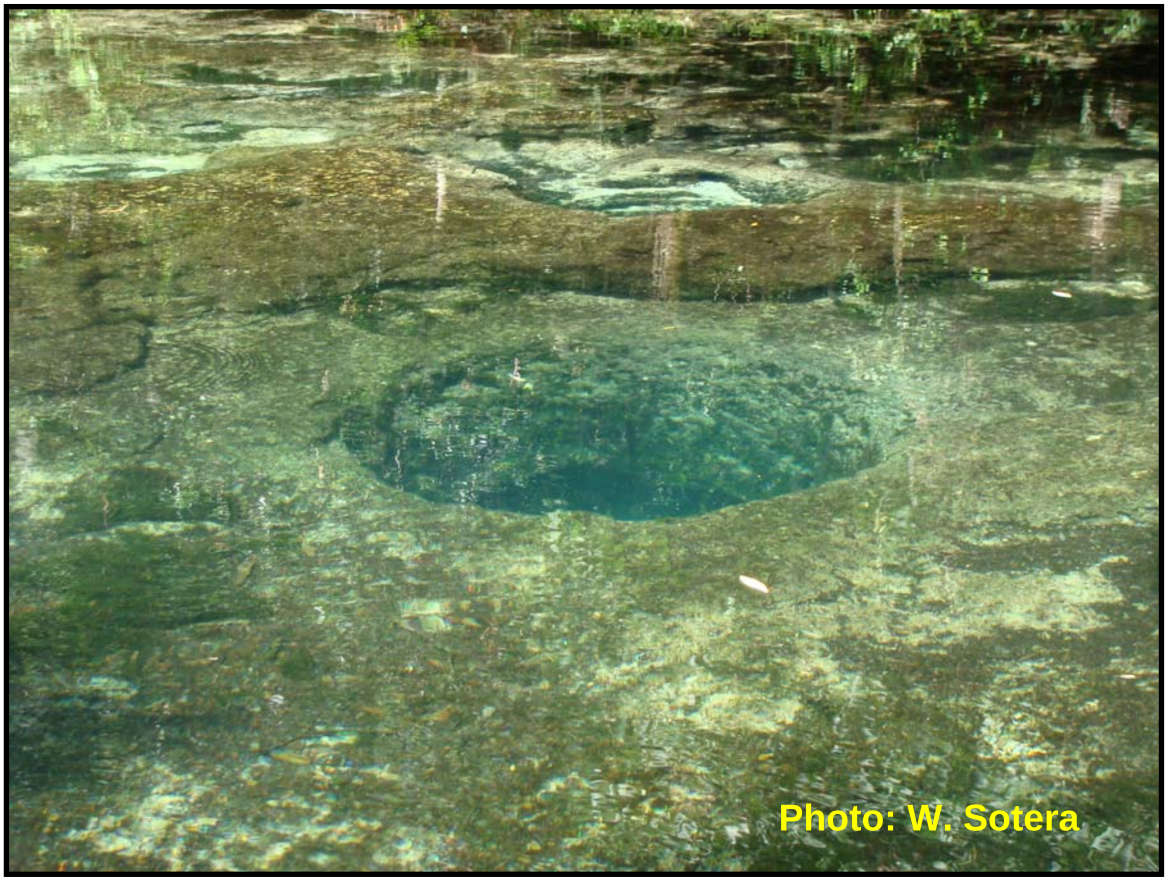
Recommended Minimum Flows For the Chassahowitzka River System



October 30, 2012

Southwest Florida Water Management District

Michael G. Heyl, Doug Leeper, Ron Basso
Southwest Florida Water Management District
Brooksville, Florida 34604-6899
and
Marty Kelly
(Formerly with Southwest Florida Water Management District)
With contributions by
Balanced Environmental Management Systems, Inc.

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Prime Contractor

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Acknowledgements

We would like to thank several of our colleagues at the Southwest Florida Water Management District for their contributions and useful suggestions concerning the work summarized in this report We are also indebted to District staff who conducted field sampling for the project (Don Hampton, Courtney James, Tammy Hinkle, Jason Hood and Richard Gant) and to Barbara Matrone for her assistance in document production. Sid Flannery provided historical datasets and valuable knowledge about prior District projects related to the Chassahowitzka River.

Finally, we would like to thank the many District contractors that contributed to this report. Dynamic Solutions LLC contributed the hydrodynamic modeling utilizing bathymetry data provided by Dr. Ping Wang of the University of South Florida (USF). Ernst Peebles with his staff and students at USF, and Tim MacDonald and his colleagues at Florida Fish and Wildlife Conservation Commission collected and analyzed the fish and invertebrate data. Ernie Estevez of Mote Marine Lab conducted the mollusk surveys and Ernie and Jay Leverone collected benthic samples for enumeration and analysis in addition to enumerating the macrophyte community. Additional analysis of the benthic results was completed by the staff at Janicki Environmental, Inc.

Using results from the individuals and organizations identified above, the staff of Balanced Environmental Management Systems (BEM), Inc., including Ken Duffy, Jay Burrell and Kevin Zhu completed the bulk of the initial analyses and much of the writing for this report. The cost of non-District support for the project was approximately $674,700, which was provided by the Coastal Rivers Basin Board and the District Governing Board.

Conversion Table		
Metric to U.S. Customary		
Multiply	By	To Obtain
cubic meters per second (m^3/s)	35.31	cubic feet per second (cfs)
cubic meters per second (m^3/s)	23	million gallons per day (mgd)
millimeters (mm)	0.03937	inches (in)
centimeter (cm)	0.3937	inches (in)
meters (m)	3.281	feet (feet)
kilometers (km)	0.6214	statute miles (mi)
square meters (m^2)	10.76	square feet ($feet^2$)
square kilometers (km^2)	0.3861	square miles (square miles)
hectares (ha)	2.471	acres
liters (l)	0.2642	gallons
cubic meters (m^3)	35.315	cubic feet ($feet^3$)
cubic meters (m^3)	0.0008110	acre-feet
milligrams (mg)	0.00003527	ounces
grams (g)	0.03527	ounces
kilograms (kg)	2.205	pounds
Celsius degrees (^oC)	1.8*(^oC) + 32	Fahrenheit (^oF)
U.S. Customary to Metric		
Multiply	By	To Obtain
inches (in)	25.40	millimeters (mm)
inches (in)	2.54	centimeters (cm)
feet (feet)	0.3048	meters (m)
statute miles (mi)	1.609	kilometers (km)
square feet ($feet^2$)	0.0929	square meters (m^2)
square miles (square miles)	2.590	square kilometers (km^2)
acres	0.4047	hectares (ha)
gallons (gal)	3.785	liters (l)
cubic feet ($feet^3$)	0.02831	cubic meters (m^3)
acre-feet	1233.0	cubic meters (m^3)
Fahrenheit (^oF)	0.5556*(^oF-32)	Celsius degrees (^oC)
U.S. Customary to U.S. Customary		
Multiply	By	To Obtain
acre	43560	square feet ($feet^2$)
square miles (square miles)	640	acres
cubic feet per second (cfs)	0.646	million gallons per day (mgd)

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Executive Summary

The headwaters for the Chassahowitzka River are formed by the Chassahowitzka Springs Group. More than a dozen springs discharge groundwater into the Chassahowitzka River from the Upper Floridan aquifer. For the purpose of minimum flows development and implementation, the Chassahowitzka River and associated springs are collectively considered the Chassahowitzka River system. The river receives a small amount of surface runoff from its 89 square miles watershed, but the majority of flow arises from the 190 square mile springshed that produces a discharge that varies little with season. The river flows 5.6 miles (9.0 km) from the headspring to the Gulf of Mexico at Chassahowitzka Bay. It is designated an “Outstanding Florida Water” and the lower half of the river is part of the more than 31,000-acre Chassahowitzka National Wildlife Refuge.

Salinity in the Chassahowitzka River system can vary from fresh to brackish at the headwater and increases substantially as water moves through the marsh and into the estuary, mixing with more saline Gulf of Mexico. The river transitions from salt marsh at the river’s mouth to freshwater-forested wetland approximately 3.1 miles (5.0 km) upstream from the river mouth.

Spring discharge is the primary freshwater source into the Chassahowitzka River system. However, continuous records are only available for the Chassahowitzka headsprings. Flow from the springs is monitored by the United States Geological Survey (USGS). A continuous discharge record begins in 1997 and stage begins in 1999. Spring discharge was estimated for periods preceding the initiation of USGS discharge measurement based on a regression equation developed for river flows and water levels in the Upper Floridan Aquifer. The median flow (uncorrected for withdrawal impacts) of the Chassahowitzka River at the current gage site based on estimated and measured flows for the reference period (January 1967 through November 2007) was 63 cubic feet per second (cfs).

There are currently no surface water withdrawals from the Chassahowitzka River permitted by the Southwest Florida Water Management District (District). However, groundwater withdrawals within the springshed may reduce discharge from the springs that contribute to the river’s flow. A regional surface water/groundwater integrated estimated that water use in the springshed for 2005 resulted in a one percent (0.7 cfs) reduction in flows. The reported results have been derived using a flow record corrected for the existing withdrawal impacts.

The Southwest Florida Water Management District by virtue of its responsibility to permit the consumptive use of water and a legislative mandate to protect water resources from “significant harm”, has been directed by statute to establish minimum flows and levels (MFL) for streams and rivers within its boundaries. As currently defined by statute, **“***the minimum flow for a given watercourse shall be the limit at which further withdrawals would be significantly harmful to the water resources or ecology of the area”.* Minimum flows and levels are established and used by the District for water resource planning, as one of the criteria used for evaluating water use permit applications, and for the design, construction, and operation of surface water management systems.

A variety of ecological resources of concern were identified for the Chassahowitzka River system and evaluated for response to reduced flows using both numeric models

and empirical regressions. Resources of concern included submersed aquatic vegetation, benthic macroinvertebrates, molluscs, planktonic and nektonic fish and invertebrates, salinity-based habitat, and thermal refuge habitat for manatees during critically cold periods. Break points in ecological response were not observed. A fifteen percent loss of resource or habitat relative to natural conditions (free of withdrawal impacts) was chosen to represent significant harm.

The minimum flow recommendation is based on the habitat, or biological resource most sensitive to reduced flow. A broad spectrum of habitat and biological responses were evaluated for the Chassahowitzka River system. Thirteen were retained and incorporated into the final analyses supporting development of the minimum flow recommendation for the Chassahowitzka River system. The two most restrictive components evaluated were the acute thermal refuge (area and volume measured from the river kilometer zero to the main spring), followed by five parts per thousand (ppt) salinity habitat. A 9 percent reduction in flow results in a 15 percent loss of thermal refuge (both area and volume) potentially used by the West Indian manatee and a 13 percent reduction in flow results in loss of 15 percent of the volume less than 5 ppt. It is recommended that the minimum flow for the Chassahowitzka River system (including all contributing springs, associated creeks, and Blind Springs) be adopted as retaining 91 percent of the natural flow. Natural flow is defined as the flow that would exist in the absence of water withdrawals that impact the system.

Compliance with the minimum flows that are adopted for the river system will be based on gaged flow measurements, application of numerical or statistical models and consideration of other appropriate information, including well water levels, reported and estimated water use, landscape alterations and rainfall. Based on the estimated withdrawal impacts on spring discharge to the river system, development of a preventative or recovery strategy in association with adoption of the revised, recommended minimum flows is not necessary. A three-component minimum flows and levels prevention strategy will be implemented to ensure that minimum flows established for the Chassahowitzka River system will not be violated as a result of water withdrawals. The strategy includes ongoing monitoring of flows and water levels; assessment of potential impacts associated with water supply development through the regional water supply planning process and other planning and assessment activities, and implementation of a protective water-use permitting program.

Because climate change, structural alterations and other changes in the watershed and groundwater basin of the Chassahowitzka River system could potentially affect surface water or groundwater flow characteristics, and because additional information relevant to minimum flows development may become available, the District is committed to periodic reevaluation and if necessary, revision of minimum flows for this priority water body. Staff recommends that minimum flows established for the river system be reevaluated 10 years after they are adopted into rule. Finally, based on insight that may be gained from additional stakeholder and Governing Board review, staff notes that the revised, recommended minimum flows presented in this report may be modified prior to adoption of associated rule amendments into Rule 40D-8.041, F.A.C.

Prologue

In accordance with Subsection 373.042(2), Florida Statute, each year the District staff submit a proposed list of priority water bodies to the public at large. Following public input, the list is finalized and submitted to the Governing Board for approval. Upon approval by the Governing Board, the list is submitted to Florida Department of Environmental Protection for acceptance. The 1996 priority list included completion of minimum flows and levels in 2011 for both the Chassahowitzka and the Homosassa River systems. Data was collected during the 2004 – 2009 timeframe and reports were developed during the 2009 – 2010 period. During this period, multiple meetings were held to keep the public abreast of the activities. Table ES1 catalogues those meetings.

Table ES 1. Public meetings prior to completion of proposed MFLs.

Date	District / Other	Group	Purpose	Location
2007-06	Other	Crystal River Rotary Club	MFLs update	
2007-09	Other	Crystal River Management Group	MFLs update	Crystal River
2008-03	Other	Citrus County Task Force	Various agency responsibilities, including MFLs	Lecanto
2008-03	Other	Crystal River Waterfront Board	MFLs update	Crystal River
2008-05	Other	Citrus County Task Force	MFLs update	Lecanto
2008-05	Other	Kings Bay Association	MFLs update	
2008-01	Other	Save the Homosassa River Alliance	Homosassa MFLs update	Homosassa
2008-05	Other	Citrus County Task Force	MFLs methods and schedule update	Lecanto
2010-03	Other	Save the Homosassa River Alliance	Homosass MFLs update	Homosassa
2010-04	District	Governing Board	Chassahowitzka MFLs prior to peer-review	Brooksville
			Public Outreach - Springs Coast MFLs.xlsx	

The initial draft of the Chassahowitzka proposed MFL report was submitted to the Peer Review Panel and the Governing Board in April 2010. The Florida Department of Environmental Protection, Florida Fish and Wildlife Conservation Commission and the US Fish and Wildlife Service were furnished copies and the report was released to the public via the District's Minimum Flows and Levels (MFL) web site at the same time. In July 2010, the proposed Homosassa MFL report was provided to the Governing Board and released to the public. Table ES 2 provides the timeline of events and public interactions subsequent to the April 2010 submittal.

Both reports generated significant public input, resulting in four stakeholder workshops held during June – October 2011. The meetings were attended by 211 stakeholders, professionals, concerned citizens and staff, and 13 hours were allocated for presentation and discussions by public and professionals alike. Agendas, presentation and meeting notes were posted following each meeting on a District web site[1] created to exchange information. Staff exchanged over a thousand emails with the public. The purpose of the workshops was primarily to solicit technical input. The advertised purpose and goals included:

- Discuss existing data and methods that have been used, or will be used, to establish minimum flows for the Chassahowitzka, Crystal, Homosassa, and Weeki Wachee River systems.

[1] http://www.swfwmd.state.fl.us/projects/mfl/springs-coast-mfl.php

- Discuss and identify additional data and/or methods that could be used to evaluate or reevaluate minimum flows for the systems.
- Support decisions regarding timelines for adoption or reevaluation of minimum flows for the systems.

The public expressed a consensus that environmental changes (namely tree die-off and upstream barnacle encroachment) should not be exacerbated by additional freshwater withdrawals. These changes are largely due to sea level rise and climate changes. Agency and public inquiries specific to the proposed Chassahowitzka River MFL as presented in the April 2010 and November 2011 draft reports, and the District's responses are included as Appendix Section 11.18 of this report.

Table ES 2. Public meetings subsequent to completion of proposed MFLs.

Date	District/Other	Group	Purpose	Location
2010-07	District	Governing Board	Homosassa MFLs prior to peer-review	Brooksville
2010-08	Other	Chassahowitzka/Crystal River National Wildlife Refuege	Homosassa & Chassahowitzka MFLs methods	Crystal River
2010-08	District	Governing Board	Chassahowitzk MFLs peer-review and staff response	Brooksville
2010-08	Other	Citrus County Task Force	MFLs schedule update	Lecanto
2010-09	Other	Florida Department of Environemntal Protection - Intera	MFLs update	Fanning Springs
2010-10	District	Rule Development Public Workshop	Homosassa MFLs	Homosassa
2010-10	District	Rule Development Public Workshop	Chassahowitzka MFLs	Brooksville
2010-11	District	Governing Board	Homosassa MFLs peer-review report and staff response	Brooksville
2010-12	Other	Citrus County Utilities Infrastructure Advisory Group	MFLs update (Chassahowitzka, Homosassa, Withlacoochee)	Lecanto
2010-12	Other	Meeting with M. Newberger, B. Whitley & P. Hubbell	Chassahowitzka MFLs	Brooksville
2010-12	District	Rule Development Public Workshop	Chassahowitzka MFLs	Lecanto
2010-12	Other	Hernando County Groundwater Guardians	Chassahowitzka MFLs	Brooksville
2011-01	Other	Chassahowitzka/Crystal River National Wildlife Refuege	Chassahowitzka, Crystal & Homosassa MFLs methods update	Brooksville
2011-01	District	Rule Development Public Workshop	Homosassa MFLs	Lecanto
2011-04	Other	Citrus County Board of County Commissioners	MFLs update	Inverness
2011-06	District	Springs Coast MFLs Workshop	MFLs methods and data	Lecanto
2011-07	District	Springs Coast MFLs Workshop	MFLs methods and data	Lecanto
2011-09	District	Springs Coast MFLs Workshop	MFLs methods and data	Lecanto
2011-10	Other	Stakeholder Representatives Springs Coast MFLs Worksh	MFLs methods and data	Lecanto
2011-10	Other	Hernando County 2012 Water Awareness Series	MFLs update	Brooksville

Several specific technical suggestions were presented. The first suggestion was to update the data on Manatee usage. The District complied with the suggestion, but it should be noted that the District's approach to evaluating thermal refuge is base on available thermal habitat and is independent of the number of manatees using the Chassahowitzka as a thermal refuge.

The presence of the endangered whooping cranes overwintering in the Chassahowitzka National Wildlife Refuge resulted in several inquiries about the District's evaluation of the blue crab, the whooping cranes primarily food source. The District reported on the response of blue crab nekton and juveniles to flow in the Chassahowitzka in earlier drafts. Subsequent to the last published draft MFL report, he Florida Fish and Wildlife Conservation Commission completed a more extensive review (funded by the District) of blue crab response to flow in Florida. The results have been incorporated into the present draft.

One suggestion presented was inclusion of primary productivity in the spring's systems as an MFL metric. The District evaluated published springs coast results (WSI, 2011) and determined that a minimum flow based on the response curve would be less protective than the minimum flow ultimately developed, and would allow a 21% reduction in natural flow.

Several reviewers inquired about the impact of sea level changes. The District evaluated the potential impact of sea level changes using a hydrodynamic model. A discussion about sea level change has been added (Section 3.1.3) and results are provided in Section 8.3.

A major change to the analyses implemented by the District in support of the revision of MFLs recommendations for the Chassahowitzka River system involved correcting the flow record for the current 0.7 cfs reduction associated with present withdrawals[2]. All flow-reduction analyses were repeated and the individual habitat and resource MFL metrics were recomputed to support development of a revised MFLs recommendation. The present report has been updated to reflect this reevaluation. In addition, Section 1.4.3 has been added to more clearly define the terms used to describe flow.

[2] Median impacted flow 1967-2007 is 62.5 while the median of the corrected flow record is 63.2. Thus, expressed to nearest cfs, the value is unchanged.

CHAPTER 1. PURPOSE & BACKGROUND OF MFL

1.1 Overview and Legislative Direction

Section 373.042 (1), Florida Statutes (F.S.) directs water management districts and the Florida Department of Environmental Protection (FDEP) to establish minimum flows and levels (MFL) for specific water bodies.. As defined by Section 373.042(1), F.S., **"***the minimum flow for a given watercourse shall be the limit at which further withdrawals would be significantly harmful to the water resources or ecology of the area. . . . The minimum flow and minimum water level shall be calculated by the department and the governing board using the best information available."* Hence, while there is no statutory requirement for the Southwest Florida Water Management District (District) to acquire new information prior to development of a minimum flow or level (MFL), traditionally the District has undertaken broad-reaching studies prior to establishing an MFL. The District's rules (Chapter 40D-8.011(5) expands on this requirement and states:

> "(*5) the MinimumFlows and Level establish in this Chapter 40D-8, F.A.C., are based on the best available information at the time the Flow or Level was established. The best available information in any particular case will vary in type, scope, duration, quantity and quality and may be less than optimally desired. In addition, in many instances the establishment of a Minimum Flow or Level requires development of methodologies that previously did not exist and so are applied for the first timein establishing the Minimum Flow or Level. The District has many ongoing environmental monitoring and data collection and analyses programs, and will develop additional programs over time."*

The development of minimum flows and levels provides vital support for resource protection and recovery efforts, as well as regulatory compliance, by establishing standards below which significant harm will occur in specific water bodies. Section 373.0421, F.S., requires development of a recovery or prevention strategy for water bodies if the " existing flow or level in a water body is below, or is projected to fall within 20 years below, the applicable minimum flow or level." Section 373.0421 (2), F.S., requires that recovery or prevention strategies be developed to: "(a) achieve recovery to the established minimum flow or level as soon as practicable; or (b) prevent the existing flow or level from falling below the established minimum flow or level." Periodic reevaluation and as necessary, revision of established minimum flows and levels are also required by Section 373.0421(3), F.S.

Section 373.0421, F.S. requires the District to consider "...changes and structural alterations to watersheds, surface waters and aquifers and the effects such changes or alterations have had, and the constraints such changes or alterations have placed, on the hydrology of the affected watershed, surface water, or aquifer...". Changes, alterations, and constraints associated with water withdrawals are not to be considered when developing minimum flows and levels. However, according to the State Water Resource Implementation Rule (Chapter 62-40.473, F.A.C.), "…consideration shall be given to the protection of water resources, natural seasonal fluctuations in water flows or levels, and environmental values associated with coastal, estuarine, aquatic and wetlands ecology, including:

1) Recreation in and on the water;
2) Fish and wildlife habitats and the passage of fish;
3) Estuarine resources;
4) Transfer of detrital material;
5) Maintenance of freshwater storage and supply;
6) Aesthetic and scenic attributes;
7) Filtration and absorption of nutrients and other pollutants;
8) Sediment loads;
9) Water quality; and
10) Navigation."

The Water Resource Implementation Rule also indicates, "minimum flows and levels should be expressed as multiple flows or levels defining a minimum hydrologic regime, to the extent practical and necessary to establish the limit beyond which further withdrawals would be significantly harmful to the water resources or the ecology of the area".

The District has developed specific methodologies for establishing minimum flows or levels for lakes, wetlands, rivers and aquifers, subjected the methodologies to independent, scientific peer-review, and in some cases, incorporated the methods into its Water Level and Rates of Flow Rule (Chapter 40D-8, F.A.C.). Components of recovery strategies needed to restore minimum flows and levels that are not currently being met have been incorporated into the District's Recovery and Prevention Strategies for Minimum Flows and Levels Rule (Chapter 40D-80, F.A.C.). A recovery plan will not be needed for the Chassahowitzka River system.

1.2 The Flow Regime

The idea that a single minimum flow is not satisfactory for maintaining a river ecosystem was most emphatically stated by Stalnaker (1995) who declared, "minimum flow is a myth." The purpose of his paper was to argue; "multiple flow regimes are needed to maintain biotic and abiotic resources within a river ecosystem" (Hill et al. 1991). The logic is that "maintenance of stream ecosystems rests on streamflow management practices that protect physical processes which, in turn, influence biological systems." Hill et al. (1991) identified four types of flows that should be considered when examining river flow requirements, including:

1) flood flows that determine the boundaries of and shape floodplain and valley features;
2) overbank flows that maintain riparian habitats;
3) in-channel flows that keep immediate streambanks and channels functioning; and
4) in-stream flows that meet critical fish requirements.

As emphasized by Hill et al. (1991), minimum flows methodologies should involve more than a consideration of immediate fish needs or the absolute minimum required to sustain a particular species or population of animals, and should take into consideration "how streamflows affect channels, transport sediments, and influence vegetation." Although not always appreciated, it should also be noted "that the full range of natural intra- and inter-annual variation of hydrologic regimes is necessary to [fully] sustain the native biodiversity" (Richter et al. 1996). Successful completion of the life cycle of many aquatic species is dependent upon a range of flows, and alterations to the flow regime may negatively influence these organisms as a result of changes in physical, chemical, and biological factors associated with particular flow conditions.

Recently, South African researchers, as cited by Postel and Richter (2003), listed eight general principles for managing river flows:

1) "A modified flow regime should mimic the natural one, so that the natural timing of different kinds of flows is preserved.
2) A river's natural perenniality or non-perenniality should be retained.
3) Most water should be harvested from a river during wet months; little should be taken during the dry months.
4) The seasonal pattern of higher baseflows in wet season should be retained.
5) Floods should be present during the natural wet season.
6) The duration of floods could be shortened, but within limits.
7) It is better to retain certain floods at full magnitude and to eliminate others entirely than to preserve all or most floods at diminished levels.
8) The first flood (or one of the first) of the wet season should be fully retained."

Common to this list and the flow requirements identified by Hill et al. (1991) is the recognition that in-stream flows and out of bank flows are important and that seasonal variability of flows should be maintained. Based on these concepts, the preconception that minimum flows (and levels) are a single value or the absolute minimum required to maintain ecologic health in most systems has been abandoned in recognition of the important ecologic and hydrologic functions of streams and rivers that are maintained by different ranges of flow. Moreover, while the term "minimum flows" is still used, the concept has evolved to one that recognizes the need to maintain a "minimum flow regime".

In Florida, for example, the Water Resource Implementation Rule indicates that "minimum flows and levels should be expressed as multiple flows or levels defining a minimum hydrologic regime, to the extent practical and necessary to establish the limit beyond which further withdrawals would be significantly harmful to the water resources or the ecology of the area" (Rule 624-40.473(2), F.A.C.). The St. Johns River Water Management District typically develops multiple flows requirements when establishing MFLs (Chapter 40C-8, F.A.C.) and for the Wekiva River noted that, "[s]etting multiple minimum levels and flows, rather than a single minimum level and flow, recognizes that lotic [running water] systems are inherently dynamic" (Hupalo et al. 1994).

General information pertaining to the establishment of minimum flows and levels in the District is available from the District's Minimum Flows and Levels (Environmental Flows) web page at: http://www.swfwmd.state.fl.us/projects/mfl/. Specific information regarding methods used to establish minimum flows and levels and established minimum flows and level is available at the District's Minimum Flows and Levels (Environmental Flows) Documents and Reports page at:
http://www.swfwmd.state.fl.us/projects/mfl/mfl_reports.html.

An alternate approach that also maintains a flow regime is to develop MFLs using a "percentage of flow" as discussed in Flannery et al. (2002). Often, the percentage of flow approach is superimposed on seasons referred to as ‘Blocks’. However, the discharge from spring-dominated systems such as the Chassahowitzka, do not always exhibit strong seasonal patterns and a single percentage reduction of flow is often appropriate. It should be noted that an MFL based on the percentage of flow cannot be expressed as a fixed quantity of flow, as it co-varies with variation in natural flow. The proposed minimum flow for the Chassahowitzka river system is based on percent of natural flow, with natural flow defined as the flow that would be expected in the absence of withdrawal related impacts.

1.3 Defining Significant Harm

While Section 373.042, F.S. requires establishment of minimum flows and levels as limits at which further withdrawals would be significantly harmful to water resources or ecology of an area, “significant harm” is not explicitly defined. In establishing minimum flows, the District has identified flows associated with fish passage and maximization of stream bottom habitat with the least amount of flow and determined that loss of these threshold flows would be significantly harmful to river systems. The District has also used quantifiable reductions in potential habitat or resources to identify significant harm and develop minimum flow recommendations. This latter approach is complicated by the fact that many structural and functional components of river ecosystems vary incrementally with flow and do not exhibit clear thresholds or “break-points”.

Given the incremental nature of much environmental change in riverine ecosystems, the District has used a 15 percent change criterion when evaluating flow-based changes in potential habitats or resources. The recommended minimum flow is based on the habitat or resource most sensitive to a flow reduction resulting in a 15 percent reduction.The basis for this management decision lies, in part, with a recommendation put forth by the peer-review panel that considered the District’s proposed minimum flows for the upper Peace River. In their report, the panelists note that “[i]n general, instream flow analysts consider a loss of more than 15 percent habitat, as compared to undisturbed or current conditions, to be a significant impact on that population or assemblage” (Gore *et al.* 2002). The panel’s assertion was based on consideration of environmental flow studies employing the Physical Habitat Simulation Model (PHABSIM) for analyzing flow, water depth and substrate preferences that define aquatic species habitats. Use of a fifteen percent change in habitat or resources as constituting significant harm and therefore, for development of minimum flow recommendations, has been extended by the District to evaluate changes in freshwater fish and invertebrate habitat, days of inundation of floodplains, snag habitat and woody debris in freshwater river segments, changes in abundances or population center-location tendencies of planktonic (free-floating) and nektonic (actively swimming) fish and invertebrates in estuarine river segments, spatial decreases in the availability of warm-water refuges for manatees during critically cold periods, and decreases in the volume, bottom area and shoreline length associated with specific salinity zones in estuarine river segments.

Peer-review panels convened to evaluate District recommendations subsequent to the findings put forth by Gore *et al.* (2002) for the upper Peace River have generally been supportive of the use of a fifteen percent change criterion for evaluating effects of potential flow reductions on habitats or resources when determining minimum flows (see peer-review reports at the District's Minimum Flows and Levels Documents and Reports web page). Recently, in response comments made by Cichra *et al.* (2007) in the peer review of the recommended minimum flows for the upper Hillsborough River, the District has sponsored a review of the percentage flow, habitat, and resource changes documented in the environmental flows literature (Jones Edmunds & Associates 2012).

Pending completion of the ongoing District-sponsored literature review of environmental flow studies or findings from other environmental flow studies, the District is continuing to utilize the fifteen percent habitat or resource change criteria for developing recommended minimum flows, including for development of the minimum flow recommendations for the Chassahowitzka River system outlined in this report. However, allowable percentage changes in habitat or resources other than fifteen percent have been used by others for environmental flow determinations.

While there does not appear to be a universally recognized threshold representing 'significant harm' in the peer-reviewed literature, much of the literature on environmental flows is taken from systems (e.g., Murray-Darling in Australia, San Francisco Bay, Caspian Sea in Russia) that have withdrawals in excess of 50 percent, impoundments or both. Exceptions include recommendations for limiting diversion to 20 percent (Dunbar et al. 1998) based on habitat loss, 30 percent habitat loss based on historical low flows (Jowett 1993) or 20 percent reduction in historical commercial harvest (Powell et al. 2002). More recently, the Nature Conservancy (Richter et al. 2011) proposed a presumptive standard of 10 percent reduction over natural flows for 'high level' protection and up to a 20 percent reduction for 'moderate level' of protection.

1.4 Minimum Evaluation Criteria

Researchers utilize regression statistics to determine the statistical strength between biological responses and inflows. The most common measure of the strength is the correlation coefficient (r) which ranges from 0.0 to +1.0 for a response that increases with increasing flow. Conversely, r can range from 0.0 to -1.0 for a response that decreases with flow. The absolute value of the correlation coefficient provides information on the strength of the modeled relationship between two variables, with larger values indicating a stronger relationship. Another statistic, the coefficient of determination (r^2) is also convenient for flow-based regression analyses, because it reflects the fraction of the response variable that is attributable to changes in flow. It must, however, be recognized that a statistically significant relationship may still be of limited value for resource management. Taking an example from fish monitoring, it is often possible to develop statistically significant relationships that relate the number of animals to flow, but coefficient of determination values for these relationships may typically be very low, about 0.1. This means that while there may be a significant relationship between the number of fish and flow, flow accounts for only10 percent of the change in numbers. The remaining 90 percent of variation in fish abundance in this example is due to residual variation in flow and to another factor (or factors) other than flow. The management question then becomes "How much weight do we place on this relationship? Should we set flow limits when the majority of response is due to something other than flow?"

A similar problem facing the decision-makers is: "*How much data do we need?"* Taken in the context of establishing statistical relationships between flow and ecological resources the analogous question is: *"How many data points should I have to develop my regression equation?"* Research has shown that as the strength of the relationship diminishes, the number of observations required increases (so called "effect size").

It often becomes necessary to try to develop relationships between flow and some response with considerably fewer observations than recommended or desirable. While the legislature has indicated that, an MFL should be based on the "best information available", at some point it becomes questionable whether a management decision should be based on a very low number of observations or a very low correlation, and it becomes preferable to establish acceptance criteria *a priori.* Heyl (2008) proposed criteria for a regression suitable for management decisions in the development of the Weeki Wachee minimum flow. The same criteria have been applied to development of the Chassahowitzka River minimum flow. Namely, there must be a minimum of ten observations for each parameter in the regression, the regression must exhibit an r^2 of at least 0.30, and the underlying assumptions about regressions must be met. A similar correlation coefficient criterion was subsequently adopted by the Texas Water Board (Batchelor and Guthrie 2008) for the reevaluation of the minimum environmental flow requirements of Galveston Bay.

1.5 Flow Definitions

The following terms define the Chassahowitzka flows associated with establishing a minimum flow for the Chassahowitzka system. It should be noted that in order to properly describe a flow record, it might be necessary to combine definitions. The term "flow" is used both as a noun (singular value of volume/time as in a daily average 'flow'), or as adjective for a collection of values (as in a 'flow' record).

Long-term is defined in Rule 40D-8.021, F.A.C. as a period that spans the range of hydrologic conditions expected to occur based upon historical records. Long-term flow is a continuous record of flow that represents a range of climatological and hydrologic conditions over several decades. Typically, the long-term flow record is used to assess and quantify descriptive metrics, such as averages or medians. Long-term flows may be expressed for various durations of time. For example, a long-term annual average flow might represent the average of 20 or more annual flow values, while a long-term daily average flow might represent the average of 7,305 daily measurements over a 20-year period.

When the MFL evaluation involves numeric modeling, which requires long computation times, typically a subset of the long-term flow is selected that replicates seasonal and annual distribution pattern exhibited by the long-term period. This representative sub-set typically includes 3-5 consecutive years selected for numeric modeling applications. In applications that use statistical relationships that are not constrained by long computation time, the entire long-term period is often used as instead of a representative period. Impacted flow is flow that includes anthropogenic impacts.

Baseline flow(s) refer to prior flows that are as free from anthropogenic impacts as possible. A baseline flow record, otherwise known as *natural, unimpacted* ,or *historic* (Rule 40D-8.021, F.A.C.) is developed by correcting for flow lost (e.g. potable withdrawals), or gained (e.g. excess irrigation water derived from groundwater or reuse) because of human activities. It should be noted that impacted flow that is corrected for the anthropogenic impacts may serve as a baseline flow.

Reported or *observed* flow is directly measured, or derived from a relationship to directly measured flows. Examples include flow reported by the United States Geological Survey (USGS), which is calculated from a regression equation relating measured spring flow to artesian groundwater levels. Reported or observed flow may be either impacted or unimpacted.

1.6 Summary of the District Approach for Developing Minimum Flows

1.6.1 Elements of Minimum Flows

It was originally intended that the technical report for the Chassahowitzka River System include establishment of minimum flows for both the freshwater riverine and the downstream estuarine portions of the river. However, during field investigations, it became apparent that all of the spring tributaries were under tidal influence and the techniques traditionally used by the District to set freshwater minimum flow criteria could not be applied in the Chassahowitzka. While the approaches and tools differ between these two evaluations, both share a common philosophical approach in attempting to establish a flow regime instead of a single threshold flow. According to Beecher (as cited by Stalnaker et al. 1995), an instream flow standard should include the following elements:

1) a goal (e.g., non-degradation or, for the District’s purpose, protection from “significant harm”);
2) identification of the resources of interest to be protected;
3) a unit of measure (e.g., flow in cubic feet per second, habitat in usable area, inundation to a specific elevation for a specified duration);
4) a benchmark period, and
5) a protection standard statistic.

The District’s approach for minimum flows development incorporates the five elements listed by Beecher (1990). Impacts on the water resources or ecology are evaluated based on an identified subset of potential resources of interest. Ten potential resources were listed in Section 1.1.They are recreation in and on the water; fish and wildlife habitats and the passage of fish; estuarine resources; transfer of detrital material; maintenance of freshwater storage and supply; aesthetic and scenic attributes; filtration and absorption of nutrients and other pollutants; sediment loads; water quality; and navigation. The approach outlined in this report identifies specific resources of interest and identifies, when it is important seasonally to consider these resources.

The initial step in developing a minimum flow for a water body requires an examination of historic and current flow conditions to determine if current flows reflect past conditions. If this is the case, the development of a minimum flow becomes a question of what can be allowed in terms of withdrawals before significant harm occurs. If there have been changes to the flow regime of a river because of withdrawals, these must be assessed to determine if significant harm has already occurred. If significant harm has already occurred, recovery is required.

For development of minimum flows for the Chassahowitzka River, a “long-term” period of flow from 1967 through 2007 was used. For flows from 1997 through November 2007, the values reported by the USGS National Water Information System were used. The USGS derived these estimates as a function of tide and water level in the Weeki Wachee well. Flows prior to 1997 were estimated from the Weeki Wachee well only, as historical tide stage is not available. Agreement between flow predicted with well level alone correlates (r^2=0.7) strongly with the USGS estimates. Typically, the maximum flows expressed in cubic feet per second (cfs) occur in September through November and the minimum flows occur in May through July. Of particular note is the constancy of the flow as evidenced by the ratio (1.1) of median September flows (67 cfs) to median flows in May (61cfs) is very small in contrast to runoff-dominated rivers where orders of magnitude differences in monthly flows are the norm. Since the Chassahowitzka River exhibits no significant seasonal flow variation, the Districts' approach using seasonal “Blocks” was not used for the development of minimum flows in this system.

Because the entire length of the Chassahowitzka River is tidally influenced, the District was unable to conduct the normal suite of analyses used to establish a recommended minimum flow for the freshwater river segment. Additionally, there is no record of flow on the freshwater tributaries. As a result, it is recommended that the minimum flows developed for the estuarine portion of the Chassahowitzka River system be applied to the tidal freshwater habitat.

1.7 Content of Remaining Chapters

In this chapter, the requirements and rationale for developing MFLs in general have been introduced. The remainder of this document considers the development of minimum flow specific to the Chassahowitzka River system, which includes the river reach from the headsprings (Chassahowitzka Main, Chassahowitzka #1and Chassahowitzka #2 and other upstream springs) located in Citrus County at the end of County Road 480, westward approximately 9.5 km to the confluence with the Gulf of Mexico, and the springs associated with the river.

Chapters 2 through 5 are intended to describe the system. Chapter 2 contains a short description of the entire river basin and springshed, the hydrogeologic setting, and considers historical and current river flows and the factors that have influenced the flow regimes. Chapter 3 focuses on describing the estuarine characteristics of the system and Chapter 4 is devoted to water quality with a focus on salinity and its relationship with flow.

Biological resources are described in Chapter 5 along with quantifiable relationships to flow that have been developed for the minimum flow evaluation. Goals and specific minimum flow resource criteria are defined in Chapter 6, while Chapter 7 is devoted to application of evaluation tools to determine what minimum flow(s) achieve the criteria established in the prior chapter. Finally, Chapter 8 provides a definition of the minimum flow recommended for the Chassahowitzka River. Chapter 9 summarizes the peer review and stakeholder input. Chapter 10 contains literature cited for the prior chapters and Chapter 10 contains review comments and the District's responses. Chapter 11 (bound separately) contains Appendices cited within the main report. Public comments and peer reviews are included in the appendices as Chapter/Section 11.18.

With the exceptions noted, the British system of measurement units has been utilized in this report. This will promote consistency with other District reports and Florida's *Plain Language Initiative*[3] that promotes a writing style easily understood by the public. The exceptions to the British system are river or shoreline distance (expressed in kilometer, km), volume (cubic meters, m^3), river bottom area (square meter, m^2), water depth (expressed in meters) and concentration (expressed as milligrams per liter, mg/l). A table of common conversions and abbreviations is provided preceding the Table of Contents.

[3.] State initiative can be found at http://www.flgov.com/pl_home

CHAPTER 2. WATERSHED CHARACTERISTICS – PHYSICAL AND HYDROLOGY

2.1 Watershed and Springshed

The Chassahowitzka River is a 9 km long[4] spring-fed river located in a region of the west coast of Florida (Figure 2-1) known as the Florida Springs Coast, which includes the coast extending from the Pithlachascotee River located north of Tampa Bay to the Waccasassa River area located south of the Suwannee River Basin (Wolfe 1990). The river originates in Citrus County and enters the Gulf of Mexico at Chassahowitzka Bay. It was designated an "Outstanding Florida Water" by the Florida Department of Environmental Protection (FDEP) in 1979 and the lower half of the river is part of the 35,000+acre Chassahowitzka National Wildlife Refuge established in 1943. Mean depth is approximately three feet (Notestein et al. 2001). The upper reach of the Chassahowitzka is relatively narrow but broadens considerably (to over 500 feet) downstream.

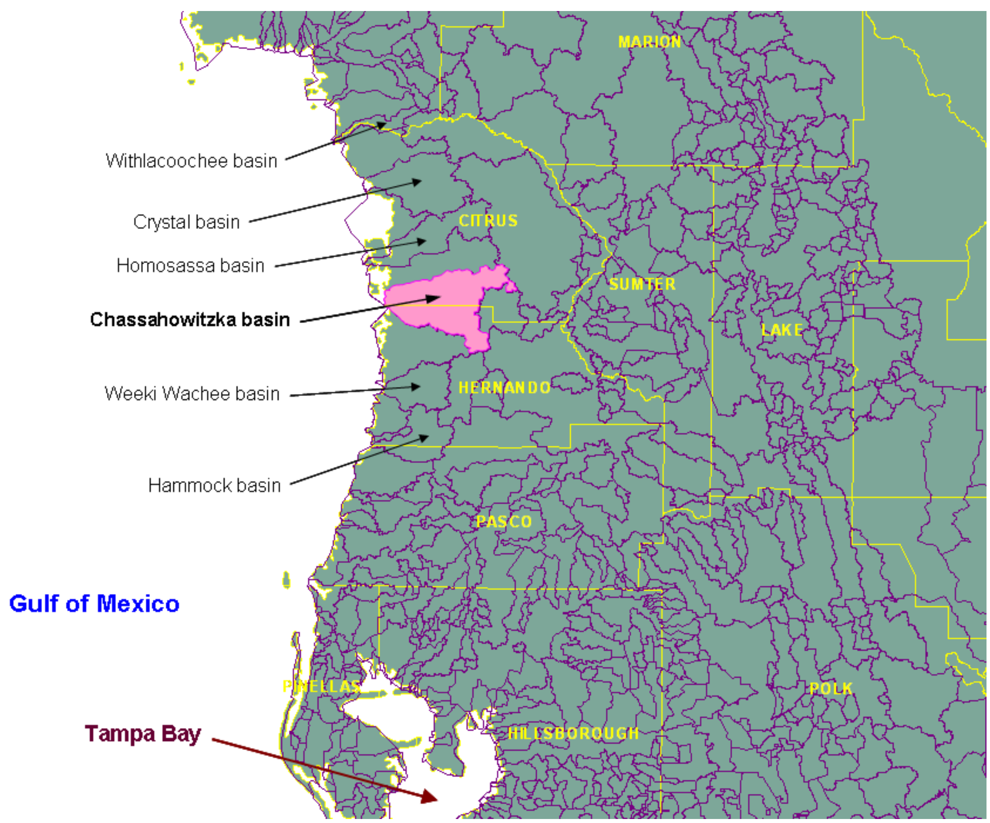


Figure 2-1. Florida Springs Coast Sub-basins including the Chassahowitzka Basin and surrounding areas.

[4] River kilometer (Rkm) measured from the seaward extent of the USGS drainage basin boundary at 28.6908 north latitude and 82.6432 west longitude. (See Figure 2-4).

The surface drainage area is approximately 89-square miles, but the springshed is significantly larger (Figure 2-2). Groundwater contribution is estimated to be from a 190-square miles area. Both the watershed and springshed are located in Citrus and Hernando Counties.

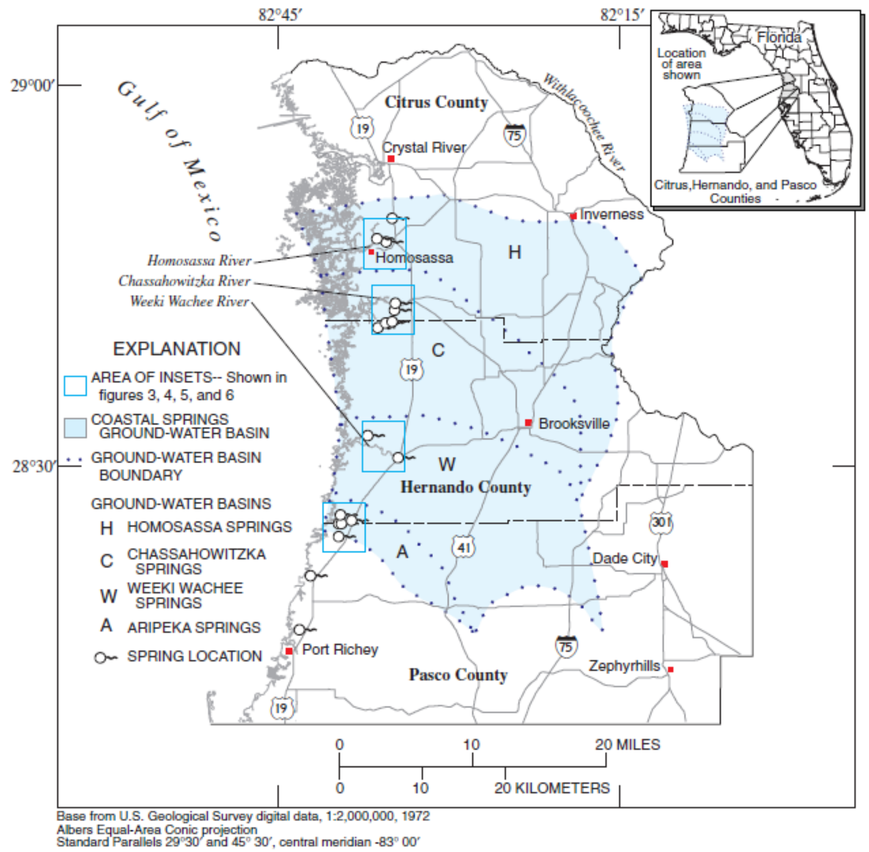


Figure 2-2. Chassahowitzka Springshed (Source: USGS Water Resources Investigation Report 01-4230)

The headwaters for the Chassahowitzka River are formed by the Chassahowitzka Main Spring, Chassahowitzka #1, Chassahowitzka #2, and several unnamed springs upstream (Scott et al. 2004). Figure 2-3 provides a location map of springs for the Chassahowitzka River system. The centerline of the river with labeled river kilometers is also depicted. The Chassahowitzka River was measured from the seaward extent of the USGS drainage basin boundary[5] (river kilometer 0.0) upstream 9.6 river kilometers (Rkm).The main spring is located about 200 feet northeast of the boat ramp at the Citrus County Chassahowitzka River Campground (near the west end of County Road 480). Chassahowitzka #1 and #2 are located 350 feet upstream (Scott et al. 2004) of the main spring in a short channel entering from the northeast. The Chassahowitzka #1 and #2 springs mark the upper boundary of the study area for this MFL report and collectively all Main and all springs upstream are considered the headsprings complex. The western

[5] River kilometer zero (Rkm 0) is defined as the confluence of the river with the seaward extent of the USGS drainage basin.

study boundary is near John's Island approximately 8.8 kilometer downstream of Chassahowitzka Main. More than a dozen springs discharge additional flow into the Chassahowitzka River. The main pool is nearly circular and about 150 feet in diameter. The bottom slopes gently toward the vent in a crevice about 25 feet long and 1 to 2 feet wide. In April 1962, the depth of the vent was 34.5 feet below water surface (Florida Geological Survey 2002). The Chassahowitzka is frequently listed (Scott et al. 2002. Wolfe 1990 and others) as a 1st magnitude spring (i.e. > 100 cfs), however that statement probably includes flow from Crab Creek and all springs above (e.g. Main, #1, #2 and unnamed springs) as the daily average flows excluding Crab Creek Spring have been on the order of 60 cfs since the USGS began measurements downstream of the Main Spring (USGS 0230650) in1997 (See Section 2.3.1 for additional details.)

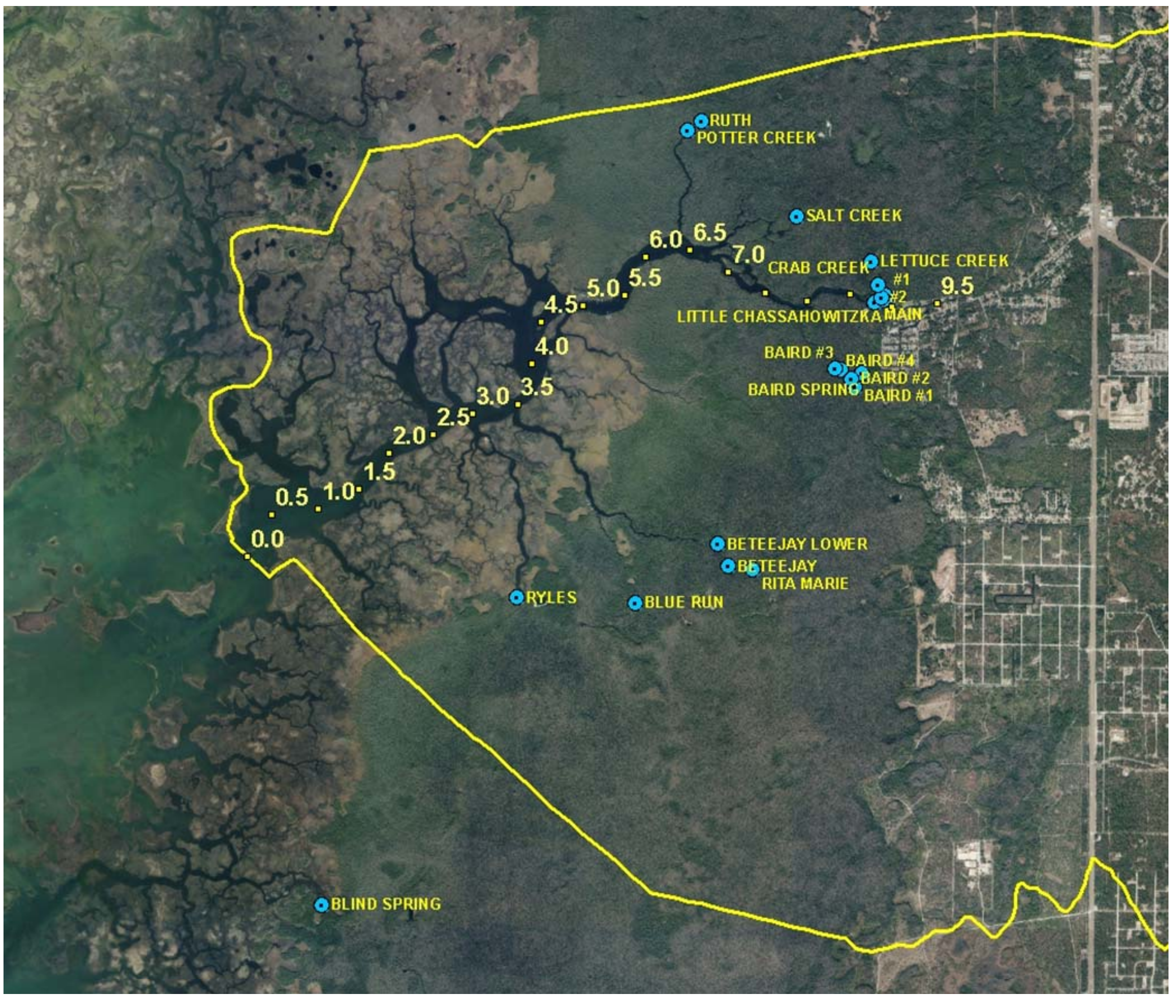


Figure 2-3. Location of Springs in the Chassahowitzka Group. Numbers indicate river kilometer (Rkm)

All groundwater discharging from the Chassahowitzka springs group is from the Upper Floridan aquifer. Tides in the area are semidiurnal and unequal, generally ranging from 2.0 to 4.6 feet (Wolfe et al.1990). Tidal water level fluctuations inversely affect discharges. In common with other streams along the Florida Springs Coast, the Chassahowitzka River flows over and drains a predominantly carbonate terrain, resulting in clear waters upstream and little or no sediment transport to the Gulf of Mexico at Chassahowitzka Bay (Wolfe et al. 1990). The lower river has a brown color from dissolved humics (Dixon and Estevez 2001) presumably derived from extensive marsh system which exists from river km 5.2 seaward (See Figure 3-10 in Section 3.4).

2.1.1 Land Use/Land Cover

The 4 km (2.5 mi) of the Chassahowitzka River below the main spring are surrounded by a deciduous tidal freshwater floodplain forest, which ends at the boundary of the Chassahowitzka National Wildlife Refuge (Dixon and Estevez 2001). Cattail (*Typha* sp.) and reeds (*Phragmites* sp.) line some portions of shoreline in the upper river, with floating mats of senescent filamentous vegetation evident (Dixon and Estevez 2001). Terrestrial canopy cover shades only about three percent of the total river area, permitting submersed aquatic vegetation (SAV) to grow (Notestein et al. 2001). In the upper river, SAV includes American eelgrass (*Vallisneria* sp.), pondweed (*Potamogeton* sp.), and *Hydrilla verticillata* (Dixon and Estevez 2001). At the boundary of the Chassahowitzka National Wildlife Refuge, the riverbank vegetation is dominated by sawgrass (*Cladium jamaicensis*) and cattail (*Typha domingensis*); with cabbage palm (*Sabal palmetto*) hammocks and some black needlerush (*Juncus roemerianus*). Dixon and Estevez (2001) noted enteromorpha-like algae, Eurasian water milfoil (*Myriophyllum spicatum*), and *Hydrilla verticillata* as being very dense in 1996 but much reduced during a drought period in 2000. Near Crawford Creek (Rkm 3.5) and Dog Island (Rkm 2.5 – See Figure 2-3 in Section 2.1), sawgrass and black needlerush line the shore, with some cattails present and *Ruppia maritima* (widgeon grass) is occasionally present (Dixon and Estevez 2001). In the lowermost portions of the river and in Chassahowitzka Bay, black needlerush is the dominant shore vegetation, with smooth cordgrass (*Spartina alterniflora*) occasionally present. Eastern oyster (*Crassostrea virginica*) forms bars in some areas and red mangrove (*Rhizophora mangle*) is present to a limited extent. Seagrasses abound in Chassahowitzka Bay, in particular turtlegrass (*Thalassia testudinum*), shoalgrass (*Halodule wrightii*) and widgeon grass (Dixon and Estevez 2001). Table 2-1 provides the general land use and land cover for both the springshed and watershed.

Table 2-1. Springshed and Watershed Land Use/Land Cover.

	Land Use / Land Cover - 2006			
	Springshed		Watershed	
Description	**Percent**	**Acres**	**Percent**	**Acres**
Disturbed Land	0	80	0	22
Mines	9	10,980	4	2,538
Non-forested Wetlands	3	4,066	6	3,701
Other Agricultural	14	16,478	10	5,800
Rangeland	1	1,371	2	1,456
Upland Forests	32	38,559	39	22,715
Urban	28	34,441	21	12,403
Water	1	1,297	2	1,170
Wetland Forests	12	14,678	15	8,928
Total	**100**	**121,951**	**100**	**58,734**

There is very little development along the Chassahowitzka River (See Figure 2-3).The town of Chassahowitzka, which is located upstream and east of Chassahowitzka #1 includes many canals that have been dredged for residences. Septic tanks were implicated (Callahan et al. 2001) as a source of historical fecal contamination in the residential canals but recently the area has been converted to central sewer[6]. However, elevated nitrate levels continue to be problematic. Downstream development along the river is limited to approximately 15-20 camps and homes downstream of Chassahowitzka Main spring. There are no permitted direct surface water withdrawals from the Chassahowitzka River.

2.2 Climate

The climate of the Springs Coast is mild and greatly influenced by the Gulf of Mexico. Mean daily summer high temperatures are in the low to mid 90s and the winter means are in the upper 50s with an annual average temperature of 70 ^{o}F. Annual precipitation averaged 55.8 inches at nearby Brooksville between 1904-2004 and is largely the result of localized convective thunderstorms during the summer (June through September) when 31.7 inches of accumulated rainfall is normal. However, unlike runoff-dominated rivers, this seasonal peak in rainfall does not translate into large differences in discharge (see 2.3.1 Discharge Estimates). Additional rain accompanies winter frontal systems, which result in a secondary peak in rainfall during February through April when another 9.8 inches of rainfall can be expected. These cold fronts result in an average of five freezing days per year (1892-2006), but can range up to 24 days (recorded in 1920).

The passage of strong winter cold fronts may cause extremes in tidal amplitude resulting in increased salinity throughout much of the river during high tide followed by exposure and desiccation of submersed vegetation during the subsequent low tide. Summer cyclonic events may also result in similar water level extremes. Between 1910 and 2004, sixteen hurricanes passed within 75 statute miles of the Chassahowitzka River, at an average frequency of once every 6.25 years. Of particular note is the 27-year period with no hurricane activity, between Hurricane Gladys (10/1968) and Hurricane Erin (8/1995).

2.3 Flow and Hydrogeology (Adapted from Wolfe 1990, Knochenmus and Yobbi 2001)

Florida as it exists today is the emergent land mass of a peninsular carbonate rock (limestone and dolostone) platform that extends southward and separates the deep waters of the Atlantic from the deep waters of the Gulf of Mexico. Portions of this platform have been episodically submerged and emergent over recent geologic time, depending upon sea level. The carbonate rocks that form the platform were deposited approximately 58 to 25 million years before present in a marine depositional environment when the sea level was higher. The historical change in sea level gives rise to step-like terraces that progress from the shoreline to the interior. The Chassahowitzka River lies within the Palimico terrace. This near-gulf terrace is part of a larger landform known as the Gulf Coastal Lowlands, which includes land from the Gulf of Mexico to an

[6]. http://citrusdaily.com/local-news/epa-grant-bringing-down-chassahowitzka-sewer-costs/2009/08/31/10599.html

elevation of approximately 98 feet (30 m) above sea level. Much of the Florida peninsula, including the Springs Coast is a notable karst landscape, characterized by springs, sinkholes, and undulating topography. Karst landscapes are a result of chemical dissolution of the underlying carbonate rocks by meteoric water. The present-day landscape of the Chassahowitzka region is formed through karst processes and from fluctuations in sea level over geologic time.

The springs that contribute water flow to the Chassahowitzka River occur in the physiographic region designated as the Coastal Swamp (White 1970). This region is an area of upward flow from the Upper Floridan aquifer and active sinkhole formation is relatively low (0-2 karst features per square mile) compared to the sand hill areas of the Gulf Coastal Lowlands where karst features number 10 to 25 per square mile (HydroGeoLogic 1997). To the east, in the sand hills of the Gulf Coastal Lowlands, recharge conditions exist so the karst feature density is higher (10-25 solution features per square mile) and the well-drained soils support a unique scrub habitat (Wolfe 1990). Structural features in the carbonate rocks such as fractures and sedimentary bedding planes tend to concentrate groundwater flow leading to additional dissolution and preferential flow pathways for groundwater movement. The result is a coastline that is dominated not by surface runoff, but by discharge of groundwater. Within the Springs Coast there are five 1st order (>100 cfs), eight 2nd order (10-100 cfs) and four 3rd order (<10 cfs) named spring systems.

2.3.1 Discharge Estimates

The District has contracted with the USGS to install and maintain monitoring stations to collect water stage, temperature, and conductivity data at a number of sites along the Florida Springs Coast (Table 2-2). Spring discharge is the primary freshwater source into the Chassahowitzka River system. However, continuous records are only available for the Chassahowitzka headsprings. The flows are monitored by the USGS gauging station 02310650 (Figure 2-4). The continuous daily discharge record began in 1997 and stage measurements began in 1999. In addition to the identified springs, the Chassahowitzka River system receives discharge from smaller springs as well as receiving diffuse groundwater discharge. Chassahowitzka Main spring is located at approximately Rkm 8.8.

2.3.1.1 Discharge from USGS 02310650

Prior to 1997, the sporadic discharge measurements reported by the USGS for site 02310650 included contribution from Crab Creek as well as the Main Spring and contributions above the main spring, while the post 1997 discharge reported for this site does not include flow contributions from Crab Creek. (personal communication. Dann Yobbi). A summary of discharge measurements for Chassahowitzka Springs, which includes Crab Creek, can be found in Table 3 of the USGS Water Resources Investigation (WRI) Report 88-4044 while the results of discrete spring discharge measurements can be found in the appendices of WRI report 92-4069 and WRI report 01-4230.

Table 2-2. Summary of USGS Gauges Near Chassahowitzka River

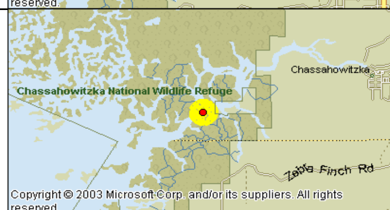
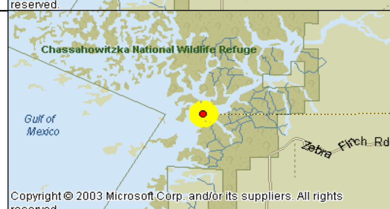
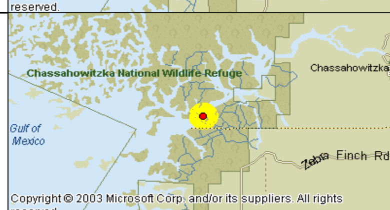
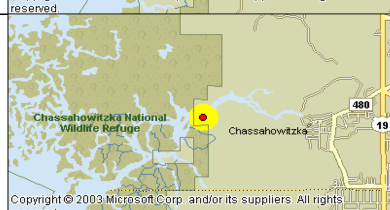
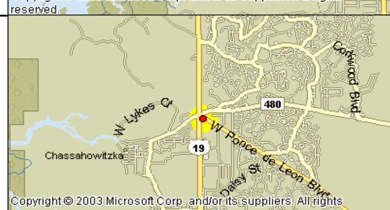
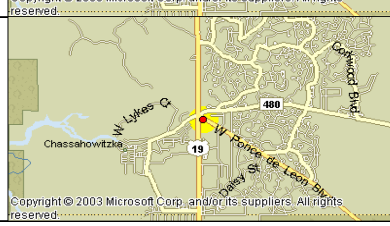
Sort	Site ID	Site Name	Location	History of Observations
1	02310650	CHASSAHOWITZKA RIVER NEAR HOMOSASSA FL		Daily data for Discharge (1997 ~ present), Water temperature (bottom, 2004 ~ present), Gage height (1999 ~ present), Specific conductance (2004 ~ present).
2	02310663	CHASSAHOWITZKA RIVER NEAR CHASSAHOWITZKA FL		Daily data for Discharge (2003 ~ present), Water temperature (bottom, 2003 ~ present), Gage height (1984 ~ present), Specific conductance (2003 ~ present).
3	02310673	CHASSAHOWITZKA R AT DOG ISL NR CHASSAHOWITZKA FL		Daily data for Water temprature (2005 ~ present), Gage height (2005 ~ present), Specific conductance (2005 ~ present).
4	02310674	CHASSAHOWITZKA R AT MOUTH NR CHASSAHOWITZKA FL		Daily data for Water temprature (2005 ~ present), Gage height (2005 ~ present), Specific conductance (2005 ~ present).
5	284152082375000	CHASSAHOWITZA RIVER AT MOUTH NEAR CHASHWTZ FL		Daily data for Salinity (1984 - 1985).
6	284254082362310	CHASSAHOWITZA R ABOVE JOHNSON CK NR CHASHWTZ FL		Daily data for Salinity (1984 - 1985).
7	284317082330601	CHASSAHOWITZKA WELL 1 NEAR CHASSAHOWITZKA FL		Daily data for Groundwater elevation (1965 ~ 2004); Grab data for: Water temperature, Specific conductance, Water quality.
8	284317082330602	CHASSAHOWITZKA WELL 2 NEAR CHASSAHOWITZKA FL		Grab data only: Groundwater elevation, Water temperature, Specific conductance, Water quality.

Figure 2-4. USGS Gauging Station 02310650 (Chassahowitzka near Homosassa)

The Chassahowitzka Spring vents above Crab Creek are estimated to contribute 50 percent of the flow to the river system. Previously reported monthly mean flows for Chassahowitzka headsprings plus Crab Creek Spring have ranged from 31.8 to 197 cfs (mean=140 cfs; data from 1930-1972 cited in Yobbi and Knochenmus 1989). Frazer et al. (2001a) reported a mean flow of approximately 140 cfs during their three-year study, but is unclear if this value is based on a consistent tide stage. Flows measured at USGS Station 02310650 (Chassahowitzka Springs above Crab Creek), from 1999 through 2005, ranged from 25 to 87 cfs, with a median flow of 59 cfs. Yobbi (1992) observed that there is a seasonal component to the spring's discharge. Lowest flows occur during June and July and the greatest flows occur during early fall, but the seasonal variation is small when compared to runoff-fed river systems.

As previously discussed, the continuous discharge record of the Chassahowitzka River headsprings, as measured at USGS Station 02310650, begins in February 1997. (Prior to this date, the discharge records for this station included flow from Crab Creek.) Flows in the Chassahowitzka River prior to February 20, 1997 can be estimated using the following regression equation of river flow with water levels from a nearby Floridan aquifer well – the Weeki Wachee well (283201082315601) (see Section11.1. Heyl 2010):

$Qest = 12.428 + 2.924\ WW\_WL;\ n = 3260,\ r^2 = 0.75$

Where:

Q(est) is the estimated daily discharge in cfs at USGS Station 02310650
WW_WL is the water surface elevation of the Week Wachee Well in feet
n = number of paired measurements used for model development; and
r^2 = coefficient of determination for the regression.

Daily estimated and reported discharges (1967-2007) are summarized by month in Table 2-3, which provides select percentile values. The mean monthly time series is portrayed in Figure 2-5. Typically, the maximum flows occur in September (median 66.7 cfs) through November (65.5 cfs) and the minimum flows occur in May (59.9 cfs) through July (60.8 cfs). Of particular note is the constancy of the flow as evidenced by a narrow range of median flows in May and September (ratio = 1.1) in contrast to runoff dominated rivers where orders of magnitude differences in monthly flows are the norm. Table 2-4 gives the range and period of observations for several additional contributing springs.

The discussion in the prior paragraph reflects the statistics of the uncorrected (impacted) flow record. Basso (2008. Section 11.2) estimated the ratio between un-impacted and impacted flow at USGS site 02310650 (1.0110), Crab Creek(1.0147) and Potter's Creek (1.0073) due to groundwater withdrawals. The median uncorrected flow of the Chassahowitzka River for 6/1966-11/2007 is 62.5 cfs while the unimpacted (corrected) long-term median flow is 63.2 cfs[7]. A long-term uncorrected median daily flow of 63 cfs was used extensively in early drafts of this report. Subsequent to the November 2010 draft (Heyl et al. 2010); all biological responses to flow were reevaluated assuming a long-term unimpacted median flow of 63.7 cfs.

For reevaluation of the daily habitat metrics (salinity and thermal) using the hydrodynamic model, the following corrections were made to the flow record:

- Daily reported flows at 02310650 were multiplied by 1.0110
- Crab Creekaverage literature value was multiplied by 1,0147
- Potter's Creek - average literature value was multiplied by 1.0073
- Other spring sources (Baird, BetteeJay, Blue Run, Ruth and Chassahowitzka #1) in the hydrodynamic model were multiplied by the average ratio of the other springs (e.g.1.0117).

[7] The median of the impacted flow record used for earlier draft MFL reports for the Chassahowitzka River system was 62.5 cfs which was rounded up to 63 cfs. The median for the corrected, unimpacted flow record is 63.2 cfs which rounds down to 63 cfs. However, since the rounded value of 63 cfs was cited extensively in early drafts, a median flow of 63.7 cfs was used for the resource re-evaluations described in this report.

Table 2-3. Monthly percentile discharge (cfs) of Chassahowitzka River 1967-2007 (Impacted flows)

Month	Percentile								
	1%	5%	10%	25%	50%	75%	90%	95%	99%
1	51.4	52.6	55.5	58.0	63.8	68.8	71.7	73.0	75.1
2	51.4	54.0	54.2	57.6	63.5	67.4	69.7	74.2	75.4
3	46.4	51.0	53.9	56.5	62.1	66.5	70.1	74.1	77.8
4	43.3	48.6	52.3	55.2	61.3	65.8	70.0	74.0	75.8
5	42.7	47.4	50.9	54.4	59.9	64.0	69.3	71.8	73.4
6	42.3	46.6	49.8	55.3	60.4	62.3	67.1	71.2	71.9
7	42.7	48.6	51.3	56.7	60.8	63.8	71.6	73.7	74.8
8	45.5	52.5	54.1	58.4	63.5	67.1	73.0	77.4	80.9
9	46.7	55.5	56.4	59.4	66.7	72.7	77.4	79.4	81.2
10	47.5	55.6	57.9	60.9	66.1	74.8	78.1	80.2	81.0
11	50.1	53.8	58.1	59.6	65.5	73.5	75.8	77.7	78.8
12	51.6	53.2	56.7	57.6	64.5	71.1	74.4	75.5	76.0

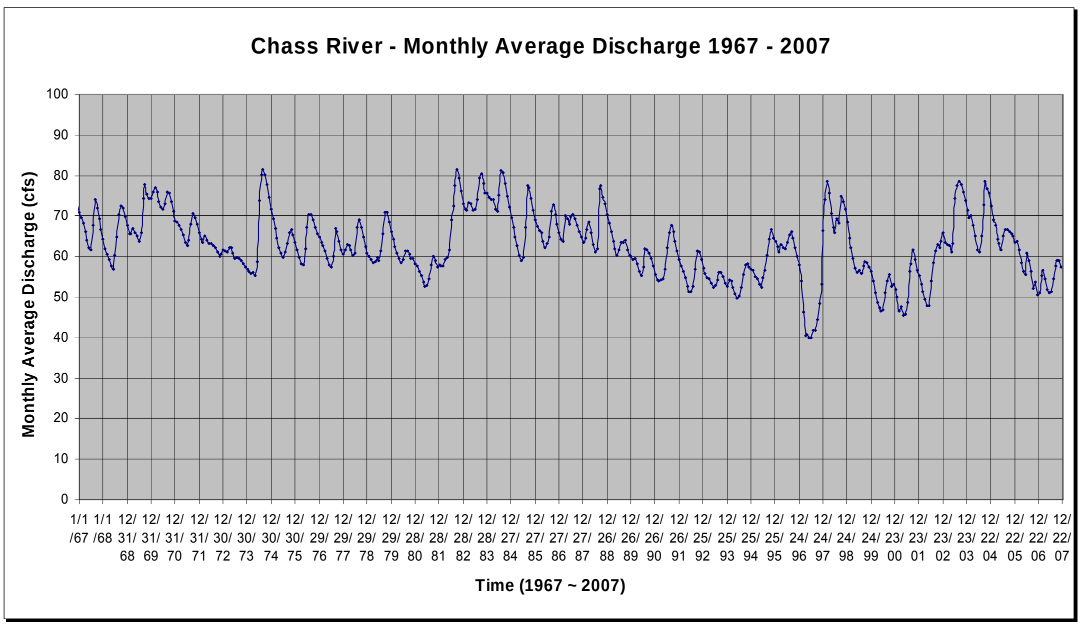


Figure 2-5. Mean monthly discharge (cfs) of Chassahowitzka River 1967-2007 (Impacted flows)

2.3.2 Long-Term flow

For development of minimum flows for the Chassahowitzka River, a “long-term” period from 1967 through 2007 was used. Flows prior to 1997 were estimated from the Weeki Wachee well. For flows from 1997 to 2007, the values reported by the USGS National Water Information System were used. Figure 2-6 depicts the mean annual flow during this time. (Uncorrected flows illustrated – see Section 2.3.1)

Table 2-4. Spring discharge in Chassahowitzka system. (Yobbi and Knochenmus,1988 Table 3. Knochenmus and Yobbi, 2001. Table 1 and Appendix B.)

Spring Discharge in Chassahowitzka System					
Spring Identification	Name	Period of Observations	Number of Observations	Range (cfs)	Mean chloride (mg/l)
Unnamed spring No. 8	Bettjay group	1961	1	10	6,400
Unnamed spring No. 9	Bettjay group	1961 - 64	3	20.9 - 35.4	136
Unnamed spring No.10	Ryle Creek	1961	1	5	4,300
Unnamed spring No. 11	Blue Head	1961 - 64	2	5 - 26.2	3,800
Unnamed spring No. 12	Rita Marie	1961 - 65	6	9.1 - 39.9	2,110
Baird Creek	Baird Creek	1964 - 65	5	11.1 - 53.1	2,350
Chassahowitzka Springs	Chassahowitzka Springs	1930 - 72	81	31.8 - 197	127
Ruth Spring	Ruth Spring	1961 - 72	6	8.0 - 11.8	460
Potter Spring	Potter Spring	1961 - 65	6	0 - 22.0	460
Crab Creek	Crab Creek	1988 - 1998	58	33.2 - 55.9	

Chass_contribQ.xls

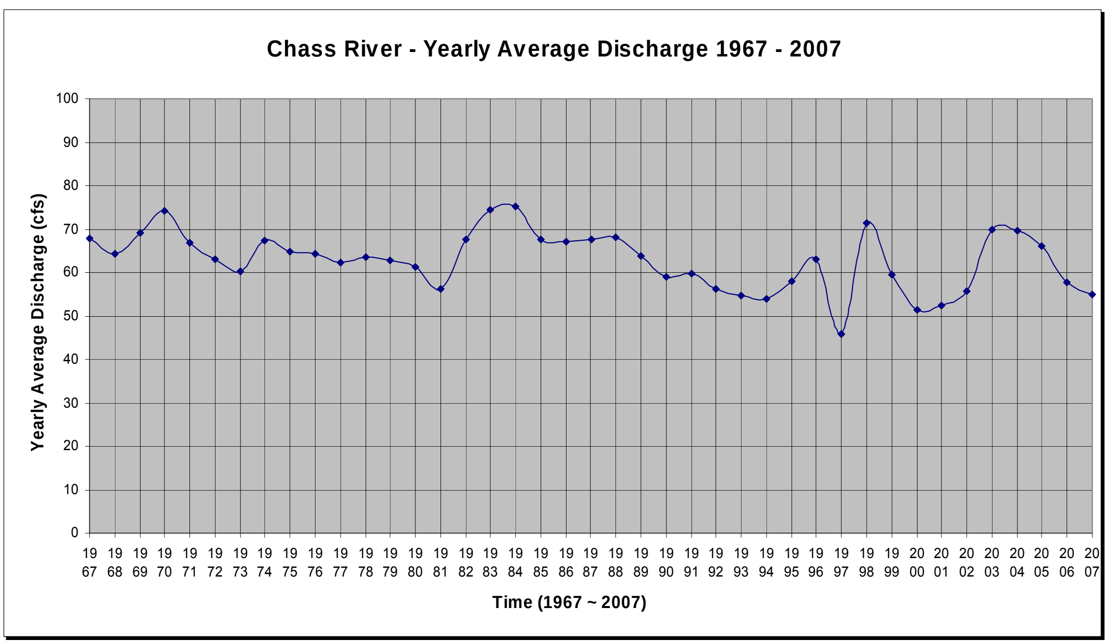


Figure 2-6. Mean annual flow (cfs) of Chassahowitzka River 1967 – 2007 (Impacted flows)

2.4 Historical Change in Discharge

There are no permitted surface water withdrawals from the Chassahowitzka River. However, groundwater withdrawals may indirectly affect the flow. A regional groundwater flow model was used to evaluate the impact of groundwater withdrawals on stream flow. The results indicate (See Section 11.2 - Basso 2008) that regional 2005 withdrawals resulted in an estimated 0.7 cfs decline on flows in the Chassahowitzka. This impact was initially considered insignificant and the earlier evaluations proceeded without flow correction. Subsequently, correction was made for this minor impact (see Section 2.3.1.1)

Based on the 1967-2007 composite discharge record, there has been a decline in annual average flow which is statistically significant (Kendall tau =-0.290, n= 41, p= 0.008). Regionally, the flow of many Florida river systems peaked in the mid-1960's, but comparison of the wet AMO period (Kelly 2004) covering 1940-1969 with the dry period (1970-1999) is not possible because the period of observations does not extent far enough in history. Nevertheless, in the absence of significant groundwater impacts, the decline is believed to be the result of climate and other natural conditions.

The Florida Geological Survey (FGS) evaluated a shorter and more recent time frame (FGS Bulletin 69 by Copeland et al. 2009) and described the 1998 – 2002 drought as "one of the worst historical droughts to affect Florida". While the FGS hypothesized that groundwater pumping increased during this period and exacerbated the effects, Bulletin 69 included the following SWFWMD findings:

> *However, within the northern portion of the SWFWMD, a water budget and a regional groundwater flow model indicated that the increase [0.2 cm/yr (+0.1 in/yr)] in groundwater withdrawals was less than 2.0% of the decline in recharge due to the decrease [18.3 cm/yr (7.2 in/yr)] in rainfall (Ron Basso, Southwest Florida Water Management District, personal communications). [page xviii]*
>
> *Groundwater quantity and quality data indicates the during Sequence C, Florida suffered from natural saltwater encroachment during the drought. . . . . The drought caused a decline in recharge which in turn lowered the potentiometric surfaces in Florida's aquifers followed by a decrease in spring flow. [page 134]*

When referencing 'trends' in climatological or hydrologic data, it is essential to specify the period of reference. Cyclic patterns can have opposite trends for each limb, but these may cancel each other across the full cycle. Figure 2-7 illustrates this point. The black dashed line is the cumulative annual departure from the average rainfall for the period 1910 – 2007 at the Brooksville Chinsegut Hill weather station (National Weather Service Coop ID 81046). Each plotted point represents the difference between the long-term annual average (56.3 inches) and the year in question, plus all the preceding differences. The dashed dark blue trend line illustrates a statistically significant (at p =0.05) increasing trend for the period 1930 -1967, while the dashed dark red line illustrates a statistically significant declining trend for the period 1967-2007.

Superimposed on the rainfall departures is the pattern of annual average discharge for the Chassahowitzka, Weeki Wachee, Rainbow and Silver rivers. The estimate of Chassahowitzka discharge could not be hind cast further than 1967. The magnitude of discharge varies with system, and in order to compare these systems, each respective flow record was divided by the respective annual average discharge for the period 1967-2007. In all cases, the pattern of spring discharge closely resembles the pattern of cumulative rainfall differences.

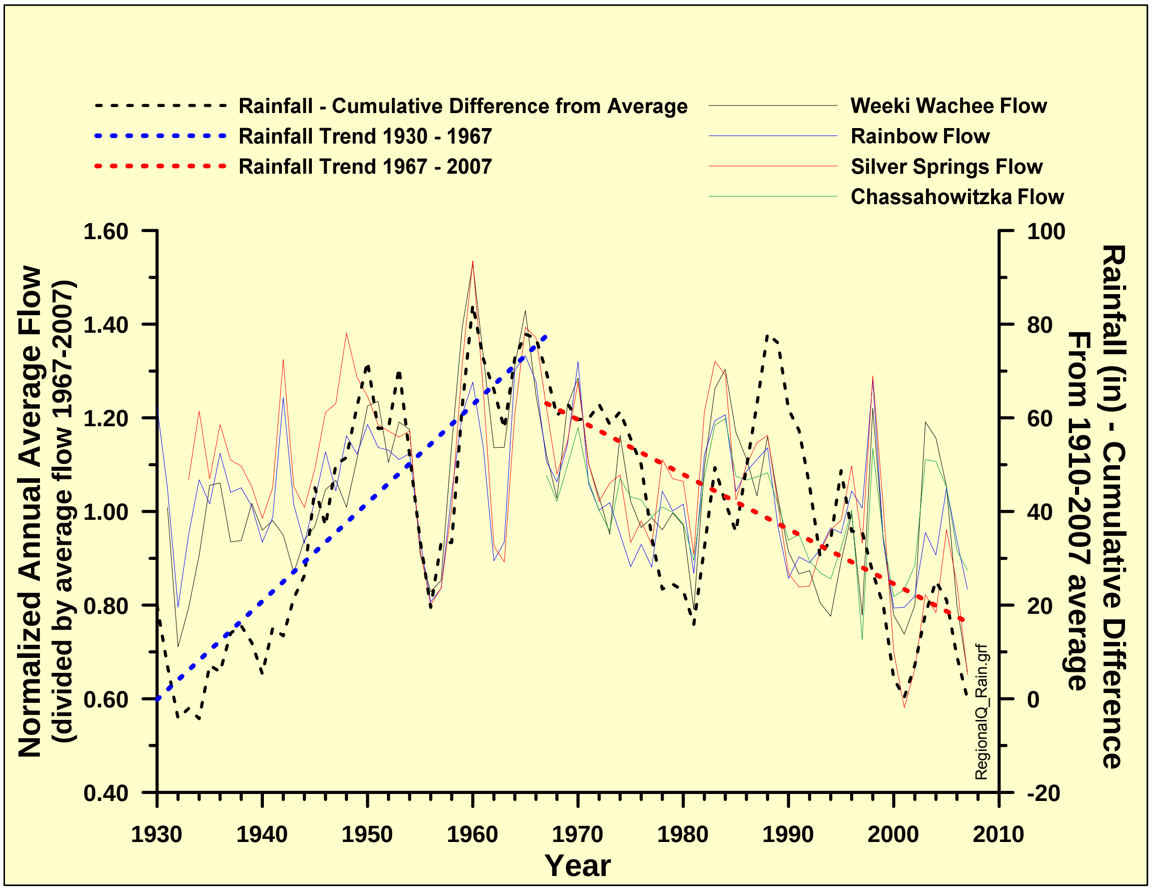


Figure 2-7. Brooksville rainfall departure from normal and regional spring discharges. See text.

2.5 Historical Discharge Measurements

In addition to the current USGS discharge estimates at station 02310650 which began in 1997, there are at least 143 historical measurements taken below Crab Creek and dating back to the 1930s. However, these results are of limited practical value for the MFL evaluation because over 90 percent of them represent only a single point measurement during a calendar day. This site is affected by tides and in order to obtain an accurate estimate of discharge, multiple measurements must be completed over the entire tide cycle. Figure 2-8 illustrates the problem associated with a single measurement of discharge in a tidally affected system. Figure 2-8 represents a time series of discharge at site 02310650 on May 9, 2012. If the single discharge measurement representing discharge on this day were taken at midnight, the flow would be + 100cfs (toward the Gulf of Mexico). On the other hand, if the single measurement were taken at 6:00 AM the flow would be -30 cfs (incoming flow). The USGS reported the May 9 average daily flow as +46 cfs. Comparison of these three flows (+100, +46 and -30 cfs) illustrates how misleading it would be to represent net daily flow using a single daily observation in a system that is so strongly affected by tides.

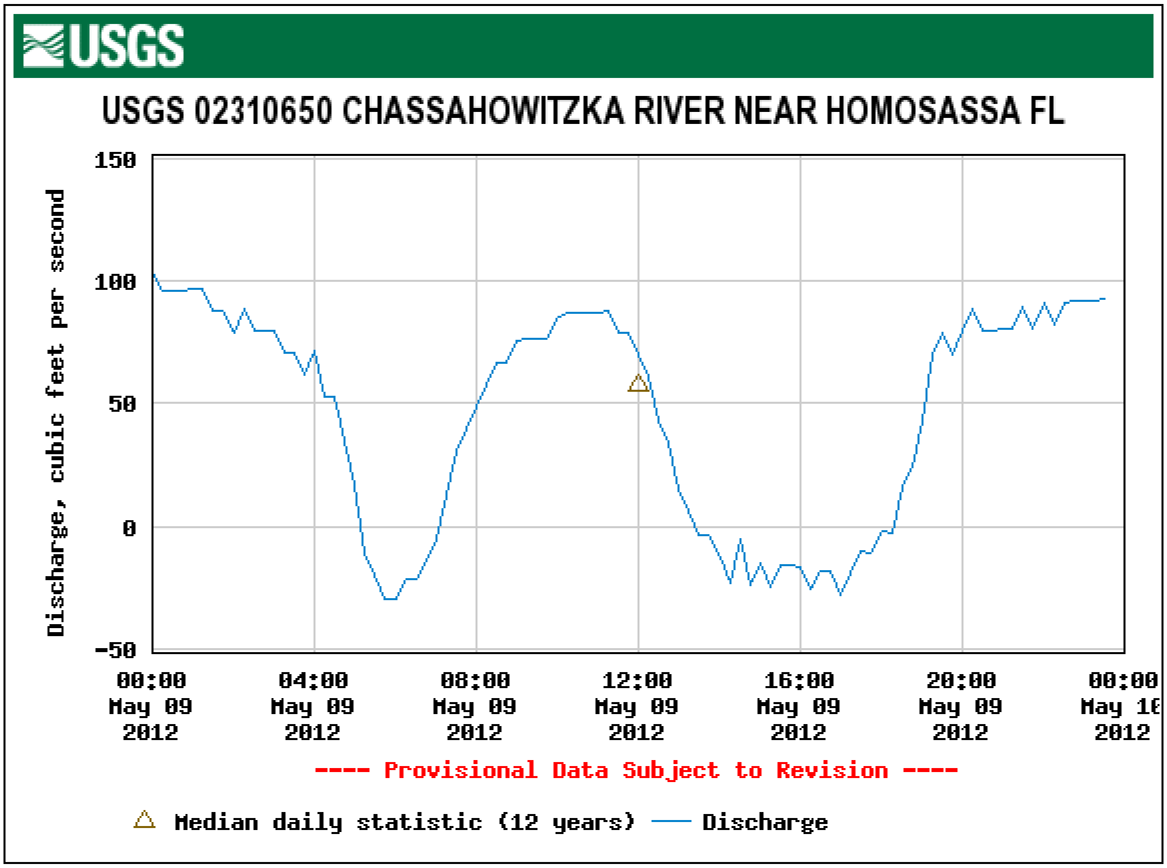


Figure 2-8. Chassahowitzka discharge May 9, 2012.

2.6 Ungaged Flow Estimates

It has long been recognized that the minor springs in the Chassahowitzka system collectively contribute a substantial amount of flow, but virtually all are tidally influenced and thus difficult and expensive[8] to gage. In addition to a changing hydraulic head, during flood tide much of the surrounding marsh is inundated. Separating these transient storage and head pressure changes from net discharge is difficult at best. Periodic measurements (Yobbi and Knochenmus 1989, Knochenmus and Yobbi 2001) have been made on most of the minor springs in the system, but none have exhibited a consistent discharge pattern or salinity as evidenced by the results in Table 2-4. Dynamic Solutions LLC (2009) combined data (Table 2-5) from Champion and Starks (2001) and Dixon and Estevez (2001) to develop average flow and salinity values as input to the hydrodynamic model.

[8] The estimated cost to install and continuously measure discharge for five years at the springs listed in Table 2-5 is $1.5M.

Table 2-5.Discharge information for several springs in the Chassahowitzka Group. (Dynamic Solutions LLC, 2009)

Spring Name	Average discharge (cfs)	Average Salinity(ppt)
Crab Creek	48.7	3.2
Potter Creek	18.6	5.5
Baird Creek Head Spring	5.6	6.5
Beteejay Springs	6.4	< 1
Blue Run Head Springs	6.6	4.3

In lieu of measuring the individual springs, two sampling events were undertaken (VHB 2008a, 2008b) by D. Yobbi (USGS retired) to characterize the magnitude of ungauged flow to the river. Transects were established at Rkm 1.5 and Rkm 3.5.

The first sampling event took place over a 4-hour period on January 10, 2008 and resulted in 32 discharge estimates at the upstream site and 18 estimates at the lower site. Over this period of observation, an increase of 90 cfs was measured. On March 27 these transects were monitored again over a 9 hour period with approximately 35 discharge measurements at each location. Regressions were established with USGS gauge 02310650 for various time lags. The investigators concluded:

> *Following review of the difference in discharge between the USGS site and the sampling transect sites; it is believe that ungaged seepage estimates below the USGS discharge site can be quantified on a limited basis using the field measurements and the regression equations. Differences in discharge and seepage estimates between the two transect sampling sites is highly dependent on river discharge above the transect sampling sites..… A better approach to quantifying discharge to the lower part of the Chassahowitzka River would be to measure individual spring runs below the USGS discharge site on a quarterly basis ….* (See Section 11.3 for original letter reports)

In lieu of additional discharge measurements of the individual spring runs, the District completed the MFL evaluation using the available discharge estimates at the USGS 02310650 site since 1997 and hind cast discharge as described in Section 2.3.1.1. It should be noted that the habitat (salinity volume, bottom area, shoreline length, and thermal habitat) MFLs derived from the hydrodynamic model (Section 7.3) were based on USGS reported flows, while the long-term (1967-2007) flows were used to develop the salinity regression model described in Section 4.2. Both flow records included adjustments for existing withdrawal impacts as described in the Section 2.3.1.1.

CHAPTER 3. ESTUARY CHARACTERISTICS

3.1 Physical

3.1.1 Linear

The Chassahowitzka River flows west approximately 2.5 miles from the headsprings area to the beginning of the associated coastal marsh complex, and then another 2.5+ miles to the Gulf of Mexico. The channel of the Chassahowitzka River ranges from 50 to 200 feet wide at its headwaters, and about 500 to 1,200 feet wide and about 5 to 15 feet deep near the Gulf of Mexico. The river is tidally affected along its entire length (Yobbi and Knochenmus 1989) and thus, navigable depth is dependent on local tide stage. Often, the river is barely navigable, a fact noted by surveyors as early as 1859.[9] The majority of stream discharge emanates from the headsprings; however, several smaller spring runs (Crab, Baird, and Potter creeks) in the upper river contribute additional flow. Tidal cycles influence both spring discharge and flow within the river (Yobbi 1992).

Surface waters in this stretch of the coast are also affected by several forcing functions not exerted on inland waters (Wolfe 1990) .Winds play a major role in setting up circulation on the shallow coast, resulting in a net long-term movement of coastal waters north and west during late spring, summer and early fall. In contrast, during the winter months a net circulation to the south and east results from the winds associated with passage of cold fronts. Short-term convective onshore/offshore forcing functions characterize the summer months.

3.1.2 Area / Volume (Adapted from Dynamic Solutions, LLC 2009)

The University of South Florida completed a bathymetric survey of the Chassahowitzka River System in 2007. Transects were collected at a maximum spacing of 492 feet (Figure 3-1). These data were referenced to North American Vertical Datum of 1988 (NAVD88), and were converted to mean tide level (MTL) by shifting the elevations +3.15 inches (the average NAVD88 minus MTL for the stations at the National Oceanic and Atmospheric stations at Clearwater (8726724) and Cedar Key (8727520)).

A digital terrain model (DTM) was produced from the University of South Florida transects and estimated depths derived from the measured data. The DTM used a 10 meter by 10-meter grid that allowed the scale assessments of the depth and volumes. River distances upstream from the Gulf of Mexico were provided by District as geographic information system (GIS coverage and all data sources were normalized to this system. Cumulative and river segment area and volume estimates based on a mean tide water level and using the polygons provided in Figure 3-2.

[9] “The channel leading into the Chassahowitzka River is only navigable by very light craft drawing 2 or 3 feet. At low water it is nearly dry” 1859. In Raabe et al. 2004.

River area and volume values associated with approximate 0.5 km river segments and cumulative river reach values were determined using the digital terrain model and polygons that were based on a centerline segment GIS layer delineated in 100-m (328.1 feet) intervals (Figure 3-3). The tabular results are given in Table 3-1

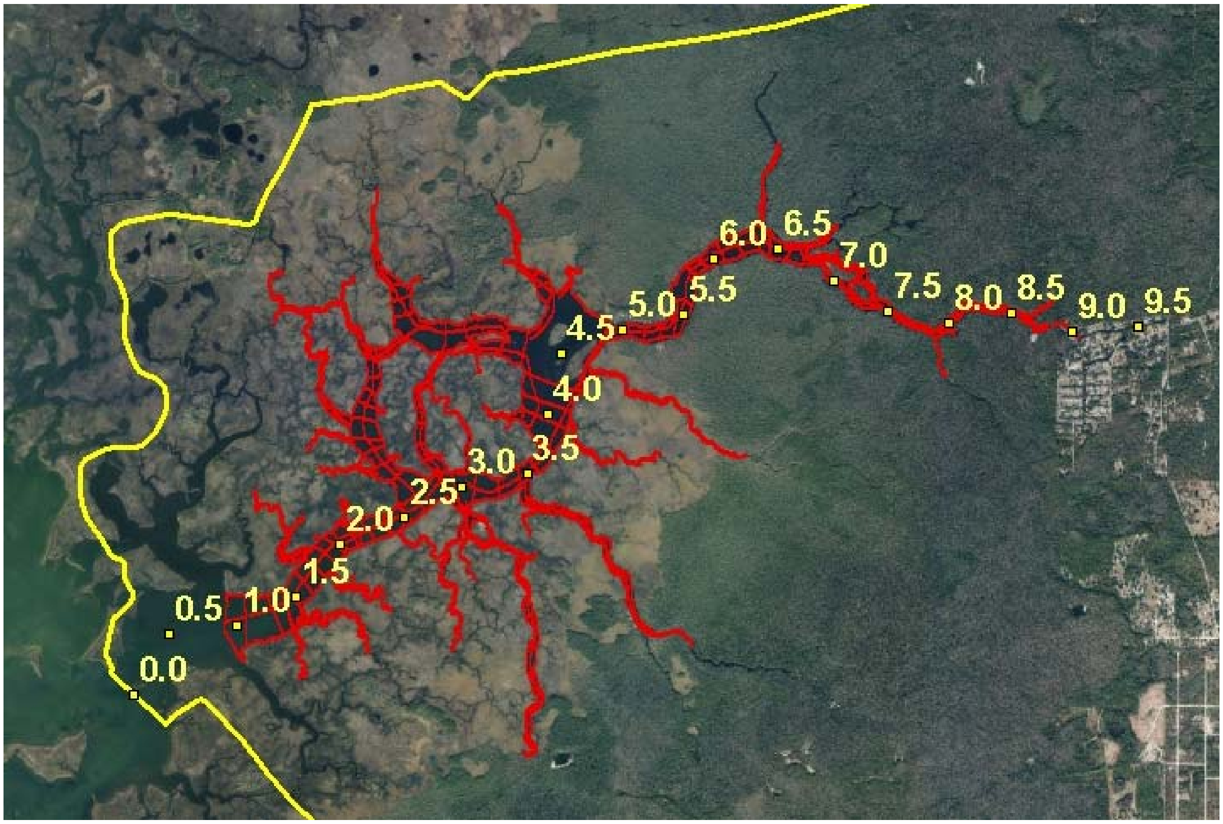


Figure 3-1. Location of bathymetric survey transects. (Red 'lines' consist of 95,485 discrete measurements.)

Bathymetric data presented in Table 3-1 were used to develop linear regressions for predicting cumulative upstream area, volume and shoreline lengths within the Chassahowitzka River for a mean tide water level (Dynamic Solutions, LLC 2009). Prediction of these morphometric parameters was necessary for modeling of salinity and biological responses used for determining minimum flow recommendations. The regressions took the following form:

Area = $-1522.2*Rkm^4 + 32925*Rkm^3 - 198581*Rkm^2 - 53880*Rkm + 2555100$, $Adj\text{-}r^2 = 0.993$;

Volume = $-1335*Rkm^4 + 26843*Rkm^3 - 131142*Rkm^2 - 340674*Rkm + 2879028$, $Adj\text{-}r^2 = 0.997$;

Shoreline length = $-0.115*Rkm^4 + 2.3117*Rkm^3 - 14.276*Rkm^2 + 17.645*Rkm + 66.915$, $Adj\text{-}r^2 = 0.988$;

where: RKm is the river kilometer location between Rkm 0 and Rkm 9.6, and
$Adj\text{-}r^2$ is the adjusted coefficient of determination for each model.

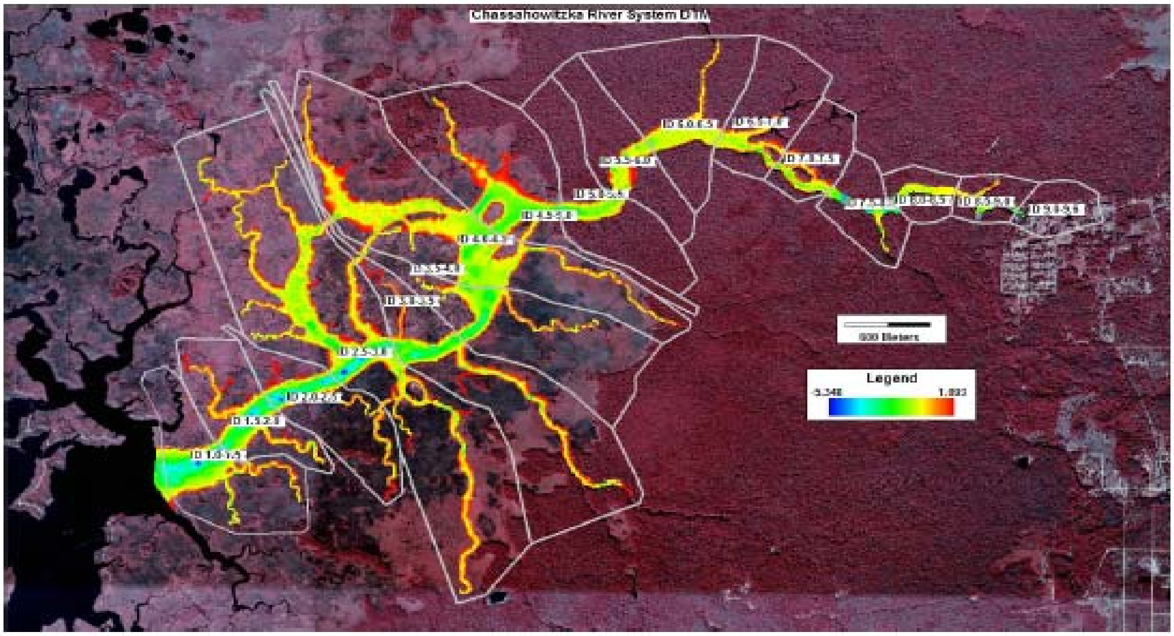


Figure 3-2. Area-volume segmentation polygons for the Chassahowitzka River system. (Best available image reproduced from Dynamic Solutions, LLC. 2009)

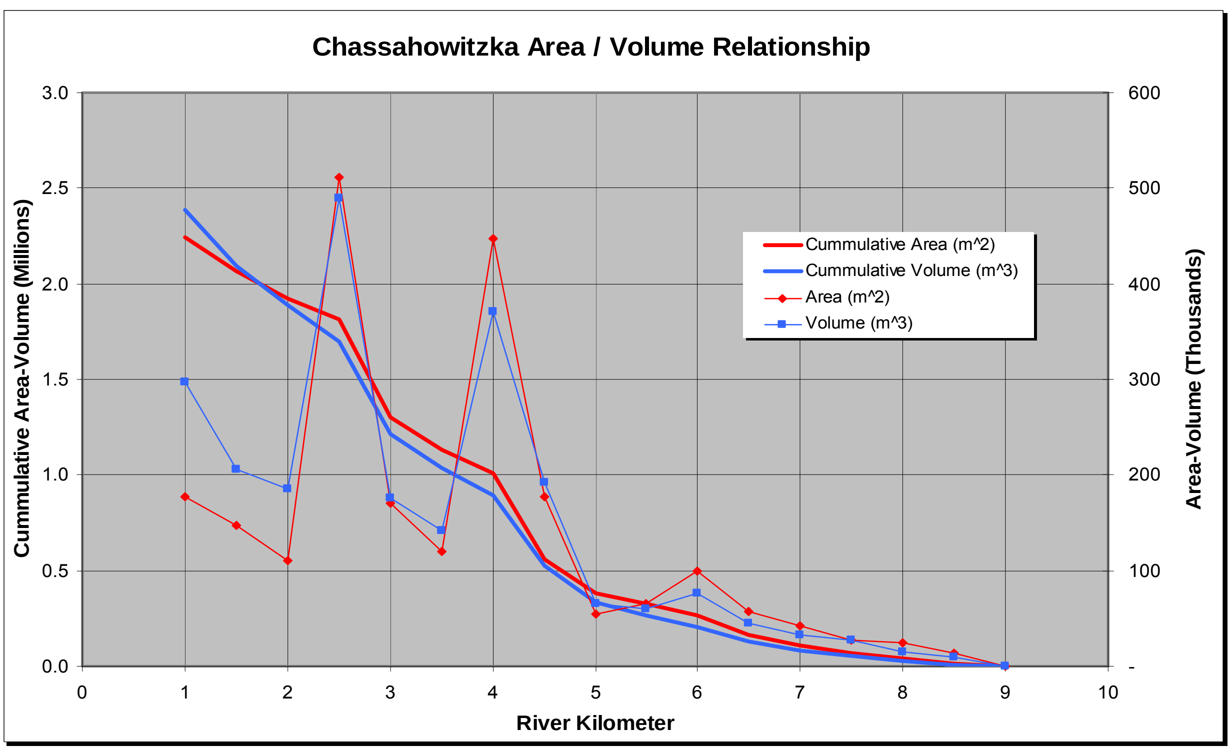


Figure 3-3 Cumulative upstream volume and area vs river kilometer at mean tide level.

Table 3-1. Volume, area and shoreline length by river kilometer for the Chassahowitzka River system.

Rkm ID	Rkm	Area (m^2)	Storage (m^3)	Length (km)	Average Depth (m)	Cumulative Area (m^2)	Cumulative Storage (m^3)	Cumulative Length (km)
1.0-1.5	1	177,300	296,908	2.498	1.67	2,245,800	2,388,000	68.959
1.5-2.0	1.5	147,200	205,239	4.684	1.39	2,068,500	2,091,092	66.461
2.0-2.5	2	110,800	184,959	4.555	1.67	1,921,300	1,885,853	61.777
2.5-3.0	2.5	510,700	489,935	19.449	0.96	1,810,500	1,700,894	57.222
3.0-3.5	3	171,000	175,353	7.183	1.03	1,299,800	1,210,959	37.773
3.5-4.0	3.5	120,600	142,344	4.052	1.18	1,128,800	1,035,606	30.59
4.0-4.5	4	447,600	370,316	10.024	0.83	1,008,200	893,262	26.538
4.5-5.0	4.5	177,300	191,605	4.334	1.08	560,600	522,946	16.514
5.0-5.5	5	54,400	65,838	0.988	1.21	383,300	331,341	12.18
5.5-6.0	5.5	65,300	59,501	1.049	0.91	328,900	265,503	11.192
6.0-6.5	6	98,900	76,005	2.315	0.77	263,600	206,002	10.143
6.5-7.0	6.5	57,000	45,152	1.774	0.79	164,700	129,997	7.828
7.0-7.5	7	42,100	32,563	1.727	0.77	107,700	84,845	6.054
7.5-8.0	7.5	27,500	26,998	1.734	0.98	65,600	52,282	4.327
8.0-8.5	8	24,000	15,619	1.011	0.65	38,100	25,284	2.593
8.5-9.0	8.5	13,800	9,593	1.441	0.7	14,100	9,665	1.582
9.0-9.6	9	300	72	0.141	0.24	300	72	0.141

3.2 Sea Level Change

Global sea level has been rising since the last inter-glacial period that ended approximately 22,000 years before present (BP). Balsilie and Donohoue (2004) have compared the rise in the Gulf of Mexico (GOM) with global sea level rise (Siddall et al. 2003) and concluded the similarity is sufficient to consider GOM results to be representative of global sea level history. Figure 3-4 is adapted from Balsillie and Donohoue (2010) and illustrates that approximately 20,000 years BP, sea level was 120 meters (~ 400 feet) lower than the present level and the shoreline was approximately 60 nautical miles west of present shoreline. Approximately 100,000 years prior to that (120,000 BP) in the late Pleistocene age, sea level was about six meters (~20 feet) higher than present. For reference, the town of Chassahowitzka would have been submerged under ~13 feet of water. Sea level change (SLC) has already begun to affect coastal vegetation throughout the springs coast area (See Section 3.5 for additional discussion on impacts)

The rate of SLC is subject to debate. Figure 3-5 presents the measured effects at Cedar Key10 and St. Petersburg11. The average of these two sites is 0.08 inches/yr (2.08 mm/yr). Recent trend has been linear, but several authors (see review by Woodworth et al. 2009) have predicted exponential increases in the future. In contrast, Houston and Dean (2011) studied 57 tide sites with 60-156 years of data and concluded that there

[10] http://tidesandcurrents.noaa.gov/sltrends/sltrends_station.shtml?stnid=8727520
[11] http://tidesandcurrents.noaa.gov/sltrends/sltrends_station.shtml?stnid=8726520

has not been an acceleration in sea level change during the 20th century. Thirty of the sites showed a slight deceleration in rate, while twenty-seven showed slight accelerations. Overall, a mean deceleration of 0.001 mm/y2 (0.00006 inches/yr2) was noted. The United States Army Corps of Engineers (USACE) has issued guidance (2011) for the design of coastal projects that incorporates the historic trend as the low estimate and several accelerated rates as increasingly severe impacts. Figure 3-6 illustrates the projection of SLC using the observed trend and the highest, lowest and an intermediate curve from the USACE guidance. Projecting to 2030, sea level at Chassahowitzka is estimated to rise between 2.1 and 7.7 inches.

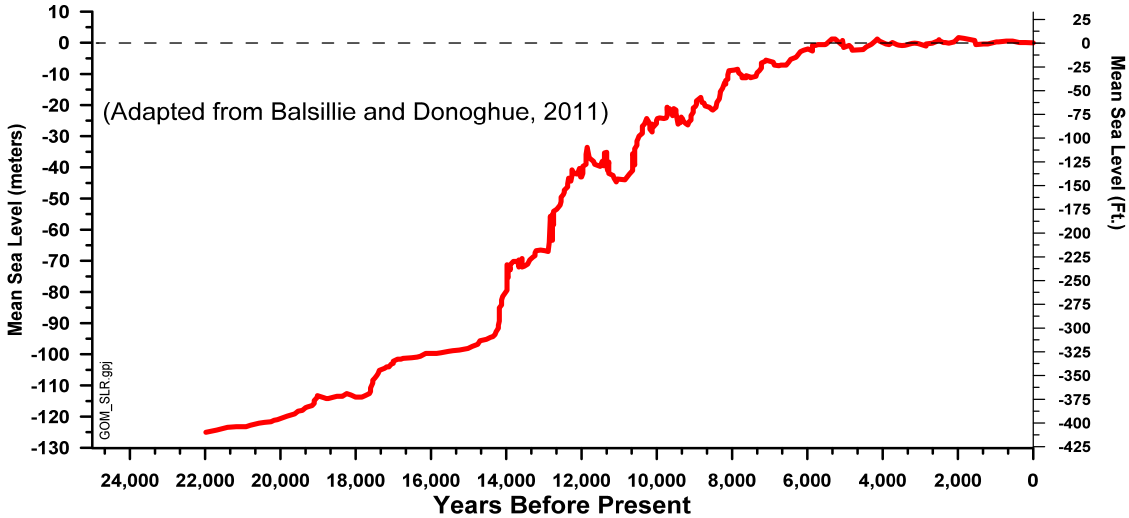


Figure 3-4. Gulf of Mexico sea level rise.

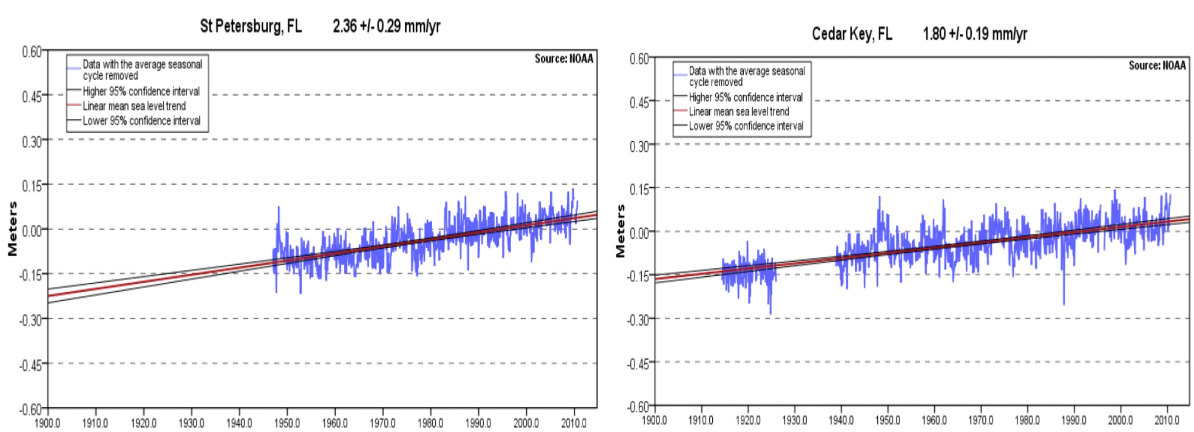


Figure 3-5. Sea Level Change - St. Petersburg and Cedar Keys Florida

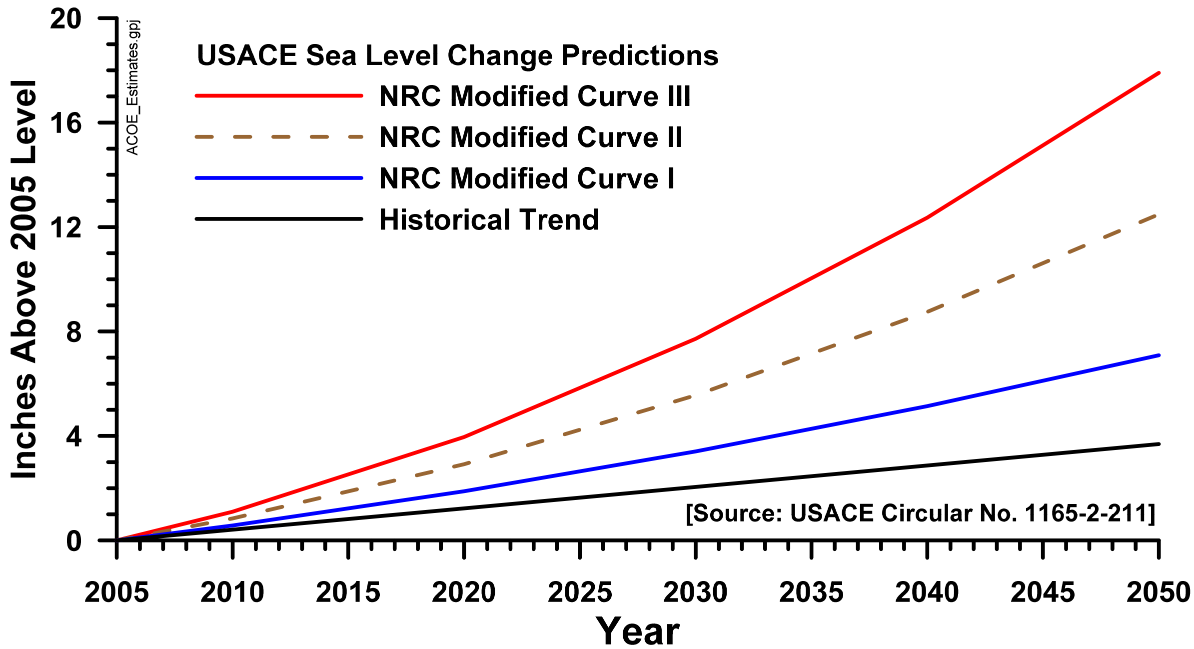


Figure 3-6. Estimates of sea level change.

3.3 Bottom Habitats

Submerged aquatic vegetation occurs throughout most of the river with a gradual decline in density with distance downstream. Common macrophytes include American eelgrass (*Vallisneria americana)*, sago pondweed (*Potamogeton pectinatus*), southern naiad (*Najas guadalupensis)* , Eurasian water milfoil *(Myriophyllum spicatum)*, and hydrilla (*Hydrilla verticillata)*. Filamentous macroalgae, including *Lyngbya* sp. and *Chaetomorpha* sp., are also abundant.

An extensive marsh system occurs at the mouth of the river and upper estuary. Seaward of the marsh, the water is generally shallow and interspersed with numerous islands. Some patchy seagrass exists in the estuary seaward of the marsh complex, but macroalgae are more prevalent (Dixon and Estevez 2001). Both attached macroalgae (e.g., *Caulerpa* spp.) and unattached (drift) forms are frequently observed in this estuary.

The physical and chemical characteristics of the Chassahowitzka River are generally favorable for growth of SAV. Mote Marine Lab (MML) conducted seven surveys from 1996 through 2000 (Dixon and Estevez 1997, 1998, 2001. Toutant et al. 2004) and sampled from Chassahowitzka Main spring to a radius of stations approximately 9.6 km offshore. Environmental Monitoring and Assessment (EMAP)[12] protocols were used to identify 38 polygons, eight of which were within the river proper. Two stations were randomly selected in each of the polygons during each sampling episode resulting in 532 samples for the duration of this study. In addition to the SAV measurements, water quality samples were collected for instrument parameters, color, turbidity, chlorophyll, and nutrients at 20 of the polygons. Seventeen water quality samplings were conducted between May 1996 and May 2000.

[12] http://www.epa.gov/emap/

In 2005, MML (See Section 11.4 - Leverone 2006) returned to conduct an additional survey at 0.5 km intervals from Rkm 0 to Rkm 9. A transect was established at each of the nineteen intervals and ten quarter-meter square quadrats were analyzed along each transect (n=190).

During an overlapping multi-year (1998-2000) research project conducted by University of Florida (UF) (Frazer et al. 2001), macroalgae, submersed macrophytes, and the periphyton associated with submersed macrophytes were sampled from five stations along each of 20 regularly spaced (approximately 0.25 km) transects (n=100) from the main spring to the marsh complex Figure 3-7 illustrates the location of the MML and UF stations.

A complete listing of the macrophytes and macroalgae observed along with their frequency of occurrence in the Chassahowitzka River during the three sampling events conducted in 1998-2000 by UF (Frazer 2001) and the eight sampling events conducted by MML (Dixon and Estevez 2001, Leverone 2006) is provided in Table 3-2. The four highest frequencies are highlighted. Macroalgae was described by MML only as “drift” or “bare” species and is therefore not included in Table 3-2.

The most frequently encountered macrophytes were *Vallisneria americana*, *Myriophyllum spicatum*, *Potamogeton pectinatus* and *Najas guadalupernsis*. Of these, all exhibited temporal and spatial variability in their patterns of distribution. Time series of frequency as a function of river kilometer is depicted in Figure 3-8 for *Vallisneria americana*, *Myriophyllum spicatum* and *Potamogeton pectinatus*. No pattern could be discerned. Mote Marine Laboratory (Toutant et al. 2004) completed a detailed change analysis of their data and cite a number of factors that are suspected of contributing the variability. An intense progression of algal blooms (initially a blue green, followed by diatoms) persisted in the near coastal waters from Weeki Wachee to Crystal River from March until September 1998. Rainfall during late 1997 and early 1998 produced cumulative values well in excess of historical means, which influenced both surface, and groundwater flows. Mean monthly flows in the adjacent Withlacoochee River were approximately four times historical averages. The effect of reduced salinity and transparency resulted in a measurable loss of some species of SAV and an increase in unvegetated bottom areas in coastal areas of the Refuge.

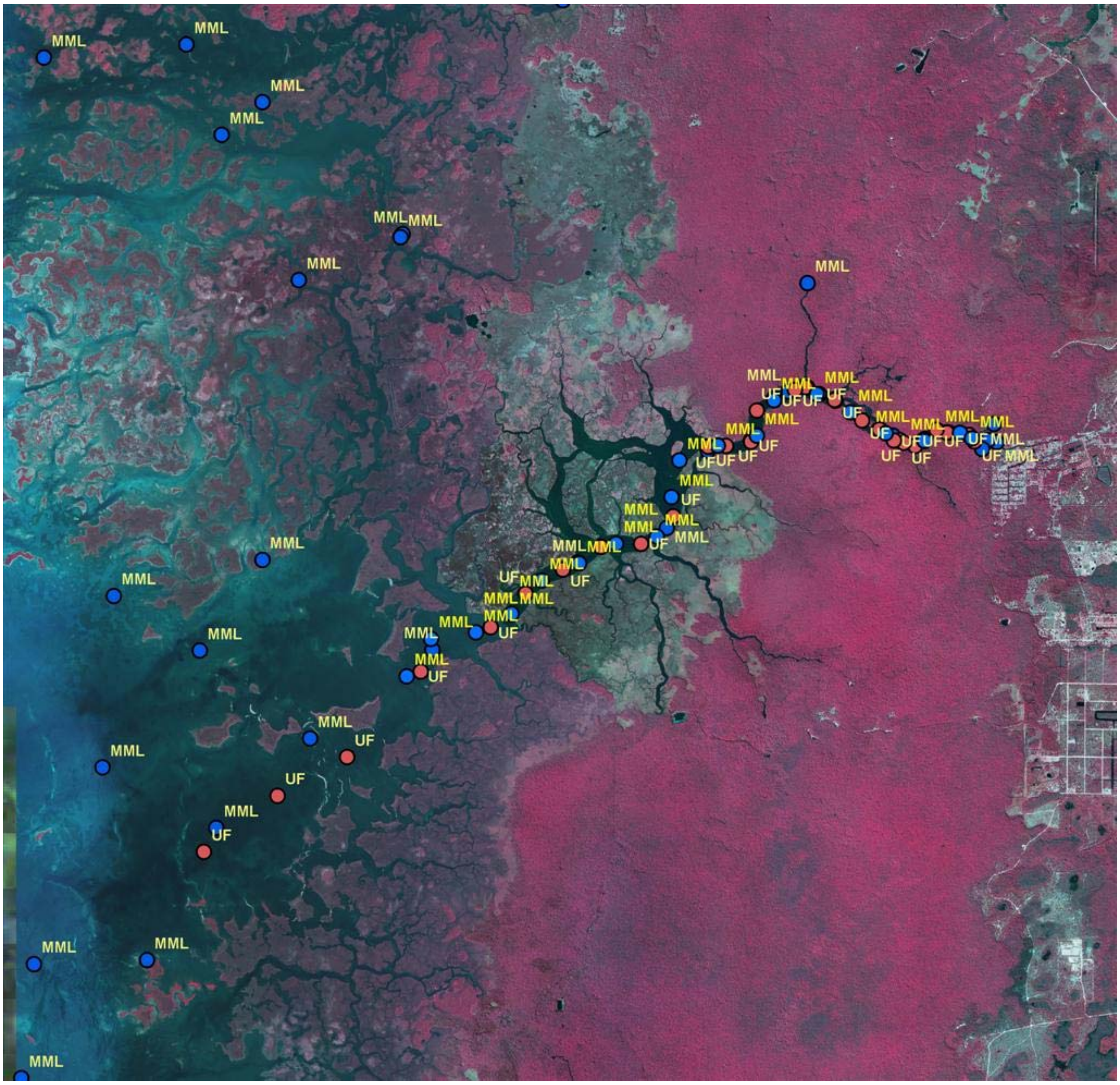


Figure *3-7*. SAV sampling locations - MML and UF 1996-2005

Table 3-2. Frequency of occurrence (% of stations sampled) of macrophyte and macroalgal species for the Chassahowitzka River by year for 1997-2006. The four most frequently encountered species are highlighted.

Year (source)	1997 (1)	1998 (1)	1998 (2)	1999 (1)	1999 (2)	2000 (1)	2000 (2)	2006 (3)	Average 1997 - 2006
Taxon									
Acetabularia crenulata	0	0	0	3	0	2	0		1
Ceratophyllum demersum	0	0	3	0	3	0	6	0	2
Chaetomorpha sp.	0	0	27	0	21	0	61	0	14
Chara spp.	0	2	0	0	0	0	0	0	0
Fontinalis sp.	0	0	0	0	0	0	1	0	0
Gracilaria sp.	0	0	1	0	4	0	22	0	3
Halodule wrightii	0	0	0	3	0	0	0	0	0
Hydrilla verticillata	13	11	48	9	18	3	13	10	16
Lyngbya sp.	0	0	29	0	35	0	26	0	11
Myriophyllum spicatum	22	27	17	34	12	4	11	35	20
Najas guadalupensis	22	6		9	49	2	26	12	18
Potamogeton pectinatus	22	17	33	25	25	2	21	18	20
Ruppia maritima	0	13	1	0	1	4	15	13	6
Sagittaria kurziana	0	0	2	0	3	0	0	0	1
Thalassia testudinum	0	2	0	0	0	0	0	0	0
Unvegetated	25	20	0	0	0	5	0	0	6
Vallisneria americana	22	14	38	16	34	2	23	19	21
Zanichellia palustris	0	0	0	0	0	0	0	5	1
Misc. Algae (Drift/Filamentous) (includes *Lyngbya sp.*)	63	59	0	84	0	15	0	0	28

Sources: 1) Dixon and Estevez, 2001 2) Frazer et al. 2001 3) Leverone 2006 frequency.xls

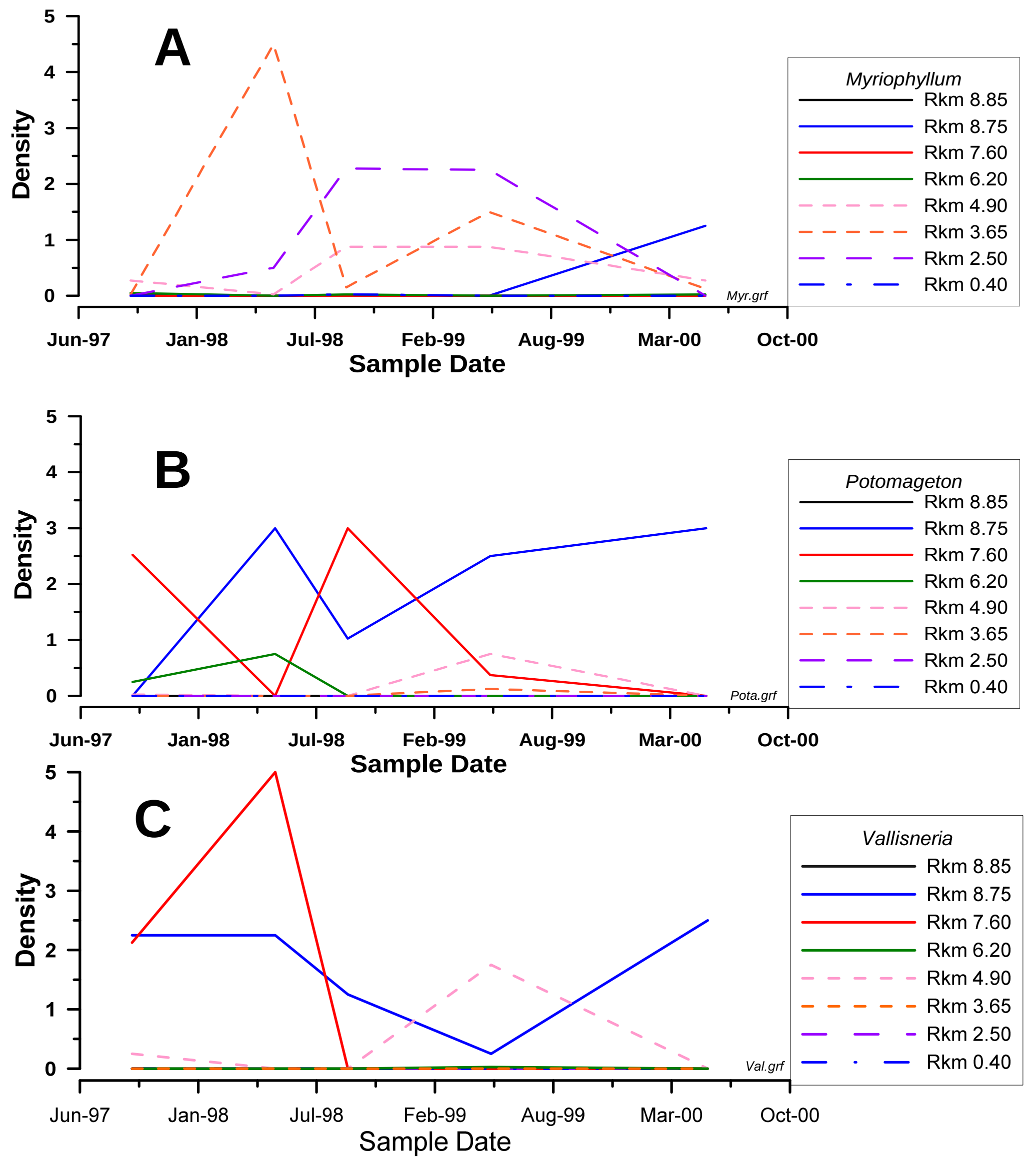


Figure 3-8.Spatial and temporal variation in density (# / m2) of three common species of SAV in the Chassahowitzka River. Lines represent changes over time for a particular taxa and location in the river (Data from Dixon and Estevez 2001).

3.4 Sediments

In general, the bottom sediments in the Chassahowitzka River are dominated by sand and mud or a combination of the two substrate types (Frazer et al. 2001). The nature of the bottom substrate is generally determined by stream velocity. Sand, silt and mud are typical of streams with low to moderate flows, like the Chassahowitzka River (Clewell et al. 2002). Characterization of sediments in the river appears to be limited to those samples collected in 1996 by Mote Marine Laboratory (Dixon and Estevez 1998) and again in 2005 in association with benthic community analysis reported by Janicki Environmental Inc. (2006). (See Section 11.5) Based on analysis of core samples sieved through a 2-mm mesh (see Leverone 2006 for methods used), Janicki Environmental, Inc. (2006) note that sediments downstream from Rkm 5 in 2005 were primarily fine and very fine sands with a mean grain size between 62.5 and 250 µm (mean Krumbein phi (φ) scale values between 2 and 4) (Figure 3-9). Medium and coarse sand-sized particles ranging in size from 0.25 to 1 mm (φ between 0 and 2) dominated the upstream sediments. Fine-grained sediments (silts and clays) accounted for ~30 percent of the sediment volume near the mouth of the river, more than 50% of the volume at Rkm 4.5, and ~15% of the sediment volume at Rkm 8 (Janicki Environmental, Inc. 2006) The peak in silt and clay distribution at Rkm 4.5 roughly corresponds to the transition zone between deciduous forest and marsh. Similar patterns in the distribution of fine and coarser-grained sediments and silt plus clay were observed by Dixon and Estevez (1998) based on analysis of un- sieved core samples collected in 1997.

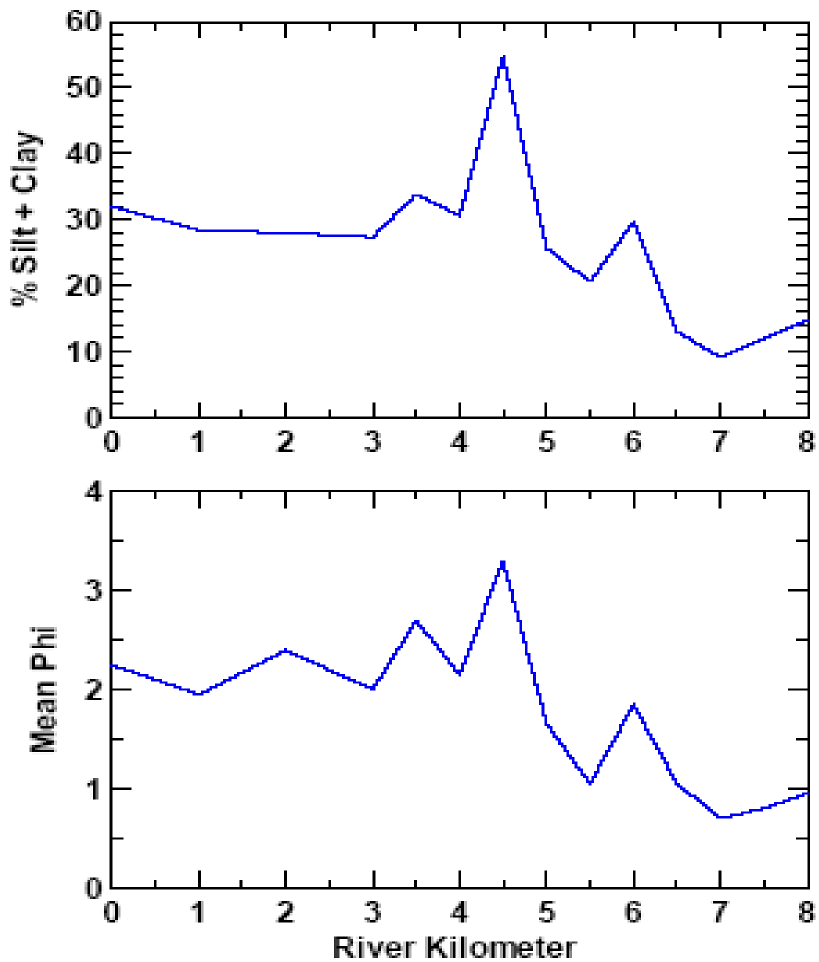


Figure 3-9. Mean percentage silt plus clay by volume (upper panel) and grain size (Krumbein phi value, lower panel) by river kilometer in 2-mm sieved sediment core samples collected from the Chassahowitzka River in May and September 2005 (reproduced from Janicki Environmental, Inc. 2006).

3.5 Tidal Wetlands and Riparian Habitats

The Chassahowitzka River is imbedded within an extensive tidal forested wetland system that transitions to saltwater marsh approximately 4 km downstream from the river headwaters. This transition and the extent of wetlands surrounding the river channel are evident in aerial photography of the region. Characterization of these coastal wetlands has been the focus of numerous reports completed during the past two decades. For example, Simons (1990) and Wolfe et al. (1990) provide a general overview of wetland and upland vegetation for the area known as the Springs Coast, an extensive portion of the west coast of Florida ranging from the Pithlachascotee River basin northward to the Waccasassa River basin. Other studies, including those completed by the Southwest Florida Water Management District (1989), Kelly (1994), Florida Marine Research Institute (1997), Dixon and Estevez (1998), Frazer et al. (2001a, b), Clewell et al. (2002), Hoyer et al. (2004), Toutant et al. (2004) and Frazer et al. (2006) provide specific information on the vegetative communities associated with the Chassahowitzka River.

Common tree species in the forested wetland systems surrounding the river include red maple (*Acer rubrum*), cabbage palm (*Sabal palmetto*), southern red cedar (*Juniperus virginiana* var. *silicicola*), sweetbay (*Magnolia virginiana*), laurel oak (*Quercus laurifolia*), water oak (*Quercus nigra*), sweetgum (*Liquidambar styraciflua*), pignut hickory (*Carya glabra*), basswood (*Tilia caroliniana*) and bald cypress (*Taxodium distichum*). Emergent and submersed aquatic vegetation in the upper river include tape grass (*Vallisneriaspp.*), sago pondweed (*Potamogeton pectinatus*), Illinois pondweed (*Potamogeton illinoensis*) water milfoil (*Myriophyllum spicatum*), hydrilla (*Hydrilla verticillata*), southern naiad (*Najas guadalupensis*), cattail (*Typha* spp.) and reeds (*Phragmites spp*.). Marine and freshwater algae, including *Chaetomorpha, Cladophora, Enteromorpha, Gracilaria*, *Lyngbya and Schizothrix* are commonly found in the upper and lower portions of the river. Sawgrass (*Cladium jamaicense*), cattail, widgeon grass (*Ruppia maritima*), cabbage palm, and black needlerush (*Juncus roemerianus*) are common at the interface or transition zone between the forested wetland and salt marsh systems. Black needlerush is the dominant salt marsh plant in the Chassahowitzka area.

The shoreline of the Chassahowitzka River was characterized along with six other rivers on the west coast of Florida by Clewell et al. (2002) (See Section 11.6) in a study designed to compare vegetation distribution and salinity across multiple systems. Field studies were conducted in 1989 and 1990 and compared to long-term salinity records. The focus of the field collection was to describe the distribution of herbaceous plants (including dominant marsh species) along the riverbank. Presence / absence was recorded for each plant species. A total 84 sites were investigated along the Chassahowitzka River, and 42 species were identified as depicted in Table 3-3.

Using data from all seven rivers, Clewell et al. (2002) noted several potential vegetation breaks. After analysis of several factors, the authors concluded “ breaks in vegetation that seem apparent as one travels by boat may be indicative of general salinity conditions but are not reliable as predictors of specific salinity regimes.” Factors cited as contributing to a lack of good correlation between plant occurrences and salinity included the narrow nature and relatively high frequency of disturbance of riverbank habitat with respect to adjacent marsh or forested habitats.

On a relatively coarse scale, land-use/cover information available from the Southwest Florida Water Management District Mapping and GIS Section provided a means for evaluating tidal wetland and riparian habitats associated with the Chassahowitzka River. For this purpose, land use/cover in a 1,640-foot buffer area surrounding a polygon approximating the location of the main stem of the river (Figure 3-10) was used to clip geospatial polygons assigned classifications based on the Florida Land Use, Cover and Forms Classification System (Florida Department of Transportation 1999). Geospatial data processing was conducted using ESRI ArcMap and Geographic Information System layers representing land use/cover classifications for the area in 1990, 1995, 1999 and 2004 through 2007 (Southwest Florida Water Management District 2003a,b, 2004a, 2007a,b,c, 2008).

Table 3-3. Percentage of Chassahowitzka sites where species occurred (Clewell et al. 2002)

Species	Percent of Occurrence
Cladium jamaicense	74
Juncus roemerianus	48
Typha domingensis	36
Crinum americanum	15
Sagittaria lancifolia	14
Acrostichum danaeifolium	13
Baccharis halimifolia	11
Myrica cerifera	11
Sagittaria subulata	11
Aster carolinianus	9
Senecio glabellus	9
Persea palustris	8
Rumex verticillatus	8
Distichlis spicata	6
Magnolia virginiana	6
Samolus valerandi	6
Solidago stricta	6
Alternanthera philoxeroides	5
Lythrum alatum	5
Scirpus americanus	5
Spartina alterniflora	5
Cicuta maculata	4
Lycium carolinianum	4
Sabal palmetto	4
Saururus cernuus	4
Acer rubrum	3
Cornus foemina	3
Iris hexagona	3
Itea virginica	3
Paspalidium geminatum	3
Scirpus robusta	3
Ampelopsis arborea	1
Aster tenuifolius	1
Boehmeria cylindrical	1
Carya aquatica	1
Ilex cassine	1
Phragmites australis	1
Pluchea odorata	1
Pontederia cordata	1
Quercus geminata	1
Tilla caroliniana	1
Ulmus americanus	1

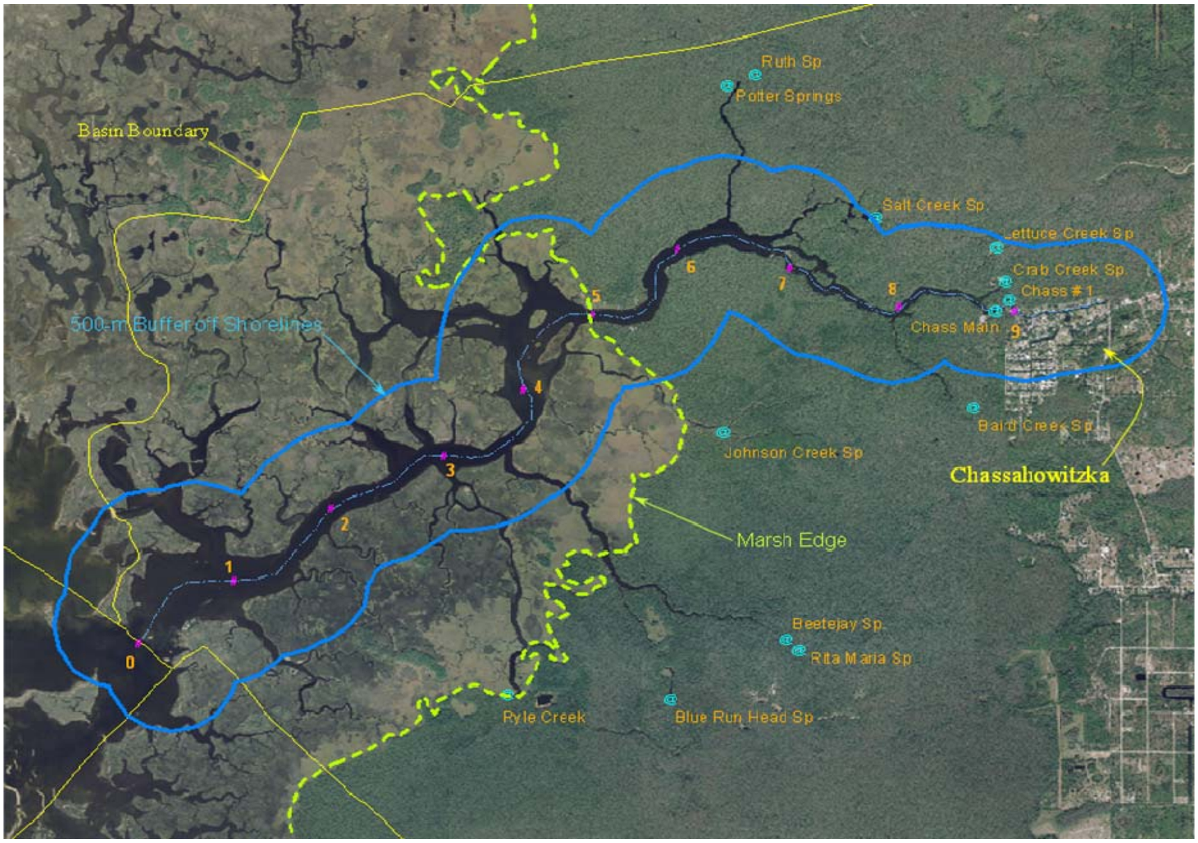


Figure 3-10. Aerial photograph illustrating the 1,640 foot (500 m) buffer used for land use/cover analyses and the approximate marsh edge in the vicinity of the Chassahowitzka river system.

The Chassahowitzka River transitions from freshwater forest to saltwater marsh at approximately Rkm 5. There is a notable vegetation demarcation visible in aerial photographs of the system (Figure 3-10), which identifies the location of the extensive saltwater marsh system. Vegetation at the transition zone of the Chassahowitzka has undergone significant and rapid change in the Chassahowitzka including extensive tree die-off (Figure 3-11). With the exception of the Bays and Estuaries and Gulf of Mexico land use/cover classes, land use/cover in the river buffer area exhibited little change in the years examined between 1990 and 2007 (Table 3-5). Land classified as Bays and Estuaries declined from 1,200-acres in1990 to 874 acres in 2004. In contrast, lands classified as Gulf of Mexico increase from 0 acres in the 1999 to approximately 300 acres in the 2004. Lands classified as Salt Marsh covered approximately 1,400 acres in 1990 and approximately 1,420 acres in all subsequent years examined. Inter-annual differences in other land use/cover classifications were generally only a few acres.

Tidal wetlands associated with coastal rivers of the southeastern United States and elsewhere are susceptible to change associated with droughts, anthropogenic alteration of natural freshwater inflows or groundwater discharge, land-use changes, hurricanes and other storms, climate change, sea-level trends and sediment or substrate subsidence (e.g., see Boesch et al. 1994, Brinson and Malvarez 2002, Kennish 2004, Doyle et al. 2007, Stedman and Dahl 2008)

Table 3-5. Land-use by acre for a 1,640-foot buffer area around and including the main stem of the Chassahowitzka River as shown in Figure 3-11. Land use/cover classes based on the Florida Land Use, Cover and Classification System (Florida Department of Transportation 1999).

Class	Description	LU1990 Acres	LU1995 Acres	LU1999 Acres	LU2004 Acres	LU2005 Acres	LU2006 Acres	LU2007 Acres
1100, 1200, 1300	Urban	79.3	79.5	82.8	86.0	86.0	86.0	86.0
1800	Recreational	0.0	2.2	2.2	2.2	2.2	2.2	2.2
3100	Herbaceous (Dry Prairie)	0.4	0.0	0.0	0.0	0.0	0.0	0.0
4340	Hardwood – Confer Mixed	5.3	5.7	5.7	5.7	5.7	5.7	5.7
5400	Bays and Estuaries	1200.0	1177.6	1177.6	873.5	873.5	872.9	872.9
5720	Gulf of Mexico	0.0	0.0	0.0	304.1	304.1	304.7	304.7
6110	Bay Swamps	4.6	4.1	4.1	4.1	4.1	4.1	4.1
6150	Stream and Lake Swamps (Bottomland)	980.6	982.7	981.4	978.2	978.2	978.2	978.2
6300	Wetland Forested Mixed	44.7	45.7	45.7	45.7	45.7	45.7	45.7
6420	Saltwater Marshes	1404.7	1423.9	1421.8	1421.8	1421.8	1421.8	1421.8
7400	Disturbed Lands	1.7	0.0	0.0	0.0	0.0	0.0	0.0
	Total	3721.3	3721.3	3721.3	3721.3	3721.3	3721.3	3721.3

Numerous investigators have considered the efects of salinity on changes in cypress-dominated and mixed bottomland swamps in tidal segments of southeastern coastal rivers. In a review of sea-level rise and coastal forests of the Gulf of Mexico, Williams et al. (1999) describe changes associated with sea level variation during the Holocene and summarize recent changes have been attributed to increased salinity in the Mississippi River delta and south Florida. Conner et al. (2007) and Krauss et al. (2007). Provide more recent summaries of saltwater induced changes in southeastern tidal swamps As part of a comprehensive review of tidal floodplain forests of the Suwannee River, Light et al. (2002) discuss potential increases in the abundance of salt-tolerant species under various flow-reduction scenarios. In the Northwest Fork of the Loxahatchee River in southeast Florida, recent decline of floodplain swamp vegetation, including bald cypress, has been associated with increased salinity (South Florida Water

Management District 2002). In response to this environmental loss and to preserve existing and stressed floodplain swamp communities, a minimum flow for the Loxahatchee River was established to maintain salinities less than 2 ppt at selected sites along the river corridor. Based on review of published salinity tolerance information for common tree species within tidal forested wetlands, including bald cypress and various hardwood species, the Suwannee River Water Management District (2005) also identified a 2 ppt salinity criterion for consideration in their development of minimum flows for the lower segment of the Suwannee River.

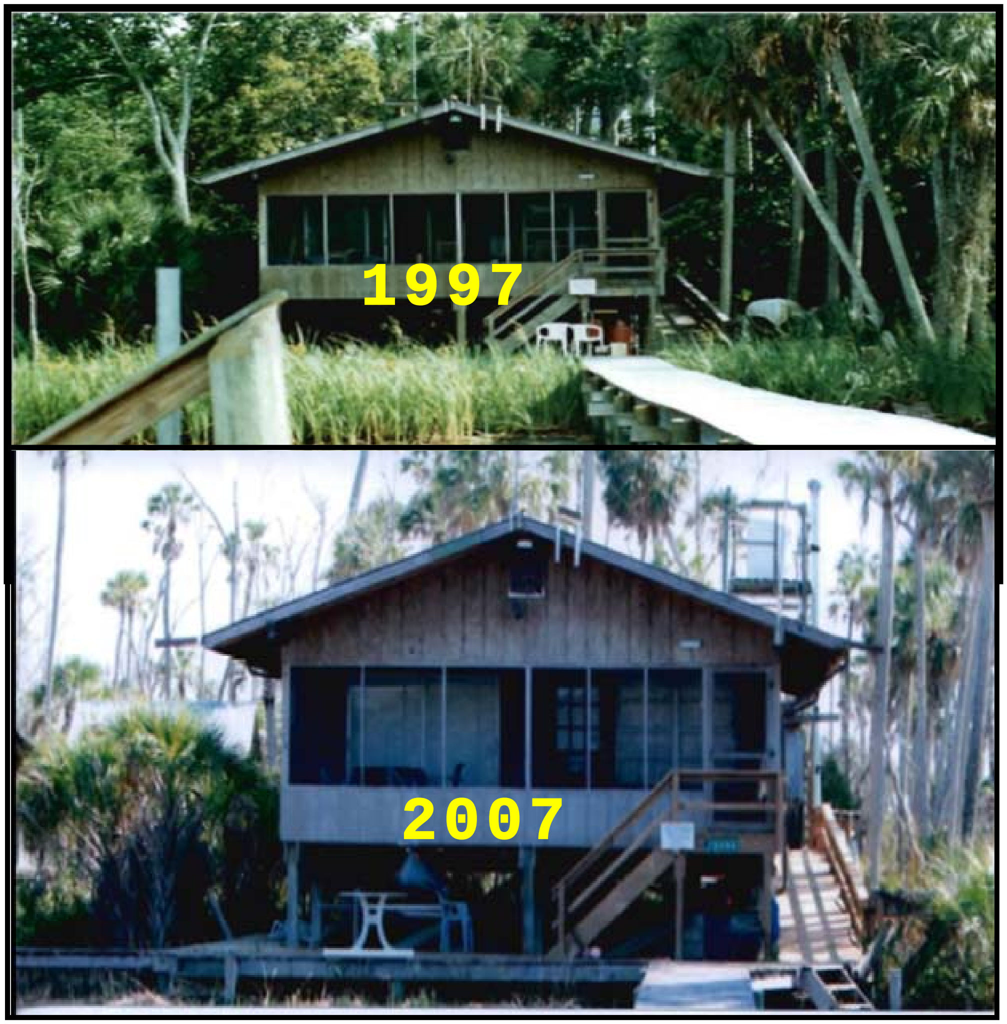


Figure 3-11. Vegetation changes at a site on the Chassahowitzka River, 1997 and 2007. (Photographs provided by M. Newberger.)

The effects of sea-level rise and increasing salinity have also been evaluated for hydric hammocks, a common forested wetland type extending along the west coast of Florida from the southern Hernando County line north to the vicinity of the St. Marks River. Reduction in the aerial coverage of hydric hammocks, which are typically dominated by cabbage palm, southern red cedar, a mixture of hardwood trees and loblolly pine (*Pinus taeda*), has been extensive during the past century (see review by Williams et al. 2007).

DeSantis et al. (2007) attributed recent declines in populations of cabbage palm and southern red cedar at Waccasassa Bay State Preserve to sea-level increase and drought, noting that recent rates of decline have exceeded predictions derived from previous studies of the area. Castaneda and Putz (2007) documented more than a 17 percent decline in coastal forest in the Waccasassa Bay State Preserve between 1973 and 2003 because of forest replacement with salt marsh species. Modeled wetland changes associated with various sea level increase scenarios for the St. Marks National Wildlife Refuge area also demonstrate potential increases in salt marsh habitat and losses in forested habitat with increased sea levels (Doyle et al. 2003). According to analyses conducted by Raabe et al. (2004), as cited by Williams et al. (2007), decline of hydric hammock vegetation along the Big Bend coastline of Florida since the mid-1800s has been less pronounced in areas with high freshwater discharge, e.g., near the Suwannee and Weeki Wachee Rivers. Field investigations of the survival of transplanted cabbage palm seedlings at Waccasassa Bay and at the Chassahowitzka National Wildlife Refuge (an area of relatively low salinity); provide some support for the mitigation of adverse salinity-effects in areas of higher freshwater discharge (Perry and Williams 1996). However, Williams et al. (2007) caution that “[g]ood quantification of the effect of freshwater discharge on the rates of forest canopy loss and coastal forest retreat requires further study.”

CHAPTER 4. TIDE, SALINITY & WATER QUALITY

4.1 Tide

The tides along the Springs Coast are mixed semidiurnal; a higher high and lower high tide, as well as a higher low and lower low tide, each day is possible. The Chassahowitzka River is tidally affected along its entire length and water levels normally fluctuate 0.5 to 1.0 foot near its headwaters. Salinity and flow relationships in the Chassahowitzka River were studied by Yobbi and Knochenmus (1989) using data on high tides, salinity, and flow. Tide-stage measurements were continuously collected at stations located 5.14 and 8.60 km (corresponding to Yobbi and Knochenmus's 2.70 and 4.85 river miles) upstream of the mouth of the Chassahowitzka River.

Table 4-1 provides a summary of tide-stage data for the Chassahowitzka River during 1984-1985. The average diurnal tidal ranges are approximately 2.1 feet near the mouth of the river. Seasonal variation exists, with tides being higher on the average in summer and fall than in winter and spring.

Table 4-1. Summary of monthly average tide-stage data for the Chassahowitzka River (Yobbi and Knochenmus 1989)

Tide	Period of Record	Month											
		Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Chassahowitzka River, Rkm 5.14													
Higher high	1984-1985	ND	1.66	1.87	1.86	1.68	1.67	1.64	1.97	ND	2.14	2.39	ND
Lower low	1984-1985	ND	-0.31	-0.39	-0.44	-0.55	-0.56	+0.45	-0.12	ND	-0.03	+0.19	ND
Chassahowitzka River, Rkm 8.60													
Higher high	1966-1978	1.91	1.88	1.84	1.76	1.81	1.92	1.99	2.05	2.06	1.99	1.99	2.05
Lower low	1966-1978	1.29	1.26	1.21	1.20	1.29	1.41	1.49	1.52	1.54	1.41	1.37	1.39
Stage data are in feet above or below sea level. 'ND' signifies no data.													

Yobbi and Knochenmus conducted multiple linear-regression analysis to relate the maximum upstream extent of 5- and 3-ppt salinities to daily mean discharge and recorded high-tide stage at Rkm 5.14. The results of their regression analysis indicated that discharge is the only independent variable that significantly affects the maximum upstream extent of the 5- and 3-ppt salinities. In 1988, Yobbi and Knochenmus wrote:

> *High tides between 1.50 and 2.55 feet appear to be of minor importance in substantially influencing the maximum extent of salinity intrusion, or else tide stage was confounded with discharge, and discharge alone is sufficient to describe location of the salinities.* [page 25]

4.2 Salinity – Longitudinal

Salinity in the Chassahowitzka River system varies from fresh to brackish at the headwater and increases sharply as water moves through the marsh and into the estuary, mixing with more saline Gulf of Mexico water. Frazer et al. (2001a, b) conducted sampling of the Chassahowitzka River during ten quarterly events between the summer of 1998 and the winter of 2000-2001. Between 2003 and 2005, Frazer et al. (2006) completed an additional 12 quarterly sampling events. Mote Marine Laboratory (Dixon and Estevez 2001) sampled in May and September from 1996 – 2004 and the District (unpublished data) sampled every other week from September 2007 through August 2008. A summary of the values is provided in Table 4-2 and is graphically depicted in Figure 4-1.

Table 4-2. Salinity by river kilometer, 1996-2008

Km Range	n=	Min	25th Pct	Mean	Median	75th Pct	Max
0.0-1.0	87.0	2.8	8.8	12.9	12.9	16.8	25.1
1.1-2.0	160.0	2.4	6.6	11.2	11.0	14.6	22.2
2.1-3.0	225.0	2.0	4.4	9.0	8.5	12.3	24.3
3.1-4.0	161.0	1.9	3.1	6.2	4.5	7.7	22.3
4.1-5.0	150.0	1.5	2.3	5.1	3.5	7.0	14.1
5.1-6.0	132.0	1.4	1.9	2.8	2.3	2.9	12.3
6.1-7.0	223.0	1.3	2.0	2.9	2.6	3.3	10.3
7.1-8.0	192.0	0.9	1.6	2.1	2.0	2.7	5.0
8.1-9.0	395.0	0.1	1.1	1.7	1.6	2.2	4.1

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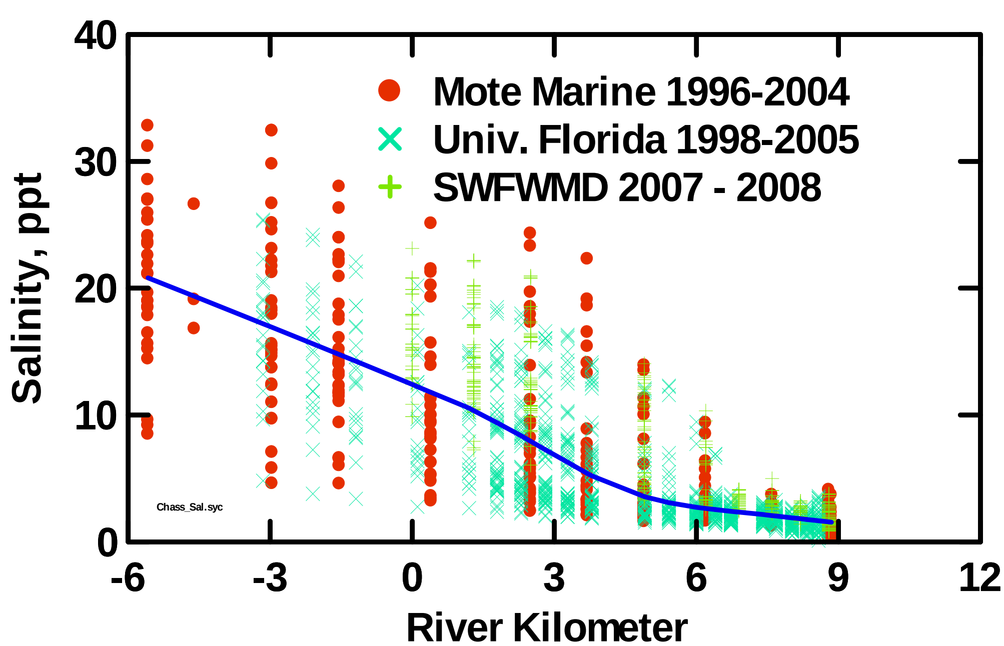


Figure 4-1. Longitudinal salinity 1996-2008

Salinity is a critical parameter for setting an estuarine minimum flow. Consequently, considerable effort was expended in an attempt to relate salinity to both the resources of concern as well as flow, which is the sole management option. Of necessity, numerous approaches were tested to determine the best technique for relating flow and salinity. This section and subordinate sub-sections include a description of observed salinity conditions and predicted salinity by river location.

Frazer et al. (2001a, b) recorded mean salinities in the Chassahowitzka River between 1.3 and 2.6 ppt at river kilometer 8.6. Within specific sampling periods, mean salinities were fairly uniform along the river above the marsh complex and were generally less than 5 ppt. Downstream of the marsh transition zone, mean salinity increased rapidly with distance into the estuary and significant variation in values among sampling periods was observed. The variation in mean values is a result of both the tidal stage at time of sampling and the discharge characteristics of the river. The highest recorded salinities were during periods when river flow was correspondingly low (Frazer et al. 2001a, 2001b).

The combined mean salinities recorded by Mote Marine Laboratory, University of Florida,and the District in the Chassahowitzka River were between 0.1 and 4.1 ppt near the headsprings (Rkm 8-9). At river kilometer zero, where the confined river ends, the mean and median salinity is 12.9 ppt and additional mixing with Gulf of Mexico waters occurs beyond Rkm 0. Mean salinities above the marsh complex were generally less than 5 ppt. Downstream of the marsh transition zone, mean salinity increased with distance into the estuary. Significant variation in values among sampling periods was observed in this segment of the Chassahowitzka River, which is similar to the 2001 results recorded by Frazer et al. (2001a, b)

Additionally, Yobbi and Knochenmus (1989) made the following observation:

> *The locations of low-concentration salinities appear to be less sensitive to changes in flow and tides and migrate over a smaller distance than high-concentration salinities. The 25-ppt salinity had a range in movement that was more than three times as great as the range in movement of the 3-ppt salinity.* [page 16]

Regressions predicting the salinity at locations along the Chassahowitzka River were developed. River kilometer, flow, and tide/stage were evaluated as candidate independent variables. This section describes the results.

A regression of the form below was evaluated to estimate salinity at any location along the Chassahowitzka River from -3 to +9 km. Several flow terms were investigated, including Flow, ln (Flow), and Flow $^{-1}$. The results were generally similar and the final form chosen used Flow, resulting in the following equation:

Salinity = $\beta_o + \beta_1$*Flow + β_2*Rkm

Where: Salinity in ppt,
Flow is spring flow (cfs), and
Rkm is river kilometer as previously defined.

The Chassahowitzka River estuary is reasonably well mixed vertically, and waters along most of the estuary are essentially uniform from top to bottom. Therefore, surface and bottom salinities are not distinguished in the regression analysis, which was based on the salinity data collected by MML during 1996 through 2004 (Dixon and Estevez 2001 supplemented with unpublished data from Dixon and Estevez), and by the District during 2007 through 2008 (unpublished data). In addition, the flow used in the regression refers to the discharge at Chassahowitzka headsprings (Heyl 2010) and does not include discharge from Crab Creek.

The investigation using data from both studies reached a strong correlation coefficient: Adj-r^2=0.74 (n=493). Because combining the data from the two studies increases the time span, the results from the combined data were adopted for the regression analysis, and the corresponding coefficients are presented below. The salinity regression is graphically depicted in Figure 4-2. Several outlier points (extreme-value salinities away from data cluster at certain river kilometers) were removed from the original data, and this treatment contributed to the improvement in correlation coefficient.

$$\text{Salinity} = 29.3749 - 0.2838 * \text{Flow} - 1.3678 * \text{Rkm}$$

This form has the advantage that one equation can be used to solve for position, flow, or salinity, once the other two terms are known or specified. This equation (herein termed the *longitudinal salinity model or,* LSM) was used extensively in evaluating the biologically based MFL criteria. In addition, the variant forms of the regression equation can be obtained through the following algebraic re-arrangement:

$\text{Flow} = (\text{Salinity} - \beta_o - \beta_2 * \text{Rkm}) * (\beta_1)^{-1}$

and

$\text{Rkm} = (\text{Salinity} - \beta_o - \beta_1 * \text{Flow}) * (\beta_2)^{-1}$

The longitudinal salinity profile under median impacted flow conditions (63 cfs) is given in Figure 4-2. Data includes observations during 1996-2004 (MML) and 2007-2008 (District).

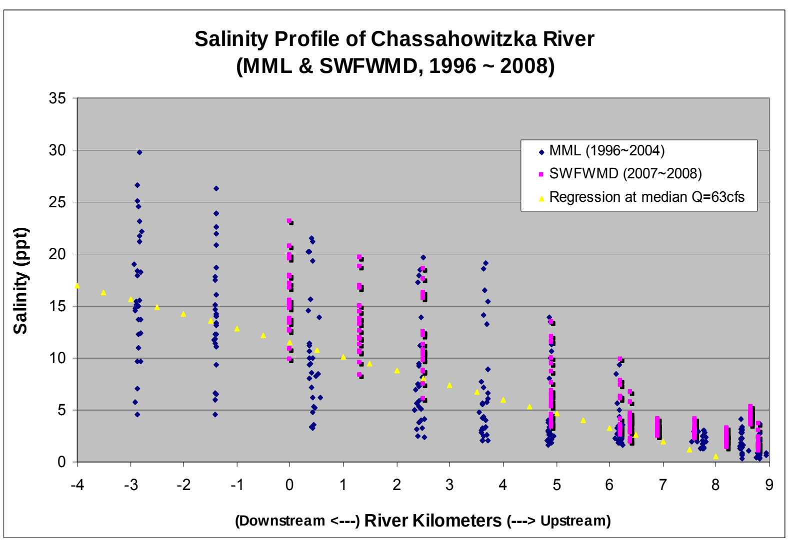


Figure 4-2 . Salinity by river kilometer (SWFWMD and Mote Marine)

[It should be noted that the salinity regression presented was not used to establish salinity habitats per se. The regression model was used to link biological responses or mollusk, benthos, and submerged vegetation to a salinity and location within the river. The thermal and salinity habitats (volume, bottom area salinity and shoreline length) were calculated using the three dimensional hydrodynamic model (Environmental Fluids Dynamic Code, EFDC) briefly described in Section 7.3. Additional details of model development can be found in Section 11.13.

4.2.1 Vertical Salinity Variability

The vertical salinity gradient varies with tides and streamflow. Salinity profiles in the Chassahowitzka River were produced by Yobbi and Knochenmus[13] (1989) for various streamflow and high tide conditions. These salinity profiles, provided as Figure 4-3, indicate that the river is reasonably well mixed vertically, for the sampled high tidal and streamflow conditions. Along most of the Chassahowitzka River, water salinity is uniform from top-to-bottom. The ratio of top-to-bottom salinity is generally greater than 85 percent in most portions of the river (Yobbi and Knochenmus 1989).

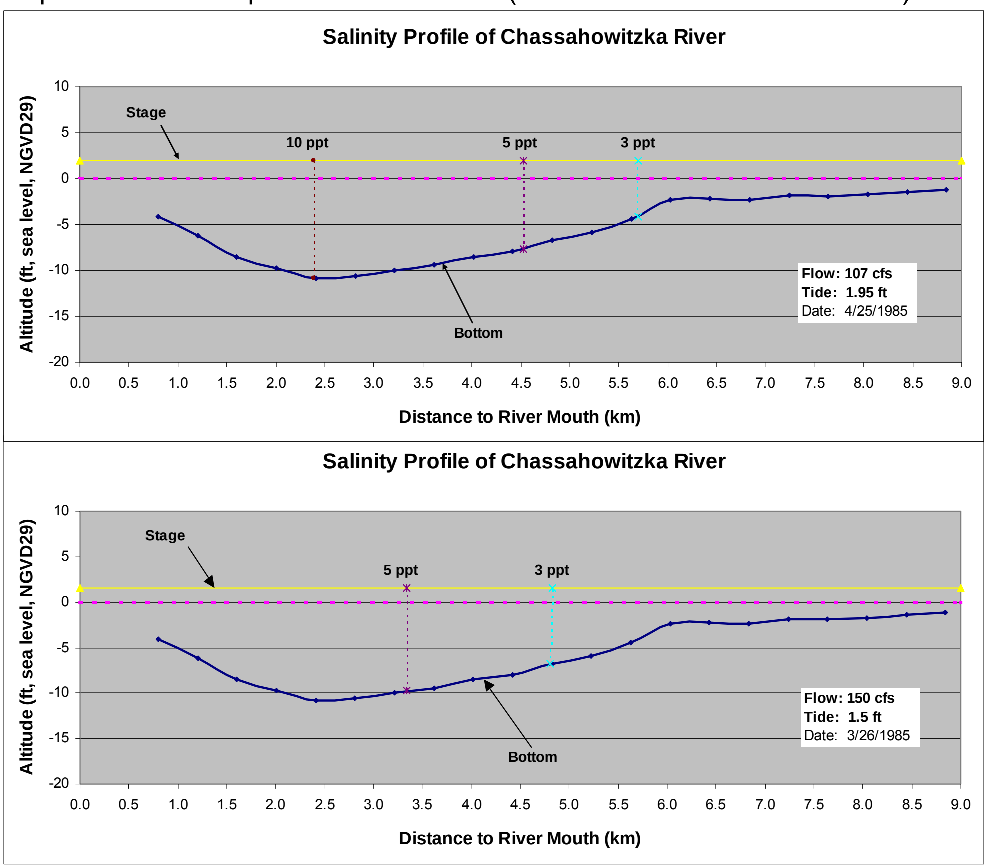
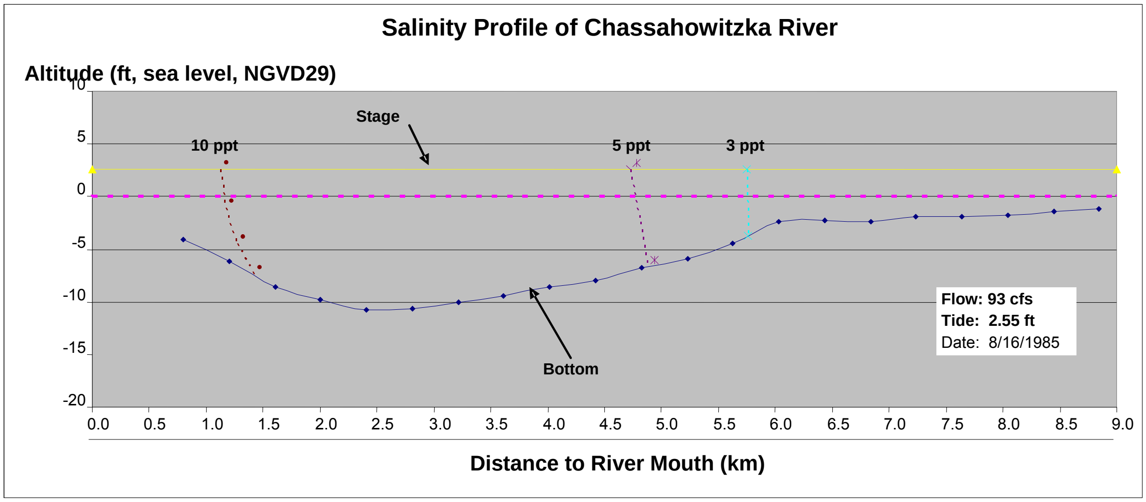
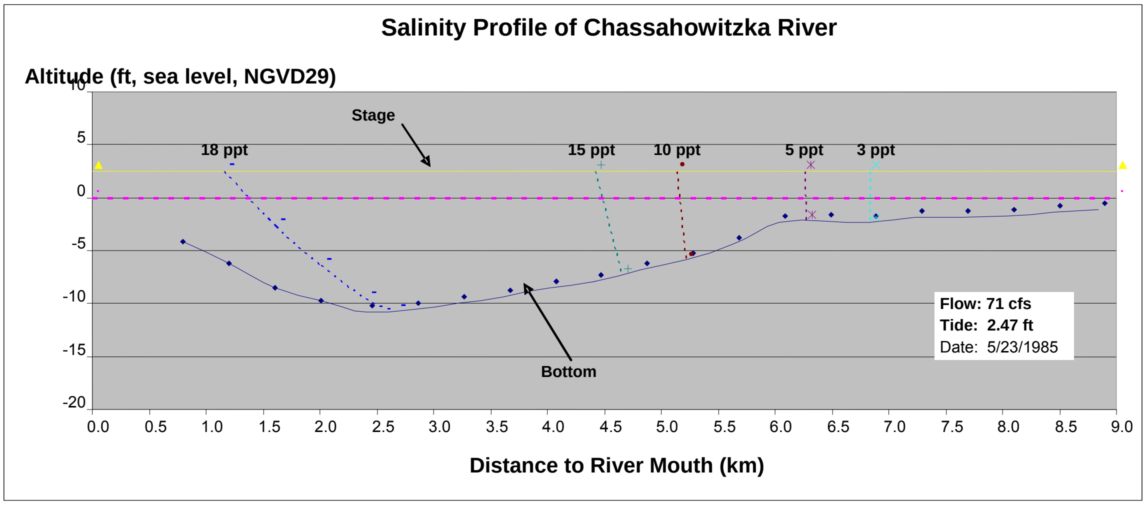


Figure 4-3. Salinity Profiles under various flow conditions (Yobbi and Knochenmus 1989) (Note – Flow includes Crab Creek)

[13] Discharge reported by Yobbi and Knochenmus for this study includes discharge from Crab Creek. Estimated discharge excluding Crab is 64 cfs on 3/26/85, 62 cfs on 4/25/85, 60 cfs on 5/23/85 and 68 cfs on 8/16/85.

Figure 4-3 (Continued)





4.3 Water Quality

4.3.1 FDEP Impaired Waters

The FDEP has included nine reaches (‘WBID’, or water body identification) in the Chassahowitzka Panning Unit as ‘impaired‘ water bodies. An ‘impaired’ water body is one that is not achieving the designated use. In the case of the Chassahowitzka River system, FDEP has designated (62-302.400 F.A.C.) waters in the Chassahowitzka as ‘Class III’. A Class III water body is intended to support recreation, propagation, and maintenance of a healthy, well-balanced population of fish and wildlife and fish taken from Class III waters are safe for consumption.

The impairment of these WBIDs has been verified according to protocols established in 62-303 F.A.C. Five of the WBIDs are listed because of nutrient impairment as evidenced by algal mats. The weighted average nutrient concentrations obtained in the verification process were TN = 0.65 mg/l (n=214) and TP = 0.019 mg/l (n=216). The FDEP included the following note in the comments section of the final verified listing[14] for each of these nutrient impaired WBIDs, where the concentration range and number of observations varied by WBID:

> *Nitrate+nitrate levels range from xx – xx mg/l (n=x) during the verified period and is the likely cause of the impairment.*

A major anthropogenic factor affecting the Chassahowitzka River and springs along the Springs Coast is the increase in nitrite+nitrate (NO_{2+3}-N), which is most likely derived from an inorganic source such as inorganic fertilizers applied to residential and golf course turf grasses along the recharge areas (Jones et al. 1997). Using isotopic signatures and other water quality characteristics, Jones reports that the average nitrate concentrations for the Chassahowitzka Springs range from 0.21 mg/l (Baird Spring) to 0.47 mg/l (Chassahowitzka #1). The mean of the nitrate concentrations for the Chassahowitzka Springs is 0.36 mg/l.

Sampling of the Chassahowitzka River, conducted by Frazer *et al*. (2001a, b) and Mote Marine Laboratory (MML) included investigations of nitrite+nitrate (NO_{2+3}-N) concentrations. The MML results are graphically depicted in Figure 4-4.

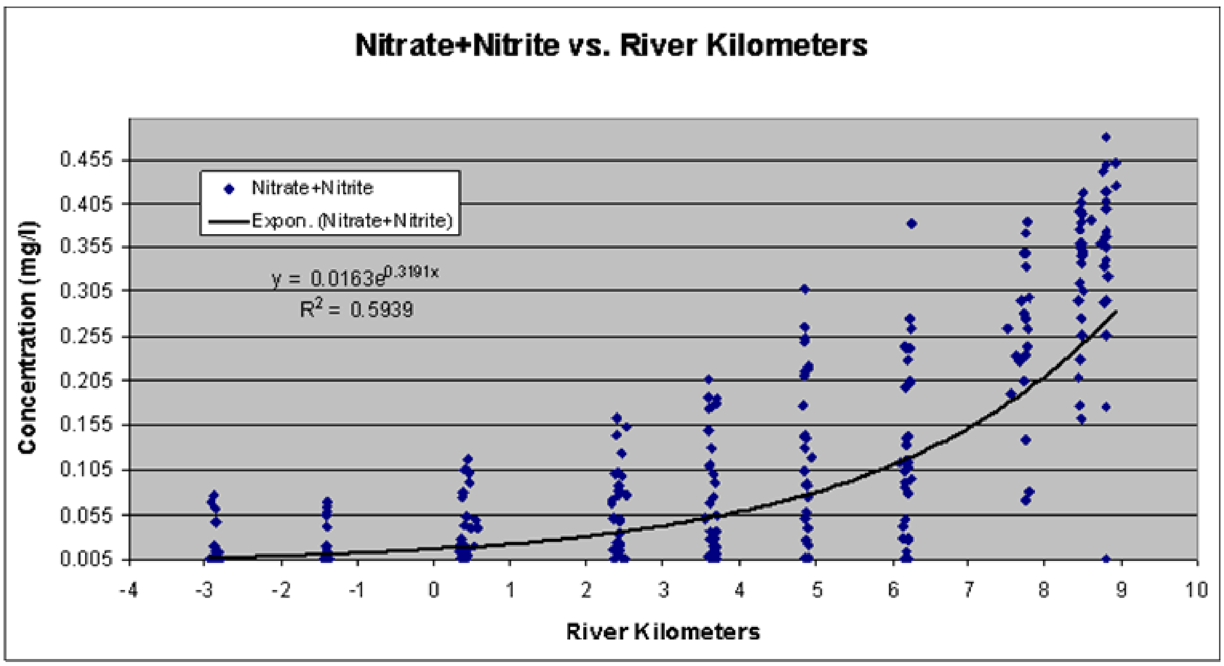


Figure 4-4. Nitrate + nitrite nitrogen concentrations from the headwaters to the Gulf of Mexico (Mote Marine Laboratory data)

Surface water nitrate concentrations decline with distance from the headwaters. The most abrupt decline in nitrate concentrations were generally observed to occur in the heavily vegetated portion of the river, upstream of the marsh transition zone. Dixon and Estevez (2001) evaluated the loss as a function of simple dilution with Gulf water and

[14] http://www.dep.state.fl.us/water/watersheds/assessment/adopted_gp5-c2.htm

concluded that the abrupt loss was the result of assimilation by macro- and micro-algal species. The relationship between salinity and nitrite+nitrate is provided in Figure 4-5. Simple mixing and dilution processes alone would result in a linear relationship between salinity and nitrite-nitrate.

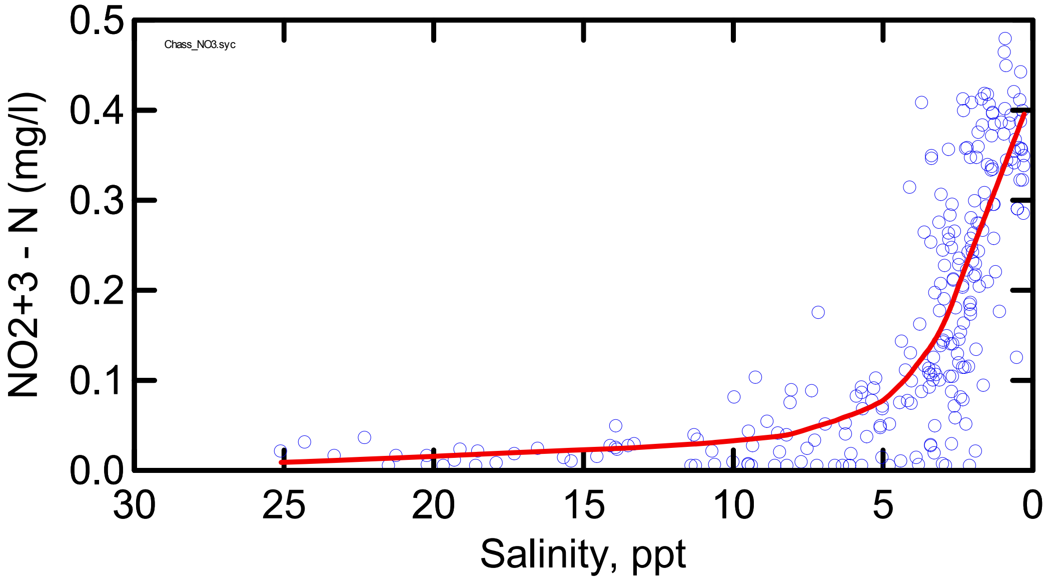


Figure 4-5. Relationship of salinity and nitrate in Chassahowitzka River

To determine if the nitrite/nitrate increase is related to flow of source water, the observed nitrate values at Chassahowitzka Main Spring were compared to the flow that existed on the sampling day (See Heyl 2012 in Section 11.16 for details). A LOWESS smooth (tension 0.5) was calculated and the variation in nitrate concentration not explained by flow (concentration residuals) was then correlated with time. Figure 4-6 (left panel) illustrates a statistically significant increase with time. The process was repeated by removing the impact of date first (right panel) and the unaccounted for NO_x residual was compared to flow. The results were not statistically significant. Similar results have been observed for Homosassa springs, Gum Springs, and Silver Springs (Section 11.16).

Groundwater discharging from the Chassahowitzka springs may be either fresh or brackish, depending on the tides and water levels in the Upper Floridan aquifer. At low tide, water quality varies among springs in the river system, with concentrations of total dissolved solids increasing from less than 500 mg/l to greater than 5,000 mg/l in springs nearest the Gulf of Mexico. Chloride concentrations may range from less than 150 mg/l to greater than 3,000 mg/l, indicating that ground-water quality is strongly influenced by the coastal transition zone even at low tide (Jones et al. 1997).

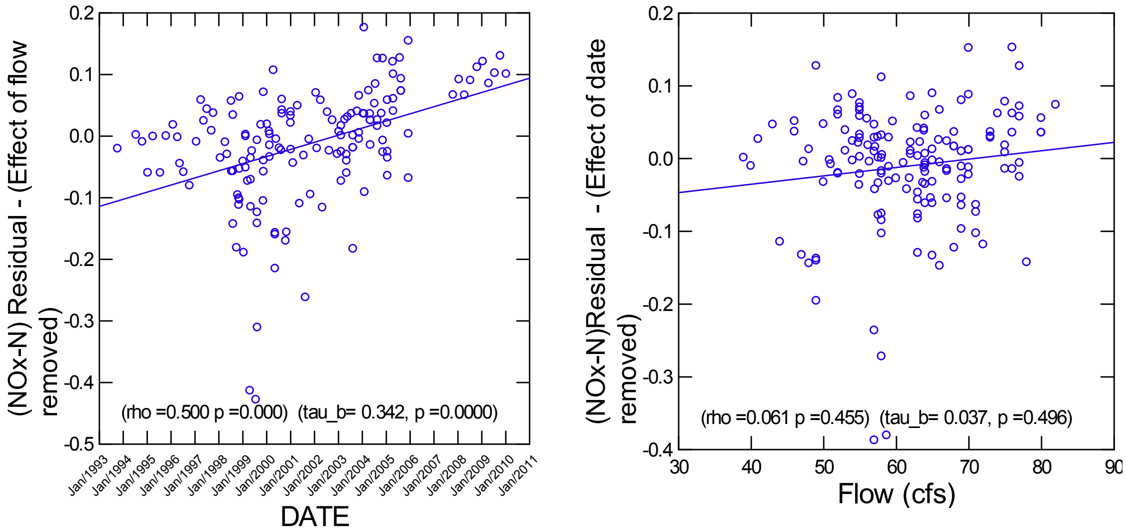


Figure 4-6. Residual plots for NO_x-N concentrations. Concentration unaccounted for by flow is significantly related to date (left panel) while concentration unaccounted for by date Is not significantly related to flow (right panel).

Ground water discharging from springs often has low dissolved oxygen (less than 5 mg/l) (Frazer et al. 2001). Frazer cited the lowest average concentrations measured occurred at the upper most transect (Transect 1) and marsh and estuarine sampling locations. However, dissolved oxygen concentrations at Transect 1 averaged 6.1 mg/l, with only 16 percent of the observations at or below 5 mg/l. Dissolved oxygen concentrations were highest in the middle vegetated section of the river (Frazer et al. 2001). In addition, there was no significant relationship between discharge and dissolved oxygen (r^2 = 0.02). This indicates that low dissolved oxygen is not a major issue with the ground water discharges.

In general, the water of the Chassahowitzka River is clear, slightly alkaline pH, essentially devoid of phosphorus, but rich in nitrogen. Due to the lack of phosphorus, primary productivity (as chlorophyll) is low, resulting in oligotrophic conditions that affect the entire ecology of the system. Water quality samples conducted by MML between 1996 and 2004 ((Dixon and Estevez, 2001) and unpublished raw data file dated 07/13/2007) were also assessed for the purposes of this minimum flow evaluation. The locations of the stations are depicted in Figure 4-7. Sampling parameters and statistics are provided in Table 4-3. The relationship of water quality to flow is included graphically in Section 11.7 for the Main Spring (MML station R0.0; Rkm = 8.8), the transition from upland to marsh (MML station R2.0; Rkm = 4.9) and at the MFL study boundary (MML station R4.0; Rkm = 0.4).

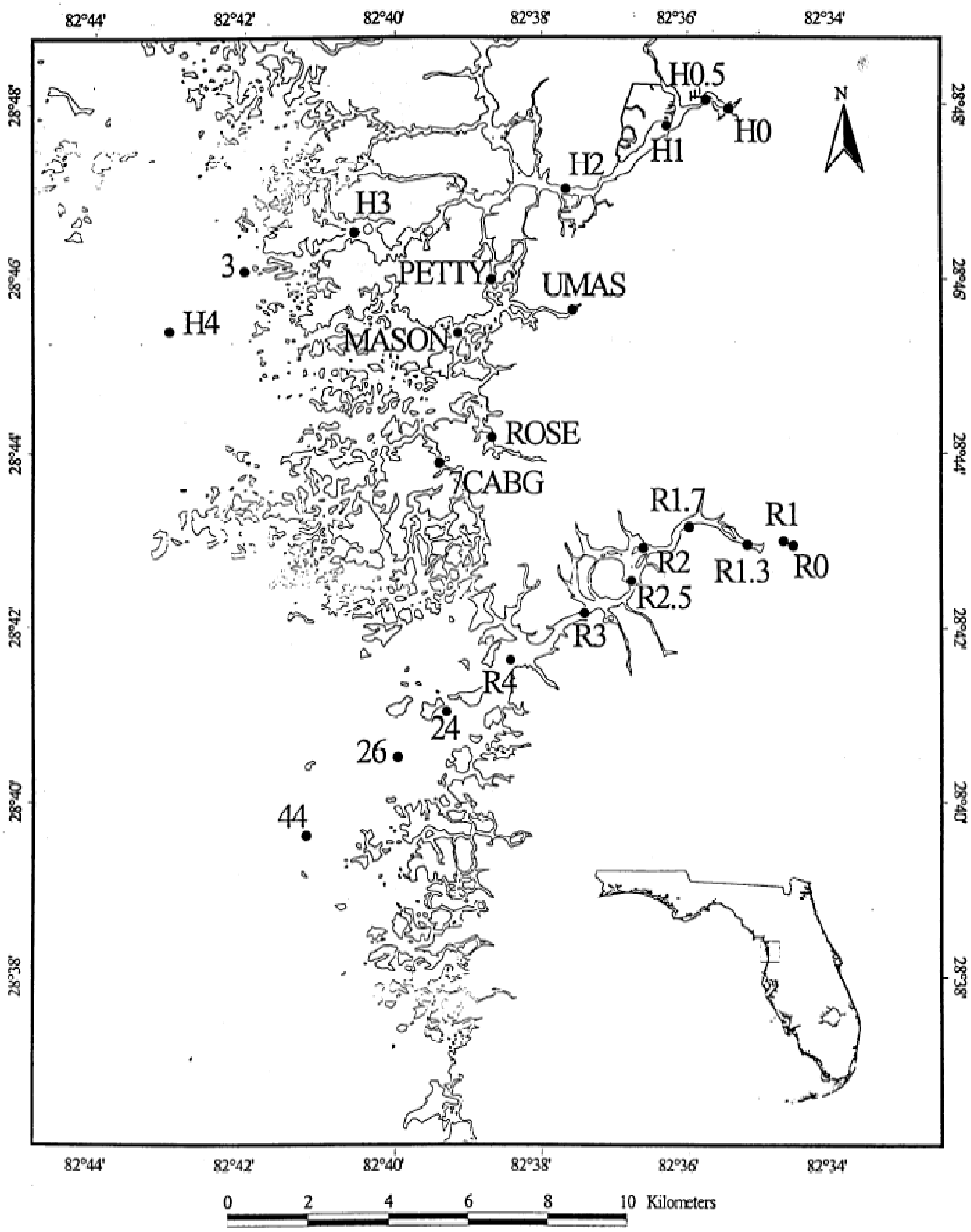


Figure 4-7. Water quality station locations (Dixon and Estevez 1998)

Table 4-3. Median water quality of Chassahowitzka River (1996-2004)

Station	Rkm (km)	Statistic	Sample Depth (m)	DO (mg/l)	Saturation of DO (%)	Specific Conductance (mmhos/cm)	Salinity (PSU)	Temp (C)	pH	Turbidity (NTU)	Color (PCU)	Color pH	TP mg/l)
R0.0	8.78	n	31	30	30	30	30	30	27	26	25	25	30
		median	0.20	6.28	73.9	1.67	0.87	23.34	7.74	0.7	6.0	7.88	0.05
R1.0	8.48	n	33	32	32	33	32	32	29	29	28	28	33
		median	0.20	7.78	92.4	2.73	1.47	23.79	7.88	1.2	7.0	8.03	0.05
R1.3	7.74	n	28	28	28	28	28	28	26	25	24	24	28
		median	0.20	10.42	122.7	3.82	2.03	24.15	8.23	1.2	10.0	8.36	0.05
R1.7	6.21	n	32	32	32	32	32	32	30	29	28	28	32
		median	0.20	8.86	103.9	4.75	2.67	24.70	7.91	1.9	16.0	8.08	0.05
R2.0	4.87	n	32	32	32	31	31	31	31	27	26	26	31
		median	0.20	6.41	77.9	5.07	2.76	24.50	7.67	2.5	22.5	7.95	0.05
R2.5	3.66	n	29	29	29	29	29	29	27	26	25	25	29
		median	0.20	6.01	82.3	9.78	5.53	25.40	7.76	2.8	36.0	8.05	0.05
R3.0	2.46	n	32	32	32	32	32	32	29	28	27	27	32
		median	0.20	6.02	84.1	11.49	6.51	25.75	7.82	2.3	36.0	8.03	0.05
R4.0	0.47	n	29	29	29	29	29	29	26	25	24	24	29
		median	0.20	6.38	84.5	16.22	9.48	25.94	7.78	2.1	34.5	8.05	0.05
24	-1.49	n	33	33	33	33	33	33	28	27	26	26	33
		median	0.20	6.54	91.6	23.27	14.03	26.99	7.94	2.3	26.5	8.18	0.05
Sampling and analysis conducted by Mote Marine Laboratory (Dixon and Estevez 2001 and unpublished data).													

Table 4-3 (Cont.)

Station	Rkm (km)	Statistic	PO4P (mg/l)	NH4N (mg/l)	NO23N (mg/l)	TKN (mg/l)	CHL_A (ug/l)	CHL_B (ug/l)	CHL_C (ug/l)	TSS (mg/l)	TN (mg/l)	Ratio TN:TP	IN (mg/l)
R0.0	8.78	n	30	30	30	30	14	14	14	4.0	30	30	30
		median	0.0175	0.005	0.380	0.08	1.4	0.5	0.5	2.0	0.437	16.7	0.399
R1.0	8.48	n	33	33	33	33	16	16	16	5.0	33	33	33
		median	0.016	0.005	0.349	0.05	3.5	0.5	0.5	2.0	0.384	14.8	0.360
R1.3	7.74	n	28	28	28	28	13	13	13	4.0	28	28	28
		median	0.014	0.010	0.263	0.09	1.9	0.5	0.5	2.5	0.351	12.0	0.271
R1.7	6.21	n	32	32	32	32	15	15	15	4.0	32	32	32
		median	0.010	0.012	0.1135	0.21	6.6	0.5	0.7	2.5	0.329	10.35	0.132
R2.0	4.87	n	31	31	31	31	15	15	15	4.0	31	31	31
		median	0.010	0.020	0.104	0.19	4.9	0.5	0.5	4.0	0.350	11.0	0.132
R2.5	3.66	n	29	29	29	29	13	13	13	5.0	29	29	29
		median	0.009	0.017	0.054	0.33	3.9	0.5	0.5	7.0	0.399	10.8	0.093
R3.0	2.46	n	32	32	32	32	15	15	15	5.0	32	32	32
		median	0.0085	0.015	0.041	0.35	3.5	0.5	0.5	6.0	0.384	12.15	0.064
R4.0	0.47	n	29	29	29	29	14	14	14	4.0	29	29	29
		median	0.007	0.014	0.021	0.33	2.45	0.5	0.5	4.0	0.370	9.7	0.046
24	-1.49	n	33	33	33	33	16	16	16	5.0	33	33	33
		median	0.005	0.009	0.005	0.42	2.2	0.5	0.6	4.0	0.423	10.1	0.016
Sampling and analysis conducted by Mote Marine Laboratory (Dixon and Estevez 2001 and unpublished data).													

CHAPTER 5. BIOLOGICAL CHARACTERISTICS

5.1 Benthos

5.1.1 Descriptive (Adapted from Janicki Environmental 2006, Grabe and Janicki 2008)

The main channel of the Chassahowitzka River was surveyed during both the dry (May) and wet seasons (September) of 2005 for infaunal and SAV associated epifaunal macroinvertebrates by Mote Marine Laboratory and the results were analyzed by Janicki Environmental (2006). In 2008, six tributaries to the upper Chassahowitzka River were sampled to determine if the benthic community within the tributaries was different from that observed in the main river (See Section 11.8 – Grabe and Janicki 2008).

A three-inch (7.63 cm) diameter core sampler was used to collect the soft sediment infauna and a sweep net was used to collect SAV-associated epifauna. Fourteen cores and sweep nets samples were collected from the Chassahowitzka River and 35 samples were collected from the six tributaries (Table 5-1).

Table 5-1. Tributaries and river strata selected for the collection of benthic samples in the Chassahowitzka River and the number of samples collected, May 2005 and April 2008 (Janicki Environmental 2006, Grabe and Janicki 2008)

Tributary	Number of Samples Collected
Upper Chassahowitzka River (May 2005)	11
Crab Spring (April 2008)	6
Lettuce Spring (April 2008)	1
Crawford Creek (April 2008)	8
Baird Creek (April 2008)*	0
Salt Creek (April 2008)	8
Potter Creek (April 2008)	8
Ryle Creek (April 2008)	4
Lower Chassahowitzka River (May 2005)	3
Total	**49**
*Baird Creek was obstructed by a fallen tree and could not be sampled.	

Dominant taxa were identified for each tributary and the Upper Chassahowitzka and Lower Chassahowitzka rivers. Dominants are identified by their dominance score, which is calculated as:

Dominance Score = (% occurrence * % composition)$^{-0.5}$.

The Dominants of the eight study areas were generally segregated into an upstream and a downstream group. The four more upstream creeks, northern shoreline systems (upstream of Rkm 6), and the Upper Chassahowitzka River had the estuarine amphipod *Grandidierella bonnieroides* as a Dominant. Oligochaete worms, which could represent either freshwater and/or estuarine species, were also dominant in the upper river, Crab, Lettuce, and Salt creeks—but not in Potter Creek (Table 5-2). Freshwater insect larvae were rarely included among the Dominants, except in the single Lettuce Creek sample (Grabe and Janicki 2008).

The dominant taxa (Dominants) in the Lower Chassahowitzka River and Crawford and Ryle creeks (downstream and southern shore) included the estuarine amphipod *Ampelisca* spp., unidentified amphipods, and, in the two creeks, *G.* bonnieroides (Table 5-2) (Grabe and Janicki 2008). Using Analysis of Similarity (ANOSIM) found in PRIMER software (Clark and Warwick, 2001), Grabe and Janicki concluded that all of the tributary communities are significantly different from the benthic community in the upper river and Ryle Creek is significantly different from the other tributary communities.

Grabe and Janicki (, 2008) reported that:

- Ryle Creek had a greater number of taxa than the upper river, but all other paired comparisons of the creeks showed similar taxa richness.
- Total abundance of benthic macroinvertebrates was similar in each of the areas studied.
- Except for Ryle Creek, paired comparisons of the remaining creeks showed no difference in taxa richness.
- Pair-wise comparisons showed that the benthic assemblage of the upper river differed from the five creeks and Ryle Creek differed from the upper river and the remaining four creeks.

Grabe and Janicki concluded, “reductions in discharge from the spring is [are] unlikely to impact the benthos of the tributary creeks, which are dominated by estuarine species.”

5.1.2 Relation to Inflow

Quantitative relationships with inflow were not developed with the benthic results, although salinity was evaluated along with other physical-chemical parameters. Data from the upper and lower Chassahowitzka river (but not the tributaries), Weeki Wachee and Mud Rivers were pooled and several summary statistics developed (Janicki Environmental 2006). The 2005 data from the main stem Chassahowitzka River (excluding the tributaries sampled in 2008) were extracted from the larger database and the relationship between salinity and richness ($\log_{10}$ number of taxa +1), Shannon-Weaver diversity H’ (using base 2) and total abundance (as $\log_{10}$ number +1 per m^2) was reevaluated as linear, quadratic and third order polynomial functions with salinity as the independent variable. Only the diversity relationships were significant at $p \leq 0.05$ and the quadratic and third order terms were not significant in the higher order relationships thus leaving the following relationship:

$$H' = 3.106 + 6.747 * \text{Salinity} \quad (n = 28,\ r^2 = 0.29,\ p = 0.002)$$

Since diversity in this data pooled from the three rivers cited above increases with salinity, the relationship offers little value toward establishing withdrawal limits.

Table 5-2. The top ten highest dominance score for macroinvertebrate taxa identified from infaunal samples collected in the Chassahowtizka River and six selected tributaries (Grabe and Janicki 2008)

TAXON	Lower River	Crab	Crawford	Lettuce	Potter	Ryle	Salt	Upper River
Athenaria	13							3
ANNELIDA								
Polychaeta								
Heteromastus filiformis						14		
Hobsonia florida		6		23				
Laeonereis culveri	15	43	15	16	17		12	22
Leitoscoloplos robustus						12		
Oligochaeta	30	42	24	45	37	15	51	49
Hirudinea				23	5			
MOLLUSCA								
Acteocina canaliculata						14		
Gastropoda			10			14		
Littoridinops palustris					12			
Bivalvia								
Cyrenoida floridana			14					
Macoma tenta			10			12		
CRUSTACEA								
Amphipoda								
Americorophium ellisi								
Ampelisca vadorum			40			61		
Ampelisca sp.	76							9
Amphilochus sp.		4						
Corophiidae	18							33
Gammarus mucronatus	13	32	17	23	58	16	38	21
Grandidierella bonnieroides	17	44	44	48	47	46	46	38
Melita sp.	11							
Monocorophium sp.							6	
Isopoda								
Cyathura polita	11	24	10	16	9		8	16
Edotea montosa		16		16	13		8	
Xenanthura brevitelson	10					21		
Tanaidacea								
Hargeria rapax/ Leptochelia forresti	11	23				26		12
Cumacea								
Almyracuma bacescui			12		8		17	3
INSECTA								
Trichoptera		4						
Diptera-Chironomidae								
Cladotanytarsus				39				
Polypedilum scalaenum		16		39	7		7	
Procladius				16				

5.2 Fish

5.2.1 Descriptive (Adapted from Greenwood et al. 2008)

A two-year study of freshwater inflow effects on habitat use by estuarine organisms in the Chassahowitzka River estuary was undertaken from August 2005 to July 2007 (See Section 11.10 – Greenwood et al. 2008) by the Florida Fish and Wildlife Commission (FWC) and the University of South Florida (USF) College of Marine Science. The general objective of this data analysis was to identify patterns of estuarine habitat use and organism abundance under variable freshwater inflow conditions and to evaluate responses. Systematic monitoring was performed to develop a predictive capability for evaluating potential impacts of proposed freshwater withdrawals and, in the process, to contribute to baseline data. The predictive aspect involves development of regressions that describe variation in organism distribution and abundance as a function of natural variation in inflows. These regressions, developed by USF and FWC, can then be applied to any proposed alterations of freshwater inflows that fall within the range of natural variation documented during the data collection period. For sampling purposes, the Chassahowitzka River estuary was divided into five zones from which plankton net, seine net and trawl samples were taken (Figure 5-1). Sampling was conducted on a monthly basis for the first year of the study (August 2005 to July 2006) and every six weeks for the remainder of the study (August 2006 to July 2007). Salinity, water temperature, dissolved oxygen and pH measurements were taken in association with each net deployment.

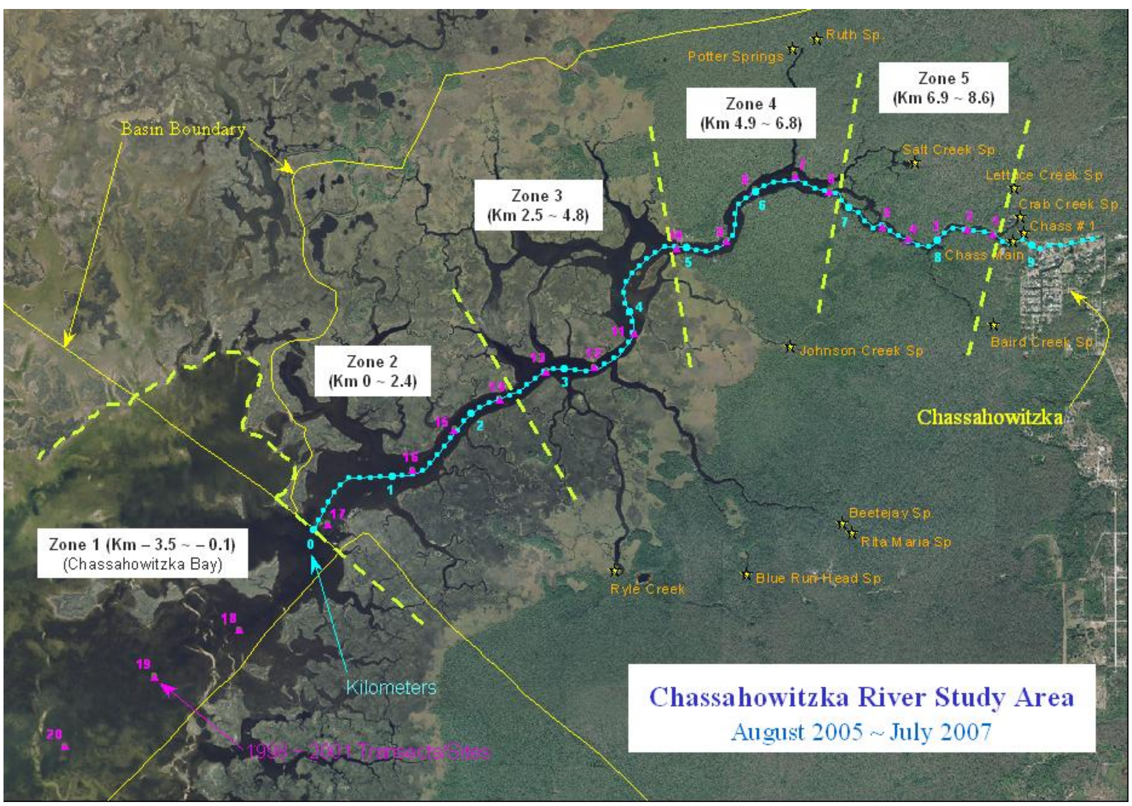


Figure 5-1. Map of the fish/invertebrate sampling zones

Three gear types were implemented to monitor organism distributions: a plankton net with a 0.02 inch (500 μm) mesh deployed during nighttime flood tides; a bag seine with 0.126 inch mesh (3.2 mm); and otter trawl with 0.126 inch mesh deployed during the day under variable tide stages. The locations for seine and trawl deployment were randomly selected within each zone during each survey, whereas the plankton-net collections were made at fixed stations within each zone.

The small organisms collected at night by the plankton net represent a combination of the zooplankton and hyperbenthos communities. The faunal mixture present in the nighttime water column includes the planktonic eggs and larvae of fishes. Although fish eggs and larvae are the target catch, invertebrate plankton and hyperbenthos usually dominate the samples numerically. The invertebrate catch largely consists of organisms that serve as important food for juvenile estuary-dependent and estuarine-resident fishes.

Seines and trawls were used to survey larger organisms that typically evade plankton nets. The data from seine hauls document habitat use by shallow-water organisms whereas the data from trawls document habitat use in deeper areas. The dominant catch for both gear types is juvenile fishes, although the adults of smaller species are also commonly caught. The seines and trawls also regularly collect a few of the larger macroinvertebrate species from tidal rivers, notably juvenile and adult blue crabs (*Callinectes sapidus*) and juvenile pink shrimp (*Farfantepenaeus duorarum*), as well as smaller invertebrates such as grass shrimp (*Palaemonetes* spp.).

The plankton net was towed behind a vessel in such a manner as to direct propeller turbulence away from the towed net. The boat towed the net along a nearly constant depth contour that was estimated to be close to the average cross-sectional depth for the local river reach. A flow meter measured volume sampled, which was typically on the order of 91-104 $yd^{3.}$ Plankton tows began within two hours after sunset and typically ended less than four hours later.

The bag seine was deployed along shoreline habitats (i.e., shorelines with water depth ≤ 5.9 feet in the Chassahowitzka River and bay) and in shallow waters (< 4.9 feet) of the bay zone. The area sampled was approximately 81 yd^2 in deeper water and 167 yd^2 in the shallows.

Trawling was conducted in the bay zone (zone 1), lowermost river zone (zone 2), and river zone 3. No trawling was conducted in the upper two zones due to unsuitable conditions. The approximate area sampled by a typical tow was 860-yd2 .Salinity, temperature, pH, and dissolved oxygen were measured at the surface and at 1-meter (3.3-foot) intervals to the bottom in association with each gear deployment.

5.2.1.1 Fish Composition

Larval gobies and anchovies dominated the plankton net's larval fish catch. *Gobiosoma* spp. and *Microgobius* spp. were the dominant goby taxa, and the anchovies were strongly dominated by the bay anchovy (*Anchoa mitchilli*). Other abundant larval fishes included silversides (*Menidia* spp.), rainwater killifish (*Lucania parva*), eucinostomus mojarras (*Eucinostomus* spp.), and blennies.

Over 90 percent of the seine catch was comprised of rainwater killifish, menidia silversides, bay anchovy, coastal shiner (*Notropis petersoni*), eucinostomus mojarras, pinfish (*Lagodon rhomboides*), bluefin killifish (*Lucania goodei*), tidewater mojarra (*Eucinostomus harengulus*), and sheepshead minnow (*Cyprinodon variegatus*). Fish collections from deeper, trawled areas were dominated by pinfish and eucinostomus mojarras. These taxa comprised over 58 percent of total trawl catch of fishes.

5.2.1.2 Invertebrate Composition

The plankton-net invertebrate catch was dominated by gammaridean amphipods, larval crabs (decapod zoeae and megalopae), cumaceans, the mysids *Americamysis almyra* and *Bowmaniella dissimilis*, prosobranch snails, and larval shrimps (decapod mysis). River plume-associated taxa, with the exception of the calanoid copepod *Acartia tonsa*, were less common than they typically are in more nutrient-rich estuarine plumes along the west-central Florida coast.

Invertebrates collected by seines were dominated by brackish grass shrimp (*Palaemonetes intermedius*), blue crab, and pink shrimp, which together comprised over 98 percent of total invertebrate catch in seines. Nearly 95 percent of the trawl catch was comprised of these same three species.

5.2.2 Relation to Inflow

Response to inflow was assessed in terms of location of maximum occurrence and in terms of quantity (abundance) of organisms present. The location metric is based on the mean location of the catch-per-unit-effort (CPUE) where the CPUE is the number of organisms per volume (plankton net) sampled or area sampled (seine or trawl). For simplicity, CPUE is abbreviated as "U". The location metric is defined as:

$$kmu = \sum (km * U) / \sum U$$

where km is distance from river mouth.

The number of organisms collected is expressed in terms of either absolute or relative abundance (*N*). For plankton tows, the total number (N) of organisms was estimated by calculating the product of mean organism density (expressed as # / m^3) and the volume of the river (corrected for tide stage at the time of capture). For the seine and trawl data, the relative abundance (*N*, #/ m^2) was calculated for each month as:

$$N = 100 * N_{total} / A_{total}$$

where
N_{total} = total number of organisms capture that month, and
A_{total} = total area swept by the seine or trawl that month.

Inflow response regressions were developed for each of the gear types and both response metrics. For plankton net collections, location was used without transformation, but for the seine and trawl data, the location was natural log transformed after addition of “1.79” to adjust for negative values when taxa were centered below the mouth of the river. For seine and trawl results, flow and relative abundance were natural log transformed (after addition of "1" to avoid censoring zero values). Plankton abundance and flow were natural log transformed without the addition of ‘1’. Mean flows were consecutively evaluated to find the maximum coefficient of determination. Ten linear and non-linear regression models were evaluated for each taxa captured in the plankton tows, while the seine and trawl results were subjected to linear and quadratic regressions models. Daily mean inflows extending as far back as 120 days were evaluated for the plankton tow results. Mean flows from the date of sampling, as well as continuously lagged weekly averages from the day of sampling to 365 days before sampling were evaluated at seven day intervals (i.e., average discharge for sampling day and preceding six days; average flow for sampling day and preceding thirteen days) for the seine and trawl captures.

5.2.2.1 Distribution – Plankton Net

Nine (14 percent) of the 66 plankton-net taxa evaluated for distribution responses to freshwater inflow exhibited significant responses. Six of these were positive responses, wherein animals moved upstream as inflows increased (Table 5-3). The remaining three taxa demonstrated negative responses, moving downstream as freshwater flows increased. The time lags for these responses were highly variable, ranging from 1 to 74 days.

5.2.2.2 Distribution – Seine and Trawl

Five (10.9 percent) of the 46 seine- or trawl-caught pseudo-species evaluated for distributional responses to freshwater inflow exhibited significant responses for at least one lagged flow period. Four of the five pseudo-species moved upstream in response to decreasing inflow (negative response) whereas the fifth pseudo-species moved upstream in response to increased inflow (positive response) (Table 5-4). The change in centers of abundance ranged from 1.7 to 3.8 km and occurred over a relatively small inflow change (13 to 27 cfs). The lag period for four of the pseudo species were relatively short (< 21 days), while the remaining species had a moderately long (49-day) lag period.

Table 5-3. Plankton-net organism distribution (kmu) responses to mean freshwater inflow (LnF), ranked by linear regression slope

Other regression statistics are sample size (n), intercept (Int.), slope probability (P) and fit (r^2). D is the number of daily inflow values used to calculate mean freshwater inflow. None of the time series data appeared to be serially correlated (Durbin-Watson statistic, p>0.05 for all taxa) (Greenwood et al. **2008).**

Description	*Common Name*	*n*	*Int.*	*Slope*	*P*	*r^2*	*D*
Parasterope pollex	*ostracod, seed shrimp*	*11*	*-119.803*	*29.851*	*0.0048*	*0.61*	*43*
Cyathura polita	*isopod*	*11*	*-87.352*	*22.371*	*0.0154*	*0.50*	*15*
polychaetes	*sand worms, tube worms*	*20*	*-47.680*	*12.162*	*0.0249*	*0.25*	*6*
pelecypods	*clams, mussels, oysters*	*16*	*-44.340*	*11.173*	*0.0432*	*0.56*	*4*
trichopteran larvae	*caddisflies*	*15*	*-37.573*	*10.765*	*0.0016*	*0.55*	*1*
Sarsiella zostericola	*ostracod, seed shrimp*	*13*	*-24.075*	*5.867*	*0.0300*	*0.36*	*42*
gastropods, opisthobranch	*sea slugs*	*15*	*39.239*	*-9.464*	*0.0007*	*0.60*	*2*
Gobiosoma spp. postflexion larvae	*gobies*	*12*	*39.937*	*-9.606*	*0.0479*	*0.34*	*2*
Lucania parva adults	*rainwater killifish*	*11*	*120.274*	*-28.283*	*0.0276*	*0.43*	*74*

Table 5-4 Best-fit seine and trawl-based pseudo-species distributional (ln(kmu)) response to continuously lagged mean freshwater inflow (ln(inflow)) for the Chassahowitzka River

Degrees of freedom (df), intercept (Int.), slope (Slope), probability that the slope is significant (P), and fit (Adj. r^2) are provided. The number of days in the continuously lagged mean inflow is represented by D. An "x" in DW indicates that the Durbin-Watson statistic was significant (p<0.05), a possible indication that serial correlation was present (Greenwood et al. **2008).**

Species	Common Name	Gear	Size (mm)	Period	df	Int.	Slope	P	Adj. r^2	DW	D
Callinectes sapidus	Blue crab	Trawl	0 to 30	Jan-Dec	19	4.352	-0.523	0.0488	0.15		1
Fundulus seminolis	Seminole killifish	Seine	0 to 999	Jan-Dec	10	4.295	-0.376	0.0308	0.33		1
Lucania parva	Rainwater killifish	Seine	0 to 999	Jan-Dec	19	5.044	-0.589	0.0461	0.15	x	49
Poecilia latipinna	Sailfin molly	Seine	0 to 30	Jan-Dec	9	6.554	-0.945	0.0210	0.40		21
Mugil cephalus	Striped mullet	Seine	0 to 999	Jan-Dec	7	-4.129	1.560	0.0349	0.42		7

5.2.2.3 Abundance – Plankton Net

Thirteen (20 percent) of the 66 plankton-net taxa evaluated for abundance relationships with freshwater inflow exhibited significant responses (Table 5-5)[15]. Negative responses were common, occurring in 10 of the 13 taxa; these are usually caused by elevated flows washing marine-derived taxa out of the survey area. Bay anchovy juveniles had a positive abundance response to inflow. This response had a relatively long lag of 106 days, which is more than twice the typical age of the bay anchovy juveniles themselves (approximately 40 days). During high inflow periods, the Chassahowitzka River estuary apparently becomes more attractive as nursery habitat for the bay anchovy, and the juveniles seek out the middle reaches of the tidal river, much as they do in more strongly surface-fed estuaries. The estuarine tanaid *Hargeria rapax* exhibited a similar pattern.

5.2.2.4 Abundance – Seine and Trawl

Twenty-three (50 percent) of the 46 pseudo-species analyzed from the seine and trawl catches had a significant abundance response to average inflow. Nine of these pseudo-species had linear responses and the remaining 14 demonstrated quadratic responses of abundance to inflow[16]. Six of the linear responses (blue crab [seines and trawls], *Synodus foetens*, *Syngnathus scovelli*, tidewater mojarra, and pinfish) were negative such that abundance increased with decreasing inflow. The negative response in these pseudo-species most likely indicates an increase in the amount of higher salinity habitat as flows decreased. Similarly, two of the three positive linear responses (bluefin killifish and spotted sunfish (*Lepomis punctatus)*) were observed for freshwater taxa that would be expected to move downstream with increases in inflow and subsequent increases in the amount of freshwater habitat. The most common quadratic response was an "intermediate-maximum" where the maximum abundance occurred at intermediate inflows and abundance was lower at both lower and higher inflows. The percentage of significant abundance responses to inflow ranged from 35.3 percent of tested pseudo-species in estuarine spawners to 85.7 percent in offshore spawners. Tidal river residents most commonly exhibited intermediate-maximum relationships to flow, while offshore spawners exhibited intermediate-maximum (3), negative (2), and intermediate-minimum (1) responses to inflow. All three of the nearshore spawners that had significant regressions demonstrated negative responses to flow.

Standard regression analyses typically correlate antecedent flow conditions with fisheries data aggregated over a sampling event. Often, these regressions rely on relatively small sample sizes. Data points that deviate largely from the average inflow or data points that have large residuals can overly influence the regression fit and calculation of the regression equation using ordinary least squares (OLS) regression. These overly influential data points include "outliers" and "leverage points". Inspection of the graphic results presented by Greenwood et al. (2008) suggest that several of the regressions presented by these authors have outliers and high leverage data.

[15] Response of abundance to flow was evaluated using plankton net data censored to days of positive capture. There were no zero abundance results included in the evaluations.
[16] Due to difficulties in interpreting the quadratic results, the FWC has abandoned using the quadratic evaluations. T. MacDonald, personal communication. Oct. 28, 2011.

Regressions using OLS that do not account for outliers and leverage points can result in lower statistical power, wider confidence intervals and/or biased prediction of the response relationship leading to false inference with respect to the predicted effects of inflow reductions on fish responses (Wessel 2009).

Robust regression is a statistical technique used for the diagnosis of outliers and leverage points that can provide more stable parameter estimates compare to OLS regression in the presence of outliers. By using iteratively re-weighted least squares methods, robust regression can down-weight the effects of outliers to provide more robust prediction of relationships especially when datasets are of relatively small sample size (Wessel 2009). Therefore, robust regression techniques were applied to the seine and trawl data presented by Greenwood et al. (2008) to develop robust relationships between inflow and fish abundance responses for the MFL determination, where appropriate. Two taxa (*Opsanus beta* and *Strongylura timucu*) were omitted from the analysis due to their low sample size (n=8 and n=11, respectively). Additionally, the robust regression for *Fundulus seminolis* would not converge. Of the twenty-two species that were analyzed using the robust regression, nineteen had robust regressions that could be analyzed further (Table 5-6).

Table 5-5. Plankton-net organism abundance responses to mean freshwater inflow (Ln (F)), ranked by linear regression slope.
Other regression statistics are sample size (n), intercept (Int.), slope probability (P) and fit (r^2). DW identifies where serial correlation is possible (x indicates p<0.05 for Durbin-Watson statistic). D is the number of daily inflow values used to calculate mean freshwater inflow (Greenwood et al. 2008). Highlighted pseudo-species are those that met evaluation criteria.

Description	Common Name	n	Int.	Slope	P	r^2	DW	D
Anchoa mitchilli juveniles	bay anchovy	18	-52.561	15.666	0.0066	0.38	x	106
Hargeria rapax	tanaid	20	-22.269	8.521	0.0024	0.41		4
dipterans, chironomid larvae	midges	20	-16.14	7.029	0.0115	0.31		47
unidentified Americamysis juveniles	opossum shrimp, mysids	20	40.506	-5.959	0.0003	0.53		106
Harrietta faxoni	isopod	20	46.556	-8.19	0.0213	0.26		26
Cumaceans	cumaceans	20	55.616	-9.591	0.0361	0.22	x	5
Polychaetes	sand worms, tube worms	20	60.455	-11.705	0.0012	0.45		90
Sarsielia zostericola	ostracod, seed shrimp	13	61.622	-12.625	0.0033	0.56		2
gobiid flexion larva	gobies	14	76.866	-15.711	0.0098	0.44		104
Pseudodiaptomus coronatus	copepod	18	75.415	-15.879	0.0006	0.53		2
Acartia tonsa	copepod	20	82.06	-16.877	0.0035	0.39		93
Parasterope pollex	ostracod, seed shrimp	11	78.838	-16.922	0.0022	0.67		14
Microgobius spp. postflexion larvae	gobies	15	91.591	-19.607	0.0019	0.54		115
Significant Durban-Watson statics not included in MFL evaluation.								

Table 5-6. Best-fit seine and trawl-based pseudo-species abundance (N+1) response to continuously lagged mean freshwater inflow (Ln(F+1)) for the Chassahowitzka River estuary from the robust regression analysis (Wessel 2009). The type of response (Resp.) is either linear (L) or quadratic (Q). Degrees of freedom (df), intercept (Int.), slope (Linear Coef.), probability that the slope is significant (Linear P), quadratic coefficient (Quad. Coef.), probability that the quadratic coefficient is significant (Quad. P) and fit (Adj. r^2) are provided. The number of days in the continuously lagged mean inflow is represented by D. An "x" in DW indicates that the Durbin-Watson statistic was significant ($p<0.05$), a possible indication that serial correlation was present (Greenwood et al. **2008). Highlighted pseudo-species are those that met evaluation criteria. Robust regression parameters from Wessel (2009)**

								Linear		Quadratic				
Species	**Common Name**	**Gear [a]**	**Size (mm)**	**Period**	**Resp.**	**df**	**Int.**	**Coef.**	**P**	**Coef.**	**P**	**Adj. r2**	**DW**	**D**
Farfantepenaeus duorarum	Pink shrimp	S	0 - 30	Jan-Dec	Q	18	-1241.5	610.89	0.0333	-75.07	0.0323	0.42	x	126
Farfantepenaeus duorarum	Pink shrimp	T	0 - 30	Jan-Dec	Q	18	-377.15	184.94	0.0008	-22.65	0.0007	0.37		182
Callinectes sapidus	Blue crab	S	0 - 30	Sep-Mar	L	10	39.08	-9	0.0024	-	-	0.52		231
Callinectes sapidus	Blue crab	T	0 - 30	Jan-Dec	L	19	2.77	-0.58	0.6452	-	-	0.20	x	168
Anchoa mitchilli	Bay Anchovy	S	31 - 50	Jan-Dec	Q	18	708.83	-352	0.0398	43.7	0.0372	0.39		28
Synodus foetens	Inshore lizardfish	T	0 - 130	May-Jan	L	14	3.63	-0.85	0.0087	-	-	0.44	x	1
Fundulus grandis	Gulf killifish	S	51 - 100	Jan-Dec	Q	18	-2127.1	1038.4	0.0127	-126.63	0.0126	0.36		259
Lucania parva	Rainwater killifish	S	0 - 999	Jan-Dec	Q	18	-2372.4	1157.57	0.0001	-140.96	0.0001	0.57	x	168
Lucania goodei	Bluefin killifish	S	0 - 50	May-Nov	L	11	-67.45	16.95	0.0032	-	-	0.55	x	175
Poecilia latipinna	Sailfin molly	S	31 - 999	Jan-Dec	Q	18	-593.84	290.45	0.0076	-35.49	0.0075	0.40		189
Syngnathus scovelli	Gulf pipefish	T	0 - 130	Jan-Dec	L	19	3.45	-0.79	0.02	-	-	0.17	x	364
Lepomis punctatus	Spotted sunfish	S	0 - 100	May-Nov	L	11	-31.05	7.82	0.0001	-	-	0.59		21
Eucinostomus harengulus	Tidewater mojarra	S	40 - 999	Jan-Dec	L	19	29.78	-6.92	0.0034	-	-	0.39	x	1
Lagodon rhomboides	Pinfish	S	0 - 50	Jan-Jun	Q	8	-3168.9	1561.57	0.0001	-192.13	0.0001	0.74	x	98
Lagodon rhomboides	Pinfish	S	51 - 100	Apr-Sep	L	8	30.13	-6.86	0.0442	-	-	0.48		168
Mugil cephalus	Striped mullet	S	0 - 999	Jan-Apr	Q	4	1582.2	-768.81	0.0001	93.39	0.0001	0.94	x	1
Microgobius gulosus	Clown goby	S	0 - 30	Jan-Dec	Q	18	-1902.1	930.84	0.0087	-113.79	0.0087	0.30		168
Microgobius gulosus	Clown goby	S	31 - 50	Jan-Dec	Q	18	-775.58	380.18	0.0018	-46.53	0.0018	0.47		56
Trinectes maculatus	Hogchoker	S	0 - 999	Jan-Dec	Q	18	-483.8	236.31	0.0719	-28.83	0.0713	0.27	x	280
a) S = seine, T=Trawl									Significant Durban-Watson statics not included in MFL evaluation.					

5.3 Mollusk

5.3.1 Descriptive

During 2007, Estevez conducted a mollusk survey of the Chassahowitzka using rapid survey techniques described by Estevez (2007) (See Section 11.11) and as applied to other tidal rivers along the west coast of Florida. The Chassahowitzka River was sampled from its mouth to Rkm 9.5 on one-kilometer intervals from Rkm 0-5 and at half-kilometer intervals from Rkm 5 to Rkm 9.5. Both live and dead material was quantified.

Species richness was low, with 13 taxa collected (Table 5-7). By comparison, richness for other systems sampled using similar techniques are 34 in both the Peace and Dona/Roberts Bay systems, 24 in the Myakka, 20 in the Alafia, and 11 in Shell Creek (Estevez 2007).

Table 5-7. Rank and order abundance of mollusk species in the Chassahowitzka River (Estevez 2007)

Species	Count	Abundance (#/m^2)	Percent	Cumulative Percent
Crassostrea virginica	201	115.52	44.37	44.37
Polymesoda caroliniana	73	41.95	16.11	60.49
Ischadium recurvum	67	38.51	14.79	75.28
Bivalvia juv.	36	20.69	7.95	83.22
Hydrobiidae	25	14.37	5.52	88.74
Corbicula fluminea	23	13.22	5.08	93.82
Neritina usnea	9	5.17	1.99	95.81
Tagelus plebeius	9	5.17	1.99	97.79
Geukensia demissa	3	1.72	0.66	98.45
Boonea cf. impressa	2	1.15	0.44	98.90
Macoma constricta	2	1.15	0.44	99.34
Melongena corona	2	1.15	0.44	99.78
Pomacea paludosa	1	0.57	0.22	100.00
Total	**453**	260	**100**	
Note: Each of the 15 total transects had a sampling area of 0.116 m^2. Total number of individuals observed includes both live and dead.				

The mollusk fauna of the Chassahowitzka is similar to that of other studied streams in terms of their overall species composition, but the Chassahowitzka River's fauna is reduced in diversity because marine influences do not extend from the Gulf of Mexico into the river. In terms of species abundance, the American oyster, *Crassostrea virginica*, was the most common native species. As depicted in Table 5-7, oysters were common in comparison to other species but this rank is an artifact of their high numbers in reefs near the river's mouth. Only two taxa of mussels were collected, which is relatively low species richness for mussels compared to other rivers. Two other intertidal species, *Polymesoda caroliniana* and *Neritina usnea* also were common. Live and dead *Corbicula* were found at the upstream-most stations. Compared to *Corbicula* in other rivers, the Chassahowitzka River specimens were small.

5.3.2 Relation to Inflow

The mollusk survey of the Chassahowitzka River was conducted on March 27 and 28, 2007(Estevez 2007). To date, the mollusk surveys done along the west coast of Florida have been one- or two-day events per river. Thus, there has been no attempt to sample across a range of stream flows. Montagna (2006. Montagna et al. 2008) using data from the Peace, Myakka, Alafia, Weeki Wachee / Mud rivers, Shell Creek and Dona/Robert's Bay (but not the Chassahowitzka) identified several species that characterize a particular salinity zone. Montagna (2006) notes that:

> *In this limited analysis of southwest Florida mollusk communities, it is concluded that mollusk species are controlled more by water quality rather than the sediment they live in or on. The most important variable correlated with mollusk communities is salinity, which is a proxy for freshwater inflow. It is impossible to directly link community changes in response to inflow changes, because no(t) replicates over time were carried out in the rivers sampled. Although total mollusk abundance was not a good indicator of inflow effects, certain indicator species have been identified however, that characterize salinity ranges in southwest Florida rivers.*

The most common mollusks observed by Montagna are included in Table 5-8 and compared to the community observed in the Chassahowitzka River by Estevez (2007). Montagna found a number of significant relationships between abundance of individual taxa and salinity, which can be expressed as:

$$y = a * \exp(-0.5*(\ln(x/x_0)/b)^2)$$

where:
y = Number of organisms/m^2
a = maximum abundance
x = salinity (ppt)
x_0 = salinity at maximum abundance
b = rate of response change

This model form assumes that there is an optimal range for salinity and that abundances may be predicted to decrease in a non-linear fashion for salinities on either side of optimal (Montagna et al. 2002). Example responses from Florida Gulf samples identified by Montagna (2006) for the three most abundant taxa (*C. virginica*, *P. caroliniana* and *I. recurvum*) identified in the Chassahowitzka by Estevez are shown in Figure 5-2. Since the Chassahowitzka results were not included in Montagna's regional evaluation, an attempt to recreate similar optimal salinity models using the Chassahowitzka River data was undertaken. The results were unsuccessful. Only the *C.virginica* model was statistically significant (p=0.03). Figure 5-3, which shows *C. virginica* abundances at 15 transect sites in the Chassahowitzka River along with modeled salinity at the sites based on the 63.7 cfs median daily unimpacted flow for the 1967-2007 long-term period used for this minimum flows analysis. The results suggest that the relatively low salinity areas sampled in the short, confined estuary may not have been adequate for characterization of oyster abundance within the system. Montagna (2006) identified an optimal salinity range of 20 to 25 ppt for *C. virginica* in other area rivers and Volety et al. (2003), as cited in Barnes et al. (2007) reports a salinity optima for the species in the range of 14-28 ppt for southwest Florida rivers. Sites sampled on the Chassahowitzka River did not include downstream areas where these salinities may have occurred.

Table 5-8. Rank mollusk abundance - Florida West Coast Tidal rivers (Montagna 2006) and the Chassahowitzka River (Estevez 2007)

Percent Composition of Community Abundance		
Taxa	Rivers* (Montagna 2006)	Chass (Estevez 2007)
Corbicula fluminea	40.4	5.08
Polymesoda caroliniana	11.1	16.11
Rangia cuneata	8.0	0
Tagelus plebeius	5.6	1.99
Amygdalum papyrium	5.2	0
Neritina usnea	3.7	1.99
Geukensia demissa	3.4	0.66
Tellina versicolor	3.3	0
Crassostrea virginica	3.2	44.37
Macoma constricta	3.2	0.44
Ischadium recurvum	2.2	14.79
Littoraria irrorata	2.2	0
Mulinia lateralis	2.1	0
Nassarius vibex	1.7	0
Total	95.0	85.0
* Includes data from the Peace, Myakka, Alafia, Weeki Wachee/Mud Rivers, Shell Creek and Dona/Robert's Bay.		

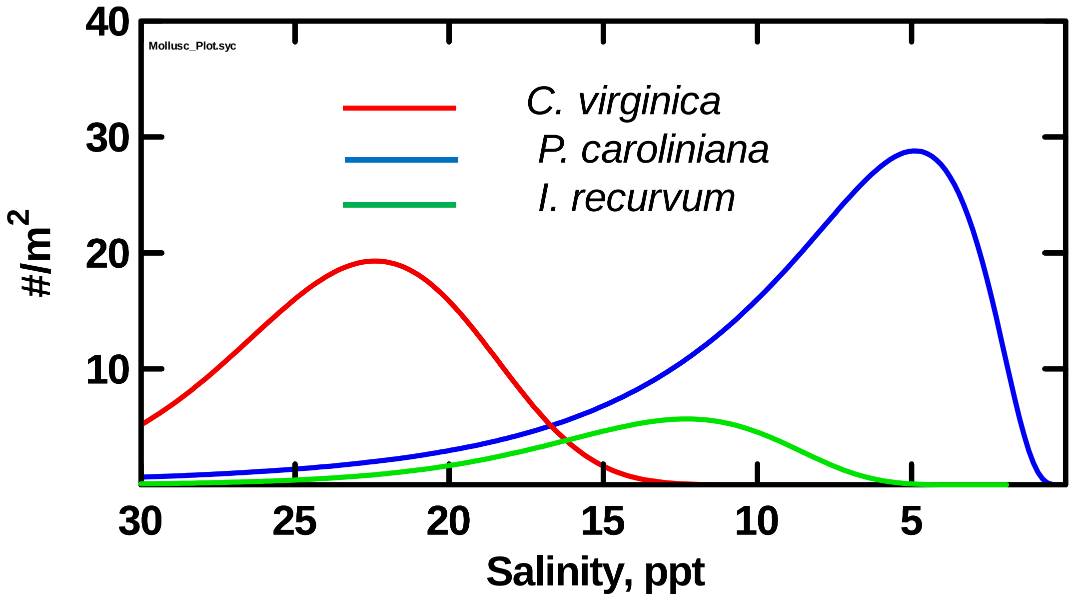


Figure 5-2. Regional salinity for three abundant molluscs found in the Chassahowitzka River (Montagna 2006). Note - Data from the Chassahowitzka was not included in the regional models.

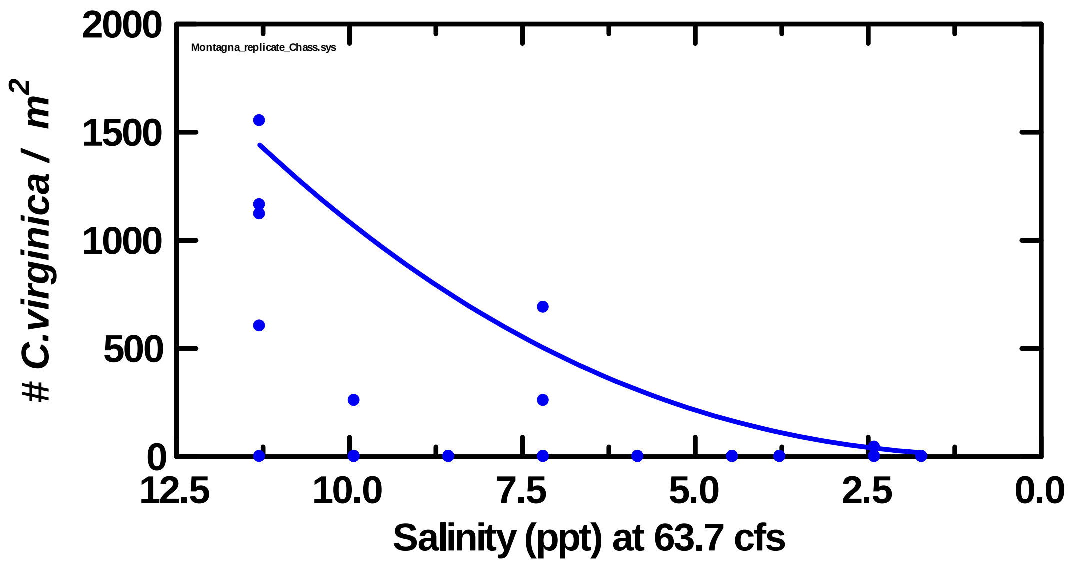


Figure 5-3. ***C. virginica*** **abundance as function of salinity - Chassahowitzka River.**

5.4 Manatee

5.4.1 Descriptive (Adapted from Laist and Reynolds (2005))

The Florida manatee (*Trichechus manatus latirostris*) is a marine mammal subspecies of the West Indian manatee and is found only in the southeastern United States. The U.S. Fish and Wildlife Service (USFWS 2001, USFWS undated) reports that the best current minimum estimate of the Florida population of around 3,276 animals based on a Florida-wide count during January 5-6, 2001, although synoptic aerial counts reported by Florida Fish and Wildlife Conservation Commission[17] in 2010 indicates that the minimum population is 5,076. The Northwest management unit (USFWS 2009) occupies the Florida Panhandle south to Hernando County and consists of approximately 400 individuals.

Many animals succumb annually to collisions with boats and from the effects of a suite of neurotoxins (brevetoxins) produced by the red-tide dinoflagellate *Karenia brevis*. The Florida manatee is federally classified as an 'endangered' species, but on April 9, 2007, the U.S. Fish and Wildlife Service recommended[18] that the designation be reduced from endangered to 'threatened'.

Manatees are poor thermal regulators. Animals exhibit a high degree of thermal conductance (poor insulation) with relatively low metabolic rates (Rouhani et al. 2006) and are generally vulnerable to exposure to temperatures below 20^{o}C (68^{o}F), although some animals can survive chronic exposure to temperatures a few degrees lower. In order to survive cold weather,

[17] http://research.myfwc.com/features/view_article.asp?id=15246
[18]. http://www.fws.gov/southeast/news/2007/r07-057.html

manatees tend to congregate in warm water natural springs or in the cooling water discharge of power plants scattered along the coast of Florida. In developing the Blue Springs minimum flow regime, St. John's Water Management District (SJRWMD) established a critical duration of 4-7 days[19] for exposure at 20°C with return frequency of 50 years, the expected long life span of a manatee (Rouhani et al. 2006). The return interval is estimated as the joint probability product of discharge, temperature, and stage. The potential loss of the artificial sources of warm water through plant closing and reduction of natural springflow due to groundwater withdrawals is of concern to the Warm-Water Task Force (WWTF), a subcommittee of the Florida Manatee Recovery Team. Evidence suggests that the location and use of warm-water refuges is a response that calves learn from their mothers and thus the potential loss of a refuge can affect generations of manatees (Worthy 2005).

The USFWS conducts routine aerial surveys along the west coast of Florida, but the Chassahowitzka River is infrequently included in those surveys. The results vary widely by survey with an average daily count of 152 animals with a standard deviation (sd) of 107 animals (1/1985 through 4/2010*).*Table 5-9 and Figure 5-4 provide the number of annual surveys by refuge area and Figure 5-5 illustrates the average number of animals by refuge. The area of heaviest use is King's Bay which averages 101 animals (std. dev. = 80) per aerial survey which represents 65 percent of all animals counted over the past 26 years. In contrast, the Chassahowitzka has averaged only seven animals per survey during the same period. The maximum number of manatees counted in the Chassahowitzka was 48 animals recorded on May 7, 1996. Manatee usage appears heaviest in the spring (average March count= 9.7 animals, April = 9.0, May =15.1 and June = 10.8) and minimal in the winter (Jan =0.6, Feb = 0.8 animals). No aerial manatee surveys of the Chassahowitzka River have been reported for December.

Some of the difference results from the disparity in number of surveys per year, but when only the surveys that included Chassahowitzka are compared, the number of animals using Chassahowitzka averages four percent of the total animals counted.

Taylor (2006) surveyed the accessibility of Florida springs for the U.S. Marine Mammal Commission and wrote this about the Chassahowitzka:

> *Chassahowitzka Main Spring: Lat. 28.7156°N, Long. 82.5762°W. The Chassahowitzka Main Spring is 360 ft northeast of a boat ramp operated by Citrus County. . . . . Like other natural warm-water sources along the central Gulf Coast, manatee use of this system has increased over the past couple of decades. Beeler and O'Shea (1998) indicated that the headwaters of the river were not easily accessible to manatees and that they were generally absent during the winter (Hartman 1974). Powell and Rathbun (1984) documented single sightings in the headwaters during the winters of 1978 and 1979. Small numbers of manatees have been documented at the Main Spring during synoptic aerial surveys (J.Kleen, USFWS, pers. Comm.). However, the Chassahowitzka area has traditionally been considered summer habitat for manatees and has not been systematically surveyed during the winter months. The Chassahowitzka River is not included on the WWTF list of important manatee warm-water sites. . .*

19. The SJRWMD Blue Sink, and the present SWFWMD Chassahowitzka evaluations use a more conservative three days for establishment of a minimum flow regime.

. Accessibility Issues: Low water during the winter months results in extremely shallow water in the spring run. This likely prevents most manatees from accessing the river during the cold season.

It should be noted that local residents familiar with the river feel strongly that the USFWS aerial survey results underestimate the number of animals utilizing the Chassahowitzka River. (Verbal comments were received at Pubic Workshop for proposed minimum flow of the Chassahowitzka River held on 10/06/2010 in Brooksville, Florida). However, it should be emphasized that presentation of the data in Table 5-9 in this report is for the sole purpose of providing background information. The evaluation of thermal refugia is independent of the actual number of manatees that use the Chassahowitzka. The District approach to setting an MFL includes an evaluation of acute and chronic thermal habitat for all spring systems, whether one or a hundred manatees have been observed in the past.

5.4.2 Relation to inflow

The primary relationship between flow and the health of the manatee is a function of providing a thermal refuge of warm water during extreme cold. All of the areas available for manatee habitat are tidally influenced and as a result, freshwater withdrawals have very little effect on the depth of water available. A reduction in flow of 11 percent is predicted to result in a reduction in water depth of 0.13 inches at the main spring where the impact would be most pronounced.

Table 5-9. Average number of surveys and manatee counts - Florida West Coast 1/1985-4/2010. J.Kleen (USFWS) personal communication.

Year	Total	KB	CRY	UHOM	LHOM	SR	PP	BC	WAC	WIT	SWR	SRE	CH	WW
Average Number of Manatee / Survey														
2010	340	249	4	61	7	4	13	0	0	0	0	0	10	4
2009	163	95	7	30	5	4	17	1	0	1	1	0	6	10
2008	165	106	8	21	7	6	14	2	0	2	0	0	0	7
2007	173	100	10	23	8	7	22	2	0	5	2	0	1	12
2006	172	102	11	21	8	10	17	1	2	1	1	4	2	19
2005	157	99	8	29	6	2	11	0	1	0	2	0	5	14
2004	171	103	6	38	5	3	14	1	1	0	7	0	4	5
2003	187	127	7	34	3	2	10	0	1	0	2	0	5	5
2002	211	141	5	46	4	1	11	1	1	3	6	33	3	16
2001	176	121	5	37	4	2	13	1	0	6	6	0	5	13
2000	216	132	8	40	5	2	17	1	3	2	6	10	7	12
1999	222	133	6	51	6	1	23	0	0	1	6	0	2	12
1998	141	86	5	35	6	4	2	0	7	2	1	8	12	9
1997	158	99	6	30	6	4	7	1	3	1	2	3	13	2
1996	186	120	8	33	7	6	11	0	0	0	0	5	14	3
1995	143	92	10	15	6	3	8	1	0	1	1	11	14	8
1994	130	97	6	11	3	3	3	1	2	3	2	7	10	
1993	142	101	7	24	3	3	8	1	0	3	0	1	19	
1992	106	81	5	20	4	2	7	1	0	1	0	5	4	0
1991	121	91	6	16	2	0	5	0	1	1	0	1	3	2
1990	142	98	11	22	1	2	8	0	3	8	9	4	8	
1989	157	108	10	27	2	2	7	5	0	1	0	4	4	
1988	136	85	9	31	1	1	5	1	1	3	2	7	8	
1987	141	104	5	29		0	4	0	0	0	0	0	2	
1986	89	55	4	26	1	2	2	0	0	1	1	2	8	
1985	63	43	6	12	1	0	0	0	0	1	1	5	1	
Overall	162	106	7	29	4	3	10	1	1	2	2	4	7	8
Average Number of Surveys / Year														
2010	11	11	11	11	11	11	11	11	1	1	1	1	2	1
2009	24	24	24	24	24	24	24	24	2	2	2	2	9	2
2008	19	19	19	19	19	19	19	19	1	1	1	1	1	1
2007	27	27	27	27	27	27	27	27	1	1	2	1	2	2
2006	25	25	25	25	25	25	25	24	2	2	2	2	3	3
2005	25	25	25	25	25	25	25	24	2	2	2	2	2	2
2004	27	27	27	27	27	27	27	27	2	2	2	2	2	2
2003	18	18	18	18	18	18	17	18	6	6	6	6	6	6
2002	22	22	22	22	22	22	22	22	2	2	1	1	1	1
2001	19	18	18	18	18	18	18	19	2	3	2	2	2	2
2000	28	28	28	28	28	28	28	28	6	8	7	7	7	7
1999	24	24	24	24	24	24	23	23	3	3	4	3	5	3
1998	22	22	22	22	22	22	22	22	1	1	2	1	2	2
1997	26	26	26	26	26	26	26	24	5	5	6	5	8	1
1996	23	23	23	23	23	23	22	22	3	3	3	3	4	2
1995	30	30	30	30	30	30	30	30	3	4	3	3	13	2
1994	25	25	25	25	25	25	25	25	5	8	5	5	6	0
1993	26	26	26	23	23	26	22	25	1	2	1	1	1	0
1992	35	35	35	20	20	34	20	16	2	2	1	2	3	1
1991	27	27	27	27	27	27	27	6	7	7	7	7	7	2
1990	19	19	19	19	19	19	18	1	1	2	1	1	1	0
1989	18	18	18	18	18	18	18	1	1	10	1	1	3	0
1988	25	25	25	25	16	25	25	5	5	10	5	5	5	0
1987	20	20	20	20	0	20	20	1	1	1	1	1	2	0
1986	31	31	31	31	3	31	31	2	2	2	2	2	2	0
1985	33	32	31	30	14	31	31	13	13	13	14	14	13	0
Overall	24	24	24	23	21	24	23	18	3	4	3	3	4	2

KB = King's Bay / CRY = Crystal River / UHOM = Upper Homosassa River / LHOM = Lower Homosassa River / SR = Salt River
PP = Crystal River Power Plant / WAC = Wacasassa / WIT = Withlacoochee / BC = Barge Canal / SWR = Suwannee River
SWE = Suwannee River Estuary / CH = Chassahowitzka River / WW = Weeki Wachee River

Mantee_Counts.xls

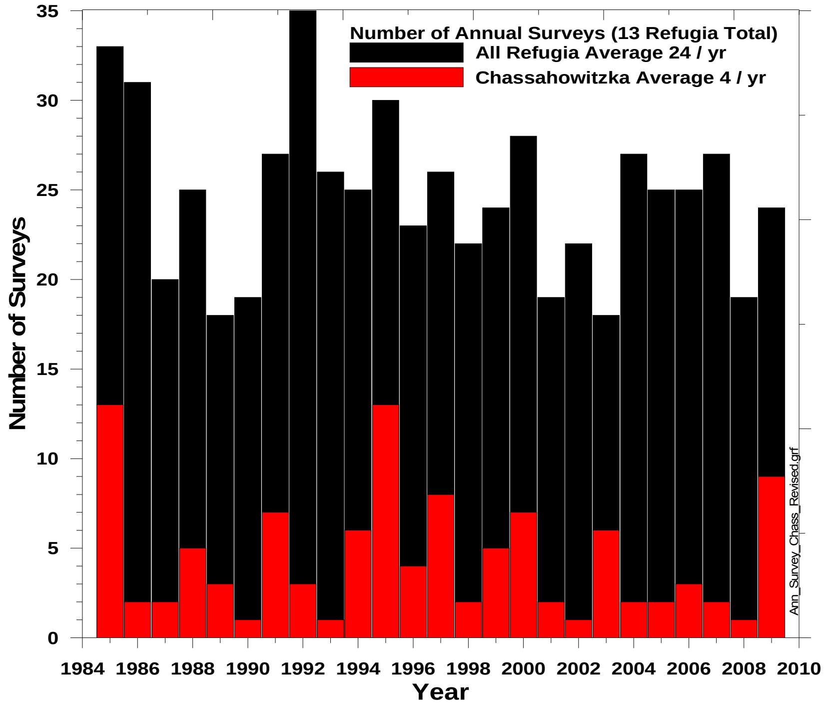


Figure 5-4 Number of aerial manatee surveys by year and refuge

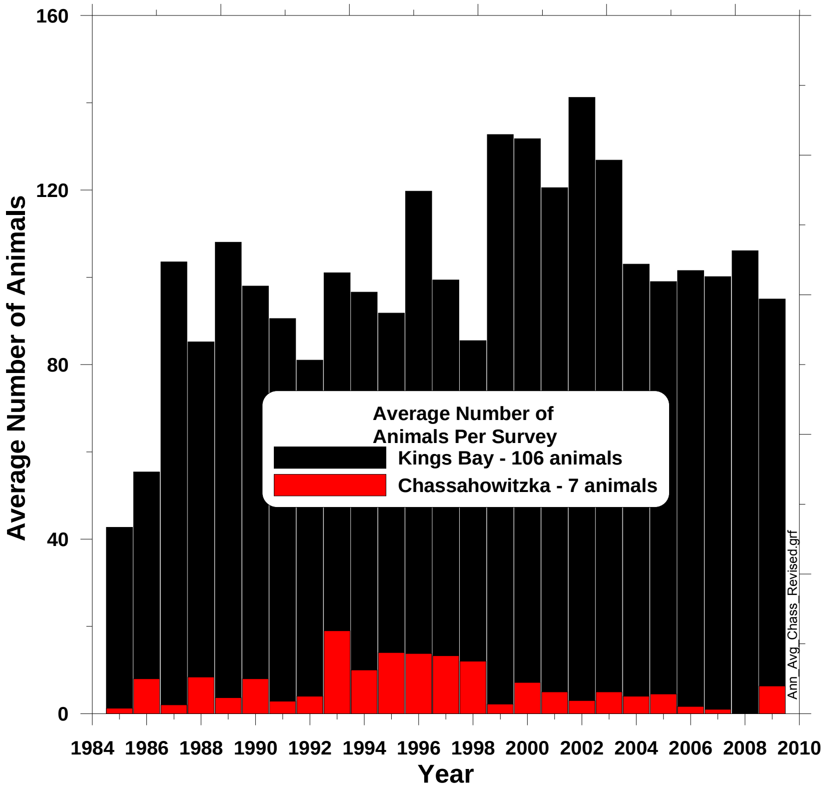


Figure 5-5. Average annual number of manatees Chassahowitzka and King's Bay

5.5 Gross Primary Productivity–Relation to inflow

Gross primary productivity (GPP) is a measure of the amount of oxygen produced by an ecosystem. Wetland Solutions, Inc. (WSI, 2010) described GPP as:

> *". . . the best available measure of a natural ecosystem's "gross domestic product" or the total amount of organic carbon fixed by photosynthesis within that system and available to meet the respiratory requirements of all plants, microbes, invertebrates, and vertebrates living in that ecosystem. GPP magnitude reflects the overall ability of a natural ecosystem to support life."*

Dr. Knight of WSI presented his findings at the October 26, 2011 springs coast stakeholders meeting and suggested that the District consider these metrics when establishing an MFL in a spring-dominated system. Dr. Knight has reported a positive relationship between discharge and GPP and GPP efficiency (GPP normalized to the amount of available photosynthetically active radiation) for many of the freshwater spring systems in Florida. In response and using WSI data (WSI 2010, WSI 2011), the District evaluated the reduction in flow that would cause a 15 percent reduction in GPP and GPP efficiency in the Chassahowitzka River system. Response equations were taken from the reference citations. Reproductions of the original figure and equations are presented below and on the following page.

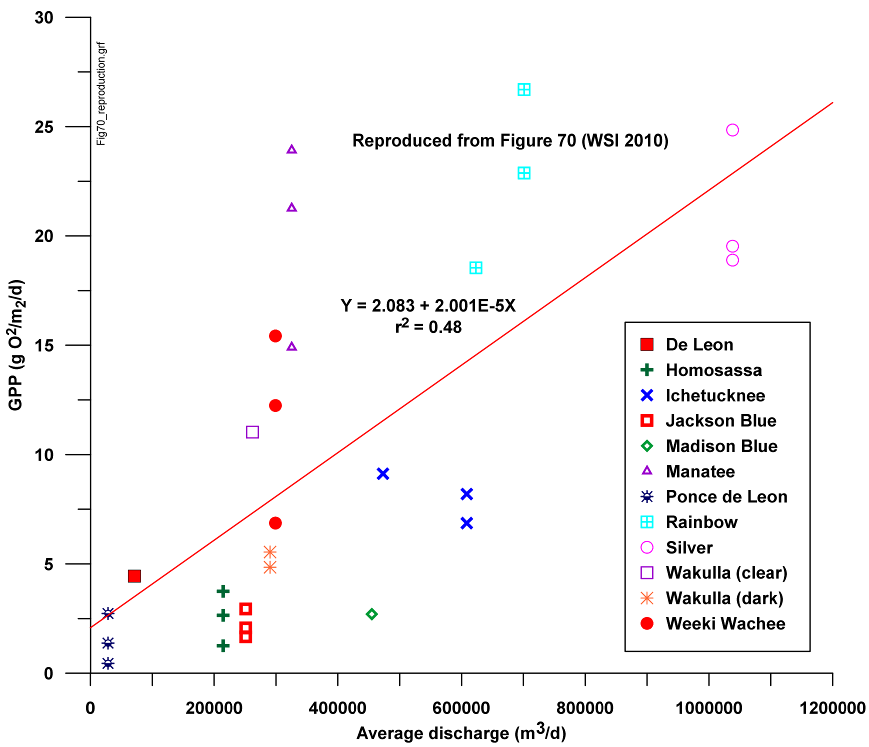


Figure 5-6. Relationship between average spring discharge and GPP. (Adapted from Figure 70. WSI 2010.)

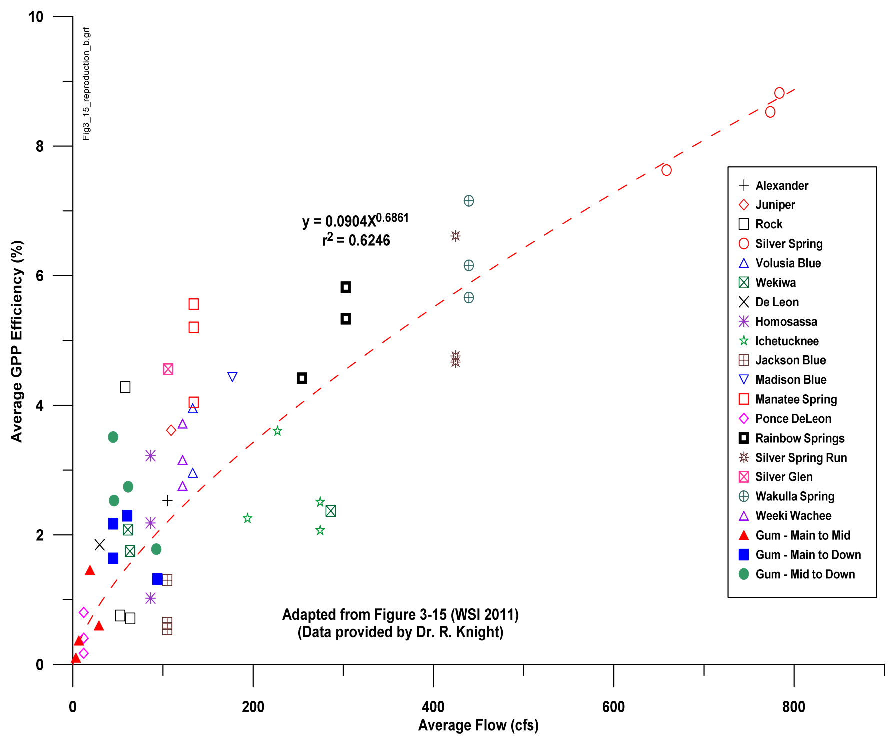


Figure 5-7. Average discharge vs. average gross primary productivity efficiency. (Adapted from Exhibit 3-15.WSI 2011.)

CHAPTER 6. CRITERIA FOR RESOURCES OF CONCERN

6.1 Resource Criteria / Goals

Response tools for salinity habitat, fish and invertebrates, and benthos were developed using observed flow record (impacted), since many of these tools were based on existing conditions and/or maximums. However, the criteria for biological resources was based on a 15 percent reduction from the median, long-term unimpacted flow (63.7 cfs). The salinity and thermal habitat criteria were based on a 15 percent change from unimpacted daily flows for the period of the hydrodynamic modeling evaluation. The authors acknowledge that salinity, expressed as an area, volume, or shoreline length of habitat, is a surrogate for a wide variety of unquantified but important processes at work in the Chassahowitzka River system.

6.1.1 Mollusk

Mollusks were not further evaluated because only the Eastern oyster, *C. virginica* exhibited a statistically significant response to salinity but the sampling domain did not capture peak abundance for this taxon. Simulating withdrawal of freshwater would lead to prediction of increased abundance of oysters. No minimum flow criterion was established for the mollusk community.

6.1.2 Fish & Invertebrates

Regression criteria for evaluation included a) minimum 10 observations per variable, b) positive linear or 'mid-flow maximum abundance' quadratic response, c) no significant serial correlation and d) an adjusted r^2 of at least 0.3. As discussed in Section 5.2.2, the plankton net collection resulted in two flow responses meeting these criteria for taxa abundance. The results (See Table 5-5) were identified as resources warranting further evaluation. The taxa included the tanaid *Hargeria rapax*, and midges (dipterans, chironomid larvae). In addition, four taxa from the seine and trawl results with the strongest positive abundance/flow responses and meeting the criteria above were chosen for further evaluation (See Table 5-6). One, the spotted sunfish, exhibited a linear response. In addition pink shrimp, Gulf killifish, and sailfin molly exhibited mid flow maximum abundance response was initially developed by the FWC staff. However, subsequent to publication of the November 2010 draft MFL report, FWC informed the District (T. MacDonald personal communication Oct. 28, 2011) that the agency has stopped evaluating this response form. Nevertheless, these three taxa were included in the reevaluation for the sake of comparison with previous draft reports. A 'significant harm' criterion was presumed to be exceeded when flow reductions resulted in a 15 percent reduction in abundance relative to abundance at 63.7 cfs.

6.1.3 Submerged Aquatic Vegetation

Resource criterion for native SAV was based on an allowable increase in salinity at the location of maximum observed density reported recently by Mote Marine Laboratory (Leverone 2006). An estimate of the long-term salinity was developed from the LSM and is provided in Table 6-1. The criteria for this resource was no more than a 15 percent reduction in observed maximum abundance at the location of observed maximum abundance.

Table 6-1. Dominant SAV - Location of maximum density and expected salinities (adapted from Leverone 2006)

Taxa	Median Flow (cfs)	Maximum Density	Rkm @ Maximum Density	Salinity at 63.7 cfs
Vallisneria americana	63.7	3.8	7.0	1.72
Najas guadalupensis	63.7	3.3	7.0	1.72
Potamogeton pectinatus	63.7	2.9	7.5	1.04
Ruppia maritima	63.7	2.8	3.5	6.51

6.1.4 Benthos

Broad community response to salinity habitat has been demonstrated both regionally and for the main stem Chassahowitzka River. However, the only statistically significant relationship obtained with the Chassahowitzka benthic data was for diversity and salinity. This relationship is positive, and thus decreasing flow will increase salinity – which will in turn increase the diversity. Thus, no MFL criterion was established for the benthic community.

6.1.5 Salinity Habitat Criteria

At the more general level, benthos habitat was evaluated in terms of bottom area in contact with a specified salinity and fish habitat was broadly evaluated as the volume of water at, or below some specified salinity. Isohaline values of 2, 5, 10 and 15 ppt were chosen for evaluation and a significant reduction in habitat was defined as greater than a fifteen percent reduction as compared to the baseline. The salinity habitat criterion is derived from the findings reported by Dynamic Solutions, LLC (2009) (See Section 3.1.2). Dynamic Solutions, LLC developed a hydrodynamic model of the Chassahowitzka River and determined salinity changes and changes in the volume and area due to reductions in spring flow. The salinity habitat criterion was based on maximum flow reduction, defined as a flow that resulted in a 15 percent loss reduction in habitat (i.e., volume, area and shoreline) associated with the specified salinities.

In addition to salinity volume and bottom habitats, the cumulative shoreline in contact with 2, 5, 10 and 15 ppt salinity was quantified and the flow reduction resulting in a 15 percent loss of shoreline length at those salinities was determined using the hydrodynamic model results.

For the minimum flows reevaluation using a corrected flow file, withdrawal impacts were estimated using the Northern District Model (NDM) and applied to the respective springs in the hydrodynamic model. The impacts identified by the NDM model include the following percentage reductions to flow: a) USGS site 02310650 1.10, b) Crab Creek 1.47, c) Potter Creek 0.73. The reevaluation used flows corrected as described in Section 2.3.1.1.

6.1.6 Manatee Thermal Refuge Criteria

Manatees cannot tolerate more than four days of water at 68°F (chronic criteria) or more than four hours at 59°F (acute criteria) and must be able to access warm water. For the purpose of this evaluation, the following criteria were established (Rouhani et al. 2006, Dynamic Solutions LLC 2009,)

<u>Chronic</u>

- Minimum depth of water at low tide = 3.8 feet
- Refuge is accessible at high tide. Minimum high tide depth > 3.8 feet
- Must remain $\geq$ 68°F for duration of critically cold three day period.

<u>Acute</u>

- Minimum depth of water at low tide = 3.8 feet
- Refuge is accessible at high tide. Minimum high tide depth $\geq$ 3.8 feet.
- The temperature cannot be $\leq$ 59°F four or more hours.

Rouhani et al. (2006) reported dimensional constraints of an adult manatee as illustrated in Figure 6-1. Figure 6-2 documents[20] observed densities in Blue Springs. These dimensions were used to derive the minimum area (28.5 ft^2) and volume (108 ft^3) requirements. Actual packing densities are typically higher. Figure 6.3 illustrates the measured Blue Springs daily densities on the days of maximum use for the 1981-2000 manatee seasons. The highest density observed was 28.5 ft^2/manatee, and the median was 100 ft^2/manatee.

The minimum depth (3.8 feet) chosen for the Chassahowitzka evaluation is shallower than the 5.0-foot minimum depth criteria used in establishing the Blue Springs MFL (Rouhani et al. 2006). On the other hand, Dr. Tripp (Director of Science and Conservation for Save the Manatee Club) has indicated that (see complete dialogue in Chapter/Section 10.18.18) :

> *On a very cold, but sunny day, shallow waters may be more preferable because manatees utilize the solar gain-both in the water and on their dark skin – they will actually rest with their backs exposed – purposefully*.

While high tide is necessary to access some areas of the refuge, the higher tides also drive the colder Gulf water further upstream. The combination of cold temperature and high tide conditions was selected with a return interval of 50 years (average life

[20] http://share2.myfwc.com/spring/Meeting%20Presentations/Volusia-Blue%20Spring%20Working%20Group/2009-06-17%20Kent%20Smith.pdf

expectancy of Florida manatee) to represent the critically cold period. Details can be found in Section 11.13 (Dynamic Solutions LLC 2009). The significant harm threshold established was no more than a 15 percent reduction in refuge volume or area meeting the above criteria under the chronic or acutely cold conditions

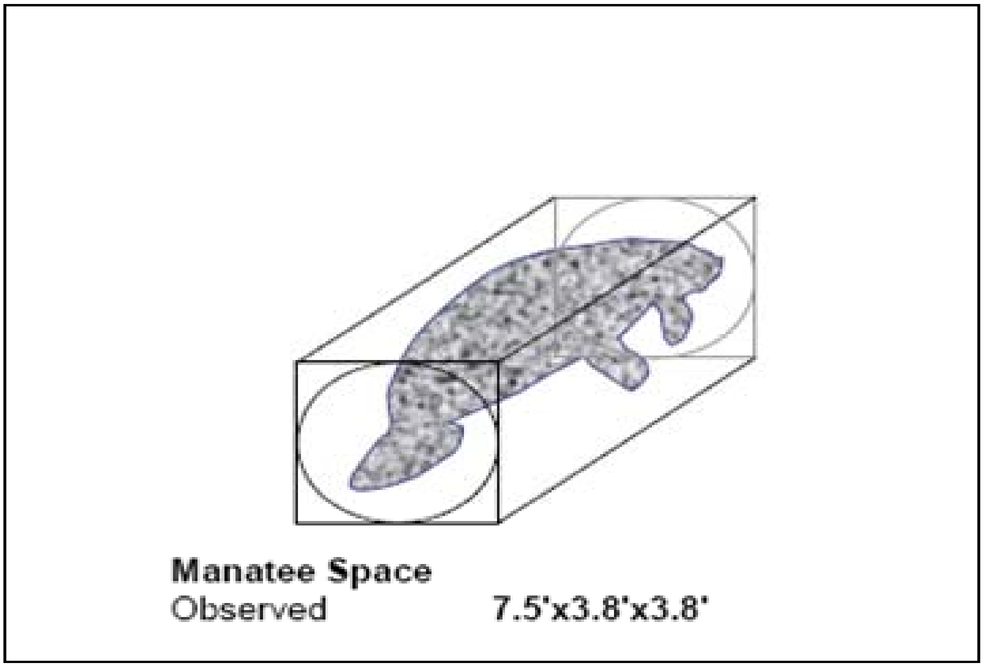


Figure 6-1. Manatee space requirements (reproduced from Rouhani et al. 2006)

Figure 6-2. Observed manatee densities – Blue Springs (K.Smith, FWC)

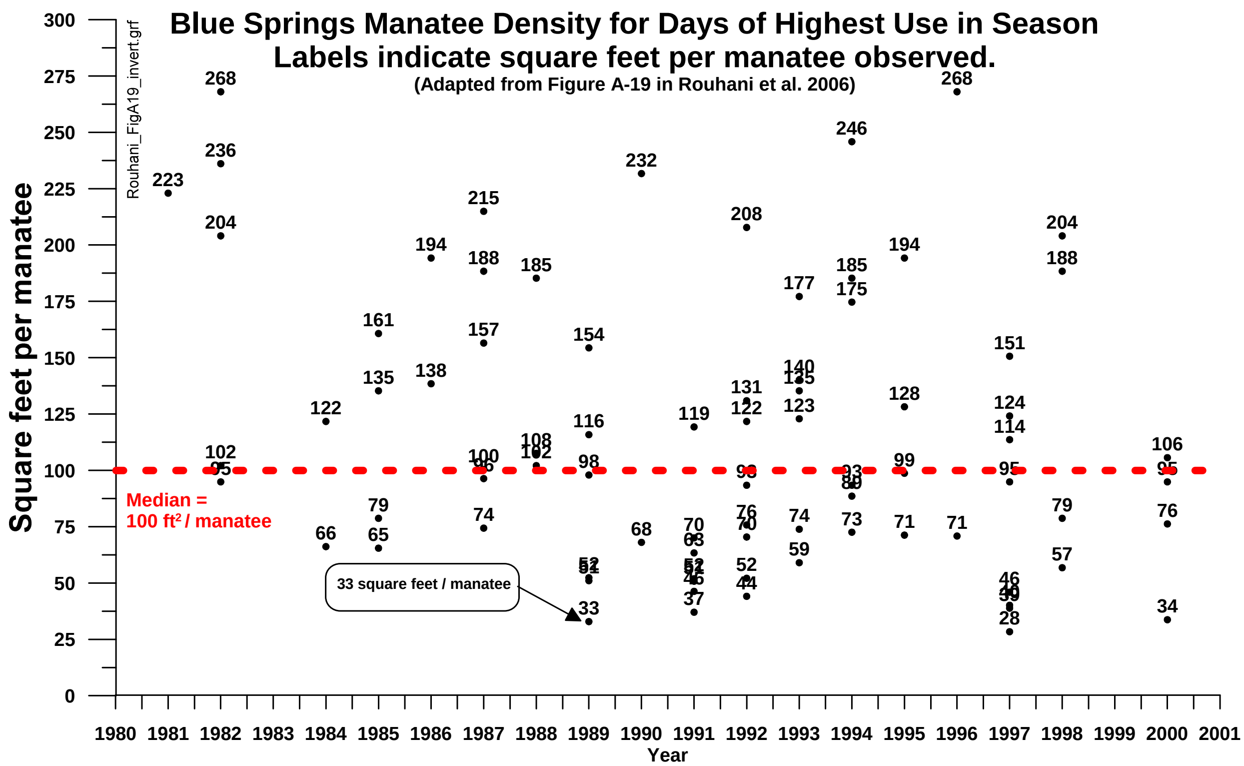


Figure 6-3. Blue Springs manatee density on day of highest seasonal use.

6.2 Gross Primary Productivity Criteria

Similar to the other biological metrics, the criteria for GPP and GPP efficiency was established at no more than a 15 percent reduction from unimpacted conditions. At a median unimpacted flow of 63.7 cfs, the estimated GPP is 5.20 g $O_2/m^2/d$ and the expected GPP efficiency is 1.56 percent. The MFL criterion for these biological metrics would be the percent of flow reduction that results in 4.42 g $O_2/m^2/d$ and 1.33 percent GPP efficiency.

CHAPTER 7. TECHNICAL APPROACH

7.1 Fish / Invertebrate Technical Approach

The fish and invertebrate resource response to flow was in general evaluated using the following equation from the robust regression analysis of seine / trawl data (See Table 5-6):

$$\ln(\text{Abundance}+1) = \text{Interception} + \text{Coef.\_linear} * \ln(\text{Lag\_Flow}+1) + \text{Coef\_quadratic} * [\ln(\text{Lag\_Flow}+1)]^2$$

where, Abundance is expressed as catch per unit effort / 100 m^2.
(Linear response evaluated by setting Coef._quadratic to zero).

The response of smaller organisms captured in the plankton net was evaluated using the following equation (See Table 5-5)

$$(\text{Abundance}) = \text{Interception} + \text{Coef.\_linear} * \ln(\text{Lag\_Flow})$$

where, Abundance is expressed in units of ^{total} number in channel.

The abundance was then reduced by fifteen percent and the flow associated with the reduced abundance was back calculated.

For *Hargeria rapax*, and dipterans/chironomid larvae (positive plankton net results), eighty-five percent of the baseline abundance is predicted to occur at reduced flows of 62.5 (1.9 percent), and 62.2 (2.3 percent) cfs respectively (Table 7-1). For *Lepomis punctatus* , the reduced abundance is predicted to occur at reduced flows of 62.7 (1.6 percent) cfs.

Table 7-1. Response of fish and invertebrate abundance to reduced flows

Taxa	Baseline Abundance		85% Abundance		Flow at 85% Abundance	Flow Reduction Evaluated
	(#/channel)	($\#/100^2$)	(#/channel)	($\#/100^2$)	(cfs)	(%)
Plankton Net						
Hargeria rapax	503,232	-----	427,747	-----	62.5	1.89%
Dipterans, chironomid larvae	469,660	-----	399,211	-----	62.2	2.29%
Seine and Trawl						
Farfantepenaeus duorarum (T)	-----	0.68	-----	0.58	51.7	18.9%
Fundulus grandis	-----	1.90	-----	1.62	55.0	13.7%
Poecilia latipinna	-----	0.21	-----	0.18	54.1	15.1%
Lepomis punctatus (seasonal)	-----	3.73	-----	3.17	62.7	1.6%
Unimpacted flow = 63.7 cfs for all starting calculations.						

These very sensitive responses to changes in flow identified for these three taxa are suspect when considering that the flow variation for the actual 61 days of sampling fish/invertebrates. The actual flow exhibited a mean of 59 cfs, and a range of 32 cfs that varied from the mean by + 72% and – 28%.

Additional concerns about the reasonableness of the results became apparent when the criteria were applied to the flow / abundance relationships for the sunfish, *L. punctatus* (< 101 mm). As shown in Figure 7-1, when the flow (21 day moving average corresponding to the lag term in the regression) is reduced 18 percent to 52.2 cfs, the predicted response is the virtual elimination of *L. punctatus* from the Chassahowitzka River system. Twenty-one day average flows equal to, or less than this value occur 957 times in the long-term unimpacted flow record. This reduced flow falls within the normal variability of the system (Mean ± 2 sd = 47 to 80 cfs) suggesting that perhaps flow is not the factor controlling the abundance of these organisms in the Chassahowitzka system.

It should be noted that the *L. punctatus* response curve is based on data collected only during May to November. The seasonal flow variation in the Chassahowitzka River system is minimal and further sub-setting the results to seasons constricts the range of the flow domain even further. In consideration of the relative constancy of flow in the system, establishing seasonally variable MFLs is not considered appropriate. Results based on seasonal catch results (e.g. *L. punctatus*) were not considered in the final determination of the MFL.

Table 7-1 provides the abundance, reduced abundance, reduced flow and percent of flow reduction resulting in a 15 percent change in abundance for all taxa that met the general regression criteria specified in Section 1.4.2 and were either a) positive linear response to flow, or exhibited mid-flow maximum for quadratic responses and otherwise met the criteria for evaluation. (These taxa were introduced as highlighted rows in Tables 5-5 and 5-6.) Also included in Table 7-1 is a listing and median for those taxa retained for determination of the MFL in the right-hand column. In the present evaluation, the median is the same whether the seasonal values are included or not. Figure 7-1 compares the application of both a robust regression (Wessel 2009) and ordinary least squares (Greenwood 2008).

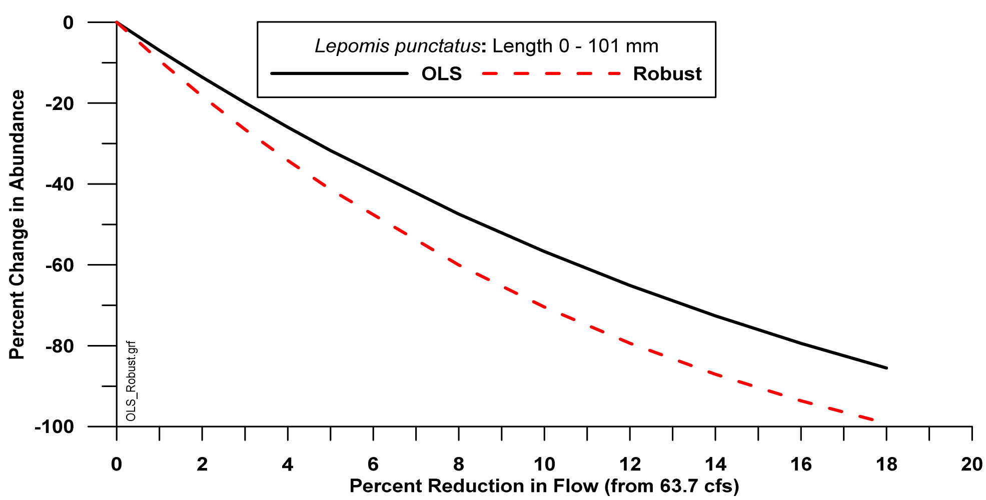


Figure 7-1. Predicted change in *Lepomis punctatus* abundance as a function of inflow reduction from the median flow (63.7 cfs) using OLS and robust methods.

A taxa of potential significance to the Chassahowitzka National Wildlife refuge is the blue crab (*Callinectes sapidus*). The endangered whooping crane over-winters in Texas and in the Chassahowitzka refuge. In recognition of the commercial and ecological significance of blue crab, the District contracted with the Florida Fish and Wildlife Conservation Commission (FWC) to review the local relationship(s) between blue crab and freshwater inflow. Over the course of several decades, FWC and the University of South Florida (USF) have conducted numerous studies along the west coast of Florida relating abundance, location and community dynamics to freshwater inflow. Gandy et al. (2011) summarized the results and discussed the limitations of these and other regional studies.. (See Section 11.16 for discussion of limitations.) Table 7-2 compares the linear responses reported for the number of organisms captured (abundance) as a function of freshwater inflow and collection gear. There does not appear to be a consistent pattern in the response of blue crab to changes in flow. In 15 of the 25 cases reported, reducing the inflow will result in increased number of blue crabs, while in the remaining 40% of the cases it would result in a decrease in the number of blue crabs. The results obtained for the Chassahowitzka sampling are in the former group and were not included in the MFL evaluation. Of particular concern is that fact the abundance of blue crab nekton in the Chassahowitzka River system is inversely related to flow, while the opposite response was detected in the Homosassa River system, another spring-dominated system six miles away.

In addition to the expressed concerns, a recent study(Wessel 2012) of 12 years of fish/invertebrate sampling results from the Alafia was analyzed using the same protocol suggest that a simple abundance/flow regression approach with 2-5 years of data is insufficient to quantify a consistent predicable response. Wesel evaluated a moving 2-year window of sampling results for several taxa commonly found in west Florida tidal rivers. Wessel found that for a given taxa there was little consistency in the predicted number of organisms as a function of flow and response reversed often. Wessel notes that *'[o]nly with at least 4 years of data collection did the slope estimates tend to stabilize toward a particular direction, and in several instances, 4 years of data was not enough to achieve statistical significance.'* Wessel added that *'[t]ogether , these issues regarding the existing analytical methods to establish the fish-flow relationship revealed that more work was needed to describe the effects of freshwater inflows on fish abundance in tidal rivers.'* Results of this study are summarized in Table 7-3.

Table 7-2. MovIng two-year fish/invertebrate abundance response to flow in Alafia River. (Wessel 2012)

Common Name \ Years Sampled	1998-1999	1999-2000	2000-2001	2001-2002	2002-2003	2003-2004	2004-2005	2005-2006	2006-2007	2007-2008	2008-2009
Mysid Shrimp		P	P	P	P	N	N	P	P	N	P
Unidentified mysid shrimp	P	P	P	P	P	N	P	P	N	P	P
Pink Shrimp	P	P	P	P	P	N	P	N	P	N	N
Seminole Killifish < 45 mm	N	P	P	N	P	P	P	P	P	P	P
Seminole Killifish > 46 mm	P	P	N	P	P	P	P	N	P	P	P
Clown Goby	N	P	P	N	P	N	N	N	N	P	P
Comb Jelly	N	N	N	N	N	N	N	N	N	N	N
Grass Shrimp	P	P	P	P	N	P	P	P	N	N	N
Red Drum 40-150 mm	P	P	N	N	P	N	N	N	N	N	N
Red Drum < 40 mm	P	P	P	P	P	P	P	N	P	N	N
"Pos." = Positive response to flow. "Neg" = Negative response to flow. **Red text** for either indicates significant at p≤0.05											

Table 7-3. Blue crab abundance response to flow reductions.

System	Months of Study	Sampling Gear	Abundance Response to Decreasing Flow
Homosassa River(<=30mm)	24	Seine	Decrease
(<=30mm)	24	Trawl	Decrease
(>30 mm)	24	Seine	Decrease
(>50 mm)	24	Trawl	Increase
Chassahowitzka River	24	Seine	Increase
	24	Trawl	Increase
Anclote River	12	Seine	Increase
	12	Trawl	Increase
Tampa Bypass Canal	72	Trawl	Increase
Alafia River (2005)	84	Seine	Increase
	84	Trawl	Increase
Little Manatee River	120	Seine	Decrease
	120	Trawl	Decrease
	36	Plankton net	Increase
Dona and Roberts Bay	14	Seine	Decrease
	14	Trawl	Decrease
Myakka River / Myakkahatchee Creek	20	Trawl	Increase
	20	Seine	Increase
Peace River	96	Seine	Increase
	96	Trawl	Increase
Shell Creek (< 40mm)	96	Seine	Increase
(<40 mm)	96	Trawl	Decrease
Shell Creek (>39 mm)	96	Seine	Decrease
(>39 mm)	96	Trawl	Increase
Caloosahatchee River	48	Trawl	Decrease
			Callinectes.xls

The number of fish/flow responses that met the *a priori* criteria (n>=10, r^2>=0.3, positive linear response, or mid-flow max quadratic) was six. Of those six, four were eliminated from further consideration because of serial correlation, seasonal responses and use of a quadratic response. Confidence was further eroded by Wessel's findings regarding sampling duration, and by inconsistent taxa response at adjacent spring systems. As a result, the fish/flow metrics were not considered appropriate for use in establishing a minimum flow for the Chassahowitzka River system.

7.2 Submerged Aquatic Vegetation Technical Approach

Aquatic vegetation sampling completed in 2005 for the District by Leverone (2006) was used to evaluate relationships between salinity and Braun- Blanquet density (Braun-Blanquet 1932) of the three most common native submersed aquatic species in the

Chassahowitzka River. Given the strong relationship between salinity and flow in the river (see Section 4.2.3), these factors were examined with the intention of using statistical relationships between salinity and plant densities to evaluate potential effects associated with inflow reductions. For the analyses, two response models were developed. The first approach was a set of fourth order polynomial regressions to approximate salinities associated with locations where maximum densities of *V. americana, N. guadalupensis, R. maritima* and *P. pectinatus* were observed in 2005

Ferguson and Wood (1994) report a salinity tolerance of 1-10 ppt for *N. guadalupensis*, although Haller et al. (1974) demonstrated toxicity when plants were exposed to 10 ppt in greenhouse growth experiments. Based on a review of available literature, Kantrud (1990) identified an optimal salinity range of 5-14 ppt for *P. pectinatus* and notes that the species distribution is often restricted or the plant is replaced by other species in areas where salinities range between 13 and 20 ppt. Tolerance ranges reported in the literature and observed in the Chassahowitzka are summarized in Table 7-4.

Table 7-4. Salinity tolerance of predominant SAV taxa in Chassahowitzka River.

	Chassahowitzka Observed Range	Literature Range	Sources
Najas guadalupensis	< 3.3	1- 14	Ferguson and Wood 1994
Ruppia maritima	2.5 - 12	0 - 60	Berns 2003 (and citations therein)
Vallisneria americana	< 3.3	0 - (10-15)	Kraemer et al. 1999 Doering et al. 2002
Potamogeton pectinatus	< 3.3	0 - 14	Kantrud 1990 Shili et al. 2007

In practice, the density response to salinity was developed by forcing the regression curve past the maximum observed density point, resulting in the following 4th order polynomial form as an approximate estimation (See coefficient values in Table 7-5):

$$\text{Density} = a*\text{Salinity}^4 + b*\text{Salinity}^3 + c*\text{Salinity}^2 + d*\text{Salinity} + e$$

The fourth order polynomial models tended to predict unrealistically high density values for the three plant species at high salinities. Laboratory growth studies and field observations of the distribution of *V. americana* in the Caloosahatchee River estuary in south Florida indicate that this species is tolerant of salinities up to 10-15 ppt (Haller et al. 1974, Kraemer *et al*1999. Doering et al. 2002), although others report lower salinity tolerance values for the species (Haller et al. 1974, Ferguson and Wood 1994, sources cited in Doering et al. 2002). The minimum flow for the Caloosahatchee River (Chapter 40E-8.221, F.A.C.) adopted in 2001 is based on maintaining a 30-day average salinity of less than 10 ppt and a 24-hour salinity of less than 20 ppt in order to protect *V. americana* in that system (South Florida Water Management District 2003).

Since the three of the four taxa chosen have low to moderate tolerances to salinity, for the polynomial regression the observed density points upstream of the point of maximum recorded density were omitted for the non-critical situation in a favorable environment (greater freshwater). In addition, the fluctuation of the regression curve at high salinities would not affect the result of evaluation because the curve's steep descending portion from the peak-point would cover a very large range of flow reduction (more than 15 percent).

The peak density was then reduced by fifteen percent and the salinity associated with the reduced density (at 85 percent of the maximum) was back calculated. Using *Vallisneria americana* as an example, the maximum density is 3.8, which occurs when the salinity is at 3.08 ppt. Eighty-five percent of the peak density is 3.23, which occurs when the salinity is at 3.28 ppt.

A second approach was developed using the optimization model form presented for mollusk in Section 5.3.2. The fitted form of these Chassahowitzka specific models and the corresponding input data is presented in Figure 7-2. The regression coefficients for the polynomial and optimization models are given in Table 7-5.

Table 7-5. Regression coefficients for SAV density response models using Leverone 2006 data.

Coefficients :	a	b	c	d	e	r^2	n =
polynomial models							
Najas guadalupensis	0.007	-0.195	1.999	-8.495	12.399	0.834	15
Ruppia maritima	0.108	-4.053	56.294	-343.531	777.237	0.963	8
Vallisneria americana	0.006	-0.178	1.927	-8.785	14.094	0.957	15
Potamogeton pectinatus	0.004	-0.104	1.027	-4.164	5.726	0.810	16
optimal salinity models							
Najas guadalupensis	4.3182	-0.1663	1.5245	---	---	0.991	18
Ruppia maritima	1.3220	-0.3020	5.4497	---	---	0.304	18
Vallisneria americana	3.9598	0.3107	1.6440	---	---	0.978	18
Potamogeton pectinatus	7.5462	0.6276	0.3639	---	---	0.758	18

As a point of discussion, the range observed in 2005 shown by red dots in Figure 7-2 should be compared to the expected range of salinities provided in Table 7-3 and the temporal variability shown in Figure 3.7. Using *V. americana* as an example, the maximum density in 2005 was found at Rkm 7.0 and no occurrences were found downstream of Rkm 6 (equivalent to salinity of 3.3 ppt),. According to the literature, this taxa should be present at least to a salinity of 10 or 15 ppt. Yet, the history of *V. americana* at Rk 7.6 (Panel C of Figure 3-7) has ranged from a maximum in May 1998, to non-existent from September1998 through May 2000, but present again in 2005. Long-term salinity at this location was approximately 1 ppt. The temporal variation confounds evaluation of withdrawal impacts, which have remained relatively constant over this period. Based on salinity requirements only, the range of SAV coverage of all four taxa should extend much further downstream in the Chassahowitzka than observed suggesting that other, stronger forcing functions are affecting the distribution and density of SAV in the Chassahowitzka.

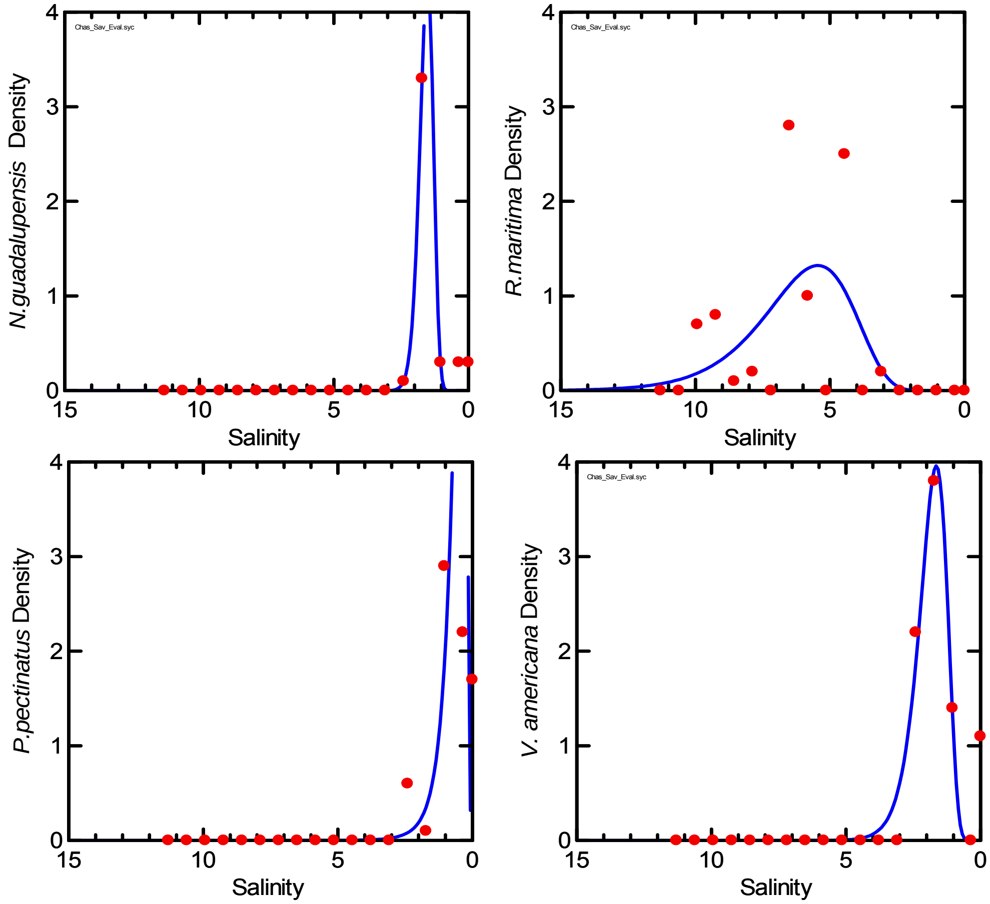


Figure 7-2. Observed SAV density in Chassahowitzka and fitted salinity model.

Calculation of the minimum flow criterion for each SAV was a sequential process. In the first step, salinity at the location of maximum observed density was estimated for a flow of 63.7 cfs using the LSM regression introduced in Section 4.2. In step two, the respective SAV response model was then solved to determine the salinity that would result in 85 percent of the maximum density observed. Knowing the higher salinity that causes a 15 percent reduction in density, the LSM was once again solved to identify the flow associated with the higher salinity.

Using *V. americana* as an example, during 2005 a maximum density of 3.8 was observed at Rkm 7.0. At a flow of 63.7 cfs, the salinity estimated at Rkm 7.0 is 1.72 ppt. A 15 percent reduction in maximum density results in a density of 3.2 which would occur (using the *V. americana* optimal salinity model) when the salinity at river kilometer 7.0 was 2.6 ppt. Returning to LSM and using Excel Goal Seek©, a flow of 60.6 cfs will result in a salinity of 2.6 ppt at RKm = 7.0. The results of all eight SAV determinations are given in Table 7-6.

Table 7-6. Response of dominant SAV density to reduced flow.

Taxa	Max Density (observed)	Rkm @ Max Density (observed)	Calculated Salinity (ppt) at Rkm	85% Max Density	Salinity @ Rkm causing 85% Max Density	Salinity Increase	Flow (cfs) Causing Increased Salinity	Flow Reduction (%)
	Results using 4th order polynomial and median unimpacted flow (63.7 cfs) as initial condition. See Table 7-4 for coefficients.							
Najas guadalupensis	3.3	7.0	1.72	2.8	1.709	0.01	63.7	-0.07
Ruppia maritima	2.8	3.5	6.51	2.4	6.568	-0.06	63.5	0.32
Vallisneria americana	3.8	7.0	1.72	3.2	1.90	-0.17	63.1	0.96
Potamogeton pectinatus	2.9	7.5	1.04	2.5	1.01	0.03	63.8	-0.16
	Results using optimal salinity model and median unimpacted flow (63.7 cfs) as initial condition. See Table 7-4 for coefficients and section 5.3.2 for model description.							
Najas guadalupensis	3.3	7.0	1.72	2.8	2.18	0.45	62.1	2.5
Ruppia maritima	2.8	3.5	6.51	2.4	6.51	5.0E-04	63.7	0.0
Vallisneria americana	3.8	7.0	1.72	3.2	2.6	0.87	60.6	4.8
Potamogeton pectinatus	2.9	7.5	1.04	2.5	3.16	2.12	56.2	11.7

It was determined that the curves are inconsistent and in most cases, provide results that suggest it may not be appropriate to rely on the modeled results. The results from the *V. americana* optimal salinity model indicate that an increase of 0.9 ppt salinity will result in a 15 percent reduction in density. This response does not seem reasonable, as the documented salinity tolerance for *Vallisneria americana* is 0 to 15 ppt. The combination the transient nature of *V. americana* (see Figure 3-7), coupled with the extremely limited observed range compared to literature values resulted a lack of confidence that the response is related to flow or salinity. Consequently**, t**he SAV models were not used in developing the Chassahowitzka River minimum flows.

7.3 Application of Salinity Habitat Model

Salinity and thermal habitat responses to changes in flow were determined using a three-dimensional hydrodynamic model consisting of 1,639 horizontal grid cells and four vertical layers for each cell (Dynamic Solutions, LLC 2009). Inputs to the model included USGS reported hourly headspring stage, temperature, salinity and daily discharge for station 02310650, along with the average discharge and salinity reported in the literature for Crab Creek, Potter Creek, Baird Creek, Blue Run and Beetejay head spring. The flow record was corrected for the impact of current withdrawals as described in Section 2.3.1.1 to estimate habitat metrics for unimpacted conditions. Following development of unimpacted conditions, a series of reduced inflow scenarios (5 – 40% reductions) were simulated and the loss of habitat determined.

For each of these flow scenarios a three-year period was simulated, reflecting a “typical” period. The “typical” period was defined as a three-year period whose cumulative distribution function (CDF) of spring discharge is similar to the long-term record. The three-year period selected was 2004-2006 (Dynamic Solutions, LLC 2009). Details of the model may be found in Section 11.13

The model runs reduced flow rates for all the spring inflows by the corresponding fraction. Using the model results, the volumes, areas and shoreline lengths for each of the salinity ranges were computed and the change in volumes, areas and shoreline lengths between the corrected, natural flow conditions and the various flow reduction scenarios were then computed and compared to the 15 percent maximum habitat reduction criteria (or retention of 85 percent of the unimpacted volume, shoreline length, or area remaining).

Unimpacted flows (see Section 6.1.5) were input to the hydrodynamic model developed by DSL and daily results of salinity habitat were extracted from the results for unimpacted flow and reduced flows(Table 7-7). Habitat metrics for less than 2 ppt salinity are presented but were not considered for establishing the MFL thresholds because of the salinity of some of the spring discharges is greater than 2 some of the time (See Table 3-3 in Section 11.13). Yobbi and Knochenmus (1989) also chose to evaluate salinities greater than or equal to 3 ppt for the same reason.

Table 7-7. Flow reductions based on a 15% reduction of volume, area or shoreline length for the salinity ranges.

Salinity Range (ppt)	Flow Reductions Based on Volumes (%)	Flow Reductions Based on Area (%)	Flow Reductions Based on Shoreline Length (%)
0 to 2	18	20	27
0 to 5	13	15	14
0 to 10	22	25	25
0 to 15	>40	>40	>40
Values reported are hydrodynamic model results using unimpacted flow record.			

7.4 Manatee

Using the critical manatee habitat thermal criteria described in Section 6.1.5, the manatee refuge area was estimated from model results for a critically cold time period of January 4-6, 2002. During this period, there were no areas inside of the Chassahowitzka River System that had manatee habitat meeting the chronic habitat criteria. Figure 7-3 shows typical plan view of water temperature during the “worst case” period. Sections of the river that are shaded in red meet the thermal criteria of >= 68°F (20°C). Much of the upper river meets the temperature criteria. However, water depths, especially at low tide, are less than 3.8 feet (1.16m) (Figure 7-4). The middle to lower part of the system has sufficient depths but is too strongly influenced by the Gulf temperatures and remains too cold to serve as a refuge. Thus, a suitable overlap of both warm and deep water under baseline conditions does not appear to exist in the Chassahowitzka and thus a chronic thermal minimum flow criterion could not be determined for the conditions evaluated.

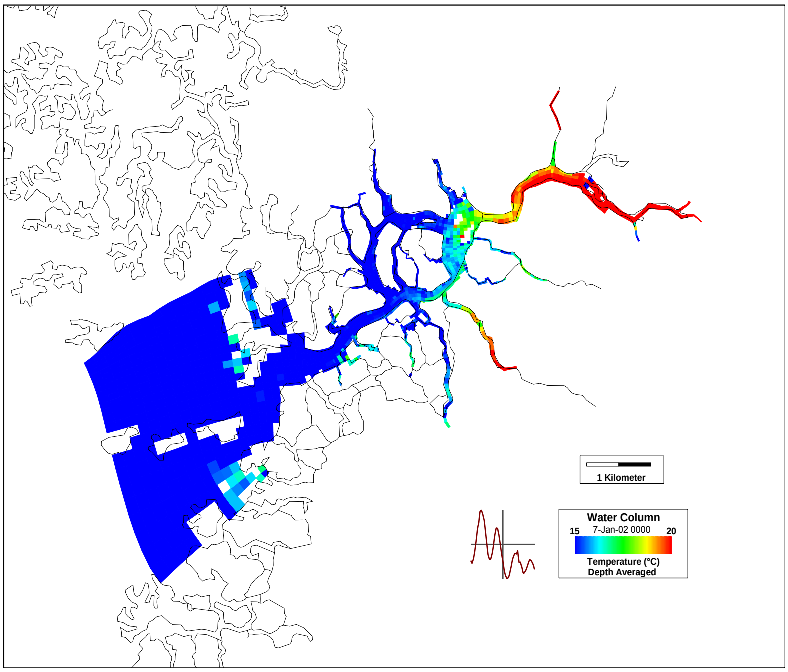


Figure 7-3. Plan view of water temperatures during the critically cold period.

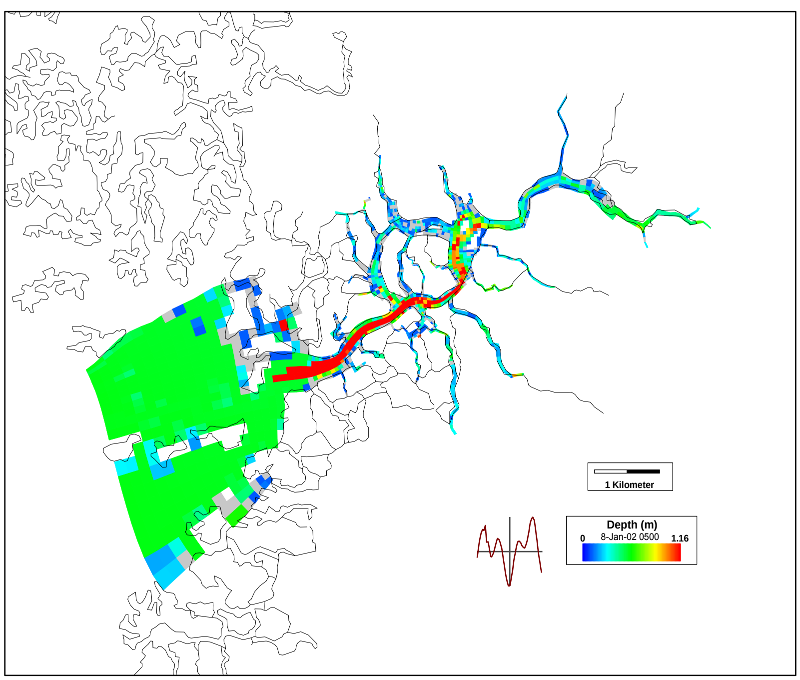


Figure 7-4. Plan view of water depths at low tide during the critically cold period.

However, evaluation of the acute conditions indicated that while the available refuge was intermittent, under unimpacted flow conditions a maximum area of 79 acres (See Figure 7-5) and 16.3 million cubic feet of suitable habitat existed. A 9 percent flow reduction resulted in the reduction of 15 percent of the area and 15 percent reduction of usable habitat volume during acute conditions when compared to the baseline conditions. . Using the maximum packing density area of 28.5 ft^2 described by Rouhani et al. (2006) for observations used in the Blue Sink MFL determination, the remaining eighty-five percent of the unimpacted acute area refuge could sustain many times the number of animals counted in all of Florida during the 2010 synoptic survey, which was the highest count on record.

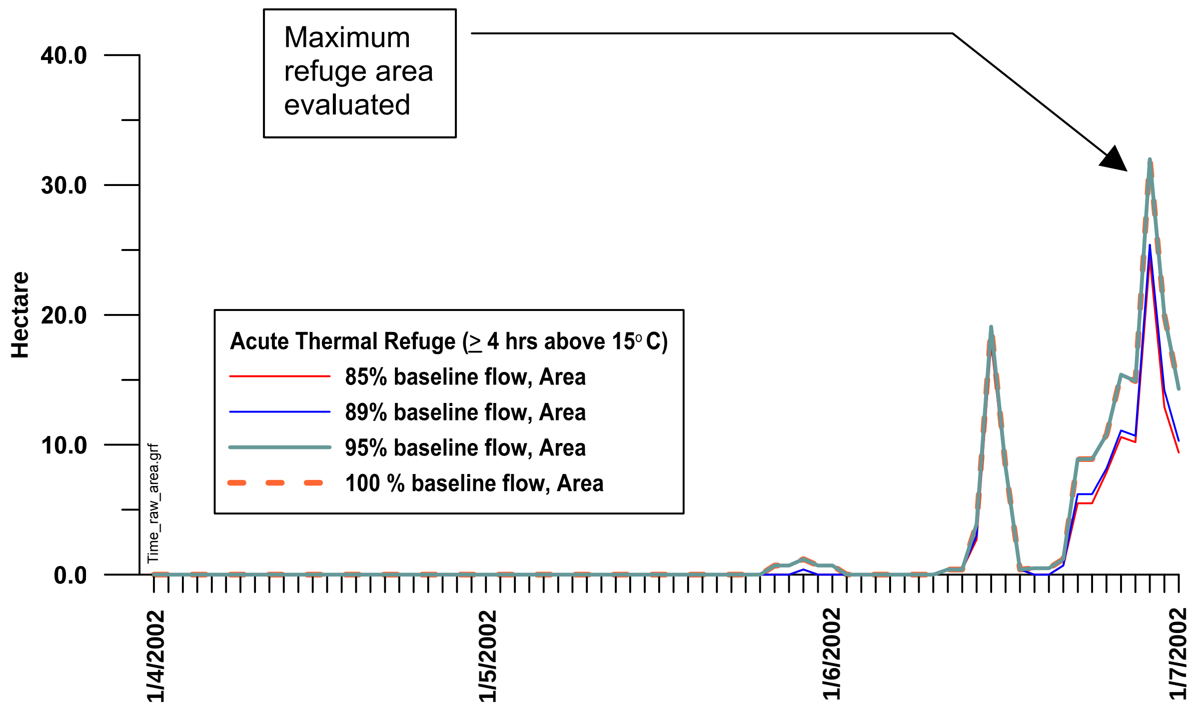


Figure 7-5. Bottom area acute thermal refuge Jan 4- 7, 2002.

7.5 Gross Primary Productivity

Gross primary productivity (GPP) and GPP efficiency responses were evaluated by calculating the respective values at unimpacted median flow of 63.7 cfs and then reducing the result by 15 percent. The response equations were then solved again to identify the reduced flow corresponding to the 15 percent reduction in GPP, or GPP efficiency. Table 7-8 identifies the steps and result using the response equations introduced in Section 5.5.

Table 7-8. GPP MFL criteria results.

Metric (units)	Value @ 63.7 cfs	15 % reduction	Flow @ 15% reduction	Allowable flow reduction
GPP (g $O_2/m^2/d$)	5.2	4.42	47.8	25%
GPP Efficiency (%)	1.56	1.33	50.3	21%

GPP_eval.xls

CHAPTER 8. CONCLUSIONS AND DISTRICT RECOMMENDATIONS FOR MFL

8.1 Summary of Outcomes

The tools described in Chapter 5 were applied to the criteria presented in Chapter 6. Examples were provided in Chapter 7. For each resource, an estimate of the percentage reduction of flow that would result in presumed significant harm (e.g. 15 percent reduction in resource or habitat) was determined. The resources evaluated and basis of flow evaluation include:

- Salinity Habitat
    - Area
    - Volume
    - Shoreline length
- Fish and Invertebrates
    - *Hargeria rapa*x (tanaid)
    - Dipterans, chironomid larvae (midges)
    - *Farfantepenaeus duorarum* (pink shrimp) (trawl)
    - *Fundulus grandis* (Gulf killifish)
    - *Poecilia latipinna* (sailfin molly)
- West Indian Manatee
    - Acute thermal habitat – area and volume
- Primary Productivity
    - Gross Primary Productivity (GPP)
    - GPP Efficiency

Flow reductions associated with significant harm threshold for the resources are summarized in Table 8-1. Two flow reduction values are provided. The first value is the result using unimpacted, natural flows (e.g. corrected for withdrawal impacts), while the values in parentheses represent the results based on uncorrected flows as reported in the November 2011 draft minimum flow report.

The results for the SAV community and the fish/invertebrate response to flow were not included because confidence in the modeled results was low.

Acute thermal refuge for the West Indian manatee was the most sensitive metric evaluated. A nine percent reduction in natural flow is predicted to result in a 15 percent reduction of both acute volume and area. However, even under natural conditions unimpacted by withdrawals, the acute thermal refuge is transient and was not permanently available under the conditions simulated. It should also be re-emphasized that the evaluation was based on habitat and not the number of manatee that have been observed in the river system. The area and volume of thermal refuge available under acute conditions associated with the allowable nine percent flow reduction would be sufficient to accommodate many times the population of manatees in the State.

Table 8-1. Summary of Chassahowitzka MFL criteria results.

Resource or Habitat	Criteria	Reduction : Unimpacted Flow (Impacted Flow)
Salinity Habitat		(%)
5 ppt - volume	15% loss in volume	13 (13)
10 ppt - volume	15% loss in volume	22 (23)
15 ppt - volume	15% loss in volume	>40 (>40)
5 ppt - area	15% loss in area	15 (15)
10 ppt - area	15% loss in area	25 (26)
15 ppt - area	15% loss in area	>40 (>40)
5 ppt - shoreline length	15% loss in length	14 (13)
10 ppt - shoreline length	15% loss in length	25 (26)
15 ppt - shoreline length	15% loss in length	>40 (>40)
Productivity		
Gross Primary Poductivity	15 % reduction	25
Gross Primary Productivity, Efficiency	16 % reduction	21
West Indian Manatee		
Acute thermal refuge (volume)	15% loss in volume	9 (15)
Acute thermal refuge (area)	15% loss of area	9 (11)
		MFL_results_637.xls

8.2 Long-Term Expected Flows and Recommended Minimum Flows for the Chassahowitzka River System

In consideration of the results presented, it is recommended that the flow for the Chassahowitzka River system be maintained at 91 percent of the natural, unimpacted baseline flow. The minimum flows for the associated creeks and springs, including Blind Spring is also recommended at a nine percent reduction in natural flows. , Long-term expected flows in the form of five and ten-year minimum mean and median flows were developed to reflect variations in climate aid in the assessment of compliance for the recommended MFL. These minimum long-term flow statistics should be maintained in the presence of withdrawals.

In order to define a hydrologic reference and to accommodate variations in climate, the recommended minimum flow (nine percent reduction) was applied to the natural unimpacted flows. For this evaluation, the groundwater impacts were assumed to begin in 1975 (first year of recorded of withdrawals) and to increase in a linear fashion up until 2005 which was assigned an impact of 0.7 cfs based on the results of the Northern District Model. It was assumed that this impact has been constant since 2005. After converting to natural flow, each daily value was reduced by nine percent to reflect the flows that might be expected with the implementation of the proposed minimum flow.

A five-year (1,826 days) moving average was calculated for the period and the minimum five-year period (ending date = 12/30/1997) was identified. The process was repeated for a ten-year moving average. Finally, the procedure was repeated using a running 5-yr and

10-yr median . The results are summarized in Table 8-2 and illustrated in Figure 8-1. These values are intended to serve only as a hydrologic reference provided climatic conditions remain similar to those experienced during the 1967 – 2011 period evaluated.

Table 8-2. Long term expected minimum flows corresponding to recommended MFL

Calculation based on Unimpacted flows X 0.91	Lowest Observed Flow
Minimum 10-Year Moving Average (based on 3,653 days)	51.74 cfs
Minimum 10-Year Moving Median (based on 3,653 days)	51.37 cfs
Minimum 5-Year Moving Average (based on 1,827 days)	50.49 cfs
Minimum 5-Year Moving Median (based on 1,827 days)	50.45 cfs

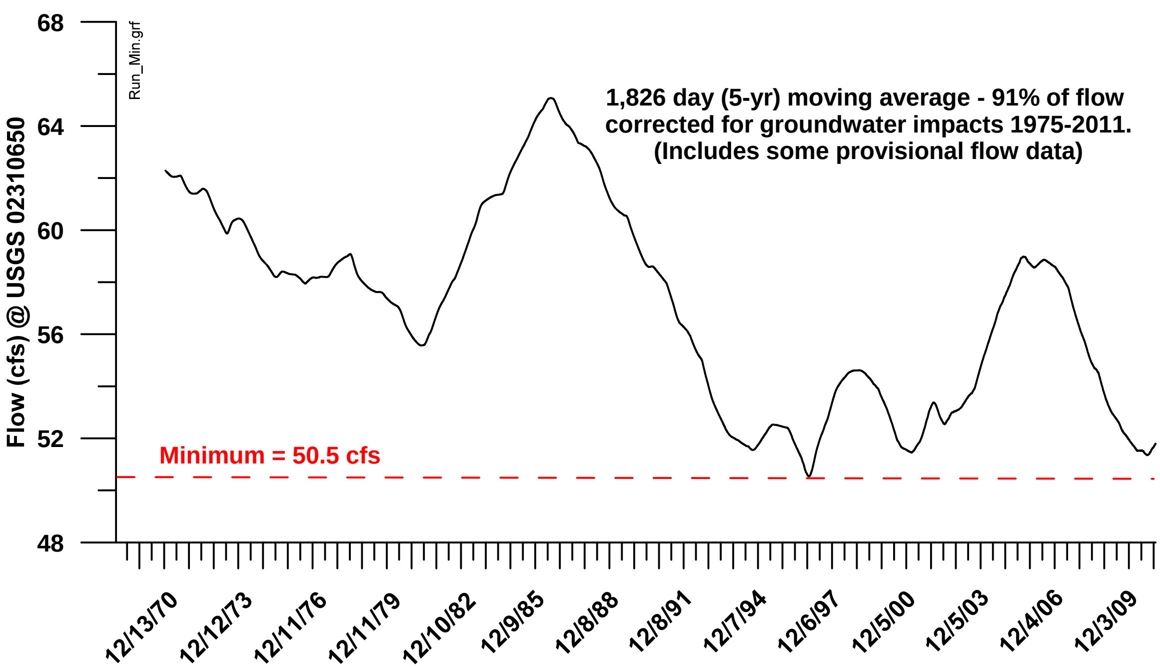


Figure 8-1. Five-year moving average of unimpacted flows times 0.91.

8.3 Implications of sea level change

Sea level has risen approximately 400 feet during the past 22,000 years (Balsillie and Donoghue 2009) and is expected to continue to do so into the foreseeable future. Tangible effects can be seen along many coastlines, including the Springs Coast. In order to address the impact of sea level change with respect to minimum flows development, several additional hydrodynamic model simulations (See Appendices 11.14 and 11.15) were conducted to evaluate the impact of a 2-inch, a 3.4-inch and a 7.7-inch sea level rise (See Section 3.1.3) on salinity habitat. Each sea level scenario was evaluated in the absence of withdrawals (USGS reported flows) and in the presence of three hypothetical withdrawal scenarios (e.g. 5%, 10% and 15% flow reductions) and the withdrawal corresponding to a 15 percent reduction in salinity habitat was calculated.

Table 8-3 provides results for modeling of habitat changes associated with three sea level rise scenarios. As was the case in the evaluation of current sea level (See Table 8-1), the most sensitive salinity habitats were the 0-5 ppt volume and shoreline length. For these 2habitat metrics, under current sea level conditions, 13 and 15 percent reductions in flows respectively resulted in a 15 percent change in these habitats (Table 8-3). From a pragmatic perspective, the allowable floe reduction associated with the most restrictive salinity habitat minimum flow criterion would not change. At the higher sea level rise (7.7 inches), a slight increase in withdrawals (up to 14 percent) of the inflow could be taken without exceeding the significant harm threshold. Figure 8-2 illustrates the concept for volumes less than 5 ppt and for volumes less than 15 ppt. Figure 8-2 also illustrates the fact that seal level rise will result in a loss in low salinity habitat concurrently with an increase in higher salinity habitat.

Table 8-3. Flow reductions resulting in 15% loss of salinity habitats under three sea level rise scenarios.

	2.0 inch SLR	3.4 inch SLR	7.7 inch SLR
Volume			
0 to 2 ppt	20%	20%	19%
0 to 5 ppt	13%	13%	14%
0 to 10 ppt	22%	21%	19%
0 to 15 ppt	>40.00%	>40.00%	>40.00%
Bottom Area			
0 to 2	20%	20%	19%
0 to 5	15%	15%	15%
0 to 10	25%	24%	21%
0 to 15	>40.00%	>40.00%	>40.00%
Shoreline Length			
0 to 2	27%	26%	25%
0 to 5	15%	15%	16%
0 to 10	25%	24%	21%
0 to 15	>40.00%	>40.00%	>40.00%

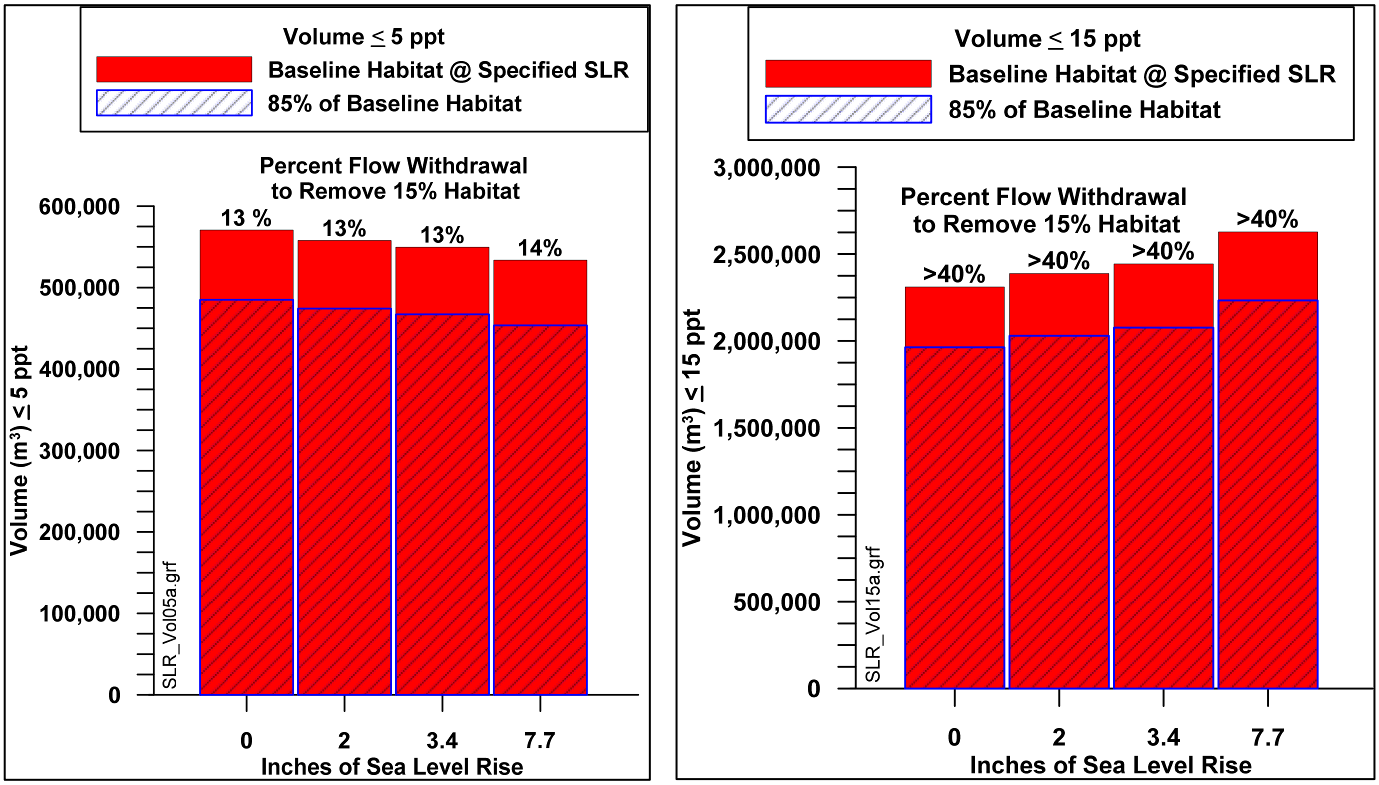


Figure 8-2. Comparison of sea level change and the impact on MFLs.

8.4 Impact of proposed MFL on water quality

Under Rule 62-302.200, F.A.C., Florida's surface water quality standards consist of four components: 1) the designated use or classification of each water body, 2) the surface water quality criteria (numeric and narrative) for each water body, which are established to protect its designated use, 3) the anti-degradation policy, and 4) moderating provisions, such as mixing zones. Each surface water body in Florida is classified according to its present and future most beneficial use, referred to as its designated use, with class-specific water quality criteria for select physical and chemical parameters, which are established to protect the water body's designated use (Chapter 62-302, F.A.C.).

Water quality criteria are designed to protect a water body's designated use. Florida's anti-degradation policy, including its policy for Outstanding Florida Waters, is designed to prevent worsening of water quality from specified activities unless it is found to be in the public interest. Florida's anti-degradation policy does not apply to water quantity decisions such as MFLs; instead, it applies to activities that incorporate a discharge of pollutants or dredge and fill activities.

The proposed minimum flow criterion is not expected to negatively affect water quality in the Chassahowitzka River system or impair the water body's designated use. Two areas of potential impact identified by stakeholders were a) increased nutrients in the Chassahowitzka River system and b) increased residence time leading to nuisance algal blooms or algal mats.

The allowable reduction in flow will not result in an increase of nutrients in the Chassahowitzka River system. Nitrate nitrogen concentration has been shown to be independent of flow (Heyl, 2012. Chapter/Section 11.17) rather, increasing over time in response to inland land management activities (Jones et al. 1997).

The second potential impact regards the concern that reducing the velocity of flow would result in longer residence time, leading to nuisance algal blooms or algal mats. District staff calculated net flushing time for the Chassahowitzka using the fraction of freshwater method (EPA,1984) for a flow of 63.7 cfs and a flow of 58.0 cfs (91 percent of 63.7 cfs). The net flushing time increased 2.8 percent (from 155 to 158 hours) in response to a nine percent reduction in flow. Such a minimal change in residence time would not result in a violation of surface water quality criteria or impair the water body's designated use.

CHAPTER 9. PEER REVIEW AND STAKEHOLDER INPUT

9.1 Introduction

The District expends substantial effort to solicit scientific review and public comment on proposed minimum flows and levels and the methods used for their development. These efforts are intended obtain feed-back to ensure that the District has identified and used the best information available in a technically appropriate manner to establish the minimum flows and level.

The District conducts extensive internal reviews of new methods and proposed minimum flows or levels using staff experts and external consultants. Also, as outlined in Rule 40D-8.011(5), F.A.C., the District coordinates with local governments and other affected and interested stakeholders to promote independent scientific and technical review of ongoing work related to minimum flows and levels. Other forms of peer review have occurred through presentation of methodological approaches in professional journals and other scientific publications.

All interested stakeholders are afforded opportunities to learn about and provide input on proposed minimum flows and levels and the methods used for their development. Distribution of reports and other materials, presentations made to stakeholder groups and individuals, public workshops concerning identification of priority water bodies for minimum flows and levels development, and public workshops addressing development of rules associated with minimum flows and levels are all completed to engage stakeholders in the minimum flows and levels development process.

9.2 Independent Scientific Peer Review

State law requires that *"[u]pon written request to the department [Department of Environmental Protection] or governing board by a substantially affected person, or by decision of the department or governing board, prior to the establishment of a minimum flow or level and prior to the filing of any petition for administrative hearing related to the minimum flow or level, all scientific or technical data, methods, and models, including all scientific and technical assumptions employed in each model, used to establish a minimum flow or level shall be subject to independent scientific peer review. Independent scientific peer review means review by a panel of independent, recognized experts in the fields of hydrology, hydrogeology, limnology, biology, and other scientific disciplines, to the extent relevant to the establishment of the minimum flow or level*" (Section 373.042(4)(a), F.S.). Findings of peer review panels are summarized in reports which are to be given "*significant weight*" when establishing MFLs (Section 373.042(4) (b), F.S.).

The District has voluntarily submitted all proposed river and estuarine MFLs to an independent peer review panel. The District's initial recommended minimum flows for the Chassahowitzka River system were outlined in a draft report titled *Chassahowitzka River Recommended Minimum Flows and Levels April 2010 Draft (*Heyl et al. 2010). This report was presented by staff to the District Governing Board during the April 2010 meeting and subsequently submitted to independent, scientific peer-review panel. The peer-review panel (Panel) was given the following instructions for developing their report:

TASK 1
Determine whether the method used for establishing the minimum flow is scientifically reasonable.

(a) Supporting Data and Information: Review the data and information that supports the method and the provisional minimum levels to determine whether:
1. the data and information used was properly collected;
2. reasonable quality assurance assessments were performed on the data and information;
3. exclusion of available data from analyses supporting development of the minimum flows or levels was justified; and
4. the data used for the development of the minimum flows or levels was the best information available.

(b) Technical Assumptions: Review the technical assumptions inherent in the methodology and determine whether:
1. the assumptions are clearly stated, reasonable and consistent with the best information available;
2. the assumptions were justified to the extent possible, based on available information; and
3. other analyses that would require fewer assumptions but provide comparable or better results are available.

(c) Procedures and Analyses: Review the procedures and analyses used in developing quantitative measures and determine whether:
1. the procedures and analyses were appropriate and reasonable, based on the best information available.
2. the procedures and analyses incorporate all necessary factors;
3. the procedures and analyses were correctly applied;
4. limitations and imprecisions in the information were reasonably handled;
5. the procedures and analyses are repeatable;
6. conclusions based on the procedures and analyses are supported by the data.

TASK 2
If a proposed method is not scientifically reasonable, the CONSULTANT shall:

(a) Deficiencies: List and describe scientific deficiencies and, if possible, evaluate the error associated with the deficiencies;
(b) Remedies: Determine if the identified deficiencies can be remedied.
(c) If the identified deficiencies can be remedied, then describe the necessary remedies and an estimate of time and effort required to develop and implement each remedy.
(d) If the identified deficiencies cannot be remedied, then, if possible, identify one or more alternative methods that are scientifically reasonable. If an alternative method is identified, provide a qualitative assessment of the relative strengths and weaknesses of the alternative method(s) and the effort required to collect data necessary for implementation of the alternative methods.

TASK 3
If a given method for establishing minimum flows or levels is scientifically reasonable, but an alternative method is preferable, the reviewer shall:

(a) List and describe the alternative scientifically reasonable method(s), and include a qualitative assessment of the effort required to collect data necessary for implementation of the alternative method(s).

The peer-review panel (Panel) convened to review the document concerning the initial proposed minimum flows included scientists with extensive experience in ecology, hydrology and freshwater inflow relationships. The Panel's findings were summarized in a report that was submitted to the District in June 2010 (Powell et. al. 2010; included as Section 11.1 of this report). The Panel's report and staff response to the peer-review was provided to the District Governing Board for consideration at the August 24, 2010 Board meeting. (See section 11.18.1.)

The Panel's report was supportive of the District's initial recommended minimum flows, but suggested additional monitoring to enhance understanding of the impacts of groundwater withdrawals on flows and salinity of the system. In reference to the District's report on the recommended minimum flows, the Panel concluded that *"Overall, it appears to the Panel that the MFL determination is adequate and based on the best available information, but the lack of detailed knowledge about eh hydrogeology of the contributing springs, which seem to behave differently from each other and vary in water quality, would suggest that any MFL expressed in cfs alone may be somewhat inadequate or at least requires careful monitoring during implementation. . . . . Therefore, the Panel recommends that the District follow the Precautionary Principle and establish the initially recommended MFL, which is based on the best available data and analyses, until more and better scientific information is available in the future to better understand how changes in the springshed and spring flows, both quantity and quality will affect the Chassahowitzka River System.*" The Panel identified five central questions that served as the primary basis for their evaluation of the District's minimum flows report. The questions and summary conclusions, reproduced below from the Panel's peer review report, are:

1. *Was an appropriate model [EFDC] employed?*
- *The Panel finds that EFDC I an adequate hydrodynamic code to apply to the Chassahowitzka River to address the issues of interest here.*

2. *Were the data employed adequate?*
- *The Panel believes that there was sufficient data available to calibrate the model, although the calibration period involved a relatively low flow period. It is technically preferred that the calibration period cover a wider range of physical events in the system (e.g., a more complete range of flows, set ups and set downs of the ocean water surface etc.). The more or less constant flow regime, dominated by the springs, let the modelers to be more comfortable with the shortened period.*

3. *Were the boundary conditions adequate?*
- *Overall, the Panel finds that the boundary conditions were based on observed data and are, thereby, considered best available over this four month period.*

4. *Were calibration / validation of the model adequate?*

- *The EPA guidelines for a calibrated salinity model is that the RMAE should be less than 20%. Since the model results are only being compared to other flow reduction simulation of the same model in the District's MFL analyses, rather than being used to make absolute predictions of the actually salinity level, the Panel concludes that the salinity calibration is adequate for estimating relative difference due to reduced freshwater inflows. . . . The Panel finds that the model does reproduce the cooling and warming trends very well and, thus, the temperature calibration is considered adequate.*

5. *Were the simulated scenarios adequate for determining an MFL?*

- *As a result, the Panel concludes that the application of the calibrated model to evaluate thermal and salinity habitats is appropriate and can be used to help determine a MFL for the Chassahowitzka River System.*

Staff supports the Panel's major recommendation that the District continue to collect data to improve understanding of water quality and flow in the Chassahowitzka River system and contributing groundwater basin. Continued data collection is considered essential for future reevaluation of the minimum flows that are to be established for the river system and other nearby spring-dominated systems. However, the District is also aware that a comprehensive mapping and understanding of the underground karst connectivity affecting the Chassahowitzka and other spring systems in the Springs Coast of northwest Florida may take many years.

9.3 Stakeholder Review and Public Outreach

In addition to subjecting the April 2010 report on proposed minimum flows for the Chassahowitzka River to independent scientific peer-review, the District has engaged a number of stakeholders to obtain input on the proposed minimum flows. The history of development and interaction with stakeholders was presented as Tables ES-1 and ES-2 in the Executive Summary. Development of minimum flows for the system was first identified on the 1996 Priority List and Schedule for the Establishment of Minimum Flows and Levels. The priority list and schedule identifies water bodies for minimum flow or levels development based on the importance of the waters to the state or region and the existence of or potential for significant harm to the water resources or ecology of the area (Section 373.042(2), F.S.). The priority list is required to include waters that are currently or may reasonably be expected to experience adverse impacts associated with water use. The list must also include all first magnitude springs and all second magnitude springs within state or federally owned lands purchased for conservation purposes. A current version of the list and schedule is available on the District Minimum Flows and Levels (Environmental Flows) Documents and Reports web page (Southwest Florida Water Management District 2011a) and in the District's Consolidated Annual Report (Southwest Florida Water Management District 2012).

Rule development workshops associated with the proposed minimum flows were held in Hernando County in October 2010 and in Citrus County in December 2010. Based on stakeholder interest in the development of minimum flows for the Chassahowitzka River system and other nearby water bodies, the District hosted a series of three public workshops and facilitated a fourth stakeholder-initiated workshop in the spring and summer of 2011 for discussion of the data and methodologies that have been or could be used to develop minimum flows for spring-dominated tidal river systems of the Springs Coast and to support decisions regarding timelines for adoption or reevaluation of minimum flows for the systems.

The spring-summer workshops were well attended and information associated with the workshop series was posted on the District's Springs Coast MFL Working Group web page[21] created specifically for exchange of relevant information.

In addition to sponsoring numerous public meetings, the District has engaged in a vigorous outreach effort involving exchange of written communications and other information to facilitate public understanding of the minimum flows process and to provide opportunities for stakeholder input. Correspondence has involved communication with individuals, and citizen groups (e.g. Sierra Club, Save the Manatee, and Chassahowitzka River Restoration Committee). Written communications and other relevant documents associated with stakeholder input and public outreach activities concerning development of minimum flows for the Chassahowitzka system are compiled in Section 11.18.

Stakeholder input received through all outreach efforts and submitted directly to the District varied in substance, but may be generally associated with a small number of issues, including the following.

Issue 1. Use of fifteen percent change criteria for developing minimum flow recommendations;

Issue 2. Not allowing additional water use based on existing, observed environmental change (*e.g.*, tree death and expanded upstream distribution of barnacles) and further environmental change;

Issue 3. Application of the Outstanding Florida Waters policy and components of the Federal Clean Water Act;

Issue 4. Development and use of improved methods, tools or models for evaluating ground water flow and water withdrawal impacts;

Issue 5. The measurement of discharge and use of discharge data for analyses supporting minimum flow recommendations;

Issue 6. Evaluation of withdrawal related changes to thermally favorable habitat for manatees during recent, extremely cold seasons; and

Issue 7. Development and use of additional predictive models for evaluating effects of flow reductions on plants, animals and ecosystem-level characteristics (*e.g.*, blue crabs, primary productivity).

Staff has carefully considered each of these issues in association with minimum flow development for the Chassahowitzka River system. Summary comments on each issue are provided below. Additional staff comments are provided in correspondence and other documents included in Section 11.18.

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[21] http://www.swfwmd.state.fl.us/projects/mfl/springs-coast-mfl.php

Staff acknowledges the perspective advanced by stakeholders that the fifteen percent change criteria currently used by the District for developing minimum flows should be modified for systems such as the Chassahowitzka River system (Issue 1). Staff notes, however, that this criterion has been reviewed and accepted by numerous independent, scientific peer-review panels, including the Panel convened to evaluate the initial minimum flow recommendations for the Chassahowitzka River system. Use of this criterion has also been accepted by policy decision of the District Governing Board for adoption of minimum flows for many priority water bodies.

Staff acknowledges environmental changes that have occurred in the Chassahowitzka Rivers system, but attributes these changes primarily to changes in sea level and variation in rainfall and the effect of this variation on discharge and salinity patterns within the Chassahowitzka River system (Issue 2). The District, has, however, attempted to incorporate potential change in sea level and associated environmental effects into analyses supporting revised minimum flow recommendations for the river system. The background is presented in Chapter 3 and the potential impacts area outlined in Chapter 8 of this revised minimum flows report.

Regarding Issue 3 above, an Outstanding Florida Waters designation is part of Florida's anti-degradation policy, which is designed to prevent worsening of water quality from specified activities unless it is found to be in the public interest. Florida's anti-degradation policy does not apply to water quantity decisions such as minimum flows and levels; instead it applies to activities that incorporate a discharge of pollutants or dredge and fill activities.

With regard to the development and use of improved methods, tools or models for evaluating ground water flow and water withdrawal impacts (Issue 4), staff agrees that competent hydrologic data and appropriate groundwater flow models are desirable for establishing and monitoring compliance with adopted minimum flows and other water management activities. However, in the interest of expediency the MFL statute (Section 373.042 (1) F.S.) directs the District to use the 'best information available' for establishment of an MFL. Staff notes that the District has developed on a rich database for construction and calibration of regional groundwater flow models for analysis of historic and projected water use impacts. The District is committed to continued development of these data and refinement of groundwater flow models, such as the Northern District Model (see Chapter 2, Basso 2010, HydroGeoLogic 2008, 2010), and other tools that can be used to evaluate withdrawal impacts on the Chassahowitzka River system and other priority water bodies.

Staff, stakeholders and staff from the United States Geological Survey have expended considerable effort in reviewing and identifying ways to enhance the measurement and reporting of discharge for sites within the Springs Coast. Based on a USGS audit of the procedures (Jenter et al. 2012), the District feels that the Chassahowitzka discharge measurements represent the 'best information available' at this time.

With regard to the reporting of historic discharge records for the Chassahowitzka River system (Issue 5), staff notes that discrete or instantaneously measured historical discharge measurements are available for the Chassahowitzka River. However, the problems associated with using discrete flow measurement to represent daily average discharge in a tidally affected system have been discussed in section 2.5. Staff contends that the “historical” Chassahowitzka discharge record should be not incorporated into the flow record unless the discharge value accurately reflects a mean daily flow.

With regard to the suggestion that withdrawal related changes to thermally favorable habitat for manatees during recent, extremely cold seasons should be evaluated (Issue 6), staff notes that the initially recommended minimum flows were developed based on the best information that was available at the time the thermal-modeling of the Chassahowitzka River system was completed. Under the worst-case scenario evaluated at that time, an available chronic refuge did not exist under baseline conditions and the acute thermal refuge was transient. Nevertheless, acute habitat under the initial proposed MFL (11 percent flow reduction), still provided refuge for over seven times the number of manatee inhabiting Florida. The revised recommended MFL is for up to a nine percent flow reduction and under those assumed conditions, there remains similar excess capacity. (See section 7.4 for details)

Staff acknowledges that it may be beneficial to continue to evaluate potential effects of reduced flows on the availability of thermally favorable manatee habitat in the Chassahowitzka River system, based on future environmental conditions, and expects that efforts directed towards this goal will be implemented when the District completes a reevaluation of minimum flows for the river system.

With regard to the development and use of predictive models for evaluating effects of flow reductions on plants, animals, and ecosystem-level characteristics (Issue 7), staff notes that as indicated in Chapter 5 of this report, relationships developed for predicting effects of flow reductions on abundances of plankton and nekton in the Chassahowitzka River system were considered to be marginally useful for developing quantitative minimum flow recommendations. Staff has examined the potential application of a statistical relationship between average discharges and measured of gross primary productivity. Staff found that the relationships do not appear to be as protective as other criteria that have been used for development of the Chassahowitzka River system minimum flow recommendations. Alternative model constructs were developed to evaluate the response of SAV to changes in salinity, but these new models gave results similar to the statistical models used in the early evaluation. The background of the approaches is given in Chapter 5 and the applications are discussed in Chapter 7 of this report.

Of additional relevance to Issue 7, staff notes that blue crabs have been identified as an important species to consider when evaluating responses to flow reductions in the Chassahowitzka River system. Commercial landings of hard-shelled blue crabs ranged from 0.3 to 1.1 million pounds annually in Citrus County from 2001 through 2010, according to the Florida Fish and Wildlife Conservation Commission (2012). In addition to their commercial value, blue crabs may be an important food source for the endangered whooping cranes that overwinter in the Chassahowitzka National Wildlife Refuge (which includes portions of the Chassahowitzka River system), as has been reported for a site in Texas. In Texas, the ecological relationship between whooping cranes, blue crab abundance and freshwater inflows is the subject of a lawsuit filed in U.S. District Court by The Aransas Project, which contends that the Texas Commission on Environmental Quality provided insufficient inflows to the San Antonio-Aransas Bay complex during 2008-2009, and this resulted in a significant loss of whooping cranes. A ruling on this case is expected during the summer of 2012.

In recognition of the commercial and ecological significance of the blue crab, the District contracted with the Florida Fish and Wildlife Conservation Commission to review relationships that have been developed between blue crab abundances and freshwater inflow along the Gulf Coast, including flows from several District rivers. Gandy et al. (2011) summarizes results from the review and discussed limitations with the various studies. Interestingly, in 15 of the 25 cases evaluated, reducing inflow was predicted to be associated with increased number of blue crabs, while in the remaining 40% of the cases flow reductions would be predicted to result in fewer crabs. As discussed in Chapter 5 of this report, flow-abundance regressions for blue crab sampled by the University of South Florida and the Florida Fish and Wildlife Conservation Commission in the Chassahowitzka River were not considered appropriate for developing minimum flow recommendation.

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CHAPTER 11. APPENDICES – NUMBERED AND BOUND SEPARATELY

11.1 Heyl, M.G. 2010. Technical Memorandum- Estimation of Historical Chassahowitzka River Flows.

11.2 Basso, R. 2008. Technical Memorandum dated December 1, 2008 to Marty Kelly and Mike Heyl- Predicted Groundwater Withdrawal Impacts to Chassahowitzka Springs based on Numerical Model Results

11.3 VHB 2008. Un-gauged Springs Discharge. Letter Reports from G. Serviss.

11.4 Leverone, J.R. 2006. Collection,Enumeration and Analysis of Invertebrate Community and Substrate in the Chassahowitzka River, Florida: Methodology and Data Report. Mote Marine Laboratory Technical Report No. 1085. Prepared for Southwest Florida Water Management District.

11.5 Janicki Environmental Inc, 2006. Analysis of Benthic Community Structure and Its Application to MFL Development in the Weeki Wachee and Chassahowitzka Rivers. Prepared for Southwest Florida Water Management District.

11.6 Clewell, A.F., M.S. Flannery, S.S. Janicki, R.D. Eisenwerth and R.T. Mongomery. 2002. An Analysis of Vegetation-Salinity Relationships in Seven Tidal Rivers of the Coast of West-Central Florida (Drafeet). A technical report of the Southwest Florida Water Management District. December, 2002.

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11.8 Grabe, S.A and A. Janicki. 2008. Analysis of Benthic Community Structure in Tributaries to the Chassahowitzka River. Prepared for Southwest Florida Water Management District. July 2008.

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11.12 Montagna, P. 2006. A Multivariariate Statistical Analysis of Relationships between Freshwater Inflows and Mollusk Distributions in Tidal Rivers in Southwest Florida. Prepared for Southwest Florida Water Management District. December 2006.

11.13 Dynamic Solutions, LLC. 2009. Impacts of Withdrawals on the Chassahowitzka River System. Prepared for Southwest Florida Water Management District.

11.14 Dynamic Solutions, LLC 2011. Sea Level Rise Simulations of the Chassahowitzka River. Prepared for Southwest Florida Water Management District June 21, 2011.

11.15 Dynamic Solutions, LLC 2011. Sea Level Rise Simulations of the Chassahowitzka River – Part Five. Prepared for Southwest Florida Water Management District September 15, 2011.

11.16 Gandy, R.L., C.E. Crowley, C.E. Machniak and C.R. Crawford. 2011. Review of the Biology and Population Dynamics of the Blue Crab , *Callinectes sapidus*, in Relation to Salinity and Freshwater Inflow. Prepared by Florida Fish and Wildlife Conservation Commission for the Southwest Florida Water Management District.

11.17 Heyl, M.G. 2012. Technical Memorandum – Impact of Flow on NO_3+NO_2-N Concentration in Six Florida Spring Discharges.

11.18 Report Reviews and District Responses

11.18.1 Peer Review Panel Report and Responses

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