Roosevelt Creek Nutrient Source Evaluation and Assessment

Final Report

September 2010

Prepared for:

Pinellas County, Florida

Prepared by:

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SECTION 1

INTRODUCTION

1.1 Project Background

This document provides a summary of field and laboratory efforts conducted by Environmental Research & Design, Inc. (ERD) for Pinellas County (County) as part of the Roosevelt Creek Nutrient Source Evaluation and Assessment Project. These work efforts were authorized by Pinellas County under PO# 230616, issued July 15, 2009. The purpose of this project is to identify the sources of elevated nutrient levels observed in the Roosevelt Creek drainage basin in Pinellas County. A general location map for the Roosevelt Creek drainage basin is given on Figure 1-1.

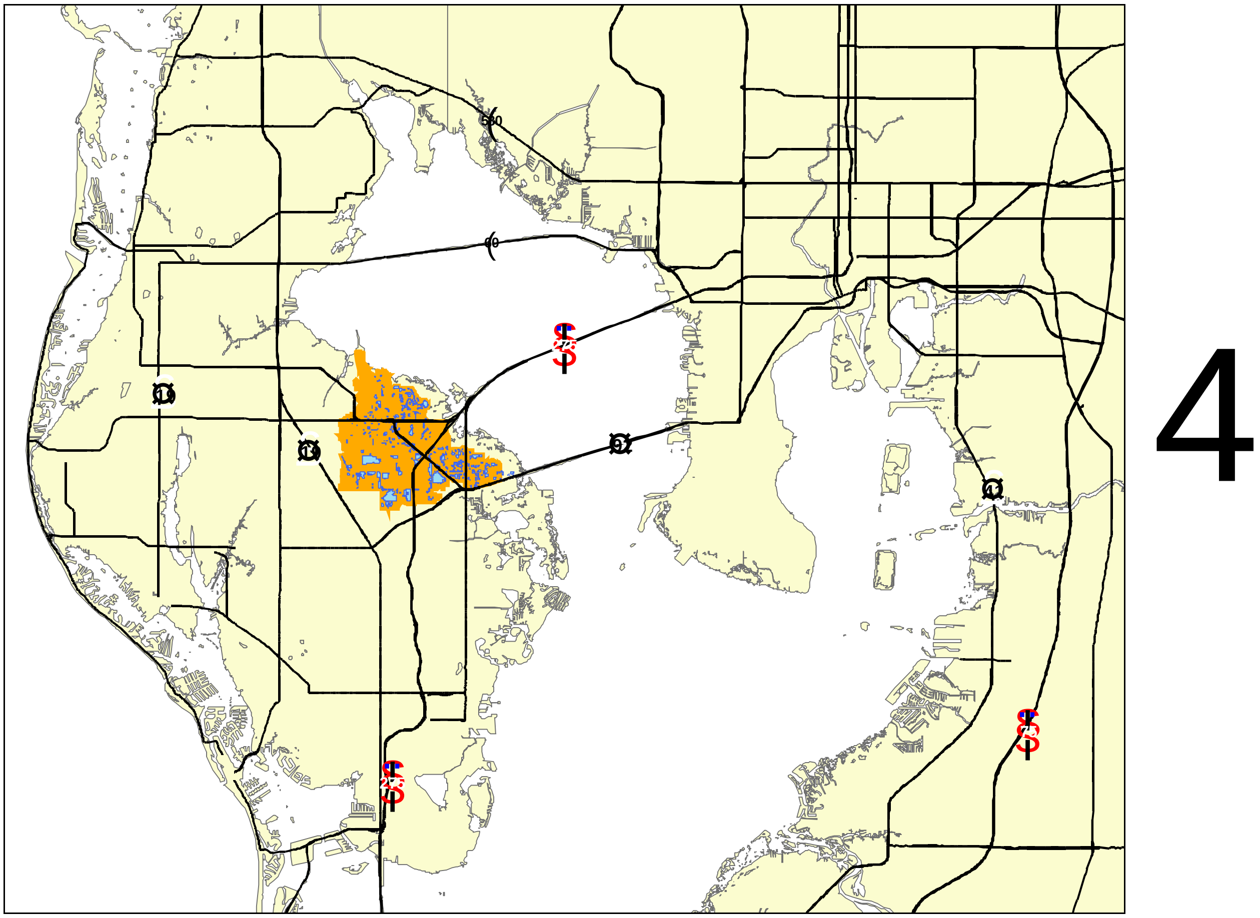


Figure 1-1. General Location Map for the Roosevelt Creek Basin.

The Roosevelt Creek watershed is located in central Pinellas County and covers an area of approximately 6748 acres. The area contains portions of the cities of Pinellas Park and St. Petersburg, and includes a combination of residential, commercial, industrial, and transportation land uses. Discharges from the Roosevelt Creek watershed flow from south to north into tidal marsh areas along Old Tampa Bay through a system of stormsewers and open ditches. The Roosevelt Creek watershed contains a significant number of industrial facilities which include three permitted wastewater facilities, the Bridgeway Acres Landfill, several closed Class I and Class II landfills, the Airco Golf Course, a waste-to-energy plant, and the St. Petersburg/ Clearwater International Airport.

The project area evaluated in this analysis includes the western portion of the overall Roosevelt Creek watershed, referred to as Sub-basin H. Surface water monitoring sites located in Sub-basin H have consistently indicated elevated nutrient concentrations, with a trend of increasing concentrations from southern to northern portions of the drainage area. Work efforts performed under this project are designed to assess the sources of nutrients which are causing elevated concentrations within Sub-basin H of the Roosevelt Creek watershed.

The specific objectives of this project, as defined by Pinellas County, are to:

1. Design a monitoring program to determine the source of nutrients within the Sub-basin H of Roosevelt Creek watershed

2. Interpret the collected data and other information to identify nutrient sources

3. Develop suggestions to alleviate the nutrient impairment

4. Prepare a Final Report which presents the results and recommendations

1.2 Work Efforts Conducted by ERD

Field monitoring was conducted by ERD from July-September 2009 within Sub-basin H of the Roosevelt Creek watershed to characterize discharges through the area. Seventeen surface water sites were monitored on a biweekly basis, which included measurement of field parameters, discharge rates, and sample collection for laboratory analyses. Each of the collected samples was analyzed in the ERD Laboratory for general parameters and nutrients. In addition, aliquots of each collected sample were shipped to the Colorado Plateau Stable Isotope Laboratory for isotope analyses of nitrogen and oxygen within the collected samples to assist in identifying potential pollutant sources. Sediment core samples were also collected at each of the monitoring sites and analyzed for physical characteristics and nutrients.

1.3 Report Organization

This report has been divided into six separate sections for presentation and analysis of the field and laboratory activities. Section 1 contains an introduction to the report and provides a summary of the work efforts performed by ERD. Section 2 contains a discussion of the characteristics of the Roosevelt Creek watershed area. A description of field monitoring and laboratory analyses conducted for this project is given in Section 3. A discussion of the results of the field and laboratory activities is given in Section 4. Nutrient management recommendations are discussed in Section 5, a summary is given in Section 6, and a list of references is given in Section 7. Appendices are also attached which contain technical data and analyses used to support the information, conclusions, and recommendations contained within this report.

SECTION 2

CHARACTERISTICS OF THE ROOSEVELT CREEK WATERSHED

2.1 General Characteristics

The Roosevelt Creek watershed is located in central Pinellas County and includes an area of approximately 6748 acres of intensely developed urban land. The watershed contains portions of the cities of Pinellas Park and St. Petersburg, and includes a combination of residential, commercial, industrial, and transportation land uses. Runoff generated within the Roosevelt Creek watershed ultimately discharges into Old Tampa Bay through three major channels and tributaries, comprised of a combination of underground stormsewers and ditches, which total more than 9.5 miles in length. Pinellas County has experienced rapid growth over the past 20 years, and much of the basin is approaching build-out conditions.

The Roosevelt Creek watershed contains a number of significant industrial facilities, with three permitted industrial wastewater facilities located in the watershed. The most significant of these is the Bridgeway Acres Landfill, operated by Pinellas County, which has a permit to discharge excess water from a large wet detention pond during emergency situations. Also located in the watershed are two closed landfills, including the Toytown Class I and the Struthers Class II Landfills. The watershed also includes the Airco Golf Course, a waste-to-energy plant, and the St. Petersburg/Clearwater International Airport.

A hydrologic evaluation of the Roosevelt Creek Watershed was conducted during 2007 by Parsons, with the results summarized in the document titled "Roosevelt Creek Watershed (L068)-Volume II: Floodplain Analysis Report", dated October 2007. According to this document, the Roosevelt Creek Watershed is divided into eight major sub-basins, designated "A" through "H". A delineation of sub-basin areas included in the Roosevelt Creek Watershed is given in Figure 2-1.

Sub-basin H, which is the subject of the work efforts outlined in this document, is the largest of the eight sub-basin areas, covering approximately 2316 acres or 34% of the overall Roosevelt Creek Watershed. Sub-basin H is a long, linear area located on the western side of the Roosevelt Creek Watershed, bounded on the south by 102nd Avenue North and on the east by 34th Street North. Drainage movement within Sub-basin H occurs in a south to north direction through a series of canals, stormsewer conveyances, and open ditches. The primary north-south conveyance feature in Sub-basin H is referred to as Channel 5. The Channel 5 tributary outfalls to Old Tampa Bay just east of the St. Petersburg/Clearwater International Airport.

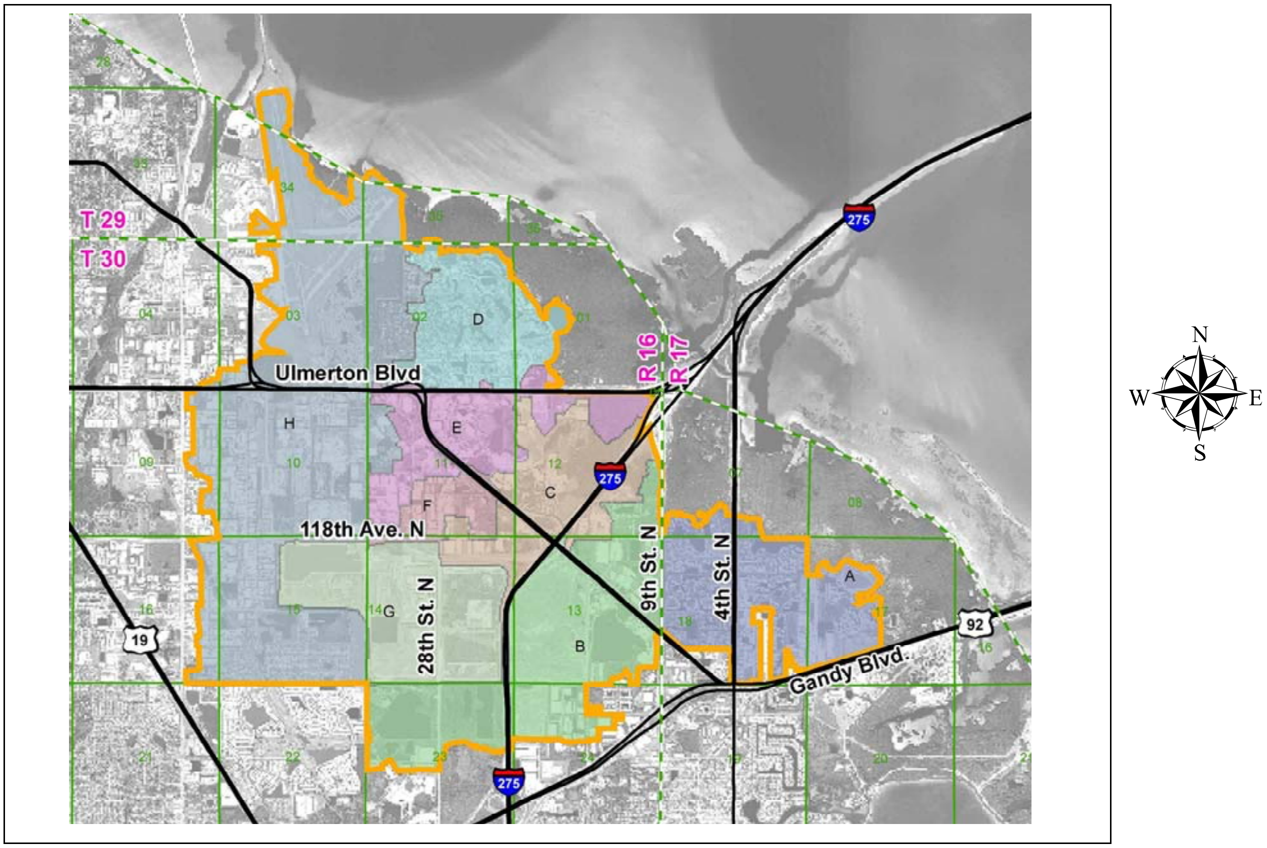


Figure 2-1. Roosevelt Creek Watershed Sub-basin Areas.

An overview of Roosevelt Creek Sub-basin H and primary conveyance channels is given on Figure 2-2. Sub-basin G is also indicated on Figure 2-2 since this sub-basin has a pumped inflow from the Bridgeway Acres Landfill directly into the main channel of Sub-basin H. According to Pinellas County Utilities, this pumped discharge is the only point of discharge for the Bridgeway Acres Landfill, with pumped discharge into Sub-basin H only on an as-needed basis.

2.2 Topography

A topographic map of the Roosevelt Creek watershed is given on Figure 2-3 based upon a LIDAR digital elevation model (2007) with 1-ft elevation contours, provided by Pinellas County. The majority of areas within the sub-basin range in elevation from sea level to approximately 15 ft (NAVD 88). Localized areas within the watershed extend to elevations as high as 40 ft in areas of current and previous landfill activities. In general, topography within the watershed is relatively mild, with an average slope of approximately 2.84 ft/mile in Sub-basin H.

2.3 Soil Characteristics

Information on soil characteristics within the Roosevelt Creek watershed were obtained from the Pinellas County GIS database. Soil information was extracted in the form of hydrologic soil groups (HSG) which classify soil types with respect to infiltration rate and runoff potential. A summary of the characteristics of each of the hydrologic soil groups is given in Table 2-1.

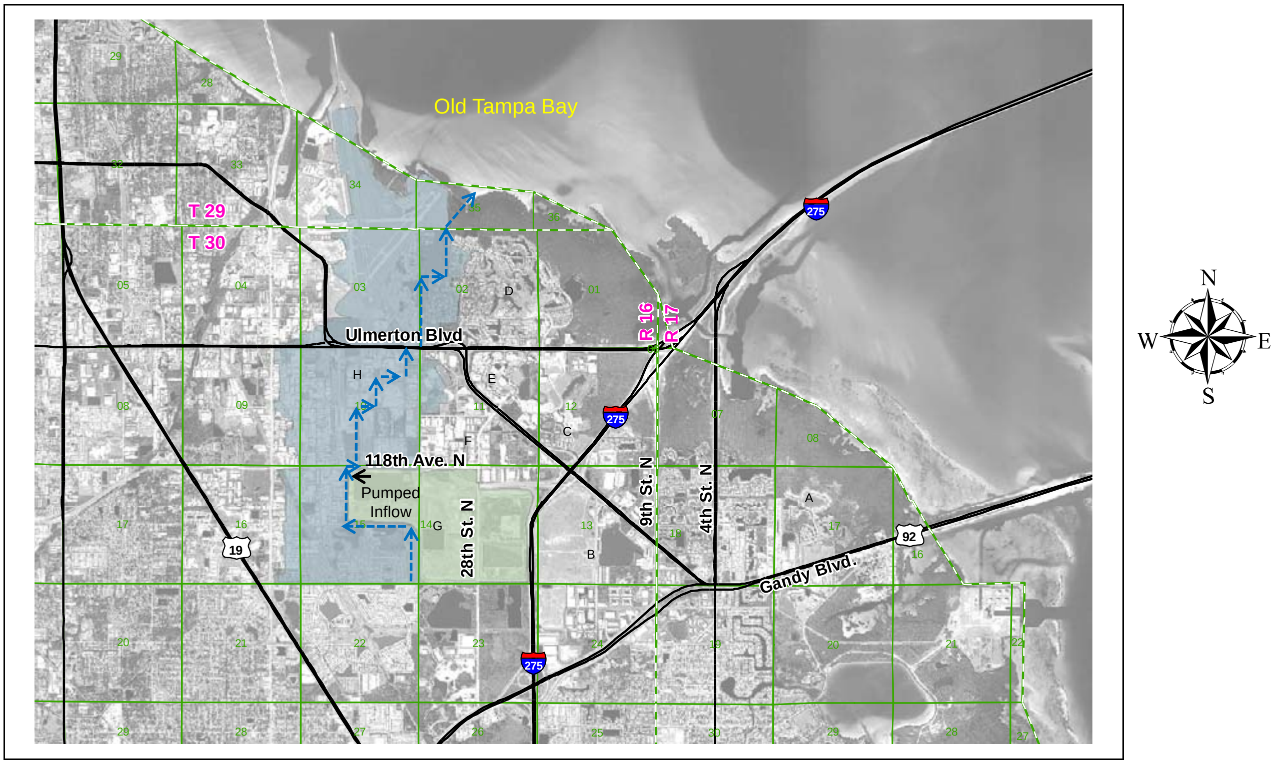


Figure 2-2. Overview of Sub-basin H and Primary Conveyance Channels in Roosevelt Creek.

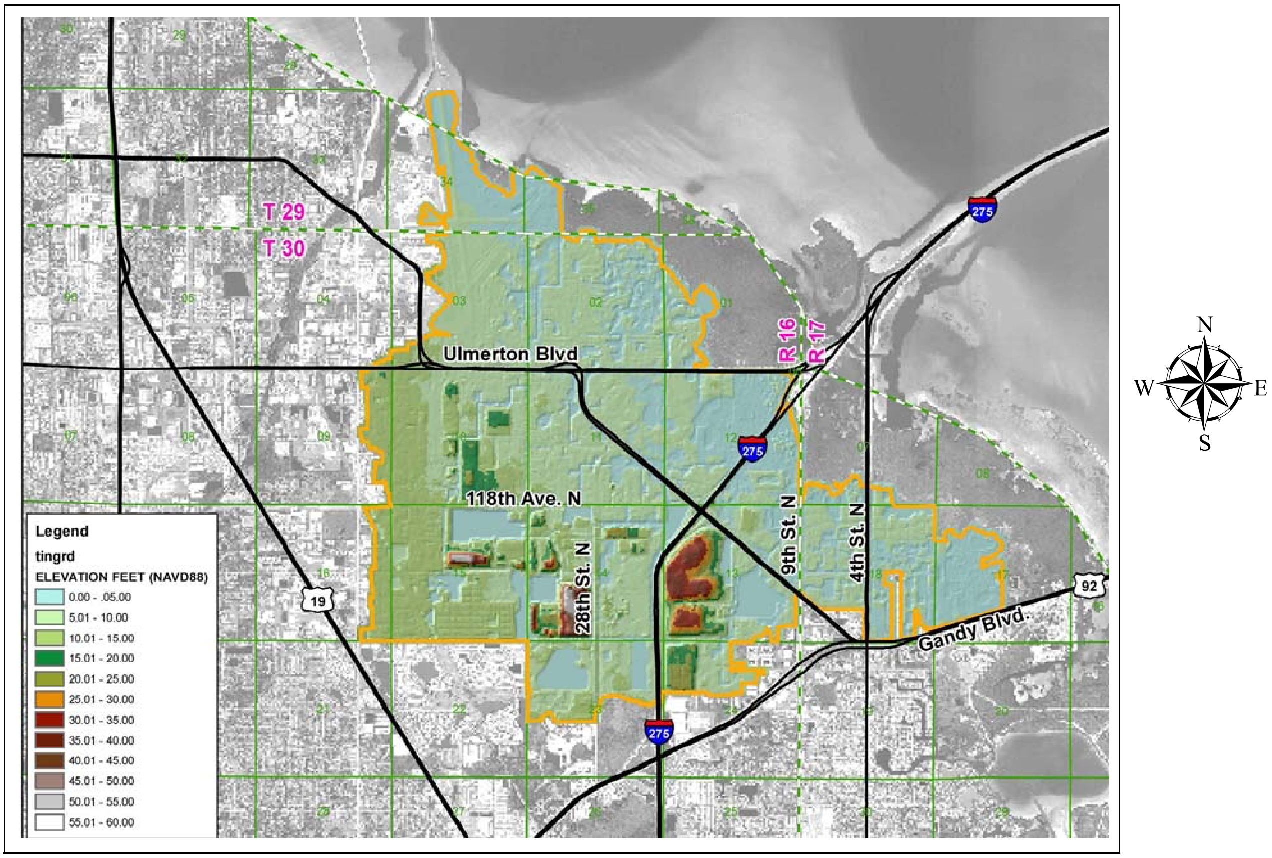


Figure 2-3. Topography Map for the Roosevelt Creek Watershed.

TABLE 2-1

CHARACTERISTICS OF SCS HYDROLOGIC SOIL GROUP CLASSIFICATIONS

SOIL GROUP	DESCRIPTION	RUNOFF POTENTIAL	INFILTRATION RATE
A	Deep sandy soils	Very low	High
B	Shallow sandy soils over low permeability layer	Low	Moderate
C	Sandy soil with high clay or organic content	Medium to high	Low
D	Clayey soils	Very high	Low to none
B/D	Shallow sandy soils in high groundwater table area	High – undeveloped Low – developed	Moderate; restricted by groundwater table in undeveloped condition
W	Wetland or hydric soils	--	--

A graphical summary of hydrologic soil groups in Roosevelt Creek Sub-basin H is given in Figure 2-4, with a tabular summary provided in Table 2-2. The vast majority of soils within the drainage basin appear to be classified in HSG B/D which consists of shallow sandy soils in a high groundwater table area, with a high runoff potential in an undeveloped state and a low runoff potential in a developed state. Under undeveloped conditions, infiltration into these soils is limited by the high groundwater table. With development, the groundwater table is often lowered, increasing the soil infiltration rate. Areas in the vicinity of the St. Petersburg/ Clearwater International Airport are characterized by soils in HSG C which consist of sandy soils with a medium to high runoff potential. A small area of HSG B soils is located in the southern portion of Sub-basin H.

TABLE 2-2

SUMMARY OF HYDROLOGIC SOIL GROUPS IN ROOSEVELT CREEK SUB-BASIN H

HSG	AREA (acres)	PERCENT OF TOTAL (%)
B	72.5	3.1
B / D	1,406	60.7
C	639	27.6
D	84.5	3.6
W	114	5.0
TOTAL:	**2,316**	**100**

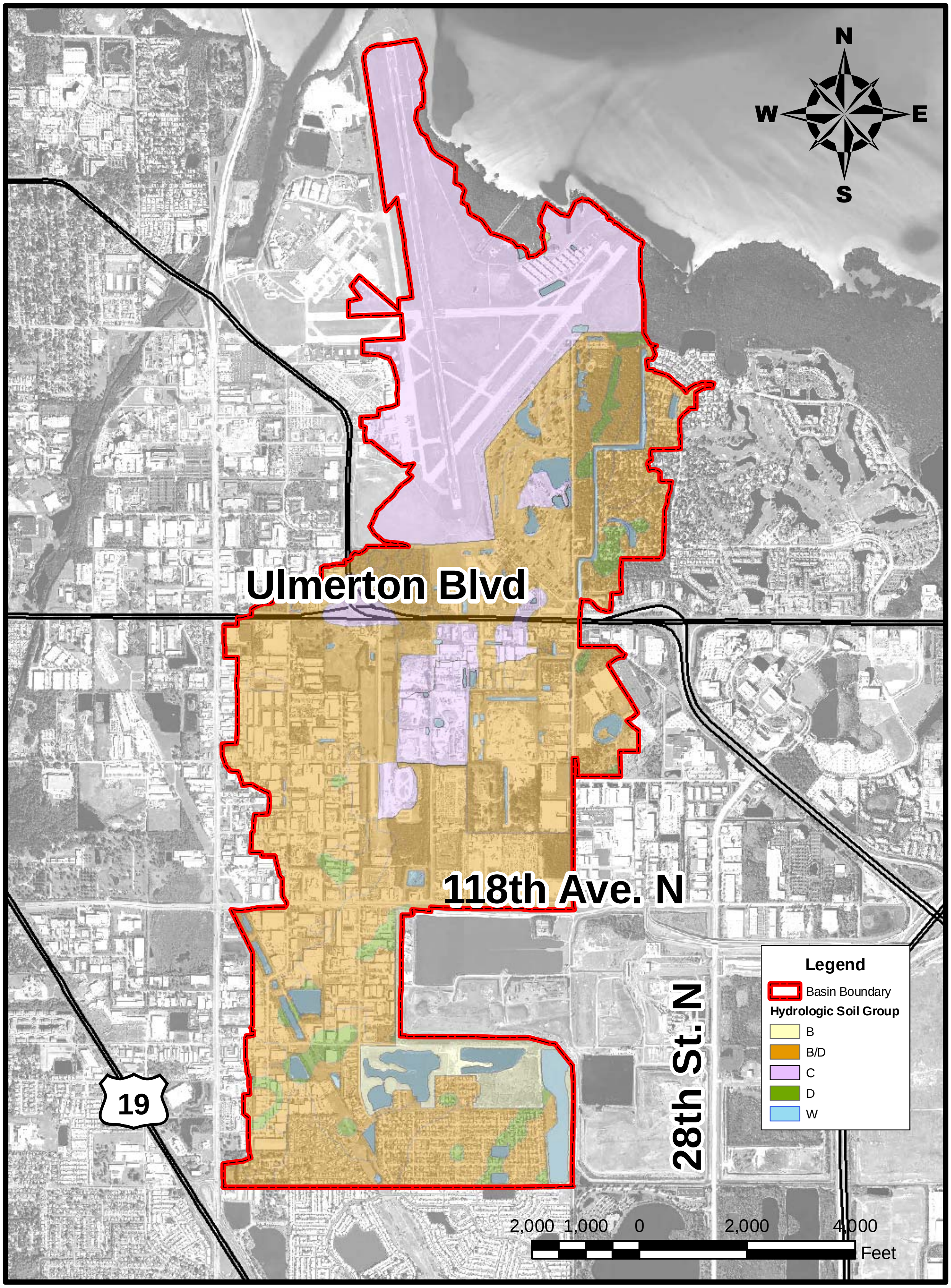


Figure 2-4. Hydrologic Soil Groups in Roosevelt Creek Sub-basin H.

2.4 Land Use

Land use data were obtained from the SWFWMD GIS database, which reflects 2008 land coverage in the form of Level 3 FLUCCS codes. A graphical overview of land use within the Roosevelt Creek Sub-basin H is given on Figure 2-5, with a tabular summary provided in Table 2-3. The dominant land use categories within Sub-basin H are industrial uses (which comprise 28.2% of the basin area) and transportation land use (which covers approximately 22.3% of the basin area). Approximately 12% of the basin area is covered by residential land uses, with 10.9% in recreational, 6.8% in commercial, and 5.4% consisting of open water. The remaining categories comprise approximately 2% or less of the land use within Sub-basin H.

TABLE 2-3

LAND USE CHARACTERISTICS IN ROOSEVELT CREEK SUB-BASIN H

LAND USE CATEGORY	AREA (acres)	PERCENT OF TOTAL (%)
Commercial	157	6.8
High-Density Residential	3.1	0.1
Industrial	654	28.2
Institutional	42.2	1.8
Medium-Density Residential	273	11.8
Open	275	11.9
Recreational	252	10.9
Transportation	517	22.3
Water	124	5.4
Wetlands	18.2	0.8
TOTAL:	**2,316**	**100**

2.5 Hydrology

An overview of the primary drainage patterns in Sub-basin H was included on Figure 2-2. In general, drainage patterns in this sub-basin are relatively complex and include a series of interconnected open ditches and underground stormsewer systems.

An inventory of primary and secondary drainage conveyance systems for Sub-basin H is given on Figure 2-6 (Parsons, 2007). This figure provides a schematic of the primary conveyance system for Channel 5, as well as secondary conveyance systems intersecting with the main channel. With the exception of the pumped inflow from the Bridgeway Acres Landfill, water movement within Sub-basin H occurs entirely by gravity.

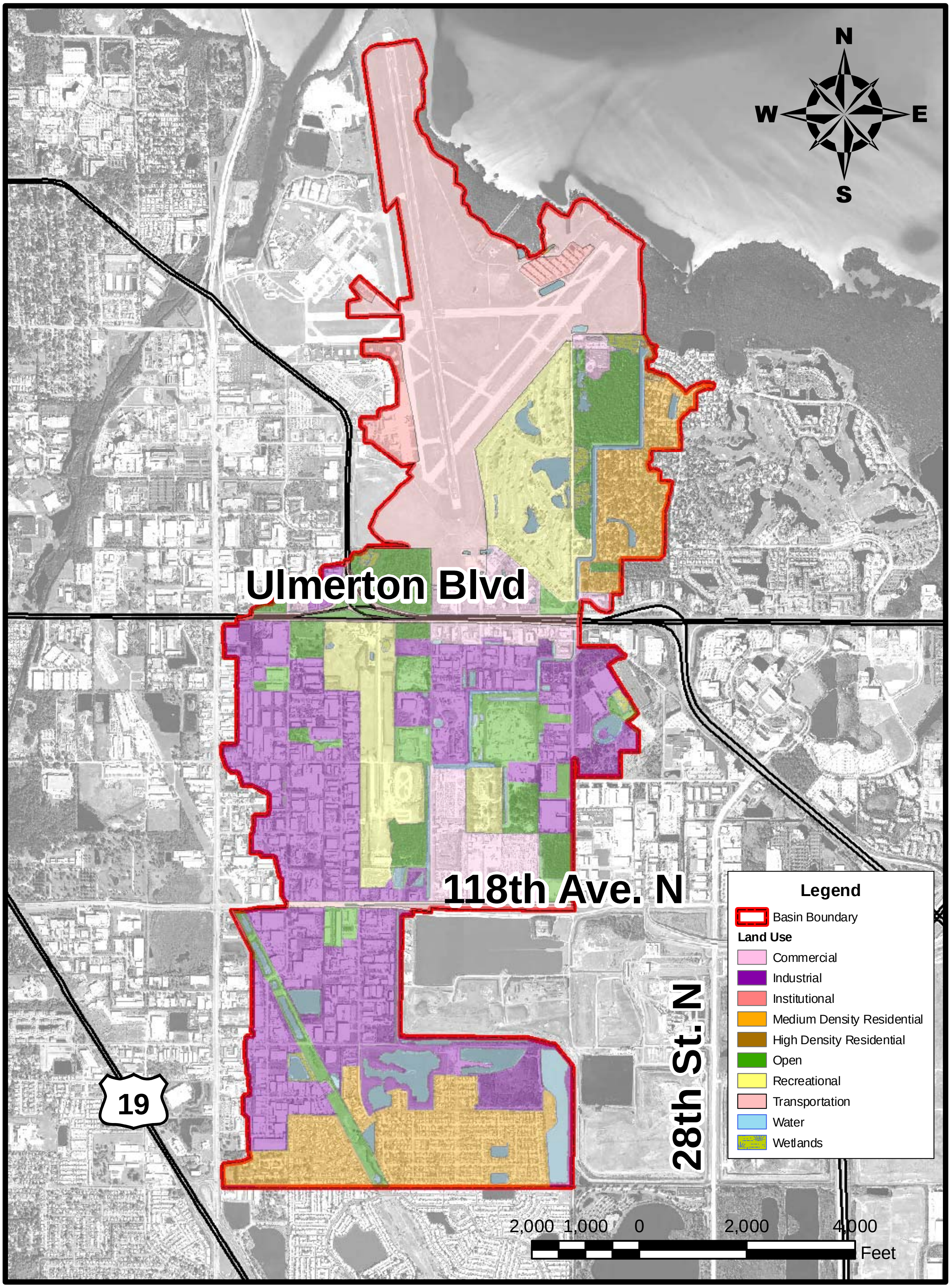


Figure 2-5. Land Use within the Roosevelt Creek Sub-basin H.

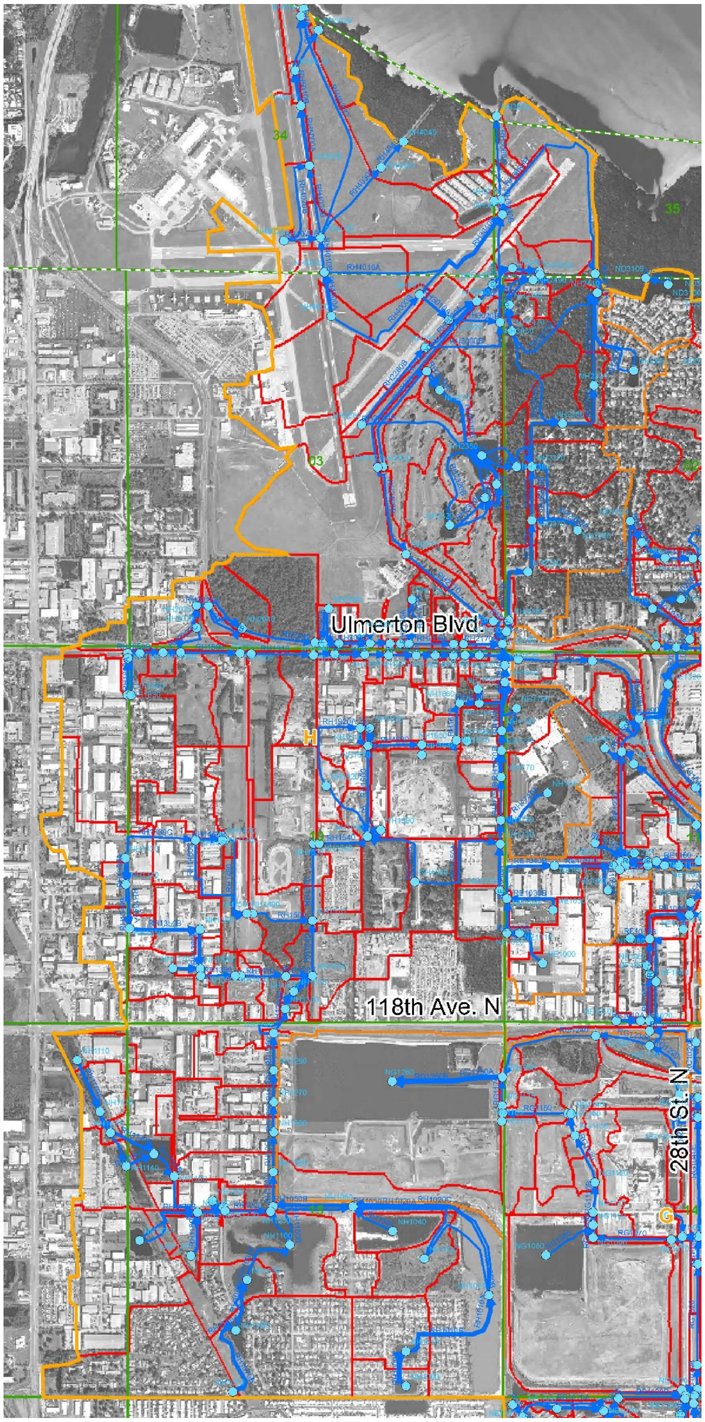


Figure 2-6. Inventory of Primary (Blue Lines) and Secondary (Red Lines) Drainage Conveyance Systems for Sub-basin H.

Discharges through Sub-basin H consist primarily of freshwater throughout much of the year. A salinity structure at elevation 2.5 ft is located at the downstream end of Channel 5 at the point of discharge into the tidal wetlands associated with Old Tampa Bay. An overview and photographs of the salinity structure are given on Figure 2-7. The salinity structure consists of a 200-ft long broad-crested concrete weir structure. Discharges over the salinity structure enter the tidally flooded mangrove forest which is interconnected with Old Tampa Bay. This site is referred to as Site 16 for the field monitoring program.

Channel 5 contains at least three weir structures designed to regulate water levels in various portions of the tributary. The most upstream water control structure consists of an 8-ft wide contracted rectangular weir which is located near the southwest corner of the Bridgeway Acres Landfill. A photograph of the weir structure is given on Figure 2-8. This structure is used to control water elevations in the canal located along the south side of the landfill. This site is designated as Site H-2 in the field monitoring program conducted by ERD.

The second water control structure is located on the south side of 118th Avenue North at the northwest corner of the Bridgeway Acres Landfill site. A photograph of the weir structure is given on Figure 2-9. This weir structure has a total length of approximately 24 ft and is used to control water surface and groundwater levels along the west side of the Bridgeway Acres Landfill. Discharges over the weir structure travel beneath 118th Avenue North and rejoin the open channel portion of Channel 5 on the west side of 40th Street North. The final water control structure consists of the salinity barrier/weir structure discussed previously.

a. General location

b. Aerial overview

c. Salinity structure/weir

d. Discharge enters tidal wetlands

Figure 2-7. Downstream Salinity Structure/Weir for Sub-basin H (Monitoring Site 16).

Figure 2-8. Weir Structure on Southwest Side of Bridgeway Acres Landfill (Monitoring Site 2).

Figure 2-9. Weir Structure on Northwest Side of Bridgeway Acres Landfill (Monitoring Site 4).

Channel 5 consists primarily of an open tributary throughout the majority of its length. Small portions of the channel have been diverted into underground stormsewer systems to accommodate roadway passages. The channel increases in both width and depth with increasing distance downstream, with upstream portions of Channel 5, characterized by widths of approximately 20-30 ft, increasing to approximately 80 ft in width near the intersection of Ulmerton Blvd., and reaching 200 ft in width at the salinity barrier/weir structure.

2.6 Impaired Waters Designation

Section 303 (D) of the Clean Water Act (CWA) requires states to submit lists of surface waterbodies that do not meet applicable water quality standards. These waterbodies are defined as “impaired waters” and Total Maximum Daily Loads (TMDLs) must be established for these waters on a prioritized schedule. FDEP has established a series of guidelines to identify impaired waters which may require the establishment of TMDLs. Waterbodies within the State of Florida have been divided into five separate groups for planning purposes, with the Tampa Bay Basin (which includes Roosevelt Creek) located within the Coastal Old Tampa Bay planning unit in Group 1.

The marine portion of the Roosevelt Creek basin (WBID 1624) is included on the May 14, 2009 verified list as impaired for nutrients based upon average annual chlorophyll-a values in the verified period exceeding the historical annual average value by more than 50% in 2001 and 2002. The freshwater portion of Roosevelt Creek (WBID 1624A) is included on the May 14, 2009 verified list as impaired for fecal coliform bacteria. Although the freshwater portion of Roosevelt Creek (WBID 1624A) is not included as impaired for nutrients, the freshwater portions of the watershed appear to be the sources for many of the loadings impacting nutrients and chlorophyll-a concentrations in marine portions of the basin.

On January 26, 2010, the U.S. Environmental Protection Agency (EPA) published proposed "Water Quality Standards for the State of Florida's Lakes and Flowing Waters" (75 FR 4173). In this proposed rule, EPA classified Florida streams into regions for application of total phosphorus and total nitrogen criteria. Streams and canals within Pinellas County are classified within the Peninsula Region. Under the current version of this rule, the total nitrogen and total phosphorus water quality criteria for streams and canals in the Peninsula Region would be 1.67 mg/l and 0.11 mg/l, respectively. The objectives of the proposed rules are to maintain healthy biological conditions within the streams and canals as well as protect downstream receiving waterbodies. As discussed in Section 2.7, median concentrations of total nitrogen and total phosphorus within Roosevelt Creek Sub-basin H substantially exceed the proposed nutrient criteria by EPA as well as proposed alternative criteria by FDEP. As a result, it appears likely that Roosevelt Creek will also be listed as impaired for nutrients under the proposed nutrient criteria rule, when adopted.

2.7 Water Quality Data

A review of available historical water quality data collected in the Roosevelt Creek Sub-basin H was conducted using the US EPA STORET database as well as the Pinellas County Water Atlas data. Much of the historical data is duplicated within the two databases, although unique data were obtained from both the STORET and Water Atlas sources which were not contained within the other system. Locations of the identified water quality monitoring sites in Sub-basin H are indicated on Figure 2-10, along with the site reference I.D. for each location. All of the historical water quality monitoring sites are located along the freshwater segment of Channel 5. A complete listing of available water quality data for the monitoring sites indicated on Figure 2-10 is given in Appendix A.1.

A summary of available water quality data sources for Roosevelt Creek Sub-basin H is given in Table 2-4. Water quality data have been collected at a total of five monitoring sites within the sub-basin area, beginning as early as 1995. One of the surface water sites was monitored by the Florida Department of Environmental Protection (FDEP), with four surface water sites monitored by Pinellas County.

Three of the five monitoring sites are located in the vicinity of the salinity barrier/weir structure at the northern end of Channel 5. Pinellas County Station 23-21 is located upstream from the salinity barrier, with Station 23-22 located downstream from the salinity barrier. Data obtained for these sites include only field measurements for temperature, dissolved oxygen, pH, and conductivity. Each of these sites was monitored for a period of approximately eight months during 2005. Monitoring Site 23-08 includes data collected from 2003-present, with both field and laboratory data generated at this site.

The remaining two monitoring sites are located in the middle portions of Channel 5 on the north side of Ulmerton Blvd. Monitoring Site 23-04 is a Pinellas County station which has data from 1995-2002, including both field and laboratory data. A substantial amount of data have been collected by Pinellas County at this site, with 275 individual monitoring events. Monitoring Site TP-454, monitored by FDEP, is also located in the general vicinity of 23-04. Both field and laboratory data were collected at this site on approximately a monthly basis from February-December 2006.

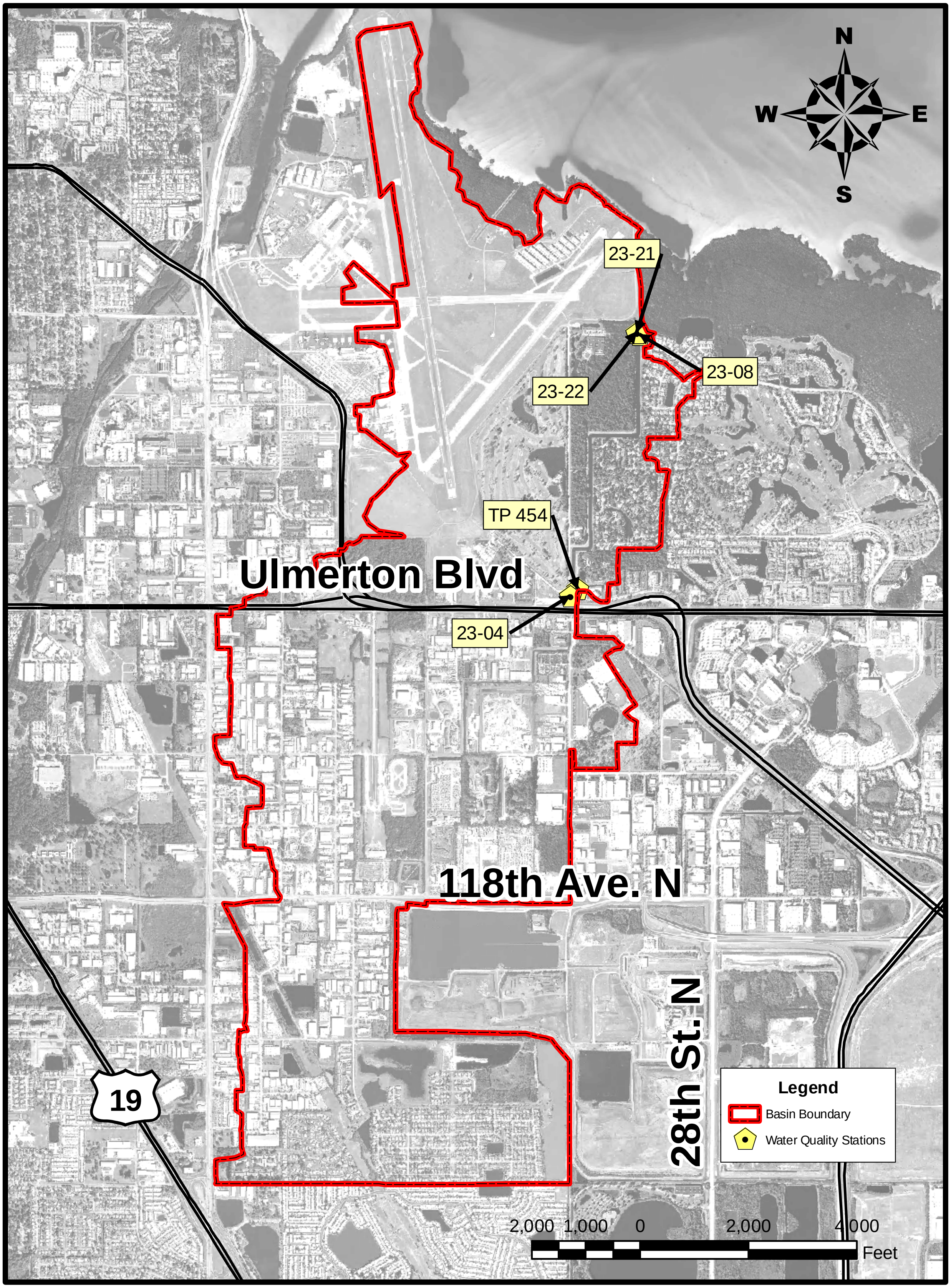


Figure 2-10. Locations of Identified Water Quality Monitoring Stations in Roosevelt Creek Sub-basin H.

TABLE 2-4

SUMMARY OF AVAILABLE WATER QUALITY DATA SOURCES FOR ROOSEVELT CREEK SUB-BASIN H

STATION I.D.	STATION NAME	DATA SOURCE	COLLECTION DATES	NUMBER OF EVENTS	TYPE OF DATA
23-04	Channel 5 (middle)	Pinellas County	1/11/95 – 11/6/02	275	Field/Lab
23-08	Channel 5 (at salinity structure)	Pinellas County	2/26/03 – 4/12/10	51	Field/Lab
23-21	Channel 5 (upstream from salinity structure)	Pinellas County	3/1/05 – 11/15/05	7	Field
23-22	Channel 5 (downstream from salinity structure)	Pinellas County	3/1/05 – 11/15/05	8	Field
TP-454	Channel 5 (middle)	FDEP	2/13/06 – 12/11/06	8	Field/Lab

A summary of mean water quality characteristics measured at monitoring sites in Sub-basin H is given in Table 2-5. The data summarized for monitoring Sites 23-21 and 23-22 reflect field measurements only, while data provided for the remaining sites include a combination of field and laboratory measurements. Measured BOD concentrations in Channel 5 have been low to moderate in value during most monitoring events. Mean values measured at monitoring Sites 23-04, 23-08, and TP-454 range from 1.9-3.4 mg/l which is typical of BOD values commonly observed in an urban tributary. Dissolved oxygen concentrations have been highly variable at each of the five monitoring sites, with multiple measurements at each site less than the Class III minimum criterion of 5 mg/l outlined in Chapter 62-302 Florida Administrative Code (FAC). However, mean dissolved oxygen concentrations at each of the monitoring sites, with the exception of Site 23-04, exceed the 5 mg/l criterion.

Measured concentrations of both total and fecal coliform bacteria have also been highly variable, ranging from low to extremely elevated for the sites where coliform data are available. Numerous exceedances of the applicable 400 cfu/100 ml criterion for fecal coliform bacteria (outlined in Chapter 62-302 FAC) were observed at each site.

A relatively high degree of variability is apparent in measured nitrogen species at the three sites where data are available. In general, measured concentrations of NO_x and ammonia appear to be low to moderate in value, with organic nitrogen comprising the largest proportion of the total nitrogen. Measured concentrations of total nitrogen at each of the three sites have ranged from relatively low to elevated throughout the various monitoring programs. Measured total phosphorus concentrations at the monitoring sites have ranged from relatively low to elevated between the monitoring events. Mean concentrations for total phosphorus range from 103-165 μg/l which reflects a moderate to slightly elevated concentration compared with values commonly observed in urban drainage systems.

Highly variable concentrations of total suspended solids (TSS) and turbidity have also been observed within Channel 5, with concentrations for both parameters ranging from low to elevated. However, the mean values for these parameters measured at Sites 23-04 and 23-08 are typical of values commonly observed in drainage systems.

TABLE 2-5

SUMMARY STATISTICS FOR ROOSEVELT CREEK SUB-BASIN H HISTORICAL WATER QUALITY

PARAMETER	UNITS	STATION														
		23-04			23-08			23-21			23-22			TP-454		
		Minimum	Maximum	Mean	Minimum	Maximum	Mean	Minimum	Maximum	Mean	Minimum	Maximum	Mean	Minimum	Maximum	Mean
BOD	mg/l	1.0	10.0	3.4	1.0	5.0	1.9	--	--	--	--	--	--	2.2	4.2	2.7
Chlorophyll-a	mg/m^3	1.4	282.0	26.6	0.5	111.0	18.9	--	--	--	--	--	--	0.9	120.0	26.3
Chlorophyll-b	mg/m^3	0.5	48.8	3.3	0.5	11.4	1.5	--	--	--	--	--	--	--	--	--
Chlorophyll-c	mg/m^3	0.5	39.4	2.7	0.5	10.8	1.9	--	--	--	--	--	--	--	--	--
Dissolved Oxygen	mg/l	0.1	13.4	3.4	1.8	15.9	7.9	4.6	8.5	7.3	1.1	12.9	6.7	3.8	13.6	7.4
Fecal Coliform	mg/m^3	10	18,000	1421	1	6000	308	--	--	--	--	--	--	20	8000	1679
Total Coliform	mg/m^3	1	3400	1069	1	6400	854	--	--	--	--	--	--	1	70,000	10,903
Flow	cfs	--	--	--	0.00	74.02	8.10	3.05	5.23	4.04	3.73	12.10	6.95	--	--	--
Ammonia	μg/l	--	--	--	10	490	154	--	--	--	--	--	--	82	1100	405
Kjeldahl Nitrogen	μg/l	440	4450	2026	100	2690	1293	--	--	--	--	--	--	1500	3100	1957
Nitrite + Nitrate	μg/l	20	1930	383	20	640	170	--	--	--	--	--	--	32	1100	358
Total Nitrogen	μg/l	640	4740	2411	--	--	--	--	--	--	--	--	--	--	--	--
Total Phosphorus	μg/l	20	480	110	20	380	103	--	--	--	--	--	--	96	230	165
SRP	μg/l	--	--	--	20	180	47	--	--	--	--	--	--	6	58	32
pH	s.u.	6.11	9.36	7.42	7.07	10.15	7.83	7.29	7.90	7.50	7.04	8.47	7.61	7.02	7.51	7.38
Salinity	ppt	0.0	5.8	0.6	0.1	4.6	0.8	0.7	2.3	1.3	1.0	12.8	2.8	0.2	0.6	0.4
Secchi Disk Depth	m	--	--	--	--	--	--	--	--	--	--	--	--	0.30	0.60	0.43
Spec. Conductivity	μmho/cm	0	10,270	1108	290	8140	1518	1225	4178	2436	1782	21,245	4843	375	1274	891
Temperature	°C	6.75	31.06	23.86	15.54	34.54	25.93	19.82	33.70	25.81	20.93	33.27	25.89	13.19	32.44	24.22
TSS	mg/l	1.0	39.0	8.1	1.0	23.0	4.1	--	--	--	--	--	--	4.0	173.0	35.3
Turbidity	NTU	1.1	23.0	6.7	0.5	14.0	2.8	--	--	--	--	--	--	3.1	65.0	16.6

Additional statistical evaluations and trend analyses were conducted for the historical water quality data collected at Pinellas County monitoring Station 23-04 and 23-08. Each of these sites contains approximately seven years of both field and laboratory data collected on a periodic basis. The remaining monitoring sites (23-21, 23-22, and TP-454) contain data for a limited period during a single year and the data are not useful for long-term evaluations. However, even though statistical evaluations and comparisons are provided for Pinellas County monitoring Sites 23-04 and 23-08, the period of record for the data sets do not overlap which limits the usefulness of data comparisons between the two sites. Data collected at Pinellas County Site 23-04 were collected from 1995-2002, with data collected at Site 23-08 from 2003-2010.

A comparison of historical concentrations of fecal coliform, dissolved oxygen, BOD, and pH measured at Pinellas County Sites 23-04 and 23-08 is given on Figure 2-11 in the form of Tukey box plots, also often called "box and whisker plots". The bottom of the box portion of each plot represents the lower quartile, with 25% of the data points falling below this value. The upper line of the box represents the 75% upper quartile, with 25% of the data falling above this value. The horizontal line within the box represents the median value, with 50% of the data falling both above and below this value. The vertical lines, also known as "whiskers", represent the 5 and 95 percentiles for the data sets. Individual values which lie outside of the 5-95 percentile range are indicated as **red dots**.

As seen in Figure 2-11, a high degree of variability was observed in measured fecal coliform counts at the two monitoring sites. A higher degree of variability in measured values is apparent at Site 23-04, located in central portions of the channel, than observed at Site 23-08 which is located at the point of discharge for Channel 5. In addition, fecal coliform counts at Station 23-04 appear to be higher than the values observed at the downstream monitoring site. Differences in fecal coliform values between these two sites may be due to the reduced amount of inflows into the main channel which occur between the two sites, as well as the longer detention time in this portion of the channel created by the expanded width and depth.

Measured concentrations of dissolved oxygen have been highly variable at each of the two sites, with a general trend of higher dissolved oxygen concentrations at the downstream site compared with Site 23-04. Many of the historical dissolved oxygen concentrations measured at Site 23-04 have been less than the applicable dissolved oxygen criterion of 5 mg/l for Class III waters. In contrast, the majority of dissolved oxygen concentrations measured at Site 23-08 have exceeded the minimum criterion of 5 mg/l. The difference in dissolved oxygen levels between the two sites may also be related to the small amount of additional inflows which occur between the two sites, the additional detention time which allows degradation of oxygen-demanding substances, and the open water portion of the canal which provides an opportunity for reaeration along with algal growth and oxygen production.

Measured BOD concentrations at monitoring Site 23-04 have been highly variable over the period of record, although the observed values are typical of BOD concentrations commonly observed in urban drainage systems. A lower BOD concentration, as well as a lower degree of variability, was observed at monitoring Site 23-08. Measured pH values appear to be slightly higher at monitoring Site 23-08 than observed at Site 23-04. The increased pH level at the spillway structure may be related to a number of factors, including occasional backflow of brackish water and algal production which occurs between the two sites.

A comparison of historical concentrations of nitrogen species measured at Pinellas County Sites 23-04 and 23-08 is given in Figure 2-12. Measured ammonia concentrations at Site 23-08 have been highly variable, ranging from extremely low to moderately elevated over the available period of record. Ammonia data are not available for monitoring Site 23-04.

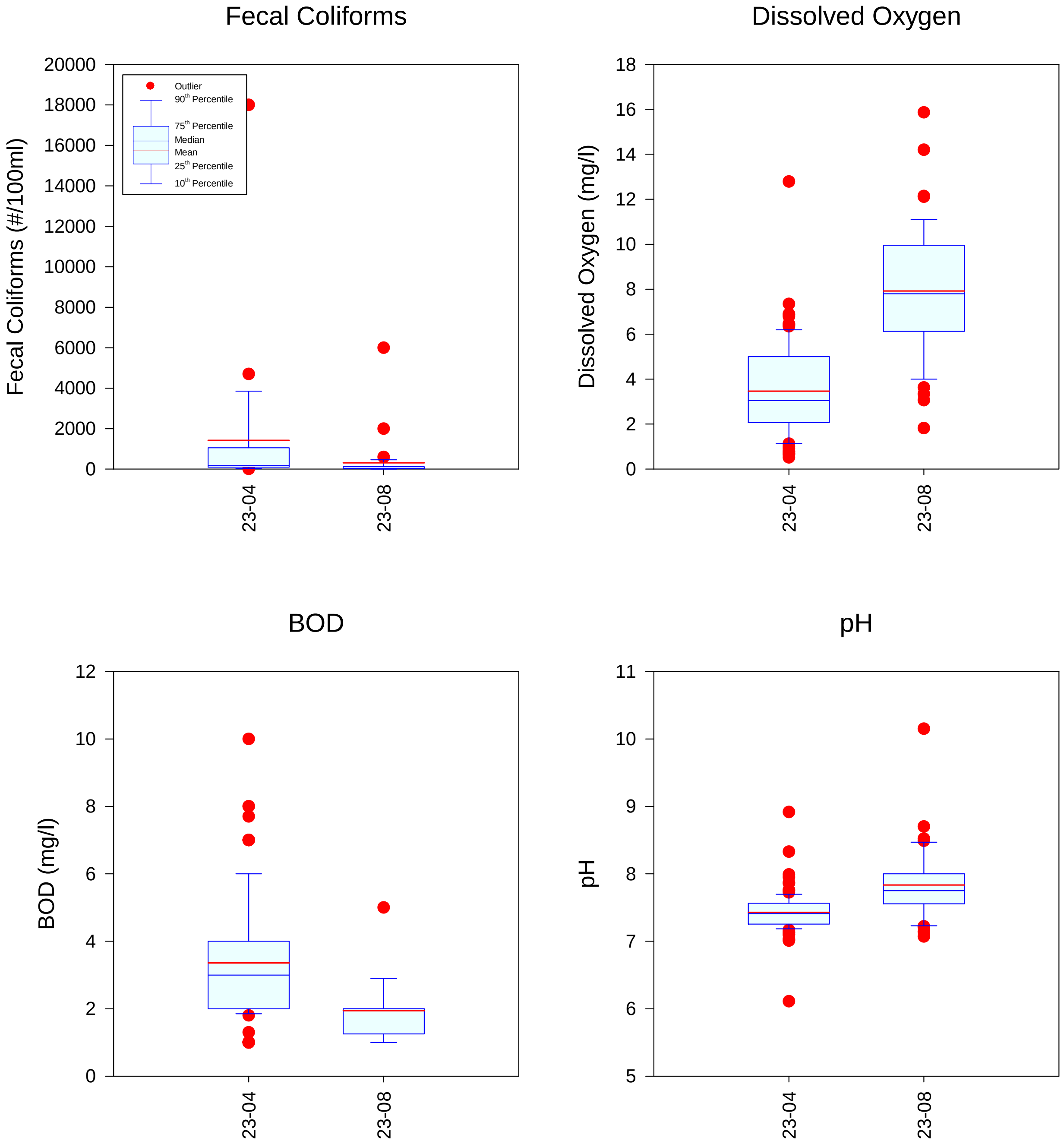


Figure 2-11. Comparison of Historical Concentrations of Fecal Coliform, Dissolved Oxygen, BOD, and pH Measured at Pinellas County Sites 22-04 (1/95-11/02) and 22-08 (2/03-4/10).

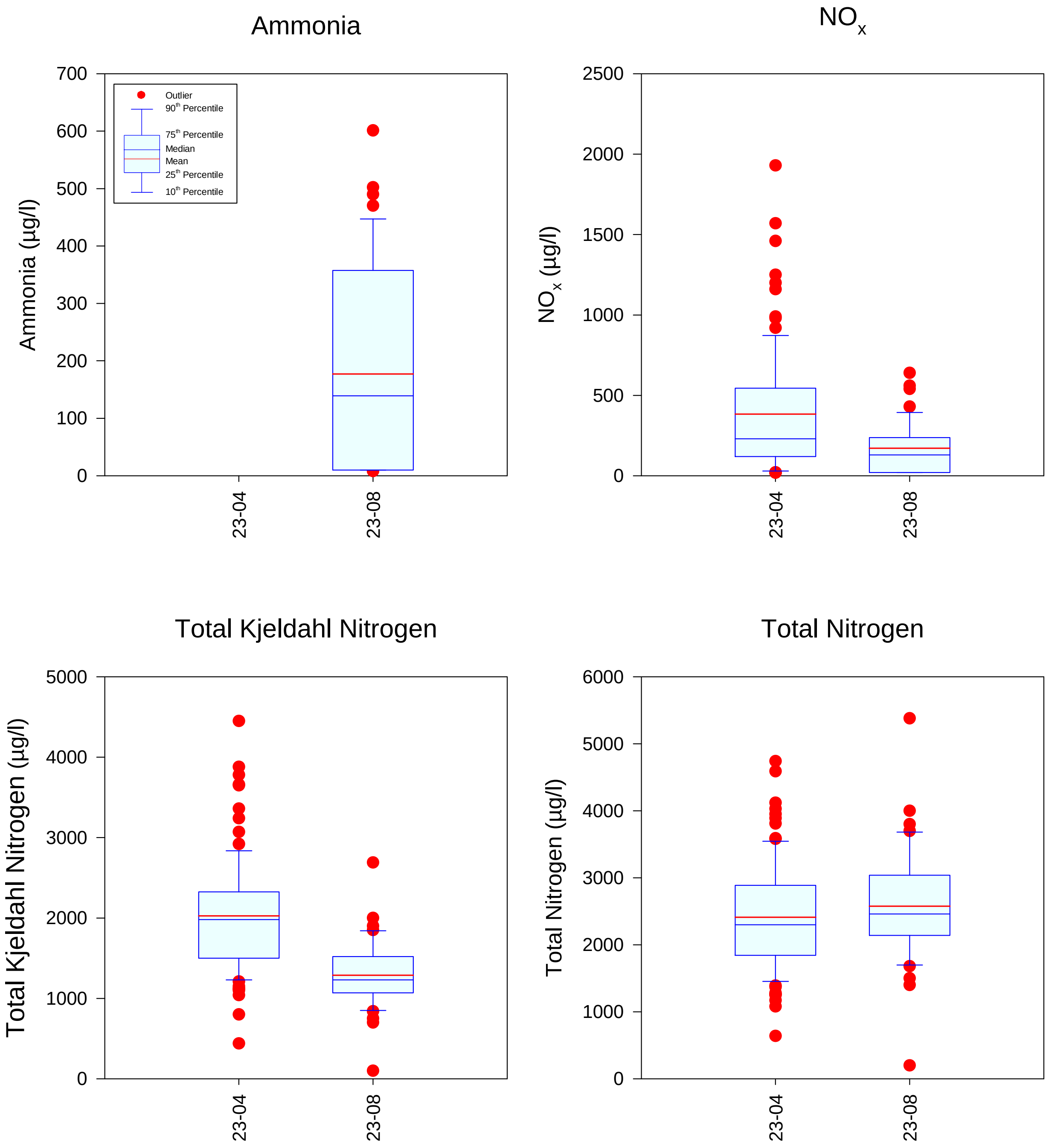


Figure 2-12. Comparison of Historical Concentrations of Nitrogen Species Measured at Pinellas County Sites 23-04 (1/95-11/02) and 23-08 (2/03-4/10).

A high degree of variability was observed in measured NO_x concentrations at each of the two sites, although Site 23-04 is characterized by a substantially higher degree of variability as well as a higher mean value. A reduction in NO_x concentrations appears to occur between the two sites, suggesting that assimilation of NO_x between the two locations exceeds the quantity of additional loadings. A similar pattern is apparent for measured concentrations of TKN, with higher concentrations and a higher degree of variability in measured values observed at Site 23-04 compared with Site 23-08.

Measured total nitrogen concentrations have also been highly variable at each of the two monitoring sites, although the variability in measured values appears to be slightly less at Site 23-08. In general, mean total nitrogen concentrations at the two monitoring sites range from approximately 2500-2800 µg/l, with a slightly higher total nitrogen concentration observed at Site 23-08. These total nitrogen concentrations appear to be elevated and approximately twice the concentration commonly observed for total nitrogen in urban drainage systems.

A comparison of historical concentrations of soluble reactive phosphorus (SRP), total phosphorus, TSS, and specific conductance at Pinellas County Sites 23-04 and 23-08 is given in Figure 2-13. Measured SRP concentrations at the two monitoring sites have exhibited a relatively high degree of variability, with a slightly higher mean concentration observed at Site 23-08. These data appear to suggest an increase in SRP concentrations between the two sites. In contrast, both variability and mean values appear to be relatively similar for total phosphorus between the two sites, with a mean phosphorus concentration of 110 µg/l at Site 23-04 and 103 µg/l at Site 23-08. These data suggest little change in phosphorus concentrations during migration within the canal between the two sites.

Measured TSS concentrations appear to be lower in value and lower in variability at the outfall monitoring site compared with monitoring Site 23-04. These data suggest that TSS may be removed within the channel during migration between the two sites. A large degree of variability has been observed in specific conductance measurements conducted at the two sites, with measurements as high as 8000-10,000 µmho/cm measured at each site. However, in general, each of the two sites appears to maintain freshwater characteristics throughout much of the year. The higher degree of variability in specific conductance measurements at Site 23-08 suggests impacts from periodic high tide conditions which cause water to back-up from the tidal areas into the channel.

A comparison of trends in historical total nitrogen concentrations in Pinellas County monitoring Sites 23-04 and 23-08 is given on Figure 2-14. A "best fit" regression line is provided for each of the two plots to assist in identifying significant water quality trends. The calculated probability value (p-value) is also provided for each regression line which indicates the level of significance associated with each regression model. A model which is significant at a 95% confidence level would be associated with a p-value of 0.05. However, waterbodies exhibit normal seasonal and cyclic variations in water quality which can reduce the statistical significance of a regression model due to normal sources of variability which are unrelated to potential temporal trends. This normal variability may lead to elevated p-values which suggest that trends may not be significant when significant trends actually exist. Therefore, for evaluating water quality trends in surface waters, a p-value of 0.1 or less is generally considered to indicate a significant statistical trend, with p-values from 0.1-0.2 indicating a likely significant trend, and p-values greater than 0.2 indicating an insignificant trend. R-square (R^2) values are also provided for each regression line which provide another indicator of the strength of the relationship between concentrations and time.

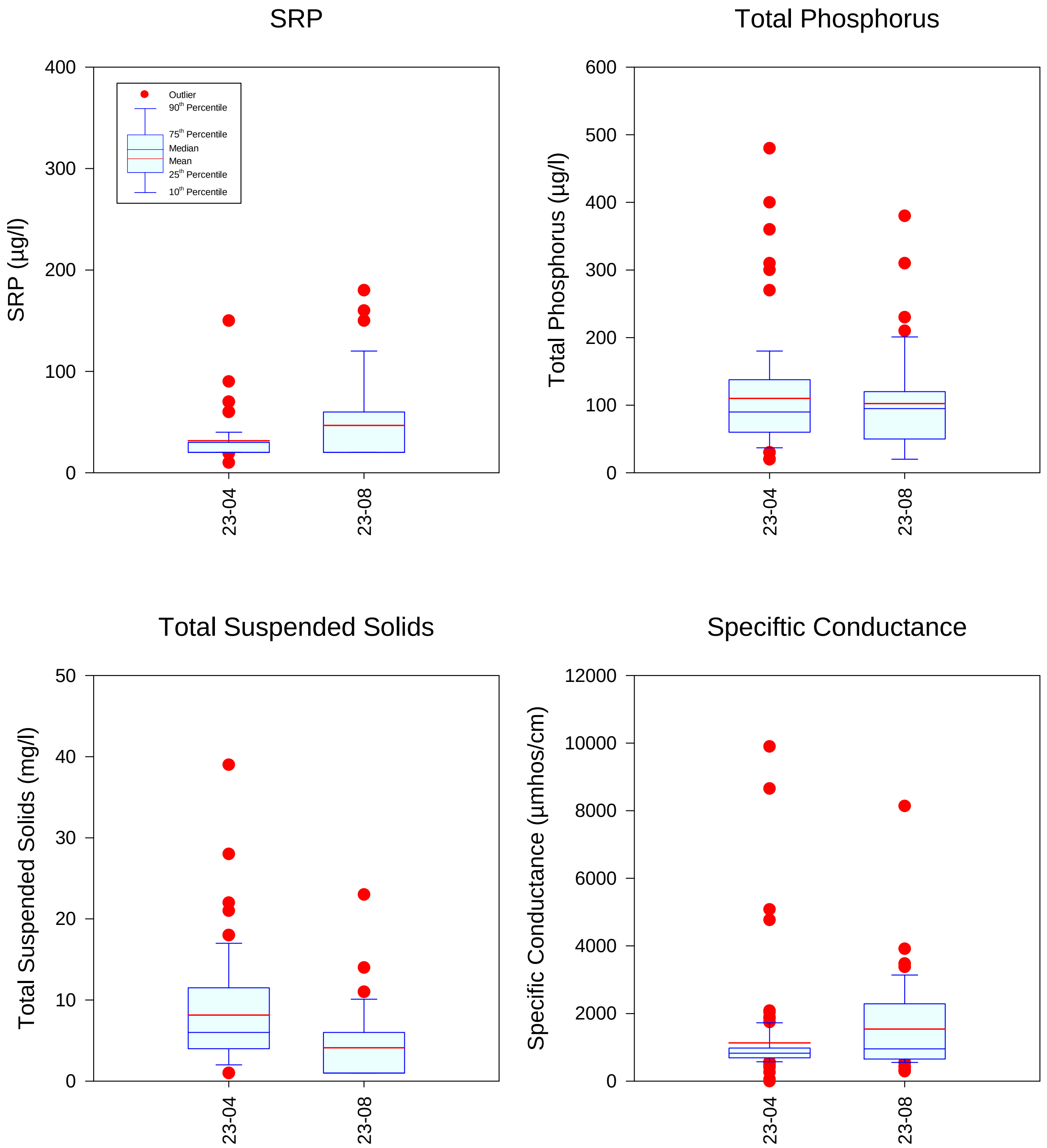
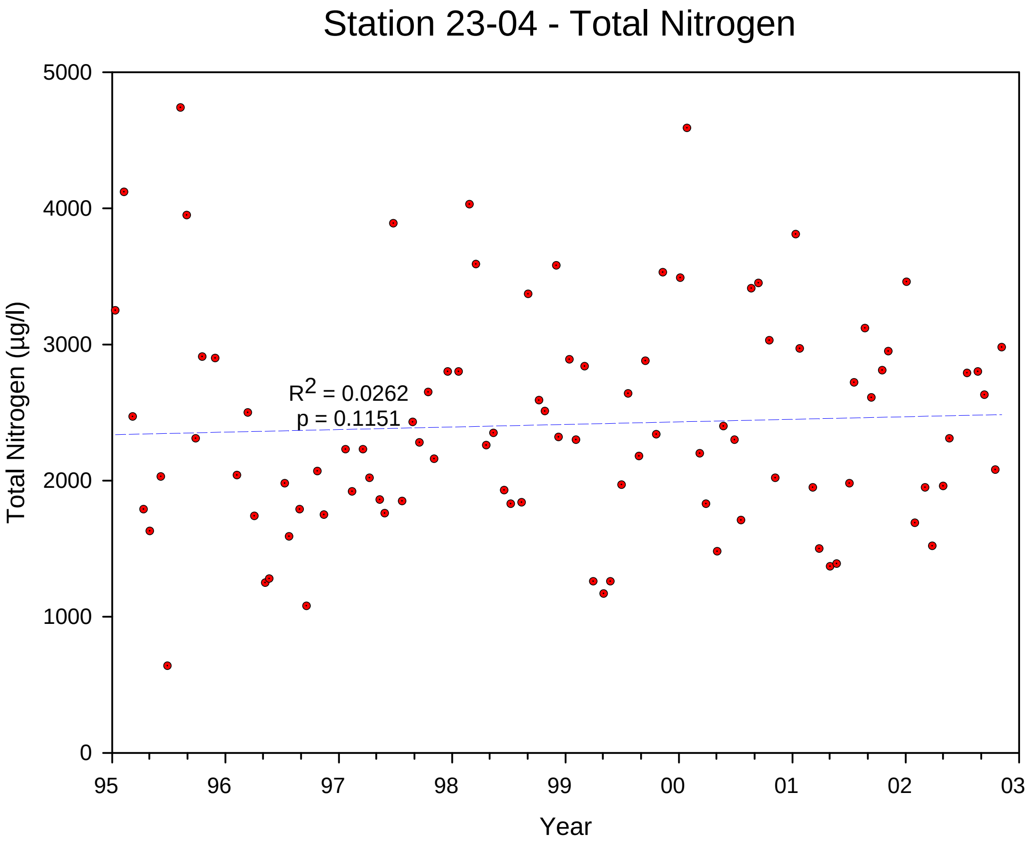


Figure 2-13. Comparison of Historical Concentrations of Phosphorus Species, TSS, and Conductivity Measured at Pinellas County Sites 23-04 (1/95-11/02) and 23-08 (2/03-4/10).



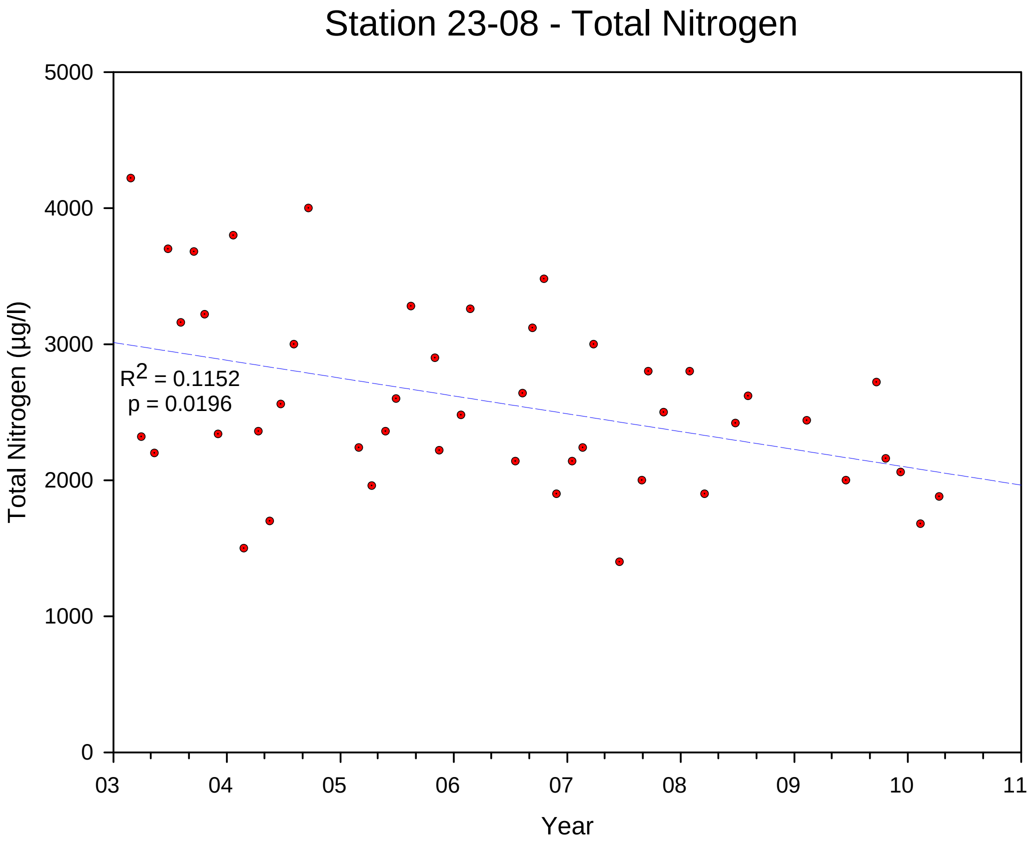


Figure 2-14. Trends in Historical Total Nitrogen Concentrations at Pinellas County Monitoring Sites 23-04 (1/95-11/02) and 23-08 (2/03-4/10).

A general trend of increasing total nitrogen concentrations is apparent at monitoring Site 23-04 over the period from 1995-2002. Based upon the calculated p-value of 0.1151, this relationship is likely significant although the visual scatter within the data and the low calculated R^2 value indicate that the relationship between concentration and time, although likely significant, is generally weak. In contrast, a trend of decreasing total nitrogen concentrations appears to exist at Station 23-08. The relationship between concentration and time is highly significant, but weak, with time explaining only 12% of the variability observed in total nitrogen concentrations. However, based upon the trend line for Station 23-08, total nitrogen concentrations appear to have decreased from approximately 3000 μg/l in 2003 to a mean of approximately 2000 μg/l in 2010.

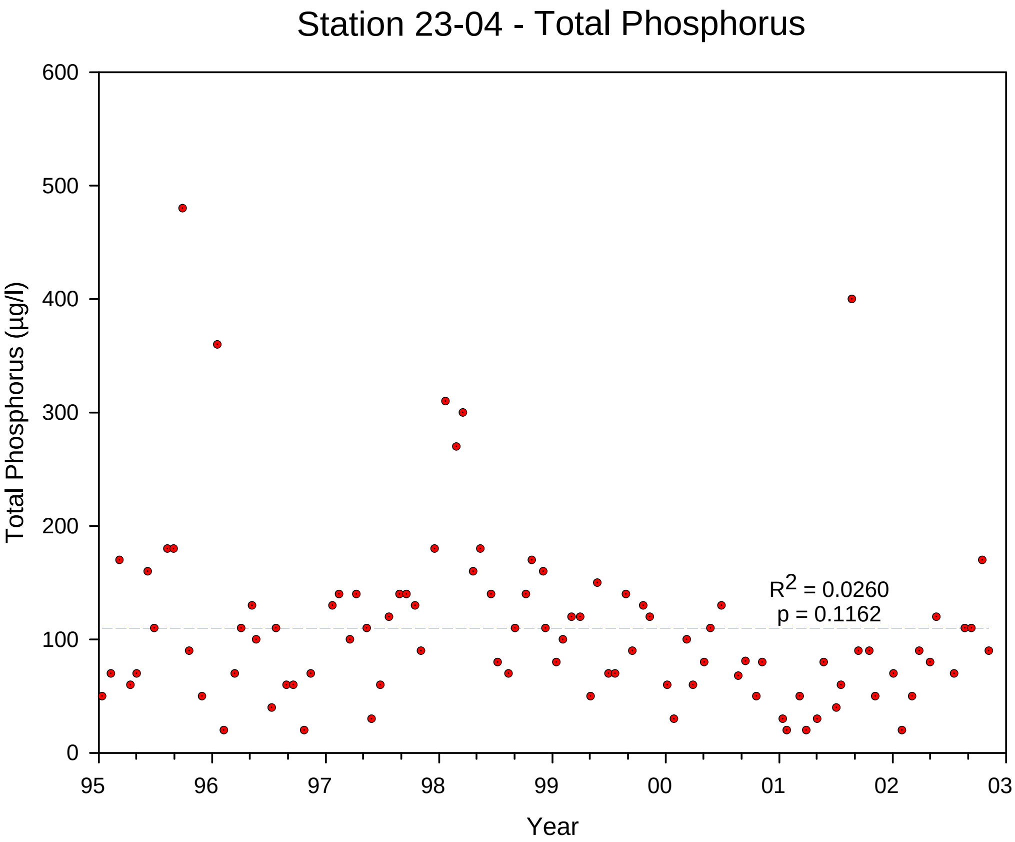
A graphical summary of trends in historical total phosphorus concentrations at Pinellas County monitoring Sites 23-04 and 23-08 is given on Figure 2-15. Based upon the calculated p-value for the regression trend line, a likely significant increase in total phosphorus concentrations occurred at Site 23-04 over the period from 1995-2002. However, the strength of this relationship is weak, with time explaining only 3% of the variability in the total phosphorus concentrations.

In contrast, a trend of decreasing total phosphorus concentrations appears to have occurred at Station 23-08 over the monitoring period from 2003-2010. This relationship is statistically significant, although time explains only approximately 7% of the variability in observed phosphorus concentrations. Based upon the trend line provided for Station 23-08, mean total phosphorus concentrations at this site appear to have decreased from approximately 150 μg/l during 2003 to 50 μg/l during 2010. However, evaluation of the data over the previous five years (2005-2010) may suggest a trend of increasing phosphorus concentrations, although a five-year period is generally too short to indicate water quality trends.

In summary, decreases in concentrations of both total nitrogen and total phosphorus appear to have occurred at the spillway structure for Channel 5 during the period from 2003-2010. Statistically significant trends of decreasing concentrations have been observed for both total nitrogen and total phosphorus at this site, although the relationship between time and concentration appears to be relatively weak based upon the calculated R^2 value. These data appear to suggest that nutrient concentrations are improving in Channel 5 compared with values measured during the 1990s and early 2000s.

2.8 Discharge Data

In addition to the water quality data summarized previously, discharge gauging and stage monitoring stations have also been maintained in Sub-basin H by USGS. Locations of identified discharge and stage monitoring stations in Roosevelt Creek Sub-basin H are indicated on Figure 2-16. Three USGS monitoring sites are located near the vicinity of the rectangular weir water control structure located at the southwest corner of the Bridgeway Acres Landfill. Two additional USGS monitoring sites are located at the salinity barrier/weir structure at the north end of Channel 5.



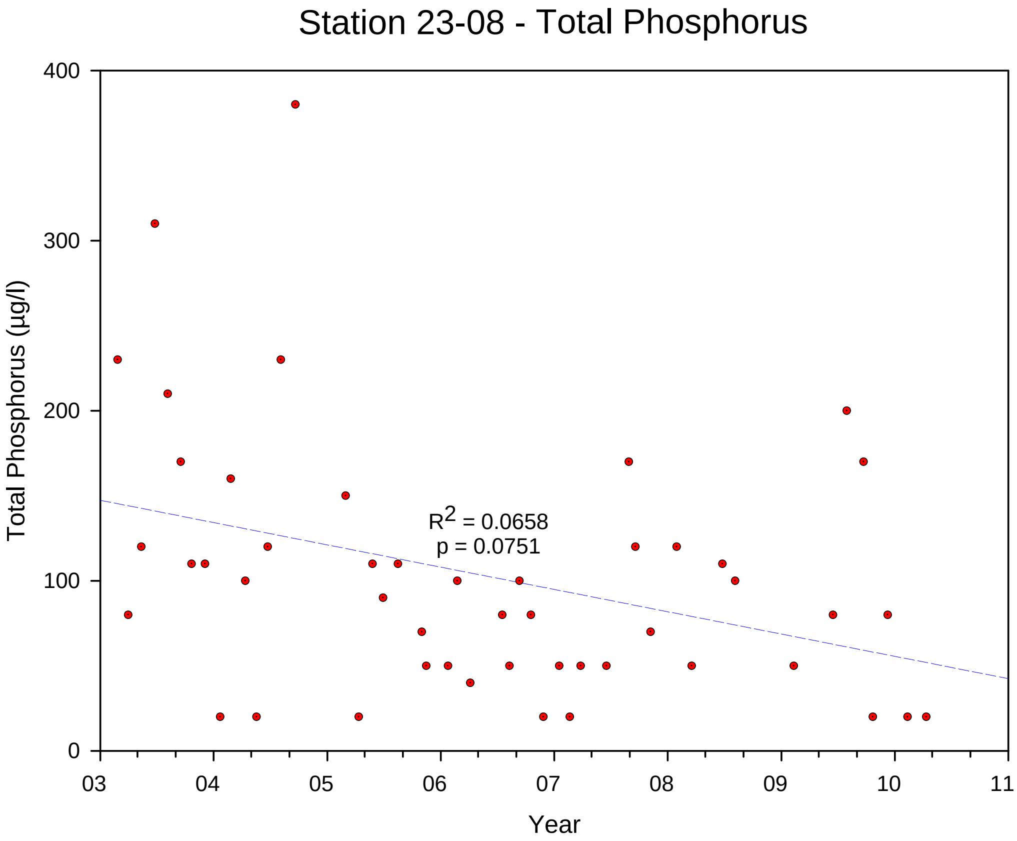


Figure 2-15. Trends in Historical Total Phosphorus Concentrations at Pinellas County Monitoring Sites 23-04 (1/95-11/02) and 23-08 (2/03-4/10).

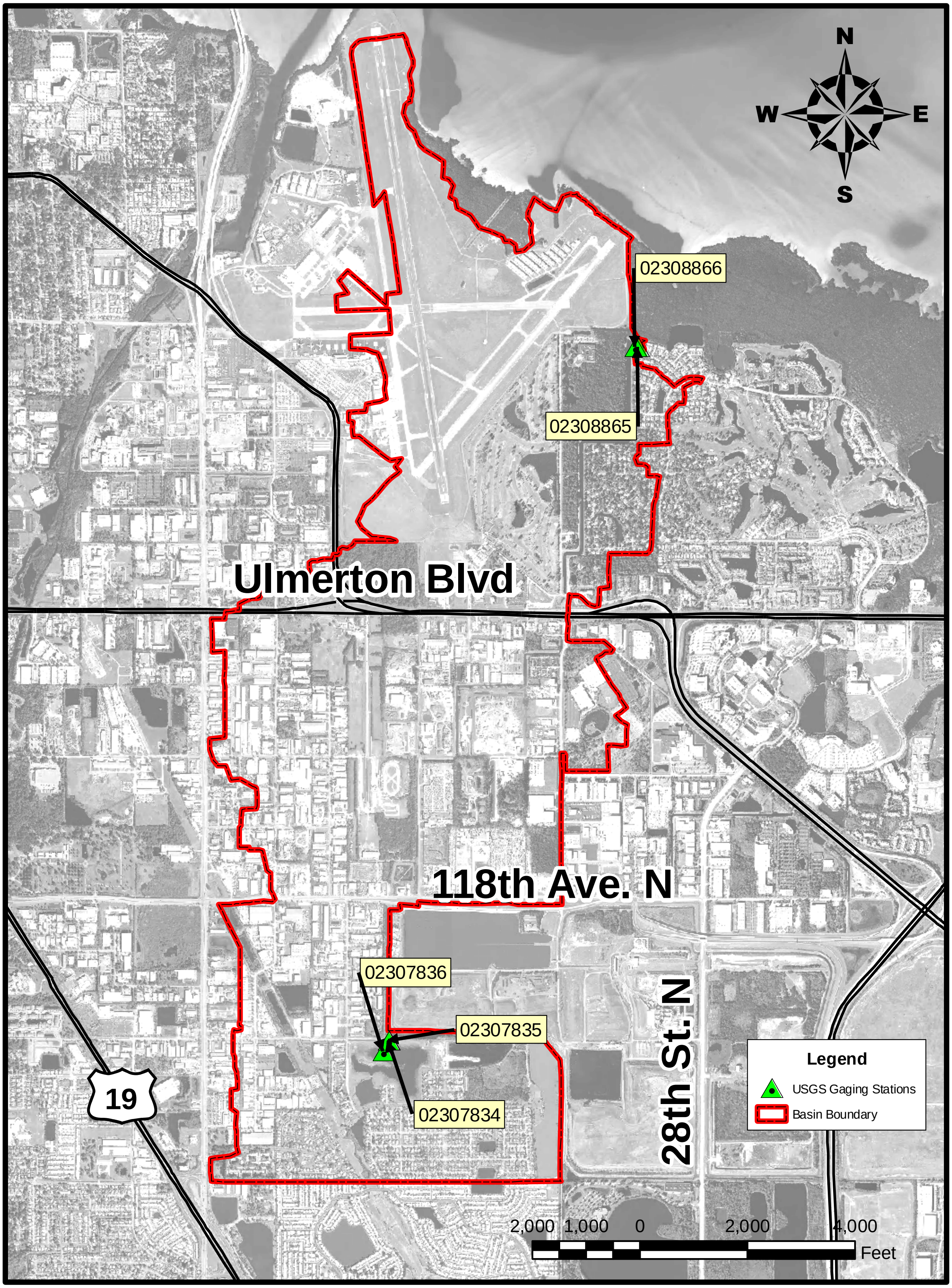


Figure 2-16. Identified Hydrologic Monitoring Stations in Roosevelt Creek Sub-basin H.

Details of the identified hydrologic monitoring stations in Roosevelt Creek Sub-basin H are summarized on Table 2-6. Each of the three stations located near the water control structure in the upstream portion of Channel 5 provide measurements of stage only. Data at these sites are available from June 18, 2002 to the present. The USGS also maintains a recording rainfall station at Site 2307834.

TABLE 2-6

DETAILS OF IDENTIFIED HYDROLOGIC MONITORING STATIONS IN ROOSEVELT CREEK SUB-BASIN H

STATION I.D. NUMBER	SITE DESCRIPTION	RANGE OF DATA	TYPE OF DATA
2307834	Upper Highlands Canal at control near Pinellas Park	6/18/02 – Present	Stage/rainfall
2307835	Upper Highlands Canal below control near Pinellas Park	6/18/02 – Present	Stage
2307836	Roosevelt Reservoir at outfall near Pinellas Park	6/19/02 – Present	Stage
2308865	Roosevelt Canal at STR 23-8 near Pinellas Park	10/1/04 – Present	Discharge
2308866	Roosevelt Canal below STR 23-8 near Pinellas Park	10/1/04 – Present	Stage

Two of the USGS hydrologic monitoring stations are located at the northern end of Channel 5 at the salinity barrier/weir structure. Station 2308865 is located upstream from the weir structure and is used to calculate discharge from Channel 5 into the tidal wetland system associated with Old Tampa Bay. Discharge data at this site are available from October 1, 2004 to the present. A photograph of the USGS monitoring equipment at this site is given on Figure 2-17. An additional hydrologic monitoring site, designated as Site 2308866, is located downstream from the weir structure and includes information on stage only.

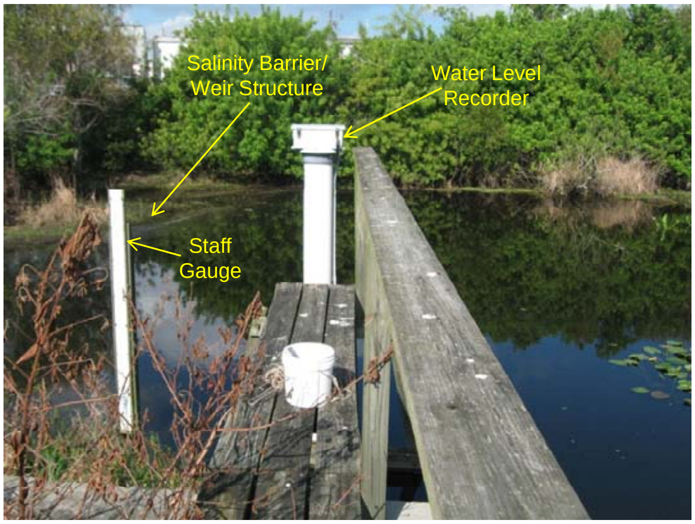


Figure 2-17. USGS Hydrologic Monitoring Equipment at the Salinity Barrier/Weir Structure (Station 2308865).

A graphical summary of discharge measurements from Channel 5 into the tidal wetland system conducted by USGS at Site 23-08 is given on Figure 2-18. Discharges from this site appear to be highly variable over the period of record, with peaks in discharge rates corresponding with significant rain events within the basin. A low level baseflow discharge appears to occur throughout much of the year in the absence of rain events. The highest recorded flow during the available period of record is approximately 336 cfs which occurred during February 2006 as a result of 11.29 inches of rain over a 24-hour period. The data provided for this site by USGS reflect mean daily discharge rates.

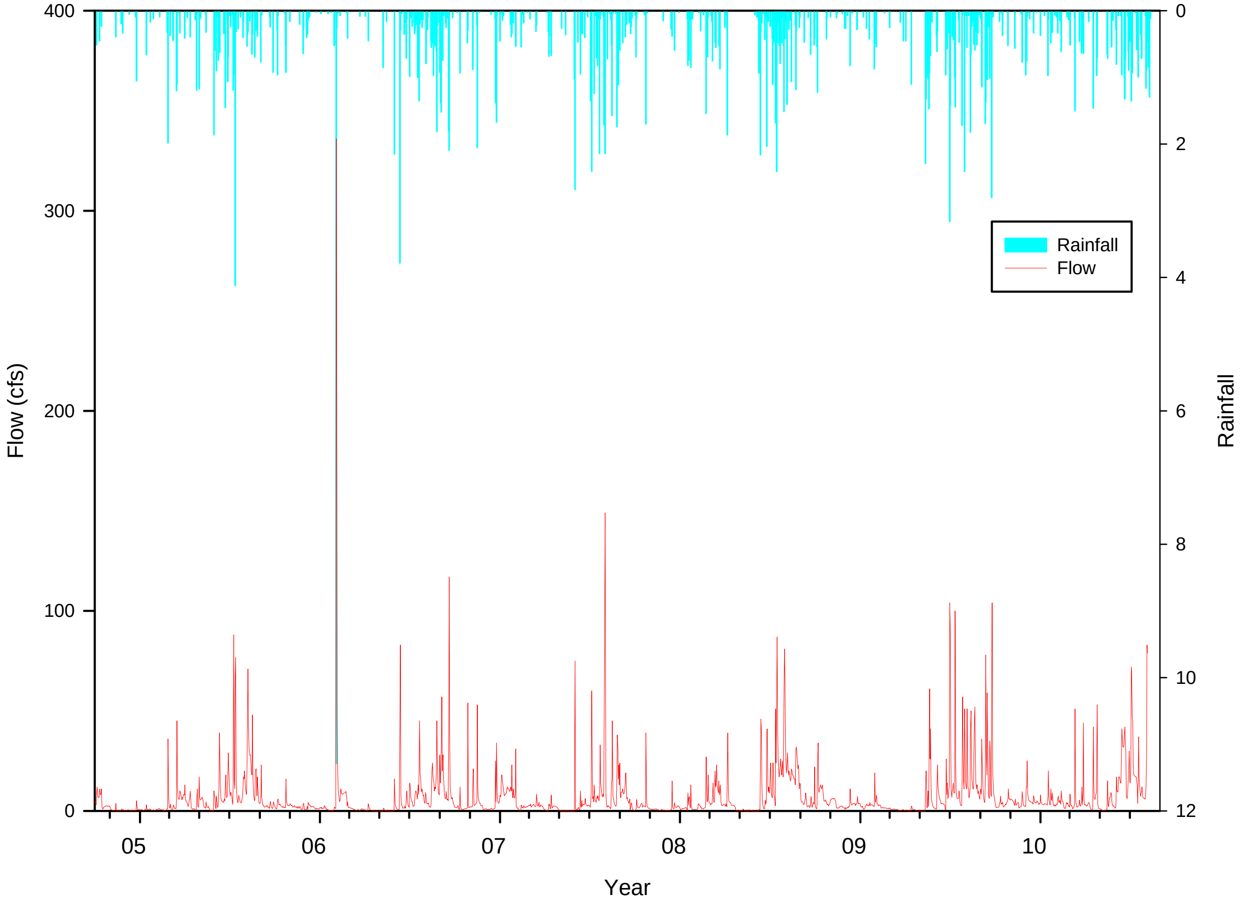


Figure 2-18. Mean Daily Discharge Measurements Conducted by USGS at Site 23-08.

A tabular summary of mean daily discharge characteristics at Site 23-08 is given on Table 2-7. Characteristics are provided for each year during the monitoring program for which a full year of data is available. Average discharge rates at Site 23-08 range from 5.44 cfs during 2007 to 8.27 cfs during 2009. The range of minimum and maximum daily discharge rates is also provided. Annual discharges from Channel 5 into the tidal wetland marsh were calculated by multiplying the mean daily discharge rates times 365 days per year. A summary of estimated annual discharges is given in the final column of Table 2-7. Annual discharges from Channel 5 range from 3938 ac-ft during 2007 to 5984 ac-ft during 2009.

TABLE 2-7

SUMMARY OF DISCHARGE CHARACTERISTICS AT SITE 23-08

YEAR	AVERAGE DISCHARGE (cfs)	NUMBER OF DAILY VALUES	MINIMUM DAILY DISCHARGE (cfs)	MAXIMUM DAILY DISCHARGE (cfs)	ANNUAL DISCHARGE (ac-ft/yr)
2005	6.01	365	0	88	4349
2006	7.30	365	0	336	5288
2007	5.44	365	0	149	3939
2008	7.99	366	0	87	5800
2009	8.27	365	0	104	5984
Mean Values:	**7.00**	**365**	**0**	**153**	**5069**

2.9 Mass Loadings

Estimates of annual mass loadings of total nitrogen and total phosphorus discharging from Channel 5 into the tidal wetland area were calculated over the period from 2005-2009. This period was selected since both hydrologic and water quality data are available at monitoring Site 23-08 over this period. A summary of the estimated annual loadings of total nitrogen and total phosphorus is given in Table 2-8. Estimates of annual discharge volumes were obtained from Table 2-7 over the period from 2005-2009. Mean annual concentrations of total nitrogen and total phosphorus were obtained from the available water quality data for Station 23-08 provided in Appendix A. The estimated annual discharge volumes were multiplied by the mean annual concentrations to obtain estimates of annual loadings for total nitrogen and total phosphorus.

TABLE 2-8

ESTIMATED ANNUAL LOADINGS OF TOTAL NITROGEN AND TOTAL PHOSPHORUS DISCHARGING FROM CHANNEL 5 FROM 2005 – 2009

YEAR	ANNUAL DISCHARGE VOLUME (ac-ft)	MEAN ANNUAL CONCENTRATION (µg/l)		ANNUAL LOAD (kg)	
		Total Nitrogen	Total Phosphorus	Total Nitrogen	Total Phosphorus
2005	4,349	2,509	86	13,436	459
2006	5,288	2,403	65	15,648	423
2007	3,939	2,297	76	11,144	367
2008	5,800	2,435	95	17,395	679
2009	5,984	2,793	100	20,587	737
Total:	**5,069**	**2,480**	**82**	**15,484**	**513**

Estimated annual discharges of total nitrogen and total phosphorus are summarized in the final column of Table 2-8. Mass loadings of total nitrogen from Channel 5 over the period from 2005-2009 ranged from 11,144 kg/yr during 2007 to 20,587 kg/yr during 2009. Annual discharges of total phosphorus from Channel 5 ranged from a low of 367 kg/yr in 2007 to 737 kg/yr in 2009. Although the historical water quality data suggest a trend of decreasing concentrations for total phosphorus over the period from 2003-2010, estimated annual mass loadings appear to be increasing.

2.10 Wastewater Disposal

Information on wastewater disposal in Roosevelt Creek Sub-basin H was provided to ERD by Pinellas County. Sanitary sewer collection lines within Roosevelt Creek Sub-basin H are currently provided by the cities of Largo and Pinellas Park. Locations of primary sanitary sewers are indicated on Figure 2-19. Currently, the City of Pinellas Park provides centralized sewer services to areas within Sub-basin H located south of 118th Avenue North. Sanitary sewer for the Ulmerton Road corridor and residential areas located in northeastern portions of the sub-basin, along with the St. Petersburg/Clearwater International Airport, are provided by the City of Largo. As a result, it appears that all areas within Roosevelt Creek Sub-basin H currently utilize centralized sewer systems for wastewater disposal. No septic tank systems are known to exist within the Sub-basin H area.

2.11 Reclaimed Water

Information on areas within Roosevelt Creek Sub-basin H which receive reclaimed water for irrigation was provided to ERD by Pinellas County. Reuse infrastructure is currently provided in Sub-basin H by the cities of Largo and Pinellas Park. Locations of reuse lines (>6-inch diameter) are indicated on Figure 2-20. Significant reuse lines are located in the central and southern portions of Sub-basin H.

An overview of areas within Sub-basin H which receive reclaimed water for irrigation purposes is given on Figure 2-21. Currently, the use of reclaimed water for irrigation is limited to two locations within Sub-basin H. One area is located in the extreme southern portions of Sub-basin H south of the Bridgewater Acres Landfill and east of the power line easement. Reclaimed water is provided by the City of Pinellas Park South Cross Bayou Wastewater Reclamation Facility which is located approximately 5 miles southwest of Sub-basin H, for irrigation over a 130-acre residential area.

Information on the water quality of reuse water provided by the South Cross Bayou Wastewater Reclamation Facility was obtained from the Pinellas County Utilities website. A summary of mean characteristics of reclaimed water generated at this facility is given on Table 2-9. The mean nitrate concentration measured in reclaimed water at this facility is 1.27 mg/l. Information is not provided on concentrations of other nitrogen species. The mean total phosphorus concentration in reclaimed water from this facility is approximately 0.88 mg/l. Information on the amount of reclaimed water applied within Sub-basin H on a monthly or annual basis does not appear to be available.

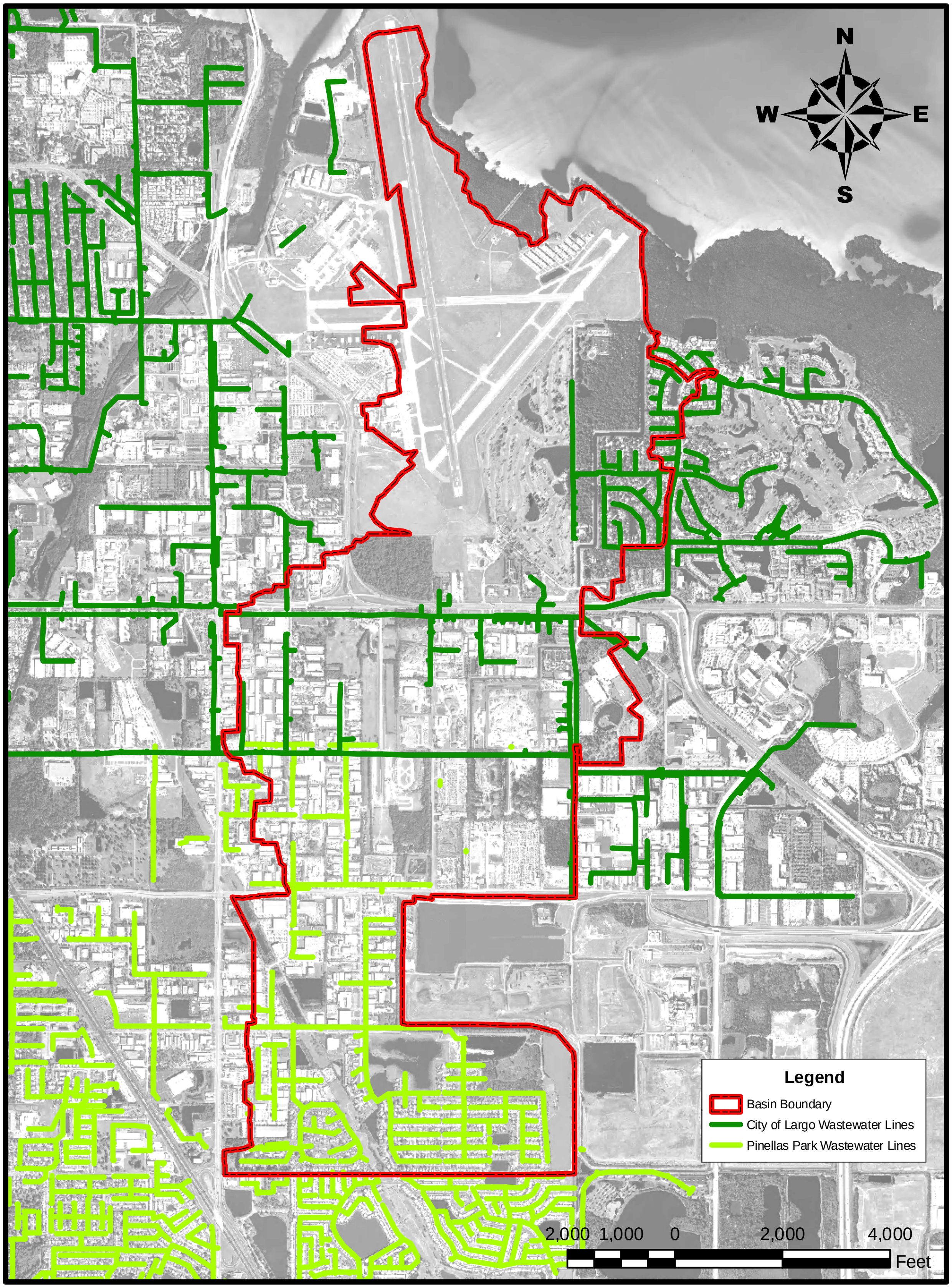


Figure 2-19. Locations of Sanitary Sewer Collection Lines in Roosevelt Creek Sub-basin H.

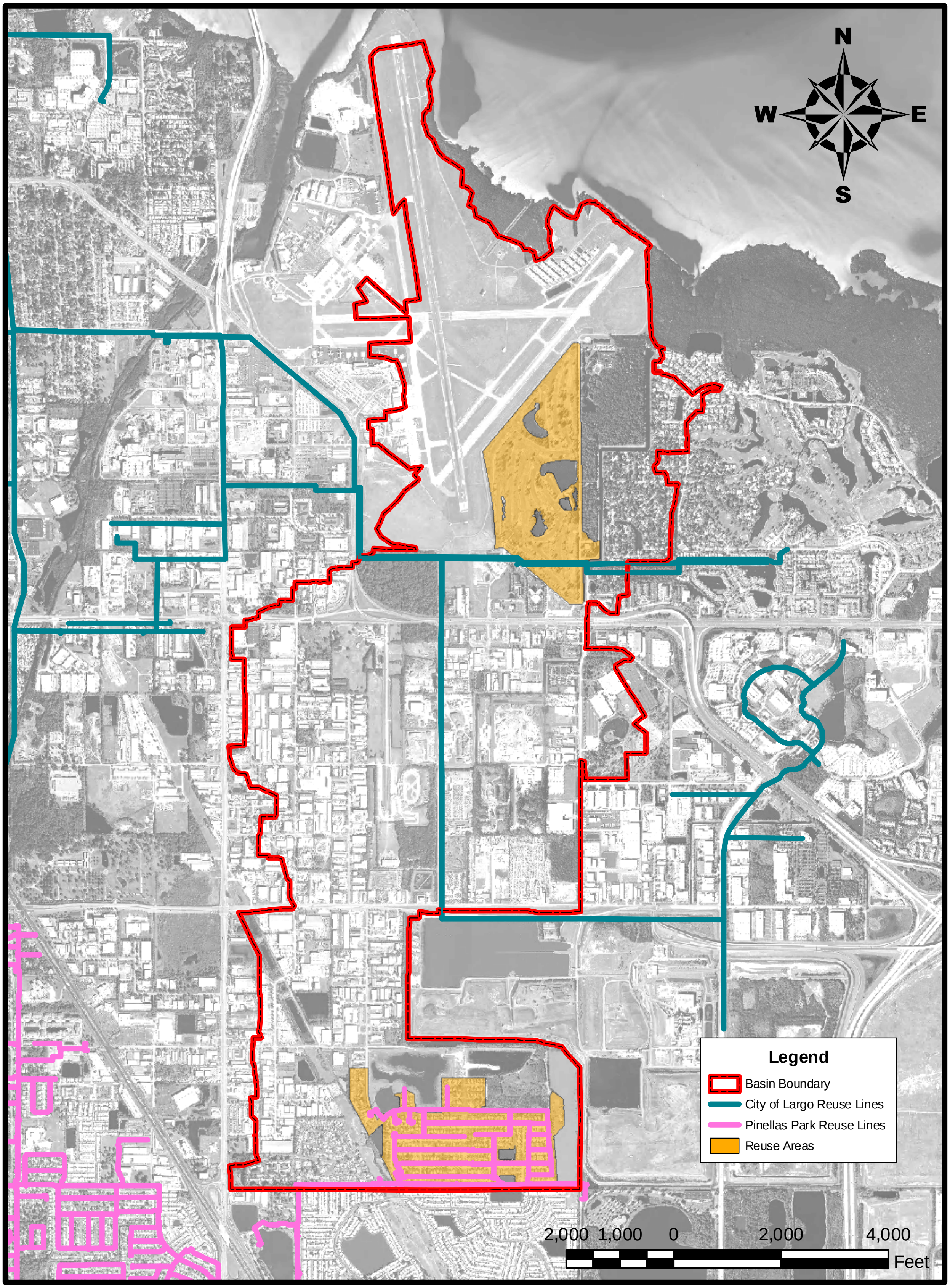


Figure 2-20. Reclaimed Wastewater Distribution System (> 6-inch Diameter) in Roosevelt Creek Sub-basin H.

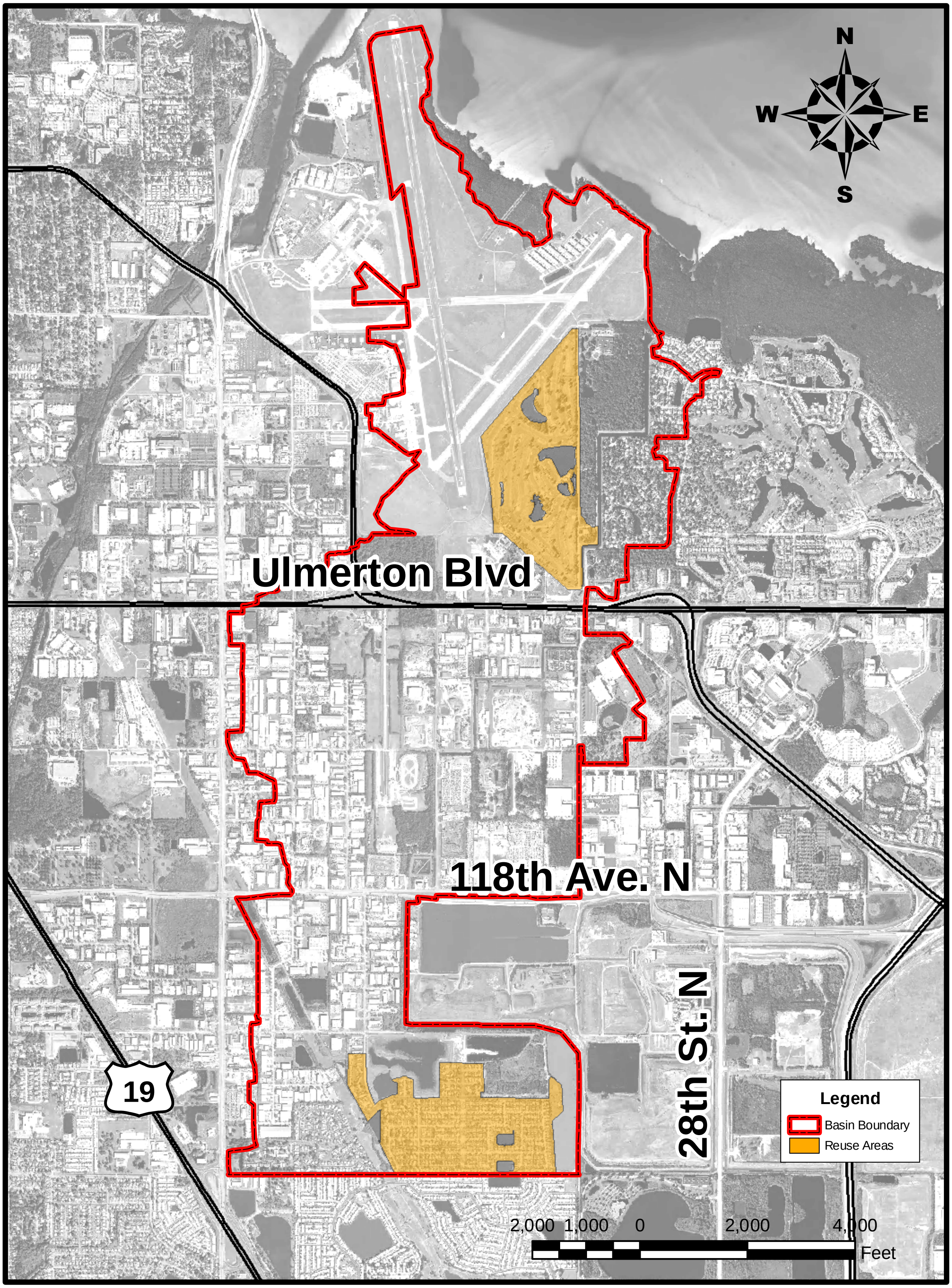


Figure 2-21. Areas Receiving Reuse Water for Irrigation in Roosevelt Creek Sub-basin H.

TABLE 2-9

CHARACTERISTICS OF RECLAIMED WATER PROVIDED BY THE SOUTH CROSS WASTEWATER RECLAMATION FACILITY
(Source: Pinellas County Utilities)

INORGANIC CONTAMINANT	UNITS	SOUTH CROSS FACILITY
Chloride	mg/l	322
Nitrate	mg/l	1.27
pH	s.u.	7.36
Phosphorus	mg/l	0.88

The second area where reclaimed water is used is located on the northern portion of Sub-basin H at the Airco Golf Course. Reclaimed water is currently used for irrigation on approximately 128 acres of the golf course. The water is metered and applied directly for irrigation as received through the reclaimed water force main. According to Pinellas County, reclaimed water is not stored in surface water ponds prior to use. Reclaimed water to the Airco Golf Course is provided by the City of Largo Wastewater Treatment Plant which is located approximately 1.2 miles northwest of the golf course at the intersection of 150th Avenue North and 49th Street North. Overall, approximately 258 acres (11%) of the 2316-acre area for Sub-basin H currently use reclaimed wastewater for irrigation.

SECTION 3

FIELD AND LABORATORY ACTIVITIES

Field and laboratory analyses were conducted by ERD from August-October 2009 within Roosevelt Creek Sub-basin H to characterize the quantity and quality of discharges through this area. Eighteen surface water sites were monitored on a biweekly basis, which included measurements of field parameters, discharge rate (if applicable), and sample collection for laboratory analyses. Five separate monitoring events were conducted at each site. Each of the collected samples was analyzed in the ERD Laboratory for general parameters and nutrients. Sediment core samples were also collected at each of the 18 monitoring sites and evaluated for physical characteristics and nutrient concentrations. In addition, aliquots of each collected sample were shipped to the Colorado Plateau Stable Isotope Laboratory for isotope analyses of nitrogen and oxygen to assist in identifying potential pollutant sources.

3.1 Field Activities

3.1.1 Monitoring Sites

A project start-up meeting was conducted with representatives of ERD, Pinellas County, and the Southwest Florida Water Management District (District) on July 24, 2009 to discuss project details and select preliminary monitoring site locations. A subsequent site visit and field reconnaissance meeting was conducted to Roosevelt Creek Sub-basin H on July 27, 2009 by representatives of ERD and Pinellas County to discuss drainage patterns and select final monitoring locations for surface water sites within the basin. A description of monitoring locations in Roosevelt Creek Sub-basin H is given in the following sections.

An overview of surface water monitoring sites selected within the Roosevelt Creek Sub-basin H study area is given on Figure 3-1. Eighteen separate monitoring sites were selected to quantify nutrient loadings discharging through the system. Five of the proposed monitoring sites are located along the main stream of Channel 5 to quantify changes in flow rates and nutrient loadings along the main path of the channel. Eleven sites reflect inputs into Channel 5 to assist in identifying potential sources of elevated nutrient inputs into the channel. Two additional sites which represent inflows directly to Old Tampa Bay from the St. Petersburg/Clearwater International Airport were also monitored. A tabular summary of monitoring sites in Roosevelt Creek Sub-basin H is given on Table 3-1. The selected monitoring sites were intended to provide an analysis of water quality characteristics, including changes in nutrient loadings, during migration through the study area.

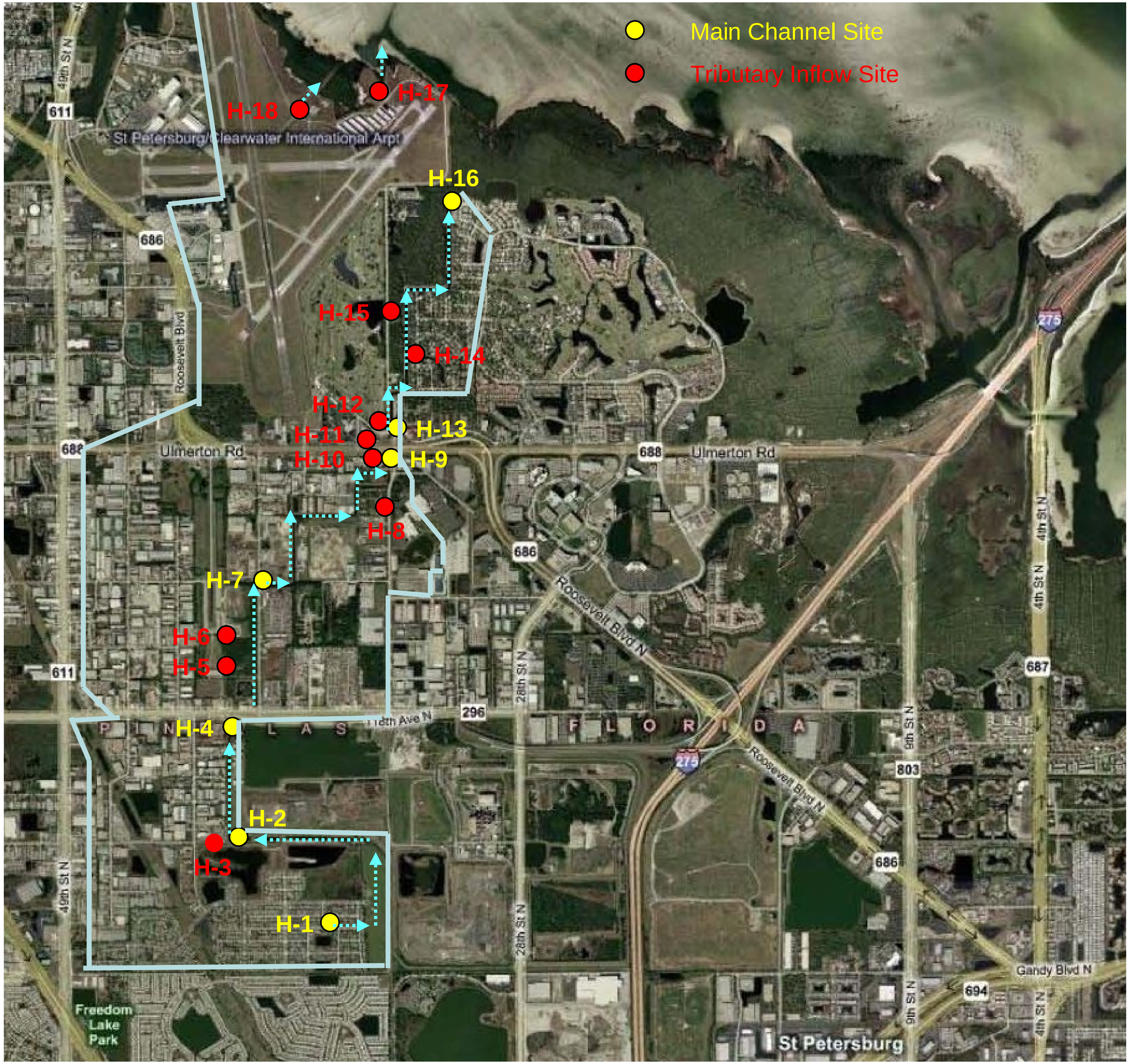


Figure 3-1.

Overview of Surface Water Monitoring Sites for Roosevelt Creek Sub-basin H.

TABLE 3-1

SUMMARY OF MONITORING SITES IN THE ROOSEVELT CREEK SUB-BASIN H STUDY AREA

SITE NO.	DESCRIPTION	PURPOSE
H-1	Piped discharge from residential subdivision pond system	Primary inflow in upstream portion of channel
H-2	Main channel site – open channel	Initial channel site to establish upstream characteristics
H-3	Open ditch inflow to channel along 110th Avenue N	Tributary inflow to main channel
H-4	Main channel site – open channel south of 118th Avenue N	Main channel site
H-5	Open ditch inflow to main channel – culvert crossing	Tributary inflow to main channel
H-6	Open ditch inflow to main channel – culvert crossing	Tributary inflow to main channel
H-7	Main channel near 40th Street N – open channel	Main channel site
H-8	Open ditch inflow to main channel – open channel	Tributary inflow to main channel
H-9	Main channel near 131st Avenue N – open channel	Tributary inflow to main channel
H-10	Open ditch south of Ulmerton Road – open channel	Tributary inflow to main channel
H-11	Open ditch north of Ulmerton Road – open channel	Tributary inflow to main channel
H-12	Open ditch along Old Roosevelt Blvd. – open channel	Tributary inflow to main channel
H-13	Main channel north of Ulmerton Road – open channel	Main channel site
H-14	Discharge from pond into main channel – discharge structure	Tributary inflow to main channel
H-15	Open ditch inflow from Airco Golf Course – culvert crossing	Tributary inflow to main channel
H-16	Structure at north end of Channel 5	Main channel site
H-17	Open channel tributary to Tampa Bay – culvert crossing	Tributary inflow to Old Tampa Bay
H-18	Open channel tributary to Tampa Bay – culvert crossing	Tributary inflow to Old Tampa Bay

The location of surface water monitoring Site H-1 is given on Figure 3-2. This site is located in the upper portions of the Roosevelt Creek Sub-basin H area and reflects the discharge from a series of interconnected ponds which provide stormwater treatment for a residential area. Field monitoring was conducted in the outfall pipe for the drainage system prior to entering the adjacent waterbody which forms the headwaters of Channel 5.

The location of surface water monitoring Site H-2 is given on Figure 3-3. This site is located southwest of the Bridgeway Acres Landfill area and is the first site located along the main channel portion of Channel 5. This site provides background conditions for evaluation of changes in water quantity and water quality during migration through the Channel 5 system. A photograph of monitoring Site H-2 is given on Figure 3-4. Samples were collected on the downstream side of the 8-ft wide rectangular weir structure.

Figure 3-2. Location of Monitoring Site H-1.

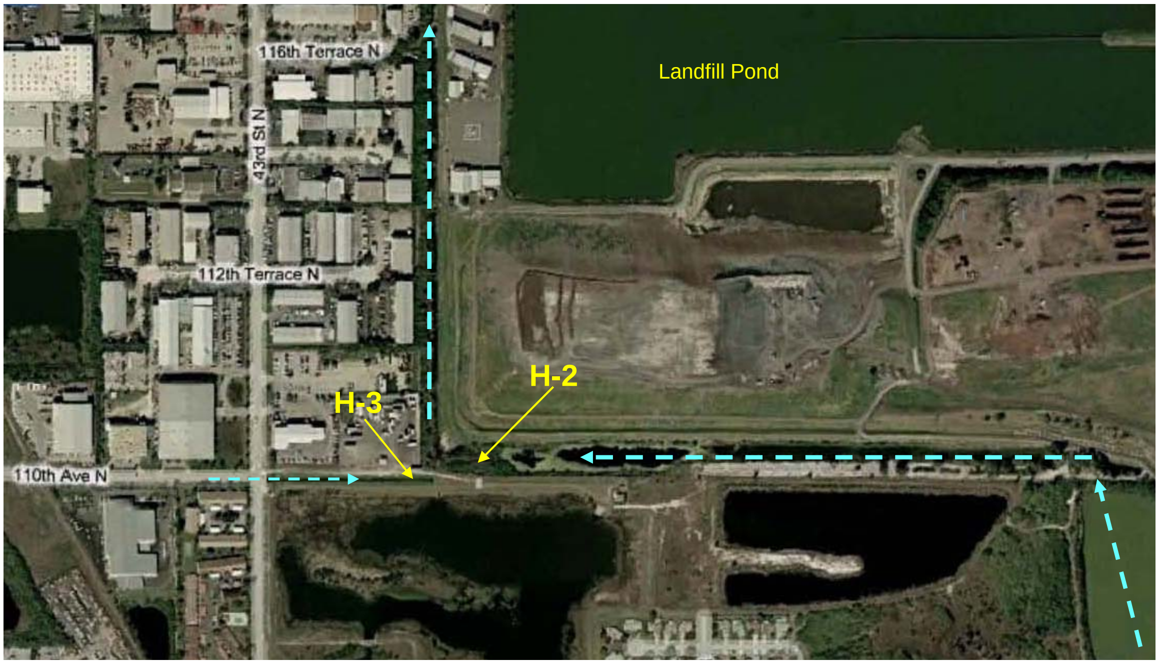


Figure 3-3. Location of Monitoring Sites H-2 and H-3.

Figure 3-4. Photograph of Monitoring Site H-2.

The monitoring location for Site H-3 is also indicated on Figure 3-3. This site represents a small tributary inflow to the main channel which includes drainage inputs originating along 110th Avenue North. Photographs of monitoring Site H-3 are given on Figure 3-5. Monitoring was conducted on the upstream side of the 72-inch RCP culvert prior to discharge into the main channel.

Figure 3-5. Photographs of Monitoring Site H-3.

Locations for surface water monitoring Sites H-4, H-5, and H-6 are indicated on Figure 3-6. Site H-4 is located within the main channel of Channel 5, immediately south of 118th Avenue North. This site reflects changes in water quantity or quality during migration through the main channel between monitoring Sites H-2 and H-4. This site is located at the weir structure on the northwest side of Bridgeway Acres Landfill which is illustrated on Figure 2-9. This structure contains a total of 24 ft of horizontal rectangular weir. The pumped inflow from the Bridgeway Acres Landfill is introduced into Channel 5 approximately 50 ft upstream from the weir structure and enters the channel through a submerged pipe which could not be monitored directly.

Figure 3-6. Location of Monitoring Sites H-4, H-5, and H-6.

Monitoring Sites H-5 and H-6 represent small tributary inflows into the main channel. Each of these inflows originates within the industrial areas located west of the main channel. Monitoring was conducted at these sites in culverts associated with road crossings immediately upstream of the point of inflow into the main channel. A photograph of monitoring Site H-5 is given on Figure 3-7. This site consists of a vegetated open ditch which receives inputs from an adjacent industrial area and sports complex. A photograph of monitoring Site H-6 is given on Figure 3-8. This site consists of an open drainage system, portions of which are heavily vegetated, and receives runoff from adjacent industrial activities, open areas, and a small racetrack.

Figure 3-7.   Photograph of Monitoring Site H-5.

Figure 3-8.   Photograph of Monitoring Site H-6.

Locations for monitoring Sites H-7 and H-8 are indicated on Figure 3-9. Site H-7 is located within the main channel of Channel 5 and is designed to evaluate changes in water quality and quantity which occur between 118th Avenue North and 40th Street North. Photographs of monitoring Site H-7 are given on Figure 3-10. This monitoring site is located on the upstream side of the four 60-inch RCPs and one 36-inch RCP which convey Channel 5 beneath 40th Street North. The channel in this area is approximately 50 ft in width with a relatively shallow flow. The bottom of the channel consists primarily of sand and muck with little vegetation.

Figure 3-9. Location of Monitoring Sites H-7 and H-8.

a. Upstream side of monitoring site

b. Downstream side of monitoring site

Figure 3-10. Photographs of Monitoring Site H-7.

Monitoring Site H-8 reflects a minor tributary inflow into the main channel which provides drainage for areas along 34th Street North. Photographs of monitoring Site H-8 are given on Figure 3-11. This site consists of a roadway drainage system which runs parallel to 34th Street North. Discharges through this channel occur primarily as a result of rain events, although a low level baseflow was observed during most monitoring events.

a. Upstream portions of Site H-8 inflow

b. Point of inflow with Main Channel

Figure 3-11. Photographs of Monitoring Site H-8.

Locations of monitoring Sites H-9 through H-13 are indicated on Figure 3-12. Monitoring Site H-9 is located within the main channel and is intended to monitor changes in water quantity and quality within the channel after migrating through the industrial areas between Sites H-7 and H-9. A photograph of monitoring Site H-9 is given on Figure 3-13. This site is approximately 400 ft south of the intersection of Channel 5 and Ulmerton Road.

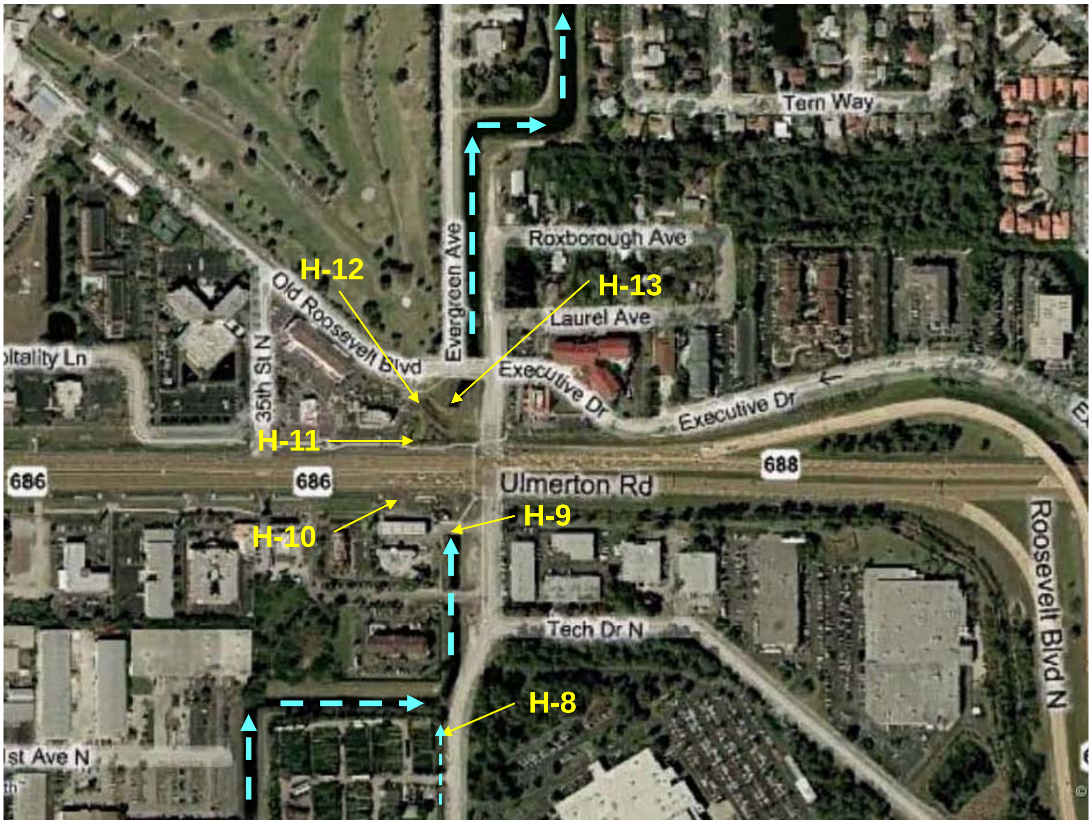


Figure 3-12. Location of Monitoring Sites H-9 through H-13.

Figure 3-13. Photograph of Monitoring Site H-9.

Monitoring Site H-10 reflects a swale drainage system which collects runoff from roadway and adjacent commercial areas along the south side of Ulmerton Road. A photograph of monitoring Site H-10 is given on Figure 3-14. This swale discharges into the west side of Channel 5, south of Ulmerton Road. The conveyance channel is vegetated with a combination of grass and herbaceous wetland species along much of the channel prior to discharging through two 36-inch RCPs and converting into a concrete lined trapezoidal channel upstream of the point of inflow into Channel 5.

a. Transition from vegetated swale to lined ditch

b. Channel inflow to main ditch

Figure 3-14. Photographs of Monitoring Site H-10.

Site H-11 reflects drainage through a 24-inch RCP from roadway and commercial areas located on the north side of Ulmerton Road, west of Channel 5. A photograph of monitoring Site H-11 is given on Figure 3-15. This inflow consists entirely of a vegetated roadside swale system which discharges into Channel 5 through a drop inlet and stormsewer system.

Figure 3-15. Photograph of Monitoring Site H-11.

Monitoring Site H-12 reflects drainage originating along Old Roosevelt Blvd. This inflow contributes runoff from adjacent golf course and residential areas and consists of a vegetated roadside swale system which discharges into a 36-inch RCP stormsewer. A photograph of monitoring Site H-12 is given on Figure 3-16.

Figure 3-16. Photograph of Monitoring Site H-12.

Monitoring Site H-13 is located at the discharge from the box culvert structure which conveys Channel 5 beneath Ulmerton Road. This site is located at the north side of Ulmerton Road downstream from the cumulative inflows contributed by Sites H-10, H-11, and H-12. A photograph of monitoring Site H-13 is given on Figure 3-17.

Figure 3-17. Photograph of Monitoring Site H-13.

Monitoring Sites H-14 and H-15 are indicated on Figure 3-18. Site H-14 reflects the outflow from a stormwater management system which provides treatment for runoff generated in a residential area east of the main channel. Photographs of the outfall structure from the residential lake system into Channel 5 are given on Figure 3-19. The outfall structure consists of three rectangular weirs (two 3-ft wide weirs and one 3.5-ft wide weir) which are used to regulate water levels within the lake system. Discharges through the outfall structure enter an underground stormsewer system and discharge directly into Channel 5.

Monitoring Site H-15 is located in a tributary which discharges from the Airco Golf Course into Channel 5. A photograph of the monitoring site is given on Figure 3-20. The channel from the Airco Golf Course consists of a shallow vegetated ditch which is conveyed into Channel 5 through a 48-inch RCP.

The location of monitoring Site H-16 is indicated on Figure 3-21. This monitoring site is located at the salinity structure/spillway on the north end of Channel 5 prior to discharge into tidal wetlands. Photographs of this site are given on Figure 2-7.

Locations of monitoring Sites H-17 and H-18 are indicated on Figure 3-22. Each of these sites is located on the St. Petersburg/Clearwater International Airport property and reflects points of primary discharge from the airport into Old Tampa Bay. Although these tributaries do not discharge directly into Channel 5, this area is still considered to be part of Sub-basin H. A photograph of monitoring Site H-17 is given on Figure 3-23. This site consists of two 24-inch CMPs which discharge directly into a dense mangrove forest. Monitoring at this site was conducted at the discharge from the pipes. A photograph of monitoring Site H-18 is given on Figure 3-24. This site consists of two 36-inch RCPs which convey drainage from a large portion of the airport property. Monitoring at this site was conducted at the discharge from the 24-inch RCP. Discharges at this site ultimately enter tidal wetlands before discharging directly into Old Tampa Bay.

Figure 3-18. Location of Monitoring Sites H-14 and H-15 H.


a. Outfall structure from lake system to Channel 5

b. Outfall structure and weirs

Figure 3-19. Photographs of the Outfall Structure at Site H-14.

Figure 3-20. Photograph of Monitoring Site H-15.

Figure 3-21. Location of Monitoring Site H-16.

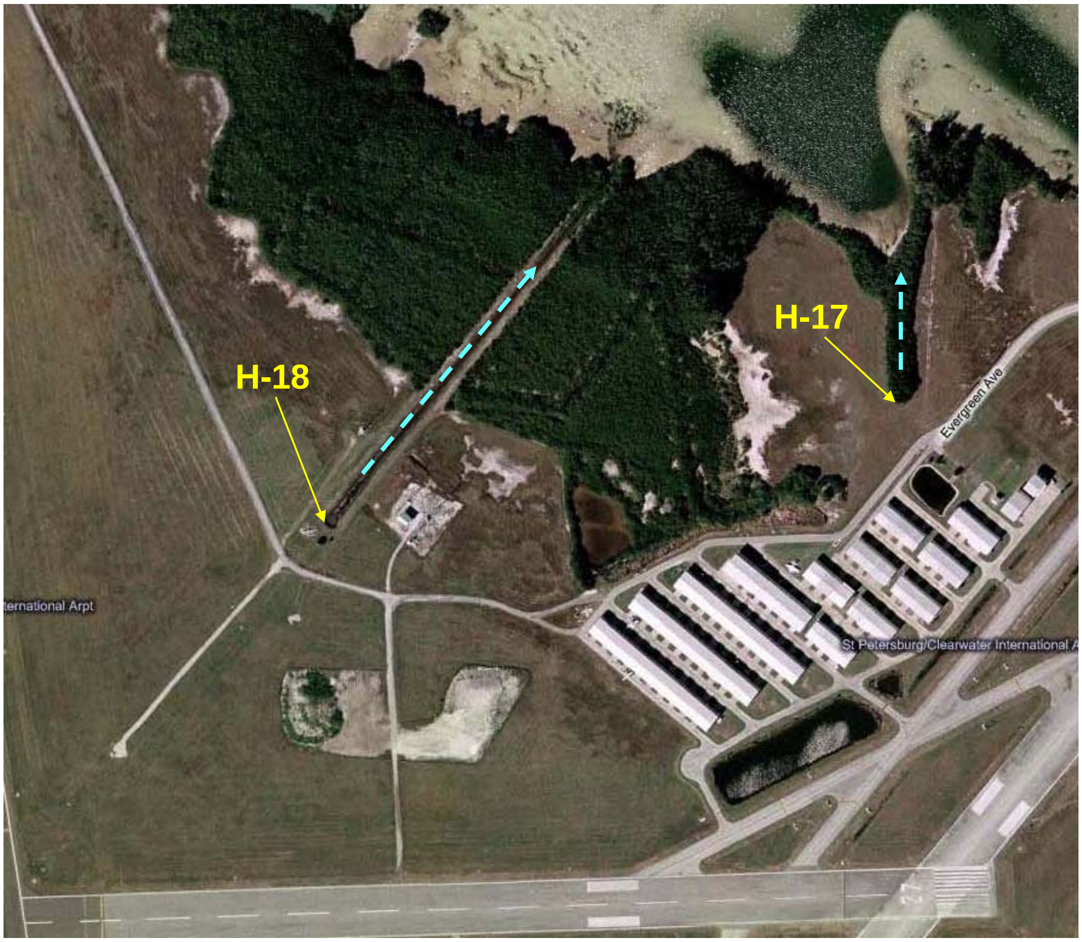


Figure 3-22. Location of Monitoring Sites H-17 and H-18.

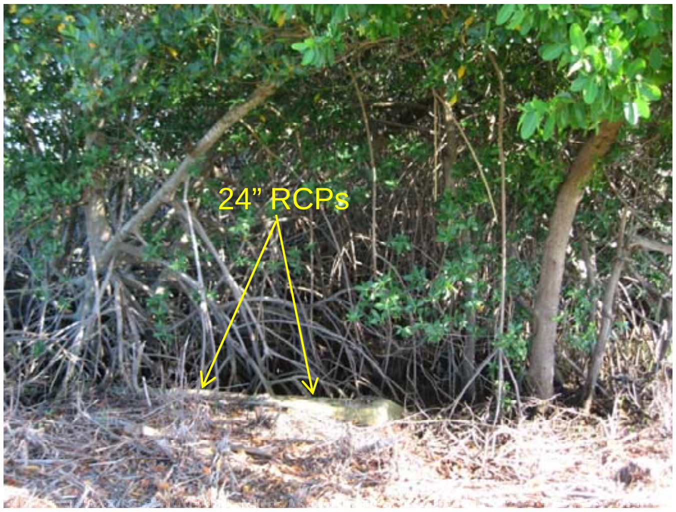


Figure 3-23. Photograph of Monitoring Site H-17.

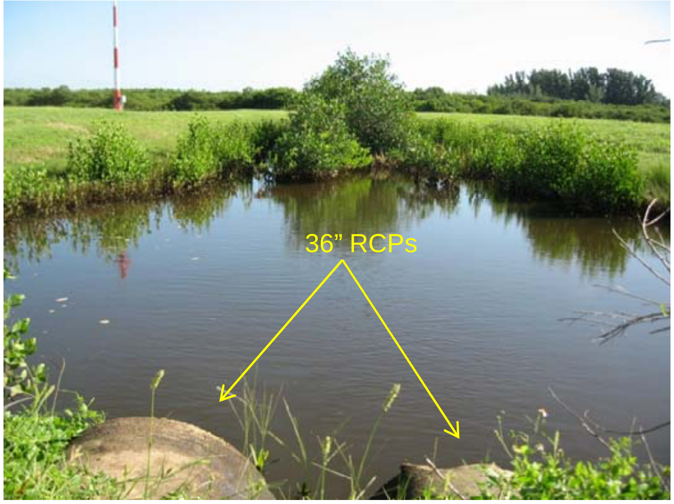


Figure 3-24. Photograph of Monitoring Site H-18.

3.2 Field Monitoring

ERD field personnel conducted biweekly monitoring at each of the monitoring sites discussed in Section 3.1 for a period of approximately three months from August-October 2009, with a total of five events conducted at each of the surface water monitoring sites. Typical field activities for surface water monitoring are discussed in the following sections.

3.2.1 Surface Water Samples

ERD field personnel visited each of the monitoring sites on approximately a biweekly basis and performed field measurements of discharge at each site, if applicable. The measurements reflect discharge conditions at the time of the monitoring event. Flow monitoring was conducted using the USGS velocity/cross-sectional area method with a Sontek acoustic Doppler flow meter. The spacing between individual velocity measurements was determined in the field such that not more than 10% of the total flow is represented by any one vertical cross-section. The depth at each cross-section was simultaneously measured using a graduated rod. A graduated tape was stretched across each channel so that reference locations can be determined for each simultaneous measurement of velocity and water depth.

If the water depth was less than 2.5 ft at a measurement point, the velocity was measured at 60% of the total water depth. If the water column depth exceeded 2.5 ft at a monitoring site, velocity measurements were performed at 20% and 80% of the total water depth, with the mean section velocity determined by taking the average of the two measurements. The velocity was then integrated over each of the cross-sectional areas to determine the total discharge through the section on each monitoring date.

During each monitoring visit, ERD field personnel performed field measurements of pH, temperature, dissolved oxygen, specific conductivity, turbidity, and ORP at each monitoring site. If the water depth at a given site was approximately 1 m or less, a single field measurement will be conducted at approximately mid-depth. If the water depth exceeded 1 m, field measurements were conducted at the surface (0.25 m), at 0.5 m, and at 0.5 m intervals to the bottom at each site.

A water sample was also collected at each site. All samples were collected as a grab sample at mid-depth in the water column at each site. All field monitoring was conducted in accordance with DEP-SOP-001/01- Department of Environmental Protection Standard Operating Procedures for Field Activities.

All collected water samples were returned to the ERD Laboratory and analyzed for the following nutrients and selected general parameters:

- Alkalinity
- Ammonia
- NO_x
- Diss. Organic Nitrogen
- Particulate Nitrogen
- Total Nitrogen
- SRP
- Diss. Organic Phosphorus
- Particulate Phosphorus
- Total Phosphorus
- Turbidity
- Total Suspended Solids
- Color
- Copper
- Chromium
- Lead
- Zinc

This monitoring program generated a total of 90 samples (18 sites x 5 events). Additional samples were also collected and analyzed, as appropriate, to meet applicable QA criteria.

In addition to the parameters listed above, aliquots of the collected samples were shipped to the Colorado Plateau Stable Isotope Laboratory at Northern Arizona University for ^{15}N and ^{18}O isotope analysis. A total of 90 samples were provided to the Stable Isotope Lab for analysis. Details of the stable isotope methodology are given in Section 3.3.

3.2.2 Sediment Samples

Sediment core samples were collected on one occasion at each of the 18 monitoring sites to evaluate the characteristics of existing sediments and potential impacts on water quality within Channel 5. Sediment core samples were collected at each of the 18 monitoring sites on September 24, 2009 by ERD personnel.

Sediment samples were collected using a stainless steel split-spoon core device which was penetrated into the sediments at each location to a minimum distance of approximately 0.25 m. After retrieval of the sediment sample, any overlying water was carefully decanted before the split-spoon device was opened to expose the collected sediments. Visual characteristics of each sediment core sample were recorded, and the 0-10 cm layer was carefully sectioned off and placed into a polyethylene container. The 0-10 cm layer was collected since physical, chemical, and biological exchange between the sediments and overlying water column is typically limited to the top 10 cm of the sediment layer. Sediments below 10 cm have little impact on water quality under most conditions.

Duplicate core samples were collected at each site, and the 0-10 cm layers were combined together to form a single composite sample for each monitoring site. The polyethylene containers used for storage of the collected samples were filled completely to minimize air space in the storage container above the composite sediment sample. Each of the collected sediment samples was stored in ice and returned to the ERD Laboratory for physical and chemical characterization.

3.2.3 Sampling Equipment

All field sampling procedures and documentation followed procedures outlined in the document titled "Department of Environmental Protection Standard Operating Procedures for Field Activities," DEP-SOP-001/01, dated February 1, 2004. A listing of sampling equipment used for this project is given in Table 3-2.

TABLE 3-2

SAMPLING EQUIPMENT

EQUIPMENT DESCRIPTION		CONSTRUCTION MATERIALS	USE
Water Sampling Equipment	Geotech Submersible Geosquirt Purging/Sampling Pump	Plastic case, S.S. impeller, vinyl tubing	Purging for monitoring wells; Sample collection for general parameters and nutrients
	Nalgene Syringe Filter System - Surface Water	Acrylic/polyethylene	Filtration for Orthophosphorus
Filtration Equipment	Geotech 0.45 µ high-capacity disposable filter	Plastic casing glass fiber filter	Filtration for isotope samples
	Masterflex E/S Portable Sampler	Silicon tubing	Filtration for isotope samples
Field Measurement Equipment	Hydrolab H2O Water Quality Monitor	Teflon	Field parameters
	SonTek FlowTracker Hand-held ADV	Polyethylene, S.S.	Measure discharge at inflow and outflow to calibrate autosampler flow meters
Sediment Sampling Equipment	2-inch diameter split-spoon core device	S.S., aluminum	Collection of sediment core samples

3.3 Laboratory Analyses

3.3.1 Analytical Methods for Water Samples

Each of the collected surface water samples was returned to the ERD Laboratory and evaluated for general parameters, nutrients, BOD, fecal coliform, and selected heavy metals. A summary of laboratory methods and MDLs for analyses conducted on water samples collected during this project is given in Table 3-3. All laboratory analyses were conducted in the ERD Laboratory (NELAC Certification No. 1031026).

TABLE 3-3

ANALYTICAL METHODS AND DETECTION LIMITS FOR LABORATORY ANALYSES ON SURFACE WATER SAMPLES

PARAMETER	METHOD OF ANALYSIS	METHOD DETECTION LIMITS (MDLs)[1]
pH	EPA-83, Sec. 150.1[2]	N/A
Conductivity	EPA-83, Sec. 120.1[2]	0.3 µmho/cm
Alkalinity	SM-21[3], Sec. 2320 B	0.5 mg/l
Ammonia	SM-21[3], Sec. 4500-NH_3 G	0.005 mg/l
NO_x	SM-21[3], Sec. 4500-NO_3 F	0.005 mg/l
Total Nitrogen	SM-21[3], Sec. 4500-N C	0.01 mg/l
Ortho-P (SRP)	SM-21[3], Sec. 4500-P F	0.001 mg/l
Total Phosphorus	SM-21[3], Sec. 4500-P F and 4500-P B.5	0.001 mg/l
Turbidity	EPA-83, Sec. 180.1[2]	0.1 NTU
Color	SM-21[3], Sec. 2120 C	1 Pt-Co Unit
TSS	EPA-83, Sec. 160.2[2]	0.7 mg/l
Chromium	SM-21[3], Sec. 3111 B	5 µg/l
Copper	SM-21[3], Sec. 3111 B	2 µg/l
Lead	SM-21[3], Sec. 3111 B	2 µg/l
Zinc	SM-21[3], Sec. 3111 B	1 µg/l

1. MDLs are calculated based on the EPA method of determining detection limits
2. Methods for Chemical Analysis of Water and Wastes, EPA 600/4-79-020, Revised March 1983.
3. Standard Methods for the Examination of Water and Wastewater, 21st Ed., 2005.

3.3.2 Analytical Methods for Sediment Samples

Each of the 18 collected sediment core samples was analyzed for a variety of general parameters, including moisture content, organic content, sediment density, total nitrogen, and total phosphorus. Methodologies utilized for preparation and analysis of the sediment samples for these parameters are outlined in Table 3-4.

TABLE 3-4

ANALYTICAL METHODS FOR SEDIMENT ANALYSES

MEASUREMENT PARAMETER	SAMPLE PREPARATION	ANALYSIS REFERENCE	REFERENCE PREPARATION/ ANALYSIS*	METHOD DETECTION LIMITS (MDLs)
pH	EPA 9045	EPA 9045	3 / 3	0.01 pH units
Moisture Content	p. 3-54	p. 3-58	1 / 1	0.1%
Organic Content (Volatile Solids)	p. 3-52	pp. 3-52 to 3-53	1 / 1	0.1%
Total Phosphorus	pp. 3-227 to 3-228 (Method C)	EPA 365.4	1 / 2	0.005 mg/kg
Total Nitrogen	p. 3-201	pp. 3-201 to 3-204	1 / 1	0.010 mg/kg
Specific Gravity (Density)	p. 3-61	pp. 3-61 to 3-62	1 / 1	NA

*REFERENCES:

1. Procedures for Handling and Chemical Analysis of Sediments and Water Samples, EPA/Corps of Engineers, EPA/CE-81-1, 1981.
2. Methods for Chemical Analysis of Water and Wastes, EPA 600/4-79-020, Revised March 1983.
3. Test Methods for Evaluating Solid Wastes, Physical-Chemical Methods, Third Edition, EPA-SW-846, Updated November 1990.

3.3.3 Quality Control

Multiple QA/QC procedures were used by ERD during this project. A summary of QA/QC procedures is given in Table 3-5. The listed QA/QC procedures are designed to evaluate both the field and laboratory systems. Approximately 90 additional laboratory QA/QC samples were evaluated by ERD in addition to the 90 collected surface water samples. In addition, more than 30 field QA/QC samples were collected and analyzed to address potential field contamination. A complete listing of QA/QC samples evaluated as part of this project is given in Appendix D.

TABLE 3-5

QA/QC PROCEDURES USED BY ERD

QC ITEM	FREQUENCY
Continuous Calibration Verification Standards	Every 10 samples
Continuing Calibration Blanks	Every 10 samples
Lab Control Samples (Check Standards)	Every 20 samples and beginning/end of each run
Method Blank	Every 20 samples and beginning/end of each run
Duplicate Samples (Precision)	Every 10 samples
Spiked Samples (Accuracy)	Every 20 samples
Initial Calibration Verification (pH)	Every run
Field Equipment Blanks	Every 10 samples
Pre-Cleaned Equipment Blank	Every 10 samples

3.4 Isotope Analyses

3.4.1 Introduction

Isotopes are atoms of an element that differ in mass, due to differing numbers of neutrons in the atoms' nucleus. Some isotopes are unstable and are referred to as radioisotopes. Other isotopes have no known decay constants and are referred to as stable isotopes. Isotopes of the same element have the same numbers of protons and electrons, and so have similar chemical properties and similar chemical reactions. But, because of the difference in bond strength due to differing numbers of neutrons, different stable isotopes react at slightly different rates. In general, molecules containing heavier isotopes react more slowly. Differences in reaction rates give rise to "fractionation", such that isotopes are distributed unevenly in natural systems. Biological systems often exhibit strong fractionation effects, such that molecules containing the light isotope of an element react more quickly with a biological enzyme than do molecules containing the heavier isotope. Thus, molecules from different sources in the environment often exhibit isotopic "fingerprints" which can be useful in source partitioning studies.

There are two stable isotopes of nitrogen, ^{14}N and ^{15}N, where the superscripts describe the atomic mass of the isotope. ^{14}N contains seven protons and neutrons, whereas ^{15}N contains seven protons but eight neutrons. ^{14}N is the more abundant isotope of nitrogen since most nitrogen reservoirs in nature (e.g., the atmosphere) contain approximately 99.6% ^{14}N and only 0.4% ^{15}N. Fractionation processes cause very slight variations in this composition, differences that can be detected using isotope-ratio mass spectroscopy, routinely distinguishing samples that differ by as little as 0.0001 atom percent ^{15}N.

3.4.2 Theory of Measurement

Stable isotopes of carbon, nitrogen, sulfur, oxygen, and hydrogen, which are the most commonly used isotopes in ecological and environmental research, are measured by gas isotope-ratio mass spectroscopy. The sample is converted into a gas, such as N_2O, CO_2, N_2, SO_2, or H_2, and the gas molecules are ionized in the Ion Source (Figure 3-25) which strips an electron from each of them, causing each molecule to be positively charged. The charged molecules then enter a flight tube. The flight tube is bent, and a magnet is positioned over it such that the charged molecules separate according to their mass, with molecules containing the heavier isotope bending less than those containing the lighter isotope.

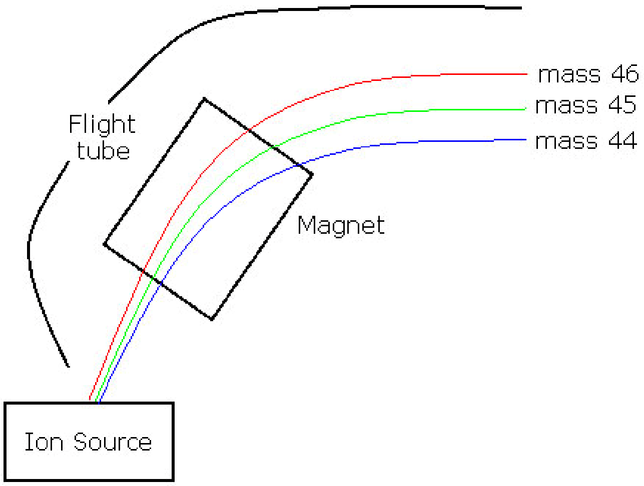


Figure 3-25. Separation of Isotopes by Gas Isotope-Ratio Mass Spectrometry.

Faraday collectors are present at the end of the flight tube to measure the intensity of each beam of ions of a given mass after they have been separated by the magnet. For N_2O, three faraday collectors are set to collect ion beams of masses 44, 45, and 46. Several masses are collected simultaneously, so that the ratios of these masses can be determined very precisely.

In the flight tube, the magnet causes the ions to be deflected, with a radius of deflection that is proportional to the mass-to-charge ratio of the ion. Heavier ions are deflected less than lighter ions. For example, N_2O, mass 46 has the largest radius of deflection, mass 44 has the smallest, and mass 45 is intermediate. Charge also affects the radius of deflection but, for the most part, this is held constant because the ion source strips only one electron from most molecules.

Stable isotope abundances are expressed as the ratio of the two most abundant isotopes in the sample compared to the same ratio in an international standard, using the “delta” (δ) notation. Because the differences in ratios between the sample and standard are very small, they are expressed as parts per thousand or “per mil” (‰) deviation from the standard:

$$\delta X\ sample\ =\ \{(\ {}^{H}X\ /\ {}^{L}X\ sample)\ /\ (\ {}^{H}X\ /\ {}^{L}X\ standard) - 1\}\ \ x\ \ 100$$

Where "^{H}X and ^{L}X" are the heavy and light stable isotopes of element X, "sample" refers to the environmental sample being analyzed, and "standard" refers to the international standard for element X. This equation defines the delta value of the standard as 0‰. For carbon, the international standard is Pee Dee Belemnite, a carbonate formation, with a generally accepted absolute ratio of ${}^{13}C/{}^{12}C$ equal to 0.0112372. Materials with ratios of ${}^{13}C/{}^{12}C$ greater than 0.0112372 have positive delta values, and those with ratios less than 0.0112372 have negative delta values.

Stable isotope techniques rely on natural differences in the ways that "heavy" and "light" isotopes are processed in the environment through chemical, biological, and physical transformations. These are referred to as "natural abundance isotope techniques". Stable nitrogen isotopes of dissolved nutrients also provide specific information about the origin of nutrients. Pastureland, residential communities, and golf courses all produce nitrogen with unique isotopic signatures (Kendall, 1998). Land that is covered with a significant amount of cattle often produce nitrate with very heavy $\delta^{15}N$ values. This isotopic signature is due to the large amount of ${}^{14}NH_3$ released during ammonia volatilization of animal wastes which leaves the remaining material enriched in the heavier nitrogen isotope, ${}^{15}N$.

Nitrogen derived from treated sewage undergoes similar biogeochemical processing through denitrification, which is the heterotrophic breakdown of organic matter. Denitrification produces N_2 with a high concentration of ${}^{14}N$, leaving the remaining bulk waste material concentrated in ${}^{15}N$. Consequently, nitrate that originates from pastureland and sewage have similar $\delta^{15}N$ values (12- 20‰). Contrastingly, nitrate derived from residential soils often has an intermediate nitrogen isotopic range (3-8‰). Possible contributions to the residential signal may include nitrogen derived from septic tanks, fertilizer application, or soil redistribution and relocation. Residential land development may also transport the ${}^{15}N$-enriched organic matter that normally occurs in deeper soil layers to the surface.

The isotopic signature of nitrogen derived from golf courses is also unique. The fertilizer applied to golf courses is often derived from atmospheric nitrogen. This causes golf course runoff to contain nitrate with ${}^{15}N$ values similar to those of atmospheric N_2 (0-3‰). Golf course areas which irrigate with reclaimed water derived from sewage often exhibit a sewage signal (i.e., 12-20‰, as above). However, $\delta^{15}N$ can be used as a tracer only if large verifiable differences in $\delta^{15}N$ exist between the potential nitrogen sources.

One complication of source partitioning using stable isotopes of N and O in nitrate is that microbial transformations of nitrate can alter its isotopic signature, potentially obscuring the identity of the original source (Kellman et al, 1998).

Nitrification and denitrification are the major fractionating processes altering the isotopic composition of nitrate. Both processes preferentially utilize the lighter substrate, such that nitrification produces NO_3^- isotopically depleted compared to the NH_4^+ substrate, whereas denitrification preferentially utilizes isotopically depleted NO_3^-, leaving behind NO_3^- relatively enriched in $\delta^{15}N$ and $\delta^{18}O$. Predictable relationships among NO_3^- concentration, $\delta^{15}N$- NO_3^-, and $\delta^{18}O$- NO_3^- provide one means of detecting whether denitrification is influencing the isotopic composition of NO_3^-. For example, co-varying enrichment of $\delta^{15}N$ and $\delta^{18}O$ in nitrate provides evidence for denitrification, if the ratio of enrichments are between 1.3:1 and 2.1:1 (Aravena and Robertson, 1998; Fukada, et al., 2003). In a system where nitrate inputs are negligible, a negative relationship between $[NO_3^-]$ and $\delta^{15}N\text{-}NO_3^-$ with a slope consistent with microbial fractionation during denitrification can also be used as a diagnostic for the importance of denitrification as a loss pathway, or in source identification, for the need to consider internal changes to $\delta^{15}N$ values observed in-situ to the expected $\delta^{15}N$ signature of the NO_3^- source. Analysis of $\delta^{15}N\text{-}NH_4^+$, and nitrification and denitrification rates at a given site can also constrain the influence of these processes on the observed isotopic signatures.

3.4.3 Analyses

All stable isotope analyses were conducted by the Colorado Plateau Stable Isotope Laboratory (CPSIL), based at Northern Arizona University (NAU). This laboratory was designed to serve students, researchers, and faculty at NAU who require stable isotope analyses for their research, although analyses are also conducted for researchers outside the university. All isotope analyses were overseen by Dr. Bruce Hungate, Professor and Director of CPSIL. Details concerning sample collection, preservation, and shipping were provided to ERD by CPSIL.

Surface waters collected in Roosevelt Creek Sub-basin H were analyzed for $\delta^{15}N\text{-}NO_3^-$ and $\delta^{18}O\text{-}NO_3^-$. The general question to be addressed was: "Are there changes in NO_3^-, $\delta^{15}N$, and $\delta^{18}O$ signatures within these systems that are consistent with internal microbial processing, and if so, is it possible to constrain the $\delta^{15}N$ and $\delta^{18}O$ signature of NO_3^- entering these systems?"

Samples were collected in the field and shipped to the Colorado Plateau Stable Isotope Laboratory at Northern Arizona University for preparation and analysis. Samples were measured for NO_3^- concentrations using automated colorimetry on a Lachat QuikChem 8000 to determine appropriate volumes for isotope analyses. The denitrifier method was used to measure the $\delta^{15}N$ and $\delta^{18}O$ composition of nitrate in each water sample (Sigman, et al., 2001; Casciotti et al., 2002; Révész and Casciotti, 2007). In this method, isotopes of both elements are measured simultaneously after the nitrate is converted to nitrous oxide (N_2O). Mass ratios of 45:44 and 46:44 distinguish $\delta^{15}N$ and $\delta^{18}O$ signatures, respectively. *Pseudomonas aurefaciens* lacks N_2O reductase, the enzyme that converts N_2O to N_2 during denitrification, so the reaction stops at N_2O, unlike normal denitrification which converts most of the NO_3^- to N_2.

Pseudomonas aurefaciens cultures were grown in tryptic soy broth, centrifuged to concentrate bacterial cells, and then concentrated suspensions of cells are added to sealed vials with headspace. The headspace vials were purged with helium gas to promote the anaerobic conditions suitable for denitrification, and the environmental samples containing NO_3^- were added to the vials and the volume of sample adjusted to obtain sufficient N_2O for analysis. Several drops of anti-foaming agent were added to each vial to reduce bubble formation during the reaction. The vials were allowed to incubate for 8 hours, during which time NO_3^- is converted completely to N_2O. After the 8-hour period, 0.1 ml of 10N NaOH was added to each vial to stop the reaction and to absorb CO_2 which can interfere with N_2O analysis. The samples were then placed on an autosampler tray interfaced with the mass spectrometer, and interspersed with standards with known $\delta^{15}N$ and $\delta^{18}O$ composition.

SECTION 4

RESULTS

Field monitoring, sample collection, and laboratory analyses were conducted by ERD from August-October 2009 to evaluate the characteristics of discharges through Roosevelt Creek Sub-basin H. A discussion of the results of these efforts is given in the following sections.

4.1 Rainfall Characteristics

A survey was conducted of available rainfall records in the vicinity of Roosevelt Creek Sub-basin H to evaluate long-term rainfall characteristics as well as rainfall occurring within Roosevelt Creek Sub-basin H during and prior to the field monitoring program. As discussed in Section 2, the USGS operates a recording rainfall station at the monitoring site designated as Site No. 2307434 on Figure 2-16. This site is located within Sub-basin H near the southwest corner of the Bridgeway Acres Landfill site. Rainfall records obtained from this site are used to estimate rainfall characteristics within Sub-basin H during and prior to the field monitoring program conducted by ERD.

Unfortunately, the rainfall data at Site 2307834 are only available beginning in 2002 and are not suitable for evaluation of long-term rainfall characteristics within the area. The closest long-term meteorological monitoring site is at Albert Whitted Field Airport which is located south of downtown St. Petersburg, approximately 8.6 miles southeast of Sub-basin H, with rainfall data available at this site as far back as the 1940s. Long-term mean rainfall characteristics were obtained from meteorological data for the St. Petersburg site over the 30-year period from 1970-2000. Monthly rainfall during this period is assumed to reflect “normal” rainfall characteristics in the St. Petersburg area.

A comparison of measured and historical rainfall in the vicinity of the Roosevelt Creek watershed is given on Table 4-1. Historical “normal” rainfall is provided on a monthly basis based upon information obtained from the St. Petersburg, FL Meteorological Station (Station No. 087886). Information on rainfall in the vicinity of Roosevelt Creek during 2009 was obtained from the USGS monitoring Site 2307834. A graphical comparison of measured and historical “normal” monthly rainfall is given on Figure 4-1.

During the field monitoring program from August-October 2009, a total of 17.63 inches of rainfall was recorded at the USGS monitoring station. The “normal” rainfall during the period from August-October 2009 in the St. Petersburg area is approximately 18.21 inches. Lower than average rainfall was reported in Sub-basin H during August and October 2009, with substantially higher than normal rainfall observed during September.

TABLE 4-1

COMPARISON OF MEASURED AND HISTORICAL RAINFALL IN THE VICINITY OF THE ROOSEVELT CREEK WATERSHED

MONTH	ST. PETERSBURG, FL SITE NO. 087886 (1970-2000)	USGS SITE NO. 2307834 (2009)
January	2.86	2.13
February	2.90	0.57
March	2.98	0.87
April	2.05	1.55
May	2.89	9.69
June	5.58	3.31
July	7.49	13.00
August	8.34	6.24
September	6.82	10.26
October	3.05	1.13
November	1.99	1.46
December	2.69	2.30
Total	**49.64**	**52.51**

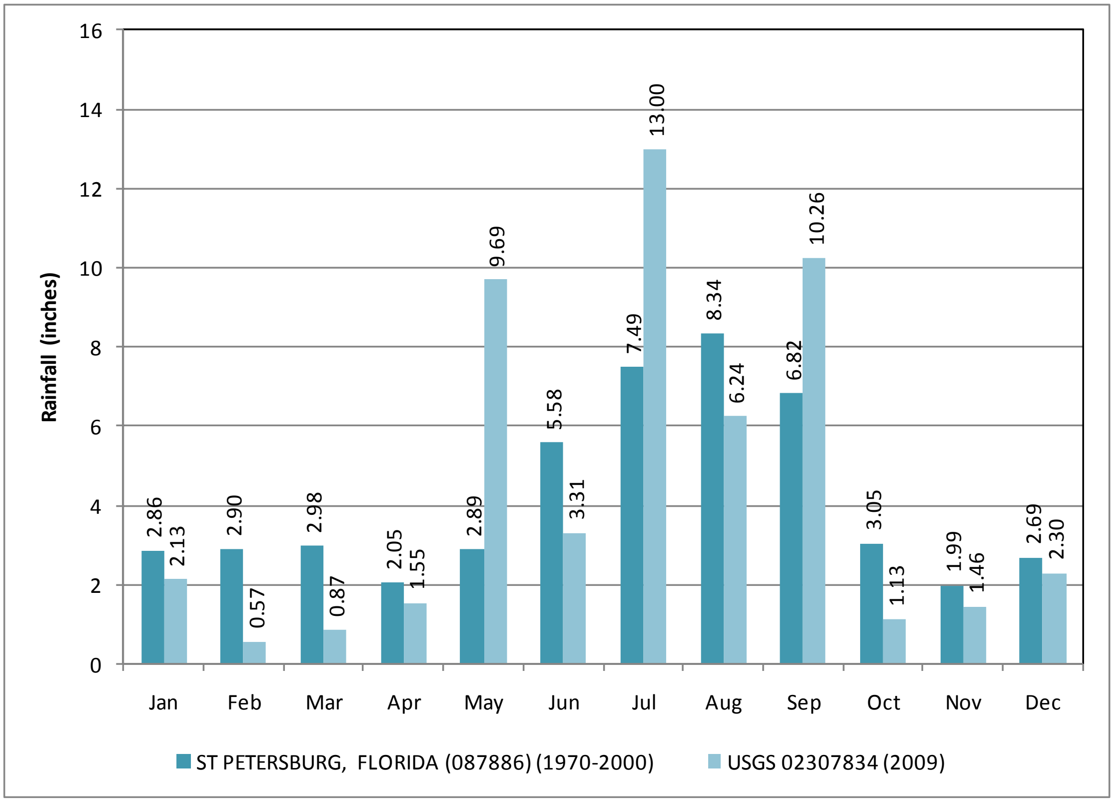


Figure 4-1. Graphical Comparison of Measured and Historical Mean Monthly Rainfall in the Vicinity of the Roosevelt Creek Watershed.

During the period from January-October 2009, a total of 48.75 inches of rainfall fell in the vicinity of the Roosevelt Creek watershed, based upon measurements conducted at the USGS monitoring site. Historical “normal” rainfall in the St. Petersburg area over this period is approximately 44.96 inches. As a result, rainfall from January-October 2009 was approximately 3.79 inches above normal. As indicated on Figure 4-1, below normal rainfall was recorded during 7 of the 10 months included in the period from January-October 2009. However, substantially higher than normal rainfall was measured during May, July, and September, resulting in an overall surplus of 3.79 inches for the year.

4.2 Discharge Measurements

A summary of measured discharge rates at the Roosevelt Creek Sub-basin H surface water monitoring sites is given in Table 4-2. Measured discharge rates are provided for each of the monitoring sites except Site H-1. Monitoring at Site H-1 was conducted inside a stormsewer manhole which was not suitable for flow monitoring since field personnel did not have access to the discharge structure for the pond system where the flow originated. Each of the monitoring sites is color-coded to reflect sites along the main portion of Channel 5, sites reflecting tributary inflows to Channel 5, and discharges from the St. Petersburg/Clearwater International Airport property.

TABLE 4-2

MEASURED DISCHARGE RATES AT THE ROOSEVELT CREEK SUB-BASIN H MONITORING SITES

SITE	TYPE	DATE					MEAN
		8/12/09	8/27/09	9/10/09	9/24/09	10/8/09	
H-2	8' Rect. Weir	2.60	1.69	0.50	1.42	0.70	1.38
H-3	72" RCP	0.52	0.60	0.09	0.71	0.05	0.39
H-4	24 ft. rect. weir	13.15	5.93	0.53	0.98	0.53	4.22
H-5	48" RCP	0.31	0.52	0.28	0.24	0.10	0.29
H-6	2-36" RCP	0.10	0.06	0.03	0.03	0.02	0.05
H-7	4-60" + 1-36" RCP	7.10	6.83	1.10	0.97	0.71	3.34
H-8	Open Channel	1.41	1.55	0.30	0.23	0.19	0.73
H-9	Open Channel	81.2	17.3	2.28	1.94	2.48	21.0
H-10	2-36" RCP	3.01	0.36	0.08	0.07	0.07	0.72
H-11	24" RCP	0.01	0.00	0.00	0.00	0.00	0.00
H-12	36" RCP	0.06	0.03	0.02	0.05	0.04	0.04
H-13	Open Channel	23.0	17.7	2.37	2.06	2.59	9.54
H-14	2-3 ft weirs + 3.5 ft weir	0.59	0.21	0.07	0.21	0.00	0.22
H-15	48" RCP	0.20	0.92	0.13	0.08	0.03	0.27
H-16	183 ft. weir	5.66	21.0	32.4	11.4	21.0	18.3
H-17	2-24" RCP	1.28	1.80	1.14	0.75	0.37	1.07
H-18	2-36" RCP	1.41	0.31	0.44	0.36	0.34	0.57

🟨 Main Channel of Channel 5
🟦 Tributaries to Channel 5
🟧 Discharges from St. Pete/Clearwater Airport

A graphical comparison of discharge measurements conducted along the main channel and in tributary inflows to Channel 5 during the monitoring program is given on Figure 4-2. A general trend of increasing flow with increasing distance downstream was observed within the main channel during most of the monitoring events.

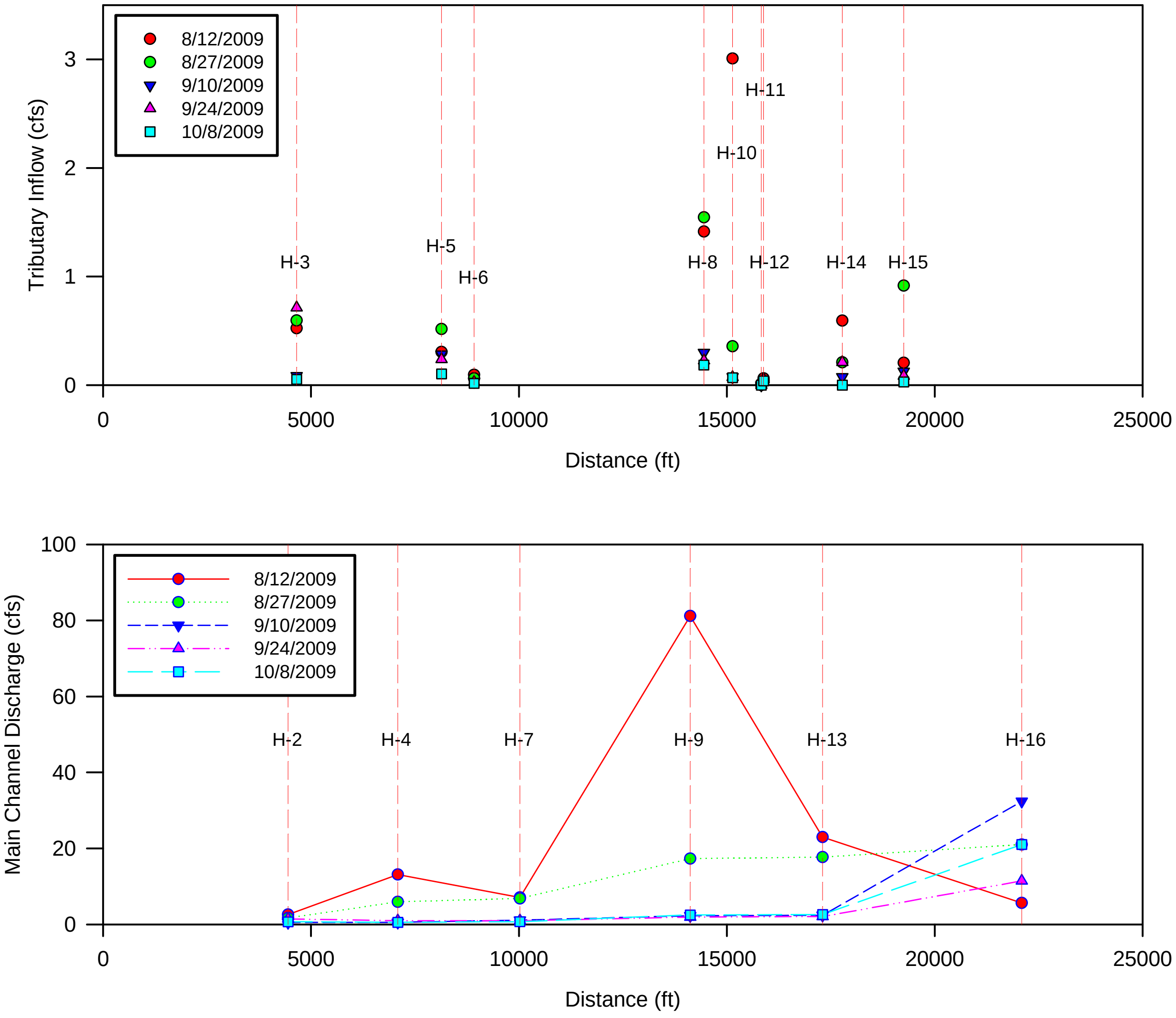


Figure 4-2. Graphical Comparison of Discharge Measurements in Main Channel and Tributary Inflows to Channel 5.

An apparent anomaly in the data set occurs for the flow measurements conducted at Site H-9 during the August 12, 2009 event. The elevated discharge rate observed at this site is due to a localized high-intensity rain event which occurred along the Ulmerton Road corridor during the field monitoring event. Each of the field monitoring events was conducted from north to south, in reverse site order, so that the monitoring conducted on the St. Petersburg/Clearwater International Airport property could be done at a time certain for airport security personnel. The storm event occurred after flow monitoring and sample collection had been completed at Site H-13 which is located on the north side of Ulmerton Road. Field monitoring was resumed following the rain event, and the elevated discharge values measured at Sites H-8, H-10, H-11, and H-12 were influenced by this rain event. Due to the localized nature of the event, significant rainfall did not occur in the vicinity of monitoring Sites H-1 through H-7, and the recorded discharge rates at these sites are not impacted by the rain event. Impacts of the rain event are not apparent in areas downstream from Site H-9 since monitoring had already been conducted at these sites prior to the rain event.

The data in Table 4-2 and on Figure 4-2 appear to indicate a relatively significant increase in discharge rates along the main channel between Ulmerton Road and the salinity barrier/spillway structure. Due to the very shallow depth of water discharging over the weir and lack of a defined channel on the downstream side of the structure, discharge measurements at the weir structure were calculated by ERD using a broad-crested weir equation and the depth of water flowing over the structure. This is the same method used by USGS to calculate discharges over the weir based upon the water level records collected at this site.

However, the weir structure is not exactly horizontal and contains a number of “high” and “low” spots along the length, particularly in western portions of the structure. Examples of “low” and “high” spots on the spillway structure are given on Figure 4-3. Measurements collected by ERD suggest that water levels can vary by an inch or more depending upon location along the weir. Although a difference of only an inch may seem like a small amount, this difference can have a significant impact on flow calculations due to the 183-ft width of the structure. The observed variability in elevations along the weir structure makes flow measurements at this site more of an estimate than an absolute value. This is true both for the data collected by ERD as well as the ongoing USGS data. Therefore, the observed increases in discharge rates through the canal between Ulmerton Road and the spillway structure may or may not reflect actual increases in discharge along the channel.

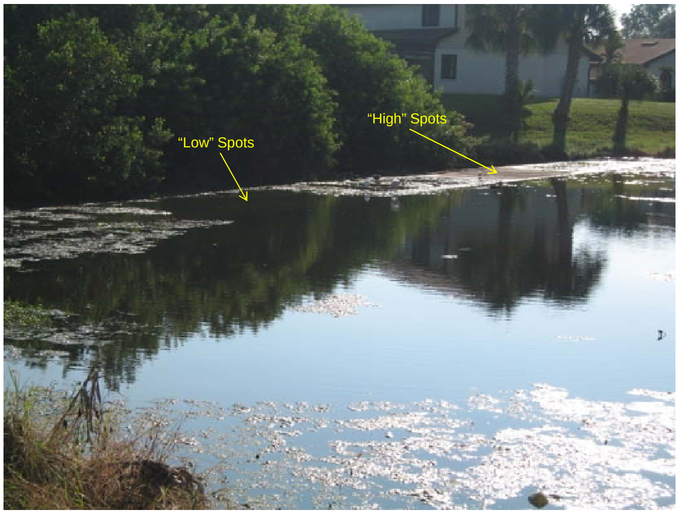


Figure 4-3. Examples of “Low” and “High” Spots on the Spillway Structure.

In general, tributary inflows into the main channel were characterized by relatively low discharge rates, with the vast majority of measured tributary flows less than 1 cfs. Two of the three measured tributary flow rates which exceed 1 cfs are associated with the localized rain event which occurred on August 12, 2009. Three of the tributary inflows, including Sites H-6, H-11, and H-12, were characterized by extremely low discharge rates during each of the field monitoring events. Impacts of these inflows on the characteristics of Roosevelt Creek appear to be minimal.

The largest tributary inflow was observed at monitoring Site H-8 which reflects a roadside drainage system which enters Channel 5 south of Ulmerton Road. Monitored discharge rates at this site ranged from 0.19-1.55 cfs, with an overall mean of 0.73 cfs. The next highest inflow into Channel 5 was observed at tributary Site H-3 which had measured discharge rates ranging from 0.05-0.6 cfs, with an overall mean of 0.39 cfs. The next most significant tributary inflows occurred at Site H-5 with a mean of 0.29 cfs, Site H-15 with a mean of 0.27 cfs, and Site H-14 with a mean of 0.22 cfs.

Discharge monitoring conducted on the St. Petersburg/Clearwater International Airport property is reflected by Sites H-17 and H-18. During the field monitoring program, the largest discharge occurred at Site H-17 with a mean of 1.07 cfs, compared with Site H-18 which had a mean discharge of 0.57 cfs. Combined together, discharges from the airport property were characterized by a mean total discharge of 1.64 cfs.

4.3 Surface Water Characteristics

Field monitoring was conducted at 18 surface water sites in the Roosevelt Creek watershed over the period from August-October 2009, with a total of five events conducted at each of the 18 monitoring sites. A discussion of the characteristics of surface water samples collected in the Roosevelt Creek watershed is given in the following sections.

4.3.1 Field Measurements

A complete listing of field measurements collected at Roosevelt Creek Sub-basin H monitoring sites from August-October 2009 is given in Appendix B.1. Field measurements of temperature, pH, conductivity, TDS, dissolved oxygen, dissolved oxygen saturation, and oxidation-reduction potential (ORP) were collected at approximately mid-depth in the water column at each monitoring site.

A summary of mean field measurements collected in Roosevelt Creek Sub-basin H from August-October 2009 is given on Table 4-3. Monitoring sites are highlighted to reflect stations located along Channel 5, tributaries which discharge to Channel 5, and direct discharges from the St. Petersburg/Clearwater International Airport.

TABLE 4-3

SUMMARY OF MEAN FIELD MEASUREMENTS COLLECTED IN ROOSEVELT CREEK FROM AUGUST – OCTOBER 2009

SITE	TEMP. (°C)	pH (s.u.)	COND. (µmho/cm)	TDS (mg/l)	DISS. O_2 (mg/l)	DO SAT. (%)	ORP (mV)
H-1	30.27	7.54	677	433	5.6	75	278
H-2	28.94	7.01	694	444	1.3	17	17
H-3	29.40	7.17	359	230	1.8	23	185
H-4	29.01	7.33	1,162	744	4.0	53	158
H-5	28.95	7.46	635	407	5.7	74	213
H-6	28.16	7.26	575	368	2.7	35	178
H-7	28.89	7.18	1,193	763	2.6	33	236
H-8	27.57	7.23	710	454	2.1	27	182
H-9	28.56	7.17	1,165	745	2.2	29	245
H-10	27.32	7.26	585	374	2.1	27	250
H-11	29.27	7.28	1,348	863	1.5	19	228
H-12	27.11	6.96	982	628	0.9	12	28
H-13	28.86	7.20	1,081	692	2.8	36	235
H-14	29.34	7.70	677	434	5.2	69	309
H-15	29.18	7.19	789	505	1.8	23	179
H-16	29.63	7.50	1,151	737	7.3	97	281
H-17	28.79	7.29	19,658	12,583	1.7	23	240
H-18	30.55	7.48	26,918	17,226	2.1	30	253

🟨 Main Channel of Channel 5
🟦 Tributaries to Channel 5
🟧 Discharges from St. Pete/Clearwater Airport

In general, surface water samples collected along the main channel and tributary inflows were approximately neutral in pH, with mean measured pH values ranging from approximately 6.96-7.54. Mean conductivity values in upstream portions of the main channel at monitoring Sites H-1 and H-2 ranged from 677-694 µmho/cm. A substantial increase in specific conductivity occurs between monitoring Sites H-2 and H-4, approximately doubling the conductivity to a mean of 1162 µmho/cm. Similar values of specific conductivity are observed at the remaining main channel sites. Conductivity measurements in tributaries discharging to Channel 5 are highly variable, ranging from a low of 359 µmho/cm at Site H-3 to a high of 1348 µmho/cm at Site H-11. In general, tributary inflows appear to have relatively little impact on specific conductivity measurements within the main channel, presumably due to the low discharge rates associated with the majority of the tributaries. The only exception to this generality occurs between main channel monitoring Sites H-2 and H-4. Two significant inflows into Channel 5 occur between these monitoring sites. The first inflow is reflected by Site H-3 which was characterized by a relatively low specific conductivity value. Therefore, in order for the conductivity to approximately double between Sites H-2 and H-4, a significant inflow of relatively elevated conductivity water must occur between these monitoring sites. The only remaining identified inflow between these sites other than H-3 is the pumped inflow from the landfill pond. However, according to Pinellas County Utilities, no pumped discharges occurred from the landfill pond into Channel H during the period of time for the field monitoring program. This statement appears to contradict direct visual observations by ERD personnel of discharges from the landfill pond into Channel H during both of the August field monitoring dates.

A similar trend was also observed in measured TDS values at the main channel and tributary monitoring sites. Substantially elevated values for both conductivity and TDS were observed at the two discharges from the St. Petersburg/Clearwater International Airport area.

Mean dissolved oxygen concentrations at the Roosevelt Creek monitoring sites were highly variable, ranging from a mean value of 0.9 mg/l at the tributary inflow monitored at Site H-12 to a high of 7.3 mg/l at the spillway discharge structure. A substantial decrease in dissolved oxygen occurs along the main channel between monitoring Sites H-4 and H-7 in spite of more elevated dissolved oxygen concentrations observed in tributary inflows between these sites. These data suggest that an inflow of oxygen-demanding substances occurs in the vicinity of monitoring Sites H-2 or H-4 which is consuming dissolved oxygen during migration through the channel. Dissolved oxygen concentrations in the vicinity of Ulmerton Road are extremely low in value, ranging from 0.9-2.8 mg/l. An increase in dissolved oxygen occurs between Ulmerton Road and the spillway structure, presumably due to increased opportunities for reaeration and the extended detention time provided by the wide and deep portion of the canal. Dissolved oxygen concentrations in discharges from the St. Petersburg/Clearwater International Airport sites were low in value.

A graphical comparison of measured concentrations of dissolved oxygen, ORP, pH, and conductivity in main channel monitoring sites along Roosevelt Creek Sub-basin H is given on Figure 4-4. Extremely low levels of dissolved oxygen were observed in upstream portions of Channel 5, with all dissolved oxygen measurements conducted at Site H-2 indicating values less than 2 mg/l. The vast majority of dissolved oxygen concentrations measured at main channel monitoring Sites H-4 through H-13 are less than the Class III criterion of 5 mg/l for freshwater systems outlined in Chapter 62-302 FAC. In contrast, virtually all of the measurements conducted at the spillway structure were characterized by dissolved oxygen levels in excess of the Class III criterion.

Tributary monitoring Site H-2 was characterized by reduced conditions during all monitoring events based upon field measurements of ORP. Reduced conditions were also observed during a majority of the monitoring events at Site H-4. However, oxidized conditions were observed at the remaining main channel sites, including the final site at the spillway structure.

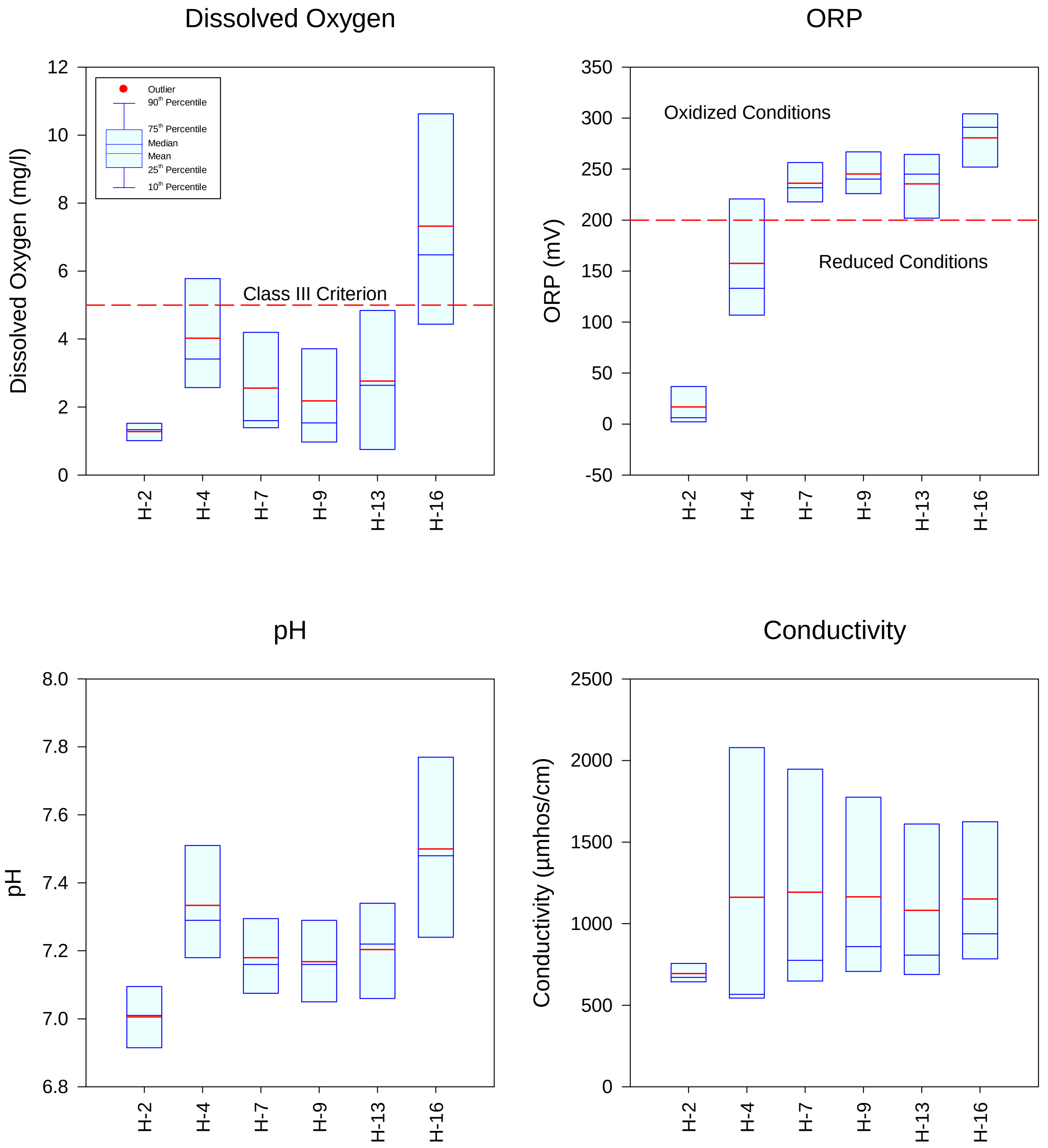


Figure 4-4. Comparison of Measured Concentrations of Dissolved Oxygen, ORP, pH, and Conductivity at Main Channel Monitoring Sites Along Roosevelt Creek Sub-basin H.

Measured pH values appear to be lowest in upstream portions of the tributary and highest in the downstream portion, presumably resulting from impacts of brackish water. The lowest conductivity levels are observed at monitoring Site H-2, with a substantial increase in conductivity observed between the two sites. The increase in conductivity observed between Sites H-2 and H-4 is more significant than the impacts of the brackish water on conductivity measurements conducted at the outfall spillway structure. In fact, conductivity measurements at Site H-4 were higher during several monitoring events than observed at the spillway structure immediately adjacent to tidal portions of Old Tampa Bay.

A graphical comparison of measured concentrations of dissolved oxygen, ORP, pH, and conductivity in tributary inflow monitoring sites along Roosevelt Creek Sub-basin H is given in Figure 4-5. Measured dissolved oxygen concentrations in the tributary inflows are highly variable, with dissolved oxygen concentrations at Sites H-3, H-6, H-8, H-10, H-11, H-12, and H-15 less than the Class III criterion, and concentrations at Sites H-1, H-5, and H-14 at or above the Class III criterion for dissolved oxygen. A high degree of variability is also apparent in ORP concentrations at the tributary inflow monitoring sites, with reduced conditions observed during all events at monitoring Site H-12 and oxidized conditions observed at all times at Sites H-1, H-10, and H-14. The remaining sites exhibited both reduced and oxidized characteristics during the field monitoring program.

Tributary inflows were characterized by approximately neutral to slightly alkaline pH values. Relatively consistent pH values were observed at Sites H-3, H-6, H-8, H-10, H-12, and H-15, with highly variable pH values observed at Sites H-1, H-5, and H-14. A high degree of variability is also observed in measured conductivity values. The lowest specific conductivity values were observed at Site H-3, which also exhibited relatively consistent concentrations between the monitoring events. Relatively similar conductivity values were observed at Sites H-1, H-5, H-6, H-8, H-10, and H-14, with more elevated concentrations observed at Sites H-12 and H-15.

A graphical comparison of measured concentrations of dissolved oxygen, ORP, pH, and conductivity at the Airport monitoring sites is given on Figure 4-6. Mean dissolved oxygen concentrations in discharges from the airport monitoring sites were low in value, with all measured concentrations less than the Class III marine criterion for dissolved oxygen of 4 mg/l. Based on field measurements conducted at the two sites, ORP values indicate oxidized conditions in spite of the low dissolved oxygen concentrations. Measured pH values at the two sites were approximately neutral, with a slightly higher pH value measured at Site H-18. Each of the two sites was characterized by elevated conductivity values, presumably resulting from the proximity to the tidal portions of Old Tampa Bay.

4.3.2 Chemical Characteristics

A complete listing of the results of laboratory analyses conducted on surface water samples collected from the Roosevelt Creek Sub-basin H is given in Appendix B.2. Water quality data are provided for each of the 18 monitoring sites and five monitoring dates, with the exception of Site H-11 where only one monitoring event was conducted due to dry conditions during the remaining monitoring events. A discussion of the chemical characteristics of water samples collected at each of the monitoring sites is given in the following sections.

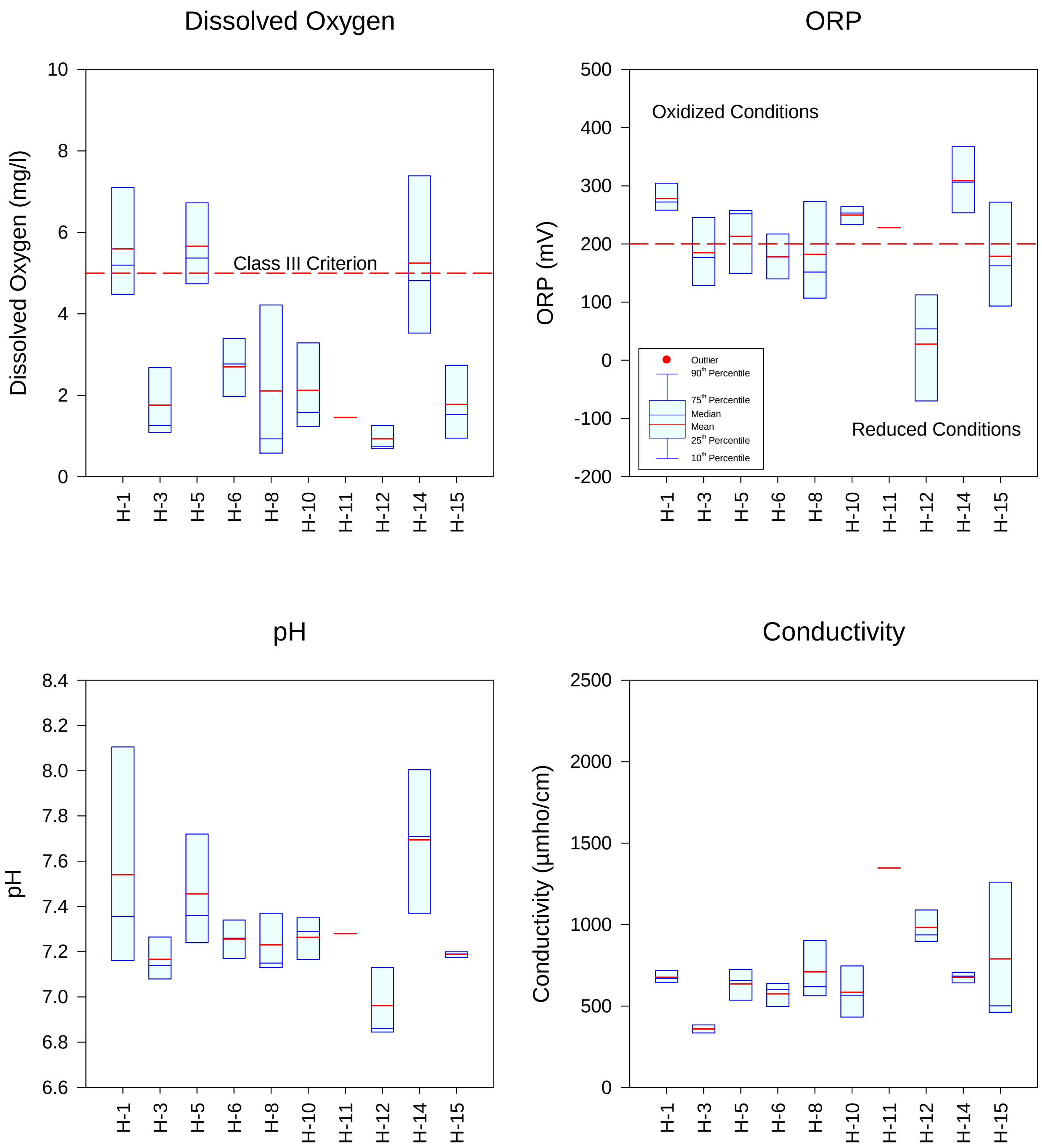


Figure 4-5. Comparison of Measured Concentrations of Dissolved Oxygen, ORP, pH, and Conductivity at Tributary Inflow Monitoring Sites Along Roosevelt Creek Sub-basin H.

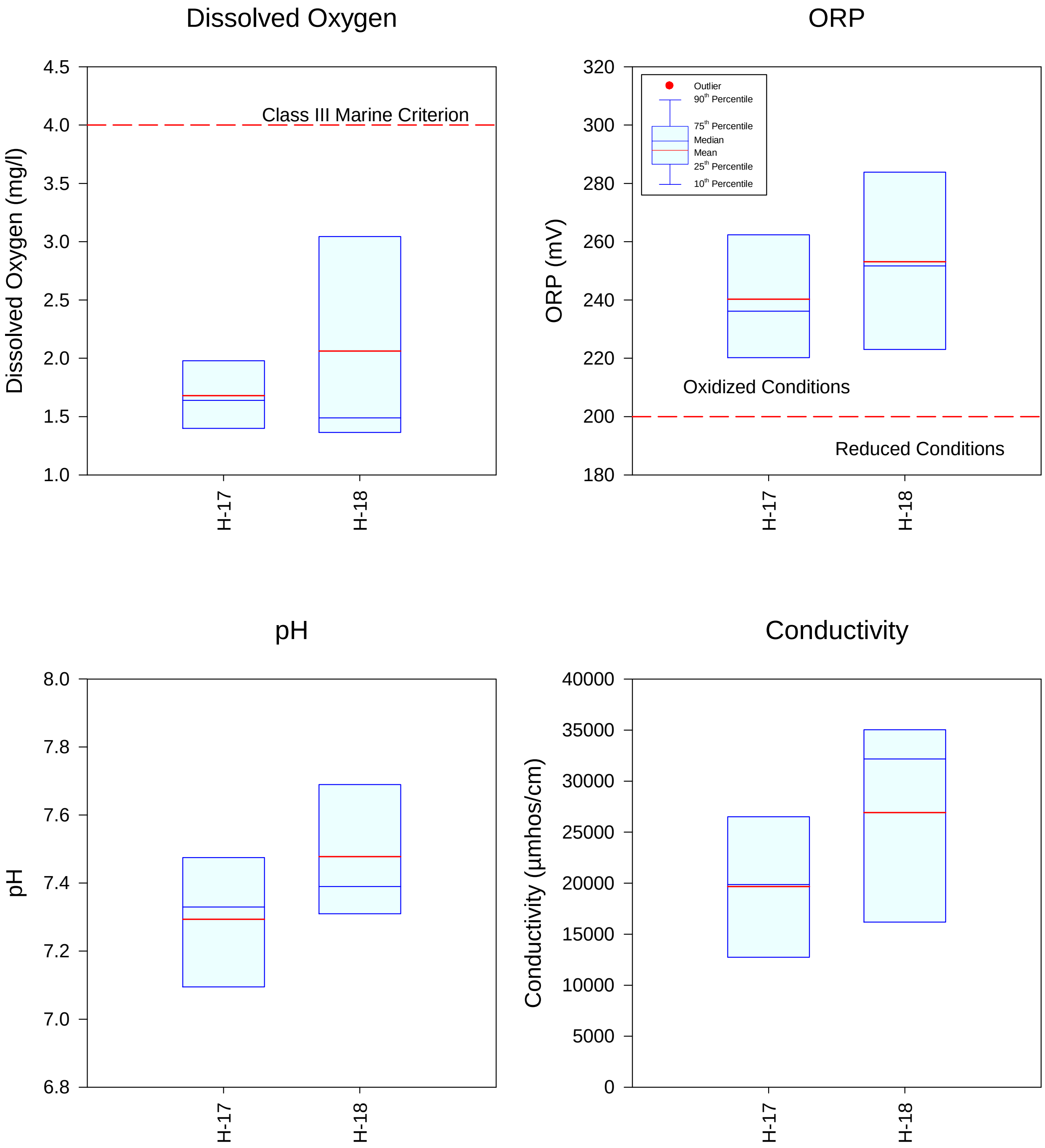


Figure 4-6. Comparison of Measured Concentrations of Dissolved Oxygen, ORP, pH, and Conductivity at the Airport Monitoring Sites Along Roosevelt Creek Sub-basin H.

4.3.2.1 Main Channel Monitoring Sites

A comparison of mean chemical characteristics of surface water samples collected along the main channel for Sub-basin H from August-October 2009 are summarized on Table 4-4. Surface water samples collected in upstream portions of the main channel were moderately well buffered, with mean alkalinities in excess of 120 mg/l. Samples collected at Site H-2 were characterized by moderate levels of ammonia and total nitrogen, with extremely low levels of NO_x. The dominant nitrogen species at Site H-2 was dissolved organic nitrogen, which comprised 55% of the total nitrogen measured at this site. Increases in ammonia, particulate nitrogen, and total nitrogen occurred between main channel Sites H-2 and H-4, with a 64% increase in total nitrogen, 143% increase in particulate nitrogen, and a 107% increase in ammonia.

TABLE 4-4

MEAN CHEMICAL CHARACTERISTICS OF ROOSEVELT CREEK MAIN CHANNEL SAMPLES COLLECTED FROM AUGUST – OCTOBER 2009

PARAMETER	**UNITS**	**SITE**					
		H-2	**H-4**	**H-7**	**H-9**	**H-13**	**H-16**
Alkalinity	mg/l	144	152	185	192	206	181
NH_3	µg/l	157	325	1433	1143	894	336
NO_x	µg/l	3	19	148	508	461	172
Diss. Org. N	µg/l	516	562	924	476	605	609
Particulate N	µg/l	258	628	546	734	346	714
Total N	µg/l	933	1534	3052	2862	2307	1831
SRP	µg/l	6	6	27	11	22	18
Diss. Org. P	µg/l	7	11	3	5	5	15
Particulate P	µg/l	28	51	91	106	59	91
Total P	µg/l	41	69	120	123	86	124
Turbidity	NTU	2.2	5.2	6.7	11.1	3.0	4.5
Color	Pt-Co	36	33	38	39	44	47
TSS	mg/l	1.2	6.8	7.0	15.7	3.5	4.2
Copper	µg/l	1.4	2.2	3.6	4.2	3.4	1.6
Lead	µg/l	< 2	< 2	< 2	< 2	< 2	< 2
Zinc	µg/l	< 2	2.6	5.4	2.6	3.8	1.4
Chromium	µg/l	3.2	3.2	2.8	3.6	3.4	1.6

Substantial increases in alkalinity and nitrogen species occurred between main channel Sites H-4 and H-7, with a two-fold increase in total nitrogen and four-fold increase in ammonia concentrations. Increases in measured concentrations of NO_x also occur between these sites, with a mean NO_x concentration of 19 μg/l at Site H-4, increasing to 148 μg/l at Site H-7. A three-fold increase in NO_x occurs between monitoring Sites H-7 and H-9, although concentrations of ammonia, dissolved organic nitrogen, and total nitrogen decrease slightly. A steady trend of decreasing total nitrogen concentrations appears to occur for the majority of nitrogen species between Sites H-9 and H-13 and between H-13 and the spillway structure. The mean total nitrogen concentration of 1831 μg/l measured at the spillway structure is approximately 60% of the total nitrogen concentration measured at Site H-7 which reflects a peak in concentrations for total nitrogen and dissolved organic nitrogen.

Measured concentrations of phosphorus species were moderate in value in upstream portions of the main channel. Steady increases in measured concentrations for the majority of phosphorus species occurred between Sites H-4 and H-7, with phosphorus concentrations at Site H-9 roughly similar to values measured at Site H-7. After passing Ulmerton Road, phosphorus concentrations decreased slightly at Site H-13, before increasing between Ulmerton Road and the spillway structure. Measured concentrations of phosphorus species at the spillway structure are similar to values measured in the vicinity of Ulmerton Road. The observed decrease in concentrations for total nitrogen between Ulmerton Road and the spillway does not occur for phosphorus species.

A similar pattern appears to occur for measured concentrations of turbidity, color, and TSS. Measured concentrations for these parameters are low to moderate in value in upstream portions of the main channel, reaching peak concentrations near Ulmerton Road, before decreasing during the portion of the canal between Ulmerton Road and the spillway structure.

Although not required by the Scope of Services, ERD also measured concentrations of total copper, total lead, total zinc, and total chromium in each of the Roosevelt Creek samples. In general, measured concentrations of each of these heavy metals were low in value along the main channel, with a peak in concentrations observed for most metals in the vicinity of Ulmerton Road. However, concentrations of metals discharging at the spillway structure easily met the Class III criteria for the evaluated metals. No detectable levels of lead were observed in any of the measured main channel samples.

A graphical comparison of measured concentrations of turbidity, alkalinity, color, and TSS in main channel monitoring sites along Roosevelt Creek Sub-basin H is given on Figure 4-7. In general, measured characteristics for turbidity and TSS are relatively similar in upstream and downstream portions of the main channel, with peaks in concentrations observed in the vicinity of Ulmerton Road. A similar, although less pronounced, phenomenon also appears to occur for alkalinity which reaches a peak in concentration in the vicinity of Ulmerton Road. In contrast, measured color concentrations appear to increase steadily along the main channel, although a slight decrease in color appears to occur at Site H-4.

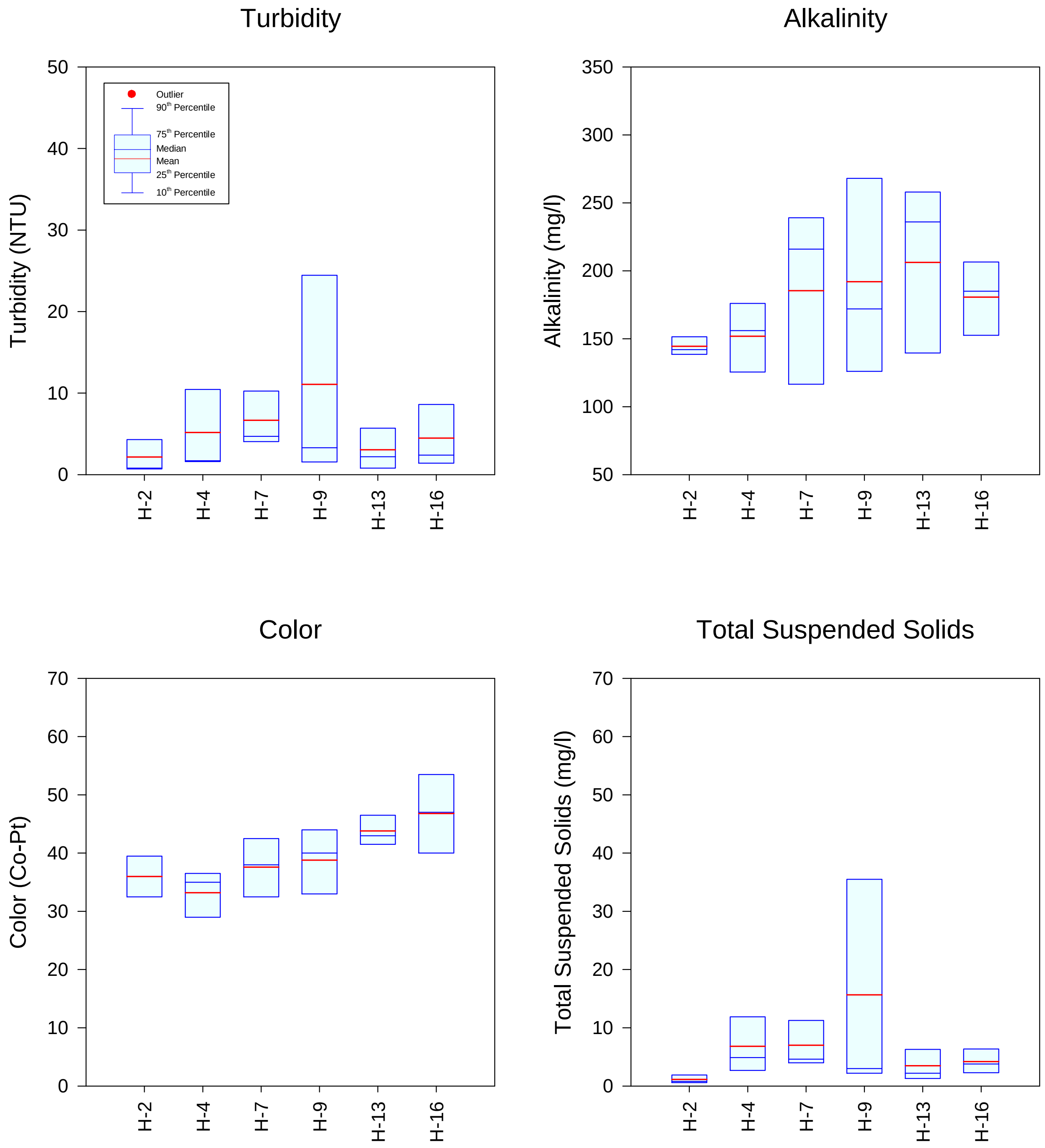


Figure 4-7. Comparison of Measured Concentrations of Turbidity, Alkalinity, Color, and TSS at Main Channel Monitoring Sites Along Roosevelt Creek Sub-basin H.

A graphical comparison of nitrogen species measured at monitoring sites along the main channel is given on Figure 4-8. Measured concentrations of ammonia, NO_x, and total nitrogen are relatively low in value in upstream portions of the main channel, reaching peak concentrations in the vicinity of Ulmerton Road, before decreasing during migration to the outfall structure. In contrast, no apparent trend in concentrations appears to occur for particulate nitrogen.

A graphical comparison of measured concentrations of phosphorus species at main channel monitoring sites is given in Figure 4-9. Peaks in SRP, particulate phosphorus, and total phosphorus appear to occur in central portions of the channel in the vicinity of Ulmerton Road. However, the trend of decreasing concentrations in downstream portions of the channel does not appear to exist for total phosphorus as was observed for nitrogen species.

A graphical comparison of heavy metal concentrations in samples collected at main channel monitoring sites is given on Figure 4-10. Peaks in concentrations for copper, and to a lesser extent zinc, appear to occur in central portions of the channel, with lower concentrations in upstream and downstream areas. Measured concentrations of chromium appear to be relatively uniform throughout the main channel, with a decrease in concentrations observed at the spillway structure. All measured concentrations for total lead were less than the minimum detection limit for this parameter.

4.3.2.2 Tributary Inflow Sites

A summary of mean chemical characteristics of tributary inflow samples collected in Roosevelt Creek Sub-basin H from August-October 2009 is given on Table 4-5. In general, each of the tributary inflows was well buffered, with mean alkalinity values ranging from 137-269 mg/l. The inflows contained highly variable concentrations of nitrogen species, with nitrogen concentrations at Site H-8 substantially higher than observed at the remaining sites. The mean ammonia concentration of 2974 μg/l measured at this site reflects an extremely elevated value which is more than 10 times higher than the next largest mean ammonia concentration measured in tributary inflows. Site H-8 is also characterized by an elevated level of dissolved organic nitrogen which is approximately two times higher than the next closest tributary site. Overall, this site is characterized by a mean total nitrogen concentration of 4401 μg/l which is more than 2-6 times greater than total nitrogen concentrations measured at the remaining tributary inflow sites.

Tributary inflows were also characterized by highly variable levels of total phosphorus. In general, relatively low levels of total phosphorus were observed in tributary inflows at monitoring Sites H-3, H-5, H-6, and H-8. However, elevated levels of total phosphorus, including substantially elevated levels of SRP, were observed at monitoring Sites H-10 and H-12 which discharge into the main channel in the vicinity of Ulmerton Road. Elevated levels of both SRP and total phosphorus were also observed in discharges from the Airco Golf Course area which are introduced into the main channel at monitoring Site H-15.

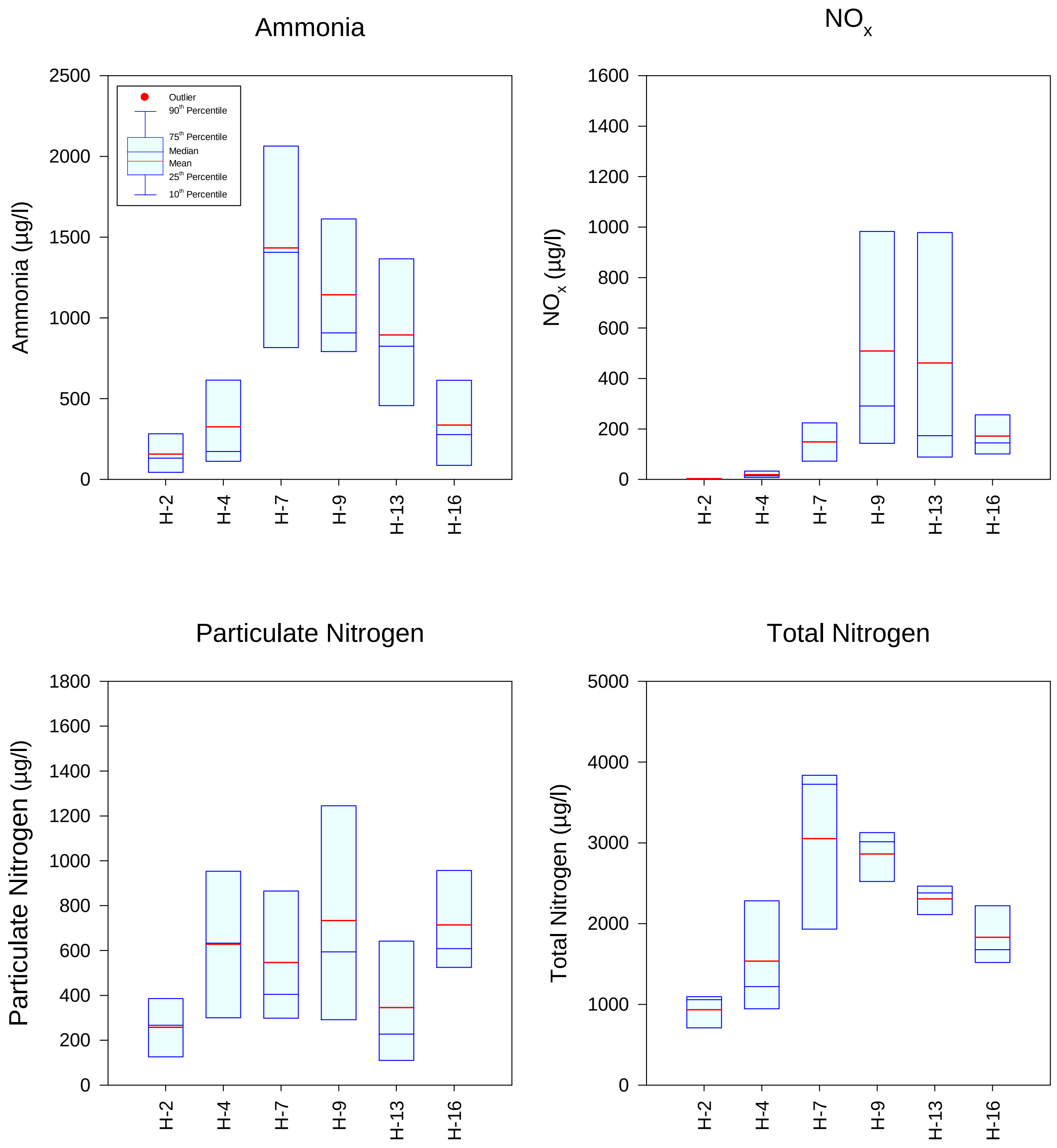
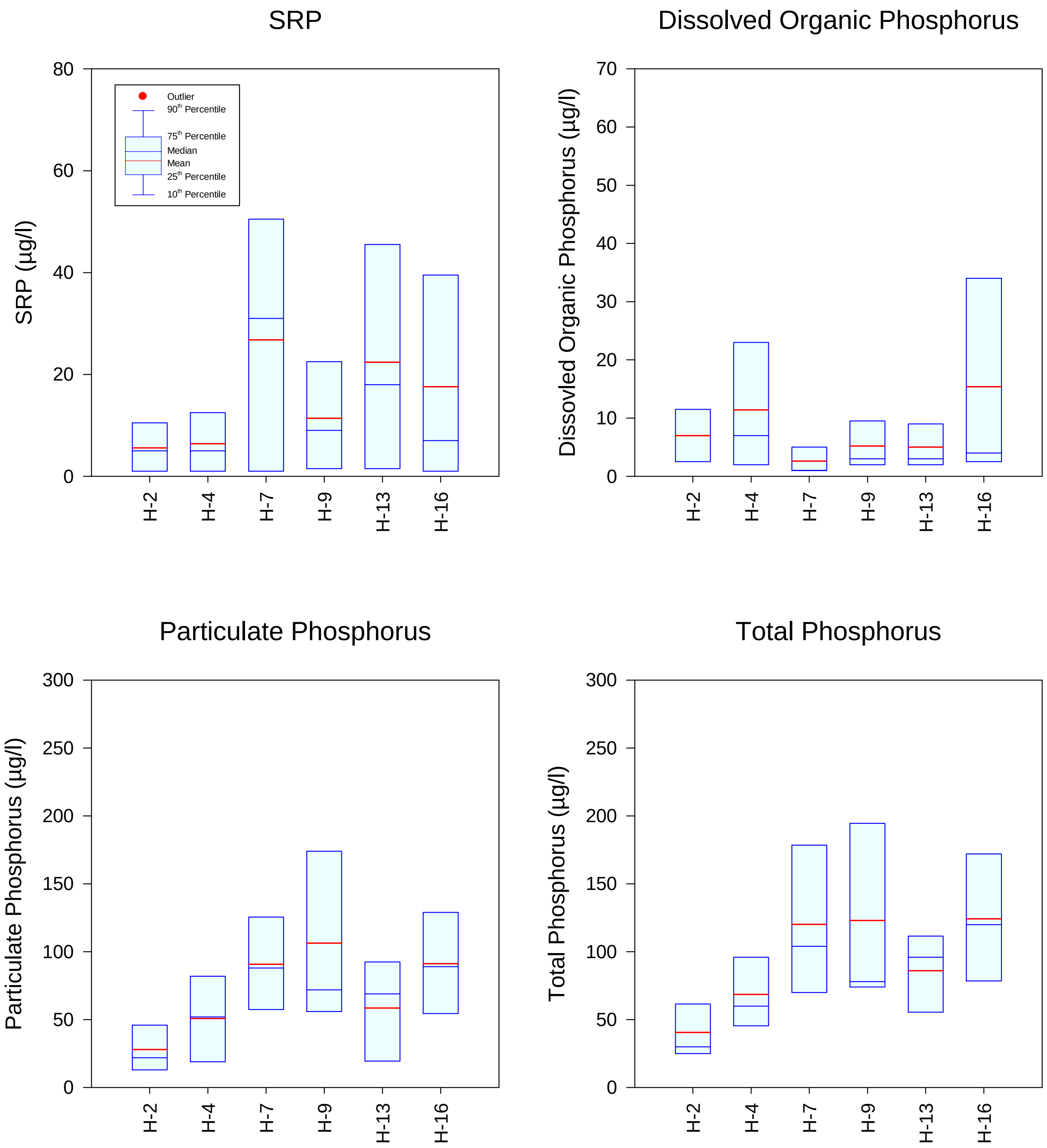


Figure 4-8. Comparison of Measured Concentrations of Nitrogen Species at Main Channel Monitoring Sites Along Roosevelt Creek Sub-basin H.


SRP

Dissolved Organic Phosphorus

Particulate Phosphorus

Total Phosphorus

Figure 4-9. Comparison of Measured Concentrations of Phosphorus Species at Main Channel Monitoring Sites Along Roosevelt Creek Sub-basin H.

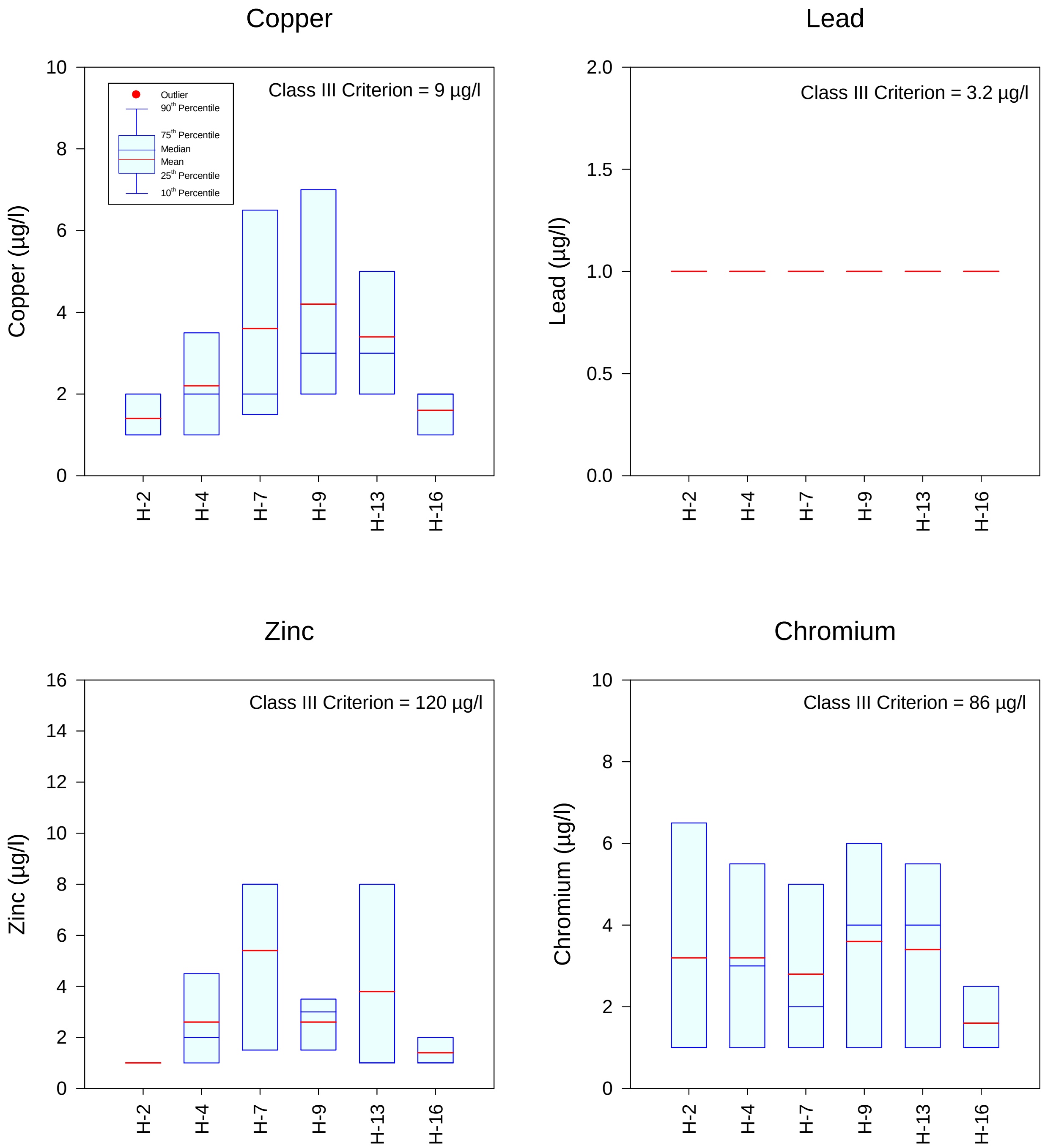


Figure 4-10. Comparison of Measured Concentrations of Heavy Metals at Main Channel Monitoring Sites Along Roosevelt Creek Sub-basin H.

TABLE 4-5

MEAN CHEMICAL CHARACTERISTICS OF ROOSEVELT CREEK TRIBUTARY INFLOW SAMPLES COLLECTED FROM AUGUST – OCTOBER 2009

PARAMETER	UNITS	SITE									
		H-1	**H-3**	**H-5**	**H-6**	**H-8**	**H-10**	**H-11**	**H-12**	**H-14**	**H-15**
Alkalinity	mg/l	122	140	245	263	269	186	176	192	144	137
NH_3	µg/l	213	105	255	55	2974	46	221	56	72	142
NO_x	µg/l	15	20	627	18	103	67	131	56	10	10
Diss. Org. N	µg/l	452	428	368	555	1274	684	597	528	589	750
Particulate N	µg/l	659	162	108	149	50	87	704	146	572	390
Total N	µg/l	1339	715	1359	777	4401	884	1653	786	1242	1291
SRP	µg/l	9	10	10	17	17	264	4	360	2	216
Diss. Org. P	µg/l	8	6	4	10	9	17	5	124	6	8
Particulate P	µg/l	86	21	12	45	31	65	92	75	58	74
Total P	µg/l	102	37	27	71	57	345	101	559	66	298
Turbidity	NTU	4.2	1.0	2.5	3.6	2.1	1.7	6.8	2.9	2.5	4.2
Color	Pt-Co	32	32	43	44	141	69	47	95	36	100
TSS	mg/l	11.9	1.4	2.9	4.3	3.3	2.2	11.8	6.2	4.1	6.2
Copper	µg/l	3.0	1.4	2.6	1.8	2.8	2.4	2.0	4.0	5.0	3.0
Lead	µg/l	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2
Zinc	µg/l	1.5	< 2	36	6.4	< 2	4.0	4.0	4.4	2.8	1.8
Chromium	µg/l	3.3	2.6	4.8	4.0	3.4	5.2	< 2	3.2	2.5	1.2

Relatively low levels of turbidity and TSS were observed in inflows to the main channel through the tributary sites. The tributary sites were characterized by moderate levels of color, with the exceptions of inflows at Site H-8 and H-15 which were characterized by elevated levels of color.

Inflows into the main channel were also characterized by relatively low levels of copper, lead, zinc, and chromium, with the exceptions of elevated chromium concentrations measured at Site H-5 which discharges into the main channel from an industrial area, and copper concentrations originating from Site H-12, reflecting urban drainage along Ulmerton Road, and Site H-14 which reflects discharges from a series of residential wet ponds.

A graphical comparison of measured concentrations of turbidity, alkalinity, color, and TSS in tributary inflow samples is given on Figure 4-11. In general, measured turbidity concentrations in inflow samples were relatively low in values, with all measured concentrations less than 8 NTU. Tributary inflow samples were well buffered, with measured alkalinity values relatively similar in the extreme upstream and downstream portions of the basin. Inflows originating in central portions of the basin were characterized by elevated alkalinity values.

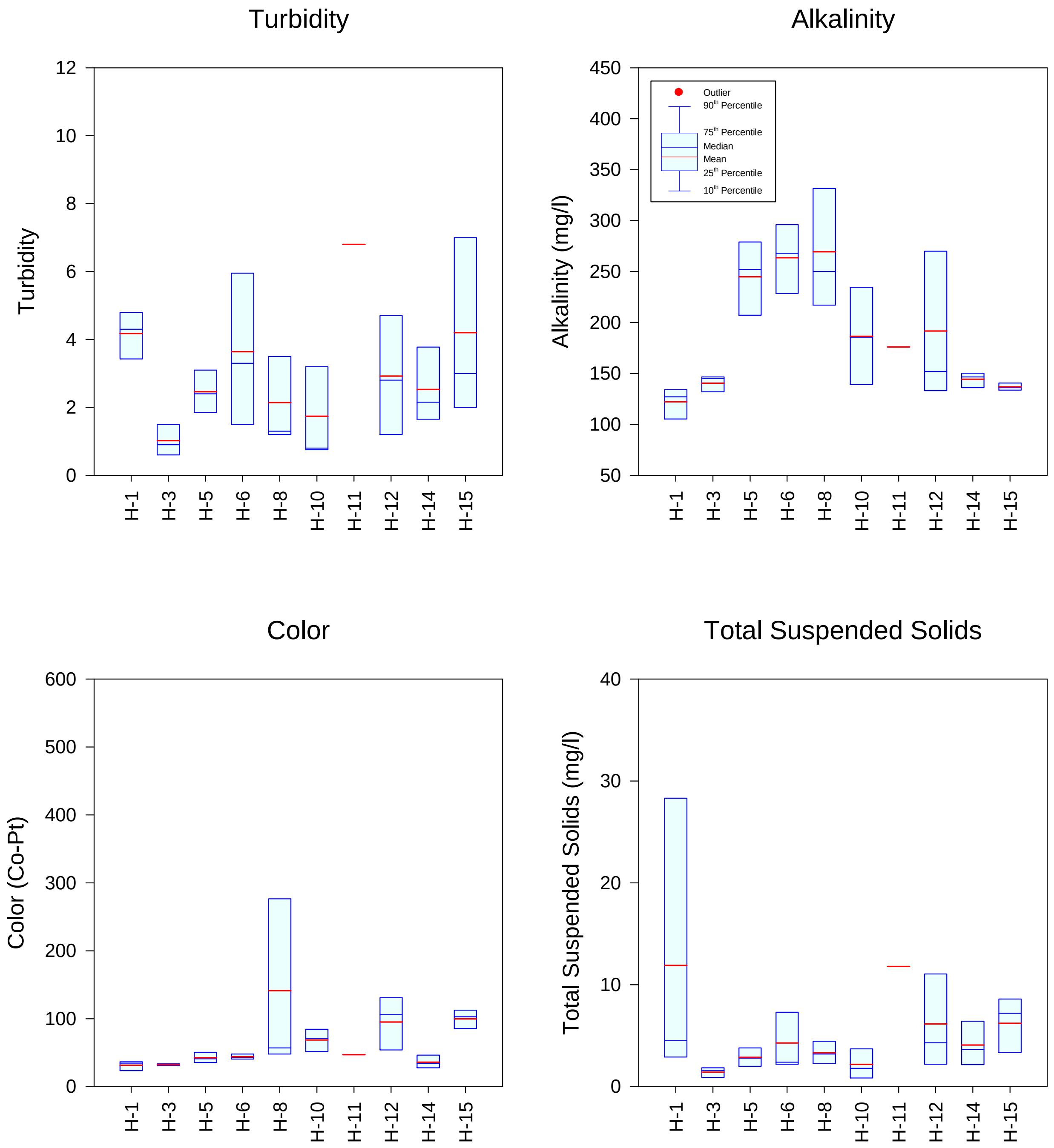


Figure 4-11. Comparison of Measured Concentrations of Turbidity, Alkalinity, Color, and TSS at Tributary Inflow Monitoring Sites Along Roosevelt Creek Sub-basin H.

Moderate to elevated color concentrations were observed in the tributary inflow samples, with moderate levels of color observed in extreme upstream and downstream portions of the basin. More elevated color concentrations were measured in central portions of the basin. Low to moderate levels of TSS were also observed at virtually all of the tributary inflow sites, with the exception of Site H-1 which appears to have more elevated TSS concentrations.

A graphical comparison of measured nitrogen species in tributary inflow samples is given in Figure 4-12. Each of the tributary inflows was characterized by relatively low levels of ammonia, with the exception of Site H-8 which was characterized by extremely elevated ammonia concentrations during virtually all monitoring events. Relatively low levels of NO_x were also observed at each of the inflow monitoring sites, with the exception of Site H-5 which was characterized by elevated NO_x levels. In contrast to the trends observed for other parameters, the most elevated levels of particulate nitrogen were observed in upstream and downstream portions of the basin, with lower concentrations of particulate nitrogen in tributary inflows in central portions of the basin. Total nitrogen concentrations measured in inflows were moderate in value at each of the monitoring sites, with the exception of Site H-8 which was characterized by extremely elevated nitrogen levels.

A graphical comparison of measured phosphorus species in tributary inflow samples is given in Figure 4-13. Low levels of SRP and dissolved organic phosphorus were observed at monitoring sites located in upstream portions of the basin area. However, elevated levels for each of these parameters were observed in the vicinity of Ulmerton Road and in inflow from the Airco Golf Course to the main channel. Particulate phosphorus concentrations were highly variable, although low to moderate in value. Total phosphorus concentrations were moderate in value in upstream portions of the drainage basin, increasing substantially in the vicinity of Ulmerton Road and in inflow from the Airco Golf Course. Total phosphorus concentrations measured at tributary inflow monitoring Sites H-10, H-12 and H-15 are higher than values commonly observed for total phosphorus in urban runoff.

A graphical comparison of measured heavy metal concentrations in tributary inflows is given on Figure 4-14. Measured copper concentrations were generally low in value in upstream portions of the drainage basin, with increases in copper observed in the vicinity of Ulmerton Road and in the inflow from the Airco Golf Course. Relatively low levels of total zinc were observed throughout the sub-basin area, with the exception of monitoring Site H-5 which reflects inputs from an industrial area. Low levels of total chromium were observed at each of the tributary inflow sites.

Estimates of Class III criteria for the evaluated heavy metals are also provided on Figure 4-14 for comparison purposes. The criteria for the listed heavy metals are based upon the hardness of the receiving water, and a hardness of 100 mg/l as $CaCO_3$ is assumed for this analysis. No violations of applicable Class III criteria were observed in any of the tributary inflows during the field monitoring program.

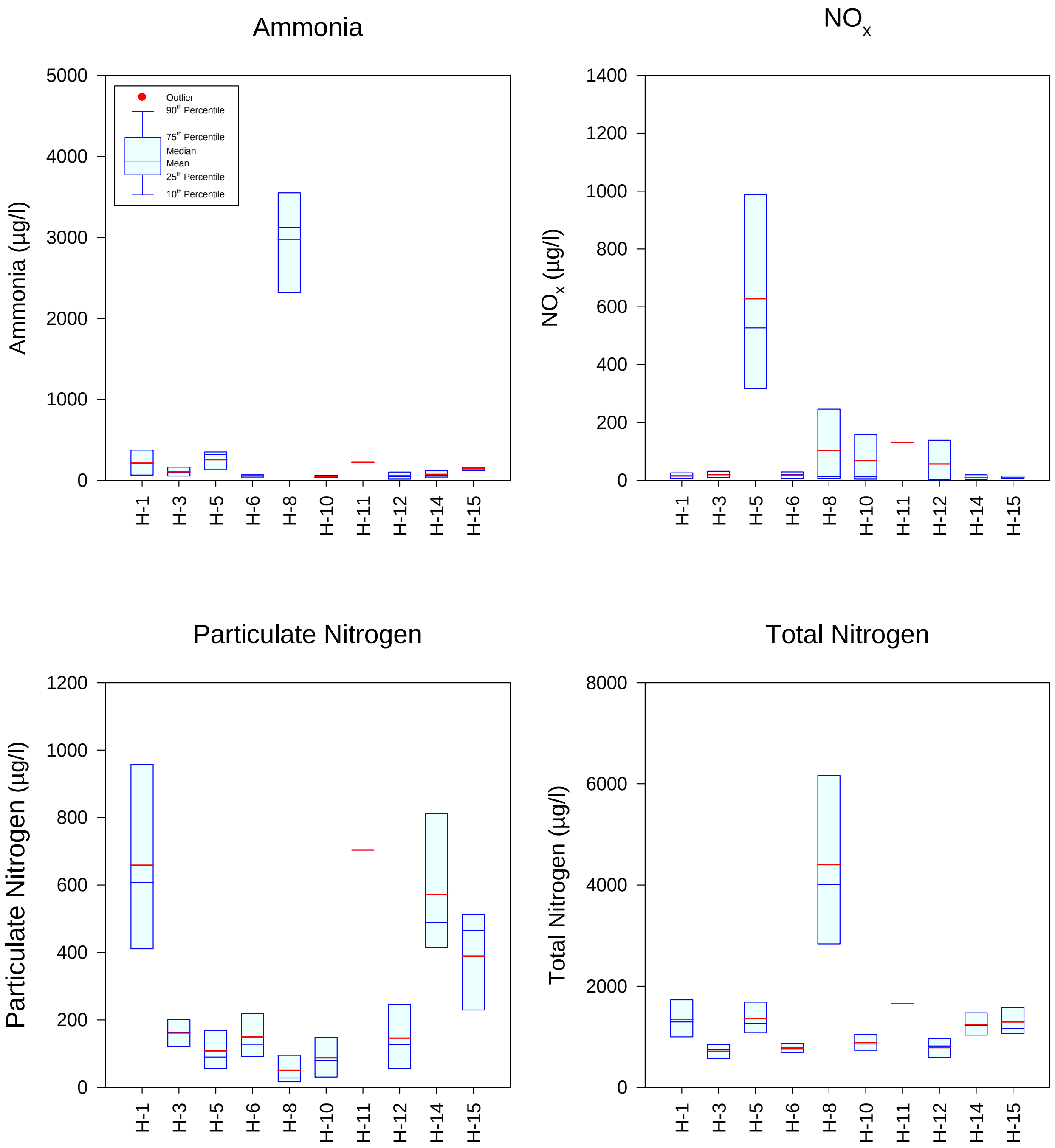


Figure 4-12. Comparison of Measured Concentrations of Nitrogen Species at Tributary Inflow Monitoring Sites Along Roosevelt Creek Sub-basin H.

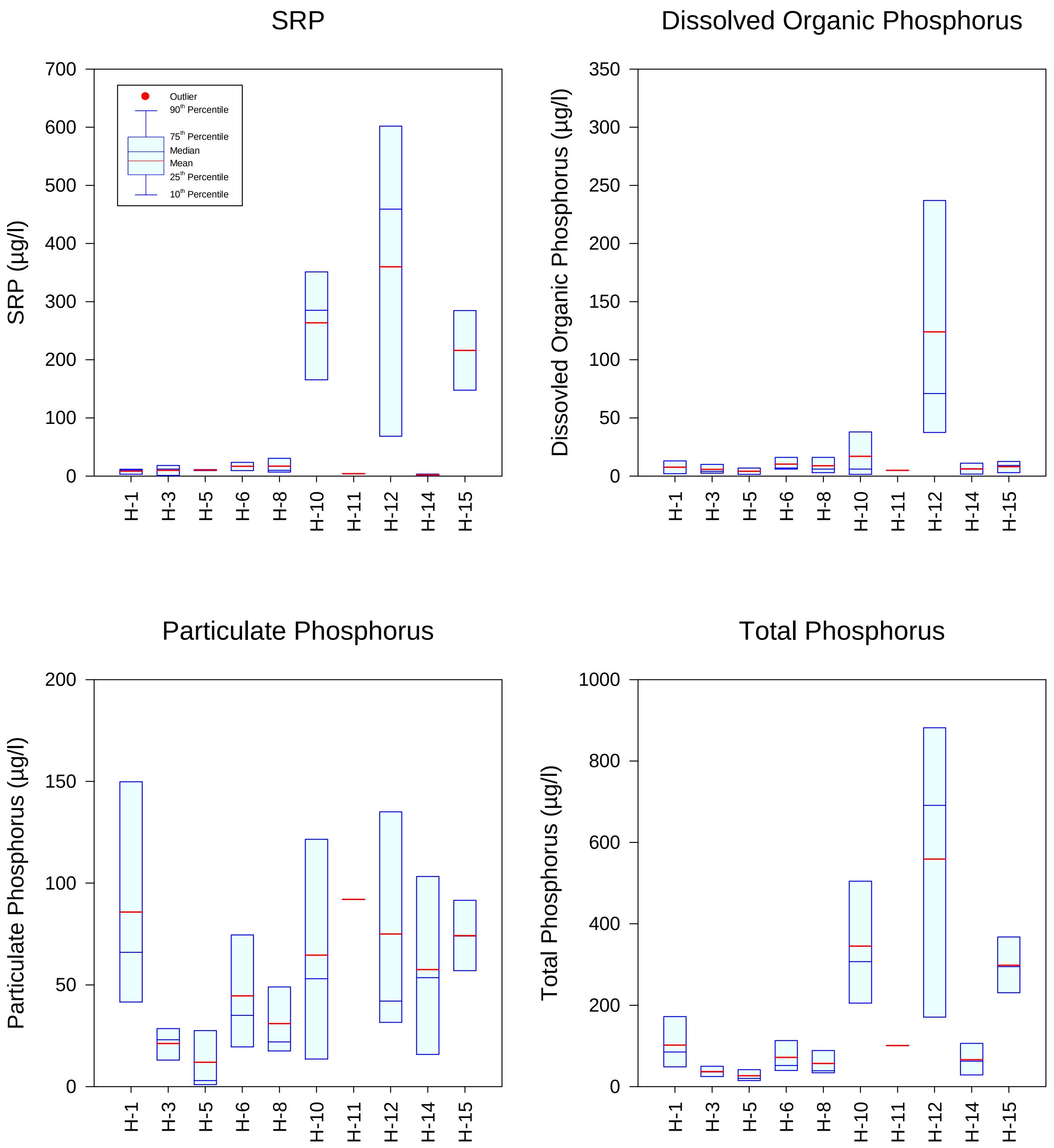


Figure 4-13. Comparison of Measured Concentrations of Phosphorus Species at Tributary Inflow Monitoring Sites Along Roosevelt Creek Sub-basin H.

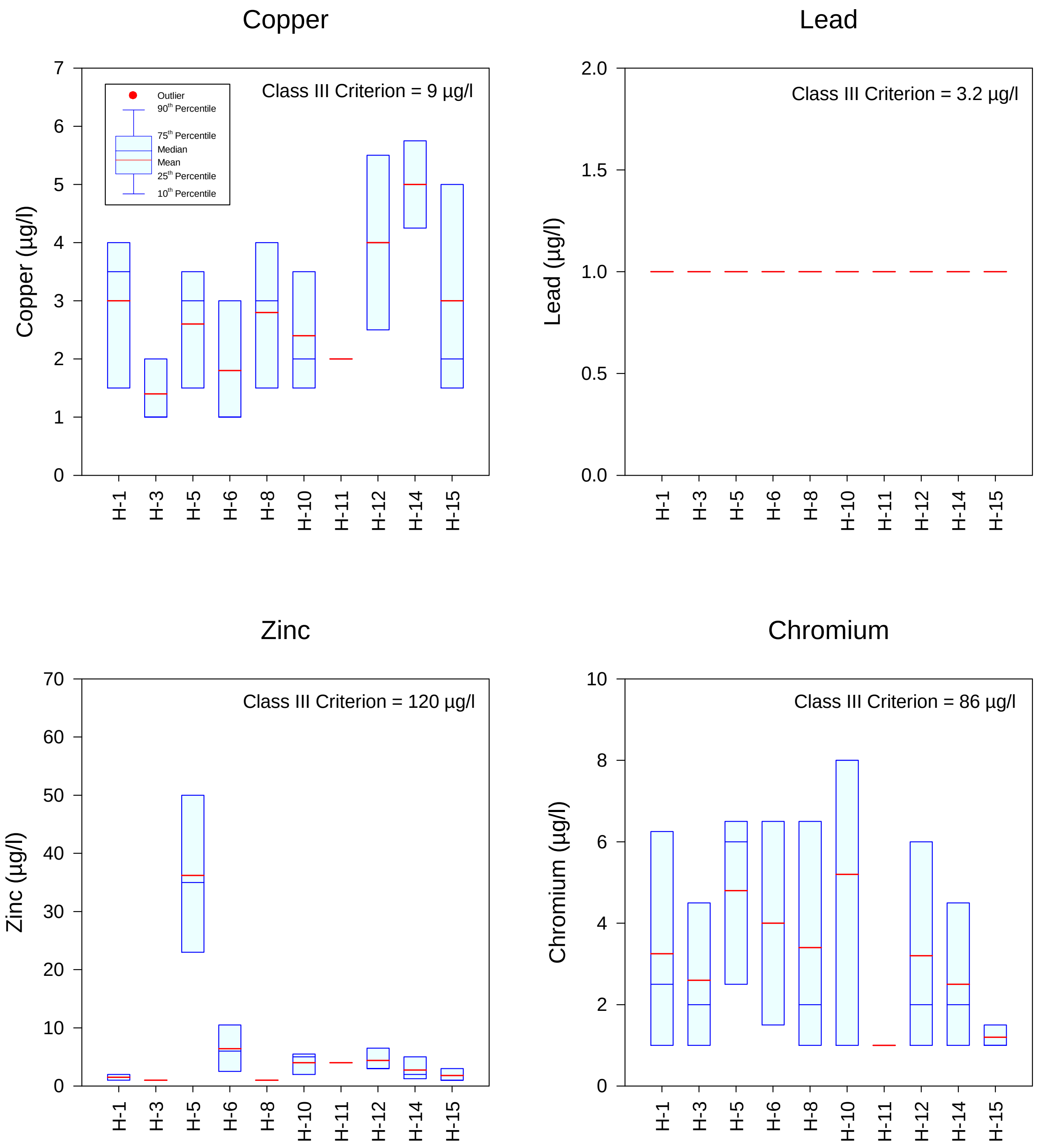


Figure 4-14. Comparison of Measured Concentrations of Heavy Metals at Tributary Inflow Monitoring Sites Along Roosevelt Creek Sub-basin H.

4.3.2.3 Airport Sites

A summary of the mean chemical characteristics of discharges from the St. Petersburg/Clearwater International Airport sites is given on Table 4-6. Discharges from the airport sites were found to be well buffered, with mean alkalinities ranging from 195-200 mg/l. Measured concentrations of nitrogen species were found to be low to moderate in value, with mean total nitrogen concentrations at each of the two sites less than 1000 µg/l. The dominant nitrogen species at each of the two monitoring sites was dissolved organic nitrogen, which comprised approximately 55-62% of the total nitrogen measured.

TABLE 4-6

MEAN CHEMICAL CHARACTERISTICS OF ST. PETERSBURG / CLEARWATER INTERNATIONAL AIRPORT DISCHARGES FROM ROOSEVELT CREEK COLLECTED FROM AUGUST – OCTOBER 2009

PARAMETER	UNITS	SITE	
		H-17	H-18
Alkalinity	mg/l	195	200
NH_3	µg/l	153	128
NO_x	µg/l	105	115
Diss. Org. N	µg/l	578	383
Particulate N	µg/l	95	77
Total N	µg/l	931	702
SRP	µg/l	79	41
Diss. Org. P	µg/l	10	6
Particulate P	µg/l	23	21
Total P	µg/l	112	67
Turbidity	NTU	2.7	4.6
Color	Pt-Co	53	39
TSS	mg/l	4.5	3.4
Copper	µg/l	10.4	6.0
Lead	µg/l	< 2	< 2
Zinc	µg/l	1.8	2.8
Chromium	µg/l	5.8	12.0

Moderate levels of phosphorus species were also observed in discharges from the airport sites, although the measured SRP concentrations, ranging from 41-79 µg/l, were higher than observed at any of the main tributary monitoring sites. SRP was the dominant phosphorus species in discharges from the airport sites, comprising approximately 61-71% of the total phosphorus measured.

The airport monitoring sites were characterized by relatively low levels of both turbidity and TSS, with moderate levels of color. Low levels of lead, zinc, and chromium were observed in discharges from the site, although somewhat elevated levels of copper were measured in the discharges. The elevated copper concentrations are likely related to either airport activities or the use of copper-based pesticides within the airport property. Since these sites discharge directly to a Class III marine environment, the standard for copper is 3.7 μg/l which was exceeded in virtually all of the samples collected at the two monitoring sites. However, no exceedances of the marine standard were observed for the remaining heavy metals.

A graphical comparison of measured concentrations for turbidity, alkalinity, color, and TSS at the airport monitoring sites is given on Figure 4-15. In general, measured concentrations for both turbidity and TSS at the airport monitoring sites were low in value. These low values are likely related to the vegetated swale drainage system used throughout the airport property which conveys runoff to the points of discharge. Each of the two sites was also characterized by elevated levels of alkalinity, presumably due to the proximity to marine waters. Moderate to elevated levels of color were also observed at each site.

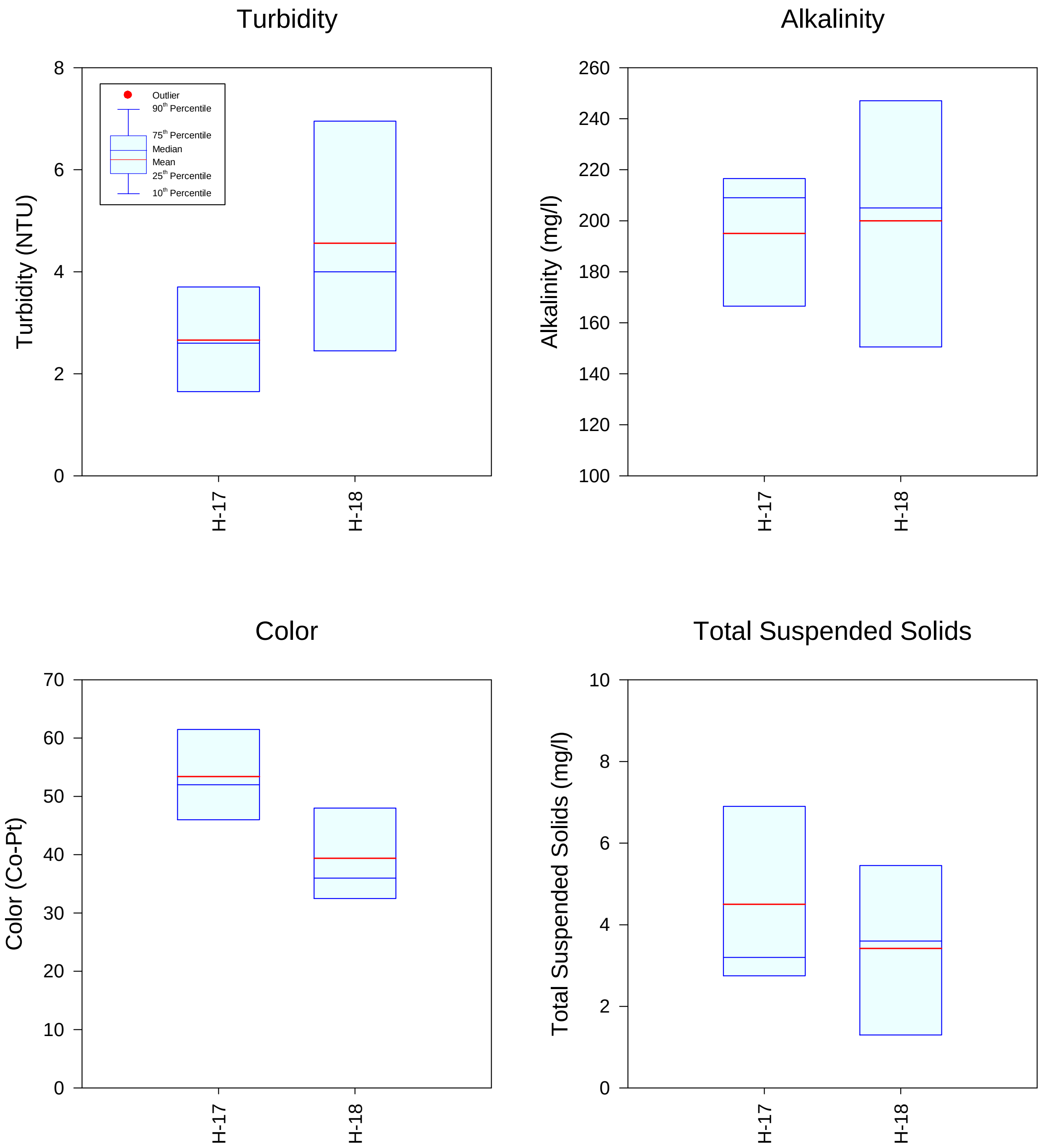
A graphical comparison of measured nitrogen species at the airport monitoring sites is given on Figure 4-16. Moderate to low levels of both ammonia and NO_x were observed at each of the two sites, with a relatively low degree of variability observed for NO_x concentrations. Particulate nitrogen concentrations at the two sites were low in value, presumably resulting from the vegetated swale drainage system. Total nitrogen concentrations in discharges from the airport property were low to moderate in value, with a relatively low degree of variability observed between monitoring dates.

A graphical comparison of measured phosphorus species at the airport monitoring sites is given on Figure 4-17. Moderate levels of SRP were observed at each of the two monitoring sites, with relatively low levels for dissolved organic phosphorus and particulate phosphorus. Low to moderate levels of total phosphorus were also observed at the monitoring sites, with a slightly higher total phosphorus concentration observed at monitoring Site H-17.

A graphical comparison of measured heavy metal concentrations at the airport monitoring sites is given on Figure 4-18. All of the samples collected at Site H-17 and four of the five samples collected at Site H-18 exceeded the Class III marine standard of 3.7 μg/l for total copper. However, exceedances of Class III marine standards were not observed for lead or zinc. There is currently no Class III marine standard for chromium. A relatively high degree of variability was observed in measured chromium concentrations in samples collected at monitoring Site H-18.

4.4 Sediment Characteristics

Sediment core samples were conducted at each of the main channel, tributary inflow, and airport monitoring sites on September 24, 2009. Duplicate sediment core samples were collected at each site, and the 0-10 cm layer was sectioned off for laboratory analyses.

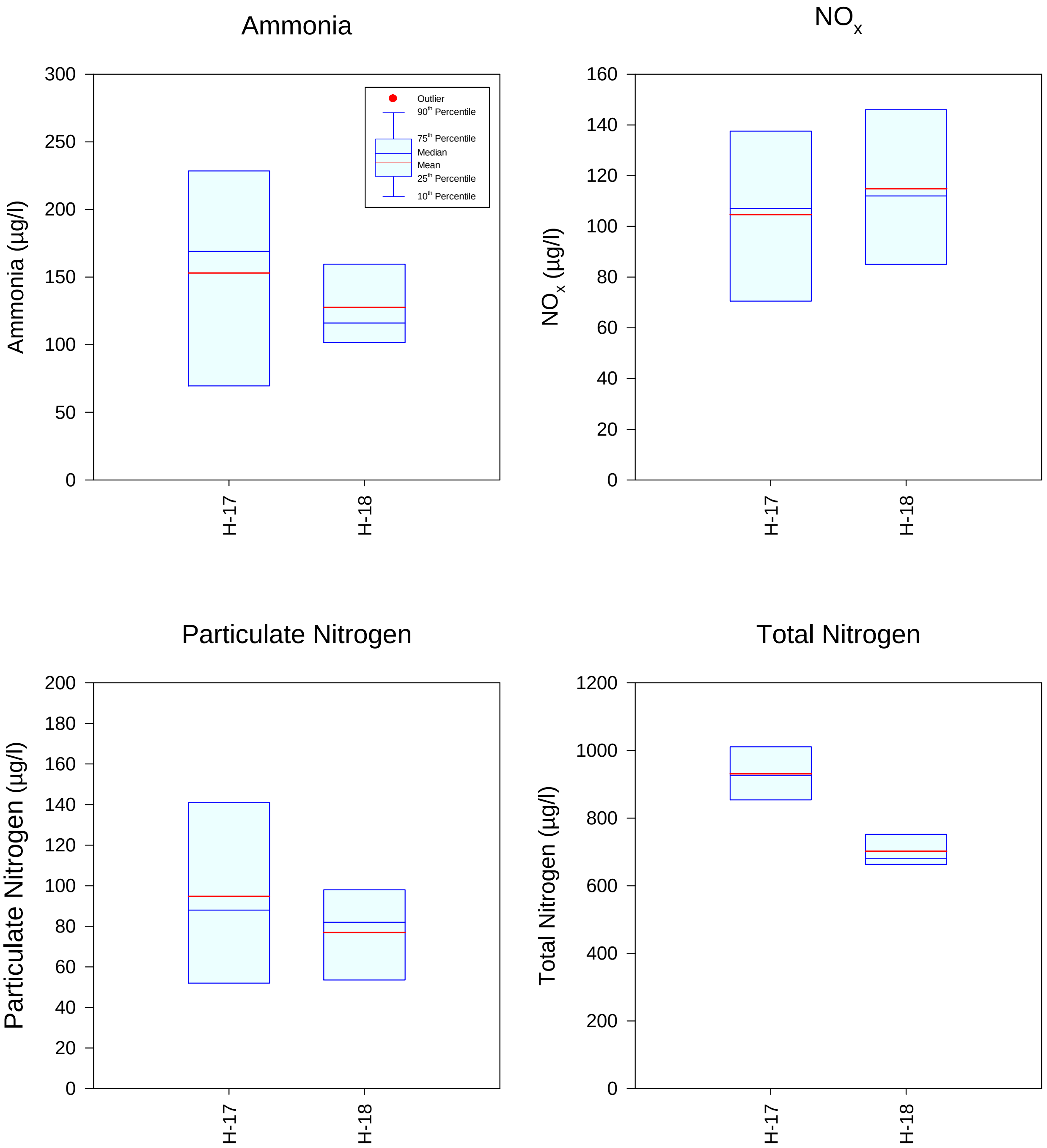

Turbidity

Alkalinity

Color

Total Suspended Solids

Figure 4-15. Comparison of Measured Concentrations of Turbidity, Alkalinity, Color, and TSS at the Airport Monitoring Sites Along Roosevelt Creek Sub-basin H.



Ammonia

NO$_x$

Particulate Nitrogen

Total Nitrogen

Figure 4-16. Comparison of Measured Concentrations of Nitrogen Species at the Airport Monitoring Sites Along Roosevelt Creek Sub-basin H.

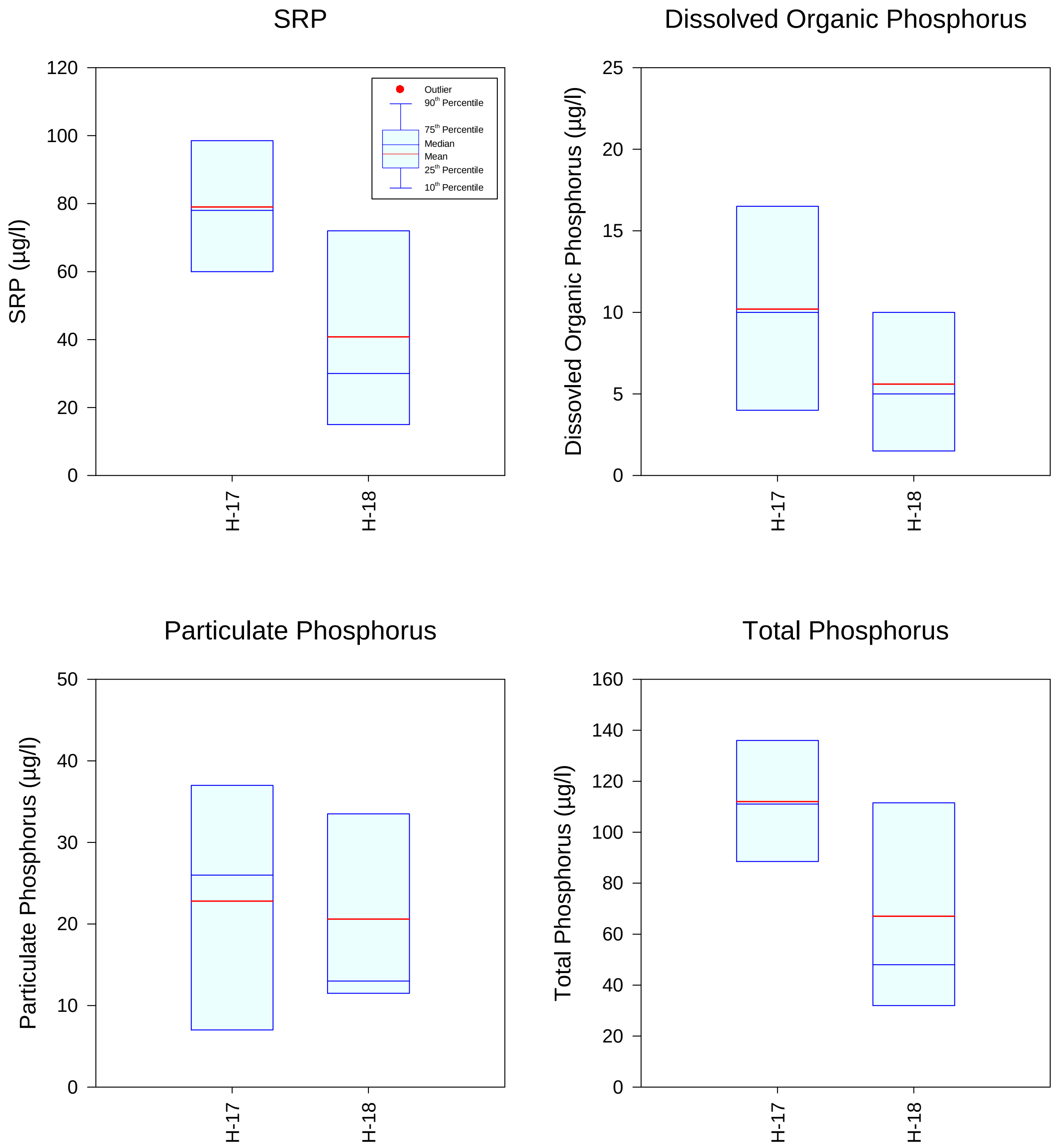


Figure 4-17. Comparison of Measured Concentrations of Phosphorus Species at the Airport Monitoring Sites Along Roosevelt Creek Sub-basin H.

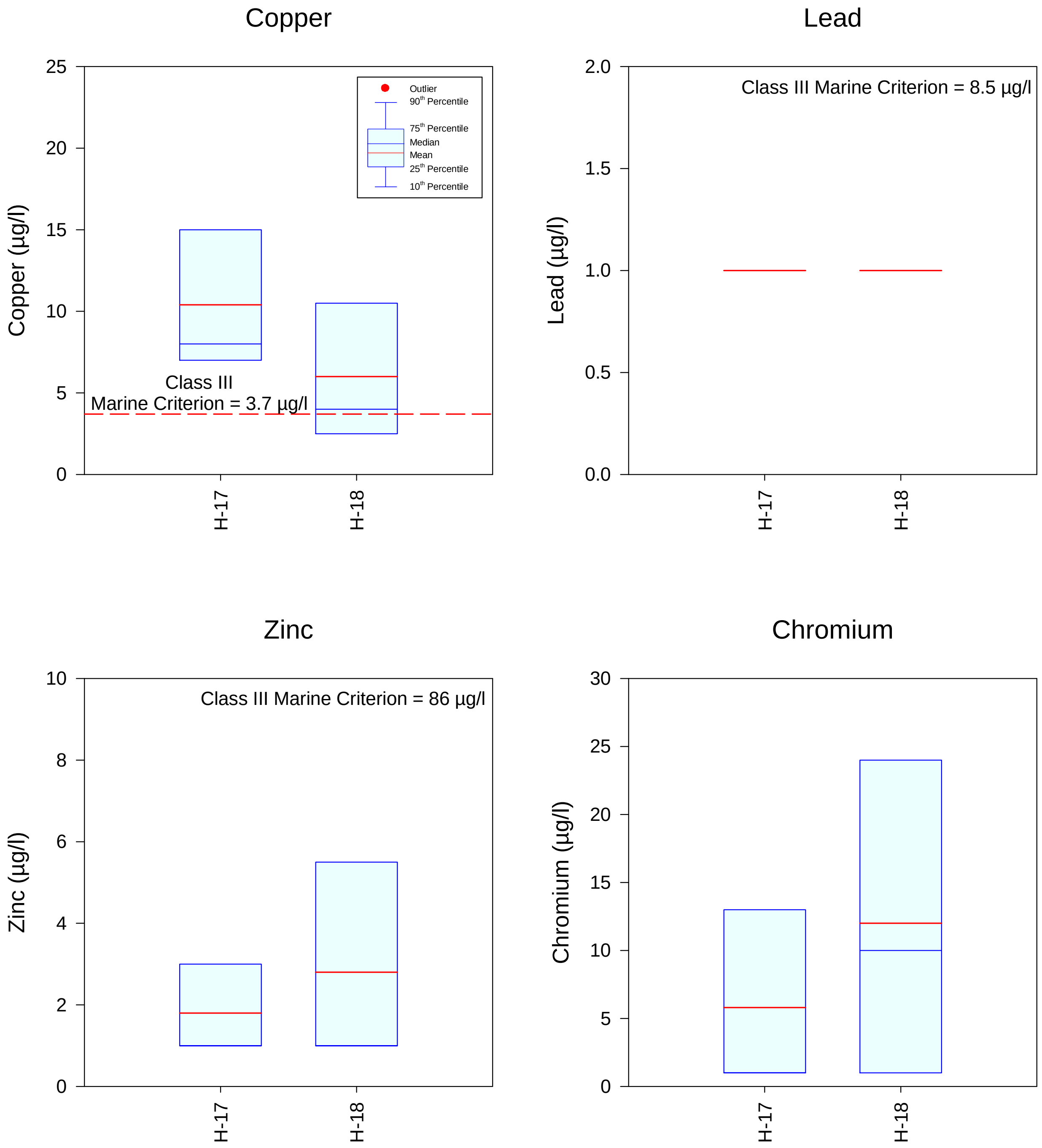


Figure 4-18. Comparison of Measured Concentrations of Heavy Metals at the Airport Monitoring Sites Along Roosevelt Creek Sub-basin H.

Typical visual characteristics of sediment core samples collected in Roosevelt Creek Sub-basin H are given on Figure 4-19. Sediment samples collected from tributary inflows and along main portions of the channel were characterized by a thin layer of organic muck, approximately 1-3 cm in depth. Below this surficial layer, the sediments consisted primarily of fine sands with varying degrees of organic matter. Sediments collected at the airport monitoring sites consisted of a mixture of sand and shell material, with no visible layer of organic muck. Build-up of organic muck in tributary, main channel, and at the airport sites is limited due to the periodic water movement throughout the basin.

a. Typical sediment characteristics in tributary inflows and main channel areas

b. Typical sediment characteristics at Sites H-17 and H-18

Figure 4-19. Visual Characteristics of Sediment Core Samples Collected in Roosevelt Creek Sub-basin H.

A summary of physical and chemical characteristics of sediment core samples collected at Roosevelt Creek Sub-basin H sites is given on Table 4-7. Sediments collected throughout Sub-basin H were approximately neutral in pH, with values ranging from 6.65-7.92. Measured moisture contents at the main channel and tributary sites were low to moderate in value, with relatively low levels of organic content at the majority of the monitoring sites. It appears that movement of water within the tributaries and main channel decreases the opportunity of settling of organic matter and accumulation of organic sediments. The majority of measured sediment densities are in excess of 2.0 g/cm^3, indicating primarily sandy sediments within Sub-basin H.

Measured concentrations of both total nitrogen and total phosphorus within the main channel and tributary sites appear to be relatively low in value. Sediment phosphorus concentrations appear to be highest in central portions of Sub-basin H, with lower values measured in the extreme downstream and upstream reaches. As discussed in previous sections, a similar trend is also observed for surface water concentrations of total phosphorus along the main channel. Measured sediment concentrations of total nitrogen and total phosphorus are substantially lower than concentrations commonly measured in urban lakes, and suggest that the sediments do not appear to be a significant source of nutrient loadings into the water column within Sub-basin H.

TABLE 4-7

CHARACTERISTICS OF SEDIMENT CORE SAMPLES COLLECTED AT ROOSEVELT CREEK SUB-BASIN H SITES ON SEPTEMBER 24, 2009

LOCATION	SITE	pH	MOISTURE CONTENT (%)	ORGANIC CONTENT (%)	DENSITY (g/cm^3)	TOTAL NITROGEN (μg/cm^3)	TOTAL PHOSPHORUS (μg/cm^3)
Main Channel	H-2	7.19	71.7	10.0	1.38	1496	171
	H-4	7.36	26.2	1.3	2.09	371	100
	H-7	7.49	21.5	1.7	2.16	97	313
	H-9	7.60	72.9	11.3	1.36	998	397
	H-13	7.28	26.6	1.5	2.08	720	310
	H-16	7.29	25.0	1.1	2.11	476	147
Tributary Inflow	H-1	7.92	20.9	0.7	2.18	238	87
	H-3	6.65	40.8	4.6	1.85	856	164
	H-5	7.51	19.9	0.5	2.20	24	198
	H-6	7.14	25.3	2.0	2.10	359	139
	H-8	7.47	28.1	2.8	2.05	128	107
	H-10	7.70	18.6	0.8	2.21	54	85
	H-11	7.75	19.4	0.6	2.20	75	79
	H-12	7.43	36.7	3.1	1.92	682	164
	H-14	7.74	30.4	2.2	2.02	820	144
	H-15	7.33	55.8	5.0	1.63	1009	325
Airport Sites	H-17	6.60	76.5	50.3	1.18	939	108
	H-18	6.85	21.7	3.4	2.13	248	763

4.5 Impacts of Tributary Inflows on Main Channel Characteristics

A graphical summary of mean concentrations of conductivity, alkalinity, color, and TSS in tributary inflows and along the main channel is given on Figure 4-20. An approximate doubling of conductivity values occurs between Sites H-2 and H-4 in spite of a significant inflow at Site H-3 with relatively low conductivity values. These data suggest that an additional input occurs into the main channel between Sites H-2 and H-4 which was not included in the tributary inflow monitoring program. The most likely sources for this additional inflow are the pumped water from the Bridgeway Acres Landfill and groundwater seepage into the channel. Measured conductivity values remain relatively consistent throughout the remaining portions of the channel, with a slight decrease observed between Sites H-9 and H-13 due to three relatively significant inputs characterized by lower conductivity values.

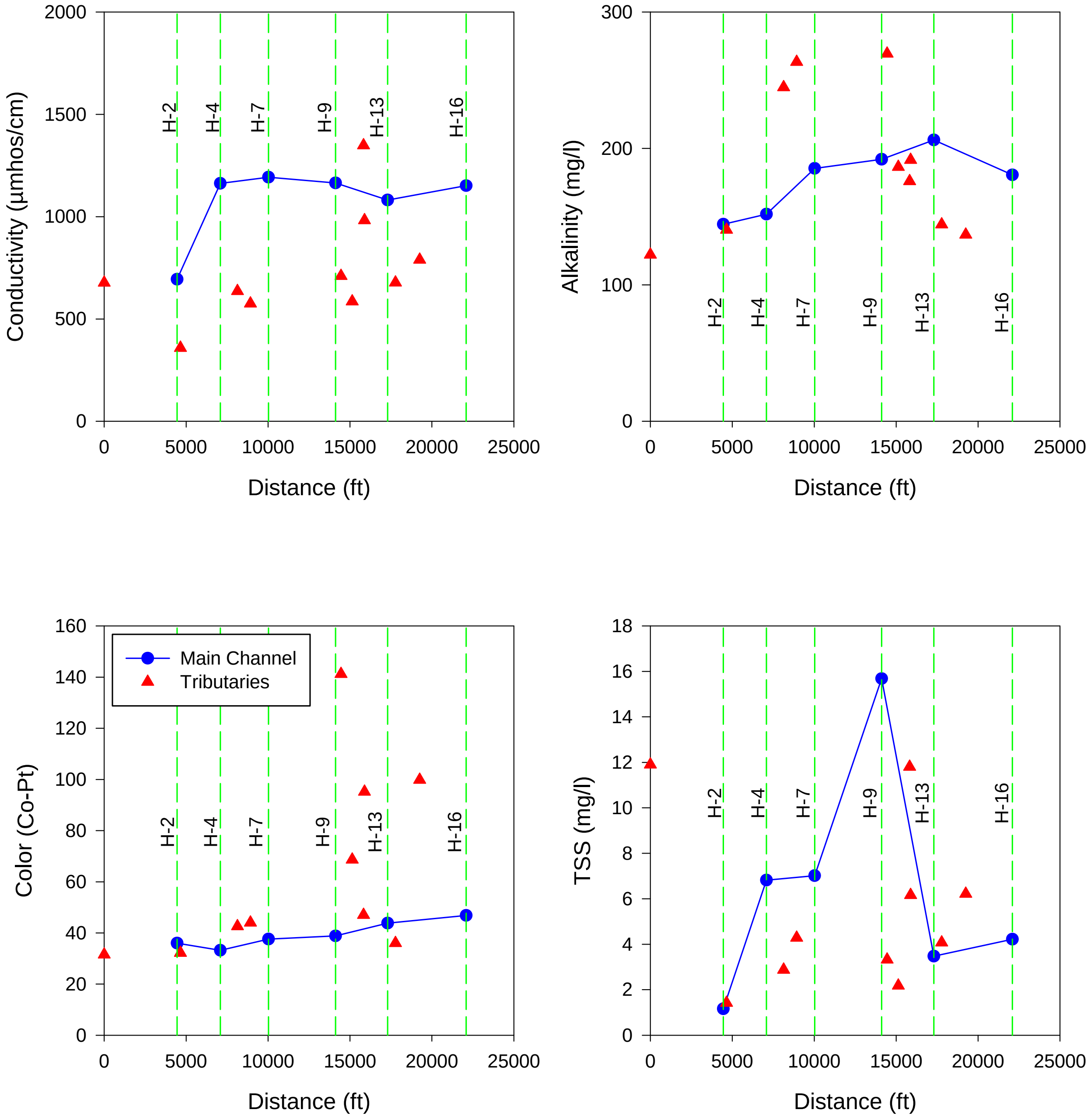


Figure 4-20. Comparison of Mean Concentrations of Conductivity, Alkalinity, Color, and TSS in Tributary and Main Channel Samples Collected in Roosevelt Creek Sub-basin H.

An increase in measured alkalinity values also appears to occur between monitoring sites H-2 and H-4 even though the monitored inflow at Site H-3 is characterized by alkalinity values slightly less than those observed at Site H-2. An increase in alkalinity also occurs between Sites H-4 and H-7 which appears to be impacted by the high alkalinity inflows at Sites H-5 and H-6. A further increase in alkalinity occurs between Sites H-9 and H-13, with one inflow having substantially higher alkalinity values and three inflows characterized by slightly lower alkalinity values. A decrease in alkalinity appears to occur between Ulmerton Road and the spillway structure which is likely related to significant inflows at Sites H-14 and H-15 with lower alkalinity values.

Color concentrations appear to increase steadily during migration through the main channel. This steady increase is likely explained by the more elevated color values measured in tributary inflows into the main channel.

Substantial increases in TSS concentrations occur between monitoring Sites H-2 and H-9, although tributary inflow concentrations of TSS over this distance appear to be relatively low in value. Additional sources for TSS may occur in discharges from the Bridgeway Acres Landfill pond, although the observed increases in TSS concentrations may be more related to increases in algal biomass within the water column resulting from the observed elevated nutrient concentrations.

A graphical comparison of mean concentrations of nitrogen species in tributary and main channel samples is given on Figure 4-21. An increase in ammonia concentrations is observed between Sites H-2 and H-4, although significant concentrations of ammonia were not measured in the inflow at Site H-3. A subsequent increase in ammonia occurs between Sites H-4 and H-7 in spite of low ammonia concentrations at inflow Sites H-5 and H-6. It appears that significant additional inputs of ammonia are occurring into the main channel between Sites H-2 and H-7 which were not included in the monitoring program. A steady decrease in ammonia concentrations occurs from Site H-7 to the spillway structure, presumably related to low concentration inflows from tributaries along that reach of the channel, along with biological uptake in the wider and slower-moving portions of the main channel.

A similar pattern is also apparent for total nitrogen concentrations along the main channel. Significant increases in total nitrogen appear to occur between sites H-2 and H-7, although relatively low total nitrogen concentrations were measured in the tributary inflows. A decrease in total nitrogen concentrations appears to occur between monitoring Sites H-7 and H-16, presumably related to the low nitrogen concentrations in the inflows between these sites, along with biological uptake. Measured NO_x concentrations also appear to peak at Site H-9, even though relatively low NO_x concentrations were measured in tributary inflows in central portions of the channel.

The trends summarized on Figure 4-21 suggest that there are additional significant inputs of nitrogen species into the main channel which were not included in the tributary monitoring program. Since all significant tributary inflows were monitored, the only potential sources for the additional nitrogen loadings appear to be discharges from the Bridgeway Acres Landfill pond and seepage of groundwater into the canal containing elevated nitrogen concentrations.

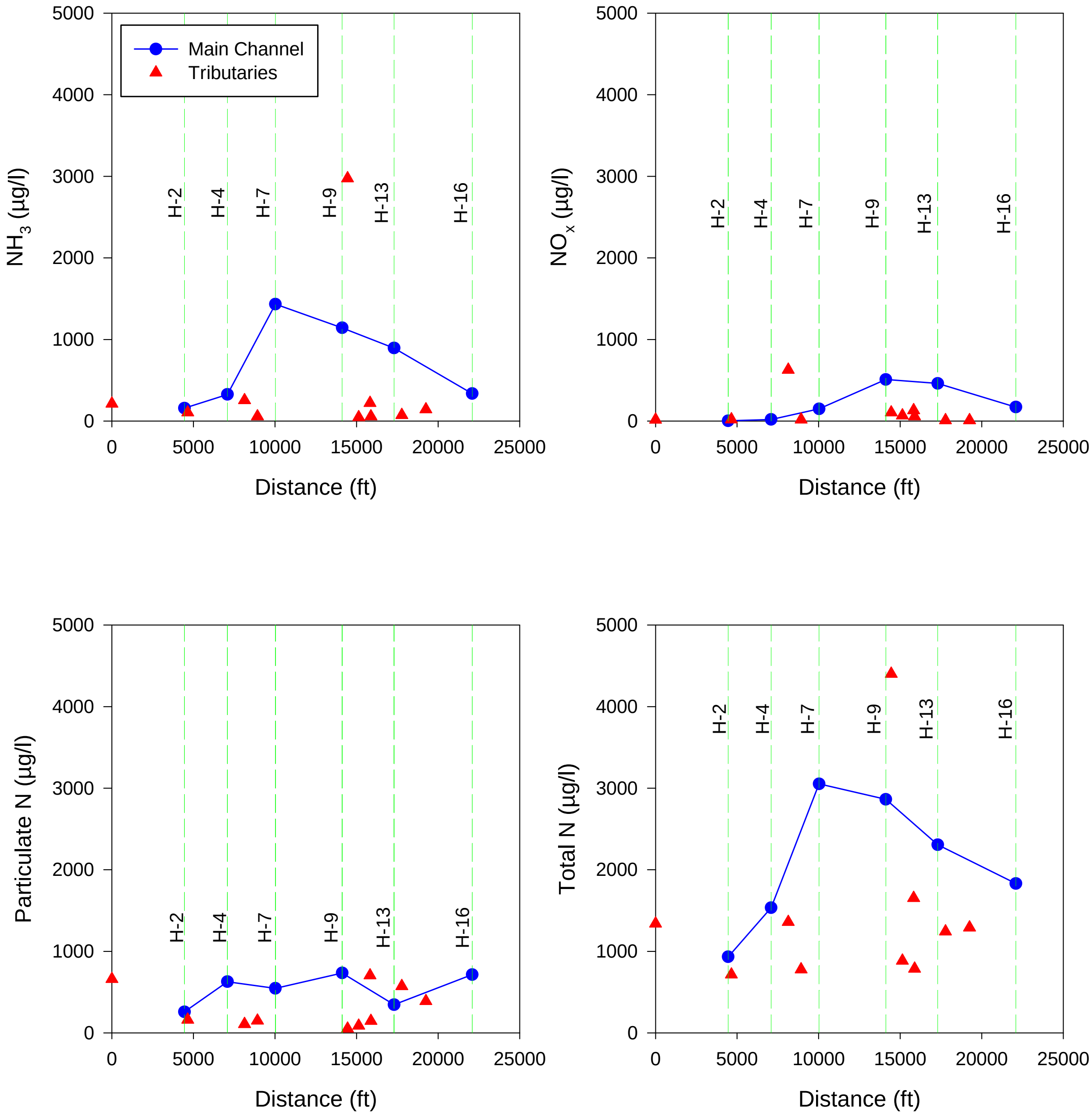


Figure 4-21. Comparison of Mean Concentrations of Nitrogen Species in Tributary and Main Channel Samples Collected in Roosevelt Creek Sub-basin H.

A comparison of mean concentrations of phosphorus species in tributary inflow and main channel samples is given on Figure 4-22. Measured concentrations of SRP and dissolved organic phosphorus appear to respond to inflows from the monitored tributaries, with no evidence of significant additional inputs for these parameters. However, increases in both particulate phosphorus and total phosphorus occur between monitoring Sites H-2 and H-7 even though the monitored inflows are characterized by lower phosphorus concentrations. Measured concentrations of particulate phosphorus and total phosphorus in downstream portions of the basin appear to reflect inflows from tributary sources. However, similar to the trend observed for nitrogen species, there appears to be an additional source of phosphorus discharging into the main channel between Sites H-2 and H-7 which does not appear to be explained by data collected at the tributary inflow sites. The likely sources for this additional phosphorus inflow are the pumped inflows from the Bridgeway Acres Landfill pond as well as groundwater seepage into the channel containing elevated phosphorus concentrations. The observed increases in particulate phosphorus and total phosphorus may also be a result of increases in algal biomass within the water column resulting from the elevated nutrient concentrations.

A graphical comparison of mean concentrations of heavy metals in tributary and main channel samples is given on Figure 4-23. Similar to the trends exhibited by total nitrogen and total phosphorus, an increase in total copper concentrations appears to occur between monitoring Sites H-2 and H-9 which cannot be accounted for by the monitored inflow sites. Copper concentrations increase by a factor of approximately 4 between these monitoring sites in spite of relatively low concentrations measured in tributary inflows. In contrast, measured concentrations for zinc and chromium along the main channel appear to be explained fairly well by metal concentrations in tributary inflows.

4.6 Mass Loadings

Estimates of mass loadings discharging through Roosevelt Creek Sub-basin H were calculated for total nitrogen, total phosphorus, TSS, and heavy metals at each of the main channel and tributary inflow monitoring sites. These estimates were generated by multiplying the measured discharge rates for each monitoring site and event times the mean measured concentrations for species of nitrogen, phosphorus, TSS, and heavy metals for each site and event date. The data collected during the initial monitoring event on August 12, 2009 were excluded from this analysis due to the impacts of the previously described localized rainfall event on mean discharge characteristics within the channel.

A summary of calculated mass loadings of total nitrogen, total phosphorus, and TSS along the main channel for each monitoring event, with the exception of the initial event, is given on Table 4-8. Steady increases in mass loadings of total nitrogen occur from upstream to downstream portions of the basin during virtually all monitored events. The rate of observed nitrogen increases appears to slow down in central portions of the basin before increasing again between Ulmerton Road and the outfall structure. However, on an average basis, nitrogen loadings appear to increase by a factor of approximately 2.5 between Ulmerton Road and the spillway structure.

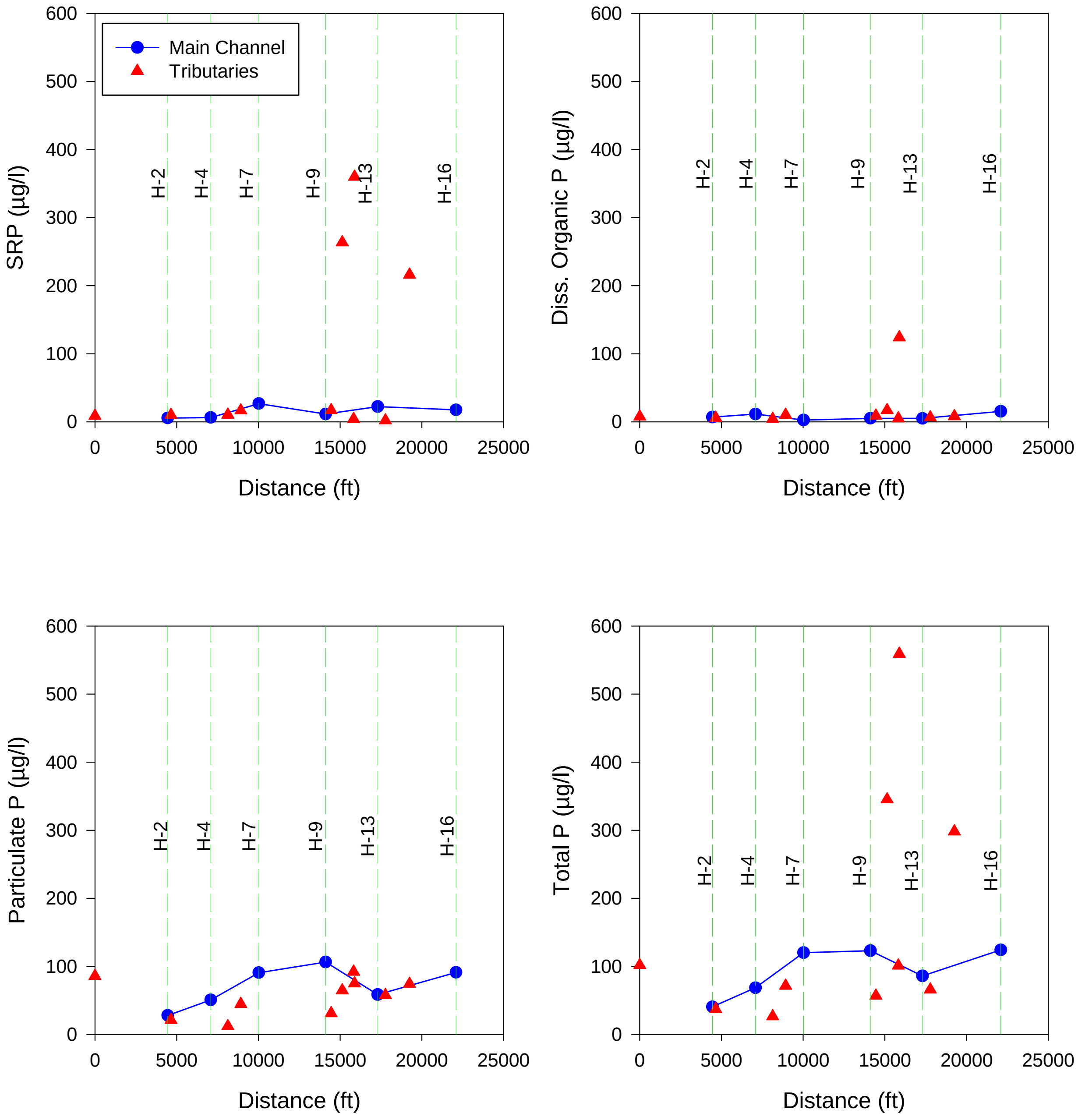


Figure 4-22. Comparison of Mean Concentrations of Phosphorus Species in Tributary and Main Channel Samples Collected in Roosevelt Creek Sub-basin H.

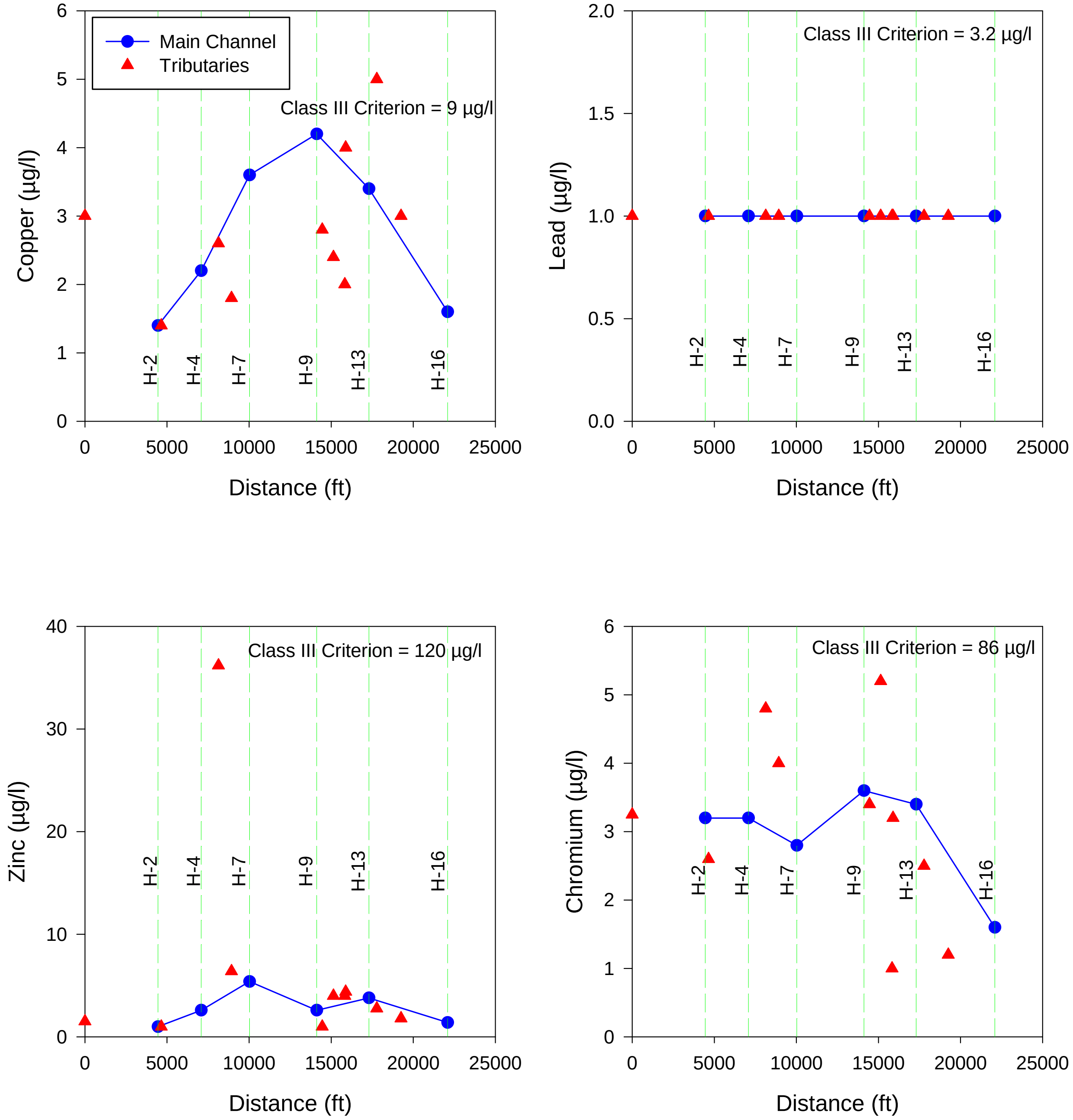


Figure 4-23. Comparison of Mean Concentrations of Heavy Metals in Tributary and Main Channel Samples Collected in Roosevelt Creek Sub-basin H.

TABLE 4-8

CALCULATED MASS LOADINGS OF TOTAL NITROGEN, TOTAL PHOSPHORUS, AND TSS ALONG THE MAIN CHANNEL IN ROOSEVELT CREEK SUB-BASIN H BY MONITORING EVENT

LOCATION	**TOTAL NITROGEN LOAD (kg/day)**				
	8/27/09	**9/10/09**	**9/24/09**	**10/8/09**	**Mean**
H-2	2.11	1.31	3.14	1.91	2.12
H-4	37.1	1.58	1.73	1.50	10.5
H-7	63.4	9.97	4.83	6.74	21.2
H-9	117	16.8	10.8	18.4	40.7
H-13	102	14.2	12.0	15.6	36.1
H-16	104	126	46.9	74.2	87.7

LOCATION	**TOTAL PHOSPHORUS LOAD (kg/day)**				
	8/27/09	**9/10/09**	**9/24/09**	**10/8/09**	**Mean**
H-2	0.09	0.04	0.10	0.09	0.08
H-4	1.12	0.06	0.11	0.15	0.36
H-7	1.50	0.28	0.34	0.37	0.62
H-9	3.30	0.41	0.55	0.45	1.18
H-13	4.15	0.21	0.63	0.47	1.37
H-16	4.88	4.90	3.69	10.9	6.09

LOCATION	**TSS LOAD (kg/day)**				
	8/27/09	**9/10/09**	**9/24/09**	**10/8/09**	**Mean**
H-2	4.13	0.98	9.68	1.37	4.04
H-4	148	3.89	5.72	6.35	41.0
H-7	172	11.8	8.51	8.01	50.0
H-9	533	12.2	14.2	13.3	143
H-13	372	12.7	20.2	7.58	103
H-16	334	174	67.1	195	193

A similar trend is apparent for calculated loadings of total phosphorus. In general, total phosphorus loadings appear to increase with increasing distance downstream during each of the monitoring events. A substantial increase in phosphorus loading was observed during the September and October events between Ulmerton Road and the spillway structure, with only a slight increase in phosphorus loadings observed during the August 27, 2009 monitoring event. However, on an average basis, phosphorus loadings increased by a factor of approximately 4.5 between Ulmerton Road and the spillway structure.

Substantial increases in TSS loadings were observed with increasing distance downstream during each monitoring event with the exception of a slight decrease in loadings observed in the vicinity of Ulmerton Road during the October monitoring event. On an average basis, TSS loadings almost double between Ulmerton Road and the spillway structure.

A summary of calculated mass loadings of total nitrogen, total phosphorus, and TSS in tributary inflows is given on Table 4-9. Data are not included for Site H-1 since flow data were not obtained at this site, as well as Site H-11 since only one sample was collected at this site. In general, mass loadings of total nitrogen from the tributary sites appear to be relatively low in value, particularly in comparison with loadings discharging along the main channel. Overall, the sum of the measured mass loadings of total nitrogen from all tributaries combined reflects only a small portion of the observed increase in total nitrogen loadings from upstream to downstream portions of the channel. The most significant tributary loadings of total nitrogen were observed at Site H-8 which exhibited a mean mass loading approximately 5 times higher than the next closest tributary loading for total nitrogen.

Measured loadings of total phosphorus in the tributary discharges were relatively low in value in comparison with loading rates measured along the main channel. In general, the sum of the tributary phosphorus loadings for a given monitoring date reflect only a small proportion of the observed increase in loadings between the upstream and downstream monitoring sites. The most significant phosphorus loadings into the channel were observed at Site H-15 which reflect inputs from the Airco Golf Course site. Loadings introduced at this site are approximately 2 times higher than the next most significant loading into the main channel and 5-10 times higher than the remaining inflows. The elevated phosphorus loadings from the golf course area likely originate as a result of application of fertilizer and/or reclaimed wastewater for irrigation. Since established golf course operations rarely use phosphorus, the observed elevated loadings are more likely related to reclaimed wastewater irrigation.

In general, tributary inflows also contributed relatively low loadings of TSS, compared with loadings discharging along the main channel. The sum of the tributary loadings for a given monitoring date reflect only a small proportion of the observed increase in TSS between upstream and downstream portions of the main channel. The most significant inputs of TSS into the main channel occur from Site H-8 which reflects a roadway drainage system along the west side of 34th Street North, and Site H-15 which reflects inflow from the Airco Golf Course site. Mass loadings of TSS from these inflows are approximately 2-3 times higher than the next most significant inflows.

TABLE 4-9

CALCULATED MASS LOADINGS OF TOTAL NITROGEN, TOTAL PHOSPHORUS, AND TSS IN TRIBUTARY INFLOWS IN ROOSEVELT CREEK SUB-BASIN H BY MONITORING EVENT

LOCATION	TOTAL NITROGEN LOAD (kg/day)				
	8/27/09	9/10/09	9/24/09	10/8/09	Mean
H-3	1.37	0.16	1.14	0.10	0.69
H-5	1.59	1.18	0.64	0.42	0.96
H-6	0.11	0.06	0.05	0.04	0.07
H-8	11.5	3.55	1.45	3.37	4.96
H-10	0.75	0.23	0.14	0.11	0.31
H-12	0.07	0.04	0.07	0.09	0.07
H-14	0.71	0.27	0.53	--	0.50
H-15	3.35	0.51	0.20	0.08	1.04

LOCATION	TOTAL PHOSPHORUS LOAD (kg/day)				
	8/27/09	9/10/09	9/24/09	10/8/09	Mean
H-3	0.03	0.01	0.07	0.01	0.03
H-5	0.03	0.01	0.01	0.01	0.01
H-6	0.01	0.00	0.00	0.01	0.00
H-8	0.11	0.03	0.02	0.04	0.05
H-10	0.24	0.06	0.09	0.08	0.12
H-12	0.02	0.03	0.12	0.08	0.06
H-14	0.06	0.01	0.01	--	--
H-15	0.75	0.09	0.04	0.03	0.23

LOCATION	TSS LOAD (kg/day)				
	8/27/09	9/10/09	9/24/09	10/8/09	Mean
H-3	2.33	0.13	2.09	0.27	1.20
H-5	3.53	1.67	0.92	0.75	1.72
H-6	0.97	0.17	0.16	0.32	0.41
H-8	9.44	3.21	1.10	2.03	3.95
H-10	1.57	0.88	0.10	0.18	0.68
H-12	0.81	0.09	1.48	0.40	0.69
H-14	2.10	0.58	0.92	--	--
H-15	16.1	1.11	0.63	0.60	4.61

A graphical comparison of mean mass loadings of nitrogen species at tributary and main channel monitoring sites is given on Figure 4-24. In general, increases in mass loadings for all measured phosphorus species appear to increase from upstream portions of the main channel to downstream portions of the main channel. These increases occur in spite of the fact that mass loadings contributed by tributary inflows are relatively low in value. It appears obvious that significant additional loadings of nitrogen occur into the main channel from sources other than the tributary inflow sites included in the monitoring program. Since all significant inflows into the main channel were monitored, the most likely source for these additional nitrogen loadings appears to be inflow of groundwater into the channel containing elevated nitrogen concentrations. Nitrogen loadings may also enter the main channel from the pumped inflow from the Bridgeway Acres Landfill, although this inflow would only explain the observed increases in nitrogen species at Site H-4 and possibly Site H-7 and does not explain the continued increases in nitrogen loadings observed with increasing distance along the channel.

A graphical comparison of mean mass loadings of phosphorus species at tributary and main channel monitoring sites is given on Figure 4-25. Similar to the trend exhibited by nitrogen species, a steady increase in phosphorus species also appears to occur with increasing distance along the main channel. The observed increases in SRP and dissolved organic phosphorus could possibly be explained by the cumulative impacts of the tributary inflows, with the exception of the substantial increase in loadings observed between Ulmerton Road and the spillway structure. The observed increases for both of these species exceeds the additional loadings contributed by the residential pond system (Site H-14) and the Airco Golf Course (Site H-15).

The observed increases in particulate phosphorus and total phosphorus appear to far exceed inputs provided by the monitored tributaries, suggesting that significant additional sources of phosphorus are present other than the monitored tributary inflows. Although some of the increases observed at Sites H-4 and H-7 can be explained by inflow from the Bridgeway Acres Landfill pond, there are clearly additional sources impacting phosphorus characteristics along the main channel. Since all significant inflows into the channel were monitored, the most likely additional source for these phosphorus loadings is groundwater inflow containing elevated phosphorus concentrations. Changes in total phosphorus concentrations between Ulmerton Road and the spillway structure appear to closely mimic the observed changes in particulate phosphorus, suggesting that the observed increases may be related to the growth of algal biomass within the water column between the two monitoring sites as a result of the elevated nutrient levels within the main channel.

A graphical comparison of mean mass loadings of alkalinity and TSS at tributary and main channel monitoring sites is given on Figure 4-26. Substantial increases in loadings of both alkalinity and TSS occur with increasing distance along the main channel which appear to be far in excess of the additional loadings for these parameters contributed by the tributary inflows. As discussed previously, some of the observed increase between Sites H-2 and H-7 could be explained by inflow from the Bridgeway Acres Landfill pond, although substantial additional inflows appear to occur as well. Since alkalinity is a dissolved constituent, a likely source for the additional loadings is groundwater inflow containing elevated alkalinity values.

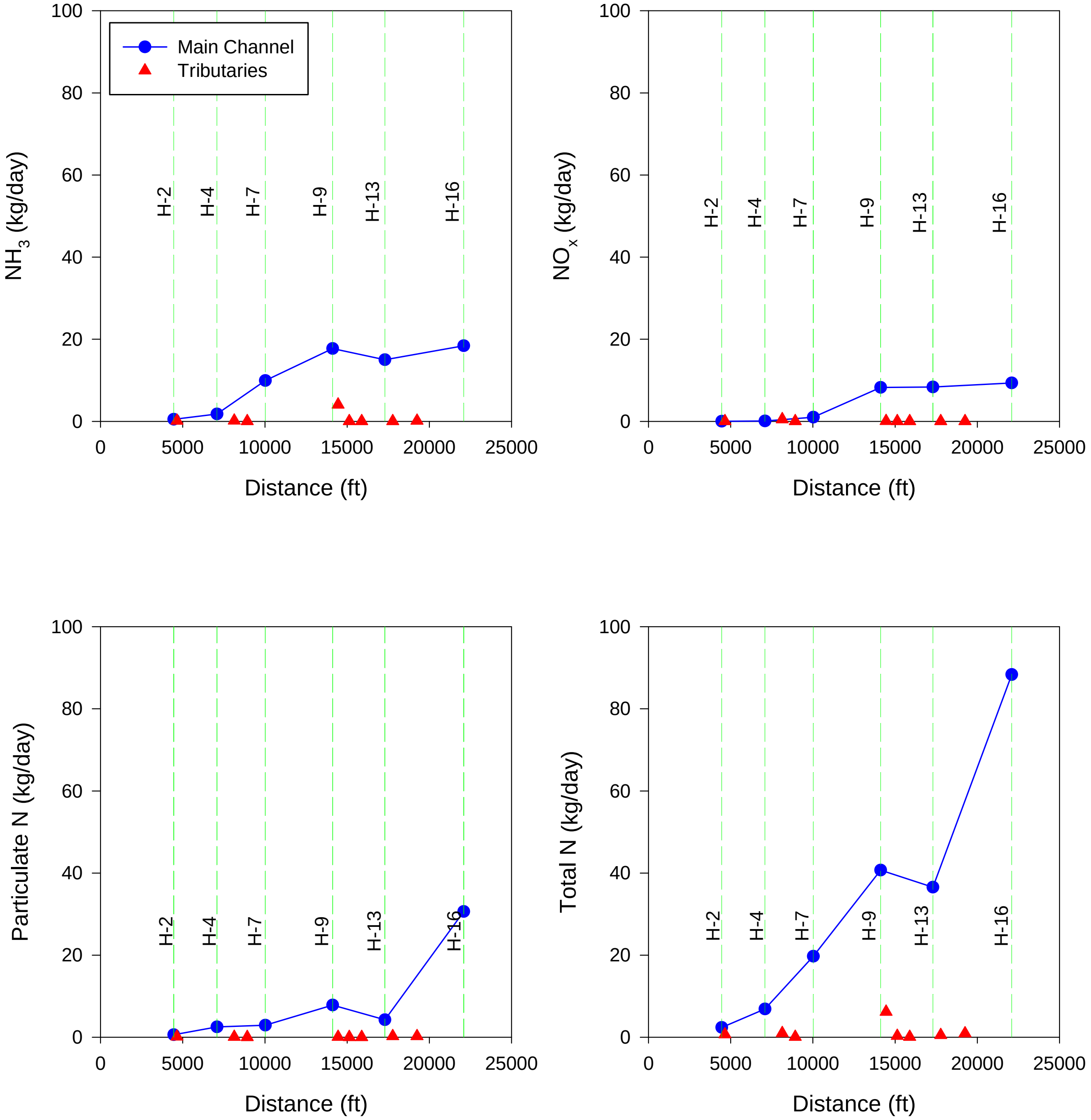


Figure 4-24. Comparison of Mean Mass Loadings of Nitrogen Species at Tributary and Main Channel Monitoring Sites.

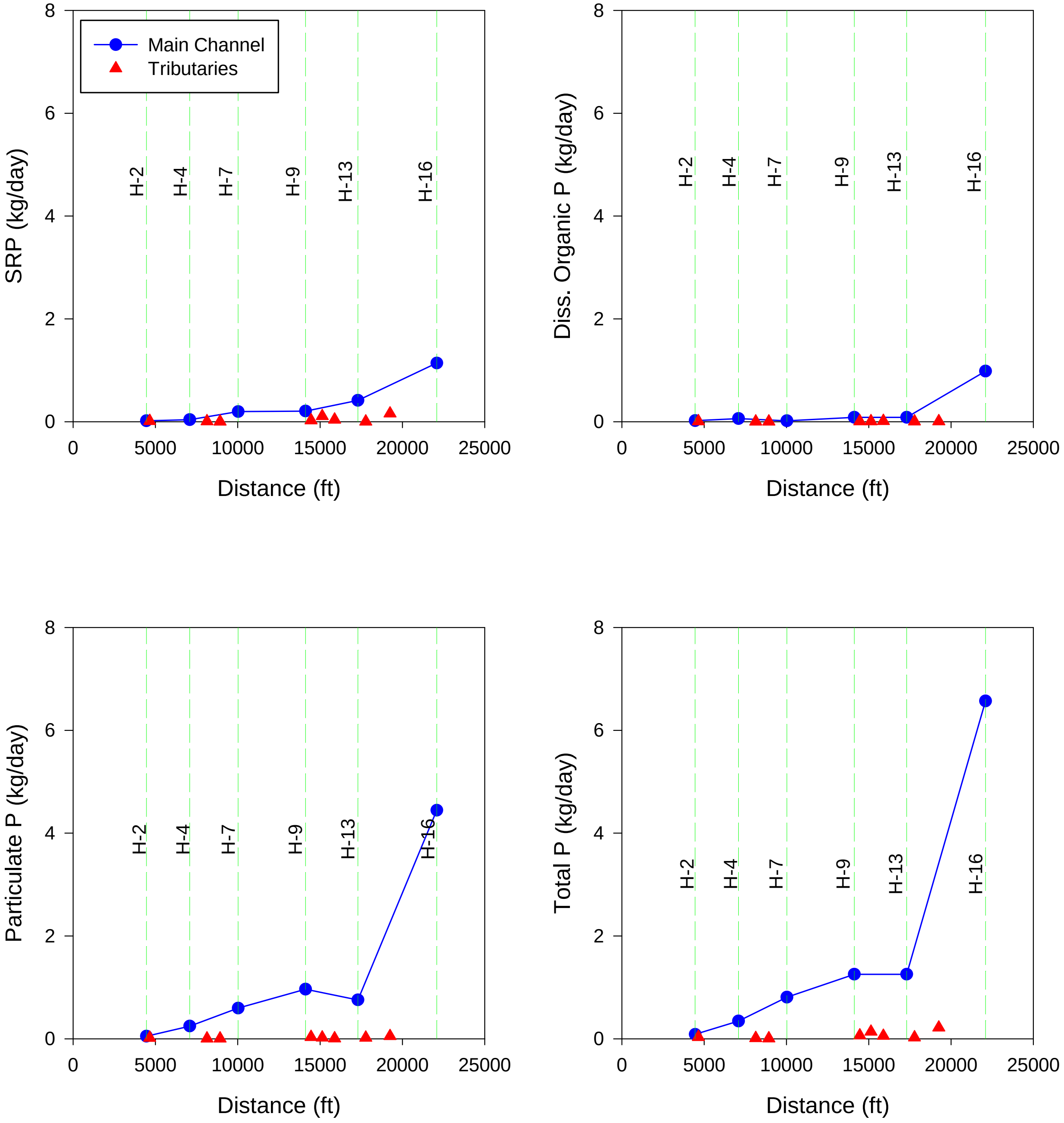


Figure 4-25. Comparison of Mean Mass Loadings of Phosphorus Species at Tributary and Main Channel Monitoring Sites.

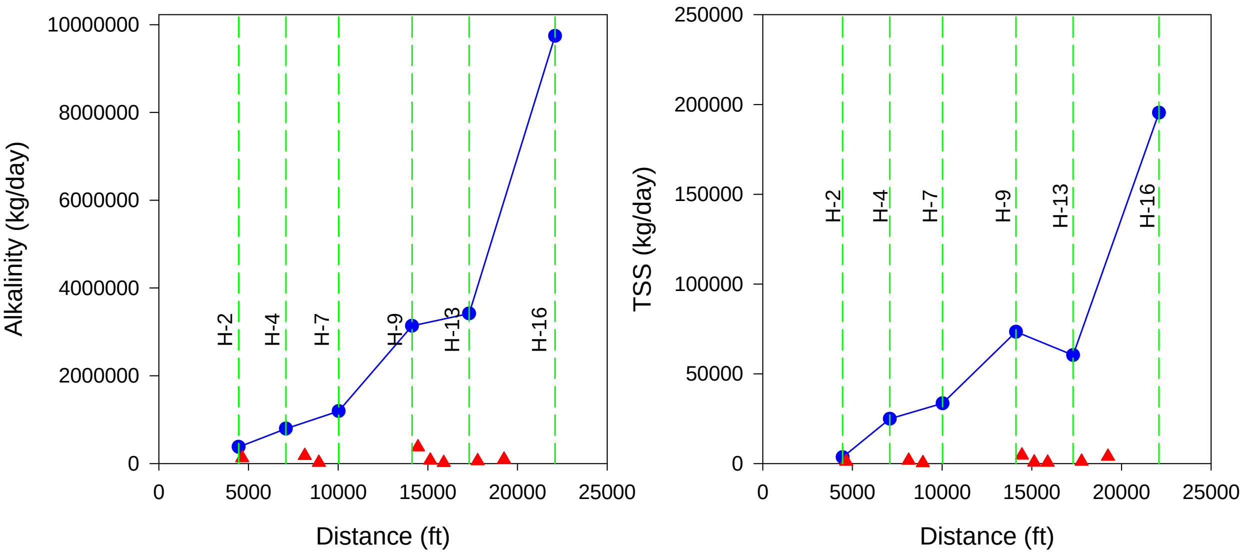


Figure 4-26. Comparison of Mean Mass Loadings of Alkalinity and TSS at Tributary and Main Channel Monitoring Sites.

Substantial increases are also observed in measured TSS concentrations with increasing distance along the channel. The same sources could potentially be impacting TSS as have been previously discussed for alkalinity, nitrogen, and phosphorus. However, since TSS would not be expected to be transported through groundwater, the observed increases in TSS are likely due to additional algal production resulting from the significant increases in nutrients along the channel. Since this would reflect TSS which was generated within the channel rather than a result of external loadings, this would explain why the TSS loading increases in spite of relatively low input loadings.

A graphical comparison of mean mass loadings of heavy metals at tributary and main channel monitoring sites is given on Figure 4-27. Significant steady increases in mass loadings were observed for each of the evaluated heavy metals with increasing distance along the main channel. The observed increases in metal loadings appear to far exceed the additional mass loadings contributed by the tributary inflows. As a result, there also appears to be a significant additional input of heavy metals which is not accounted for in the field monitoring program. The most likely additional sources for these heavy metals appear to be inflow from the Bridgeway Acres Landfill and groundwater seepage entering the main channel containing elevated metal concentrations.

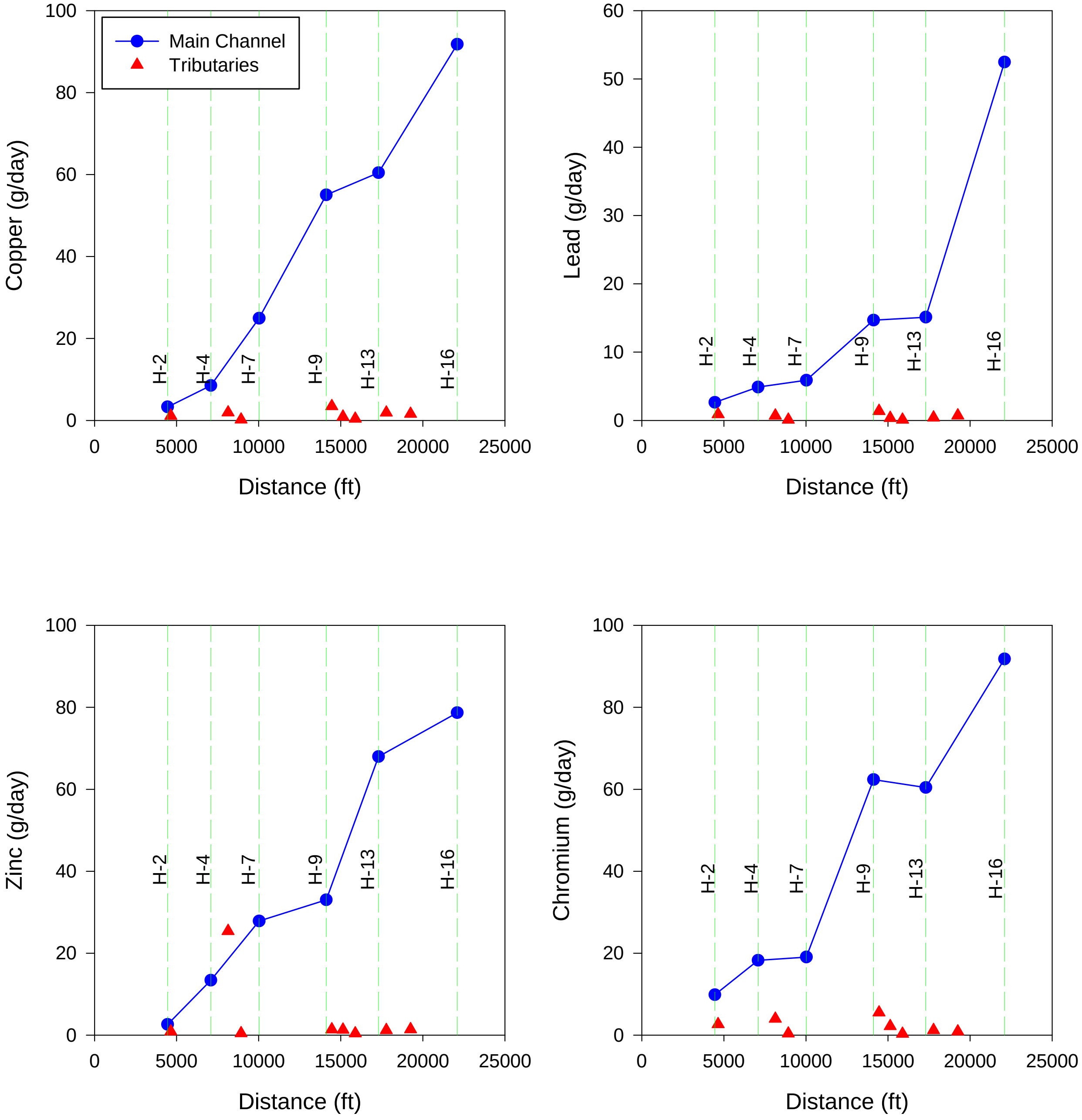


Figure 4-27. Comparison of Mean Mass Loadings of Heavy Metals at Tributary and Main Channel Monitoring Sites.

4.7 Isotope Analyses

As discussed in Section 3.4, analyses were conducted for stable isotopes of nitrogen and oxygen on tributary and main channel samples collected from Roosevelt Creek Sub-basin H during the field monitoring program. Sample analyses were conducted by the Colorado Plateau Stable Isotope Laboratory of Northern Arizona University. At the completion of the analyses, a summary report was prepared by Dr. Bruce Hungate which described the work efforts and results of the isotope analyses. A complete version of this report is given in Appendix C, and a summary of the results is given below.

The isotope methodology involves analysis of NO_x as well as stable isotopes of NO_x. A discussion of NO_x concentrations in tributary inflow and main channel samples has been previously provided based upon analyses conducted by ERD. However, a discussion of the NO_x analyses conducted by the Colorado Plateau Stable Isotope Laboratory are included below along with a discussion of isotope determinations.

4.7.1 Nitrate + Nitrite (NO_x) Concentrations

Nineteen of the samples analyzed had NO_x concentrations lower than the detection limits of the method (0.02 mg N L^{-1}) used at the Isotope Laboratory. These samples were distributed throughout the dataset. For calculation purposes, NO_x concentrations in these samples are assumed to be 0.01 mg N L^{-1}, midway between the detection limit and zero.

NO_x concentrations varied from below detection limit (0.02 mg N L^{-1}) to 3.98 mg N L^{-1}, with an average of 0.37 and a median of 0.09 mg N L^{-1}. In general, mean NO_x concentrations were similar between tributary and main channel sites. In both the main channel and tributary sites, NO_x concentrations increased over time at an average rate of 0.01555 mg N L^{-1} d^{-1} for the tributaries (r = 0.40), and 0.0116 mg N L^{-1} d^{-1} for the main channel (r = 0.33). In general, increased concentration was associated with reduced precipitation during the preceding week, suggesting that higher NO_x concentrations were associated with reduced water inputs throughout the sub-basin.

Mean NO_x concentrations in the main channel were lower at upstream Sites H-2 and H-4 compared to downstream Sites H-7, H-9, and H-13, falling again at Site H-16. Concentrations at each site varied over time. There was a tendency for higher concentrations during the later sampling dates, a trend which was only marginally significant in a multiple regression (p = 0.075).

NO_x concentrations in the tributary sites varied. Site H-15 had consistently low NO_x concentrations, either below or right at detection limits. For each of Sites H-1, H-3, H-6, H-12, and H-14, all but one sample were below 0.10 mg N L^{-1}, with higher concentrations measured for each site on only one sampling date, though the particular date with higher concentrations was not consistent across sites. Sites H-5, H-8, and H-10 had higher (and more consistently high) NO_x concentrations compared to the other sites. Sites H-17 and H-18 had intermediate NO_x concentrations. In general, NO_x concentrations in the tributary sites increased over time.

4.7.2 Analysis of δ^{15}N and δ^{18}O of Nitrate + Nitrite (NO_x)

All samples had sufficient NO_x for isotope determination, even those below the detection limits for colorimetric determination of NO_x concentrations, consistent with NO_x of at least 0.005 mg N L^{-1}. On average, δ^{15}N and δ^{18}O values of NO_x were low to intermediate. Across all sites and times, δ^{15}N averaged 2.3 (± 0.7) ‰, and δ^{18}O averaged 4.2 (± 1.6) ‰. Values of δ^{15}N ranged from -18.5 to 13.8‰, and δ^{18}O values ranged from -19.6 to 62.6‰. In the main channel sites, δ^{15}N-NO_x increased downstream and over time, and δ^{18}O-NO_x declined downstream and through time, both patterns revealed by multiple regression. δ^{15}N and δ^{18}O signatures were not systematically related to NO_x concentrations. These patterns suggest temporal and spatial changes in the sources of NO_x in the watershed. In the tributary sites, δ^{18}O-NO_x decreased over time, the same pattern found in the main stem, but no systematic temporal pattern emerged for δ^{15}N-NO_x, nor any spatial trend for either isotope.

During the initial sampling date, some sites had unusually high δ^{18}O signatures (above 17 per mil and as high as 62.6 per mil), including Sites H-2, H-4, H-6, H-8, H-9, H-10, H-11, H-12, and H-14. Such high δ^{18}O signatures, and the broad distribution of the signature across the watershed, are consistent with NO_x in atmospheric deposition, including precipitation. NO_x concentrations in these samples ranged from below detection limits (Site H-2) to 0.37 mg N L^{-1} (Site H-8), the higher concentrations indicating the potential for atmospheric deposition to be an appreciable source of NO_x to the watershed during some periods of time.

δ^{15}N-NO_x and δ^{18}O-NO_x signatures from both tributary and main stem sites were primarily consistent with manure, sewage, and in-situ nitrification of soil nitrogen as major sources of NO_x. Some δ^{15}N- δ^{18}O pairs from tributary sites were unusually low, but these typically had quite low NO_x concentrations as well, and thus are likely unimportant sources of NO_x to the watershed.

4.7.3 Evidence for in-situ Denitrification

Two lines of evidence could support in-situ denitrification as a major pathway of NO_3^- removal, and thus as a confounding signal for interpreting isotopes in source partitioning. One sign of denitrification is a negative slope for the relationship between [NO_3^-] and δ^{15}N-NO_3^-, reflecting preferential removal of NO_3^- through denitrification. Another sign is a positive relationship between δ^{15}N and δ^{18}O with a characteristic slope (from 1.3 to 2.1), reflecting the greater fractionation against ^{18}O because of the larger mass difference between ^{18}O and ^{16}O compared to ^{15}N and ^{14}N. Neither analysis provided any evidence that denitrification influenced the δ^{15}N and δ^{18}O values of NO_x in the Roosevelt Creek system. Whether analyzed over the entire dataset (combining sites and times), or by individual site, or by sample date, significant relationships between δ^{15}N and [NO_x] or between δ^{15}N and δ^{18}O were rare. Even when they occurred, the nature of the relationship was inconsistent with denitrification. For example, at Site H-15, the relationship between δ^{15}N and [NO_x] was strong but positive, opposite of the direction expected for denitrification. For Site H-7, δ^{15}N and δ^{18}O were correlated, but the correlation was negative, again opposite the expectation for denitrification. Furthermore, strong correlations were rare, suggesting that denitrification, to the extent it occurred, had only a minor influence on [NO_x] concentrations and isotopic signatures throughout the Roosevelt Creek system. The absence of a strong denitrification signal supports direct interpretation of the δ^{15}N and δ^{18}O values in source identification.

4.7.4 Conclusions: Source Identification

The measured $\delta^{15}N$ and $\delta^{18}O$ values are primarily consistent with manure, sewage, and wastewater inputs, all of which have similar isotopic signatures, as sources of NO_x in Roosevelt Creek. In-situ nitrification of soil organic matter cannot be ruled out, but is less likely, as measured signatures of $\delta^{15}N$ and $\delta^{18}O$ were less frequently consistent with a putative soil source than with manure, sewage and wastewater. There was also strong evidence in elevated $\delta^{18}O$ signatures for atmospheric inputs on the earliest sample date.

4.8 Summary

Field monitoring, sample collection, and laboratory analyses were conducted by ERD from August-October 2009 to evaluate the characteristics of discharges through Roosevelt Creek Sub-basin H. Rainfall during the field monitoring program was approximately normal, although more than 60% of the total rainfall occurred during a single month.

Discharge rates through the main channel increased steadily with increasing distance downstream during each of the field monitoring events. However, the observed increases in discharges rates exceed the additional inflows contributed by the monitored tributary inflows, suggesting that additional inputs occur into the main channel other than the monitored tributary inflow sites.

Steady increases in measured concentrations were observed for virtually all measured parameters with increasing distance along the channel. Increases in concentrations for many parameters appear to peak in the vicinity of Ulmerton Road, with a decrease in concentrations between Ulmerton Road and the outfall structure. The observed increases in concentrations along the main channel appear to be in excess of concentration increases caused by tributary inflows.

The highest concentrations of nitrogen species in tributary inflows were observed at monitoring Site H-8 which consists of a roadside drainage swale system located on the west side of 34th Street North. This site contained extremely elevated levels of both ammonia and dissolved organic nitrogen, suggesting a fertilizer source as the origin of the elevated nitrogen concentrations. The most elevated total phosphorus concentrations in tributary inflows were observed at monitoring Sites H-10 and H-12, both of which reflect roadside drainage along Ulmerton Road, as well as Site H-15 which reflects discharge from the Airco Golf Course.

Substantial increases in mass loadings of nitrogen and phosphorus species, along with TSS and alkalinity, were observed with increasing distance along the main channel. The observed increases in loadings far exceed the additional loadings contributed by tributary inflows into the main channel. These data suggest that significant additional sources of nutrient loadings occur into the main channel which are not contributed by tributary inflows. Likely sources for these additional loadings include pumped discharges from the Bridgeway Acres Landfill pond and groundwater seepage into the canal containing elevated nutrient levels. The increases in mass loadings are primarily a function of increasing discharge rates along the channel rather than continuing increases in nutrient concentrations since nutrient concentrations either remain constant or decrease slightly between Ulmerton Road and the spillway structure.

Increases in TSS along the main channel, particularly between Ulmerton Road and the spillway structure, appear to be explained primarily by growth of algal biomass resulting from the elevated nutrient concentrations. Steady increases in mass loadings of heavy metals were also observed with increasing distance along the main channel. Similar to the trend observed for nutrients, the observed increases in heavy metal loadings far exceed the additional inputs from tributary inflows, suggesting significant additional sources of metal inputs into the main channel other than from tributary inflows.

Isotope analyses conducted on samples collected from both tributary and main channel sites indicate that the isotope signatures are consistent with manure, sewage, and in-situ nitrification of soil nitrogen as major sources of NO_x. Isotopic signatures also suggest that atmospheric deposition may be a significant contributor of NO_x in samples collected early during the monitoring program.

SECTION 5

NUTRIENT MANAGEMENT RECOMMENDATIONS

As discussed in Section 4, substantial increases in mass loadings of both nitrogen and phosphorus, as well as heavy metals, was observed from upstream to downstream portions of Channel 5 in Roosevelt Creek Sub-basin H. The observed increases in nutrient loadings are a result of several factors, primarily increases in water volume and discharge rates along Channel 5, combined with elevated loadings of both nitrogen and phosphorus originating from monitoring Site H-8 (reflecting inflow from the swale drainage system along 34th Street North) and discharges from the Airco Golf Course into the main channel. A discussion of potential management recommendations for each of these sources is given in the following sections. Substantially elevated concentrations of total phosphorus were also observed in discharges into the main channel from monitoring Sites H-10 and H-12, although the volumetric inputs for these sites were low in value, resulting in a low mass loading from these basins.

5.1 Volumetric Inputs into the Main Channel

As discussed in Section 4.2, volumetric discharge measurements increase steadily with increasing distance along the main channel. The observed increases in discharge appear to be greater than the sum of volumetric inputs contributed by the tributary inflows between the various monitoring sites along the main channel. A relatively significant increase in discharge rates was observed along the main channel between Ulmerton Road and the salinity barrier/spillway structure which far exceeds the measured inputs from the known tributary inflows.

The most likely explanation for the observed increases in discharge rates along the main channel is influx of groundwater seepage from areas adjacent to the canal. Many portions of the main channel have been cut well below the level of the existing land surface, and the resulting water levels within the canal are substantially lower than the anticipated groundwater table elevations within the watershed based upon soil types and proximity to Old Tampa Bay. It appears that large amounts of groundwater are seeping into the main channel and causing the observed increases in discharge with increasing distance downstream.

However, a complicating factor in this assumption is the conclusion reached by Dr. Bruce Hungate as a result of the isotope analyses conducted on tributary and main channel samples. Dr. Hungate concluded that the isotopic signatures of NO_x in both tributary and main channel samples are primarily consistent with manure, sewage, and wastewater inputs as sources of NO_x in the Roosevelt Creek basin. There was also strong evidence in the evaluated $\delta^{18}O$ signatures for significant atmospheric inputs of NO_x during the earliest sampling date. This conclusion is consistent with the elevated rainfall patterns which occurred during early parts of the field monitoring program. However, the conclusion that NO_x concentrations in all parts of the watershed over all dates are consistent with manure, sewage, or wastewater inputs cannot be explained since all areas within the watershed are currently served by a centralized sewer system, and reuse water is only applied in extreme southern and northern portions of the basin on a relatively limited basis.

The steady observed increases in discharge rates through the basin, combined with the apparent wastewater signature prevalent throughout the sub-basin area, suggest that the two processes may somehow be related, and the observed additional increases in volume recorded along the channel may somehow be related to a wastewater source of some kind. It is very interesting that a wastewater signature is prevalent throughout the basin when known wastewater sources are extremely limited. For this to occur, groundwater with a wastewater signature would need to be seeping or upwelling throughout the basin area. However, evaluation of this potential phenomenon is well beyond the Scope of Services for this project. Further evaluation of potential linkage between the observed water volume increases and the wastewater signature appears warranted.

5.2 Sub-basin H-8 Inflow

As discussed in Section 4, inflow from Sub-basin H-8 is characterized by total nitrogen concentrations approximately 3-5 times higher than observed at any of the other tributary monitoring sites and contributes nitrogen mass loadings approximately 5 times higher than the next closest tributary loading. This site also contributes the second highest mass loadings of TSS for all of the evaluated tributary sites.

An overview of drainage patterns in basin areas for Site H-8 is given on Figure 5-1. Inflows at monitoring Site H-8 originate from a relatively large area, consisting primarily of industrial and commercial activities. Drainage for this tributary inflow originates at the intersection of 34th Street North and 118th Avenue North, immediately north of the Bridgeway Acres Landfill. Drainage in many of the industrial and commercial areas travels in either an east-to-west or west-to-east direction until reaching the swale drainage system located along the eastern and western sides of 34th Street North. Several interconnections which convey the eastern swale system into the western swale system, and ultimately into the main channel, are located immediately south of the point of inflow for the tributary into the main channel.

An overview of land activities in the northern portion of Site H-8 tributary drainage basin area is given on Figure 5-2. Northern portions of the tributary basin include a variety of land use types, including a landscape nursery, several industrial sites, as well as small and large office complexes. Many of the industrial activities contain large expanses of bare earth which are capable of discharging elevated nutrient concentrations as well as suspended solids into the Site H-8 tributary system. However, the most likely source for the elevated nutrient concentrations observed at Site H-8 is the landscape nursery which is located southwest of the intersection of the H-8 tributary and the main channel. The elevated nitrogen concentrations observed at Site H-8 were primarily contributed by elevated levels of ammonia and dissolved organic nitrogen, both of which are consistent with a fertilizer source for the elevated nitrogen concentrations. Although the data do not confirm that the elevated nitrogen concentrations originated from the landscape nursery area, the nursery appears to be a likely candidate and deserves further on-site review by Pinellas County.

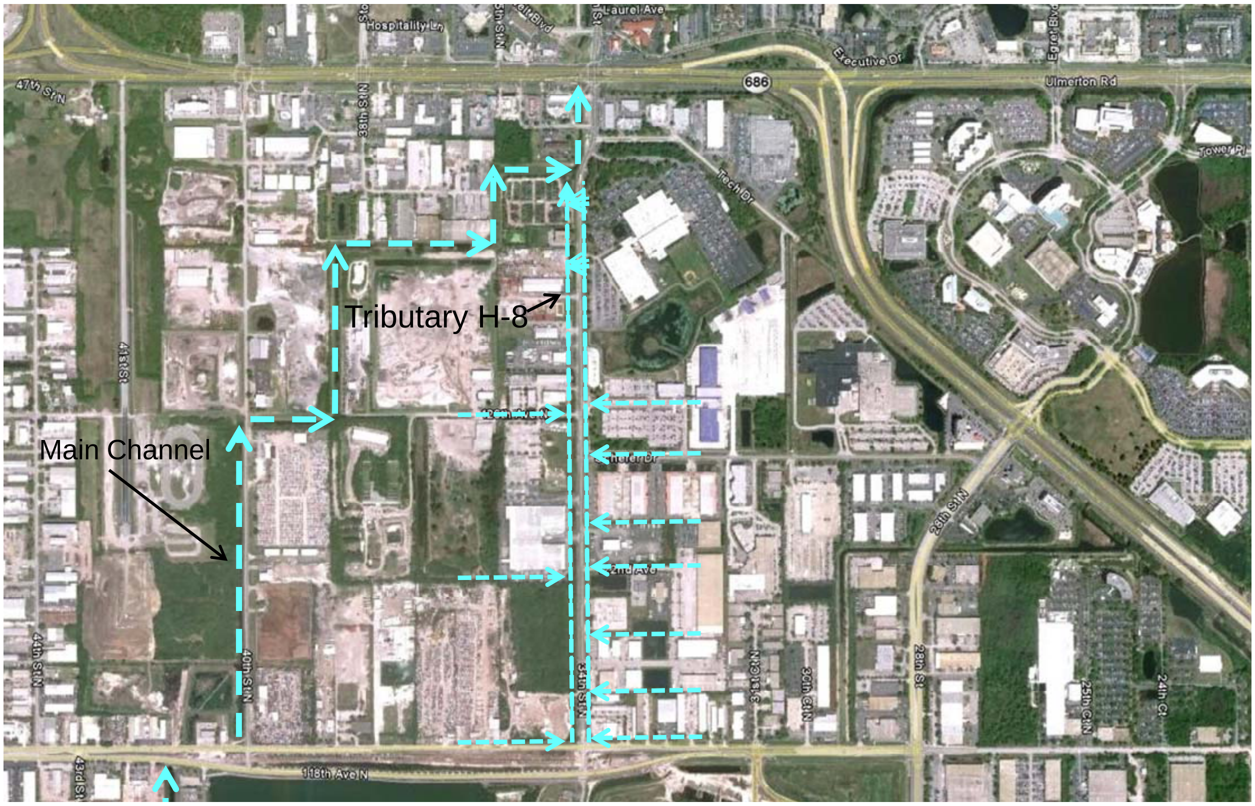


Figure 5-1. Drainage Patterns in Basin Areas for Site H-8

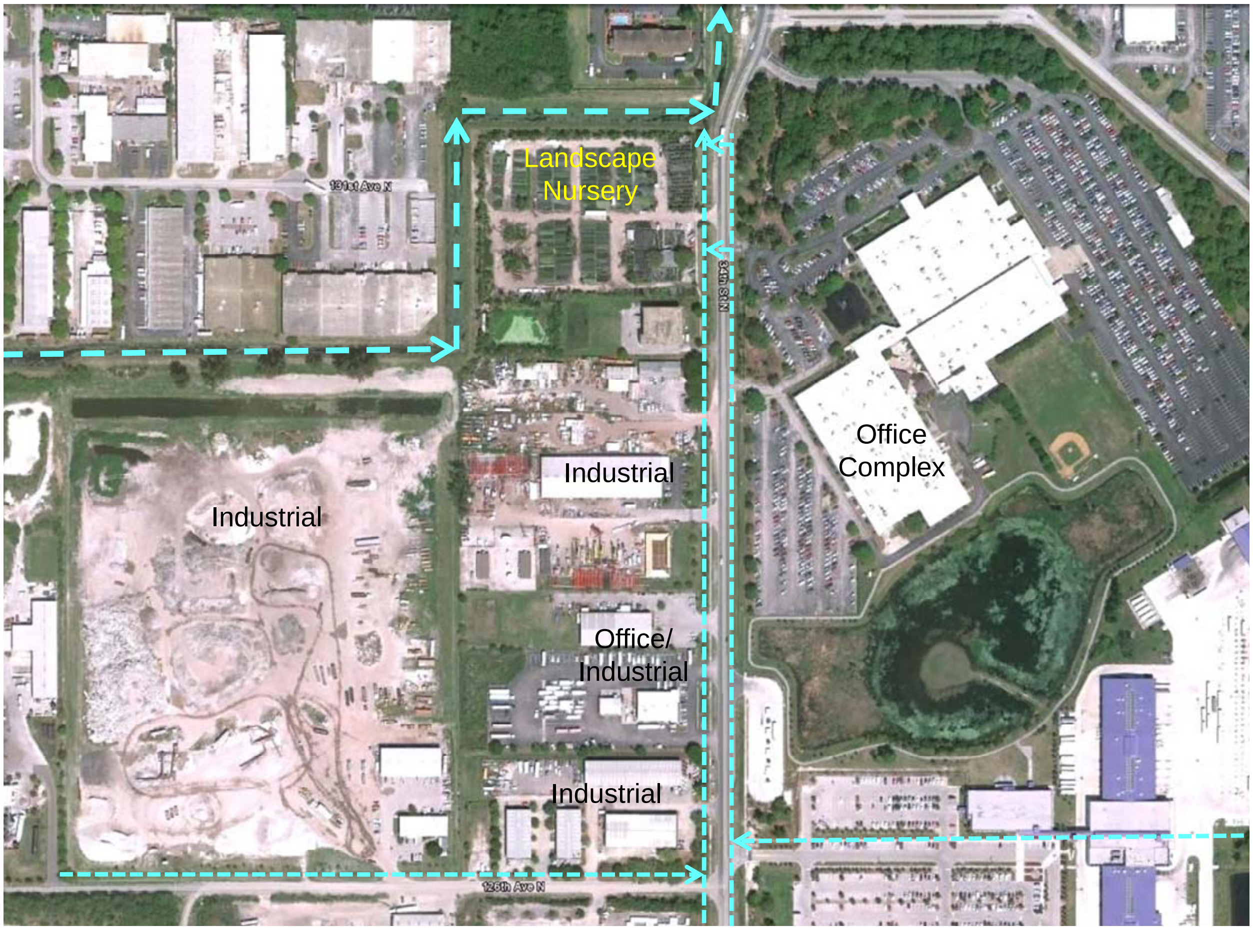


Figure 5-2. Overview of Land Activities in Northern Portions of the Site H-8 Tributary.

Although the observed nitrogen characteristics in the Site H-8 tributary are consistent with a fertilizer source, inputs from the industrial activities cannot be ruled out as a significant contributor to pollutant loadings within the basin. Even if these industrial areas do not contribute significant quantities of nutrients, the large expanses of bare earth suggest an obvious TSS source from these activities.

An overview of land activities in central portions of the Site H-8 tributary system is given on Figure 5-3. Land use within this portion of the drainage basin consists primarily of industrial activities on the west side of 34th Street North, and office complexes and parking areas on the east side. Many of the existing office complexes and parking areas appear to have stormwater management systems which should reduce pollutant loadings from these areas.

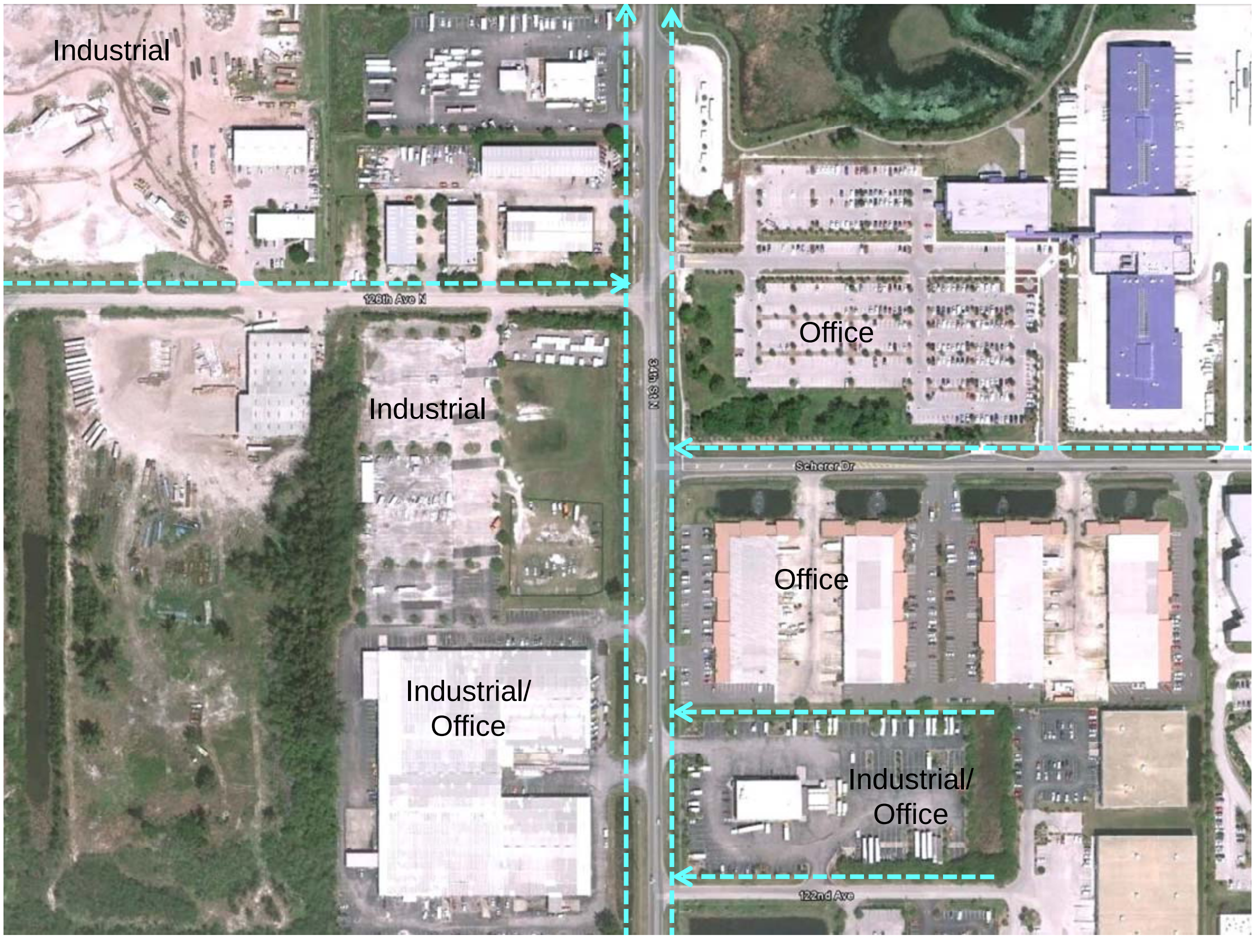


Figure 5-3. Overview of Land Activities in Central Portions of the Site H-8 Tributary.

An overview of land activities in southern portions of the Site H-8 tributary basin is given on Figure 5-4. Land use in this portion of the basin consists primarily of industrial activities, as well as a large wetland system, west of 34th Street North, with a combination of industrial, office and commercial activities on the east side of the roadway. Stormwater management facilities are scattered throughout the office and commercial areas on the east side of 34th Street North. However, aerial photographs of these areas suggest that many of the stormwater ponds appear to be highly enriched with nutrients, as indicated by visible algal growth in the overhead photos, and these areas may also be contributing additional nutrient loadings into the tributary system.

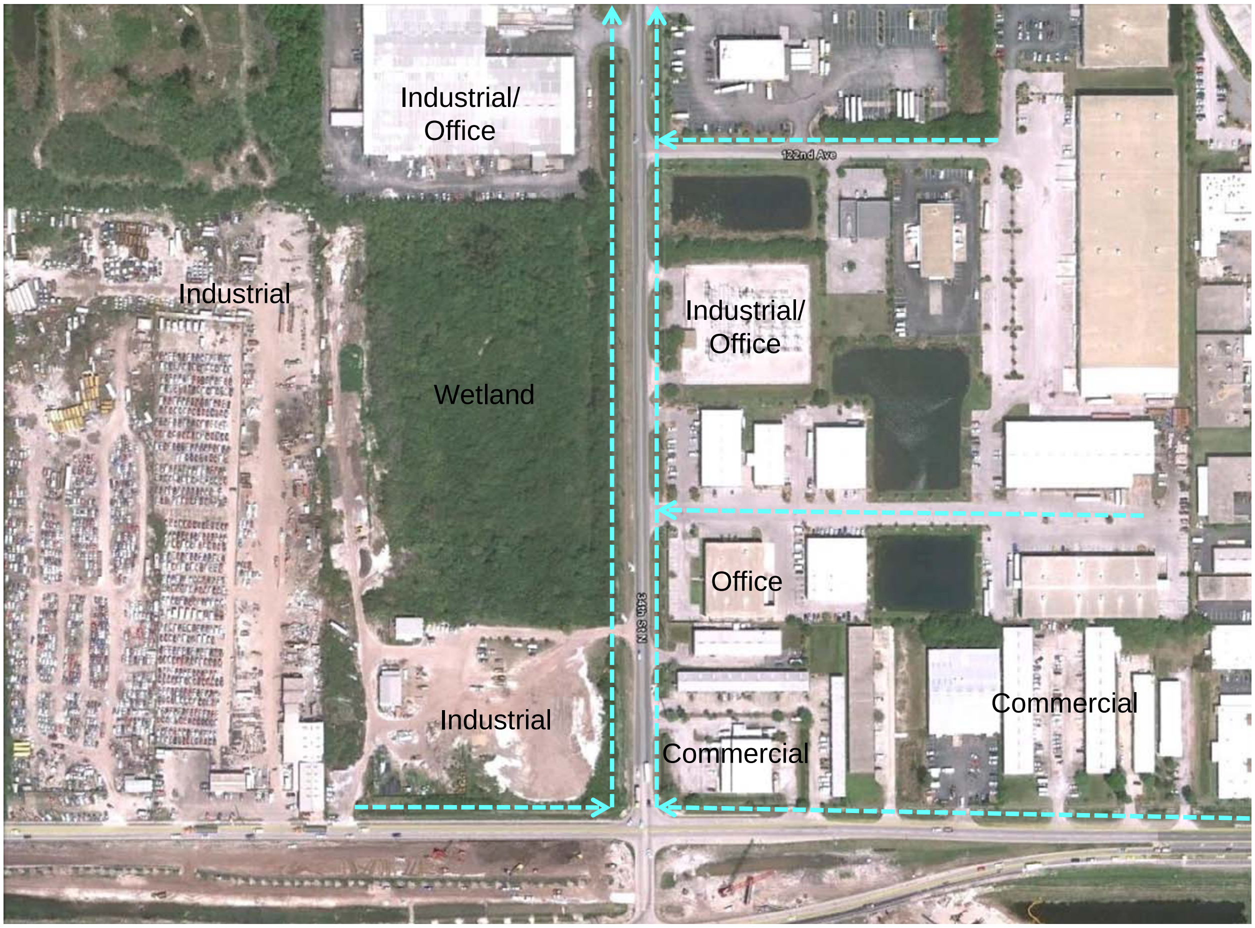


Figure 5-4. Overview of Land Activities in Southern Portions of the Site H-8 Tributary.

ERD recommends that additional evaluations be conducted to further constrain the potential sources of nutrients within the Site H-8 tributary system. Although the most obvious source appears to be the landscape nursery located in northern portions of the tributary area, nutrient enrichment cannot be ruled out for areas in southern portions of the basin as well.

5.3 Sub-basin H-15 Inflow

Drainage entering the main channel from monitoring Site H-15 originates primarily from the Airco Golf Course area. Phosphorus concentrations measured at this site were more than twice as high as phosphorus concentrations measured at any of the monitoring sites along the main channel and 2-10 times higher than phosphorus concentrations measured at a majority of the remaining tributary inflow sites. The only sites which exhibited higher total phosphorus concentrations during the field monitoring program were Site H-10 (which reflects drainage from roadway and commercial areas along the south side of Ulmerton Road) and Site H-12 (which reflects discharges into the main channel from Old Roosevelt Blvd.). Monitoring Site H-12 may also reflect impacts from the Airco Golf Course site since a significant portion of the drainage system reflected at this site borders along the southwest side of the golf course. However, even though these sites exhibit elevated total phosphorus concentrations, the volumetric discharges from these sites were low in value, resulting in a relatively low phosphorus loadings from these sources. The phosphorus loading contributed at monitoring Site H-15 is approximately twice the phosphorus loading observed at Site H-10 and four times the phosphorus loading observed at Site H-12. Discharges at Site H-15 also constitute the largest mass loading of TSS into the main channel for all of the evaluated tributary inflows.

An overview of drainage patterns in the vicinity of the tributary inflow at Site H-15 from the Airco Golf Course is given on Figure 5-5. Discharges at the H-15 monitoring site originate from the wet detention pond located west of Airport Perimeter Road. The golf course area is currently irrigated by reuse water provided by the City of Largo Wastewater Treatment Plant which is used to irrigate approximately 128 acres of golf course area.

Figure 5-5. Drainage Patterns in the Vicinity of Tributary Inflow from the Airco Golf Course.

Perhaps the easiest method for reducing nutrient loadings from the golf course site into the main channel is to reduce the volumetric discharges from the golf course site. During the field monitoring program, the mean discharge monitored at Site H-15 was approximately 0.27 cfs. If this discharge were to remain relatively constant over an annual cycle, the total discharge from the golf course property into the main channel would be approximately 195 ac-ft or approximately 18 inches over the entire irrigated area of the golf course. This discharge is equivalent to approximately 0.35 inches/week over the irrigated area, reflecting approximately one-third to one-half of the irrigation requirements for the golf course turf grasses. Therefore, a simple method of reducing loadings discharging from the golf course site is to utilize on-site waterbodies as the initial source of irrigation water, with reuse irrigation used only to supplement available on-site water. This manipulation could be managed to substantially reduce or perhaps eliminate the volume of discharges from the Airco Golf Course property which would result in a corresponding reduction in mass loadings discharging into the main canal.

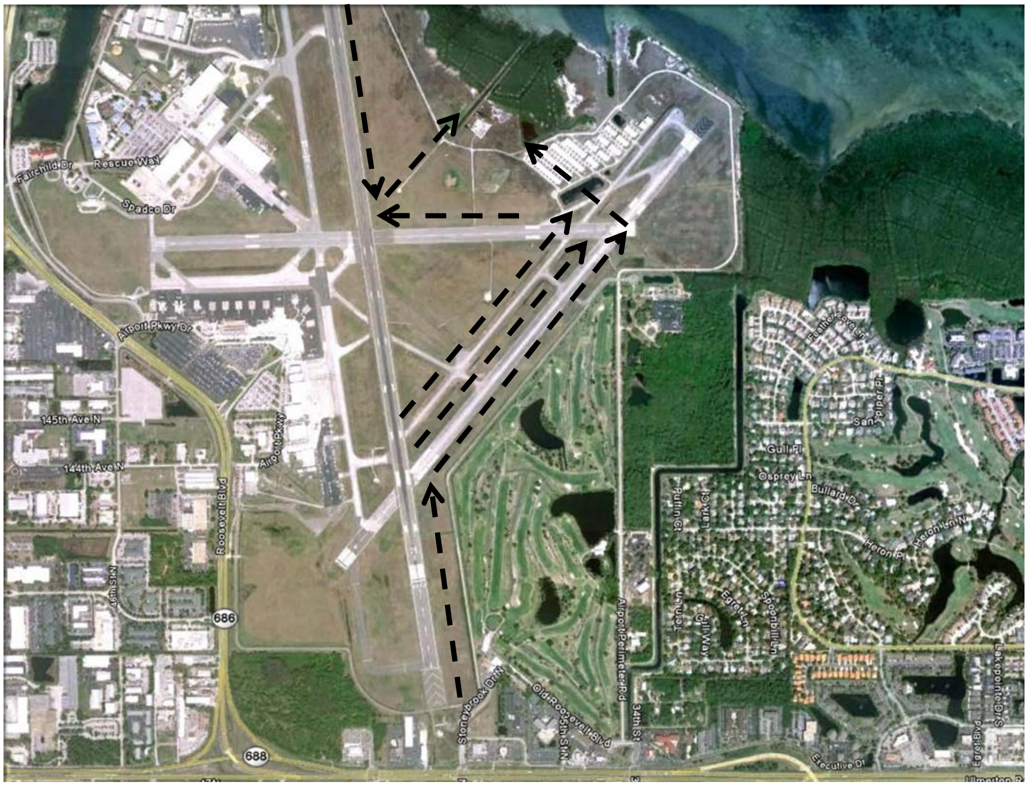
The proposed hydrologic manipulation of the irrigation system would require installation of a supplemental pump since irrigation water is now applied directly from the force main system. The pump would initially provide irrigation from on-site waterbodies until a pre-set water level was reached. At that time, the pump would shut off and an automatic valve would open, allowing irrigation from the reclaimed water source. The analyses conducted during this study suggests that reuse irrigation could be safely cut by approximately one-third to one-half without impacting the necessary volume of irrigation required by the golf course. This technique would minimize discharge of elevated nutrients into the main channel and contain virtually all of the nutrient loadings from the golf course on-site.

The golf course area also shares an extensive common border with the St. Petersburg/ Clearwater International Airport property. Further reductions in total loadings to Old Tampa Bay could be achieved by redirecting runoff from portions of the airport property into the adjacent pond system for the Airco Golf Course. This redirected drainage would then be available for use as irrigation water, further reducing the requirements for reuse irrigation as well as reducing direct discharges from the airport property into Old Tampa Bay. Since the airport property is drained primarily by vegetated swale systems, this drainage modification could be achieved relatively inexpensively using simple grading techniques. This relatively simple modification, combined with the proposed irrigation system from the on-site ponds, could achieve a substantial reduction in nutrient loadings to Old Tampa Bay.

A comparison of current and proposed drainage patterns at the St. Petersburg/Clearwater International Airport property is given on Figure 5-6. Under existing conditions, drainage generated within the airport site discharges through a series of shallow vegetated swales, ultimately discharging through two primary outfalls into Old Tampa Bay. The proposed re-grading modifications would redirect the swale drainage to a control structure which would discharge into the lake system associated with the Airco Golf Course site. The additional runoff inflow would then be used for irrigation purposes.

Another potential opportunity for reducing off-site nutrient discharges from the golf course area is to increase the opportunity for nutrient retention on-site. Since all surface runoff is ultimately directed to on-site storage ponds, one of the best opportunities for nutrient reduction is to increase the uptake capacity of the on-site waterbodies. Under current conditions, waterbodies within the golf course area contain little littoral zone vegetation, with most of the ponds maintained in a weed-free condition through spraying and other maintenance activities. Littoral zone vegetation provides a diverse habitat which can support organisms that can be responsible for improving water quality in lakes.

Therefore, it is recommended that littoral zone vegetation be established within each of the on-site golf course ponds to the maximum water depth allowed by the selected vegetation. Although littoral zone plants have limited nutrient uptake capacity themselves, these areas will provide a diversity of aquatic habitats which are important in maintaining water quality. The use of herbicides of any kind, including both copper sulfate and organic compounds, should be discontinued within on-site waterbodies since herbicides kill aquatic plants as well as algae which are significant uptake mechanisms for nutrients in waterbodies. These activities will maximize the uptake potential of the on-site ponds and assist in reducing off-site discharges.



a. Current Conditions

b. Proposed Conditions

Figure 5-6. Current and Proposed Drainage Patterns at the St. Petersburg/Clearwater Airport Property.

5.4 Wetland Treatment Systems

Another potential treatment option for reducing nutrient concentrations in loadings discharging through Roosevelt Creek is a wetland treatment system. Pinellas County currently owns two parcels, consisting primarily of wetlands and open waterbodies, on the west side of Roosevelt Creek in the vicinity of the spillway/outfall structure on the downstream end of the creek. An overview of the County-owned lands in downstream portions of Roosevelt Creek is given on Figure 5-7.

As indicated on Figure 5-7, the County-owned lands include the canal itself as well as maintenance easements on both sides of the canal. Of the combined parcel area of 56.38 acres, approximately 46.18 acres of the parcel are located west of Roosevelt Creek and east of Evergreen Avenue. An additional 2.1 acres of the County-owned land is contained within the 35-ft wide maintenance berm along the west side of the canal, and approximately 3.56 acres of the County-owned parcels are open waterbodies, leaving 40.52 acres of wetland area.

According to Pinellas County, significant cultural and archeological resources currently exist on the County-owned parcels which must not be impacted by any implemented surface water treatment system. These archeological resources cover approximately 12 acres of the remaining area, leaving approximately 28.5 acres available for incorporation into a wetland treatment system.

Based upon long-term water elevation data collected by USGS at the spillway/salinity structure, water elevations within the Roosevelt Creek canal range from approximately 3.5-4.5 ft (NGVD) or approximately 2.6-3.6 ft NAVD, assuming a correction factor of 0.86 ft between the two datums. Information provided by Pinellas County indicates that land surface elevations within the two County parcels range from approximately 4-5.5 ft NAVD, approximately 1.5-2 ft higher than water elevations within the canal. As a result, water would have to be pumped from the canal into any proposed wetland treatment system. This would require a significant pumping station to accommodate even a relatively modest inflow rate of 10 cfs. Conversion of portions of the wetland into a treatment system would require construction of berms in many portions of the wetland to isolate the significant historical and archeological areas and to contain the water within the desired flow path. Elevated areas within the wetlands may need to be scraped down to allow the inflow to spread throughout the available wetland area. Assuming that approximately 1.5 acres of the site would be consumed by berms, the available wetland area for a treatment system would be approximately 27 acres.

For evaluation purposes, a constant inflow into the proposed system of 10 cfs is assumed which is approximately equal to the median canal discharge over the period from 2005-2009 measured at the adjacent spillway structure. It is also assumed that a water elevation increase of approximately 0.5 ft can be tolerated without alteration of existing wetland communities. As a result, the available detention volume within the wetland would be approximately 13.5 ac-ft (27 acres x 0.5 ft deep). A constant inflow of 10 cfs into this system would correspond to a detention time of approximately 16 hours. In general, wetland treatment systems are typically designed for detention periods ranging from approximately 2-3 days to achieve optimum removal efficiencies. The estimated detention time of approximately 16 hours would be substantially lower than normally proposed for wetland treatment systems, resulting in a lower removal efficiency.

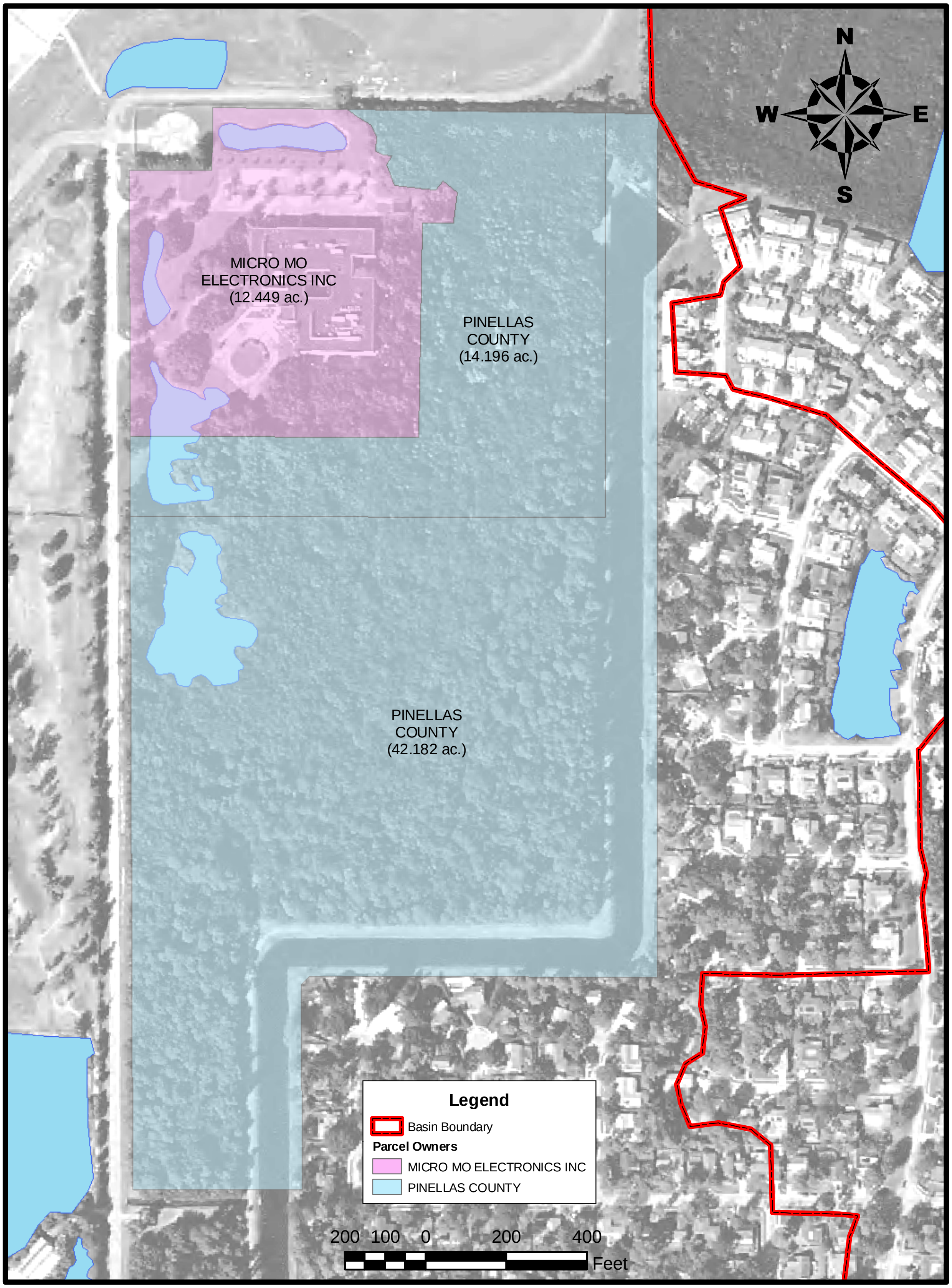


Figure 5-7. County-Owned Lands in Downstream Portions of Roosevelt Creek.

A proposed wetland treatment system would require a pumped inflow at the south end of the County-owned parcel, near the discharge canal from the Airco Golf Course into Roosevelt Creek. The pumped canal water would then flow north, migrating through the available wetland areas, ultimately discharging back into the canal at a location upstream from the spillway/salinity barrier structure. Significant additional expense would be incurred to construct the berm structures throughout the property to isolate and protect the archeological and historical areas.

A summary of treatment calculations for a proposed wetland treatment system based on an inflow rate of 10 cfs is given on Table 5-1. This table includes a probability distribution of mean daily discharge rates measured at the spillway structure over the period from 2005-2009. Estimates are also provided of the total volume discharged through the canal as well as the volume which would be diverted into a wetland treatment system based upon a diversion flow of 10 cfs. Based upon this analysis, a constant inflow rate of 10 cfs would provide treatment for approximately 57.7% of the annual discharge through Roosevelt Creek. As a result, only slightly more than half of the canal discharge would be diverted into a potential wetland treatment system.

TABLE 5-1

SUMMARY OF TREATMENT CALCULATIONS FOR THE PROPOSED WETLAND TREATMENT SYSTEM BASED ON AN INFLOW RATE OF 10 cfs

(Data for 2005-2009 @ USGS Site 2308865)

MEAN DAILY DISCHARGE RANGE (cfs)	NUMBER OF EVENTS	AVERAGE DISCHARGE (cfs)	TOTAL VOLUME (ac-ft)	TREATED DISCHARGE (cfs)	VOLUME TREATED (ac-ft)	PERCENT TREATED (%)
0-0.25	178	0.06	21	0.06	21	100.0
0.25-0.5	97	0.37	71	0.37	71	100.0
0.5-1.0	182	0.71	257	0.71	257	100.0
1-2	263	1.47	768	1.47	768	100.0
2-5	502	3.12	3107	3.12	3107	100.0
5-10	278	7.14	3938	7.14	3938	100.0
10-15	119	11.86	2799	10.00	2360	84.3
15-20	57	16.91	1912	10.00	1131	59.1
20-25	49	21.84	2122	10.00	972	45.8
25-30	22	27.27	1190	10.00	436	36.7
30-40	28	34.21	1900	10.00	555	29.2
40-50	15	43.93	1307	10.00	298	22.8
50-75	21	58.57	2440	10.00	417	17.1
75-100	8	82.38	1307	10.00	159	12.1
100-200	5	114.80	1139	10.00	99	8.7
200-300	1	210.00	417	10.00	20	4.8
> 300	1	336.00	666	10.00	20	3.0
TOTAL:	**1,826**	**7.00**	**25,360**	**4.04**	**14,628**	**57.7**

Another factor which should be considered is the ambient concentrations of total nitrogen and total phosphorus in the canal near the proposed wetland treatment system. Based upon monitoring conducted by ERD at the spillway structure, the canal water in this area was characterized by a total nitrogen concentration of 1800 μg/l and 124 μg/l for total phosphorus. Typical equilibrium total nitrogen concentrations discharged from treatment wetlands range from approximately 1000-1500 μg/l, with an equilibrium concentration of approximately 100 μg/l for total phosphorus. Therefore, the observed concentrations for total nitrogen and total phosphorus at the spillway structure are already in the general vicinity of minimum equilibrium concentrations for total nitrogen and total phosphorus which can be achieved in hardwood wetland systems. Therefore, in view of the existing concentrations for total nitrogen and total phosphorus in the canal, the relatively short detention time provided by the proposed wetland treatment system, and the limited amount of water which would be treated within the system, treatment of canal water within a hardwood wetland system would be expected to have relatively small impact on overall loadings discharging from the canal to downstream waters.

Other small wetland parcels also exist in upstream portions of the drainage basin. However, these wetland areas are generally small and have been heavily impacted by both non-native and upland species. Even if these wetland areas could be successfully converted into a treatment system, the amount of water which would be treated by these systems is very small in comparison to the amount of water which ultimately discharges from the canal. Therefore, significant reductions in nutrient loadings are not anticipated for wetland treatment systems constructed in upland portions of the basin.

5.5 General Watershed Maintenance

General observations of areas within the Roosevelt Creek watershed, conducted by ERD personnel during this project, suggest that many portions of the drainage basin are relatively “dirty” as indicated by excessive amounts of dust, soils, vegetation debris, and litter on both roadway and parking surfaces. These “dirty” areas are particularly prevalent in the middle industrial portions of the basin. Virtually all of these areas are currently developed, and opportunities for nutrient reductions through structural projects are relatively limited. However, non-structural source control programs have been shown to be effective in reducing pollutant accumulations within watersheds and have a valid potential for improving the characteristics of stormwater runoff in the Roosevelt Creek watershed.

Source reduction programs have the potential to provide effective reductions in stormwater concentrations, particularly for nutrients and suspended solids. Source reduction techniques, such as street sweeping and public education, are capable of reducing loadings of pollutants entering receiving waterbodies by reducing pollutant accumulation within the watershed. If properly conducted, source reduction programs can be almost as effective as changes in stormwater regulations for reducing pollutant loadings to lakes. The two most common source reduction techniques are street sweeping and public education which are discussed in the following sections.

5.5.1 Street Sweeping

Street sweeping is an effective best management practice (BMP) for reducing total suspended solids and associated pollutant wash-off from urban streets. Street sweeping is well suited to an urban environment where little land is available for installation of structural controls. Street sweeping can be extremely effective in commercial business districts, industrial sites, and intensely developed areas in close proximity to receiving waters.

Street sweeping involves the use of machines which basically pick-up contaminants from the street surface and deposit them in a self-contained bin or hopper. Mechanical sweepers are the most commonly used sweeping devices and consist of a series of brooms which rotate at high speeds, forcing debris from the street and gutter into a collection hopper. Water is often sprayed on the surface for dust control during the sweeping process. The effectiveness of mechanical sweepers is a function of a number of factors, including: (1) particle size distribution of accumulated surface contaminants; (2) sweeping frequency; (3) number of passes during each sweeping event; (4) equipment speed; and (5) pavement conditions. Unfortunately, mechanical sweepers perform relatively poorly for collection of particle sizes which are commonly associated with total phosphorus loadings in stormwater runoff. During the 1980s, the U.S. EPA concluded that street sweeping using mechanical sweepers had no significant impact on runoff characteristics.

Over the past decade, improvements have been made to street sweeping devices which substantially enhance the performance efficiency. Vacuum-type sweepers, which literally vacuum the roadway surface, have become increasingly more popular, particularly for parking lots and residential roadways. The overall efficiency of vacuum-type sweepers is generally higher than that of mechanical cleaners, especially for particles larger than 3 mm. Estimated efficiencies of mechanical and vacuum-assisted sweepers are summarized in Table 5-2 based upon information provided by the Federal Highway Administration. Mechanical sweepers can provide approximately 40% removal of phosphorus in roadway dust and debris, while vacuum-assisted sweepers can provide removals up to 74%. Recent studies in Hamilton County, Ohio indicated a significant reduction in runoff concentrations of nutrients after implementation of a vacuum sweeper program in residential areas.

The efficiency of street sweepers is highly dependent upon the sweeping interval. To achieve a 30% annual removal of street dirt, the sweeping interval should be less than two times the average interval between storms. Since the average interval between storms in the St. Petersburg area is approximately three days, a sweeping frequency of once every six days is necessary to achieve a 30% removal of street dirt. To achieve a 50% annual removal, sweeping must occur at least once between storm events. In the Roosevelt Creek area, a 50% removal would require street sweeping to occur approximately once every three days.

Street sweeping activities can be particularly effective during periods of high leaf fall by removing solid leaf material and the associated nutrient loadings from roadside areas where they can easily become transported by stormwater flow. Previous research by ERD has indicated that leaves release large quantities of both nitrogen and phosphorus into surface water within 24-48 hours after becoming saturated in an aquatic environment. Loadings to waterbodies from leaf fall are often the most significant loadings to receiving waters during the fall and winter months. Street sweeping operations are typically performed on a monthly basis, with increased frequency during periods of high leaf fall.

TABLE 5-2

EFFICIENCIES OF MECHANICAL (BROOM) AND VACUUM-ASSISTED SWEEPERS

CONSTITUENT	MECHANICAL SWEEPER EFFICIENCY (%)	VACUUM-ASSISTED SWEEPER EFFICIENCY (%)
Total Solids	55	93
Total Phosphorus	40	74
Total Nitrogen	42	77
COD	31	63
BOD	43	77
Lead	35	76

SOURCE: Federal Highway Administration (FHWA) – Report No. WI-11-01 – “Pollutant Loadings to Stormwater Runoff from Highways: The Impact of a Freeway Sweeping Program”.

Capital costs for street sweepers range from approximately $70,000-150,000, with the lower end of the range associated with mechanical street sweepers and the higher end of the range associated with vacuum-type sweepers. The useful life span is typically 4-8 years, with an operating cost of approximately $70/hour.

One potential drawback for the use of street sweepers in the Roosevelt Creek Sub-basin H area is the lack of curbs throughout much of the area. Many of the existing industrial and commercial areas have roadways which slope directly into roadside drainage systems without a standard curb and gutter system. The use of mechanical sweepers requires a curb and gutter system for proper operation. Therefore, street sweeping within much of Sub-basin H would need to be conducted using vacuum-assisted sweepers rather than mechanical broom sweepers. Although this would substantially enhance the efficiency of the sweeping process, vacuum-assisted sweepers are relatively rare in public works departments and may not be available to the governmental entities with jurisdiction within Sub-basin H.

5.5.2 Public Education

Public education is one of the most important nonpoint source controls which can be used in a watershed. Many residents appear to be unaware of the direct link between watershed activities and the water quality in adjacent waterbodies. The more a resident or business owner understands the relationship between nonpoint source loadings and receiving water quality, the more that person may be willing to implement source controls.

Several national studies have indicated that it is an extremely worthwhile and cost-effective activity to periodically remind property owners of the potential for water quality degradation which can occur due to misapplication of fertilizers and pesticides. Periodic information pamphlets can be distributed by hand or enclosed with water and sewer bills which will reach virtually all residents within the watershed. These educational brochures should emphasize the fact that taxpayer funds are currently being utilized to treat nonpoint source water pollution, and the homeowners have the opportunity to reduce this tax burden by modifying their daily activities. A comprehensive public education program should concentrate, at a minimum, on the following topics:

1. Relationship between land use, stormwater runoff, and pollutants
2. Functions of stormwater treatment systems
3. How to reduce stormwater runoff volume
4. Impacts of water fowl and pets on runoff characteristics and surface water quality
5. County stormwater program goals and regulations
6. Responsible use of fertilizer, pesticides and herbicides
7. Elimination of illicit connections to the stormwater system
8. Controlling erosion and turbidity
9. Proper operation and maintenance of stormwater systems

The public education program can be implemented in a variety of ways, including homeowner and business seminars, newsletters, performing special projects with local schools (elementary, middle and high schools), Earth Day celebrations, brochures, and special signage at stormwater treatment construction sites. Many people do not realize that stormsewers eventually drain to area waterbodies. Many cities and counties in Florida have implemented a signage program which places a small engraved plaque on each stormsewer inlet indicating "Do Not Dump, Drains to Waterbody". ERD recommends that an aggressive public education program be implemented in the Roosevelt Creek watershed which incorporates all of the elements discussed previously. This program should be targeted to all land use categories including industrial, commercial, and residential areas.

Anticipated load reductions for implementation of public education programs are difficult to predict and depend highly upon the degree of implementation by the homeowners within the basin. The impacts of public education programs also depend, to a large extent, on the degree to which water quality within the Roosevelt Creek basin is currently being impacted by uneducated and uninformed activities by current homeowners. Several regional and national studies are currently being performed which will attempt to document the pollutant removal effectiveness of public education programs.

SECTION 6

RECOMMENDATIONS

Based upon the analyses and results discussed in the previous sections, the following recommendations are made to improve water quality characteristics in Roosevelt Creek Sub-basin H.

1. The cause of the observed volumetric increases along the main channel should be further evaluated, particularly in view of the findings from the isotope studies which suggest that both tributary and main channel samples contained a common wastewater signature.

2. The sources of elevated nutrient concentrations in discharges observed at tributary monitoring Site H-8 should be further evaluated. Although the existing landscape nursery operation appears to be the most likely cause of these elevated nutrient concentrations, other industrial and commercial areas within this tributary basin should not be excluded.

3. Hydrologic manipulation of waterbodies within the Airco Golf Course could be used to reduce loadings from this area into the main channel. On-site waterbodies should be used as the initial source of irrigation water, with reclaimed water used only as a supplement to existing on-site sources.

4. The feasibility of regrading drainage patterns within the St. Petersburg/Clearwater International Airport property should be further evaluated for potential connection with ponds located in the golf course area. The additional inflow from the airport property would provide additional sources for irrigation using on-site water supplies, resulting in a reduction in the amount of required reclaimed water for irrigation as well as a reduction in total nutrient loadings to Old Tampa Bay.

5. Street sweeping should be initiated in the industrial and commercial portions of Sub-basin H to reduce accumulations of dirt, dust, vegetation, and debris within these areas which can contribute to nutrient loadings within the main channel.

6. A public education program should be initiated and targeted to residents and property owners within Sub-basin H to provide educational links between personal activities and water pollution.

SECTION 7

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APPENDICES

APPENDIX A

HISTORICAL WATER QUALITY
DATA FOR CHANNEL 5

Station	Organization	Collection Date	Alkalinity, Carbonate as CaCO3 (mg/l)	Apparent Color (PCU)	BOD, Biochemical oxygen demand (mg/l)	Chlorophyll a, corrected for pheophytin (mg/m^3)	Depth (m)	Dissolved oxygen (DO) (mg/l)	Dissolved oxygen saturation (%)	Dissolved Solids (mg/l)	Enterococcus Group Bacteria (MPN/100ml)	Fecal Coliform (cfu/100ml)	Flow, runoff (cfs)	Nitrogen, ammonia as N (µg/l)	Nitrogen, Kjeldahl (µg/l)	Nitrogen, Nitrite (NO2) + Nitrate (NO3) as N (µg/l)	Nitrogen, Total (µg/l)	pH (s.u.)	Phosphorus, orthophosphate as P (µg/l)	Phosphorus, Total as P (µg/l)	Salinity (ppth)	Secchi disk depth (m)	Specific conductance (mS/cm)	Sulfur, sulfate (SO4) as SO4 (mg/l)	Temperature, water (deg C)	Total Coliform (cfu/100ml)	Total Suspended Solids (TSS) (mg/l)	Turbidity (NTU)
23-04	Pinellas County	1/11/95	---	---	3.3	4.7	---	2.6	---	---	---	150	---	---	1680	1570	3250	7.23	40	50	0.4	---	824	---	16.20	450	5	3.6
23-04	Pinellas County	2/8/95	---	---	7.7	9.7	---	4.2	---	---	---	120	---	---	2920	1200	4120	7.43	40	70	0.4	---	873	---	14.94	1400	4	4.5
23-04	Pinellas County	3/8/95	---	---	3.1	7.2	---	3.4	---	---	---	1200	---	---	1690	780	2470	7.66	60	170	0.4	---	792	---	22.38	---	18	12
23-04	Pinellas County	4/12/95	---	---	2.0	4.4	---	2.8	---	---	---	2200	---	---	1230	560	1790	7.29	40	60	0.3	---	637	---	24.52	3200	2	2.8
23-04	Pinellas County	5/2/95	---	---	1.3	21.1	---	1.1	---	---	---	40	---	---	1120	510	1630	7.09	40	70	0.4	---	680	---	26.10	600	3	1.8
23-04	Pinellas County	6/7/95	---	---	2.6	27.8	---	1.6	---	---	---	240	---	---	1900	130	2030	7.10	40	160	0.0	---	55	---	20.57	300	5	1.1
23-04	Pinellas County	6/28/95	---	---	3.2	17.6	---	2.3	---	---	---	4700	---	---	440	200	640	7.33	40	110	0.3	---	604	---	28.32	2600	6	4.2
23-04	Pinellas County	8/9/95	---	---	2.2	47.9	---	2.7	---	---	---	900	---	---	4450	290	4740	7.33	40	180	0.4	---	741	---	29.63	200	7	4.9
23-04	Pinellas County	8/29/95	---	---	3.0	13.2	---	0.7	---	---	---	18000	---	---	3880	70	3950	7.03	90	180	0.4	---	843	---	28.70	---	5	3.4
23-04	Pinellas County	9/27/95	---	---	2.2	17.0	---	2.5	---	---	---	700	---	---	2280	30	2310	7.30	340	480	0.9	---	1720	---	27.90	1500	1	5.5
23-04	Pinellas County	10/18/95	---	---	1.8	12.0	---	2.5	---	---	---	1100	---	---	2740	170	2910	7.57	40	90	0.3	---	731	---	23.31	2900	5	4.16
23-04	Pinellas County	11/29/95	---	---	4.0	19.1	---	4.2	---	---	---	3000	---	---	2220	680	2900	7.76	40	50	0.5	---	941	---	20.86	---	1	7.43
23-04	Pinellas County	1/17/96	---	---	5.8	10.4	---	2.4	---	---	---	600	---	---	---	190	---	7.27	150	360	0.5	---	1000	---	16.19	---	7	8.51
23-04	Pinellas County	2/7/96	---	---	2.7	8.1	---	6.9	---	---	---	100	---	---	1810	230	2040	7.67	40	20	0.4	---	749	---	12.23	1000	4	4.55
23-04	Pinellas County	3/13/96	---	---	2.3	3.3	---	6.5	---	---	---	20	---	---	1750	750	2500	7.59	10	70	0.4	---	831	---	14.24	400	7	3.6
23-04	Pinellas County	4/3/96	---	---	3.1	11.0	---	4.8	---	---	---	120	---	---	1420	320	1740	7.41	30	110	0.4	---	681	---	18.50	900	---	6.2
23-04	Pinellas County	5/8/96	---	---	3.7	18.1	---	3.1	---	---	---	110	---	---	1040	210	1250	7.37	20	130	0.4	---	745	---	27.26	380	---	6.24
23-04	Pinellas County	5/21/96	---	---	3.2	20.7	---	3.8	---	---	---	60	---	---	1250	30	1280	7.67	20	100	0.4	---	807	---	27.48	200	---	4.2
23-04	Pinellas County	7/10/96	---	---	4.1	12.0	---	1.1	---	---	---	120	---	---	1820	160	1980	7.24	70	40	0.3	---	568	---	27.53	500	---	2.9
23-04	Pinellas County	7/24/96	---	---	2.7	17.0	---	2.2	---	---	---	250	---	---	1120	470	1590	6.11	20	110	0.4	---	811	---	30.50	500	---	5
23-04	Pinellas County	8/27/96	---	---	3.0	31.9	---	3.6	---	---	---	10	---	---	1350	440	1790	7.45	20	60	0.4	---	697	---	27.89	3400	---	4.4
23-04	Pinellas County	9/18/96	---	---	1.9	14.8	---	2.2	---	---	---	100	---	---	800	280	1080	7.63	60	60	0.4	---	736	---	29.34	600	---	5.42
23-04	Pinellas County	10/23/96	---	---	2.1	16.0	---	3.8	---	---	---	70	---	---	1550	520	2070	7.40	20	20	0.4	---	712	---	23.00	350	---	4.29
23-04	Pinellas County	11/13/96	---	---	3.6	10.6	---	5.5	---	---	---	190	---	---	1210	540	1750	7.68	20	70	0.5	---	977	---	16.88	1	---	7.86
23-04	Pinellas County	1/22/97	---	---	2.0	9.1	---	5.3	---	---	---	---	---	---	1370	860	2230	7.41	20	130	0.4	---	867	---	14.03	---	---	3.6
23-04	Pinellas County	2/12/97	---	---	2.0	10.5	---	4.3	---	---	---	---	---	---	1400	520	1920	7.50	20	140	0.5	---	869	---	16.95	---	---	5.4
23-04	Pinellas County	3/19/97	---	---	3.0	25.8	---	2.6	---	---	---	---	---	---	2090	140	2230	7.55	20	100	0.5	---	951	---	22.66	---	---	6.4
23-04	Pinellas County	4/9/97	---	---	6.0	50.7	---	4.6	---	---	---	---	---	---	1820	200	2020	7.35	20	140	0.4	---	779	---	22.78	---	---	10.1
23-04	Pinellas County	5/12/97	---	---	6.0	30.9	---	5.3	---	---	---	---	---	---	1500	360	1860	7.46	20	110	0.4	---	825	---	25.50	---	---	7.3
23-04	Pinellas County	5/28/97	---	---	3.0	17.8	---	5.0	---	---	---	---	---	---	1720	40	1760	7.25	30	30	0.4	---	795	---	28.66	---	---	7.4
23-04	Pinellas County	6/25/97	---	---	6.0	57.4	---	2.4	---	---	---	---	---	---	3660	230	3890	7.42	20	60	0.3	---	668	---	27.54	---	---	16

Station	Organization	Collection Date	Alkalinity, Carbonate as CaCO3 (mg/l)	Apparent Color (PCU)	BOD, Biochemical oxygen demand (mg/l)	Chlorophyll a, corrected for pheophytin (mg/m^3)	Depth (m)	Dissolved oxygen (DO) (mg/l)	Dissolved oxygen saturation (%)	Dissolved Solids (mg/l)	Enterococcus Group Bacteria (MPN/100ml)	Fecal Coliform (cfu/100ml)	Flow, runoff (cfs)	Nitrogen, ammonia as N (µg/l)	Nitrogen, Kjeldahl (µg/l)	Nitrogen, Nitrite (NO2) + Nitrate (NO3) as N (µg/l)	Nitrogen, Total (µg/l)	pH (s.u.)	Phosphorus, orthophosphate as P (µg/l)	Phosphorus, Total as P (µg/l)	Salinity (ppth)	Secchi disk depth (m)	Specific conductance (mS/cm)	Sulfur, sulfate (SO4) as SO4 (mg/l)	Temperature, water (deg C)	Total Coliform (cfu/100ml)	Total Suspended Solids (TSS) (mg/l)	Turbidity (NTU)
23-04	Pinellas County	7/23/97	---	---	2.0	9.2	---	1.9	---	---	---	---	---	---	1810	40	1850	7.87	40	120	0.3	---	543	---	28.55	---	---	14
23-04	Pinellas County	8/26/97	---	---	4.0	54.9	---	3.3	---	---	---	---	---	---	2310	120	2430	7.38	20	140	0.9	---	1747	---	27.70	---	---	6.1
23-04	Pinellas County	9/17/97	---	---	2.0	41.1	---	4.9	---	---	---	---	---	---	2060	220	2280	7.41	20	140	1.1	---	2033	---	29.87	---	---	11
23-04	Pinellas County	10/15/97	---	---	7.0	73.3	---	3.8	---	---	---	---	---	---	2420	230	2650	7.23	20	130	0.8	---	1550	---	25.49	---	---	6.1
23-04	Pinellas County	11/3/97	---	---	4.0	21.0	---	2.2	---	---	---	---	---	---	2020	140	2160	7.26	60	90	0.6	---	1185	---	21.69	---	---	---
23-04	Pinellas County	12/17/97	---	---	3.0	14.2	---	4.5	---	---	---	---	---	---	2580	220	2800	7.21	20	180	0.5	---	980	---	15.35	---	---	15
23-04	Pinellas County	1/21/98	---	---	7.0	91.1	---	6.4	---	---	---	---	---	---	2190	610	2800	7.52	20	310	0.7	---	1320	---	16.34	---	---	21
23-04	Pinellas County	2/25/98	---	---	8.0	94.7	---	5.4	---	---	---	---	---	---	3780	250	4030	7.37	30	270	0.5	---	1010	---	17.11	---	---	23
23-04	Pinellas County	3/18/98	---	---	10.0	282.0	---	12.8	---	---	---	---	---	---	3360	230	3590	7.49	20	300	0.8	---	1461	---	20.86	---	39	20
23-04	Pinellas County	4/20/98	---	---	6.0	5.8	---	3.7	---	---	---	---	---	---	2170	90	2260	7.43	20	160	0.9	---	1713	---	25.45	---	11	7.4
23-04	Pinellas County	5/13/98	---	---	5.0	50.8	---	2.2	---	---	---	---	---	---	2120	230	2350	7.43	20	180	1.1	---	2083	---	26.80	---	15	18
23-04	Pinellas County	6/17/98	---	---	4.0	57.5	---	2.3	---	---	---	---	---	---	1910	20	1930	7.56	30	140	0.6	---	1119	---	30.37	---	11	6.1
23-04	Pinellas County	7/8/98	---	---	4.0	44.6	---	1.1	---	---	---	---	---	---	1810	20	1830	7.39	30	80	0.5	---	983	---	29.37	---	10	8.2
23-04	Pinellas County	8/12/98	---	---	3.0	22.0	---	0.8	---	---	---	---	---	---	1700	140	1840	7.17	20	70	0.4	---	602	---	30.03	---	7	5.7
23-04	Pinellas County	9/2/98	---	---	3.0	30.6	---	2.5	---	---	---	---	---	---	2770	600	3370	7.44	20	110	0.4	---	803	---	29.70	---	13	10
23-04	Pinellas County	10/7/98	---	---	4.0	32.4	---	2.1	---	---	---	---	---	---	2490	100	2590	7.19	20	140	1.0	---	1863	---	27.83	---	14	8
23-04	Pinellas County	10/26/98	---	---	8.0	36.9	---	5.9	---	---	---	---	---	---	2180	330	2510	7.55	20	170	1.0	---	1890	---	23.33	---	14	5.2
23-04	Pinellas County	12/2/98	---	---	5.0	50.1	---	6.8	---	---	---	---	---	---	3070	510	3580	7.75	30	160	0.5	---	967	---	22.52	---	21	17
23-04	Pinellas County	12/9/98	---	---	4.0	50.9	---	5.8	---	---	---	---	---	---	1810	510	2320	7.72	20	110	0.5	---	942	---	22.76	---	15	11
23-04	Pinellas County	1/13/99	---	---	3.0	15.4	---	7.3	---	---	---	---	---	---	2100	790	2890	7.43	20	80	0.4	---	806	---	15.12	---	12	8.3
23-04	Pinellas County	2/3/99	---	---	4.0	19.7	---	2.2	---	---	---	---	---	---	2070	230	2300	7.39	20	100	0.3	---	546	---	22.05	---	14	14
23-04	Pinellas County	3/3/99	---	---	4.0	41.3	---	6.9	---	---	---	---	---	---	2140	700	2840	8.92	20	120	0.5	---	937	---	19.60	---	22	16
23-04	Pinellas County	3/31/99	---	---	5.0	47.1	---	5.1	---	---	---	---	---	---	1230	30	1260	7.95	20	120	0.5	---	991	---	23.32	---	18	12
23-04	Pinellas County	5/3/99	---	---	4.0	28.1	---	5.6	---	---	---	---	---	---	1150	20	1170	8.33	20	50	4.9	---	8654	---	23.65	---	13	9.2
23-04	Pinellas County	5/25/99	---	---	2.0	20.4	---	1.7	---	---	---	---	---	---	1240	20	1260	7.40	70	150	5.6	---	9900	---	29.71	---	17	10
23-04	Pinellas County	6/30/99	---	---	2.0	7.5	---	0.7	---	---	---	---	---	---	1890	80	1970	7.01	20	70	0.3	---	721	---	28.21	---	4	5.7
23-04	Pinellas County	7/21/99	---	---	1.0	3.2	---	1.4	---	---	---	---	---	---	2200	440	2640	7.25	30	70	0.4	---	817	---	30.94	---	2	2.3
23-04	Pinellas County	8/25/99	---	---	2.0	7.6	---	1.7	---	---	---	---	---	---	2090	90	2180	7.20	20	140	0.5	---	971	---	28.12	---	6	9.8
23-04	Pinellas County	9/15/99	---	---	2.0	9.4	---	1.7	---	---	---	---	---	---	2680	200	2880	7.19	30	90	0.5	---	930	---	25.98	---	6	6.5
23-04	Pinellas County	10/20/99	---	---	1.0	4.9	---	0.8	---	---	---	---	---	---	2060	280	2340	7.24	20	130	0.7	---	1256	---	26.24	---	2	5.2
23-04	Pinellas County	11/10/99	---	---	2.0	5.4	---	0.5	---	---	---	---	---	---	2800	730	3530	7.39	40	120	0.5	---	876	---	21.96	---	2	2.6

Station	Organization	Collection Date	Alkalinity, Carbonate as CaCO3 (mg/l)	Apparent Color (PCU)	BOD, Biochemical oxygen demand (mg/l)	Chlorophyll a, corrected for pheophytin (mg/m^3)	Depth (m)	Dissolved oxygen (DO) (mg/l)	Dissolved oxygen saturation (%)	Dissolved Solids (mg/l)	Enterococcus Group Bacteria (MPN/100ml)	Fecal Coliform (cfu/100ml)	Flow, runoff (cfs)	Nitrogen, ammonia as N (µg/l)	Nitrogen, Kjeldahl (µg/l)	Nitrogen, Nitrite (NO2) + Nitrate (NO3) as N (µg/l)	Nitrogen, Total (µg/l)	pH (s.u.)	Phosphorus, orthophosphate as P (µg/l)	Phosphorus, Total as P (µg/l)	Salinity (ppth)	Secchi disk depth (m)	Specific conductance (mS/cm)	Sulfur, sulfate (SO4) as SO4 (mg/l)	Temperature, water (deg C)	Total Coliform (cfu/100ml)	Total Suspended Solids (TSS) (mg/l)	Turbidity (NTU)
23-04	Pinellas County	1/5/00	---	---	4.0	14.7	---	3.9	---	---	---	---	---	---	2330	1160	3490	7.69	20	60	0.6	---	1050	---	18.91	---	3	5.8
23-04	Pinellas County	1/27/00	---	---	1.0	4.8	---	5.0	---	---	---	---	---	---	2660	1930	4590	7.60	20	30	0.3	---	623	---	10.33	---	3	2.3
23-04	Pinellas County	3/8/00	---	---	2.0	12.7	---	1.5	---	---	---	---	---	---	1980	220	2200	7.54	20	100	0.5	---	909	---	22.25	---	5	6.1
23-04	Pinellas County	3/28/00	---	---	3.0	17.9	---	2.1	---	---	---	---	---	---	1740	90	1830	7.58	20	60	0.4	---	823	---	23.08	---	8	7.9
23-04	Pinellas County	5/3/00	---	---	1.0	7.6	---	4.9	---	---	---	---	---	---	1360	120	1480	7.58	40	80	2.6	---	4765	---	24.41	---	3	2.2
23-04	Pinellas County	5/23/00	---	---	2.0	17.7	---	5.4	---	---	---	---	---	---	2280	120	2400	7.99	20	110	2.8	---	5080	---	29.33	---	10	6.3
23-04	Pinellas County	6/28/00	---	---	3.0	24.0	---	1.3	---	---	---	---	---	---	2200	100	2300	7.34	20	130	0.2	---	453	---	27.35	---	4	6.86
23-04	Pinellas County	7/19/00	---	---	3.0	24.0	---	3.1	---	---	---	---	---	---	1500	210	1710	7.24	---	---	0.3	---	569	---	28.28	---	28	2.33
23-04	Pinellas County	8/21/00	---	---	---	16.0	---	2.0	---	---	---	---	---	---	3240	172	3412	7.20	19	68	0.3	---	605	---	29.69	---	8	8.6
23-04	Pinellas County	9/13/00	---	---	1.0	7.8	---	0.9	---	---	---	---	---	---	2768	683	3451	7.30	30	81	0.4	---	828	---	29.13	---	2	3.4
23-04	Pinellas County	10/18/00	---	---	1.0	9.3	---	2.2	---	---	---	---	---	---	2050	980	3030	7.52	20	50	0.5	---	972	---	23.14	---	4	1.8
23-04	Pinellas County	11/6/00	---	---	4.0	37.6	---	6.2	---	---	---	---	---	---	1920	100	2020	7.49	20	80	0.5	---	1003	---	24.65	---	10	6.5
23-04	Pinellas County	1/11/01	---	---	2.0	12.1	---	6.3	---	---	---	---	---	---	3650	160	3810	7.58	20	30	0.3	---	656	---	12.88	---	7	6.8
23-04	Pinellas County	1/24/01	---	---	2.0	9.1	---	6.0	---	---	---	---	---	---	1980	990	2970	7.69	20	20	0.4	---	841	---	13.78	---	5	2.4
23-04	Pinellas County	3/7/01	---	---	2.0	4.2	---	5.3	---	---	---	---	---	---	1680	270	1950	7.41	20	50	0.2	---	471	---	16.69	---	4	3.5
23-04	Pinellas County	3/28/01	---	---	1.0	2.3	---	5.4	---	---	---	---	---	---	1100	400	1500	7.38	20	20	0.3	---	617	---	19.37	---	2	3.1
23-04	Pinellas County	5/2/01	---	---	2.0	1.4	---	6.2	---	---	---	---	---	---	1350	20	1370	7.61	20	30	0.4	---	713	---	22.46	---	2	1.4
23-04	Pinellas County	5/23/01	---	---	2.0	8.9	---	3.4	---	---	---	---	---	---	1370	20	1390	7.34	20	80	0.4	---	807	---	27.09	---	3	3.2
23-04	Pinellas County	7/3/01	---	---	2.0	17.2	---	2.4	---	---	---	---	---	---	1420	560	1980	7.02	20	40	0.4	---	768	---	28.98	---	5	3
23-04	Pinellas County	7/18/01	---	---	2.0	16.0	---	1.0	---	---	---	---	---	---	1800	920	2720	7.20	20	60	0.4	---	683	---	28.30	---	4	3.8
23-04	Pinellas County	8/22/01	---	---	7.0	193.0	---	1.2	---	---	---	---	---	---	2720	400	3120	7.14	20	400	0.4	---	728	---	29.44	---	17	3.8
23-04	Pinellas County	9/12/01	---	---	2.0	6.2	---	0.7	---	---	---	---	---	---	2330	280	2610	7.13	20	90	0.3	---	644	---	27.67	---	2	2.8
23-04	Pinellas County	10/17/01	---	---	2.0	24.7	---	2.8	---	---	---	---	---	---	2050	760	2810	7.43	30	90	2.1	---	0	---	24.77	---	4	4.5
23-04	Pinellas County	11/5/01	---	---	---	2.2	---	4.0	---	---	---	---	---	---	1700	1250	2950	7.59	20	50	0.4	---	849	---	23.06	---	5	2
23-04	Pinellas County	1/3/02	---	---	2.0	6.6	---	4.8	---	---	---	---	---	---	2000	1460	3460	7.56	20	70	0.4	---	820	---	15.29	---	5	4.1
23-04	Pinellas County	1/30/02	---	---	2.0	10.8	---	3.3	---	---	---	---	---	---	1330	360	1690	7.32	20	20	0.4	---	819	---	23.36	---	3	2.1
23-04	Pinellas County	3/4/02	---	---	---	10.8	---	6.5	---	---	---	---	---	---	1400	550	1950	7.50	20	50	0.4	---	686	---	17.83	---	5	4.9
23-04	Pinellas County	3/27/02	---	---	4.0	7.1	---	2.2	---	---	---	---	---	---	1490	30	1520	7.42	20	90	0.4	---	822	---	24.25	---	7	2.6
23-04	Pinellas County	5/1/02	---	---	3.0	6.4	---	1.2	---	---	---	---	---	---	1900	60	1960	7.38	20	80	0.4	---	836	---	27.71	---	5	4.4
23-04	Pinellas County	5/21/02	---	---	7.0	56.0	---	4.8	---	---	---	---	---	---	2210	100	2310	7.86	20	120	0.4	---	758	---	25.29	---	13	7
23-04	Pinellas County	6/26/02	---	---	---	---	---	1.6	---	---	---	---	---	---	---	---	---	7.25	---	---	0.1	---	263	---	26.72	---	---	---

Station	Organization	Collection Date	Alkalinity, Carbonate as CaCO3 (mg/l)	Apparent Color (PCU)	BOD, Biochemical oxygen demand (mg/l)	Chlorophyll a, corrected for pheophytin (mg/m^3)	Depth (m)	Dissolved oxygen (DO) (mg/l)	Dissolved oxygen saturation (%)	Dissolved Solids (mg/l)	Enterococcus Group Bacteria (MPN/100ml)	Fecal Coliform (cfu/100ml)	Flow, runoff (cfs)	Nitrogen, ammonia as N (µg/l)	Nitrogen, Kjeldahl (µg/l)	Nitrogen, Nitrite (NO2) + Nitrate (NO3) as N (µg/l)	Nitrogen, Total (µg/l)	pH (s.u.)	Phosphorus, orthophosphate as P (µg/l)	Phosphorus, Total as P (µg/l)	Salinity (ppth)	Secchi disk depth (m)	Specific conductance (mS/cm)	Sulfur, sulfate (SO4) as SO4 (mg/l)	Temperature, water (deg C)	Total Coliform (cfu/100ml)	Total Suspended Solids (TSS) (mg/l)	Turbidity (NTU)
23-04	Pinellas County	7/17/02	---	---	2.0	21.5	---	2.4	---	---	---	---	---	---	2520	270	2790	7.21	20	70	0.4	---	750	---	30.17	---	6	4.7
23-04	Pinellas County	8/21/02	---	---	4.0	27.6	---	2.5	---	---	---	---	---	---	2500	300	2800	7.26	20	110	0.3	---	670	---	28.80	---	7	4.1
23-04	Pinellas County	9/11/02	---	---	3.0	15.6	---	1.3	---	---	---	---	---	---	2460	170	2630	7.19	20	110	0.3	---	636	---	28.83	---	5	3.9
23-04	Pinellas County	10/16/02	---	---	5.0	48.1	---	3.0	---	---	---	---	---	---	1940	140	2080	7.29	40	170	0.2	---	407	---	25.58	---	14	8.8
23-04	Pinellas County	11/6/02	---	---	5.0	25.8	---	3.4	---	---	---	---	---	---	2130	850	2980	7.52	20	90	0.5	---	924	---	25.01	---	8	3.1
23-08	Pinellas County	3/1/05	---	---	2.0	1.6	---	7.1	---	---	20	180	2.53	490	1120	130	---	7.86	120	150	1.1	---	2090	---	21.19	1800	2	1.5
23-08	Pinellas County	5/26/05	---	---	1.0	0.5	0.05	6.2	---	---	78	50	0.16	50	1180	20	---	7.80	20	110	1.2	---	2320	---	27.41	40	1	0.7
23-08	Pinellas County	8/16/05	---	---	1.0	8.7	0.07	5.9	---	---	8	100	---	400	1640	60	---	7.40	100	110	0.4	---	783	---	33.49	370	1	1.4
23-08	Pinellas County	11/1/05	---	---	1.0	3.4	0.13	9.6	---	---	10	57	---	410	1450	330	---	7.97	60	70	1.3	---	2362	---	22.65	200	1	0.6
23-08	Pinellas County	2/23/06	---	---	5.0	58.9	0.06	8.1	---	---	4	93	4.17	220	1630	140	---	7.45	20	100	0.7	---	1361	---	21.60	400	11	4.9
23-08	Pinellas County	8/10/06	---	---	1.0	---	0.02	6.9	---	---	8	600	---	110	1320	20	---	7.67	20	50	0.4	---	805	---	30.89	---	1	1.7
23-08	Pinellas County	10/18/06	---	---	2.0	36.0	0.24	9.7	---	---	192	170	1.6	200	1740	430	---	7.96	20	80	1.4	---	2655	---	26.53	---	5	2.8
23-08	Pinellas County	2/20/07	---	---	2.0	10.9	0.02	14.2	---	---	4	83	---	10	1120	360	---	8.25	20	20	1.5	---	2723	---	18.81	---	1	0.8
23-08	Pinellas County	8/29/07	---	---	2.0	52.2	0.20	6.4	---	---	483	1	16	150	1000	60	---	7.87	90	170	0.2	---	427	---	31.06	---	7	5.6
23-08	Pinellas County	11/7/07	---	---	2.0	9.5	0.06	10.3	---	---	51	320	---	100	1250	180	---	8.03	20	70	0.5	---	953	---	22.62	---	1	1.1
23-08	Pinellas County	3/18/08	---	---	2.0	6.1	0.26	10.9	---	---	21	1	---	10	950	230	---	8.10	20	50	0.3	---	547	---	23.04	---	1	1.4
23-08	Pinellas County	6/25/08	---	---	2.0	37.5	0.14	7.6	---	---	96	45	---	10	1210	20	---	7.57	20	110	0.5	---	898	---	30.03	---	7	3.7
23-08	Pinellas County	6/16/09	---	---	2.0	3.1	0.13	4.6	---	---	36	100	3.7	10	1000	20	---	7.56	20	80	1.0	---	1950	---	32.59	---	1	1.3
23-08	Pinellas County	9/22/09	---	---	2.0	18.4	0.14	3.1	---	---	204	6000	10	420	1360	180	---	7.21	100	170	0.2	---	331	---	29.27	---	1	4.8
23-08	Pinellas County	12/9/09	---	---	2.0	3.4	0.12	8.4	---	---	114	200	0	190	1030	540	---	7.63	50	80	0.8	---	1576	---	21.59	---	1	1.4
23-08	Pinellas County	4/12/10	---	---	2.0	3.1	0.18	11.8	---	---	7	7	2.6	10	940	20	---	8.10	20	20	0.4	---	755	---	24.23	---	1	1.5
23-08	Pinellas County	2/26/03	---	---	---	5.4	---	4.6	---	---	---	---	---	931	2110	190	---	7.52	130	230	0.4	---	690	---	23.89	---	3	2
23-08	Pinellas County	4/1/03	---	---	---	9.1	---	8.2	---	---	---	---	---	148	1160	390	---	10.15	20	80	0.4	---	710	---	21.74	---	1	1
23-08	Pinellas County	5/13/03	---	---	---	51.6	---	7.8	---	---	---	---	---	8	1100	20	---	7.63	20	120	0.7	---	1340	---	30.80	---	10	5.1
23-08	Pinellas County	6/26/03	---	---	---	45.2	---	6.4	---	---	---	---	---	420	1850	90	---	7.28	120	310	0.3	---	550	---	30.17	---	9	2
23-08	Pinellas County	8/6/03	---	---	---	9.7	---	4.6	---	---	---	---	---	445	1580	140	---	7.23	160	210	0.4	---	790	---	30.65	---	5	2.7
23-08	Pinellas County	9/17/03	---	---	---	87.7	---	11.1	---	---	---	---	---	8	1840	20	---	7.75	20	170	0.7	---	1240	---	29.89	---	11	6.4
23-08	Pinellas County	10/22/03	---	---	---	20.8	---	7.4	---	---	---	---	---	82	1610	640	---	7.95	20	110	0.4	---	820	---	26.18	---	6	2.7
23-08	Pinellas County	12/4/03	---	---	---	8.2	---	10.6	---	---	---	---	---	66	1170	80	---	8.52	30	110	4.6	---	8140	---	20.65	---	10	4.2
23-08	Pinellas County	1/22/04	---	---	---	1.3	---	6.8	---	---	---	---	1.96	601	1900	560	---	7.67	20	20	0.8	---	1539	---	17.01	---	1	0.7
23-08	Pinellas County	2/25/04	---	---	---	6.5	---	6.6	---	---	---	---	74.02	165	750	130	---	7.63	60	160	0.1	---	290	---	18.56	---	10	10

Station	Organization	Collection Date	Alkalinity, Carbonate as CaCO3 (mg/l)	Apparent Color (PCU)	BOD, Biochemical oxygen demand (mg/l)	Chlorophyll a, corrected for pheophytin (mg/m^3)	Depth (m)	Dissolved oxygen (DO) (mg/l)	Dissolved oxygen saturation (%)	Dissolved Solids (mg/l)	Enterococcus Group Bacteria (MPN/100ml)	Fecal Coliform (cfu/100ml)	Flow, runoff (cfs)	Nitrogen, ammonia as N (µg/l)	Nitrogen, Kjeldahl (µg/l)	Nitrogen, Nitrite (NO2) + Nitrate (NO3) as N (µg/l)	Nitrogen, Total (µg/l)	pH (s.u.)	Phosphorus, orthophosphate as P (µg/l)	Phosphorus, Total as P (µg/l)	Salinity (ppth)	Secchi disk depth (m)	Specific conductance (mS/cm)	Sulfur, sulfate (SO4) as SO4 (mg/l)	Temperature, water (deg C)	Total Coliform (cfu/100ml)	Total Suspended Solids (TSS) (mg/l)	Turbidity (NTU)
23-08	Pinellas County	4/12/04	---	---	---	6.2	---	4.0	---	---	---	---	8.31	156	1180	220	---	7.38	50	100	0.3	---	600	---	22.18	---	7	5.8
23-08	Pinellas County	5/18/04	---	---	---	2.3	---	10.7	---	---	---	---	0.47	8	850	20	---	8.49	20	20	0.3	---	564	---	30.47	---	2	1.2
23-08	Pinellas County	6/23/04	---	---	---	12.8	---	9.6	---	---	---	---	1.21	33	1280	20	---	8.44	40	120	1.7	---	3138	---	34.54	---	3	1.5
23-08	Pinellas County	8/4/04	---	---	---	1.1	---	3.6	---	---	---	---	33.73	502	1500	120	---	7.14	150	230	0.3	---	617	---	28.40	---	5	7.6
23-08	Pinellas County	9/20/04	---	---	---	39.0	---	6.1	---	---	---	---	2.48	173	2000	150	---	7.47	180	380	1.9	---	3475	---	28.73	---	14	4.8
23-08	Pinellas County	4/12/05	---	---	---	0.5	0.21	10.9	---	---	10	20	0.06	10	980	20	---	8.47	20	20	0.5	---	906	---	28.22	1	1	0.8
23-08	Pinellas County	6/29/05	---	---	---	24.8	0.09	5.1	---	---	300	2000	25	290	1300	270	---	7.33	20	90	0.3	---	622	---	30.13	6400	5	4.1
23-08	Pinellas County	11/15/05	---	---	---	0.5	0.07	8.4	---	---	4	7	---	160	1110	120	---	7.79	20	50	1.3	---	2458	---	25.15	15	1	0.5
23-08	Pinellas County	1/24/06	---	---	---	1.2	0.12	8.5	---	---	4	47	4.03	150	1240	130	---	7.89	50	50	0.6	---	1146	---	23.46	140	1	1.1
23-08	Pinellas County	4/6/06	---	---	---	0.5	0.17	7.3	---	---	91	3	---	10	100	20	---	7.71	20	40	0.5	---	1002	---	26.42	15	1	2.5
23-08	Pinellas County	7/18/06	---	---	---	17.0	0.08	10.8	---	---	34	17	---	130	1070	20	---	7.90	20	80	0.8	---	1544	---	33.77	14	1	1.4
23-08	Pinellas County	9/11/06	---	---	---	26.6	0.22	4.9	---	---	105	1	---	380	1560	140	---	7.64	60	100	0.3	---	587	---	29.46	---	6	4
23-08	Pinellas County	11/27/06	---	---	---	44.3	0.06	12.1	---	---	29	31	---	10	950	210	---	8.39	20	20	0.5	---	926	---	19.53	---	6	2.8
23-08	Pinellas County	1/17/07	---	---	---	3.8	0.08	12.1	---	---	299	1	---	100	1070	290	---	8.19	20	50	0.4	---	746	---	21.01	---	1	1.1
23-08	Pinellas County	3/27/07	---	---	---	14.9	0.11	10.2	---	---	2	7	---	10	1500	20	---	8.70	20	50	1.5	---	2734	---	26.59	---	1	0.7
23-08	Pinellas County	6/18/07	---	---	---	14.4	0.14	7.3	---	---	40	25	---	10	700	20	---	7.67	20	50	1.8	---	3377	---	30.91	---	1	1.6
23-08	Pinellas County	9/19/07	---	---	---	48.9	0.07	5.0	---	---	25	33	---	230	1400	120	---	7.60	70	120	0.3	---	628	---	28.53	---	6	4.2
23-08	Pinellas County	1/30/08	---	---	---	7.8	0.11	9.2	---	---	32	7	0.28	110	1400	220	---	7.85	20	120	0.4	---	683	---	17.83	---	1	0.9
23-08	Pinellas County	8/5/08	---	---	---	10.9	0.19	3.3	---	---	98	80	---	380	1310	330	---	7.07	90	100	0.4	---	672	---	30.98	---	1	2.4
23-08	Pinellas County	2/10/09	---	---	---	0.5	0.04	8.4	---	---	2	5	1.15	430	1220	120	---	7.73	20	50	0.3	---	616	---	18.63	---	1	0.9
23-08	Pinellas County	7/30/09	---	---	---	111.0	0.21	1.8	---	---	261	1	11	10	2690	140	---	7.22	20	200	2.1	---	3913	---	29.29	---	23	14
23-08	Pinellas County	10/22/09	---	---	---	14.4	0.12	15.9	---	---	19	167	0	10	1080	240	---	8.45	20	20	1.5	---	2735	---	25.63	---	1	1.6
23-08	Pinellas County	2/11/10	---	---	---	5.6	0.14	13.0	---	---	13	3	3.3	10	840	380	---	8.08	20	20	0.7	---	1226	---	15.54	---	1	1
23-08	Pinellas County	11/2/04	---	---	---	---	---	5.4	---	---	---	---	0.09	---	---	---	---	7.61	---	---	0.9	---	1609	---	28.46	---	---	---
23-08	Pinellas County	1/13/05	---	---	---	---	---	6.8	---	---	---	---	2.644	---	---	---	---	7.55	---	---	1.2	---	2253	---	21.88	---	---	---
23-21	Pinellas County	3/1/05	---	---	---	---	---	7.5	---	---	---	---	3.05	---	---	---	---	7.50	---	---	2.3	---	4178	---	19.82	---	---	---
23-21	Pinellas County	11/1/05	---	---	---	---	0.22	8.5	---	---	---	---	3.42	---	---	---	---	7.45	---	---	1.4	---	2673	---	22.31	---	---	---
23-21	Pinellas County	4/12/05	---	---	---	---	0.21	7.6	---	---	---	---	---	---	---	---	---	7.90	---	---	0.7	---	1225	---	25.67	---	---	---
23-21	Pinellas County	6/29/05	---	---	---	---	0.38	7.6	---	---	---	---	4.9	---	---	---	---	7.37	---	---	1.3	---	2458	---	31.40	---	---	---
23-21	Pinellas County	11/15/05	---	---	---	---	0.20	4.6	---	---	---	---	5.23	---	---	---	---	7.29	---	---	0.9	---	1653	---	24.74	---	---	---
23-21	Pinellas County	4/28/05	---	---	---	---	0.21	7.6	---	---	---	---	3.59	---	---	---	---	7.57	---	---	0.8	---	1581	---	23.02	---	---	---

Station	Organization	Collection Date	Alkalinity, Carbonate as CaCO3 (mg/l)	Apparent Color (PCU)	BOD, Biochemical oxygen demand (mg/l)	Chlorophyll a, corrected for pheophytin (mg/m^3)	Depth (m)	Dissolved oxygen (DO) (mg/l)	Dissolved oxygen saturation (%)	Dissolved Solids (mg/l)	Enterococcus Group Bacteria (MPN/100ml)	Fecal Coliform (cfu/100ml)	Flow, runoff (cfs)	Nitrogen, ammonia as N (µg/l)	Nitrogen, Kjeldahl (µg/l)	Nitrogen, Nitrite (NO2) + Nitrate (NO3) as N (µg/l)	Nitrogen, Total (µg/l)	pH (s.u.)	Phosphorus, orthophosphate as P (µg/l)	Phosphorus, Total as P (µg/l)	Salinity (ppth)	Secchi disk depth (m)	Specific conductance (mS/cm)	Sulfur, sulfate (SO4) as SO4 (mg/l)	Temperature, water (deg C)	Total Coliform (cfu/100ml)	Total Suspended Solids (TSS) (mg/l)	Turbidity (NTU)
23-21	Pinellas County	8/24/05	---	---	---	---	0.21	7.7	---	---	---	---	---	---	---	---	---	7.45	---	---	1.8	---	3287	---	33.70	---	---	---
23-22	Pinellas County	3/1/05	---	---	---	---	---	12.9	---	---	---	---	12.1	---	---	---	---	8.47	---	---	1.3	---	2409	---	20.93	---	---	---
23-22	Pinellas County	5/26/05	---	---	---	---	0.20	4.3	---	---	---	---	3.83	---	---	---	---	7.43	---	---	1.7	---	3069	---	27.63	---	---	---
23-22	Pinellas County	11/1/05	---	---	---	---	0.16	6.5	---	---	---	---	7.92	---	---	---	---	7.38	---	---	1.6	---	2934	---	21.46	---	---	---
23-22	Pinellas County	4/12/05	---	---	---	---	0.42	1.1	---	---	---	---	3.73	---	---	---	---	7.04	---	---	12.8	---	21245	---	24.72	---	---	---
23-22	Pinellas County	6/29/05	---	---	---	---	0.24	10.6	---	---	---	---	9.05	---	---	---	---	7.93	---	---	1.2	---	2265	---	31.21	---	---	---
23-22	Pinellas County	11/15/05	---	---	---	---	0.38	4.3	---	---	---	---	8.17	---	---	---	---	7.27	---	---	1.0	---	1782	---	24.24	---	---	---
23-22	Pinellas County	8/24/05	---	---	---	---	0.12	9.1	---	---	---	---	---	---	---	---	---	7.79	---	---	1.6	---	2971	---	33.27	---	---	---
23-22	Pinellas County	5/5/05	---	---	---	---	0.28	4.7	---	---	---	---	3.83	---	---	---	---	7.56	---	---	1.1	---	2071	---	23.68	---	---	---
TP 454	FDEP	2/13/06	130	80	---	120.0	0.40	9.2	87.8	699000	---	3000	---	240	3100	140	---	7.46	6	200	0.6	0.3	1274	99	13.19	3600	31	20
TP 454	FDEP	3/13/06	306	50	---	4.4	0.40	5.9	70.8	540	---	20	---	450	1900	1100	---	7.49	37	96	0.5	0.4	970	34	24.26	60	9	3.1
TP 454	FDEP	4/11/06	293	60	---	31.0	0.40	7.0	82.9	549	---	310	---	82	1600	32	---	7.51	58	200	0.5	0.4	933	28	23.83	490	12	6
TP 454	FDEP	6/13/06	102	80	4.2	3.8	0.80	3.8	46.9	206	---	8000	---	210	1500	82	---	7.25	45	230	0.2	0.6	375	18	26.22	70000	173	65
TP 454	FDEP	7/10/06	238	60	2.2	1.7	0.70	9.1	121.1	464	---	90	---	400	1700	53	---	7.02	23	130	0.4	0.6	828	17	30.31	2000	4	4.8
TP 454	FDEP	8/14/06	236	80	2.3	22.0	0.50	13.6	188.3	476	---	---	---	350	1700	96	---	7.45	26	190	0.4	0.4	841	21	32.44	---	6	12
TP 454	FDEP	10/9/06	322	50	2.2	0.9	0.40	4.6	57.3	559	---	---	---	1100	2200	1000	---	7.40	26	110	0.5	0.4	969	24	26.27	---	12	5.6
TP 454	FDEP	12/11/06	---	---	---	---	0.30	6.5	68.3	---	---	---	---	---	---	---	---	7.49	---	---	0.5	0.3	935	---	17.21	---	---	---
TP 454	FDEP	8/15/06	---	---	---	---	---	---	---	---	---	310	---	---	---	---	---	---	---	---	---	---	---	---	---	1	---	---
TP 454	FDEP	12/12/06	---	---	---	---	---	---	---	---	---	25	---	---	---	---	---	---	---	---	---	---	---	---	---	169	---	---

APPENDIX B

CHARACTERISTICS OF SURFACE WATER SAMPLES COLLECTED IN THE ROOSEVELT CREEK WATERSHED FROM AUGUST – OCTOBER 2009

1. **Field Measurements**
2. **Laboratory Analyses**

1. Field Measurements

Field Measurements Collected in Roosevelt Creek from August - October 2009

Site	Date	Time	Depth (m)	Temp. (°C)	pH (s.u.)	Cond. (µmho/cm)	TDS (mg/l)	Diss. O_2 (mg/l)	DO Sat. (%)	ORP (mV)
H-1	8/13/09	10:53	0.35	32.04	8.31	663	424	7.6	104	314
H-1	8/27/2009	10:48	0.16	28.95	7.49	676	433	5.7	74	267
H-1	9/10/2009	10:28	0.19	30.11	7.22	730	467	4.4	59	277
H-1	9/24/2009	11:16	0.49	29.98	7.14	639	409	4.7	63	255
	Mean Value:		**0.30**	**30.27**	**7.54**	**677**	**433**	**5.6**	**75**	**278**
	Minimum Value:		**0.16**	**28.95**	**7.14**	**639**	**409**	**4.4**	**59**	**255**
	Maximum Value:		**0.49**	**32.04**	**8.31**	**730**	**467**	**7.6**	**104**	**314**
H-2	8/13/09	10:12	0.08	30.18	7.06	703	450	0.8	11	-2
H-2	8/27/2009	11:00	0.40	28.64	7.13	650	416	1.7	21	6
H-2	9/10/2009	10:44	0.45	28.43	7.01	810	518	1.3	17	35
H-2	9/24/2009	11:29	0.27	29.66	6.90	670	429	1.2	16	6
H-2	10/8/2009	10:52	0.57	27.81	6.93	637	407	1.4	18	39
	Mean Value:		**0.35**	**28.94**	**7.01**	**694**	**444**	**1.3**	**17**	**17**
	Minimum Value:		**0.08**	**27.81**	**6.90**	**637**	**407**	**0.8**	**11**	**-2**
	Maximum Value:		**0.57**	**30.18**	**7.13**	**810**	**518**	**1.7**	**21**	**39**
H-3	8/13/09	10:10	0.42	30.38	7.29	327	209	2.7	35	275
H-3	8/27/2009	11:06	0.40	28.84	7.24	342	219	1.3	16	177
H-3	9/10/2009	10:42	0.35	28.95	7.09	382	244	1.2	16	130
H-3	9/24/2009	11:27	0.39	30.13	7.14	357	229	2.7	36	216
H-3	10/8/2009	10:45	0.40	28.71	7.07	386	247	1.0	13	127
	Mean Value:		**0.39**	**29.40**	**7.17**	**359**	**230**	**1.8**	**23**	**185**
	Minimum Value:		**0.35**	**28.71**	**7.07**	**327**	**209**	**1.0**	**13**	**127**
	Maximum Value:		**0.42**	**30.38**	**7.29**	**386**	**247**	**2.7**	**36**	**275**
H-4	8/13/09	8:38	0.22	29.83	7.29	1,803	1,154	3.2	42	214
H-4	8/27/2009	11:23	0.36	28.76	7.70	2,355	1,507	7.1	92	106
H-4	9/10/2009	10:56	0.36	28.55	7.17	566	362	2.0	26	108
H-4	9/24/2009	11:45	0.28	28.71	7.19	557	356	4.5	58	133
H-4	10/8/2009	11:05	0.27	29.20	7.32	532	340	3.4	45	228
	Mean Value:		**0.30**	**29.01**	**7.33**	**1,162**	**744**	**4.0**	**53**	**158**
	Minimum Value:		**0.22**	**28.55**	**7.17**	**532**	**340**	**2.0**	**26**	**106**
	Maximum Value:		**0.36**	**29.83**	**7.70**	**2,355**	**1,507**	**7.1**	**92**	**228**
H-5	8/13/09	8:54	0.23	28.19	7.36	487	312	5.4	69	252
H-5	8/27/2009	11:49	0.20	28.40	7.31	584	374	4.6	59	140
H-5	9/10/2009	11:21	0.29	30.02	7.86	717	459	7.9	104	263
H-5	9/24/2009	12:13	0.21	29.00	7.17	657	420	5.6	73	159
H-5	10/8/2009	11:19	0.28	29.16	7.58	732	469	4.9	64	253
	Mean Value:		**0.24**	**28.95**	**7.46**	**635**	**407**	**5.7**	**74**	**213**
	Minimum Value:		**0.20**	**28.19**	**7.17**	**487**	**312**	**4.6**	**59**	**140**
	Maximum Value:		**0.29**	**30.02**	**7.86**	**732**	**469**	**7.9**	**104**	**263**

Field Measurements Collected in Roosevelt Creek from August - October 2009

Site	Date	Time	Depth (m)	Temp. (°C)	pH (s.u.)	Cond. (µmho/cm)	TDS (mg/l)	Diss. O_2 (mg/l)	DO Sat. (%)	ORP (mV)
H-6	8/13/09	9:05	0.15	27.60	7.14	424	271	2.8	35	244
H-6	8/27/2009	11:37	0.13	26.73	7.26	571	366	3.1	39	127
H-6	9/10/2009	11:13	0.17	28.05	7.33	603	386	3.7	47	190
H-6	9/24/2009	12:03	0.18	28.22	7.20	627	401	2.6	34	178
H-6	10/8/2009	11:31	0.17	30.22	7.35	650	416	1.3	18	153
	Mean Value:		**0.16**	**28.16**	**7.26**	**575**	**368**	**2.7**	**35**	**178**
	Minimum Value:		**0.13**	**26.73**	**7.14**	**424**	**271**	**1.3**	**18**	**127**
	Maximum Value:		**0.18**	**30.22**	**7.35**	**650**	**416**	**3.7**	**47**	**244**
H-7	8/13/09	9:20	0.20	29.60	7.25	1,689	1,081	3.6	48	274
H-7	8/27/2009	12:10	0.24	28.45	7.34	2,203	1,410	4.8	62	232
H-7	9/10/2009	11:44	0.11	28.52	7.16	662	424	1.6	21	239
H-7	9/24/2009	12:33	0.16	28.80	7.07	634	405	1.4	19	226
H-7	10/8/2009	11:47	0.16	29.07	7.08	775	496	1.4	18	210
	Mean Value:		**0.17**	**28.89**	**7.18**	**1,193**	**763**	**2.6**	**33**	**236**
	Minimum Value:		**0.11**	**28.45**	**7.07**	**634**	**405**	**1.4**	**18**	**210**
	Maximum Value:		**0.24**	**29.60**	**7.34**	**2,203**	**1,410**	**4.8**	**62**	**274**
H-8	8/12/09	14:47	0.26	29.78	7.36	618	395	4.6	61	294
H-8	8/27/2009	8:45	0.20	26.66	7.15	520	333	0.9	12	152
H-8	9/10/2009	8:59	0.18	26.47	7.15	728	466	0.7	9	106
H-8	9/24/2009	10:59	0.47	28.28	7.11	607	389	3.8	49	252
H-8	10/8/2009	9:28	0.17	26.67	7.38	1,077	689	0.5	6	108
	Mean Value:		**0.26**	**27.57**	**7.23**	**710**	**454**	**2.1**	**27**	**182**
	Minimum Value:		**0.17**	**26.47**	**7.11**	**520**	**333**	**0.5**	**6**	**106**
	Maximum Value:		**0.47**	**29.78**	**7.38**	**1,077**	**689**	**4.6**	**61**	**294**
H-9	8/12/09	15:04	0.22	30.10	7.42	1,665	1,066	4.8	64	273
H-9	8/27/2009	8:36	0.26	27.55	7.16	1,884	1,206	1.5	20	228
H-9	9/10/2009	8:47	0.20	28.29	7.16	724	463	2.6	34	260
H-9	9/24/2009	10:49	0.21	28.40	7.01	691	442	1.3	17	224
H-9	10/8/2009	9:10	0.23	28.48	7.09	860	550	0.6	8	240
	Mean Value:		**0.22**	**28.56**	**7.17**	**1,165**	**745**	**2.2**	**29**	**245**
	Minimum Value:		**0.20**	**27.55**	**7.01**	**691**	**442**	**0.6**	**8**	**224**
	Maximum Value:		**0.26**	**30.10**	**7.42**	**1,884**	**1,206**	**4.8**	**64**	**273**
H-10	8/12/09	14:25	0.30	28.23	7.37	301	193	5.0	64	274
H-10	8/27/2009	8:21	0.21	26.69	7.29	567	363	1.6	20	228
H-10	9/10/2009	8:36	0.11	26.91	7.33	811	519	1.6	20	253
H-10	9/24/2009	10:39	0.23	27.39	7.13	563	360	1.1	14	239
H-10	10/8/2009	9:03	0.25	27.39	7.20	682	437	1.4	18	255
	Mean Value:		**0.22**	**27.32**	**7.26**	**585**	**374**	**2.1**	**27**	**250**
	Minimum Value:		**0.11**	**26.69**	**7.13**	**301**	**193**	**1.1**	**14**	**228**
	Maximum Value:		**0.30**	**28.23**	**7.37**	**811**	**519**	**5.0**	**64**	**274**

Field Measurements Collected in Roosevelt Creek from August - October 2009

Site	Date	Time	Depth (m)	Temp. (°C)	pH (s.u.)	Cond. (µmho/cm)	TDS (mg/l)	Diss. O_2 (mg/l)	DO Sat. (%)	ORP (mV)
H-11	8/12/09	14:10	0.11	29.27	7.28	1,348	863	1.5	19	228
H-11	8/27/2009				Dry - No monitoring performed					
H-11	9/10/2009				Dry - No monitoring performed					
H-11	9/24/2009				Dry - No monitoring performed					
H-11	10/8/2009				Dry - No monitoring performed					
	Mean Value:		**0.11**	**29.27**	**7.28**	**1,348**	**863**	**1.5**	**19**	**228**
	Minimum Value:		**0.11**	**29.27**	**7.28**	**1,348**	**863**	**1.5**	**19**	**228**
	Maximum Value:		**0.11**	**29.27**	**7.28**	**1,348**	**863**	**1.5**	**19**	**228**
H-12	8/12/09	13:26	0.08	28.33	7.11	876	561	1.2	15	152
H-12	8/27/2009	7:59	0.06	26.64	7.15	918	587	1.4	17	73
H-12	9/10/2009	8:07	0.12	27.01	6.83	1,119	716	0.7	9	-43
H-12	9/24/2009	8:34	0.15	27.28	6.86	937	600	0.8	10	54
H-12	10/8/2009	8:32	0.16	26.30	6.86	1,060	679	0.7	8	-97
	Mean Value:		**0.11**	**27.11**	**6.96**	**982**	**628**	**0.9**	**12**	**28**
	Minimum Value:		**0.06**	**26.30**	**6.83**	**876**	**561**	**0.7**	**8**	**-97**
	Maximum Value:		**0.16**	**28.33**	**7.15**	**1,119**	**716**	**1.4**	**17**	**152**
H-13	8/13/09	11:09	0.69	29.79	7.22	1,425	912	3.3	44	283
H-13	8/27/2009	10:12	0.61	27.67	7.24	1,796	1,150	2.6	34	246
H-13	9/10/2009	9:17	0.22	30.02	7.44	698	447	6.4	85	238
H-13	9/24/2009	8:55	0.59	28.20	7.00	679	434	0.8	10	245
H-13	10/8/2009	8:45	0.79	28.64	7.12	807	516	0.7	10	166
	Mean Value:		**0.58**	**28.86**	**7.20**	**1,081**	**692**	**2.8**	**36**	**235**
	Minimum Value:		**0.22**	**27.67**	**7.00**	**679**	**434**	**0.7**	**10**	**166**
	Maximum Value:		**0.79**	**30.02**	**7.44**	**1,796**	**1,150**	**6.4**	**85**	**283**
H-14	8/12/09	13:52	0.33	30.71	7.90	678	434	5.6	75	291
H-14	8/27/2009	12:31	0.23	28.84	8.04	690	442	8.0	104	241
H-14	9/10/2009	7:52	0.27	28.83	7.52	712	456	3.4	44	383
H-14	9/24/2009	8:20	0.31	28.98	7.32	630	403	4.0	53	322
	Mean Value:		**0.29**	**29.34**	**7.70**	**677**	**434**	**5.2**	**69**	**309**
	Minimum Value:		**0.23**	**28.83**	**7.32**	**630**	**403**	**3.4**	**44**	**241**
	Maximum Value:		**0.33**	**30.71**	**8.04**	**712**	**456**	**8.0**	**104**	**383**
H-15	8/12/09	11:28	0.38	31.40	7.18	1,959	1,254	2.1	28	310
H-15	8/27/2009	8:59	0.33	28.52	7.17	562	360	1.5	20	46
H-15	9/10/2009	9:13	0.39	28.77	7.19	501	321	1.2	16	141
H-15	9/24/2009	9:14	0.36	29.42	7.20	444	284	3.4	45	234
H-15	10/8/2009	10:07	0.41	27.79	7.20	479	307	0.7	9	163
	Mean Value:		**0.37**	**29.18**	**7.19**	**789**	**505**	**1.8**	**23**	**179**
	Minimum Value:		**0.33**	**27.79**	**7.17**	**444**	**284**	**0.7**	**9**	**46**
	Maximum Value:		**0.41**	**31.40**	**7.20**	**1,959**	**1,254**	**3.4**	**45**	**310**

Field Measurements Collected in Roosevelt Creek from August - October 2009

Site	Date	Time	Depth (m)	Temp. (°C)	pH (s.u.)	Cond. (µmho/cm)	TDS (mg/l)	Diss. O_2 (mg/l)	DO Sat. (%)	ORP (mV)
H-16	8/12/09	11:49	0.12	32.16	7.66	1,943	1,244	9.9	137	310
H-16	8/27/2009	9:14	0.13	28.50	7.36	1,306	836	4.9	64	248
H-16	9/10/2009	10:05	0.19	28.99	7.48	773	495	6.5	85	291
H-16	9/24/2009	9:31	0.14	29.07	7.12	794	508	3.9	51	256
H-16	10/8/2009	10:18	0.18	29.41	7.88	938	600	11.3	149	298
	Mean Value:		**0.15**	**29.63**	**7.50**	**1,151**	**737**	**7.3**	**97**	**281**
	Minimum Value:		**0.12**	**28.50**	**7.12**	**773**	**495**	**3.9**	**51**	**248**
	Maximum Value:		**0.19**	**32.16**	**7.88**	**1,943**	**1,244**	**11.3**	**149**	**310**
H-17	8/12/09	10:36	0.12	29.71	7.33	19,857	12,710	1.4	20	264
H-17	8/27/2009	9:37	0.34	28.38	7.51	26,822	17,170	1.4	20	228
H-17	9/10/2009	9:33	0.28	28.87	7.44	26,167	16,750	1.8	26	261
H-17	9/24/2009	10:12	0.21	28.95	6.98	7,633	4,885	2.1	28	213
H-17	10/8/2009	9:41	0.11	28.06	7.21	17,809	11,400	1.6	23	236
	Mean Value:		**0.21**	**28.79**	**7.29**	**19,658**	**12,583**	**1.7**	**23**	**240**
	Minimum Value:		**0.11**	**28.06**	**6.98**	**7,633**	**4,885**	**1.4**	**20**	**213**
	Maximum Value:		**0.34**	**29.71**	**7.51**	**26,822**	**17,170**	**2.1**	**28**	**264**
H-18	8/12/09	11:05	0.29	33.20	7.83	36,148	23,130	1.3	21	309
H-18	8/27/2009	9:51	0.25	28.58	7.55	29,783	19,060	1.4	21	225
H-18	9/10/2009	9:47	0.15	28.83	7.34	2,578	1,650	3.3	43	252
H-18	9/24/2009	10:21	0.41	31.20	7.39	32,162	20,580	2.8	43	259
H-18	10/8/2009	9:54	0.34	30.94	7.28	33,921	21,710	1.5	23	221
	Mean Value:		**0.29**	**30.55**	**7.48**	**26,918**	**17,226**	**2.1**	**30**	**253**
	Minimum Value:		**0.15**	**28.58**	**7.28**	**2,578**	**1,650**	**1.3**	**21**	**221**
	Maximum Value:		**0.41**	**33.20**	**7.83**	**36,148**	**23,130**	**3.3**	**43**	**309**

2. Laboratory Analyses

Characteristics of Roosevelt Creek Samples Collected from August - October 2009

Sample Site	Date	Alkalinity (mg/l)	NH$_3$ (µg/l)	NO$_X$ (µg/l)	Diss. Org. N (µg/l)	Part. N (µg/l)	Total N (µg/l)	SRP (µg/l)	Diss. Org. P (µg/l)	Part. P (µg/l)	Total P (µg/l)	Turbidity (NTU)	Color (Pt-Co)	TSS (mg/l)	Copper (µg/l)	Lead (µg/l)	Zinc (µg/l)	Chromium (µg/l)
H-1	8/13/09	98.4	27	5	535	375	942	1	1	37	39	4.9	20	2.6	4	<2	2	<2
H-1	8/27/09	126	419	20	347	1045	1831	10	14	174	198	4.1	35	36.0	<2	<2	2	7
H-1	9/10/09	136	178	9	541	697	1425	12	10	55	77	3.2	34	3.8	4	<2	<2	<2
H-1	9/24/09	128	227	27	386	518	1158	11	5	77	93	4.5	37	5.2	3	<2	<2	4
Mean Value:		**122**	**213**	**15**	**452**	**659**	**1339**	**9**	**8**	**86**	**102**	**4.2**	**32**	**11.9**	**3**	**<2**	**2**	**3**
Minimum Value:		**98.4**	**27**	**5**	**347**	**375**	**942**	**1**	**1**	**37**	**39**	**3.2**	**20**	**2.6**	**<2**	**<2**	**1**	**1**
Maximum Value:		**136**	**419**	**27**	**541**	**1045**	**1831**	**12**	**14**	**174**	**198**	**4.9**	**37**	**36.0**	**4**	**<2**	**2**	**7**
Log-Normal Mean:		**121**	**146**	**12**	**444**	**613**	**1299**	**6**	**5**	**72**	**86**	**4.1**	**31**	**6.6**	**3**	**<2**	**1**	**2**
H-2	8/13/09	142	72	4	608	374	1058	1	3	66	70	5.5	35	0.4	2	<2	<2	<2
H-2	8/27/09	137	16	3	441	52	512	1	7	13	21	0.7	30	1.0	<2	<2	<2	9
H-2	9/10/09	161	131	2	672	267	1072	5	2	22	29	0.8	39	0.8	2	<2	<2	<2
H-2	9/24/09	142	352	3	354	199	908	9	8	13	30	3.1	40	2.8	<2	<2	<2	<2
H-2	10/8/09	140	213	3	503	397	1116	12	15	26	53	0.7	36	0.8	<2	<2	<2	4
Mean Value:		**144**	**157**	**3**	**516**	**258**	**933**	**6**	**7**	**28**	**41**	**2.2**	**36**	**1.2**	**1**	**<2**	**<2**	**3**
Minimum Value:		**137**	**16**	**2**	**354**	**52**	**512**	**1**	**2**	**13**	**21**	**0.7**	**30**	**0.4**	**1**	**<2**	**<2**	**1**
Maximum Value:		**161**	**352**	**4**	**672**	**397**	**1116**	**12**	**15**	**66**	**70**	**5.5**	**40**	**2.8**	**2**	**<2**	**<2**	**9**
Log-Normal Mean:		**144**	**103**	**3**	**503**	**210**	**899**	**4**	**6**	**23**	**37**	**1.5**	**36**	**0.9**	**1**	**<2**	**<2**	**2**
H-3	8/13/09	125	35	32	284	119	470	1	4	31	36	1.9	31	1.6	2	<2	<2	<2
H-3	8/27/09	145	97	1	611	231	940	1	6	17	24	0.9	35	1.6	<2	<2	<2	6
H-3	9/10/09	147	69	19	534	125	747	15	1	9	25	0.7	31	0.6	2	<2	<2	<2
H-3	9/24/09	139	121	18	355	163	657	12	4	26	42	1.1	32	1.2	<2	<2	<2	2
H-3	10/8/09	146	203	30	356	170	759	21	14	23	58	0.5	32	2.1	<2	<2	<2	3
Mean Value:		**140**	**105**	**20**	**428**	**162**	**715**	**10**	**6**	**21**	**37**	**1.0**	**32**	**1.4**	**1.4**	**<2**	**<2**	**2.6**
Minimum Value:		**125**	**35**	**1**	**284**	**119**	**470**	**1**	**1**	**9**	**24**	**0.5**	**31**	**0.6**	**1.0**	**<2**	**<2**	**1.0**
Maximum Value:		**147**	**203**	**32**	**611**	**231**	**940**	**21**	**14**	**31**	**58**	**1.9**	**35**	**2.1**	**2.0**	**<2**	**<2**	**6.0**
Log-Normal Mean:		**140**	**90**	**13**	**411**	**157**	**697**	**5**	**4**	**20**	**35**	**0.9**	**32**	**1.3**	**1.3**	**<2**	**<2**	**2.0**
H-4	8/13/09	104	173	14	750	1070	2007	1	7	52	60	11.6	29	13.6	4	<2	2	<2
H-4	8/27/09	194	1020	3	699	836	2558	1	3	73	77	9.3	29	10.2	<2	<2	3	8
H-4	9/10/09	156	151	31	581	456	1219	12	1	32	45	1.7	35	3.0	2	<2	<2	<2
H-4	9/24/09	147	209	13	361	145	728	13	27	6	46	1.6	36	2.4	3	<2	<2	3
H-4	10/8/09	158	73	35	419	633	1160	5	19	91	115	1.6	37	4.9	<2	<2	6	3
Mean Value:		**152**	**325**	**19**	**562**	**628**	**1534**	**6**	**11**	**51**	**69**	**5.2**	**33**	**6.8**	**2**	**<2**	**3**	**3**
Minimum Value:		**104**	**73**	**3**	**361**	**145**	**728**	**1**	**1**	**6**	**45**	**1.6**	**29**	**2.4**	**1**	**<2**	**1**	**1**
Maximum Value:		**194**	**1020**	**35**	**750**	**1070**	**2558**	**13**	**27**	**91**	**115**	**11.6**	**37**	**13.6**	**4**	**<2**	**6**	**8**
Log-Normal Mean:		**149**	**210**	**14**	**540**	**518**	**1395**	**4**	**6**	**37**	**64**	**3.4**	**33**	**5.5**	**2**	**<2**	**2**	**2**

Characteristics of Roosevelt Creek Samples Collected from August - October 2009

Sample Site	Date	Alkalinity (mg/l)	NH_3 (µg/l)	NO_X (µg/l)	Diss. Org. N (µg/l)	Part. N (µg/l)	Total N (µg/l)	SRP (µg/l)	Diss. Org. P (µg/l)	Part. P (µg/l)	Total P (µg/l)	Turbidity (NTU)	Color (Pt-Co)	TSS (mg/l)	Copper (µg/l)	Lead (µg/l)	Zinc (µg/l)	Chromium (µg/l)
H-5	8/13/09	192	345	275	349	90	1059	11	6	42	59	3.2	54	4.6	2	<2	35	<2
H-5	8/27/09	222	320	360	468	116	1264	9	2	13	24	1.4	47	2.8	<2	<2	36	6
H-5	9/10/09	293	109	671	706	222	1708	11	4	3	18	2.3	41	2.4	4	<2	12	6
H-5	9/24/09	252	353	527	196	29	1105	10	1	1	12	2.4	37	1.6	3	<2	34	4
H-5	10/8/09	265	148	1304	122	84	1658	11	8	1	20	3.0	34	3.0	3	<2	64	7
Mean Value:		**245**	**255**	**627**	**368**	**108**	**1359**	**10**	**4**	**12**	**27**	**2.5**	**43**	**2.9**	**3**	**<2**	**36**	**5**
Minimum Value:		**192**	**109**	**275**	**122**	**29**	**1059**	**9**	**1**	**1**	**12**	**1.4**	**34**	**1.6**	**1**	**<2**	**12**	**1**
Maximum Value:		**293**	**353**	**1304**	**706**	**222**	**1708**	**11**	**8**	**42**	**59**	**3.2**	**54**	**4.6**	**4**	**<2**	**64**	**7**
Log-Normal Mean:		**242**	**229**	**539**	**308**	**89**	**1332**	**10**	**3**	**4**	**23**	**2.4**	**42**	**2.7**	**2**	**<2**	**32**	**4**
H-6	8/13/09	198	66	34	410	128	638	28	15	47	90	3.3	42	2.2	<2	<2	10	<2
H-6	8/27/09	268	68	20	583	92	763	9	6	29	44	4.2	43	6.5	4	<2	11	2
H-6	9/10/09	259	39	23	612	90	764	19	6	10	35	0.8	39	2.2	2	<2	2	6
H-6	9/24/09	289	63	8	513	162	746	10	7	35	52	2.2	44	2.4	<2	<2	3	4
H-6	10/8/09	303	40	3	658	275	976	17	17	102	136	7.7	52	8.1	<2	<2	6	7
Mean Value:		**263**	**55**	**18**	**555**	**149**	**777**	**17**	**10**	**45**	**71**	**3.6**	**44**	**4.3**	**2**	**<2**	**6**	**4**
Minimum Value:		**198**	**39**	**3**	**410**	**90**	**638**	**9**	**6**	**10**	**35**	**0.8**	**39**	**2.2**	**1**	**<2**	**2**	**1**
Maximum Value:		**303**	**68**	**34**	**658**	**275**	**976**	**28**	**17**	**102**	**136**	**7.7**	**52**	**8.1**	**4**	**<2**	**11**	**7**
Log-Normal Mean:		**261**	**54**	**13**	**548**	**136**	**770**	**15**	**9**	**34**	**63**	**2.8**	**44**	**3.6**	**2**	**<2**	**5**	**3**
H-7	8/13/09	113	397	66	618	737	1818	1	1	48	50	9.8	33	12.2	<2	<2	8	<2
H-7	8/27/09	120	1235	79	1494	993	3801	1	1	88	90	10.7	32	10.3	8	<2	8	<2
H-7	9/10/09	216	1838	256	1227	405	3726	31	6	67	104	4.7	38	4.4	2	<2	<2	2
H-7	9/24/09	216	1406	149	295	194	2044	37	1	105	143	4.0	44	3.6	5	<2	8	5
H-7	10/8/09	262	2290	192	987	403	3872	64	4	146	214	4.1	41	4.6	2	<2	2	5
Mean Value:		**185**	**1433**	**148**	**924**	**546**	**3052**	**27**	**3**	**91**	**120**	**6.7**	**38**	**7.0**	**4**	**<2**	**5**	**3**
Minimum Value:		**113**	**397**	**66**	**295**	**194**	**1818**	**1**	**1**	**48**	**50**	**4.0**	**32**	**3.6**	**1**	**<2**	**1**	**1**
Maximum Value:		**262**	**2290**	**256**	**1494**	**993**	**3872**	**64**	**6**	**146**	**214**	**10.7**	**44**	**12.2**	**8**	**<2**	**8**	**5**
Log-Normal Mean:		**175**	**1237**	**131**	**801**	**471**	**2896**	**9**	**2**	**85**	**107**	**6.0**	**37**	**6.2**	**3**	**<2**	**4**	**2**
H-8	8/12/09	250	3126	364	494	28	4012	10	21	60	91	4.4	57	3.2	4	<2	<2	<2
H-8	8/27/09	200	2538	7	344	147	3036	4	5	21	30	1.1	52	2.5	4	<2	<2	2
H-8	9/10/09	262	3128	13	1711	11	4863	24	1	14	39	1.3	480	4.4	<2	<2	<2	<2
H-8	9/24/09	234	2103	128	380	22	2633	10	6	22	38	1.3	44	2.0	3	<2	<2	4
H-8	10/8/09	401	3973	5	3441	44	7463	37	11	38	86	2.6	73	4.5	2	<2	<2	9
Mean Value:		**269**	**2974**	**103**	**1274**	**50**	**4401**	**17**	**9**	**31**	**57**	**2.1**	**141**	**3.3**	**3**	**<2**	**<2**	**3**
Minimum Value:		**200**	**2103**	**5**	**344**	**11**	**2633**	**4**	**1**	**14**	**30**	**1.1**	**44**	**2.0**	**1**	**<2**	**<2**	**1**
Maximum Value:		**401**	**3973**	**364**	**3441**	**147**	**7463**	**37**	**21**	**60**	**91**	**4.4**	**480**	**4.5**	**4**	**<2**	**<2**	**9**
Log-Normal Mean:		**262**	**2906**	**29**	**824**	**34**	**4104**	**13**	**6**	**27**	**51**	**1.8**	**86**	**3.2**	**2**	**<2**	**<2**	**2**

Characteristics of Roosevelt Creek Samples Collected from August - October 2009

Sample Site	Date	Alkalinity (mg/l)	NH_3 (µg/l)	NO_X (µg/l)	Diss. Org. N (µg/l)	Part. N (µg/l)	Total N (µg/l)	SRP (µg/l)	Diss. Org. P (µg/l)	Part. P (µg/l)	Total P (µg/l)	Turbidity (NTU)	Color (Pt-Co)	TSS (mg/l)	Copper (µg/l)	Lead (µg/l)	Zinc (µg/l)	Chromium (µg/l)
H-9	8/12/09	104	886	291	495	1541	3213	1	3	269	273	42.9	28	58.4	6	<2	4	<2
H-9	8/27/09	148	1525	96	188	950	2759	2	4	72	78	6.0	40	12.6	8	<2	2	<2
H-9	9/10/09	240	907	598	1075	434	3014	11	1	62	74	1.4	38	2.2	2	<2	<2	4
H-9	9/24/09	172	1701	190	243	150	2284	34	3	79	116	3.3	42	3.0	3	<2	3	4
H-9	10/8/09	296	697	1367	381	594	3039	9	15	50	74	1.7	46	2.2	2	<2	3	8
Mean Value:		**192**	**1143**	**508**	**476**	**734**	**2862**	**11**	**5**	**106**	**123**	**11.1**	**39**	**15.7**	**4**	**<2**	**3**	**4**
Minimum Value:		**104**	**697**	**96**	**188**	**150**	**2284**	**1**	**1**	**50**	**74**	**1.4**	**28**	**2.2**	**2**	**<2**	**1**	**1**
Maximum Value:		**296**	**1701**	**1367**	**1075**	**1541**	**3213**	**34**	**15**	**269**	**273**	**42.9**	**46**	**58.4**	**8**	**<2**	**4**	**8**
Log-Normal Mean:		**180**	**1078**	**337**	**392**	**563**	**2842**	**6**	**4**	**86**	**106**	**4.6**	**38**	**6.4**	**4**	**<2**	**2**	**3**
H-10	8/12/09	96.0	68	290	355	149	862	70	11	54	135	5.4	51	2.6	2	<2	5	<2
H-10	8/27/09	182	58	5	781	13	857	261	1	13	275	0.8	85	1.8	4	<2	5	8
H-10	9/10/09	260	42	12	1032	147	1233	291	2	14	307	1.0	71	4.8	<2	<2	<2	<2
H-10	9/24/09	185	37	3	701	48	789	411	65	53	529	0.8	84	0.6	3	<2	6	8
H-10	10/8/09	209	26	25	549	80	680	285	6	189	480	0.7	52	1.1	2	<2	3	8
Mean Value:		**186**	**46**	**67**	**684**	**87**	**884**	**264**	**17**	**65**	**345**	**1.7**	**69**	**2.2**	**2**	**<2**	**4**	**5**
Minimum Value:		**96**	**26**	**3**	**355**	**13**	**680**	**70**	**1**	**13**	**135**	**0.7**	**51**	**0.6**	**1**	**<2**	**1**	**1**
Maximum Value:		**260**	**68**	**290**	**1032**	**149**	**1233**	**411**	**65**	**189**	**529**	**5.4**	**85**	**4.8**	**4**	**<2**	**6**	**8**
Log-Normal Mean:		**177**	**44**	**17**	**643**	**64**	**867**	**228**	**6**	**40**	**311**	**1.2**	**67**	**1.7**	**2**	**<2**	**3**	**3**
H-11	8/12/09	176	221	131	597	704	1653	4	5	92	101	6.8	47	11.8	2	<2	4	<2
Mean Value:		**176**	**221**	**131**	**597**	**704**	**1653**	**4**	**5**	**92**	**101**	**6.8**	**47**	**11.8**	**2**	**<2**	**4**	**<2**
Minimum Value:		**176**	**221**	**131**	**597**	**704**	**1653**	**4**	**5**	**92**	**101**	**6.8**	**47**	**11.8**	**2**	**<2**	**4**	**<2**
Maximum Value:		**176**	**221**	**131**	**597**	**704**	**1653**	**4**	**5**	**92**	**101**	**6.8**	**47**	**11.8**	**2**	**<2**	**4**	**<2**
Log-Normal Mean:		**176**	**221**	**131**	**597**	**704**	**1653**	**4**	**5**	**92**	**101**	**6.8**	**47**	**11.8**	**2**	**<2**	**4**	**<2**
H-12	8/12/09	122	23	274	178	146	621	9	10	39	58	2.8	32	2.4	2	<2	3	<2
H-12	8/27/09	152	48	1	573	343	965	128	71	84	283	3.8	108	10.7	4	<2	3	<2
H-12	9/10/09	292	106	3	581	127	817	584	65	42	691	1.0	106	2.0	5	<2	3	9
H-12	9/24/09	248	6	1	493	64	564	459	306	186	951	5.6	154	11.4	3	<2	7	3
H-12	10/8/09	144	95	2	817	49	963	620	168	24	812	1.4	76	4.3	6	<2	6	2
Mean Value:		**192**	**56**	**56**	**528**	**146**	**786**	**360**	**124**	**75**	**559**	**2.9**	**95**	**6.2**	**4**	**<2**	**4**	**3**
Minimum Value:		**122**	**6**	**1**	**178**	**49**	**564**	**9**	**10**	**24**	**58**	**1.0**	**32**	**2.0**	**2**	**<2**	**3**	**1**
Maximum Value:		**292**	**106**	**274**	**817**	**343**	**965**	**620**	**306**	**186**	**951**	**5.6**	**154**	**11.4**	**6**	**<2**	**7**	**9**
Log-Normal Mean:		**181**	**37**	**4**	**474**	**115**	**767**	**180**	**75**	**57**	**388**	**2.4**	**84**	**4.8**	**4**	**<2**	**4**	**2**

Characteristics of Roosevelt Creek Samples Collected from August - October 2009

Sample Site	Date	Alkalinity (mg/l)	NH_3 (µg/l)	NO_X (µg/l)	Diss. Org. N (µg/l)	Part. N (µg/l)	Total N (µg/l)	SRP (µg/l)	Diss. Org. P (µg/l)	Part. P (µg/l)	Total P (µg/l)	Turbidity (NTU)	Color (Pt-Co)	TSS (mg/l)	Copper (µg/l)	Lead (µg/l)	Zinc (µg/l)	Chromium (µg/l)
H-13	8/13/09	126	507	95	652	602	1856	2	3	93	98	6.7	43	1.4	<2	<2	<2	<2
H-13	8/27/09	153	1152	82	451	682	2367	1	3	92	96	4.7	43	8.6	6	<2	2	4
H-13	9/10/09	240	825	557	980	98	2460	18	1	18	37	0.8	40	2.2	3	<2	<2	4
H-13	9/24/09	236	1579	173	401	227	2380	46	10	69	125	2.2	47	4.0	3	<2	14	7
H-13	10/8/09	276	408	1399	541	122	2470	45	8	21	74	0.8	46	1.2	4	<2	<2	<2
Mean Value:		**206**	**894**	**461**	**605**	**346**	**2307**	**22**	**5**	**59**	**86**	**3.0**	**44**	**3.5**	**3**	**<2**	**4**	**3**
Minimum Value:		**126**	**408**	**82**	**401**	**98**	**1856**	**1**	**1**	**18**	**37**	**0.8**	**40**	**1.2**	**1**	**<2**	**1**	**1**
Maximum Value:		**276**	**1579**	**1399**	**980**	**682**	**2470**	**46**	**10**	**93**	**125**	**6.7**	**47**	**8.6**	**6**	**<2**	**14**	**7**
Log-Normal Mean:		**198**	**791**	**254**	**574**	**257**	**2294**	**9**	**4**	**47**	**80**	**2.1**	**44**	**2.6**	**3**	**<2**	**2**	**3**
H-14	8/12/09	133	40	22	460	540	1062	2	4	74	80	4.2	50	7.2	6	<2	2	<2
H-14	8/27/09	145	128	1	344	903	1376	1	1	113	115	1.8	35	4.1	4	<2	2	5
H-14	9/10/09	148	40	6	1022	438	1506	4	8	33	45	2.5	26	3.2	5	<2	6	3
H-14	9/24/09	151	80	9	529	407	1025	1	12	10	23	1.6	33	1.8	5	<2	<2	<2
Mean Value:		**144**	**72**	**10**	**589**	**572**	**1242**	**2**	**6**	**58**	**66**	**2.5**	**36**	**4.1**	**5**	**<2**	**3**	**3**
Minimum Value:		**133.0**	**40**	**1**	**344**	**407**	**1025**	**1**	**1**	**10**	**23**	**1.6**	**26**	**1.8**	**4**	**<2**	**1**	**1**
Maximum Value:		**151**	**128**	**22**	**1022**	**903**	**1506**	**4**	**12**	**113**	**115**	**4.2**	**50**	**7.2**	**6**	**<2**	**6**	**5**
Log-Normal Mean:		**144**	**64**	**6**	**541**	**543**	**1226**	**2**	**4**	**41**	**56**	**2.3**	**35**	**3.6**	**5**	**<2**	**2**	**2**
H-15	8/12/09	136	114	19	565	465	1163	172	2	80	254	10.5	73	8.8	6	<2	<2	<2
H-15	8/27/09	137	168	10	829	492	1499	216	15	103	334	3.5	114	7.2	4	<2	<2	<2
H-15	9/10/09	144	149	8	974	532	1663	248	4	43	295	1.9	103	3.6	2	<2	<2	2
H-15	9/24/09	131	126	9	686	180	1001	123	10	74	207	2.1	111	3.1	<2	<2	3	<2
H-15	10/8/09	136	154	3	695	279	1131	321	9	71	401	3.0	98	8.4	2	<2	3	<2
Mean Value:		**137**	**142**	**10**	**750**	**390**	**1291**	**216**	**8**	**74**	**298**	**4.2**	**100**	**6.2**	**3**	**<2**	**2**	**1**
Minimum Value:		**131**	**114**	**3**	**565**	**180**	**1001**	**123**	**2**	**43**	**207**	**1.9**	**73**	**3.1**	**1**	**<2**	**1**	**1**
Maximum Value:		**144**	**168**	**19**	**974**	**532**	**1663**	**321**	**15**	**103**	**401**	**10.5**	**114**	**8.8**	**6**	**<2**	**3**	**2**
Log-Normal Mean:		**137**	**141**	**8**	**737**	**361**	**1268**	**205**	**6**	**71**	**291**	**3.4**	**99**	**5.7**	**2**	**<2**	**2**	**1**
H-16	8/12/09	160	277	145	760	1236	2418	1	2	117	120	8.9	37	6.2	<2	<2	<2	<2
H-16	8/27/09	145	715	125	623	561	2024	1	5	89	95	8.3	47	6.5	2	<2	<2	4
H-16	9/10/09	188	107	77	731	677	1592	7	3	52	62	2.4	49	2.2	2	<2	<2	<2
H-16	9/24/09	185	513	190	485	488	1676	71	4	57	132	1.3	58	2.4	<2	<2	<2	<2
H-16	10/8/09	225	68	321	446	609	1444	8	63	141	212	1.5	43	3.8	2	<2	3	<2
Mean Value:		**181**	**336**	**172**	**609**	**714**	**1831**	**18**	**15**	**91**	**124**	**4.5**	**47**	**4.2**	**2**	**<2**	**1**	**2**
Minimum Value:		**145**	**68**	**77**	**446**	**488**	**1444**	**1**	**2**	**52**	**62**	**1.3**	**37**	**2.2**	**1**	**<2**	**1**	**1**
Maximum Value:		**225**	**715**	**321**	**760**	**1236**	**2418**	**71**	**63**	**141**	**212**	**8.9**	**58**	**6.5**	**2**	**<2**	**3**	**4**
Log-Normal Mean:		**179**	**236**	**153**	**595**	**674**	**1799**	**5**	**6**	**85**	**115**	**3.2**	**46**	**3.8**	**2**	**<2**	**1**	**1**

Characteristics of Roosevelt Creek Samples Collected from August - October 2009

Sample Site	Date	Alkalinity (mg/l)	NH_3 (µg/l)	NO_X (µg/l)	Diss. Org. N (µg/l)	Part. N (µg/l)	Total N (µg/l)	SRP (µg/l)	Diss. Org. P (µg/l)	Part. P (µg/l)	Total P (µg/l)	Turbidity (NTU)	Color (Pt-Co)	TSS (mg/l)	Copper (µg/l)	Lead (µg/l)	Zinc (µg/l)	Chromium (µg/l)
H-17	8/12/09	209	256	127	365	177	925	95	10	32	137	3.5	52	5.6	6	<2	<2	<2
H-17	8/27/09	148	42	81	745	105	973	78	6	3	87	1.4	62	8.2	8	<2	<2	8
H-17	9/10/09	185	97	60	859	32	1048	102	22	11	135	1.9	41	3.2	20	<2	<2	<2
H-17	9/24/09	212	169	107	454	88	818	53	11	26	90	3.9	61	2.8	8	<2	5	<2
H-17	10/8/09	221	201	148	469	72	890	67	2	42	111	2.6	51	2.7	10	<2	<2	18
Mean Value:		**195**	**153**	**105**	**578**	**95**	**931**	**79**	**10**	**23**	**112**	**2.7**	**53**	**4.5**	**10**	**<2**	**2**	**6**
Minimum Value:		**148**	**42**	**60**	**365**	**32**	**818**	**53**	**2**	**3**	**87**	**1.4**	**41**	**2.7**	**6**	**<2**	**1**	**1**
Maximum Value:		**221**	**256**	**148**	**859**	**177**	**1048**	**102**	**22**	**42**	**137**	**3.9**	**62**	**8.2**	**20**	**<2**	**5**	**18**
Log-Normal Mean:		**193**	**129**	**100**	**549**	**82**	**928**	**77**	**8**	**16**	**110**	**2.5**	**53**	**4.1**	**9**	**<2**	**1**	**3**
H-18	8/12/09	205	149	81	369	82	681	86	11	33	130	6.8	34	6.4	2	<2	<2	<2
H-18	8/27/09	113	87	89	460	37	673	16	2	11	29	4.0	47	2.4	4	<2	<2	20
H-18	9/10/09	249	116	152	440	102	810	30	5	13	48	1.7	36	0.2	7	<2	<2	10
H-18	9/24/09	245	170	112	301	70	653	14	9	12	35	7.1	49	3.6	3	<2	9	<2
H-18	10/8/09	188	116	140	344	94	694	58	1	34	93	3.2	31	4.5	14	<2	2	28
Mean Value:		**200**	**128**	**115**	**383**	**77**	**702**	**41**	**6**	**21**	**67**	**4.6**	**39**	**3.4**	**6.0**	**<2**	**2.8**	**12.0**
Minimum Value:		**113**	**87**	**81**	**301**	**37**	**653**	**14**	**1**	**11**	**29**	**1.7**	**31**	**0.2**	**2.0**	**<2**	**1.0**	**1.0**
Maximum Value:		**249**	**170**	**152**	**460**	**102**	**810**	**86**	**11**	**34**	**130**	**7.1**	**49**	**6.4**	**14.0**	**<2**	**9.0**	**28.0**
Log-Normal Mean:		**193**	**124**	**111**	**378**	**73**	**700**	**32**	**4**	**18**	**57**	**4.0**	**39**	**2.2**	**4.7**	**<2**	**1.8**	**5.6**

APPENDIX C

ISOTOPE ANALYSIS REPORT FROM CLIMATE-WISE SOLUTIONS, INC.

CLIMATEWISE SOLUTIONS, LLC

Stable Isotope ($\delta^{15}N$ and $\delta^{18}O$) Composition of Nitrite+Nitrate of Surface Waters from Roosevelt Creek, Pinellas County, Florida

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Introduction

Nitrate (NO_3^-) in surface waters can originate from multiple sources, including fertilizer application, animal waste, septic systems, and soil and natural deposition. Stable isotope analysis can help distinguish which of the sources is more likely to contribute to contamination in a given site, because these sources often differ in stable isotope composition. For example, high δ^{15}N values can be traced to animal waste and sewage inputs (e.g., Wassenaar 1995; Kendall 1998; Kendall et al. 1996). Atmospheric N deposition as NO_3^- or NH_4^+, N derived from synthetic fertilizers, and soil-derived N typically differ in δ^{15}N and δ^{18}O (Table 1). Stable isotopes of oxygen are also useful in source partitioning, in some cases increasing resolution when combined with δ^{15}N. Atmospherically derived NO_3^- is enriched in δ^{18}O compared to synthetic fertilizer, and both tend to be enriched compared to NO_3^- produced in soils through microbial nitrification (Table 1).

One complication of source partitioning using stable isotopes of N and O in nitrate is that microbial transformations of nitrate can alter its isotopic signature, potentially obscuring the identity of the original source (Kellman 2005).

Table 1. Typical values and ranges (10-90% confidence limits) for δ^{15}N of ammonium and nitrate and δ^{18}O of nitrate from various sources.

Source	Species	δ^{15}N ‰	δ^{18}O ‰
Synthetic Fertilizer	Ammonium	-1.0 (-5.6 to 4.8)	
	Nitrate	1.0 (-4.4 to 6.1)	22.1(15.5 to 25.6)
Fertilizer from region**	Organic	7.4 ± 0.2	N.A.
Precipitation	Ammonium	-1.6 (-13.4 to 12.8)	
	Nitrate	0.2 (-7.8 to 8.7)	57.9 (25.6 to 77.2)
Manure	Ammonium	10.5 (5.3 to 25.3)	
Sewage and Wastewater	Ammonium	10.0 (4.3 to 19.6)	
Nitrification	Nitrate	3.5 (-4.1 to 7.9)	7.4 (0.4 to 15.1)+
Soils	Bulk	4.0 (-2.0 to 8.0)*	

*Unpublished data of Hungate et al. from Florida spodosols shows typical values of -6 to -2 for soil organic nitrogen in the region. Negative δ^{15}N values are typical of surface horizons with low clay content.

+ For the region in question, the δ^{18}O of precipitation is -2 to -6 ‰ vs SMOW (GNIP, www-naweb.iaea.org/napc/ih/GNIP/). In nitrification, two atoms of oxygen are derived from local water, and one from atmospheric O_2 (22.5 ‰), allowing theoretical prediction of the δ^{18}O of nitrate derived from nitrification, after allowing for 5 per mil enrichment of local water due to evaporative enrichment (Mayer et al. 2001). Therefore, the expected δ^{18}O of nitrate produced by nitrification is 3.8 to 11.5 ‰. Values within this range are consistent with *in situ* microbial origin.

**This datum is from direct analysis of δ^{15}N of organic fertilizer provided by ESS to CWS, analyzed at the CPSIL at Northern Arizona University. The composition of the fertilizer was: 16.4% N, 14.0% C, with a δ^{13}C value of -17.3 ‰ vs. PDB, consistent with an organic fertilizer (the label indicated urea and unspecified organic N were the major N sources).

Nitrification and denitrification are the major fractionating processes altering the isotopic composition of nitrate. Both processes preferentially utilize the lighter substrate, such that nitrification produces NO_3^- isotopically depleted compared to the NH_4^+ substrate, whereas denitrification preferentially utilizes isotopically depleted NO_3^-, leaving behind NO_3^- relatively enriched in δ^{15}N and δ^{18}O. Predictable relationships among NO_3^- concentration, δ^{15}N- NO_3^-, and δ^{18}O-NO_3^- provide one means of detecting whether denitrification is influencing the isotopic composition of NO_3^-. For example, co-varying enrichment of δ^{15}N and δ^{18}O in nitrate provides evidence for denitrification, if the ratio of enrichments are between 1.3:1 and 2.1:1 (Aravena and Robertson 1998, Fukada et al. 2003). In a system where nitrate inputs are negligible, a negative relationship between [NO_3^-] and δ^{15}N-NO_3^- with a slope consistent with microbial fractionation during denitrification can also be used as diagnostic for the importance of denitrification as a loss pathway, or, in source identification, for the need to consider internal changes to δ^{15}N values observed in situ to the expected δ^{15}N signature of the NO_3^- source. Analysis of δ^{15}N-NH_4^+, and nitrification and denitrification rates at a given site can also constrain the influence of these processes on the observed isotopic signatures.

In the study conducted here, surface and ground water samples from a number of sites in two sub-basins feeding Lake Tibet, Florida, were analyzed for NO_x [NO_3^- + NO_2^-], $\delta^{15}N$-NO_3^- and $\delta^{18}O$-NO_3^-. N fertilizer used in the region was also analyzed for $\delta^{15}N$. Three general questions were addressed: 1) are there changes in NO_3^-, $\delta^{15}N$, and $\delta^{18}O$ signatures within these systems that is consistent with internal microbial processing, and if so, is it possible to constrain the $\delta^{15}N$ and $\delta^{18}O$ signature of NO_3^- entering these systems? 2) Are there spatial and temporal patterns in $\delta^{15}N$, $\delta^{18}O$, and [NO_x] throughout the area sampled, such that adjacent sites are more likely to be similar (i.e., share a common source)? And 3) Do the estimates of the $\delta^{15}N$ and $\delta^{18}O$ signature of source NO_3^- match any of the putative sources identified?

Methods

Samples were collected in the field and shipped to the Colorado Plateau Stable Isotope Laboratory at Northern Arizona University for preparation and analysis. Samples were measured for NO_3^- concentrations using automated colorimetry on a Lachat QuikChem 8000, to determine appropriate volumes for isotope analyses. The denitrifier method was used to measure the $\delta^{15}N$ and $\delta^{18}O$ composition of nitrate in each water sample (Sigman et al. 2001, Casciotti et al. 2002, Révész and Casciotte 2007). In this method, isotopes of both elements are measured simultaneously after the nitrate is converted to nitrous oxide (N_2O). Mass ratios of 45:44 and 46:44 distinguish $\delta^{15}N$ and $\delta^{18}O$ signatures, respectively. *Pseudomonas aureofaciens* lacks N_2O reductase, the enzyme that converts N_2O to N_2 during denitrification, so the reaction stops at N_2O, unlike normal denitrification which converts most of the NO_3^- to N2. *P. aureofaciens* cultures were grown in tryptic soy broth, centrifuged to concentrate bacterial cells, and then concentrated suspensions of cells are added to sealed vials with headspace. The headspace vials were purged with He gas to promote the anaerobic conditions suitable for denitrification, and then environmental samples containing NO_3^- were added to the vials, the volume of sample adjusted to obtain sufficient N_2O for analysis. Several drops of antifoaming agent were added to each vial to reduce bubble formation during the reaction. The vials were allowed to incubate for 8 hours, during which time NO_3^- is converted completely to N_2O. After the 8-hour period, 0.1 mL of 10N NaOH was added to each vial to stop the reaction, and to absorb CO_2, which can interfere with N_2O analysis (since CO_2 has the same masses as N_2O, 44, 45, and 46). The samples were then placed on an autosampler tray interfaced with the mass spectrometer, and interspersed with standards with known $\delta^{15}N$ and $\delta^{18}O$ composition (USGS32, USGS 34, USGS 35, and IAEA NO3).

Results

Nitrate + Nitrite (NO_x) concentrations

Nineteen of the 81 samples analyzed had NO_x concentrations lower than the detection limits of the method (0.02 mg N L^{-1}). These samples were distributed throughout the dataset. For calculation purposes, NOx concentrations in these samples are assumed to be 0.01 mg N L-1, midway between the detection limit and zero.

NO_x concentrations varied from below detection limit (0.02 mg N L^{-1}) to 3.98 mg N L^{-1}, with an average of 0.37 and a median of 0.09 mg N L^{-1}. Mean NO_x concentrations were similar between tributary and main channel sites (Table 1). In both the main channel and tributary sites, NO_x concentrations increased over time (Figure 1), at an average rate of 0.0155 mg N L^{-1} d^{-1} for the tributaries (r=0.40), and 0.0116 mg N L^{-1} d^{-1} for the main channel (r=0.33). In general, increased concentration was associated with reduced precipitation during the preceding week, suggesting that higher NO_x concentrations were associated with reduced water inputs throughout the basin (Figure 2).

Mean NO_x concentrations in the main channel were lower at upstream sites H-2 and H-4 compared to downstream sites H-7, H-9, and H-13, falling again at site H-16. Concentrations at each site varied over time. There was a tendency for higher concentrations during the later sampling dates (Table 1), a trend which was only marginally significant in a multiple regression (P=0.075, Table 5).

NOx concentrations in the tributary sites varied (Table 1). Sites H-15 had consistently low NOx concentrations, either below or right at detection limits. For each of sites H-1, H-3, H-6, H-12, and H-14, all but one sample were below 0.10 mg N L-1, with higher concentrations measured for each site on only one sampling date, though the particular date with higher concentrations was not consistent across sites. Sites H-5, H-8, and H-10 had higher (and more consistently high) NOx concentrations compared to the other sites. Sites H-17 and H-18 had intermediate NOx concentrations. In general, NOx concentrations in the tributary sites increased over time (Table 5, multiple regression).

δ^{15}N and δ^{18}O of Nitrate + Nitrite (NO_x)

All samples had sufficient NO_x for isotope determination, even those below the detection limits for colorimetric determination of NO_x concentrations, consistent with NO_x of at least 0.005 mg N L^{-1}. On average, δ^{15}N and δ^{18}O values of NO_x were low to intermediate. Across all sites and times, δ^{15}N averaged 2.3 (±0.7) ‰, and δ^{18}O averaged 4.2 (±1.6) ‰. δ^{15}N values ranged from -18.5 to 13.8 ‰, and δ^{18}O values ranged from -19.6 to 62.6 ‰. In the main channel sites, δ^{15}N-NO_x increased downstream and over time, and δ^{18}O-NO_x declined downstream and through time, both patterns revealed by multiple regression (Table 5). δ^{15}N and δ^{18}O signatures were not systematically related to NO_x concentrations (Table 5). These patterns suggest temporal and spatial changes in the sources of NO_x in the watershed. In the tributary sites, δ^{18}O-NO_x decreased over time, the same pattern found in the main stem, but no systematic temporal pattern emerged for δ^{15}N-NO_x, nor any spatial trend for either isotope (Table 5).

During the 12 and 13 August sample date, some sites had unusually high δ^{18}O signatures (above 17 per mil and as high as 62.6 per mil, Table 3), including sites H-2, H-4, H-6, H-8, H-9, H-10, H-11, H-12, and H-14. Such high δ^{18}O signatures, and the broad distribution of the signature across the watershed, are consistent with NO_x in atmospheric deposition, including precipitation. NO_x concentrations in these samples ranged from below detection limits (H-2) to 0.37 mg N L^{-1} (H-8, see Table 1), the higher concentrations indicating the potential for atmospheric deposition to be an appreciable source of NO_x to the watershed during some periods of time.

δ^{15}N and δ^{18}O NO_x signatures from both tributary and main stem sites were primarily consistent with manure, sewage, and *in situ* nitrification of soil N as major sources of NO_x. Some δ^{15}N-δ^{18}O pairs from tributary sites were unusually low, but these typically had quite low NO_x concentrations as well, and thus are likely unimportant sources of NO_x to the watershed.

No evidence for in situ denitrification

Two lines of evidence could support *in situ* denitrification as a major pathway of NO_3^- removal, and thus as a confounding signal for interpreting isotopes in source partitioning. One sign of denitrification is a negative slope for the relationship between [NO_3^-] and δ^{15}N-NO_3^-, reflecting preferential removal of ^{14}N-NO_3^- through denitrification. Another sign is a positive relationship between δ^{15}N and δ^{18}O with a characteristic slope (from 1.3 to 2.1, Aravena and Robertson 1998, Fukada et al. 2003), reflecting the greater fractionation against ^{18}O because of the larger mass difference between ^{18}O and ^{16}O compared to ^{15}N and ^{14}N. Neither analysis provided any evidence that denitrification influenced the δ^{15}N and δ^{18}O values of NO_x in the Roosevelt Creek system (Table 4). Whether analyzed over the entire dataset (combining sites and times), or by individual site, or by sample date, significant relationships between δ15N and [NO_x] or between δ^{15}N and δ^{18}O were rare. Even when they occurred, the nature of the relationship was inconsistent with denitrification. For example, for site H-15, the relationship between δ^{15}N and [NO_x] was strong, but positive – opposite the direction expected for denitrification. For site H-7, δ^{15}N and δ^{18}O were correlated, but the correlation was negative, again opposite the expectation for denitrification. Furthermore, strong correlations were rare, suggesting that denitrification, to the extent it occurred, had only a minor influence on [NO_x] concentrations and isotopic signatures throughout the Roosevelt Creek system. The absence of a strong denitrification signal supports direct interpretation of the δ^{15}N and δ^{18}O values in source identification.

Conclusions: Source identification

The measured δ^{15}N and δ^{18}O values are primarily consistent with manure, sewage, and wastewater inputs as sources of NO_x in Roosevelt Creek (Figure 4). *In situ* nitrification of soil organic matter cannot be ruled out, but is less likely, as measured signatures of δ^{15}N and δ^{18}O were less frequently consistent with a putative soil source than with manure, sewage and wastewater. There was also strong evidence in elevated δ^{18}O signatures for atmospheric inputs at the earliest sample dates (12 and 13 August).

Citations

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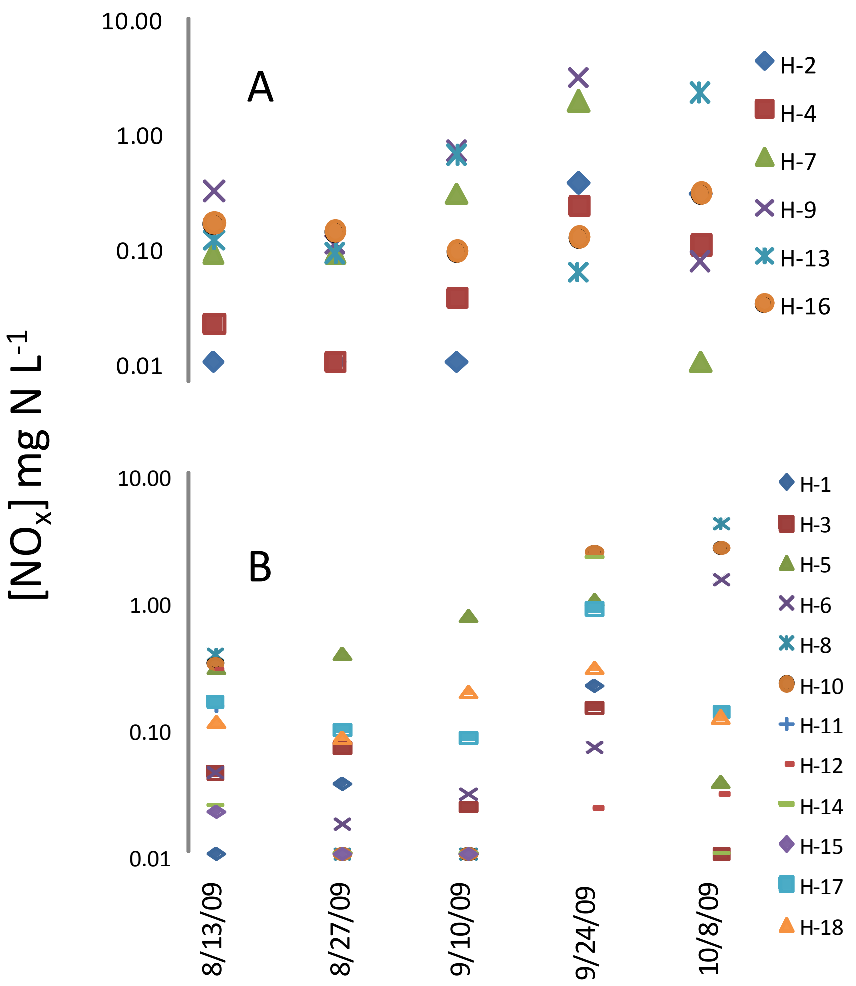

Figure 1. Concentrations of NO$_x$ (mg N L^{-1}, log scale) in the main channel (A) and in the tributaries (B) increase over time.

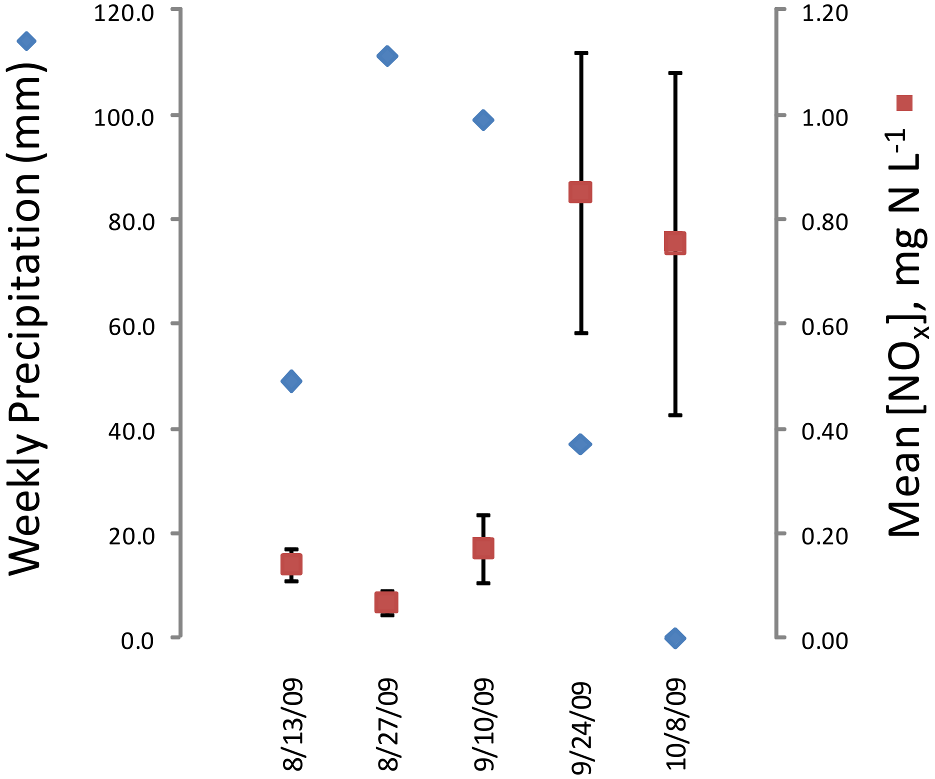

Figure 2. NO$_x$ concentration (right axis, squares) and cumulative, local precipitation one week prior to the sampling date (left axis, diamonds). NO$_x$ and precipitation inversely related, r=-0.80, suggesting that increased rainfall dilutes NO$_x$ concentrations. Precipitation may be a major driver of NO$_x$ concentrations throughout the Roosevelt Creek system.

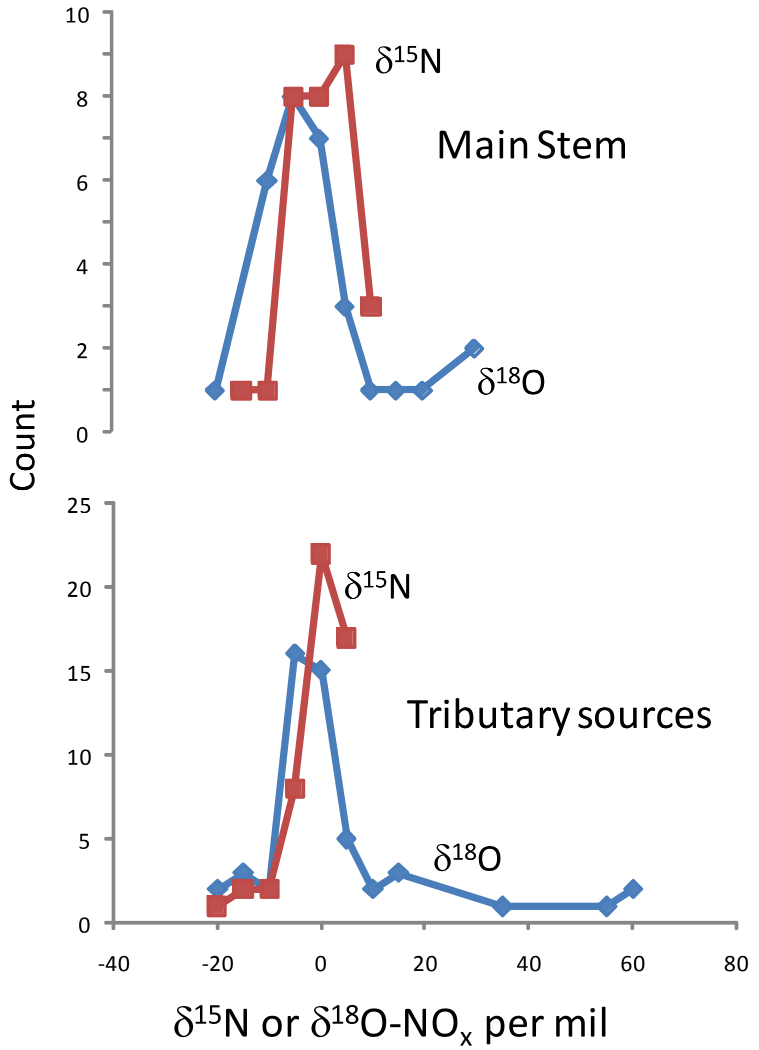

Figure 3. Frequency distribution of $\delta^{15}N$ and $\delta^{18}O$ in main stem (A) and tributary (B) sites in the Roosevelt Creek watershed. $\delta^{15}N$ and $\delta^{18}O$ values are plotted on the x-axis, with the number of cases on the y (count).

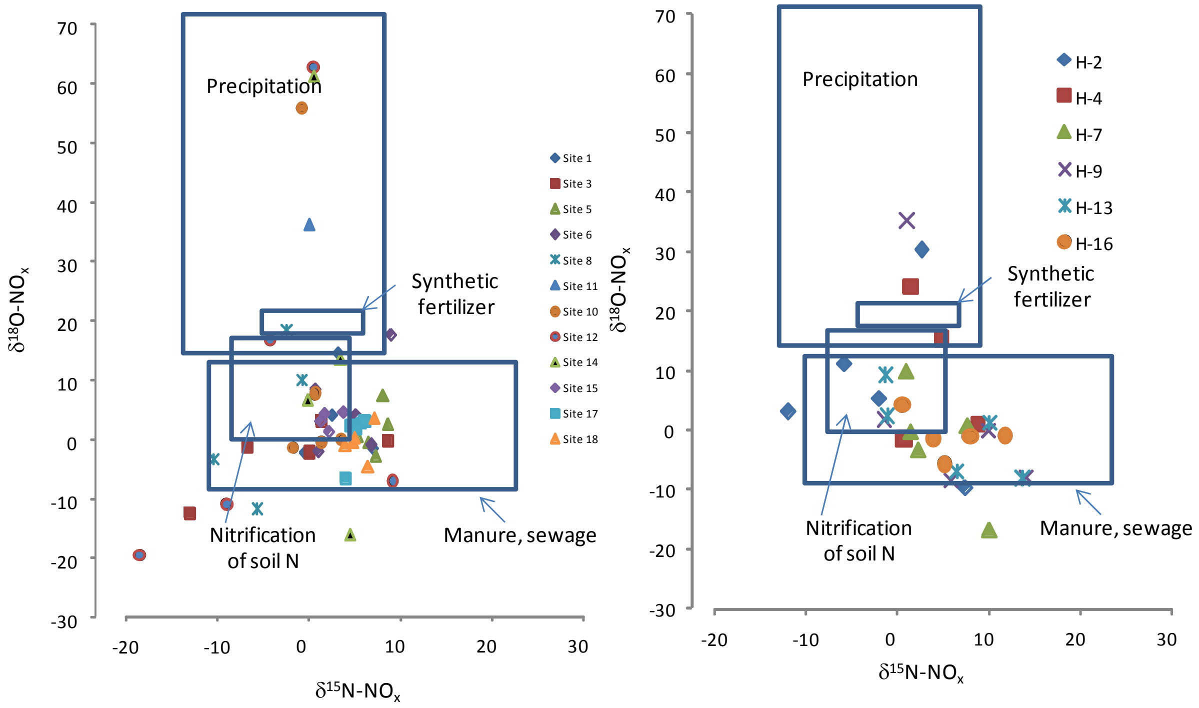

Figure 4. δ^{15}N and δ^{18}O of NO$_x$ in (A) tributary input sites and (B) main channel sites. Also shown are typical ranges of isotopic signatures for primary sources of N to ecosystems (blue boxes, from Kendall 1998 and Kool 2010).

APPENDIX D

FIELD AND LABORATORY QA / QC DATA

Roosevelt Creek Project

Matrix Spike Recovery Study

Samples Collected from August - October 2009

PARAMETERS	UNITS	SAMPLE ID	SAMPLE DESCRIPTION	DATE COLLECTED	DATE RECEIVED	DATE ANALYZED	INITIAL CONC.	INITIAL VOLUME (ml)	SPIKE CONC.	SPIKE VOLUME ADDED (ml)	Dilution Factor	THEOR. CONC.	ACTUAL CONC.	PERCENT RECOVERY	ACCEPTANCE RANGE
Alkalinity	mg/l	09-2563	H-5	08/13/09	08/13/09	08/13/09	192	50	1,000	0.5	1	202	212	105%	95.6 - 105
Alkalinity	mg/l	09-2779	H-17	08/27/09	08/27/09	08/28/09	146	50	1,000	0.5	1	156	160	103%	95.6 - 105
Alkalinity	mg/l	09-3059	H-1	09/10/09	09/10/09	09/10/09	136	50	1,000	0.5	1	146	147	101%	95.6 - 105
Alkalinity	mg/l	09-3069	H9	09/10/09	09/10/09	09/10/09	241	50	1,000	0.5	1	251	260	104%	95.6 - 105
Alkalinity	mg/l	09-3414	H-15	09/24/09	09/24/09	09/25/09	130	50	1,000	0.5	1	140	142	101%	95.6 - 105
Alkalinity	mg/l	09-3615	H-18	10/08/09	10/08/09	10/09/09	186	50	1,000	0.4	1	194	204	105%	95.6 - 105
Turbidity	NTU	09-2563	H-5 Dup	08/13/09	08/13/09	08/14/09	3.3	50	4,000	0.25	1	23	23	97%	87.4 - 110
Turbidity	NTU	09-2770	H-9	08/27/09	08/27/09	08/27/09	6.2	50	4,000	0.25	1	26	27	101%	87.4 - 110
Turbidity	NTU	09-3059	H-1	09/10/09	09/10/09	09/11/09	3.2	50	4,000	0.25	1	23	24	102%	87.4 - 110
Turbidity	NTU	09-3416	H17	09/24/09	09/24/09	09/25/09	3.7	50	4,000	0.25	1	24	22	92%	87.4 - 110
Turbidity	NTU	09-2556	H-18	08/12/09	08/12/09	08/14/09	6.8	50	4,000	0.25	1	27	27	101%	87.4 - 110
Turbidity	NTU	09-3606	H-9	10/08/09	10/08/09	10/09/09	1.7	50	4,000	0.375	1	32	31	98%	87.4 - 110
SRP	µg/l	09-2779f	H-17	08/27/09	08/27/09	08/28/09	78	10	10,000	0.4	1	478	489	102%	90-110
SRP	µg/l	09-3059F	H-1	09/10/09	09/10/09	09/11/09	12	10	10,000	0.3	1	312	281	90%	90-110
SRP	µg/l	09-3078F	H-18	09/10/09	09/10/09	09/11/09	30	10	10,000	0.3	1	330	308	93%	90-110
SRP	µg/l	09-3415f	H-16	09/24/09	09/24/09	09/25/09	71	10	10,000	0.5	1	571	532	93%	90-110
SRP	µg/l	09-3615f	H-18	10/08/09	10/08/09	10/09/09	58	10	10,000	0.5	1	558	543	97%	90-110
NOx	µg/l	09-2558f	H-1	08/13/09	08/13/09	08/14/09	5	10	100,000	0.15	1	1505	1410	94%	92-111
NOx	µg/l	09-2779f	H-17	08/27/09	08/27/09	08/28/09	81	10	100,000	0.1	1	1081	1136	105%	92-111
NOx	µg/l	09-3059F	H-1	09/10/09	09/10/09	09/11/09	9	10	100,000	0.2	1	2009	2167	108%	92-111
NOx	µg/l	09-3078F	H-18	09/10/09	09/10/09	09/11/09	152	10	100,000	0.2	1	2152	2170	101%	92-111
NOx	µg/l	09-3415f	H-16	09/24/09	09/24/09	09/25/09	190	10	100,000	0.1	1	1190	1215	102%	92-111
Total N	µg/l	09-2548Fp	H-11	08/12/09	08/12/09	11/04/09	949	5	100,000	0.1	1	2949	2979	101%	90-110
Total N	µg/l	09-2552p	H-14 Field Dup	08/12/09	08/12/09	11/04/09	1008	5	100,000	0.1	1	3008	2880	96%	90-110
Total N	µg/l	09-2567Fp	H-13	08/13/09	08/13/09	11/04/09	1254	5	100,000	0.1	1	3254	3380	104%	90-110
Total N	µg/l	09-3598Fp	H-2	10/08/09	10/08/09	11/09/09	719	5	100,000	0.1	1	2719	2949	108%	90-110
Total N	µg/l	09-2776Fp	H-14	08/27/09	08/27/09	11/10/09	473	5	100,000	0.1	1	2473	2652	107%	90-110
Total N	µg/l	09-3069p	H-9	09/10/09	09/10/09	11/12/09	3014	5	100,000	0.15	1	6014	5647	94%	90-110
Total P	µg/l	09-2548Fp	H-11	08/12/09	08/12/09	11/04/09	9	5	50,000	0.05	1	509	483	95%	94-106
Total P	µg/l	09-2552p	H-14 Field Dup	08/12/09	08/12/09	11/04/09	89	5	50,000	0.05	1	589	563	96%	94-106
Total P	µg/l	09-2567Fp	H-13	08/13/09	08/13/09	11/04/09	5	5	50,000	0.05	1	505	477	94%	94-106
Total P	µg/l	09-3598Fp	H-2	10/08/09	10/08/09	11/09/09	27	5	50,000	0.05	1	527	535	102%	94-106
Total P	µg/l	09-2776Fp	H-14	08/27/09	08/27/09	11/10/09	1	5	50,000	0.05	1	501	469	94%	94-106
Total P	µg/l	09-3069p	H-9	09/10/09	09/10/09	11/12/09	74	5	50,000	0.05	1	574	555	97%	94-106

Roosevelt Creek Project

Matrix Spike Recovery Study

Samples Collected from August - October 2009

PARAMETERS	UNITS	SAMPLE ID	SAMPLE DESCRIPTION	DATE COLLECTED	DATE RECEIVED	DATE ANALYZED	INITIAL CONC.	INITIAL VOLUME (ml)	SPIKE CONC.	SPIKE VOLUME ADDED (ml)	Dilution Factor	THEOR. CONC.	ACTUAL CONC.	PERCENT RECOVERY	ACCEPTANCE RANGE
Ammonia	µg/l	09-2545p	H-8	08/12/09	08/12/09	08/19/09	3126	10	10,000	1.0	1	4126	4092	99%	80-120
Ammonia	µg/l	09-2565p	H-6	08/13/09	08/13/09	08/19/09	66	10	10,000	1.0	1	1066	1098	103%	80-120
Ammonia	µg/l	09-2770p	H-9	08/27/09	08/27/09	09/18/09	1525	10	10,000	1.0	1	2525	2572	102%	80-120
Ammonia	µg/l	09-3059p	H-1	09/10/09	09/10/09	09/23/09	54	10	10,000	0.8	1	804	764	95%	80-120
Ammonia	µg/l	09-3416p	H-17	09/24/09	09/24/09	10/14/09	169	10	10,000	0.8	1	919	849	92%	80-120
Ammonia	µg/l	09-3615p	H-18	10/08/09	10/08/09	10/29/09	116	10	10,000	0.1	1	216	235	109%	80-120
Color	PCU	09-2563f	H-5	08/13/09	08/13/09	08/14/09	54	25	500	1	5	154	138	90%	80-120
Color	PCU	09-2567f	H-13	0812/09	0812/09	08/14/09	43	25	500	0.15	5	58	59	102%	80-120
Color	PCU	09-2780f	H-18	08/27/09	08/27/09	08/28/09	50	25	500	0.75	5	125	125	100%	80-120
Color	PCU	09-3059f	H-1	09/10/09	09/10/09	09/11/09	35	25	500	0.75	2	65	63	97%	80-120
Color	PCU	09-3416f	H-17	09/24/09	09/24/09	09/25/09	68	25	500	0.75	5	143	144	101%	80-120
Color	PCU	09-3615f	H-18	10/08/09	10/08/09	10/09/09	44	25	500	0.75	5	119	113	95%	80-120
Copper	µg/l	09-3403	H-6	09/24/09	09/24/09	11/30/09	2	100	100,000	0.15	1	152	160	105%	94-104
Copper	µg/l	09-3602	H-6	10/08/09	10/08/09	11/30/09	0	100	100,000	0.125	1	125	117	94%	94-104
Copper	µg/l	09-3563	H-5	08/13/09	08/13/09	11/30/09	0	100	100,000	0.15	1	150	140	94%	94-104
Copper	µg/l	09-3062	H-4	09/10/09	09/10/09	11/30/09	0	100	100,000	0.15	1	150	142	95%	94-104
Lead	µg/l	09-2563	H-5	08/13/09	08/13/09	12/02/09	2	100	100,000	0.225	1	227	240	106%	94-106
Lead	µg/l	09-3062	H-4	09/10/09	09/10/09	12/02/09	0	100	100,000	0.225	1	225	232	103%	94-106
Lead	µg/l	09-3403	H-6	09/24/09	09/24/09	12/02/09	0	100	100,000	0.225	1	225	234	104%	94-106
Lead	µg/l	09-3602	H-6	10/08/09	10/08/09	12/02/09	10	100	100,000	0.175	1	185	192	104%	94-106
Zinc	µg/l	09-2563	H-5	08/13/09	08/13/09	12/03/09	35	100	100,000	0.2	1	235	225	96%	95-110
Zinc	µg/l	09-3062	H-4	09/10/09	09/10/09	12/03/09	0	100	100,000	0.2	1	200	195	98%	95-110
Zinc	µg/l	09-3403	H-6	09/24/09	09/24/09	12/03/09	3	100	100,000	0.15	1	153	168	110%	95-110
Zinc	µg/l	09-3602	H-6	10/08/09	10/08/09	12/03/09	6	100	100,000	0.15	1	156	169	108%	95-110
Chromium	µg/l	09-2563	H-5	08/13/09	08/13/09	11/25/09	0	100	1,000,000	0.175	1	1750	1840	105%	95-110
Chromium	µg/l	09-3062	H-4	09/10/09	09/10/09	11/25/09	6	100	1,000,000	0.2	1	2006	2210	110%	95-110
Chromium	µg/l	09-3403	H-6	09/24/09	09/24/09	12/08/09	4	100	1,000,000	0.02	1	204	221	108%	95-110
Chromium	µg/l	09-3602	H-6	10/08/09	10/08/09	12/08/09	7	100	10,000	2.5	1	257	250	97%	95-110

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PARAMETERS	UNITS	SAMPLE ID	SAMPLE DESCRIPTION	DATE COLLECTED	DATE RECEIVED	DATE ANALYZED	REPEAT 1	REPEAT 2	MEAN	s	% RELATIVE STD. DEVIATION (RSD)	ACCEPTANCE RANGE (% RSD)
Alkalinity	mg/l	09-2553	H-15	08/12/09	08/12/09	08/13/09	136	136	136.0	0.0	**0.0**	0-4
Alkalinity	mg/l	09-2563	H-5	08/13/09	08/13/09	08/13/09	192	192	192.0	0.0	**0.0**	0-4
Alkalinity	mg/l	09-2567	H-13	08/13/09	08/13/09	08/13/09	126	126	126.0	0.0	**0.0**	0-4
Alkalinity	mg/l	09-2769	H-8	08/27/09	08/27/09	08/28/09	200	200	200.0	0.0	**0.0**	0-4
Alkalinity	mg/l	09-2779	H-17	08/28/09	08/28/09	08/28/09	148	146	147.0	1.4	**1.0**	0-4
Alkalinity	mg/l	09-3059	H-1	09/10/09	09/10/09	09/10/09	136	137	136.5	0.7	**0.5**	0-4
Alkalinity	mg/l	09-3069	H-9	09/10/09	09/10/09	09/10/09	240	241	240.5	0.7	**0.3**	0-4
Alkalinity	mg/l	09-3078	H-18	09/10/09	09/10/09	09/10/09	249	248	248.5	0.7	**0.3**	0-4
Alkalinity	mg/l	09-3404	H-7	09/24/09	09/24/09	09/25/09	216	215	215.5	0.7	**0.3**	0-4
Alkalinity	mg/l	09-3414	H-15	09/24/09	09/24/09	09/25/09	131	130	130.5	0.7	**0.5**	0-4
Alkalinity	mg/l	09-3605	H-8	10/08/09	10/08/09	10/09/09	401	400	400.5	0.7	**0.2**	0-4
Turbidity	NTU	09-2553	H-15	08/12/09	08/12/09	08/14/09	11	10	10.5	0.1	**0.7**	0 - 3.7
Turbidity	NTU	09-2563	H-5	08/13/09	08/13/09	08/14/09	3	3	3.3	0.1	**2.2**	0 - 3.7
Turbidity	NTU	09-2760	PCEB	08/27/10	08/27/10	08/27/10	0	0	0.1	0.0	**0.0**	0 - 3.7
Turbidity	NTU	09-2770	H-9	08/27/10	08/27/10	08/27/10	6	6	6.1	0.1	**2.3**	0 - 3.7
Turbidity	NTU	09-3059	H-1	09/10/09	09/10/09	09/11/09	3	3	3.2	0.0	**0.0**	0 - 3.7
Turbidity	NTU	09-3069	H-9	09/10/09	09/10/09	09/11/09	1	1	1.4	0.0	**0.0**	0 - 3.7
Turbidity	NTU	09-3615	H-18	10/08/09	10/08/09	10/09/09	3	3	3.2	0.0	**0.0**	0 - 3.7
Turbidity	NTU	09-3078	H-18	09/10/09	09/10/09	09/11/09	2	2	1.7	0.0	**2.5**	0 - 3.7
Turbidity	NTU	09-3406	H-8	09/24/09	09/24/09	09/25/09	1	1	1.3	0.0	**0.0**	0 - 3.7
Turbidity	NTU	09-3416	H17	09/24/09	09/24/09	09/25/09	4	4	3.8	0.1	**3.7**	0 - 3.7
Turbidity	NTU	09-3606	H-9	10/08/09	10/08/09	10/09/09	2	2	1.7	0.0	**0.0**	0 - 3.7
TSS	mg/L	09-2551	H-14	08/12/09	08/12/09	08/14/09	7.2	7.6	7.4	0.3	**3.8**	0 - 13
TSS	mg/L	09-2561	H-3 Field Dup	08/13/09	08/13/09	08/14/09	3.0	3.3	3.2	0.2	**4.9**	0 - 13
TSS	mg/L	09-2769	H-8	08/27/09	08/27/09	09/03/09	2.5	2.3	2.4	0.1	**4.8**	0 - 13
TSS	mg/L	09-3067	H-8	09/10/09	09/10/09	09/16/09	4.4	4.6	4.5	0.1	**3.1**	0 - 13
TSS	mg/L	09-3077	H-17	09/10/09	09/10/09	09/16/09	3.2	3.2	3.2	0.0	**0.9**	0 - 13
TSS	mg/L	09-3404	H7	09/24/09	09/24/09	09/28/09	3.6	3.9	3.8	0.2	**4.9**	0 - 13
TSS	mg/L	09-3602	H6	10/08/09	10/08/09	10/13/09	8.1	7.7	7.9	0.3	**3.6**	0 - 13
TSS	mg/L	09-2560	H-3	08/13/09	08/13/09	08/14/09	1.6	1.7	1.7	0.1	**4.3**	0 - 13
TSS	mg/L	09-2776	H-14	08/27/10	08/27/10	09/03/09	4	4	4.1	0.1	**1.7**	0 - 13
TSS	mg/L	09-3074	H-14	09/10/09	09/10/09	09/16/09	3	3	3.1	0.1	**4.6**	0 - 13
TSS	mg/L	09-3613	H16	10/08/09	10/08/09	10/13/09	4	4	3.9	0.1	**3.8**	0 - 13

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SRP	µg/l	09-2547	H-10	08/12/09	08/12/09	08/14/09	70	73	71.5	2.1	**3.0**	0-5
SRP	µg/l	09-2558	H-1	08/13/09	08/13/09	08/14/09	0	0	0.1	0.0	**0.0**	0-5
SRP	µg/l	09-2567	H-13	08/13/09	08/13/09	08/14/09	2	1	1.5	0.1	**4.9**	0-5
SRP	µg/l	09-2769	H-8	08/27/09	08/27/09	08/28/09	4	4	4.0	0.0	**0.0**	0-5
SRP	µg/l	09-2779	H-17	08/27/09	08/27/09	08/28/09	78	80	79.0	1.4	**1.8**	0-5
SRP	µg/l	09-3059	H-1	09/10/09	09/10/09	09/11/09	12	11	11.3	0.4	**3.1**	0-5
SRP	µg/l	09-3069	H-9	09/10/09	09/10/09	09/11/09	11	11	11.0	0.0	**0.0**	0-5
SRP	µg/l	09-3078	H-18	09/10/09	09/10/09	09/11/09	30	30	30.0	0.0	**0.0**	0-5
SRP	µg/l	09-3405	H-7 Field Dup	09/24/09	09/24/09	09/25/09	39	38	38.5	0.7	**1.8**	0-5
SRP	µg/l	09-3415	H-16	09/24/09	09/24/09	09/25/09	71	70	70.5	0.7	**1.0**	0-5
NOx	µg/l	09-2547	H-10	08/12/09	08/12/09	08/14/09	290	301	295.5	7.8	**2.6**	0-4
NOx	µg/l	09-2558	H-1	08/13/09	08/13/09	08/14/09	5	5	5.0	0.0	**0.0**	0-4
NOx	µg/l	09-2567	H-13	08/13/09	08/13/09	08/14/09	95	96	95.5	0.7	**0.7**	0-4
NOx	µg/l	09-2769	H-8	08/27/09	08/27/09	08/28/09	5	6	5.5	0.1	**1.3**	0-4
NOx	µg/l	09-2779	H-17	08/27/09	08/27/09	08/28/09	81	81	81.0	0.0	**0.0**	0-4
NOx	µg/l	09-3059	H-1	09/10/09	09/10/09	09/11/09	9	9	9.0	0.0	**0.0**	0-4
NOx	µg/l	09-3069	H-9	09/10/09	09/10/09	09/11/09	598	594	596.0	2.8	**0.5**	0-4
NOx	µg/l	09-3078	H-18	09/10/09	09/10/09	09/11/09	152	160	156.0	5.7	**3.6**	0-4
NOx	µg/l	09-3405	H-7 Field Dup	09/24/09	09/24/09	09/25/09	147	146	146.5	0.7	**0.5**	0-4
NOx	µg/l	09-3415	H-16	09/24/09	09/24/09	09/25/09	190	189	189.5	0.7	**0.4**	0-4
Total N	µg/l	09-2548fp	H-11	08/12/09	08/12/09	11/04/09	949	932	940.5	12.0	**1.3**	0-10
Total N	µg/l	09-2558fp	H-1	08/13/09	08/13/09	11/04/09	567	549	558.0	12.7	**2.3**	0-10
Total N	µg/l	09-2552p	H-14 Field Dup	08/12/09	08/12/09	11/04/09	1008	871	939.5	96.2	**10**	0-10
Total N	µg/l	09-2567fp	H-13	08/13/09	08/13/09	11/04/09	1254	1224	1239.0	21.2	**1.7**	0-10
Total N	µg/l	09-2562p	H-4	08/13/09	08/13/09	11/04/09	2007	1934	1970.5	51.6	**2.6**	0-10
Total N	µg/l	09-3606p	H-9	10/08/09	10/08/09	11/09/09	3039	3037	3038.0	1.4	**0.0**	0-10
Total N	µg/l	09-3402P	H-5	09/24/09	09/24/09	12/02/09	1105	1076	1090.5	20.5	**1.9**	0-10
Total N	µg/l	09-3412P	H-13 Field Dup	09/24/09	09/24/09	12/02/09	1839	1912	1875.5	51.6	**2.8**	0-10
Total N	µg/l	09-3401fp	H-4	09/24/09	09/24/09	12/02/09	583	602	592.5	13.4	**2.3**	0-10
Total N	µg/l	09-3411fp	H-13	09/24/09	09/24/09	12/02/09	2153	2080	2116.5	51.6	**2.4**	0-10
Total N	µg/l	09-3598p	H-2	10/08/09	10/08/09	12/10/09	1116	1072	1094.0	31.1	**2.8**	0-10

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Total P	µg/l	09-2548fp	H-11	08/12/09	08/12/09	11/04/09	9	8	8.5	0.7	**8.3**	0-5
Total P	µg/l	09-2558fp	H-1	08/13/09	08/13/09	11/04/09	2	2	2.0	0.0	**0.0**	0-5
Total P	µg/l	09-2552p	H-14 Field Dup	08/12/09	08/12/09	11/04/09	89	80	84.5	6.4	**7.5**	0-5
Total P	µg/l	09-3606p	H-9	10/08/09	10/08/09	11/09/09	74	73	73.5	0.7	**1.0**	0-5
Total P	µg/l	09-3598fp	H-2	10/08/09	10/08/09	11/09/09	27	25	26.0	1.4	**5.4**	0-5
Total P	µg/l	09-2778p	H-16	08/27/09	08/27/09	11/10/09	95	89	92.0	4.2	**4.6**	0-5
Total P	µg/l	09-2767fp	H-7	08/27/09	08/27/09	11/10/09	0	0	0	0.0	**0.0**	0-5
Total P	µg/l	09-3069p	H-9	09/10/09	09/10/09	11/12/09	74	74	74.0	0.0	**0.0**	0-5
Total P	µg/l	09-3059fp	H-1	09/10/09	09/10/09	11/12/09	2	3	2.5	0.1	**2.9**	0-5
Total P	µg/l	09-3059p	H-1	09/10/09	09/10/09	11/12/09	57	59	58.0	1.4	**2.4**	0-5
Total P	µg/l	09-3598p	H-2	10/08/09	10/08/09	12/10/09	53	52	52.5	0.7	**1.3**	0-5
Ammonia	µg/l	09-2545	H-8	08/12/09	08/12/09	08/19/09	3126	3079	3102.5	33.2	**1.1**	0-10
Ammonia	µg/l	09-2554	H-16	08/12/09	08/12/09	08/19/09	277	276	276.5	0.7	**0.3**	0-10
Ammonia	µg/l	09-2565	H-6	08/13/09	08/13/09	08/19/09	66	67	66.5	0.7	**1.1**	0-10
Ammonia	µg/l	09-2760	PCEB	08/27/09	08/27/09	09/18/09	419	419	419.0	0.0	**0.0**	0-10
Ammonia	µg/l	09-2770	H-9	08/27/09	08/27/09	09/18/09	1525	1544	1534.5	13.4	**0.9**	0-10
Ammonia	µg/l	09-2780	H-18	08/27/09	08/27/09	09/18/09	87	87	87.0	0.0	**0.0**	0-10
Ammonia	µg/l	09-3059	H-1	09/10/09	09/10/09	09/23/09	178	179	178.5	0.7	**0.4**	0-10
Ammonia	µg/l	09-3069	H-9	09/10/09	09/10/09	09/23/09	907	913	910.0	4.2	**0.5**	0-10
Ammonia	µg/l	09-3406	H-8	09/24/09	09/24/09	10/14/09	2103	2116	2109.5	9.2	**0.4**	0-10
Ammonia	µg/l	09-3416	H-17	09/24/09	09/24/09	10/14/09	169	166	167.5	2.1	**1.3**	0-10
Ammonia	µg/l	09-3606	H-9	10/08/09	10/08/09	10/29/09	697	663	680.0	24.0	**3.5**	0-10
Color	PCU	09-2553	H-15	08/12/09	08/12/09	08/14/09	73	72	72.5	0.7	**1.0**	0-5
Color	PCU	09-2563	H-5	08/12/09	08/12/09	08/14/09	54	54	54.0	0.0	**0.0**	0-5
Color	PCU	09-2567	H-13	08/12/09	08/12/09	08/14/09	43	44	43.5	0.7	**1.6**	0-5
Color	PCU	09-2769	H-8	08/27/09	08/27/09	08/28/09	52	52	52.0	0.0	**0.0**	0-5
Color	PCU	09-2780	H-18	08/27/09	08/27/09	08/28/09	48	50	49.0	1.4	**2.9**	0-5
Color	PCU	09-3059	H-1	09/10/09	09/10/09	09/11/09	34	35	34.5	0.7	**2.0**	0-5
Color	PCU	09-3069	H-9	09/10/09	09/10/09	09/11/09	38	38	38.0	0.0	**0.0**	0-5
Color	PCU	09-3406	H-8	09/24/09	09/24/09	09/25/09	44	44	44.0	0.0	**0.0**	0-5
Color	PCU	09-3416	H-17	09/24/09	09/24/09	09/25/09	61	62	61.5	0.7	**1.1**	0-5
Color	PCU	09-3606	H9	10/08/09	10/08/09	10/09/09	46	46	46.0	0.0	**0.0**	0-5
Color	PCU	09-3615	H18	10/08/09	10/08/09	10/09/09	31	32	31.5	0.7	**2.2**	0-5

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Copper	µg/l	09-3403	H-6	09/24/09	09/24/09	11/30/09	1	1	1.0	0.0	**0.0**	0-10
Copper	µg/l	09-3413	H-14	09/24/09	09/24/09	11/30/09	5	5	5.0	0.0	**0.0**	0-10
Copper	µg/l	09-3602	H-6	10/08/09	10/08/09	11/30/09	1	1	1.0	0.0	**0.0**	0-10
Copper	µg/l	09-3615	H-18	10/08/09	10/08/09	11/30/09	14	16	15.2	1.1	**7.4**	0-10
Copper	µg/l	09-2553	H-15	08/12/09	08/12/09	11/30/09	6	5	5.5	0.1	**1.3**	0-10
Copper	µg/l	09-2563	H-5	08/13/09	08/13/09	11/30/09	2	2	2.0	0.0	**0.0**	0-10
Copper	µg/l	09-3062	H-4	09/10/09	09/10/09	11/30/09	2	2	2.0	0.0	**0.0**	0-10
Lead	µg/l	09-2553	Roosevelt H-15	08/12/09	08/12/09	12/02/09	1	1	1.0	0.0	**0.0**	0-10
Lead	µg/l	09-2563	Roosevelt H-5	08/13/09	08/13/09	12/02/09	1	1	1.0	0.0	**0.0**	0-10
Lead	µg/l	09-2775	Roosevelt H-13 FD	08/27/09	08/27/09	12/02/09	1	1	1.0	0.0	**0.0**	0-10
Lead	µg/l	09-3062	Roosevelt H-4	09/10/09	09/10/09	12/02/09	1	1	1.0	0.0	**0.0**	0-10
Lead	µg/l	09-3398	Roosevet H-1	09/24/09	09/24/09	12/02/09	1	1	1.0	0.0	**0.0**	0-10
Lead	µg/l	09-3403	Roosevelt H-6	09/24/09	09/24/09	12/02/09	1	1	1.0	0.0	**0.0**	0-10
Lead	µg/l	09-3413	Roosevelt H-14	09/24/09	09/24/09	12/02/09	1	1	1.0	0.0	**0.0**	0-10
Lead	µg/l	09-3602	Roosevelt H-6	10/08/09	10/08/09	12/02/09	10	12	11.0	0.8	**7.1**	0-10
Zinc	µg/l	09-2553	Roosevelt H-15	08/12/09	08/12/09	12/03/09	1	1	1.0	0.0	**0.0**	0-10
Zinc	µg/l	09-2563	Roosevelt H-5	08/13/09	08/13/09	12/03/09	35	35	35.0	0.0	**0.0**	0-10
Zinc	µg/l	09-2775	Roosevelt H-13 FD	08/27/09	08/27/09	12/03/09	2	2	2.0	0.0	**0.0**	0-10
Zinc	µg/l	09-3062	Roosevelt H-4	09/10/09	09/10/09	12/03/09	1	1	1.0	0.0	**0.0**	0-10
Zinc	µg/l	09-3398	Roosevet H-1	09/24/09	09/24/09	12/03/09	1	1	1.0	0.0	**0.0**	0-10
Zinc	µg/l	09-3403	Roosevelt H-6	09/24/09	09/24/09	12/03/09	3	3	3.0	0.0	**0.0**	0-10
Zinc	µg/l	09-3413	Roosevelt H-14	09/24/09	09/24/09	12/03/09	1	1	1.0	0.0	**0.0**	0-10
Zinc	µg/l	09-3602	Roosevelt H-6	10/08/09	10/08/09	12/03/09	6	5	5.5	0.1	**1.3**	0-10
Chromium	µg/l	09-2553	Roosevelt H-15	08/12/09	08/12/09	11/25/09	1	1	1.0	0.0	**0.0**	0-10
Chromium	µg/l	09-2563	Roosevelt H-5	08/13/09	08/13/09	11/25/09	2	2	2.0	0.0	**0.0**	0-10
Chromium	µg/l	09-2775	Roosevelt H-13 FD	08/27/09	08/27/09	11/25/09	15	16	15.5	0.7	**4.6**	0-10
Chromium	µg/l	09-3062	Roosevelt H-4	09/10/09	09/10/09	11/25/09	6	6	6.0	0.0	**0.0**	0-10
Chromium	µg/l	09-3398	Roosevelt H-1	09/24/09	09/24/09	12/08/09	9	9	9.0	0.0	**0.0**	0-10
Chromium	µg/l	09-3403	Roosevelt H-6	09/24/09	09/24/09	12/08/09	4	5	4.5	0.1	**1.6**	0-10
Chromium	µg/l	09-3413	Roosevelt H-14	09/24/09	09/24/09	12/08/09	7	7	7.0	0.0	**0.0**	0-10

Roosevelt Creek Project

Laboratory Calibration Standard (Blank Spike) Study

Analyzed from August 2009 to October 2009

PARAMETERS	UNITS	SAMPLE DESCRIPTION	DATE PREPARED	DATE ANALYZED	INITIAL CONC.	INITIAL VOLUME (ml)	SPIKE CONC.	SPIKE VOLUME ADDED (ml)	THEOR. CONC.	ACTUAL CONC.	PERCENT RECOVERY	ACCEPTANCE RANGE
Alkalinity	mg/l	LCS	08/13/09	08/13/09	1	50	1000	0.5	11.0	10.2	93%	91 - 109
Alkalinity	mg/l	LCS	08/28/09	08/28/09	0.8	50	1000	0.5	10.8	10.2	94%	91 - 109
Alkalinity	mg/l	LCS	09/10/09	09/10/09	0.8	50	1000	0.5	10.8	10.4	96%	91 - 109
Alkalinity	mg/l	LCS	09/10/09	09/10/09	0.8	50	1000	0.5	10.8	10.6	98%	91 - 109
Alkalinity	mg/l	LCS	09/25/09	09/25/09	1	50	1000	0.5	11.0	11.2	102%	91 - 109
Alkalinity	mg/l	LCS	10/09/09	10/09/09	0.6	50	1000	0.4	8.6	8.2	95%	91 - 109
Turbidity	NTU	LCS	10/09/09	10/09/09	0	50	4000	0.375	30.0	30.1	100%	87 - 104
SRP	µg/l	LCS	08/28/09	08/28/09	0	10	10000	0.25	250	236	94%	90 - 110
SRP	µg/l	LCS	09/11/09	09/11/09	0	10	10000	0.25	250	229	92%	90 - 110
SRP	µg/l	LCS	09/11/09	09/11/09	0	10	10000	0.25	250	251	100%	90 - 110
SRP	µg/l	LCS	09/25/09	09/25/09	0	10	10000	0.25	250	227	91%	90 - 110
SRP	µg/l	LCS	10/09/09	10/09/09	0	10	10000	0.45	450	471	105%	90 - 110
NOx	µg/l	LCS	08/14/09	08/14/09	0	10	100000	0.35	3500	3525	101%	85 - 115
NOx	µg/l	LCS	08/28/09	08/28/09	0	10	100000	0.35	3500	3267	93%	85 - 115
NOx	µg/l	LCS	09/11/09	09/11/09	0	10	100000	0.45	4500	4297	95%	85 - 115
NOx	µg/l	LCS	09/11/09	09/11/09	0	10	100000	0.45	4500	4303	96%	85 - 115
NOx	µg/l	LCS	09/25/09	09/25/09	0	10	100000	0.45	4500	4306	96%	85 - 115
Total N	µg/l	LCS	11/04/09	11/04/09	0	5	20000	0.75	3000	3145	105%	90 - 110
Total N	µg/l	LCS	11/04/09	11/04/09	0	5	20000	0.75	3000	3160	105%	90 - 110
Total N	µg/l	LCS	11/04/09	11/04/09	0	5	20000	0.75	3000	2774	92%	90 - 110
Total N	µg/l	LCS	11/09/09	11/09/09	0	5	20000	0.75	3000	2738	91%	90 - 110
Total N	µg/l	LCS	11/10/09	11/10/09	0	5	20000	0.75	3000	2774	92%	90 - 110
Total N	µg/l	LCS	11/12/09	11/12/09	0	5	20000	0.75	3000	2738	91%	90 - 110
Total P	µg/l	LCS	11/04/09	11/04/09	0	250	25000	10	1000	991	99%	90 - 110
Total P	µg/l	LCS	11/04/09	11/04/09	0	250	25000	10	1000	942	94%	90 - 110
Total P	µg/l	LCS	11/04/09	11/04/09	0	250	25000	10	1000	1094	109%	90 - 110
Total P	µg/l	LCS	11/09/09	11/09/09	0	250	25000	10	1000	1003	100%	90 - 110
Total P	µg/l	LCS	11/10/09	11/10/09	0	250	25000	10	1000	1017	102%	90 - 110
Total P	µg/l	LCS	11/12/09	11/12/09	0	250	25000	10	1000	1017	102%	90 - 110
Ammonia	µg/l	LCS	08/19/09	08/19/09	0	10	10000	1.0	1000	989	99%	80 - 120
Ammonia	µg/l	LCS	08/19/09	08/19/09	0	10	10000	1.0	1000	993	99%	80 - 120
Ammonia	µg/l	LCS	09/18/09	09/18/09	0	10	10000	1.0	1000	996	100%	80 - 120
Ammonia	µg/l	LCS	09/23/09	09/23/09	0	10	10000	1.5	1500	1323	88%	80 - 120
Ammonia	µg/l	LCS	10/14/09	10/14/09	0	10	10000	1.5	1500	1351	90%	80 - 120
Ammonia	µg/l	LCS	10/29/09	10/29/09	0	10	8220	0.7	575	586	102%	80 - 120
Color	PCU	LCS	08/14/09	08/14/09	0	25	500	0.75	15	15	100%	80 - 120
Color	PCU	LCS	08/14/09	08/14/09	0	25	500	0.75	15	15	100%	80 - 120
Color	PCU	LCS	08/28/09	08/28/09	0	25	500	0.75	15	15	100%	80 - 120
Color	PCU	LCS	09/11/09	09/11/09	0	25	500	0.75	15	15	100%	80 - 120
Color	PCU	LCS	09/25/09	09/25/09	0	25	500	1.00	20	19	95%	80 - 120
Color	PCU	LCS	10/09/09	10/09/09	0	25	500	1.00	20	19	95%	80 - 120
Copper	µg/l	LCS	11/30/09	11/30/09	0	100	100000	0.15	150.0	152	101%	95 - 110
Copper	µg/l	LCS	11/30/09	11/30/09	0	100	100000	0.6	600.0	604	101%	95 - 110
Copper	µg/l	LCS	11/30/09	11/30/09	0	100	100000	0.5	500.0	483	97%	95 - 110
Copper	µg/l	LCS	11/30/09	11/30/09	0	100	100000	0.6	600.0	660	110%	95 - 110
Lead	µg/l	LCS	12/02/09	12/02/09	0	100	100000	0.6	600.0	613	102%	94 - 106
Lead	µg/l	LCS	12/02/09	12/02/09	0	100	100000	0.7	700	715	102%	94 - 106
Lead	µg/l	LCS	12/02/09	12/02/09	0	100	100000	0.7	700.0	740	106%	94 - 106
Lead	µg/l	LCS	12/02/09	12/02/09	0	100	100000	0.8	800.0	791	99%	94 - 106
Zinc	µg/l	LCS	12/03/09	12/03/09	0	100	100000	0.7	700.0	685	98%	95 - 110
Zinc	µg/l	LCS	12/03/09	12/03/09	0	100	100000	0.7	700.0	685	98%	95 - 110
Zinc	µg/l	LCS	12/03/09	12/03/09	0	100	100000	0.7	700.0	665	95%	95 - 110
Zinc	µg/l	LCS	12/03/09	12/03/09	0	100	100000	0.6	600.0	589	98%	95 - 110
Chromium	µg/l	LCS	11/25/09	11/25/09	0	100	100000	0.6	600.0	589	98%	95 - 110
Chromium	µg/l	LCS	11/25/09	11/25/09	0	100	100000	0.6	600.0	627	105%	95 - 110
Chromium	µg/l	LCS	12/08/09	12/08/09	0	100	100000	0.6	600.0	629	105%	95 - 110
Chromium	µg/l	LCS	12/08/09	12/08/09	0	100	100000	0.6	600.0	661	110%	95 - 110