Crystal River/Kings Bay
Technical Summary

1966 - 2004

Surface Water Improvement and Management Program
Resource Management Department

Southwest Florida
Water Management District

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Executive Summary

Crystal River/Kings Bay is located in Citrus County approximately 60 miles north of Tampa, Florida. The first magnitude spring system that forms the 600-acre Kings Bay embayment has an average total discharge rate of 975 cubic feet per second (cfs) and is the second largest spring system, as measured by discharge, in the state of Florida. This tidally influenced embayment is the headwater of Crystal River, which terminates approximately 6 miles west in the Gulf of Mexico. The Crystal River/Kings Bay watershed supports numerous listed and unlisted wildlife species, including the West Indian manatee. Accordingly, the unique ecological attributes of Crystal River/Kings Bay were recognized by the state of Florida in 1983 through its designation as an Outstanding Florida Water (OFW). To date, commercial and recreational activities associated with the distinctive habitat and wildlife of Kings Bay have supported the local economy. However, rapid development of the watershed has occurred, coincident with increases in the County's population from approximately 9,268 in 1960 to approximately 118,085 in 2000. This development has increased human-related activities that are impacting water quality and natural systems in Kings Bay.

In 1988, the Southwest Florida Water Management District (District) included Crystal River/Kings Bay in the list of priority water bodies established for the Surface Water Improvement and Management (SWIM) Program. Subsequently, four primary management issues were identified and incorporated in the original Crystal River/Kings Bay SWIM Plan (SWFWMD 1989). These issues included septic tank/wastewater treatment plant effluent, urban and agricultural stormwater, recreational uses, and sediment/aquatic vegetation. Collaborative projects between the District and partners, to address the management issues, were initially diagnostic in nature with limited implementation/monitoring efforts. Results of these early projects, completed from 1991 through 1995, provided much needed information on ground water quality discharging from the Kings Bay springs, sediment contamination, sediment composition and factors affecting growth of *Lyngbya* sp. in the bay. In 1991 and 1992, prioritization of stormwater projects and installation of channel markers to protect manatees and facilitate boat traffic were implemented, respectively, in Kings Bay. A volunteer water quality monitoring program, LAKEWATCH, was initiated by the District and University of Florida in 1992; which continues at a reduced scale to date. Implementation of stormwater projects by the District and City of Crystal River and the cessation of effluent discharge, in 1992, from the City of Crystal River's wastewater treatment plant into Kings Bay were initial strides in addressing the wastewater effluent and stormwater issues.

However, by the mid-1990's growing concerns led to the initiation of diagnostic and implementation projects aimed at improving water clarity in Kings Bay. Results of the diagnostic studies characterized the bay's complex circulation and flushing patterns and identified suspended solids as the leading factor impacting water clarity. A dredging project to remove sediments and *Lyngbya* mats from Hunters Spring and Tarpon Hole was completed in 1997. Anecdotal reports indicated that the springs quickly silted in following completion of the dredging project.

In 2000, the first update of the Crystal River/Kings Bay SWIM Plan (SWFWMD 2000) redefined the management issues to emphasize projects addressing water clarity, proliferation of *Lyngbya* and resuspension of sediments. Continued diagnostic studies from 2001 through 2003 focused on water clarity and aquatic plants, including the possible relationship between these management issues. A pilot restoration effort to replant native Tapegrass (*Vallisneria Americana*) in areas of Kings Bay indicated that large-scale plantings would likely fail because of manatee grazing. In 2003, the District and City of Crystal River completed implementation of three stormwater improvement projects designed to reduce nutrients and suspended solids entering the bay through stormwater runoff

Recognizing the need to improve the coordination of restoration and management activities in Kings Bay, the District facilitated the formation of an inter-agency advisory group that includes public participation. From the initial meeting on October 2, 2003, the advisory group has reviewed the results of diagnostic studies, data from water quality monitoring programs and success of implementation projects completed to date in Kings Bay. Additionally, the advisory group has evaluated impacts on rooted aquatic plants from the use of mechanical harvesters to remove benthic algal mats and proposed a cooperative shoreline restoration project to buffer seawalls with stands of emergent plants. Collectively, the advisory group supports active management of nitrogen loading, in the form of nitrate, within the Kings Bay watershed through implementation of stormwater improvement projects and public education activities. District activities proposed and/or initiated in 2004 to address nitrate management include continued implementation of stormwater projects, origination of education and outreach programs and identification of land uses within the watershed with potentially elevated nitrate concentrations. Discussions with the advisory group have led District staff to propose three studies to address the effects of light, sediments and natural shoreline on the growth and success of rooted aquatic plants in the bay. Results of these studies will help determine if sustainable aquatic plant communities can be established, based on the current light and sediment conditions, in Kings Bay.

A more detailed discussion of the results of completed and ongoing diagnostic studies, monitoring programs, storm water, dredging and restoration projects implemented in Kings Bay is included in the body of this report. This report summarizes the technical studies completed to date for Crystal River/Kings Bay. The report provides resource managers and policy makers with historical and current information on the Crystal River/Kings Bay system.

Technical Summary

Similar to other spring-fed rivers in Florida's Springs Coast, the natural systems and water quality of Crystal River/Kings Bay have been impacted by development. Since approximately 1960, rapid development of the immediate Kings Bay watershed has altered surface and ground water chemistry, reduced wetlands in the watershed, hardened natural shorelines, disturbed bay sediments, introduced exotic plant and animal species, increased disturbances related to recreational activities, diminished rooted aquatic plant coverage and impaired water clarity. However, measures to protect the endangered West Indian manatee, conserve adjoining natural lands and manage nutrient inputs have led to improvements in the bay in the past decade. Since the inclusion of Crystal River/Kings Bay as a SWIM Priority water body in 1988, the District and partners have worked together in identifying management issues and developing management strategies to improve conditions in this unique tidally influenced first magnitude spring system. The management issues and strategies identified and implemented by the District and its' partners are summarized in this report. A more complete discussion of the technical information available for Crystal River/Kings Bay is included in Appendix A. Issue Analysis and Technical Assessments.

Management Issues

Water Quality

Current management issues related to water quality in Kings Bay focus on nutrient loading and water clarity. Excess nutrients fuel the growth of phytoplankton, epiphytic algae and filamentous green and blue-green algae. The living and decaying cells of these algal species contribute to the decline in water clarity which, in turn, impacts rooted aquatic plants.

Ground Water – Discharge (~975 cubic feet per second) from approximately 30 springs provides nearly 99 percent of the fresh water entering Kings Bay. An estimated 335 and 38 tons of nitrogen and phosphorus, respectively, are introduced to the bay annually in this spring discharge. These nutrient loads represent 94 percent of total nitrogen and 84 percent of total phosphorus entering the bay each year; amounts that have not significantly changed from 1991 to present. Approximately 61 percent of the total nitrogen discharged annually by Kings Bay springs is in the form of nitrate, which is believed to be above background levels established for the Springs Coast region. The primary sources of groundwater nitrogen are turf fertilizers and septic tank discharge. Development-related nitrogen loadings in spring discharge are expected to increase in Kings Bay over time as the contributing springshed is further developed. In addition to further deteriorating water quality in Kings Bay, these projected nitrogen increases could impact downstream receiving estuaries if the levels exceed the assimilative capacity of the bay's plant communities. Therefore, strategies to reduce existing nitrogen loadings to ground water are needed to offset future impacts.

Surface Water – After spring discharge, the three major sources of nutrient loads to Kings Bay include (in order of contribution); sewage treatment effluent (currently commercial and residential package plants), septic tank leachate and stormwater runoff. In 1991, it was estimated that 24 tons of total nitrogen and 7 tons of total phosphorus

enter Kings Bay annually through sewage treatment effluent and septic tank leachate combined. Diversion of effluent from the City of Crystal River Wastewater Treatment Plant, in 1992, reduced annual loadings of total nitrogen and total phosphorus by approximately 13 and 4 tons, respectively. Transferring local package plants and septic tank systems to municipal wastewater treatment, implementing stormwater improvement projects and encouraging best management practices for residential and commercial fertilizer application may further reduce or maintain existing nutrient levels in Kings Bay.

Water Clarity – Recreational activities in Kings Bay related to diving, snorkeling and manatee viewing rely substantially on unimpaired water clarity. Substantial declines in the bay's water clarity since the 1970s – 1980s have been repeatedly reported by the local community. However, because historical data from this time period are not available, these declines cannot be quantitatively estimated. Periodic data collected from 1994 to 2004 indicate that water clarity has not significantly changed in the last decade. Current data are not sufficient to determine a quantitative goal for water clarity. Consequently, additional data are being collected to determine if improved water clarity is feasible or whether the goal is to "hold the line" at current standards. Factors known, or suspected, to affect water clarity in Kings Bay include concentrations of chlorophyll (a proxy measure of phytoplankton abundance), flushing from spring discharge, and resuspension of dead algal material and sediments from the bay bottom or from rooted aquatic plants. Resuspension of particulate materials can be exacerbated by boat traffic, manatee grazing and recreational activities related to diving and snorkeling. Additionally, periods of reduced rooted aquatic plant coverage have been linked by the University of Florida to periods of degraded water clarity. Therefore, improving water clarity will rely on implementing projects that enhance coverage of rooted aquatic plants, reduce nutrient loading and decrease suspended materials in the water column.

Aquatic Vegetation

Submerged, rooted aquatic plants provide habitat and food for many wildlife species in Kings Bay. In this shallow water body, rooted aquatic plants also act to reduce wave action and assimilate nutrients that would otherwise promote growth of nuisance algal species; functions that help maintain water clarity. With the advent of development in the surrounding watershed (circa 1960), nuisance and exotic plant species were introduced to Kings Bay. The initial exotic plant species impacting the bay's native aquatic plant communities was *Hydrilla verticillata*, a plant frequently associated with the aquarium trade. Hydrilla rapidly expanded throughout the bay and efforts to control the species have ranged from sulfuric acid applications, herbicide treatments and mechanical harvesting. Utilization of copper based herbicides were subsequently reduced when elevated levels of copper were found in the tissues of local dead manatees. Sensitive to salinity, Hydrilla coverage was reportedly reduced by a significant storm (Storm of the Century) in 1993. A more salt-tolerant exotic plant species, *Myriophyllum spicatum*, and the filamentous blue-green alga, *Lyngbya* sp., subsequently became the predominant species in the bay. Extensive mats of *Lyngbya* sp. became common in the bay, overlaying and shading rooted aquatic plants. An interest in enhancing coverage of native aquatic plants in the bay led to two restoration efforts that removed exotic plant species and replanted the cleared areas with a desired

native species, *Vallisneria americana*. These efforts failed when the newly installed Vallisneria plants were quickly consumed by resident manatees. Documented factors affecting the growth of nuisance plant species include salinity levels, nutrient concentrations and interspecific competition. With the important roles rooted aquatic plants play in improving water clarity and providing wildlife food and habitat, measures to enhance overall rooted plant coverage need to be highlighted with a secondary emphasis on managing nuisance aquatic plant species.

Sediments

Decaying organic material from the three predominant nuisance plant species (*Hydrilla verticillata*, *Lyngbya* sp. and *Myriophyllum spicatum*) may have altered sediment composition in Kings Bay by increasing the proportion of silty and fine grained sediments over time. The only sediment evaluation completed to date, in 1993, characterized the sediments as shallow (generally less than 3.4 feet), comprised largely of fine-grained particles and low in organic matter. A paucity in historical data prohibits an estimate of how sediments might have changed from a pre-development time period to 1993. However, if fine-grained sediments and organic matter have increased from 1993 to present this may have amplified current impacts to water clarity, rooted aquatic plants and nutrient loading. Actions to determine the role of sediments in restoring rooted aquatic plants and actions to reduce the resuspension of flocculent sediments deserve consideration in management efforts to improve water clarity and natural habitat in Kings Bay.

Wildlife

The Crystal River/Kings Bay watershed supports numerous listed and unlisted wildlife species including; 21 species of amphibians, 191 species of birds, 22 species of mammals and 47 species of reptiles. Foremost among these species is the endangered West Indian manatee. In 1983, the United States Fish and Wildlife Service (USFWS) established the Crystal River National Wildlife Refuge to protect manatees utilizing Kings Bay for foraging and refuge from the cold waters of the Gulf of Mexico. During the winter, manatees in Florida congregate near spring vents which discharge water at a fairly consistent temperature of 72°F. These overwintering congregations risk greater exposure to boats and can intensify grazing pressure on submerged rooted aquatic plants in the vicinity. Therefore, management strategies must balance responsibilities to protect manatees with activities designed to protect and enhance existing stands of rooted aquatic plants, for the benefit of other wildlife species and improved water clarity.

Management Strategies

The following strategies and projects have been implemented since 1983 to address management issues in Crystal River/Kings Bay.

Management Actions for Water Quality

- Identification of Crystal River/Kings Bay as an Outstanding Florida Water and Surface Water Improvement and Management (SWIM) Priority Water Body in 1983 and 1988, respectively, has improved protection of the bay's water quality and natural systems. These designations enhanced coordination among

responsible management agencies and increased public awareness of issues affecting Kings Bay.

- An analysis of the relationship between spring discharge and salinity concentrations in Kings Bay was completed by the United States Geological Survey in 1989. Decreased springflow would increase salinities and potentially impact water quality/clarity in Crystal River and Kings Bay (through increased residence time). Further work is needed and will be done in conjunction with the District's Minimum Flows and Levels Section.

- In 1990, nutrient loading sources to the bay were identified and prioritized by the District. The four primary loading sources, in order of contribution, were spring discharge, sewage treatment effluent, septic tank leachate and stormwater runoff. Results of the study were used to initiate stormwater improvement projects by the District and City and, in conjunction with a State assessment in 1989, led to the diversion of the treatment plant effluent in 1992. A substantial reduction in surface water nutrients in northern Kings Bay was subsequently documented by the University of Florida. To date, permitted discharge of wastewater effluent from smaller treatment systems known as package plants still occurs in conjunction with local motels, mobile home parks and apartment/condominium communities.

- The City of Crystal River (City) has been implementing the transfer of commercial and residential septic tank systems within the City limits to municipal wastewater treatment. In coordination with the County, the City will extend municipal wastewater treatment services to County residents and businesses located within the immediate Kings Bay watershed. This program will reduce the amount of nutrients entering ground water and surface water through septic tank leachate

- A groundwater monitoring program was established in 1991 by the District's Ambient Ground-Water Monitoring Program, now known as the Water Quality Monitoring Program (WQMP). The program monitors constituents such as total nitrogen, total phosphorus and specific conductance for the major contributing springs in Kings Bay.

- In fall of 2004, the Florida Geological Survey assumed responsibility for quarterly sampling of the Kings Bay springs; District staff will continue annual sampling. Data will be used to better define the interactions between groundwater chemistry and water clarity, salinity and nutrients in Kings Bay. Additionally, data may be used to prioritize the implementation of groundwater BMPs in areas of nutrient enriched ground water.

- In 1992, the LAKEWATCH volunteer monitoring program was initiated by the University of Florida and District. Program volunteers measure nutrients, chlorophyll a and water clarity, using vertical Secchi distance, in six locations throughout the bay. These surface water quality data indicate a significant increase (p-value = 0.033) in mean annual chlorophyll a concentrations and slight decreases in mean annual nutrient levels from 1992 to 2002.

- Adjacent canal systems were evaluated as potential nutrient loading sources in 1997. Results indicated that the canals were not contributing significant loads of total nitrogen and total phosphorus to the bay.

- Numerous stormwater improvement projects have been completed cooperatively by the District and City since the 1990s and continue to date. These projects improve water quality in Kings Bay by decreasing nutrient concentrations and suspended solids entering the bay through stormwater runoff.

- Assessments completed to date indicate that water clarity in Kings Bay is related to suspended solids in the water column. Probable factors affecting suspended solids include rooted aquatic plant coverage, flocculent sediments and spring discharge. Results of these assessments led to the initiation of a more intensive monitoring program by the District to evaluate spatial and temporal differences in water clarity throughout the bay.

- A cooperative salinity monitoring program was established in the bay by Citrus County (County), the District and the Florida Department of Environmental Protection (FDEP) in 2003. Salinity data collected by the program may be utilized to assess changes in aquatic plant coverage based on fluctuating salinity levels in the bay.

- An intensive surface water quality monitoring program was initiated by the District in 2003. District and FDEP staff measure parameters affecting water quality and water clarity every other month at twelve stations in Kings Bay. The data will be maintained, analyzed and used by District staff to create a site-specific optical model. The model will be used to identify strategies to improve water clarity within the differing areas of Kings Bay.

- In 2004, the research phase of a watershed education plan was initiated by the District. Staff with the Communications Department will survey current public knowledge of nutrient Best Management Practices (BMPs) through focus group meetings. Results of the survey will be used to develop and distribute educational material related to implementing BMPs known to reduce nutrient loading.

Management Actions for Aquatic Vegetation

- Exotic plant control activities have been implemented by the County to reduce abundance of nuisance species such as *Hydrilla verticillata*, *Myriophyllum spicatum* and *Lyngbya* sp. in Kings Bay. Activities currently employed by the County to reduce nuisance aquatic plants include mechanical harvesting (to control *Myriophyllum* and *Lyngbya*), skimming (to reduce floating mats of *Lyngbya*) and selective herbicide applications (to diminish *Pistia stratiotes* or water lettuce).

- Factors affecting the growth of *Lyngbya* sp. were assessed by the University of South Florida in 1990 and determined to include abundance of *Hydrilla verticillata* and levels of salinity. Coverage of *Lyngbya* was significantly less in areas with high abundance of *Hydrilla* and elevated salinity levels. Results of this study

- supported the initiation of a salinity monitoring program to track the effects of fluctuating salinity levels on aquatic plants in Kings Bay.

- Coverage of the eight predominant plant species in Kings Bay; *Myriophyllum spicatum*, *Lyngbya* sp., *Vallisneria americana*, *Potamogeton pectinatus*, *Najas guadalupensis*, *Hydrilla verticillata*, *Chara* sp. and *Ceratophyllum demersum*, were assessed and mapped in the bay in 2001. Recently, data suggest that *Ruppia maritima* is another rooted aquatic plant species that periodically may be common in the bay. Data from the mapping effort are used by the District and partners to identify existing stands of native and nuisance plants species for the assessment of plant control activities and restoration/enhancement actions.

- Restoration projects completed in 2001 and 2003 suggest that large scale replantings of the native *Vallisneria americana* will likely not succeed in the presence of manatee grazing. Based on the outcome of these projects, the District has no plans to replant large areas of the bay with native plant species. Instead, the District and partners will work to identify strategies to enhance and expand existing stands of native aquatic plants in Kings Bay.

- The Kings Bay Advisory Group coordinated a study to evaluate the use of mechanical harvesters to remove mats of *Lyngbya* from bay sediments (a process known as "grubbing") in 2004. Prior to the pilot study, there were public concerns that grubbing was impacting rooted aquatic plants. Results of this pilot study indicated that grubbing was not significantly reducing the abundance of rooted aquatic plants. However, it appeared that the process was not eliminating *Lyngbya* from the bay. Due to budget constraints, funding for grubbing activities in Kings Bay was suspended by the FDEP in 2004.

- In August 2004, an effort to review light availability for submerged aquatic plant growth was completed. It was determined that sufficient light is available to support existing stands of submerged aquatic plants in Kings Bay. The District will move forward with projects to identify other potential impacts to rooted aquatic plants.

- A repeat mapping of submerged aquatic vegetation in Kings Bay was initiated by the District in February 2004. Coverage of aquatic plant species will be recorded and mapped on a quarterly basis by the University of Florida to assess seasonal changes in the plant communities and evaluate success of plant-related management strategies.

Management Actions for Sediments

- In 1993, sediments in Kings Bay were characterized by the Florida Institute of Technology and described as shallow, comprised largely of fine grained particles and low in organic matter. Data from the study will provide baseline information for future assessments to track changes in sediment depth and composition and information related to potential nutrient loading from bay sediments.

- A dredging restoration project to remove sediments and mats of *Lyngbya* sp. from the Tarpon Hole and Hunters Spring was completed in 1997. Anecdotal

- reports suggest that the springs quickly silted in following completion of the dredging project.

Management Actions for Wildlife

- Creation of the Crystal River National Wildlife Refuge by the USFWS in 1983 provided protection for the endangered West Indian manatee. Staff with the USFWS continue to mark and patrol manatee sanctuaries, located near major spring vents, from November 15 through March 31 each year.

- Qualitative monitoring of submerged aquatic plants by the USFWS and the USGS was established to track available food resources for the West Indian manatee. The program provides presence/absence data for the predominant plant species at fifteen stations throughout Kings Bay.

- A survey of terrestrial and aquatic wildlife in the Crystal River/Kings Bay watershed was completed by the Florida Game and Fresh Water Fish Commission (now known as the Florida Fish and Wildlife Conservation Commission or FWCC) in 1992. The survey documented many listed and unlisted wildlife species inhabiting the watershed and recommended improving water quality and protecting undeveloped shoreline to benefit these species.

- Assessments of the effects of copper (incorporated from bay sediments into aquatic plant tissues) on the West Indian manatee and levels of mercury in Largemouth bass in Kings Bay were completed by the USFWS in 1991 and 1994, respectively. Results indicated that sediment copper levels were insufficient to cause manatee mortality and that mercury levels in Largemouth bass did not kill the fish but did represent a threat to birds of prey feeding upon the bass.

Future Work

Specific actions to address the current management issues of water quality and aquatic vegetation are outlined in the following project descriptions. These projects are projected for implementation by the District and/or partners over the next five to ten years.

Crystal River/Kings Bay Watershed Education Plan: Design and Implementation – Public education materials will be developed and distributed by the District to educate the public and commercial entities on BMPs capable of reducing nutrients in ground water entering Kings Bay. Implementation of BMP's to reduce ground water nutrient concentrations is compatible with the management strategy of improving water quality.

Kings Bay Sediment Evaluation 2005 – Changes in the depth and composition of sediments in Kings Bay since 1993 will be evaluated by the District and Florida Institute of Technology. Data will be used to determine the capacity of bay sediments to support rooted aquatic plants and impact water clarity.

Additionally, an estimate of nutrient loading from bay sediments will be provided. These activities will assist the management strategies of reducing sediment resuspension, improving water clarity and water quality and sustaining aquatic vegetation in Kings Bay.

Springs Cleanup Initiative – Sinkholes associated with the region's five first magnitude spring systems; Weeki Wachee, Homosassa, Chassahowitzka, Kings Bay and Rainbow River, will be prioritized for removal of discarded materials. The District will subsequently hire a contractor to survey and remove debris from submersed portions of identified priority sinkholes and/or the springs themselves.

Mapping and Database for Springs in the Coastal Rivers Basin – The District will initiate a project to map watersheds and springsheds contributing to the region's springs. The project will also identify land uses with potentially elevated nutrients within the mapped watersheds and springsheds.

Crystal River Watershed Management Plan – Staff with the District have proposed a project to review existing water quality resources and identify/implement nutrient BMPs within the Crystal River/Kings Bay watershed; consistent with the management strategy of improving water quality. Project costs for this cooperatively funded effort are estimated at $300,000. To date, the District, Citrus County and the Florida Department of Transportation have secured funding for the project.

Transfer of Residential and Commercial Properties with Septic Tanks to Municipal Wastewater Treatment – The City of Crystal River and Citrus County will coordinate efforts to connect local private residences and commercial entities, supported by septic tanks, to the City of Crystal River Wastewater Treatment Facility. Over time, a reduction of septic tank and package plant leachates will be realized. Decreasing nutrient loadings to the bay supports the management strategy of improving water quality.

Identification and Prioritization of Stormwater Sub-basins Within the Kings Bay Watershed – The District will delineate and prioritize, by level of nutrient loading, sub-basins within the Kings Bay watershed. The results will be used to prioritize stormwater improvement projects on a local scale for future implementation. Implementation of effective stormwater improvement projects will assist in the reduction of nutrient and sediment loadings to the bay.

Kings Bay Chlorophyll Source Identification Project – Staff with the District's SWIM Program will initiate a project to identify the sources of chlorophyll, produced by species of algae, in Kings Bay. The information will be used to develop, where possible, strategies to target and reduce dominant species of algae. Implementing actions to reduce algal abundance supports the management strategy of improving water clarity in Kings Bay.

Minimum Flows and Levels – The District will establish minimum flows and levels necessary to protect the water resources and ecology of the Crystal River/Kings Bay system. Maintenance of functional flows is central to sustaining aquatic vegetation and improving water clarity.

Appendix A. Issue Analysis and Technical Assessments

Background

Crystal River/Kings Bay is located in Citrus County approximately 60 miles north of Tampa, Florida (Figure 1). The first magnitude spring system that forms the 600-acre Kings Bay embayment has an average total discharge rate of 975 cubic feet per second (cfs) (Yobbi and Knochenmus 1989) and is the second largest spring system, as measured by discharge, in the state of Florida (Rosenau et al., 1977). As a result, collective discharge from the approximately 30 known springs located in Kings Bay accounts for approximately 99 percent of the freshwater entering the bay (Hammett et al., 1996). This tidally influenced embayment is the headwater of Crystal River, which terminates approximately 6 miles west in the Gulf of Mexico.

Inhabited by man since about 500 BC, significant changes in the land use of the Crystal River/Kings Bay watershed began with European settlement of the area in the mid 1700s. During the 1800s major land uses included agriculture, horse and cattle ranching, and timber harvesting. By the 1900s timber and mining activities were predominant throughout the watershed, with timber and distillation of turpentine directly affecting Kings Bay (Dunn 1976). Rapid development of the watershed during the latter part of the 1900s resulted in significant increases in urban land use. Analysis of land use and cover codes indicate that acreage utilized for urban activities within the watershed increased by 16,007 from 1944 to 1995 (Southwest Florida Water Management District, 2000) (Figure 2). During this same time period, upland forested acreage decreased by 16,451 acres (Figure 2). These land use changes within the Crystal River/Kings Bay watershed were coincident with rapid increases in the county's population over a 40-year period. The estimated population of Citrus County increased from approximately 9,268 in 1960 to an approximate 118,085 by the year 2000 (Sources: University of Florida and Withlacoochee River Planning Council 2001; United States Census Bureau) (Figure 3).

Impacts of land use activities on the Crystal River/Kings Bay system are potentially amplified if the watershed, as defined by the United States Geological Survey (Figure 4), is expanded to include the groundwater recharge area estimated by the Southwest Florida Water Management District (District). The resulting District management area for Crystal River/Kings Bay covers approximately 240 square miles or nearly 40% of the entire county and extends as far as east Lake Tsala Apopka (Figure 5). Therefore, land use activities within approximately 40% of Citrus County have the potential to affect, through direct runoff and groundwater discharge, water quality in Kings Bay, Crystal River and the near shore estuaries of the Gulf of Mexico.

Significant urbanization of the immediate Kings Bay watershed began in the mid-1900s, prior to the implementation of many Best Management Practices (BMPs). As a result, water quality in Crystal River/Kings Bay has been, and continues to be, affected by stormwater runoff and nutrient loadings from local septic tanks and spring discharge. Projects to address stormwater loadings began approximately ten years ago and continue to date. Additionally, extensive dredge and fill activities (circa 1960) altered much of the Kings Bay and portions of the Crystal River shorelines (Figure 6).

Designed to provide residential and commercial boat access to Kings Bay and Crystal River, these activities created numerous sea walls and dead-end canal systems; which have altered the hydraulic regime and historical natural wetlands of Kings Bay.

The following sections summarize published and unpublished data archived by the District pertinent to the Kings Bay embayment. Several of the data sets were made available to the District by federal and state agencies for the preparation of this document. It is recognized, however, that the data included in this document, while substantive, likely do not represent all available information for the Crystal River/Kings Bay system.

Water Quality

Ground Water

In 1990, Romie identified four major sources of nutrient loading to Kings Bay; spring discharge, sewage treatment effluent, septic tank leachate and stormwater runoff. Proportionate loadings from each source were estimated and it was determined that spring discharge contributed approximately 94% of total nitrogen (TN) and 84% of total phosphorus (TP) entering the bay. Average TN and TP concentrations from nine springs sampled during the project were 0.35 and 0.04 mg/L, respectively.

The District's Ambient Ground-Water Quality Monitoring Program (AGWQMP), now known as the Water Quality Monitoring Program (WQMP), analyzed water chemistry samples collected from 103 wells located within the identified Kings Bay recharge area in 1991. These data were combined with water chemistry information collected from significant springs in the Kings Bay springs complex to characterize the local ground-water quality. Results of the two-year study were as follows (Jones et al. 1994):

- Approximately 335 and 38 tons of nitrogen and phosphorus, respectively, are discharged from the Kings Bay springs annually.
- Approximately 205 of the 335 tons, or 61%, of nitrogen discharged annually are in the form of nitrate.
- Although spring and ground water data are not sufficient to indicate any trend in nitrate concentrations, the average concentration reported was 0.2 mg/l (1991 – 1992); which is approximately 20 times greater than the generally accepted background level of 0.01 mg/l (uncontaminated waters of the Floridan Aquifer). However, it is unknown whether historical nitrate concentrations in discharge from the Kings Bay springs complex were ever equivalent to 0.01 mg/l.
- The spring's ground water sources originate from a drainage basin approximately bounded by the Withlacoochee River and a flow-line divergence in south-central Citrus County (Figure 5).
- Groundwater in the Crystal River/Kings Bay recharge area has most likely entered the Floridan aquifer within the last 50 years.
- Small, localized loadings of development-related nitrogen (turf fertilizers and septic tank discharges) associated with the eastern portion of the City of Crystal River drainage basin most likely comprise the majority of the low levels of nitrogen in spring discharge.

- Additional natural and anthropogenic nitrogen loadings are anticipated to impact ground water discharges into Kings Bay in the near future. These sources of nitrogen-enriched ground water are traveling towards Kings Bay from the east-central and north-central portions of the recharge area and will affect the bay dependent upon travel time through the Floridan aquifer.

The District's Water Quality Monitoring Program (WQMP) has continued to collect quarterly water chemistry data from Tarpon Hole and Hunters Spring from 1991 to 2004. In fall 2004, the Florida Geological Survey assumed responsibility for quarterly sampling of the Kings Bay springs; District staff will continue annual monitoring. In summary, mean total nitrogen, total phosphorus and nitrate concentrations recorded by the District for Tarpon Hole and Hunters Spring (1991 through 2002) were:

Spring	Total Nitrogen (mg/L TN)	Total Phosphorus (mg/L TP)	Nitrate (mg/L NO_3)
Tarpon Hole	0.29	0.04	0.165
Hunters Spring	0.51	0.03	0.291

There is no indication that concentrations of TN, TP or nitrate have significantly increased during the period of record (1991 – 2002) for Tarpon Hole or Hunters Spring discharge.

However, data collected by the District's WQMP indicates a small increase in mean annual specific conductance since 1991 (range 1231 – 3299 μS/cm) for Tarpon Hole discharge. Increasing specific conductance could result from the spring's location in the Coastal Transition Zone; the salt water/fresh water interface in ground water (Figure 7). Therefore, a longer collection period would be recommended before concluding an increasing trend in the specific conductance of Kings Bay springs discharge has occurred.

In summary, the Kings Bay springs complex discharges relatively young water (< 50 years) and contributes the majority of total nitrogen and total phosphorus loads entering Kings Bay. Significant increases in average TN, TP and nitrate concentrations have not occurred since 1991. However, a small increase in specific conductance from 1991 to present has been recorded, possibly indicating greater salinities in spring discharge. Although nutrient concentrations discharging from the Kings Bay springs are low relative to spring complexes in more developed areas, they are elevated over levels in surrounding undeveloped lands and are higher than levels reported seven years earlier. While current efforts to reduce nitrate levels in ground water may not be realized immediately in the springs discharge, such efforts could "hold the line" in the face of future development within the Crystal River/Kings Bay recharge area.

Surface Water

Of the reports that include surface water quality information for Kings Bay, the Springs of Florida (Rosenau 1977) possibly contains the oldest data recorded for the system. Data collected from a surface sample over Tarpon Hole spring indicated a nitrate concentration of 0.06 mg/l and a specific conductivity of 555 μmhos/cm.

In 1989, Yobbi and Knochemus compiled data relevant to river discharge, high-tide stage, and salinity to characterize salinity distributions within Crystal River. Of interest, vertically averaged salinities ranged from one to three practical salinity units (psu) at a site located upstream from Miller's Creek (Figure 1), at river mile 6.16. The study concluded that increased ground water withdrawals could reduce spring flow and generate an upstream movement of vertically averaged salinities (through tidal fluctuations) in Crystal River and Kings Bay.

Salinity concentrations of approximately two to three psu have been suggested by the University of Florida to reduce total plant biomass in Kings Bay (Hoyer et al., 2001). Average salinities in Kings Bay might be elevated to these levels by tidal surges during storm events, landward movement of the coastal transition zone (Figure 7) or alterations in the bay's salinity regime through reduced fresh water inflow. Frazer et al. (2001b) reported bottom salinities ranging from a minimum of 0.74 psu to a maximum of 15.36 psu, with a mean salinity of 2.1 psu for the one-year study period. It was proposed that the levels were sufficient to alter distribution and abundance of particular plant species within the bay. Additionally, Frazer et al. suggested that long-term increases in average salinity, adequate to significantly reduce total plant biomass, might have occurred since 1989. The District has requested and acquired data collected by the United States Geological Survey (USGS) and the United States Fish and Wildlife Service (USFWS) (collection period: approximately 1982 – 2003) to determine if salinity levels in Kings Bay have increased during the past two decades. District staff have compiled the hard copy data into an electronic spreadsheet and will analyze the information in conjunction with data provided by current water quality and vegetative monitoring projects.

Concerns over effluent discharge into Kings Bay from the City of Crystal River Sewage Treatment Plant (STP) led to an evaluation of water quality in the receiving Crystal River Canal System (Nearhoof 1989). Water quality samples were collected three to four times daily, over a two-day period, at fourteen stations within the canal system. Concentrations for total kjeldahl nitrogen, nitrite + nitrate, total phosphorus and chlorophyll *a* were reported as follows:

- TKN: 0.03 – 3.64 (mg/l)
- $NO_2 + NO_3$: 0.0 – 8.2 (mg/l)
- TP: 0.04 – 3.97 (mg/l)
- Chl a: 1.0 – 50.1 (μg/l)

It was concluded that nutrients discharged by the STP were not fully assimilated in the Crystal River Canal System and were consequently affecting water quality in Kings Bay.

As part of the District's study to quantify contributions of the four main nutrient loading sources (springs discharge, sewage treatment effluent, septic tank leachate and

stormwater runoff) into Kings Bay, Romie (1990) established and sampled approximately 12 ambient surface water quality stations throughout the bay. Estimated contributions of TN and TP from the four main nutrient loading sources were:

TN:	Springs Discharge	94%
	Sewage Treatment Effluent	3%
	Septic Tank Leachate	2%
	Stormwater Runoff	1%
TP:	Springs Discharge	84%
	Sewage Treatment Effluent	13%
	Septic Tank Leachate	2%
	Stormwater Runoff	1%

Average TN and TP concentrations for the 12 surface water stations were 0.387 and 0.04 mg/l, respectively.

Anderson et al. (1991) subsequently utilized Romie's data set in 1991 to evaluate the nutrient loading potential of various wastewater sources in Kings Bay. This evaluation estimated annual nutrient loads into Kings Bay from septic tank systems and wastewater treatment facilities combined were 22,000 kg/y of TN and 6,400 kg/y of TP in 1991.

In March 1992, the City of Crystal River ceased discharging effluent from the City of Crystal River Sewage Treatment Plant into Kings Bay. Following the diversion, the University of Florida initiated a volunteer water quality monitoring program (LAKEWATCH) in August 1992 to assess changes in the bay's overall water quality and aquatic plant communities (Bishop and Canfield 1995). Volunteers measured water clarity and water quality parameters monthly from 1992 to 1994 at 21 stations. However, during the last year of the study (June 1994 to June 1995) the number of stations sampled by the volunteers was reduced from 21 to 10 stations. Aquatic plant abundance and biomass data utilized for the Bishop and Canfield study included abundance data collected by the National Biological Service (1979-1983 and 1985–1994: 15 stations) and biomass data generated by the LAKEWATCH volunteers (1993-1994: 30 stations). Conclusions of the report were as follows:

- TN and TP concentrations in Cedar Cove (Figure 1) declined significantly following the removal of wastewater discharge.
  - Prior to Removal: Total Nitrogen – 620 μg/l
    Total Phosphorus - 105 μg/l
  - After Removal: Total Nitrogen – 220 μg/l
    Total Phosphorus – 27 μg/l

- TN and TP concentrations in southern Kings Bay were not affected.
  - Prior to Removal: Total Nitrogen – 300 μg/l
    Total Phosphorus - 24 μg/l
  - After Removal: Total Nitrogen – 260 μg/l
    Total Phosphorus – 28 μg/l

- Short-term increases in TN and TP concentrations were noted after the "Storm of the Century"; which occurred in March 1993. However, an increase in chlorophyll concentrations, related to the short-term increases in nutrients, was not evident following the storm.
- No significant differences in TN, TP and chlorophyll concentrations were seen between high and low tides in Kings Bay.

To assess the impact of nutrient loads from canal systems on water clarity in Kings Bay, Hoyer et al. (1997) analyzed nutrient concentrations from several canals and open water stations located in southeastern Kings Bay. The University of Florida analyzed LAKEWATCH (1993-1997) data in conjunction with data collected for the study from 19 sites located in southeastern Kings Bay (1996-1997) to compare nutrient concentrations between canal and open water sites. Results indicated that TN and TP concentrations in the canals were not significantly different from the open water sites and were therefore unlikely to impact water clarity through increasing algal populations in the bay. The University noted positive relationships between chlorophyll and nutrient concentrations, in the open water sites in Kings Bay. However, linear regression of logarithmic transformed data suggested that the relationships were weak, with TN and TP accounting for approximately 4% and 8% of the variance in chlorophyll concentrations.

From 1995 to present, LAKEWATCH volunteers have continued to collect samples from four open water and two canal sites within Kings Bay. Data collected by the LAKEWATCH volunteer monitoring program (1992-2002) indicate that mean TN and mean TP concentrations for surface water sites are 0.241 and 0.026 mg/l, respectively. A small decrease in the mean annual TN and TP concentrations for surface water sites in Kings Bay has been noted in the past ten years (Figure 8). Mean annual concentrations of chlorophyll a have significantly increased (p-value = 0.033) during the same time period.

While a potentially weak relationship between nutrients and chlorophyll exists in Kings Bay, discharge of nutrients from the bay into Crystal River remains a concern. During an assessment of the physical, chemical and vegetative characteristics of rivers in the Springs Coast area, Frazer et al. (2001) determined that the majority of the nutrients leaving Kings Bay were not assimilated in Crystal River and were instead exported to the nearshore estuaries in the Gulf of Mexico (Figure 9). Nutrients entering the estuaries have the potential to increase phytoplankton production and negatively impact existing sea grass meadows.

To date, many activities to reduce and monitor nutrients in Kings Bay have been implemented. Most notably, discharge of effluent into the bay from the City of Crystal River Sewage Treatment Plant was diverted to a spray-field approximately 5 miles north of Kings Bay in 1992. While a notable improvement, the spray-field is in close proximity to the bay and may continue to affect nutrient loads through ground water infiltration. Additionally, the City has implemented several stormwater treatment projects (Figure 10) and successfully transferred a substantial number of residences from onsite disposal systems to municipal wastewater treatment. Homes with septic tanks located outside the city limits are also under consideration by the City of Crystal River for municipal wastewater treatment. In support of the City's efforts to address stormwater

related impacts, District staff is currently developing a project to identify sub-basins within the Kings Bay watershed that contribute significant nutrients and suspended solids to the storm water entering the bay. Accordingly, a drainage basin specific to Kings Bay, excluding Crystal River, has been delineated by the District. Collectively, this information will assist the City, County and District in prioritizing future stormwater improvement projects.

Additionally, the District's SWIM program initiated a water quality/clarity monitoring program for Kings Bay in June 2003. The program is designed to collect data every other month from 12 fixed sites for up to three years. The data will be used to track fluctuations in water quality, evaluate changes in SAV and to create region specific optical models within the bay. These models will help identify factors affecting water clarity in the differing areas of Kings Bay.

In conclusion, surface water quality in Kings bay is typified by fluctuating salinity concentrations and levels of total nitrogen and total phosphorus that are low relative to water bodies in more developed areas. Mean TN and TP concentrations from 1992 to 2002 were approximately 0.241 and 0.026 mg/l, respectively. However, these concentrations are likely higher than historical nutrient levels and are sufficient to support periodic algal blooms that decrease water clarity in Kings Bay and potentially the near shore estuaries of the Gulf of Mexico. Spring discharge appears to be the primary source of nutrients to the bay with secondary contributions from package plant (on-site waste water treatment plants) effluent, septic tank leachate and stormwater runoff. Nutrient concentrations in the canals of southeastern Kings Bay are not significantly elevated relative to those in adjacent open water sites and are unlikely to increase concentrations of TN and TP in the bay. Salinity concentrations affect which submersed plant species succeed in Kings Bay and can reduce total plant biomass when the plant community is dominated by freshwater species. At this time, mean salinities in the bay are approximately 2 psu. Current District SWIM activities in Kings Bay, related to water quality characterization, include developing a refined nutrient budget, determining if a change the bay's salinity regime has occurred in the last 20 years and creating region specific optical models.

Water Clarity

Recreational activities in Kings Bay related to diving, snorkeling and manatee (*Trichechus manatus*) viewing contribute substantially to the local economy. These activities depend a great deal upon unimpaired water clarity. Clear water has historically been a significant characteristic of the bay; however, declines in water clarity have reportedly occurred since the 1980's. Quantitative estimates of the reduction in water clarity since this time period are not available since water clarity data, measured as horizontal Secchi distance, prior to 1994 have not been reported (Figure 11). To assess changes in water clarity from 1994 to 2004, comparable sites and time periods for samples collected during the previous water clarity efforts needed to be established. During the last decade, five water clarity assessments have been completed by LAKEWATCH (1994), University of Florida (1997, 1999-2000) and the District (2001, 2003-2004); however each assessment has varied significantly in both the number of sites sampled and the number of samples collected. Comparison of spatially and

temporally equivalent data indicates that water clarity has not significantly changed since 1994 (Figure 12).

Resuspension of the fine sediments and silts currently comprising Kings Bay sediments may contribute to the declines noted in water clarity. In 2001, the University of Florida analyzed areas in Kings Bay where sediments were most susceptible to wind-driven disturbance (Bachmann et al., 2001). This analysis modeled the contribution of sediment resuspension to declining water clarity. It was concluded that resuspension of bottom sediments by wind-driven waves was not the primary factor reducing water clarity in the bay. Instead, Bachmann et al. suggested that water clarity was impacted to a greater degree by wave action dislodging periphyton and detritus from submersed macrophytes. However, calculations used for the analysis were conservative and may underestimate the role of sediments in reducing water clarity in Kings Bay.

In 1995, the University of Florida analyzed data collected by the LAKEWATCH volunteer monitoring program (August 1992 to August 1995) to assess the effects of the wastewater effluent removal in 1992 on aquatic plant communities in Kings Bay (Bishop and Canfield 1995). Data included in the report indicated that visibility in the bay appeared to be associated primarily with algal cells in the water column. It was proposed that the bay's canal systems were a significant source of phytoplankton that would flush in the bay during increased flows and decrease visibility within Kings Bay. However, further analysis of the LAKEWATCH data by Hoyer et al. (1997) determined that phytoplankton abundance in the canals was not significantly different than in the open waters of the bay; dismissing the canals as the primary source of clarity-reducing phytoplankton. The Hoyer et al. study did document an inverse relationship between the abundance of aquatic plants and chlorophyll concentrations in Kings Bay. As increases in phytoplankton standing crop typically reduce water clarity (Figure 13) and phytoplankton standing crop rise during periods of low aquatic plant abundance (Figure 14), it was suggested that there is a direct link between aquatic plant abundance and water clarity in the bay.

Water clarity in Kings Bay is inter-related with the extent of aquatic plant coverage. Aquatic plants can improve water clarity through the following mechanisms (Hoyer et al., 2001):

- possible competition with algae over available nutrients;
- stabilization of sediments; and
- reduction of wind-driven wave action.

Aquatic Vegetation

Submersed aquatic plant communities support wildlife species, stabilize sediments and remove contaminants from the water column and sediments. These functions alone substantiate the importance of healthy aquatic plant communities in a water body. Historical anecdotal evidence suggests that extensive Tapegrass or *Vallisneria americana* beds once dominated the vegetative community of Kings Bay. The introduction of nuisance species (Figure 15) such as *Hydrilla verticillata* (circa 1960), *Myriophyllum spicatum* (or Eurasian Water Milfoil) (circa 1960) and *Lyngbya spp.* (circa 1980) adversely altered the composition of submerged aquatic vegetation in the bay. Efforts to eradicate nuisance aquatic plants and filamentous algae have ranged from sulfuric acid treatments in 1965 (Phillippy 1966) to herbicide applications (circa 1960s – 1970s), mechanical harvesting (circa 1980s) and skimming/grubbing (circa 1990s).

In 1990, the University of South Florida completed a study analyzing factors affecting growth of *Lyngbya* sp. (Cowell 1990). Results revealed that specific conductivity (a surrogate for salinity) and abundance of *Hydrilla* together explained 61.8 percent of the variability in *Lyngbya* sp. biomass. Conversely, *Lyngbya* biomass and total phosphorus together explained 41 percent of the variability in *Hydrilla* biomass. Therefore, it was concluded that two factors impair the abundance of *Lyngbya* in Kings Bay; abundance of *Hydrilla verticillata* and increased salinity concentrations. Possibly, interspecific competition with other rooted aquatic plant species, beyond *Hydrilla*, might reduce abundance of *Lyngbya*.

Similarly, salinity was determined to affect presence of aquatic macrophytes in the Bishop and Canfield study (1995); designed to assess effects of the 1992 wastewater effluent removal on Kings Bay's aquatic plant communities. During the study period, tidal surges, associated with the "Storm of the Century" in March 1993, presumably increased salinity concentrations in Kings Bay. It was noted that both *Hydrilla verticillata* and *Lyngbya* sp. were absent from the fifteen stations monitored by the National Biological Service (as analyzed by Bishop and Canfield) following the "Storm of the Century". Although the reductions were short-lived (< 1 year), the data support the ability of salinity to alter the composition of aquatic vegetation in the bay. While *Hydrilla verticillata* and *Lyngbya* sp. were negatively affected by the storm, the native *Vallisneria americana* and the exotic *Myriophyllum spicatum* were relatively undisturbed by the increased salinities. Bishop and Canfield concluded that increased salinities had greater impact on the composition of aquatic plants in Kings Bay than nutrient reductions effected by the diversion of wastewater effluent in 1992 (Figure 15). In areas of the bay periodically affected by increased salinities, *Vallisneria* and *Myriophyllum* could have a competitive advantage over *Hydrilla* and *Lyngbya*, a factor determining site-specific differences in aquatic plant composition in Kings Bay.

In 2001, the University of Florida monitored water clarity, water chemistry, and aquatic macrophyte abundance in Kings Bay to characterize the relationship between aquatic vegetation and water clarity (Hoyer et al., 2001). Historical LAKEWATCH data were used to augment data collected for the study. Results supported the substantive effects of aquatic plant abundance on water clarity in Kings Bay; primarily through the inverse relationship between abundance of rooted plants and algae suspended in the water column. Ten species of submersed aquatic plants and algae were identified as part of

the study, of which the four predominant species were *Myriophyllum spicatum*, *Hydrilla verticillata*, *Lyngbya* sp., and *Vallisneria americana*. Hoyer et al. substantiated the effects of salinity on the abundance and distribution of aquatic plants in Kings Bay. Greater occurrences of *Myriophyllum* and *Vallisneria,* over *Hydrilla verticillata* and *Lyngbya* sp., in locations with higher mean specific conductance were recorded during the study. Additionally, *Myriophyllum* and *Vallisneria* displayed quicker recovery times following periods of highly elevated salinities (via storm surges) than either *Hydrilla verticillata* or *Lyngbya* sp.. These data are consistent with the persistence of *Vallisneria* in systems of high specific conductance such as Salt Spring (noted by District staff during field reconnaissance). Water chemistry data for the study indicated Kings Bay is frequently a nitrogen-limited system, where total plant biomass is potentially more sensitive to increases in total nitrogen than total phosphorus.

An atlas depicting the coverage for eight of the documented plant and filamentous algal species was submitted with the Hoyer report (Frazer and Hale 2001). Overall, representatives of the native genera *Potamogeton, Najas, Ceratophyllum,* and *Chara* were typically reported to sparsely cover (5 – 25% coverage) upstream areas in the west-central and southern portions of Kings Bay. More substantial coverage (5 – 75% coverage) of the salt tolerant species *Vallisneria americana* (Figure 16) and *Myriophyllum spicatum* (Figure 17) occurred in the central areas of the bay surrounding Buzzard Island, adjacent to the mouth of the Crystal River. Coverages of the exotic nuisance species *Hydrilla verticillata* (Figure 18) and *Lyngbya* sp. (Figure 19) were also substantial (5 – greater than 75%) and were concentrated in areas of the bay north of Buzzard Island. Moderate (50-75%) to extensive (greater than 75%) coverage by exotic species was much more frequent than that documented for native species.

In support of a more comprehensive effort by the University of Florida (Hauxwell et al. 2003), the District concluded a pilot study in 2001 investigating the potential of removing *Lyngbya* mats from five sites in Kings Bay and revegetating with *Vallisneria americana.* In each instance, newly planted *Vallisneria americana* were quickly consumed by manatees, regardless of size or density of the installed plants. Hauxwell et al. (2003) found that excluding manatees from newly planted *Vallisneria* beds increased survivability. However, abundance of the protected plants was then reduced through competition with other species, primarily *Myriophyllum spicatum*. Moreover, allowing the *Vallisneria* plants to establish, for an approximate 5-month period, did not increase survivability once protective fencing was removed (Figure 20). Results of both studies indicate that extensive restoration of *Vallisneria Americana,* through replanting activities, is not currently feasible in Kings Bay.

Emphasis on the composition and extent of submersed aquatic plant communities in Kings Bay has resulted from the following concerns:

- The reciprocal relationship between aquatic plant coverage and water clarity;
- Possible long-term decline of aquatic plant coverage;
- Negative impacts of nuisance aquatic plants and algae on recreational activities; and,
- Habitat impairment resulting from changes in aquatic plant composition (i.e. community shifts from native to exotic nuisance plant and algal species).

Since the introduction of exotic nuisance plant species in approximately 1960, the submersed aquatic plant communities in Kings Bay have been altered by three predominant exotic species; *Hydrilla*, *Lyngbya* and *Myriophyllum spicatum*. In addition to displacing native submersed plant species and providing less favorable habitat for wildlife, these exotic plant and algal species significantly impact recreational activities in the bay. Although public awareness has historically focused on the presence of *Hydrilla* and *Lyngbya* within Kings Bay, the exotic *Myriophyllum spicatum* currently dominates the system (Figure 21). The ability to tolerate periodic increases in salinity gives *Myriophyllum* greater potential to compete with the native *Vallisneria* and increase its' already extensive current coverage in the bay. Greater attention should be paid to the current and future roles of *Myriophyllum* in Kings Bay. Additional concerns include the possible declines in total aquatic plant coverage over the last decade and the resulting effects on water clarity in Kings Bay. Therefore, in Spring 2004, the District contracted with the University of Florida to assess the biomass and map the coverage of aquatic plants in the bay quarterly over an approximate two to three year period. Results of the project will be used to track changes in vegetative coverage from 2001 to 2004 and to depict the seasonal and inter-annual variation in the aquatic plant communities of Kings Bay.

Sediments

Dependent on ambient conditions, sediments can have a significant effect on water quality by either releasing or binding, nutrients, chemical contaminants and heavy metals. Additionally, resuspension of sediments into the water column can contribute to the impairment of water clarity; affecting recreational activities and growth of submersed aquatic plants. Two documents addressing the sediments of Kings Bay are archived by the District. In particular, the Coastal Springs Restoration Project outlines a dredging project initiated by Citrus County and the City of Crystal River in 1995 (Citrus County 1997). After initial delays, the project effected removal of silt and benthic algal mats from Tarpon Hole Spring and Hunters Spring with a cutterhead vacuum system in 1997. Anecdotal reports indicate the springs quickly silted in following completion of the dredging.

In 1993, the Florida Institute of Technology submitted a baseline sediment mapping and analysis for Crystal River/Kings Bay and Lake Panasoffkee to the District (Belanger et al., 1993). Characteristics of Kings Bay sediments were reported as follows:

- shallow (range 0.0 – 3.4 feet) (Figure 22);
- comprised largely of fine grained particles;
- have low average percent organic matter;

- contain elevated copper* and slightly elevated lead* and zinc* concentrations (* normalized with aluminum data);
- moderate nutrient concentrations (TKN range: 337 – 2,400 mg/kg, TP range: 189 – 474 mg/kg);
- undetectable levels of organochlorine pesticides;
- past dredging activities have resulted in sediments that are a poor candidate for paleoecological analysis; and

- sources of sediment organic matter vary within the bay (Figure 23)
    - western Cedar Cove – *Lyngbya* sp.
    - eastern Cedar Cove – terrestrial
    - northwest Banana Island – aquatic algae
    - south Banana Island – terrestrial
    - southern Kings Bay – *Typha* sp. detritus.

To assess changes in the composition and depth of the bay's sediments since 1993 the District will initiate a second sediment evaluation in 2005. In addition to evaluating sediment depth and composition, the project will estimate the extent of nutrient loading from sediments into the water column. Through diffusion and resuspension, enriched sediments can release nutrients into the overlaying water column and affect growth of submersed plants and aquatic algae.

Hydraulics

As a tidally influenced embayment, Kings Bay receives substantial fresh water inflows from spring discharge, but is affected daily by tidal inflows from Crystal River. The result is a complex interaction between spring flow exiting the bay and tidal fluctuations of incoming and outgoing tides. The average tidal range in Kings Bay stage is approximately three feet.

Flushing and circulation characteristics modeled by Hammett et al. (1996) indicate that the open waters of the bay are flushed relatively quickly; mean residence times were reported as follows:

Low inflow conditions – 59 hours;
Typical inflow conditions – 50 hours; and
Low inflow with reduced friction – 56 hours.

For purposes of the two-dimensional hydrodynamic model, low and typical inflow conditions were determined to equal a net spring discharge of 735 cfs and 975 cfs, respectively. Low inflow conditions with reduced friction represented a simulation of decreased bottom roughness through reduced vegetative coverage (i.e. *Hydrilla)*. Circulation patterns, identified by the hydrodynamic model, were almost identical between the three simulated hydrologic conditions listed above. Figure 24 depicts the modeled circulation patterns, under typical inflow conditions, in three areas of Kings Bay. Circulation patterns were similar for the three spring groups included in the computer model; each exiting the bay north of Buzzard Island. The combined discharge acts to separate waters north of Buzzard Island from the remainder of the bay. This reduced mixing between the two water masses likely diminished the effects of wastewater effluent from the City's municipal WWTP on water quality in southern Kings Bay.

Wildlife

A visible component of the Crystal River/Kings Bay watershed, wildlife enhance the local economy by supporting commercial and recreational fishing, diving and snorkeling activities and manatee viewing tours. Accordingly, research projects and protective measures implemented in Kings Bay to date by federal and state wildlife agencies have focused largely on fish and the West Indian manatee.

In August 1983, the USFWS established the Crystal River National Wildlife Refuge for the protection of the endangered West Indian Manatee and other wildlife species. The refuge oversees designated manatee sanctuary areas (November 15 through March 31) and year round slow and idle boat speed zones designed to reduce boat-related manatee mortalities. Staff for the refuge also participates in annual aerial manatee surveys and collect water chemistry and vegetative coverage data every other month. It is estimated that 25-30% of the statewide manatee population take refuge in Kings Bay during the winter. The statewide manatee population increased approximately 53% from 1991 – 2003 (Florida Fish and Wildlife Conservation Commission 2003). Anecdotal evidence suggests that the concomitant rise in manatees overwintering in Kings Bay has increased grazing and impacted resident aquatic plant communities.

Upon the discovery of elevated copper in the tissues of dead manatees in the 1980s, a study was initiated by the USFWS to assess contaminant concentrations in Kings Bay sediments (Facemire 1991). Copper from herbicides applied to control *Hydrilla* in the 1970s had accumulated in the sediments and it was suggested that the copper was being bio-transported through submersed plants to the grazing manatees. Although sediment concentrations were elevated at all sites sampled during the study, it was not conclusive that transport of copper by submersed plants was efficient enough to reach levels lethal to the bay's manatees.

In 1992, the Florida Game and Fresh Water Fish Commission (now known as the Florida Fish and Wildlife Conservation Commission) surveyed animal species inhabiting the Crystal River watershed (Florida Game and Fresh Water Fish Commission 1992). Species reported included 21 species of amphibians, 191 species of birds, 22 species of mammals and 47 species of reptiles. At the time of the report three species were new sightings within Citrus County: the Cope's gray tree frog, the little grass frog and the non-native brown anole. In addition to documenting extant species, the Commission provided recommendations to improve and protect important wildlife habitat. Two of the recommendations included improvement of water quality and protection of undeveloped shoreline to benefit many listed and unlisted species.

In 1994, the USFWS analyzed mercury levels in tissues of Largemouth bass caught in the Crystal River National Wildlife Refuge (Brim et al. 1994). Results of the study indicated that levels of mercury found in the fish tissues were insufficient to kill the Largemouth bass. However, through bioaccumulation, the recorded concentrations of mercury were above levels believed to harm predatory birds feeding upon the bass.

Since approximately 1983, Citrus County has conducted bacteriological tests on the waters of Hunters Spring Park for the City of Crystal River. On occasion, levels of

coliform bacteria are high enough to close the park's beach to swimming. It is unclear if bacteriological data from other areas in Kings Bay exist.

In summary, the Crystal River/Kings Bay watershed supports numerous listed and unlisted wildlife species, including the West Indian manatee. Species reported in 1991 included 21 species of amphibians, 191 species of birds, 22 species of mammals and 47 species of reptiles. Concerns regarding the effects of metal contaminants in the bay's sediments on the West Indian manatee were determined to be unfounded. However, bioaccumulation of mercury in the tissues of fish could affect fish-eating or piscivorous birds in Kings Bay. Diverse wildlife is an integral part of a functioning habitat and the utilization of Kings Bay by the eco-tourism industry. Consequently, management of Kings Bay for the benefit of wildlife is consistent with the objectives of both resource managers and local residents.

Future Work

Following the addition of Crystal River/Kings Bay to the District's list of SWIM Priority Water Bodies in 1988, the District initiated and participated in numerous projects to further our understanding and improve the condition of this unique system. Recognizing the need to improve the coordination of restoration and management activities in Kings Bay, the District facilitated the formation of an inter-agency advisory group that includes public participation. Since the initial meeting on October 2, 2003, the Kings Bay Advisory Group has reviewed and discussed the findings of the diagnostic studies, water quality monitoring programs and storm water/dredging projects completed to date in Kings Bay. Additionally, the group has completed two data collection efforts to evaluate the effects of "grubbing" (a method used to remove benthic algal mats) on rooted aquatic plants and will begin a shoreline restoration project to buffer seawalls with emergent plants in 2005.

Collectively, the advisory group is working towards identifying activities that reduce nutrient loading, enhance water clarity and promote growth of rooted aquatic plants in the bay. Based on discussions within the Kings Bay Advisory Group, the following four outstanding questions related to aquatic vegetation were identified by the District in 2004:

1. Is rooted aquatic vegetation limited by light in Kings Bay? If so, where?
2. Are sediments limiting the success of rooted aquatic vegetation in Kings Bay? If so, where?
3. If light and sediments are not limiting rooted aquatic plants in Kings Bay, are there opportunities to enhance and sustain existing communities?
4. Can "buffering" seawalls with stands of emergent plants enhance rooted aquatic plants by reducing wave disturbance?

District SWIM staff recently completed a brief study to address the question of light limiting aquatic plant growth in the bay. Results of the effort indicated that sufficient light is available throughout the majority of Kings Bay to support aquatic plant growth. However, it is unknown whether the light levels are sufficient to support restoration

efforts using young plants; which may have higher light requirements than mature plants.

To address concerns over sediments impacting the success of rooted aquatic vegetation in Kings Bay, the District has initiated a sediment evaluation and mapping project for 2005. The project will compare results of the 2005 sediment mapping and evaluation to 1993 data to assess changes in composition, distribution, and accumulation of sediments. An additional project task will determine the extent of nutrient loading from sediments to the water column. Based on the results of the project, the District and its' partners will determine if a feasible course of action is available to improve sediment conditions in Kings Bay.

If the District and partners subsequently determine that neither light nor sediments are limiting the success of rooted aquatic plants, a brief technical workshop will be held to determine other potential impacts to rooted aquatic plants and if there are further opportunities to enhance and sustain existing plant communities.

Specific projects to address the current management issues of water quality and aquatic vegetation are proposed for implementation by the District and/or partners over the next five to ten years. These future actions include the following:

Crystal River/Kings Bay Watershed Education Plan: Design and Implementation – Public education materials will be developed and distributed by the District to educate the public and commercial entities on BMPs capable of reducing nutrients in ground water entering Kings Bay.

Kings Bay Sediment Evaluation 2005 – Changes in the depth and composition of sediments in Kings Bay since 1993 will be evaluated by the District and Florida Institute of Technology. Data will be used to determine the capacity of bay sediments to support rooted aquatic plants and impact water clarity. Additionally, an estimate of nutrient loading from bay sediments will be provided.

Springs Cleanup Initiative – Sinkholes associated with the region's five first magnitude spring systems; Weeki Wachee, Homosassa, Chassahowitzka, Kings Bay and Rainbow River, will be prioritized for removal of discarded materials. The District will subsequently hire a contractor to survey and remove debris from submersed portions of identified priority sinkholes and/or the springs themselves.

Mapping and Database for Springs in the Coastal Rivers Basin – The District will initiate a project to map watersheds and springsheds contributing to the region's springs. Additionally, the project will identify land uses with potentially elevated nutrients within the mapped watersheds and springsheds.

Crystal River Watershed Management Plan – Staff with the District have proposed a project to review existing water quality resources and identify/implement nutrient BMPs within the Crystal River/Kings Bay watershed. Project costs for this cooperatively funded effort are estimated at $300,000. To date, the District, Citrus County and the Florida Department of Transportation have secured funding for the project.

Identification and Prioritization of Stormwater Sub-basins Within the Kings Bay Watershed – The District will delineate and prioritize, by level of nutrient loading, sub-basins within the Kings Bay watershed. The results will be used to prioritize stormwater improvement projects on a local scale.

Kings Bay Chlorophyll Source Identification Project – Staff with the District's SWIM Program will initiate a project to identify the sources of chlorophyll, produced by species of algae, in Kings Bay. The information will be used to develop, where possible, strategies to target and reduce dominant species of algae. Implementing actions to reduce algal abundance supports the management strategy of improving water clarity in Kings Bay.

Minimum Flows and Levels – The District's Ecologic Evaluation Section will establish minimum flows and levels necessary to protect the water resources and ecology of the Crystal River/Kings Bay system.

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Figure 1. Kings Bay location map.

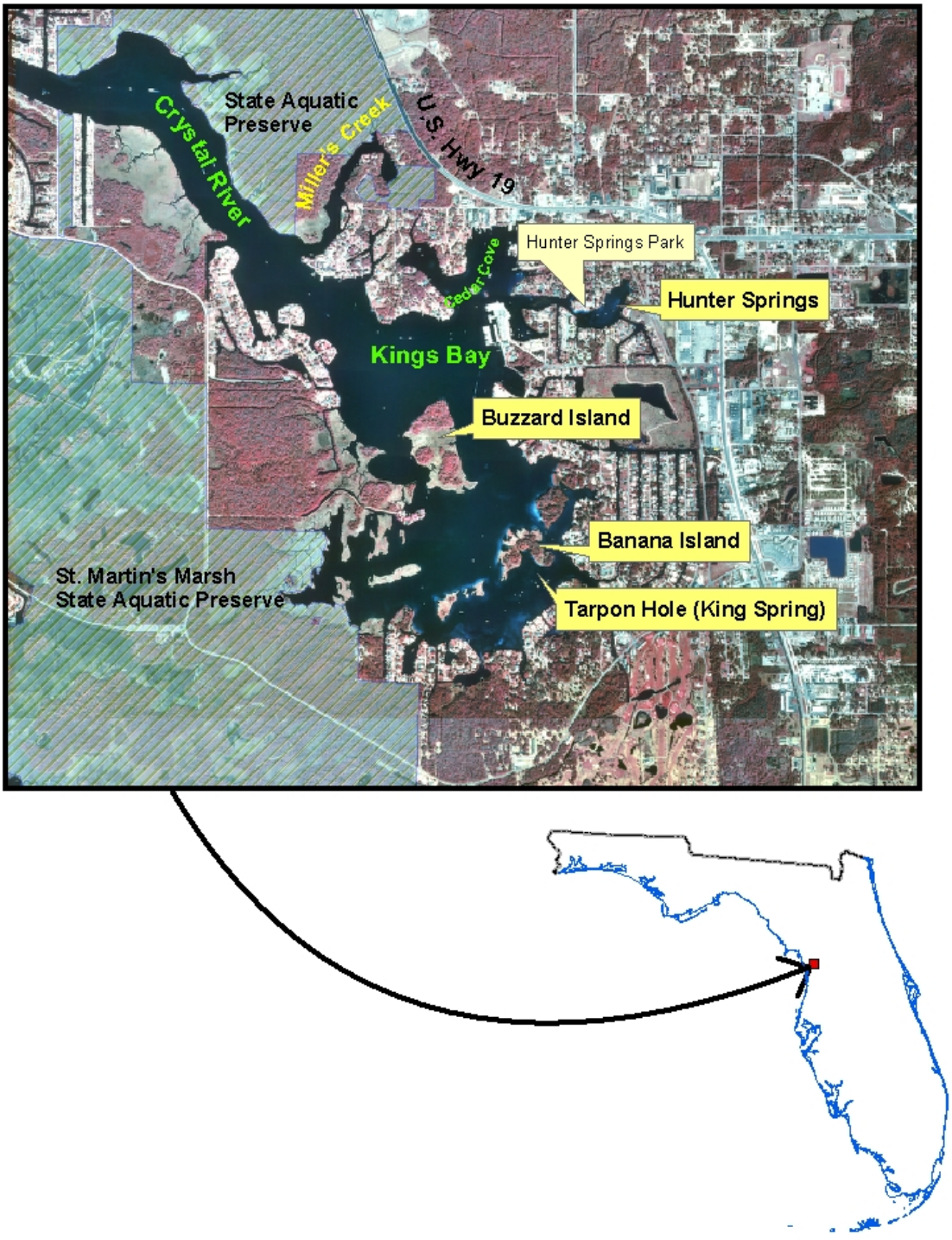


Figure 2. Land use in the Crystal River watershed: 1944 to 1995.

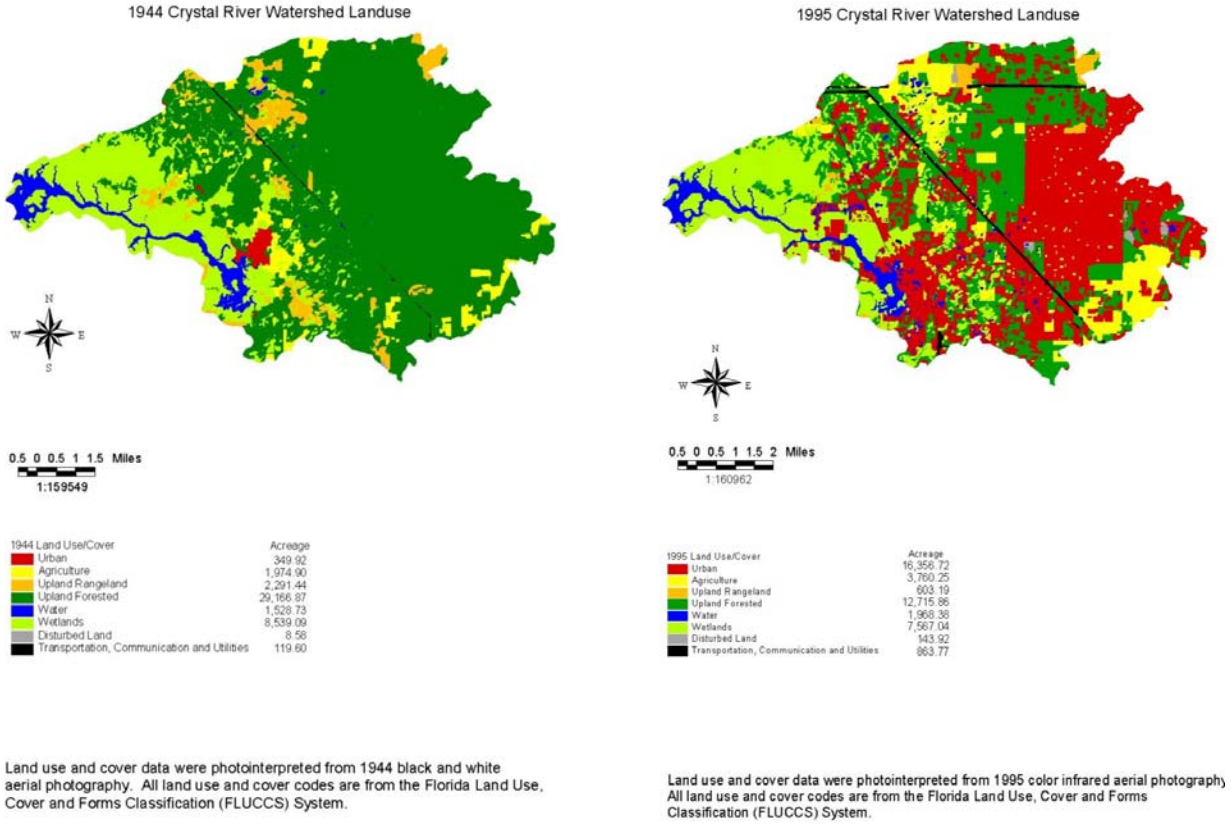


Figure 3. Population estimates for Citrus County 1890 – 2000 (Sources: United States Census Bureau, University of Florida, and Withlacoochee River Planning Council).

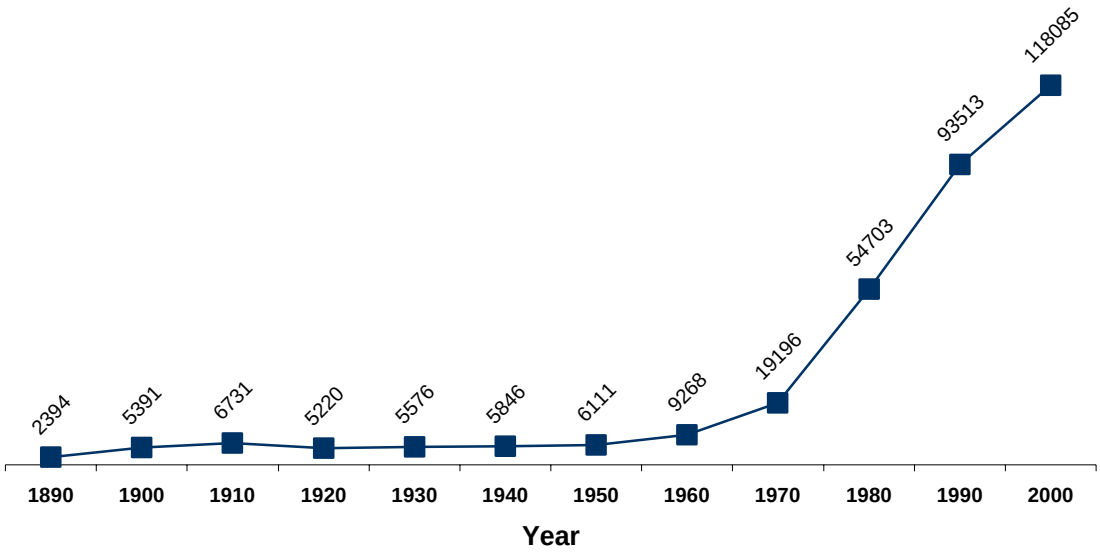


Figure 4. Crystal River/Kings Bay watershed defined by the United States Geological Survey.

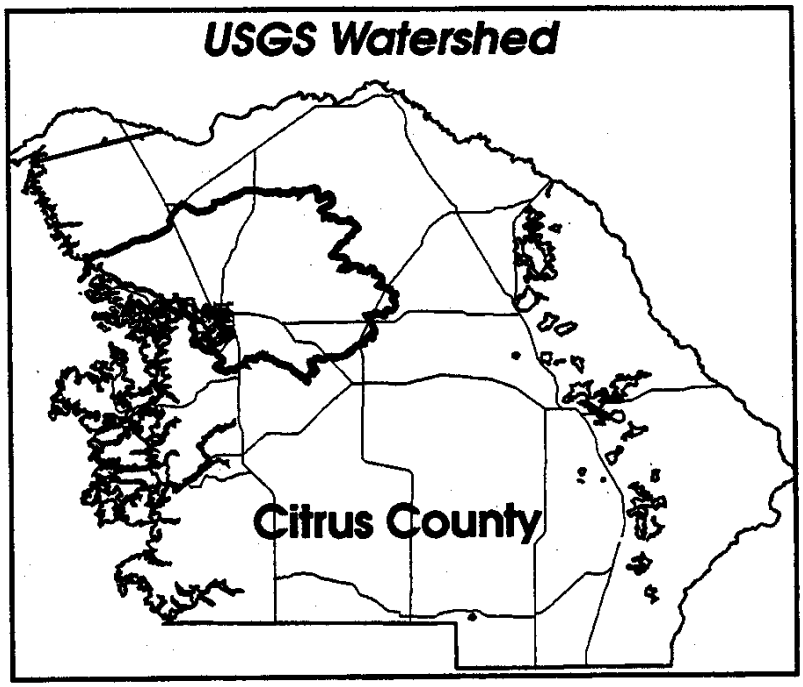


Figure 5. Crystal River/Kings Bay management area defined by the Southwest Water Management District.

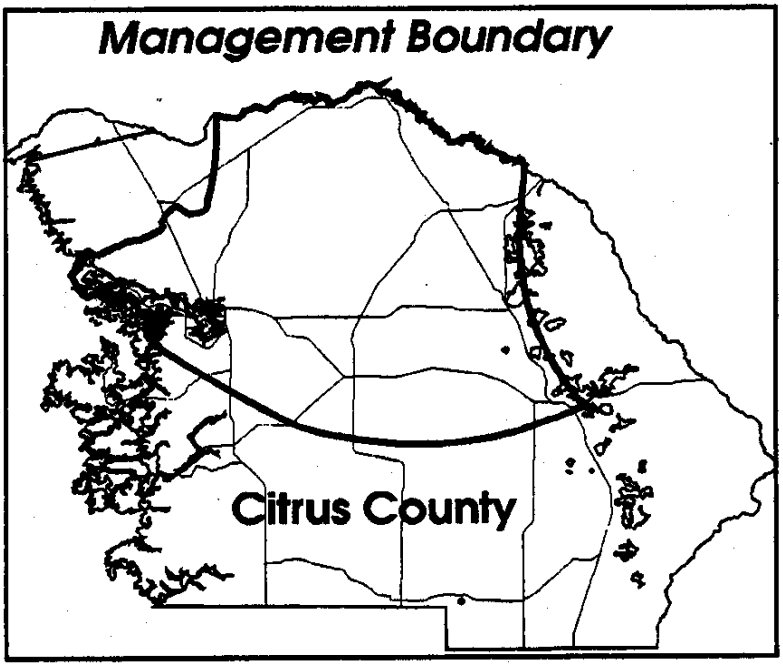


Figure 6. Dredge and fill activities in Kings Bay, Florida, circa 1944 - 1999.

Figure 7. Location of the Coastal Transition Zone (salt water/fresh water interface in ground water) in relation to the King's Bay spring complex (Source: Champion and Starks 2001).

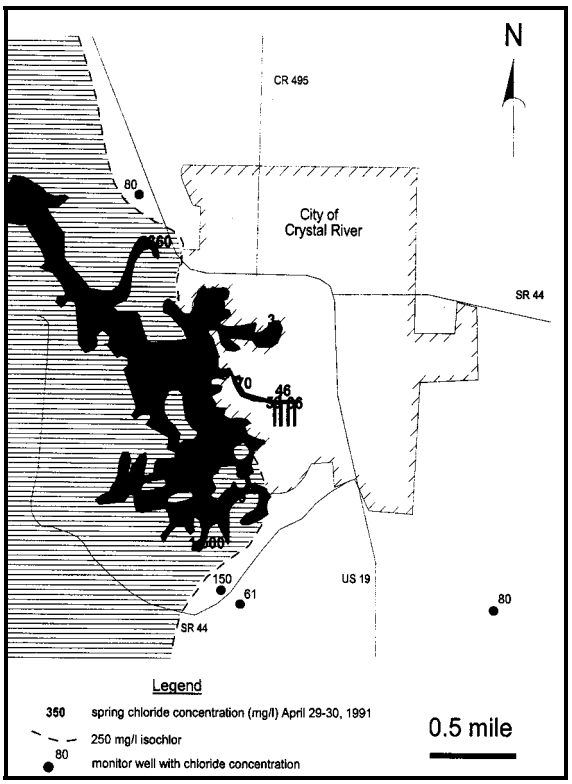


Figure 8. Mean annual total nitrogen and total phosphorus concentrations in Kings Bay from 1989 to 2002.

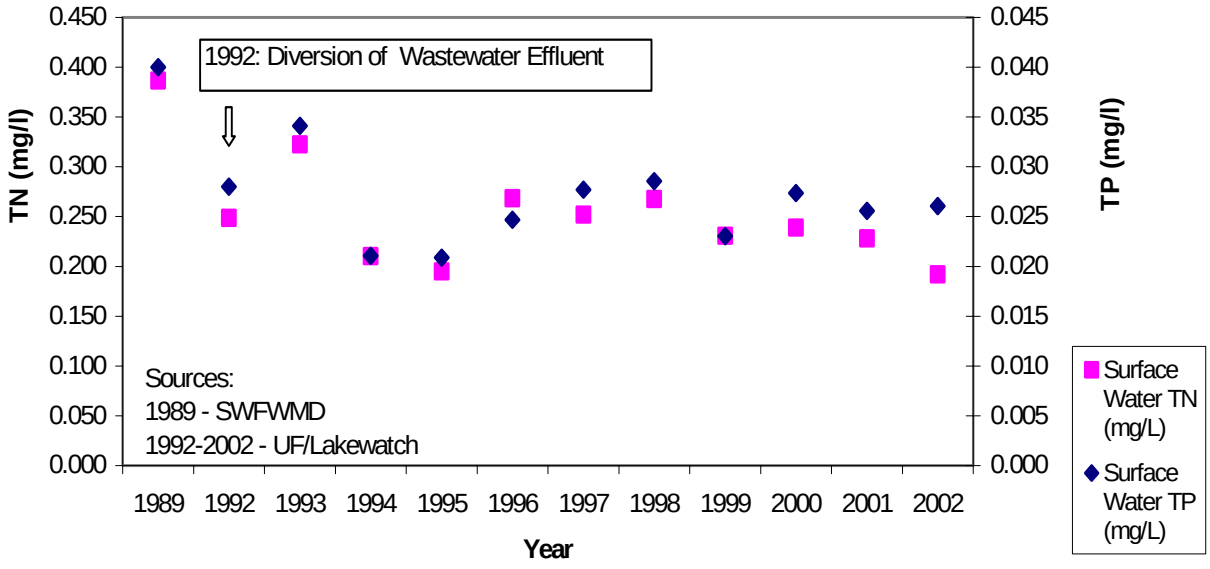


Figure 9. Nitrate concentrations from upstream sites to estuaries in four Springs Coast rivers (adapted from Frazer et al., 2001).

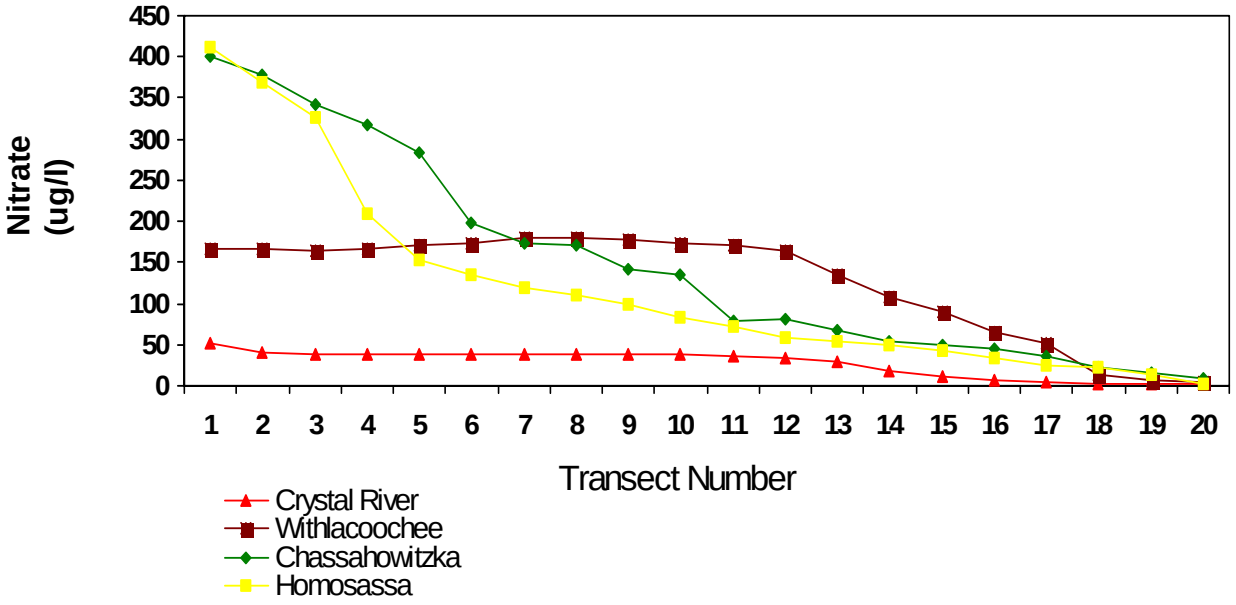


Figure 10. Approximate locations of stormwater treatment projects implemented by the City of Crystal River to date.

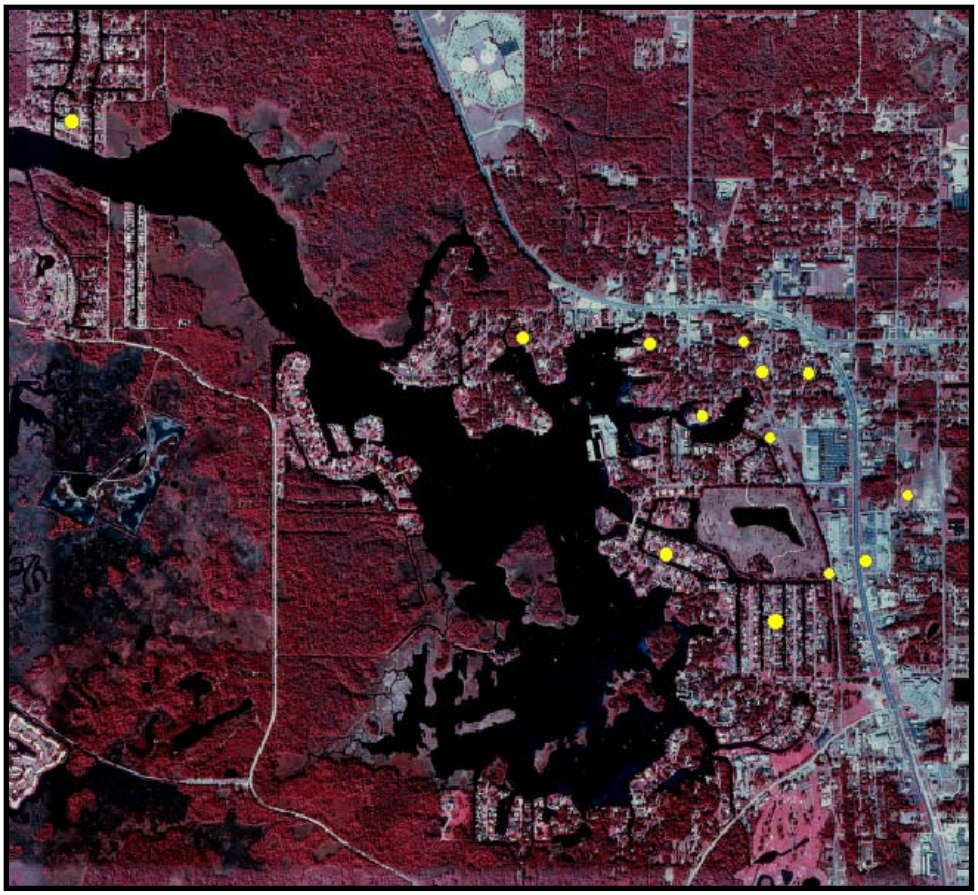


Figure 11. Water clarity, as measured by horizontal Secchi distance, in Kings Bay (Sources: Bishop and Canfield 1995, Hoyer et al. 1997, Hoyer et al. 2001 and SWFWMD 2001, 2003-04).

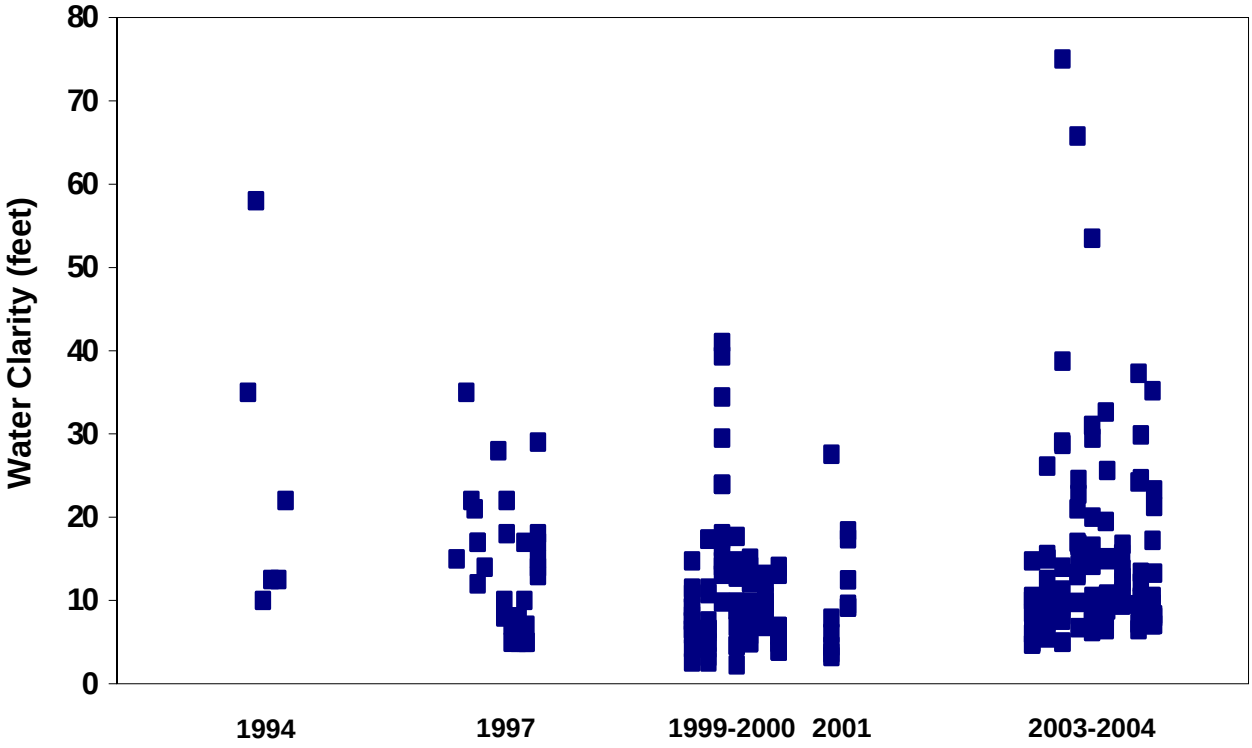


Figure 12. Changes in water clarity, as measured by horizontal Secchi distance, since 1994. (Sources: Bishop and Canfield 1995, Hoyer et al. 1997, Hoyer et al. 2001 and SWFWMD 2001, 2003-04).

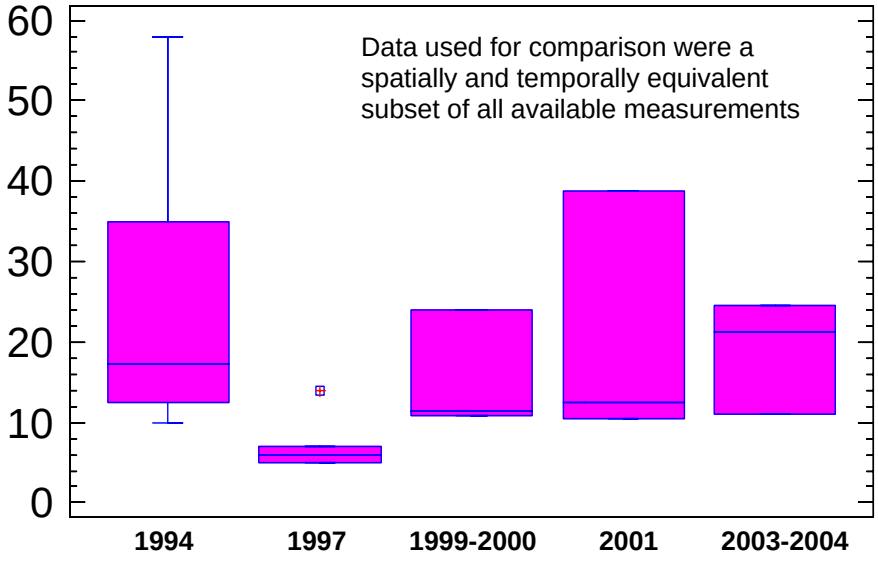


Figure 13. Relationship between chlorophyll *a* concentrations and water clarity (SWFWMD Data: June 2003 – April 2004).

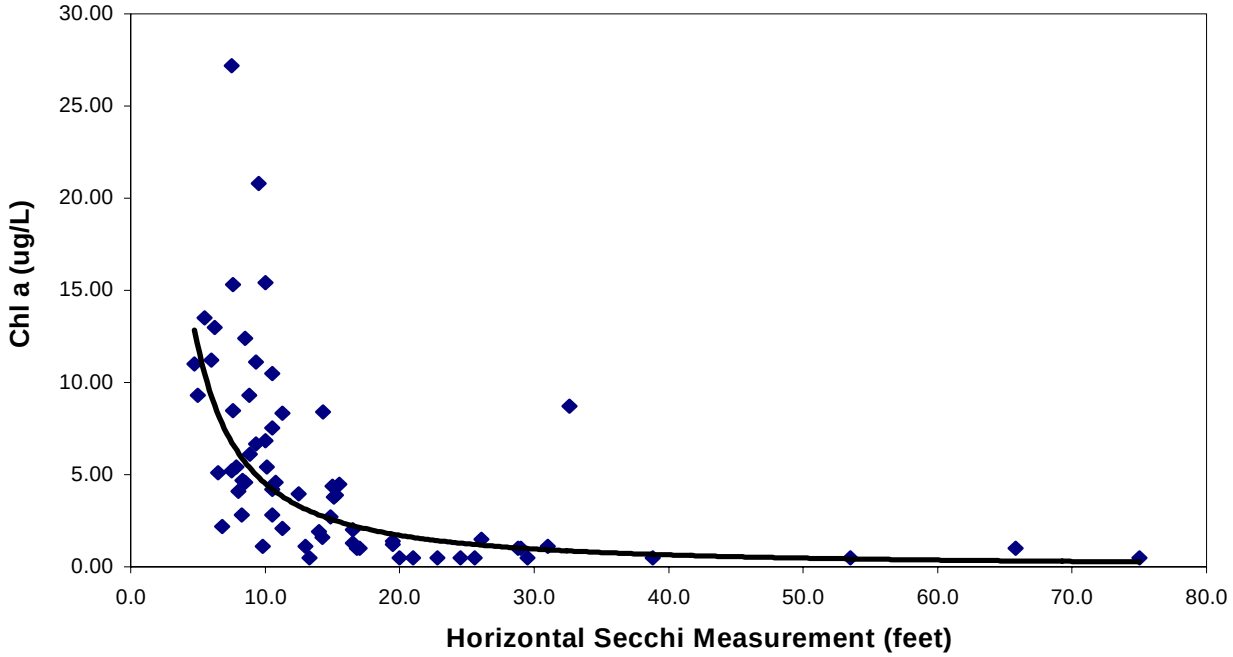


Figure 14. Relationship between submersed plant biomass and chlorophyll concentrations (as a proxy measure of phytoplankton abundance) in Kings Bay (adapted from Hoyer et al., 2001).

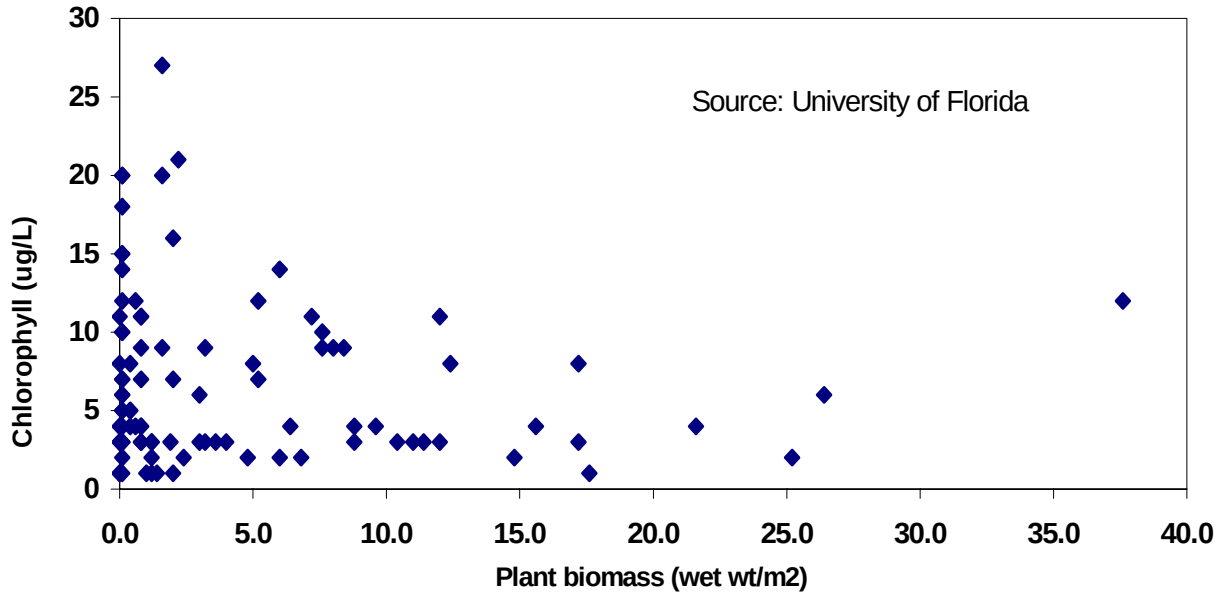


Figure 15. Timeline of significant events and activities in Kings Bay, Florida.

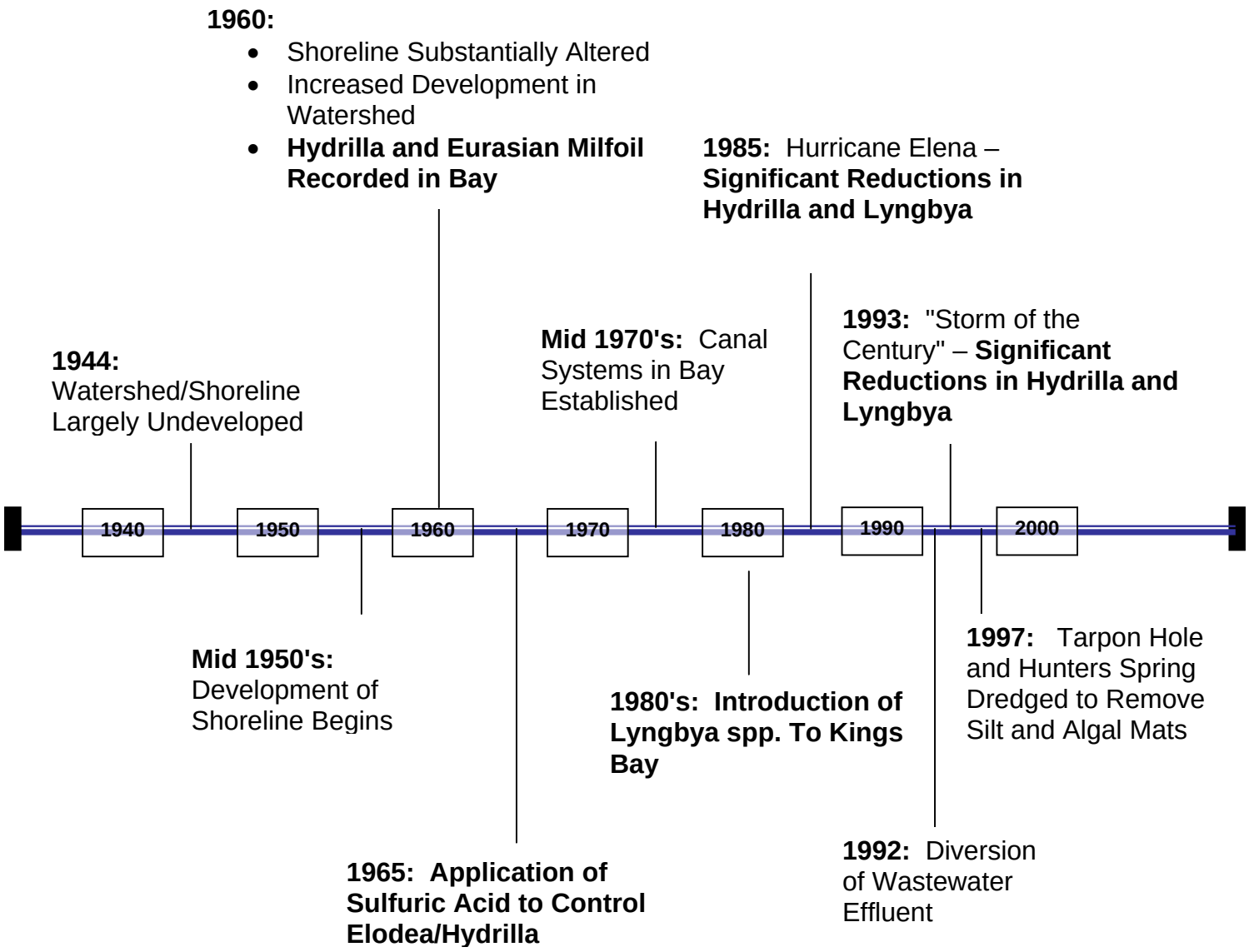


Figure 16. Percent cover per square meter of *Vallisneria americana* in Kings Bay (adapted from Frazer and Hale 2001).

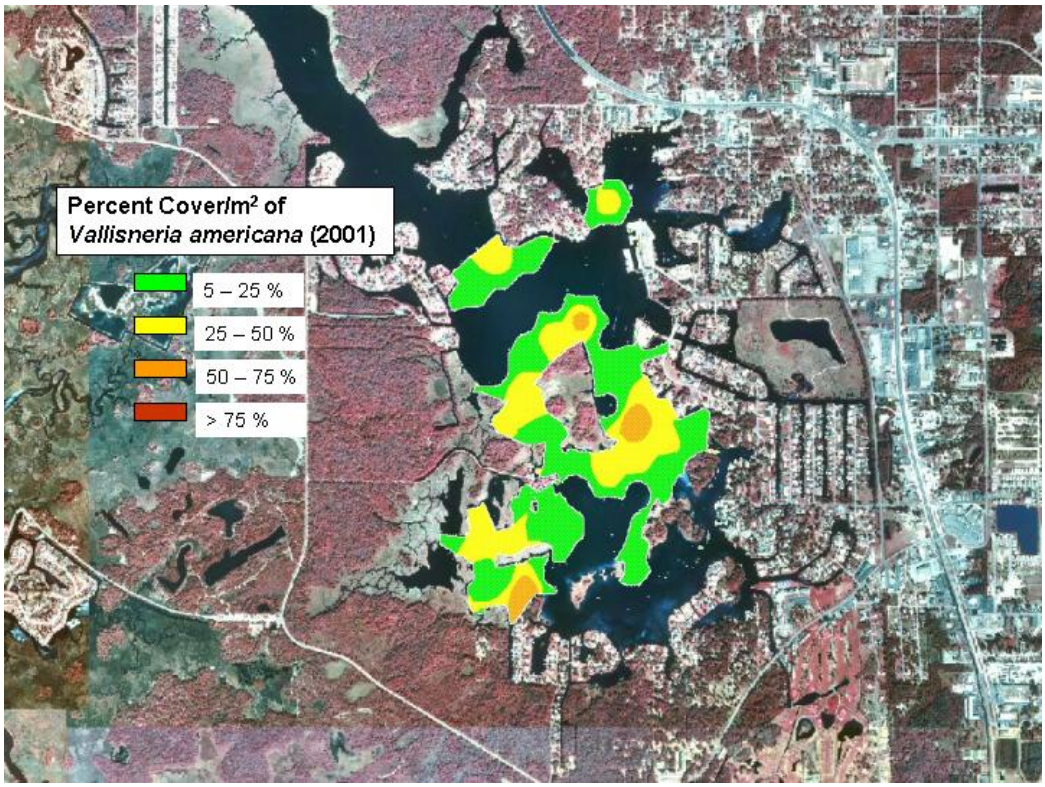


Figure 17. Percent cover per square meter of *Myriophyllum spicatum* in Kings Bay (adapted from Frazer and Hale 2001).

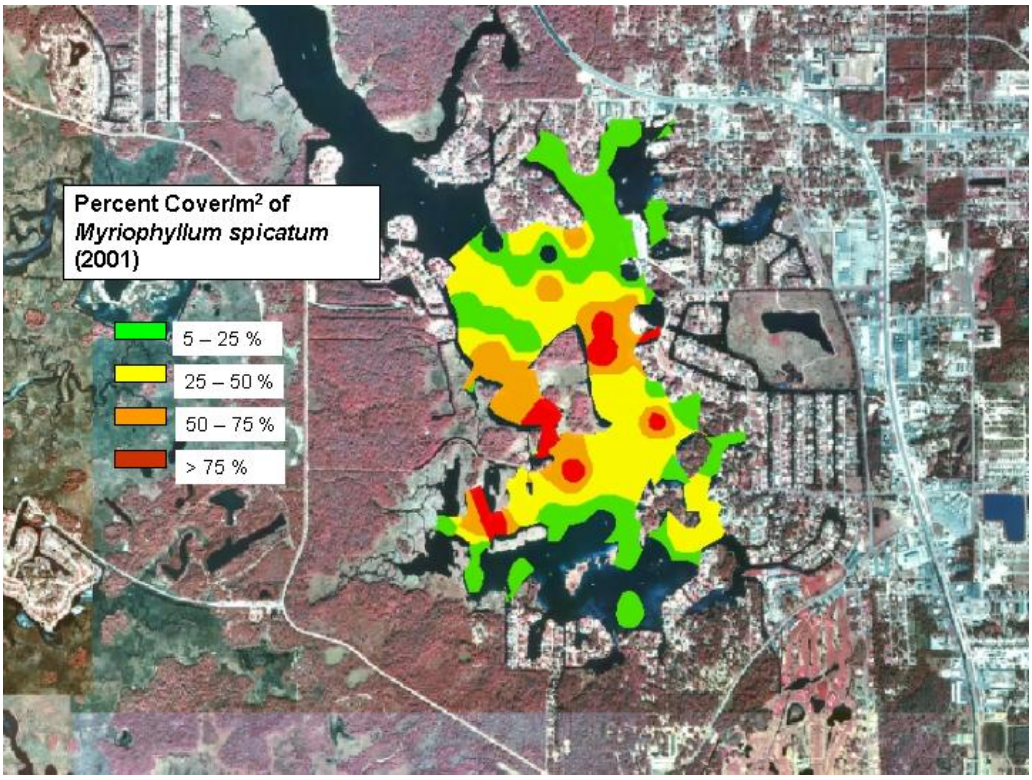


Figure 18. Percent cover per square meter of *Hydrilla verticillata* in Kings Bay (adapted from Frazer and Hale 2001).

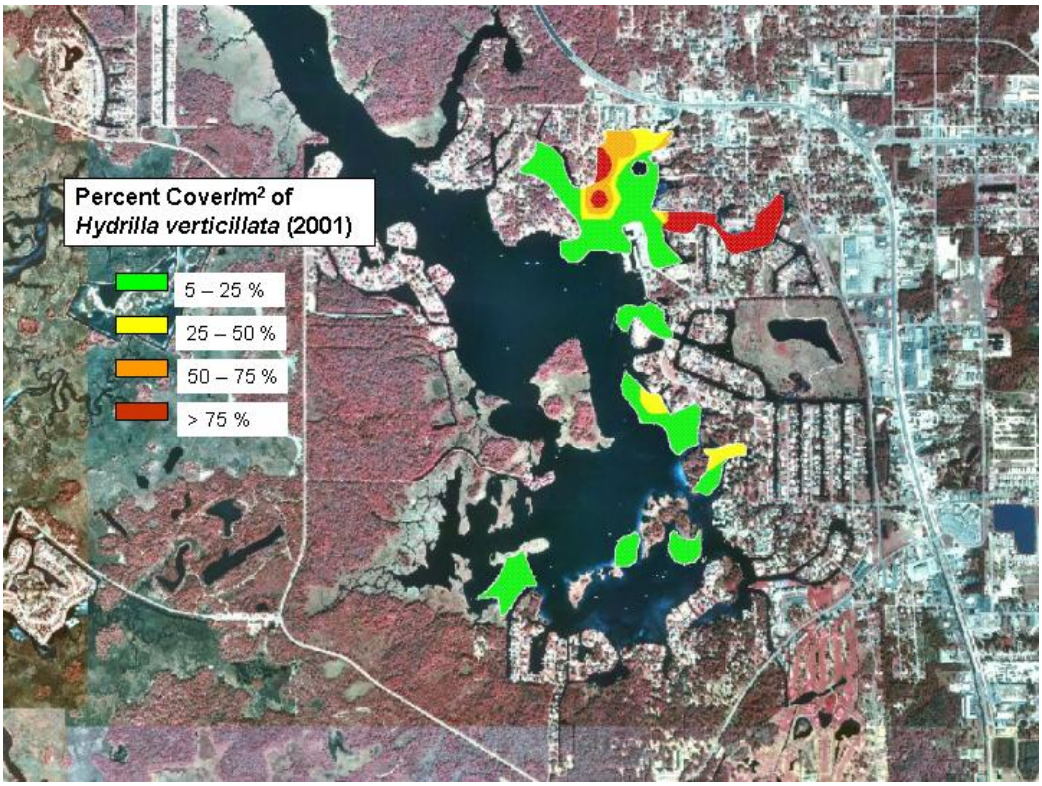


Figure 19. Percent cover per square meter of *Lyngbya* sp. in Kings Bay (adapted from Frazer and Hale 2001).

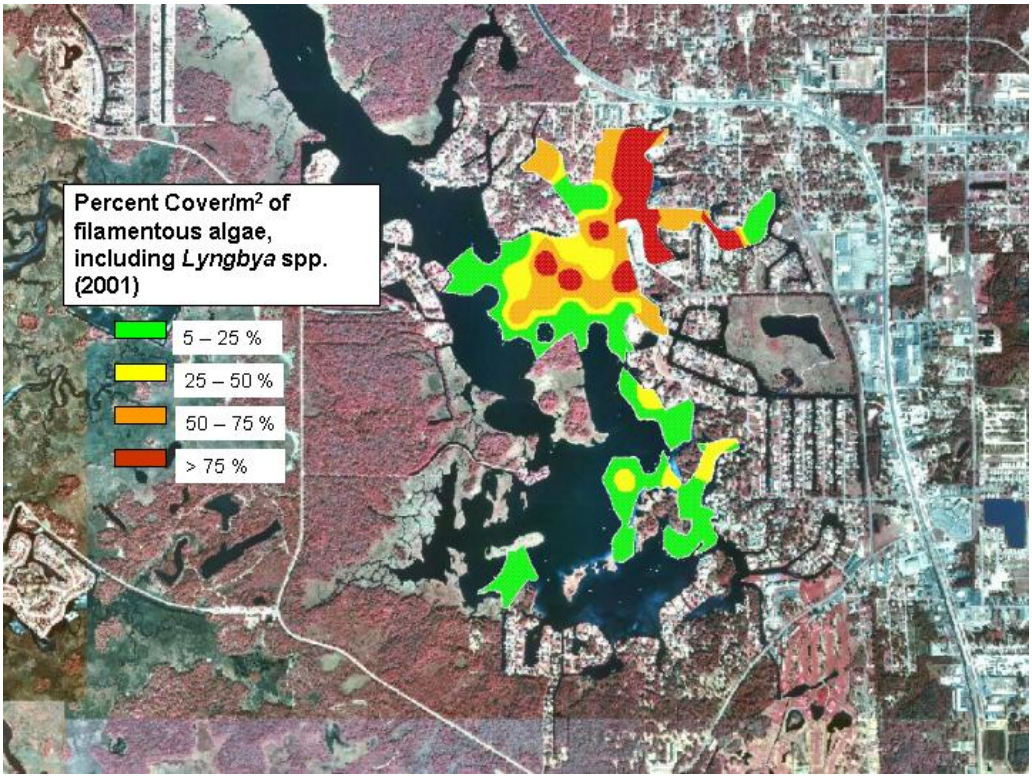


Figure 20. Density of *Vallisneria americana* shoots in transplanted plots: either protected from or exposed to herbivores following an initial establishment period (Hauxwell et al., 2003).

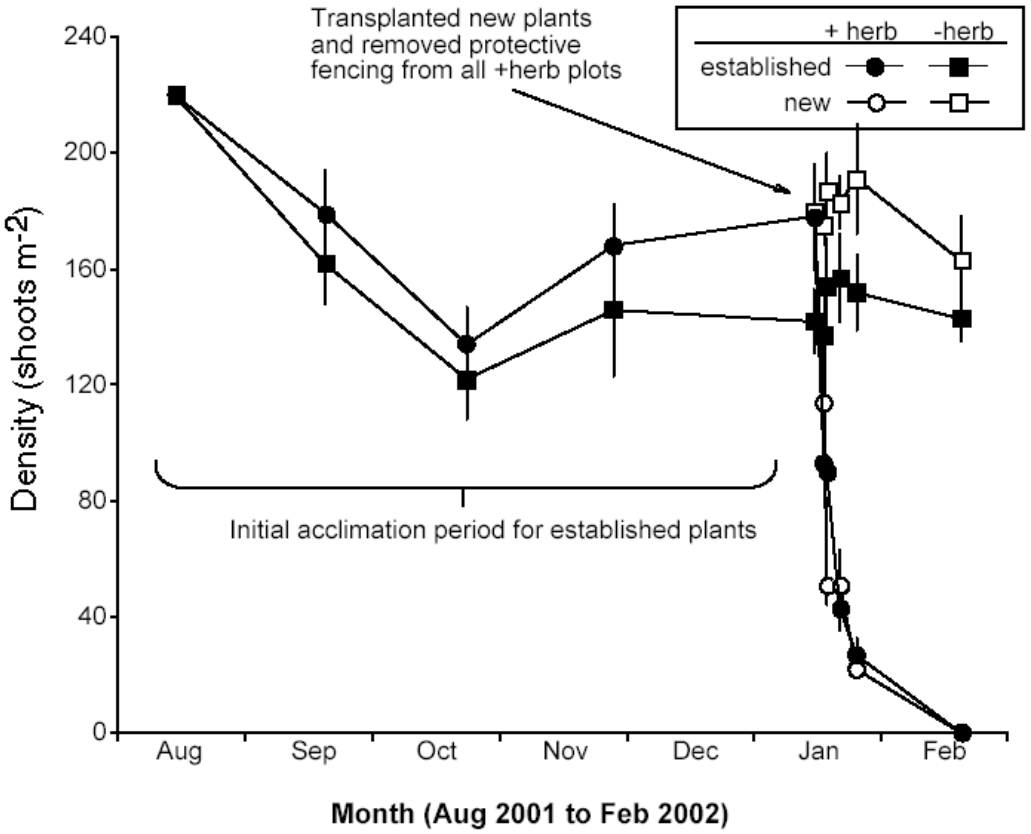
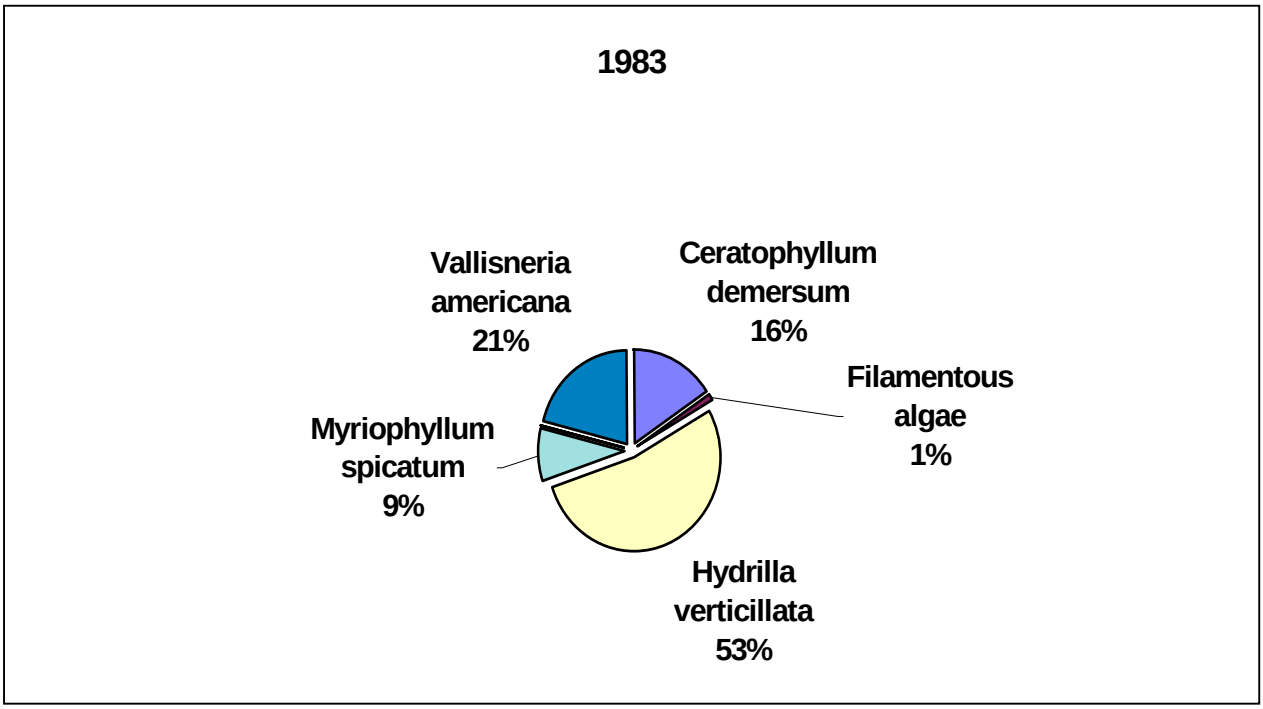


Figure 21. Estimates of aquatic plant coverage for Crystal River and Kings Bay in 1983 and 1995 (Source: FDEP – Bureau of Invasive Plant Management).



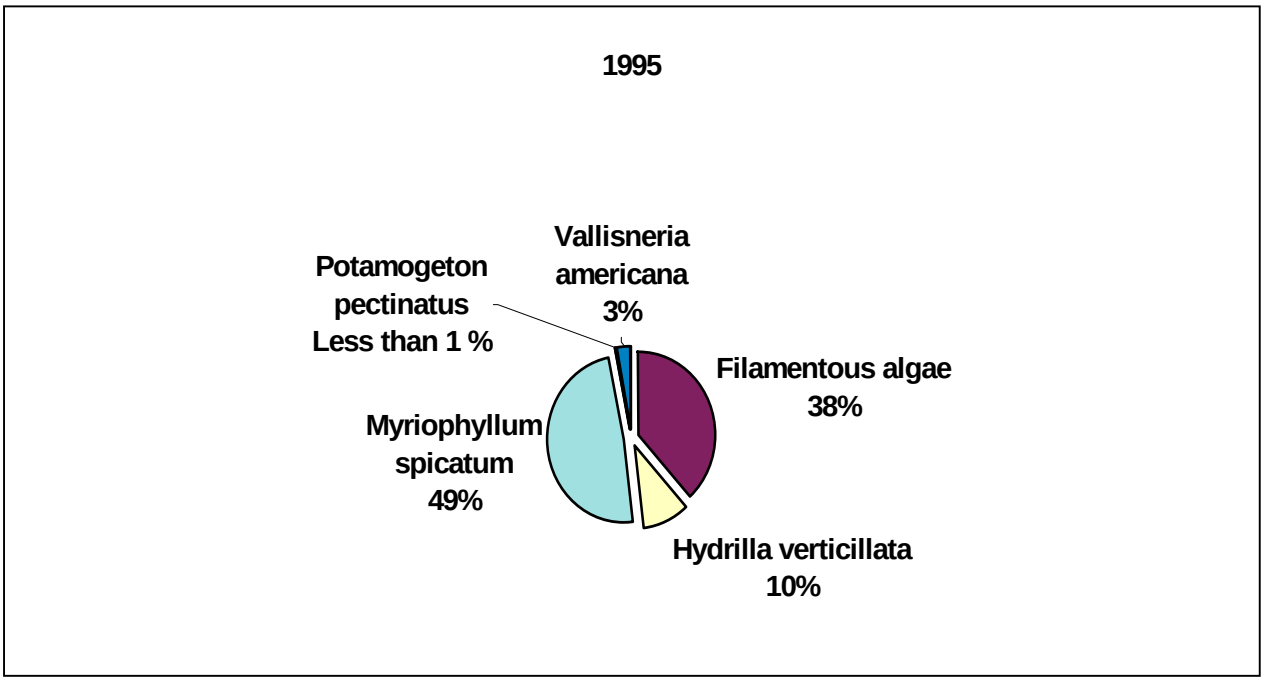


Figure 22. Sediment depth (ft) in Kings Bay, Florida (adapted from Belanger et al., 1993).

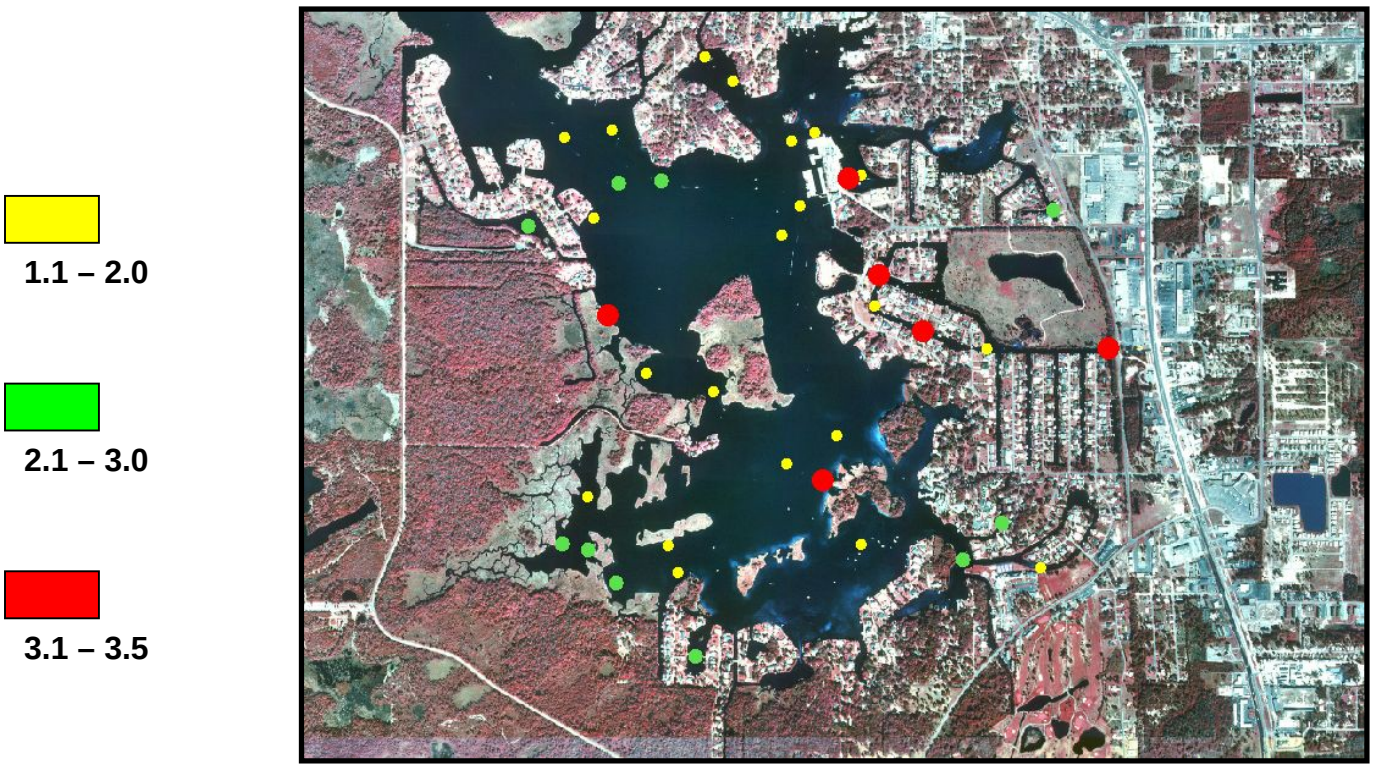


Figure 23. Sources of sediment organic matter in Kings Bay, Florida (adapted from Belanger et al., 1993)

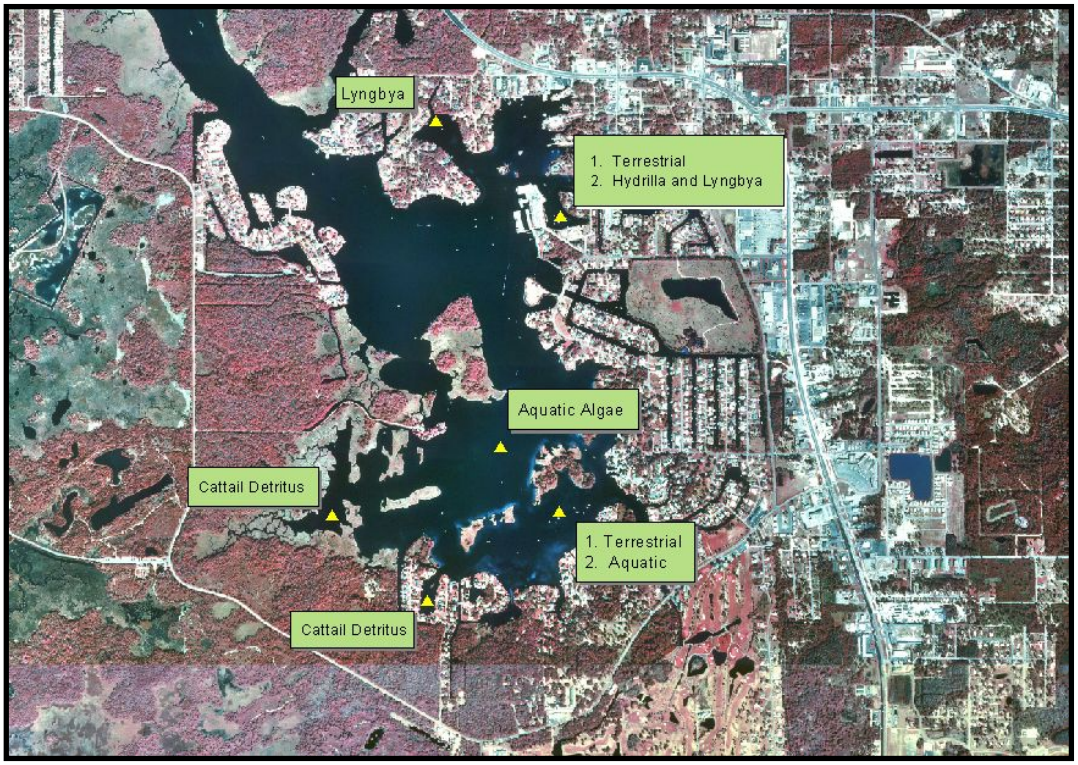
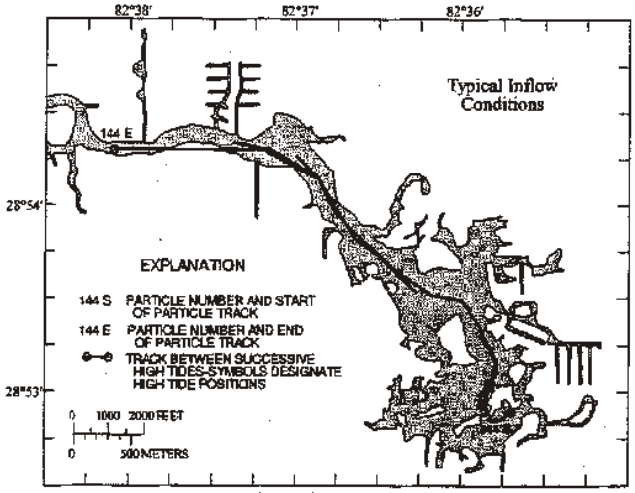
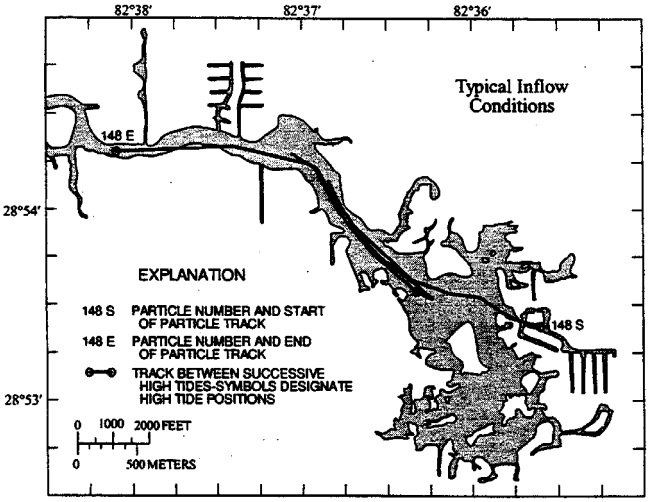
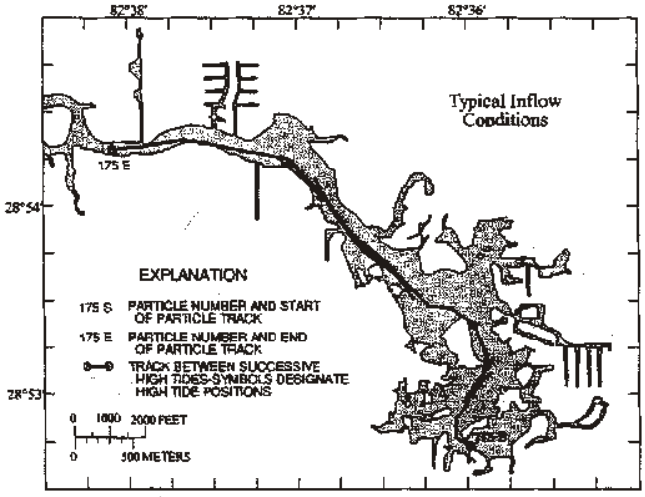


Figure 24. Modeled circulation patterns, under typical (975 cfs) inflow conditions, in three areas of Kings Bay.

A) Circulation pattern of flows originating near Tarpon Hole spring.



B) Circulation pattern of flows originating in eastern Kings Bay.



C) Circulation pattern of flows originating near Black spring.