Acknowledgments

Current and former Pinellas County Environmental Management staff acknowledged for their contributions to the monitoring program include: Geoff Duncan, Eric Fehrmann, Dannielle Grimes, Melissa Harrison, Don Hicks, Robert McWilliams, Jim Meyer, Sue Myers, Anamarie Rivera, Steve Robinson, Ryan Ryczek, Joe Torok, and Melanie Weed. Department staff is grateful for permission granted by numerous citizens to access their property for the purpose of sampling surface water quality monitoring sites throughout the County.
Executive Summary

Since October 1990, the Pinellas County Department of Environmental Management has monitored surface water quality within 45 of the County's 52 drainage basins, four lakes, and nine receiving water bodies. In January 2003, a revised monitoring program (Janicki 2003) was implemented to provide better geographical coverage of County waters and to provide more statistically defensible results compared to the original (1991-2002) program.

In this report, spatial and temporal trends in water quality are summarized by site, by basin, and for the entire County from 2003-2006. Parameters measured in situ included temperature, flow, salinity, specific conductance, pH, dissolved oxygen, depth, and Secchi. Analyses of grab samples collected from the field included chlorophyll (a, b, c), nutrients (total Kjeldahl nitrogen, ammonia nitrogen, nitrate + nitrite nitrogen, total phosphorus, and dissolved orthophosphorus), total suspended solids, transmissivity, total and fecal coliform, and turbidity.

Additionally, Pinellas County data were compared to the State of Florida's Impaired Surface Waters Rules (IWR). IWR violations occur when a certain percentage or number of samples do not meet State water quality standards. Open water strata and fixed land sites were labeled not impaired (no IWR violation) or potentially impaired (IWR exceedances occurred).

Based on the 2003-2006 monitoring data, 19 fixed land sites, west stratum W5, and lakes Seminole and Tarpon were potentially impaired for dissolved oxygen (Figure 1). East strata, E1 through E5, and west stratum W5, were potentially impaired for chlorophyll-a. Ten fixed land sites were potentially impaired for chlorophyll-a. Lake Tarpon and Lake Seminole were potentially impaired for chlorophyll-a and Trophic State Index (Figure 2). Pinellas County did not collect bacteria data or biological oxygen demand data during 2003 and 2004. These parameters were added to the monitoring program in 2005. Twenty-nine fixed land sites were potentially impaired for bacteria (Figure 3).

The following statements can be made about water quality in Pinellas County based on analyses of PCDEM data from 2003-2006:

- Water quality is better in open water strata compared to enclosed or semi-enclosed strata.
- Water quality is typically better during the dry season compared to the wet season.
- Land sites (streams, creeks, and canals) with the highest flow were typically associated with the highest nitrogen loadings including the Lake Tarpon outfall canal, Brooker Creek, Curlew Creek, Alligator Creek, Roosevelt Channel 5, and the Seminole Bypass Canal.
- Land sites with the lowest flow were typically associated with the lowest nitrogen loadings including Church Creek, Bishop Creek, Cow Branch Creek, and Cedar Creek.
• Water Quality in Long Bayou and Cross Bayou (stratum W5) was poor due to discharges from three eutrophic systems; Lake Seminole, the Seminole Bypass Canal, and the Cross Bayou Canal.

• Lake Tarpon and Lake Seminole did not meet state water quality standards for four different criteria.
Figure 1. Potentially impaired waters for bottom dissolved oxygen based on Impaired Waters Rule criteria (2003-2006)
Figure 2. Potentially impaired waters for Chlorophyll-a and Trophic State Index (SA, SB, and T) based on Impaired Waters Rule criteria (2003-2006)
Figure 3. Potentially impaired waters for bacteria based on Impaired Waters Rule criteria (2003-2006)
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April 2007
1.0 Introduction

The Water Resources Management Section of the Pinellas County Department of Environmental Management initiated a surface water monitoring program in October 1990 and began reporting results from samples collected in January 1991. The program monitors water quality in a variety of creeks, streams, lakes, and open marine water bodies. Much of the rationale behind the water quality monitoring program is associated with County watershed planning initiatives consistent with State Water Policy (Chapter 62-40, Florida Administrative Code (FAC)) and the County Comprehensive Plan. Pinellas County's existing watershed planning and water quality monitoring programs were originally developed largely in response to directives under Chapters 62-40.430 FAC (Water Quality) and 62-40.432 FAC (Surface Water Protection and Management) of State Water Policy. These activities serve to support the goals, objectives and policies of both the County Comprehensive Plan (hereafter referred to as the County CP), and the Tampa Bay Estuary Program Comprehensive Conservation and Management Plan (CCMP).


PINELLAS COUNTY PROGRAM

The monitoring program was in part a result of the adoption of the County CP in 1989, which mandated implementation of ambient water quality monitoring under Goal 3 of the Conservation Element. The Plan was amended in 1998 and provisions for water quality protection of the County's waters now appear in the Surface Water Management Element. Specifically Goal 1 of the Surface Water Management Element states:

"...SURFACE WATERS SHALL BE MANAGED TO PROVIDE FLOOD PROTECTION FOR THE CITIZENS OF PINELLAS COUNTY, TO PRESERVE AND ENHANCE THE WATER QUALITY OF RECEIVING WATER BODIES, AND FOR THE PURPOSES OF NATURAL RESOURCE PROTECTION, ENHANCEMENT AND RESTORATION, PLANT AND WILDLIFE DIVERSITY, AND ESTUARINE PRODUCTIVITY."

CP objectives and policies emphasize the critical link between watershed management planning and monitoring of the County's waters to prioritize planning efforts based on need and to evaluate the effect of implemented management activities on the quality of receiving water bodies. Furthermore, objectives and policies call for continued collaborative efforts with federal, state, regional, and local agencies and governments in assessing water pollution problems and evaluating management actions to remedy identified problems. Selected objectives and policies under Goal 1 in support of the County water quality monitoring program are listed below.

Objective 1.4: Pinellas County shall show measurable improvements in the quality of County waters, and their associated habitats, as a result of management activities.
Policy 1.4.5: In the development of specific watershed/water body management plans, Pinellas County shall give priority to those water bodies whose water is known, or suspected, to be impaired, and to those high quality water bodies whose quality may be in danger of impairment, as identified by the Departments of Public Works and Environmental Management through such means as the watershed ranking process.

Objective 1.5: Pinellas County shall participate with federal, state, regional, and local agencies and governments in gathering and evaluating the data necessary to identify major pollution problems in the County’s waters.

Policy 1.5.2: Pinellas County shall continue to conduct a surface water monitoring program within the Waters of the County.

Policy 1.5.3: Pinellas County shall continue its program of surface water monitoring as a means of evaluating the degree of watershed/water body impairment, the overall effect of management activities, the quality of surface waters and the overall health of dependent living resources.

Objective 1.7: The Surface Water Management Element shall continue to be coordinated with all affected jurisdictions and agencies, as well as federal, state and regional goals for surface water control, protection, enhancement, restoration and management, and shall be supported by provisions in related elements.

Policy 1.7.7: Pinellas County shall continue to support the Tampa Bay National Estuary Program (TBNEP) and its partnership approach to the protection and restoration of Tampa Bay.

The County water quality sampling network was originally designed to carry out the goals of the County CP, specifically (1) to characterize the relative priority of each receiving water for development of management plans, (2) to identify those tributaries contributing the greatest contribution of pollutants, and (3) to provide a baseline for evaluating the impacts of management programs on receiving water quality. Further sampling site selection criteria are discussed in Section 3.0.

WATER QUALITY MONITORING IN TAMPA BAY

In addition to the County's intent to monitor freshwater creeks, streams, and lakes, Pinellas County has made special commitments to collaborate with local governments and public agencies for long-term water quality monitoring of Tampa Bay waters. These collaborative monitoring efforts were implemented as a Tampa Bay National Estuary Program initiative (TBNEP 1996) to better meet the goals of the CCMP. Upon signing of the CCMP in 1996, the TBNEP was renamed the Tampa Bay Estuary Program (TBEP). The signing represented a responsibility of local governments - the counties of Hillsborough, Pinellas, and Manatee; and the cities of Clearwater, St. Petersburg, and Tampa - to monitor Tampa Bay water quality.
The ongoing monitoring efforts in Tampa Bay are carried out by the Environmental Protection Commission of Hillsborough County, the Pinellas County Department of Environmental Management (PCDEM), the Manatee County Environmental Management Department, and the City of Tampa Bay Study Group. The coordinated efforts of these governmental entities have resulted in an on-going sampling program with coverage in each of seven Tampa Bay segments. These program representatives, and others from the region, have formed a group (referred to as the Southwest Florida Regional Ambient Monitoring Program) that meet quarterly to split water samples for interlaboratory comparisons and to discuss approaches to strengthen overall monitoring program compatibility.


DATA AVAILABILITY

To facilitate data sharing among local, regional, state, and federal agencies and governments, as well as the public at large, all County ambient monitoring data results are periodically uploaded into the United States Environmental Protection Agency's STORET database. Data can also be downloaded from the Pinellas County Water Atlas (http://www.pinellas.wateratlas.usf.edu/) or by contacting the Department of Environmental Management's Water Resources Management Section at (727) 464-4425.
2.0 **Methodology**

Field sample collections and measurements were carried out according to Florida Department of Environmental Protection (FDEP) Standard Operating Procedures (FDEP, 2002).

**FIELD MEASUREMENTS AND SAMPLE COLLECTION**

Physical parameters including temperature, pH, dissolved oxygen, conductivity, and salinity were measured using Hydrolab® multiprobe units. Surface readings were taken at a depth of 0.2m from the surface. If the total water column depth was >0.5m but <1.0m, data were recorded for surface and bottom. For depths greater than 1.0m, data were also recorded at mid-depth.

Water samples were collected at 0.2m using a horizontally-oriented Alpha bottle water sampler.

Flow measurements were collected using a modification of the US Geological Survey's (USGS) streamflow methodology with a Marsh Mc Birney Model 2000 Flow-Mate™ or by using data collected at real-time USGS monitoring locations.

**LABORATORY METHODS**

All water samples were delivered to the Pinellas County Utilities Department the same day and usually within six hours of sample collection at any given site. The Pinellas County Utilities Department Laboratory, a National Environmental Laboratory Accreditation Conference (NELAC) certified lab, performed most sample analyses. E-lab, a NELAC certified laboratory, also provided analysis services for this program.

The Pinellas County Utilities lab follows analysis protocol from:


3.0 **Open Water Sites**

From 2003 to 2006, the ambient water quality program consisted of two types of sample sites distinguished by site selection method. The first type is randomly selected sites in open water bodies around the County in Tampa Bay, from Oldsmar south to Pinellas Point, along the western mainland shore, from the mouth of the Anclote River south to Ft. DeSoto, and the two largest lakes, Lake Tarpon and Lake Seminole. Samples collected at these sites are used to assess status and trends in County receiving water bodies. The second type is a set of fixed land-based sites along streams, ditches, canals, and the Anclote River. Water quality samples and flow data were collected nine times per year and are used to assess the condition of the waterway and for estimation of nutrient and sediment loads from these waterways to receiving water bodies. Lake Chautauqua and Alligator Lake were sampled as fixed sites.

The stratified random monitoring program was designed for PCDEM by Janicki Environmental, Inc. PCDEM provided a set of goals and objectives as well as budgetary and logistic constraints for the program. The consultant designed a monitoring program with a probabilistic design consisting of an Environmental Protection Agency (EPA) Environmental Monitoring Assessment Program (EMAP)-based element and a stratified random sampling element. The EMAP-based design element consists of overlaying hexagonal grids on strata, and randomly selecting a sample location within each grid. This allows for estimating surface area for water quality conditions within each stratum. The stratified random element allows for statistical methods to be applied to estimate population means and confidence limits for water quality metrics. The stratified random element also has a temporal and spatial component.

Lake Tarpon, Lake Seminole, and the marine waters along the shores of Pinellas County were subdivided into 19 strata (Figure 4 and Appendix D). East and west coastal reporting units were selected based on the location of causeways, bridges, and the Tampa Bay Estuary Program boundaries (Pribble et al, 1999).

The temporal unit is a daytime period of approximately four hours. There are two temporal units in each day, representing morning and afternoon. The order of visitation (i.e., morning vs. afternoon) within each strata was randomized. The temporal population of interest was defined as a one-year set of all possible temporal units excluding Fridays, Saturdays, Sundays, holidays, and days before holidays.

The calendar year was divided into nine evenly spaced sample periods of 40.5 days. Primary and secondary sampling dates were randomly selected from the first 25 days of each of the nine sample periods. The remaining days were reserved as secondary sampling days if the primary dates were missed due to weather or scheduling conflicts.

The spatial unit is defined as a location within each stratum. The unit is a circle approximately 30-meters across to allow for a reasonable error in the Global Positioning System (GPS) unit and boat drift while at the station. For east coast strata, the spatial population of interest is the set of all spatial units from the Pinellas County shoreline to the 2-meter mean low water isobath in Tampa Bay. For west coast strata, the spatial population of interest is the set of all spatial units...
from the shoreline of the peninsula mainland to the eastern shore of the barrier islands. Also, the populations of interest in the eastern and western coastal reporting units were defined so each reporting unit was not located within more than one Tampa Bay Estuary Program bay segment reporting unit. The Lake Seminole population of interest was stratified geographically into a northern and southern lobe. This stratification was imposed to ensure that an equal number of samples were collected in each lobe. Lake Tarpon comprises a single stratum.

In each calendar year, a total of 36 sample sites were selected for each stratum. At least one of these 36 sites was located in each hexagonal grid in the respective stratum. These 36 sites are called the primary sampling sites. Four sites are assigned to a sample period; there are nine sampling periods in the calendar year. In the event a primary sampling site could not be used, sets of randomly selected secondary and tertiary sites were available as alternates.
Figure 4. Open water strata
4.0 Land Basins and Site Locations

A total of 48 fixed monitoring sites were sampled in 2003, 2004, and 2006, while 50 fixed monitoring sites were monitored in 2005. Sites were chosen from the list of Pinellas County watershed basins (Figure 5). Eight sites were in tidally influenced areas or lakes and only water quality data were collected. At all other sites both water quality data and flow data were collected. For six of these sites, United States Geological Survey (USGS) discharge flow data were available. County staff measured flow at the time of sample collection at all remaining sites.

Fixed sites were visited nine times per year. Fixed sites were grouped geographically. A set of fixed sites was sampled on the same day as east and west stratified random sites were sampled. Sampling took place during the same random schedule determined for the open water program.

Sampling site descriptions are found in Appendix C.
Figure 5. Pinellas County watershed basins
5.0 Parameter Descriptions

Water quality indicators covered in this report are salinity, suspended solids, total phosphorus, total nitrogen, bottom and surface dissolved oxygen, transmissivity, Trophic State Index (TSI), flow, and chlorophyll-a.

**Chlorophyll-a:** Water column chlorophyll-a (Chl-a) concentrations are a measure of the quantity or biomass of planktonic algae or phytoplankton in a water body. Excessive nutrient loadings into a water body can result in high phytoplankton biomass conditions known as algae blooms. High algal biomass can greatly reduce water clarity, which in turn may limit the growth and distribution of desirable bottom vegetation such as seagrasses and can seriously degrade the aesthetic quality of a water body. In addition, persistent conditions of high algae biomass often result in die-off, sinking, and decay of the algae in water bodies. Decaying matter consumes oxygen and often results in fish kills.

**Dissolved Oxygen:** Dissolved oxygen (DO), measured in mg/L, is another variable that strongly influences where organisms live. Oxygen enters the aquatic environment from the atmosphere (wind, waves, direct diffusion), plant photosynthesis, and mixing and diffusion from more oxygenated water masses. A physical property of water is that the solubility of oxygen is greater in cold water than in warm water therefore, less oxygen can be dissolved in water as water temperature increases. Biological factors such as increased metabolic rates and oxygen uptake rates of aquatic organisms may further reduce dissolved oxygen levels. Since biological oxygen uptake is often the greatest in bottom waters compared to surface waters, the first signs of an oxygen stressed water body are usually observed as low bottom water dissolved oxygen levels. Such conditions often result in isolated or widespread fish kills.

**Fecal Coliform:** A common water pollutant, fecal coliform, is found in the intestinal tracts of animals and humans. Its presence can be natural or from a man-made source like a sewage spill.

**Flow:** Flow was measured at fixed land sites. Width and depth data was collected to estimate cross section area of the channel. Water velocity was measured on-site using a flowmeter. The flow was then calculated in cubic feet per second (cfs). Flow volume was combined with water quality parameter concentrations to estimate loading for Total nitrogen, Total Phosphorus, and Total Suspended Solids.

**Nutrients:** This report presents two nutrient values, Total Phosphorus (TP) and Total Nitrogen (TN). Nutrients are chemical elements such as nitrogen and phosphorus that sustain life and promote growth. The amount of nutrients available in a water body is one of the controlling factors for plant growth. Waters containing few nutrients cannot support a large plant community and will not attract animal life, as there won't be a source of food. Nutrients cause problems when they are overabundant. In particular, microscopic plants or algae, when under bloom conditions, may appear as green "clouds" in the water. The poor water clarity from such nutrient-induced algae blooms can limit water column light transparency, which in turn, will often limit available light necessary for desirable types of bottom vegetation, such as seagrasses,
to grow. Data on specific phosphorus and nitrogen components are available on request from PCDEM.

**Salinity:** Salinity is a measure of the total amount of dissolved solids in seawater and is measured in parts per thousand (ppt). Sodium and chloride make up 86% of sea salts, with sulfur, magnesium, potassium, and calcium accounting for 13%. Salinities in Pinellas County generally vary between 0 ppt (freshwater) and 33 ppt. Salinity is affected by precipitation, evaporation, freshwater inputs, springs, and mixing with other water masses such as the Gulf or streams. At sites with minimal or no salinity (i.e. 0.05 ppt or less), salinity sampling was either discontinued during the program or is not reported for the basin.

**Total Coliform:** Total coliform measures the presence of a group of bacteria used to indicate contamination of water sources from the intestines of warm- and cold-blooded animals.

**Total Suspended Solids:** Total Suspended Solids (TSS) are the amount of particulate material in the water including algae, sediments, and microorganisms. TSS affects the amount of light that can penetrate the water column and thus is part of what determines where plants grow. Increases in TSS can be caused by algae blooms, increased runoff into a system, erosion, and by resuspension of bottom sediments in shallow areas.

**Transmissivity:** Transmissivity is the measurement of the percent transmittance of a 660nm light over a 10cm pathlength. The information provided is useful in determining total concentrations of matter in the water and as a measure of water clarity (Wet Labs, 2001).

**Trophic State Index:** The Trophic State Index (TSI) is a method to classify lakes based on total nitrogen, total phosphorus, and chlorophyll-a concentrations. Based on 2005-2006 color data from January to August all of our lakes are classified as colored. For colored lakes, a TSI scale from 1 to 100 is used. A lake with a TSI below 59 is considered to have good water quality, 60 to 69 is fair water quality, and a TSI of over 70 is considered poor water quality.

**Turbidity:** Turbidity is an expression of the optical property that causes light to be scattered and absorbed rather than transmitted. Turbidity is measured in nephelometric turbidity units (NTU).
6.0 Analysis Methodology

SAS® statistical analysis programs that produce cumulative distribution frequency (CDF) plots were provided to the County by Janicki Environmental (available upon request). The estimated surface areas for water quality conditions within each stratum are plotted as CDF plots (Appendix A Figures A-28 to A-122). Confidence limits were not included in each plot but are available upon request. Statistical comparisons of least square means of water quality metrics were made within east and west strata (n=1152) between wet (n=384) and dry (n=768) seasons and among strata (Appendix B). A general linear model (GLM) was used to calculate least square means, their standard errors, t-statistics, and their associated means. Otherwise, the non-parametric Wilcoxon two-sample test and Kruskal-Wallis test were used to test for differences between sets of data. Water quality metrics used in analyses include bottom dissolved oxygen, chlorophyll-a, total suspended solids, turbidity, and transmissivity.

STATE OF FLORIDA WATER QUALITY COMPARISONS AND TAMPA BAY ESTUARY WATER QUALITY TARGET COMPARISONS

Pinellas County data from 2003 through 2006 were compared to constituent concentrations and narrative nutrient criteria in the State Impaired Surface Water Rules (Chapter 62-302, FAC.) to determine if land sites and open water strata could potentially be included on the State’s verified list of impaired waters. The State uses the most recent seven-and-a-half years of data when considering inclusion of water bodies on the verified impaired waters list. In this report only the four most recent years of water quality data were used so the list of potentially impaired sites and strata in this report will not necessarily match the State’s verified list.

State methodology to develop the verified list and clarification provided by the Florida Department of Environmental Protection (personal communications) were used to assess if sites and strata could be included in the list. Sites or strata were assessed as potentially impaired if there was a single exceedance of an acute toxicity level for any water quality metric; or if the number of exceedances of criteria for surface water quality classification (62-302.530) was greater than the number allowed in the State Impaired Surface Water Rules; or annual mean chlorophyll-a values were greater than nutrient narrative criteria of 11 μg/L for western strata; or annual mean chlorophyll values were greater than TBEP chlorophyll-a targets (see below); or annual mean chlorophyll-a values were greater than the nutrient narrative criteria of 20 μg/L for streams; or annual mean Trophic State Index exceeded TSI criterion for lakes with mean color greater than 40 platinum cobalt units. Exceedances of State Impaired Surface Water Rules criteria are summarized in Appendix C.

Pinellas County chlorophyll-a data for eastern strata, excluding Riviera Bay, were compared to Tampa Bay Estuary Program chlorophyll-a targets. Strata E1 through E4 were compared to the 8.5 μg/L Old Tampa Bay target and strata E5 through E7 were compared to the 7.5 μg/L Middle Tampa Bay target. Further statistical comparisons were made within each strata between wet (n=48) and dry (n=96) seasons, and within was season among strata.
ANNUAL LOAD CALCULATIONS FOR STREAM AND CREEK SITES

Annual loads for total nitrogen, total phosphorus, and total suspended solids were calculated for 2003 through 2006 for all land-based sites where both water quality and flow data were collected. Annual flow was also estimated for these sites.

During 2003-2006, water quality data were collected at all sites at each of the nine sampling periods. The frequency of flow measurements varied among the sites and among years. To estimate flow, the cross sectional area of the stream was measured and velocity was measured with a Marsh McBirney Model 2000 Flow-Mate® flow meter. At six sites, daily mean flow measured at nearby United States Geological Survey (USGS) stream flow stations was used for flow estimates. At eight remaining sites only water quality samples were collected because the sites were tidally influenced or located in lakes. Since no flow data were collected, loads were not calculated for these sites.

In 2003, flow was estimated only when water quality samples were collected. Additional flow data were collected in the wet season from 2004-2006 at sites where the total annual nitrogen load exceeded five tons. Additional flow data were collected at these 14 sites from 2004-2005, and six sites were sampled in 2006.

For sites with nine water quality and flow measurements, annual loads were estimated by first calculating an instantaneous load in tons/second. Instantaneous load was calculated by multiplying the concentration of the water quality metric by flow in cubic feet per second. The instantaneous load was assumed to be the same through the period of time associated with the load. The load was multiplied by the number of seconds in 40.5 days (the sample period) to estimate the load per period. Loads for all periods were summed for each year to get the annual load.

For sites with nine regular ambient sampling events and eight additional flow measures, annual loads were calculated as follows. In the dry season, loads were calculated as described above for sites with nine water quality and flow measures. In the wet season, water quality metrics from the most recent regular ambient trip were assumed to represent water quality for each extra flow measure. The time period associated with a flow measure was one half the time between the current and previous date of flow measure plus one half the time between current and future date of flow measure. Loads associated with the flows were calculated by determining the instantaneous load in tons/second. The instantaneous load was calculated by multiplying the concentration of the water quality metric by flow in cubic feet per second. The instantaneous load was assumed to be the same through the period of time associated with the load. The load was multiplied by the number of seconds in the sample period.

For the streamditch sites located close to USGS flow stations, water quality metrics were assumed to be the same throughout the 40.5 day sample period. Daily loads at these sites were
estimated using the water quality data from the same sample period and daily mean stream flow data calculated by the USGS. Daily loads are summed to estimate annual loads.

Horizontal bar charts depicting annual loads for total nitrogen, total phosphorus, and total suspended solids in tons; flow in millions of gallons; annual loads per acre, in pounds; and annual flow per acre, in millions of gallons, are in Appendix A.

DETERMINATION OF WET AND DRY SEASONS

Wet and dry seasons for 2003-2006 were determined using rainfall data from the Southwest Florida Water Management District (Southwest Florida Water Management District, 2007). The data were plotted (Figure 6) then wet and dry seasons were visually assessed. The dry season was from January through May and from October through December. The wet season was from June through September.

Figure 6. Monthly weighted rainfall sums from SWFWMD data (2003 - 2006)
7.0 Spatial Analysis Graphs

The spatial interpolation methods used in this analysis (Figures 7, 8, and 9) included Inverse Distance Weighting (IDW) and Ordinary Kriging (OKRG). The Inverse Distance Weighting method performs well with a limited sample size and random data points. The data does not need to meet the assumption of normality for IDW. The IDW is a deterministic and exact interpolation method and robust when dealing with limited datasets. IDW uses the neighboring points to interpolate the area between the points based on a weighted distance function. Kriging is based on the concept of random functions requiring the data to be from a stationary stochastic process and in most cases a normal distribution. This interpolation method is based on statistical methods. This model is stochastic and can be exact or inexact depending on the error associated with the data measures. The flexibility of the model relies on the parameter settings. It also assesses autocorrelation and errors of the prediction surface making OKRG the preferred analysis method.

The variables analyzed included chlorophyll-a, bottom dissolved oxygen, and transmissivity. The data were checked for location, qualifiers, and normality prior to interpolation. The normality of the data was analyzed using the normality histogram plot and Q-Q normal plot. If the data met the assumption of normality, then OKRG was used. If the data were not normally distributed, then IDW was applied (Table 1). The ESRI® ArcGeographic Information System (GIS) software was used for the construction and creation of the interpolation surfaces. The ESRI® Geostatistical Analyst Extension calculated the interpolation surfaces.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Strata</th>
<th>Method</th>
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<th>Model</th>
<th>Neighbors</th>
<th>Mean/Root-Mean-Sq</th>
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<td>East/West</td>
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<td>1873</td>
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<td>Lake Tarpon</td>
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<td></td>
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<td>3-8</td>
<td>0.012/3.153</td>
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<tr>
<td>Chlorophyll-a</td>
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Table 1. Spatial Data Analysis Interpolation Methods and Calculation Parameters
Figure 7: Spatial analysis of transmissivity data (2003-2006)
Figure 8: Spatial analysis of bottom chlorophyll-a data (2003-2006)
Figure 9: Spatial analysis of bottom dissolved oxygen data (2003-2006)
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8.0 Results and Discussion

EASTERN AND WESTERN STRATA:

General Geographic Trends

Water quality trends in Pinellas County coastal waters were depicted from the results (Appendix A) of the stratified random monitoring program initiated in January 2003. Geographical trends were apparent based on mean and median values of bottom dissolved oxygen (DO), water clarity (measured by transmissivity and turbidity), and chlorophyll-a (Chl-a). Water quality along the east coast of the County generally improved from north to south (Appendix A, Figures A-1, A-3, A-5, A-7, and A-9) with the best conditions in the coastal waters of southern St. Petersburg and poorer conditions from Weedon Island northward to Safety Harbor.

Water quality along the west coast was relatively poor in the mid-county regions from Gulfport northward to Clearwater compared to the good water quality conditions observed both north and south of this mid-county region (Appendix A, Figures A-2, A-4, A-6, A-8, and A-10). Overall the County’s coastal water quality was better in open water strata compared to enclosed or semi-enclosed strata.

State Water Quality Standards and Tampa Bay Estuary Program (TBEP) Target Comparisons

As part of the data analysis, water quality data were compared to state Impaired Waters Rule criteria and Tampa Bay Estuary Program water quality standards and targets. Results from these comparisons showed that east strata, E1 through E5 and west stratum W5 were potentially impaired for Chl-a (Appendix C). Additionally, waters in W5 violated state DO standards and could potentially be impaired for DO. Stratum W5 received significant discharges from three eutrophic water bodies; the Cross Bayou canal, Lake Seminole, and the Seminole bypass canal. These discharges, as expected, had a negative impact on water quality in this area.

Wet and Dry Season Variation

Based on the data analysis for bottom DO and Chl-a, water quality declined during the wet season in both eastern and western strata (Appendix A, Figures A-1 to A-4). Overall, there was little variation in transmissivity (Appendix A, Figures A-5 and A-6); however, in eastern strata, transmittance was higher in middle Tampa Bay than in Old Tampa Bay. In western strata, the most prominent seasonal difference occurred in stratum W5 where transmittance declined from an annual mean of 73% during the dry season to approximately 53% during the wet season. The large decline in wet season water clarity in stratum W5 was most likely due to discharges of poor quality water from the eutrophic water bodies located upstream. There were no significant differences in the mean and median values of total suspended solids between the wet and dry seasons in east and west strata, though there were significant differences in the variability of the data, with higher individual readings in the dry season. Mean and median values for turbidity were slightly elevated in E1 and E2, and W5 during the wet season, though the overall change in the value ranges were small (Appendix A, Figures A-9 to A-10).
LAND SITES:

Impaired Waters Rule

As part of the data analysis, water quality data were compared to state standards as applied by the Impaired Waters Rule (IWR). Results from the analysis indicate that 35 of 51 land-based sites were potentially impaired for bacteria, 10 were potentially impaired for Chl-a, and 19 were potentially impaired for DO. Two sites in Brooker Creek, 04-02 and 04-03, also exceeded the pH criterion (Appendix C).

Annual Flow and Loadings and Area-Based Loadings

In addition to the IWR comparisons, calculations were made to estimate annual flow volumes and nutrient loadings calculated in tons and in pounds per acre. As expected, sites with the highest annual flow generally had the highest annual total nitrogen (TN), total phosphorus (TP), and TSS loads. Sites with the highest annual flow and loadings from 2003-2006 in descending order were: Lake Tarpon outfall canal (06-04), Brooker Creek (04-03), Curlew Creek (10-2), Alligator Creek (14-11), Roosevelt channel 5 (23-08), and the Seminole Bypass canal (25-02 and 25-07) (Appendix A, Figures A-11 to A-14). The five sites with the highest annual flow per acre accounted for four of the five highest TN, TP, or TSS loads per acre (Appendix A, Figures A-15 to A-18).

LAKES:

State Water Quality Standards

Water quality data collected from Lake Seminole and Lake Tarpon were compared to state water quality standards as referenced in the IWR. Based on these comparisons, Lake Tarpon and Lake Seminole did not meet state standards for DO, Chl-a, TSI, or pH during the 2003-2006 monitoring period (Appendix C).

Wet and Dry Season Variation

Wet and dry season statistical comparisons for Lake Tarpon and Lake Seminole were completed and are shown in Appendix A, Figures A-19 to A-23. In both the north and south lobes of Lake Seminole, mean and median DO, TSS, and Chl-a values were higher in the dry season compared to wet. There was no difference in turbidity and transmissivity between seasons. On Lake Tarpon, mean and median values for DO and transmissivity were higher in the dry season, while Chl-a was higher in the wet season. Values for TSS and turbidity were similar between seasons.

Trophic State Index (TSI)

Trophic state indices were calculated for Lake Tarpon, Lake Seminole (both north and south lobes), Lake Chautauqua, and Alligator Lake for the 2003-2006 reporting period (Appendix A, Figures A-24 to A-27). Lakes are classified as colored lakes where a TSI of <59 is good, 60-69 is fair, and >70 is poor (Hand et al, 1992). Spanning the years 2003-2006, Lake Tarpon had an
average TSI of 55, Alligator Lake had an average TSI of 55, and Lake Chautauqua had an average TSI of 34, all indicating good water quality. Lake Seminole’s average TSI during the reporting period was 80 indicating poor water quality. Additionally, TSIs for each sample period were calculated and plotted by date of collection to show seasonal trends (Appendix A, Figures A-24 to A-27). Lake Tarpon’s TSI was typically higher during the warm wet months and lower during the cool dry months. There was no increase in TSI between years. Lake Seminole did not show any apparent seasonal trend in TSI and was consistently high (poor) throughout all four years. Both Lake Chautauqua and Alligator Lake showed no seasonal pattern in TSI readings.

CUMULATIVE DISTRIBUTION FREQUENCY PLOTS:

Cumulative distribution frequency (CDF) plots were developed to estimate the percentage of the area of a stratum that exceeds or was below given values for each water quality metric. Plots for strata E1-E7 (including RB) displayed an improving water quality trend from north to south (Appendix A, Figures A-28 to A-67). For instance, the average estimated percent area that met the TBEP Chl-a target of 8.5µg/L was between 45-55% in strata E1 through E3. The percent area increased to 75-90% in E6 and E7 where the TBEP Chl-a target is 7.5µg/L. Among the west coast strata (Appendix A, Figures A-68 to A-107), the estimated percent area meeting the 11µg/L Chl-a standard ranged from 62% in stratum W5 to 85-100% in W1, W2, and W8. This trend was also similar in other water quality parameters. Western strata sampling locations closer to open waters of the Gulf of Mexico and southern Boca Ciega Bay showed a greater proportion of their areas meeting state water quality standards and TBEP targets.

Comparisons of the cumulative frequency distribution plots for the lakes reflected better water quality for Lake Tarpon compared to Lake Seminole (Appendix A, Figures A-108 to A-122). The Lake Seminole plots of Chl-a, TSS, and turbidity covered a range of water quality measurements greater than similar plots for Lake Tarpon. The transmissivity data showed extremely poor light penetration in Lake Seminole.

CONCLUSIONS BASED ON THE ANALYSIS OF PINELLAS COUNTY WATER QUALITY DATA FROM 2003-2006:

• Water quality is better in open water strata compared to enclosed or semi-enclosed strata.

• Water quality is typically better during the dry season compared to the wet season.

• Land sites (streams, creeks, and canals) with the highest flow were typically associated with the highest nitrogen loadings including the Lake Tarpon outfall canal, Brooker Creek, Curlew Creek, Alligator Creek, Roosevelt Channel 5, and the Seminole Bypass Canal.

• Land sites with the lowest flow were typically associated with the lowest nitrogen loadings including Church Creek, Bishop Creek, Cow Branch Creek, and Cedar Creek.
• Water quality in Long Bayou and Cross Bayou (stratum W5) is poor due to discharges from three eutrophic systems: Lake Seminole, the Seminole Bypass Canal, and the Cross Bayou Canal.

• Lake Tarpon and Lake Seminole did not meet state water quality standards for four different criteria: DO, Chl-a, TSI, and pH.
9.0 References


April 2007


