CALOOSAHATCHEE ESTUARY AND CHARLOTTE HARBOR CONCEPTUAL MODEL

A: Model Leads

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B: Introduction

The Caloosahatchee Estuary and Charlotte Harbor are located on the lower west coast of Florida. The Caloosahatchee River was originally a shallow, meandering river with headwaters in the proximity of Lake Hicpochee and tidal influence almost to La Belle. To accommodate navigation, flood control, and land reclamation needs, the freshwater portion of the river was reconfigured into a canal known as C-43. Many canals were constructed along the banks of the river in support of the many agricultural communities associated with the river. In addition, three lock-and-dam structures (S-77, S-78, and S-79) were added to control flow and stage height. The Caloosahatchee River watershed includes the adjacent basins drained by the river from the Charlotte Harbor estuarine system which includes San Carlos Bay, Matlacha Pass, Pine Island Sound and the estuaries and nearshore waters associated with Sanibel Island, Captiva, North Captiva and the Immokalee Rise areas

Today, the Caloosahatchee River extends 105 km from Lake Okeechobee to San Carlos Bay. The freshwater portion ranges from 50 m to 130 m in width and 6 m to 9 m in depth. Many of the original bends remain as oxbows along both sides of the canal. The width of the estuarine portion is irregular, from 160 m in the upper portion to 2,500 m downstream at San Carlos Bay (Scarlatos 1988). The narrow section extends from Franklin Lock and Dam to Beautiful Island. This area has an average depth of 6 m, and the area downstream of Beautiful Island has an average depth of 1.5 m (Scarlatos 1988). The pattern and period of flow of the Caloosahatchee River is highly variable based on demand (Drew and Schomer 1984).

The tidal Caloosahatchee basin includes portions of Lee and Charlotte Counties. The estuary between Franklin Lock and Shell Point is 42 km long and is bordered by Fort Myers on the southern shore and Cape Coral on the northern shore. Water discharges from the Caloosahatchee pass Shell Point and enter the Gulf of Mexico at San Carlos Bay. Because of the long and narrow configuration of the estuary, changes in wind, tide, runoff, or precipitation can have effects on estuarine features such as flow, water depth, salinity, and turbidity. Therefore, due to the dynamic nature of the estuary, characterization of the system is difficult.

Major changes in the hydrology of the Caloosahatchee watershed are the result of significant modifications in land and canal development, as well as water management policy. Adverse ecological impacts in the estuary have occurred as a result of hydrological changes in the timing, distribution, quality, and volume of fresh water released into the estuary from the watershed and Lake Okeechobee (SFWMD 1999). Despite these impacts, the Caloosahatchee Estuary continues to be an important environmental and economic resource. Understanding how this system responds to stressors will provide a basis for well-informed management decisions.

Charlotte Harbor is America's 17th largest and Florida's second largest open water estuary. It has a broad barrier island chain, large parts of which are in public ownership: its mangrove shoreline is largely intact and in public management. The Harbor is dominated by rivers that flow into the coastal areas. Unlike other estuaries in Southwest Florida that are most influenced by the Gulf of Mexico, Charlotte Harbor's special characteristics are created by large rivers, such as the Caloosahatchee. Large fluctuations of seasons strongly affect the salinity and water characteristics in Charlotte Harbor.

Geographically, the watershed stretches from the headwaters of the Peace River in Polk County to the southern end of Estero Bay in Lee County, a distance of more than 100 miles.

The model boundary for the Caloosahatchee Estuary and Charlotte Harbor Conceptual Model extends east to the S-79 structure. This is the final downstream structure and marks the beginning of the Caloosahatchee Estuary. Also known as the W.P. Franklin Lock and Dam, this structure maintains specified water levels upstream, regulates freshwater discharge into the estuary, and acts as an impediment to saltwater intrusion to the river. From there, the model extends southwest to the northern boundary of Estero Bay and into the Gulf of Mexico through Big Carlos Pass and includes a freshwater plume that extends approximately 3 miles offshore. The area of Bokeelia, at the northern end of Pine Island serves as the northern boundary. The model's western boundary extends 3 miles offshore of Sanibel and Captiva Islands, making a turn through Captiva Pass.

C: External Drivers and Ecological Stressors

External Drivers

Water Management

Water Management practices have resulted in drastic hydrologic and habitat alterations to the Caloosahatchee Estuary and Charlotte Harbor systems in order to convey more watershed runoff and include regulatory releases from Lake Okeechobee. These changes have caused large fluctuations in the volume, timing, and frequency of freshwater inflow to the estuary and have had an overwhelming impact on the ecology of the estuarine systems through the alteration of salinity zonation.

Natural Phenomenon

Sea level rise is an important natural phenomenon that is causing the inland movement of marine conditions into the estuary transition zone (Tampa Bay Regional Planning Council, 1993, Wanless et al. 1994, Meeder et al. 1996,). Sea level has been rising along Florida's west coast and is projected to rise at an accelerated rate because of global warming (Tampa Bay Regional Planning Council, 1993). The inland movement of marine conditions due to sea level rise is happening independent from societal-driven stressors.

Growth & Development

Changes in land use of a result of increased growth and development along with agricultural demands have led to loss and fragmentation of coastal and shoreline habitat, and changes in water use and an increase in water demands. Decreased water quality, resulting from an increased input of nutrients and dissolved organics into the system, has also had an effect on this urban and agriculture pressure.

An additional ecological stressor is that placed on the natural systems by boating and fishing pressures. The need for navigation from the east coast through Lake Okeechobee to the west coast has resulted in the dredging and the channelization of the original Caloosahatchee River to the current C-43 canal. The continued channelization of the C-43 has had a profound impact in decreasing the amount of submerged aquatic vegetation within the estuary. Furthermore increases in manatee mortality and decreases in native fish populations have been a consequence of both boating activity in the estuary and harbor as well as fishing pressures.

Ecological Stressors

Altered Hydrology & Freshwater Flow

Altered hydrology and freshwater flow is one of the predominate stressors of the system and takes the form of excessive water withdrawals (demand) and over drainage. This causes changes in the timing and quality of the watershed runoff to the estuary and harbor, which now includes regulatory releases from Lake Okeechobee. These alterations result from providing flood protection and water supply to a growing agriculture and urban population. The altered hydrology is facilitated by the physical changes made in the watershed, which include the development of a complex network of secondary canals, enlargement of C-43 to convey more water, and the addition of three water control structures on C-43, which connect the canal to Lake Okeechobee. Accompanying these hydrologic changes is a decrease in water quality, marked by increases in turbidity and nutrient loading, changes in water residence time in the estuary, and alteration in the natural salinity regime.

Altered estuarine and harbor salinity has resulted from man-made hydrological modifications that have dramatically altered the natural quantity, quality, timing, and distribution of flows to the estuary, often without proper regard to the biological integrity of the estuary (Haunert et al., 2000). During the wet season, rainfall runoff that was historically retained within the undeveloped watershed now reaches the river in greater volume and less time (USCOE, 1957). Additionally, the construction of S-79 has confined the estuary by restricting freshwater/low salinity waters from the upper reaches of the estuary during the dry season. Alterations in the delivery of freshwater at S-79 cause salinity to vary widely in time and space (USCOE, 1957). Rapid and unnatural fluctuations in salinity have contributed to major impacts on submerged plant abundance and distribution, including a loss of the natural gradient of grass species between Downtown Fort Myers and the mouth of the Caloosahatchee River.

The estuarine flora and fauna are sensitive to freshwater releases and disruption of the volume, distribution, circulation, and temporal patterns of freshwater discharges could place severe stress on the entire ecosystem. "Such salinity patterns affect productivity, population distribution, community composition, predator-prey interactions, and food web structure in the inshore marine habitat. In many ways, salinity is a master ecological variable that controls important aspects of community structure and food web organization in coastal systems" (Myers and Ewel, 1990).

Habitat Alteration and Loss

Habitat alterations to the estuary and harbor have also impacted the presence and abundance of species historically found within the system. These alterations include conversion of wetlands, dredging of channels and spoil disposal, changes in shoreline, snagging of navigation hazards, and decrease in spatial extent of the estuaries through construction of barriers (such as S-79) (Harris *et al.* 1983). The addition of the Intracoastal Waterway and the Sanibel Causeway altered water flow and habitat (Harris, et al. 1983). Changes in the physical dimension of the estuary, which resulted from the addition of S-79, reduced (or eliminated) the upstream oligohaline portion of the estuary, especially during the dry season (Chamberlain and Doering 1998a). This salinity zone is an important nursery area, feeding area, and refugia for juvenile stages of desirable sport and commercial fishes. Construction and operation of the water control structures may interfere with migrations patterns of many estuarine species, by acting as a barrier between the freshwater and saline water habitats and have historically resulted in deaths of manatees attempting to pass through these structures.

Changes in Water Quality & Increased Sediment Contaminants

Nutrients and dissolved organics enter the system as a result of anthropogenic activities in the watershed. The greatest loadings come from agricultural runoff facilitated by water management practices, urban runoff, and point source discharges to the estuary from sewage treatment plants (Post, Buckley, Schuh, and Jernigan and W. Dexter Bender and Associates, Inc 1999, Drew and Schomer 1984). In addition, atmospheric deposition contributes to nitrogen loading (Squires *et al.* 1998). These constituents lead to increased phytoplankton production and interact with altered salinity patterns, increased water color, and sediment loading to reduce light penetration. This can lead to declines in submerged plant abundance. Increases in areas of low dissolved oxygen and shifts in species composition of benthic invertebrates to more pollution tolerant organisms are linked to increased nutrient levels (Barbour *et al.* 1996).

Toxins which include pesticides, fungicides, herbicides, coliforms from sewage treatment plants, oils, greases, mercury, and other heavy metals such as copper and zinc can be introduced into the system from urban development, agricultural practices, and boating. Direct toxic effects have been documented in other south Florida systems on zooplankton and fish. Indirect effects can occur through the process of bioaccumulation or biomagnification through the food web, increasing the toxic load to top predators (Day *et al.* 1989). Studies in the Caloosahatchee Watershed have been unable to detect serious contamination of sediments with toxins (La Rose and McPherson 1983, Fernandez. *et al.* 1999). It is recommended that monitoring be continued.

Boating and Fishing Pressure

Boating pressure is a stressor to the estuary through direct impacts such as seagrass scarring, sediment resuspension, wake erosion, and construction of boating channels. In addition, boat collisions are the leading cause of human-related manatee mortality (W. Dexter Bender and Associates 1995). Fishing pressure from sport and commercial fisheries has impacted standing stocks of many species (Post, Buckley, Schuh, and Jernigan, Inc. 1999) and in turn impacted those species that depend on fish as their primary food source. Recent resource trends for local fisheries show some increase as a result of changes in the management process (Muller et al. 1996, McMichael 1997).

D: Ecological Attributes

Eight attributes have been identified in the Caloosahatchee Estuary and Charlotte Harbor as the biological or ecological indicators of environmental stress.

Submerged Aquatic Vegetation Community Structure, and Function

Submerged Aquatic Vegetation (SAV), for the purpose of this conceptual model, include only the vascular underwater plants that live throughout the estuary and in near-coast waters. SAV play several roles in maintaining an estuary's health. They provide habitat and nursery grounds for many fish and invertebrate communities and are especially important in benthic based primary productivity. SAV and the organisms that live on them are important food sources in the estuarine system. Manatees, waterfowl and wading birds rely heavily on seagrass systems as forage areas. SAV help maintain water clarity by trapping fine sediments and they improve water quality by taking up large quantities of nutrients that would otherwise accelerate the eutrophication of the estuarine system.

Tape grass (*Vallisneria americana)* is the dominant submerged aquatic vegetation in the upper Caloosahatchee Estuary and occurs in well-defined beds in shallow water. *Vallisneria americana* is an important habitat for a variety of freshwater and estuarine invertebrate and vertebrate species, including some commercially and recreationally important fishes (Bortone and Turpin 1999). Additionally, it can serve as a food source for the Florida manatee (*Trichechus manatus*). Shoal grass (*Halodule wrightii),* turtle grass *(Thalassia testudinum)*, and manatee grass *(Syringodium filiforme)* are the most common higher salinity grasses in the Caloosahatchee Estuary and Charlotte Harbor. *Argopectin sp.,* the bay scallop, prefers shoal and turtle grass beds. Increasing scallop populations to resemble historic distributions is currently a goal of the Charlotte Harbor Estuarine Program (CHNEP 1999).

All species of SAV have a preferred and tolerable salinity range. They respond unfavorably when salinity alterations exceed these ranges. Degraded water quality and physical alterations, such as the Sanibel Causeway and the Intracoastal Waterway have also shown negative impacts to the seagrasses. The result has been a regional decrease of seagrass coverage (Chamberlain and Doering 1998a). This decline negatively impacts the fish and invertebrate communities. It also causes destabilization of sediments and a shift in primary productivity from benthic macrophytes to phytoplankton, both of which provide negative biofeedback to further affect seagrass beds.

Oyster Bar Community Structure, and Function

Oysters are sensitive to salinity and siltation. They require salinity levels above 4-5 ppt (Loosanoff 1932) with an optimal salinity range between 14 and 28 ppt (Chanley 1958, Galtsoff 1964) varying with geographical region. Higher salinity levels increase negative effects from saltwater predators such as oyster drills (Hofstetter 1977, White and Wilson 1996) and the protozoan parasite *Perkinsus marinus* (Dermo) (Volety 1995), the primary oyster pathogen in the Gulf of Mexico (Soniat 1996). Dermo is estimated to have killed 80% of the oysters in a bed under optimal salinity and temperature within Chesapeake Bay (Andrews 1988). Presently, increased oligohaline conditions have limited distribution of oysters in the Caloosahatchee estuarine systems.

Oyster bars provide several important functions, including habitat and food for other species. Wells (1961) lists 303 species that depend on oyster bars either directly or indirectly. Individual oysters filter 4 to34 liters of water per hour, removing phytoplankton, particulate organic carbon, sediments, pollutants, and microorganisms from the water column (Volety pers. com.). This process results in greater light penetration and promotes the growth of submerged aquatic vegetation immediately downstream of the oyster bars.

The epidemiology of Dermo disease coupled with physiological responses of oysters in relations to environmental and anthropogenic stress will yield critical information on conditions necessary for healthy oyster reefs. Salinity and water quality conditions that yield enhanced distribution of healthy oyster reefs can be used as hydrological targets for restoring and maintaining suitable salinity and water quality in the Caloosahatchee Estuary and Charlotte Harbor.

Mesohaline Benthic Community Structure and Function

Open bottoms in the Caloosahatchee Estuary and Charlotte Harbor are composed of mixtures of sand, mud, shell, and bedrock. Macroinvertebrates, including mollusks, are dominant elements of both the estuarine and tidal river Caloosahatchee and Charlotte Harbor ecosystems.

The number, diversity, dispersion, and condition of macroinvertebrates have been studied for decades, forming a large and robust body of information on adaptations of numerous phyla to the physical and chemical conditions unique to estuaries. Numerous studies have demonstrated that spatial and temporal trends in macroinvertebrate attributes vary in consistent form with variations in river flow, current speed, salinity, dissolved oxygen, and foodstuffs such as particulate organic carbon, phytoplankton, macrophytes, and prey. In recent years, a variety of studies have been published which indicate the extent to which macroinvertebrate attributes can be related specifically to independent variables such as freshwater inflow and salinity alterations.

The mesohaline clams *Rangia cuneata,* (Bivalvia: Mactridae), and *Polymesoda carolineata* (Bivalvia: Corbiculidae), are commonly found associated with mud and sandy bottoms in the Caloosahatchee Estuary. Both of these mollusks require lower salinities and can be used as indicators of estuarine condition. Furthermore, because mollusks leave behind their shells upon death, it is possible to look at the death assemblage to construct historical salinity regimes. Shell characteristics such as size, shape, and ornamentation vary according to salinity and can be used to construct historical salinity regimes. The death assemblage, which is sampled along with live community, can be utilized as an indicator of conditions prior to recent alterations to the system and provide a useful target when compared with current conditions.

Fisheries Community Structure and Function

At least 70% of Florida's recreationally sought fishes depend on estuaries for at least part of their life histories (Harris *et al.* 1983, Estevez 1998, Lindall 1973). Within the estuary, seagrass communities provide critical refugia for juvenile fish such as redfish, grouper, snook, and spotted seatrout. The decline in juvenile abundance and distribution of these and other species, along with the overall decline in species richness may be related to a decline in this seagrass habitat and/or a result of alterations in the salinity regime and the timing of the freshwater discharges.

Commercial and recreational fishing pressure has also increased along the west coast of Florida. With this increase, there has been a decline in reported landings (Post, Buckley, Schuh, and Jernigan and W. Dexter Bender and Associates, Inc 1999). In Lee County clear evidence for this decrease can be seen with the spotted seatrout where there has been a decline on catch-per-unit-effort from 1986 to 1995 (Bortone and Wilzbach, 1997).

The blue crab fishery is the largest, year-round fishery in the upper and middle portion of the Caloosahatchee River and Charlotte Harbor. This commercial fishery is intensely fished virtually every day of the year by several hundred crab traps and will be able to provide fishery landings data that can be correlated to other estuarine components to provide evidence of the overall productivity of the system. Blue crabs also move freely about the system are good monitors of localized changes in conditions relative to temperature, salinity and other water quality parameters.

Manatee Demographics

Manatees are a very visible and publicly appreciated feature of the Caloosahatchee Estuary and Charlotte Harbor. They have been listed by the state and federal government as an endangered species and are protected throughout their range. In the study area, the largest concentration of manatees is found in the upper tidal reaches of the Caloosahatchee Estuary, near the Orange River and the warm water outflow of the Florida Power and Light power generating plant (USFWS, 1995).

The Florida manatee is an opportunistic herbivore, feeding on a wide variety of plants. Seagrasses, especially *V. Americana,* can be an important food resource for manatees in the Caloosahatchee Estuary. Other critical requirements for the manatee are warm water in winter months and access to fresh water. They prefer waters with salinities less than 25 ppt, but can move freely between fresh and salt water (USFWS, 1999)

Lee County leads the west coast of Florida in the total number of manatee deaths. Some of these deaths can be attributed to watercrafts, entanglement with crab lines, rope, or gill nets, and ingestion of monofilament line or pieces of plastic. Lee County also leads all other west coast counties in the number of deaths in the categories of dependent calves, natural causes, and undetermined.

Shoreline Community Structure and Function

In 1982 approximately 674,260 acres of mangrove forests occurred in Florida (Lewis *et al*., 1985). Approximately 2,995 acres of mangroves are found in the Lower Caloosahatchee River Subbasin (Post, Buckley, Schuh, and Jernigan and W. Dexter Bender and Associates, Inc 1999). In the Caloosahatchee Estuary and Charlotte Harbor, mangroves support fish and macro-invertebrate communities by providing protected nursery areas for fishes, crustaceans, and shellfish, and food for a multitude of important commercial and recreational marine species such as snook, snapper, tarpon, jack, sheepshead, red drum, oyster, and shrimp (Harris *et al*. 1983, Lindall 1973). Mangrove roots act to trap sediments and prevent shoreline erosion and provide attachment surfaces for various marine organisms. Additionally, mangrove forests provide habitat for a highly diverse population of birds (Odum *et al.* 1982).

Mangrove shoreline habitats have decreased in spatial extent and in function. Large areas of mangroves have been lost or fragmented through dredge-and-fill activities (National Safety Council 1998, Estevez 1998). In addition, mangroves are sensitive to alterations in upland drainage. In some areas, drainage for agricultural and urban development has reduced overland flows of freshwater to the mangroves. This results in an increased amount of concentrated runoff, which in turn changes the salinity balance, reduces the flushing of detritus, and washes nutrients directly into the estuary without the benefit of filtration by the mangrove system (Estevez, 1998).

Algal Blooms Community Structure & Function

Periodic blooms of algae, including true algae, dinoflagellates, and cyanobacteria or blue-green algae have been reported within the marine and freshwater portions of the Caloosahatchee Estuary and Charlotte Harbor. In many instances these algal blooms are merely an aesthetic nuisance, however certain species producing toxins that kill fish, invertebrates, birds and mammals (USGS 1988). Pigmented algal blooms that are toxic to the marine environment are referred to as "red tides", while those produced by cyanobacteria in freshwater are termed cyanobacterial blooms (USGS 1988). Florida red tide blooms typically begin in the Gulf of Mexico 40-80 miles offshore and move slowly with the prevailing ocean currents toward southwest Florida. As the bloom progresses, the density of red tide organisms increase to several million cells in each liter of sea water, and the effected area expands to many square miles.

Red tides within Charlotte Harbor can and have presented to marine animals. Marine algal toxins, such as brevetoxin, bioaccumulate and are thereby magnified in the food chain, while anatoxins from freshwater cyanobacteria affect the nervous system. There have been several documented cases in the field where blooms of *Karenia brevis*, a brevetoxin that produces neurotoxins and the major species of harmful algal bloom in Gulf waters which causes red tides, have killed both vertebrate and invertebrate species. At least 17 invertebrate species normally present in Tampa Bay, Florida, have been recorded absent immediately after a red tide incidents (FMRI 2000). Various species of bivalve shellfish, especially oysters, clams and coquinas can accumulate so much toxin that they become toxic to both marine animals and humans as well (MML 2002).

During two of the largest recorded red tide out breaks (1946–1947 and 1953–1955) in southwest Florida catastrophic mortalities of marine animals were recorded (FMRI 2000). Among the affected organisms during these periods were reports of dead bottlenose dolphins (*Tursiops truncatus*), sea turtles, and numerous fish species. Because fish die quickly from exposure and contact with red tides the toxins do not have time to build up in their tissue. Those fish exposes to lower and hence sub lethal concentrations of red tide may accumulate these toxins in their body. Such bioaccumulation of toxins in fish eaten that then eaten by dolphins may a major factor in the marine mammals mortality in the study area. The largest red tide-associated dolphin mortality involved more than 740 bottlenose dolphin strandings along the Atlantic coast from June 1987 to May 1988. Although other infections were present in examined dolphin carcasses, brevetoxin was suspected as the proximate cause of the mortality during this mass stranding.

Along with toxin effects, algal blooms negatively influence aquatic organisms by depleting dissolved oxygen concentrations in the water through their proliferation, death, decay and nightly respiration (USGS 1988). Although coastal pollution has enhanced red tide blooms in other areas of the world, the Florida red tides represent a natural phenomenon not caused by pollution. These blooms serve a purpose in the ecology of Florida Gulf coastal regions (MML 2000).

Wading Birds Community Structure & Function

A number of ecological factors are negatively influencing wading bird species in the Caloosahatchee Estuary and Charlotte Harbor, chief among these are loss of shoreline habitat, decreased availability of SAV and fish within the mangroves and littoral zones as well as potential influence from increased nutrients and contaminant runoff.

Environmental contaminants, such as pesticides and heavy metals, used for agricultural and urban needs throughout much of South Florida pose a variety of potential threats to fauna, as they can be concentrated in organisms through food webs in the Caloosahatchee Estuary and Charlotte Harbor regions. These bioaccumulated toxins can have significant effects on the health of populations of macroinvertebrates and fish, and ultimately on the survival of wading bird species. Contaminants can also significantly affect aquatic fauna without being bioaccumulated, particularly for those species with gills or permeable surfaces exposed to water.

Many bird species can be affected by algal toxins (USGS 1988). Most reports of mortality are from die-offs that occur in conjunction with a bloom that had worked its way into that specie's food chain. During a long duration outbreak of *K. brevis* red tide on the Florida west coast between October 1973 to May 1974, large numbers of aquatic birds, particularly double-crested cormorants, *Phalacrocorax auritus*, red-breasted mergansers, *Mergus merganser*, and lesser scaup, *Aythya affinis*, were found moribund or dead in red tide areas. Over an eight-week period several thousand lesser scaup died (FMRI 2000).

E: Ecological Effects

Loss of Shoreline Habitat and Function

Relationship of loss of shoreline habitat and function and shoreline community structure and function. The ecological functionality of shoreline habitat in the Caloosahatchee Estuary and Charlotte Harbor systems is predominantly composed of mangrove habitat. Urbanization and shoreline development have resulted in the extensive loss of mangrove habitat along the Caloosahatchee Estuary and within Charlotte Harbor. Among the ecological functions carried out by mangroves are land formation (Warming, 1925; Davis, 1940), sediment stabilization, primary productivity, filtration of land runoff, absorption and recharge floodwaters. The mangroves also serve as habitats and nurseries providing food and cover for a multitude of native fish and wildlife (MacNae, 1968, Odum *et al.*, 1982; Harris *et al.*, 1983; Dawes 1998). These functions help to maintain water quality, recycle nutrients, and control erosion (Harris *et al.*, 1983). In south Florida, mangroves have been destroyed by dredge-fill operations to create real estate, and port and industrial facilities. Mangrove destruction results in a chain of reactions that affect estuarine and off shore production. In the Tampa Bay estuarine system, one similar in structure and function to the Caloosahatchee, 44% of the mangrove and salt marsh land has been lost due to construction and resultant turbidity from runoff and pollution (Lewis and Estevez 1988). This loss in the Tampa Bay Estuary has been linked to declines in fin fish and commercial shrimping in the region (Dawes 1998).

Relationship of loss of shoreline habitat and function and wading bird community structure and function. Mangroves, the dominant shoreline habitat for the lower Caloosahatchee Estuary and Charlotte Harbor, carry out a number of ecological functions; in particular this ecosystem serves as primary habitat and nursery grounds for both wading birds species and their various prey organisms such as estuarine invertebrates and fish. Productivity in the shoreline mangrove systems are also depressed as a result of diminished upland flows of freshwater to the mangroves. It is these low salinity mangrove forests have been recognized as critical nursery habitat for species such as blue crab, snook, tarpon, and ladyfish (Odum *et al.* 1982, Gilmore *et al.* 1983, Lewis *et al.* 1985). Much of this habitat has been lost or highly modified. In many areas, freshwater upland flows to these mangrove systems have been decreased or depleted due to a rerouting of the water through canals. Changes in freshwater discharge have also altered the structure of mangrove forests. The reduction and modification of this habitat type may represent a limiting factor in total population sizes of some estuarine-dependent species (Lewis 1990).

Altered Salinity Regime

Relationship of altered salinity regime and fisheries. Alterations in the salinity regime places undo stress on the sensitive life history stages of many estuarine species (Emery 1957, Odum 1970, Lindall 1973, Perry and McIlwain 1986, Chamberlain and Doering 1998b). Within the Caloosahatchee Estuary and Charlotte Harbor altered salinity regimes have impacts on the community structure and function of fisheries, oyster bars, SAV and benthos. While estuarine species are generally well adapted to cope with varying salinity conditions, larger shifts these conditions can be a problem. Such changes in the natural salinity regime and timing of freshwater discharges have resulted in a decline in juvenile fish abundance, distribution, and species richness. For example, the egg stage of spotted seatrout. Trout eggs are neutrally buoyant at about 20-22 ppt (Pattillo et al. 1997). They spawn during the warmer months of the year (Lassay 1983). If large and protracted reductions in salinity were to occur during the summer months, it could lead to the reduction or elimination of an entire year-class of spotted seatrout.

Relationship of altered salinity regime and oysters. Alterations in freshwater flow have lead to dry season salinity increases in the estuary and harbor. Salinity is an important factor in determining the distribution of coastal and estuarine bivalves. Adult oysters in the Gulf of Mexico normally occur at salinities between 10 and 30 ppt but they tolerate a salinity range of 2 to 40 ppt (Gunter and Geyer 1955). Short pulses of freshwater inflow can greatly benefit oyster populations by killing predators, such as the southern oyster drill and the welk that cannot tolerate low salinity water (Owen 1953, Marshall 1954), while excessive freshwater inflows may kill entire populations of oysters (Gunter 1953, Schlesselman 1955, MacKenzie, 1977).

Relationship of altered salinity regimes and SAV. Different species of SAV have different desirable salinity ranges. When salinity falls outside of these ranges the SAV is negatively impacted and may result in a reduction in densities and distribution (Chamberlain and Doering 1998b). Increases or decreases in salinity may give one species a competitive advantage over another (Livingston 1987). Tabb et al (1962) stated: “Most of the effects of man-made changes on plant and animal populations in Florida estuaries are a result of alterations in salinity and turbidity”.

Relationship of altered salinity regime and the benthic community. Alterations in SAV community structure and function brought by changes in the natural salinity regime has resulted in substantial losses of mesohaline benthic species, such as mollusks and blue crabs along with a decrease in larval and adult fish recruitment into the estuary and harbor.

Relationship of altered salinity regime and algal blooms. Research has found that high mortalities in estuary and harbor organisms such as the manatee appear related to concentration and geographic distribution of the red tide outbreaks, in relation to salinity, as well as the persistence of the bloom in relation to the distribution and exposure time by of the organisms to the bloom (Landsberg, J.H. and K. A. Steidinger, 1998). An unusual number of manatee deaths were documented in 1996 (U.S. Marine Mammal Commission, 1996). The beginning and ending of this event coincided with an inshore bloom of *Karenia brevis* in southwest Florida (Baden, 1996).Eighty one of 149 manatee deaths associated with this bloom of red tide occurred in Lee County, primarily in the Caloosahatchee Estuary (Dryden pers. com.). Fish mortalities associated with *K. brevis* events are very common, widespread, and impact hundreds of species and various life history stages. Brevetoxin is absorbed directly across the gill membranes of fish or through ingestion of *K. brevis* cells.

Relationship of altered salinity regime to manatee demographics. Algal blooms, such as red tides, present a major threat towards manatee populations is red tide which historically been responsible for an increase in manatee mortality. Although marine mammal mortality associated with red tide is poorly known several mortalities have been recorded in this region from this toxin. Red tide was linked to the deaths of seven manatees in 1963 near Fort Myers (Layne 1965, Bossart et al 1998). More recently, during a 1996 die off of manatees, a large number of manatees aggregated in warm waters near the Fort Myers power plant in the Caloosahatchee River. Final reports conclude that brevetoxins from a bloom of red tide were responsible for the death of those manatees. Toxins were found in the manatee carcasses in the liver, kidney, and lung tissues, and also in stomach contents (USFWS 1999). Manatee deaths are often attributed to red tide. However, in 1996 their increased vulnerability was due to their congregating near this warm water refuge and circumstances of the estuary when the tide occurred.

Increased Manatee Mortality

Relationship of increased manatee mortality and manatee demographics. Manatee populations and their habitats in the Caloosahatchee Estuary and Charlotte Harbor are continually threatened by human activity. The greatest present threat to manatees in southwest Florida is the high rate of morality caused by watercraft collisions. Boat channels are often used by manatees to travel from one region to another (Curran 1989, Sirenia 1993). Manatees do not always move out of the way of boats using these channels which make them vulnerable to collisions. Watercrafts using shallow coastal areas for fishing and site seeing also increase the likelihood of a manatee injury or death if the boat passes over them.

The second most significant threat to manatees is the loss and degradation of habitat, due primarily to direct damage by aquatic recreational and commercial boating activities, coastal construction, and pollution from sewage discharge and storm water runoff (MMC 1992, Smith 1993). The seagrass beds that manatees rely on for foraging, mating, calving incur direct damage from boat propellers (Zieman 1982). Propeller dredging of bottom habitat by boats, propeller wash, and wave wake disturbance cause boat induced turbidity. Sediments around seagrasses become unconsolidated and suspended. This delays recolonization of the grasses for two to five years or longer, depending on the species type.

Decrease of SAV

Relationship of decreased SAV and manatee demographics. Manatees depend on the submerged aquatic vegetation for food and habitat in the Caloosahatchee Estuary and Charlotte Harbor. Seagrass beds and mangroves provide important areas for manatee foraging, calving, resting, and mating. Preferred manatee habitat in south Florida is characterized by the availability of submerged aquatic vegetation (Smith 1993).

Manatees are opportunistic herbivores and feed on a variety of submergent, emergent, and floating vegetation with seagrasses comprising the largest component of their diet in south Florida (Hartman 1979, Zieman 1982, Smith 1993). Manatees usually forage in shallow grass beds that are adjacent to deeper channels (Hartman 1979, Powell and Rathbun 1984). Some manatees have been observed to return to the same seagrass beds year after year and may show preference for certain areas (USFWS 1999).

Relationship of decreased SAV and wading bird community structure and function. Negative changes, namely decreases, in SAV community structure and function has resulted in reduced nutrients and nurseries for wading birds or their prey. Substantial losses in mollusk populations and a decrease in larval and adult fish recruitment into the estuary are a direct result of declining SAV populations in the estuary and harbor.

Fish densities are typically greater in grass bed habitat within south Florida's estuaries and coastal lagoons than in adjacent habitats (Reid 1954, Tabb et al. 1962, Roessler 1965, Yokel 1975, Weinstein et al. 1977). The grass beds provide protection from predation for animals living in it. The dense seagrass blades and rhizomes associated with the grasses provide cover for invertebrates and small fishes while also interfering with the feeding efficiency of their potential predators (Zieman 1982). Reduction in size and health of SAV beds effects the location, abundance, and speciation of fisheries in the estuary.

Relationship of decreased SAV and SAV community structure and function. Reduction in penetration of light into the water column is often blamed for the disappearance and diminishing of previously healthy seagrass meadows (US EPA 1983). Because seagrasses are rooted plants attached to the bottom, reduced light reduces photosynthesis, growth, and reproduction. This condition is cited as a major source of seagrass decline in Florida estuarine systems. (Durako 1988).

Increased nutrients, such as nitrogen and phosphorous, can lead to light deprivation by stimulating the growth of phytoplankton. These blooms cloud the water and severely diminish sunlight penetration (Livingston 1987). This turbidity can increase to such a level that seagrasses persist only in patches (Zieman 1982). Nutrients can also trigger a thick growth of epiphytes which can also block the sunlight before it can reach the surface of the seagrass (Murray et al. 1999). In fact, nutrient input has such an effect that relatively minor changes in water quality can lead to sharp reductions in the productivity of seagrasses which can lead to broad habitat changes (Livingston 1984).

Relationship of decreased SAV and fisheries community structure and function. A decline in the amount of seagrass habitat/coverage has occurred in the Caloosahatchee and Charlotte Harbor drainage. The consequences of this decline is a reduction in potential habitat for a number of seagrass dependent species, and especially the juvenile life stages of most estuarine dependent species (Virnstein 1987, Stoner 1984, Zieman 1982). Specifically, larval gag (*Mycteroperca microlepis*) use sea grass beds a settlement substrate after having hatched offshore on natural hard bottom structures. The larvae settle in the higher salinity areas of San Carlos Bay and Pine Island Sound in the spring of each year. After attaining a size of about 60 - 80 mm TL they migrate offshore to take up residence on offshore reefs (Jory and Iverson 1989). Juvenile spotted seatrout (*Cynoscion nebulosus*) use grass beds for protection from predation while adults feed on many of the seagrass associated species such as shrimp and smaller fishes (Pearson 1929, Miles 1950, Perret et al. 1980).

Increased Nutrients & Contaminants

Relationship of increased nutrients and contaminants and algal blooms community structure and function. The amount of nutrients entering the Caloosahatchee River and Charlotte Harbor has important effects on the water quality of the system. Organisms use these nutrients, but excessive amounts may have negative impacts (Neilson and Cronin 1981). Algal blooms and epiphyte growth may cause decreased water clarity and block sunlight for aquatic plants (Day 1989). As algae die, organic decomposition depletes the oxygen in the water (LaRose and McPherson 1983, Drew and Schomer 1984, Day 1989). Low levels of dissolved oxygen can have negative effects on fish and other aquatic organisms (Heyl 1998). Eutrophication may also result in an increase in red tide blooms (Gore 1992).

Relationship of increased nutrients and contaminants and wading birds community structure and function. Natural communities in South Florida are adapted to surface waters with a chemical composition that contains low concentrations of dissolved minerals and nutrients. Changes in surface water quality typically involve increased nutrient and mineral concentrations coming from ditch and canal outflows into natural wetlands (Drew and Schomer 1984). These increased concentrations can produce dramatic shifts in the amounts of nutrients within the water column, increasing turbidity and having detrimental effects on SAV species which are adapted to specific nutrient and dissolved mineral concentrations. Any detrimental influence to SAV populations is immediately conferred to wading bird community structure and function in the form of lost productive nursery and prey habitat.

Changes in Sediment

Relationship of changes in sediment and SAV community structure and function. The submerged aquatic vegetation in the Caloosahatchee Estuary and Charlotte Harbor will increase as estuarine conditions improve. The extent of this increase depends on available area with suitable salinity, substrate, water clarity, and temperature.

Seagrasses require light for photosynthesis. A number of factors can influence water clarity and light penetration. These include color and suspended solids. The different species of SAV have distinct requirements for light. Numerous research indicates that *Thallassia testudium, Halodule wrightii,* and *Syringodium filiforme* require levels of at least 10-15% of surface irradiance, while *Halophila decipiens, Halophila englemannii, Halophila johnsonii,* and *Ruppia maritima* appear to have somewhat lower requirements, perhaps as low as 2-3% of surface irradiance (URS Greiner Woodward Clyde 1999).

Most seagrasses appear to tolerate a wide range of substrate conditions. Virtually all seagrasses seem to grow on sandy or silty muds and on sands with some mud contents (Reid 1954, Voss and Voss 1955, Phillips 1960) and require a sufficient depth of sediment for proper development. Substrates most also contain nutrients, especially nitrogen and phosphorous, available for SAV growth (Duarte 1991). The microbially mediated chemical processes in marine sediments provide a major source of these nutrients (Capone and Taylor 1980).

Each species of SAV has their own temperature and salinity tolerance ranges and their tolerance to salinity variation is similar to their temperature tolerances. *Halodule wrightii* is the most broadly euryhaline, *Thallassia testudium* is intermediate, and *Syringodium filiforme* and *Halophila* have the narrowest tolerance ranges (McMillian 1979, Zieman 1982). *Vallisneria americana* is generally a freshwater grass but can tolerate salinities of near 10 ppt. Therefore, *Vallisneria* is also an important component of the oligohaline estuarine SAV community (Twilley and Barko 1990, Adair et al. 1994, Kraemer et al. 1999).

Decrease of Fish Populations

Relationship of decreased fish populations and wading bird community structure and function. A direct consequence from the decline in shoreline habitat and decreased SAV is a reduction in potential habitat for a numerous fish species found in the seagrass and littoral zone communities on which wading birds are dependant. Accompanying this reduction in habitat for specific life histories of various fishes, the reduction in grass beds also has led to an overall reduction in wading bird species diversity within the system.

Relationship of decreased fish populations and fisheries community structure and function. Caloosahatchee Estuary and Charlotte Harbor provide habitat and nursery grounds for a variety of estuarine fish communities. These fishes are an integral component of the estuarine food web and have a significant societal value for sport and commercial harvesting. Fish community measures are sensitive to both short and long term changes to the overall biotic integrity of estuarine systems. Regarding these regions, with their history of anthropogenic manipulation, information that would permit the assessment of overall changes (replacement, additions and subtractions) of its native fish community relative to environmental change is lacking.

F: Research Questions

Relationship of water management practices to estuarine protection and restoration.

How can estuaries of national importance, including the Caloosahatchee River; and the pristine resources of the Charlotte Harbor Aquatic Preserve be protected or recover from water management practices associated with freshwater pulsing, alternation in timing and duration of base and seasonal flows, contaminants, overnutrification and red tide?

Relationship of Manatee Mortality to Red Tide

Will changes in salinity, nutrient load, and water residence time due to the restoration of the recommended estuarine salinity envelope reduce the occurrence of red tide in inland waters at times coincident to when manatees move between inland waters and estuarine waters?

Relationship of Blue Crab Fishery to Temperature, Salinity and Other Water Quality Parameters

How does CPUE of the blue crab fishery respond to the combined effects of temperature, salinity and other water quality parameters in the Caloosahatchee estuary? Can blue crab CPUE be used as an indicator of estuarine health in the estuary?

Relationship of Mollusk Populations and Fish Recruitment to Submerged Aquatic Vegetation and Salinity

Will changing the salinity regime to a more natural condition and increasing the coverage of submerged aquatic vegetation in the Caloosahatchee estuary provide a more suitable environment for estuarine mollusks and fishes? Will this lead to an increase in population density and community diversity?

Relationship of Current and Historical Submerged Aquatic Vegetation Coverage to Potential Distribution

What areas in the estuary potentially provide optimal conditions for seagrass reestablishment? Will we see this reestablishment with changing conditions?

G: Hydrological Performance Measures

See addendum titled Southwest Florida Feasibility Study – Caloosahatchee Estuary Hydrologic Evaluation Performance Measures.

H: Ecological Performance Measures

Submerged Aquatic Vegetation Community Structure & Function

The performance measures for submerged aquatic vegetation community structure and function are SAV distribution, density/abundance, and community composition. Seagrass beds must be reestablished in the Caloosahatchee Estuary and Charlotte Harbor to increase biodiversity within the system and enhance habitat value for fish, caridean shrimp, wading birds, and manatees. The coverage of seagrasses must increase in areas that are indicated to be suitable habitat. To achieve these targets, flows needed to achieve the proper salinity range for SAV must be maintained.

Oyster Bar, Community Structure and Function

The performance measures for oyster bar community structure and function are oyster growth, disease, mortality and recruitment. The targets are to increase the abundance and health of oysters, restore oyster beds in suitable habitat, and maintain habitat function of oyster beds for fish, crabs and birds. To achieve these targets, flows needed to achieve the proper salinity range for oysters must be maintained (see Salinity Envelope under Hydrologic Performance Measures).

Mesohaline Benthic Community Structure and Function

The performance measures for sand/mud bottom community structure and function are mesohaline clam abundance, growth and recruitment. The target is to obtain targeted normal distribution, population size, and condition across optimal salinity ranges for these freshwater species of clam.

Shoreline Community Structure and Function

The performance measure for shoreline mangrove habitat is shoreline mangrove percent cover. The targets are to restore and maintain shoreline mangrove habitat and to increase or maintain functionality of the mangrove system. To achieve these targets, further loss of mangrove habitat must be eliminated; mangrove habitat must be restored when possible. The mangrove tree crab will be used an indicator species to measure increase or loss of functionality in the mangrove system.

Fisheries Community Structure and Function

The performance measure for estuarine fish community structure and function are fish community structure and diversity. The target is to restore assemblages with abundance, taxonomic composition, diversity and representation of life stages characteristic of targeted salinity regimes for each estuary.

Manatee Demographics

The performance measures for manatee demographics are manatee birth, death, survival, distribution and abundance. Restoration and preservation of the manatee population in the Caloosahatchee Estuary and Charlotte Harbor will be achieved by maintaining and enhancing current habitat and foraging areas for manatees in the estuaries and canals to promote species recovery, especially near the Florida Power and Light warm water refugia. Also, manatee habitat values in canals should be maintained or enhanced, as reflected by continued use of canals by manatees. Manatee deaths in categories "undetermined" and "calves" need to decrease.

Algal Blooms Community Structure & Function

The performance measures for algal blooms community structure and function are algal bloom frequency, duration, identity, concentration and negative effects.

Wading Bird Community Structure & Function

The performance measures for wading bird community and structure are wading bird foraging and nesting surveys.

H: Baseline Conditions and Drivers for Water Quality in the Caloosahatchee Estuary and Lower Charlotte Harbor

Anthropogenic changes in water quality can act as stressors in estuarine systems. Drivers and pathways of water quality problems may include, among others, urban stormwater runoff (e.g., lawns, golf courses, "street dust"), agricultural runoff, surface mining runoff, septic systems, discharges from Publicly Owned Treatment Works (POTWs), direct industrial discharges (e.g., citrus processing plants, power plants), landfill runoff, as well as atmospheric deposition of contaminants from varied sources (for a review of drivers in southern Florida, see USGS 1998). Although much of the focus (and control) has been on point sources, considerable evidence has been amassed to suggest nonpoint sources, such as urban stormwater runoff, and diffuse pathways, such as atmospheric deposition, can play very significant roles in local WQ problems. Atmospheric deposition of contaminants from varied sources (both local and distant) can be an important driver in estuarine WQ in one of two ways. Direct atmospheric deposition of a contaminant to the estuary includes loading from dry deposition and wet deposition. Indirect deposition from the atmosphere to the estuary occurs when the contaminant is initially deposited to the watershed and then transported to the estuary through runoff and tributaries and, hence, a function of water management. Along with the growing appreciation of potential impacts from atmospheric transport and deposition also comes a realization that we can no longer rely on the "dilutive effects of the ocean environment" to solve coastal pollution. Evidence has accumulated that anthropogenic contaminants, as well as natural occurring materials, in riverine discharges can be transported and have biological effects far removed from their discharge site (Rabalais et al. 1996; Goolsby, 1994, Rudnick et al., 1999). As one example, algal blooms in western Florida Bay have been linked to nutrient transport along the southwest shelf of Florida (Rudnick et al., 1999).

A number of different federal, state and local government programs outside of CERP are in place or will be in place in the future to address WQ problems resulting from both point and nonpoint sources. These include the federal Clean Water Act, Clean Air Act, Coastal Zone Act Reauthorization Amendments along, Florida's Watershed Restoration Act and Water Resources Act that address implementation of the National Pollutant Discharge Elimination System permits, Total Maximum Daily Load requirements, Surface Water Improvement and Management (SWIM) programs, as well as both agricultural and urban nonpoint source management programs. Any recommendations related to water quality for alternatives analysis will first evaluate the efficacy of remedies brought about by these outside programs. However, as will become evident from the current conditions discussed below, these programs are rarely 100 percent effective. Further, several examples will be presented to show that local WQ problems may have drivers outside of the study area and, thus, may not be remedied through local or state programs. During these assessments and during any subsequent alternatives analysis the following baseline conditions and drivers should be considered when identifying major stressors in estuarine water quality:

Results of a number of recent water quality assessments of the Caloosahatchee Estuary and Lower Charlotte Harbor show remarkable agreement (Table 1). In their preliminary assessment, FDEP classified three waterbodies in the Caloosahatchee Estuary as potentially impaired based on chlorophyll-a, dissolved oxygen (DO), fecal coliform, copper, lead and or biology (for methodology and legislative authority, see Impaired Surface Waters Rule [IWR], Chapter 62-303 F.A.C.). In a separate assessment, U.S. EPA (2000) also found that parts of the tidal Caloosahatchee and its tributaries had degraded water quality based on values of key parameters. These findings have added significance given the presence of the following Outstanding Florida Waters (OFWs) within the Caloosahatchee Estuary and Lower Charlotte Harbor: Caloosahatchee National Wildlife Refuge (40 acres located in the Caloosahatchee near Interstate 75), J.N. "Ding" Darling NWR, Matlacha Pass NWR, Pine Island Sound NWR, Estero Bay State Buffer Preserve, Matlacha Pass Aquatic Preserve, Pine Island Sound State Aquatic Preserve.

Although the state's IWR focuses on chlorophyll-a rather than absolute concentrations of nutrients (i.e., because there are no numerical water quality standard [WQS] for nutrients), Doering and Chamberlain (1998) and Janicki Environmental Inc., (2002) both found total nitrogen (TN) and total phosphorus (TP) to be elevated in the Caloosahatchee compared to statewide median concentrations, reference site concentrations and compared to historical data (for TP). Doering and Chamberlain (1998) also report TP and TN exceeded targets that FDEP (Degrove, 1981) had set for the Caloosahatchee. Most of these assessments also found a sag in DO (Table 1), especially in bottom water in the upper Caloosahatchee (i.e., adjacent to S79). Color was another parameter not considered under the IWR assessments but that was found to be unusually high (Doering and Chamberlain, 1998; ERD 2003). Accelerated decomposition of organic matter in the historic peat deposits in the northern Everglades (due to land-use change) has been shown to provide a significant source of dissolved organic matter (DOM) and nutrients (Wang et al., 2003). ERD (2003) reports that color at the S79 structure reached 67 Pt-Co units and 164 Pt-Co units in the dry and wet season, respectively (statewide median for estuaries is 22.5 Pt-Co; Friedemann and Hand, 1989). Color in the Caloosahatchee may have greater significance given the optical model developed by Dixon and Kirkpatrick (1999) for upper and lower Charlotte Harbor. They found that color accounted for 66% of light attenuation in the water column; whereas, chlorophyll, and turbidity accounted for only 4% and 31%, respectively. A finding that color accounts for much of the water column light attenuation in Charlotte Harbor is also consistent with a report from McPherson et al. (1996). Humic materials, which make up much of the color, may also be implicated in reports of a dark flocculant material settling on grassbeds in San Carlos Bay (G. Romeis, FDEP, pers. comm.). This could represent a "salting out" of DOM. Besides shading, DOM has significance both as a primary nutrient and as a micronutrient and, consequently, may lead to increased biological oxygen demand (BOD). It is important to note that Dixon and Kirkpatrick (1999) found light was further attenuated, from 21% to 44% (annual averages), at the surface of seagrass blades by epiphytic growth, which is also a familiar result of nutrification. Despite all this, grassbeds are currently found in deep water (2.43 m) near the mouth of the Caloosahatchee relative to other areas within Charlotte Harbor and elsewhere (Dixon and Kirkpatrick, 1999; Crean et al., in review), suggesting adequate light penetration.

Not surprisingly, a recent assessment by Janicki Environmental, Inc., (2003b) found water quality has declined in the Caloosahatchee over time. They found statistically significant temporal trends over the last 10 – 15 years with increases in BOD, increases in total suspended solids (TSS) and turbidity, increases in fecal coliform bacteria, increases in many species of nutrients, and decreases in DO levels.

In terms of spatial variation, Doering and Chamberlain (1998) and ERD (2002) both report a strong longitudinal gradient with most constituents decreasing in concentration with increasing distance from the S79 structure. Based on this, both assessments conclude freshwater discharge from S79 plays a crucial role on water quality within the Caloosahatchee. Equally important, because of the steepness in the gradients, both assessments found relatively good water quality downstream in San Carlos Bay, as evidenced by relatively low chlorophyll-a and high DO (Table 1). Likewise, Pine Island Sound and Matlacha Pass also exhibited low chlorophyll-a and high DO (Table 1, Doering and Chamberlain, 1998). This is consistent with FDEP's (2003) finding that these three waterbodies met uses except for bacteria in shellfish (Table 1; note, San Carlos Bay is classified as a Class II waterbody, i.e., for shellfish propagation or harvesting). FDEP's IWR assessment is consistent with the Janicki Environmental, Inc. (2003b) evaluation that found water quality in Pine Island Sound and Matlacha Pass acceptable based on an informal application of the IWR. However, it should be noted that they also found statistically significant increases over time in nutrients, TSS, and BOD. Further, they also reported that some stations in this basin had frequent exceedances of DO and ammonia.

As mentioned above, Doering and Chamberlain (1998) and ERD (2002) both identified freshwater discharge from S79 as playing a crucial role in water quality within the Caloosahatchee. ERD (2003) reports that, depending on the season (i.e., wet or dry), discharge from the S79 structure contributes from 90% to 95% of the mean daily mass of TN and TP to the Caloosahatchee Estuary (up to 11,051 kg of TN per day and 1040 kg TP per day). The next largest contributor to the Caloosahatchee Estuary was the Orange River with 1.1%to 3.8% of the daily mass of TN and TP. Nevertheless, for a complete understanding of water quality drivers within the region, especially localized effects within Matlacha Pass and Pine Island, loadings from Ft. Myers, Cape Coral, Pine Island and Sanibel cannot be ignored.

These findings are consistent with other loading assessments in southwest Florida that find the greatest nutrient loadings come from agricultural runoff and urban runoff (Post, Buckley, Schuh, and Jernigan Inc., 1999; Post, Buckley, Schuh, and Jernigan Inc. and W. Dexter Bender and Associates, Inc., 1999; Drew and Schomer 1984). South Florida's high level of agricultural productivity can be a significant driver in WQ problems as a result of various activities including the substantial usage of soil amendments, including mineral fertilizers and biosolids (fertilizer usage estimated at 1.6 million tons in the year ending June 30, 1996; USEPA 1999), or simply due to soil disturbance and decomposition of organic peat (estimates as high as 2 billion g-N per year to the northern Everglades; Wang et al., 2002). Nitrogen release from disturbance and peat decomposition in the Everglades Agricultural Area has been speculated to be a possible driver of outbreaks of "blackwater" in southwest Florida coastal waters (Zollo, 2002). However, stormwater runoff is not the only means by which agricultural activities may be a driver. Nitrogen can volatilize directly from the surface of fields (dependent on application method) or animal waste lagoons, or can be blown off as particles. Yet, there are other sources, potentially even more significant than agricultural activities. Prospero et al. (1996) estimated that present day deposition on nitrogen (including ammonia) to the North Atlantic Ocean to be five times greater than pre-industrial times, primarily due to fossil fuel combustion and biomass burning. Given this, it is not surprising that atmospheric deposition of nitrogen (potentially from a distant source) could be a driver (external to the study area) contributing to WQ problems in southwest Florida (Squires *et al.* 1998). Atmospheric deposition of nitrogen has been estimated to be responsible for 21% of external nitrogen loading to Tampa Bay. Nonetheless, we cannot lose site of the fact that urban and agricultural runoff remain the greatest source of nonpoint nitrogen loading to Tampa Bay (Pribble *et al.* 2001), and likely to Charlotte Harbor, as well.

Unlike nitrogen, phosphorus has no stable gas phase in the atmosphere and is transported only as particulates, thus limiting its atmospheric residence time.

Based on the information presented above, Janicki Environmental, Inc. (2003a), under contract to FDEP, developed a regression-based model between chlorophyll-a concentration in the Caloosahatchee and TN loads across S79. Use of TN in the model rather than TP was consistent with Doering and Chamberlain (1998) that found that ratio of dissolved inorganic nitrogen to dissolved inorganic phosphorus (i.e., DIN:DIP) to be less than 16, suggesting the system is nitrogen limited. Janicki Environmental, Inc. (2003a), developed regressions for both the dry and wet season and found greater sensitivity to nutrient loading during the former (i.e., greater slope or greater increase in chlorophyll-a per unit increase in TN load). However, it should be noted that the dry season regression had a lower coefficient of determination ($R^2 = 0.4$). Other factors, including ammonia from the sewage treatment plants discharging to the Caloosahatchee (see ERD, 2003), could account some of the unexplained variability in chlorophyll-a. As previously mentioned, FDEP has set numerical nutrient targets for the Caloosahatchee (Degrove, 1981); they have also established water quality based effluent limits (WQBELs) for these facilities (Baker, 1990).

The increased sensitivity to nutrients in the dry season could be related to increased residence time in the Caloosahatchee (P. Doering, pers. communication). Alternatively, Doering and Chamberlain (1998) and Janicki Environmental, Inc. (2003b) both report instances of “wash out” under high flow conditions (i.e., low chlorophyll-a under unusually high loading and, more importantly high flows: >150 m^3/s). A study in the Potomac estuary demonstrated a similar interaction between load and hydrology. USEPA (2001) summarized data attributed to Boynton (1997) showing peak chlorophyll-concentrations in the estuary (also regressed against TN load) occurred under average flow conditions. Blooms did not form in the Potomac estuary during maximum freshwater inflows because of a strong vertical density stratification and, more importantly, because nutrients were advected downstream into the lower Chesapeake Bay. Similarly, it is likely that, during high flow events across S79, impacts from nutrient loads could be further downstream (i.e., coastal nutrification). Residence time and “wash out” will likely have significant implications for alternatives analysis for CERP both as they are influenced by CERP-components, such C43 BSR, whose goal is to provide minimum flows during the dry season (i.e., potential for longer residence time) and from both a redirection of Lake Okeechobee water south and with-in basin storage facilities that should reduce high flow events (and, thus, likely reduce frequency of “wash outs”).

From the discussion above, it is clear that a strong case can be made to consider TN loading at S79 as a means of reducing chlorophyll-a in the Caloosahatchee. However, it should also be clear that water column chlorophyll-a is only one of several water quality concerns, some of which are not assessed by the IWR (e.g., color, DOM, BOD, “wash outs”), and that discharge from S79 is only one of many proximate sources. Although any remedial action to reduce TN at S79 would likely have colateral benefits (both in terms of reducing other constituents and impacts to other resources) and would, in of itself, be an ambitious first step, it should be recognized that it would not be a cure-all.

In this context, red tides are a prefect illustration of the potential significance of other nutrient sources on other resources, as well as the potential significance of “wash outs”. Blooms of *Karenia brevis*, i.e., red tides, have been linked to direct atmospheric deposition of ammonia (Steidinger et al., 1998). Alternatively, Lenes et al. (2001) make a compelling argument that red tide outbreaks may be linked to long-range atmospheric transport of iron (a known growth factor) and bloom stimulation of the nitrogen fixing *Trichodesmium*, which, through the release of nitrogen containing exudates, could fertilize *Karenia brevis*. Hence, this important southwest Florida issue may have external drivers not under local control. Not surprisingly, modelers remain "stymied by the chaos of unknown initial conditions" that stimulate red tides in southwest Florida (Walsh et al. 2002). Red tides have been documented along the west coast of Florida well before the “age of water management” (Geesey and Tester 1993) and will likely continue despite out best efforts. Consequently, occurrence of red tides will not be a performance measure (either evaluation or assessment) for the SWFFS. Nonetheless, it is conceivable that some reduction in red tide magnitude, duration, or frequency is achievable if coastal nutrification were reduced (especially as a result "wash outs").

As a result of productivity level, crop variety, multiple planting seasons, and climate, Florida agriculture requires the usage of a wide variety of pesticides, i.e., insecticides, herbicides, and fungicides. Residues of some of these pesticides (i.e., both organics and metals) have been detected in sediments and surface water at District structures at various times (Pfeuffer and Matson, 2002). As mentioned above, fertilizers are also extensively used in Florida. Several studies have measured metals (e.g., cadmium, lead, nickel and copper; USEPA 1999) in mineral ores and resulting fertilizers. Organic and biosolid fertilizers may also have measurable concentrations of metals. However, agriculture may no longer be the primary source of pesticides to the environment. Contrary to public perception, USGS reports that pesticides occur more frequently in urban streams than in most agricultural streams (USGS, 1999).

As mentioned previously, FDEP has listed two waterbodies (WBID 3240B and 3240A) within this region as potentially impaired for copper and lead. Although the focus of the IWR assessment is on water column concentrations, metal impairment is consistent with a survey of sediments in the Caloosahatchee by Fernandez et al. (1999). They found levels of cadmium, copper, lead, and zinc above "natural background" concentrations. At certain stations, one or more of these metals exceeded either the threshold effects level or, worse, the probable effects level (Fernandez et al., 1999). They further reported that immunoassays were positive for the organochlorine pesticides DDT and cyclodienes (as chlordane), with levels exceeding the probable effects level at several sites (Fernandez et al., 1999). These findings are consistent with results of the District's monitoring of sediment just upstream of S79 that found DDT, DDE and PCB-1245, with levels occasionally exceeding the threshold effects level (for detail, see quarterly reports by Pfeuffer and Matson, 2002). Since 1992, the District's surface water monitoring program at S79 has detected low levels of the herbicides ametryn, atrazine, bromacil, diuron, hexazinone, norflurazon, and simazine at relative high frequency (frequency of detection >20%). The following pesticides and degradates: atrazine desethyl, atrazine desisopropyl endosulfan sulfate, metalaxyl, ethoprop, and metribuzin were detected less frequently. However, based on various criteria, the concentrations of detected pesticides should not pose a significant risk to fish or aquatic invertebrates (Pfeuffer and Matson, 2002 and references therein).

Atmospheric loading is also the dominant proximate source of inorganic mercury to many water bodies, with the ultimate primary drivers being coal-fired utility boilers and municipal and medical waste incinerators (USEPA 1997a). However, the complication lies in the relationship between influx of inorganic mercury and the amount that is methylated post deposition by sulfate-reducing bacteria. The latter process is of fundamental concern because methylmercury (MeHg) is the more toxic and bioaccumulative form that can build up in the food chain to levels harmful to humans and other fish-eating animals. Rarely is the state WQS for mercury, which is based on total mercury rather than MeHg, exceeded in south Florida; however, many south Florida waterbodies are considered impaired by FDEP based on fish consumption advisories for mercury. The principal pathway for mercury exposure to humans is through the consumption of marine fish and fish products. Studies of south Florida estuaries have found elevated levels of mercury (both the inorganic and methyl form) in surface water discharges and, more importantly, in fish (Adams and McMichael, 2003; Rumbold et al. 2003). FDEP lists the entire southwest coastal area as potentially impaired for mercury based on fish consumption advisories (Table 1). Currently, limited consumption advisories have been issued for the following coastal fish based on their mercury content: King Mackerel, Spanish Mackerel, all sharks, spotted seatrout, Little Tunny, Cobia, Greater Amberjack, Bluefish and Crevalle Jack. (Florida Department of Health 2003).

Table 1. Summary of findings of water quality assessments in the Caloosahatchee Estuary, San Carlos Bay, Pine Island Sound and Matlacha Pass.

Waterbody	Doering and Chamberlain, 1998[a]	Janicki Environ. Inc., 2002[b]	FDEP, 2002; 2003[c]	ERD, 2003[d]	Janicki Environ Inc., 2003[e]	Tetra Tech, Inc., 2003[f]
Upper Caloosahatchee (WBID 3240C)	Chl a>11 ug/L TP>state median TN>state median DO<WQS Color rel. high	Chl a>ref. site, IWR TN>ref. site TP>historic, ref. site DO<historic, ref. site, IWR Turbidity>historic	Impaired for: Chl a, DO, coliform	Strong gradient with decreasing conc. of most constituents with increasing dist. from S79; Chl a>11 ug/L DO<WQS	Unaccept. based on informal IWR: Chl a, DO, coliform; trend of declining WQ in BOD, TSS, nutrients, secchi depth	
Middle Caloosahatchee (WBID 3240B)	Chl a>11 ug/L TN > state median	Chl a>ref. site, IWR TN>ref. site TP>ref. site DO<ref. site, IWR Turbidity>ref. site	Impaired for: Chl a, DO, copper, coliform	Spike in downstream gradient in ammonia, TKN, TN and Chl a. Chl a>11 ug/L	Unaccept. based on informal IWR: Chl a, DO, coliform; trend of declining WQ in BOD, TSS, nutrients, secchi depth	
Lower Caloosahatchee (WBID 3240A)	TN>state median	Chl a>ref. site, IWR TN>ref. site TP>historic, ref. site DO<historic, ref. site, IWR Turbidity>historic	Impaired for: Chl a, DO, copper, lead, biology	Mean DO>WQS	Unaccept. based on informal IWR: Chl a, DO, coliform; trend of declining WQ in BOD, TSS, nutrients, secchi depth	
San Carlos Bay (WBID 2065H)	Chl a rel. low TN>state median DO rel. high Turbidity rel. low TSS>state median	not assessed	No listed impairment	Concentration of most constituents substantially reduced Chl a<11 ug/L Mean DO>WQS	Assessed under Matlacha Pass	
Pine Island Sound (WBID 2065E and G)	Chl a rel. low TN>statewide median DO rel. high TSS>state median	not assessed	Impaired for: bacteria (in shellfish)	not assessed	Accept. based on informal IWR; exceedances in ammonia and DO at some stations	

Matlacha Pass (WBID 2065F)	Chl a rel. low TN>state median DO rel. high	not assessed	No listed impairment	not assessed	Accept. based on informal IWR; improving trends in secchi depth and TN	
SW coast	not assessed	not assessed	Mercury	not assessed		

a. Doering and Chamberlain 1998, based on SFWMD data collected from 1985 – 1995.

b. Janicki Report (2002): report to FDEP on current conditions in the Caloosahatchee comparing it to historical data, reference sites and the Impaired Water Rule (Chapter 62-303 F.A.C.); data sources included SFWMD, Lee County, STORET (Legacy and Modern), USGS.

c. FDEP. 2002. Basin Status Report Draft: Caloosahatchee, 12/02; FDEP. 2003. Basin Status Report Draft: Charlotte Harbor. 9/03: potential impairment based on Impaired Water Rule (IWR, Chapter 62-303 F.A.C.) on data from STORET.

d. Environmental Research and Design, Inc. 2003: assessment based on intense data collection during two months of the year (wet and dry season collections) for 2000-2002.

e. Janicki Report (2003b): draft report to the CHNEP on water quality based on status and trends, and IWR assessment of period of record data (all available data). March 2003.

f. Tetra Tech, Inc., (2003): water quality assessment of the SWFFS area based on unofficial assessment using IWR and status and trends of data from period-of-record (all available data)

I: Linkages Between Water Quality and Attributes

This section provides specific examples of critical linkages between water quality stressors and valued ecosystem components. This list should not be considered exhaustive. This section will examine how deviations, from a defined baseline, in the chemical and physical parameters measuring water quality, stress the ecological system by affecting the health and distribution of the indicators that describe the system's attributes. The SWFFS differs from other similar feasibility studies, in particular IRL-South and Florida Bay / Florida Keys, in that cause-and-effect research within the study boundary has been limited and technical-policy documents are few in number. In the absence of local information, WQ data will be assessed for potential linkage based on benchmarks established in surrogate studies.

- ### Phytoplankton and SAV

  i. Phytoplankton and SAV species have a preferred and tolerable range of salinity. When salinity falls outside of these ranges the SAV is negatively impacted and may result in a reduction in densities and distribution (Chamberlain and Doering 1998). Increases or decreases in salinity may give one species a competitive advantage over another (Livingston 1987; Zieman 1982).

- ### Benthic Communities and Fish Populations

  i. Salinity is a "master ecological variable" controlling community structure and food web organization in coastal systems (Myers and Ewel, 1990). Negative impacts to oysters can lead to shellfish closures.

  ii. Alterations in the salinity regime places stress on the sensitive life history stages of many estuarine species (Odum 1970, Chamberlain and Doering 1998b).

- Mangroves

i. Mangrove communities are sensitive to salinity levels. Where freshwater flow has been insignificant over a long period of time, and salinity levels increase above historic levels, mangroves displace cypress and wetland plant communities.

DO

- **Phytoplankton and SAV**

i. As a result of primary production, daylight levels of DO can actually reach supersaturation levels in the presence of phytoplankton blooms or thick stands of macrophytes. However, both phytoplankton and SAV utilize DO and, in the dark, are a net sink for DO, this can result in hypoxic and sometimes anoxic conditions (Mitchell-Tapping et al., 1998)

- **Benthic Communities and Fish Populations**

i. Hypoxia (low dissolved oxygen) can be a significant problem in certain estuaries, especially those receiving excessive nutrient loads, impacting the health of fish and shellfish populations (EPA 2000b).

ii. The response of benthic communities to alterations in sediment and water quality is relatively well understood and is often expressed as changes in community structure, density, and diversity (for review, see Mitchell-Tapping et al., 1998; EPA 1999).

- **Sediment chemistry**

i. Increased nutrient loading, suspended solids and dissolved organic material from the watershed can result in higher BOD, higher sediment oxygen demand (SOD) or both and, consequently, hypoxia or even anoxia, especially when freshwater flows produce a density stratification (CDM, 1998; Turner, 2001; *cf.* Doering and Chamberlain, 1997).

ii. Anoxic conditions can result in altered redox conditions and altered chemistry in the sediment

Total Suspended Solids and Water Clarity (e.g., Turbidity, TSS, Color)

- **Phytoplankton and SAV**

i. Inorganic suspended sediments, organic nonchlorophyll-based detritus, and, of particular importance in south Florida, humic materials (McPherson et al. 1996) may reduce water clarity and shade out SAV. A statistically significant inverse correlation has been reported between the depth of the deep edge of a seagrass bed and color and turbidity in southern Indian River Lagoon; preliminary targets have been established based on WQ observed at these deep seagrass beds (Crean et. al., in review).

ii. Because seagrasses are rooted plants attached to the bottom, reduced light reduces photosynthesis, growth, and reproduction. This condition is cited as a major source of seagrass decline in Florida estuarine systems (Durako 1988).

iii. Under certain circumstances, dissolved organics (e.g., humics, etc.) and attendant water color and clarity have been thought to reduce undesirable algal growth under high nutrient conditions (McPherson et al. 1996).

iv. SAV need suitable substrate for successful recruitment and establishment. Deposits of silt / muck can displace or modify normal substrate in the estuary and contribute to the decrease in extent of SAV beds.

- ### Benthic Communities and Fish Populations

i. Suspended solids may clog gills and interfere with filtering and respiration of oysters (Cake 1983).

ii. Humic materials can influence the chemical speciation, bioavailability and, in some cases, toxicity of certain metals and organics (McCarthy et al. 1994).

- ### Shoreline Habitat functionality

i. Sediment load caused by dredge and fill operations and in runoff from shoreline construction has been identified as a cause of mangrove loss and salt marsh destruction.

Nutrients (macro- and micronutrients)

- ### Phytoplankton and SAV

i. Nuisance algal blooms: Tampa Bay National Estuary Program produced an empirical regression-based WQ model that showed strong relationship between TN load and Chl-*a* (as a measure of phytoplankton abundance; Janicki and Wade 1996). A similar relationship has been established for the C43 Basin / Calooshatchee River (Janicki Environmental, Inc. 2003).

ii. Nutrification can lead to subtle responses such as changes in communities at the species level, altered rates of biogeochemical processes (e.g., nutrient recycling, sediment oxygen demand, etc.), and shifts in seasonal patterns (i.e., spring versus summer primary production) or magnitude of variability (for review, see Cloern, 2001; EPA, 2001).

iii. Resource competition, not just in terms of N or P, but also their specific form (e.g., concentration of ammonium to nitrate) can also result in species shifts. Many organic N molecules are not readily available to phytoplankton, while many organic P molecules are, due to the activity of phosphatase enzymes (Vitousek and Howarth, 1991).

iv. Nutrients can trigger a thick growth of epiphytes which can reduce the amount of light that can reach the surface of the seagrass blade (Murray et al. 1999).

v. Relatively minor changes in nutrient input can lead to sharp reductions in the productivity of seagrasses, which can lead to broad habitat changes (Livingston 1984). Encourages growth of more nutrient tolerant species that cause undesirable effects such as mono specific communities which decrease the value for fisheries and benthic invertebrate species.

vi. Unnaturally low ratios of silicon (Si) to P or Si:N (due to increases in P or N) are thought to favor the selection and possible ascendancy of lightly-silicified diatoms and non-diatoms (Dortch & Whitledge 1992).

- **Sediment Chemistry**

i. Nutrification can lead to altered rates of biogeochemical processes (e.g., nutrient recycling, sediment oxygen demand, redox, etc. CDM, 1998, Turner, 2001; for review, see Cloern 2001), which, in turn, can lead to further changes in water quality (e.g., solubility of metals).

ii. Nutrification can also lead to saturation of soils where substrate becomes a source, and not a sink, for additional nutrients (internal loading).

Toxicants

- **Benthic Communities and Fish Populations**

i. Both acute and chronic effects have been reported for both organic and inorganic toxicants to a wide variety of aquatic species (National Toxics Rule, 57 FR 60848, December 22, 1992; USEPA 2002 and references therein, Wiener et al. 2002).

ii. Many of these substances are either insoluble in water or tend to associate with particulate matter that flocculates (i.e., “salting-out") often resulting in concentrations much higher in the estuarine sediments than that observed within the overlying water column.

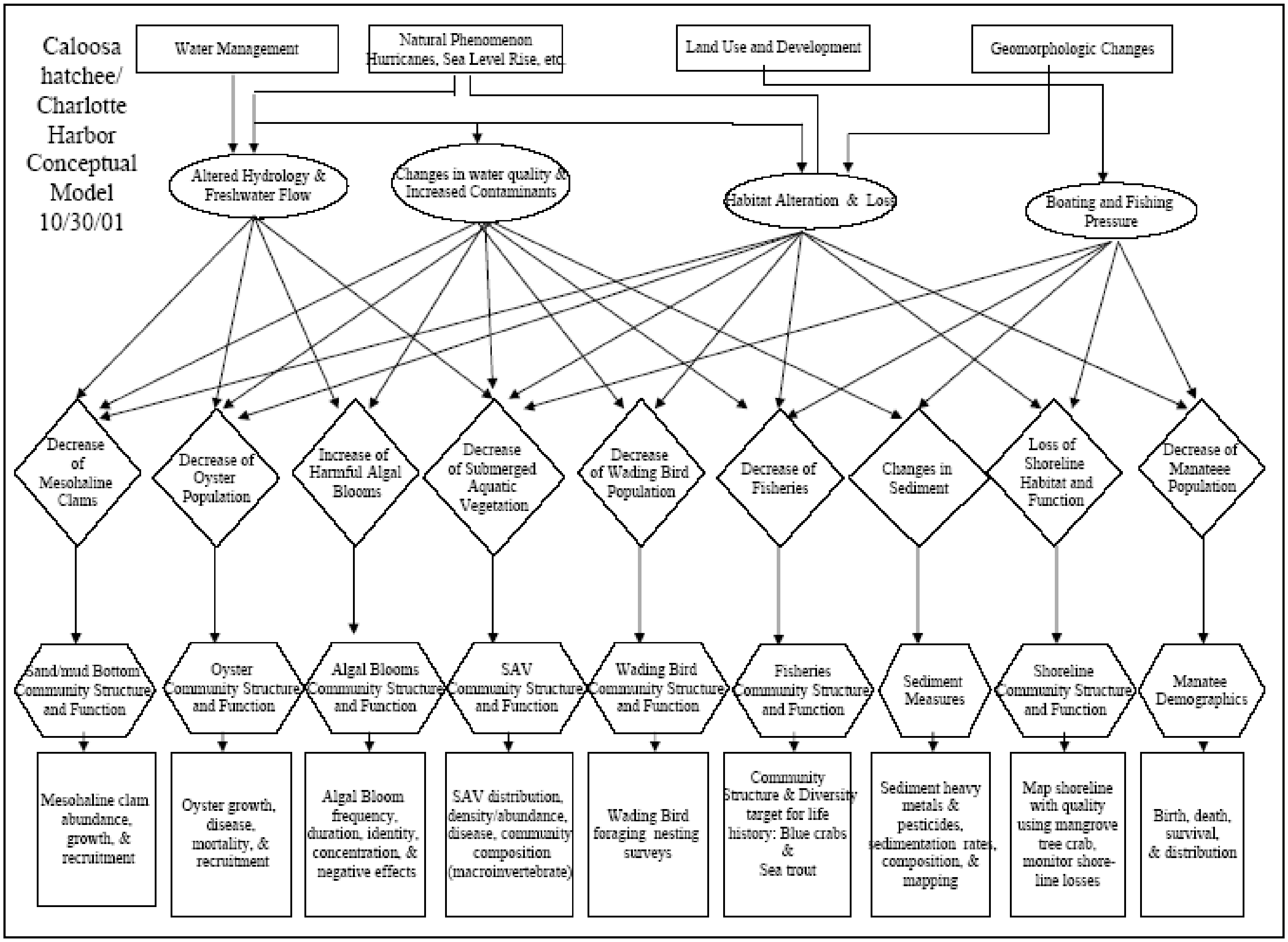
- **Upper trophic level predators, including listed species**

i. Persistent bioaccumulative toxicants (PBTs) can pose a risk to upper trophic level predators (USEPA, 1997b, Rumbold, 2000)

- **Human health**

i. Persistent bioaccumulative toxicants (PBTs) can pose a risk to humans (EPA, 2002 and references therein)

J: Model



Caloosa hatchee/ Charlotte Harbor Conceptual Model 10/30/01
Water Management
Natural Phenomenon Hurricanes, Sea Level Rise, etc.
Land Use and Development
Geomorphologic Changes
Altered Hydrology & Freshwater Flow
Changes in water quality & Increased Contaminants
Habitat Alteration & Loss
Boating and Fishing Pressure
Decrease of Mesohaline Clams
Decrease of Oyster Population
Increase of Harmful Algal Blooms
Decrease of Submerged Aquatic Vegetation
Decrease of Wading Bird Population
Decrease of Fisheries
Changes in Sediment
Loss of Shoreline Habitat and Function
Decrease of Manateee Population
Sand/mud Bottom Community Structure and Function
Oyster Community Structure and Function
Algal Blooms Community Structure and Function
SAV Community Structure and Function
Wading Bird Community Structure and Function
Fisheries Community Structure and Function
Sediment Measures
Shoreline Community Structure and Function
Manatee Demographics
Mesohaline clam abundance, growth, & recruitment
Oyster growth, disease, mortality, & recruitment
Algal Bloom frequency, duration, identity, concentration, & negative effects
SAV distribution, density/abundance, disease, community composition (macroinvertebrate)
Wading Bird foraging nesting surveys
Community Structure & Diversity target for life history: Blue crabs & Sea trout
Sediment heavy metals & pesticides, sedimentation rates, composition, & mapping
Map shoreline with quality using mangrove tree crab, monitor shore-line losses
Birth, death, survival, & distribution

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Addendum

SUMMARY FORM (3 PAGES)

SOUTHWEST FLORIDA FEASIBILITY STUDY – CALOOSAHATCHEE ESTUARY

HYDROLOGIC EVALUATION PERFORMANCE MEASURES

Name of Performance Measures Document : S-79, Shell Point, and San Carlos Bay Freshwater Inflow

Status (date this 3 page summary created/revised): 12 May 2005

For: 5/12/05 DRAFT of full Performance Measures Document (attached). Previous Draft 4/20/05

Category: Hydrologic – (Water Levels, **Flow Volumes**)

Justification: The Caloosahatchee River is the major source of freshwater for the Caloosahatchee Estuary and southern Charlotte Harbor aquatic environment. The river bisects its watershed and now functions as a primary canal (C-43) that conveys both runoff from the Caloosahatchee watershed and regulatory releases from Lake Okeechobee. The C-43 has undergone numerous physical changes to facilitate increased freshwater discharge for flood protection and meet water supply demands. Together, these physical changes and alterations of the natural freshwater inflow to the Caloosahatchee Estuary have caused unnatural large scale fluctuations in the salinity and water quality within the area above Shell Point, as well as reduction in environmental stability for the San Carlos Bay area. The area's biotic richness and significant economic value are threatened by long-term shifts in water quantity and quality.

Description of Performance Measure: Reduce the high variability in freshwater inflow to the Caloosahatchee Estuary, thereby restoring the full range of salinity along its longitudinal axis required to support naturally occurring conditions for estuarine biota. This can be accomplished by: (1) reduction of wet season high flow from the watershed, capturing and storing this water, and then releasing it during the dry season in a more environmentally sensitive and beneficial manner to estuarine resources; and (2) reducing discharges from Lake Okeechobee to the Caloosahatchee Estuary.

SWFFS/CERP Targets & Current Condition:
Ecological Performance targets

1. (a) Maintain a 30-day moving average salinity $\leq$ 10 ppt during the dry season at the Ft. Myers continuous salinity sensor (near the surface at the Ft. Myers Yacht Basin), such that *Vallisneria americana* (tape grass) in the Beautiful Island area does not decrease below 20% coverage and blade length is $\geq$ 10 cm (values are provisional and may be adjusted after current

research (MML 2004 and 2007 reports) are evaluated); (b) Daily average salinity shall not exceed 20 ppt at Ft. Myers more than once every two years, and neither shall the 30-day moving average salinity of 10 ppt (MFL Rule: SFWMD 2000); (c) Limit the occurrence of average monthly salinity <15 ppt at the Cape Coral Bridge sensor, so salinity ≥ 20 ppt is promoted in Iona Cove, which is supportive of minimum seagrass density (coverage ≥ 30% at 1 meter water depth and average blade length ≥ 10 cm - values are provisional and may be adjusted upon further research); and (d) Maintain daily salinity at Piney Point > 5 ppt, so that minimum conditions are provided for the recruitment, survival, and growth of juvenile oysters upstream of Shell Point during March – October (juvenile oyster growth ≥ 2.5 mm a month; recruitment ≥ 3 spats per substrate shell a month; and mortality < 20% per month - values are based on information interpreted from Volety et al. 2003).

2) Maintain an average monthly salinity ≥ 25 ppt, as measured at the Sanibel Causeway Bridge near surface continuous sensor, so that historical seagrass density and coverage in the San Carlos Bay area (as determined from previous surveys, hydroacoustic monitoring, and aerial photography) is protected and restored to a previous condition (at least circa Harris et al. 1983) that includes reestablishment of continuous coverage at deeper depths in the San Carlos Bay area between Shell Point and the Sanibel Causeway.

Hydrologic performance targets to achieve the Ecological targets

1a). For each alternative, compare the number of times that mean monthly inflows from the Caloosahatchee watershed fall below a low-flow limit of **450** cfs, measured at S-79, during October to July . The alternative with the fewest number of times that monthly average flows fall below **450** cfs will be considered better for protecting aquatic vegetation, oysters, and fish communities.

1b). For each alternative, compare the frequency that the mean monthly low-flow limit of **450** cfs through S-79 from the watershed was not met for just one month (not followed by another month below this low-flow limit), as well as the frequency for 2, 3, 4… etc. consecutive months. The water management alternative with the fewest number of consecutive months below **450** cfs will be considered better for protecting estuarine aquatic resources.

1c). For each alternative, compare the frequency that the mean monthly low-flow limit of **450** cfs through S-79 from the watershed was not met for just one year (not followed by another year with months below **450** cfs), as well as the frequency for 2, 3, 4…etc. consecutive years. The water management alternative with the fewest number of years and consecutive years with average monthly flow occurrences below **450** cfs will be considered better for protecting estuarine aquatic resources

1d). Couple the hydrodynamic model with the *Vallisneria* model to estimate plant coverage and other metrics within the limits of the model. The alternative that provides the best *Vallisneria* model results for the region upstream of U.S. 41 Bridges in Ft. Myers will be considered more desirable.

2a). For each management alternative, compare the number of times that mean monthly inflow from the watershed exceeds 2,800 cfs at S-79. The alternative with the fewest number of times that this criterion is exceeded at any time of year will be considered better for protecting both SAV and juvenile oysters at Shell Point and upstream. Additionally, a better ranking will be given to the alternative with the least number of discharges above these limits during March through October, in order to limit critically low salinity conditions from occurring both upstream and downstream of Shell Point, which threatens estuarine resources, including SAV and juvenile oyster recruitment and survival

2b). For each alternative, compare the frequency that the mean monthly inflow from the watershed, measured at S-79, exceeds 2,800 cfs for just one month (not followed by another month above this limit), as well as the frequency for 2, 3, 4… etc. consecutive months. The alternative with the fewest consecutive months that violate this criterion throughout the year will be considered better for protecting estuarine resources, including juvenile oyster recruitment and survival. Additionally, a better ranking will be given to the alternative with the least number of discharges above these limits during March through October, in order to limit critically low salinity conditions from occurring both upstream and downstream of Shell Point, which threatens estuarine resources, including SAV and juvenile oyster recruitment and survival

3a). For each alternative, compare the number of times that mean monthly and mean weekly inflows from the watershed exceed 4,500 cfs at S-79 (weekly is important for protecting oyster recruitment and survival). The alternative with the least number of times flows exceed these limits will be considered better for protecting the estuarine resources, including those downstream in the San Carlos Bay region. Additionally, a better ranking will be given to the alternative with the least number of discharges above these limits during March through October, in order to limit critically low salinity conditions from occurring both upstream and downstream of Shell Point, which threatens estuarine resources, including SAV and juvenile oyster recruitment and survival.

3b). For each alternative, compare the frequency that mean monthly and mean weekly inflows from the watershed, measured at S-79, exceeds 4,500 cfs for just one month and 1 week (not followed by another month or week above this limit), as well as the frequency for 2, 3, 4…etc. consecutive months and weeks. The alternative with the fewest number of consecutive months and weeks that violate this criterion will be considered better for protecting aquatic resources, including juvenile oysters. Additionally, a better ranking will be given to the alternative with the least number of consecutive discharge periods above these limits during March through October, in order to limit critically low salinity conditions from occurring both upstream and downstream of Shell Point, which threatens estuarine resources, including SAV and juvenile oyster recruitment and survival.

4). For each alternative, compare the frequency distribution of monthly average freshwater inflows through S-79 for the entire period of record being evaluated. The alternative with the frequency distribution of inflows that best approaches the range (EST05) defined in the main Performance Measures Document will be considered better for protecting estuarine resources, while further promoting biotic diversity. Specifically, the alternative that maximizes up to 75% of flows from S-79 in the **450 to 800** cfs and almost all the remaining flows in the 800-2800 cfs range will be considered the most desirable.

The preferred flow distribution (EST05) may change as more information is provided regarding: predevelopment flow and salinity conditions; natural variation; what salinity conditions were naturally (historically) associated with droughts and flood events; and what flows are needed to protect and restore the biotic features in the current and future developed system.

Rationale: The Caloosahatchee River is the major source of freshwater for the Caloosahatchee Estuary and southern Charlotte Harbor aquatic environment. The Caloosahatchee Estuary and downstream region supports a wide diversity of estuarine organism of environmental and commercial value. Alteration to the natural freshwater inflow to the estuary have caused unnatural large scale fluctuations in the salinity and water quality within the area above Shell Point, as well as reduction in environmental stability for the San Carlos Bay area. The resulting impacts to seagrass, oysters, benthic invertebrates, and fishes can be dramatic and long lasting. It is the goal of the Southwest Florida Feasibility Study (SWFFS) and relevant CERP efforts to reduce the high variability in freshwater inflow to the Caloosahatchee Estuary, so to restore a full range of salinity along its longitudinal axis that is supportive of naturally occurring estuarine biota. This goal can be accomplished by reducing high flows during the wet season, capturing and storing this water, then releasing it in a more environmentally sensitive manner that is beneficial to estuarine resources during the dry season.

Modeling Evaluation Protocol: Regional and subregional models will be used to simulate historical (base) and predicted flows to the estuary with and without SWFFS and CERP project features for each alternative considered. Natural system flows to the Caloosahatchee Estuary from its watershed and tidal basins may also be considered in order to compare flows associated with the developed basins. Output (flows) from the above model runs will be used to evaluate the level that hydrologic targets are achieved for each alternative and base condition.

Model output will be used as input for the estuarine salinity model to further assess changes in salinity. To help evaluate if ecological goals will be met, the estimated salinity will be used to assess the impact on key biota by employing habitat suitability indices related to salinity.

Monitoring Assessment Protocol:

1). Define and assess appropriate attributes (specific species and/or community values) to ascertain if this project's ecological goals are attained and there is a discernable positive impact on the estuary, specifically including SAV, oyster, and fish as follows:

a). Routinely (at seasonally important intervals) monitor SAV coverage, density, and canopy height to at

least 1.5-2.0 m depth at key species locations.

b). Routinely monitor (at seasonally important intervals) oyster survival and recruitment at key locations. c). Routinely monitor (seasonally) water quality, including temperature, D.O., salinity, nutrients,

chlorophyll, suspended solids, and water clarity along the longitudinal axis of the estuary (S-79 -

Sanibel Causeway and into lower Pine Island Sound and Matlacha Pass).

d). Monitor routinely (at appropriate seasonal intervals) species and biotic groups of concern as separately

defined in performance measure documents and the CE conceptual model. At a minimum, insure the

Monitoring Assessment Plan (MAP) effort within RECOVER is being fulfilled.

2). Scientifically assess and publicly agree what constitutes desirable natural variability (predevelopment

conditions) related to salinity and causal freshwater inflow from S-79 and the tidal basin.

3). Install and monitor flow gages in downstream tidal tributaries to begin assembling a long term data set to: verify model predictions of flows; determine actual amount and timing of tidal tributary flows related to MFL requirements for achieving the salinity criteria; and to help assess flow impacts on biota being monitored for CERP (RECOVER).

4). Monitoring S-79 discharge adherence to the selected alternative flow distribution.

5). Continue to maintain and monitor existing 7 salinity recorders and other permanent sensors in the Caloosahatchee Estuary. Install new sensors to monitor salinity and other water quality parameters of concern at key locations for VEC. Suggest additional sensors be located in western San Carlos Bay, lower Pine Island Sound, and Matlacha Pass.

6). Assess limits of SAV morphology for providing suitable habitat as a VEC and its relationship to flow, salinity, and water quality conditions.

7). Finish development of the: tape grass model; Caloosahatchee Hydrodynamic/Salinity Model; a water quality model component; habitat suitability models; and a seagrass model for the lower estuary.

Comments: