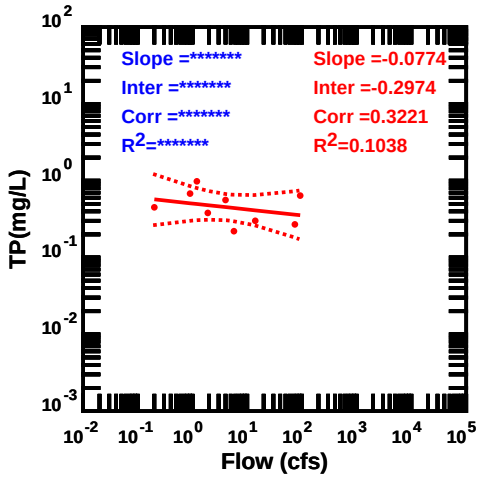
95% Confidence Interval











Regression analysis, Station 20773

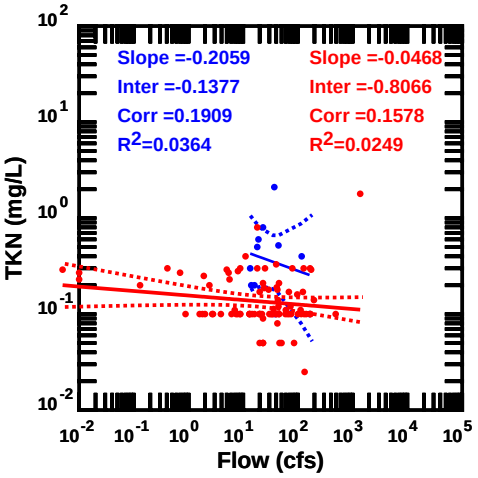
Nueces Tributaries, Texas (1970-2014)

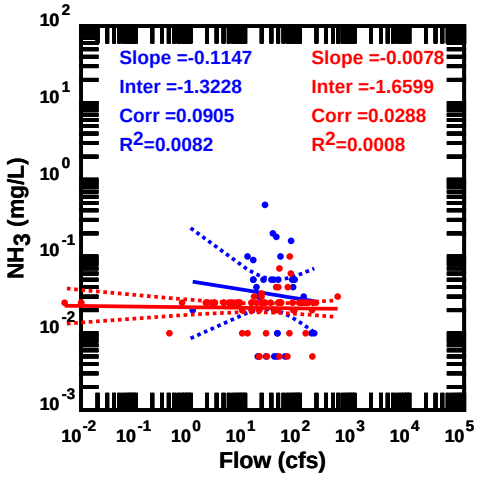
Before 1986

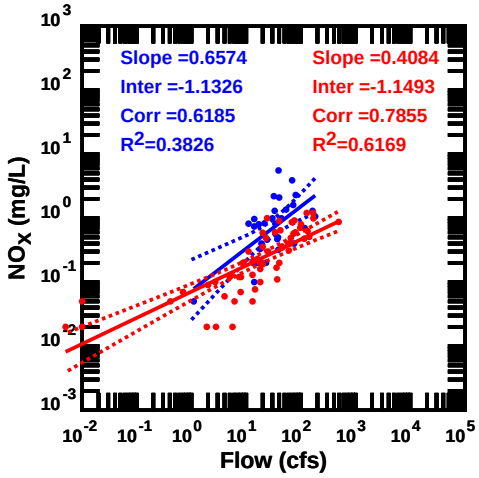
- **Observed Data**
- **95% Confidence Interval**

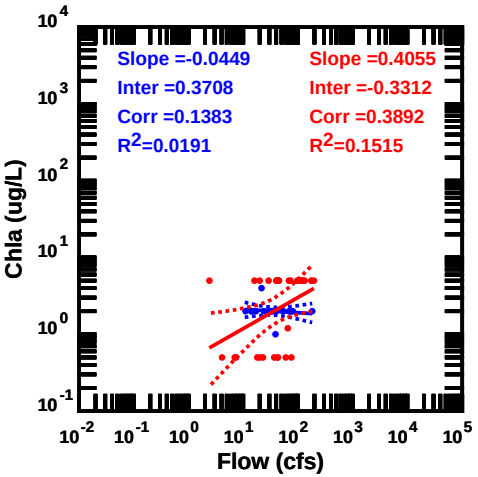
After 1986

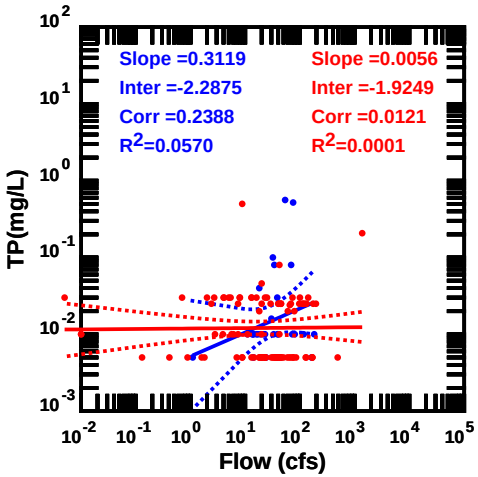
- **Observed Data**
- **95% Confidence Interval**

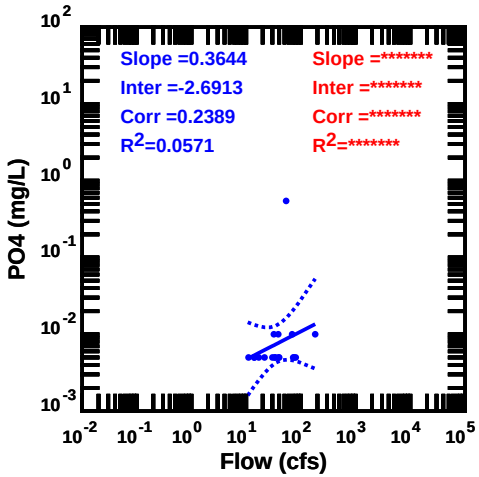












Regression analysis, Station 12994

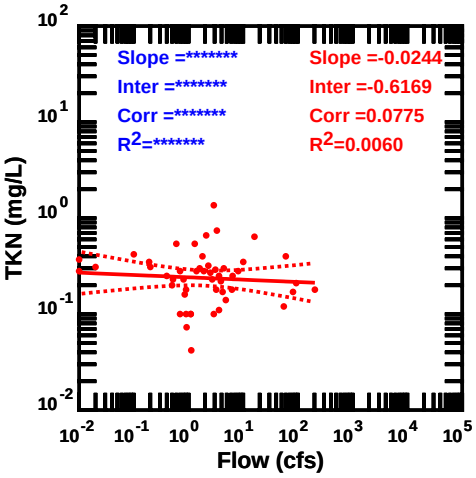
Nueces Tributaries, Texas (1970-2014)

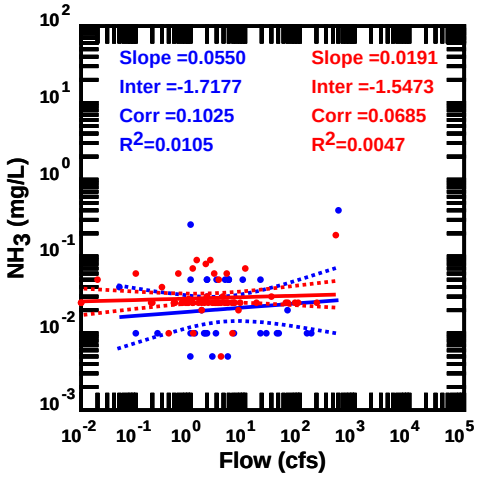
Before 1986

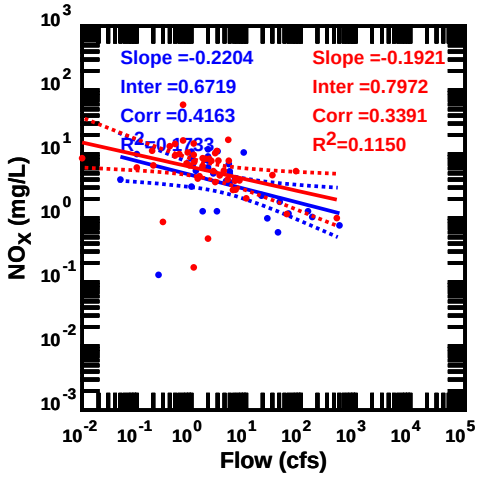
- Observed Data
- 95% Confidence Interval

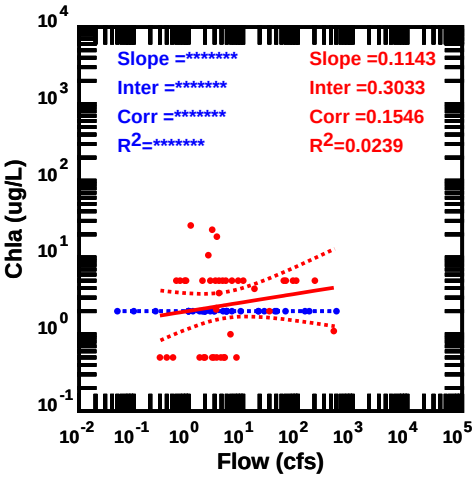
After 1986

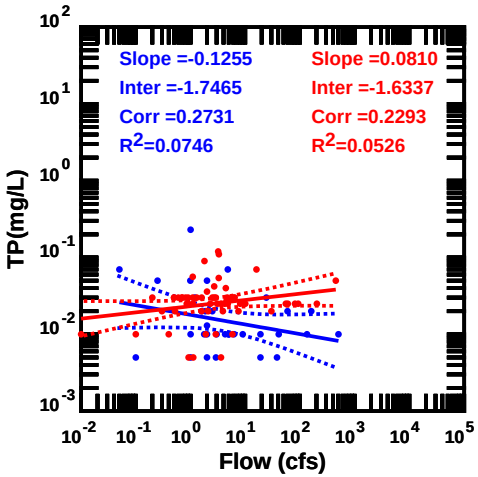
- Observed Data
- 95% Confidence Interval

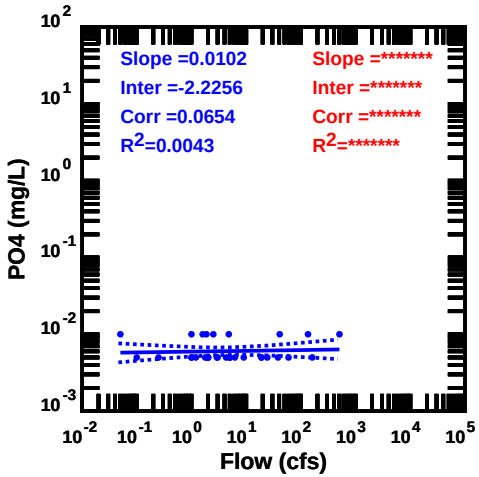












Regression analysis, Station 12993

Nueces Tributaries, Texas (1970-2014)

Before 1986

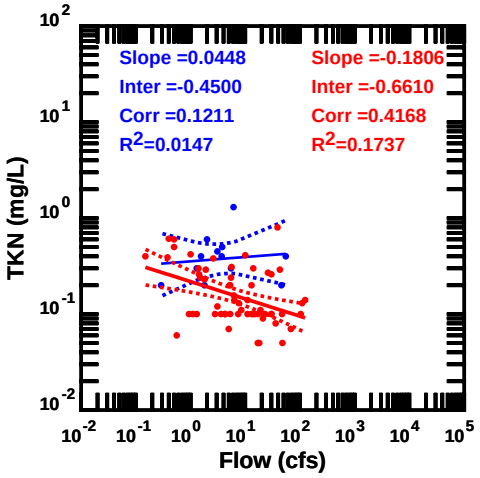
Observed Data

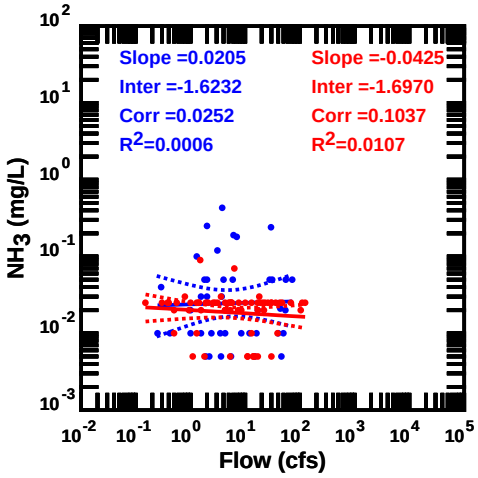
95% Confidence Interval

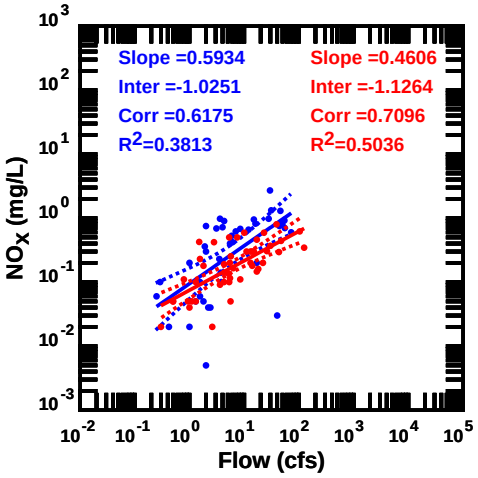
After 1986

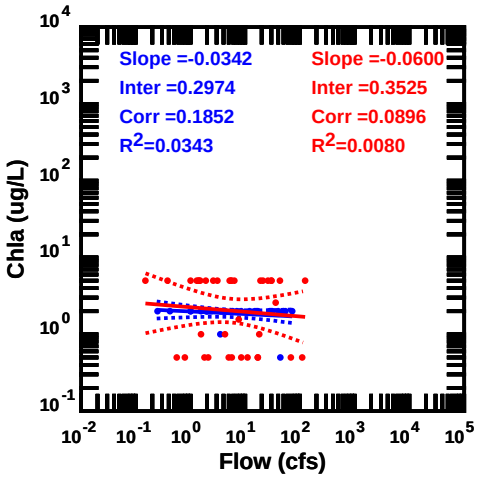
Observed Data

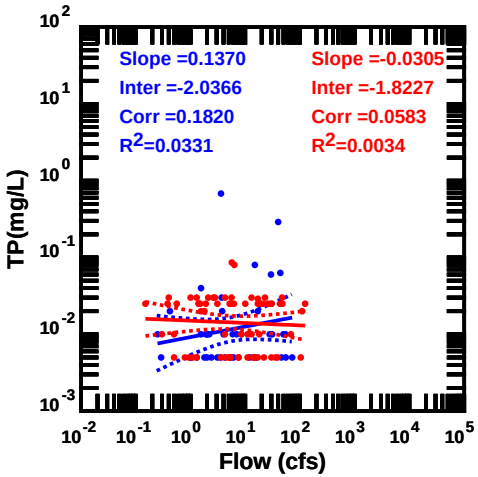
95% Confidence Interval

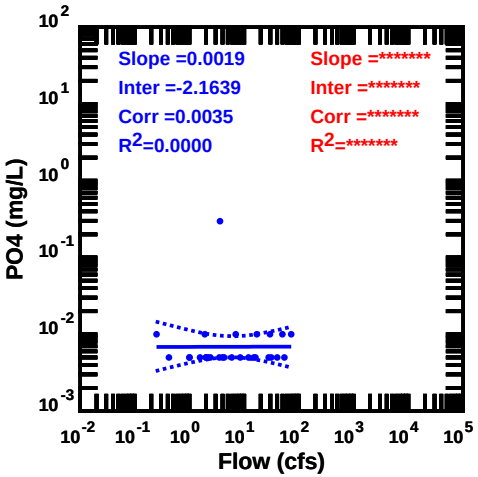












Regression analysis, Station 13013

Nueces Tributaries, Texas (1970-2014)

Before 1986

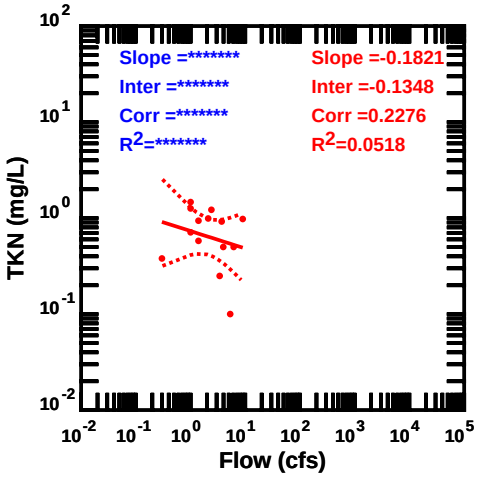
Observed Data

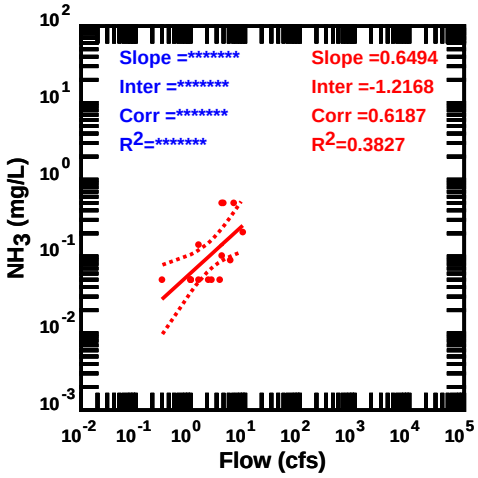
95% Confidence Interval

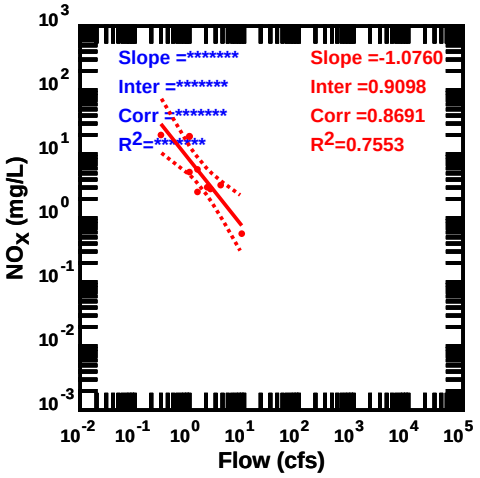
After 1986

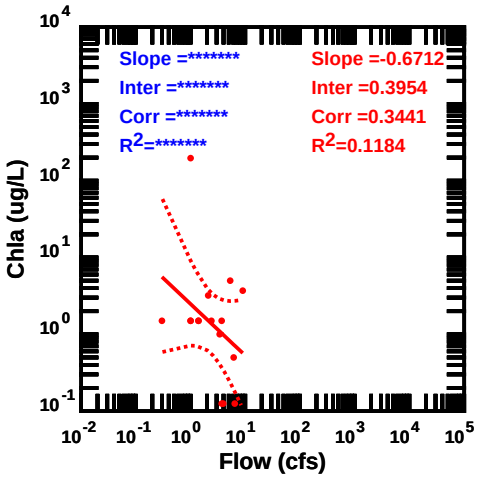
Observed Data

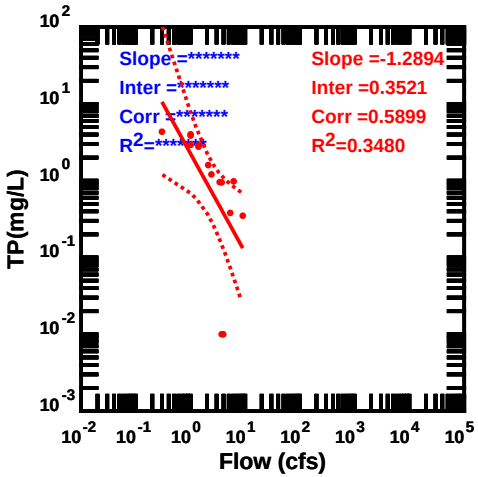
95% Confidence Interval











Regression analysis, Station 17900

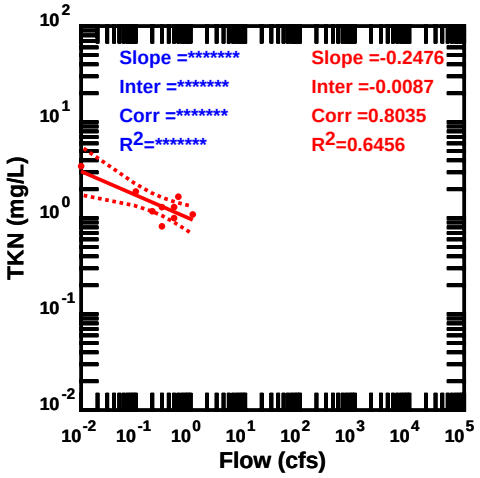
Nueces Tributaries, Texas (1970-2014)

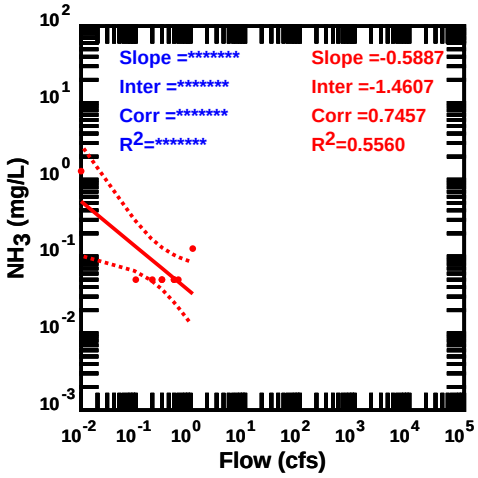
Before 1986

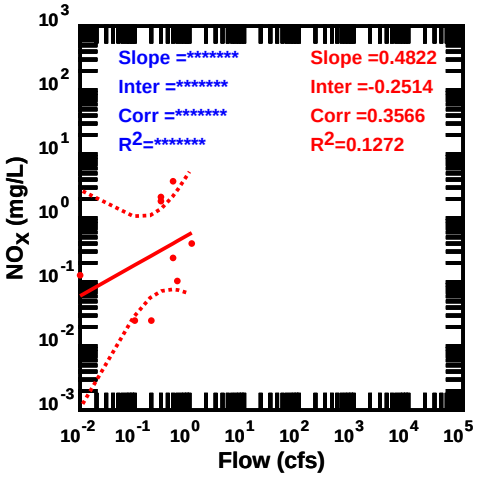
- Observed Data
- 95% Confidence Interval

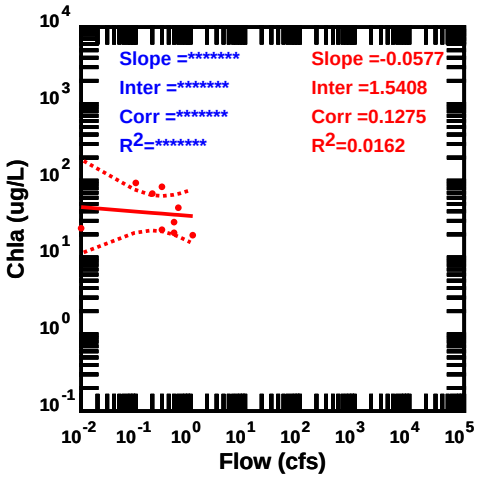
After 1986

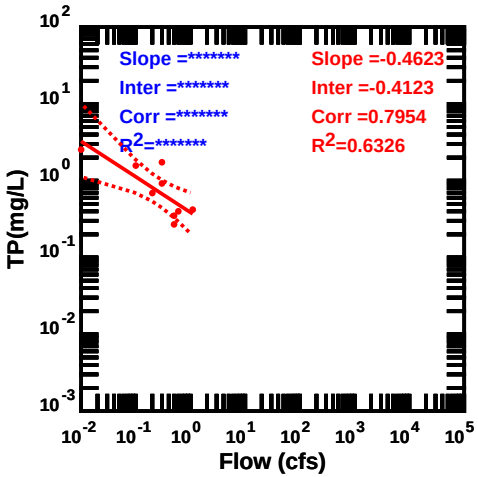
- Observed Data
- 95% Confidence Interval











Regression analysis, Station 20762

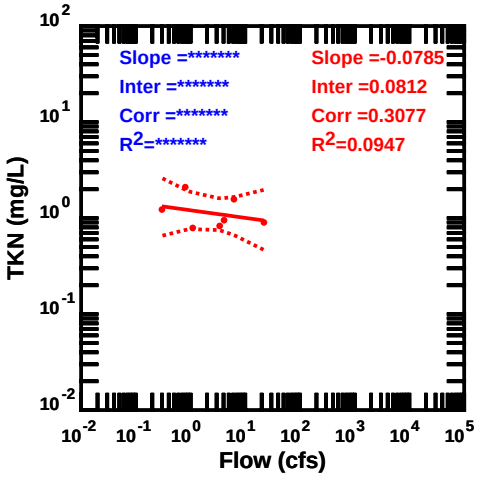
Nueces Tributaries, Texas (1970-2014)

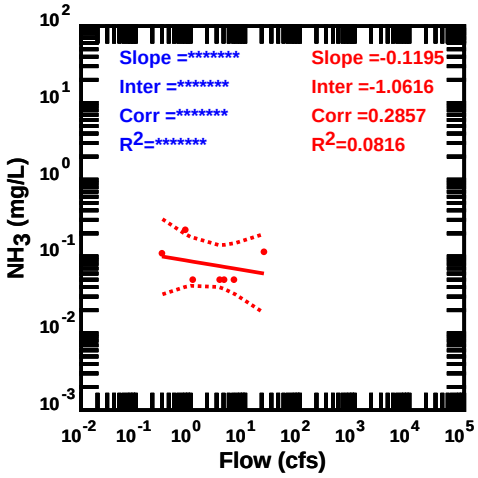
Before 1986

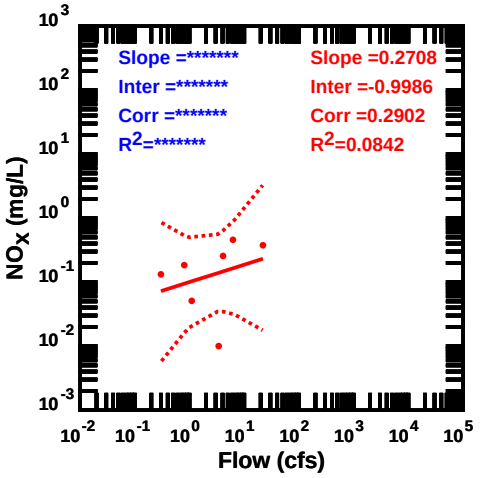
- **Observed Data**
- **95% Confidence Interval**

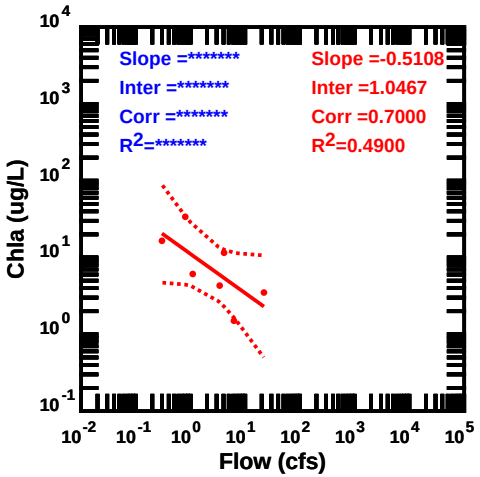
After 1986

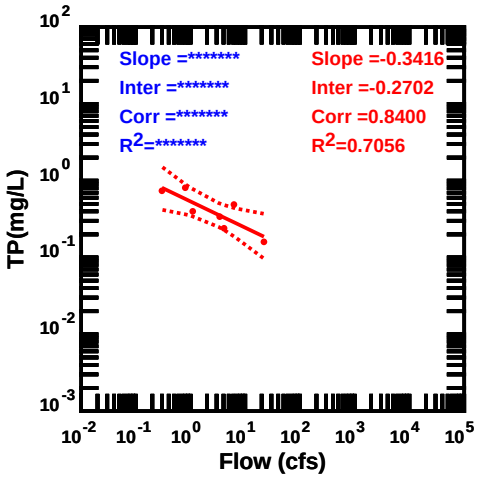
- **Observed Data**
- **95% Confidence Interval**











Regression analysis, Station 20764

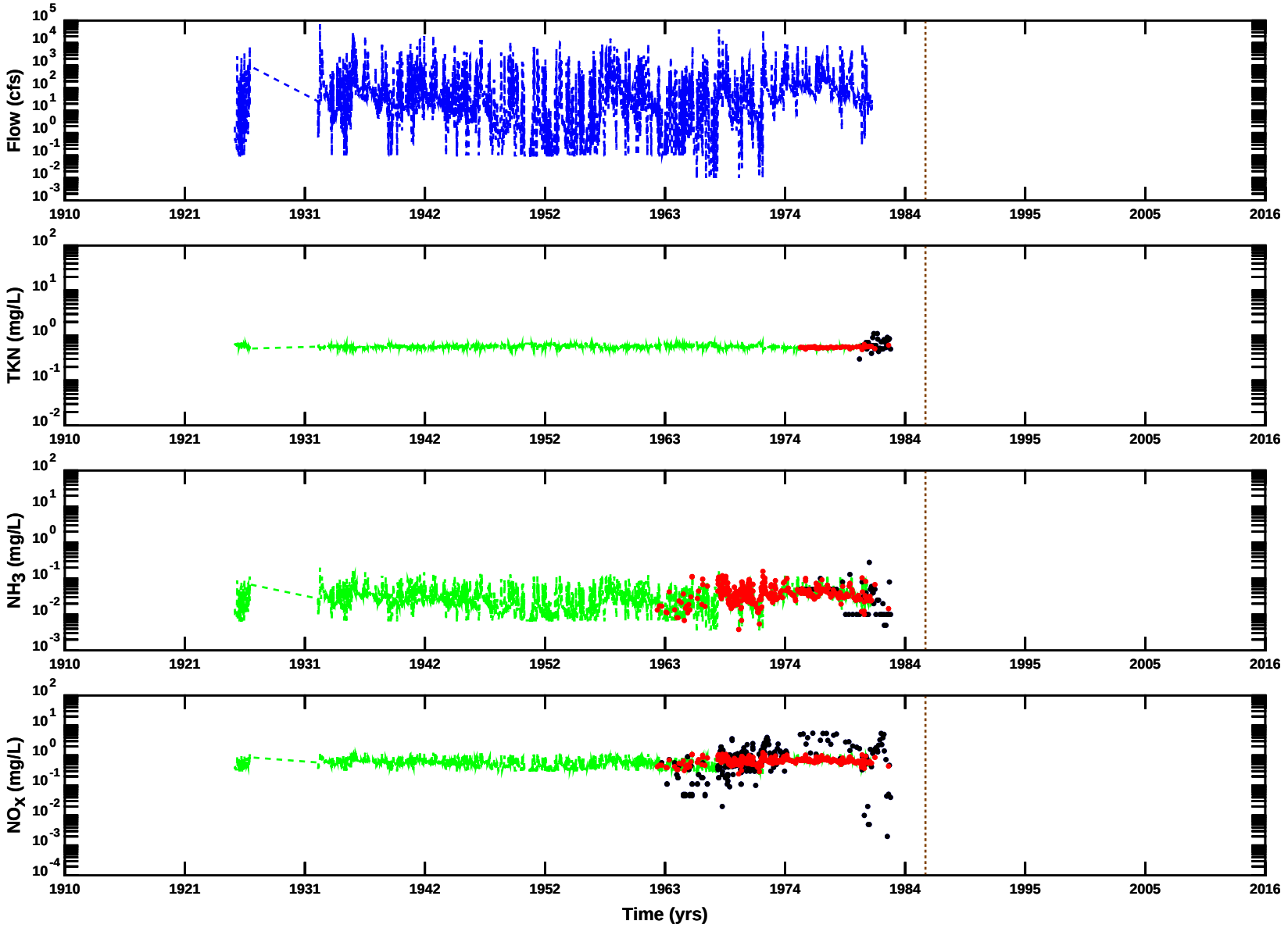
Nueces Tributaries, Texas (1970-2014)

Before 1986

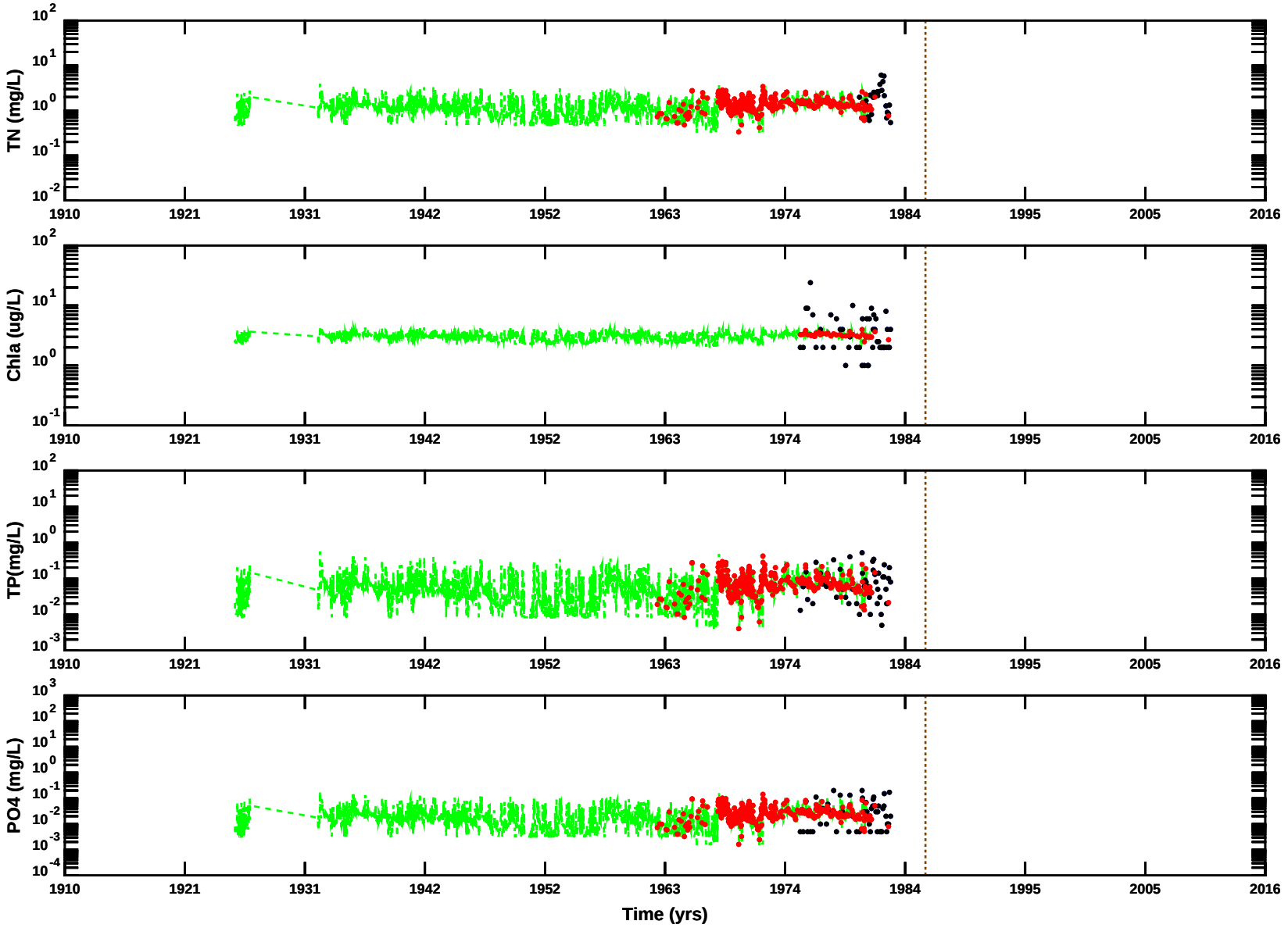
- Observed Data
- 95% Confidence Interval

After 1986

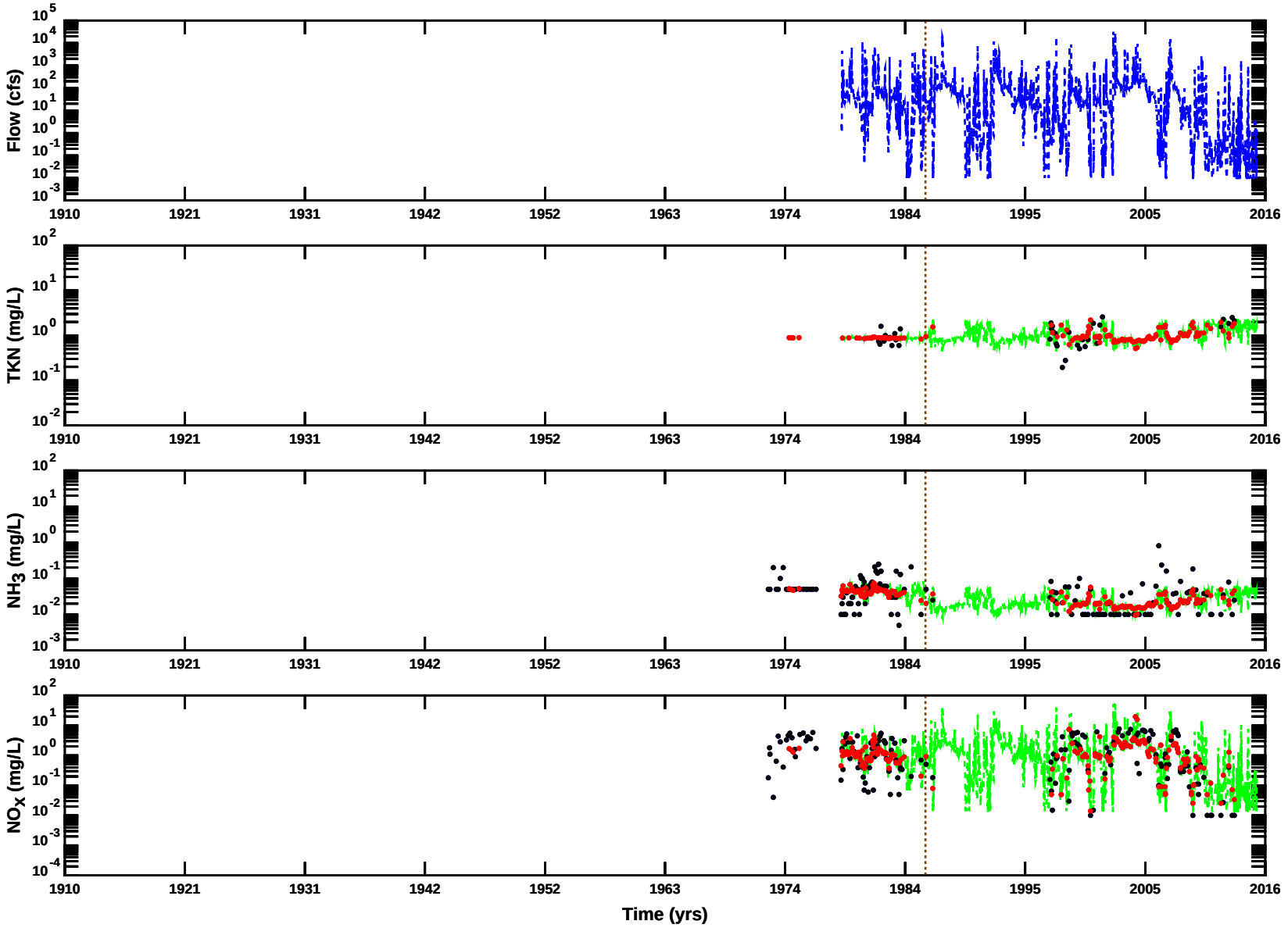
- Observed Data
- 95% Confidence Interval



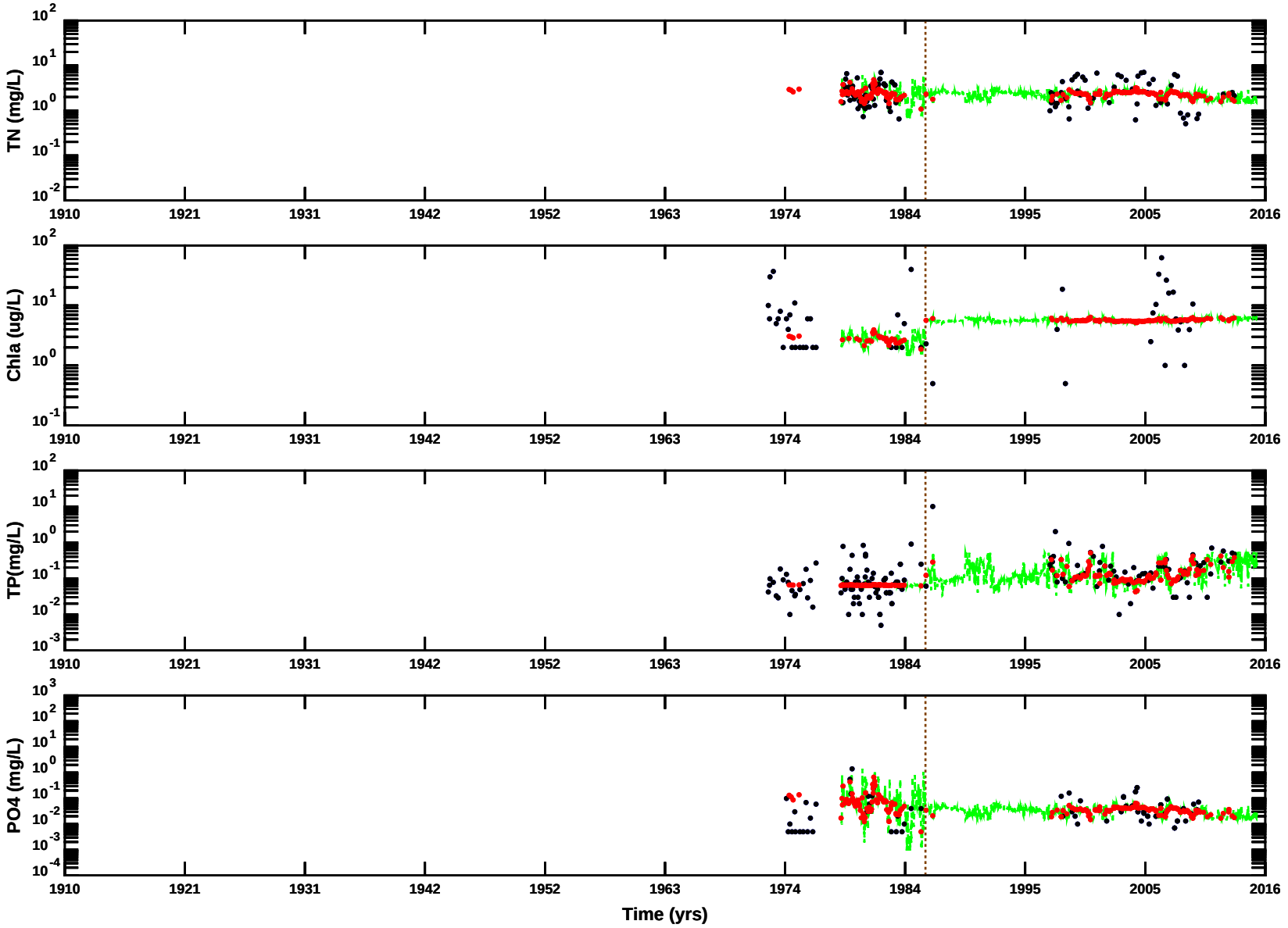
Nutrients Distribution, Station 13021
Nueces Tributaries, Texas (1910-2015)



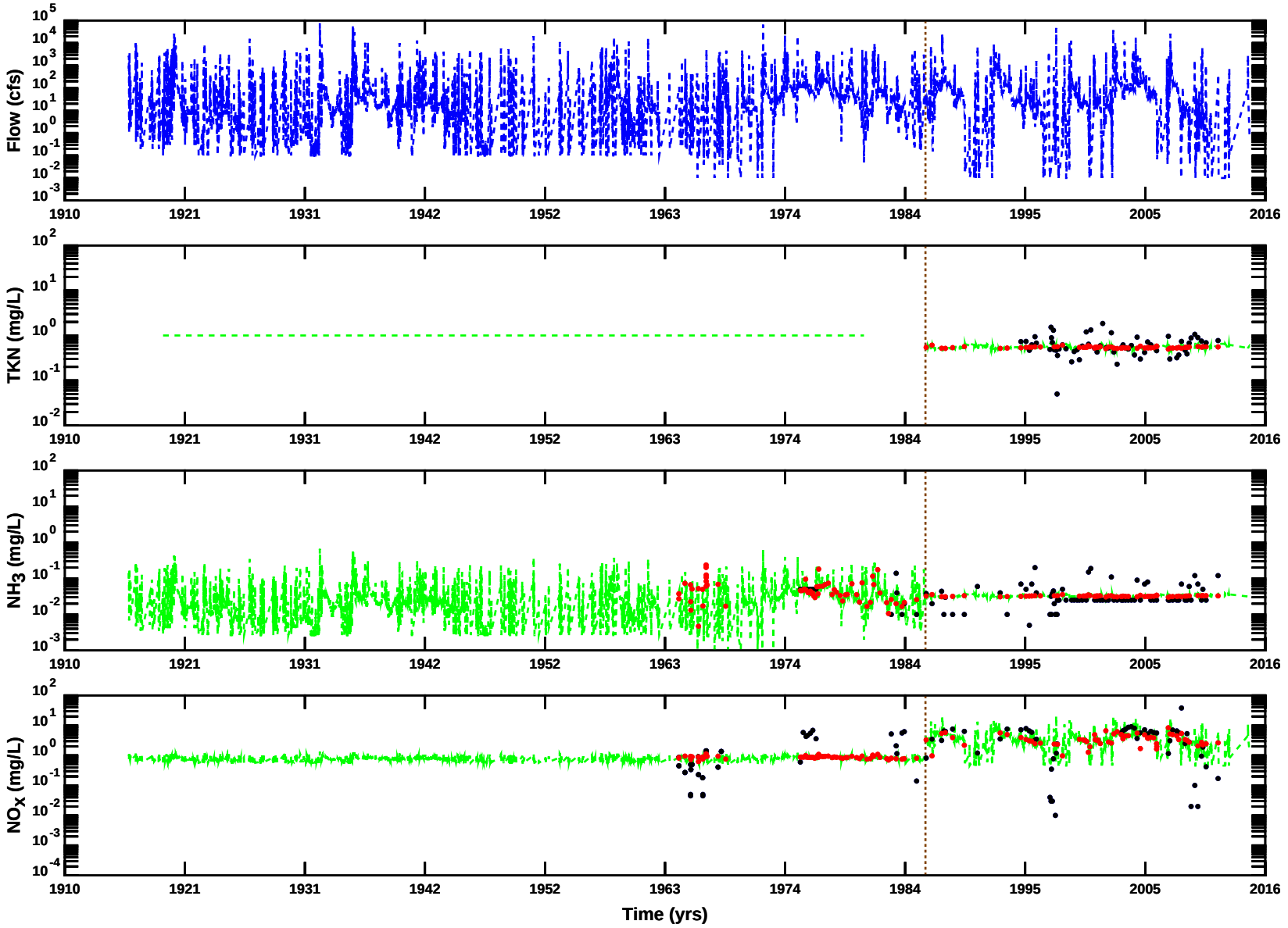
Nutrients Distribution, Station 13021
Nueces Tributaries, Texas (1910-2015)



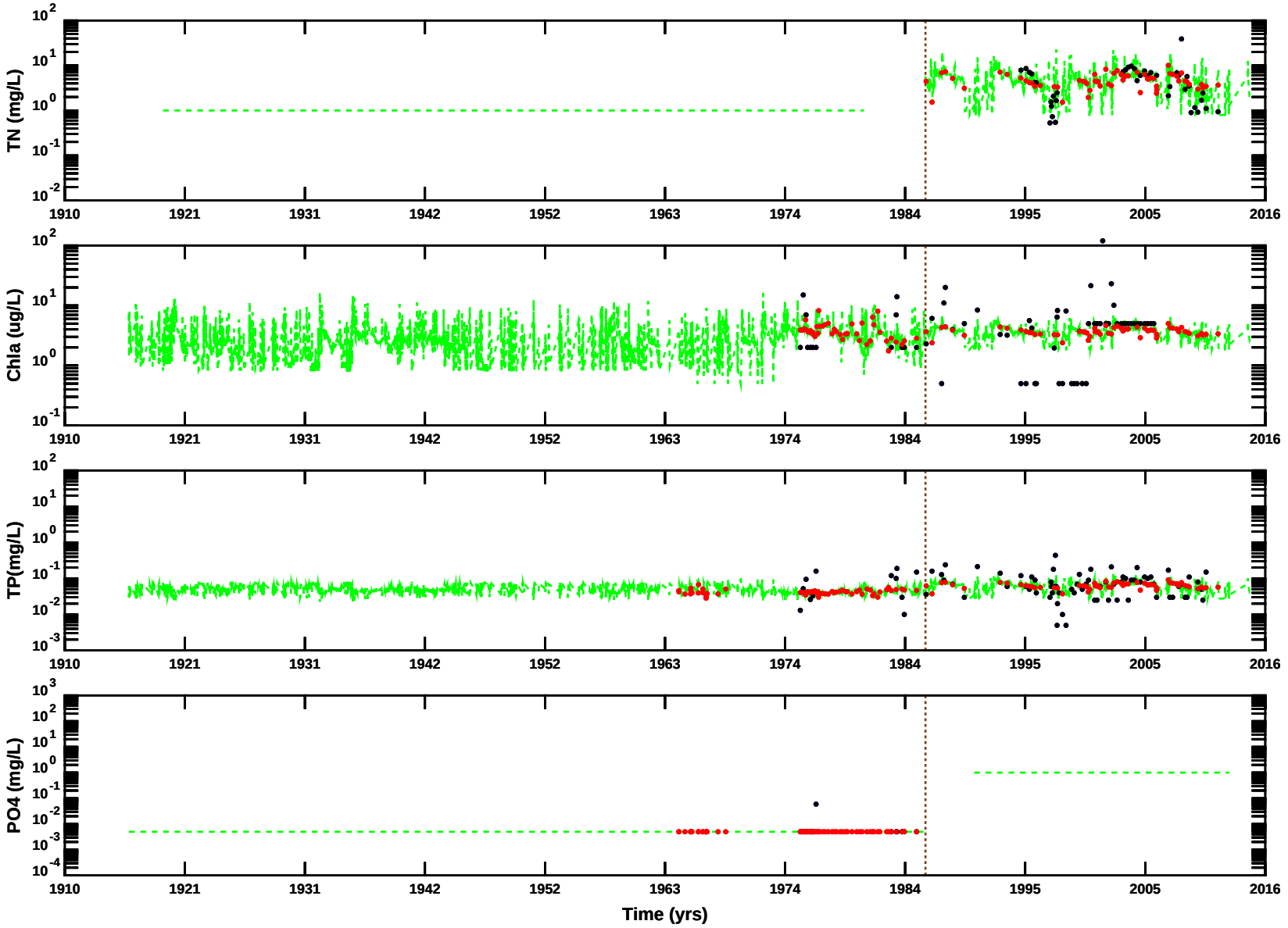
Nutrients Distribution, Station 13023
Nueces Tributaries, Texas (1910-2015)



Nutrients Distribution, Station 13023
Nueces Tributaries, Texas (1910-2015)

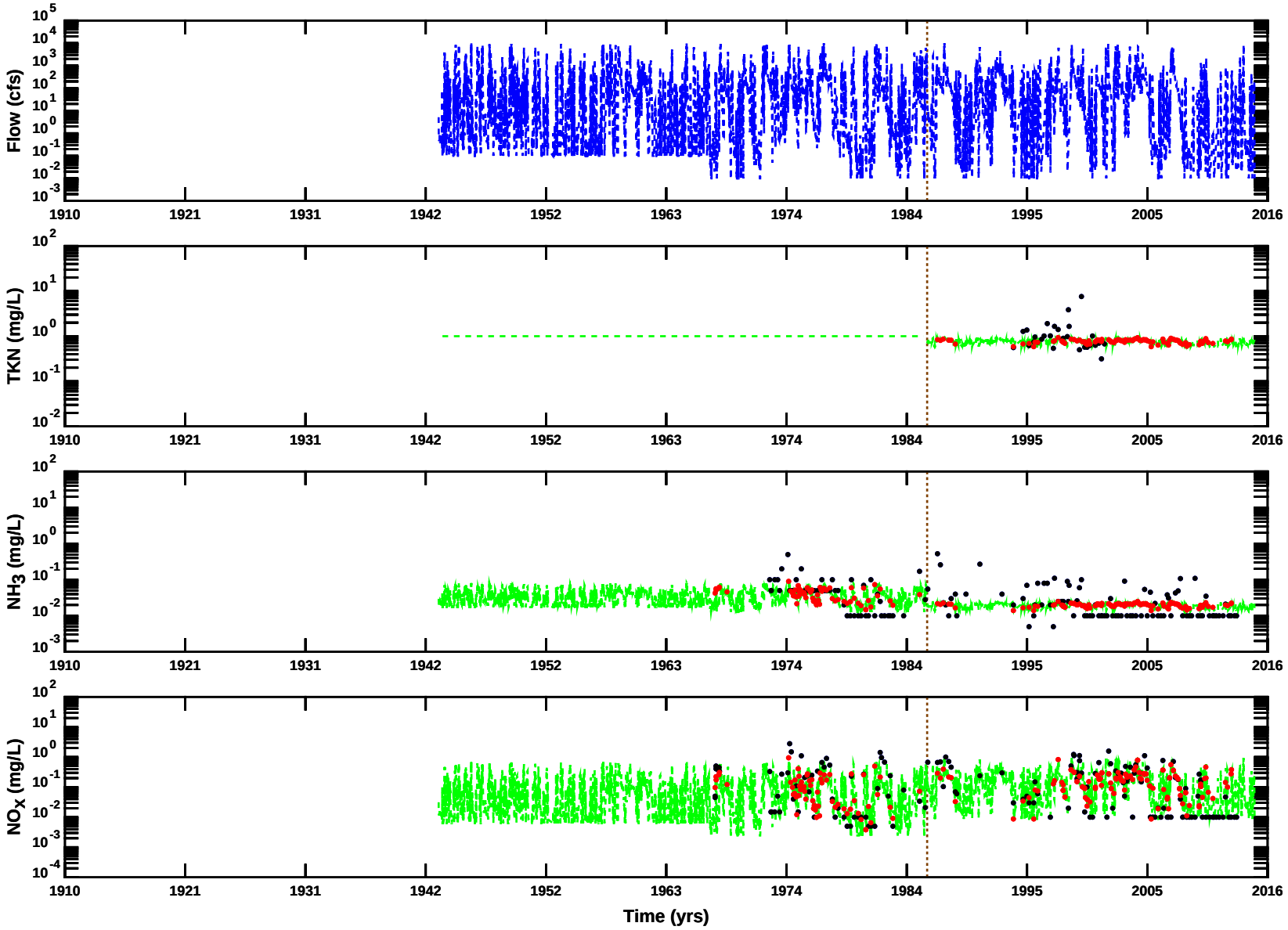


Nutrients Distribution, Station 13024
Nueces Tributaries, Texas (1910-2015)

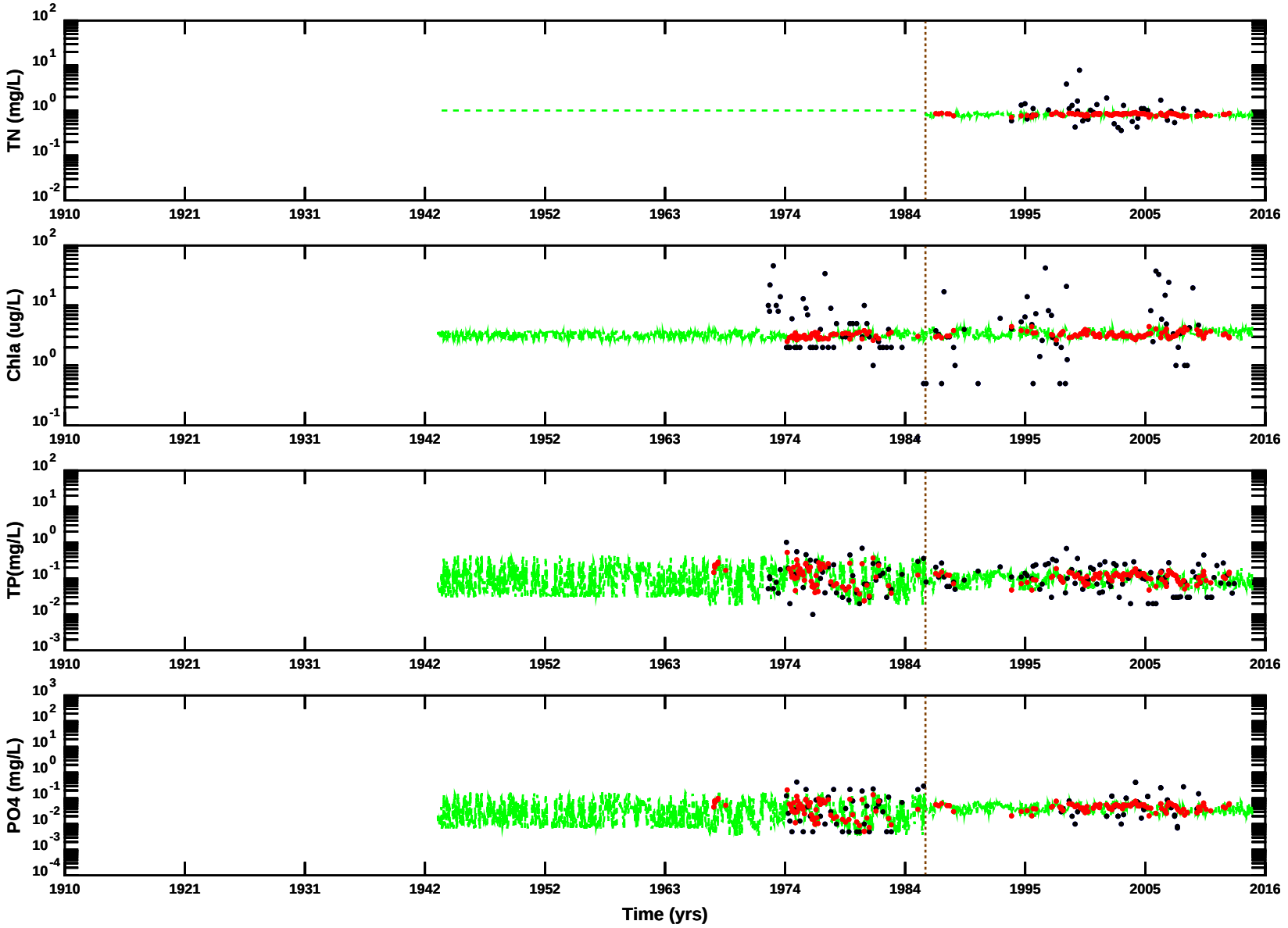


Nutrients Distribution, Station 13024
Nueces Tributaries, Texas (1910-2015)

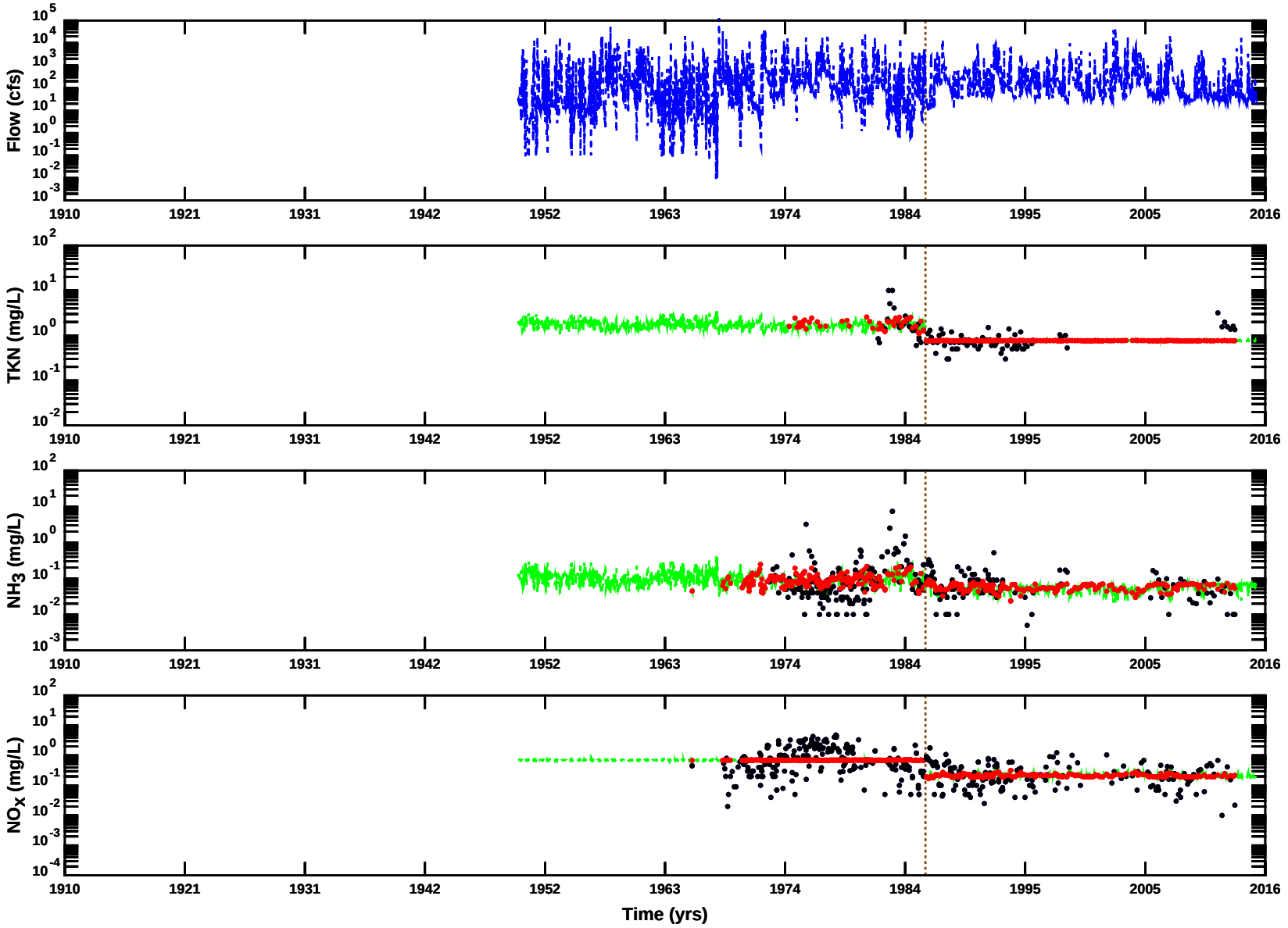
- Observed Concentration
- Estimated Concentration
- Estimated Concentration from 8205500 USGS flow
- Flow at 8205500 USGS station



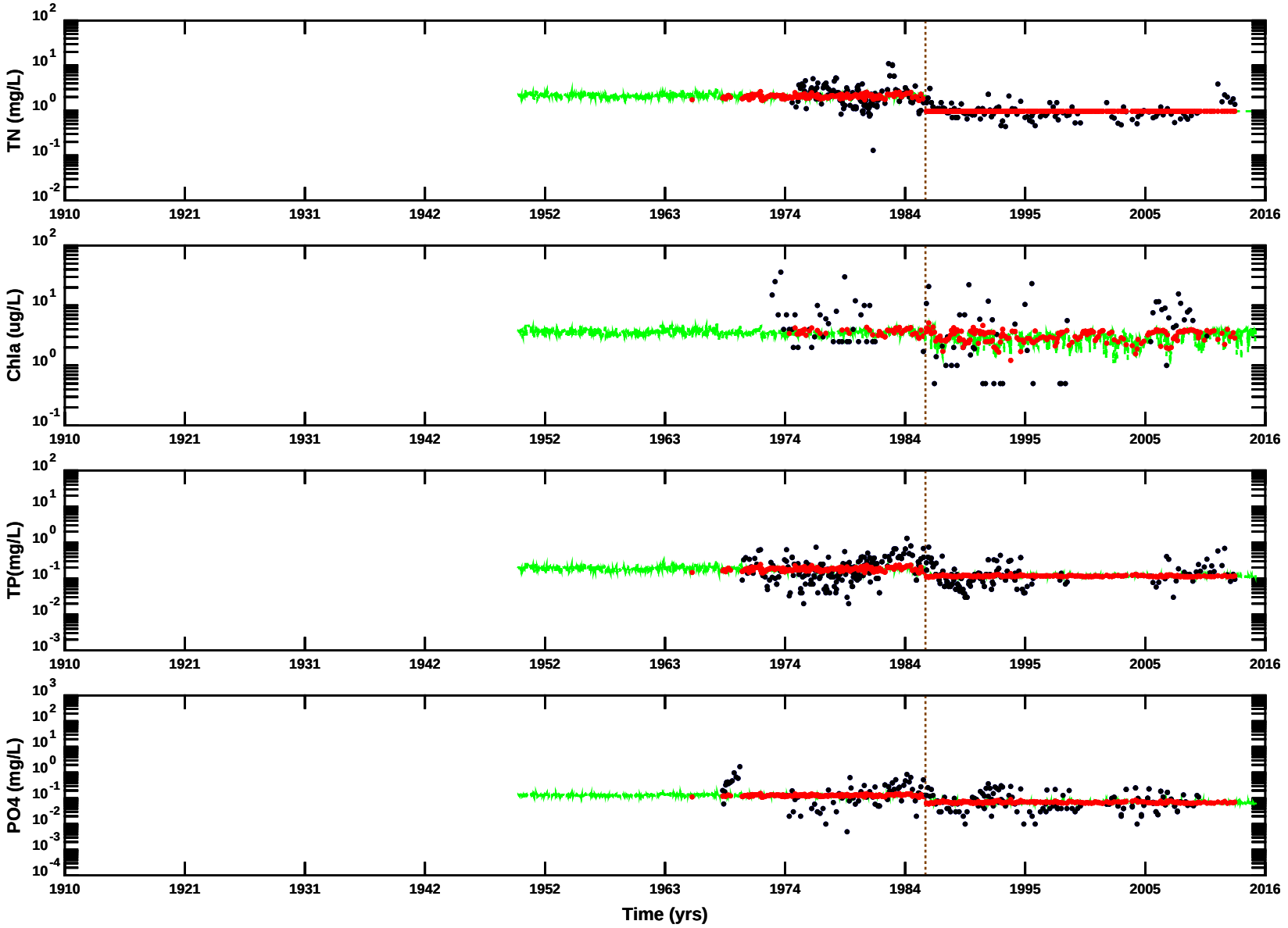
Nutrients Distribution, Station 12973
Nueces Tributaries, Texas (1910-2015)



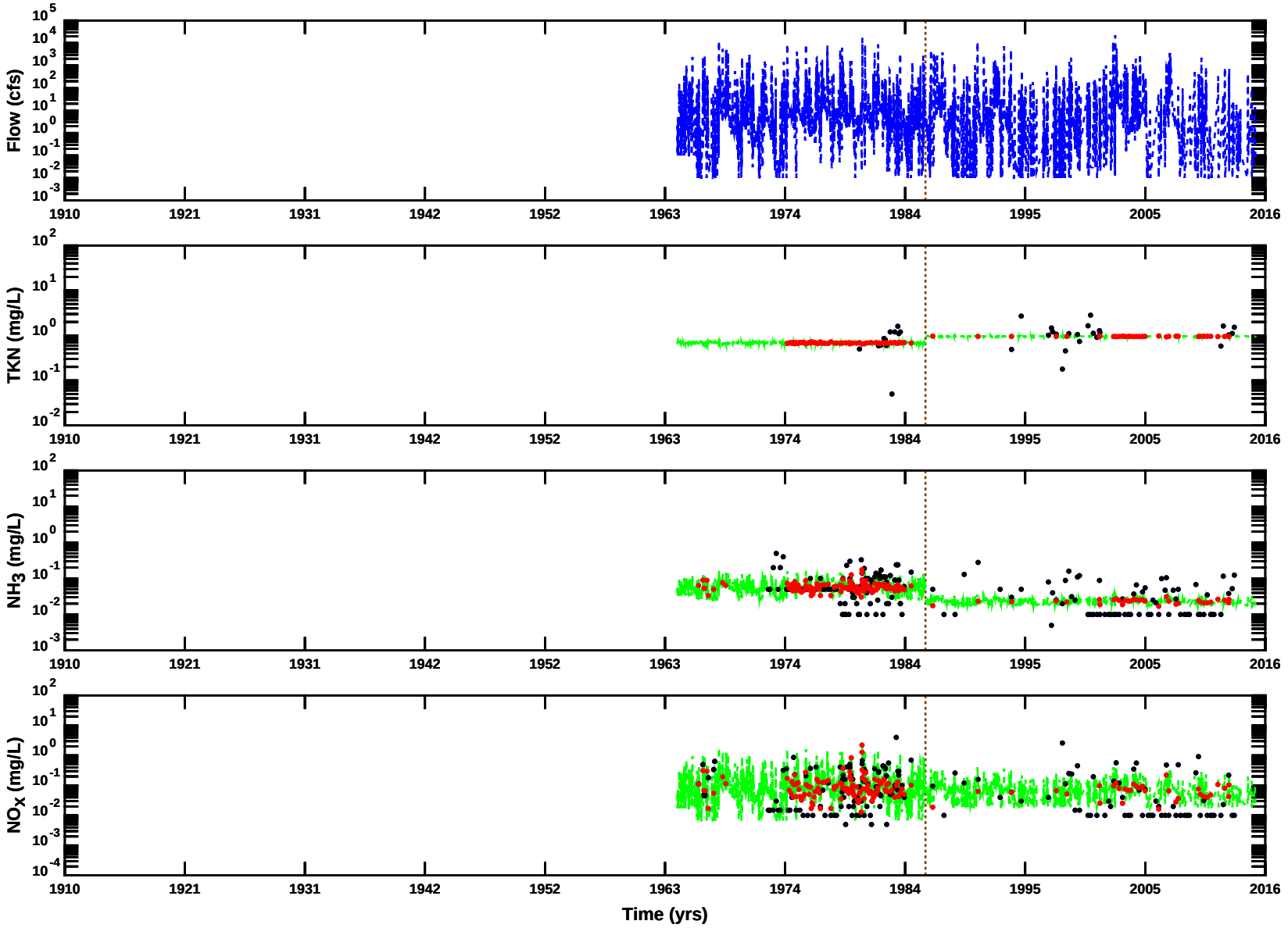
Nutrients Distribution, Station 12973
Nueces Tributaries, Texas (1910-2015)



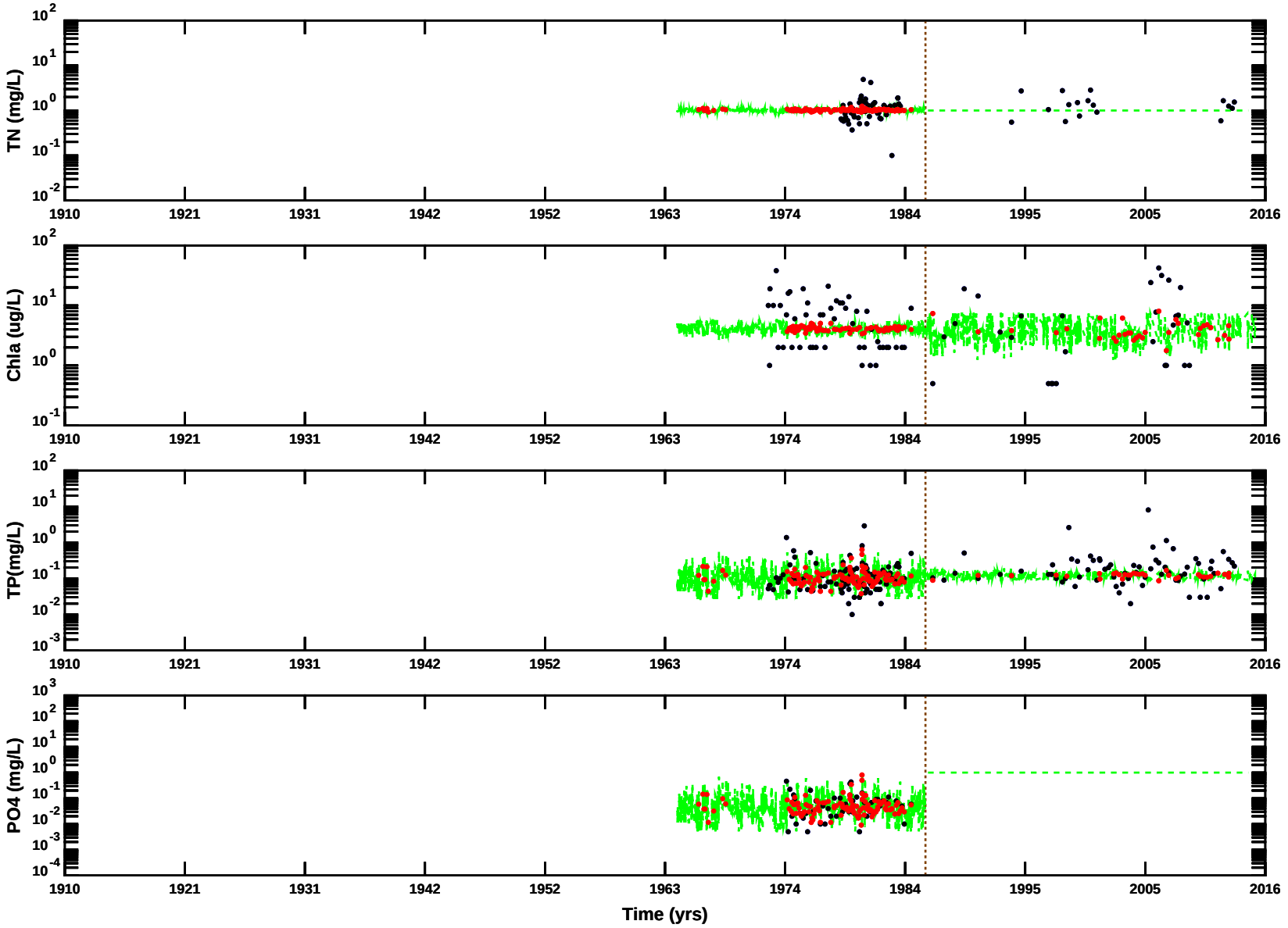
Nutrients Distribution, Station 12979
Nueces Tributaries, Texas (1910-2015)



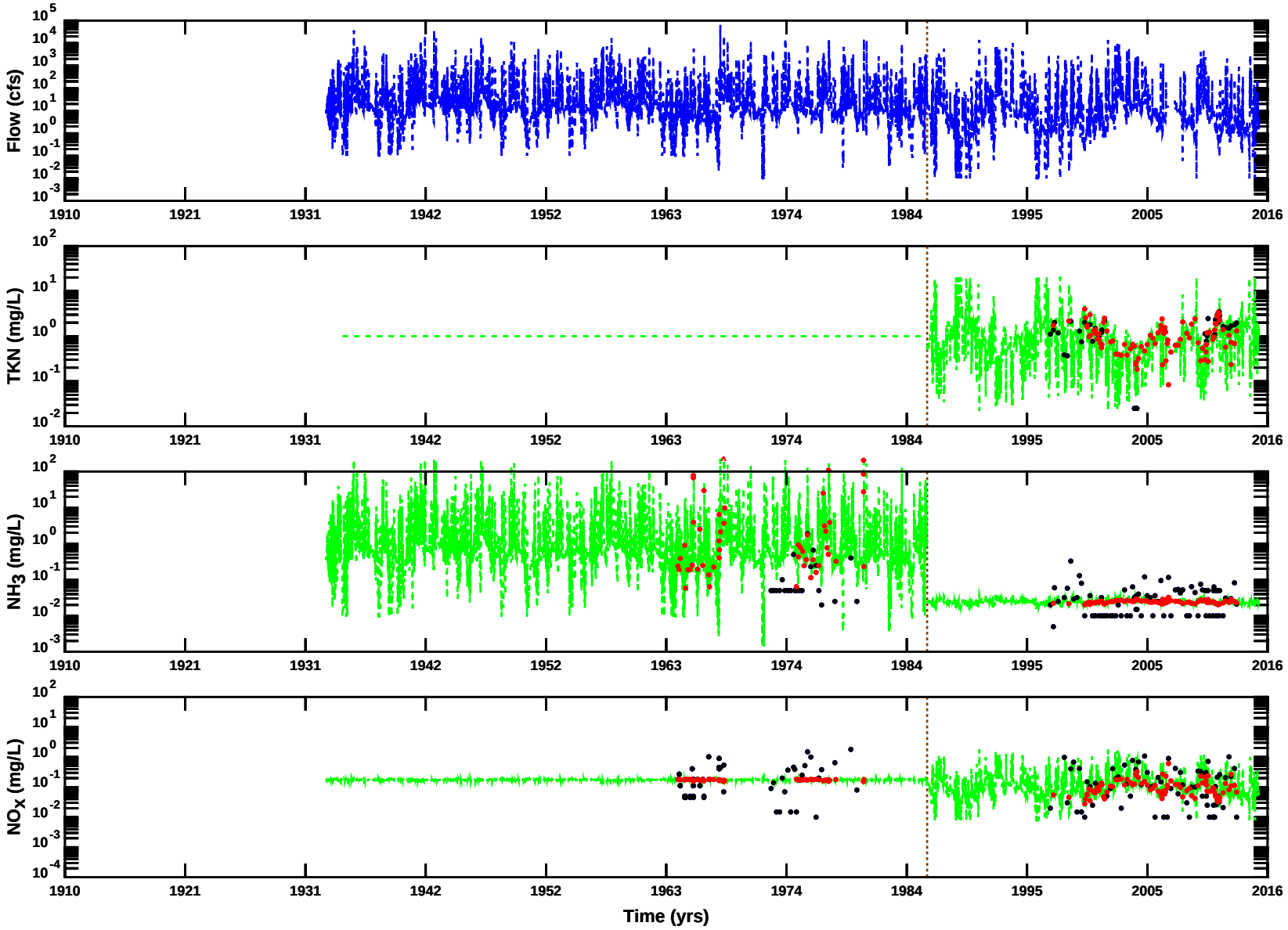
Nutrients Distribution, Station 12979
Nueces Tributaries, Texas (1910-2015)



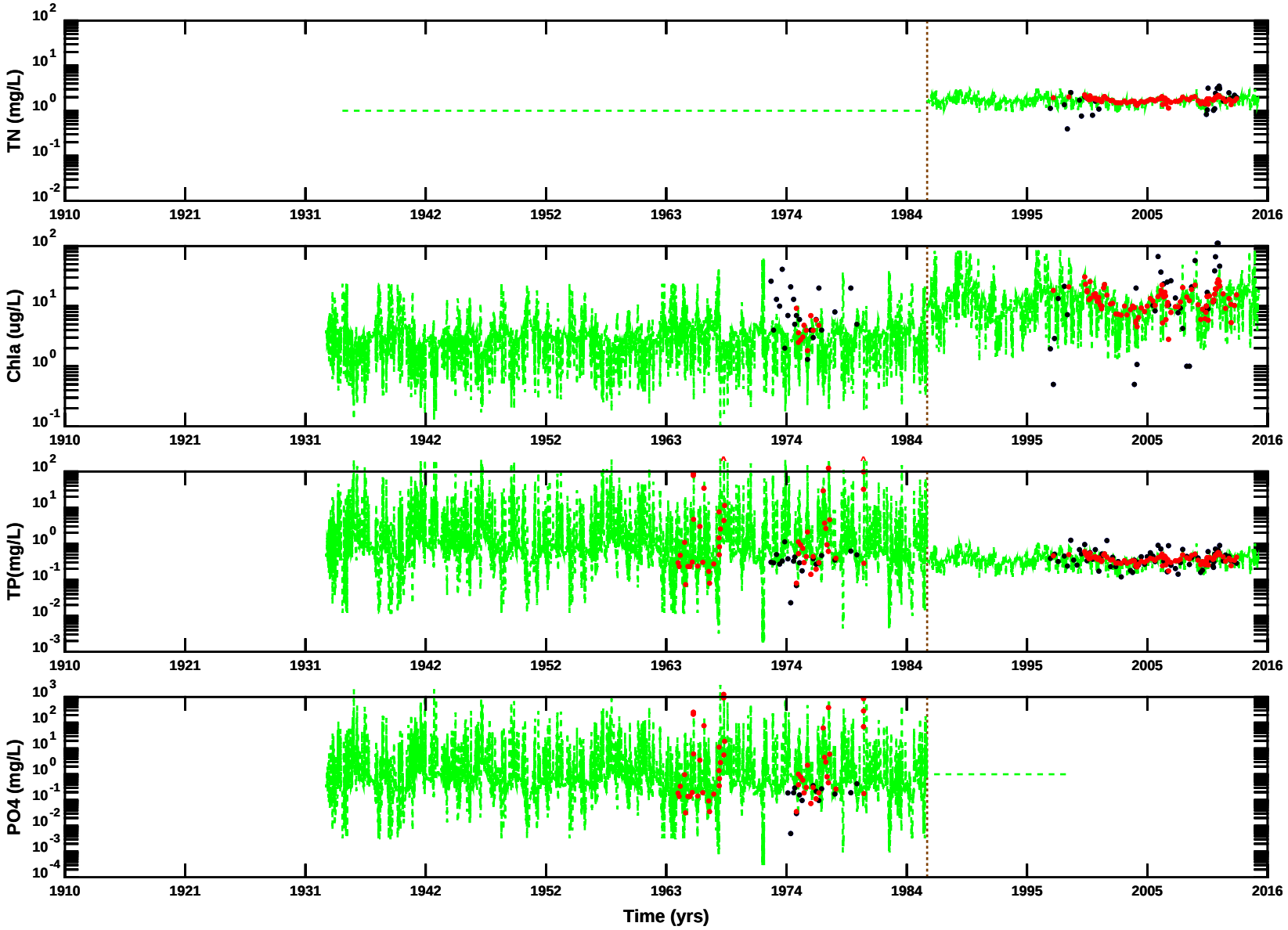
Nutrients Distribution, Station 12983
Nueces Tributaries, Texas (1910-2015)



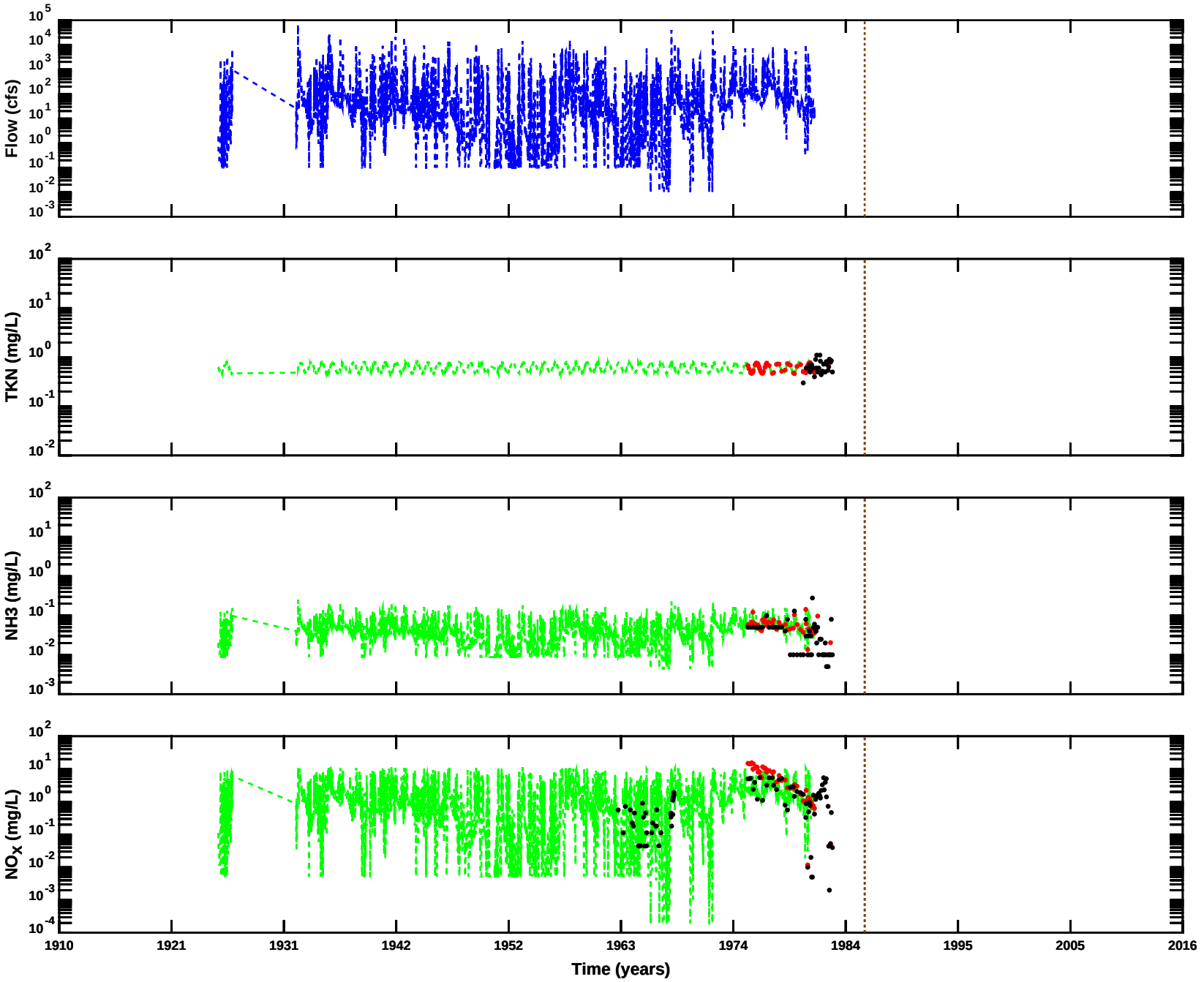
Nutrients Distribution, Station 12983
Nueces Tributaries, Texas (1910-2015)



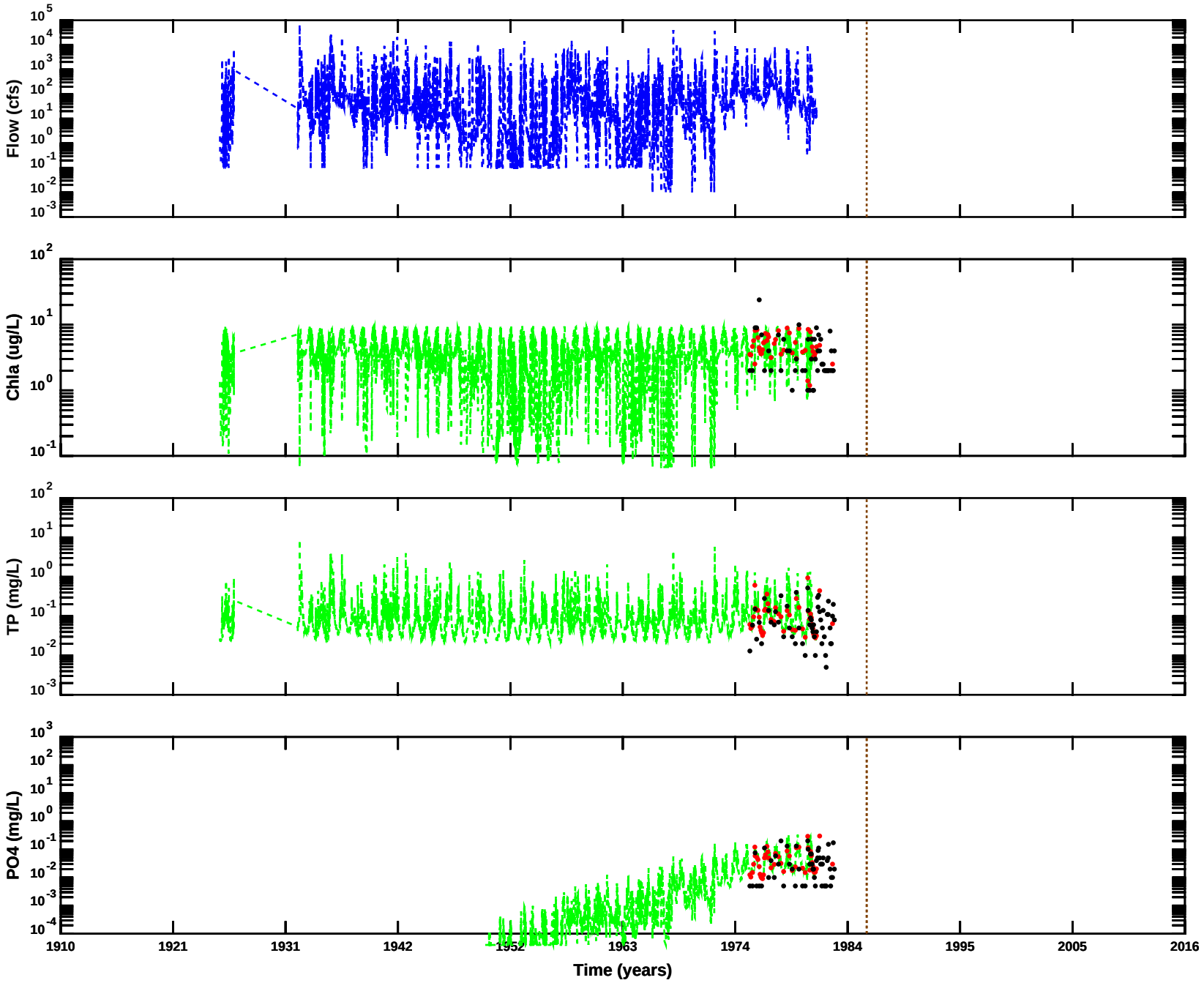
Nutrients Distribution, Station 12980
Nueces Tributaries, Texas (1910-2015)



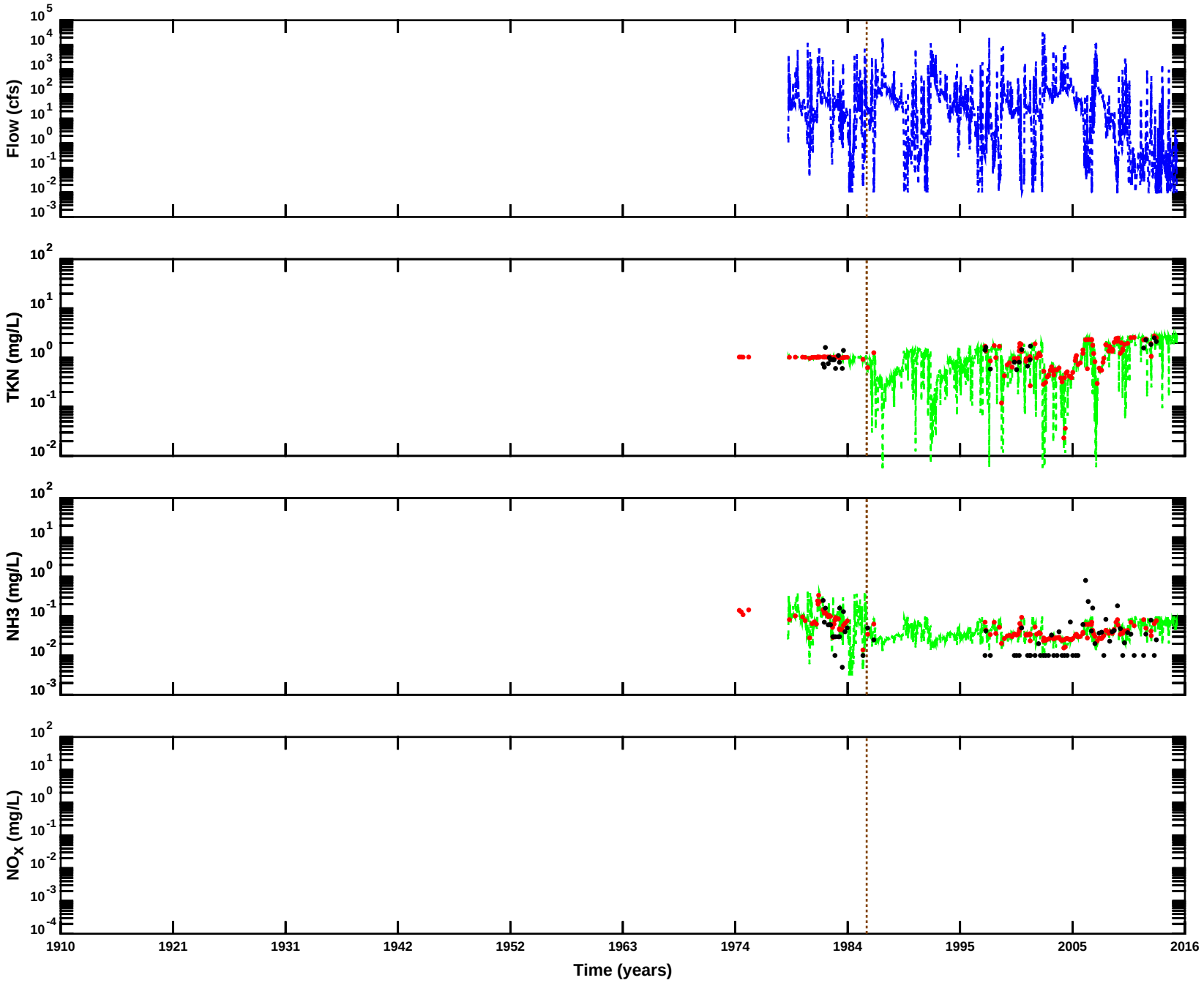
Nutrients Distribution, Station 12980
Nueces Tributaries, Texas (1910-2015)



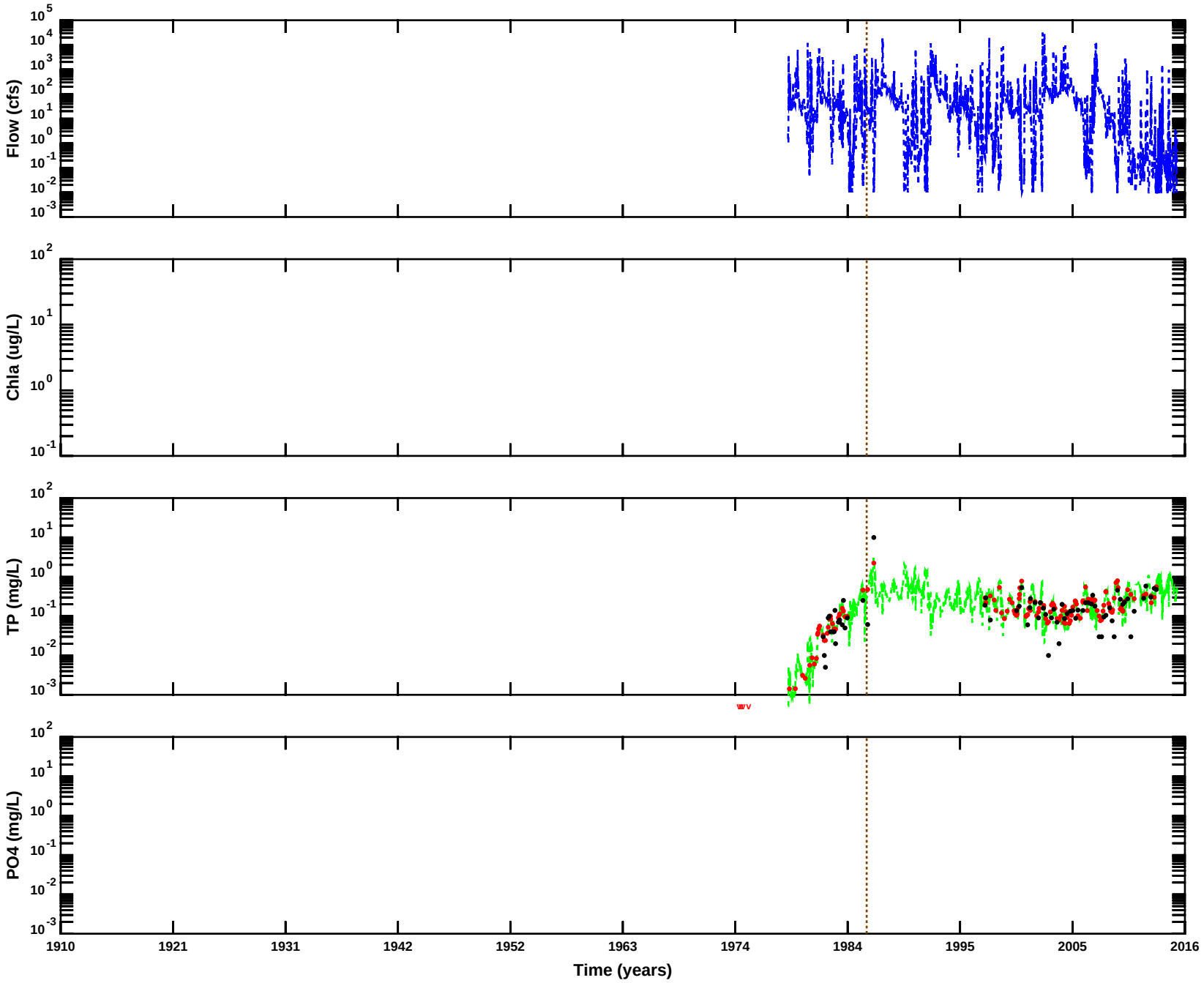
Observed Data vs. Loadest Estimated Concentration, Station 13021 Nueces Tributaries, Texas (1910-2015)



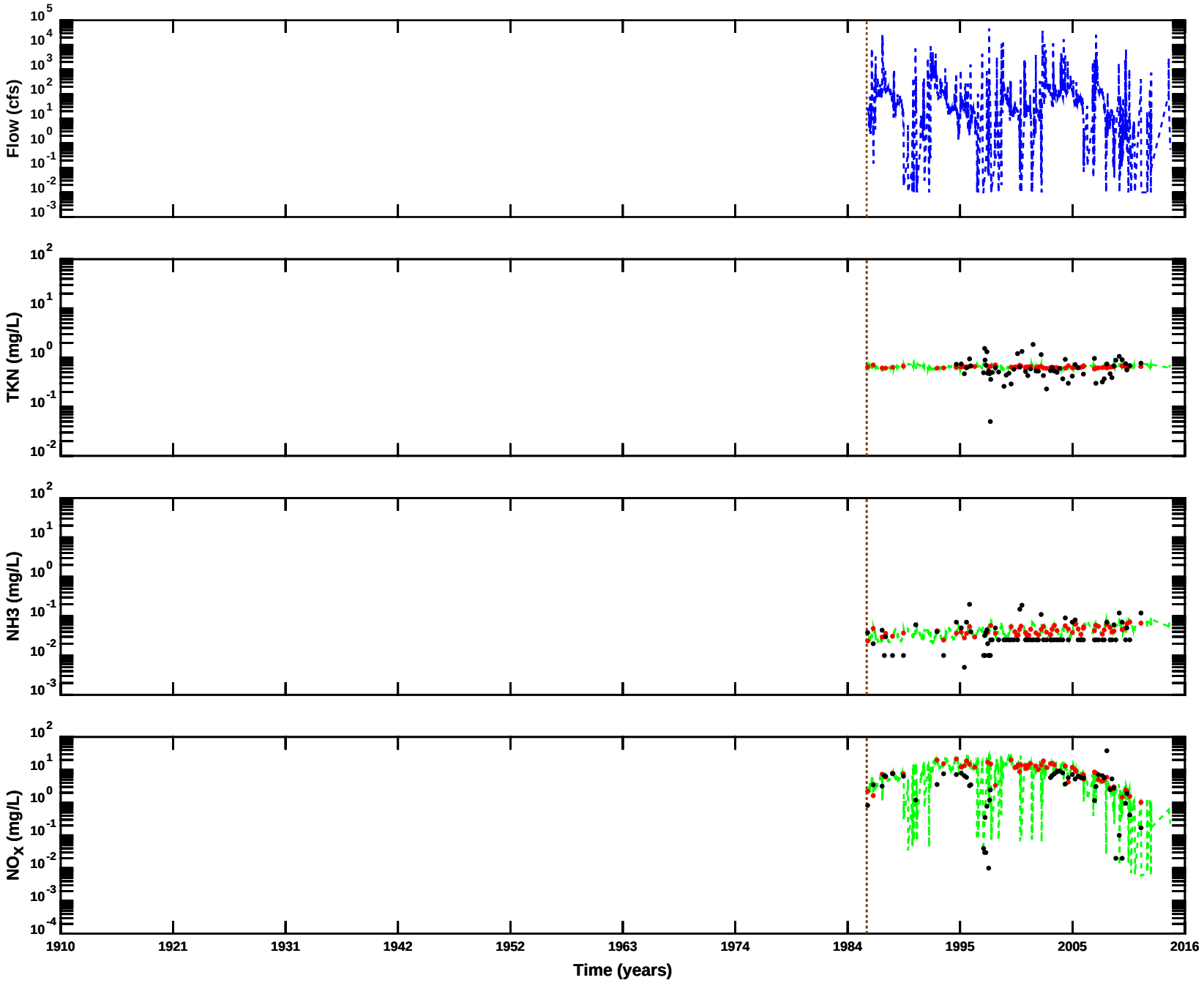
Observed Data vs. Loadest Estimated Concentration, Station 13021 Nueces Tributaries, Texas (1910-2015)



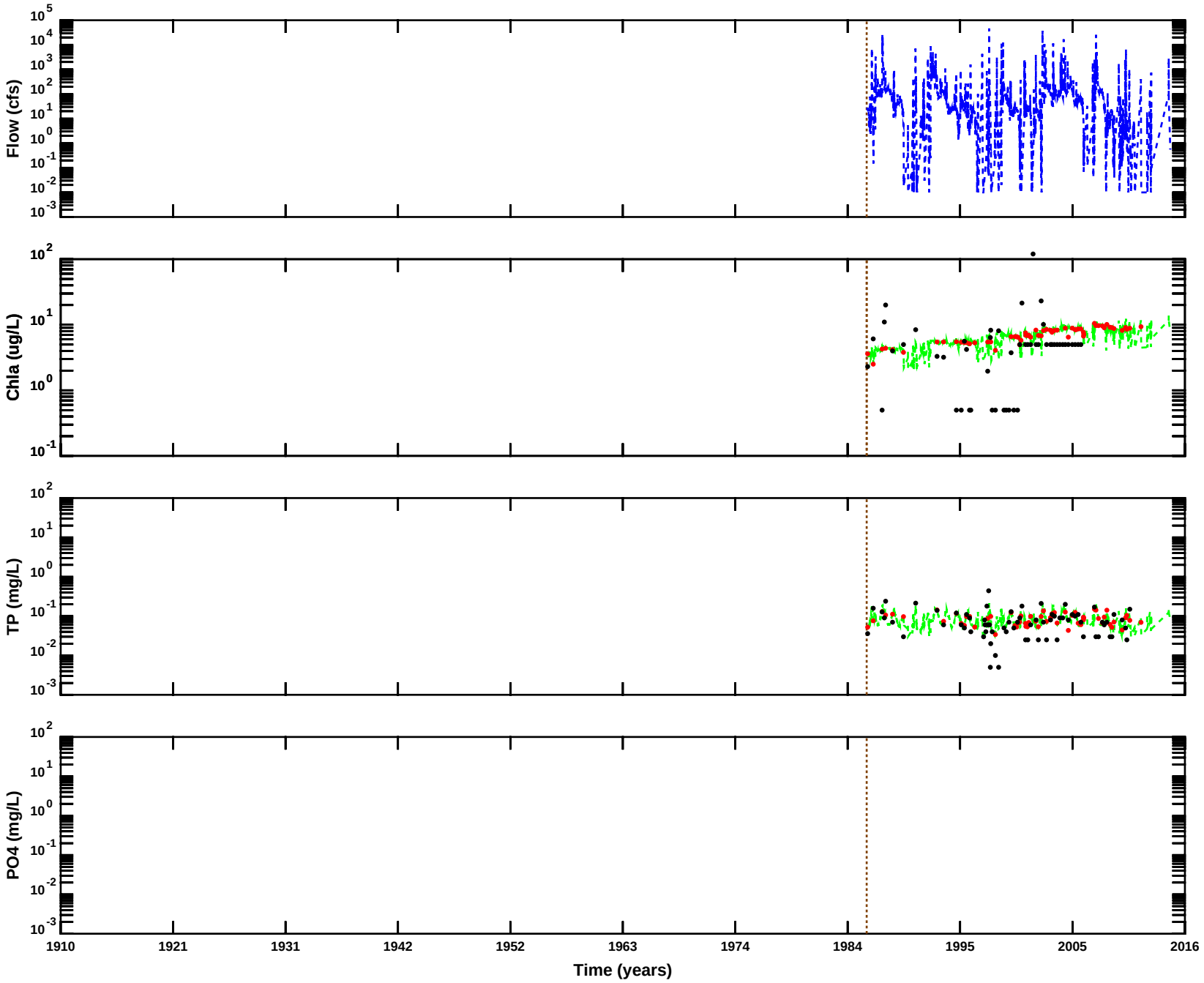
Observed Data vs. LOADEST Estimated Concentration, Station 13023 Nueces Tributaries, Texas (1910-2015)



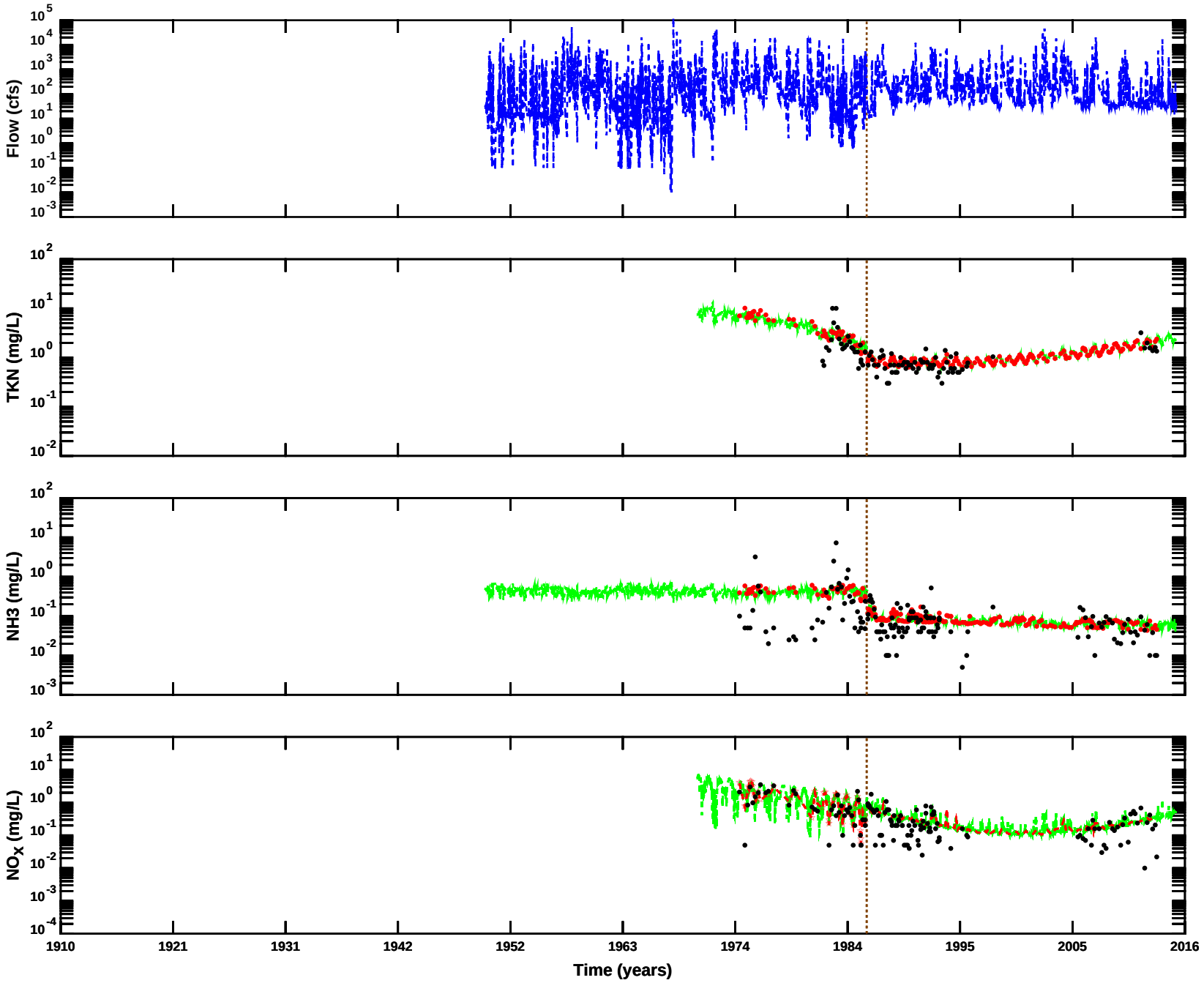
Observed Data vs. LOADEST Estimated Concentration, Station 13023 Nueces Tributaries, Texas (1910-2015)



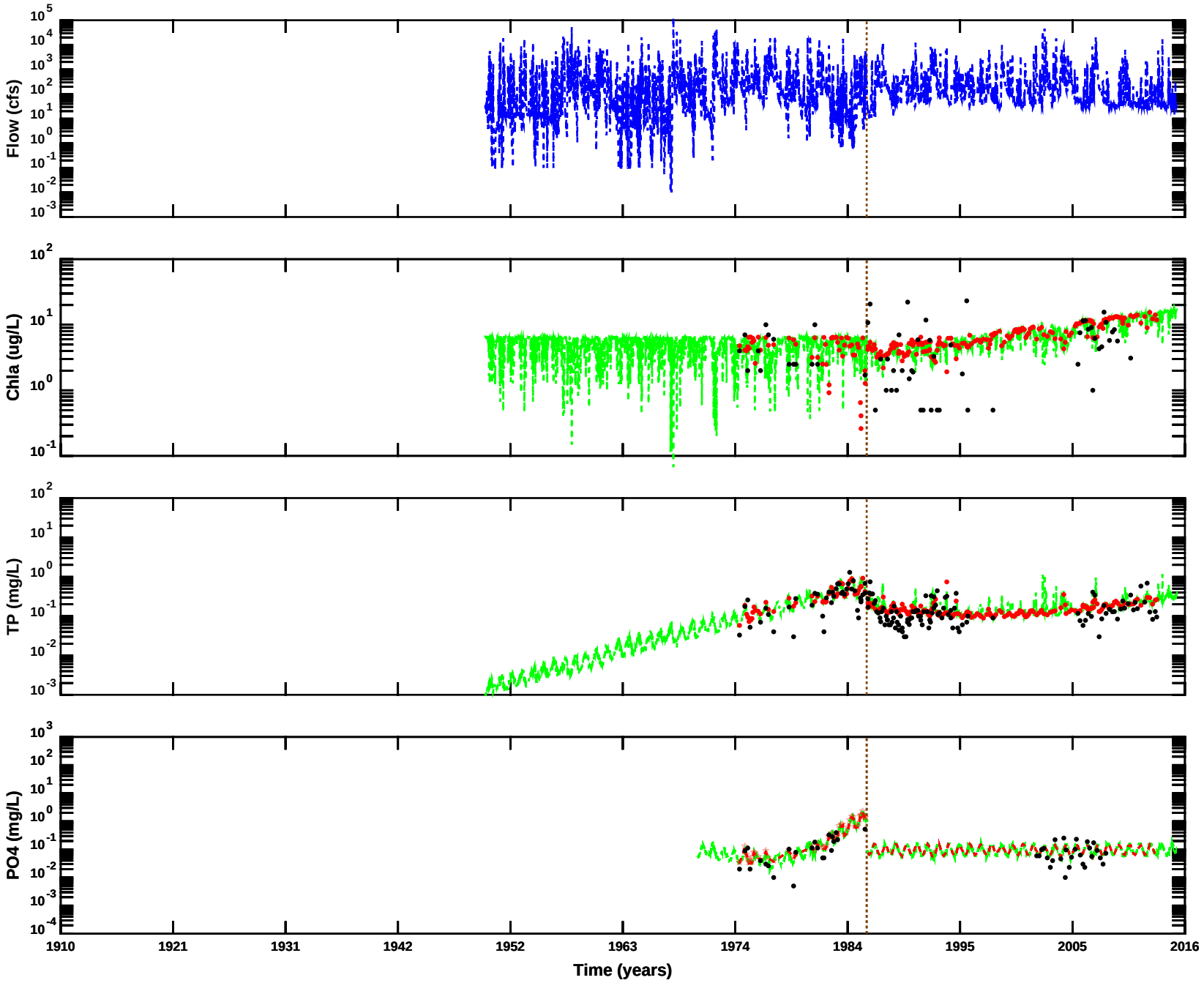
Observed Data vs. Loadest Estimated Concentration, Station 13024 Nueces Tributaries, Texas (1910-2015)



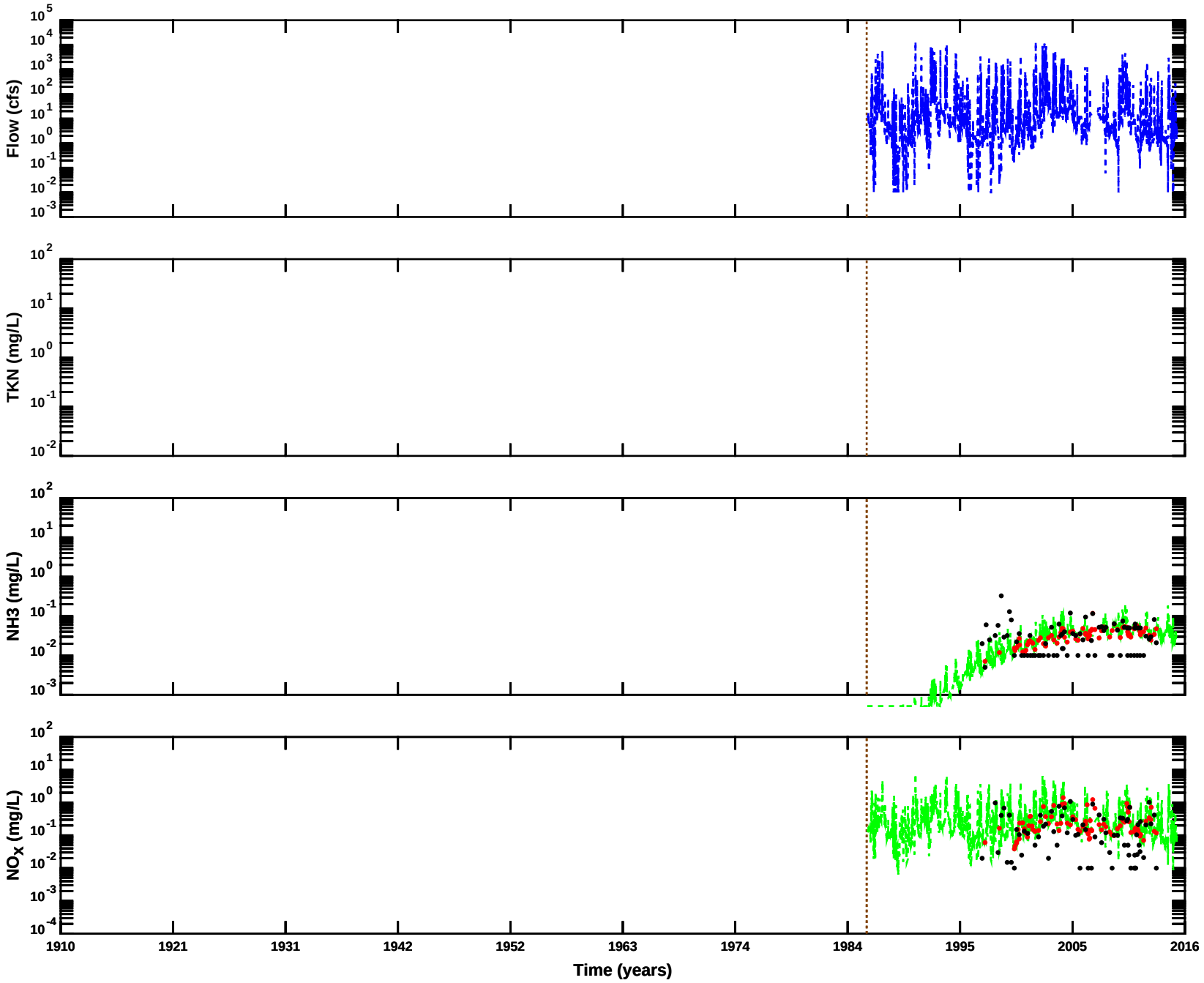
Observed Data vs. Loadest Estimated Concentration, Station 13024 Nueces Tributaries, Texas (1910-2015)



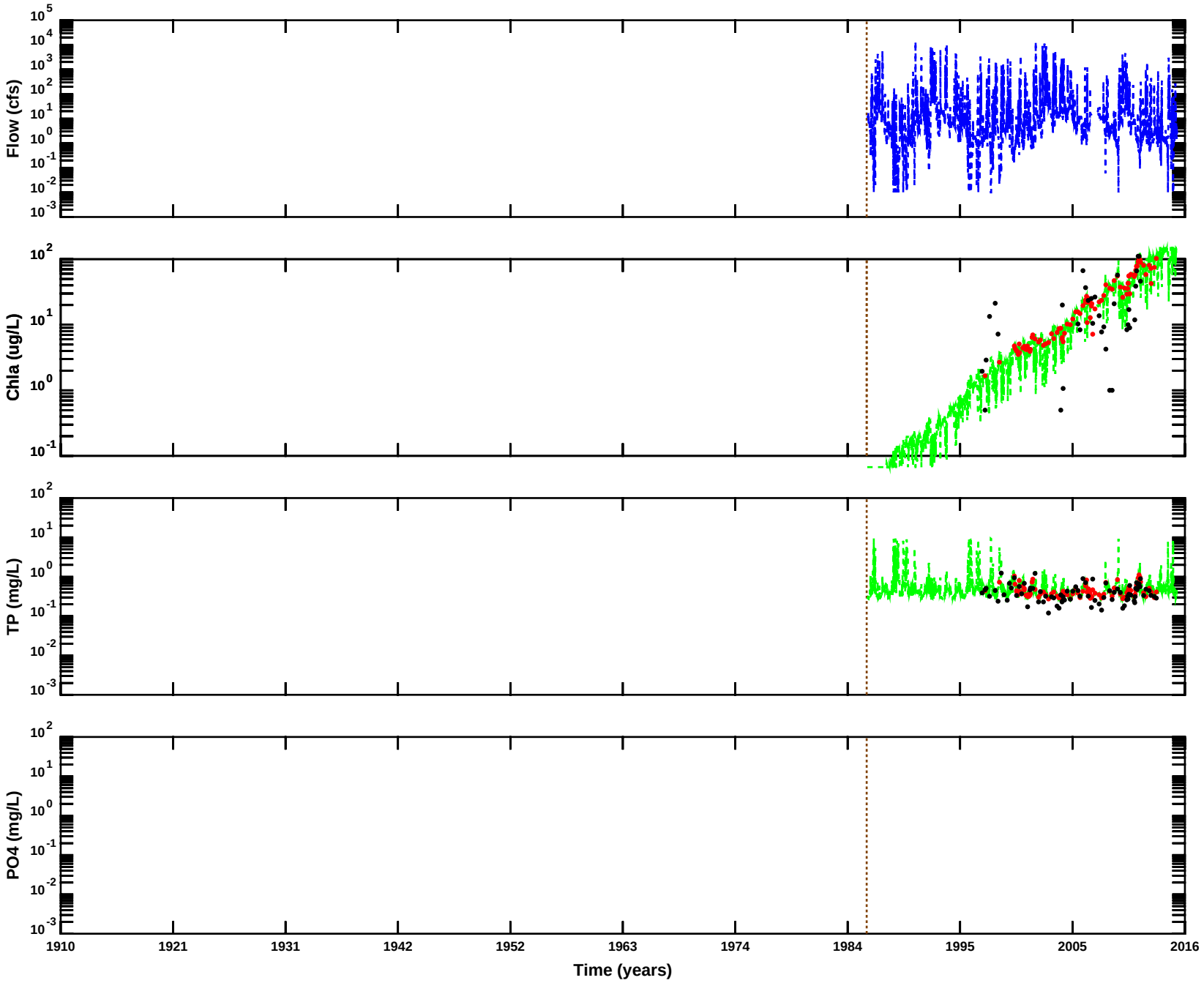
Observed Data vs. LOADEST Estimated Concentration, Station 12979 Nueces Tributaries, Texas (1910-2015)



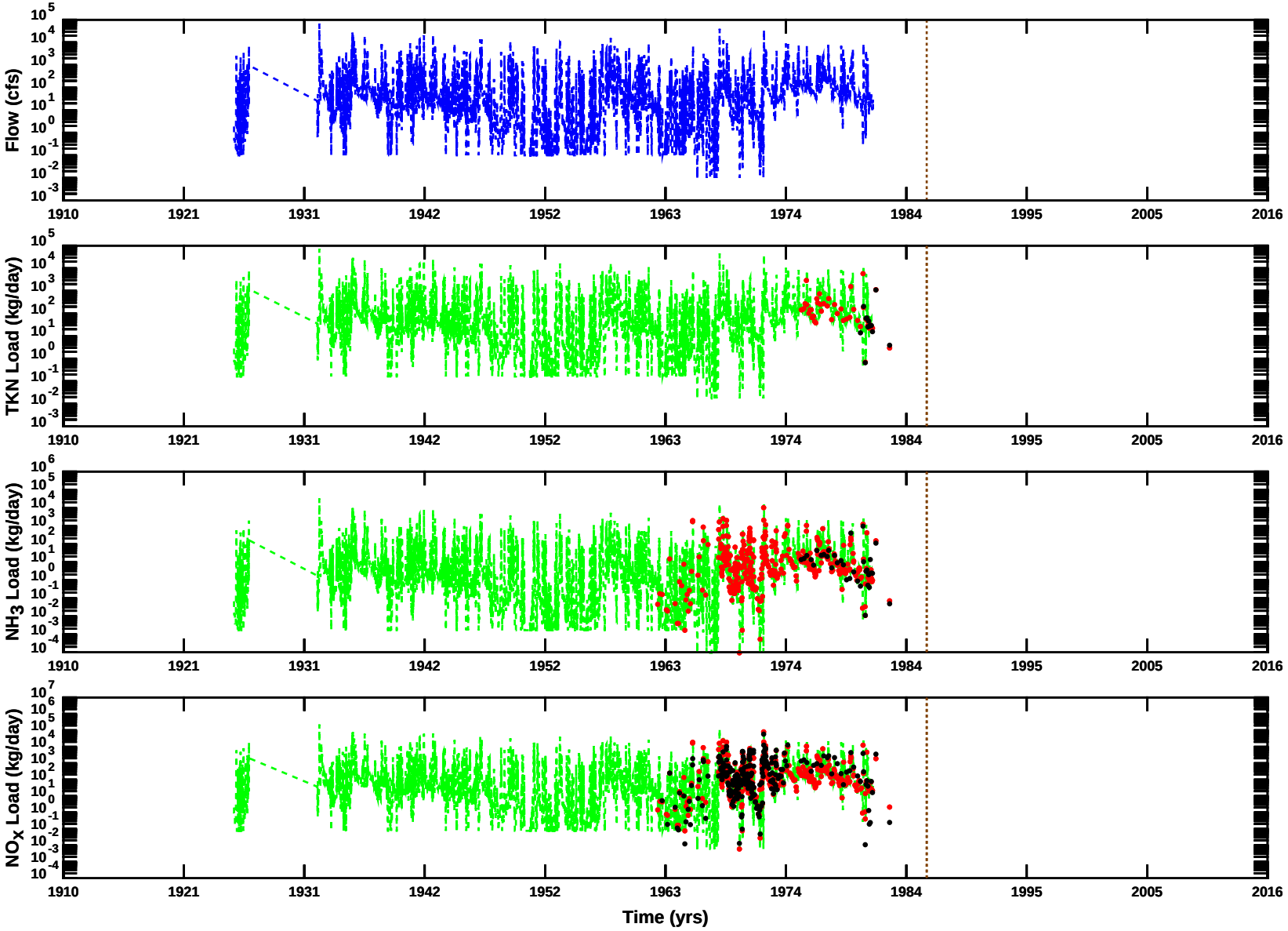
Observed Data vs. LOADEST Estimated Concentration, Station 12979 Nueces Tributaries, Texas (1910-2015)



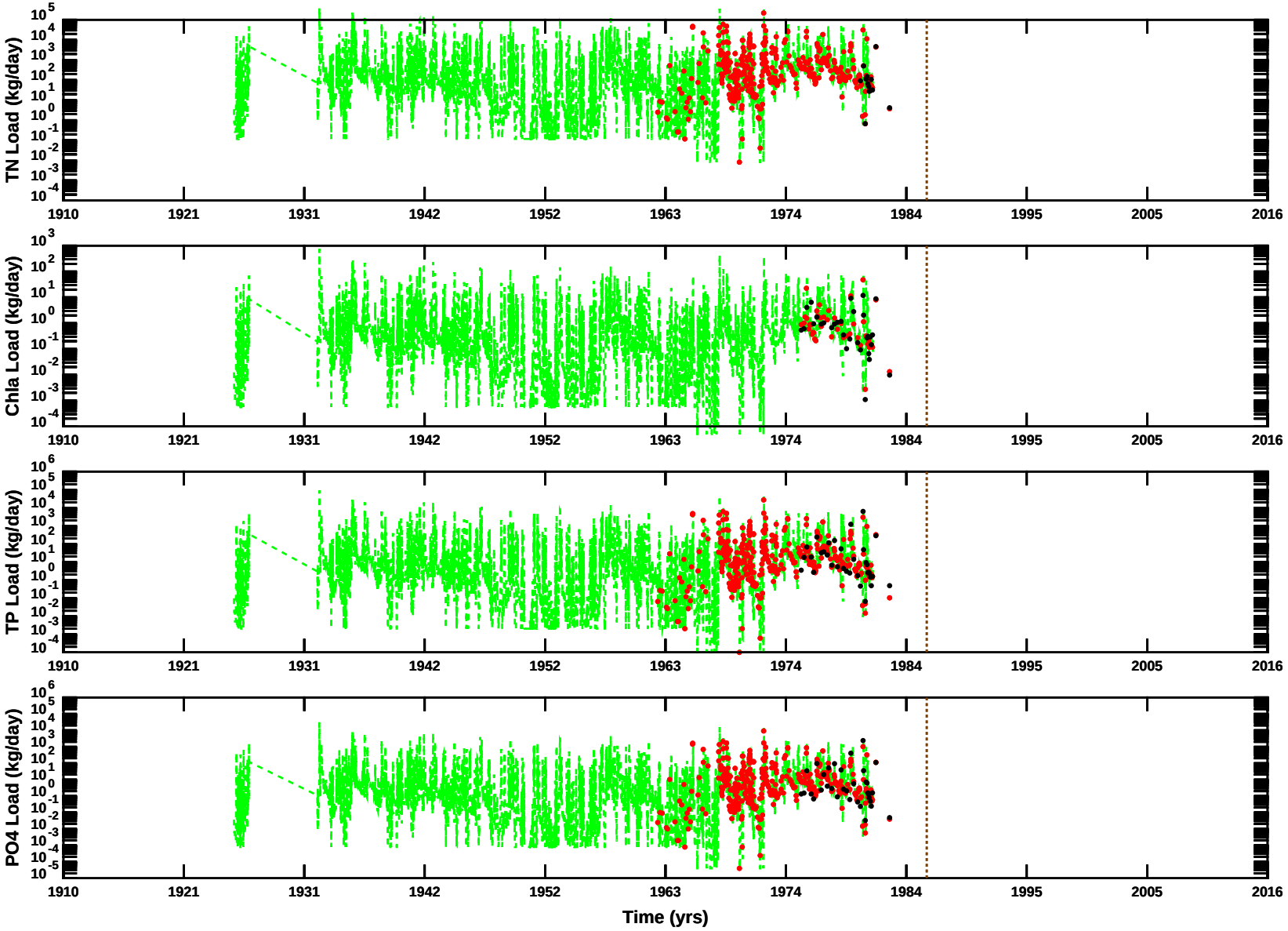
Observed Data vs. Loadest Estimated Concentration, Station 12980 Nueces Tributaries, Texas (1910-2015)



Observed Data vs. Loadest Estimated Concentration, Station 12980 Nueces Tributaries, Texas (1910-2015)

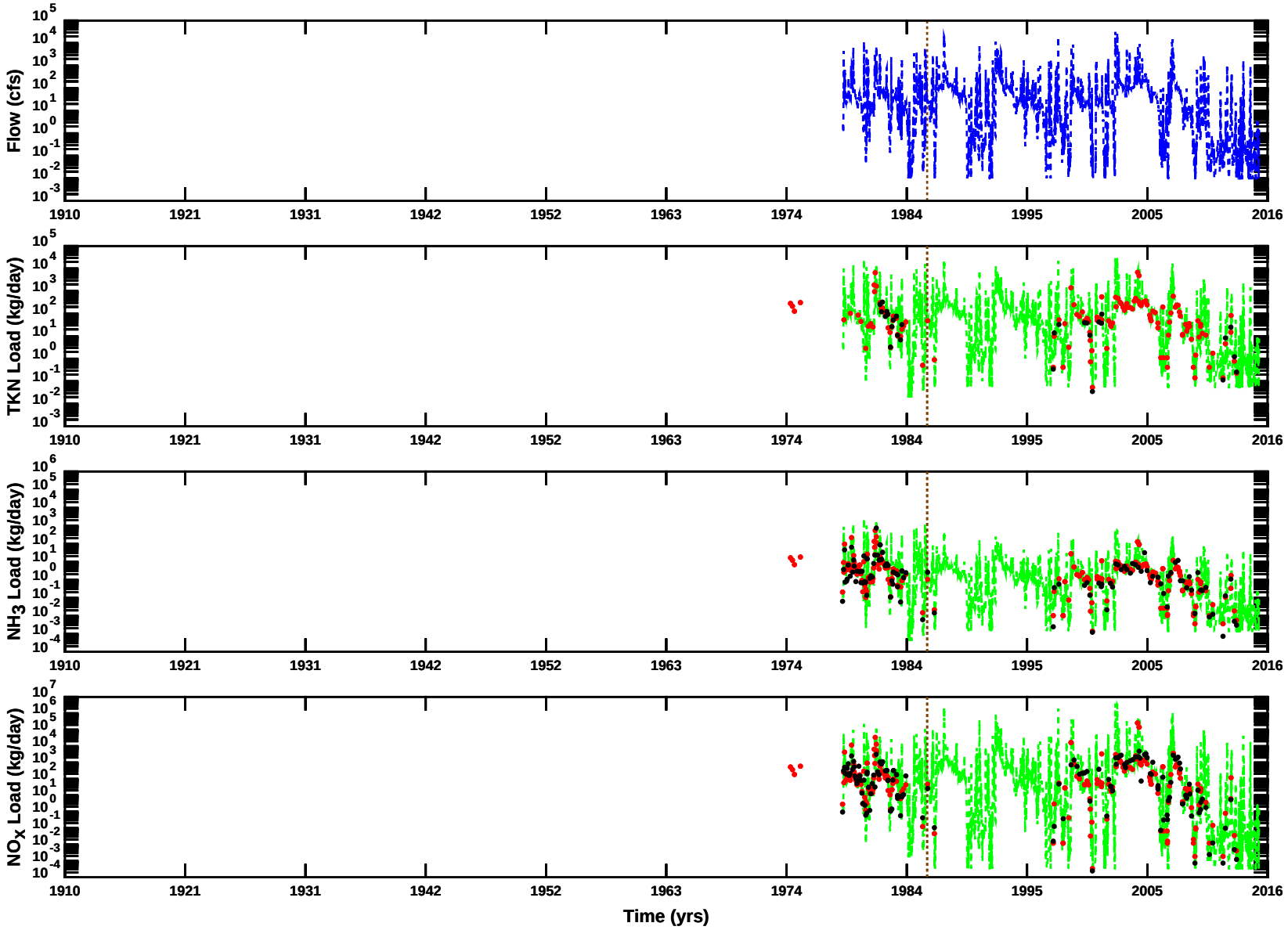


Nutrients Distribution, Station 13021
Nueces Tributaries, Texas (1910-2015)

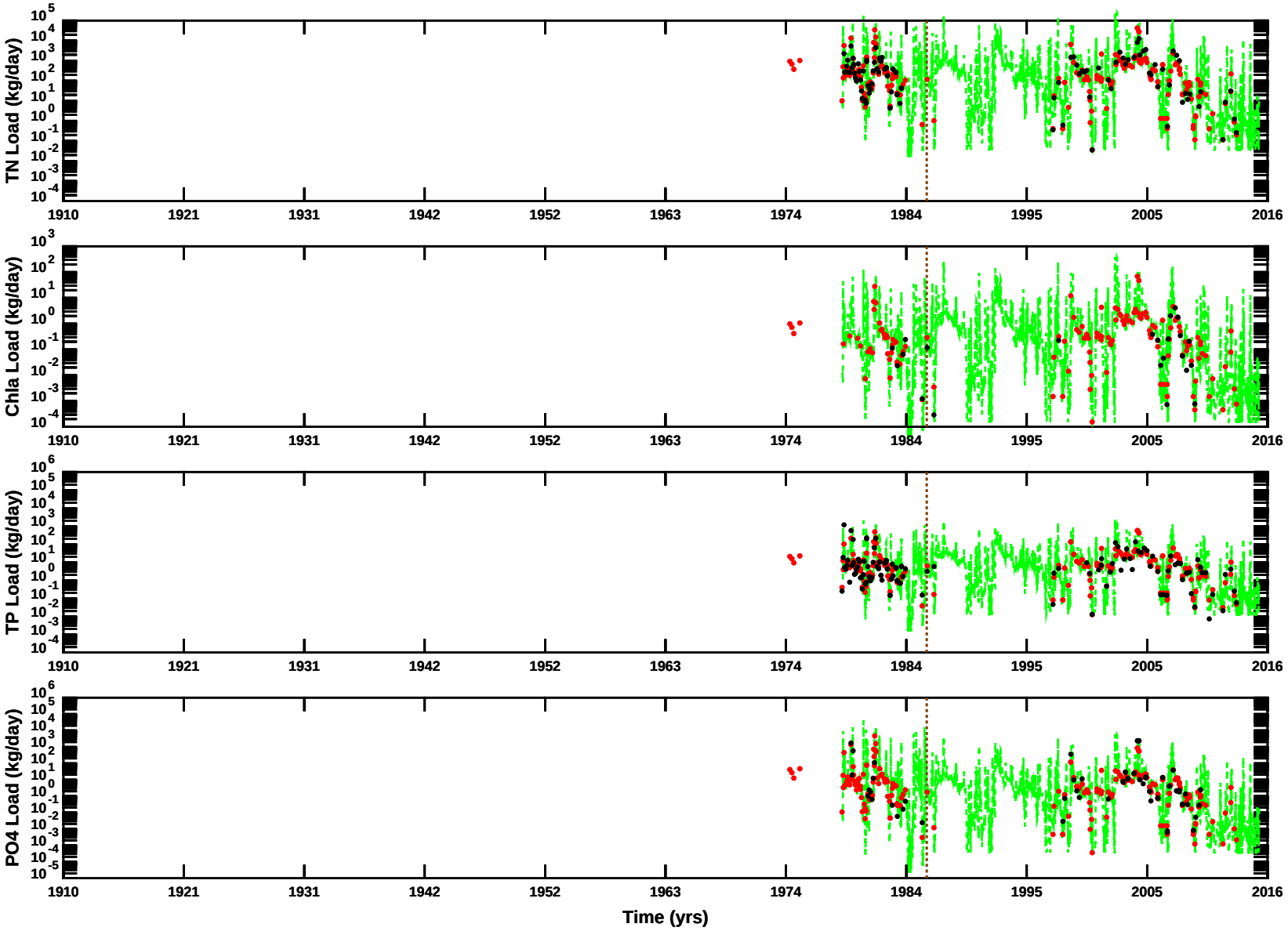


Nutrients Distribution, Station 13021
Nueces Tributaries, Texas (1910-2015)

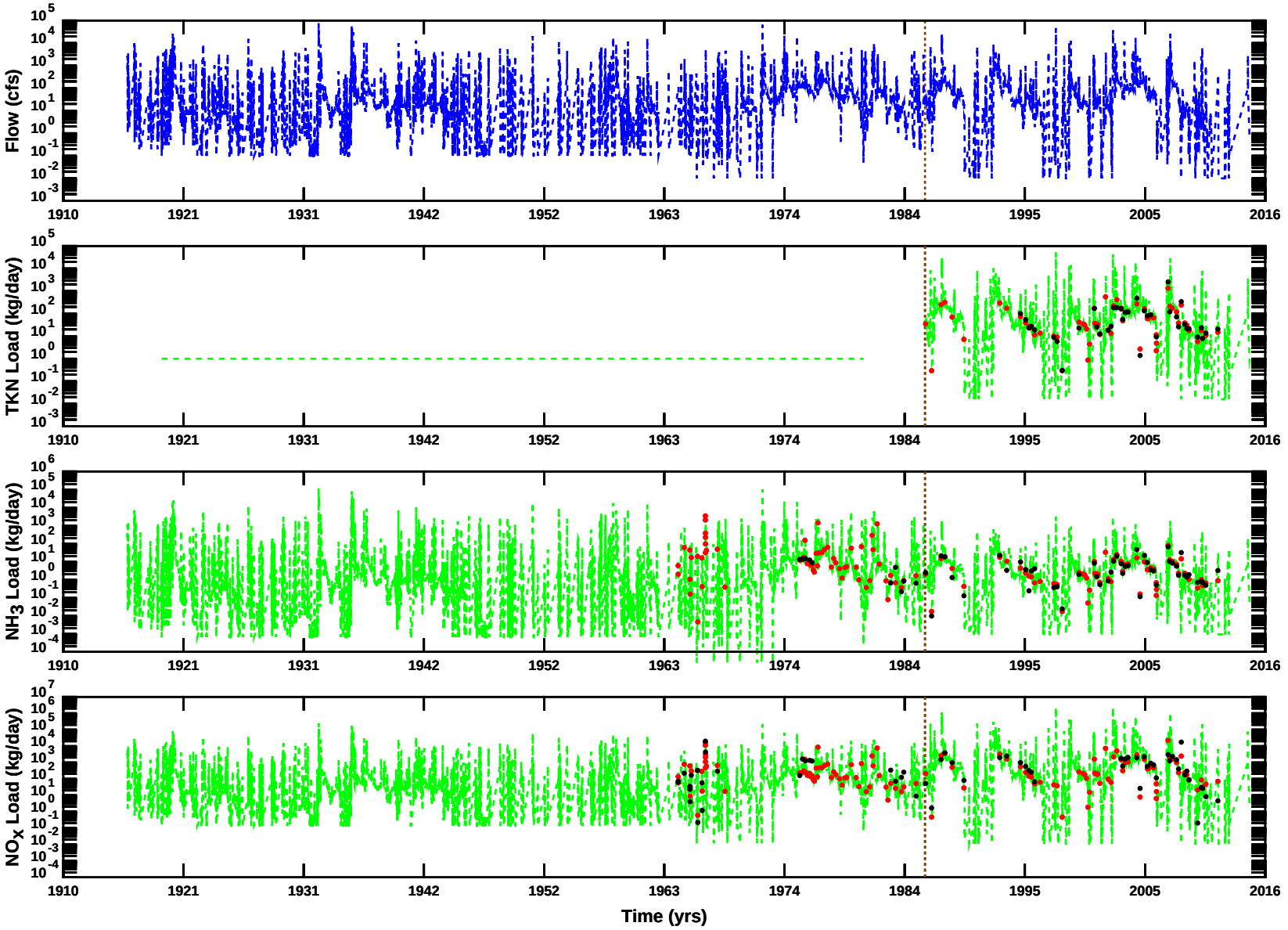
- Observed Load
- Estimated Load
- Estimated Load from 8207000 USGS flow
- Flow at 8207000 USGS station



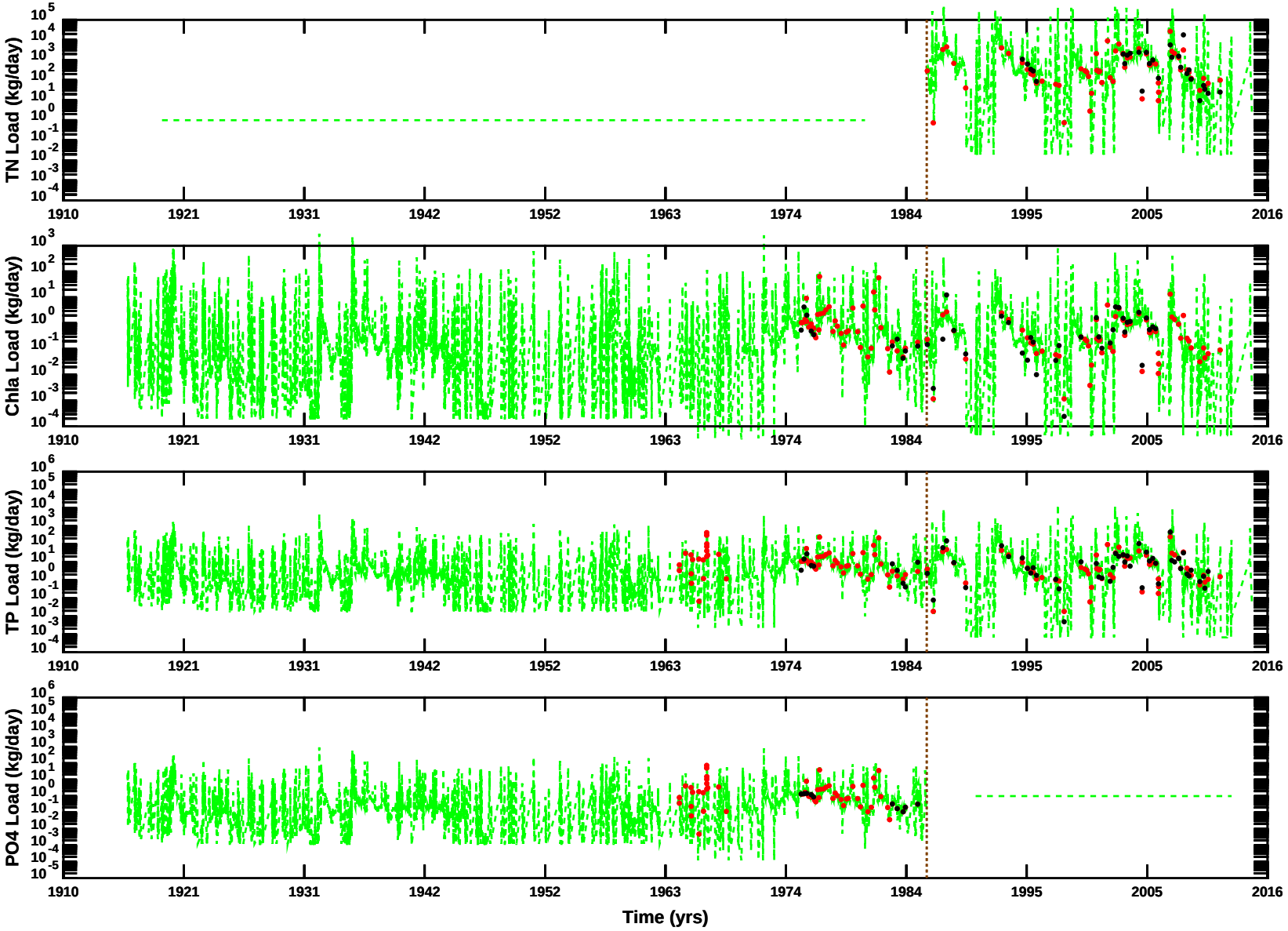
Nutrients Distribution, Station 13023
Nueces Tributaries, Texas (1910-2015)



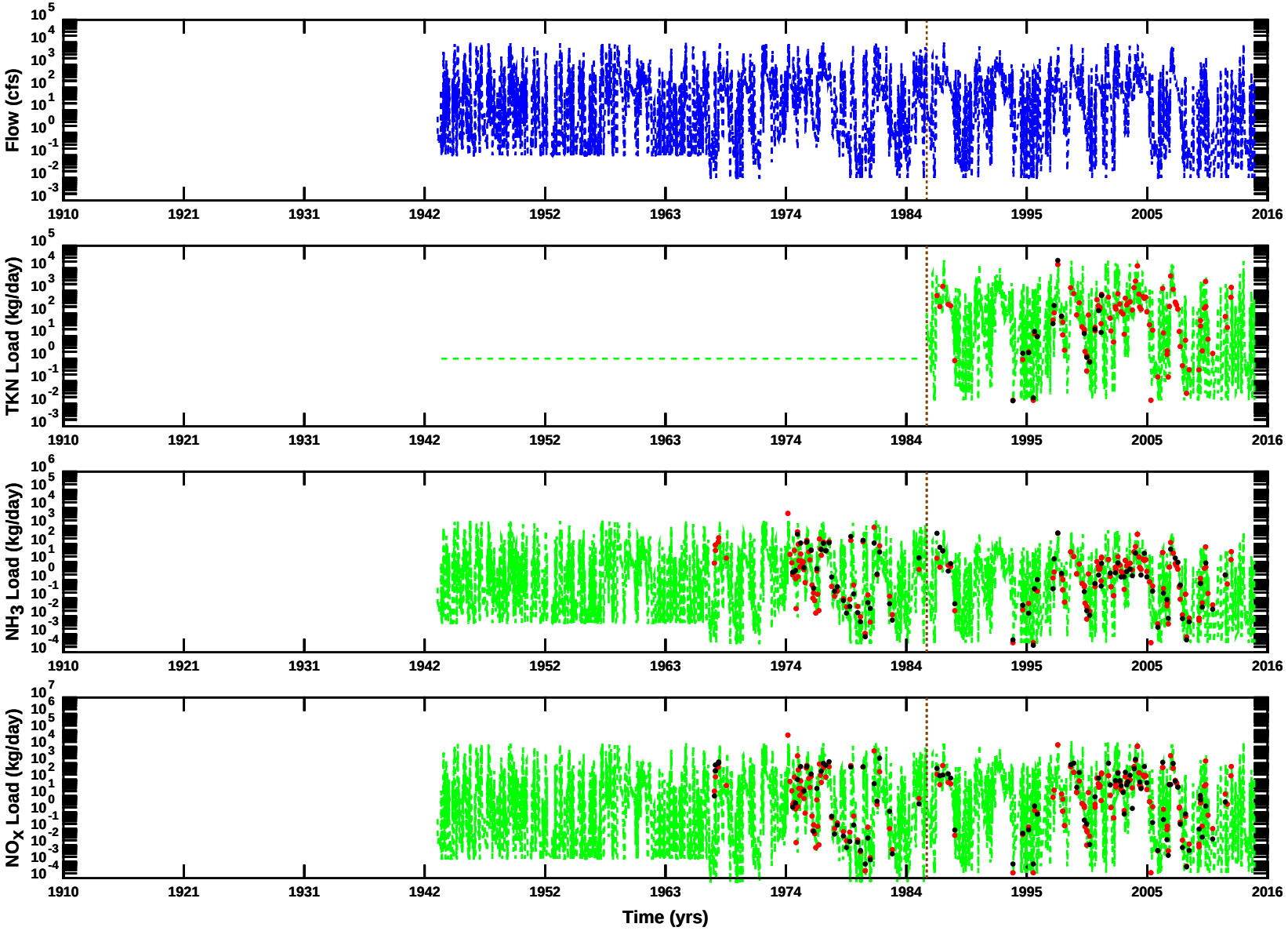
Nutrients Distribution, Station 13023
Nueces Tributaries, Texas (1910-2015)



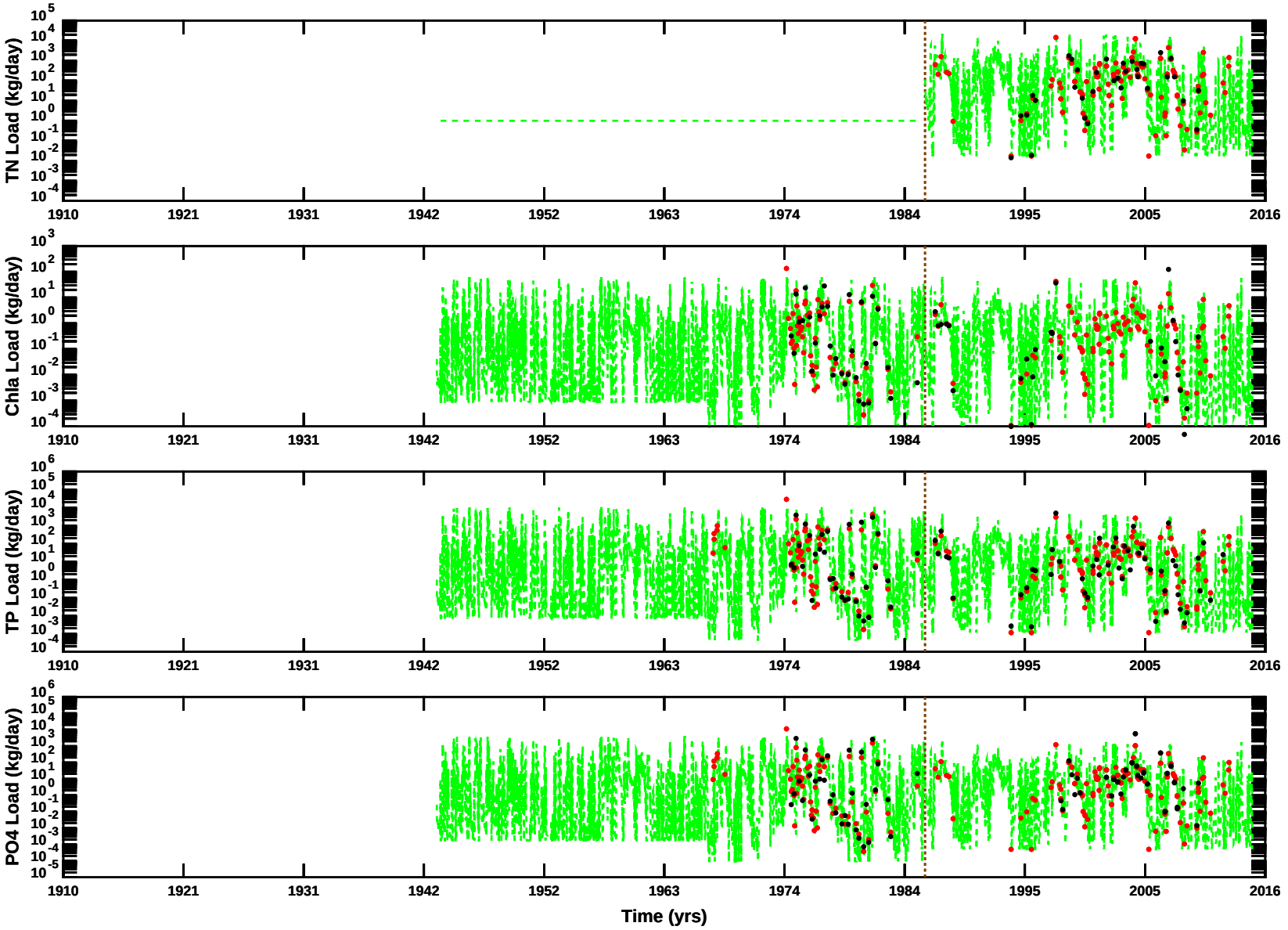
Nutrients Distribution, Station 13024
Nueces Tributaries, Texas (1910-2015)



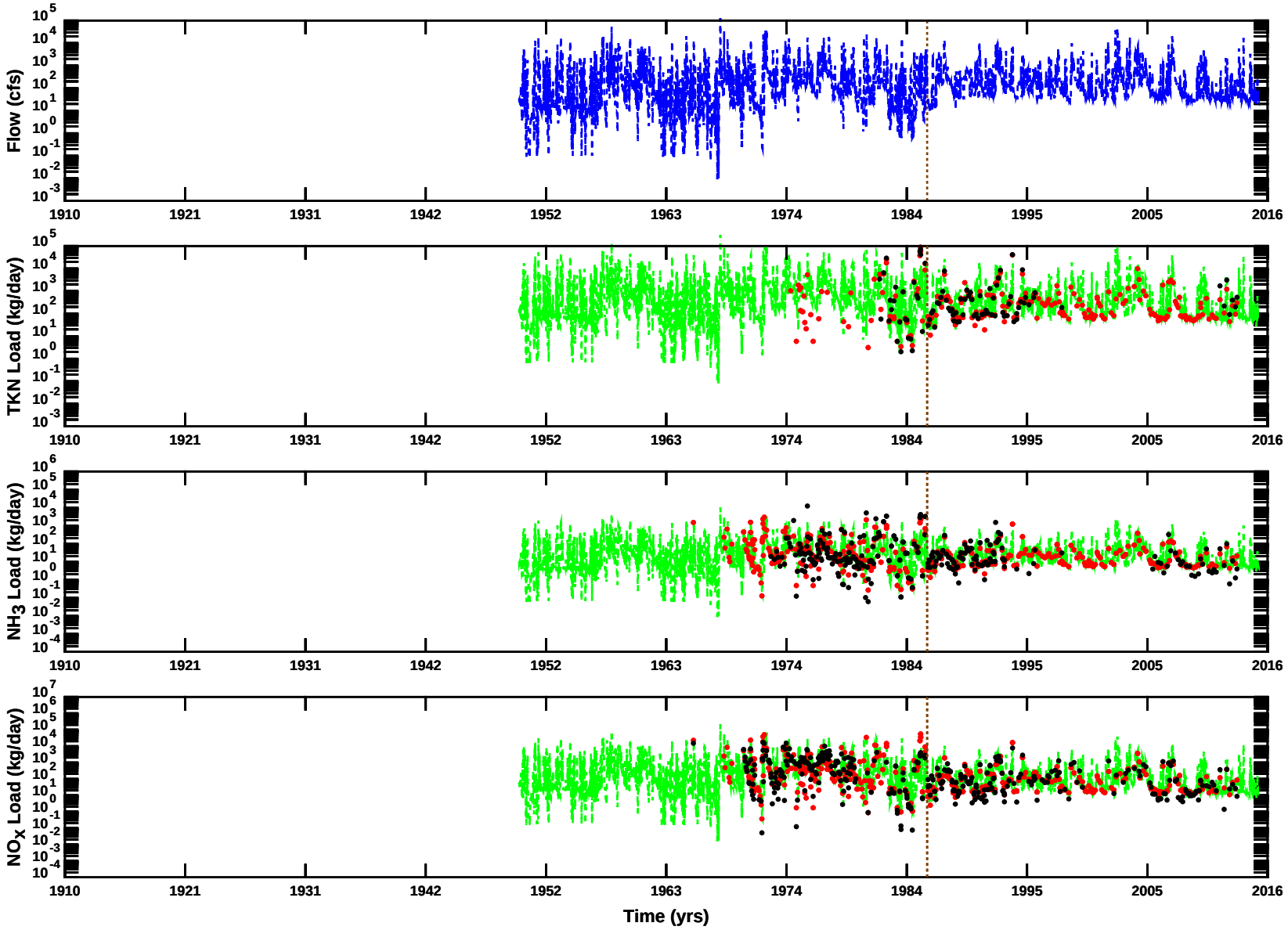
Nutrients Distribution, Station 13024
Nueces Tributaries, Texas (1910-2015)



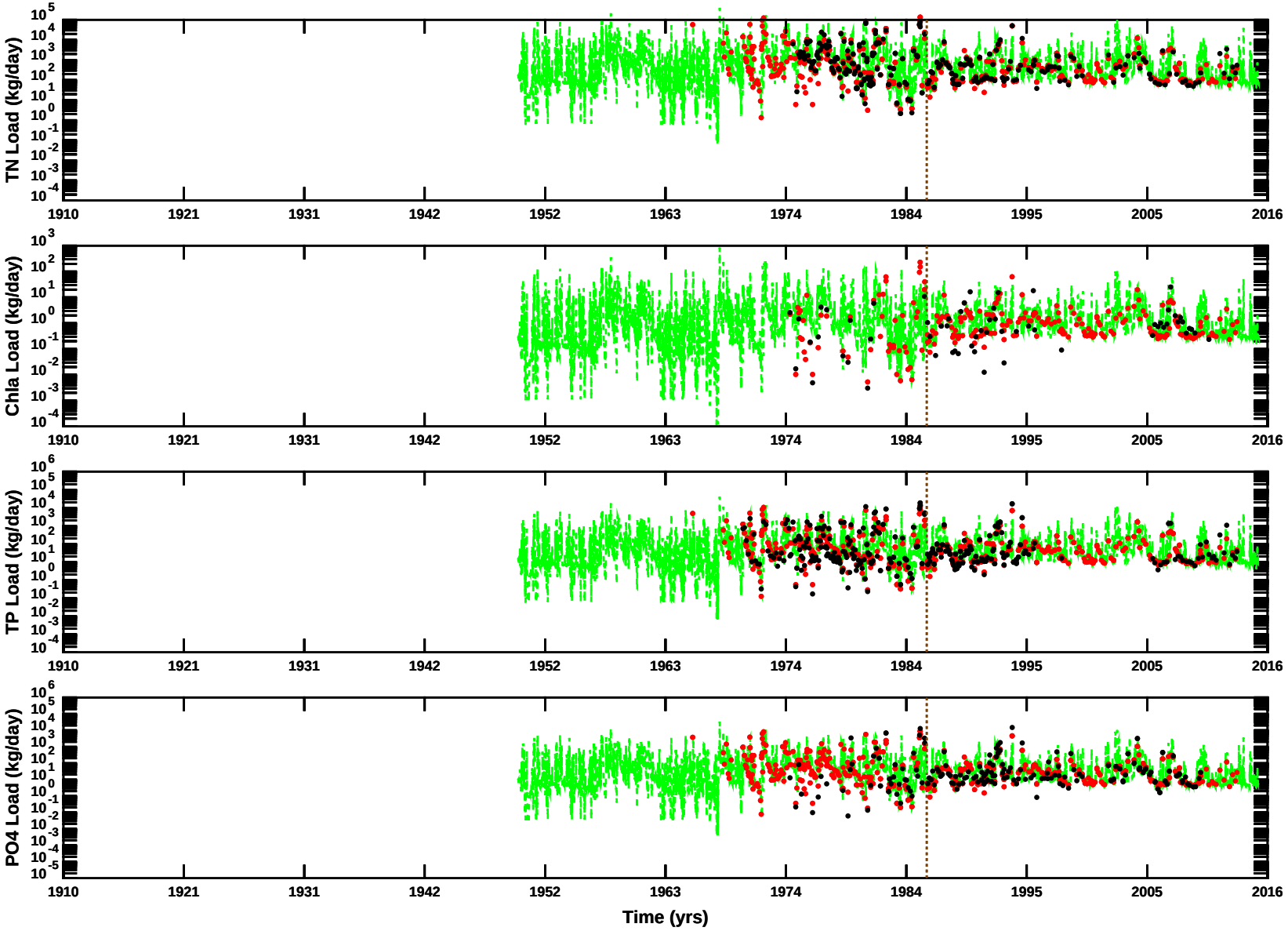
Nutrients Distribution, Station 12973
Nueces Tributaries, Texas (1910-2015)



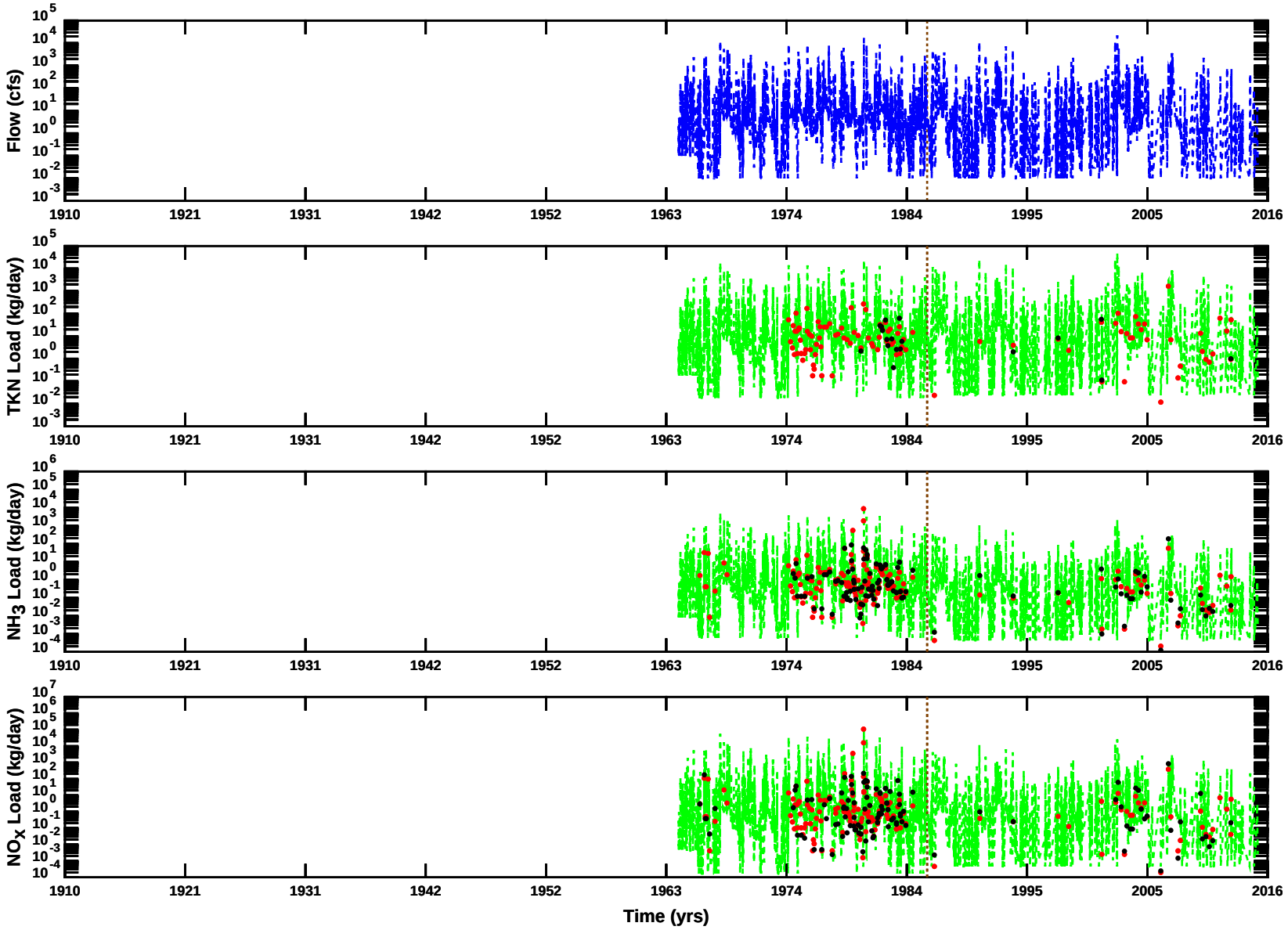
Nutrients Distribution, Station 12973
Nueces Tributaries, Texas (1910-2015)



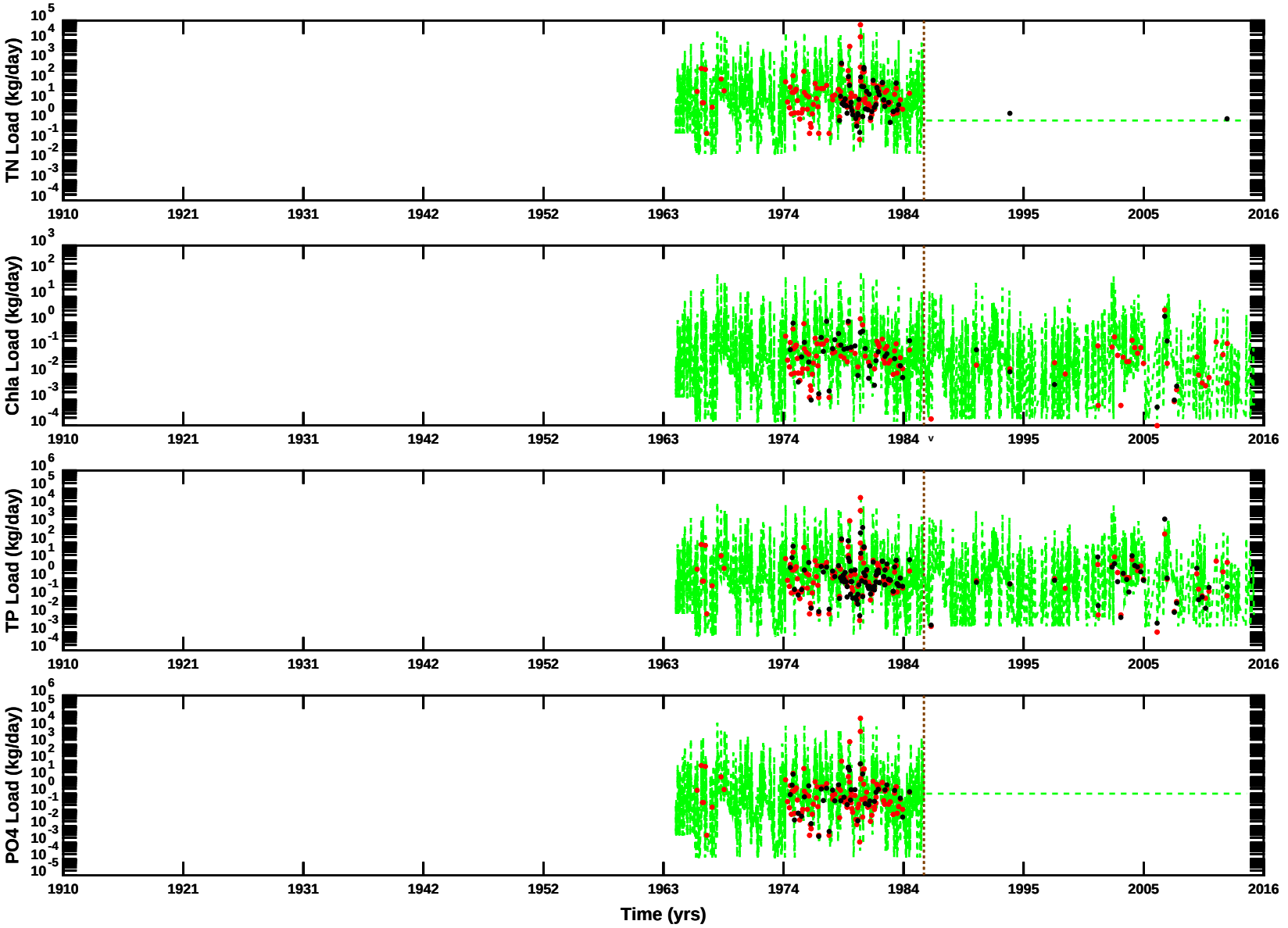
Nutrients Distribution, Station 12979
Nueces Tributaries, Texas (1910-2015)



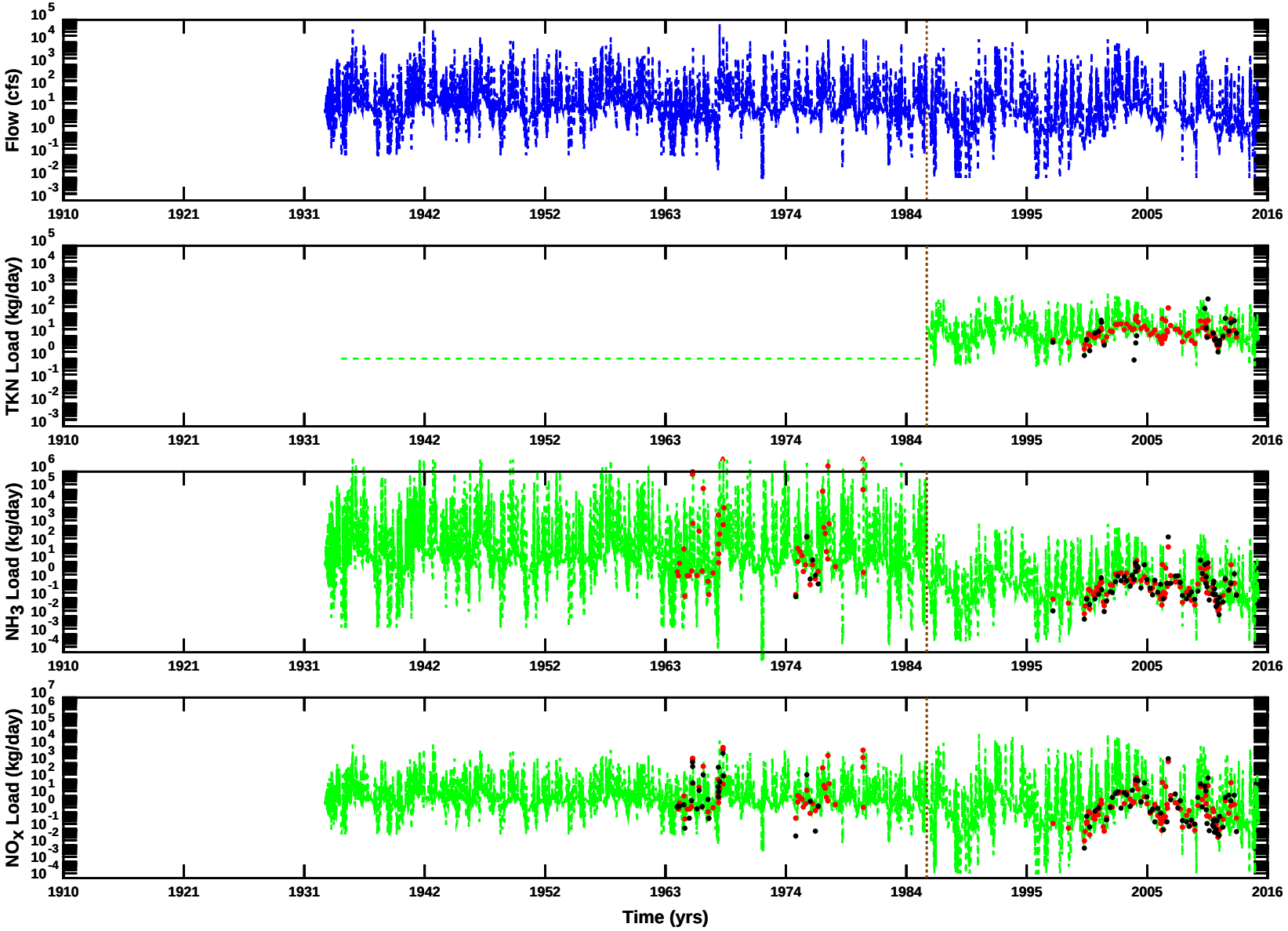
Nutrients Distribution, Station 12979
Nueces Tributaries, Texas (1910-2015)



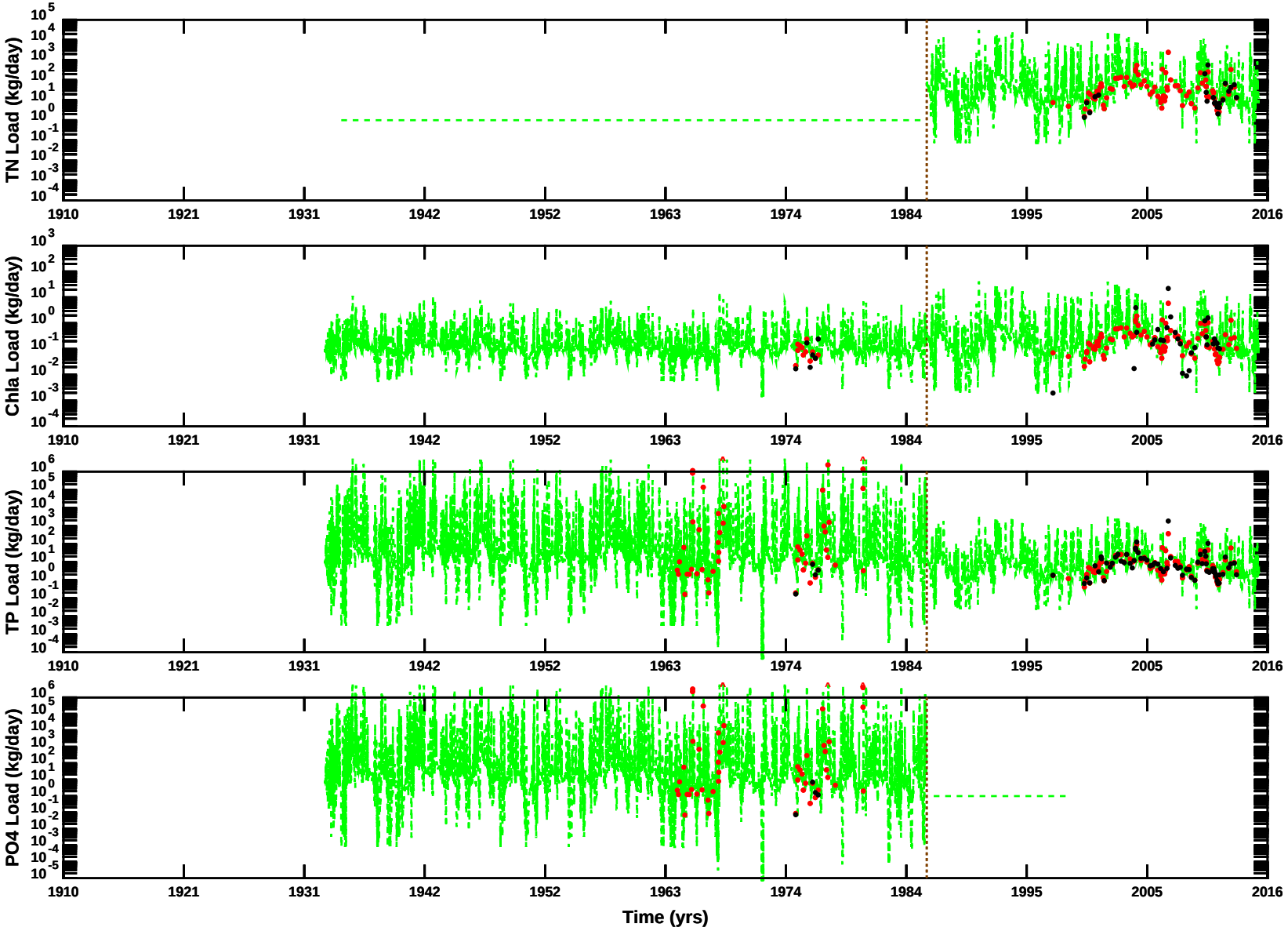
Nutrients Distribution, Station 12983
Nueces Tributaries, Texas (1910-2015)



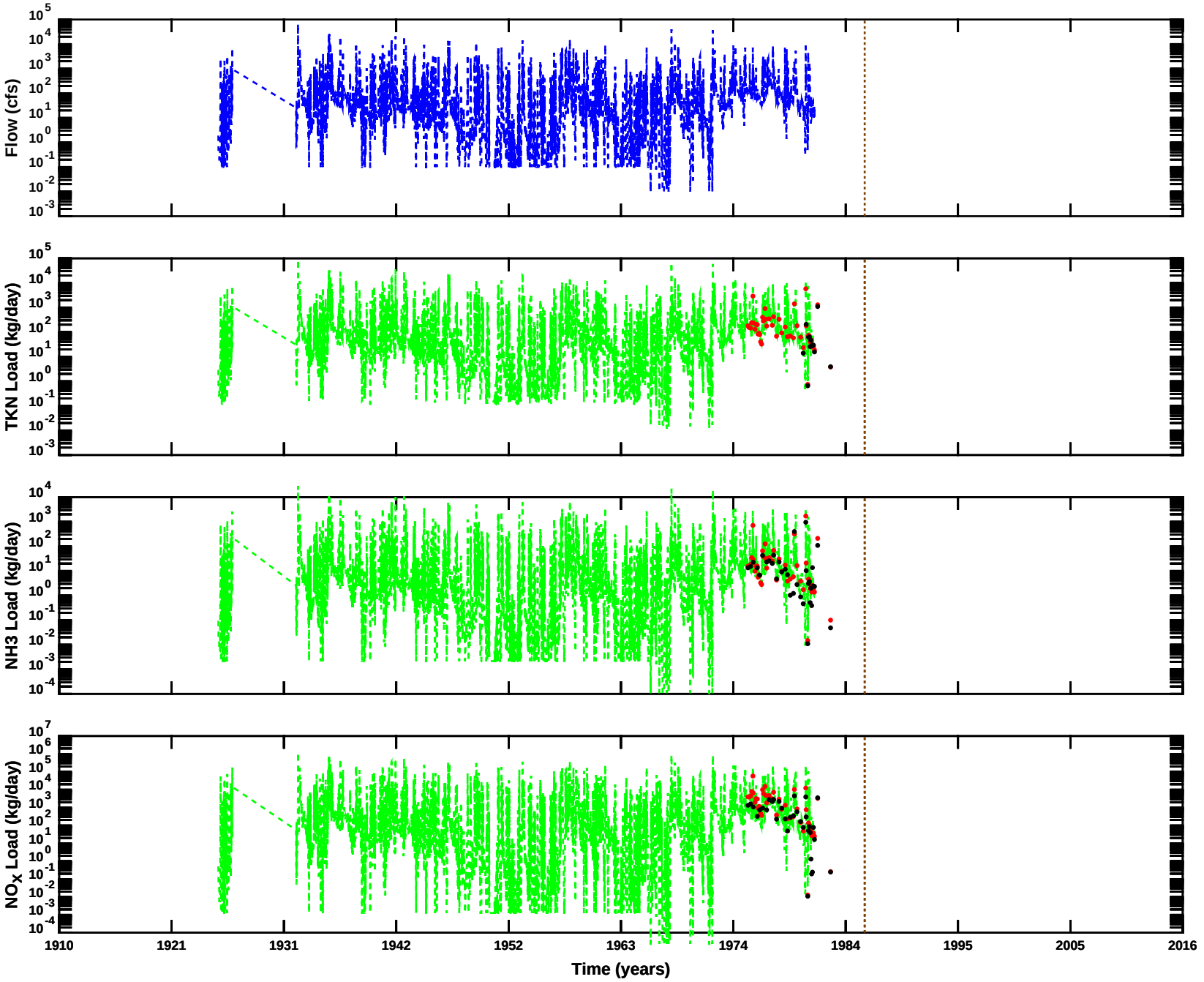
Nutrients Distribution, Station 12983
Nueces Tributaries, Texas (1910-2015)



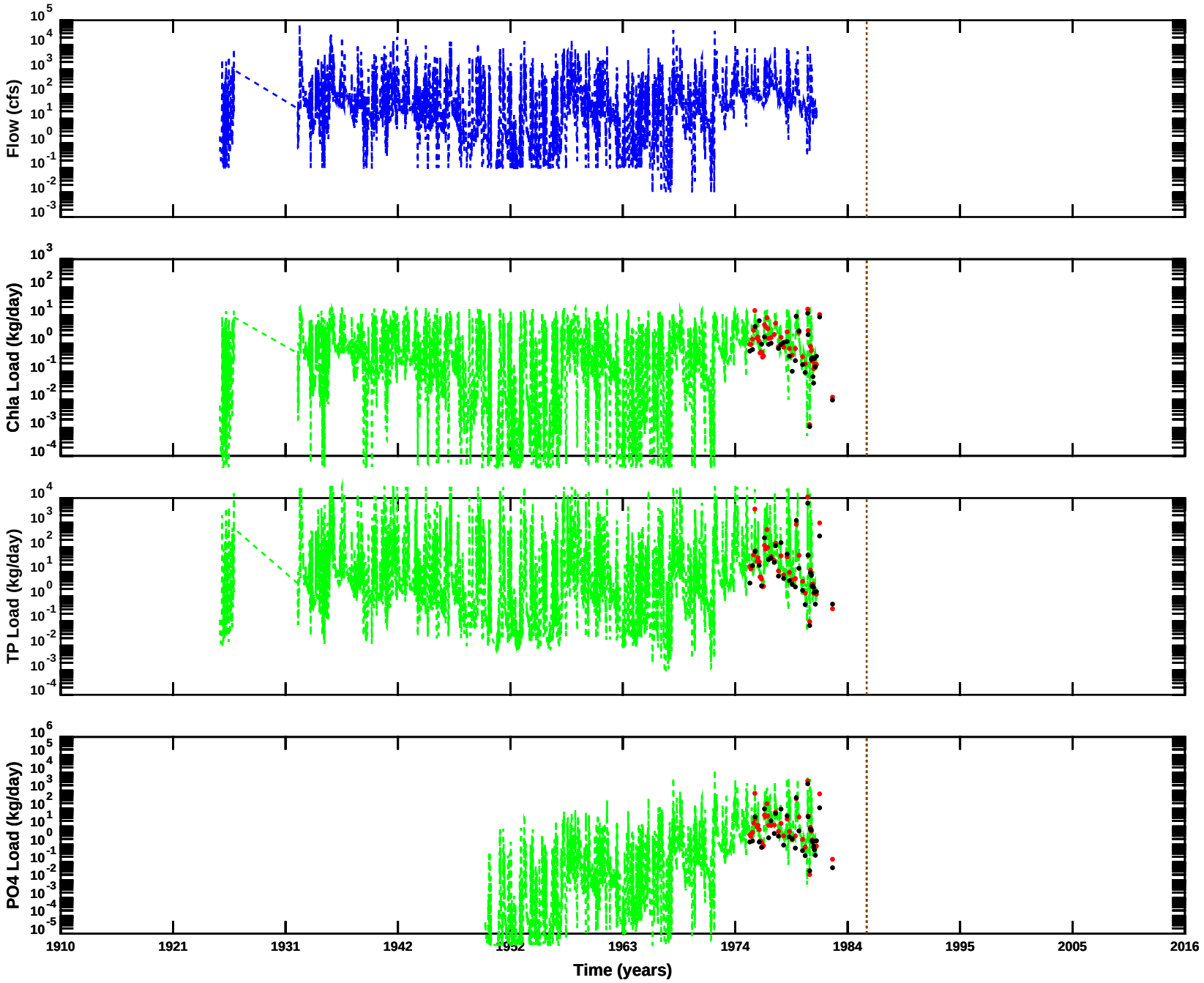
Nutrients Distribution, Station 12980
Nueces Tributaries, Texas (1910-2015)



Nutrients Distribution, Station 12980
Nueces Tributaries, Texas (1910-2015)

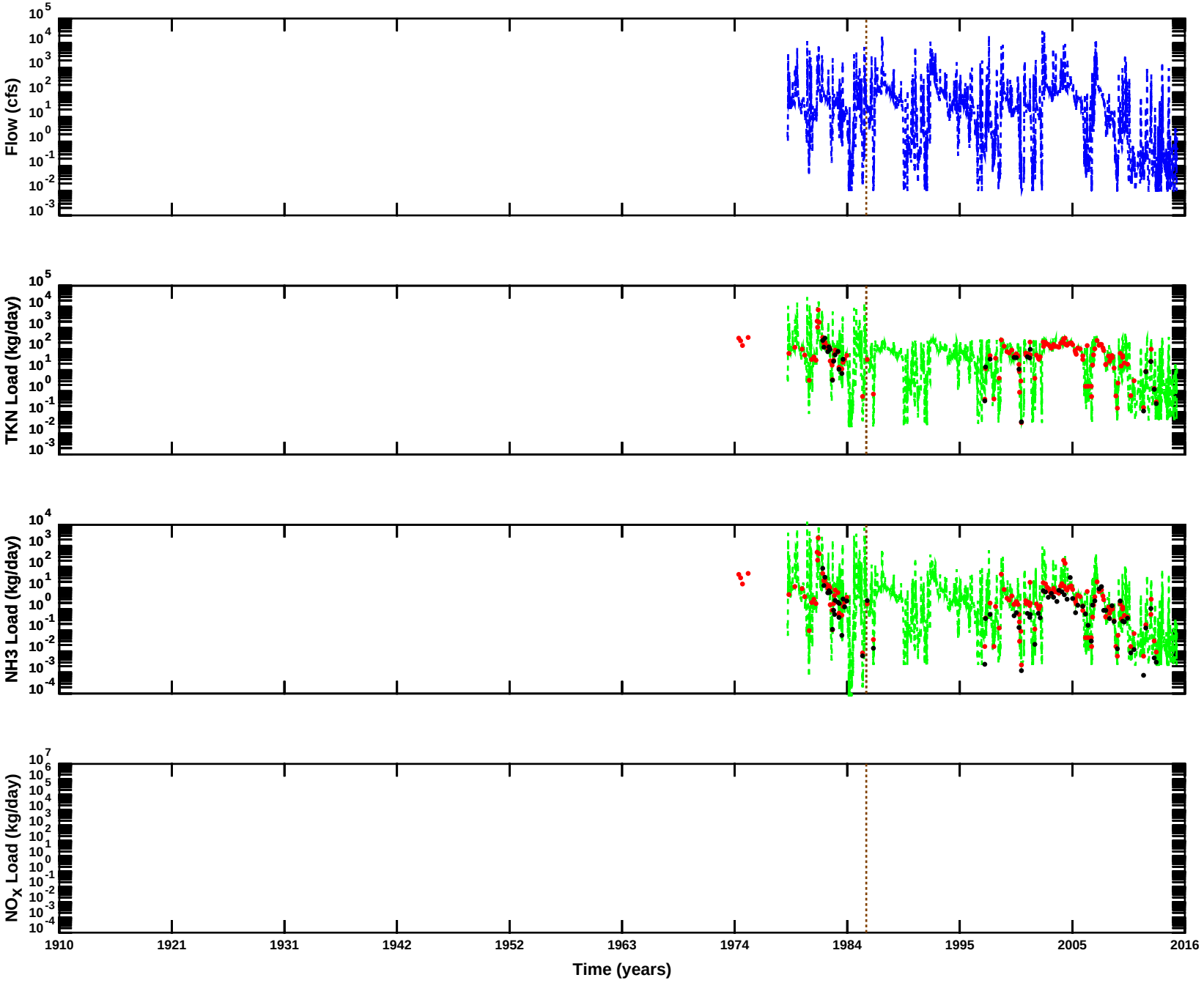


Observed Load vs. LOADEST Estimated Load, Station 13021
Nueces Tributaries, Texas (1910-2015)



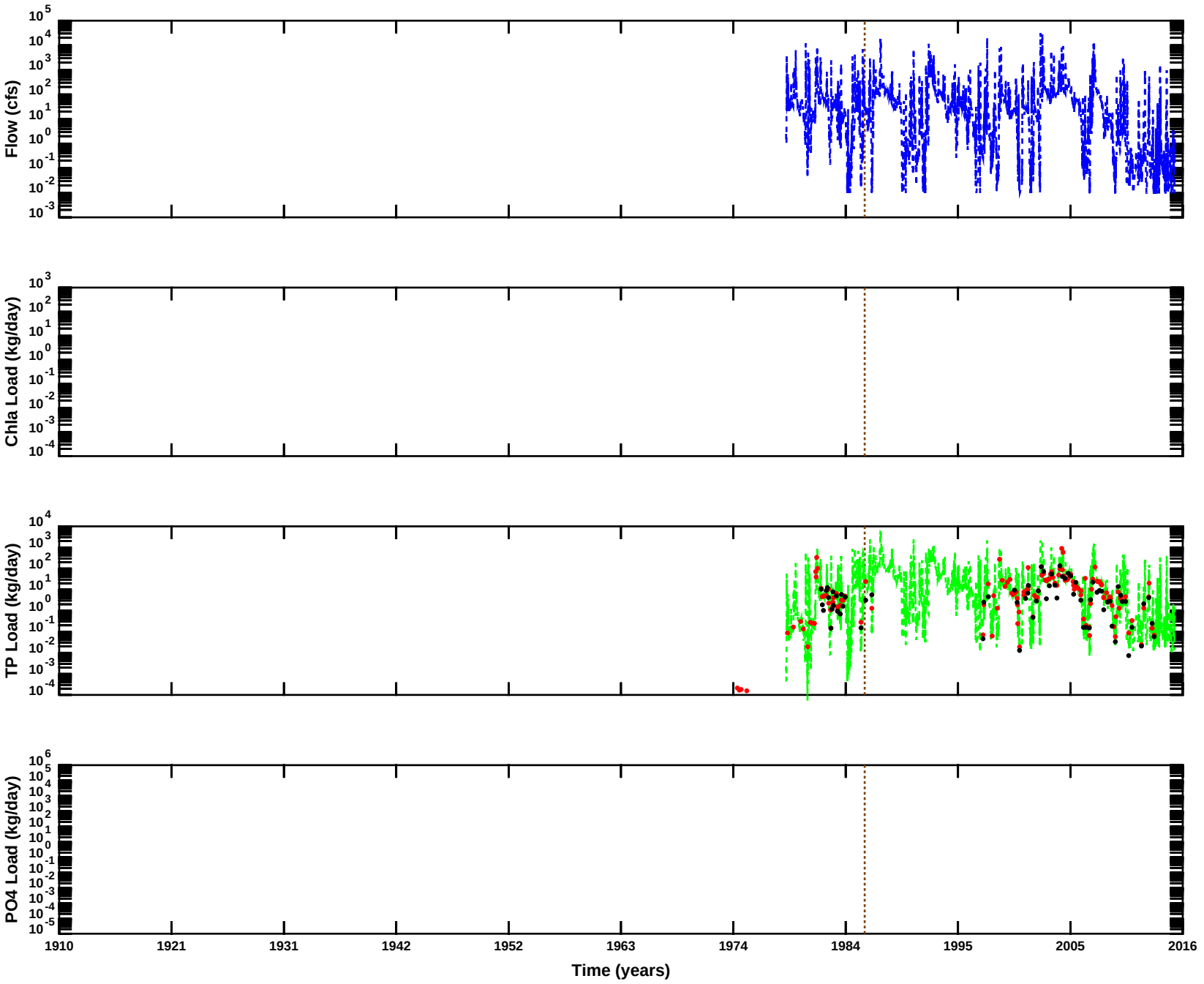
Observed Load vs. LOADEST Estimated Load, Station 13021
Nueces Tributaries, Texas (1910-2015)

- Observed Load
- LOADEST Estimated Load
- LOADEST Estimated Load from 8207000 USGS Flow
- Flow at 8207000 USGS station

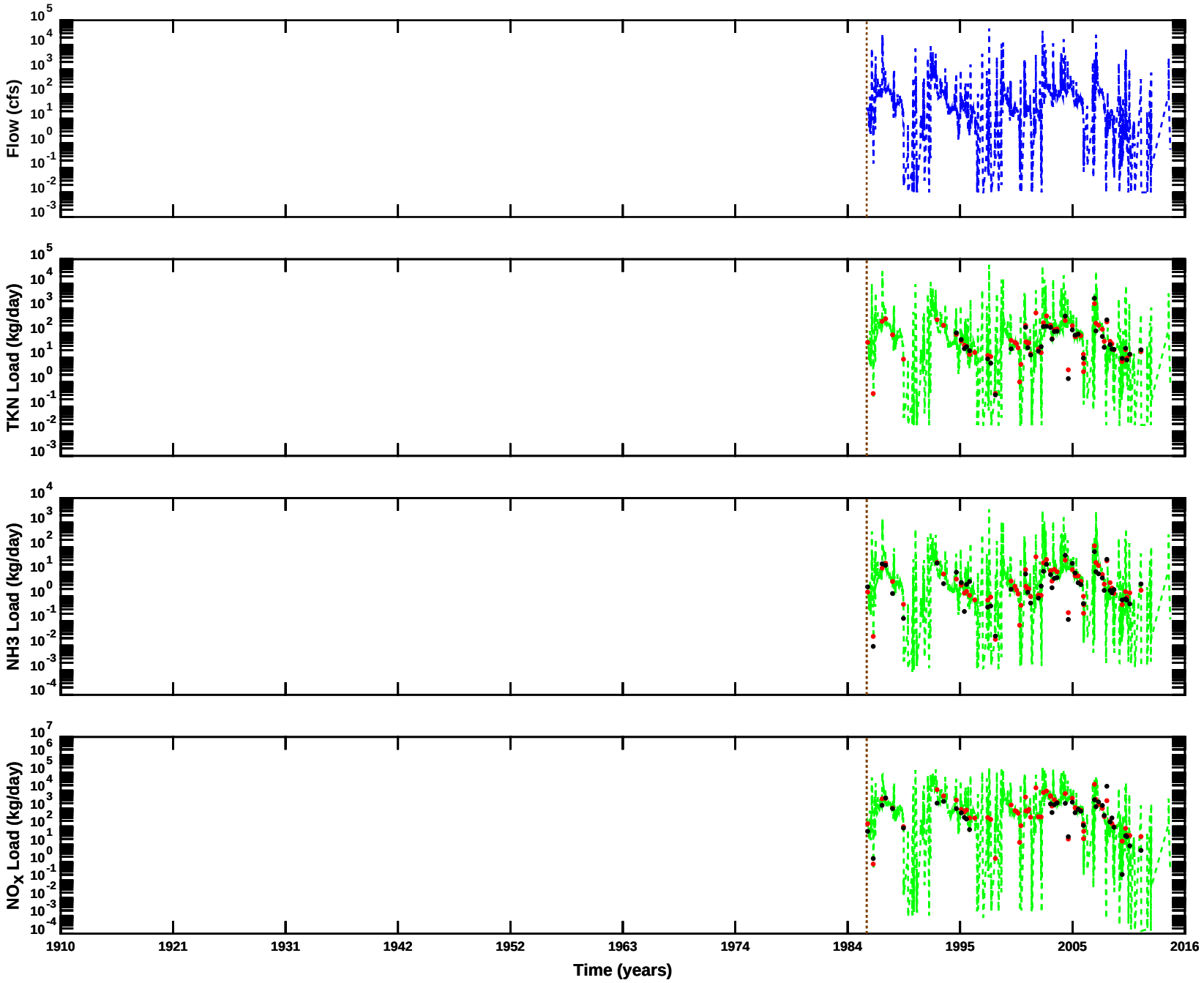


Observed Load vs. LOADEST Estimated Load, Station 13023
Nueces Tributaries, Texas (1910-2015)

- Observed Load
- LOADEST Estimated Load
- LOADEST Estimated Load from 8206600 USGS Flow
- Flow at 8206600 USGS station

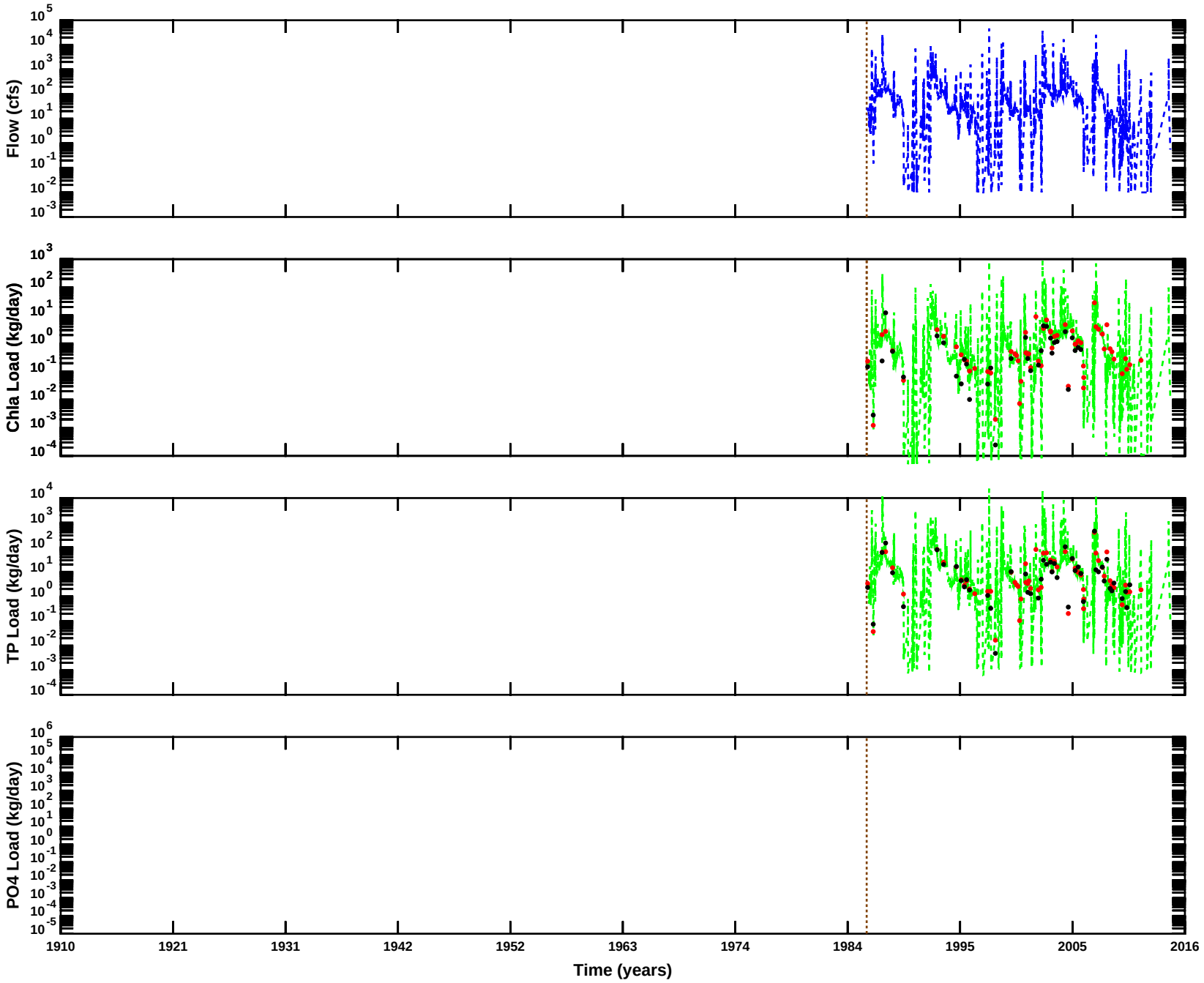


Observed Load vs. LOADEST Estimated Load, Station 13023
Nueces Tributaries, Texas (1910-2015)

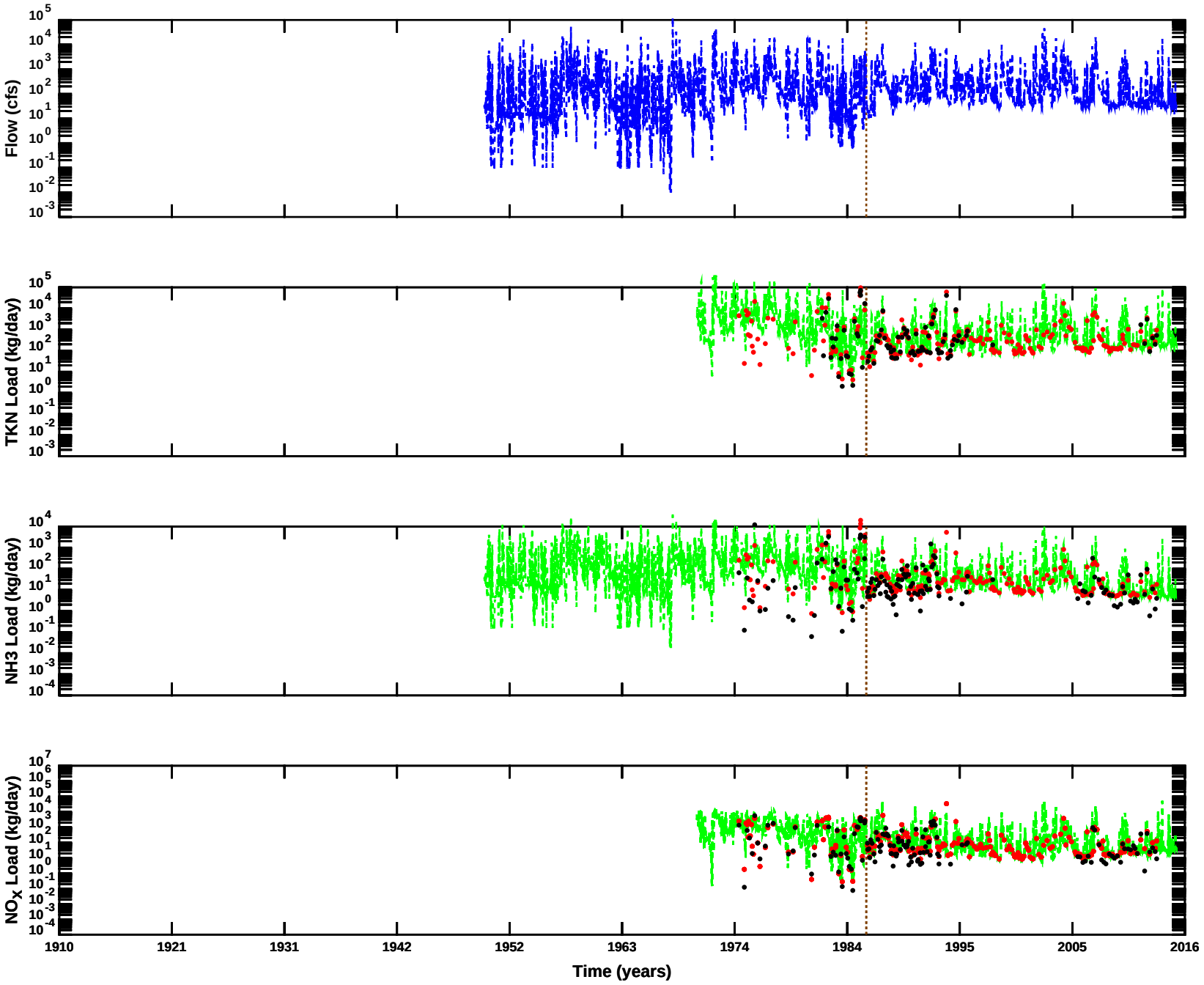


Observed Load vs. LOADEST Estimated Load, Station 13024
Nueces Tributaries, Texas (1910-2015)

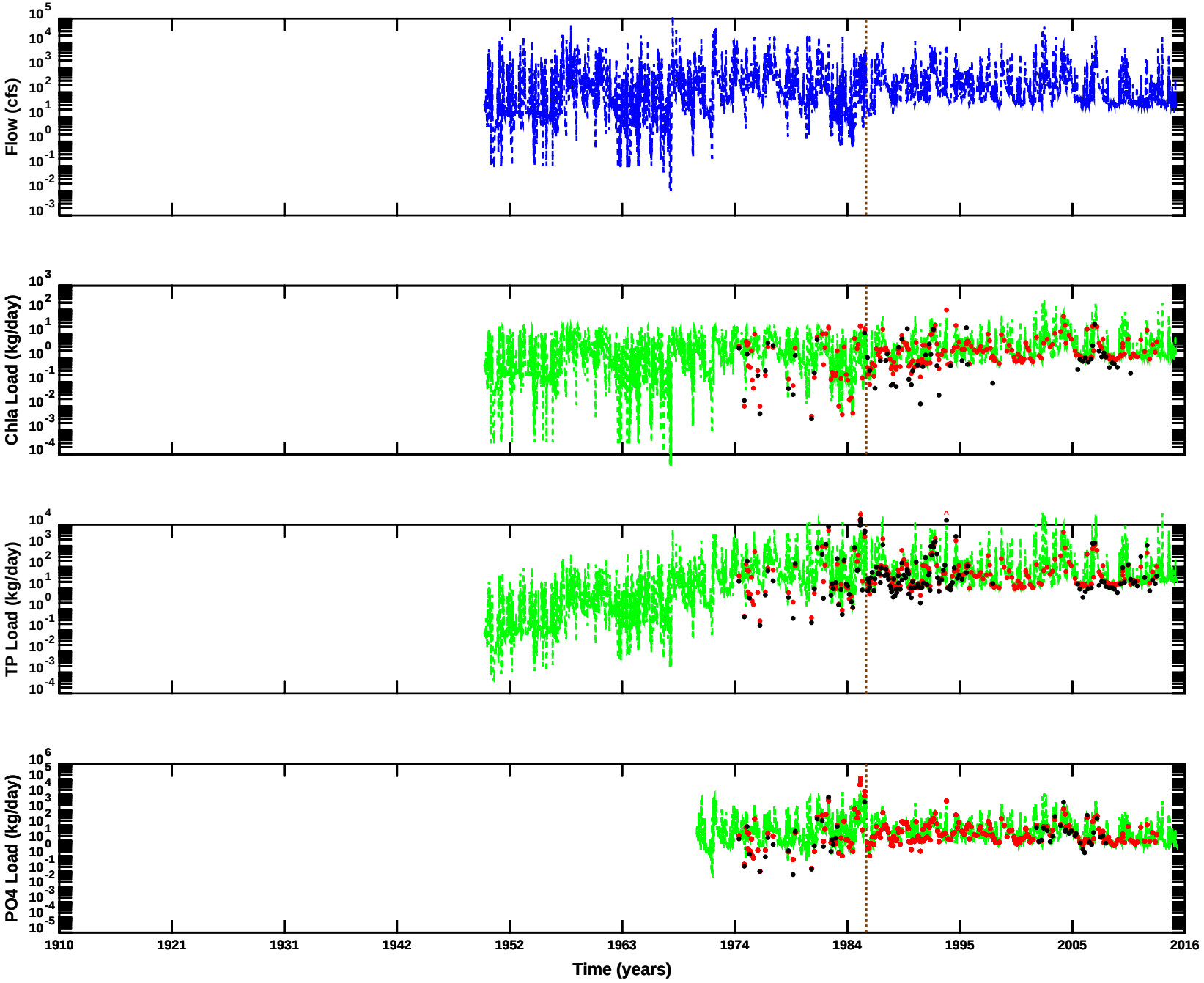
- Observed Load
- LOADEST Estimated Load
- LOADEST Estimated Load from 8205500 USGS Flow
- Flow at 8205500 USGS station



Observed Load vs. LOADEST Estimated Load, Station 13024
Nueces Tributaries, Texas (1910-2015)

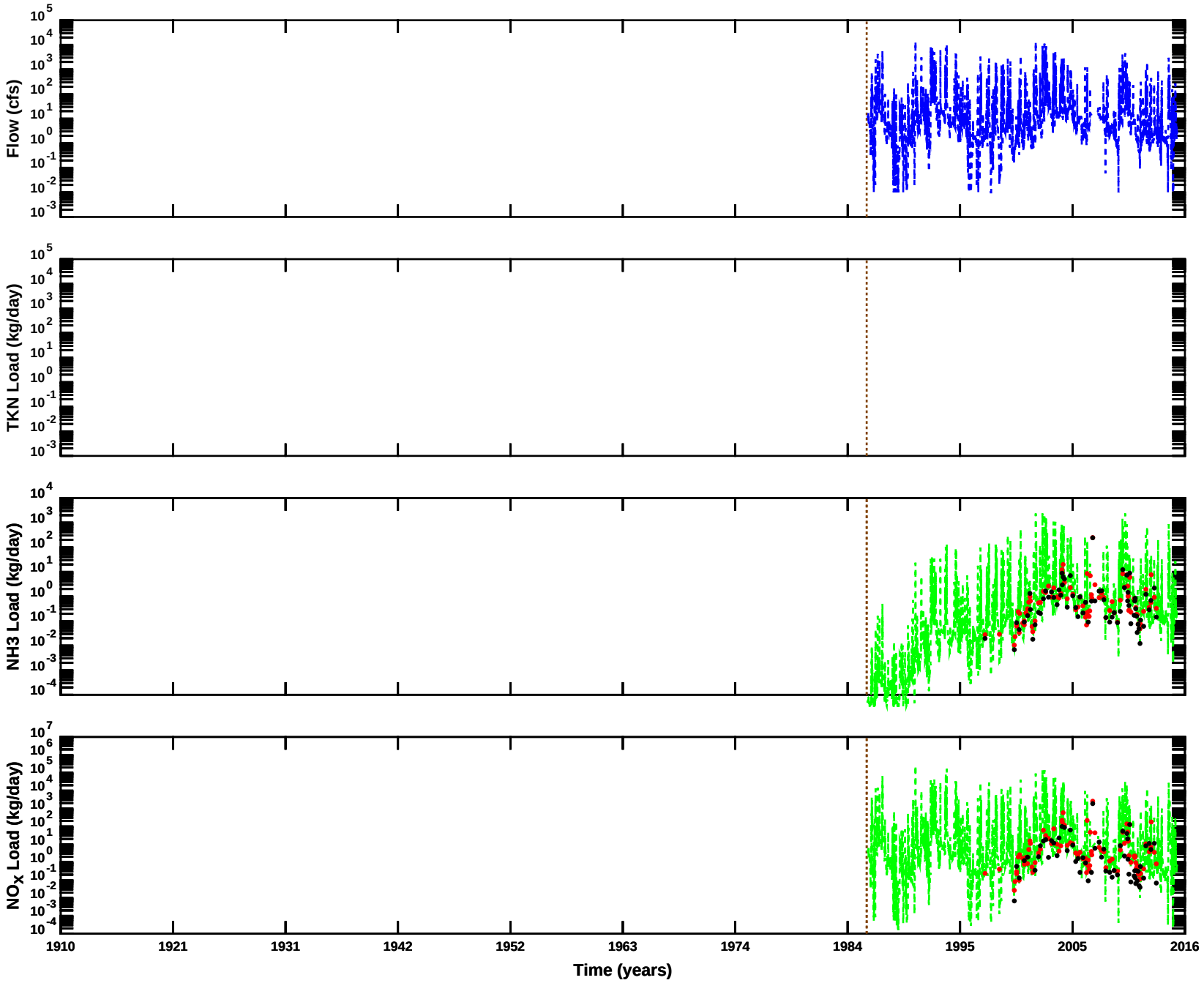


Observed Load vs. LOADEST Estimated Load, Station 12979
Nueces Tributaries, Texas (1910-2015)

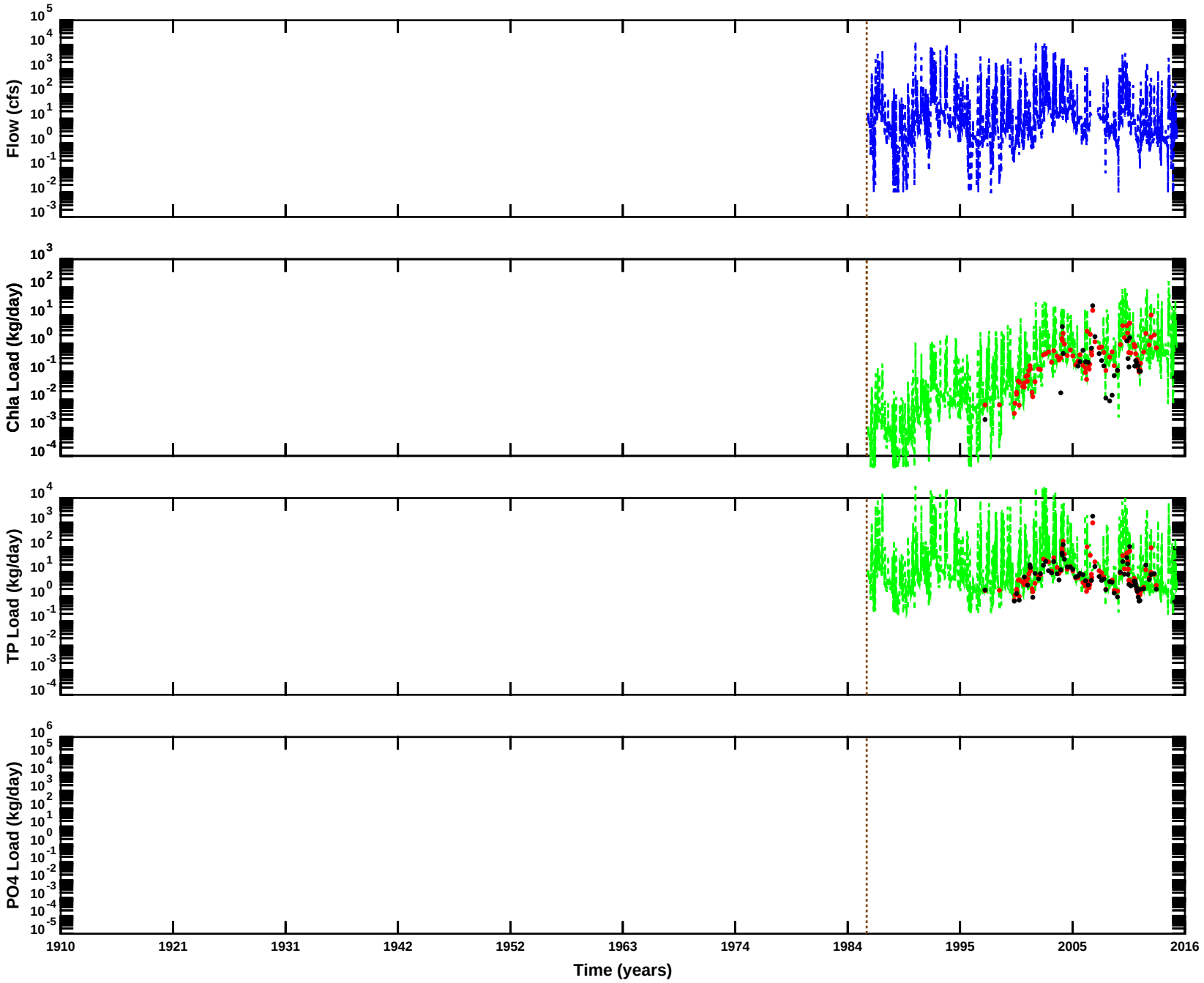


Observed Load vs. LOADEST Estimated Load, Station 12979
Nueces Tributaries, Texas (1910-2015)

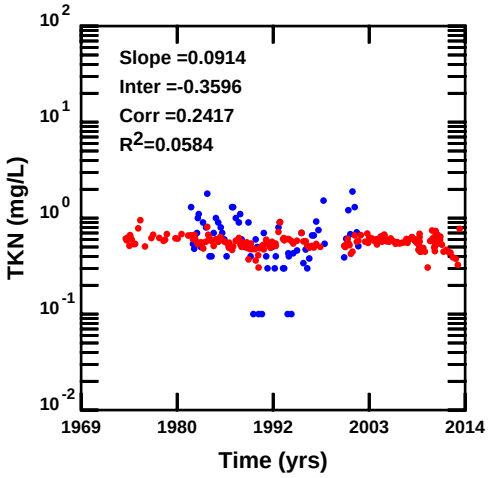
- Observed Load
- LOADEST Estimated Load
- LOADEST Estimated Load from 8210000 USGS Flow
- Flow at 8210000 USGS station

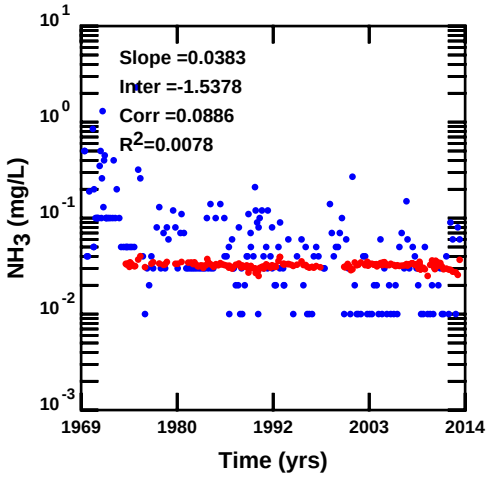


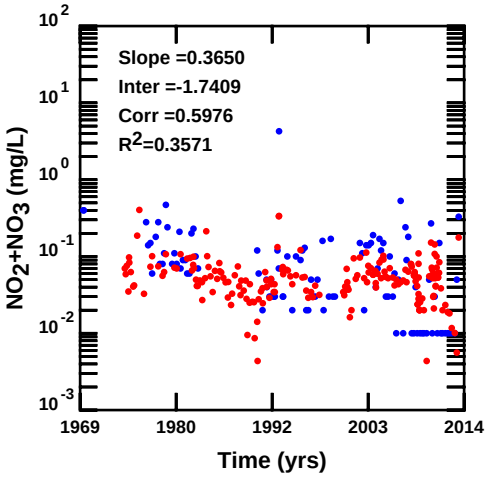
Observed Load vs. LOADEST Estimated Load, Station 12980 Nueces Tributaries, Texas (1910-2015)

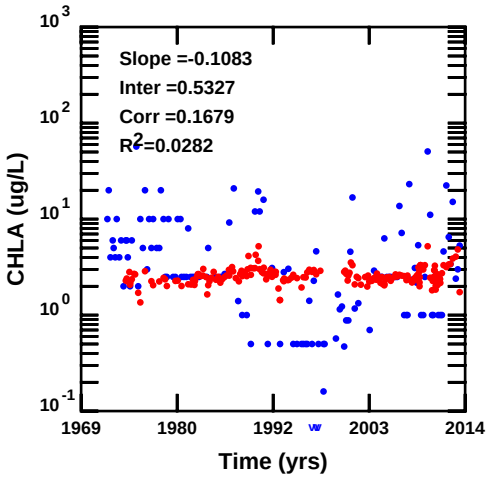


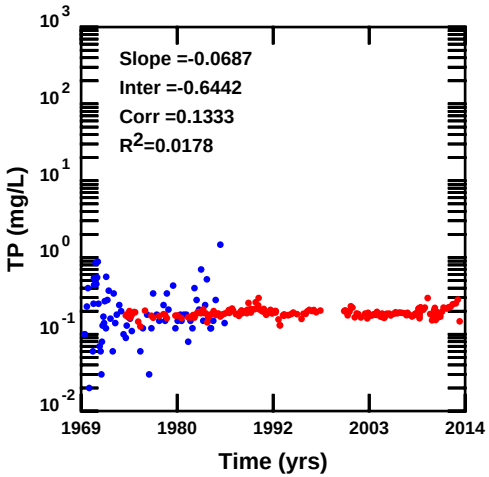
Observed Load vs. LOADEST Estimated Load, Station 12980 Nueces Tributaries, Texas (1910-2015)

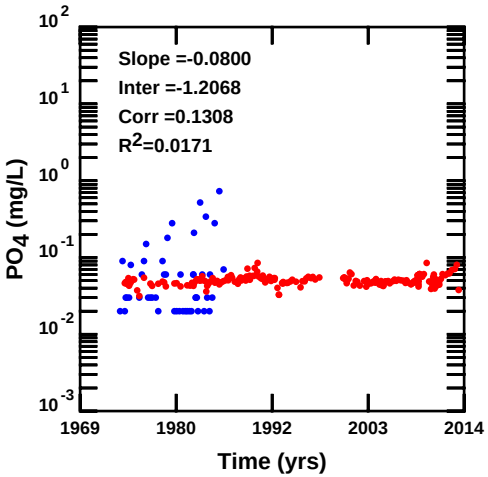


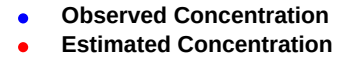






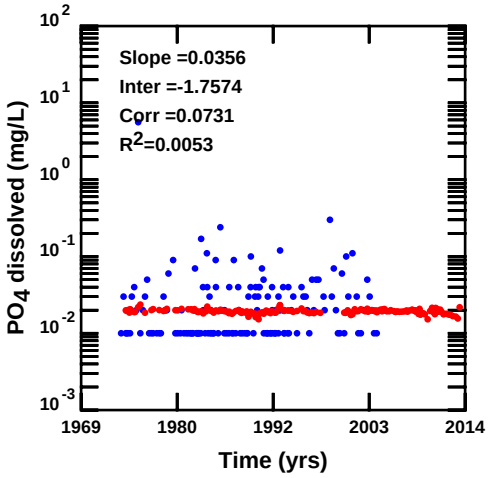


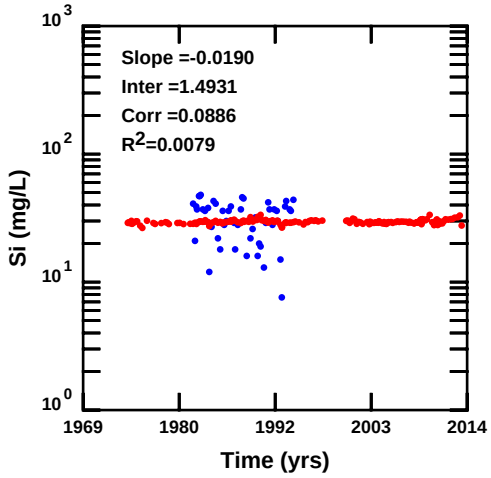


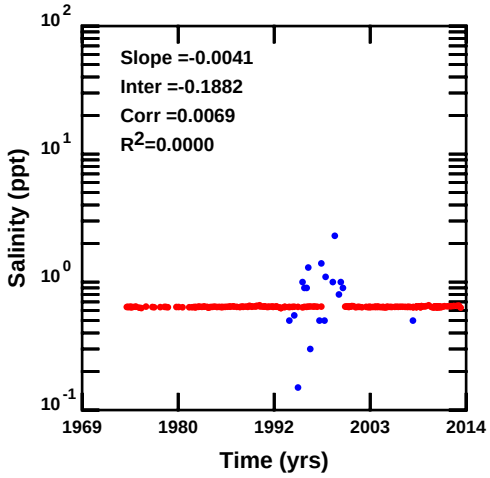


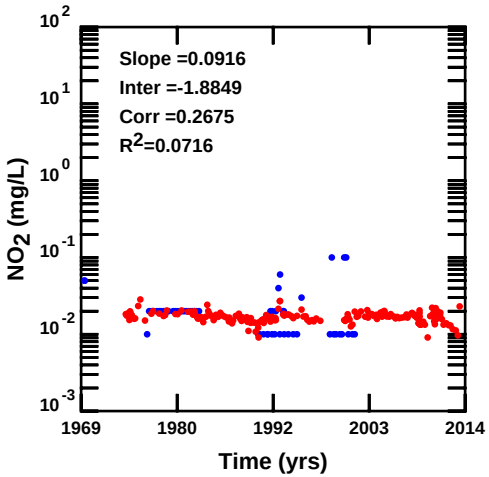
Nutrients Distribution, Station 12944

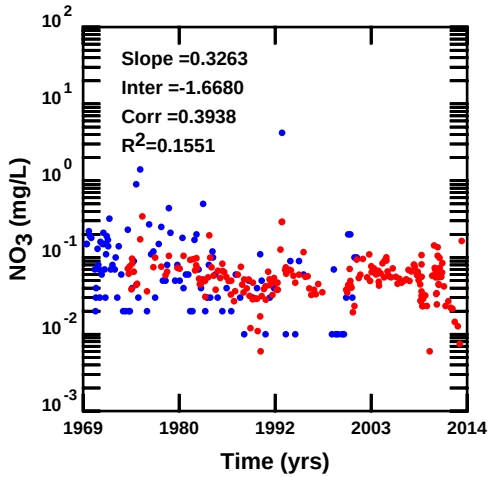
Basin 20, Texas (1969-2014)

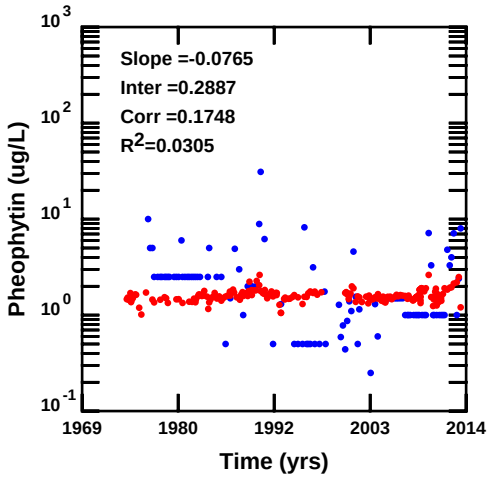








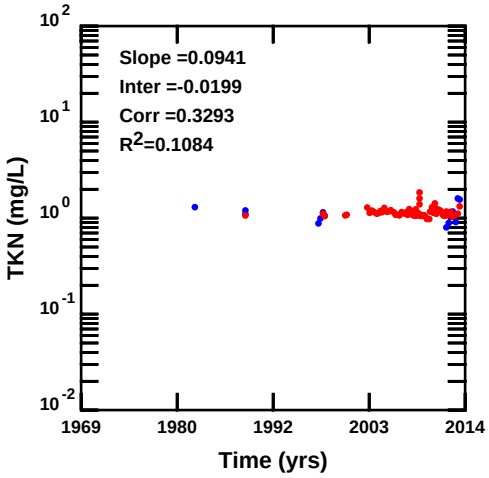


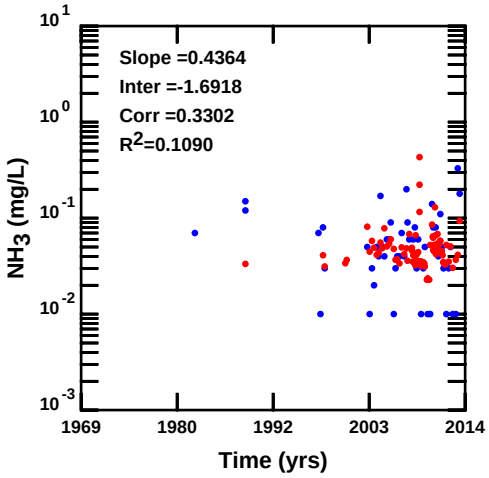


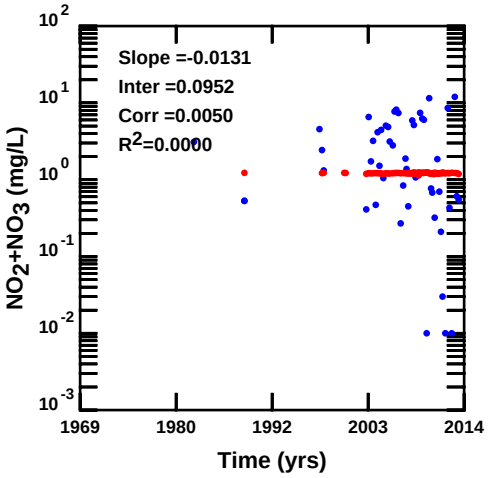
Observed Concentration
Estimated Concentration

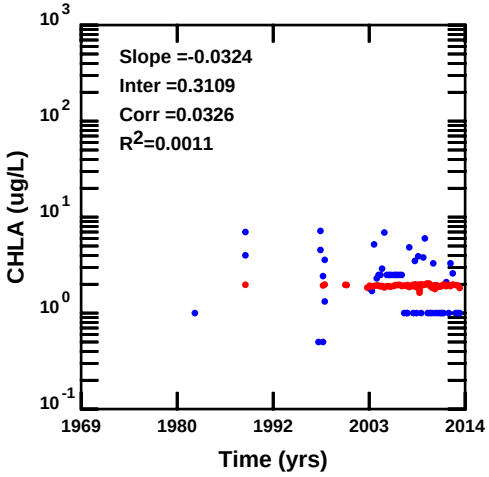
Nutrients Distribution, Station 12944

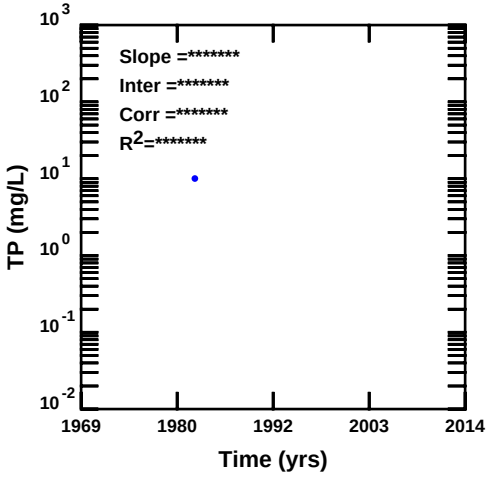
Basin 20, Texas (1969-2014)

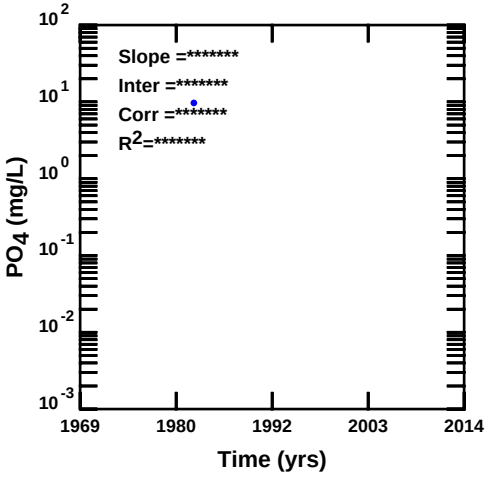


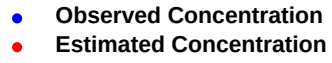






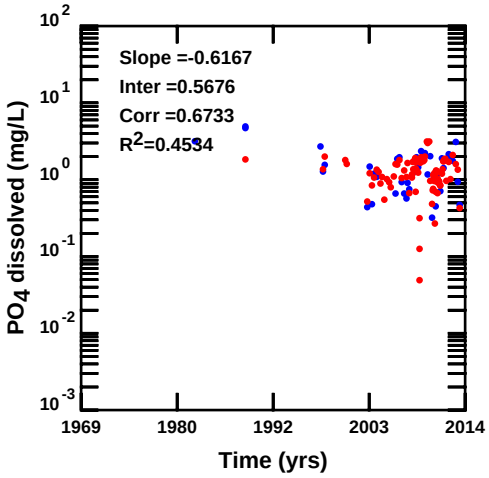


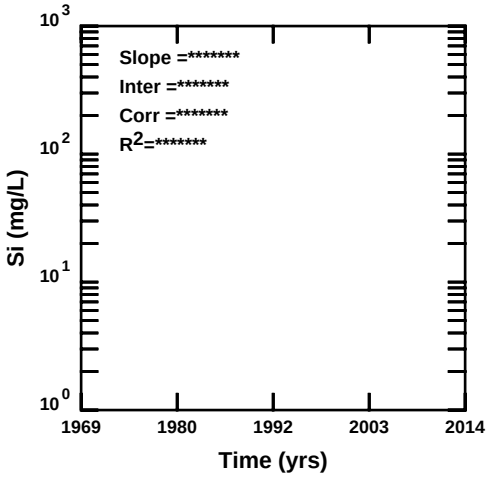


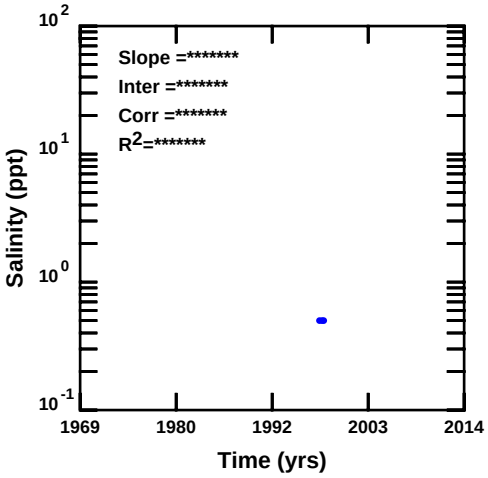


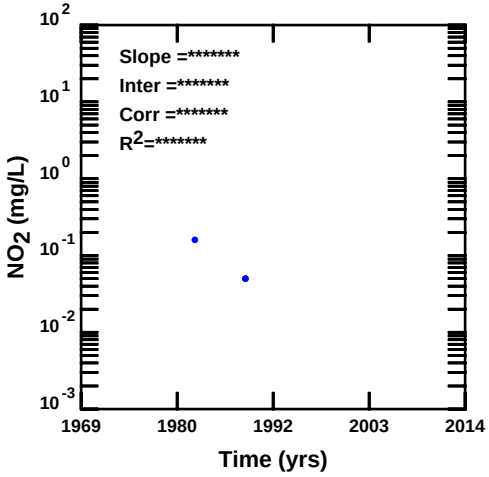
Nutrients Distribution, Station 12952

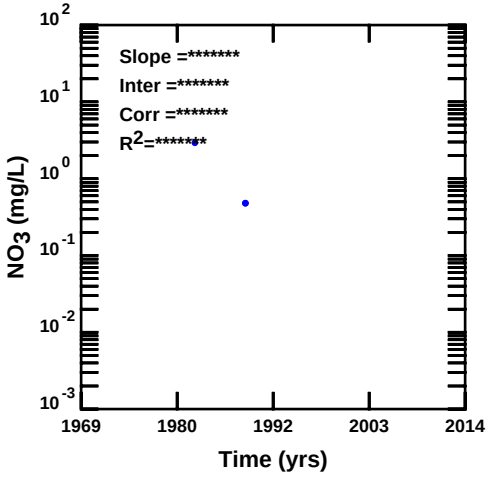
Basin 20, Texas (1969-2014)

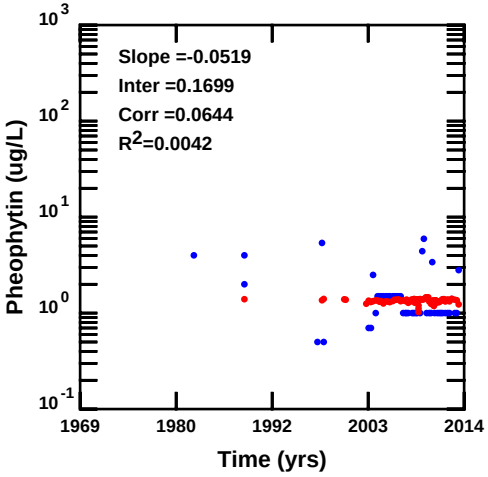








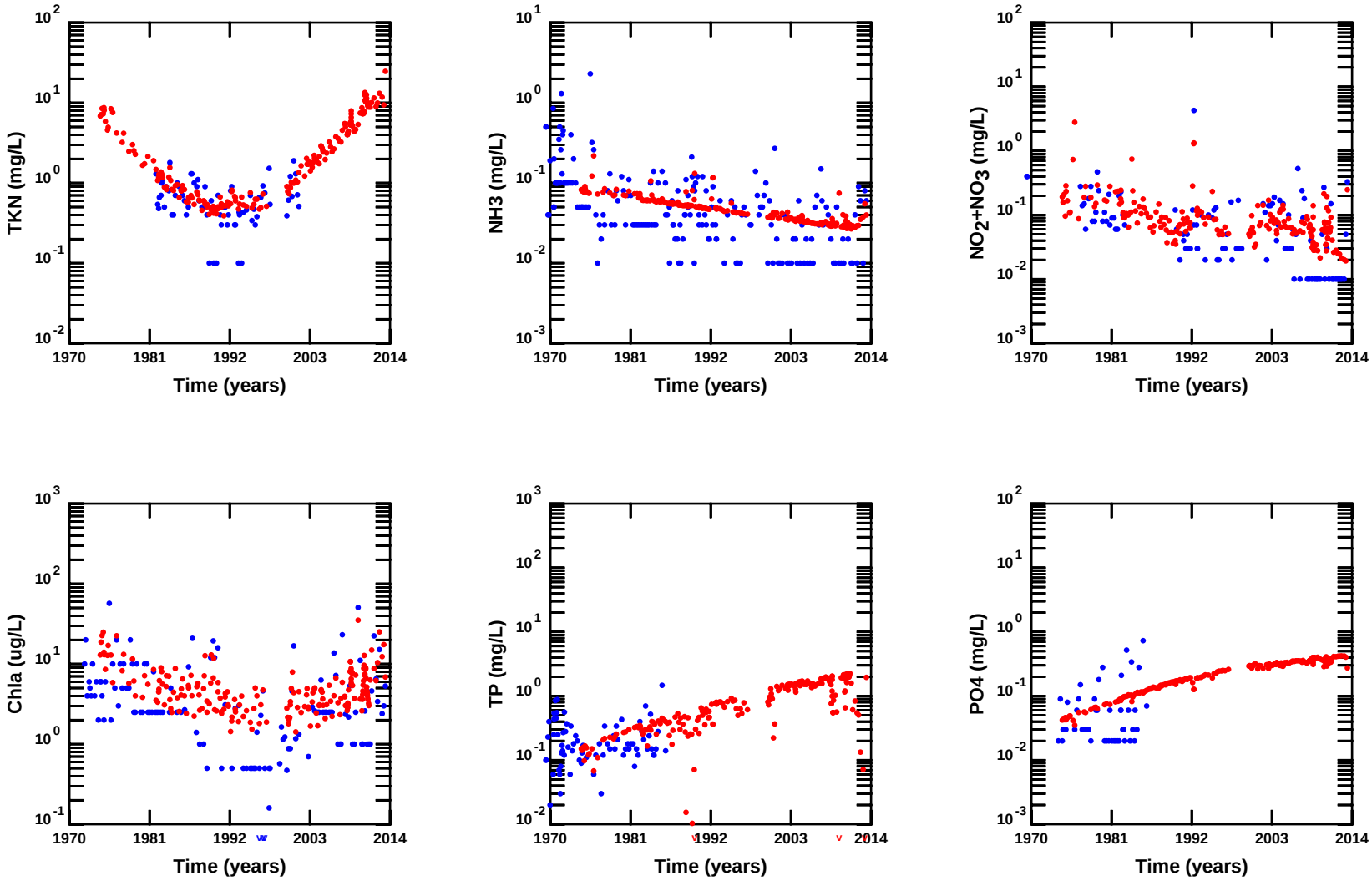




Observed Concentration
Estimated Concentration

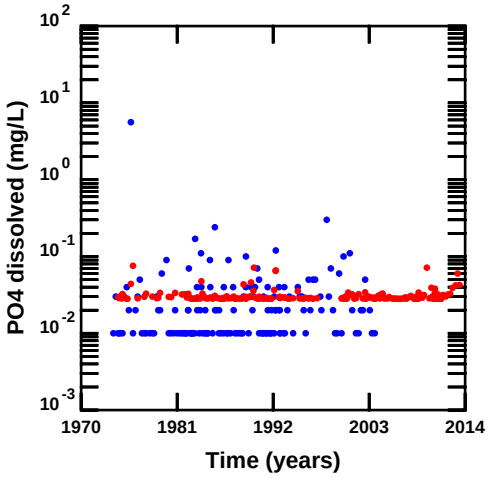
Nutrients Distribution, Station 12952

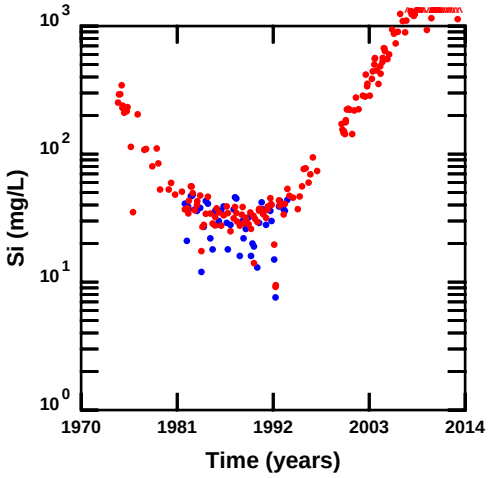
Basin 20, Texas (1969-2014)

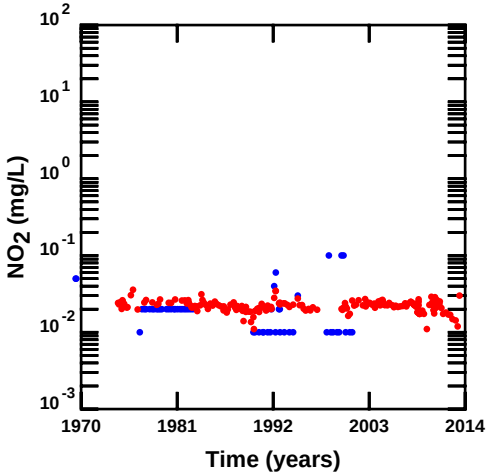


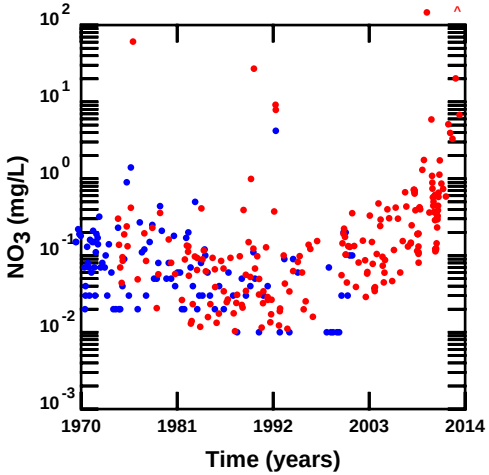
Observed Data vs. Loadest Estimated Concentration, Station 12944

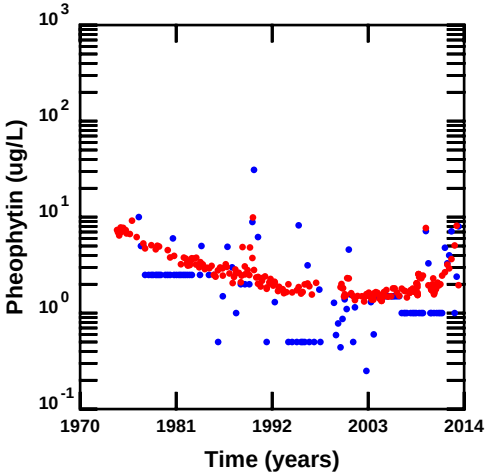
Basin 20, Texas (1970-2014)







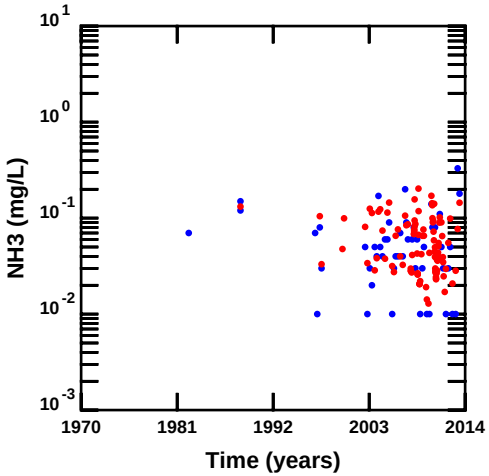


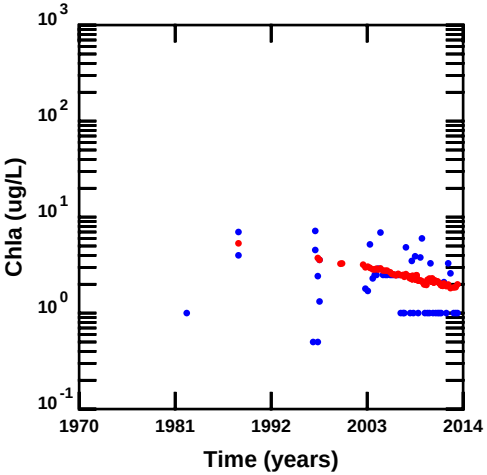


* Observed Concentration
* Loadest Estimated Concentration

Observed Data vs. Loadest Estimated Concentration, Station 12944

Basin 20, Texas (1970-2014)

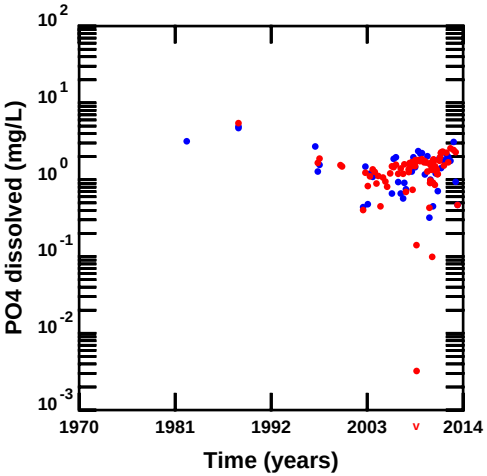


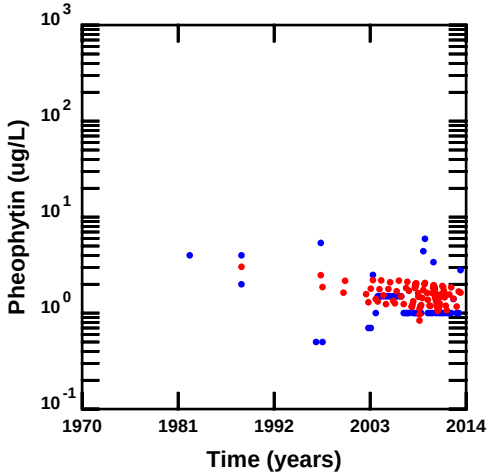


* Observed Concentration
* Loadest Estimated Concentration

Observed Data vs. Loadest Estimated Concentration, Station 12952

Basin 20, Texas (1970-2014)

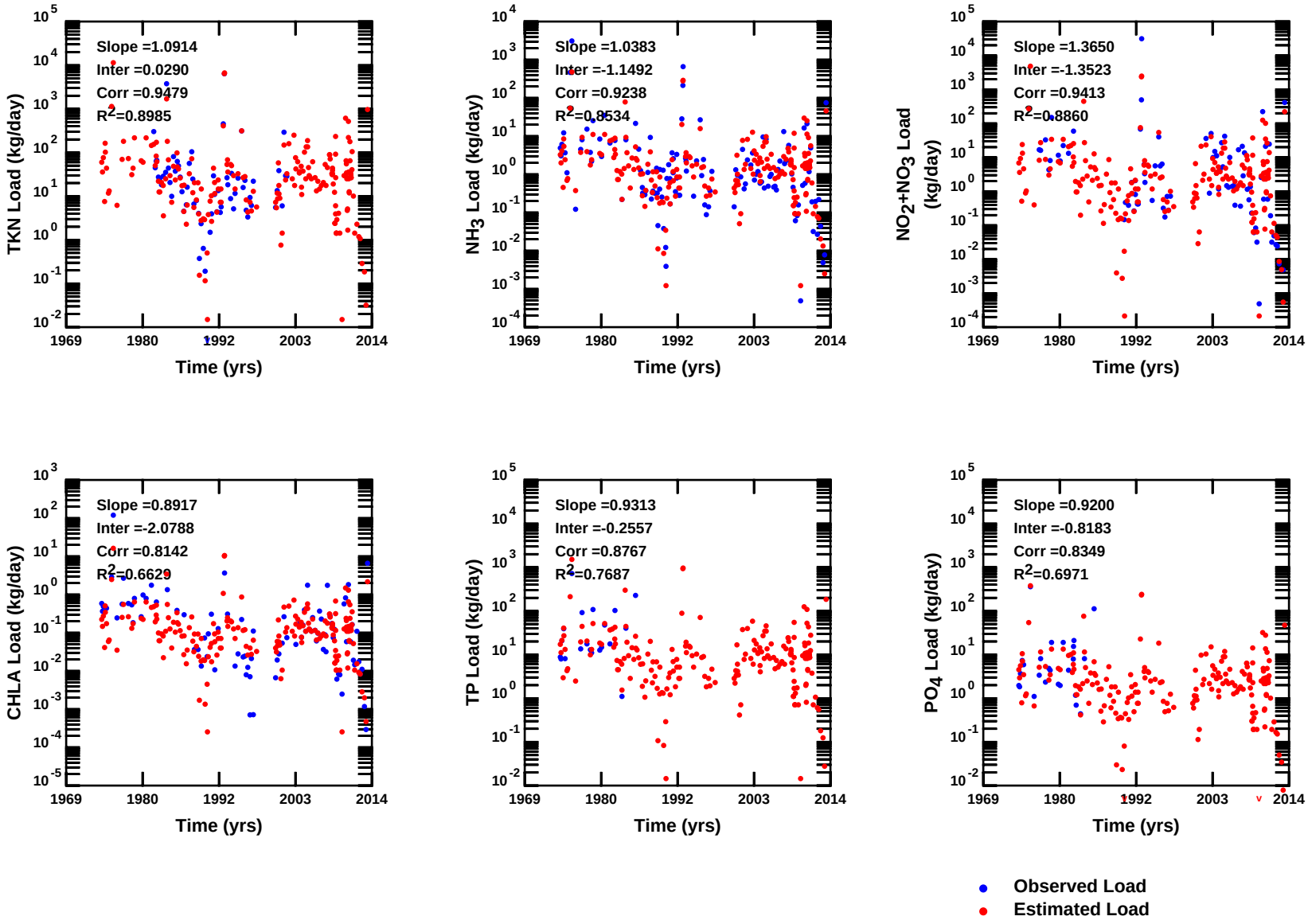




* Observed Concentration
* Loadest Estimated Concentration

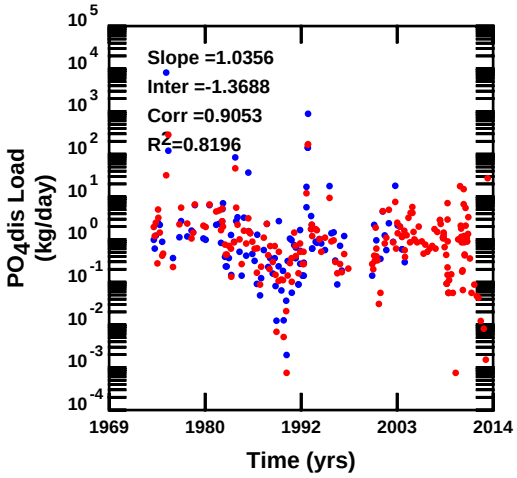
Observed Data vs. Loadest Estimated Concentration, Station 12952

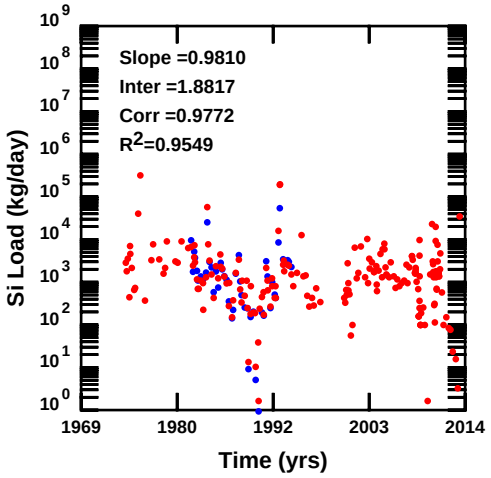
Basin 20, Texas (1970-2014)

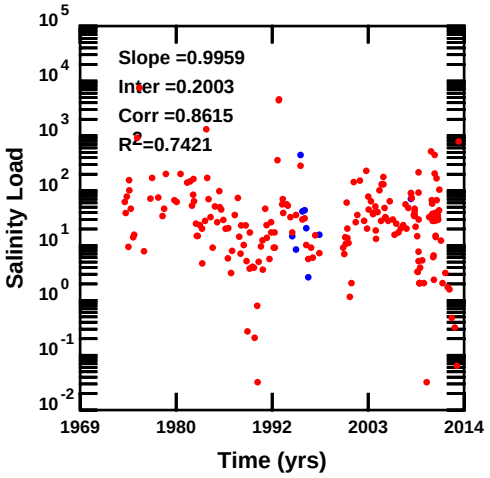


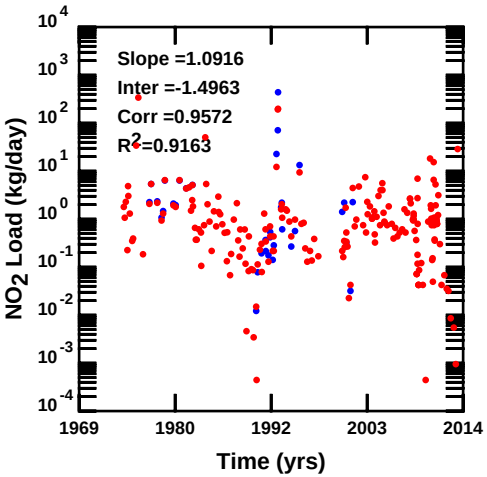
Nutrients Distribution, Station 12944

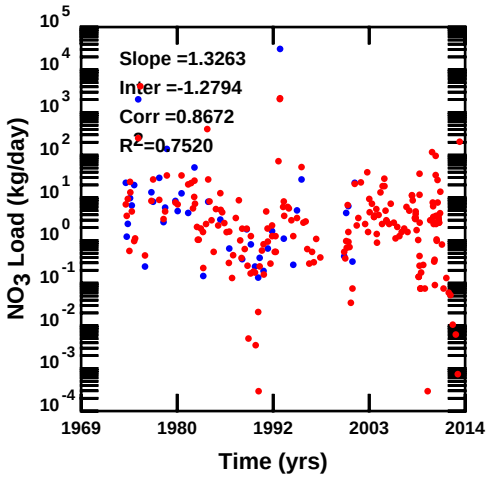
Basin 20, Texas (1969-2014)

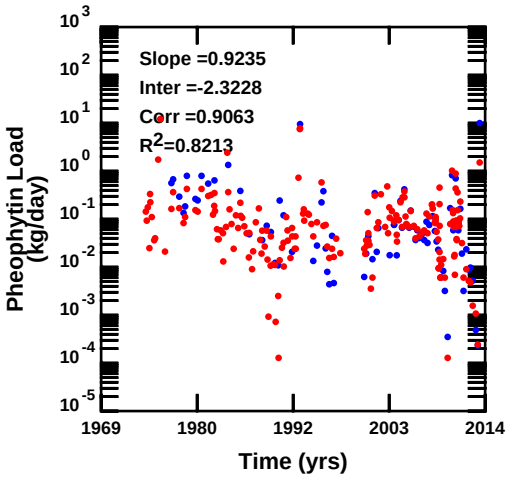






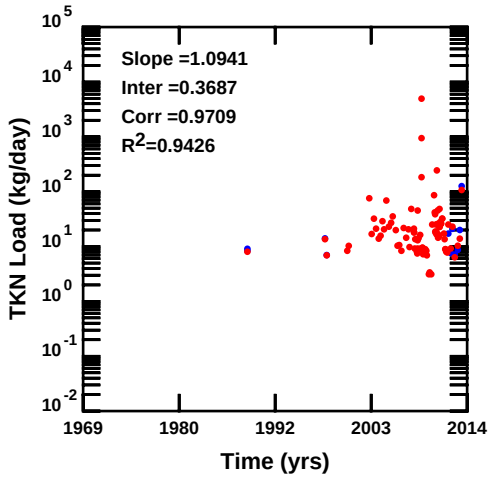


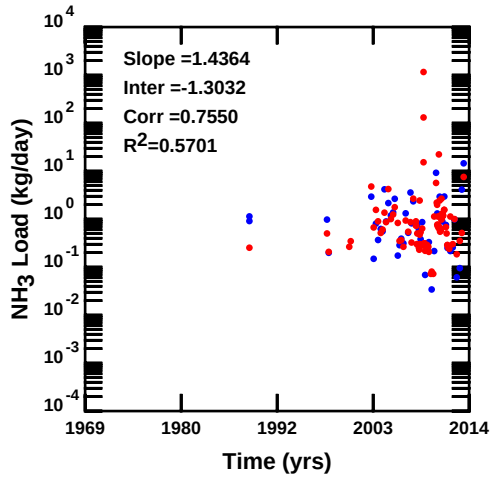


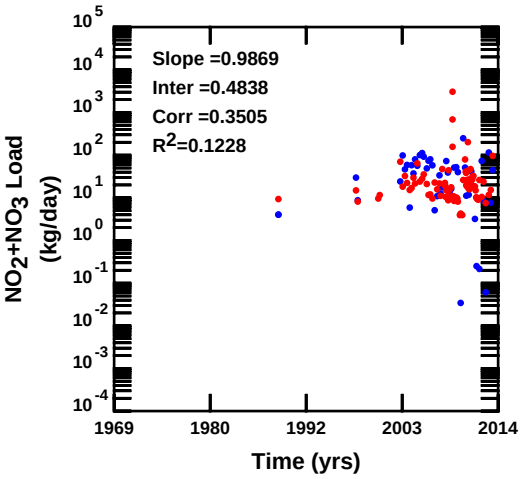


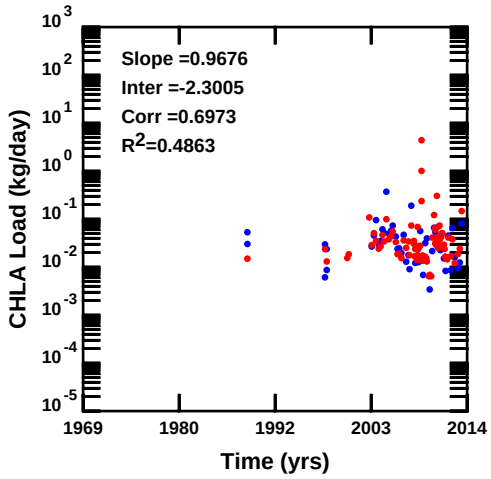
Nutrients Distribution, Station 12944

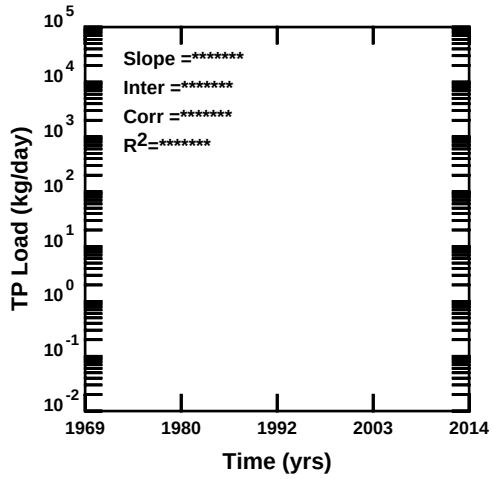
Basin 20, Texas (1969-2014)

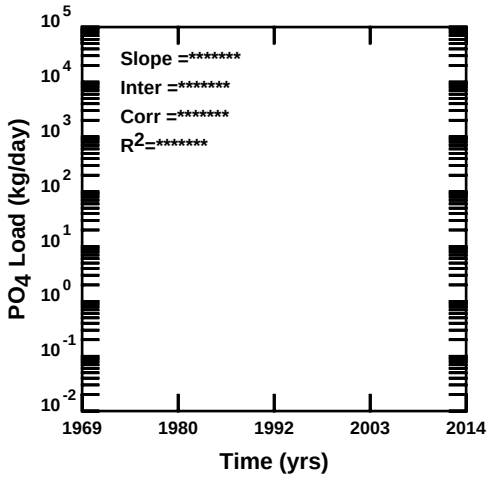






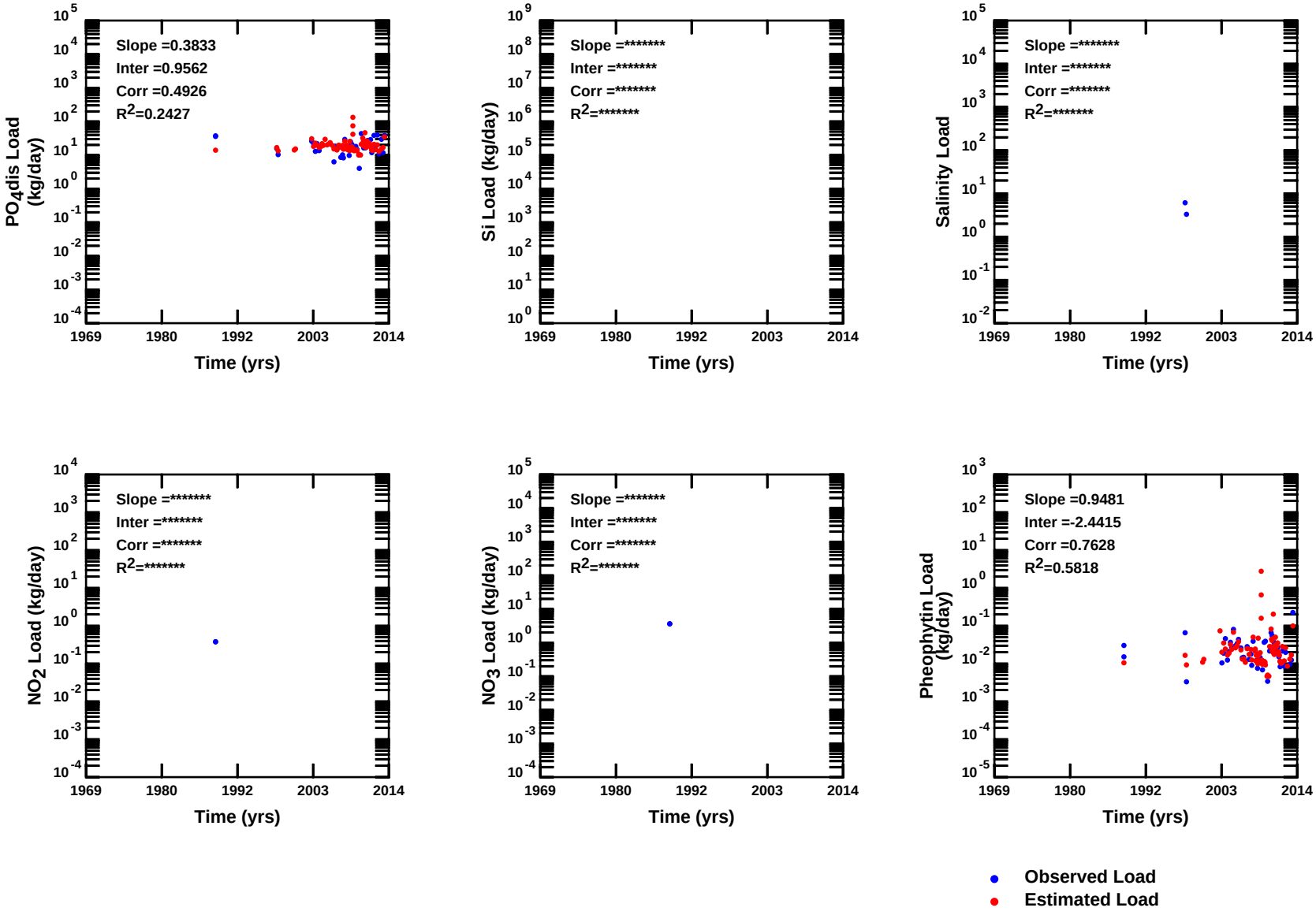






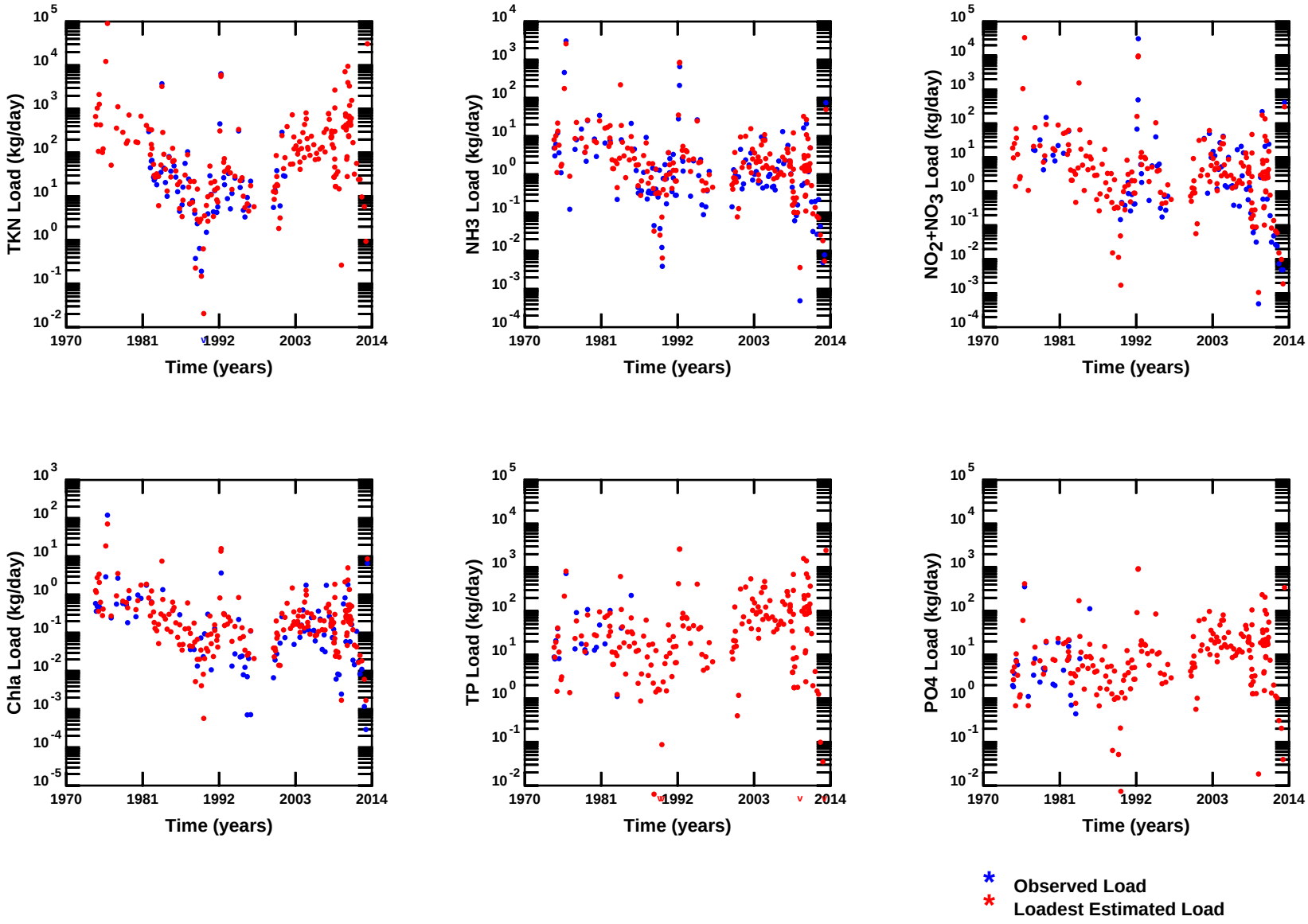
Nutrients Distribution, Station 12952

Basin 20, Texas (1969-2014)



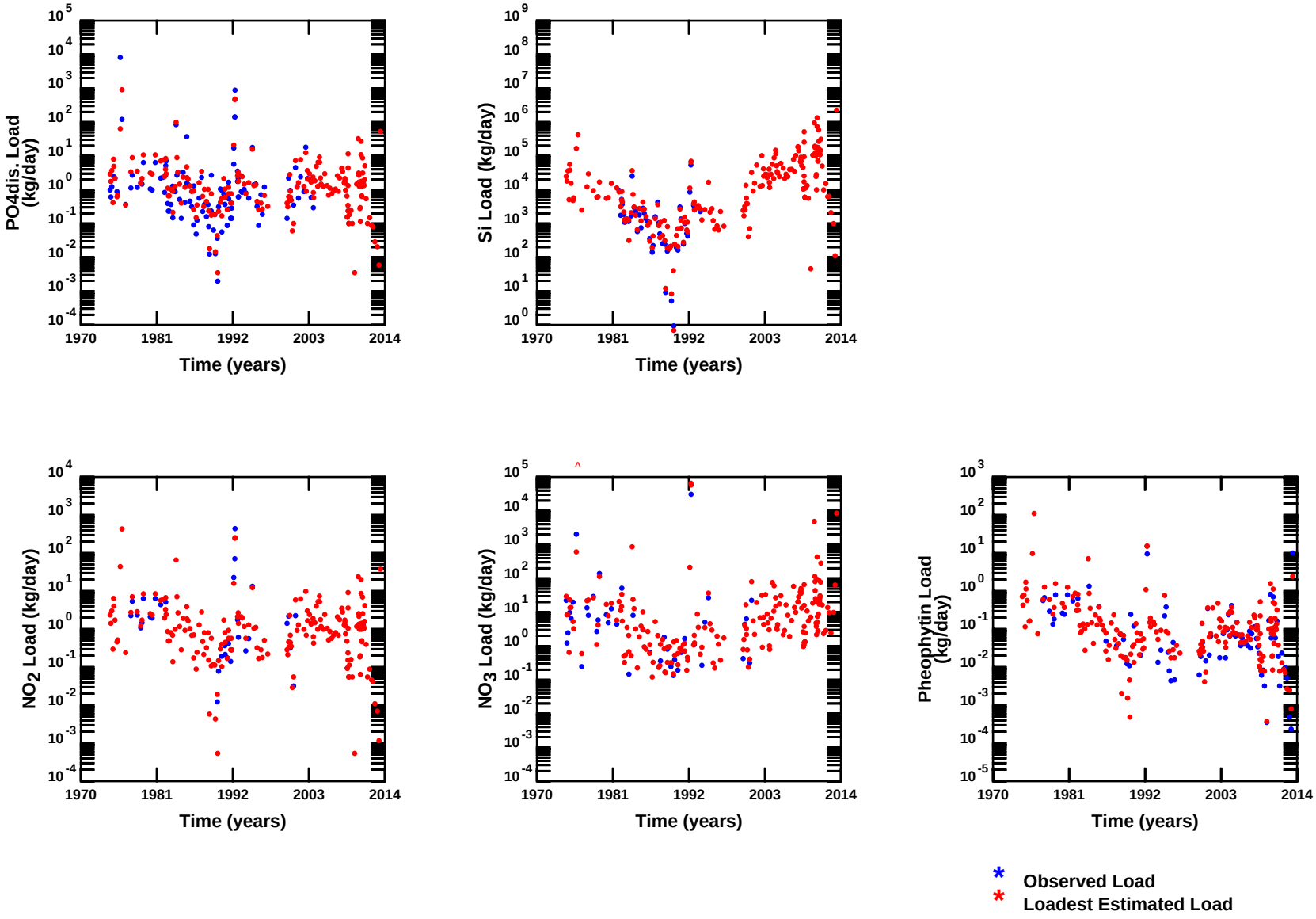
Nutrients Distribution, Station 12952

Basin 20, Texas (1969-2014)



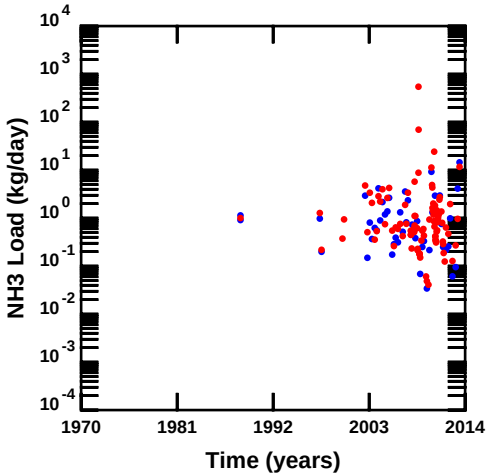
Observed Load vs. Loadest Estimated Load, Station 12944

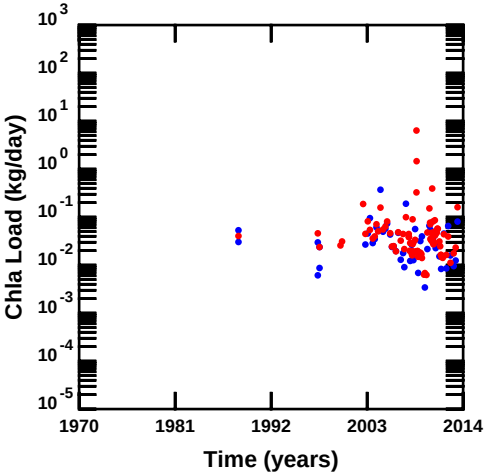
Basin 20, Texas (1970-2014)



Observed Data vs. Loadest Estimated Load, Station 12944

Basin 20, Texas (1970-2014)

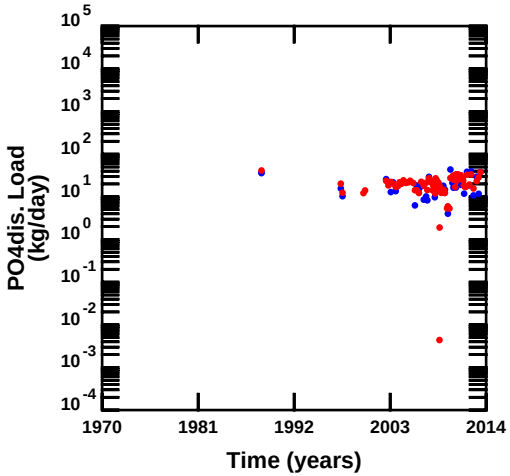


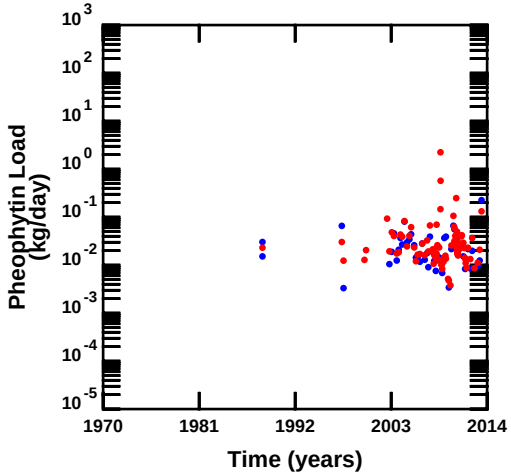


* Observed Load
* Loadest Estimated Load

Observed Load vs. Loadest Estimated Load, Station 12952

Basin 20, Texas (1970-2014)





Observed Load
Loadest Estimated Load

Observed Data vs. Loadest Estimated Load, Station 12952

Basin 20, Texas (1970-2014)

Appendix F. Executive Administrator's draft report comments

Texas Water Development Board

P.O. Box 13231, 1700 N. Congress Ave.
Austin, TX 78711-3231, www.twdb.texas.gov
Phone (512) 463-7847, Fax (512) 475-2053

August 3, 2015

Ms. Paula Jo Lemonds
HDR Engineering, Inc.
4401 West Gate Blvd., Suite 400
Austin, Texas 78745

RE: Research Contract between the Texas Water Development Board (TWDB) and HDR Engineering, Inc. (HDR), TWDB Contract No. 1400011718, Draft Report Comments

Dear Ms. Lemonds:

Staff members of the TWDB and external reviewers have completed a review of the draft report prepared under the above-referenced contract. ATTACHMENT I provides the comments resulting from this review. In addition to these comments, please ensure that the cover page of the final report includes the following language:

PURSUANT TO SENATE BILL 1 AS APPROVED BY THE 83RD TEXAS LEGISLATURE, THIS STUDY REPORT WAS FUNDED FOR THE PURPOSE OF STUDYING ENVIRONMENTAL FLOW NEEDS FOR TEXAS RIVERS AND ESTUARIES AS PART OF THE ADAPTIVE MANAGEMENT PHASE OF THE SENATE BILL 3 PROCESS FOR ENVIRONMENTAL FLOWS ESTABLISHED BY THE 80TH TEXAS LEGISLATURE. THE VIEWS AND CONCLUSIONS EXPRESSED HEREIN ARE THOSE OF THE AUTHOR(S) AND DO NOT NECESSARILY REFLECT THE VIEWS OF THE TEXAS WATER DEVELOPMENT BOARD.

As stated in the TWDB contract, HDR will consider revising the final report in response to comments from the Executive Administrator and other reviewers. In addition, HDRA will include a copy of the Executive Administrator's draft report comments in the Final Report.

The TWDB looks forward to receiving one (1) electronic copy of the entire Final Report in Portable Document Format (PDF) and six (6) bound double-sided copies. **Please further note, that in compliance with Texas Administrative Code Chapters 206 and 213 (related to Accessibility and Usability of State Web Sites), the digital copy of the final report must comply with the requirements and standards specified in statute. For more information, visit http://www.sos.state.tx.us/tac/index.shtml.** If you have any questions on accessibility, please contact David Carter with the Contract Administration Division at (512) 936-6079 or David.Carter@twdb.texas.gov

HDR shall also submit one (1) electronic copy of any computer programs or models, and, if applicable, an operations manual developed under the terms of this Contract.

If you have any questions concerning the contract, please contact Caimee Schoenbaechler, the TWDB's designated Contract Manager for this project at (512) 463-3128.

Sincerely,

Robert E. Mace, Ph.D., P.G.
Deputy Executive Administrator
Water Science and Conservation

Enclosures

c: Caimee Schoenbaechler, TWDB

Nueces Watershed Pre- and Post-Development Nutrient Budgets

Paula Jo Lemonds, P.E., P.G.
Contract #1400011718
TWDB/BBASC Comments to Final Report

REQUIRED CHANGES

General Draft Final Report Comments:

Please add the following statement to the cover page of the final report:
PURSUANT TO SENATE BILL 1 AS APPROVED BY THE 83RD TEXAS LEGISLATURE, THIS STUDY REPORT WAS FUNDED FOR THE PURPOSE OF STUDYING ENVIRONMENTAL FLOW NEEDS FOR TEXAS RIVERS AND ESTUARIES AS PART OF THE ADAPTIVE MANAGEMENT PHASE OF THE SENATE BILL 3 PROCESS FOR ENVIRONMENTAL FLOWS ESTABLISHED BY THE 80TH TEXAS LEGISLATURE. THE VIEWS AND CONCLUSIONS EXPRESSED HEREIN ARE THOSE OF THE AUTHOR(S) AND DO NOT NECESSARILY REFLECT THE VIEWS OF THE TEXAS WATER DEVELOPMENT BOARD.

This study scope of work focused on quantifying nutrient loading to Nueces Bay both for the pre-development and present condition. The goal of this study was to quantify and better understand the changes that have occurred over time in nutrient loading to the bay from a watershed perspective. The draft report adequately meets the tasks identified in the scope of work.

Please check the document thoroughly for grammar, spelling, and typographical errors.

Please ensure that all figure titles are self-explanatory and include a description of all elements presented in the figure. When reporting results, please be sure to cite the plot to which the stated result refers.

Please ensure distinct and consistent use of ammonium (NH_4) and ammonia (NH_3) throughout the report.

Specific Draft Final Report Comments:

1. Common abbreviations, page 11: Please change NH_4 to Ammonium, instead of Ammonia (NH_3).

2. Executive Summary, page 12, 3rd ¶: The reference to TWDB 2015b cites the TWDB coastal hydrology website. Please cite the publication from which the reported statistic came.

3. Executive Summary, page 12, *Study Area*: Please change the (TWDB, 2015) citation to (TWDB, 2015a).

4. Executive Summary, page 16, 1st full sentence: The statement, "To understand nutrient balances and biological productivity in Nueces Bay, nutrient fate and transport in the upstream watershed must be understood," is confusing after Conclusion #1 states that the upper reaches of the watershed have a relatively small effect on nutrient deliveries to Nueces Bay. Please add clarification.

5. Section 2.1.1, page 18: Please spell out 'DO' the first time it is mentioned in the text.

6. Section 2.1.1, page 18 (and various other locations throughout the report): Please correct the capitalization from "Nueces, Frio, and Sabinal Rivers" to Nueces, Frio, and Sabinal **r**ivers."

7. Section 3.1, page 20: Please clarify that Figures 5.2.1 thru 5.2.6 in the BBEST report are presented in this report as Figures 3-1 thru 3-6, respectively.

8. Section 3.2, page 28, 2nd ¶: Section 5.2 of the 2012 BBASC Report is cited, but the information described is found in Section 4.2 of the 2012 BBASC Report. Please make this correction.

9. Section 3.3, page 30: Please make a note that Figure 4 as referenced in the BBASC report is presented as Figure 3-7 in this report.

10. Section 4.2, Page 33, 2nd ¶: Please correct 'Coastal Bend Bays & Estuary Program (CBBEP)' to 'Coastal Bend Bays & **Estuaries** Program (CBBEP).'

11. Section 4.2, page 33 – 34: Please add a summary of the June 22, 2015 NEAC meeting.

12. Section 5, page 34, 1st ¶: HRI was previously defined. Please use only the acronym after it has been defined once.

13. Section 5.1, page 34: Please refer to the TCEQ database as the Surface Water Quality Monitoring Information System (SWQMIS).

14. Section 5.1, page 35, last ¶: This paragraph describes the Rio-Grande - Nueces coastal watershed. Please correct "the primary rivers in the watershed are the Mission and Aransas Rivers" to "the primary streams in this watershed are the Oso, Petronila Creek, and San Fernando Creeks." Also, please list Nueces first when referring to the Rio-Grande - Nueces coastal watershed, becoming "Nueces – Rio Grande coastal watershed."

15. Section, 5.4, page 44: The 2013 Effluent Monitoring Report includes data for 2012 and 2013 which is referenced on page 45 and used for Table 5.1. Please change the '2012 Effluent Monitoring Report' to the '**2013** Effluent Monitoring Report."

16. Section 5.4.1, page 45, 2nd ¶: Please clarify whether the 54,000 ac-ft/yr of return flows is to Corpus Christi Bay proper, or to the entire Nueces Estuary.

17. Section 5.6, page 52: Please make the correction to the following text to: "Documentation of outliers and associated analysis is included in Appendix **D**."

18. Section 6.1, page 52: Please add "Initially Prepared Plan" to the 2016 Coastal Bend Regional Water Plan reference.

19. Section 6.2, page 54, 2nd ¶: Please revise the text, "The Rincon pipeline and pump station does not operated continuously" to "The Rincon pipeline and pump station does not **operate** continuously."

20. Section 7.2, page 56: Please clarify whether all TCEQ stations have data for the same period of record (1970 – 2015), or if period of record varies. In the last two sentences, Table 7-2 lists 37 stations, not 47. Please make the correction in the text.

21. Section 7.3, page 59: Please include a statement or discussion on why the furthest downstream TCEQ Station 12964 was not used in the analysis.

22. Section 7.3.2, page 76: The most downstream station 12979 is influenced by the Frio and Atascosa Rivers, as discussed in Section 7.8.1. Please clarify this point, and/or report on the results from the most downstream station which is not influenced by these rivers (Station 12973).

23. Section 7.3.2, page 76, last sentence: Please make the distinction that "observed loads" are calculated loads based on observed/measured concentrations, and consider making a note that the figures use the term "observed load" for brevity.

24. Section 7.4, page 86, next to last ¶, last sentence: Please clarify and correct whether this is a conclusion for the Nueces River that belongs in the previous section, or a conclusion for the Frio River, or a comparison that is being made to the analysis for the Nueces River.

25. Section 7.8, pages 138 – 139: Ammonium, NH_4, is discussed in the text but ammonia, NH_3, is reported on the plots. Please maintain consistent reporting throughout the document.

26. Section 7.8.4, page 139: Station 12944 does not appear to be shown on the map in Figure 5-2. Please ensure that it is on the map, or correct the text to reference a station that is on the map.

27. Section 8, page 141, next to last ¶: Please revise the first sentence to increase clarification. For example, "In developing the nutrient loads, the simple linear regression analysis were

used instead of the LOADEST regressions **which** include temporal variability as part of the regression, whereas the linear regression analysis uses flow/concentration sets.

Figures and Tables Comments:

1. Table 2-1, page 19: Please insert a proper citation for the 2013 Integrated Report in the Table title.

2. Figure 3-1, page 22: Please insert a proper citation for the Nueces BBEST report in the Figure title, so that there is no confusion about which report is being referred to.

3. Figure 3-2, page 23: Same comment as above.

4. Figure 3-3, page 24: Same comment as above. Also, locations of each station shown are referring to BBEST Figure titles and also should be referenced to the Figure numbering scheme in this report, Figure 3-1 and Figure 3-2.

5. Figure 3-4, page 25: Same two comments as above. The reference to figures in the BBEST report showing station locations also should refer to Figures 3-1 and 3-2 in this report.

6. Figure 3-5, page 26: Same comment as above. Please insert a proper citation for the Nueces BBEST report in the Figure title, so that there is no confusion about which report is being referred to.

7. Figure 3-6, page 27: Same comment as above

8. Figure 3-7, page 32: Same comment as above.

9. Figure 5-1, page 36: Please add to the title that the monitoring stations are labeled by TCEQ stream segment identification number and explain what the various colors represent. Also, the map is very hard to read even when zoomed into. Please consider replacing the map with one that has larger font and easier to read. Figure 5-1 does not appear to have USGS gages on the map as they are in Figures 5-2 and 5-3. Please add USGS gages to the map.

10. Figure 5-2, page 37: Please add to the title that the monitoring stations are labeled by TCEQ stream segment identification number and explain what the other colors represent. Please add USGS gages to the legend.

11. Figure 5-3, page 38: Same comment as above to ensure that the title is self-explanatory and explain what the other colors represent. Please also add USGS gages to the legend.

12. Figure 5-9, page 45: Please specify whether the discharge locations in the Figure include storm-water outfalls, or just wastewater outfalls, or both?

13. Figure 5-11, page 50: Please expand the Figure title to be self-explanatory, including that the Ecoregions of Texas shown in the map are EPA delineations for the development and adoption of nutrient criteria.

14. Table 7-2, page 57: Please add the period of record for each station to the Table. If the period of record is the same for all stations, please make that explicit either in the table itself or in the title.

SUGGESTED CHANGES

Specific Draft Final Report Comments:

1. Executive Summary, page 14: Consider noting which of the bulleted stations represent the upper, middle and lower sections of the basin.

2. Executive Summary, page 16, and Section 9.2, page 151, 1st bullet points: The statement that "This study showed that adequate data to develop statistically significant relationships are limited," appears to be a significant conclusion that should be explicitly stated in the Conclusions section of the report. Consider describing this point at more length in the Conclusions section.

3. Section 2.1, Watershed Description, page 17: Please consider also that water is supplied to the San Antonio – Nueces Coastal Basin.

4. Section 2.1.1, page 18 -19: Consider comparing/updating this information with the Draft 2014 Integrated Report.

5. Section 5, page 34: Please consider a summary table (perhaps an Appendix) which lists all the various sources of data used in this study, including information such as type of data, stations analyzed, period of record available, or other applicable information.

6. Section 5.4.1, page 46, 1st ¶: Consider including a statement or discussion on how much of the discharge is related to storm water versus waste water.

7. Section 5.5, page 49, last ¶: Consider making a note that the majority of the basin is in Subecoregion 31.

8. Section 6.2, page 54, end of first ¶: Consider specifying that the last discharge of the demonstration project occurred in August 2011.

9. Section 7.2, page 59, 1st ¶: Please consider commenting on whether or not an attempt was made to change all non-detect values to the lowest non-detect value in order to make some use of the lower measured values.

10. Section 7.3, page 60: Consider re-phrasing the results to state that the variation can be explained by **flow**, rather than by the regression equations. Also, at station 12973 and for the parameters reported on, the R^2 range should be 0.28 to 0.37, rather than 0.30 to 0.37.

11. Section 7.4, page 97, 2nd ¶: Please consider that the Sabinal WWTP was relocated and began operations in July 2011. Refer to page 27 in the 2013 Basin Summary Report.

12. Section 7.8.1, page 138, 2nd ¶: Consider also discussing the trend at the most downstream station which is not influenced by the Frio and Atascosa Rivers Station 12973.

13. Section 7.8.4, page 139: Please consider stating which stations on the Aransas River showed high nutrient concentrations. The cultivated crop land in the Aransas River is in the Chiltipin Creek subwatershed, which is downstream of a WWTP and is effluent dominated.

14. Section 9.2, Recommendations, page 151 (and Executive Summary, page 16): Consider recommending a study to measure N-cycling and uptake experiments in the reservoirs to help determine sources and sinks. There could be denitrification, ammonification, or even nitrogen fixation occurring in the reservoir.

Figures and Tables Comments:

1. Table 2-1, page 19: Consider adding a map that shows the location of river segments listed in Table 2-1.

2. Table 5-1, page 46 – 47: Please consider listing the facilities in order of increasing or decreasing discharge, or right-justify the numbers to make it easier to see which facilities discharge the least and the most.

MEMORANDUM

TO: Caimee Schoenbaechler CAS

FROM: Vicki Karaffa VK

DATE: July 29, 2015

RE: Research Contract between the Texas Water Development Board (TWDB) and HDR Engineering, Inc. (HDR), TWDB Contract No. 1400011718, Draft Report Comments

DRAFT REPORT RECEIVED: July 7, 2015

Enclosed is the draft report comment letter.

Please forward to Robert E. Mace for his signature.

Thank you.