# *Upper Peace River*
# *An Analysis of Minimum Flows and Levels*

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**DRAFT**

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## Acronyms and Abbreviations

AMO - Atlantic Multidecadal Oscillation
cfs - cubic feet per second
CADD - Computer Aided Design
CHEC - Charlotte Harbor Environmental Center
CSA - clay settling area
DEP - Department of Environmental Protection
dbh - diameter at breast height
DO - dissolved oxygen
ENSO - El Nino Southern Oscillation
F.A.C. - Florida Administrative Code
FFWCC - Florida Fish and Wildlife Conservation Commission
FIPR - Florida Institute of Phosphate Research
Fl - Fluoride
FLUCS - Florida Land Use Codes
FNAI - Florida Natural Areas Inventory
F.S. - Florida Statutes
GIS - Geographic Information Service
HEC-RAS - Hydrologic Engineering Center-River Analysis System
K - Potassium
LMF - Low Minimum Flow
LWPIP - lowest wetted perimeter inflection point
MFLs - Minimum Flows and Levels
mg/l - milligrams per liter
mgd - million gallons per day
N - nitrogen
n - sample size
NGVD - National Geodetic Vertical Datum
P - phosphorus
NWI - National Wetlands Inventory
SAS - Statistical Analysis System
SCS - Soil Conservation Service
SJRWMD - St. Johns River Water Management District
SWFWMD - Southwest Florida Water Management District
SWUCA - Southern Water Use Caution Area
USDA - United States Department of Agriculture
USFWS - United States Fish and Wildlife Service
USGS - United States Geological Survey

Chapter One

# Minimum Flows and Levels

## 1.1 Overview

The Southwest Florida Water Management District (SWFWMD) has been directed to establish minimum flows and levels (MFLs) for priority waterbodies within its boundaries (Section 373.042, Florida Statutes) by virtue of its responsibility to permit the consumptive use of water and a legislative mandate to protect water resources from “significant harm.” The SWFWMD’s purpose in establishing MFLs is to create hydrologic and ecologic standards against which permitting or planning decisions can be made regarding water withdrawals, either surface or ground-water. The legislative directives pertaining to MFLs and the general technical approach employed by the SWFWMD are described in the following sections.

### 1.1.1 Legislative Direction

As part of the Water Resources Act of 1972, the Florida Legislature mandated that the five water management districts establish MFLs for surface waters and aquifers in their jurisdictions (Section 373.042, F.S.). Although that Section has been revised in subsequent years, the definitions of MFLs that were established in 1972 have remained the same. Minimum flows are defined as “**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 levels are defined as “**the minimum water levels shall be the level of groundwater in an aquifer and the level of surface water at which further withdrawals would be significantly harmful to the water resources of the area.**” It is generally interpreted that ecological resources are included in the water resources of the area mentioned in the definition of minimum water level. As describe in more detail in Section 1.6, the establishment of MFLs for flowing watercourses can incorporate both minimum flows and minimum levels.

Given the above definitions, a basic function of minimum flows is to ensure that the hydrologic requirements of natural systems associated with streams and rivers are met and not jeopaardized by excessive withdrawals. In turn, establishment of minimum flows is important for water supply planning and regulation, since it affects how much water from a river or stream is available for withdrawal. Mere adoption of minimum flows does not protect a waterbody from significant harm nor regulate water availability. It is the application of minimum flows through planning and regulatory mechanisms that ensures the hydrologic requirements of natural systems are met while allowing waters to be available

According to Florida Statutes, minimum flows and levels shall be calculated "using the best information available. When appropriate, minimum flows and levels may be calculated to reflect seasonal variations. The department [Florida Department of Environmental Protection] and the governing board [of the relevant water management district] shall also consider, and at their discretion may also provide for, the protection of non-consumptive uses [traditionally considered aesthetics, recreation, and navigation] in establishment of minimum flows and levels." Guidance regarding uses of the water resource to be considered is provided in the State Water Resources Implementation Rule (Chapter 62-40.473, Florida Administrative Code), which states that "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:

(a) Recreation in and on the water;
(b) Fish and wildlife habitats and the passage of fish;
(c) Estuarine resources;
(d) Transfer of detrital material;
(e) Maintenance of freshwater storage and supply;
(f) Aesthetic and scenic attributes;
(g) Filtration and absorption of nutrients and other pollutants;
(h) Sediment loads;
(i) Water quality; and
(i) Navigation."

Identification of severe water resource problems in the Northern Tampa Bay area in the mid-1990s (*e.g.*, see SWFWMD 1996) precipitated renewed interest by the Florida Legislature concerning the establishment of minimum flows and levels (MFLs). In 1997, Section 373.042 F.S. was revised to provide additional guidance on factors to be considered when establishing MFLs. According to Section 373.0421(1a), F.S., when establishing MFLs the governing board "shall consider changes and structural alterations have had, and the constraints such changes or alterations have placed, on the hydrology of the affected watershed, surface water, or aquifer, provided that nothing in this paragraph shall allow significant harm as provided by s. 373.042(1) caused by withdrawals" (Section 373.0421, F.S.). In essence, the District is to evaluate and account for the effects of previous structural alterations on a watercourse when assessing the potential for withdrawals to cause significant harm.

Because minimum flows will be used for more than long range planning, and since the setting of minimum flows can potentially impact (restrict) the use and allocation of water, the methods, data and analyses on which minimum flows are based must be technically sound. For this reason, the science upon which a minimum flow is based, including assumptions made, will be independently reviewed through a formal voluntary peer review process.

## 1.2 Historical Perspective

For freshwater streams and rivers, the development of instream flow legislation and methodologies can be traced to the work of fisheries biologists. Advances in methodologies have been rather recent, dating back approximately 35 years. A survey completed in 1986 (Reiser et al. 1989) indicated that only 15 states had legislation explicitly recognizing that fish and other aquatic resources required a certain level of instream flow for their protection. Nine of the 15 states were western states "where the concept for and impetus behind the preservation of instream flows for fish and wildlife had its origins" (Reiser et al. 1989). Stalnaker et. al (1995) summarized the minimum flows approach as one of standards development, stating that, "Following the large reservoir and water development era of the mid-twentieth century in North America, resource agencies became concerned over the loss of many miles of riverine fish and wildlife resources in the arid western United States. Consequently, several western states began issuing rules for protecting existing stream resources from future depletions caused by accelerated water development. Many assessment methods appeared during the 1960s and early 1970s. These techniques were based on hydrologic analysis of the water supply and hydraulic considerations of critical stream channel segments, coupled with empirical observations of habitat quality and an understanding of riverine fish ecology . . . Application of these methods usually resulted in a single threshold or 'minimum' flow value for a specified stream reach."

### 1.2.1 The Flow Regime

The idea that a single minimum flow is not satisfactory for maintaining a river ecosystem was most emphatically expressed by Stalnaker (1990) who published a paper titled "Minimum Flow is a Myth". The purpose of his paper was to argue that "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.

These are:

1) flood flows that determine the boundaries of and shape of 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), any minimum flows methodology involves more than a consideration of immediate fish needs or the absolute minimum needed to sustain a particular species or population of animals, but should take into consideration "how streamflows affect channels, transport sediments, and influence vegetation." 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 a number of important ecologic and hydrologic functions of streams and rivers maintained by different flow values. And while the term "minimum flows" is still used, the concept has evolved to one that recognizes the need to maintain a "minimum flow regime". The St. Johns River Water Management District (SJRWMD) in developing minimum flows for the Wekiva River noted that, "Setting 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).

The biotic makeup, structure and function of an aquatic ecosystem (lake, wetland or stream) depends largely on the hydrologic regime that shaped its development. If unaltered by man, the natural flow regime of a stream will reflect the watershed characteristics and climatic patterns of a region (Poff et al. 1997). Although, not always fully appreciated, it should be apparent "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). The successful completion of the life-cycle of many aquatic organisms is dependent on certain intra-annual variation in hydrologic conditions. In addition, alterations in the hydrologic regime of an aquatic system can have indirect effects on the biota by altering certain physical and chemical habitat characteristics, such as temperature, oxygen content, substrate particle size, and flow. Richter et al. (1996) are critical of basing management decisions on the "known or perceived hydrologic requirements of only one, or at most a few, target aquatic species, potentially neglecting the needs of other species and ecosystem processes and functions in general."

In addition to biological communities associated with the river channel, the evaluation of streamflow needs should also account for the hydrologic requirements of the river floodplain to provide for the biota that directly use floodplain habitats and the ecological interactions that floodplains have with instream communities. The St Johns River Water Management (SJRWMD) concludes that, "conservation of riparian wetlands requires that a minimum level and flow regime include a range of flows resulting in inundation of the floodplain" (Hupalo et al. 1994). Periodic high flows and levels are needed to deposit sediment in the floodplain as part of the floodplain forming process (Hill et al. 1991), and for exchange of nutrients and organic matter (McArthur 1989), and because wetland biota rely on the periodic inundation of the floodplain for habitat.

### 1.3 Ecologic Integrity and Significant Harm

Although it is clear that multiple flows are needed to maintain the ecological systems that encompass streams, riparian zones and valleys, much of the fundamental research needed to quantify the ecological links between the instream and out of bank resources remains to be done because of the expense and complexity involved. This research is needed to develop more refined methodologies, and will require a multi-disciplinary approach involving hydrologists, geomorphologists, aquatic and terrestrial biologists, and botanists (Hill et al. 1991). As stated by Richter et al. (1996), "A goal of ecosystem management is to sustain ecosystem integrity by protecting native biodiversity and the ecological (and evolutionary) processes that create and maintain that diversity. Faced with the complexity inherent in natural systems, achieving that goal will require that resource managers explicitly describe desired ecosystem structure, function, and variability; characterize differences between current and desired conditions; define ecologically meaningful and measurable indicators that can mark progress toward ecosystem management and restoration goals; and incorporate adaptive strategies into resource management plans."

It will be necessary to demonstrate with site specific information the effects of implementation and compliance with the proposed minimum flow will have to justify adoption of a minimum flow for purposes of maintaining ecologic integrity. As described in Florida's legislative requirement to develop minimum flows, the minimum flow is to prevent "significant harm" to the state's rivers and streams. Not only must "significant harm" be defined so that it can be measured; it also implies that some deviation from the purely natural or existing long-term hydrologic regime must occur before significant harm occurs. The goal of a minimum flow would, therefore, not be to preserve a hydrologic regime without modification, but rather to establish the threshold(s) at which modifications to the regime begin to affect the aquatic resource and at what level significant harm occurs. If changes have already "significantly harmed" the resource, Section 373.0421 requires the development of a recovery plan.

## 1.4 Components of a Minimum Flow

As noted by Beecher (1990), "it is difficult [in most statutes] to either ascertain legislative intent or determine if a proposed instream flow regime would satisfy the legislative purpose", but 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 SJRWMD developed a method for establishing minimum flows for the Wekiva River (Hupalo et al. 1994) that recognized the need and rationale for setting multiple flows. Multiple flows are needed to protect or conserve various ecological attributes of a stream. In addition to low minimum flows, they proposed a medium range flow that would be sustained for extended periods to maintain the peaty soils and associated wetland communities commonly found along the Wekiva River. They proposed higher flows that would completely inundate the riparian wetlands and recur frequently enough so that sediment, detritus, nutrients and propagules are transported and distributed throughout the floodplain. This periodic flooding would allow the needs of stream biota that periodically utilize the floodplain habitat for feeding, reproduction and refugia to be met.

### 1.5 Summary of Approach

Fundamental to the approach used for development of minimum flows for the Upper Peace River is the realization that a flow regime is necessary to protect the ecology of the river. The initial step in this process requires a comparison of the historic and current flow conditions to determine if flows have shown any trends over time. This should be done on different streamflow parameters (e.g., seasonal flows, low and high flows) to determine if any components of the flow regime have changed. If there are not trends that are problematic, then the development of minimum flows and levels 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 the river, these must be assessed to determine, if significant harm has already occurred. If significant harm has occurred, recovery becomes an issue. An important consideration related to recovery is the effect that various factors other than withdrawals may play in the ability to attain (or not) a desirable flow regime.

Given this approach, the determination of minimum flows for the Upper Peace River first involved an assessment of the historic and current flow regime and the factors that have shaped historic and current regimes. This followed with a consideration of the absolute minimum instream flow needs, or the flow which historically has been most often equated with the idea of a "minimum flow." In the case of the Upper Peace River, this flow became the lowest acceptable flow under the lowest anticipated flow conditions (typically the month of May, before the onset of summer rains). The Upper Peace River, historically received a portion of its baseflow from artesian discharge from the intermediate and Floridan aquifers. Because this baseflow contribution exceeded the flow necessary to maintain fish passage and a desirable wetted perimeter (minimal wetted habitat for benthic organisms), a flow that would insure fish passage or maintain a desirable wetted perimeter was considered the lowest acceptable minimum flow. As will be demonstrated based on an assessment of historic flows, in the case of the Upper Peace River, this will require recovery to an earlier flow condition.

Much of the desirable instream habitat, particularly in blackwater streams such as the Peace River where aquatic grass beds are not substantial, may be associated with structures such as "snags and roots" which occur at elevations above that which would allow for fish passage and a minimum acceptable wetted perimeter. Because desirable in-stream habitats such as snags and roots provide substrate for the development and colonization of food organisms, and cover for various aquatic species, it was considered desirable to evaluate how often these habitats are inundated each year in an effort to determine when significant harm will occur to the resource. While these habitats can be periodically exposed, they may require innundation for a portion of each annual cycle because of their importance as habitat for aquatic organisms.

Riparian hardwood and cypress swamps can be expected to occur at elevations lower than other floodplain wetlands. It is expected that these systems will require flooding on at least a seasonal basis to maintain their biological integrity, and if historic flow records indicate a fairly sustained period of inundation, their flow needs can be assessed on the basis of the inundation requirements of certain associated biota (e.g., frog life histories). The lower and upper floodplains (as described in this report) occur at elevations higher than swamp systems. At the very least flooding at a sustained inundation is required to keep upland vegetation from becoming permanently established in the floodplain.

While the proposed approach takes into account several factors, ultimately what constitutes "significant harm" will be determined by the Board of the SWFWMD. Several different approaches can be taken in determining a minimum flow regime for a river. From a biological perspective, a minimum flow regime may be set with the intent of protecting a specific habitat type(s), or may be set on the basis of the habitat requirements of one or several indicator species. It is anticipated that in the short term (over the next several years), minimum flows for ecologic purposes will be set from the perspective of protecting particular habitat types (e.g., macroinvertebrate habitat and/or riparian wetland habitat). This is simply because there is not yet adequate data to do otherwise, although data collection strategies can be designed to collect the needed data. As noted previously, the legislative mandate indicates that best available data should be used; however, it is implicit that better data may become available.

## 1.6 Flows and Levels

Although somewhat semantical, there is a distinction between velocities, levels and volumes that should be appreciated. All terms apply to the setting of "minimum flows" for flowing (lotic) waters. Streamflow rates are most often reported in terms of a unit volume (e.g., cubic feet or meters) per unit time (e.g., second, minute or day). However, broken down into its component parts, flow rate is comprised of separate (but inter-related) hydrologic variables. Velocity is the rate of speed that water moves downstream. A certain water velocity may be required to physically move particles heavier than water; for example, periodic high flows will transport sand from upstream to downstream; higher flows will move gravel; and still higher flows will move rubble or even boulders. Flow velocity may be important as a cue for some organisms; for example, certain fish species search out areas of flow for reproduction and may move against flow or into areas of reduced or low flow to spawn. Certain macroinvertebrates drift or release from stream substrates in response to changes in flow. This release and drift, among other things, allows for colonization of downstream areas. Other macroinvertebrates such as caddisflies spin nets in the stream to catch organisms and detritus carried downstream, and their success in gathering/filtering prey is at least partially a function of flow. Other aquatic species have specific body morphologies that allow them to inhabit and exploit specialized niches located in flowing water. Some species have bodies that are flattened (dorsally-ventrally compressed) to allow them to live under rocks or in crevices; others may have special holdfast structures  such as hooks or even secrete a glue that allows them to attach to submerged objects.

Discharge refers to the volume of water moving past a point. Depending on the size of the stream (cross sectional area), similar volumes of water can be moved with quite large differences in the rate of flow (velocity). The volume of water moved through a stream can be particularly important to an estuary.  It is the volume of freshwater that mixes with salt water that determines what the salinity will be in a fixed area of an estuary.  This is especially important for organisms that require a certain range of salinity.  The volumes of fresh and marine water determine salinity, not necessarily the flow rate; therefore, volume rather than velocity is the important variable to these biota.

In other cases, the water level or the elevation of the water above a certain point is the critical variable for dependent biota.  For example, the wetland fringing a stream channel is dependent on a certain hydroperiod or seasonal pattern of inundation.  On average, the associated wetland requires a certain level and frequency of inundation.  Water level and the duration that it is maintained will determine to a large degree the types of vegetation that can occur in an area.  Similarly, the periodic use of floodplain habitats by fishes and other aquatic organisms depends on water levels of sufficient elevation to top stream banks and allow access to the floodplain. The width or expanse of water in a channel or floodplain is also an important variable related to elevation and will determine the amount of habitat that may be used by aquatic and floodplain organims.

There is a distinction between volumes, levels and velocities that should be appreciated. Although levels can be related to velocities and volumes in a given stream (stream gaging, in fact, depends on the relationship between stream stage or level and discharge), the relationship varies between streams and progressively from upstream to downstream in the same system.  Because relationships can be empirically determined between levels, velocities and volumes, it is possible to speak in terms of, for example, minimum flows. However, one needs to appreciate that individual species (biota) and many physical features may be most dependent on a given velocity, level or volume or some combination of the three for their continued survival or occurrence.  The resultant ecosystem is dependent on all three.

### 1.7 Content of Remaining Chapters

Chapter One has summarized the requirements and rationale for developing minimum flows and levels in general. The remainder of this document considers the development of minimum flows specific to the Upper Peace River. Chapter Two provides a description of the basin, its hydrology, land use and development. Chapter Three considers in some detail the historic and current flows, and the factors that affect these flows with some emphasis on rainfall patterns in the basin. Water quality changes related to flow are also summarized in this chapter. Chapter Four identifies and discusses the resources of concern. Chapter Five outlines the methodologies used to evaluate minimum flows associated with the resources of concern, while Chapter Six presents the results of staff analyses with minimum flow recommendations for the Upper Peace River.

# Chapter Two

# Upper Peace River

## 2.1 Prologue

*"The Peace River originates in Lake Hamilton, one of many beautiful lakes that dot the heart of interior peninsular Florida in northern Polk County, although some of its waters can be traced as far to the north and northwest as the great reservoir of the Green Swamp .... Just to the east of the river's source and paralleling its course through Polk County is Florida's natural spine, the chain of high sandy hills known as "The Ridge," which marked in ancient times all of peninsular Florida remaining above the sea.*

*From Lake Hamilton the narrow stream of Peace River today is channeled by drainage canals first to the south and then to the west where, just to the north of Polk's county seat of Bartow, it joins Saddle Creek, an outlet of Lake Hancock two miles to the north. From the junction, the river plunges southward again past Bartow and the town of Fort Meade. Three miles below Fort Meade the stream, continuing its southward course, is combined with the waters of Bowlegs Creek, which rises to the east on the Ridge, near Lake Buffum.*

*At Bowling Green, a little less than 40 miles along its course, the river enters Hardee County as well as beginnings of the low South Florida prairie through which it will pass on most of its remaining journey to the sea. For half of the distance through Hardee's 21-mile width, the river continues its southward flow, edging in its progress the county seat of Wauchula. At Zolfo Springs, however, its course bows to the southwest, then turns to the south before bowing again, this time to the southeast and a junction with Charlie Apopka Creek at a point just to the north of the DeSoto County line. The enlarged river then carries its waters to the southwest and, on an ever more twisting and turning course, passes Arcadia and Fort Ogden, strengthened along the way by the discharges of Joshua and Horse creeks. Three miles below Fort Ogden the widening stream enters Charlotte County and begins a slow turn to the west, which carries it beyond Punta Gorda to its meeting with the sea at Charlotte Harbor on Florida's southwest Gulf of Mexico coast. On a straight line Peace River's length totals only about 110 miles, but its often serpentine course doubles that distance."*

- Prologue to ***Florida's Peace River Frontier*** by Canter Brown, Jr., 1991.University of Central Florida Press, Orlando

## 2.2 Basin Characteristics

This chapter defines the boundaries of the Upper Peace River for this MFL assessment, and describes the physical setting, climate, hydrology and geology of the area. A chronology is also presented of significant historical events related to the Peace River and its watershed.

### 2.2.1 Watershed Location

For purposes of this report the Upper Peace River is bounded by USGS gaging sites located on the northern end near Bartow and the southern end near Zolfo Springs. The USGS gage near Bartow is located just downstream of the confluence of Saddle Creek (which drains Lake Hancock and its watershed) and the Peace Creek Canal (which drains the Lake Alfred and Winter Haven areas). The Zolfo Springs gage is located on the Peace River in the approximate center of Hardee County; therefore, as defined in this report, the Upper Peace River is a 36 mile reach of the river formed at the confluence of the Saddle Creek and Peace Creek Canal (Figure 2-1). It receives input from Bowlegs Creek on the east side of the river between Fort Meade in Polk County and Bowling Green just inside the Hardee County line. Payne Creek is another major tributary that delivers flow from the west approximately one mile south of Bowling Green.

The above account by Brown (1991) provides a good description of the setting of the Peace River. The Peace River, with a drainage basin of 2,350 square miles, is approximately 105 miles long from the confluence of the Peace Creek Drainage Canal and Saddle Creek to Charlotte Harbor. The watershed of the entire Peace River includes portions of the cities of Lakeland, Auburndale and Haines City in northern Polk County and extends south to the city of Cape Coral in Lee County. Its western boundary includes portions of Hillsborough, Manatee and Sarasota Counties and portions of Highlands and Glades Counties on the east. The watershed includes major portions of Polk, Hardee, DeSoto and Charlotte Counties. The Upper Peace River watershed is the uppermost 826 square miles of this larger watershed.

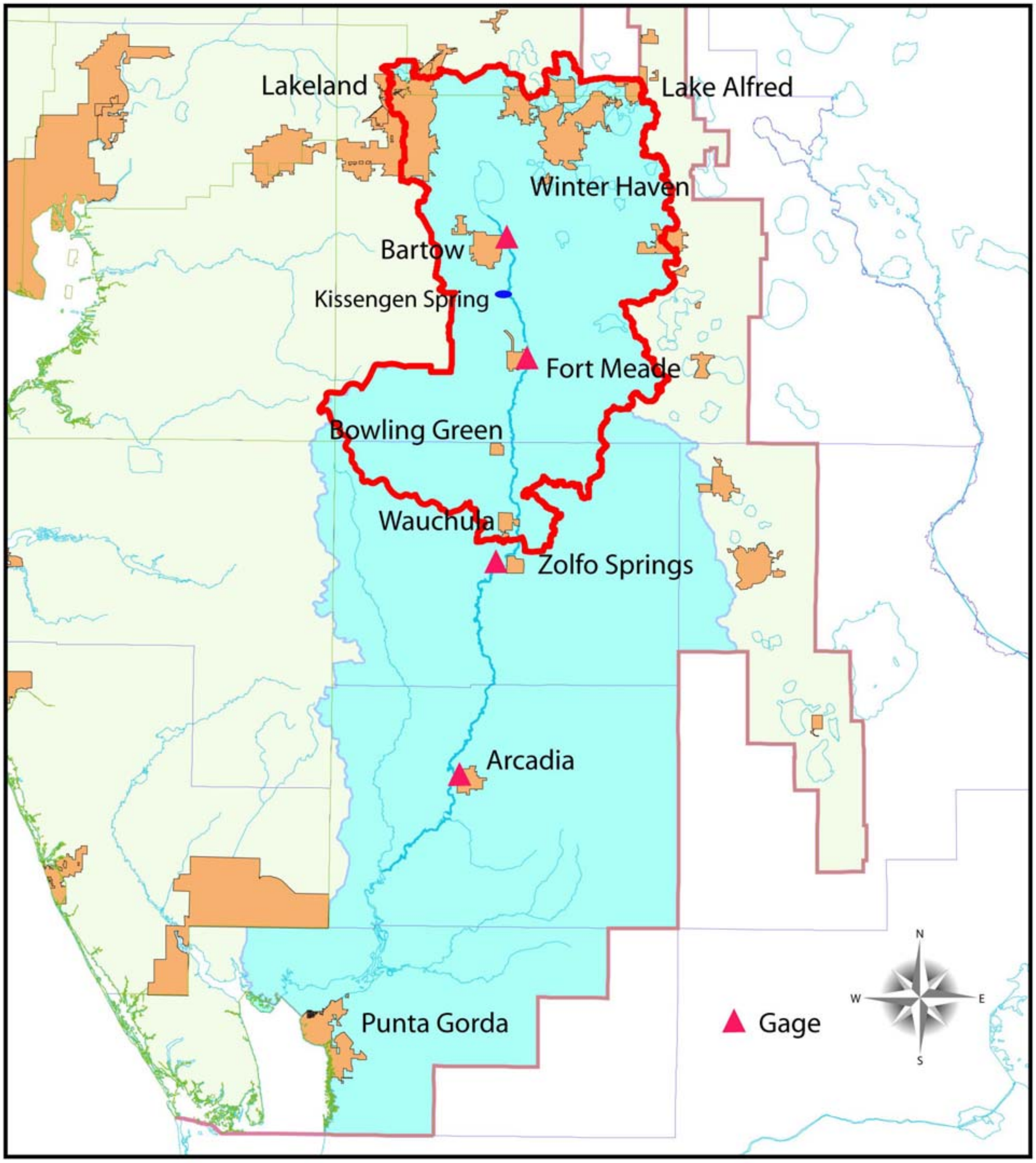



Figure 2-1. Peace River watershed showing location of USGS gage sites. The Upper Peace River is defined as that portion of the watershed above the USGS Zolfo Springs gage and is outlined in red.

### 2.2.2 Climate and Rainfall

The climate of central Florida is classified as humid subtropical and is characterized by warm relatively wet summers and mild dry winters. Average annual temperature is approximately 72 degrees F (SWFWMD 2001a), and average annual rainfall is approximately 51 to 52 inches. Rainfall is unevenly distributed; on average 58% of the annual rainfall occurs during the summer months of June, July, August and September (Figures 2-2). Rainfall is unevenly distributed during the summer months, because most of the summer rainfall is derived from local showers or thunderstorms. Conversely, winter rainfall tends to be more evenly distributed since rainfall generally results from large frontal systems as cold air masses from the north move south through the area. November and December are typically the months of lowest rainfall (around two inches each), although stream flows, lake stages and levels tend to reach annual lows in April and May (Figure 2-2) due to a combination of prolonged low rainfall and high evaporation rates (Hammett 1990, SWFWMD 2001a).

Tropical storms and hurricanes produce the most severe weather in the area and are readily apparent in stream flow hydrographs for all streams in the central Florida area (e.g., see Figure 2-3). The sustained peak in 1959 and 1960 is attributable to unusually wet back to back years; 83 inches in 1959 and 74 inches in 1960 as recorded at the Bartow gage. March rainfall in both years was atypically high 11.53 inches in 1959 and 8.99 inches in 1960 at Bartow ( a month which has averaged 3.3 inches for the 100 year period of record). Total rainfall in September 1960 (Hurricane Donna) was 15.6 inches (more than twice the monthly mean of 6.7 inches). This was preceded by 17.6 inches in July (typically the wettest month of the year averaging 8.4 inches at Bartow). Annual rainfall patterns with their potentially extreme annual variation are the result of three interacting weather patterns, large frontal systems (in the winter), highly variable and spotty wet season rain events, combined with the possibility of tropical depressions and hurricanes that can move through the area in the late summer and early fall.

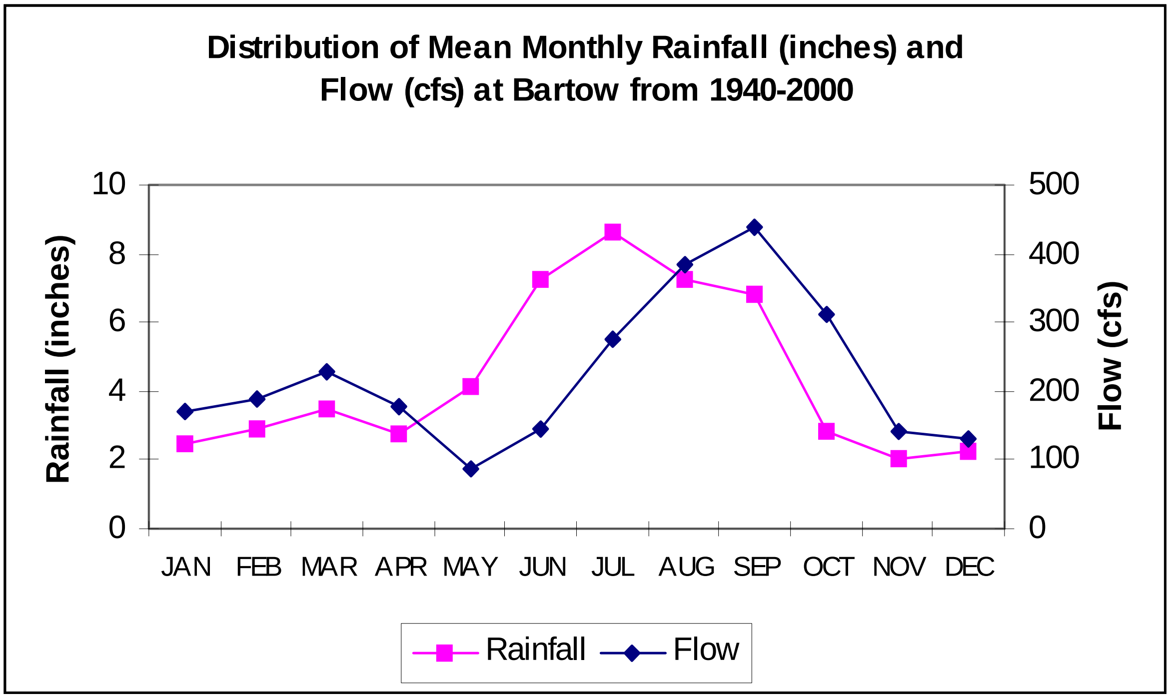



Figure 2-2. Distribution of rainfall and flow by month at Bartow in the Upper Peace River.

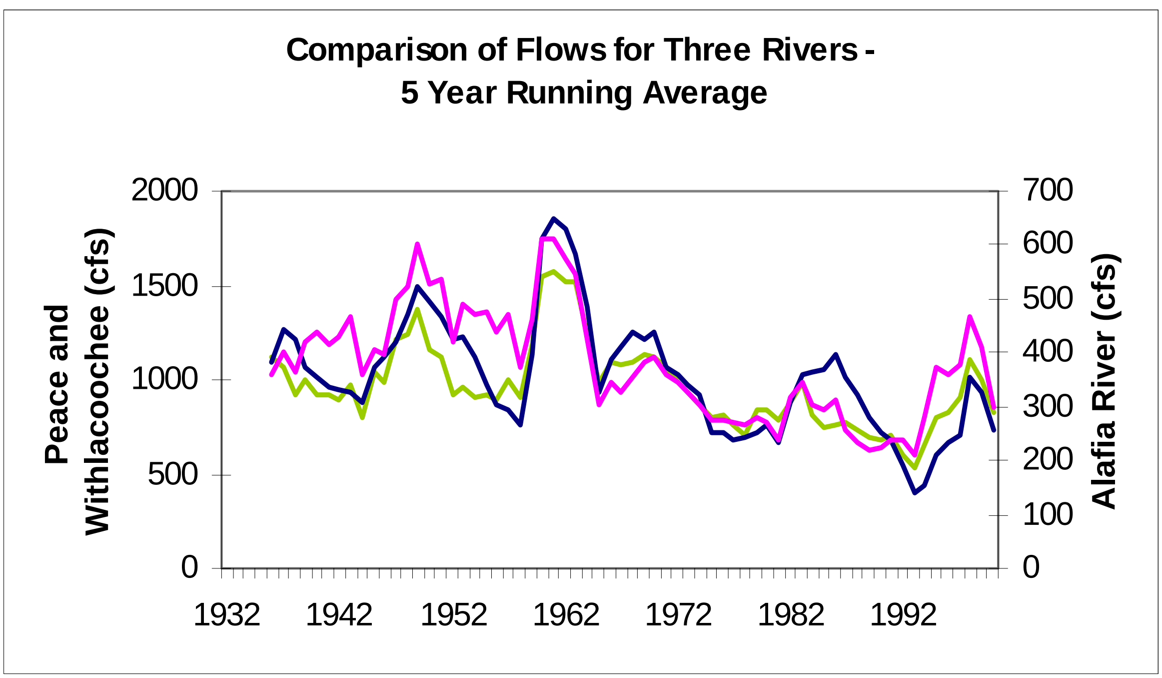



Figure 2-3. 5-year running averages of mean annual flows for three rivers: Peace River at Arcadia (in red), Withlacoochee at Holder (blue), and Alafia River at Lithia (green).

### 2.2.3 Physiography

(abstracted from *Peace River Comprehensive Watershed Management Plan, 2001 Volume 1 - Draft; SWFWMD 2001a*)

The three major physiographic provinces present in the Peace River watershed are the Polk Upland, the DeSoto Plain and the Gulf Coast Lowlands (White 1970). These general regions have been subdivided into the Bone Valley Uplands, DeSoto Slope and Barrier Island Coastal Strip (Brooks 1981). The physiographic boundaries generally correspond to paleoshorelines (ancient shorelines). A paleoshoreline at the 100-foot elevation separates the upland regions from the plain, and the 30-foot elevation separates the plain from the low coastal region (Lewelling et al. 1998).

The physiography of the Peace River watershed ranges from an internally drained lake district with highland ridges in Polk County, to a poorly-drained upland that extends into the northern half of Hardee County, to a broad, gently-sloping plain with well-developed surface drainage in southern Hardee and most of DeSoto Counties. The Bartow Embayment, which extends from above Lake Hancock to directly north of Homeland, is an internally drained, local, erosional basin that has been partially infilled with phosphate-rich siliclastic deposits (Brooks 1981). The Polk Upland (White 1970) extends south from Homeland to Zolfo Springs, and it corresponds to the Bone Valley Uplands defined by Brooks (1981). Polk Upland land surface elevations are generally greater than 130 feet above sea level. The area contains flatwoods, wetlands and lakes that occupy a poorly-drained plateau underlain by deeply weathered sand and clayey sand of the Bone Valley Member of the Peace River Formation. Natural drainage upstream of Bowling Green has been altered by area phosphate mining activity. The DeSoto Slope (Brooks 1981), or the DeSoto Plain (White 1970), consists of wet prairie, swamp, and flatwoods with a well-developed surface drainage system. The Gulf Coastal Lowlands (White 1970) and the Barrier Islands Coastal Strip (Brooks 1981) are located where the Peace River discharges into the Charlotte Harbor Estuary.

### 2.2.4 River Channel and Floodplain Morphology

Although the morphology of the river channel and the floodplain will be discussed more fully in Chapter Six, a brief overview is provided below. The Upper Peace River is a low gradient stream. The stream bed elevation drops vertically from approximately 90 feet NGVD at the Bartow Gage to 33 feet NGVD at the Zolfo Springs Gage (Figure 2-4); a total of 57 feet over 37.4 miles for an average drop in elevation of 1.52 feet per mile. The section of river between Zolfo Springs and Ft. Meade is only slightly steeper (1.55 feet/mile) than the section between Bartow and Ft. Meade (1.44 feet/mile), although the river becomes noticeably more incised below Ft. Meade. The river bottom widens, the height to top of bank increases and bank slopes tend to increase. In general the floodplain is less steep and wider above Ft. Meade. The stream channel proper is capable of conveying much more water within its banks below Ft. Meade than above. The change between channel morphology above and below Ft. Meade is rather abrupt causing a similarly abrupt change in the riparian vegetation.

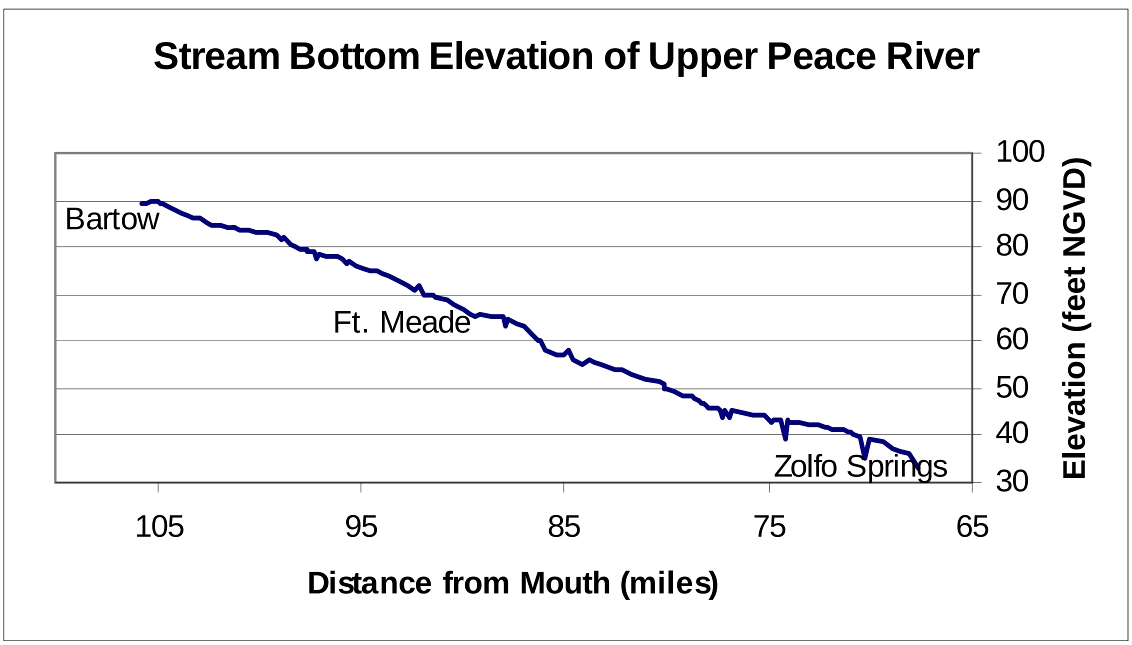



Figure 2-4. Change in river bed elevation between Bartow Gage and Zolfo Springs Gage, the upper and lower bounds of the Upper Peace River.

### 2.2.5 Hydrology/Hydrogeology

In general, the geology underlying the west-central Florida area consists of a series of clastic sediments overlying carbonate rocks. In the Upper Peace River basin there are three recognized aquifer systems (refer to Figure 2-5). At the surface, the surficial aquifer is unconfined, and is generally composed of unconsolidated quartz sand, silt and clayey sand. Beneath the surficial is the confined intermediate aquifer system which consists of a series of thin, interbedded limestone and phosphatic clays of typically low permeability. Underlying the intermediate aquifer system is the confined Floridan aquifer system which is a series of limestone and dolomite formations. The Floridan aquifer is divided into the Upper and Lower Floridan aquifers which is separated by a middle confining unit of a thick, massive sequence of evaporite materials of extremely low permeability. The Lower Floridan has only been used for waste disposal via deep well injection in west-central Florida, because of its poor water quality, great depth, and limited ability to yield water.

#### 2.2.5.1 Surficial Aquifer

The surficial aquifer, the unconfined and uppermost aquifer, ranges in thickness from a thin veneer of sand to greater than 50 feet. Near Bartow and Ft. Meade, surficial thickness averages less than ten feet. The surficial aquifer is composed of undifferentiated sands, clay and shell. The quartz sand, which is generally uniform throughout the unit, grades to clay with depth as the surficial aquifer system approaches the intermediate aquifer system's upper confining unit. Minor amounts of organic material, gravel, and phosphate are also present in the surficial aquifer (Basso 2002, SWFWMD 2001a). The surficial aquifer is mainly recharged by rainfall, and the depth to water averages five to ten feet below land surface. However, the water table is exposed along river cut banks or is at land surface within the swampy floodplain and adjacent lowlands. The head gradient of the surficial aquifer is generally toward the river, and the confinement between the surficial and intermediate aquifer is well established (SWFWMD 2001a).

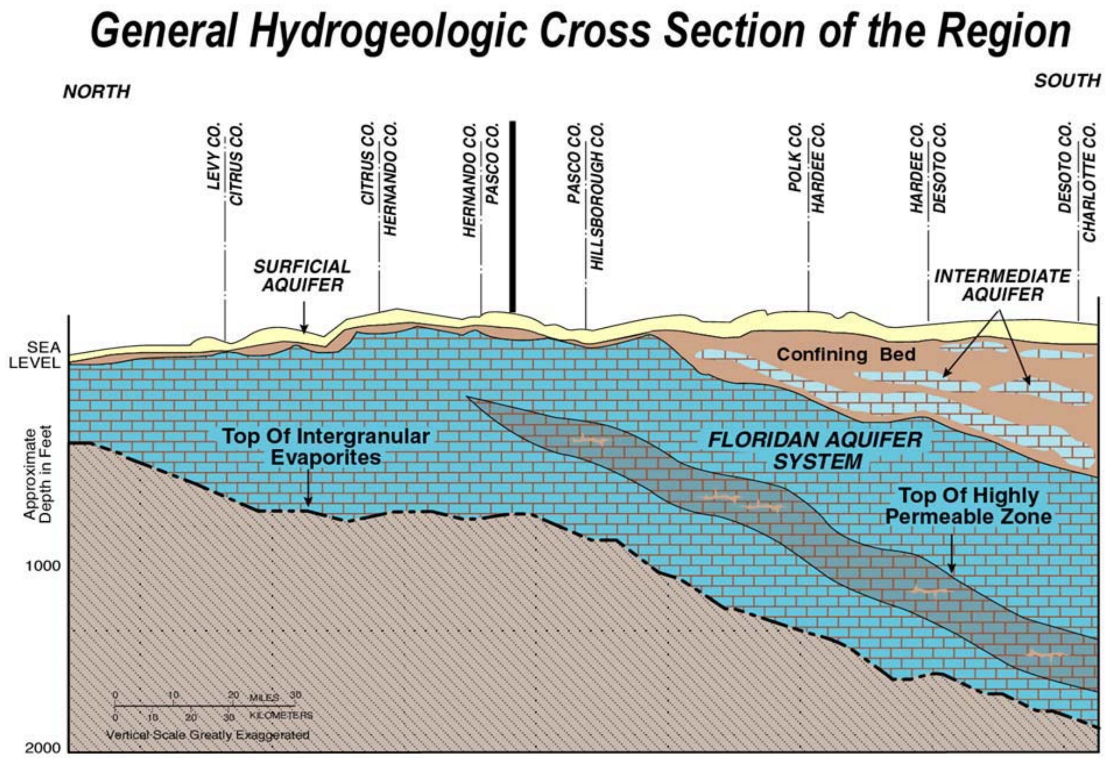



Figure 2-5. Generalized hydrogeologic cross section through the area of the Southwest Florida Water Management District, beginning with Levy County in the north and extending southward to Charlotte County.

### 2.2.5.2 Intermediate Aquifer

The intermediate aquifer and its confining units occur within the Hawthorne Group, which ranges in thickness from 50 to greater than 250 feet. The dominant geologic formations within the Hawthorn Group are the Peace River and Arcadia Formations. The lithology of the Hawthorn Group is variable and generally consists of gray to green to brown phosphate clay, minor sand, with occasional thin layers of residual limestone and dolostone.

The Peace River Formation forms rock ledges or outcrops within the floodplain and streambed. The upper unit of the Peace River Formation, the Bone Valley Member, is the clayey and phosphate-rich object of mining activities (Lewelling et al. 1998). The confining units present in the intermediate aquifer system retard the movement of water between aquifers. Generally, the upper and lower confining units are thinner near the Peace River (Metz 1995). The intermediate aquifer is generally thicker and more confined toward the southwest. Basso (2002) described the intermediate aquifer as a series of interbedded phosphatic clays, sands, gravels, dolomite and thin limestone beds. “As a whole, the entire system can often be categorized as a confining unit that separates the surficial aquifer from the Upper Floridan aquifer, although permeable units occur with the clay matrix.” The intermediate aquifer thins out toward the north, and the transition from an aquifer system (with confining units) to a confining unit occurs from a line extending from southwest Hillsborough County to north-central Polk County, although thin discontinuous aquifers may locally exist north of this line. The intermediate dips toward the south-southwest and thickens considerably to more than 450 feet by the time it reaches northern DeSoto County. Generally the confining units of the intermediate have very low hydraulic conductivity, and the movement of water is retarded between the overlying surficial and underlying Upper Floridan aquifer. However, water does leak from one aquifer to another depending upon hydraulic gradients. The existence of considerable karstic features along the upper segment of the river between Bartow and Ft. Meade as mapped by Patton (1981) provides at some points a direct hydraulic connection between the surface and lower aquifers. Regionally, however, away from the river the hydraulic connection appears to be low, and the leakance is an order of magnitude lower along the river south of the Polk-Hardee County line to central Hardee County than it is north of the county line to Bartow (Basso 2002).

Groundwater has the potential to move upward in areas where the potentiometric surface in the underlying aquifer is above the water table of the surficial aquifer. It has the potential to move downward where the potentiometric surface of the underlying aquifer is lower than the water table. In September 1989, Yobbi (1996) determined the head potential was downward from upstream of Bartow to the Polk-Hardee County line (see Figure 2-6). From the Polk-Hardee County line to south of Arcadia, leakage was upward. Location and aquifer response depends on annual and seasonal variations in water use, rainfall and recharge.

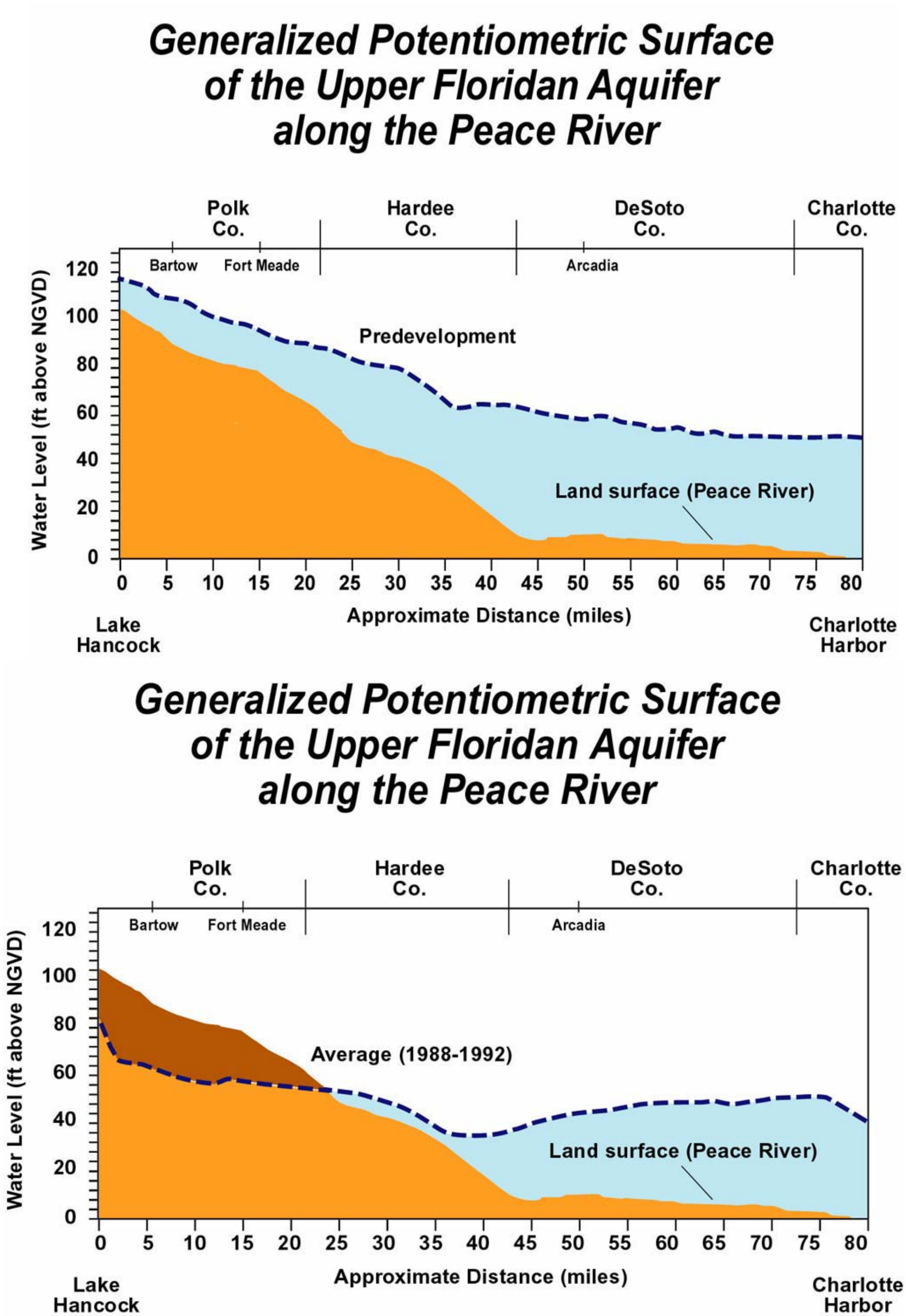



Figure 2-6. Generalized potentiometric surface of the Upper Floridan Aquifer along the Peace River. The upper plot represents pre-development condition (pre-1935), and lower plot is for the period 1988-1992 (after Yobbi 1996).

#### 2.2.5.3 Upper Floridan Aquifer

Carbonate units that make up the Upper Floridan Aquifer are the Suwannee Limestone, Ocala Limestone and Avon Park Formation. The Upper Floridan consists of two permeable zones and one semi-confining unit. The top of the Upper Floridan coincides with the top of the Suwannee Limestone and is the upper permeable zone. While the permeability of the Suwannee Limestone is primarily intergranular, in the northern part of the Upper Peace River basin (which coincides with the Upper Peace River as defined in this report) solution cavities and conduits are more prominent due to the thinning of the intermediate confining unit. The upper permeable zone is separated from the highly productive and transmissive lower permeable zone by a semi-confining unit (the top of the Ocala Limestone) which is composed mostly of soft, chalky, fine-grained, foraminiferal calcilutite and calcarenitic limestone. The lower permeable zone is the most productive zone in the Upper Floridan aquifer, and transmissivities can be very high in this zone; however, the hydraulic conductivity of this zone is more variable than overlying zones due to the existence of fractures (Basso 2002).

Water movement in the Upper Floridan Aquifer is generally from the northeast to southwest through Polk, Hardee and DeSoto counties. In 1995, the general flow direction in DeSoto County shifted to a more northwesterly direction. It was influenced by large depressions in the Upper Floridan potentiometric surface caused by withdrawals in Sarasota and Manatee counties (Lewelling et al. 1998).

#### 2.2.5.4 Relationship of Upper Peace River to the Underlying Aquifers

In the first half of the twentieth century, the Peace River was a gaining stream throughout its entire length (Figure 2-6). The Upper Peace River is now a losing stream, and while the potentiometric surface of the Floridan aquifer has rebounded in the upper Peace watershed, ground-water baseflow in the upper reaches remains low to at times non-existent. Lewelling et al. (1998) demonstrated, that from Bartow downstream to Ft. Meade, the Peace River channel and floodplain is predominantly a ground-water recharge area. This is a reversal of the natural ground-water heads of the 1950's. During the dry season (April - May), ground-water heads in both the intermediate and Upper Floridan aquifer systems are below the elevation of the river bed from upstream of Bartow to downstream of Ft. Meade. During wetter periods, ground-water heads in the intermediate aquifer can be higher than the river stage for short periods. Because ground-water heads of the Upper Floridan aquifer are lower than for the intermediate aquifer system, the intermediate system may simultaneously recharge the underlying Upper Floridan and simultaneously discharge into the overlying Peace River. Lewelling et al. (1998) documented the observation of flow loss into sinkholes and sand filled depressions in the Upper Peace River (see Figure 2-7). The cavernous porosity in the underlying limestone was documented in a dye study in 1981 on three sinkhole complexes along the river when dye was observed in an Upper Floridan aquifer well approximately one mile south of the dye injection point only eight hours after injection (Lewelling et al. 1998).

As documented by Peek (1951), there were areas of artesian flow in the Upper Peace

River prior to the regional lowering of the potentiometric surface. Kissengen Spring discharge was approximately 20 mgd when first measured by the USGS on December 21, 1898. Monthly measurements of flow were made beginning in 1932, and for the following five years, the flow averaged 19 mgd. After 1936, flows steadily declined until the continuous discharge ceased in February 1950. Peek (1951) calculated that at the time of his report, the maximum withdrawal of ground water in southwestern Polk County was approximately 110 mgd of which 75 mgd was attributed to phosphate mining.

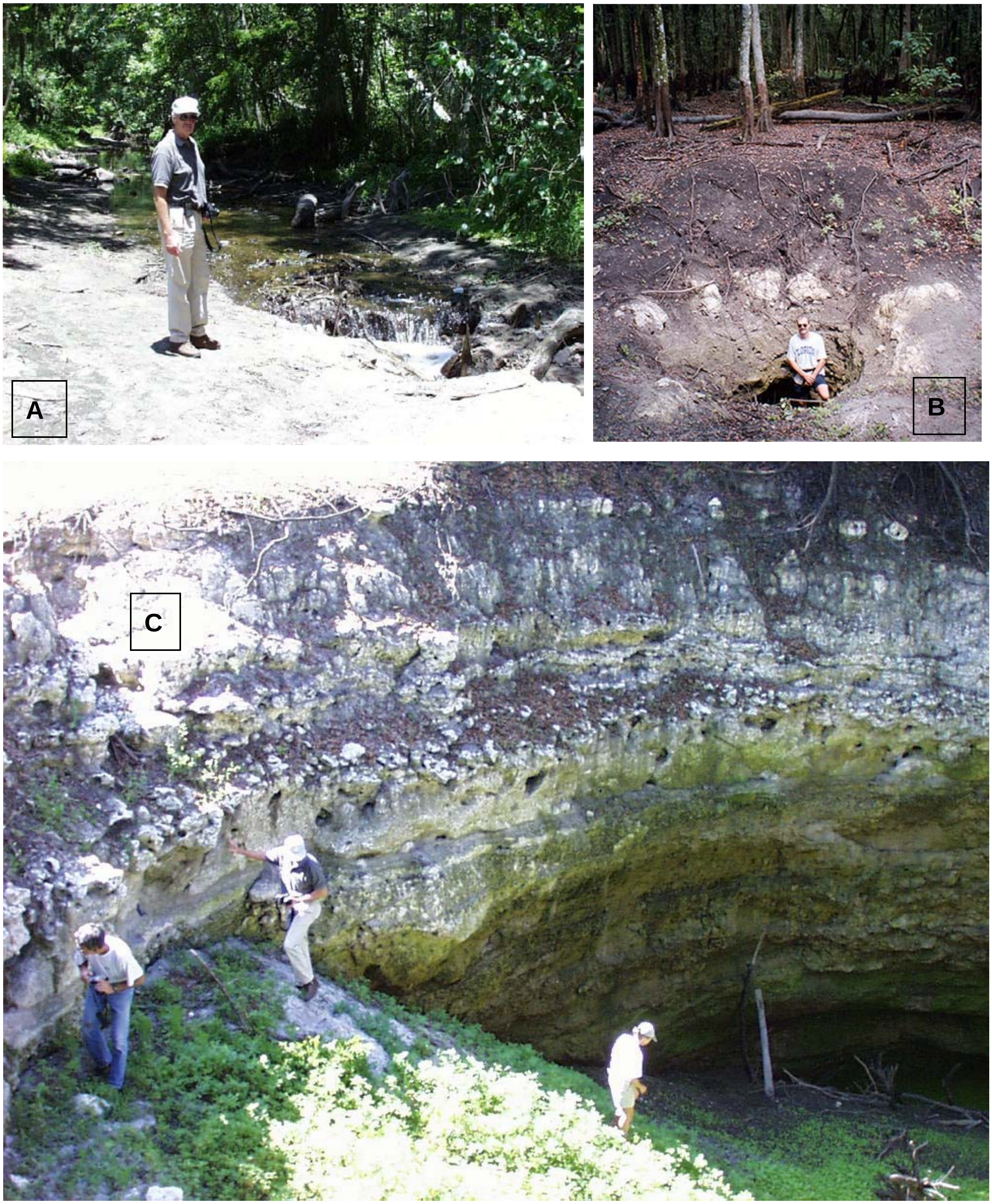



Figure 2-7. Karstic features located in the riverbed (upper right) and floodplain of the Upper Peace River. (Photographs A and C: J. Morales, SWFWMD, 2001; Photogarph B: T. King, FFWCC, 1998)

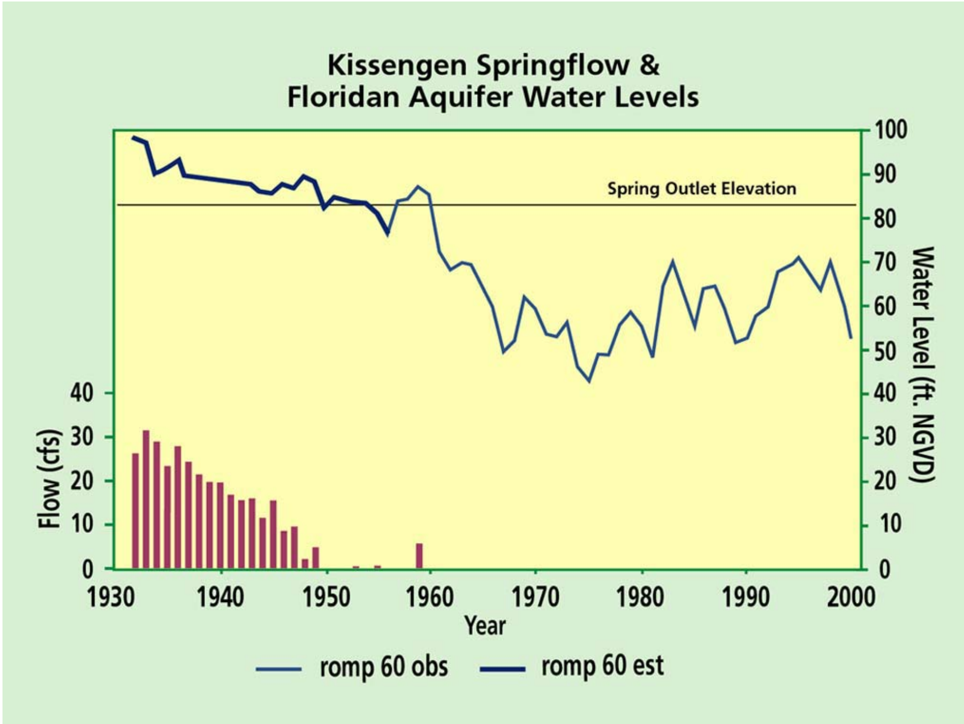




Figure 2-8. Kissengen Spring: upper plot shows measured flow at Kissengen Spring (vertical bars) and estimated and observed water level in nearby Floridan aquifer monitor well (ROMP 60). Photo was taken at Kissengen Spring in 1894. The spring has not discharged since 1960. (Photo from Louise Frisbie collection, the Florida Photographic Collection, Florida Department of State, Bureau of Archives and Records)

## 2.3 Chronology of Watershed Development

Unlike many of the rivers in the northeastern United States, little intensive development occurred along the Peace River until relatively recently. Except for small transient native populations that apparently exerted little impact on the area, the Peace River watershed was essentially unsettled and undeveloped until about 200 years ago. It is believed that first permanent Native American settlement did not occur until 1819, and human activity did not change markedly until the mid-1800's when settlers began farming and cattle ranching. In 1881 commercially mineable deposits of pebble phosphate were discovered in the river itself, and phosphate mining soon became a major industry in the basin.

A chronology of some important historical events is outlined below to establish a sense of the history of the area, and the roles of agriculture, phosphate mining, and urbanization in that history.

| | |
|---|---|
| 1800-1820 | Creeks, Seminoles and escaped slaves established plantations and cattle ranching in settlements along the upper "Peas River" (Peace River). (source: *Florida's Peace River Frontier* by Canter Brown, Jr. 1991. University of Central Florida Press, Orlando) |
| by 1819 | First permanent village in the basin, Talakchopco, established on the Talakchopco hatchee ("River of the Long Peas") by Creek and Seminole Indians. (source: *Florida's Peace River Frontier* by Canter Brown, Jr. 1991. University of Central Florida Press, Orlando) |
| April 16, 1836 | Talakchopco burned by Colonel Goodwyn during the Second Seminole War. (source: *Florida's Peace River Frontier* by Canter Brown, Jr. 1991. University of Central Florida Press, Orlando) |
| Mid - 1800s | Increasing settlement of the basin by white settlers who moved into the basin in increasing numbers following the end of the Third Seminole War; farming and cattle ranching were the dominant land uses during this time. (source: *Florida's Peace River Frontier* by Canter Brown, Jr. 1991. University of Central Florida Press, Orlando) |
| 1881 | Capt. J. Francis LeBaron, an engineer with the U.S. Army Crops of Engineers, made a survey of the Peace River to determine the feasibility of opening a navigable waterway from the St. Johns River to Charlotte. Although he found the proposed waterway impractical, he did discover in the river bed deposits of sand, gravel and pebble or bone phosphate. (source: *Florida's Peace River Frontier* by Canter Brown, Jr. 1991. University of Central Florida Press, Orlando) |
| 1888 | "In 1888 phosphate mining on a commercial scale began in Florida. The source was the river pebble phosphate found in the channel of the Peace River, and the section at Arcadia was worked extensively through the utilization of barges and floating dredges. Shortly after |

| | |
|---|---|
| | the turn of the century the land pebble beds were found to be more economical to work . . . Today [1953], pebble phosphate mining is carried out on both sides of the Peace River where the spoil banks are prominent features of the landscape between Bartow and Bowling Green." (from: Lanquist, Ellis. 1953. A biological survey of the Peace River, Florida. Master's Thesis. University of Florida.) |
| 1930's | Referring to Peace Creek, which runs from the Winter Haven Chain of Lakes area southwesterly to confluence with Saddle Creek Canal to form Peace River, "This stream was modified during the 1930's when it was dredged and in some areas a new channel was constructed in order to drain the prairie and low flatwoods. The work progressed from Winter Haven to a point near the Posmico Mine northeast of Bartow." (from: Lanquist, Ellis. 1953. A biological survey of the Peace River, Florida. Master's Thesis. University of Florida.) |
| Mid 1930's | "One event of some importance in the history of the stream occurred during the mid-thirties under the Work Progress Administration. The channel was cleared of logs and other debris from a point below the Homeland Bridge in Polk County to the mouth of the stream at Charlotte Harbor." (from: Lanquist, Ellis. 1953. A biological survey of the Peace River, Florida. Master's Thesis. University of Florida.) |
| February 1950 | Kissengen Spring "became the only major artesian spring of Florida to cease flowing completely . . . Records of United States Geological Survey show that the discharge of the spring was about 20 million gallons a day when it was first measured in 1898. . . . After 1936, however, the flow declined progressively until, in February 1950 it ceased altogether. . . . The present maximum withdrawal of ground water in southwestern Polk county is approximately 110 million gallons a day, of which about 75 million gallons a day is used by the phosphate companies." (from: Peek, H. M. 1951. Cessation of Flow of Kissengen Spring in Polk County, Florida. U.S. Geological Survey.) |
| 1950 | Lanquist, in citing the Polk County Health Department, documents the release of 2000 gpm of a mine waste apparently unique to the Armour Company plant at Bartow into Bear Branch which flows into the Peace River. The waste stream reportedly contained 300-500 ppm dissolved phosphate, sulfates of 637 ppm, and fluorides of 138 ppm. The pH of the effluent was often below 3.4 and usually near 2.5. (source: Lanquist, Ellis. 1953. A biological survey of the Peace River, Florida. Master's Thesis. University of Florida.) |
| August, 1953 | Lanquist documents "the importance of Lake Hancock to the fertility of the river . . . The lake is of irregular outline with a maximum length of five miles and width of three miles. It is quite shallow, having a maximum depth of approximately eight feet . . . much of the depth, |

however, is occupied by muck or pulpy peat; and consequently in some areas of the lake there remains but two or three feet of clear water . . Its sources of surface water are three streams rising in the Lakeland and Auburndale sections: (1) a small, hyacinth-choked canal flows east into Lake Hancock from Banana Lake which receives the sewage of Lakeland; (2) originating in cypress swamps northeast of Lakeland are several small streams and canals which are collectively designated on charts and locally as Saddle Creek; (3) the third and smallest is an unnamed creek which is the outlet of Lake Lena in Auburndale and flows through a narrow swamp for a distance of seven miles to Lake Hancock." (from: Lanquist, Ellis. 1953. A biological survey of the Peace River, Florida. Master's Thesis. University of Florida.)

August, 1953 — Lanquist documents results of his biological (macroinvertebrate) study of the Peace River. He also documents the occurrence of two "slime" spills from a mine located just above Ft. Meade, and the effect of citrus wastes on Peace Creek. He states, "The Snively Citrus plant at Eloise contributed a heavy load of wastes having a comparatively high oxygen demand. The odor of citrus wastes was quite strong in May and June, 1952, at this station." Lanquist recorded the effects of high concentrations of plankton originating in Lake Hancock and the effect of decaying water hyacinths on the water quality in Saddle Creek Canal downstream of Lake Hancock. Dissolved oxygen concentrations of 0.0 ppm were common at one of his study sites immediately downstream of Lake Hancock. It should be noted that water hyacinths are an exotic aquatic plant that has impacted water quality and navigation on many waterways throughout Florida. (from: Lanquist, Ellis. 1953. A biological survey of the Peace River, Florida. Master's Thesis. University of Florida.)

September, 1960 — Hurricane Donna (scale 4 storm) - "Only one scale 5 storm, the "Labor Day Hurricane" of 1935, passed near Charlotte Harbor. The 1926 storm and Hurricane Donna in 1960 were the most severe direct hits. The last hurricane to pass within 50 mi of the harbor was Hurricane Alma in 1966." (from: Hammett, K.M. 1990. Land use, water use, streamflow characteristics, and water-quality characteristics of the Charlotte Harbor inflow area, Florida. U.S. Geological Survey Water-Supply Paper 2359)

1960-65 — "Hammett (1990) identified the years 1960-65 as a transitional period separating two distinctly different time periods with respect to annual streamflow in the Peace River. A shift in rainfall-streamflow relationships was observed . . . . The period 1965-1984 displayed lower discharge per unit rainfall than was observed for the period prior to 1960. Hammett (1990) notes the observed rainfall deficit in the Peace River watershed, but suggests that the declining trend in Peace River streamflow may also be partially attributable to factors other than rainfall, e.g., lowered artesian water levels in the Floridan aquifer with subsequent lower spring flow to the river and higher infiltration from the river to the underlying groundwater." (from: Coastal Environmental, Inc. 1995. Estimates of total nitrogen, total phosphorus, and total suspended solids loadings to Charlotte Harbor, Florida.)

| | |
|---|---|
| 1970 | 140,350 - Estimated population in Peace River watershed based on 1970 census. (from: Southwest Florida Water Management District. 2001a. Draft - The Peace River Comprehensive Watershed Management Plan - Volume 1) |
| July 1, 1975 | "Prior to July 1, 1975, lands that were mined did not have to be reclaimed; and although reclamation is now required, the habitat or community that was destroyed by mining is not always the habitat or community type that is recreated in the reclamation process. Wetland mitigation is required, but uplands are generally reclaimed as some other land use, typically pasture. Of the 152,000 acres of nonmandatory lands, reclamation of 47,000 acres has been funded. Approximately 25,000 acres of this total are in the Peace River watershed. Another 28,500 have no funds dedicated to reclamation." (from: Southwest Florida Water Management District. 2001a. Draft - The Peace River Comprehensive Watershed Management Plan - Volume 1) |
| 1980 | 215,644 - Estimated population in Peace River watershed based on 1980 census - this is a 54% increase over the 1970 census. (from: Southwest Florida Water Management District. 1999. Draft - The Peace River Comprehensive Watershed Management Plan - Volume 1) |
| 1983 | "Lake Hancock, with extremely poor water quality, is fed by three polluted streams or canals. One of these, Lake Lena Run, had one of the worst water quality index values in the State in 1983. During two sampling events in the spring of 1981, only three species of macroinvertebrates were found . . . Most of its flow is made up of effluent from three citrus processing companies, a chemical plant, a distillery, the Auburndale WWTP, and runoff from rangeland, a sprayfield, and a dump site for citrus waste." (from: Department of Environmental Protection. 1994. 1994 Water Quality Assessment for the State of Florida: Technical Appendix.) |
| 1987 | Zellars-Williams Company, under contract to Florida Institute of Phosphate Research, completed a report that examined the feasibility of restoring Lake Hancock by mining the phosphate mineral beneath the lake. |
| 1990 | 295,331 - Estimated population in Peace River watershed based on 1990 census - this is a 37% increase over the 1980 census and a 110% increase over the 1970 census. (source: Southwest Florida Water Management District. 2001a. Draft - The Peace River Comprehensive Watershed Management Plan - Volume 1) |

in 1990 General Development Utilities water plant on the Peace River near Fort Ogden was diverting 4 to 5 mgd for public supply. The city of Punta Gorda maintains a water supply reservoir on Shell Creek which diverts 2 to 4 mgd from the creek. There were 25 permits from the DEP to discharge a combined 20 mgd of treated domestic effluent to the river, although the actual discharge may be considerably less. DEP had also permitted 60 facilities to discharge industrial effluent to the Peace River. Half the permits are associated with the chemical and phosphate industry in Polk County. About one-quarter of the permits are to food and citrus processing plants, and the remaining one-quarter are to limerock and other assorted industries. (source: Hammett, K.M. 1990. Land use, water use, streamflow characteristics, and water-quality characteristics of the Charlotte Harbor inflow area, Florida. U.S. Geological Survey Water-Supply Paper 2359)

Water quality trends - increasing trend in total organic nitrogen (possible source suggested to be effluent from wastewater treatment plants); increases in chloride, sulfate and dissolved solids (probably represent an increased contribution from ground water from irrigation runoff and industrial processing); increasing trend in specific conductance which could result from either wastewater or mineralized ground water). A decreasing (and unexpected) trend in total phosphorus was also observed. (source: Hammett, K.M. 1990. Land use, water use, streamflow characteristics, and water-quality characteristics of the Charlotte Harbor inflow area, Florida. U.S. Geological Survey Water-Supply Paper 2359)

1995 “A watershed-wide analysis of land use and land cover, based on 1995 data, indicates that over 60 percent of the total land area has been converted from its pre-alteration natural cover. The primary sources of conversion, listed in descending order of total lands converted, have been: agricultural development (680,000 acres, or 40 percent of the watershed); “structural” development for residential, commercial and industrial purposes (194,000 acres, or 12.0 percent of the watershed); and “extractive” uses (126,000 acres, or 8.0 percent of the watershed), which have consisted primarily of phosphate mining in the upper watershed. . . . The predominant agricultural uses include pasture and citrus cultivation.” (from: Southwest Florida Water Management District. 2001a. Draft - The Peace River Comprehensive Watershed Management Plan - Volume 1)

1998 Streamflow trends were examined at long-term gaging sites. “Streamflow throughout the watershed [the Charlotte Harbor watershed] generally declined from the late 1950s to the mid-1970s or 1980s. At all gages, however, trend tests conducted on flows since 1975 have shown either non-significant positive slopes or significant increasing trends. Rainfall has shown a similar pattern with deficits during the 1960s and 1970s being most pronounced in the Peace

River basin. Water levels in the Upper Floridan aquifer in the upper Peace River basin have shown some recovery since the mid-1970s, due largely to improved water use efficiencies by the phosphate industry. Flows in the upper river remain comparatively low, however. . ." (from: Flannery, M.S. and M. Barcelo. 1998. Spatial and temporal patterns of streamflow trends in the Upper Charlotte Harbor watershed. In Proceedings of The Charlotte Harbor Public Conference and Technical Symposium. Charlotte Harbor National Estuary Program. Technical Rept. No. 98-02).

Since the late 1970's there has been a significant increase in baseflow in Joshua Creek (tributary to Peace River), and it was concluded "that the observed increases in low flows are the result of agricultural use." (from: Flannery, M.S. and M. Barcelo. 1998. Spatial and temporal patterns of streamflow trends in the Upper Charlotte Harbor watershed. In Proceedings of The Charlotte Harbor Public Conference and Technical Symposium. Charlotte Harbor National Estuary Program. Technical Rept. No. 98-02).

By 2020

A recent draft of the District's Regional Water Supply Plan has projected population growth by county in the planning region. Summing the estimated total populations of Charlotte, DeSoto, Hardee and Polk Counties yields a population total for the four counties in the year 2000 of 724,822. The population of the four counties is projected to exceed one million by the year 2020 (i.e., 1,027,736). This represents a projected population increase of approximately 42% in the next 20 years. (source: Southwest Florida Water Management District. 2001b. Regional Water Supply Plan - Board Approved - August 2001.) Please note: that these projections are not directly comparable to census numbers presented for the years 1970, 1980 and 1990 presented above, because they cover different geographic areas.

## Chapter Three

## Hydrologic Trends and Water Quality of the Upper Peace River

### 3.1 Overview

The assessment of minimum flows and levels for the Upper Peace River was supported by analyses of long-term streamflow records that date to the 1930s. Significant declining trends in flows in the Peace River have been documented by a number of workers and are a major management issue in the region (Hammett 1990, Coastal Environmental 1996a, Lewelling et al. 1998, Flannery and Barcelo 1998, Hickey 1998, Basso 2002, Garlanger 2002). Trend analyses of flows are updated in this report using data through the year 2000. In order to examine how different components of the river's flow regime have changed over time, trends are examined on a monthly basis and for various annual percent exceedance flows. Water quality in the river is examined as it is related to changes in the river's flow regime. Factors affecting trends in streamflow and water quality in the Peace River are discussed.

#### 3.1.1 Gage Sites and Periods of Record

Analyses focused on three USGS gage sites located on the main stem of the Upper Peace River and one long-term gage site located further downstream (Figure 3-1) . The most upstream gage, the Peace River at Bartow (USGS #02294650), is located just east of the city of Bartow, approximately two miles downstream of the confluence of the Peace Creek Canal and Saddle Creek. This gage is located 105 miles upstream from the mouth of the river and measures discharge from a surface watershed of approximately 390 square miles. Daily discharge records exist for this site beginning October 1, 1939. For the period of record through the year 2000, the flow exceeded 50% of the time (the median daily flow) at Bartow was 102 cfs.

The Ft. Meade gage (USGS # 02294898) is located 13 stream miles downstream from the Bartow gage or 92 miles upstream from the river mouth. It captures flow from a drainage area of 480 square miles. Periodic flow measurements were made at this site prior to 1974; however, continuous measurements of daily streamflow began June 1, 1974, and any reference to period of record flow data begin with this date. The median daily flow for the period of record is 77 cfs. The lower median flow at Ft. Meade compared to the Bartow gage is partly related to its shorter period of record (the median flow at Bartow for the same period is 55 cfs).

The Zolfo Springs Gage (USGS # 02295637) was established in September 1933. It is located in Hardee County, approximately 0.8 miles north of Zolfo Springs or 69 miles upstream from the river mouth. This gage measures flow from a drainage area of 826 square miles. The median daily flow over the period of record is 317 cfs.

Although not considered part of the Upper Peace River, comparisons are made to flows at the Peace River at Arcadia gage (USGS # 02296750). This site is located in DeSoto County, approximately 33 miles downstream from the Zolfo Springs gage or 36 miles upstream from the mouth of the river. This is the most downstream gage on the main stem

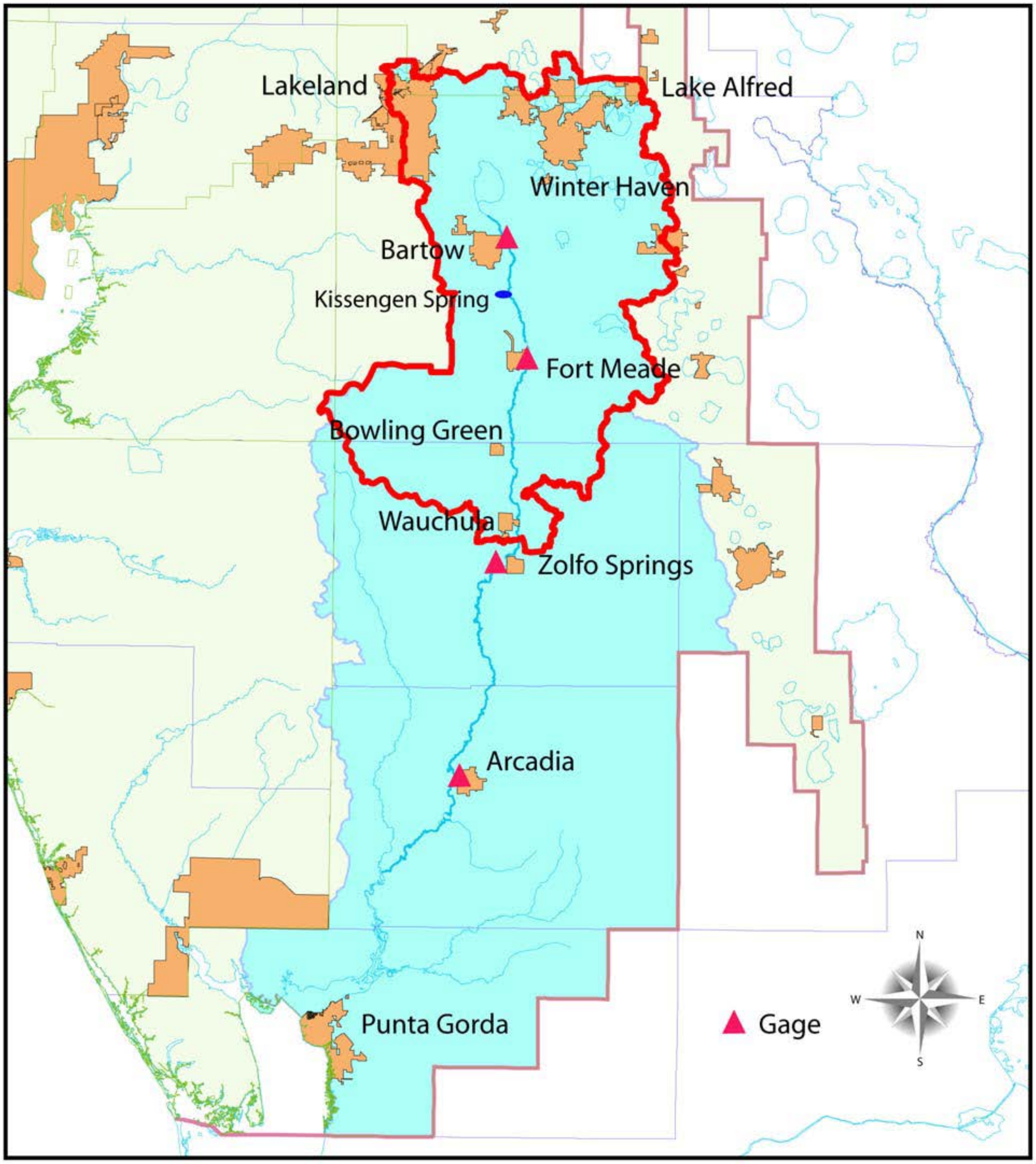



Figure 3-1. Peace River watershed showing location of USGS gage sites. The Upper Peace River is defined as that portion of the watershed above the USGS Zolfo Springs gage and is outlined in red.

of the Peace River and encompasses a drainage area of 1,367 square miles. Flow records at this site began in April 1931. The median flow for the Arcadia gage is 455 cfs.

## 3.2. Documentation of Declining Flow Trends

The first report to draw attention to declining flows in the Peace River was by Hammett (1990), who reported statistically significant declines in mean annual flows for the period of record at the Bartow, Zolfo Springs, and Arcadia gaging stations. Hammett used the non-parametric Kendall tau procedure on data collected through 1984. Using flow data through 1994, Coastal Environmental (1996a) documented significant declining trends for both dry and wet season flows at the Bartow and Zolfo Springs gages, but only for wet season flows at the Arcadia gage. In a more recent study, Lewelling et al. (1998) also documented significant declining flows at all sites when the entire period of record was evaluated. However, no trends were detected, using a 90% confidence level, when the most recent twenty years of data were examined (1975-1994).

Using data through 1996, Flannery and Barcelo (1998) similarly documented significant declining trends at gages on the Peace River for the period of record, but noted that rates of change in streamflow have varied considerably over time. They observed the steepest rates of decline occurred from the late 1950s to the late 1970s or early 1980's. Similar to Lewelling et al. (1998), they did not find any continued declining trends when streamflow data from 1975 forward were analyzed.

### 3.2.1 Recent Trend Analyses at Long-Term Gages

Hydrographs of mean annual flows at four USGS streamflow gages on the Peace River are presented in Figure 3-2. For comparative purposes, the trend analysis performed by Hammett (1990) and Lewelling et al. (1998) on the three long-term gages (Bartow, Zolfo Springs, and Arcadia) using the non-parametric Kendall tau test on mean annual streamflow values were repeated. Trend tests were run for the period 1940 through 2000 for all gages in order to make the results most comparable (Table 3-1). As found by Hammett (1990) and Lewelling et al. (1998), there is, using a 90% confidence level, a significant declining trend in flows at all three gages when long-term data are examined. Also, as reported in these previous studies, the slopes of these declining trends (expressed as percent change in the long-term mean at each site) are most pronounced at Bartow, indicating that the severity of declining flows increases in an upstream direction.

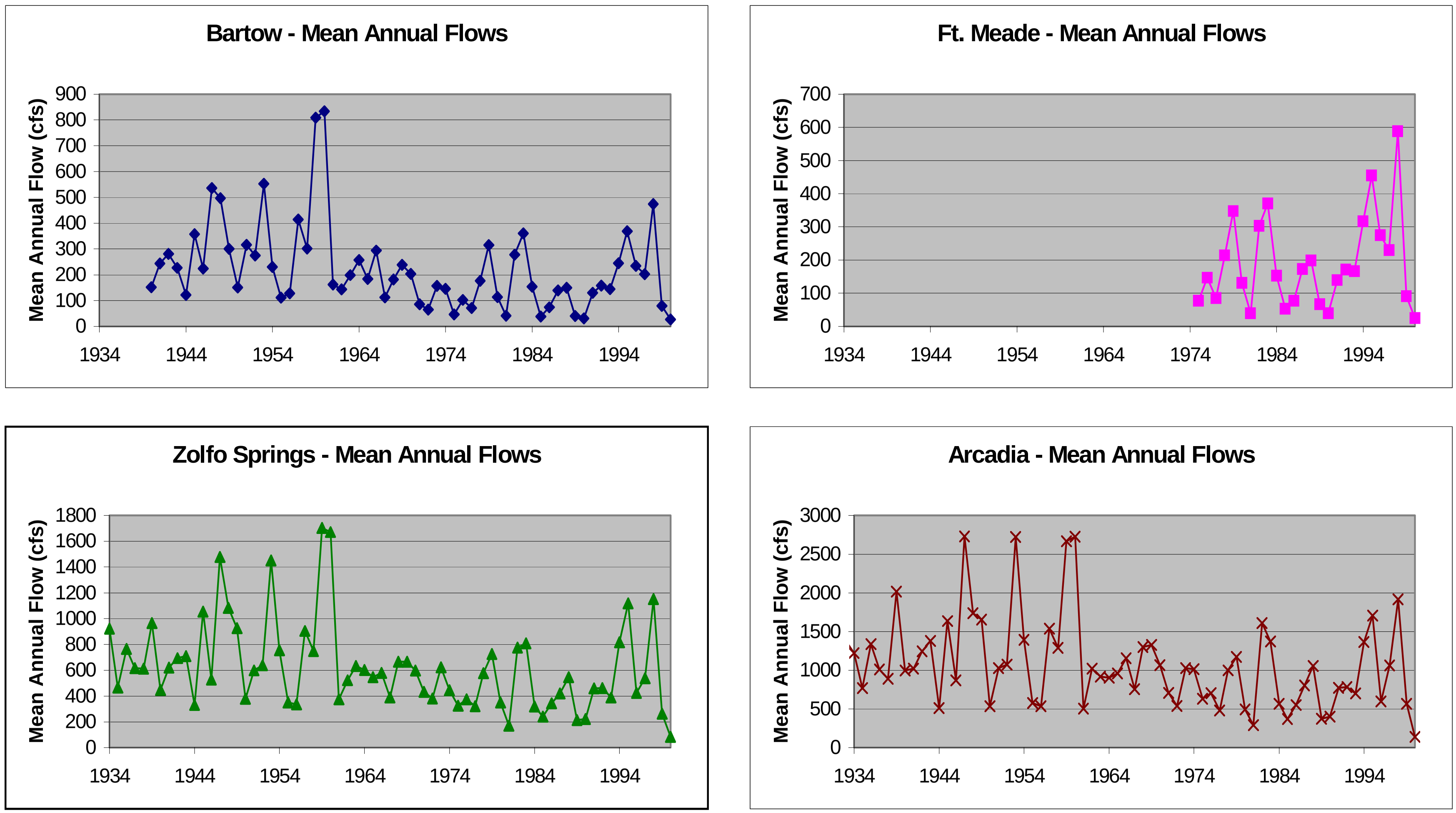



Figure 3-2. Hydrographs of mean annual flows at four USGS streamflow gages on the Peace River.

Table 3-1. Kendall tau for mean annual and monthly mean flows for different time periods at three USGS gage sites on Peace River. Slopes and significance levels given; all significance values of p<0.1 are highlighted in bold. For Annual flows the slopes are expressed as a percentage of the annual mean.

| MONTH | PERIOD 1940-2000 | | | 1940-1960 | | | 1970-2000 | | | 1985-2000 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Bartow | Zolfo Springs | Arcadia | Bartow | Zolfo Springs | Arcadia | Bartow | Zolfo Springs | Arcadia | Bartow | Zolfo Springs | Arcadia |
| **ANNUAL** | **-2.6028** | **-5.7595** | **-9.7655** | 11.0022 | 18.3531 | 32.0532 | 1.8136 | -8.6283 | -13.1706 | 11.8732 | 11.8522 | 27.2600 |
| | **0.0029** | **0.0050** | **0.0113** | 0.1236 | 0.1742 | 0.1941 | 0.5184 | 0.1236 | 0.2389 | 0.1151 | 0.3004 | 0.3004 |
| % of Period Mean | -1.1620 | -0.9426 | -0.9230 | 3.2745 | 2.2139 | 2.2557 | 1.1625 | -1.7938 | -1.5811 | 7.5147 | 2.4692 | 3.3163 |
| January | **-1.5129** | -2.2444 | -1.6898 | 5.6215 | 6.2540 | 5.5516 | 0.7512 | -2.6532 | -2.4386 | 3.3967 | 11.9253 | 10.8612 |
| | **0.0365** | 0.1691 | 0.3870 | 0.1558 | 0.4874 | 0.5661 | 0.6463 | 0.7398 | 0.8326 | 0.6853 | 0.3444 | 0.4995 |
| February | **-1.5935** | -2.9294 | -2.2673 | **9.1558** | 13.2452 | 15.0929 | -0.6830 | 0.0066 | -7.6326 | 2.9491 | 7.3725 | 5.5611 |
| | **0.0419** | 0.1369 | 0.3045 | **0.0852** | 0.1941 | 0.1941 | 0.5184 | 1.0000 | 0.6506 | 0.2604 | 0.4995 | 0.4995 |
| March | **-1.7326** | -2.6180 | -2.3007 | 10.5032 | 26.6180 | 27.5778 | -0.5750 | 3.3606 | 6.0211 | -0.1907 | -10.9113 | -17.0839 |
| | **0.0105** | 0.1403 | 0.3803 | 0.1558 | 0.1095 | 0.2639 | 0.3768 | 0.6946 | 0.5260 | 0.8926 | 0.6204 | 0.5584 |
| April | **-1.0820** | -2.4760 | -0.0978 | 8.0567 | **22.6170** | 30.8375 | -0.2764 | -0.8917 | 1.6787 | -0.3668 | 0.4139 | -3.1171 |
| | **0.0203** | 0.1436 | 0.2680 | 0.1236 | **0.0967** | 0.1236 | 0.7085 | 0.7398 | 0.8326 | 0.8926 | 0.9641 | 0.9641 |
| May | **-1.0390** | **-1.7688** | -1.0495 | **9.2590** | **17.3099** | **19.4301** | **-0.7290** | -6.4882 | -4.5729 | 0.4594 | 1.4401 | 3.6984 |
| | **0.0002** | **0.0247** | 0.3603 | **0.0086** | **0.0072** | **0.0201** | **0.0381** | 0.1558 | 0.4874 | 0.7526 | 0.8219 | 0.5584 |
| June | **-1.4821** | **-4.1202** | **-4.8092** | **7.0778** | 3.8616 | 1.7778 | **-1.4549** | **-20.7963** | **-25.6900** | 0.1524 | 1.4071 | 4.3597 |
| | **0.0015** | **0.0130** | **0.0646** | **0.0655** | 0.6077 | 0.8799 | **0.0570** | **0.0171** | **0.0372** | 0.9641 | 0.8219 | 0.7526 |
| July | **-3.1833** | **-9.1908** | **-6.8436** | -0.0020 | -20.5344 | -64.4570 | -0.2312 | **-18.6919** | -24.1688 | 3.6764 | -10.4158 | 6.7559 |
| | **0.0051** | **0.0028** | **0.0035** | 1.0000 | 0.4149 | 0.3492 | 0.8784 | **0.0852** | 0.2906 | 0.6204 | 0.4440 | 0.8926 |
| August | **-1.9731** | **-9.0138** | **-17.9105** | 2.3114 | 12.4827 | 15.9062 | -0.6613 | -11.9268 | -16.2244 | 2.5807 | -24.2249 | -32.7269 |
| | **0.0031** | **0.0308** | **0.0263** | 0.8800 | 0.6946 | 0.8326 | 0.7857 | 0.3812 | 0.5661 | 0.6853 | 0.4995 | 0.5584 |
| September | **-4.4544** | **-9.5349** | **-24.5062** | 20.0038 | 45.0250 | 77.8883 | -0.1083 | -13.3704 | -37.7082 | 4.3617 | -11.7167 | -96.3667 |
| | **0.0073** | **0.0145** | **0.0029** | 0.2157 | 0.2157 | 0.3812 | 0.9458 | 0.4874 | 0.3190 | 0.8219 | 0.8219 | 0.6853 |
| October | **-2.6508** | **-5.8219** | **-13.6890** | **31.0000** | 58.1659 | 96.0927 | **3.3844** | -4.8376 | -9.2316 | **18.1254** | 15.8410 | 37.9100 |
| | **0.0135** | **0.0255** | **0.0360** | **0.0852** | 0.1742 | 0.1236 | **0.0892** | 0.3811 | 0.5661 | **0.0428** | 0.3004 | 0.1917 |
| November | **-2.1326** | **-3.3612** | -3.4507 | **11.5400** | 17.1866 | 24.0214 | 1.4333 | -2.5532 | 0.6167 | 3.6508 | 4.1777 | 3.5250 |
| | **0.0025** | **0.0203** | 0.2156 | **0.0655** | 0.1390 | 0.1558 | 0.1965 | 0.4874 | 0.9759 | 0.5584 | 0.7526 | 0.8219 |
| December | **-1.5034** | **-2.4355** | -1.8954 | **5.8196** | 7.7204 | 10.4866 | -0.0412 | -2.4145 | -1.6542 | 0.2005 | -5.1143 | -7.0468 |
| | **0.0008** | **0.0202** | 0.1691 | **0.0967** | 0.1646 | 0.1941 | 0.9729 | 0.5260 | 0.9278 | 0.8926 | 0.6853 | 0.6204 |

A Seasonal Kendall test was also run using mean monthly flows for the 1940-2000 period (Table 3-2), similar to the technique used by Flannery and Barcelo (1998). Similar patterns were observed, as significant (based on 90% confidence level) declining trends were found at all gage sites (Bartow, Zolfo Springs, Arcadia), with the percentage rates of decline being most pronounced upstream.

Trend tests were also performed using both methods on flows from 1970 to 2000 and 1985 to 2000. Over the last 16 years (1985-2000) there was a significant ($p<0.01$) increasing trend at the Bartow gage. These findings agree with the findings of Lewelling et al (1998) and Flannery and Barcelo (1998), in that it appears there has been some leveling off of flow trends in the Peace River. However, the hydrographs in Figure 3.2 show the Peace River generally experienced greater flows prior to 1960. This is especially pronounced at Bartow. In 21 years of streamflow records from 1940 to 1960, the lowest mean annual flow values at Bartow was 500 cfs in 1956. In contrast, during the 31 years since 1970, slightly over one-third (n=11) of the mean annual flows at Bartow were less than that amount. Similar, but much less pronounced, patterns are seen in mean annual flows before and after 1960 at the Zolfo Springs and Arcadia gages.

Table 3-2. Trends in streamflow for four gages on Peace River for three time periods beginning in different years. All periods end in 2000. Slopes expressed as cfs per year and as percent of long-term (1940-2000) median flow per year. Significance levels of trends calculated using the Seasonal Kendall test on monthly values. Trends at $p<0.10$ are shown in bold.

| Gage | | Beginning year of trend analysis | | |
|---|---|---|---|---|
| | | 1940 | 1970 | 1985 |
| Bartow | slope (cfs) | **-1.869** | -0.249 | **1.344** |
| | slope (% median) | **-1.80%** | -0.24% | **1.30%** |
| | significance | **0.000** | 0.380 | **0.094** |
| Ft. Meade | slope (cfs) | | | 1.195 |
| | slope (% median) | | | not applicable |
| | significance | | | 0.281 |
| Zolfo Springs | slope (cfs) | **-3.614** | **-2.895** | 0.714 |
| | slope (% median) | **-1.10%** | **-0.92%** | 0.22% |
| | significance | **0.000** | **0.011** | 0.785 |
| Arcadia | slope (cfs) | **-4.061** | -1.915 | -3.908 |
| | slope (% median) | **-0.89%** | -0.42% | -0.86% |
| | significance | **0.000** | 0.185 | 0.368 |

Although daily records are not as long at the Ft. Meade gage (1975 to current), some of more informative streamflow data for the Peace River comes from this station. As described in Chapter 2 and discussed in more detail later in this report, the Peace River is frequently a losing stream above the Ft. Meade gage in that the river loses flow as recharge to the ground-water system. The losing nature of the stream is evident in a comparison of daily flows at the Bartow gage with those at the Ft. Meade gage. During the time that the Ft. Meade gage has been in operation (the first complete year of daily flow records was 1975), there have been many days when daily flow values recorded at Bartow have exceeded the same-day flows at Ft. Meade. Table 3.3 lists the number of days each year when daily flows at Bartow exceeded the same-day flows at Ft. Meade. The average number of days per year is 123 days (a full third of the year), ranging from 26 days in 1989 to 256 days in 1981. While some of these differences could be due to the travel time of storm peaks between the two gages, many of the differences in daily flows are attributable to water lost from the river to the ground-water system.

Table 3-3 Number of days (n) that flow at the Bartow gage exceeded flow at Ft. Meade, and the mean, minimum, and maximum values of the differences in flow (cfs) for those days. The yearly average value is the average rate of flow lost between the two gages if the total loss of flow on days when Bartow exceeded Ft. Meade is averaged over 365 days.

| YEAR | n | Mean | Minimum | Maximum | Yearly Average |
|---|---|---|---|---|---|
| 1975 | 65 | 6.9 | 0.2 | 61.0 | 1.2 |
| 1976 | 42 | 31.5 | 1.0 | 185.0 | 3.6 |
| 1977 | 112 | 10.1 | 0.7 | 60.0 | 3.1 |
| 1978 | 59 | 44.2 | 2.0 | 146.0 | 7.1 |
| 1979 | 120 | 67.2 | 1.0 | 320.0 | 22.1 |
| 1980 | 135 | 30.0 | 1.0 | 316.0 | 11.1 |
| 1981 | 256 | 11.7 | 1.0 | 79.0 | 8.2 |
| 1982 | 143 | 55.3 | 1.0 | 420.0 | 21.6 |
| 1983 | 126 | 68.3 | 1.0 | 416.0 | 23.6 |
| 1984 | 203 | 24.2 | 1.0 | 279.0 | 13.5 |
| 1985 | 197 | 6.6 | 0.2 | 24.9 | 3.6 |
| 1986 | 162 | 22.3 | 0.4 | 192.0 | 9.9 |
| 1987 | 74 | 47.4 | 0.3 | 445.0 | 9.6 |
| 1988 | 45 | 24.1 | 1.0 | 89.0 | 3.0 |
| 1989 | 26 | 37.0 | 0.1 | 139.0 | 2.6 |
| 1990 | 130 | 12.4 | 0.3 | 129.0 | 4.4 |
| 1991 | 190 | 16.3 | 0.2 | 338.0 | 8.5 |
| 1992 | 81 | 36.8 | 0.1 | 263.0 | 8.2 |
| 1993 | 121 | 32.8 | 1.0 | 180.0 | 10.9 |
| 1994 | 159 | 26.6 | 0.7 | 178.0 | 11.6 |
| 1995 | 75 | 32.7 | 1.0 | 283.0 | 6.7 |
| 1996 | 97 | 67.3 | 1.0 | 610.0 | 17.9 |
| 1997 | 166 | 22.2 | 0.1 | 166.0 | 10.1 |
| 1998 | 43 | 3.9 | 0.2 | 20.0 | 0.5 |
| 1999 | 124 | 20.6 | 0.7 | 134.0 | 7.0 |
| 2000 | 255 | 20.7 | 0.0 | 69.0 | 14.5 |

More recent physical evidence of losses to the ground-water system are seen in the number of subsidence features that occur in the river channel and its floodplain. Patton (1981) and Lewelling et al (1998) documented the occurrence of numerous sinkholes and subsidence features in the bed of the river between Bartow and Ft. Meade. During dry periods, the river can be observed flowing into these sinkholes in the reach between Bartow and Ft. Meade. Some of these features in the floodplain are quite large and capable of capturing substantial quantities of flow (Figure 2-8). The quantity of flow loss between the two gages during some years is considerable. Mean flow loss rates exceeded 30 cfs during twelve years between 1975 and 2000, with the highest mean flow losses reaching 67 cfs in 1979 and 1996. The accuracy of the rating curves used to calculate discharge at these stations could be a factor contributing to these estimated losses. However, the capacity of the large sinkholes in the river channel and floodplain to capture large quantities of streamflow remains an important issue.

### 3.2.2 Trends in Annual Percent Exceedance Flows

It is important in the determination of minimum flows and levels to examine how different components of a river's flow regime may be changing. The two approaches applied here for evaluating changes in the flow regime of the Upper Peace River are the assessment of trends in flows for each month and trends in annual percent exceedance flows. Annual percent exceedance flows are flows that are exceeded by a certain percentage of the daily values within each year. Such flows can serve as useful indicators of how the low, medium, or high flow characteristics may be changing (Lins and Slack 1999).

Flows were examined at each of the three long-term gage sites for the following annual percent exceedance flows: the flow exceeded 90% of the time (low flow), the flow exceeded 75% of the time, the flow exceeded 50% of the time (the median flow), the flow exceeded 30% of the time (which is close to the mean annual flow for most sites), and the flow exceeded 10% of the time (high flow). Hydrographs of the yearly minima, 90%, 50%, and 10% exceedance flows are shown for each gage in Figures 3.3a to 3.3d. The results of trend analyses on these flows using the Kendall tau test are listed in Table 3.4.

For the period of record ending in 2000, all yearly exceedance flows at the Bartow and Zolfo Springs gages have declining trends (significant negative slopes). This indicates that in the upper reaches of the river the low, medium, and high flows have all declined. Inspection of Figure 3.3 indicates these declines have been most pronounced at the Bartow gage. In contrast, only the 10% and 30% exceedance flows have significant declining trends (exceeded a 90% confidence level) at the Arcadia gage, although non-significant negative slopes were observed for the other percent exceedance values. This indicates the declines in flows at Arcadia have been most pronounced for high flows, with low flows being less affected.

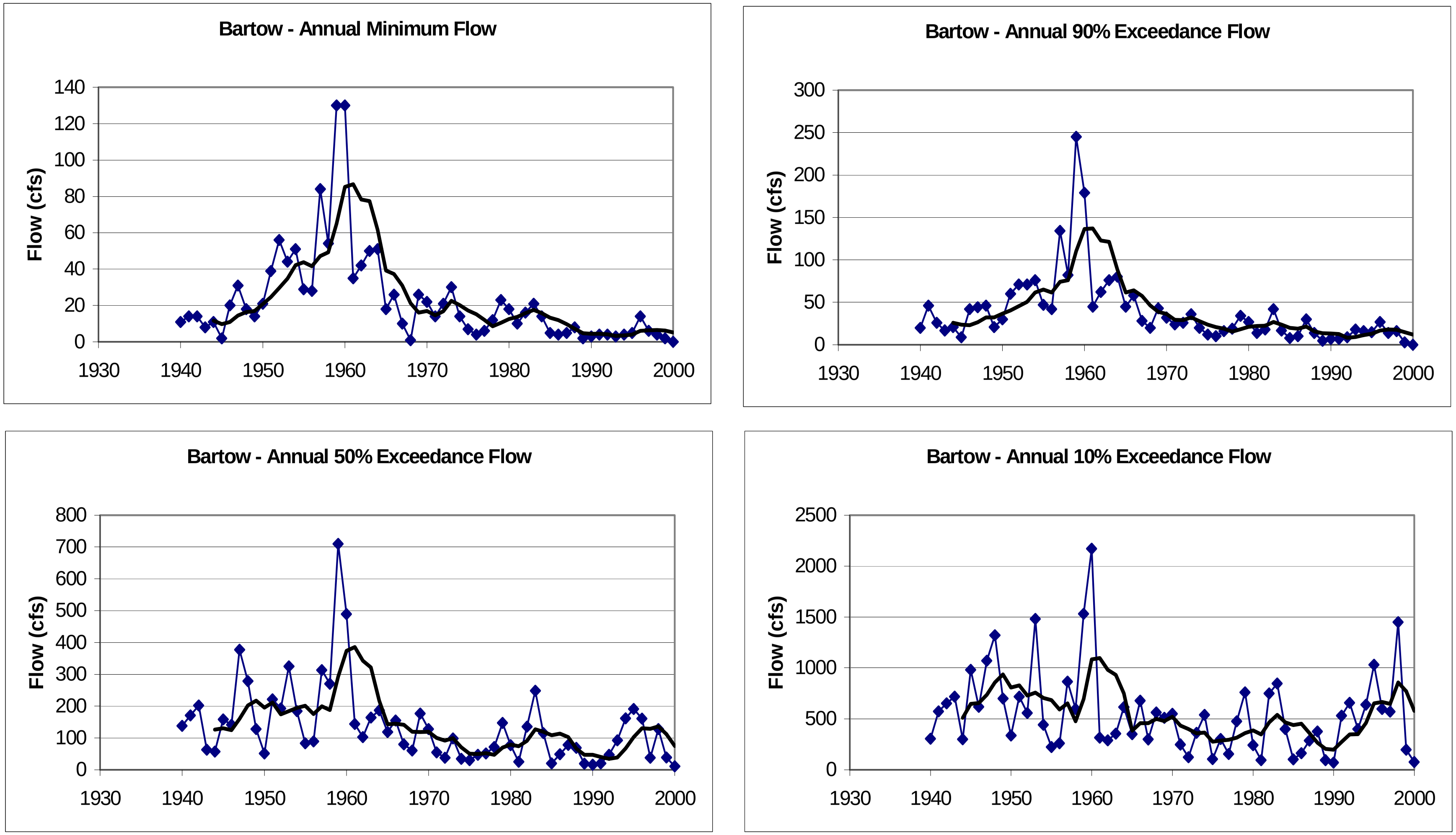



Figure 3-3a. Hydrographs of the minimum, 90%, 50% and 10% annual exceedance flows at the USGS Bartow Gage. Solid black line is the 5-year moving average for the respective exceedance flow.

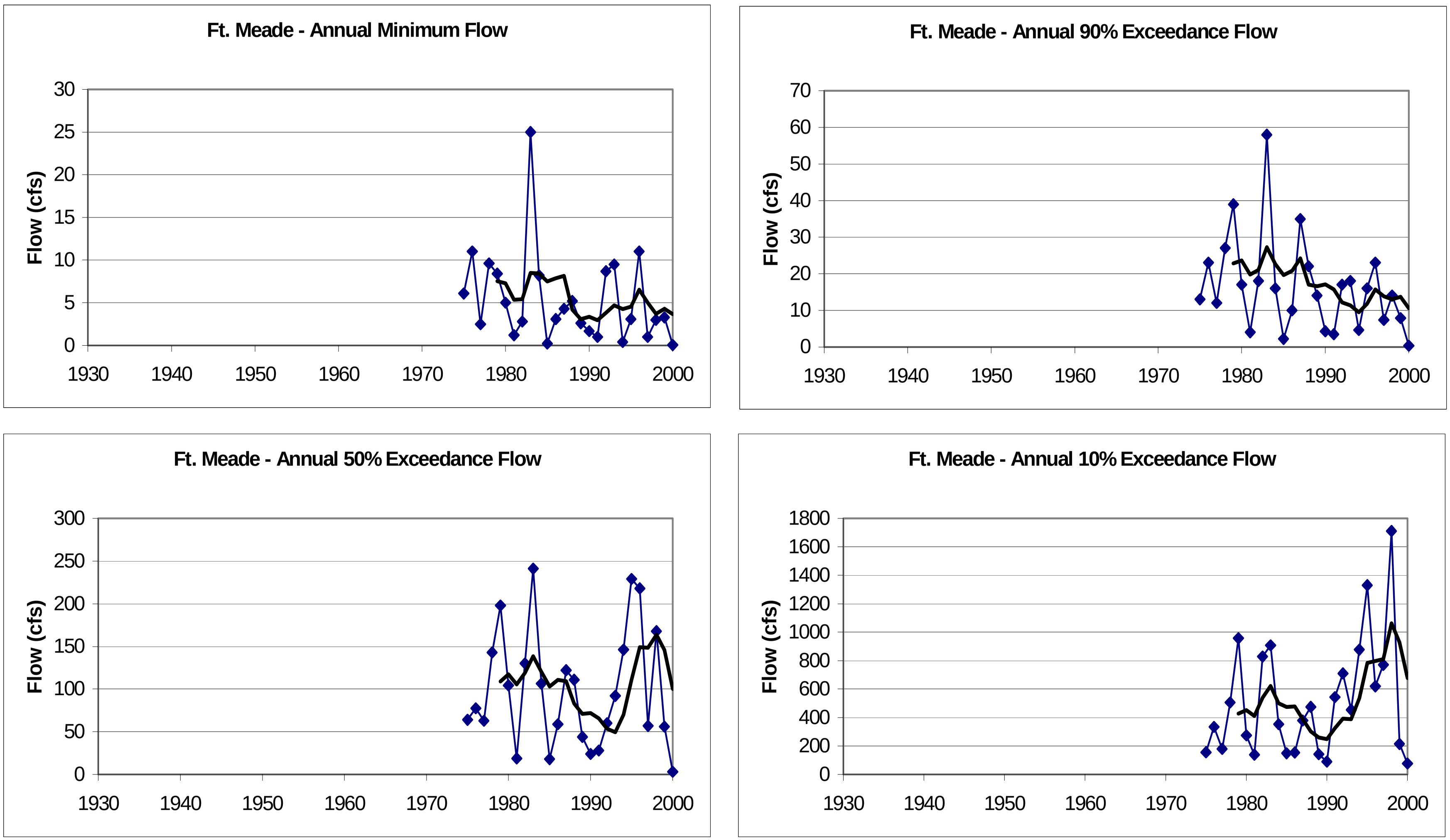



Figure 3-3b. Hydrographs of the minimum, 90%, 50% and 10% annual exceedance flows at the USGS Ft. Meade Gage. Solid black line is the 5-year moving average for the respective exceedance flow.

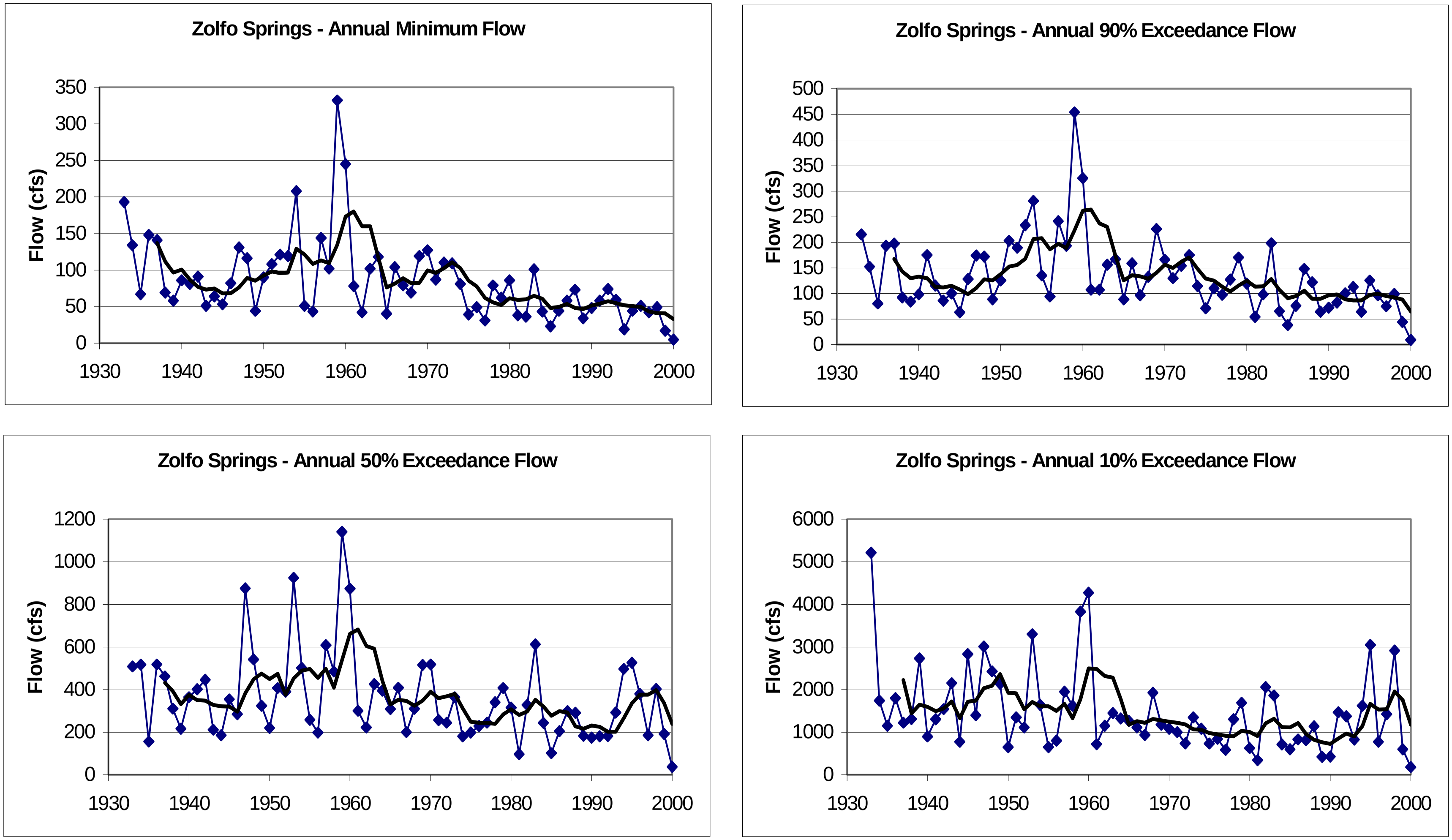



Figure 3-3c. Hydrographs of the minimum, 90%, 50% and 10% annual exceedance flows at the USGS Zolfo Springs Gage. Solid black line is the 5-year moving average for the respective exceedance flow.

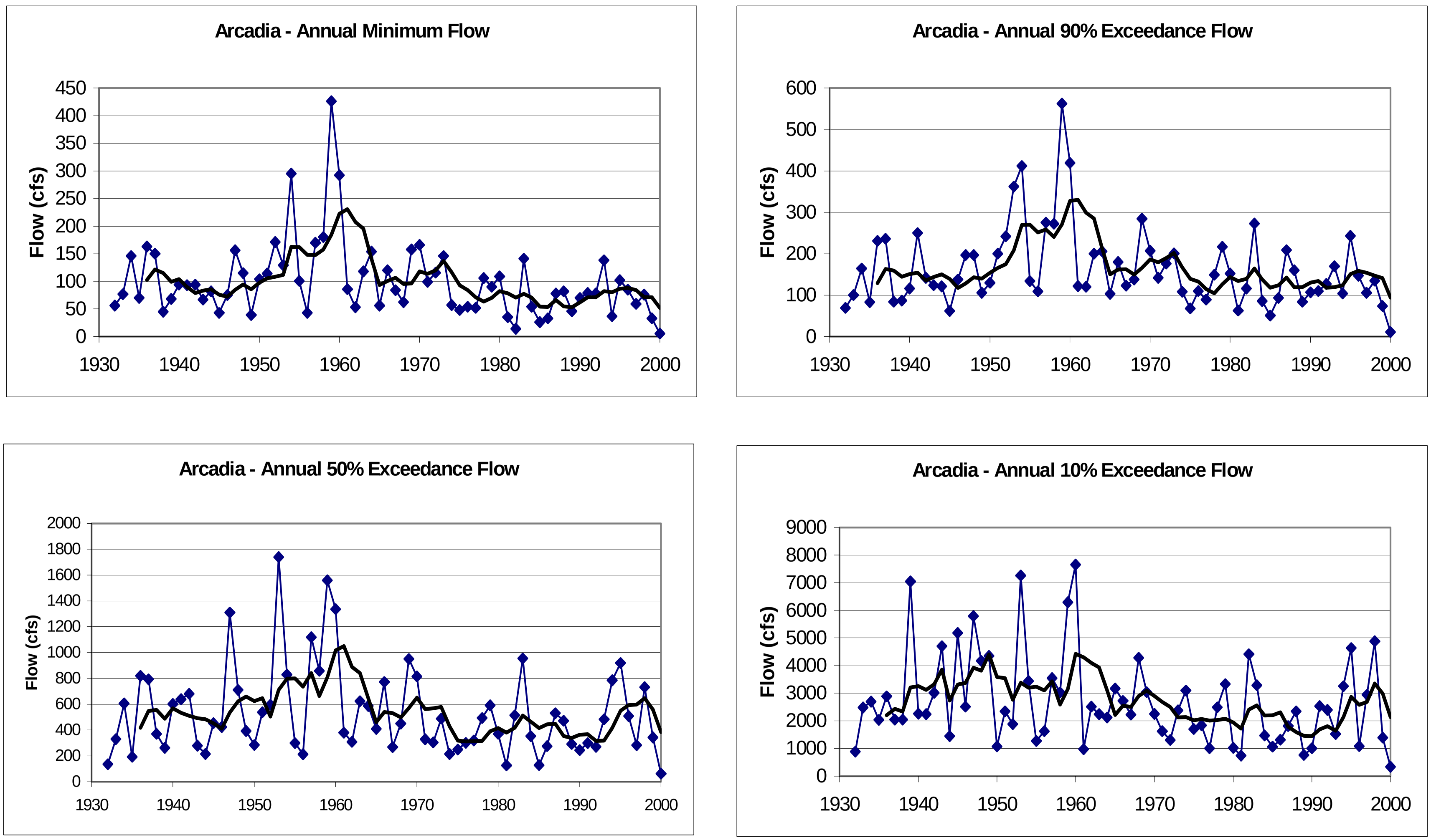



Figure 3-3d. Hydrographs of the minimum, 90%, 50% and 10% annual exceedance flows at the USGS Arcadia Gage. Solid black line is the 5-year moving average for the respective exceedance flow.

Trends in percent exceedance flows were also examined for more recent time periods. The only significant declining trends (based on exceedance of the 90% confidence level) observed since 1970 were the 90% and 75% exceedance flows for the Bartow gage and the 90% exceedance flow at the Zolfo Springs gage for the period 1970 to 1990. No flow trends, based on exceedance of a 90% significance level, were observed at the Arcadia gage for more recent periods (1970-1990 or 1985-2000).

It is useful to note how yearly percent exceedance flows correspond to mean annual flows in the Peace River. Figure 3-4 plots the five-year moving average for mean annual flows at the Bartow gage plotted against the five-year moving average for selected percent exceedance flows. The mean annual flow more closely approximates the 30% exceedance flow than the median (50% exceedance) flow, and visually demonstrates that the mean annual flow is a high flow statistic. For the period of record, the median flow at Bartow (105 cfs) is slightly less than half of the mean annual flow (225 cfs). Given this characteristic, trends or observations made with respect to the mean annual flows are often biased toward high flows and may not reflect changes in low to medium flows.

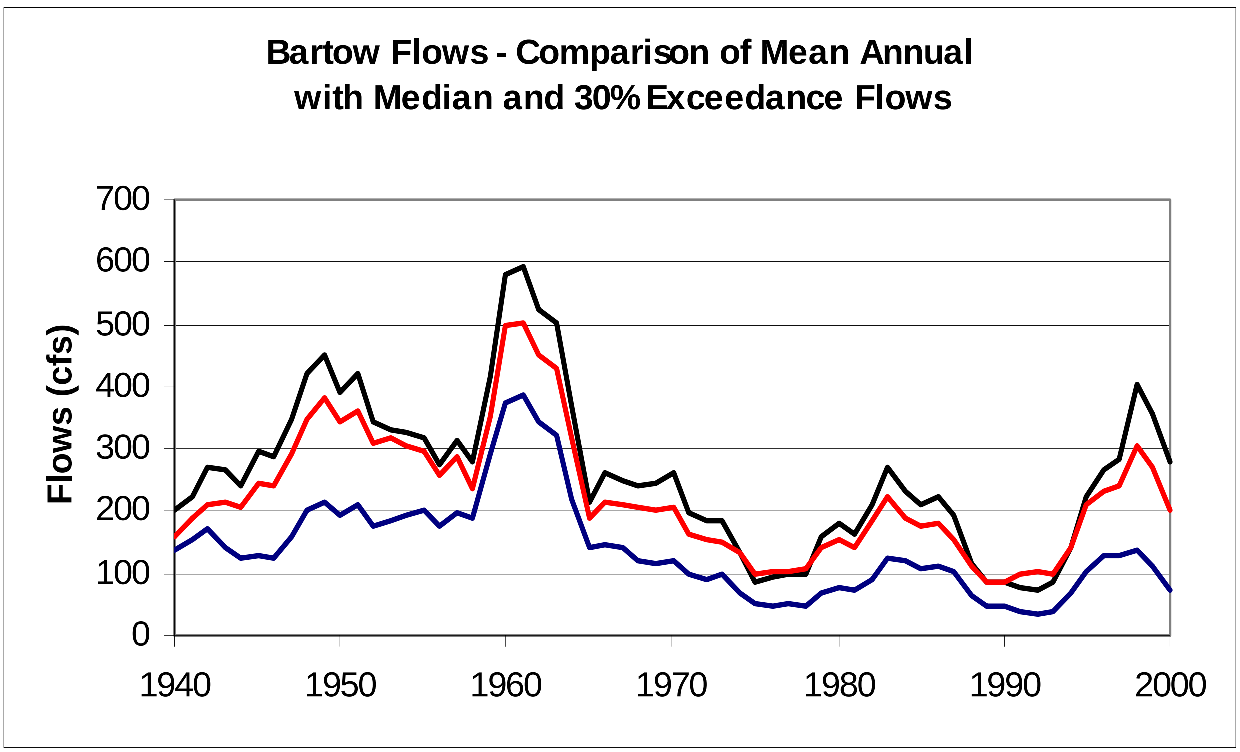



Figure 3-4. Comparison of 5-year moving averages for mean annual flow (red - center plot) with 30% exceedance flow (black -upper plot) and median flow (blue - bottom plot) for Peace River flows as measured at Bartow gage over period of record.

Table 3-4. Trends in percent exceedance flows at three gage sites on the Peace River. The Kendall tau test was run on percent exceedance flows for selected time periods. Slopes and significance levels are given with trends significant at $p<0.10$ shown in bold.

| | | POR | | 1940 to 1960 | | 1970 to 1990 | | 1985 to 2000 | |
|---|---|---|---|---|---|---|---|---|---|
| | | Slope | p | Slope | p | Slope | p | Slope | p |
| Bartow | 90% | **-0.7216** | **0.0000** | **4.3452** | **0.0001** | **-0.8385** | **0.0254** | -0.0550 | 0.9640 |
| | 75% | **-1.3066** | **0.0000** | **6.0000** | **0.0122** | **-0.9688** | **0.0901** | 0.2111 | 0.6847 |
| | 50% | **-2.2222** | **0.0001** | **10.3971** | **0.0655** | -1.0000 | 0.4149 | 2.2500 | 0.5886 |
| | 30% | **-3.4152** | **0.0032** | 11.5500 | 0.1558 | -1.9375 | 0.3812 | 14.3413 | 0.1151 |
| | 10% | **-4.8174** | **0.0285** | 19.5455 | 0.2768 | -6.1000 | 0.2639 | 38.0208 | 0.1373 |
| Zolfo Sprin | 90% | **-1.0939** | **0.0026** | **9.6616** | **0.0019** | **-3.5692** | **0.0497** | -1.8700 | 0.5281 |
| | 75% | **-1.4909** | **0.0046** | **10.1882** | **0.0274** | -3.3333 | 0.1742 | -1.9444 | 0.7526 |
| | 50% | **-2.6786** | **0.0083** | **16.5556** | **0.0967** | -4.3509 | 0.2045 | 1.7857 | 0.4440 |
| | 30% | **-4.9700** | **0.0080** | 19.1071 | 0.3337 | -6.5214 | 0.3812 | 18.4500 | 0.1917 |
| | 10% | **-12.2553** | **0.0045** | 49.1667 | 0.2768 | -17.9902 | 0.2045 | 29.6806 | 0.5584 |
| Arcadia | 90% | -0.5306 | 0.2699 | **10.7857** | **0.0065** | -2.2818 | 0.3190 | -0.7083 | 0.8926 |
| | 75% | -0.6019 | 0.4014 | **16.5694** | **0.0611** | -1.5000 | 0.6723 | 0.2273 | 1.0000 |
| | 50% | -1.6148 | 0.2460 | 30.7885 | 0.1095 | -2.0635 | 0.6946 | 5.4643 | 0.3923 |
| | 30% | **-6.3333** | **0.0782** | 28.3974 | 0.2639 | -7.5543 | 0.5661 | 26.6333 | 0.4440 |
| | 10% | **-15.5455** | **0.0773** | 65.5042 | 0.3492 | -33.8158 | 0.3337 | 75.8333 | 0.2604 |

### 3.2.3 A Comparison of High-Flow and Low-Flow Months from Bartow to Arcadia

A comparison of flows during high-flow and low-flow months from Bartow to Arcadia offers insight into the relative importance of baseflow and storm runoff contributions from different reaches of the river. A hydrograph of average monthly flows for the Peace River at Arcadia is shown in Figure 3.5. Based on long-term averages, the lowest flow month is May and the highest flow month is September. Flows show a lag over rainfall; the wettest months are typically June - September which account for approximately 58% of the annual rainfall. The highest flow months are July - October which similarly account for 58% of the annual streamflow.

Flow trends were examined on a monthly basis to determine how flows have changed during different times of the year. Using the period of record and other selected time periods, trends were evaluated separately for each month at the Bartow, Zolfo Springs and Arcadia gages (Table 3.1; on page 3-5). For the period of record (1940-2000) at the Bartow gage, there was a significant negative trend in mean discharge for each month of the year based on exceedance of a 90% confidence level. At Zolfo Springs, the decline was significant (based on exceedance of 90% confidence level) for the eight months from May through December, with negative slopes for the other months. At the Arcadia gage, a negative trend exceeding a 90% confidence level was observed only for the wet season months of July through October, although all slopes were negative. The results of the monthly flow analysis for the period of record are similar to the results for the percent exceedance flows in that both low and high-flow months have declined in the upper reaches of the river, but only in high-flow season at Arcadia. When the 1970-2000 period was examined, declining trends that exceeded the 90% confidence level were observed only during May and June at Bartow, June and July at Zolfo Springs, and June at Arcadia. The only trend for the 1985-2000 period that exceeded a 90% confidence level was an increasing trend in October at Bartow.

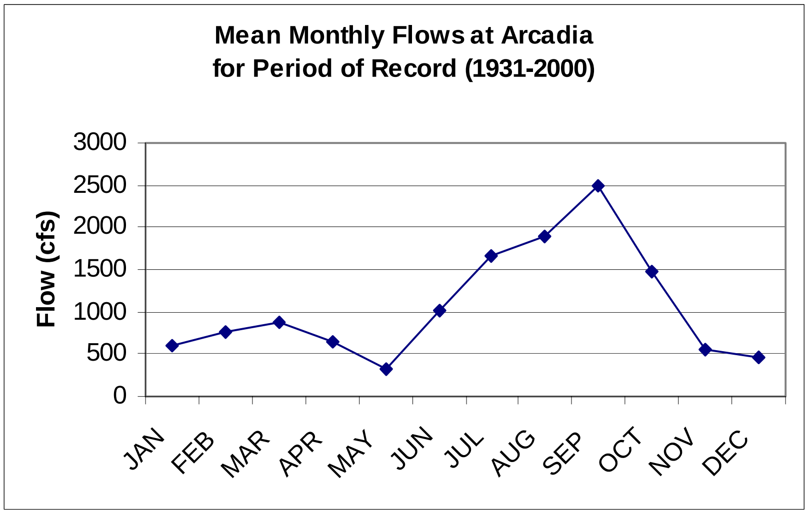



Figure 3-5. Mean monthly flows at Arcadia for the period of record - 1931 to 2000.

### 3.2.3.1 Flow Contributions from Upstream Reaches

To examine possible changes in flow contributions from the upstream reaches, a calculation was made of the percent of flow at Arcadia comprised by flow at Bartow, Ft. Meade and Zolfo Springs under both low (May) and high-flow (September) conditions. While not all flow originating at an upstream site will necessarily reach a downstream site, and while there is greater travel time involved with increasing distance between sites, the comparison does provide useful insight into the relative contribution of increasing watershed size on low and high flows. As noted earlier, the drainage basin above the Bartow gage is approximately 390 square miles; above Ft. Meade approximately 480 square miles; above Zolfo Springs 826 square miles; and above Arcadia 1,367 square miles. Therefore, the Bartow gage encompasses 28% of the surface watershed above Arcadia; the Ft. Meade gage captures 35% of the watershed above Arcadia; the Zolfo Springs gage captures 60% of the watershed above Arcadia. It should be noted that there is greater natural storage potential in the upper watershed as attested to by the high concentration of lakes in this area, particularly in the Lakeland and Winter Haven areas. One might, therefore, expect to see less runoff from this area during the early part of the wet season compared to other parts of the basin of comparable size. However, no adjustments were made for purposes of the following comparison.

The mean monthly flow for September of each year at each site was determined for the period of record. The mean monthly flow at each of the three upstream sites (Bartow, Ft. Meade, Zolfo Springs) was divided by the corresponding monthly flow at the Arcadia site to determine the flow at the upstream site as a percentage of the Arcadia flow. The results for September mean flows at the Bartow and Zolfo Springs sites are plotted in Figure 3-6 with trend lines fitted by linear regression, and all results are tabulated in Table 3-5 (Ft. Meade was not plotted because of its comparatively short period of record). Since on a watershed area basis, the Bartow gage encompasses 28% of the Arcadia watershed, it is interesting to note that the site captures 18% of the September flow as measured at Arcadia. Similarly, the Zolfo Springs gage which represents 60% of the Arcadia watershed area captures approximately 54% of the mean September flow as measured at Arcadia.

A different pattern, however, emerges for the low flow month of May. Flows at Bartow represent 28% of the May flow at Arcadia as measured over the period 1940-2000. However, the contribution from the Bartow area has decreased considerably over the 60 year period (see Figure 3-7 and Table 3-6). While the flow at Bartow was 31% of the flow at Arcadia between 1940-1960, it was less than half this value (12%) over the period 1985-2000. For the period 1940-2000, the Zolfo Springs May flow was 78% of the Arcadia May flow; however, from 1985-2000, the Zolfo Springs site represented a flow contribution commensurate with its watershed area (60%). It appears that until recently (since approximately the mid 1980s), the area between Bartow and Zolfo Springs accounted for half (50%) of the flow observed during May at the Arcadia site. Unfortunately, May flows cannot be considered baseflows. Inspection of monthly means by year shows the extreme variability in flows even during typically low flow months; for example, the 1957 mean May flow was 2,597 cfs at Arcadia and 2,035 cfs at Zolfo Springs (Zolfo Springs flow was 78%

of the Arcadia flow).

In summary, it appears that during the highest flow month (September) flow at Zolfo Springs as a percentage of Arcadia flow is proportional to the contributing watershed area. This relationship does not appear to have changed over the period of record. During the low flow month of May, however, the upper watershed area (i.e., the area above Zolfo Springs) until recently contributed a greater percentage of flow to Arcadia than would be expected based on watershed area alone.

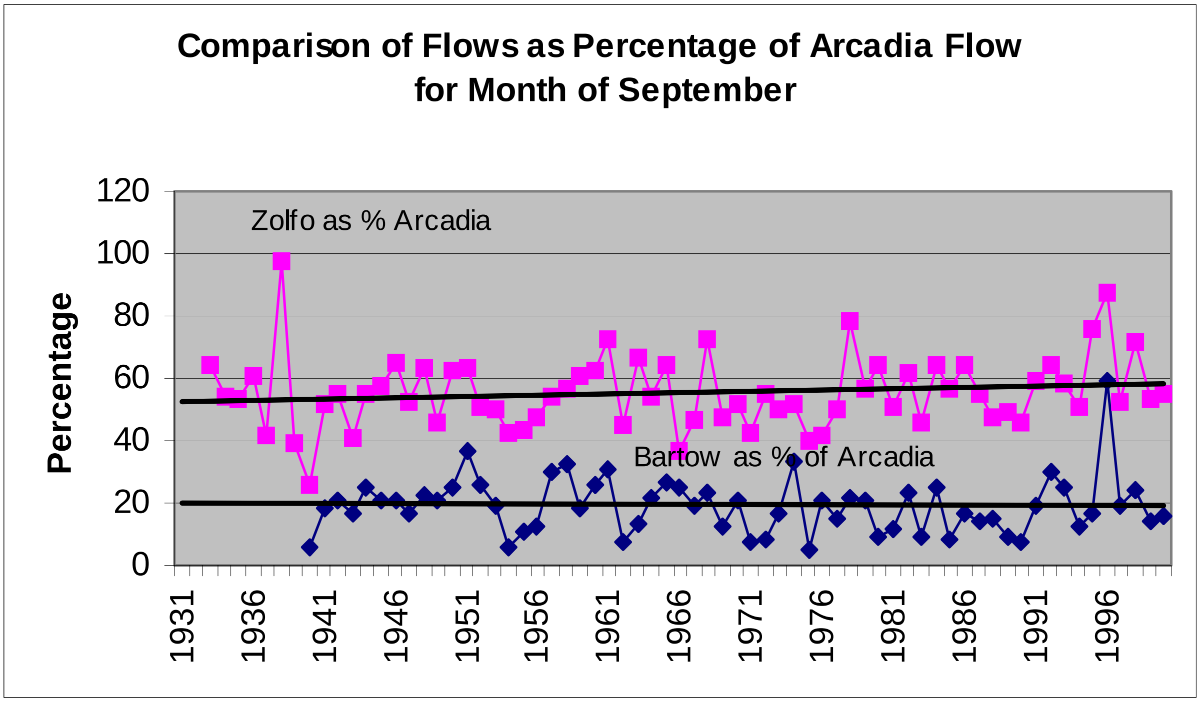



Figure 3-6. Zolfo Springs (red) and Bartow (blue) September flows as a percentage of September flow at Arcadia.

Table 3-5. Bartow, Ft. Meade, and Zolfo Springs September flows as a percentage of flow at Arcadia for selected time periods.

| | Mean Annual September Flows (cfs) for | | | | Percentage contribution to Arcadia Flow | | |
|---|---|---|---|---|---|---|---|
| Flow Period | Arcadia | Bartow | Ft Meade | Zolfo Springs | Bartow | Fort Meade | Zolfo Springs |
| Period of Record | 2502 | 437 | 356 | 1366 | | | |
| From 1940-2000 | 2374 | 437 | | 1285 | 18.4 | | 54.1 |
| From 1940-1960 | 3453 | 688 | | 1841 | 19.9 | | 53.3 |
| From 1940-1950 | 3317 | 620 | | 1714 | 18.7 | | 51.7 |
| From 1961-2000 | 1808 | 306 | | 993 | 16.9 | | 54.9 |
| From 1974-2000 | 1711 | 301 | 356 | 972 | 17.6 | 20.8 | 56.8 |
| From 1985-2000 | 1757 | 309 | 386 | 1044 | 17.6 | 22.0 | 59.4 |

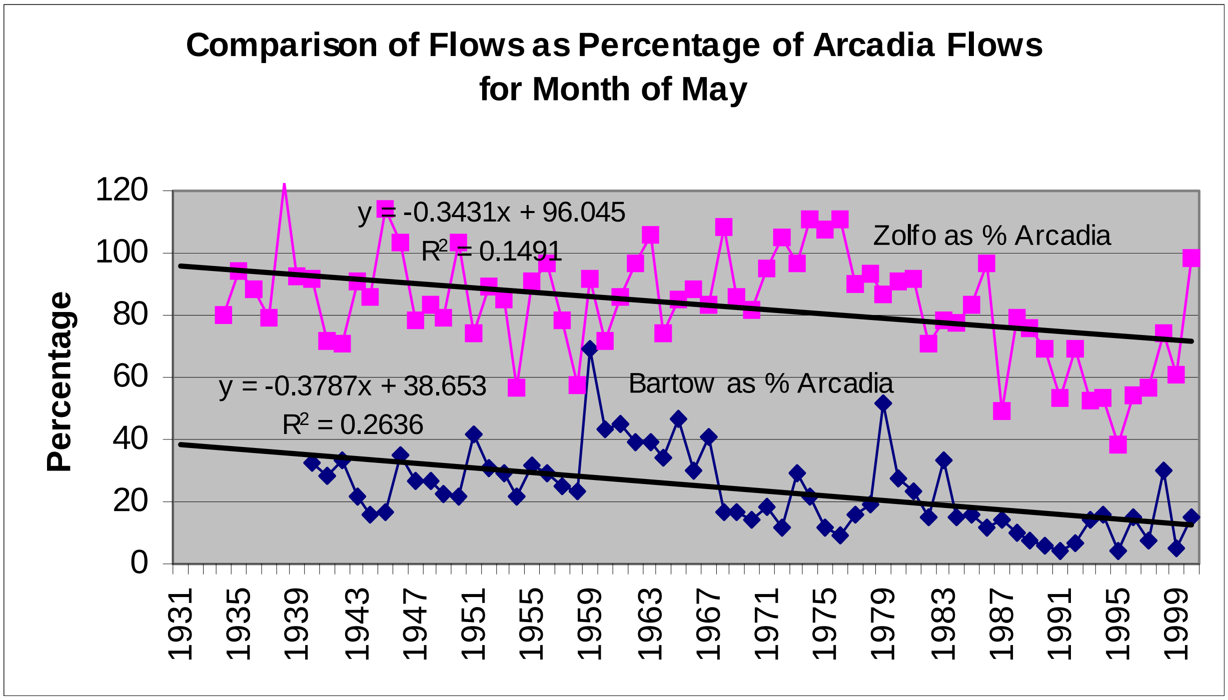



Figure 3-7. Zolfo Springs (red) May and Bartow (blue) May flows as percentage of May flows at Arcadia.

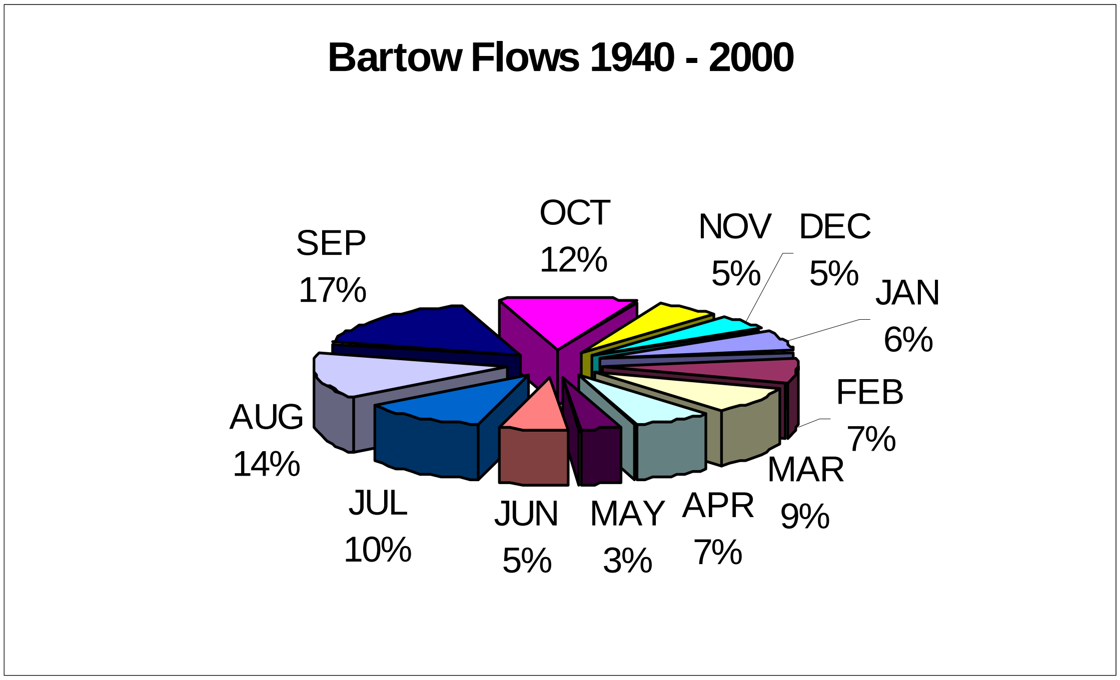
Table 3-6. Bartow, Ft. Meade and Zolfo Springs May flows as a percentage of flow at Arcadia for selected time periods.

| | Mean Annual May Flows (in cfs) for | | | | Percentage contribution to Arcadia Flow | | |
|---|---|---|---|---|---|---|---|
| Flow Period | Arcadia | Bartow | Ft Meade | Zolfo Springs | Bartow | Fort Meade | Zolfo Springs |
| Period of Record | 331 | 88 | 73 | 255 | | | |
| From 1940-2000 | 319 | 88 | | 249 | 27.5 | | 78.1 |
| From 1940-1950 | 208 | 58 | | 173 | 27.6 | | 83.1 |
| From 1940-1960 | 454 | 142 | | 348 | 31.2 | | 76.8 |
| From 1961-2000 | 249 | 60 | | 197 | 24.0 | | 79.3 |
| From 1974-2000 | 252 | 55 | 73 | 188 | 21.8 | 29.1 | 74.7 |
| From 1985-2000 | 195 | 23 | 30 | 114 | 11.7 | 15.4 | 58.7 |

### 3.2.4 Changes in Monthly Flows

Figure 3-8a shows the percent contribution of mean monthly flows to the mean annual flow at the Bartow Gage for the period of record (1940-2000); Figure 3-8b gives actual contributions (flow in cfs) by month. The plot clearly shows that the months of July -October are the high flow months, and account for 53% of the mean annual flow. These plots are particularly relevant when compared with similar plots encompassing different time frames; a number of these comparisons are presented in Appendix QM. Perhaps, however, the most revealing comparison for the Bartow Gage is the comparison of the period of record and the most recent sixteen years (1985-2000). The period beginning around 1985 is particularly significant to the Upper Peace River, since it appears to be about the time that a number of anthropogenic discharges to the river were either eliminated or curtailed as evidenced by changes in water quality (see water quality discussion).

Although most of the natural Floridan and intermediate aquifer contributions to baseflow in the Upper Peace River were probably lost prior to 1960, this loss was partially offset by anthropogenic discharges to the river (primarily from mining related industries and municipal waste water treatment plants). Comparison of Figure 3-8 with Figure 3-9, indicates that for most months the relative (percent) contribution by month to annual flow has not changed appreciably except for the months of May and June. When compared to the period of record (1940-2000), flow reductions on a month by month basis are on the order of 20 to 30% less in the 1985-2000 period. The exceptions are the months of December and January where flow reductions are less than 10% (only 2% for January), and the months of May and June where there has been a large decline in flows of around 75% for both months. The period of record flows at Bartow in May and June are 88 cfs and 146 cfs, respectively. The Bartow May and June flows for the 1985-2000 period were 23 cfs and 35 cfs, respectively. A large percentage of this loss is believed attributable to the combined effects of diversion, reduction and/or elimination of man related discharges and to some extent deficit rainfall during April and May.



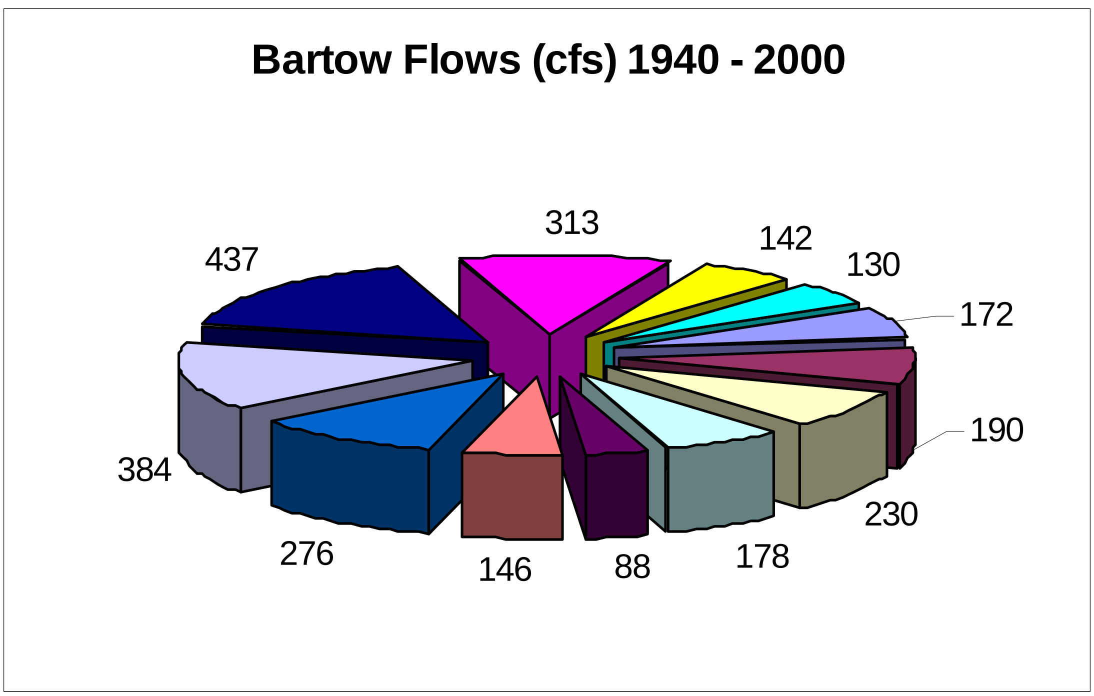
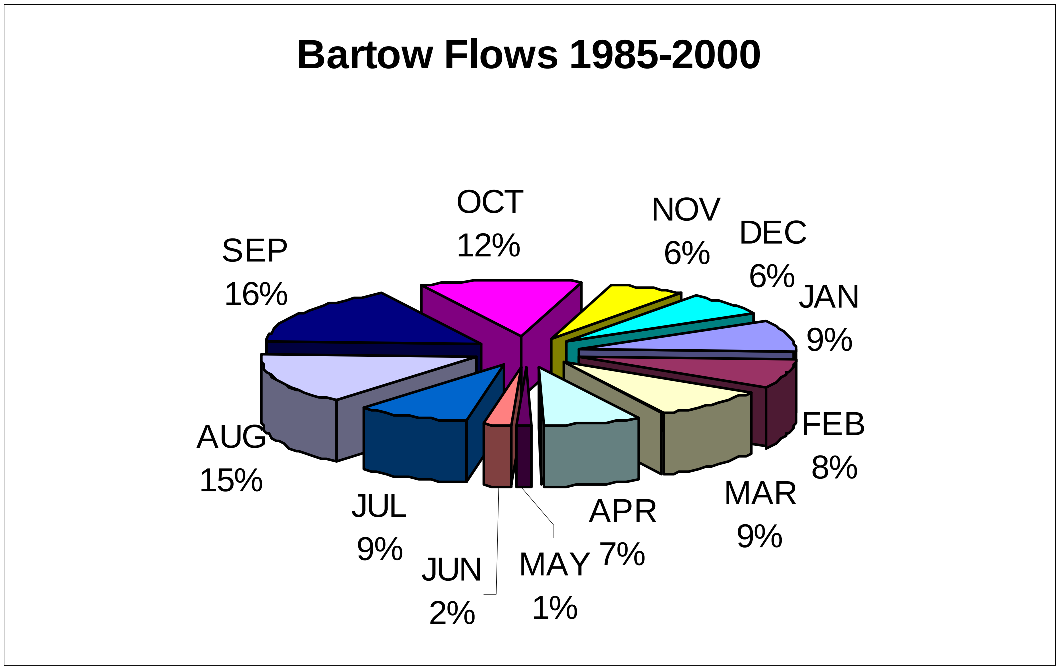




Figure 3-8. Contribution of mean monthly flows (percentage - upper diagram; cubic feet per second - lower diagram) to the mean flow at the USGS Bartow Gage for the period of record (1940-2000).



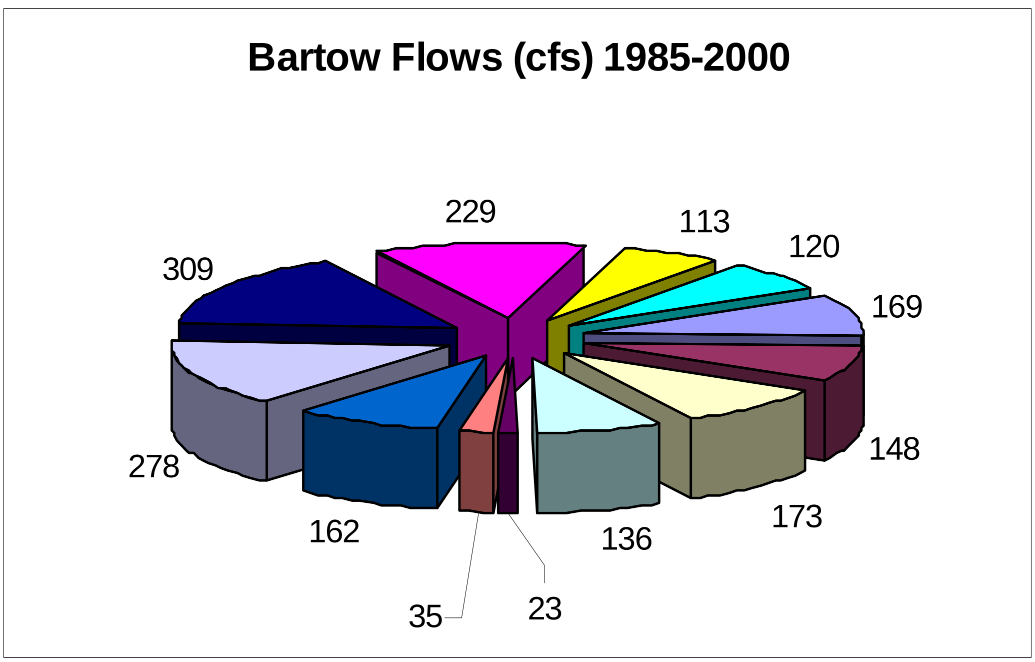




Figure 3-9. Contribution of mean monthly flows (percentage - upper diagram; cubic feet per second - lower diagram) to the mean flow at the USGS Bartow Gage for the period 1985 to 2000.

### 3.2.5 Trends in Water Levels

The hydrologic analyses previously presented focused on trends in streamflow, or the rate of flow in cfs. As discussed in Section 1.6, the level of water in a river system is an ecologically important hydrologic variable, and it is informative to examine trends in water levels. Water level records for the long-term gages on the Peace River are among the longest water level records in southwest Florida.

Time series plots of four yearly percent exceedance levels at the Bartow and Zolfo Springs gages are shown in Figures 3-9 and 3-10. The four exceedance levels are the yearly minimum, the 90% exceedance, the 50% exceedance (median), and the 10% exceedance levels. Trends for these levels were statistically evaluated using the Kendall tau test (Table 3-7). Significant ($p < 0.05$) declining trends were observed for all levels at the Bartow gage, except the 10% exceedance level. Prolonged periods of decline for the other three levels were observed from 1960 to the mid-1970s. As was described for low flows, continued drops in low water levels (minimum and 90%) occurred from the mid-1980s forward. The lack of a significant decline in the 10% exceedance level indicates the inundation of very high elevations in the Bartow area have not changed nearly as much. However, significant ($p<0.05$) declining trends were observed in 10% exceedance flows (Table 3-4). This apparent disagreement is due to the nonlinear relationship of water level to flow. Due to the broad cross-sectional area of the river at high flows, small changes in water levels can result in large changes in flow, thus trends in flows are more readily apparent.

Significant declines were also observed for the minimum, 90% and 50% exceedance levels at Zolfo Springs, although these reductions in levels were not as pronounced as at Bartow, based on a comparison of slopes (Table 3-7). The time series plots indicate there has been a continued decline in the minimum and 90% levels at Zolfo Springs from 1970 forward, but the median level exhibits little consistent change since 1961 (Figure 3-10). There was evidence of a declining trend for the 10% exceedance level, but at less statistical confidence ($p < 0.08$) than for the other levels.

Table 3-7. Slopes (feet per year) and confidence levels (p value) of trends in four, yearly percent exceedance water levels at Bartow and Zolfo Springs.

| | | Minimum | 90% | 50% | 10% |
|---|---|---|---|---|---|
| Bartow | (slope) | -0.035 | -0.040 | -0.036 | -0.008 |
| | (p value) | 0.0000 | 0.0000 | 0.0002 | 0.2089 |
| Zolfo Springs | (slope) | -0.024 | -0.026 | -0.024 | -0.031 |
| | (p value) | 0.0000 | 0.0000 | 0.0002 | |

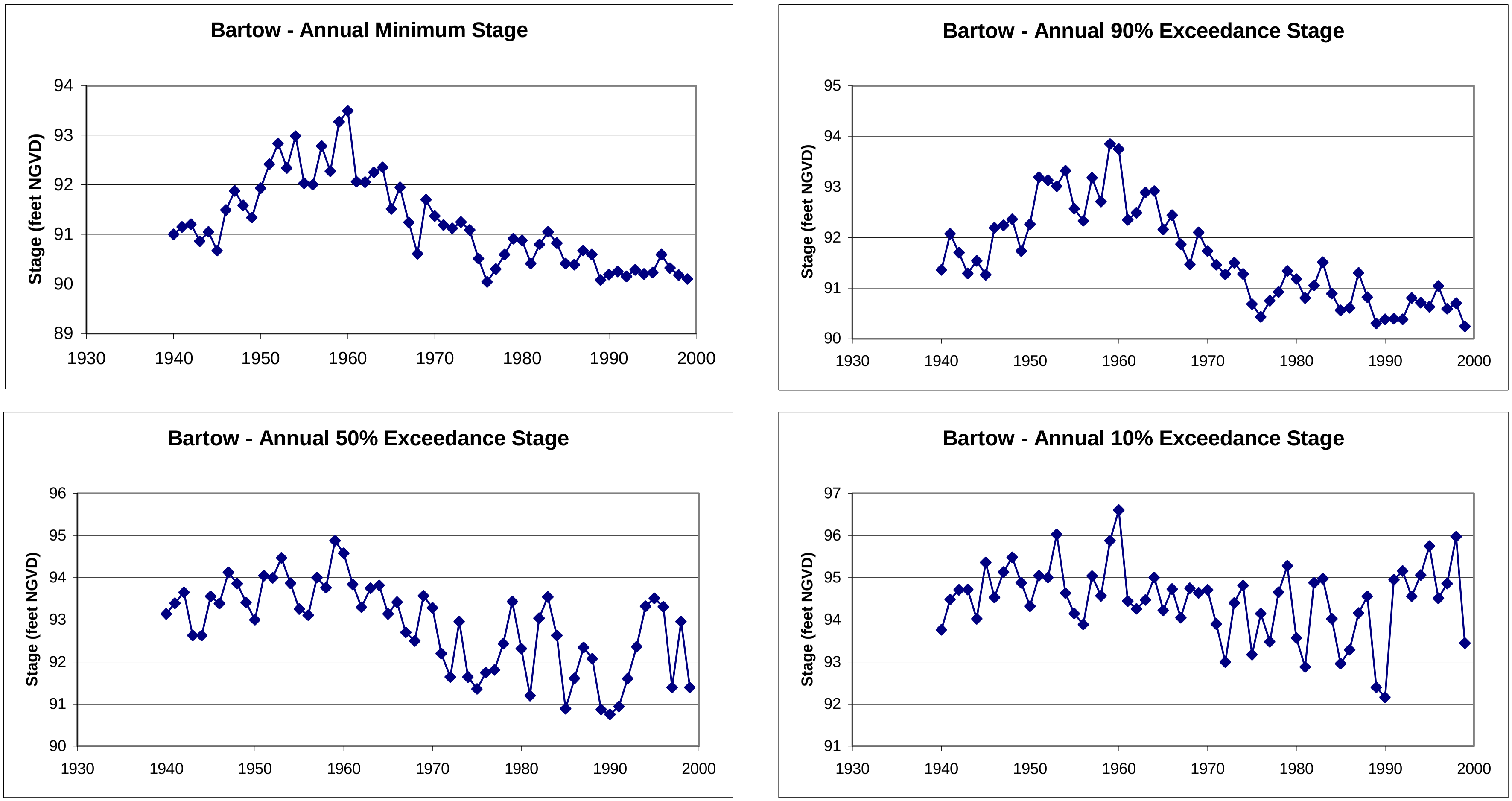



Figure 3-10. Hydrographs of the minimum, 90%, 50% and 10% annual exceedance stage at the USGS Bartow Gage.

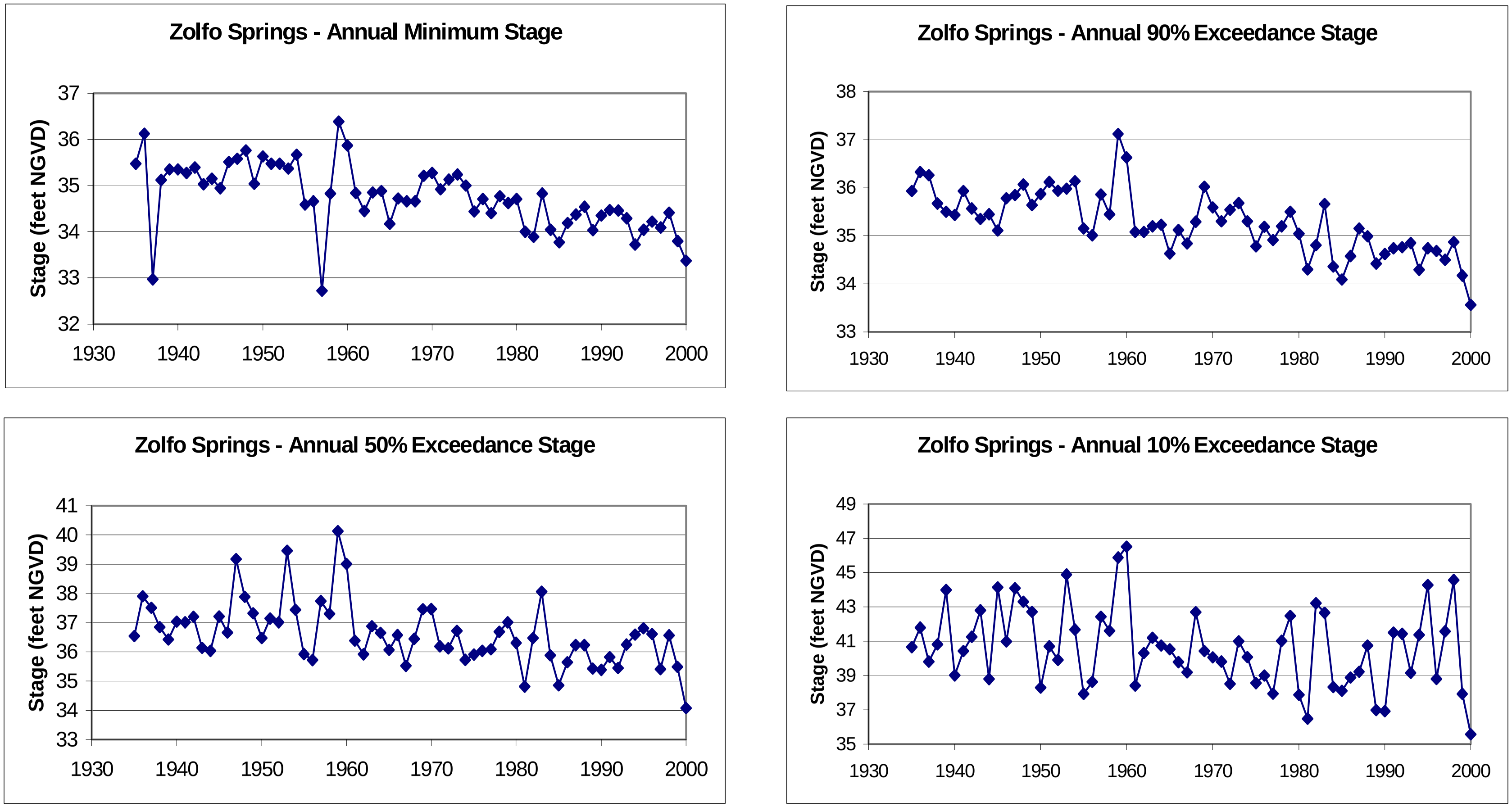



Figure 3-11. Hydrographs of the minimum, 90%, 50% and 10% annual exceedance stage at the USGS Zolfo Springs Gage.

### 3.3 Factors Affecting Flow in the Upper Peace River

As described in previous sections, there have been significant reductions in flow in the Upper Peace River. Documented reductions in spring flow contributions started as early as the 1930s. Reductions in the entire flow regime are evident after 1960, and in terms of low flows an additional decline appears evident after the mid-1980s. There are many factors that have resulted in these flow reductions that need to be assessed prior to establishing minimum flows.

Florida Statutes prescribe that existing structural alterations and changes are to be considered when establishing minimum flows and levels. This requires that the minimum flows are to be set recognizing there have been substantial changes from pre-development watershed characteristics in many areas of the state. Examples of structural alterations and changes include: an extensive network of canals, ditches and other drainage components that were constructed during the past 150 years, mainly to claim marginal lands and provide flood protection; dredging and filling of floodplains, isolated wetlands and cypress swamps that bordered many of the lakes, for agricultural, mining and urban purposes; land use alterations that changes evapotranspiration, infiltration and runoff characteristics; lowering and raising control elevations of lakes, which change a basins' storage and discharge characteristics; diversion of waste streams to other watersheds, etc. In most cases, the cumulative impact of these anthropogenic alterations and changes on stream flow are extremely difficult to determine.

In addition to these anthropogenic factors, long-term and seasonal climatic factors can greatly affect flows. Long-term trends in rainfall and resultant impacts on streamflow have been extensively investigated in the Upper Peace River. The weight of evidence indicates that the entire stream flow regime in the Upper Peace River and adjacent watersheds has changed as a result of cycles of long-term wet weather periods (1930s through early 1960s) and dry periods (early 1960s through at least the early 1990s). The impact of these climatic cycles is also difficult to assess and hampers the ability to compare the oldest stream-flow records (1930s, 40s and 50s) to the later records. Seasonal climatic patterns are significant but more easily understood and require that the established minimum flows and levels be set on a seasonal basis, or that the minimum flows be based on percent exceedance to account for low, medium and high flows that typically follow seasonal patterns.

In addition to the factors described above, the impact from ground and surface-water withdrawals needs to be well defined. Declines in artesian aquifer levels in the area underlying the Upper Peace River are some of the largest in peninsular Florida. These declines, which exceed 30 feet, and their affect on springflow have been extensively documented (Peek 1951, Hammett 1990, Lewelling et al. 1998, Basso 2002). Historically, Kissengen Spring appears to have routinely provided 20 cfs to more than 30 cfs of flow to the Upper Peace River. By 1950, ground-water withdrawals had resulted in the cessation of flow from this spring. It is the only spring in Florida of this size to permanently stop flowing. Additionally, Stewart (1966) reported the occurrence of flowing wells in 1948 at Saddle Creek near the headwaters of the Peace River. At a minimum, the loss of this artesian flow has impacted low flow conditions in the Upper Peace River. Other than gains and losses from structural alterations and changes noted above, surface-water withdrawals in the Upper Peace River are very small and hydrologically insignificant.

The following is a discussion of each of these factors, their impact on streamflow and their relevance to establishing minimum flows and levels in the Upper Peace River.

### 3.3.1 Effects of Long-Term Changes in Rainfall

Since the late 1970s, a number of investigators have reported on a long-term change in rainfall conditions in central Florida. Much of this discussion has focused on an area that includes the headwaters of the Peace River. Palmer and Bone (1977) appear to have been the first to comprehensively examine changes in rainfall amounts. Utilizing 23 National Weather Service rainfall stations with records from 1915-76, they found that 1961 marked the beginning of a distinct change in rainfall patterns in much of the SWFWMD. This was determined by comparing the sixty-two year (1915-76) rainfall averages for each station to the sixteen-year (1961-76) rainfall averages for each station. The accumulated deficits for the period 1961-76 were as high as 90 inches. They reported that the highest deficits occurred in a belt extending from the Tampa Bay area on the west coast of Florida, eastward through Polk County and on to Orlando. They concluded that monthly rainfall values indicated that the deficits resulted from chronically below average rainfall in the spring, summer, and early autumn months, March through October. The rainfall stations used stretched from Lake City in the north, southward to Ft. Myers and eastward to Orlando.

Texas Instruments (1978) reported on variations in long-term rainfall in central Florida. Utilizing the National Oceanic and Atmospheric Administration's (NOAA) annual reports, they reported a significant extended period of lower-than-normal rainfall in central Florida since the early 1960s. They further concluded that on an annual basis for the entire south-central climate district (Brevard, DeSoto, Indian River, Hardee, Highlands, Hillsborough, Manatee, Okeechobee, Osceola, Pinellas, Polk, Sarasota, and St. Lucie Counties) rainfall exceeded "normal" values only twice for the sixteen year period,1960-76; these years of higher-than-normal rainfall were 1960 and 1969. The total deficit during the period amounted to approximately one year's rainfall.

Palmer and Nguyen (1986) published a follow-up to Palmer's initial work (Palmer and Bone 1977) using data from fourteen National Weather Service rainfall stations in central Florida with rainfall records to 1901. These stations extended from Titusville and Ft. Pierce on the Atlantic coast to Tarpon Springs and Bradenton on the Gulf Coast, and from Brooksville on the north to Arcadia in the south. They compared monthly and annual averages for the period 1961-85 against those for 1901-60 and found that rainfall had decreased at thirteen of the fourteen stations (only Titusville showed an increase) with resulting cumulative deficits ranging from 2 inches to over 150 inches (equivalent of almost three full years of average rainfall) at Kissimmee. Bartow had a cumulative deficit of 145 inches and Tampa, Plant City and Orlando had deficits of over 100 inches. As in the 1977 study, deficits decreased both to the north and south of the central belt, and toward the coasts. They also conducted an analysis of monthly surpluses and deficits and found that there were four distinct periods or seasons. For the period of November through February, all stations showed a net surplus. For March and April all stations showed a net deficit, as was the case with the period of July through October. During the May-June period eight stations had net surpluses and six had net deficits. The interior stations constituting the core of the study experienced the greatest "seasonal" deficits and the smallest surpluses.

Since the 1980s, numerous investigators have reported on the long-term below average rainfall in central Florida. Hammett (1990), Barcelo et al. (1990), Moore (1996), Coastal Environmental (1996), Hickey (1998), Flannery and Barcelo (1998), Garlanger (2002), and Basso and Schultz (2002) all focused significant attention on this issue. Until recently there seemed to be no convergence on the possible cause of this climatic signature. However, such a convergence is now seemingly emerging as explained by Basso and Schultz (2002) who discussed several recent publications (Gray et al. 1997, Landsea et al. 1999, Goldenberg et al. 2001, Einfield et al. 2001) that attributed long-term climatic changes in the Atlantic Ocean Basin to decade long cycles in water temperature changes in the North Atlantic.

Basso and Schultz (2002) concluded that:

> "Over the last century, there has been no significant change in annual rainfall. However, if the record is partitioned into shorter intervals, several decade-long cycles of above-or-below average rainfall are evident. These cycles have been closely linked with the Atlantic Multidecadal Oscillation (AMO), a naturally occurring variation in North Atlantic Ocean temperatures that occurs every 20 to 50 years. Einfield and others (2001) indicate that warmer than average sea-surface temperature periods of the AMO lead to increased wet-season rainfall while cooler than average ocean temperatures decrease summer rainfall on the Florida peninsula. Higher sea-surface temperatures also lead to atmospheric circulation patterns that tend to increase the frequency of major tropical cyclones in the Atlantic and Caribbean Basins. Throughout Florida's history, tropical systems have produced extremely high rainfall, with a single storm event producing as much as one-third of annual wet-season rainfall.
>
> Based on the five-year moving average, mean and median statistics, cumulative departure analysis, single mass techniques and time series plots, it is apparent that the decades of the 1930s, 1940s, 1950s, and early 1960s were wetter than the subsequent three decades. Averaged from six stations within or adjacent to the Peace River basin, mean and median decline in rainfall between two 30-year periods ranged between 4.5 and 5.5 inches per year. Changes in wet-season rainfall, primarily linked to the AMO, accounted for about 80 percent of the rainfall difference. An analysis of rainfall associated with tropical systems found that the lull in tropical cyclone activity

experienced from 1970-1994 contributed up to one-third of the observed decline in wet-season rainfall. Dry-season rainfall, using the January through May periods, has also declined slightly between the two 30-year periods, perhaps reflecting changes in the frequency and strength of El Nino Southern Oscillation (ENSO) events, which influences spring-season rainfall.

The issue of statistical significance regarding changes in the rainfall regime was addressed by examining annual data from 21 stations throughout west-central Florida. The hypothesis that the most recent 30-year period (1966-1995) was drier than the previous 30-year period (1936-1965) was tested using a two-sample t-test and the non-parametric Wilcoxon Rank Sum method to test for differences in mean and median rainfall, respectively, between the two periods. Prior to the test, 19 of the 21 stations had lower mean and median rainfall for the most recent 30-year period compared to the previous one. After testing for significance, 17 of the 21 rain stations examined had probabilities of drier recent conditions in excess of 80 percent. There also appears to be an east-to-west trending band from Avon Park in Highlands County to the Tampa Bay region of very high probability (confidence levels exceed 95 percent) of drier recent conditions. It is not surprising that these same stations exhibited the largest decline in mean and median rainfall between the two time periods.

The Lakeland and Clermont stations were the only two rainfall sites that did not reflect drier conditions during the most recent 30-year period. Mean difference in rainfall between the two 30-year periods at Lakeland was essentially zero. In order to gain some insight into the sensitivity of the statistical significance calculation, mean rainfall amounts were incrementally increased by 0.5 inches for the period of 1936-1965 to investigate the effect of increasing differences on the confidence level. The results demonstrate that a two-inch increase in the mean annual rainfall for the first period increases the confidence level of a drier second period to 80 percent. By the time the mean annual increase has reached four inches the confidence level has increased to 96 percent.

Estimates of changes in Peace River flow through regression of empirical data and surface-water model results indicated that a five-inch per year decline in rainfall could result in stream-flow volume changes ranging from 22 to 35 percent, expressed as a percentage of mean flow. Using single-mass analysis and results from the regression of empirical data, about 90 percent of observed stream-flow decline at the Zolfo Springs and the Arcadia stations can be attributed to a post-1970 rainfall departure of 5.7 inches per year. At the Bartow station, about 75 percent of the observed stream-flow decline can be related to long-term changes in rainfall."

Although he did not determine a percent decline in long-term streamflow relative to long-term rainfall changes Moore (1996) described similarities in long-term streamflow declines in the Upper Alafia, Hillsborough, Peace and Withlacoochee River watersheds, and how they appear to be related to long-term rainfall trends. The major reason for his inference was that although there is a tremendous variance in the degree of agricultural activity, mining, urbanization, and degree of lowering of the artesian aquifer levels between the upper parts of these watersheds (Upper Peace is most impacted, Alafia second most impacted, less impacts in Upper Hillsborough and minimal impacts in Upper Withlacoochee), all four basins showed similar long-term declines in mean annual streamflow during the past four decades. The one common thread observed by Moore (1996) was the long-term climatic signature present in central Florida. Hickey (1998) independently concluded that these long-term declines in flow were related to long-term rainfall patterns.

Garlanger (2002) evaluated the various factors contributing to declining flows in the Peace River watershed. He attributed 387 cfs of the 436 cfs decline in mean annual flow at Arcadia to long-term changes in rainfall, and up to 49 cfs decrease in mean annual flow to the cumulative effect of all anthropogenic activities in the basin. Essentially, Garlanger (2002) attributed 89 percent of the reduction of flow at Arcadia to a five-inch difference in mean total rainfall between the two periods he studied (thirty year periods ending in 1963 and 1998). In an effort to evaluate the effects of changes in rainfall on streamflow trends in the Peace River, Coastal Environmental (1996) developed regressions to predict streamflow as a function of rainfall separately for the pre-1961 and post-1965 periods. By applying the pre-1961 regressions to the post-1965 rainfall records, they estimated how much of the observed changes in streamflow after 1965 could be attributed to changes in rainfall. Similar to Garlanger's findings, Coastal Environmental concluded that 90 percent of the change in streamflow at the Arcadia gage could be explained by changes in rainfall. However, the change in streamflow that could be explained by rainfall declined progressively upstream, as other factors presumably became more important to the observed reductions in streamflow.

The significance of this long-term rainfall signature on establishment of minimum flows is that it hampers the ability to use older stream-flow data, when anthropogenic impacts were not as extensive (although they were significant by 1950 in the Upper Peace River) as a reference period. Because wet-season rainfall has changed by about ten to fifteen percent, determining the impacts of rainfall changes is especially difficult for average or high stream flows. The affect of such substantial changes in long-term rainfall patterns is being recognized elsewhere in peninsular Florida. The South Florida Water Management District is now considering adjusting their operation and management of Lake Okeechobee water levels to account for the AMO 20 to 50 year cycles.

### 3.3.2 Effects of Ground-Water Withdrawals

The progressive decline of the potentiometric surface of the Floridan aquifer system as a result of ground-water withdrawals is well documented (Peek 1951, Kaufman 1967, Robertson 1973, Mills and Laughlin 1976, Wilson 1977, Geraghty and Miller 1980, Yobbi, 1983, Hammett 1990, Barcelo et al. 1990, SWFWMD 1990, Basso 2002). Ground-water withdrawals for agriculture, industry, ore extraction, public supply and recreational uses lowered the potentiometric surface of the Upper Floridan aquifer over 40 feet since the 1930's in south-central Polk County.

These declines have resulted in several detrimental impacts to the water resources of the area. Peek (1951) linked these withdrawals to cessation of flow of Kissengen Spring; Geraghty and Miller (1980) and Barcelo et al. (1990) demonstrated impacts to lake levels in the Highlands Ridge area, a major recharge area for the ground-water basin that entails the Peace River watershed. Hammett (1990) attributed some of the reduction in Peace River flows to withdrawals, and SWFWMD (1993) described how withdrawals contributed to concerns of saltwater intrusion in the coastal areas of Hillsborough, Manatee, Sarasota, Charlotte and DeSoto Counties.

The major use of ground water in and adjacent to the Peace River watershed has historically been for agricultural irrigation and activities associated with the mining and processing of phosphatic ore. Peek (1951) estimated annual ground-water withdrawals of 22 mgd in southwest Polk County by 1940, which increased to 90 mgd by 1950. He attributed about 70 percent of the total ground water withdrawn to mining and processing of phosphatic ore. Kaufman (1967) estimated that citrus irrigation in the Peace and Alafia basins was about 55 mgd in 1956. Ground-water withdrawals continued to increase in Polk County, reaching about 230 mgd in 1960, and over 410 mgd by 1975 (Marella 1992, Duerr and Trommer 1981). Water use by the phosphate industry in Florida peaked at about 257 mgd in 1975, gradually decreasing to 114 mgd in 1996. Water conserving practices in agriculture and mining have reduced Polk County ground-water use by about 100 mgd since the mid-1970s. Currently, ground-water withdrawals average between 300 and 400 mgd from Hardee and Polk Counties.

Declines of 30 to 40 feet in the elevation of the potentiometric surface of the Upper Floridan aquifer have occurred since predevelopment due to ground-water withdrawals. Kissengen Spring discharge averaged between 20 cfs and 30 cfs during the 1930s and eventually ceased continuous flow in 1950 due to the gradual lowering of the Upper Floridan aquifer potentiometric surface (refer to Figure 2-9). Under current conditions, estimates of baseflow reduction and streamflow losses due to the potentiometric surface decline are difficult to calculate due to the extensive presence of karst features in the river and floodplain from Bartow to Ft. Meade.

Patton (1981) documented several sinks and subsidence features along the river corridor between Bartow and Ft. Meade (Figure 3-10). The age of these features is unknown, but it is probable that some of them are of recent origin since large groundwater withdrawals can cause sinkhole development (Sinclair 1982, Tihansky 1999). Lewelling et al. (1998) reported a flow loss of 17.6 cfs (11.4 mgd) along a 3.2-mile section of the upper Peace River during high-baseflow conditions in May 1996. During high streamflow conditions in August 1995, when discharge at Bartow exceeded 970 cfs, Lewelling et al. (1998) indicated a loss of 118 cfs (76 mgd) or 10 percent of total river flow along a 7.2-mile reach from the Clear Springs mine bridge to the Mobil mine bridge near Ft. Meade, but did note that the magnitude of most seepage loss calculated during the high-streamflow seepage run along the 13-mile reach between Bartow and Ft. Meade was within the range of discharge measurement error (five to eight percent of flow).

Graphical analysis and numerical flow model simulations indicate that existing dry season ground-water withdrawals would need to be reduced by 60 to 80 percent (or 100 percent within a 676 square-mile area) to return flow to Kissengen Spring and contribute Upper Floridan aquifer baseflow to half of the heavily-impacted section of the river from Bartow to Ft. Meade (Basso 2002). The ground-water reduction scenarios were focused on the spring dry season since maintaining minimum low stream flow is most critical during this time and gravity drainage to the underlying confined aquifers periodically results in ephemeral conditions on the river from Bartow to Homeland.

There is no doubt that ground-water withdrawals have impacted the flows in the Upper Peace River, especially base flows. Prior to significant ground-water withdrawals in the area, Kissengen Springs and other artesian springs and seeps comprised much of the upper river's base flow. The ability of numerous karst features to capture this base flow contribution under pre-development conditions would have been limited because artesian conditions existed over the entire reach of the Peace River. Under current conditions there is minimal, if any, artesian contribution to the Peace River above Ft. Meade, other than runoff from water pumped to land surface for irrigation, mining, industrial or potable use. Any artesian contribution that does exist is most likely captured by the presence of extensive karst features.

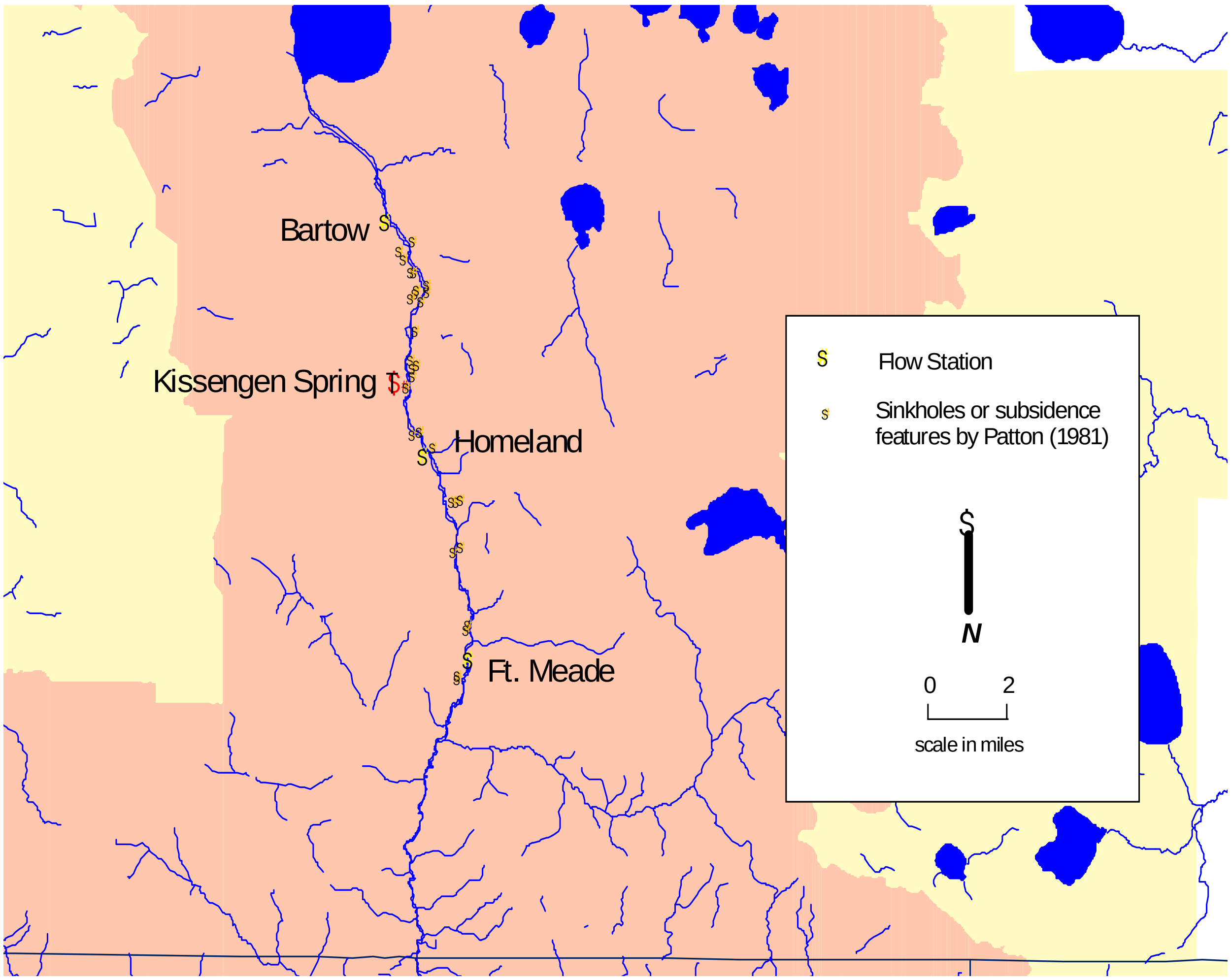


Figure 3-12. Location of karst features along the upper Peace River (from Basso 2002 as modified from Lewelling et al. 1998).

### 3.3.3 Reduction or Elimination of Waste Water Discharges

While rainfall patterns have clearly played a major role in observed flow declines, it is suggested that anthropogenic factors have been a major factor responsible for the loss of baseflow. In addition, it is suggested that much of the decline in low flows in recent years (since approximately 1985) may be due to the removal of waste water discharges. This would also negatively affect flows. As documented by the USGS (e.g., Lewelling et al. 1998, Hammett 1990) and others (Flannery and Barcelo 1998, Basso 2002), large declines in the potentiometric surface of both the intermediate and Floridan aquifers have caused the Upper Peace River to go from a gaining stream to a losing stream.

While it is not possible to determine precisely when most of the upper reach became a losing stream, losses (or positive net deep recharge) should most readily be apparent during the dry months when a proportionately greater percentage of the streamflow should be baseflow from underlying aquifers. Inspection of low river flows (e.g., 90% annual exceedance flows) shows that the greatest decline occurred in the mid-1980s through the 1990s. This would not be expected by consideration of mean annual flows which trended upwards during that time as did rainfall.

One explanation for this apparent paradox is that beginning about 1985 a number of wastewater discharges to the river were either curtailed or eliminated. These discharges included water used for phosphate processing, discharges from associated chemical plants, as well as from several wastewater treatment plants. Relatively large reductions in fluoride and phosphorus concentrations in the Upper Peace River (also readily apparent at the Arcadia Gage) indicated that a significant source was removed around 1985. This source was directly related to mining activity. Further declines in flow are believed due to the removal of point source discharges from the basin. For example, in 1987 the 9 mgd to 10 mdg discharge of the City of Lakeland's wastewater treatment plant was removed from Stahl Canal (which flowed into Banana Lake then to Lake Hancock to Saddle Creek to the Upper Peace River). Although the Upper Peace River technically became a losing stream in the 1950s to 1960s, low flows were not as noticeably affected as one might anticipate, because loses of a significant portion of the true baseflow (artesian contribution from the underlying aquifers) were at least partially offset (or masked) by increases in anthropogenic discharges to the Peace River. As anthropogenic discharges were removed, low flows declined even further.

### 3.3.4 Effects of Structural Alterations and Changes

As discussed above, in strictly terms of mean annual flow, the most significant long-term influence on flows of the Peace River as measured at Arcadia during the past 40 years is changes in long-term rainfall. Further up the watershed rainfall continues to be a major factor, however, ground-water withdrawals are the primary cause for cessation of spring flow and greatly influence reductions in base flow. Considerable quantities of streamflow are loss as recharge through sinkholes. In addition to these factors, extensive land use changes over the past 150 years have also impacted flow. These changes include mining, draining, paving, and re-contouring of lands for purposes of residential and commercial development, transportation, agriculture, recreation, timbering, power generation, ore and mineral extraction, and many other land uses. These changes affect the basin's water storage capacity, timing of flows, drainage pattern and roughness coefficient, evapotranspiration, ground-water recharge and other important hydrologic parameters. As a result, the amount of runoff produced by an equivalent amount of rain changes in terms of volume and timing.

These changes are often extremely difficult to isolate, especially at a basin or sub-basin scale. Although they have been extensively studied and reported on, there continues to be substantial differences in opinion as to their cumulative impacts. Discussed below are landcover and to some extent land use changes that have occurred in the four sub-basins that comprise the drainage basin of the Upper Peace River.

#### 3.3.4.1 Landcover in the Upper Peace River

The Peace River Basin is composed of ten sub-basins as shown in Figure 3-11. Four of these sub-basins compose the Upper Peace River basin; these sub-basins are the Peace Creek, Saddle Creek, and Payne Creek basins and the basin draining to the river reach from Bartow to Zolfo Springs (hereafter referred to as the Zolfo Springs sub-basin). As a matter of perspective, 1999 FLUCS landcover is summarized for all ten sub-basins and for the Peace Basin in Table 3-7. To facilitate comparisons and for graphical presentations that follow, the FLUCS landcovers have been grouped into seven major landcover categories. These seven major categories are: rangeland, citrus, other agriculture (which includes the FLUCS designations for cropland and pastureland, row crops and "other agriculture"), urban (composed of lands designated as barren or urban using FLUCS), water, mining, and wetland/forests (which includes the remaining FLUCS landcover types representing various natural lands in Table 3-7).


Figure 3-13. Map of the Peace River basin showing the ten major sub-basins that compose it.

Table 3-8. 1999 Landcover for 10 sub-basins composing the Peace River watershed. Data presented by Florida Land Use Code descriptors and by major landcover categories as described in text.

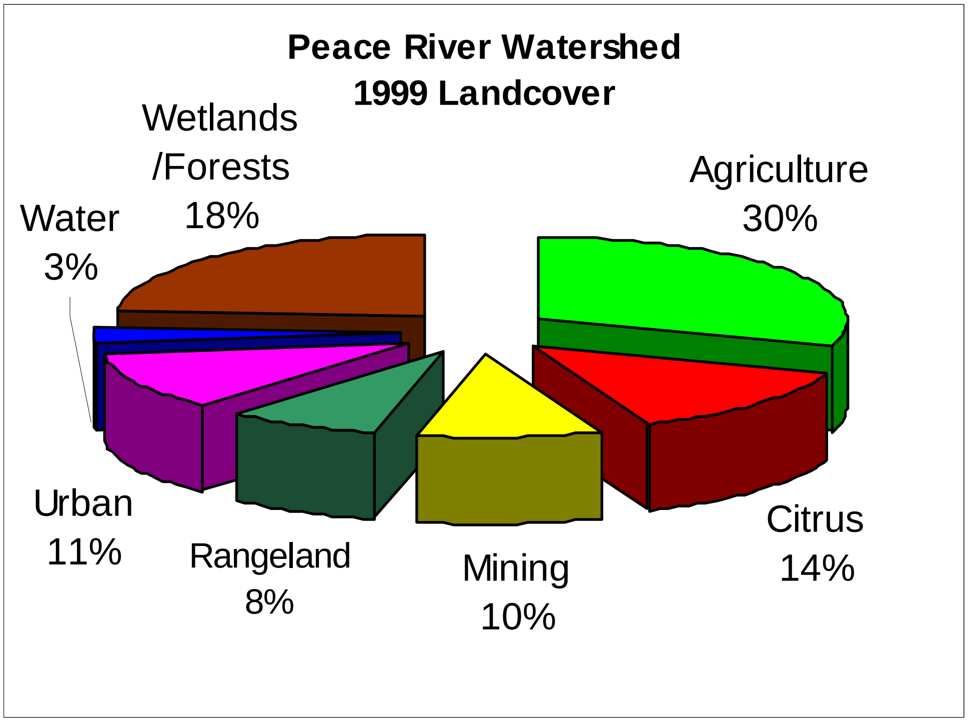
| LANDCOVER | ARCADIA | CHARLIE CK | COASTAL | HORSE CK | JOSHUA CK | PAYNE CK | PEACE CK | SADDLE CK | SHELL CK | ZOLFO SPGS | PEACE RIVER BASIN | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Acres | Acres | Acres | Acres | Acres | Acres | Acres | Acres | Acres | Acres | Acres | quare Mile | % of Total |
| FLUCSDESC1 | | | | | | | | | | | | | |
| BARREN | 46 | 48 | 618 | 91 | 13 | 88 | 88 | 553 | 301 | 417 | 2263 | 4 | 0.1% |
| CITRUS | 22525 | 29364 | 12165 | 12708 | 23137 | 6586 | 27622 | 4812 | 47184 | 28865 | 214968 | 336 | 14.1% |
| CROPLAND AND PASTURELAND | 49478 | 88634 | 21697 | 58466 | 33206 | 6876 | 28034 | 8415 | 68556 | 46741 | 410103 | 641 | 26.9% |
| CYPRESS | 68 | 3327 | 3528 | 1168 | 82 | 144 | 380 | 1346 | 1118 | 528 | 11689 | 18 | 0.8% |
| MANGROVE SWAMPS | | | 7855 | | | | | | | | 7855 | 12 | 0.5% |
| MINING | 187 | 130 | 535 | 9513 | | 51313 | 1953 | 12171 | 67 | 72390 | 148259 | 232 | 9.7% |
| MIXED HARDWOOD/PINE FOREST | 7785 | 9114 | 4776 | 11549 | 1625 | 1682 | 3704 | 3101 | 5155 | 4252 | 52743 | 82 | 3.5% |
| NON-FORESTED WETLANDS | 5091 | 8324 | 13480 | 8358 | 3817 | 1093 | 9760 | 1490 | 20966 | 4751 | 77130 | 121 | 5.1% |
| OTHER AGRICULTURE | 1910 | 4097 | 4397 | 2130 | 1179 | 1502 | 4551 | 1676 | 7399 | 2153 | 30994 | 48 | 2.0% |
| PINE FLATWOODS | 8802 | 14029 | 36477 | 11453 | 1947 | 1442 | 2445 | 1188 | 15101 | 3385 | 96269 | 150 | 6.3% |
| RANGELAND | 7528 | 15235 | 26175 | 21164 | 5406 | 1390 | 2976 | 662 | 34076 | 7686 | 122298 | 191 | 8.0% |
| ROW CROPS | 1519 | 1741 | 1171 | 3941 | 1127 | 161 | 273 | 77 | 3867 | 1231 | 15108 | 24 | 1.0% |
| SALTWATER MARSHES | | | 2838 | | | | | | | | 2838 | 4 | 0.2% |
| URBAN | 4047 | 11598 | 56200 | 2359 | 3324 | 906 | 33171 | 35838 | 3249 | 16723 | 167415 | 262 | 11.0% |
| WATER | 247 | 271 | 8524 | 194 | 217 | 1660 | 19821 | 14068 | 932 | 3808 | 49742 | 78 | 3.3% |
| WETLAND HARDWOOD FORESTS | 18891 | 22448 | 13217 | 15304 | 3011 | 5279 | 9265 | 6701 | 4150 | 17196 | 115462 | 180 | 7.6% |
| | | | | | | | | | | | | | |
| SUB-BASIN SIZE | | | | | | | | | | | | | |
| Total (acres) | 128124 | 208360 | 213653 | 158398 | 78091 | 80122 | 144043 | 92098 | 212121 | 210126 | 1525136 | | |
| Total (square miles) | 200 | 326 | 334 | 247 | 122 | 125 | 225 | 144 | 331 | 328 | | 2383 | |
| Percentage of Watershed | 8.2% | 13.3% | 13.7% | 10.1% | 5.0% | 5.1% | 9.2% | 5.9% | 13.6% | 13.4% | | | 100.0% |
| | | | | | | | | | | | | | |
| MAJOR LANDCOVER CATEGORIES | | | | | | | | | | | | | |
| Agriculture | 52907 | 94472 | 27265 | 64537 | 35512 | 8539 | 32858 | 10168 | 79822 | 50125 | 456205 | 713 | 29.9% |
| Citrus | 22525 | 29364 | 12165 | 12708 | 23137 | 6586 | 27622 | 4812 | 47184 | 28865 | 214968 | 336 | 14.1% |
| Mining | 187 | 130 | 535 | 9513 | 0 | 51313 | 1953 | 12171 | 67 | 72390 | 148259 | 232 | 9.7% |
| Rangeland | 7528 | 15235 | 26175 | 21164 | 5406 | 1390 | 2976 | 662 | 34076 | 7686 | 122298 | 191 | 8.0% |
| Urban | 4093 | 11646 | 56818 | 2450 | 3337 | 994 | 33259 | 36391 | 3550 | 17140 | 169678 | 265 | 11.1% |
| Water | 247 | 271 | 8524 | 194 | 217 | 1660 | 19821 | 14068 | 932 | 3808 | 49742 | 78 | 3.3% |
| Wetlands/Forests | 40637 | 57242 | 82171 | 47832 | 10482 | 9640 | 25554 | 13826 | 46490 | 30112 | 363986 | 569 | 23.9% |
| | | | | | | | | | | | | | |
| Total (acres) | 128124 | 208360 | 213653 | 158398 | 78091 | 80122 | 144043 | 92098 | 212121 | 210126 | 1525136 | 2383 | 100.0% |

Before considering individually the four sub-basins that make up the Upper Peace River basin, a general comparison of the Upper Peace River basin with the Peace River Basin highlights to some extent several important landcover considerations (refer to Figure 3-12). The Upper Peace River basin is characterized by considerably more open water features, more urbanization, and much more mining activity than the remainder of the basin.

Mined lands encompass about 232 square miles or approximately 9.5% of the total watershed area of the Peace River basin, and most of this land, 215 square miles ( or 93% of the mine lands) is located in two sub-basins of the Upper Peace, the Payne Creek and Zolfo Springs sub-basins. These mined areas tend to retain initial rainfall volumes and provide surface discharge only after internal storage areas are filled. Lands that were mined after July 1, 1975 have had a mandatory reclamation requirement. Fifty-nine percent of lands in Florida that were mine between July 1, 1975 and December 1, 2000 have been reclaimed. Reclamation techniques have evolved singe 1975, and reclaimed lands in the Upper Peace River basin reflect a mix of reclamation strategies.

According to 1999 FLUCS landcover maps, there are approximately 262 square miles of urbanized land in the 2,383 square mile Peace River watershed. Population (urbanization) centers are located in the uppermost part of the basin or in the Charlotte Harbor area. Of the 262 square miles of urbanized area, 135 square miles or 52%, can be found in the Upper Peace River in the vicinity of Winter Haven and Lakeland. Urbanization results in increases in impervious areas which generally reduce infiltration (recharge) and increase runoff. Approximately 52% of the urbanized area in the Peace River basin occurs in the Upper Peace River basin. The Upper Peace River basin accounts for 822 square miles (based on 1999 FLUCS landcover maps) or 34.5% of the 2,383 square mile Peace River watershed.

Excluding open water associated with Charlotte Harbor, most open water features (e.g., lakes, reservoirs, and mine pits) in the Peace River basin are found in the Upper Peace River basin. Sixty-one of the 78 square miles of open freshwater system (79%) that occur in the Peace River basin can be found in the Upper Peace River basin. As discussed in some detail in the section on the Peace Creek sub-basin (Section 3.3.4.1), the lakes found in the Upper Peace Basin can potentially store large quantities of water; however, there is evidence to indicate that considerable storage potential has been lost due to lowering of lakes in the area.



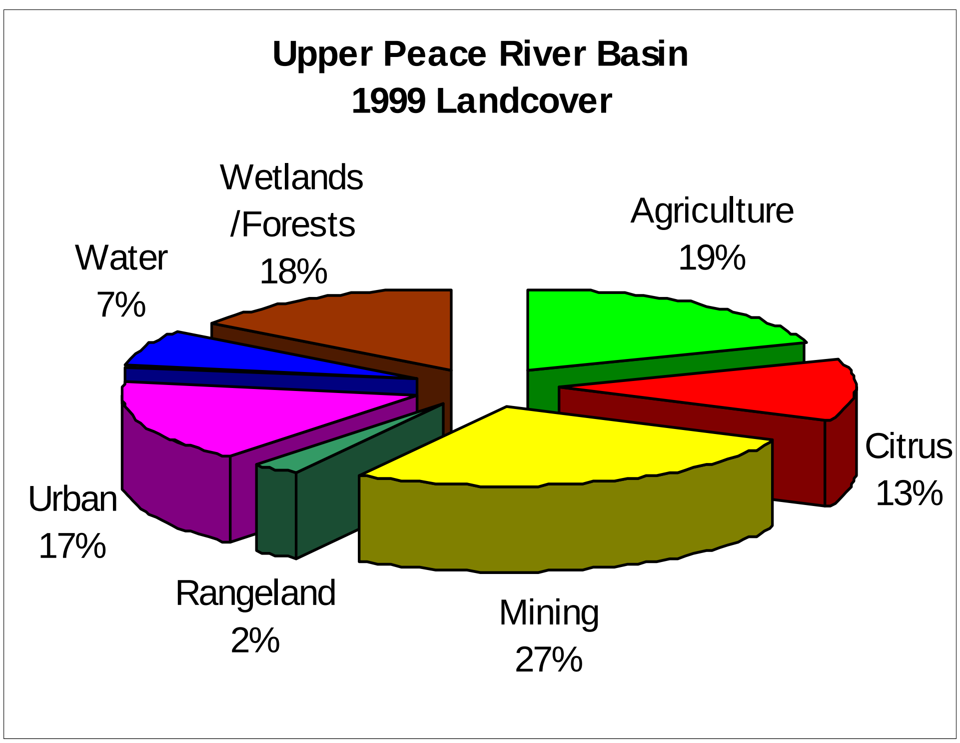




Figure 3-14. A comparison of 1999 landcover in the Peace River drainage basin and the Upper Peace River drainage basin.

Table 3-9. 1999 Landcover for sub-basins comprising the Upper Peace River watershed. Data presented by Florida Land Use Code (FLUCS) descriptors and by major landcover categories as described in text.

| Landcover Descriptor | Payne Ck Acres | Peace Ck Acres | Saddle Ck Acres | Zolfo Spgs Acres | Upper Peace Watershed Acres | Upper Peace Watershed Square Miles | Upper Peace Watershed % of total | % of Peace River Watershed |
|---|---|---|---|---|---|---|---|---|
| FLUCSDESC1 | | | | | | | | |
| BARREN | 88 | 88 | 553 | 417 | 1146 | 2 | 0.2% | 0.1% |
| CITRUS | 6586 | 27622 | 4812 | 28865 | 67885 | 106 | 12.9% | 4.5% |
| CROPLAND AND PASTURELAND | 6876 | 28034 | 8415 | 46741 | 90066 | 141 | 17.1% | 5.9% |
| CYPRESS | 144 | 380 | 1346 | 528 | 2398 | 4 | 0.5% | 0.2% |
| MANGROVE SWAMPS | | | | | 0 | 0 | 0.0% | 0.0% |
| MINING | 51313 | 1953 | 12171 | 72390 | 137827 | 215 | 26.2% | 9.0% |
| MIXED HARDWOOD/PINE FOREST | 1682 | 3704 | 3101 | 4252 | 12739 | 20 | 2.4% | 0.8% |
| NON-FORESTED WETLANDS | 1093 | 9760 | 1490 | 4751 | 17094 | 27 | 3.2% | 1.1% |
| OTHER AGRICULTURE | 1502 | 4551 | 1676 | 2153 | 9882 | 15 | 1.9% | 0.6% |
| PINE FLATWOODS | 1442 | 2445 | 1188 | 3385 | 8460 | 13 | 1.6% | 0.6% |
| RANGELAND | 1390 | 2976 | 662 | 7686 | 12714 | 20 | 2.4% | 0.8% |
| ROW CROPS | 161 | 273 | 77 | 1231 | 1742 | 3 | 0.3% | 0.1% |
| SALTWATER MARSHES | | | | | 0 | 0 | 0.0% | 0.0% |
| URBAN | 906 | 33171 | 35838 | 16723 | 86638 | 135 | 16.5% | 5.7% |
| WATER | 1660 | 19821 | 14068 | 3808 | 39357 | 61 | 7.5% | 2.6% |
| WETLAND HARDWOOD FORESTS | 5279 | 9265 | 6701 | 17196 | 38441 | 60 | 7.3% | 2.5% |
| Total (acres) | 80122 | 144043 | 92098 | 210126 | 526389 | | | |
| Total (square miles) | 125 | 225 | 144 | 328 | | 822 | | |
| Percentage of Watershed | 15.2% | 27.4% | 17.5% | 39.9% | 33.7% | | 100.0% | 34.5% |
| Major Landcover Categories | | | | | | | | |
| Agriculture | 8539 | 32858 | 10168 | 50125 | 101690 | 159 | 19.3% | 6.7% |
| Citrus | 6586 | 27622 | 4812 | 28865 | 67885 | 106 | 12.9% | 4.5% |
| Mining | 51313 | 1953 | 12171 | 72390 | 137827 | 215 | 26.2% | 9.0% |
| Rangeland | 1390 | 2976 | 662 | 7686 | 12714 | 20 | 2.4% | 0.8% |
| Urban | 994 | 33259 | 36391 | 17140 | 87784 | 137 | 16.7% | 5.8% |
| Water | 1660 | 19821 | 14068 | 3808 | 39357 | 61 | 7.5% | 2.6% |
| Wetlands/Forests | 9640 | 25554 | 13826 | 30112 | 79132 | 124 | 15.0% | 5.2% |
| Totals | 80122 | 144043 | 92098 | 210126 | 526389 | 822 | 100.0% | 34.5% |

### 3.3.4.1 Peace Creek

The Peace Creek encompasses approximately 225 square miles, comprising the eastern-most headwaters of the Peace River. General land uses within the watershed consist predominately of urban development within the upper portion, and agricultural lands, mainly pasture lands, within the lower portion. Figure 3-12 is SWFWMD's most recent (1999) landcover map of the Peace Creek sub-basin, and Table 3-9 summarizes landcover in this sub-basin.

During the early part of the 20$^{th}$ century, several local drainage districts were created and programs of construction were completed in the Peace Creek Basin. These early systems of channels were designed primarily for drainage and did much to encourage the present degree of agricultural development (Johnson 1960). Once constructed, the canals effectively drained much of the region. Mann (1983) stated that the canals resulted in damage to fish and wildlife, and lowered water levels in the ground and surface-water systems. Additionally, Johnson (1960) reported that Peace Creek Basin historically received more of the drainage from the Green Swamp before construction of the Atlantic Coast Line Railroad and Highway 17-92.

The average topographical elevation of the Peace Creek Basin is about 140 feet above sea level. The northern area is more urbanized than the southern and includes Winter Haven, Lake Alfred, Haines City, Lake Hamilton and part of Auburndale. There are two major interconnected lake systems, the Lake Hamilton and the Winter Haven chains, and the Haines City Canal system. The Lake Hamilton chain of lakes is located northeast of Winter Haven and consists of seven interconnected lakes (Lake Haines, Rochelle, Conine, Smart, Fannie, Henry and Hamilton) which drain through Lake Hamilton to the Peace Creek Canal. Lake Alfred, although not affected by the downstream lake levels in this system, is hydraulically connected to the system. The small size and high elevation of a box culvert immediately downstream severely limit discharge from Lake Alfred. Four control structures regulate flow between the lakes within the system. These structures are on Lake Henry (P-5), Lake Smart (P-6), Lake Fannie (P-7) and Lake Hamilton (P-8). The P-8 structure controls flow from Lake Hamilton into the Peace Creek Canal. A constriction in the outfall channel about one-half mile downstream of the P-8 structure restricts discharge from the lake and thereby the ability to control flooding on the lake by release of water through P-8 (SWFWMD 1996b).

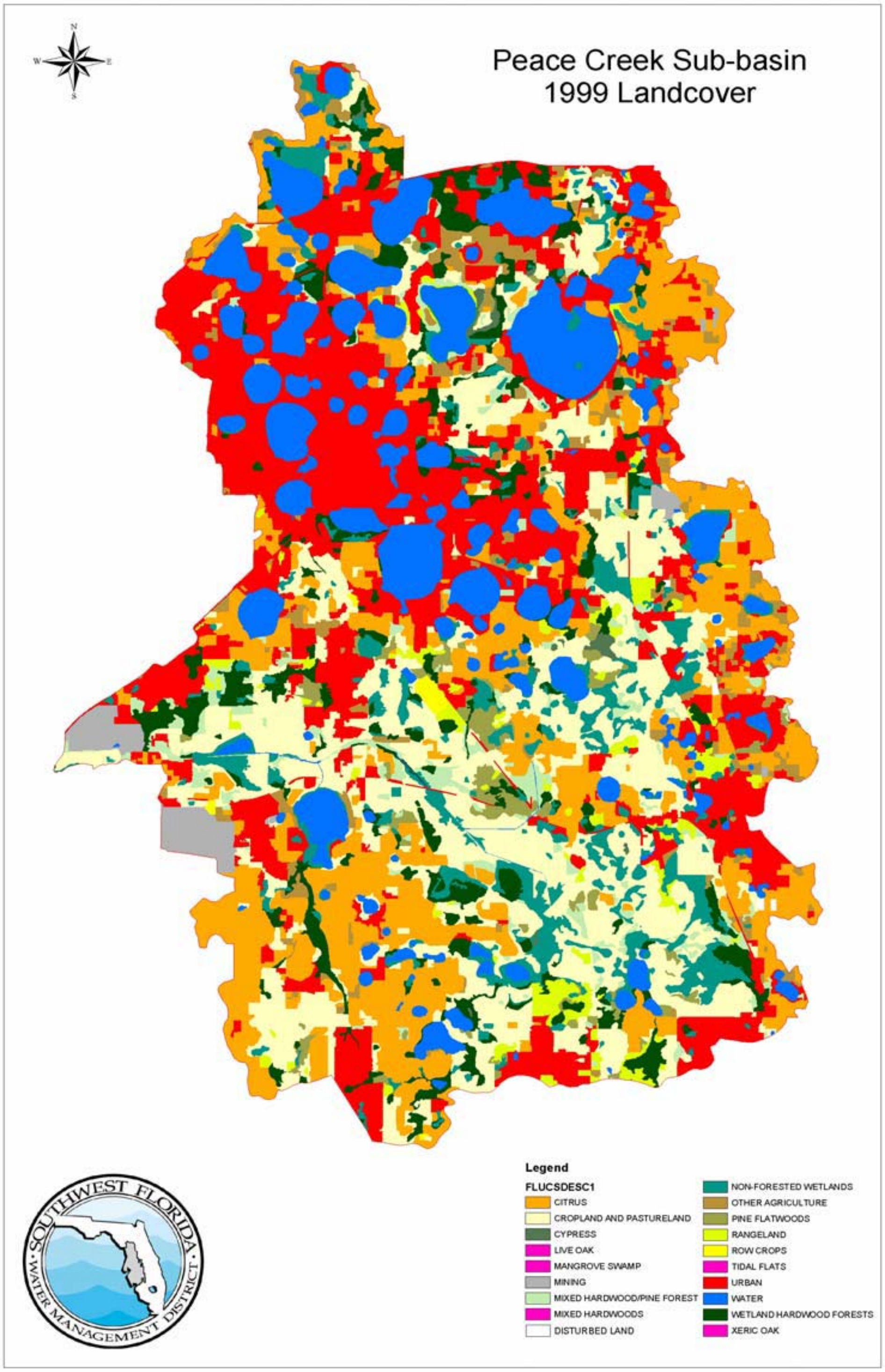
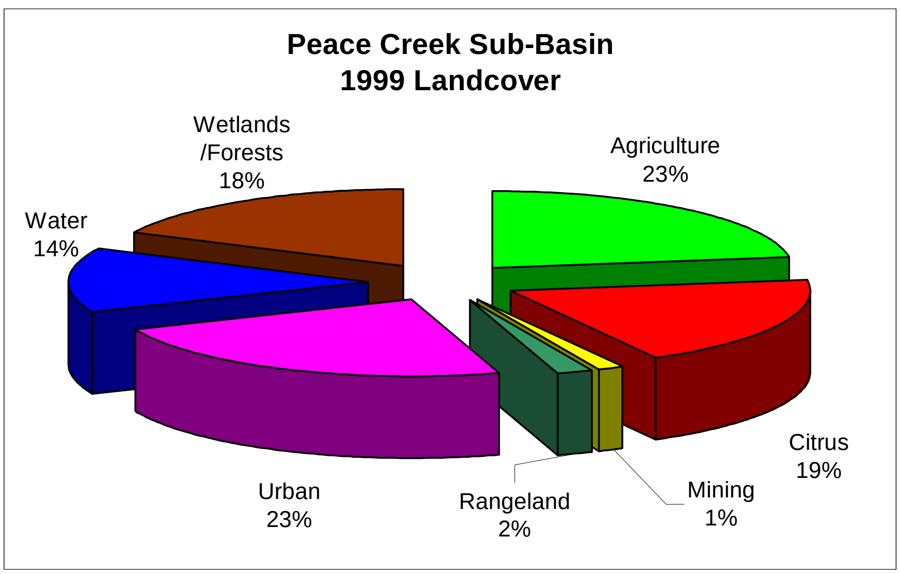



Figure 3-15. 1999 Landcover in the Peace Creek Canal sub-basin of the Upper Peace River.

Table 3-10. 1999 landcover in the Peace Creek sub-basin. Data presented according to Florida Land Use Codes (FLUCS) and by major landcover categories as described in text.

| | Peace Creek Acres | % of Peace Creek | % of Upper Peace River | % of Peace River |
|---|---|---|---|---|
| FLUCSDESC1 | | | | |
| BARREN | 88 | 0.1% | 0.0% | 0.0% |
| CITRUS | 27622 | 19.2% | 5.2% | 1.8% |
| CROPLAND AND PASTURELAND | 28034 | 19.5% | 5.3% | 1.8% |
| CYPRESS | 380 | 0.3% | 0.1% | 0.0% |
| MANGROVE SWAMPS | | 0.0% | 0.0% | 0.0% |
| MINING | 1953 | 1.4% | 0.4% | 0.1% |
| MIXED HARDWOOD/PINE FORES | 3704 | 2.6% | 0.7% | 0.2% |
| NON-FORESTED WETLANDS | 9760 | 6.8% | 1.9% | 0.6% |
| OTHER AGRICULTURE | 4551 | 3.2% | 0.9% | 0.3% |
| PINE FLATWOODS | 2445 | 1.7% | 0.5% | 0.2% |
| RANGELAND | 2976 | 2.1% | 0.6% | 0.2% |
| ROW CROPS | 273 | 0.2% | 0.1% | 0.0% |
| SALTWATER MARSHES | | | | 0.0% |
| URBAN | 33171 | 23.0% | 6.3% | 2.2% |
| WATER | 19821 | 13.8% | 3.8% | 1.3% |
| WETLAND HARDWOOD FOREST | 9265 | 6.4% | 1.8% | 0.6% |
| | | | | |
| Total (acres) | 144043 | 100.0% | 27.4% | 9.4% |
| Total (square miles) | 225 | | | |
| | | | | |
| Major Landcover Catgories | | | | |
| Agriculture | 32858 | 22.8% | 6.2% | 2.2% |
| Citrus | 27622 | 19.2% | 5.2% | 1.8% |
| Mining | 1953 | 1.4% | 0.4% | 0.1% |
| Rangeland | 2976 | 2.1% | 0.6% | 0.2% |
| Urban | 33259 | 23.1% | 6.3% | 2.2% |
| Water | 19821 | 13.8% | 3.8% | 1.3% |
| Wetlands/Forests | 25554 | 17.7% | 4.9% | 1.7% |
| | | | | |
| Totals | 144043 | 100.0% | 27.4% | 9.4% |



The other major chain of lakes is the Winter Haven Chain of Lakes consisting of a series of interconnected lakes (Lakes Marianna, Jessie, Idylwild, Hartridge, Cannon, Mirror, Deer Howard, May, Shipp, Eloise, Winterset and Lulu) which drain a large area extending from the south side of Auburndale to the west and south sides of Winter Haven. An outlet structure on Lake Lulu regulates the water levels in the chain of lakes and discharges into the Wahneta Drainage Canal that in turn discharges into the Peace Creek Canal. During some flood periods, the crest of the Lake Lulu weir is submerged, thereby affecting the water levels in the lake chain. The two major chains of lakes are interconnected by a control structure between Lake Hartridge of the Winter Haven chain and Lake Conine of the Lake Hamilton chain. The structure, in a small connecting canal that crosses under U.S. 17, consists of a fixed weir 10 feet wide with a crest elevation at 131.80 feet above sea level (SWFWMD 1996b).

Most of the lakes in the Peace River Watershed are located in the headwaters of the Upper Peace River above the confluence of Saddle and Peace Creeks. The total number of lakes in the headwaters area (above the confluence of Saddle and Peace Creeks) is 152, with a combined surface area of over 32,000 acres. There are 115 lakes in the Peace Creek Basin, and they range in size from 2 to 2,162 acres (Lake Hamilton). Nearly all of these lakes have been altered. For example, the lakes that comprise the Winter Haven Chain of Lakes historically differed in surface-water elevations over a range of most likely several feet, however, with the construction of interconnecting canals in the 1920s, these lakes now fluctuate at approximately the same elevation under control of the structure on Lake Lulu.

A map of the Peace Creek Drainage District dated December 19, 1914 shows stages on a number of lakes taken in November and December of that year (Table 3-10). The map is entitled, "Peace Creek Drainage District, Polk County Florida, Showing the Plan of Reclamation, Prepared to Accompany the Report of the Chief Engineer, December 14, 1914", and, in addition to selected lake stage elevations, indicates the location of proposed drainage canals constructed in subsequent years. Review of rainfall records from Bartow indicates that 1914 was not an especially wet year. Bartow received 1.59 and 3.88 inches of rain in November and December, respectively. Rainfall, however, was heavy in 1912, and Bartow recorded rainfall totals of 66.09, 52.48 and 52.31 in 1912, 1913 and 1914, respectively. Since lake stage elevations were determined in November and December of 1914, it is likely that lakes were near their seasonal high, but rainfall data does not suggest that stages should have been unusually high. However, the impetus for creation of the Peace Creek Drainage District may have been the high lake water level conditions experienced in 1912. Johnson (1960) reported that the area experienced a 100-year flood in 1912.

Table 3-10 compares the recorded 1914 elevations at a number of lakes within the drainage district to elevations taken from USGS Quadrangle maps (most of these maps were generated in the 1950s) and to established management levels (minimum flood elevations) determined by the District. Where available, the current invert elevation of the lake outlet is given. Since the elevations on the old map were surveyed prior to adoption of the 1929

NGVD, there is some question regarding the accuracy of these levels, and it is believed that they may be off by several feet. Assuming that the elevations are correct in a relative sense, that is the difference between lake elevations are accurate, some inferences are made regarding possible changes in lake stage and volume. For example, Lake Fannie was reported to have an elevation of 132.9 feet and nearby Lake Hamilton was reported to have an elevation of 132.2 feet, a difference of 0.7 feet. Today the minimum flood levels for these two lakes are 125.75 and 121.5 feet respectively, a difference of 4.25 feet or an increase in the difference between the seasonal highs of 3.55 feet (4.25 feet minus 0.7 feet). This suggests that even if Lake Fannie has not been lowered from its historic condition, that Lake Hamilton has been lowered by at least 3.55 feet with respect to Lake Fannie. It is believed, however, that Lake Fannie would have been lowered to some extent, since the northern most extent of Peace Creek Drainage Canal actually begins in a wetland area between the two lakes.

Based on the historic elevation and the most conservative of several current elevations (USGS Quad map elevation, adopted minimum flood elevation, or outlet elevation), the smallest difference between any set of elevations for each lake was determined. The smallest change in elevation between historic and current was from Lake Garfield and was 4.2 feet. By applying this correction factor, we are essentially assuming that Lake Garfield has not been lowered from its historic condition. We believe this may be a conservative assumption when computing loss of storage volume due to drainage modifications.

Accepting that lakes would be at or near the elevation of their outlet invert at the end of the rainy season and assuming after application of a correction factor that the adjusted 1914 elevations are valid, many of the lakes appear to have been lowered considerably between 1915 and 1950. For example, the lakes of the Winter Haven Chain of Lakes were interconnected in the 1920s and now fluctuate at approximately the same elevation under control of the structure located on Lake Lulu. The old drainage district map suggests that Lake Eloise (the largest lake in the Chain) had a seasonal high elevation of about 134.1 feet (138.3 feet map elevation minus 4.2 feet); however, it is now under the control of the Lake Lulu structure at a maximum invert elevation of 132.5 feet. In preparation for establishing levels on this lake, District crews surveyed the buttress inflection point of cypress trees at a mean elevation of 135.19 feet which is indicative of a past seasonal high water level. Based on the drainage map elevation and the hydrologic indicator (cypress buttressing), Lake Eloise now fluctuates at a level approximately two to three feet below its historic elevation. Making several conservative assumptions (lowering the old map elevations by 4.2 feet, using current lake surface area, and taking the higher of the three most recent elevations – USGS Quad map elevation, adopted minimum flood elevation or outlet invert elevation), we calculated loss in storage volume of the twenty lakes included on the old drainage district map. This information is summarized in Table 3-10.

While largely speculative, it is believed that the above analysis presents a conservative estimate of the loss of lake storage volume that could have resulted from the construction of the Peace Creek Drainage Canal system. Summing values in Table 3-10, the total projected loss in storage from the 20 lakes is equivalent to 32,810 acre-feet or 10.7 billion gallons. When the same data presented are left uncorrected (i.e., historic elevations are used as given on the old drainage map), the above estimates are essentially twice as high.

Additional information that supports the above analysis relates to Lake Hamilton, one of Florida's 236 "meandered lakes". What is now the State of Florida was ceded to the United States by treaty with Spain in 1819. In 1824, the Federal Government began sending survey crews into the newly acquired territory to subdivide and record the extent of its new territory. Over the next 60 years, a number of lakes (236) were recorded on survey maps and records. If included in one of these original surveys, the lake was considered navigable and thus established State sovereignty. When Lake Hamilton was meandered (surveyed), it included as part of Lake Hamilton several lakes (Lake Crystal, Sara and Little Lake Hamilton) that now appear as separate basins. In addition it is noted that the map prepared by the Peace Creek Drainage District does not show separate basins for Middle Lake Hamilton and Little Lake Hamilton. This suggests that these lake basins were at one timed joined. Inspection of current topographic maps suggests that Lake Hamilton would have to be raised above the 125 feet contour (possibly higher) to join all the lake basins. Lake Hamilton has fluctuated between 117 and 124 feet, since records were first continuously collected beginning in 1945 (the mean of 10,700 lake stage elevations taken since 1945 is 119.55 feet NGVD).

The southern area of the Peace Creek Basin is much flatter having an average elevation of about 120 feet above sea level, and does not have the abundance of lakes as in the north. Most of this area consists of agricultural lands with only moderate urbanization on the high terraces along its eastern boundary. Urbanization is more extensive in and around the City of Lake Wales. The southern area contains the lower sections of the Peace Creek Canal including its main tributary the Wahneta Farms Drainage Canal. The conveyance system within the southern watershed consists predominately of excavated canals with a network of smaller natural streams and improved ditches draining into them. The smaller natural streams and improved ditches are similarly restricted and experience flooding during higher than normal rainstorms (SWFWMD 1996).

Table 3-11. Estimated loss of storage in 20 lakes in the Peace Creek sub-basin due to drainage modifications in the watershed.

| Lake | Surface Area (acres) | Historic Elevation (feet above sea level) December 9, 1914 | Adjusted Historic Elevation (feet) | Elevation on USGS Quad Map (feet NGVD) | Adopted Minimum Flood Elevation (feet NGVD) | Invert of Outlet (feet NGVD) | Projected Seasonal High Elevation (feet NGVD) | Projected Stage Reduction (feet) | Lost Storage (acre-ft) | Lost Storage (million gallons) | Equivalent Loss in MGDs |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Annie | 539 | 129 | 124.8 | 119 | 119 | | 119 | 5.8 | 3126 | 1019 | 2.79 |
| Bess | 148 | 130.8 | 126.6 | 125 | 125.25 | | 125.25 | 1.4 | 200 | 65 | 0.18 |
| Daisey | 133 | 138.3 | 134.1 | 131 | 130 | 128.64 | 131 | 3.1 | 412 | 134 | 0.37 |
| Dexter | 153 | 140.4 | 136.2 | 132 | 132 | 129.12 | 132 | 4.2 | 643 | 209 | 0.57 |
| Effie | 102 | 127 | 122.8 | 117 | 118 | 116.5 | 118 | 4.8 | 490 | 160 | 0.44 |
| Eloise | 1160 | 138.3 | 134.1 | 131 | 132 | 132.5 | 132.5 | 1.6 | 1856 | 605 | 1.66 |
| Fannie | 829 | 132.9 | 128.7 | 125 | 125.75 | 125.5 | 125.75 | 3.0 | 2446 | 797 | 2.18 |
| Florence | 74 | 136.9 | 132.7 | 128 | 128.75 | 127.8 | 128.75 | 4.0 | 292 | 95 | 0.26 |
| Fox | 55 | 143.1 | 138.9 | 136 | 135 | 132.28 | 132.28 | 6.6 | 364 | 119 | 0.33 |
| Garfield | 655 | 108.4 | 104.2 | 100 | 104.25 | | 104.25 | 0.0 | -33 | -11 | -0.03 |
| Gordon | 213 | 126 | 121.8 | 114 | na | | 114 | 7.8 | 1661 | 541 | 1.48 |
| Hamilton | 2162 | 132.2 | 128 | 120 | 121.5 | 121.5 | 121.5 | 6.5 | 14053 | 4579 | 12.55 |
| Mariam | 199 | 136 | 131.8 | 127 | 124.75 | 124 | 127 | 4.8 | 955 | 311 | 0.85 |
| Myrtle | 413 | 128.3 | 124.1 | 118 | 118.5 | | 118.5 | 5.6 | 2313 | 754 | 2.06 |
| Ned | 74 | 135.9 | 131.7 | 131 | 128.5 | 129 | 131 | 0.7 | 52 | 17 | 0.05 |
| Pembroke | 110 | 124.8 | 120.6 | 109 | na | | 109 | 11.6 | 1276 | 416 | 1.14 |
| Rattlesnake | 120 | 126.8 | 122.6 | none given | na | | na | 4.1 | 492 | 160 | 0.44 |
| River | 26 | 146 | 141.8 | 137 | 139.5 | | 139.5 | 2.3 | 60 | 19 | 0.05 |
| Ruby | 255 | 130.8 | 126.6 | 125 | 125.25 | | 125.25 | 1.4 | 344 | 112 | 0.31 |
| Winterset | 548 | 139.5 | 135.3 | 131 | 132 | | 132 | 3.3 | 1808 | 589 | 1.61 |
| TOTALS | 7968 | | | | | | | | 32810 | 10692 | 29.29 |

### 3.3.4.2 Saddle Creek

The Saddle Creek sub-basin encompasses approximately 144 square miles (92,098 acres). The dominant landcover in this sub-basin is urban (Figure 3-14). At 40%, it is percentage-wise the most urbanized sub-basin in the Peace River watershed, and second only to the Coastal sub-basin in total urbanized acreage (35,858 acres versus 56,818 acres). In addition to its urbanized acreage, this sub-basin like the Peace Creek sub-basin, has a substantial area in open water features (primarily lakes and phosphate mine pits). There are over 14,000 acres in surface water including the largest lake in the Peace River basin (i.e., Lake Hancock).

Lake Hancock has been mentioned as a potentially important factor affecting both water quality and flow to the Upper Peace River. According to Hammett (1981), Lake Hancock "is part of the headwaters of the Peace River. Saddle Creek flows through the lake and then joins the Peace Creek Drainage Canal about 3 miles south of the lake to form the Peace River. Lake Hancock, with a surface area of 4,540 acres, is the largest lake in the Peace River basin and the fourth largest in Polk County". "Outflow from Lake Hancock into Saddle Creek is regulated by Structure P-11, operated under the jurisdiction of the Southwest Florida Water Management District. Structure P-11, completed in August 1963, replaced the previous control, a concrete and timber weir. It is composed of two 20-foot by 7-foot radial gates atop a concrete spillway" (Hammett et al. 1981).

It has have postulated that a structure placed on the outlet of Lake Hancock in 1963 had an impounding effect, causing more water to be stored in the lake and thus less available for downstream flow. Because a plot of accumulated rainfall versus accumulated stream flow shows an inflection around 1965 (e.g., as seen in Figure 11 of Hammett 1990), attempts at explaining declining flows focus on possible causative events they may have occurred near this time period. The Lake Hancock structure has been critically viewed because the time of the installation of the newest structure (1963) occurred near a time corresponding to the flow decline seen in the Upper Peace River.

While it is interesting speculation, there is evidence to suggest that historic water levels in Lake Hancock frequently fluctuated above the control elevation of the current structure which is 98.5 feet. A report prepared by Patton (1980), on the ordinary high water line of Lake Hancock, identified two terraces presumably representative of former lake shore elevations. Based on analysis of a number of transects, a pronounced scarp was identified between elevation 100.4 and 100.8 feet, and a second scarp was found near 103 feet. "The sequences of terraces, therefore, indicates a two-step drop in the level of Lake Hancock, from an elevation near 103' to an elevation near 100.5', then down to the present elevation of the lake near 98 feet" (Patton 1980). Patton (1980), also found that soils and certain vegetative indicators suggested similar prior high water lines, and he concluded, "based on the three separate lines of evidence, it is our opinion that the Historical Water Line on Lake Hancock was located at or near 100.5' of elevation prior to phosphate mining." [Note: In preparing to set minimum lake levels on Lake Hancock, District crews also surveyed a high water level elevation on February 8, 1979 with field notes recording a "Point

2/3 up buttress of lakeside cypress (average of several trees) 102.00 feet."]

Patton (1980) further noted that, "until the 1950's the edges of Lake Hancock supported primarily cattle and timber industries. Since then mining and development of the underlying phosphate resources have crept up on both the South and East shores." Patton was aware of "a decrease of nearly 10% in annual precipitation" after 1960, but nevertheless concluded that the lowering of the lake from the 100.5' elevation was due either to a change in elevation in the Saddle Creek outlet or a change in conditions in the local water table, or both.

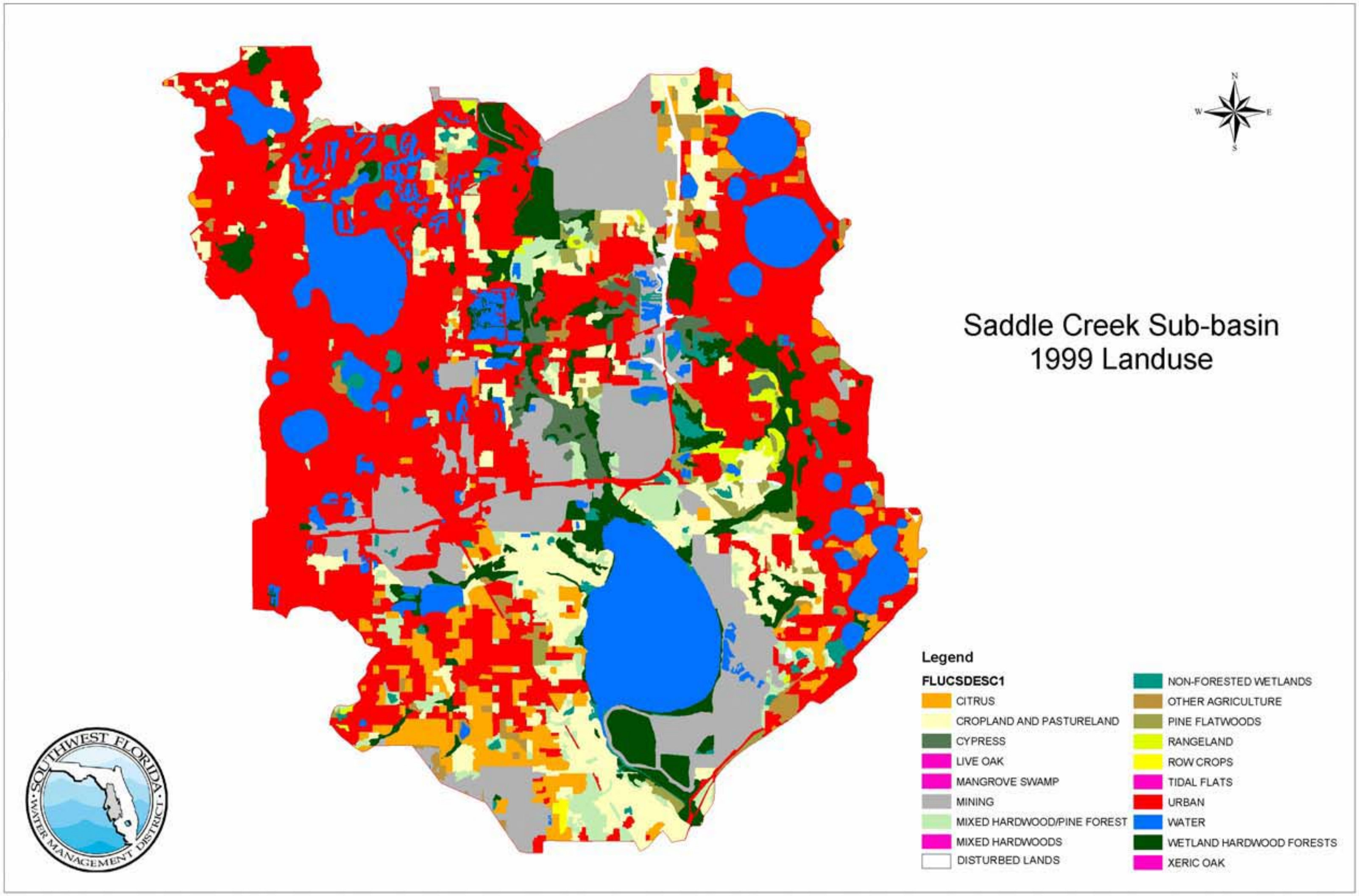
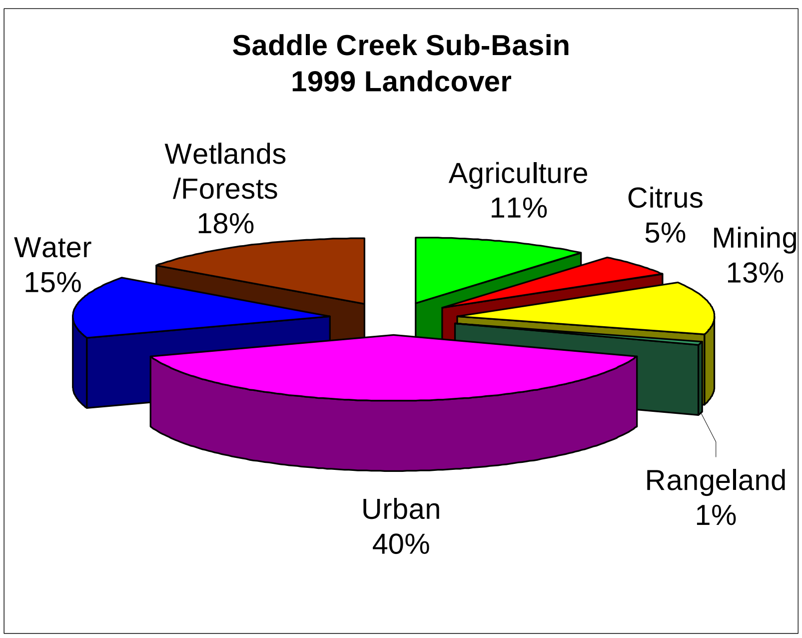



Figure 3-16. 1999 Landcover in the Saddle Creek sub-basin of the Upper Peace River.

Table 3-12. 1999 landcover in the Saddle Creek sub-basin. Data presented according to Florida Land Use Codes (FLUCS) and by major landcover categories as described in text.

| | Saddle Ck Acres | % of Saddle Creek | % of Upper Peace River | % of Peace River |
|---|---|---|---|---|
| FLUCSDESC1 | | | | |
| BARREN | 553 | 0.6% | 0.1% | 0.0% |
| CITRUS | 4812 | 5.2% | 0.9% | 0.3% |
| CROPLAND AND PASTURELAND | 8415 | 9.1% | 1.6% | 0.6% |
| CYPRESS | 1346 | 1.5% | 0.3% | 0.1% |
| MANGROVE SWAMPS | | | 0.0% | 0.0% |
| MINING | 12171 | 13.2% | 2.3% | 0.8% |
| MIXED HARDWOOD/PINE FOREST | 3101 | 3.4% | 0.6% | 0.2% |
| NON-FORESTED WETLANDS | 1490 | 1.6% | 0.3% | 0.1% |
| OTHER AGRICULTURE | 1676 | 1.8% | 0.3% | 0.1% |
| PINE FLATWOODS | 1188 | 1.3% | 0.2% | 0.1% |
| RANGELAND | 662 | 0.7% | 0.1% | 0.0% |
| ROW CROPS | 77 | 0.1% | 0.0% | 0.0% |
| SALTWATER MARSHES | | | | 0.0% |
| URBAN | 35838 | 38.9% | 6.8% | 2.3% |
| WATER | 14068 | 15.3% | 2.7% | 0.9% |
| WETLAND HARDWOOD FORESTS | 6701 | 7.3% | 1.3% | 0.4% |
| Total (acres) | 92098 | 100.0% | 17.5% | 6.0% |
| Total (square miles) | 144 | | | |
| Major Landcover Catgories | | | | |
| Agriculture | 10168 | 11.0% | 1.9% | 0.7% |
| Citrus | 4812 | 5.2% | 0.9% | 0.3% |
| Mining | 12171 | 13.2% | 2.3% | 0.8% |
| Rangeland | 662 | 0.7% | 0.1% | 0.0% |
| Urban | 36391 | 39.5% | 6.9% | 2.4% |
| Water | 14068 | 15.3% | 2.7% | 0.9% |
| Wetlands/Forests | 13826 | 15.0% | 2.6% | 0.9% |
| Totals | 92098 | 100.0% | 17.5% | 6.0% |



### 3.3.4.3 Peace River at Zolfo Springs

The Zolfo Springs sub-basin is the largest of the four sub-basins composing the Upper Peace River drainage basin. Although accounting for only 34% of the landcover in the sub-basin, the area designated “mining” totals 72,390 acres (113 square miles) in this basin alone. Inspection of the Zolfo Springs landcover map clearly shows that most of this mining related acreage occurs in the upper half of the basin (above Ft. Meade) with mining acreage lining both sides of the Upper Peace River from Bartow to south of Ft. Meade. Tributaries to this reach of the river (e.g., Six Mile Creek and Barber Branch) were mined, and their basins are now part of the water control systems for the mined lands, which periodically release stored water to the river via regulated NPDS discharges or reclaimed stream channels.

As described by Basso (2002), surface-water drainage in the upper portion of the river (from Bartow to the Polk-Hardee County line) is mostly limited to phosphate-mine releases and reclaimed stream channels. Much of the pre-mining hydrography has been altered. There are numerous clay-settling areas (CSAs) in the upper basin, which individually may cover several hundred acres. These are a dominant reclaimed land form along much of the upper river (Lewelling et al. 1998). Further, as described by the Florida Institute of Phosphate Research (FIPR 1996), “Clays account for approximately one-third of the material extracted along with phosphate ore. During the beneficiation process, water is used to separate the clays from the phosphate matrix, producing a clay slurry with a 94-97 percent water content. A mine can produce 30,000 to 150,000 gallons of phosphate clay slurry per minute. The clay slurry is deposited in large clay settling areas (CSA) so that the suspended clay particles can consolidate and the water can be reused. Clay particles take a considerable amount of time to consolidate.” A CSA is an above-grade impoundment that may range in area from 70 to 600 acres that is ultimately reclaimed by grading and contouring; however, as noted by the FIPR, “the properties of the subterranean clay virtually prevent rain or surface water from soaking through the soil and recharging the aquifer. This will likely have a negative impact on water supplies [and likely river flows] unless rainfall is channeled to a reservoir or recharge area.” At the time of the FIPR report, it was estimated that there were 328 CSAs in Polk County encompassing almost 95,000 acres. It was estimated that 23,000 acres had been reclaimed and 72,000 had not. These estimates did not include an estimated 36,000 acres of “old mine land” where reclamation was not required. Additionally, many of these mined areas have controlled and permitted point source discharge outfalls. Subsequently, freshwater flows from many of these internally-drained sub-basins consist of significant quantities of industrial point source discharges (Coastal Environmental, Inc. 1995).

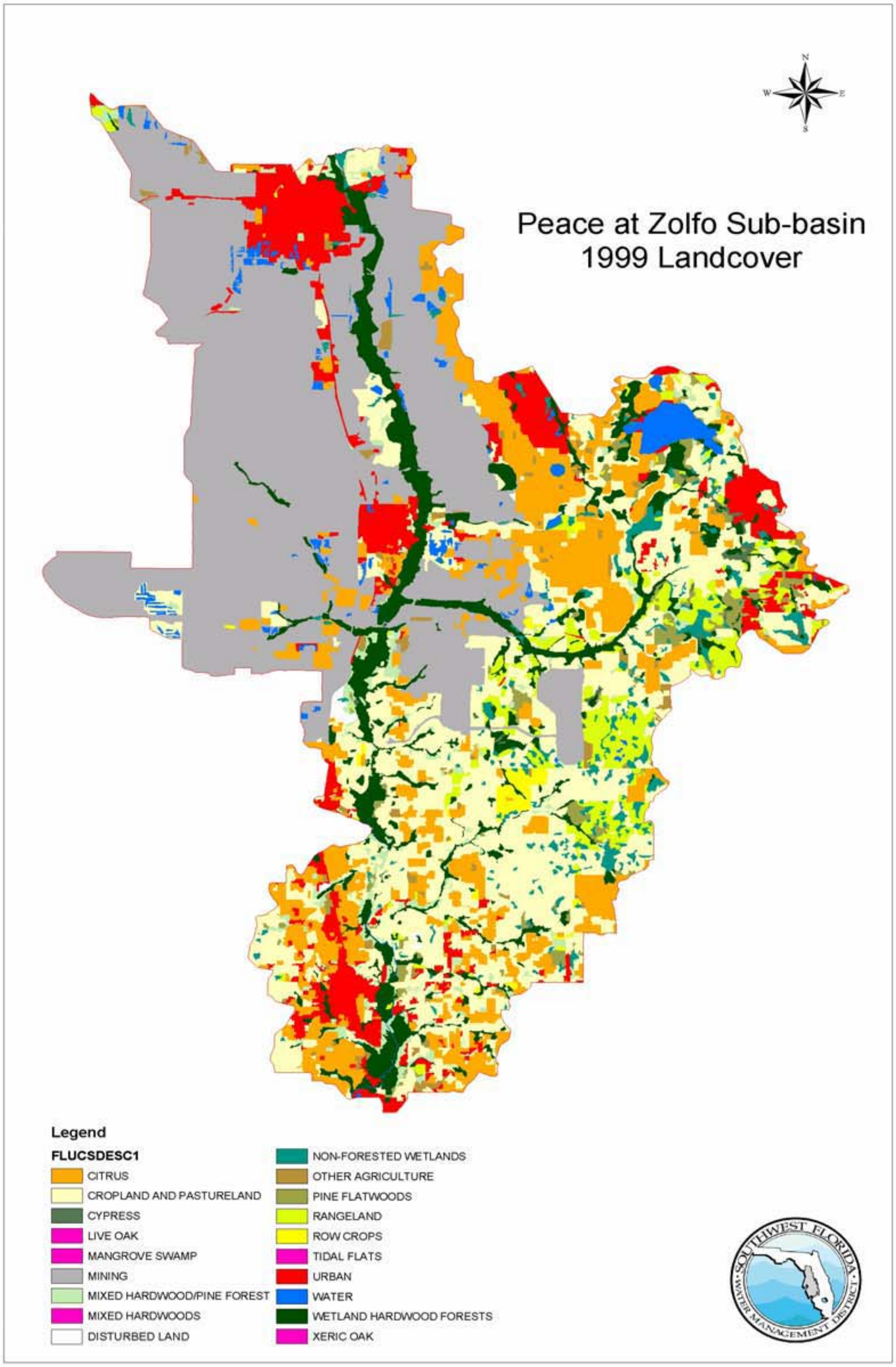
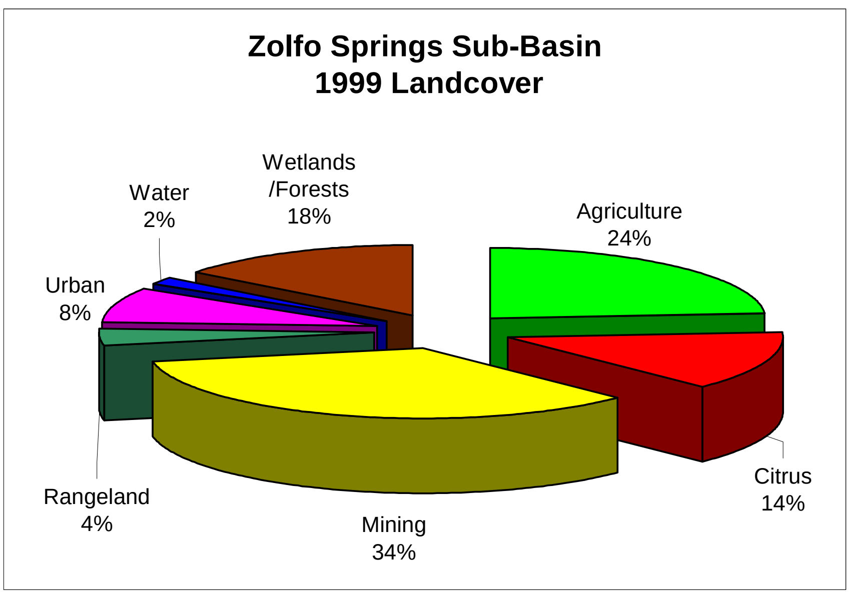



Figure 3-17. 1999 Landcover in the Zolfo Springs sub-basin of the Upper Peace River.

Table 3-13. 1999 landcover in the Zolfo Springs sub-basin. Data presented according to Florida Land Use Codes (FLUCS) and by major landcover categories as described in text.

| | Zolfo Spgs Acres | % of Zolfo Springs | % of Upper Peace River | % of Peace River |
|---|---|---|---|---|
| FLUCSDESC1 | | | | |
| BARREN | 417 | 0.2% | 0.1% | 0.0% |
| CITRUS | 28865 | 13.7% | 5.5% | 1.9% |
| CROPLAND AND PASTURELAND | 46741 | 22.2% | 8.9% | 3.1% |
| CYPRESS | 528 | 0.3% | 0.1% | 0.0% |
| MANGROVE SWAMPS | | | 0.0% | 0.0% |
| MINING | 72390 | 34.5% | 13.8% | 4.7% |
| MIXED HARDWOOD/PINE FOREST | 4252 | 2.0% | 0.8% | 0.3% |
| NON-FORESTED WETLANDS | 4751 | 2.3% | 0.9% | 0.3% |
| OTHER AGRICULTURE | 2153 | 1.0% | 0.4% | 0.1% |
| PINE FLATWOODS | 3385 | 1.6% | 0.6% | 0.2% |
| RANGELAND | 7686 | 3.7% | 1.5% | 0.5% |
| ROW CROPS | 1231 | 0.6% | 0.2% | 0.1% |
| SALTWATER MARSHES | | | | |
| URBAN | 16723 | 8.0% | 3.2% | 1.1% |
| WATER | 3808 | 1.8% | 0.7% | 0.2% |
| WETLAND HARDWOOD FORESTS | 17196 | 8.2% | 3.3% | 1.1% |
| | | | | |
| Total (acres) | 210126 | 100.0% | 39.9% | 13.8% |
| Total (square miles) | 328 | | | |
| | | | | |
| Major Landcover Catgories | | | | |
| Agriculture | 50125 | 23.9% | 9.5% | 3.3% |
| Citrus | 28865 | 13.7% | 5.5% | 1.9% |
| Mining | 72390 | 34.5% | 13.8% | 4.7% |
| Rangeland | 7686 | 3.7% | 1.5% | 0.5% |
| Urban | 17140 | 8.2% | 3.3% | 1.1% |
| Water | 3808 | 1.8% | 0.7% | 0.2% |
| Wetlands/Forests | 30112 | 14.3% | 5.7% | 2.0% |
| | | | | |
| Totals | 210126 | 100.0% | 39.9% | 13.8% |



### 3.3.4.4 Payne Creek

Although one of the smallest sub-basins in the Peace River watershed, Payne Creek is second only to the Zolfo Springs sub-basin in terms of mining landcover. The 51,313 acres designated as mining (Table 3-13) constitute 64% of this 125 square mile drainage basin. It should be noted that the FLUCS landcover does not distinguish between acreage reclaimed, not reclaimed or actively being mined; however, this coverage does denote acreage that is or was at one time affected by mining.

### 3.3.4.5 Summary of Structural Alterations and Changes

As discussed above there have been extensive structural alterations and changes in the Upper Peace Creek watershed. Loss of substantial historic storage most likely results in a net reduction in base flow during sustained dry conditions. Pavement and other infiltration retardant surfaces decrease evapotransporation, reduce infiltration and results in greater runoff per unit of rainfall. Evidence of this appears to exist related to tropical storm Gabriel, which passed over the watershed in September 2001. The storm resulted in stream flow at Arcadia that had not been exceeded since 1948, in spite of coming on the heels of probably the worst three-year drought since rainfall was monitored over a century ago. In contrast, Hurricane Donna passed over the watershed in September 1960, on the heels of probably the three wettest years, yet peak flows in the Peace River Watershed were not as great. Additionally, mining, urban development, dredge and fill activities for agricultural activities, and other land use practices have forever changed significant areas of the Upper Peace River and associated creeks and floodplains. As previously discussed quantifying the cumulative impacts of these changes on flow is extremely difficult and will require sophisticated analyses such as fully intergrated, and adequately calibrated, surface and ground-water models.

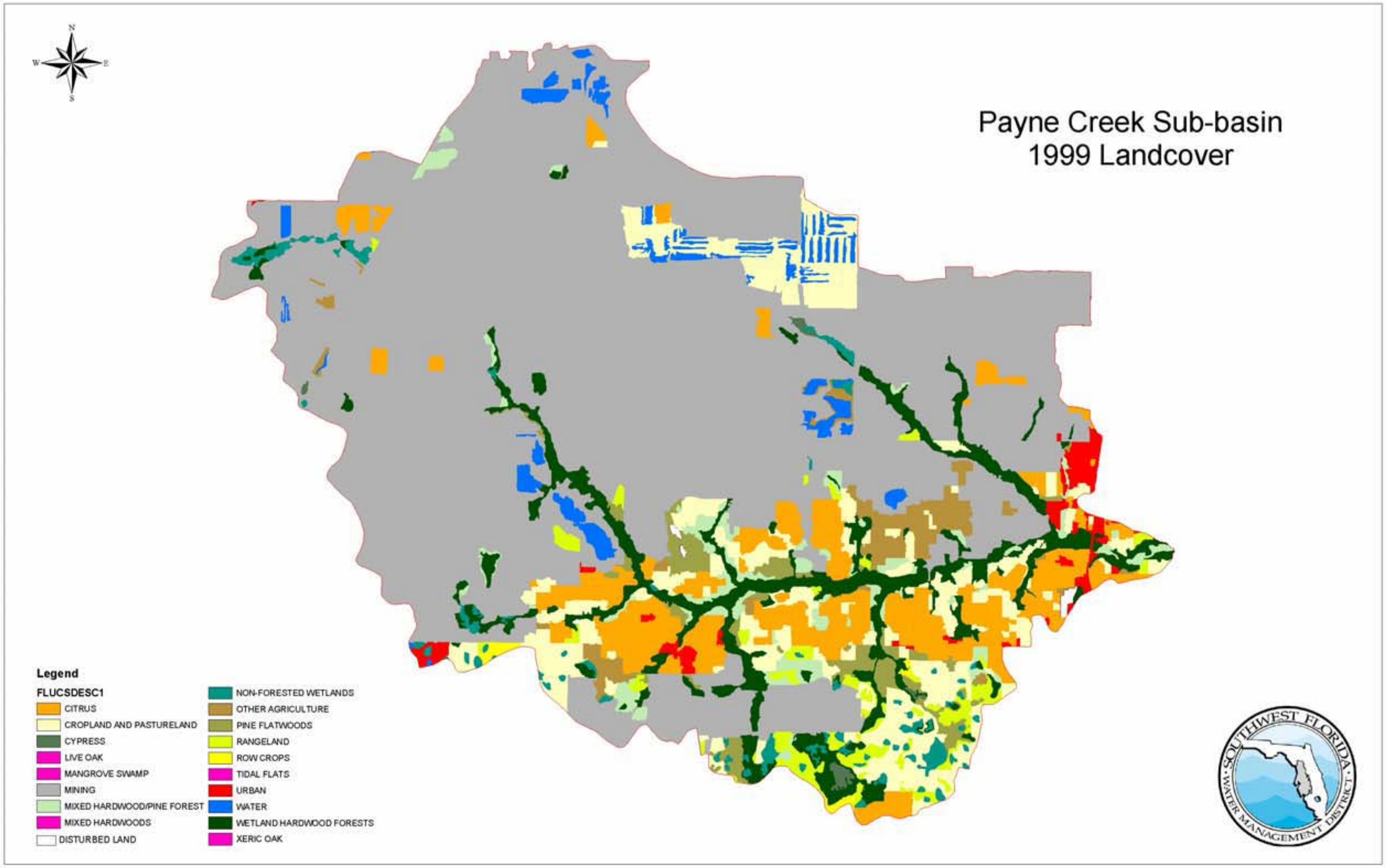
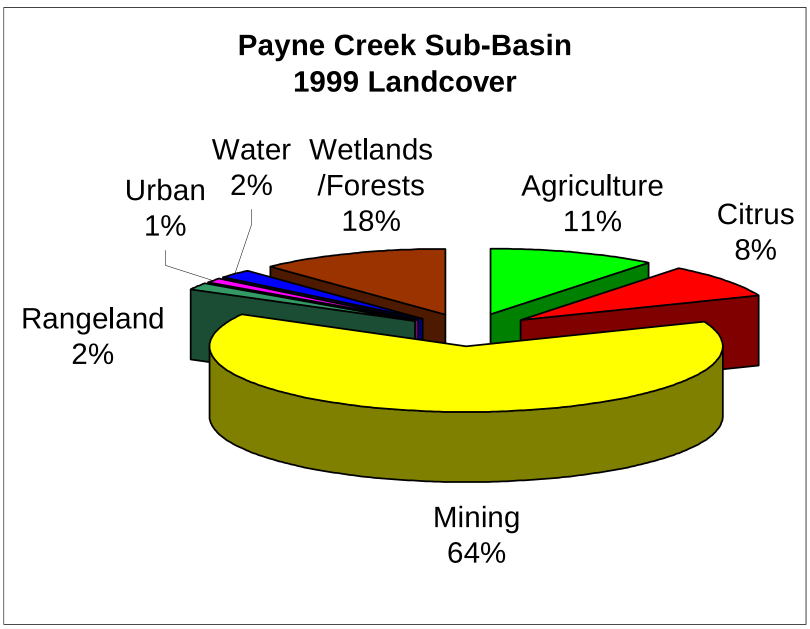



Figure 3-18. 1999 Landcover in the Payne Creek sub-basin of the Upper Peace River.

Table 3-14. 1999 landcover in the Payne Creek sub-basin. Data presented according to Florida Land Use Codes (FLUCS) and by major landcover categories as described in text**.**

| | Payne Ck Acres | % of Payne Creek | % of Upper Peace River | % of Peace River |
|---|---|---|---|---|
| FLUCSDESC1 | | | | |
| BARREN | 88 | 0.1% | 0.0% | 0.0% |
| CITRUS | 6586 | 8.2% | 1.3% | 0.4% |
| CROPLAND AND PASTURELAND | 6876 | 8.6% | 1.3% | 0.5% |
| CYPRESS | 144 | 0.2% | 0.0% | 0.0% |
| MANGROVE SWAMPS | | 0.0% | 0.0% | 0.0% |
| MINING | 51313 | 64.0% | 9.7% | 3.4% |
| MIXED HARDWOOD/PINE FOREST | 1682 | 2.1% | 0.3% | 0.1% |
| NON-FORESTED WETLANDS | 1093 | 1.4% | 0.2% | 0.1% |
| OTHER AGRICULTURE | 1502 | 1.9% | 0.3% | 0.1% |
| PINE FLATWOODS | 1442 | 1.8% | 0.3% | 0.1% |
| RANGELAND | 1390 | 1.7% | 0.3% | 0.1% |
| ROW CROPS | 161 | 0.2% | 0.0% | 0.0% |
| SALTWATER MARSHES | | | | |
| URBAN | 906 | 1.1% | 0.2% | 0.1% |
| WATER | 1660 | 2.1% | 0.3% | 0.1% |
| WETLAND HARDWOOD FORESTS | 5279 | 6.6% | 1.0% | 0.3% |
| Total (acres) | 80122 | 100.0% | 15.2% | 5.3% |
| Total (square miles) | 125 | | | |
| Major Landcover Catgories | | | | |
| Agriculture | 8539 | 10.7% | 1.6% | 0.6% |
| Citrus | 6586 | 8.2% | 1.3% | 0.4% |
| Mining | 51313 | 64.0% | 9.7% | 3.4% |
| Rangeland | 1390 | 1.7% | 0.3% | 0.1% |
| Urban | 994 | 1.2% | 0.2% | 0.1% |
| Water | 1660 | 2.1% | 0.3% | 0.1% |
| Wetlands/Forests | 9640 | 12.0% | 1.8% | 0.6% |
| Totals | 80122 | 100.0% | 15.2% | 5.3% |



### 3.3.5 Relevance of All Impacts to Declining Upper Peace River Stream Flow on Establishment of Minimum Flows

As described above there are a multitude of impacts to streamflow in the Upper Peace River. Florida Statute prescribes that existing structural alterations and changes be considered when establishing minimum flows and levels. This provision provides guidance that the minimum flows are to be set recognizing that there have been substantial changes from pre-development in many areas of the state. Florida Statutes also prescribe that minimum flows are to be set such that further withdrawals will not result in significant harm the water resources and ecology of the area. Finally, Florida Statute prescribes that minimum flows be established where deemed appropriate.

It is clear that ground-water withdrawals have significantly affected low-flow conditions in the Upper Peace River. Based on existing data and analysis, the effects of ground-water withdrawals on medium and high-flow conditions are not separable from structural alterations and changes, and the effects of long-term changes in climatic conditions. As a result, minimum flows are being recommended for only low-flow conditions at this time. The intent is to continue to evaluate the affects of anthropogenic and climatic changes on average and high-flow conditions and set minimum flows when these conditions are adequately understood.

It is extremely important to recognize that the proposed minimum low flows will require a recovery plan, as they are not presently being met. Such a plan will result in improvement to not only low flows, but also average and high flows as additional data and analyses are collected and conducted. This is consistent with past SWFMWD practice to not establish minimum flows and levels until an adequate understanding of the water body and factors affecting it is achieved. It is believed that this is also consistent with the intent of Florida statute to establish minimum flows and levels where it is appropriate to do so (i.e., adequate understanding of the water body exists).

## 3.4 Water Quality

Although flows can affect water quality, it is not expected that the adoption and achievement of minimum flows will necessarily lead to substantial changes in Peace River water quality; however, it is appropriate to review the water quality of the Peace River to fully appreciate how land use impacts have affected the river. The Peace River exhibits high nutrient concentrations rarely encountered in flowing water systems, because of its unique geologic setting and the mining of phosphate deposits in its watershed. The examination of water quality data is also useful in understanding the complex nature of flow changes in the Peace River, and in the case of dissolved potassium concentrations, may offer some insight into changing land use patterns.

Long-term water quality changes were evaluated using USGS data gathered at gage sites near Bartow, Ft. Meade, Zolfo Springs and Arcadia. Comparisons of water quality data with flow records were made for considering possible relationships between flow and land use. In addition, comparisons were made with sites on other river systems, specifically the Alafia River at Lithia (for which MFLs are currently being developed), the Withlacoochee River at Holder, and the Myakka River near Sarasota for reference purposes. The Withlacoochee River in contrast to the Alafia and Peace Rivers exhibits relatively good water quality. This is in part attributable to land use differences and in part attributable to inherent differences in geologic setting. Because both the Alafia and Peace River watersheds lie in the Bone Valley geologic formation and because both watersheds have been mined for phosphate, it was deemed desirable to evaluate water quality on a river system minimally impacted by phosphate mining. Phosphate mining has occurred historically in the Withlacoochee River watershed, specifically in the Dunnellon-Rainbow River area.

For the following analyses, all available water quality data were retrieved from the USGS on-line database. While some data are available on many water quality parameters, analysis was restricted to those parameters for which it was felt that a sufficient number of observations existed for inspection of trends. The USGS has long-term flow and water quality data for a number of gage sites throughout the District. Flow records at many sites exceed 50 to 60 years, and some of these have water quality records of 40 years or more. Except for special studies of relatively short duration, water quality at most USGS sites was typically monitored on a quarterly basis.

### 3.4.1 Macronutrients: Phosphorus and Nitrogen

Concentrations of the two major macronutrients, phosphorus and nitrogen, have been monitored for some time at Peace River gage sites. The exact form of the nutrient monitored has changed over time (e.g., total nitrate, dissolved nitrate, nitrate+nitrite, total nitrogen, etc.), however.

#### 3.4.1.1 Phosphorus

Phosphorus has over the years been variously reported by the USGS as total phosphorus, dissolved phosphate and as ortho-phosphate. For purposes of this discussion, it was assumed that dissolved phosphate and ortho-phosphate are essentially equivalent. Any values reported as mg/l phosphate were converted to mg/l phosphorus (P). Historic phosphorus concentrations measured at all Peace River mainstem sites were impressive. As can be seen (Figure 3-19)**,** historic phosphorus concentrations frequently exceeded 5 and at times exceeded 20 mg/l as P at upstream sites. These high concentrations were attributed to water discharged from phosphate mining operations or their associated chemical plants. While elevated phosphate concentrations in streams can potentially be ascribed to numerous sources (e.g., waste water treatment plant discharges, some industrial discharges, fertilizer applications by agriculture or from residential areas), there can be little doubt that the elevated concentrations seen in the Peace River from approximately the 1950s (when routine water quality analysis began) to the mid1980s are directly associated with phosphate mining activities. Supporting data are seen in elevated concentrations of other chemical constituents, for example fluoride, which are commonly found in association with phosphate deposits. Beginning in the early to mid-1980s there is a rather sudden decline in phosphorus and other chemical constituents found in association with phosphate ore (e.g., fluoride, silica). This decline is graphically apparent in the mid 1980s (see Figure 3-19 and 3-20), and close inspection suggests another decline around 1990-1992. Concomitant declines in fluoride and phosphorus are evidence of a change in mining practices that lead to dramatic reductions in phosphorus (and other constituent) loading to the Peace River system around 1983-1985. The reductions in the early 1990s may be attributable to diversion of domestic wastewater treatment plant discharges.

Unfortunately, there are no long-term records of in-stream phosphorus concentrations at mainstem sites on the Peace River prior to phosphate mining in the upper watershed. Therefore, it is difficult to determine if current in-stream concentrations approach those that would have been expected absent mining impacts. It should be noted that while there has been a considerable decrease in loading (perhaps an order of magnitude or more), concentrations of phosphorus (the majority of which is in the most biologically available form, phosphate) are still high when compared to most natural stream systems. Friedemann and Hand (1989) determined the typical ranges of various constituents found in Florida lakes, streams and estuaries. Based on their findings 95% of all Florida streams exhibited total phosphorus concentrations less than 1.99 mg/l P, and 90% had concentrations below 0.87 mg/l P. Therefore, the Peace River at best is still in the 90th percentile of streams with respect to phosphorus concentration. It should also be noted that given the co-occurrence of large phosphate concentrations and relatively high nitrite-nitrate nitrogen concentrations over the length of the Peace River from Bartow to Arcadia that neither nutrient is limiting primary productivity.

Similar trends in instream phosphorus concentrations are also evident in the Alafia River. Phosphorus concentrations in Alafia River system historically exceeded 5 to10 mg/l P. As with the Peace River, these elevated levels were also attributable to past mining practices and discharges from related chemical plants. Similarly to the Peace River, a dramatic decreases in concentrations have also occurred in the Alafia River (Figure 3-21); the decrease in the Alafia predated the decrease in the Upper Peace and occurred around 1980. Like the Peace River, other constituents found in association with phosphate also followed similar trends in concentration (Figure 3-21) and similar declines as phosphate mining practices changed. Unlike the Upper Peace River, phosphorus and nitrogen concentrations were not significantly negatively correlated with flow. The relationship between nutrient concentrations and flow in the Alafia River is confounded by the fact that low flows are being maintained by an unnaturally higher baseflow (apparently mining and agriculturally related).

Both the Peace and Alafia River watersheds lie within the Bone Valley geologic area, and thus elevated phosphorus concentrations might be expected. Trends in phosphorus concentrations of the Withlacoochee River at the USGS Holder gaging site were examined (Figure 3-22). Like both the Alafia and Peace Rivers, the headwaters of the Withlacoochee River lie within the Green Swamp; however, unlike the Alafia and Peace Rivers, phosphate has not been extensively mined in the watershed. As a result, one might expect to find lower naturally occurring in-stream concentrations of phosphorus. Phosphorus concentrations in the Withlacoochee River, as measured at the Holder gaging site, are more than an order of magnitude lower than concentrations now encountered in the Peace River. There has been little change in phosphorus concentrations in the Withlacoochee River at the Holder site other than what one might expect as a result of natural variation.

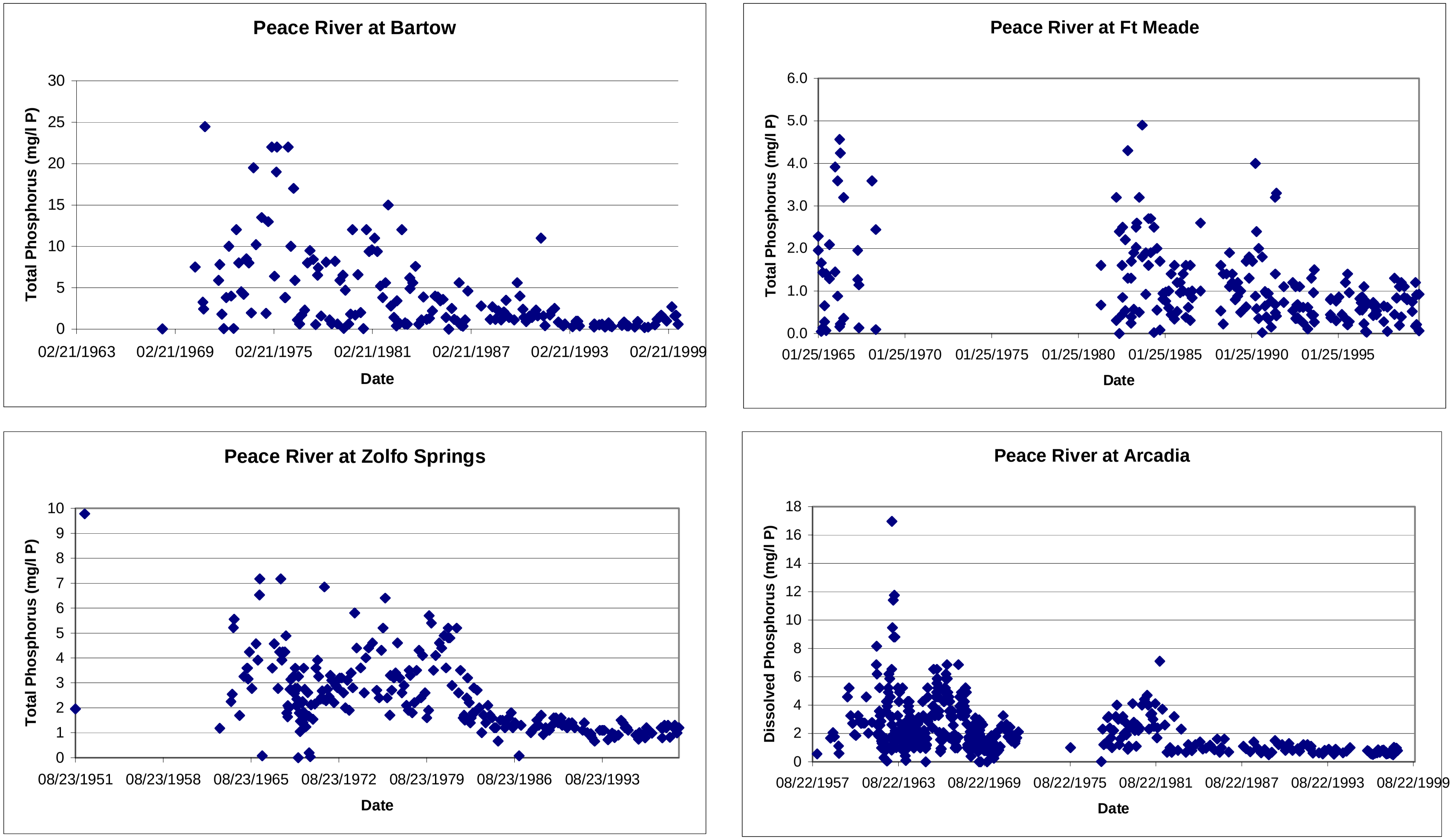



Figure 3-19. Phosphorus concentrations in water samples collected by USGS at four long-term gage sites on the Peace River.

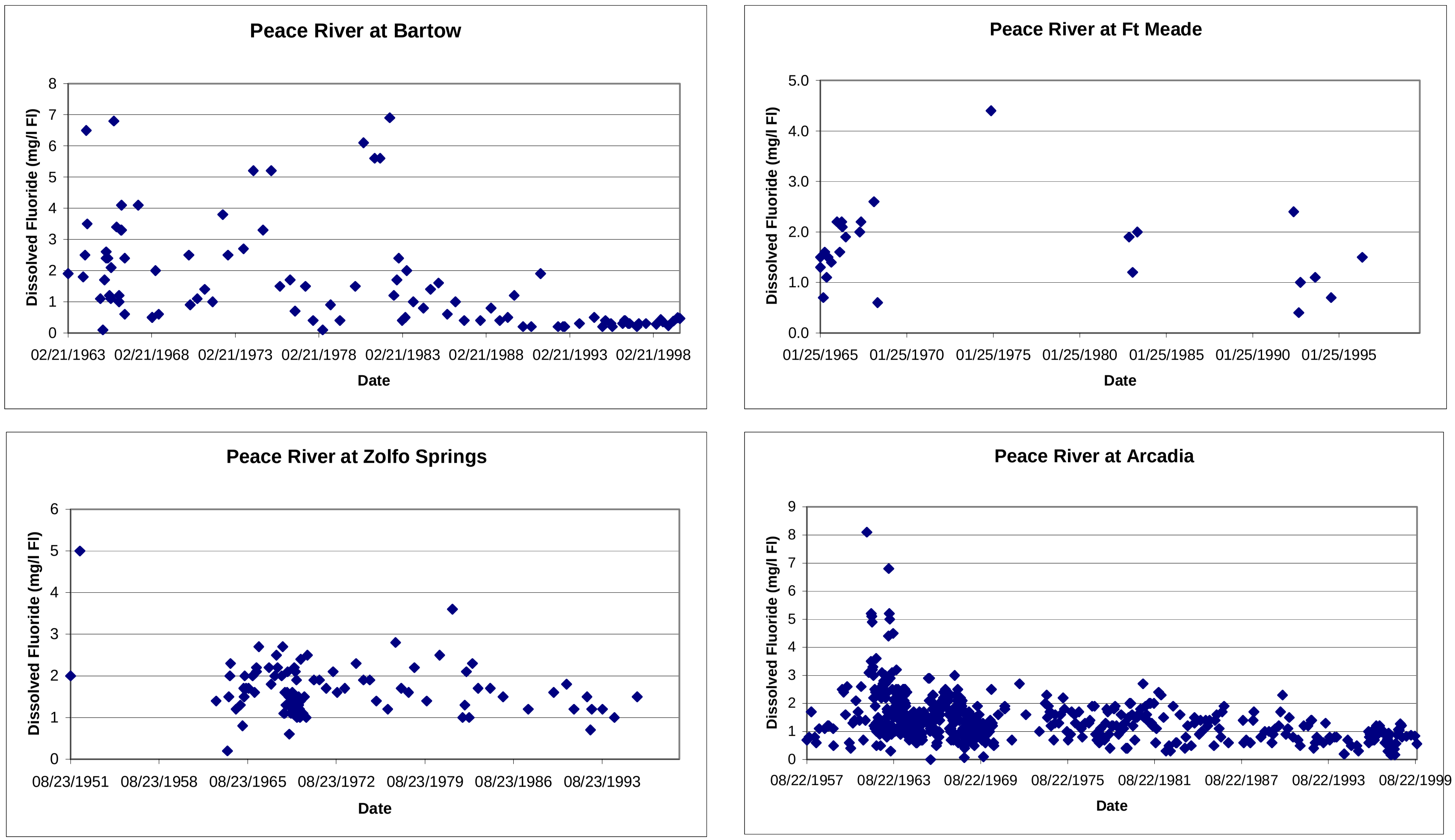



Figure 3-20. Dissolved fluoride concentrations in water samples collected by UGSS at four long-term gage sites on the Peace River.

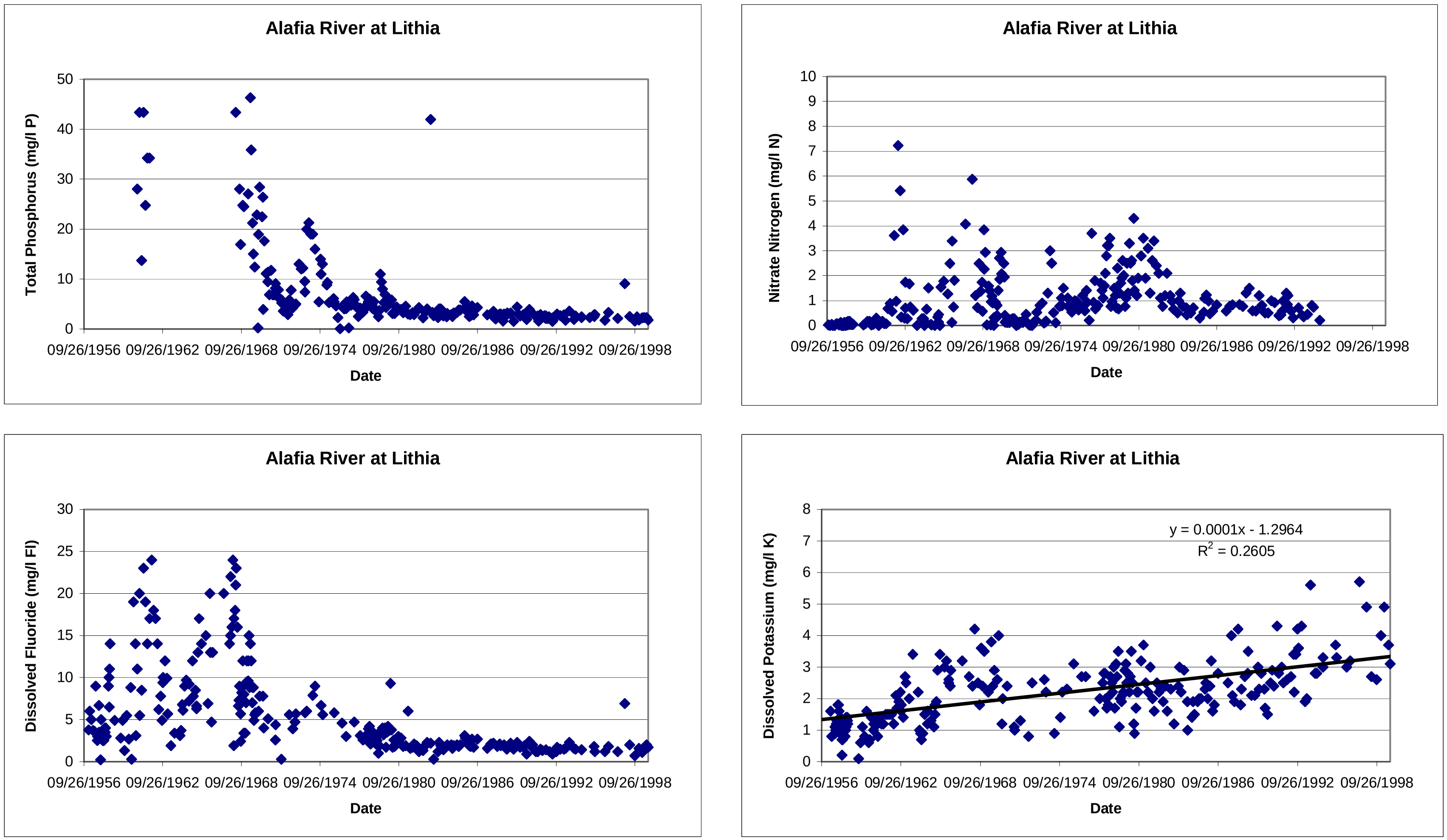



Figure 3-21. Concentrations of selected parameters in water samples collected by USGS at the Lithia Gage on the Alafia River.

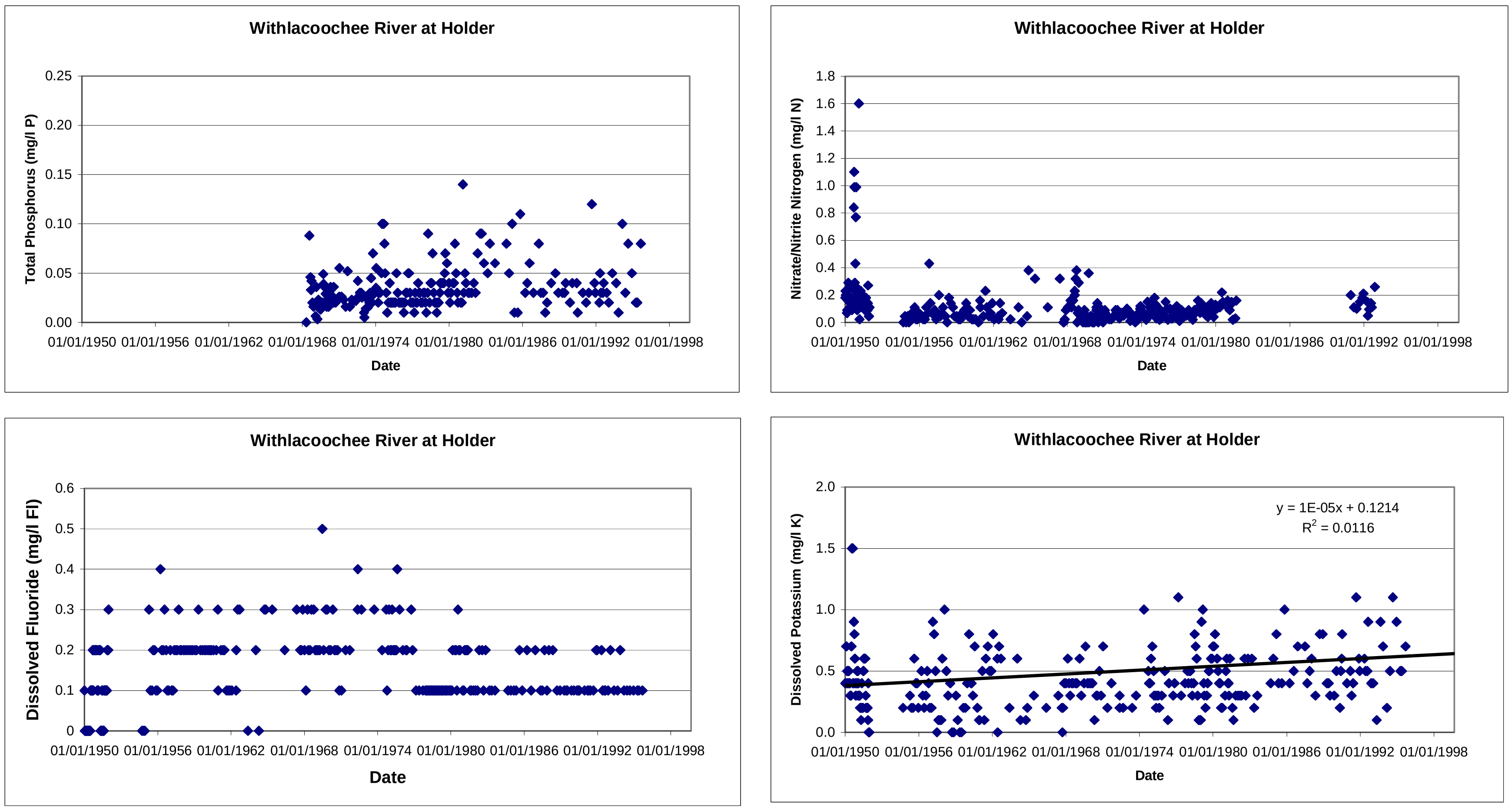



Figure 3-22. Concentrations of selected parameters in water samples collected by USGS at the Holder Gage on the Withlacoochee River.

### 3.4.1.2 Nitrogen

Nitrogen has most often been reported by the USGS in the more readily bio-available form; either nitrate or nitrate+nitrite. Concentrations have been variously expressed as mg/l nitrate and mg/l nitrogen. For purposes of this discussion, it was assumed that total nitrate, dissolved nitrate, and nitrate+nitrite were essentially equivalent, unless both were reported. In this case, the highest concentration was used for data analysis. Total Kjeldahl nitrogen, total organic nitrogen, ammonia nitrogen (also a readily bio-available from) and total nitrogen are not considered here, because considerably fewer observations were generally made for these parameters. All concentrations for nitrogen are reported as mg/l N. Although data were reviewed for the Ft. Meade gage site, the record at this station is considerably shorter than at the other mainstem sites. Figure 3-23 for nitrate+nitrite concentrations at mainstem Peace River stations indicates a general decrease in inorganic nitrogen concentrations; historically concentrations of 1.0 mg/l were commonly encountered at all sites, and despite the fact that nitrate-nitrite nitrogen was significantly negatively correlated with discharge (correlation matrix for each site included in Appendix WC) at most sites (Bartow was the only exception), concentrations were typically higher downstream from Bartow. The mean and median nitrite+nitrate concentrations at Bartow were 0.35 and 0.23 mg/l N compared with concentrations of 0.71 and 0.64 mg/l N at Arcadia and 0.91 and 0.77 mg/l N at Zolfo Springs. Inorganic nitrogen concentrations likewise tended to be positively correlated with phosphorus concentrations. Given the large decrease in inorganic phosphorus concentrations (see discussion below), the apparent decrease in inorganic nitrogen concentrations which have occurred over the last decade or so, and the fact that both nutrients tended to be negatively correlated to flow, it can be inferred that inorganic nutrient loading to downstream areas is now less than that which occurred historically.

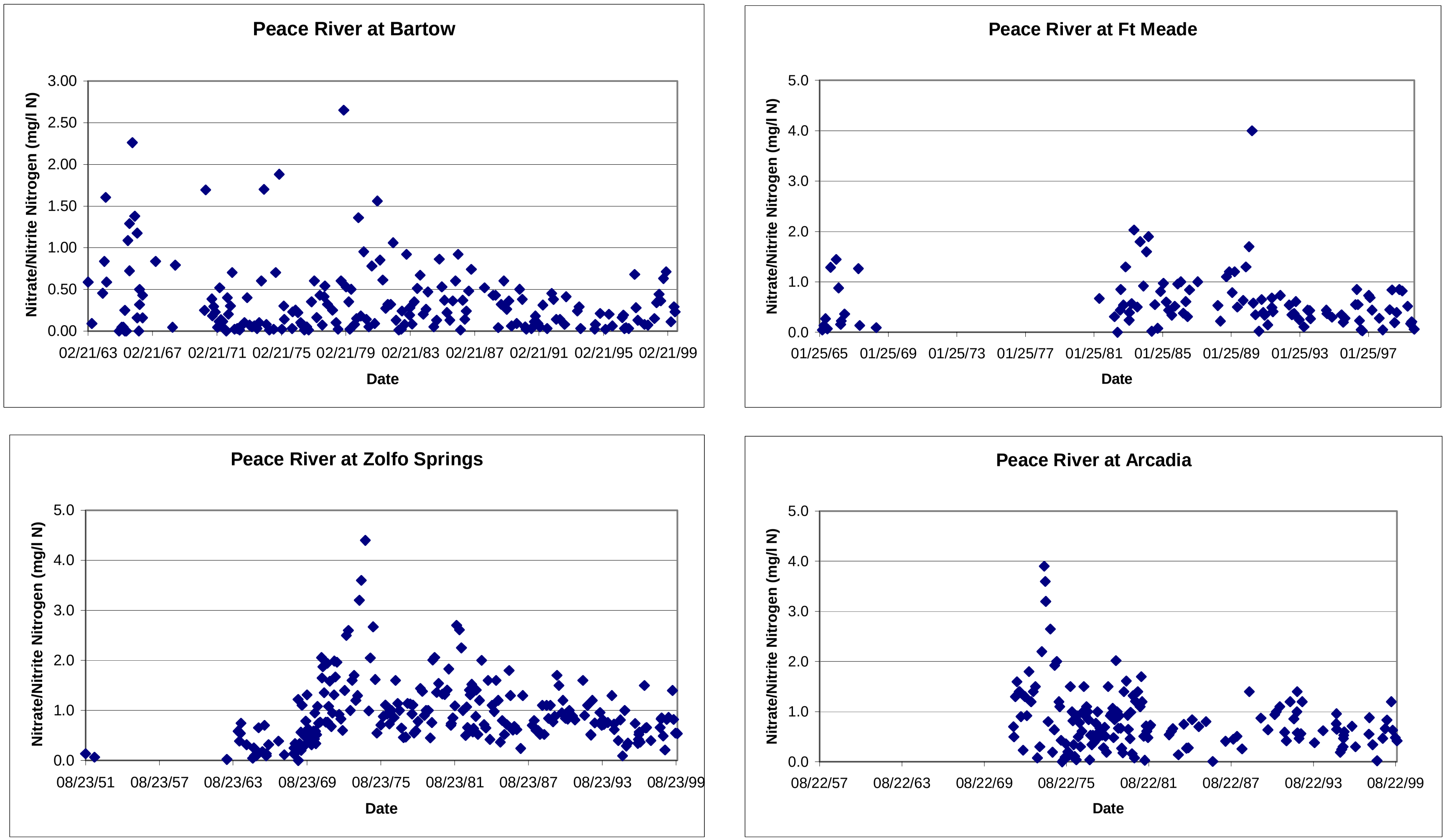



Figure 3-23. Nitrate/nitrogen concentrations in water samples collected by USGS at four long-term gage sites on the Peace River.

### 3.4.2 Potassium

One of the more interesting and unanticipated findings of the analysis of gage site water quality data was an apparent increasing trend in dissolved potassium concentration (Figure 3-24a; Peace River at Arcadia). A Seasonal Kendall test was run on the data to factor out any affect due to discharge, and the results were highly significant (Table 3-15). The increasing trend, irrespective of flow, denotes a real trend toward increasing loading of dissolved potassium. It is speculated that this trend is most likely attributable to increasing fertilizer application within the watershed and thus may have some value as an indicator of increasing agricultural activity. However, there is currently no known biological consequence that can be attributed to this increasing trend. Inspection of dissolved potassium values at the Withlacoochee River at Holder (Figure 3-22) and inspection of ground water concentration data suggest that dissolved potassium rarely exceeds 1.0 mg/l under natural conditions. The upper Myakka River watershed is known to be impacted by agricultural activity which has artificially increased baseflow. The watershed is largely rural. Because of these factors, water quality data were inspected to see if there was an increasing trend in dissolved potassium in this stream as well. It was reasoned that if the increasing trend in potassium was agriculturally related, it should be apparent in this watershed. Although the period of record is comparatively short and there are relatively few observations, there has been a noticeable increase in dissolved potassium concentration (and several other parameters) in the Myakka River (Figure 3-24b; Myakka River at Sarasota).

Table 3-15. Results of Seasonal Kendall trend test on dissolved potassium data for USGS gage at Arcadia. Analysis done using MiniTab.

| Variable | N | N* | Mean | Median | TrMean | StDev |
|---|---|---|---|---|---|---|
| Date | 694 | 0 | 26901 | 25415 | 26681 | 3978 |
| Residual | 543 | 151 | 0.2195 | -0.1371 | 0.1221 | 1.243 |

| Variable | SE Mean | Minimum | Maximum | Q1 | Q3 |
|---|---|---|---|---|---|
| Date | 151 | 14549 | 36432 | 23862 | 29102 |
| Residual | 0.0533 | -2.9297 | 6.5047 | -0.6283 | 0.7053 |

Data Display

| Row | SEA2 | N_SEA | S_TAU | TAU_A | Z_S | P_VALUE | INTRCEPT |
|---|---|---|---|---|---|---|---|
| 1 | 1 | 38 | 259 | 0.3684 | 3.2436 | 0.0012 | -3.8607 |
| 2 | 2 | 47 | 428 | 0.3959 | 3.9166 | 0.0001 | -5.2582 |
| 3 | 3 | 53 | 604 | 0.4383 | 4.6254 | 0.0000 | -3.9365 |
| 4 | 4 | 44 | 210 | 0.2220 | 2.1139 | 0.0345 | -3.5037 |
| 5 | 5 | 46 | 323 | 0.3121 | 3.0487 | 0.0023 | -3.5834 |
| 6 | 6 | 53 | 832 | 0.6038 | 6.3744 | 0.0000 | -5.3659 |
| 7 | 7 | 47 | 547 | 0.5060 | 5.0071 | 0.0000 | -6.9420 |
| 8 | 8 | 40 | 548 | 0.7026 | 6.3731 | 0.0000 | -6.6999 |
| 9 | 9 | 55 | 983 | 0.6620 | 7.1292 | 0.0000 | -7.2759 |
| 10 | 10 | 45 | 694 | 0.7010 | 6.7792 | 0.0000 | -6.6969 |
| 11 | 11 | 33 | 273 | 0.5170 | 4.2150 | 0.0000 | -5.6096 |
| 12 | 12 | 42 | 475 | 0.5517 | 5.1369 | 0.0000 | -4.3725 |

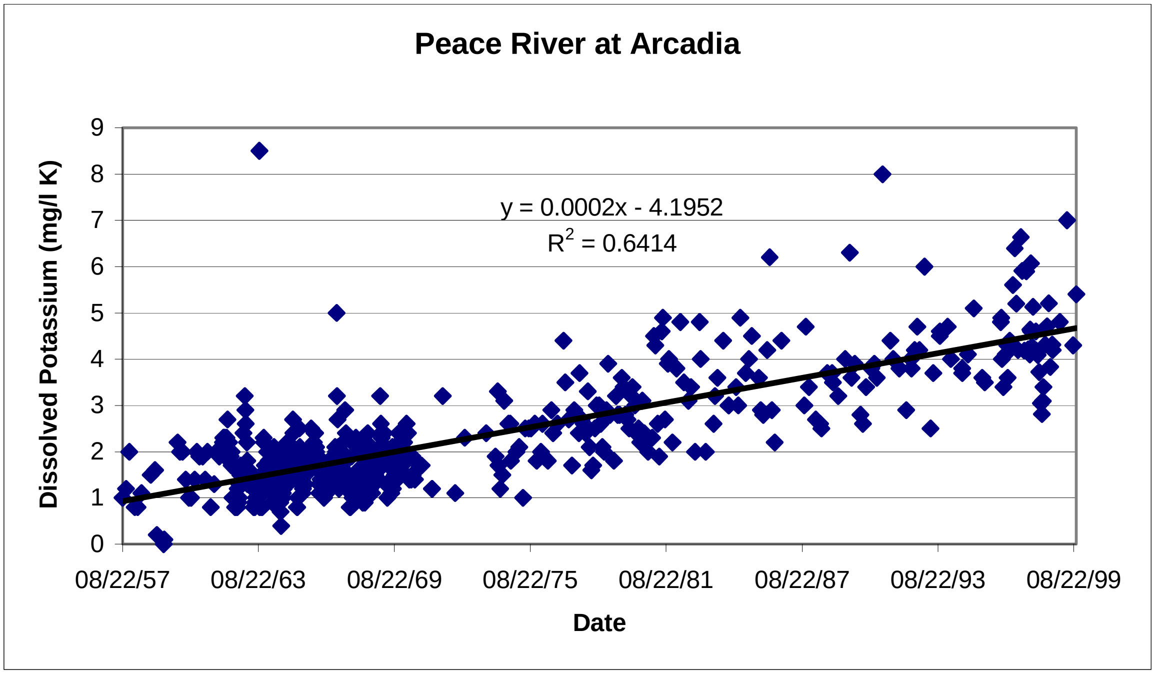
| SLOPE | | | | | | |
|---|---|---|---|---|---|---|
| | 0.0002 | 0.0002 | 0.0002 | 0.0001 | 0.0001 | 0.0002 |
| | 0.0003 | 0.0002 | 0.0003 | 0.0003 | 0.0002 | 0.0002 |

********************************************

COMBINEI SEASONAL KENDALL OVERALL RESULTS

Data Display

| Row | N_ALL | S_ALL | TAU_ALL | Z_ALL | PVAL_ALL | SEAINTER | SEASLOPE |
|---|---|---|---|---|---|---|---|
| 1 | 543 | 6176 | 0.5043 | 16.8378 | **0.0000** | -5.4414 | **0.0002** |



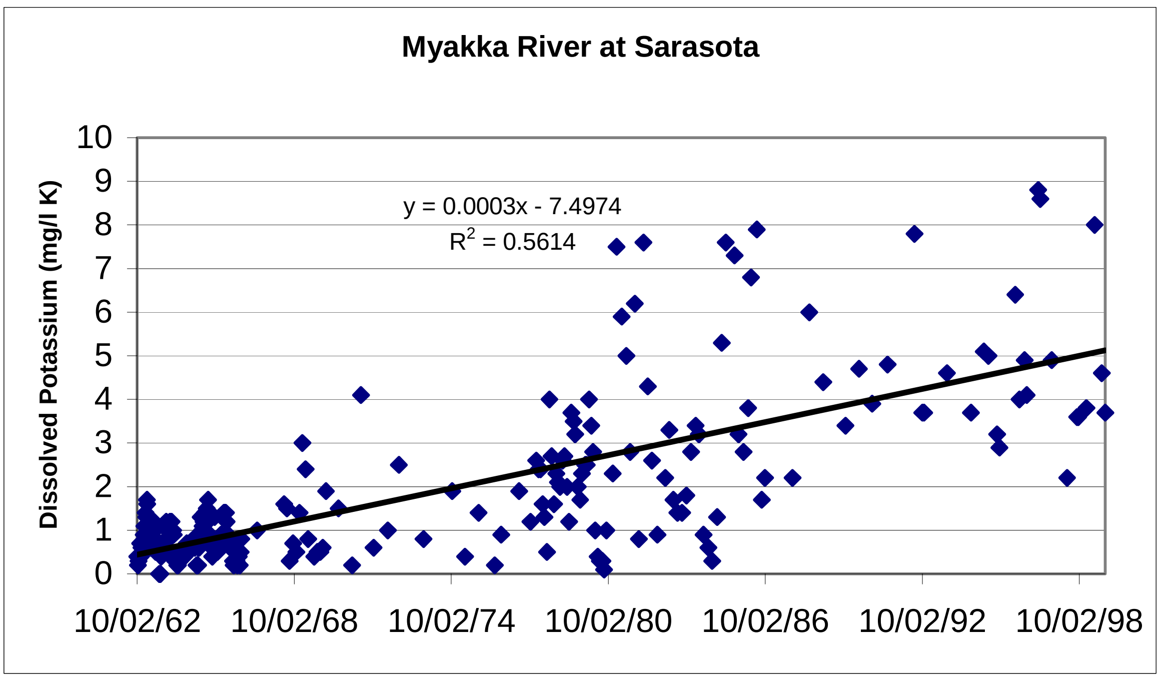




Figure 3-24. Concentrations of dissolved potassium in water samples collected by USGS at the Arcadia gage on the Peace River and at the Myakka River gage near Sarasota.

### 3.4.3 Dissolved Oxygen

Past reports summarizing water quality have noted that concentrations of dissolved oxygen (DO) frequently fall below the state standard of 4.0 mg/l in the Upper Peace River, and it has been implied, if not explicitly stated that this is an indication of poor water quality related to pollution. However, it is also known that DO concentrations can fall below this standard due to natural circumstances. For example, blackwater (swamp water) released from isolated wetlands during higher flows can even lead to fish kills in rivers and streams. The accumulation of muck and peaty soils characteristic of swamps occurs because anoxic conditions exist in these environs. While it is believed that the low DO concentrations seen in the Upper Peace River from Bartow to Ft. Meade are related to organic loading from hypereutrophic Lake Hancock, single DO measurements on a sampling date are not sufficient to adequately assess this impact. Inspection of DO plots for the various gage sites reveals the wide variance to be expected. DO is known to show a diel fluctuation, and it is expected that lowest concentrations should be encountered at early morning before photosynthesis begins, and that concentrations should increase throughout the day until dusk. It was noted by inspection of correlation matrixes for each site that DO was significantly negatively correlated with flow except at Bartow (r=-0.048, p=0.522) suggesting a contribution of lower DO (swamp) water as flows increase. This negative correlation was also seen for the Withlacoochee River at Holder (r=-0.450, p<0.001) and suggested by a non-significant negative correlation on the Alafia River at Lithia (r=-0.115, p=0.064). Despite these results, it is believed that re-establishment of baseflow under low flow conditions will only serve to improve DO concentrations in the uppermost river segment.

### 3.4.4 Other Water Quality Studies / Information

“In 1996 a watershed assessment project . . . . raised questions regarding the adequacy of the currently-available water quality data to support watershed management decisions, and recommended that more frequent (e.g., biweekly or monthly) water quality monitoring be initiated at selected stream gaging stations in the Peace” basin (CHEC 2001). As a result of this recommendation, a cooperative effort is now underway which is monitoring eleven stations in the Peace River basin. Monitoring stations are co-located at USGS stream gaging sites making it possible to compute loading rates as well as concentrations of various water quality parameters. The 2001 Annual Report examined current and long term trends (1970-1998) in water quality at numerous sites within the Peace and Myakka River basins. Some of these trends will be reviewed in light of our understanding of flows in the Upper Peace River watershed.

CHEC (2001), for example noted statistically significant upward trends in annual mean specific conductance at three tributary sites (presumably due to increasing discharges of agriculturally applied groundwater). Downward trends were noted at three sites including the Bartow and Zolfo Springs gages. CHEC (2001) concluded that, “the downward trends presumably reflect declining inputs of groundwater to surface waters in the areas where those trends occurred, perhaps in response to regional declines in the potentiometric surface of the Upper Floridan aquifer." While it is true that declines are probably due to declining inputs of groundwater, these declines are not likely the response to continual and recent declines in the potentiometric surface. As has been demonstrated by a number of workers, the potentiometric surface was sufficiently lowered prior to 1970 that it is doubtful that natural discharges from the Floridan and intermediate aquifers have substantially contributed to the baseflow in the Upper Peace River for some time. The fact that Kissengen Springs ceased flowing in 1950 is evidence that the aquifer probably contributed little if any to baseflow by 1970. Rather it is believed, that based on inspection of water quality data (for example, phosphorus and fluoride) and stream flow data, that reductions in specific conductance represent the elimination or substantial curtailment of phosphate mining and related chemical plant discharges initially (prior to 1985) followed by the removal of wastewater treatment plant discharges in the upper part of the watershed (in the later 1980s to early 1990s).

CHEC (2001) observed statistically significant downward trends in annual mean nitrate+nitrite concentrations at upper Peace River sites and speculated that these trends may be due to "land use changes and other anthropogenic activities." CHEC (2001) suggested that "such activities be examined as potential causes underlying the trends." Again, based on inspection of concentration plots over time, it is suggested that these reductions are largely due to the curtailment or reduction of phosphate mining and related chemical plant discharges, although it is likely that some further reduction in nitrate+nitrite concentrations resulted due to improvement in wastewater treatment and elimination or diversion of discharges. The significant downward trends in phosphorus and total nitrogen noted by CHEC (2001) are again attributable to improvement in mining operations, removal or curtailment of discharges from mining and associated chemical plants followed by improvements in wastewater treatment practices.

### 3.4.5 Water Quality Summary

In summary, there have been rather dramatic improvements in water quality in the Upper Peace due to reduction or elimination of phosphate mine and associated chemical plant discharges, with some further improvement possibly due to improved wastewater treatment practices. Recent reductions (since 1970) in conductance are not related to loss of natural baseflow, but rather the elimination of discharges that in some respects masked the earlier loss of baseflow. As was stated earlier in the discussion of flows in the Upper Peace River watershed, while Kissengen Springs ceased discharging around 1950 as a result of the generalized lowering of the potentiometric surface, the full ecological effects of loss of natural baseflow were not fully realized until anthropogenic discharges were greatly reduced. Finally, it is suggested that an unanticipated increasing trend in potassium may be related to increasing fertilizer application in the watershed.

# Chapter Four

# Ecological Resources of Concern and Key Habitat Indicators

## 4.1. Resources and Area of Concern

The resources addressed by this minimum flows and levels analysis include the surface waters and biological communities associated with the Upper Peace River system, including the river channel and its floodplain. The Upper Peace River system comprises one of the most important hydrologic and ecological features in west-central Florida. The river system is physiographically complex, with a meandering channel and extensive floodplain wetlands. This hydrologic and physical setting provides habitat for a diverse array of plant and animal populations. The Peace River system has been identified as a critical component of a wildlife corridor network for the region (Cox et al. 1984, SWFWMD 2001a). Accordingly, a primary objective of this minimum flows and levels analysis is to provide for the hydrologic requirements of biological communities associated with the Upper Peace River system.

Human uses of the natural resources of the Upper Peace River are also an important consideration for the establishment of minimum flows and levels . Such uses include fishing, wildlife observation, general recreation, aesthetic enjoyment, canoeing and boating.

## 4.2. Resource Management Goals and Key Habitat Indicators

A habitat based approach was primarily used for development of minimum flows and levels for the Upper Peace River. The Upper Peace River system includes a great variety of aquatic and wetland habitats that support an array of biological communities. To facilitate the minimum flows and levels analysis, it was necessary to identify certain key habitats and the hydrologic requirements for specific biotic assemblages. It was assumed that addressing these management goals would also provide for other ecological functions of the river system that are harder to quantity, such as organic matter transport and the maintenance of river channel geomorphology.

The resource management goals for the upper river addressed by this minimum flows analysis are listed in summary bullets on the next page.  This is followed by the rationale for each of these goals and a description of their corresponding habitats or ecological indicators.  The field and analytical methods used to assess the distribution and hydrologic requirements of these habitats and indicators are described in Chapter Five, and the results of the minimum flows and levels analysis is presented in Chapter Six.

Resource Management Goals

- Maintain minimum depths for fish passage and canoeing in the upper river
- Maintain depths above inflection points in the wetted perimeter of the stream bottom
- Inundate woody habitats in the stream channel
- Meet the hydrologic requirements of floodplain biological communities

### 4.2.1. Fish Passage

Under lowest flow conditions it was deemed desirable to maintain water levels to allow fish passage on the Upper Peace River. It was reasoned that depths adequate for fish passage were historically maintained by groundwater baseflow in the upper river. In recent years, however, much of the upper river becomes separated into a series of isolated pools during prolonged dry periods. As dry season conditions persist, many of these pools contract in size and dry completely, greatly impacting fish populations and other aquatic life in the upper river. Accordingly, determining flows that would allow fish passage is an important goal for establishing minimum flows and levels for the Upper Peace River.

It was further reasoned that maintaining depths adequate for fish passage would ensure continuous flow and allow for recreational navigation (e.g., canoeing), improve aesthetics, and avoid or lessen other potential problems related to pool isolation (e.g., high water temperatures, low dissolved oxygen concentrations, localized phytoplankton blooms, and increased predatory pressure resulting from loss of habitat/cover).

### 4.2.2. Wetted Perimeter Inflection Point

A useful technique for evaluating the relation between the quantity of stream habitat and the rate of streamflow involves an evaluation of the “wetted perimeter” of the stream bottom. Wetted perimeter is defined as the distance along the stream bed and banks at a cross section where there is contact with water. According to Annear and Conder (1984), wetted perimeter methods for evaluating streamflow requirements assume that a direct relationship between wetted perimeter and fish habitat exists in streams. By plotting the response of wetted perimeter to incremental changes in discharge, an inflection can be identified in the resulting curve where small decreases in flow result in increasingly greater decreases in wetted perimeter. This point on the curve represents a flow at which the water surface recedes from stream banks and fish habitat is lost at an accelerated rate. Stalnaker et at. (1995) describe the wetted perimeter approach as a technique for using “the break or inflection point in the stream’s wetted perimeter versus discharge relation as a surrogate for minimally acceptable habitat. The inflection point represents that flow above which the rate of wetted perimeter gain begins to slow.” When this approach is applied to riffle (shoal) areas, “the assumption is that minimum flow satisfies the needs for food production, fish passage and spawning.”

We view the wetted perimeter approach as an important technique for evaluating minimum flows and levels in the low end of the flow regime for the Upper Peace River. Studies on streams in the southeast (Benke et al. 1985) have demonstrated that the greatest amount of macroinvertebrate biomass per unit reach of stream occurs on the stream bottom. Although production on a unit area basis may be greater on snag and root habitat, the greater area of stream bottom along a reach makes it the most productive habitat under low flow conditions. Recovery of water levels in the Upper Peace River at the wetted perimeter inflection point in the channel would provide for large increases in bottom habitat for relatively small increases of flow. This point is defined as the “the lowest wetted perimeter inflection point” or LWPIP . It was not assumed that LWPIP met fish passage needs or addressed possible wetted perimeter inflection points outside the river channel. Instead, it was concluded the LWPIP provides the greatest amount of inundated bottom habitat in the channel of the river on a per-unit flow basis.

### 4.2.3. Instream Woody Habitat

Stream ecosystem theory emphasizes the role of instream habitats in maintaining ecosystem integrity. Habitats form a mosaic of geomorphically defined substrate patches (Brussock et al. 1985), each with characteristic disturbance regimes and macroinvertebrate assemblages (Huryn and Wallace 1987). For instance, invertebrate community composition and production in a blackwater river varies greatly among different habitat types, where the habitats are distinguished by substrates of different stability (e.g.,sand, mud and woody debris) (Benke el al. 1984, Smock et al. 1985, Smock and Roeding 1986). Eventually, ecosystem dynamics are influenced by the relative abundance of these different habitat types. Changes in community composition and function occurring along the river continuum are in part a consequence of the relative abundance of different habitat patches which are under the control of channel geomorphology and flow. Key habitats and features that play a significant role in the ecology of the Upper Peace River were identified using a habitat based approach that includes a combination of best available data, published research, and site specific field work.

Among the various instream habitats that can be influenced by different flow conditions, woody habitats (snags and roots) are especially important. In low-gradient streams of the southeastern U.S.A. coastal plain, wood is recognized as important habitat (Cudney and Wallace 1980; Benke et al. 1984, Wallace and Benke 1984; Thorp et al. 1990; Benke and Wallace 1990). Wood habitats harbor the most biologically diverse instream fauna and are the most productive habitat on a per unit area basis (Benke et al., 1985). Comparisons of different instream habitats, indicate that production on snags was at least twice as high as that found in any other habitat (Smock et al. 1985).
Wood provides advantages as habitat, as it is relatively stable and long lived compared to sand substrata which constantly shift (Edwards and Meyer 1987). Even bedrock

substrates, though the most stable of all, are susceptible to smothering by shifting sand and silt. Wood is a complex structural habitat with microhabitats (such as interstices that increase surface area) that provide cover for a variety of invertebrates. As an organic substrate, wood is also a food resource for utilization by microbial food chains, which in turn supports colonization and production of macroinvertebrates.

As physical impediments to flow, woody structures enhance the formation of leaf packs and larger debris dams. These resulting habitats provide the same functions as woody substrata in addition to enhancing habitat diversity instream. Higher trophic levels such as fish have been shown to also depend on woody structures either for cover, as feeding grounds, or as nesting areas.

Since woody habitats are potentially the most important instream habitat for macroinvertebrate production, inundation of these habitats for sufficient periods is considered critical to secondary production (including fish and other wildlife) and the maintenance of aquatic food webs. Not only is inundation considered important, but sustained inundation prior to colonization by invertebrates is necessary to allow for microbial conditioning and periphyton development. Without this preconditioning, the habitat offered by snags and wood is essentially a substrate for attachment without associated food resources. The development of food resources (microbes) on the substrate is needed by the assemblage of macroinvertebrates that typically inhabit these surfaces. After the proper conditioning period, continuous inundation is required for many taxa to complete development.

### 4.2.4. Hydrologic Requirements of Floodplain Biological Communities

A goal of the minimum flows and levels approach for the Upper Peace River is to ensure that the hydrologic requirements of biological communities associated with the river floodplain are met. The periodic inundation of riparian floodplains by high flows is closely linked with the overall biological productivity of river ecosystems (Crance 1988, Junk et al, 1989). Many fish and wildlife species associated with rivers utilize both instream and floodplain habitats, and inundation of the river floodplain greatly expands the habitat and food resources available to these organisms (Wharton et al. 1982, Ainsle et al. 1999, Hill and Cichra 2002). Inundation during high flows also provides a subsidy of water and nutrients that supports high rates of primary production in river floodplains (Conner and Day 1979, Brinson et al. 1981, Uranowski et al. 2002). This primary production produces large amounts of organic detritus, which is critical to food webs on the floodplain and within the river channel (Vannote et al. 1980, Gregory et al. 1991). Floodplain inundation also contributes to other physical-chemical processes that can affect biological production, uptake and transformation of macro-nutrients (Kuensler 1989, Walbridge and Lockaby 1994).

Alluvial processes associated with highly variable flow regimes cause river floodplains to be topographically complex. River floodplains can contain a range of land features including levees, sloughs, secondary stream channels, and broad gently sloping plains (Leopold et al. 1964, Stanturf and Schoenholtz 1998). These landforms provide a diverse mosaic of habitats for a wide range of plant and animal species (Wharton et al 1982, Wigley and Lancia 1998). Hydrologic conditions also vary within the floodplain, with the duration of soil saturation and inundation varying with factors such as surface elevation, channel connectivity and groundwater levels (Light et al. 1998, Williams 1998). These hydrologic gradients also contributes biological diversity (Mitsch and Gosselink 1993, Uranowski et al. 2002).

In some cases, the hydrologic requirements of dominant plant and animal taxa and communities occurring on river floodplains may be similar. In other cases, hydrologic needs may vary considerably, with some taxa or communities requiring relatively narrow or well defined patterns of inundation or flow. Differences in hydrology may also be reflected in the soils that develop and support the various floodplain communities. Evaluation of the hydrologic requirements of dominant taxa or communities and the distribution of floodplain soils may be important for determining minimum flows in the high end of the flow regime for the Upper Peace River.

#### 4.2.4.1 Wetland plant communities

River floodplains typically exhibit gradients in plant communities that correspond to changes in topography, the length and depth of inundation, and soil saturation (Brinson et al. 1981, Mitsch and Gosselink 1993, Hodges 1998). Light (2002) identified fourteen forest types and four major forest groups in the non-tidal floodplain of the lower Suwannee River. Typically, the forested communities lateral transitioned along an elevation gradient from riverine swamps to low and high bottomland hardwood forests to oak/pine uplands. Differences in hydroperiod and soils were found to correspond with changes in vegetation. Brown and Shafer (as cited in SJRWMD 1994) identified mixed hardwood swamps and hydric hammocks as the two major forest types in the floodplain of the Wekiva River, with bayheads and cypress swamps occurring in some areas. Hydrologic conditions in these communities, including the water table depth and the period of inundation, were shown to differ in a predictable manner.

In this assessment of minimum flows and levels for the Upper Peace River, plant communities were identified across the river floodplain at a number of sites, and periods of inundation were reconstructed on an annual basis. These results were examined to characterize the hydrologic relationships of these communities and determine if their hydrologic requirements are being met.

#### 4.2.4.2 Soils

Soils in river floodplains have physical and chemical properties that are important to the overall function of the river ecosystem (Wharton et al 1982, Stanturf and Schenholtz 1998). Anaerobic soil conditions can persist in areas where river flooding or soil saturation is of sufficient depth and duration. The decomposition of organic matter is much slower in anaerobic environments, and mucky or peaty organic soils can develop in such floodplain zones (Tate 1980, Brown 1990). Although these soils may dry out on a seasonal basis, typically long hydroperiods contribute to their high organic content. Plant species that grow on flooded, organic soils are tolerant of anoxic conditions and the physical structure of these soils (Hook and Brown 1973, McKevlin et al. 1998). Such adaptations can be an important selective mechanism that determines plant community composition.

Organic soils can serve important ecological roles in river/floodplain systems. Organic soils have higher water retention capability than mineral soils and can retain water after the flood season ends, partially mitigating the effects of dry periods (Light et al 2002). Organic soils in riverine wetlands also tend to bind nutrients, which could be an important function in rivers which are nutrient enriched (Kuensler 1989, Walbridge and Locaby 1994, Locaby and Walbridge 1998 Uranowski et al. 2002). Denitrification, or the conversion of nitrate to nitrogen gas, is a microbial process that occurs in saturated floodplain soils that could be a significant process for maintaining or improving water quality in rivers that have experienced nitrate enrichment (Light et al 2002).

The maintenance of organic soils can be a criterion for streamflow management. Organic matter oxidizes more rapidly in aerobic environments, and prolonged exposure of organic soils can result in soil dessication and organic matter loss (Stephens 1974). In a minimum flows assessment of the Wekiva River, the SJRWMD (Hupalo et al. 1994) suggested that water tables not fall 0.25 below the surface of highly organic peat soils for prolonged periods of time be prevent their oxidation and encroachment of non-wetland plant species.

Mineral soils in river floodplains can also have characteristics that are related to river flooding and the alluvial transport and deposition of materials such as sands, silts and clays (Stanturf and Schoenholtz 1998). The properties and distribution of mineral versus organic soils can affect soil water retention capability and the zonation of plant and animal communities within the floodplain (Wharton et al. 1982). Changes in river hydrology can potentially affect the distribution and characteristics of floodplain soils . Accordingly, soils distribution and relation to river hydrology were investigated as part of the minimum flows and level for the Upper Peace River.

#### 4.2.4.3 Fish and Wildlife

Floodplain habitats support a variety of fish and wildlife species that differ greatly in their life histories and hydrologic requirements (Wigley and Lancia 1998). These organisms range from fully aquatic (e.g. fish) to aerial (birds), or have early life stages that live in the water with later stages emerging to terrestrial or aerial habitats (many amphibians and insects). Life stages of taxa that are not fully aquatic may still be wetland dependent since wetlands provide much of their food resources.

The use of the floodplain habitats by fish and wildlife species is closely related to the inundation of those habitats by river waters (Drayton and Hook 1989, Uranowski et al . 2002). The amount of floodplain that is inundated varies with the rate of streamflow, ranging from moderately high flows that inundate adjoining swamps to periodic floods that extend far into the floodplain. These medium to high flows vary greatly in their temporal characteristics. Flows that inundate riverine swamps may occur for prolonged periods on a seasonal basis, whereas floods that extend far into the floodplain may occur only briefly every several years. An assessment of habitat utilization by fish and wildlife must therefore consider not only the size of the habitat inundated by a given rate of flow, but also the frequency and duration of inundation.

In evaluating minimum flows and levels for floodplain habitats, it is not practical to evaluate the hydrologic requirements of all floodplain species. It is rather more practical to investigate the interaction of the flow regime with distribution of various habitats (channels, marshes, forested wetlands) and the major faunal groups that may be expected to populate those habitats. Life history requirements of these groups can then be related to the amount of suitable habitat that is available over different time periods (months, seasons, years). This approach is applied in Chapter Six, in which the inundation of different zones in the river floodplain are related to the hydrologic requirements of faunal groups that utilize those habitats.

# Chapter Five

# Technical Approach for Establishing Minimum Flows and Levels for the Upper Peace River

## 5.1 Overview: Determining the Hydrologic Requirements of Key Habitat Indicators

Field studies were conducted to document the distribution of the habitats and indicators corresponding to the resource management goals described in Chapter Four. Elevational land surveys were conducted along transects across the river channel and floodplain at eighteen representative locations to identify the lateral and vertical distribution of instream and floodplain habitats. Hydraulic modeling using the Hydrologic Engineering Center - River Analysis System (HEC-RAS) and statistical analyses of streamflow records were then used to estimate the inundation characteristics of different habitats along these transects for the period of streamflow record on the upper river.

HEC-RAS output was used to evaluate fish passage depths and wetted perimeter inflection points at the eighteen transect sites, plus all sites where cross-sectional information was available from the USGS. The HEC-RAS model is described below, followed by methods employed to evaluate fish passage depths and wetted perimeter inflection points. This is followed by a discussion of methods employed to determine the distribution of instream and floodplain habitats at the eighteen transects surveyed for this project.

## 5.2 HEC-RAS Modeling

In the mid-1970s, the USGS developed a step-backwater, flood profile model for the Peace River that included cross-sectional data collected at 183 sites on the river between Bartow and Arcadia (Murphy et al. 1977). The USGS (Lewelling 2002) recently developed a revised step-backwater model for the river that incorporates much of the previously collected cross-sectional information. The revised model uses the HEC-RAS program for estimating water surface profiles along the length of the river. The HEC-RAS model is a one-dimensional hydraulic model developed at the US Army Corps of Engineers' Hydrologic Engineering Center (1998) that can be used to analyze water surface profiles in rivers. Version 2.2 of the HEC-RAS model supports water surface profile calculations for steady flows that can be subcritical, supercritical, or mixed. Profile computations begin at a cross-section with known or assumed starting condition and proceed upstream for subcritical flow or downstream for supercritical flow.

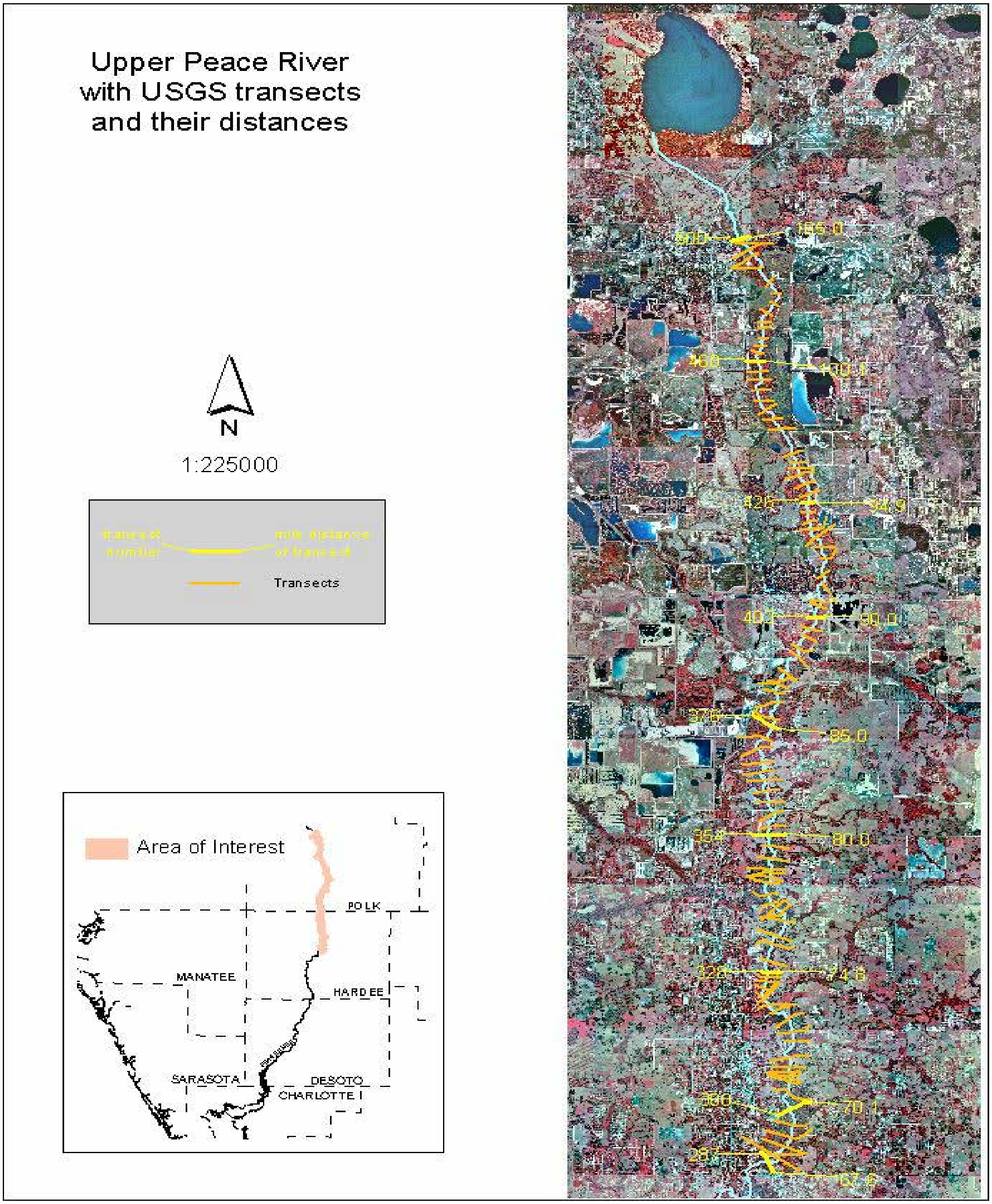



Figure 5-1. Location of USGS HEC-RAS transects on Upper Peace River.

The HEC-RAS model solves the one-dimensional energy equation. Energy losses between two neighboring cross sections are caused by friction and contraction/expansion. While Manning's equation is used to calculate the energy loss caused by friction, energy loss due to contraction or expansion is calculated by multiplying the change in velocity head with a coefficient. For areas where the water surface profile changes rapidly (e.g., hydraulic jump, bridges, river confluences, etc.), the momentum equation is solved. Data required for performing HEC-RAS simulations for the river include geometric data and steady flow data. The geometric data consist of connectivity of the river system, cross-section data, reach length, energy loss coefficients due to friction and contraction/expansion, stream junction information, and hydraulic structure data, including bridges, culverts, etc. The steady flow data consist of flow regime, boundary conditions, and peak discharge information. As part of the project to develop the HEC-RAS model, the USGS developed a method for apportioning flows at different cross sections based on drainage basin ratios along the Upper Peace River (Lewelling 2002). For a given flow at the downstream gage, the USGS predicted flows at a series of upstream sites.

In December 2000, the SWFWMD obtained a copy of the HEC-RAS model for the Peace River from the USGS. The Upper Peace River was divided into two segments in the model: (1) from Bartow to Ft. Meade and (2) from Ft. Meade to Zolfo Springs. The segment between Bartow and Ft. Meade has 60 USGS cross-sections and the segment between Ft. Meade and Zolfo Springs includes 95 USGS cross-sections (Figure 5-1). The eighteen cross-sections surveyed by the District in 2001 were added to the original USGS geometric data files for the model.

Simulated water surface profiles for sixteen steady flow rates were provided by the USGS with the HEC-RAS model. They were the 89, 50, 30, 20, 10, 2, 0.5, and 0.1 percent exceedance flows and flows corresponding to 10 percent reductions from each for these flow rates. To establish minimum flows and levels for the upper river it was necessary to examine water surface profiles for flows lower than those originally provided with the model. For this purpose, twelve additional low steady flows were simulated for the river segments from Bartow to Ft. Meade and from Ft. Meade to Zolfo Springs. The twelve additional flow rates modeled for the Bartow to Ft. Meade segment were 2.5, 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, and 60 cfs at the Bartow gage. The twelve additional flow rates modeled for the Ft. Meade to Zolfo Springs segment were 2.83, 5.67, 11.33, 17, 22.7, 29.2, 35, 40.5, 46, 52, 57.5, and 69 cfs at the Ft. Meade gage.

Boundary conditions for each of the two river segments were specified with known water surface elevations for each of the flow rates at the downstream gage. In other words, rating curves at the downstream gages were used as the boundary condition. Upstream rating curves for each river segment were used for model calibration. For example, the rating curve at Ft. Meade was used to calibrate the calculation for the river segment between Ft. Meade and Zolfo Springs. Model calibration generally involved tuning model parameters (e.g. Manning's roughness coefficient) to get a good match between the calculated flow-stage relationship and the rating curve at the upstream boundary.

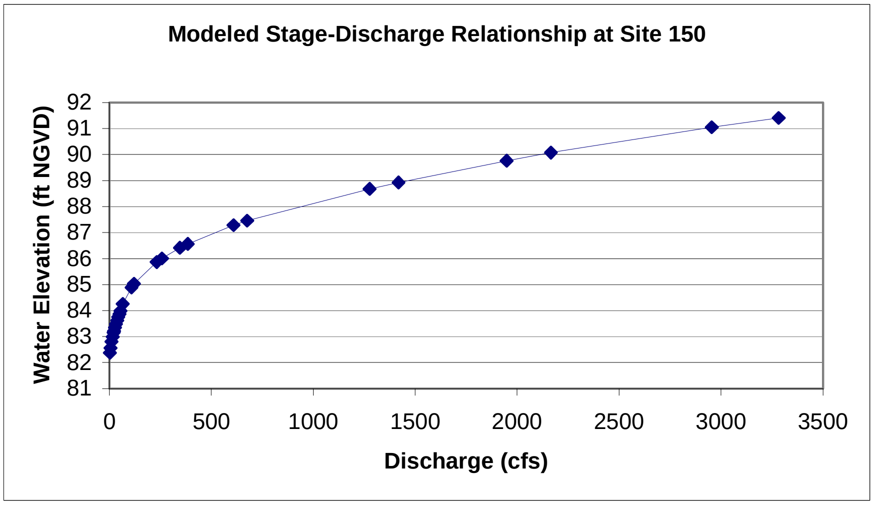
### 5.3 Application of HEC-RAS for Determination of Fish Passage Depths

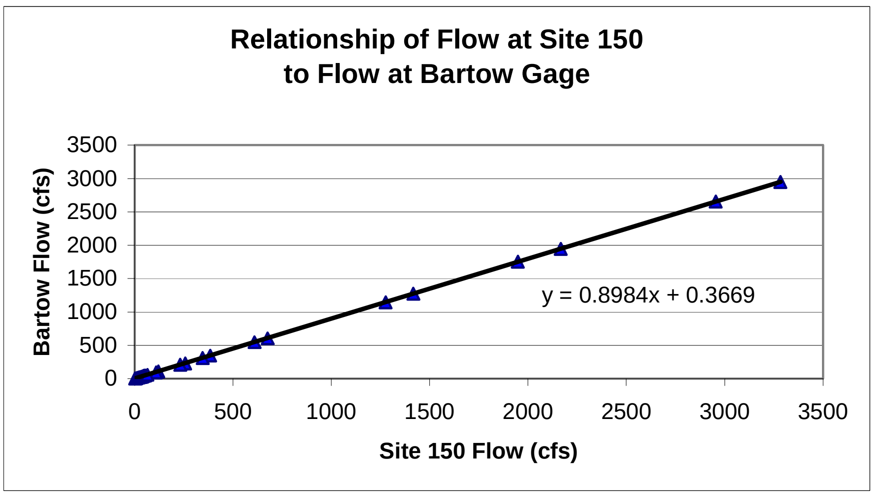
Output from the HEC-RAS model was used to evaluate water depths necessary to allow fish passage throughout the channel of the Upper Peace River. Since channel morphology can vary considerably from site to site, cross-sectional data were evaluated from as many sites as possible, including the eighteen transects surveyed in 2001 and the 142 sites between Bartow and Zolfo Springs in the original USGS model. The HEC-RAS model includes values for the minimum channel depth at each site, plus output for a number of other physical parameters (e.g. stream depth, width, and wetted perimeter) for a range of flows and water levels at each site. Table 5-1 provides an example of output for selected parameters at the Bartow gage and SWFWMD study Site 150 for the twenty-eight model runs performed for the project.

Output from the HEC-RAS model was inspected to determine the minimum channel elevation at each cross section site. The minimum channel elevation represents the deepest part of the river, where it is assumed that fish passage would occur during times of extreme low water. Using model generated stage-discharge relationships for each site as shown in Figure 5-2, 0.6 feet was added to the minimum channel elevation at each site and the flow necessary to achieve the desired elevation (i.e., minimum elevation + 0.6 feet = fish passage elevation) was determined for that site. This analysis was performed on all USGS cross sections and the eighteen sites added by the District. Once all site specific flows were determined, they were plotted against distance (river miles from the mouth of the Peace River) and visually evaluated to determine the flows needed to allow fish passage along the different reaches of the Upper Peace River.

Table 5-1. Example of model output for two transects - Bartow gage and SWFWMD Transect 150. Output was used to develop stage discharge relationship at a site and to relate flow at a site to flow at a long-term USGS flow monitoring site.

| Model Run # | Bartow Gage Flow (cfs) | Bartow Mininum Channel Elevation (feet NGVD) | Bartow Water Surface Elevation (feet NGVD) | Transect 150 Flow (cfs) | Trans 150 Minimum Channel Elevation (feet NGVD) | Trans 150 Water Surface Elevation (feet NGVD) |
|---|---|---|---|---|---|---|
| 1 | 2.5 | 90 | 90.45 | 2.67 | 81.8 | 82.38 |
| 2 | 5 | 90 | 90.56 | 5.33 | 81.8 | 82.56 |
| 3 | 10 | 90 | 90.76 | 10.67 | 81.8 | 82.8 |
| 4 | 15 | 90 | 90.92 | 16 | 81.8 | 82.99 |
| 5 | 19 | 90 | 91.04 | 21 | 81.8 | 83.15 |
| 6 | 20 | 90 | 91.07 | 21.33 | 81.8 | 83.16 |
| 7 | 21 | 90 | 91.09 | 23 | 81.8 | 83.21 |
| 8 | 25 | 90 | 91.19 | 27.5 | 81.8 | 83.34 |
| 9 | 30 | 90 | 91.31 | 33 | 81.8 | 83.48 |
| 10 | 35 | 90 | 91.42 | 38.5 | 81.8 | 83.62 |
| 11 | 40 | 90 | 91.52 | 44 | 81.8 | 83.75 |
| 12 | 45 | 90 | 91.62 | 49.5 | 81.8 | 83.87 |
| 13 | 50 | 90 | 91.72 | 55 | 81.8 | 83.99 |
| 14 | 60 | 90 | 91.91 | 66 | 81.8 | 84.25 |
| 15 | 98 | 90 | 92.4 | 109 | 81.8 | 84.89 |
| 16 | 109 | 90 | 92.51 | 121 | 81.8 | 85.03 |
| 17 | 209 | 90 | 93.06 | 232 | 81.8 | 85.87 |
| 18 | 232 | 90 | 93.16 | 258 | 81.8 | 86.01 |
| 19 | 311 | 90 | 93.48 | 346 | 81.8 | 86.41 |
| 20 | 346 | 90 | 93.6 | 385 | 81.8 | 86.56 |
| 21 | 547 | 90 | 94.16 | 609 | 81.8 | 87.28 |
| 22 | 608 | 90 | 94.3 | 676 | 81.8 | 87.46 |
| 23 | 1147 | 90 | 95.33 | 1276 | 81.8 | 88.68 |
| 24 | 1274 | 90 | 95.55 | 1418 | 81.8 | 88.93 |
| 25 | 1751 | 90 | 96.33 | 1949 | 81.8 | 89.77 |
| 26 | 1946 | 90 | 96.6 | 2166 | 81.8 | 90.08 |
| 27 | 2655 | 90 | 97.52 | 2955 | 81.8 | 91.06 |
| 28 | 2950 | 90 | 97.83 | 3283 | 81.8 | 91.41 |




Transect Flow to Bartow Flow
Conversion Formula

| Site 150 Fl | Bartow Flow |
|---|---|
| 10000 | 8984 |
| 1000 | 899 |
| 100 | 90 |
| 50 | 45 |
| 10 | 9 |
| 2 | 2 |

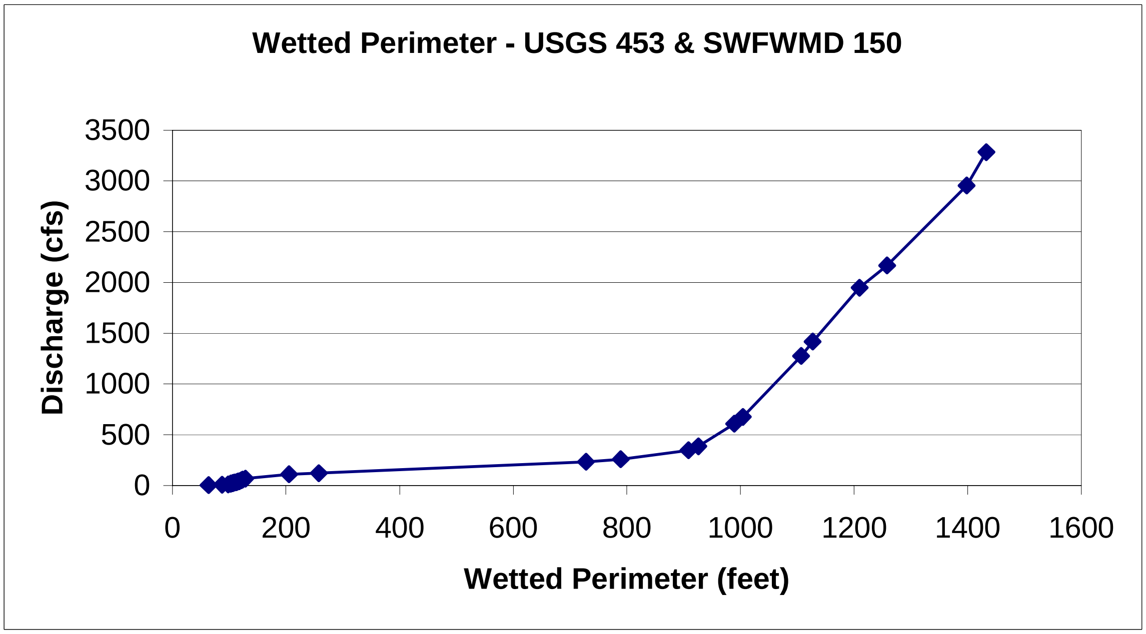
Figure 5-2. Example of graphic outputs generated from modeled flow data used to (a) develop stage-discharge curves at each transect site to determine discharge needed at the site to achieve a target water level, and (b) to convert from site flow to gage site flow to evaluate historic inundation.

## 5.4 Application of HEC-RAS to Determination of Wetted Perimeter Inflection Points

Output from the HEC-RAS model was entered into a spreadsheet which was used to generate a wetted perimeter versus flow plot for each transect using the series of modeled flows (see Figure 5-3 for SWFWMD Transect 150). Each of the transect plots was visually examined for inflection points. Although wetted perimeter plots were examined at low flows for the inflection point that would yield the LWPIP as described in Section 4.2.2, other inflection points could be discerned and can be related to topographic breaks, such as top of bank, transition from swamp to lower flood plain, etc. Using Site 150 as the example, a fairly clear inflection point occurs around 10 cfs when the wetted perimeter length is about 100 feet (Figure 5-3). By examining the model output for this site (Table 5-2) at the modeled flow of 10.67 cfs, the calculated wetted perimeter is 98.64 feet. When the discharge is increased almost six fold (to 66 cfs), the calculated wetted perimeter for this discharge is only 128.51 feet. Stated differently, it would take a 600% increase in flow to increase the wetted perimeter by less than 30%. A flow of 10 cfs makes a relatively large area of habitat available for colonization by aquatic macroinvertebrates considering the flow provided. Many of the transects had no apparent inflection points between the lowest modeled flow and 100 cfs. These transects were located in pool areas, where standing water above the lowest wetted perimeter can be present even though the rate of streamflow is very low.

## 5.5 Establishment of Low Minimum Flows and Levels

Fish passage depths and wetted perimeter inflection points were evaluated jointly to establish minimum flows and levels for the low end of the flow regime of the Upper Peace River. It was not assumed that fish passage needs will be met by the wetted perimeter approach. Rather, both approaches were used in tandem to evaluate the low minimum flow requirement, and have used the higher flow of the two as a conservative means for establishing the Low Minimum Flow (LMF).



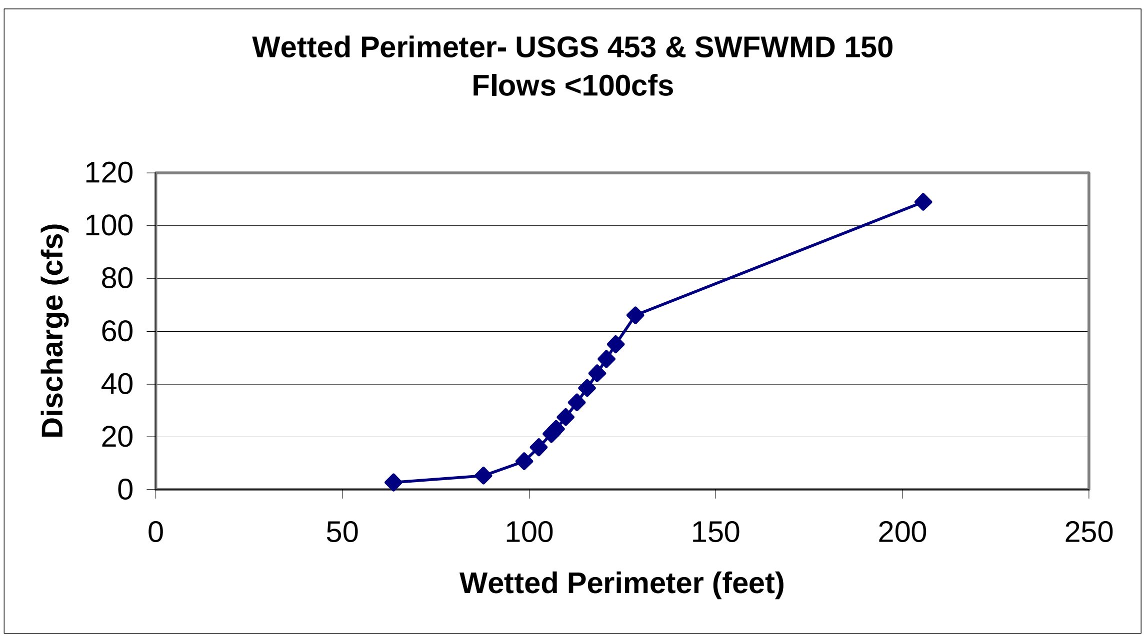




Figure 5-3. Plots of wetted perimeter versus discharge at SWFWMD Site 150. Upper plot is for the entire transect length. Lower plot is for flows less than 120cfs.

Table 5-2. Example of HEC-RAS model output used to generate wetted perimeter plots. Data are for SWFWMD Site 150 on the Upper Peace River.

| Transect No. | Water Surface Elevation (ft NGVD) | WP - Wetted Perimeter Length (feet) | Q - Discharge (cfs) | Change WP/Change Q |
|---|---|---|---|---|
| 150 | 82.38 | 63.7 | 2.7 | 23.85 |
| 150 | 82.56 | 87.7 | 5.3 | 9.03 |
| 150 | 82.80 | 98.6 | 10.7 | 2.04 |
| 150 | 82.99 | 102.7 | 16.0 | 0.75 |
| 150 | 83.15 | 106.0 | 21.0 | 0.66 |
| 150 | 83.16 | 106.2 | 21.3 | 0.61 |
| 150 | 83.21 | 107.2 | 23.0 | 0.62 |
| 150 | 83.34 | 109.8 | 27.5 | 0.58 |
| 150 | 83.48 | 112.8 | 33.0 | 0.54 |
| 150 | 83.62 | 115.5 | 38.5 | 0.50 |
| 150 | 83.75 | 118.2 | 44.0 | 0.49 |
| 150 | 83.87 | 120.8 | 49.5 | 0.47 |
| 150 | 83.99 | 123.3 | 55.0 | 0.45 |
| 150 | 84.25 | 128.5 | 66.0 | 0.48 |
| 150 | 84.89 | 205.6 | 109.0 | 1.79 |
| 150 | 85.03 | 258.1 | 121.0 | 4.38 |
| 150 | 85.87 | 727.9 | 232.0 | 4.23 |
| 150 | 86.01 | 789.4 | 258.0 | 2.37 |
| 150 | 86.41 | 908.4 | 346.0 | 1.35 |
| 150 | 86.56 | 925.8 | 385.0 | 0.45 |
| 150 | 87.28 | 988.8 | 609.0 | 0.28 |
| 150 | 87.46 | 1004.5 | 676.0 | 0.23 |
| 150 | 88.68 | 1107.2 | 1276.0 | 0.17 |
| 150 | 88.93 | 1127.2 | 1418.0 | 0.14 |
| 150 | 89.77 | 1209.5 | 1949.0 | 0.15 |
| 150 | 90.08 | 1258.4 | 2166.0 | 0.23 |
| 150 | 91.06 | 1398.5 | 2955.0 | 0.18 |
| 150 | 91.41 | 1433.2 | 3283.0 | 0.11 |

### 5.6 Cross Sectional Surveys of Instream and Floodplain Habitats

Eighteen transects were surveyed across the Upper Peace River floodplain for the evaluation of the inundation characteristics of instream and floodplain habitats. This was necessary to identify the lateral and vertical distribution of important topographic and ecological communities in the river channel and floodplain. These cross-sectional data were entered into the HEC-RAS model and inundation characteristics of selected habitats were determined using the methods described below. Presented first are the criteria by which the locations of the transects were selected.

#### 5.6.1 Transect Selection

Eighteen cross sections of the Upper Peace River and its floodplain were surveyed in the river reach between Bartow and Zolfo Springs. These transects ran perpendicular to the river channel and extended across both sides of the river floodplain. Selection of the study transects was based on a stratified random approach that used river segments and wetland communities as stratification parameters. In designing the plan for determining the location of the transects, the District and its consultant for the floodplain component of the project (PBSJ, Inc.) reviewed a series of maps and data bases for the Upper Peace River. These included information on:

- vegetation communities, based on Natural Wetland Inventory and Florida GAP vegetation classification;
- protected species, using FFWCC (Cox et al. 1984) and FNAI data coverages;
- HSG and USDA soils classification;
- USGS elevation / topography;
- USGS water level gage locations;
- aerial photography; and
- land use.

Based on review of this information, the Upper Peace River was divided into four segments that generally corresponded to changes in the river's physiography (Figure 5-4). Two segments were located above Ft. Meade, where the river banks are low and the floodplain is broad and flat. The two other segments were located below Ft. Meade, where the river channel is more incised and the floodplain is generally narrower.

National Wetlands Inventory (NWI) vegetation classifications were used to stratify study sites within different wetland types within the four segments identified for the Upper Peace River study corridor. Classifications followed the System/Subsystem/Class/Subclass hierarchy of Cowardin et al. (1979) with water regime modifiers. The NWI vegetation classifications for the upper river are consistent with other available data for land elevations, water levels, and soils in the Peace River corridor. A map of the NWI classifications in the Upper Peace River corridor is shown in Figure 5-5. A description of NWI codes and classifications is provided in Appendix NWI.

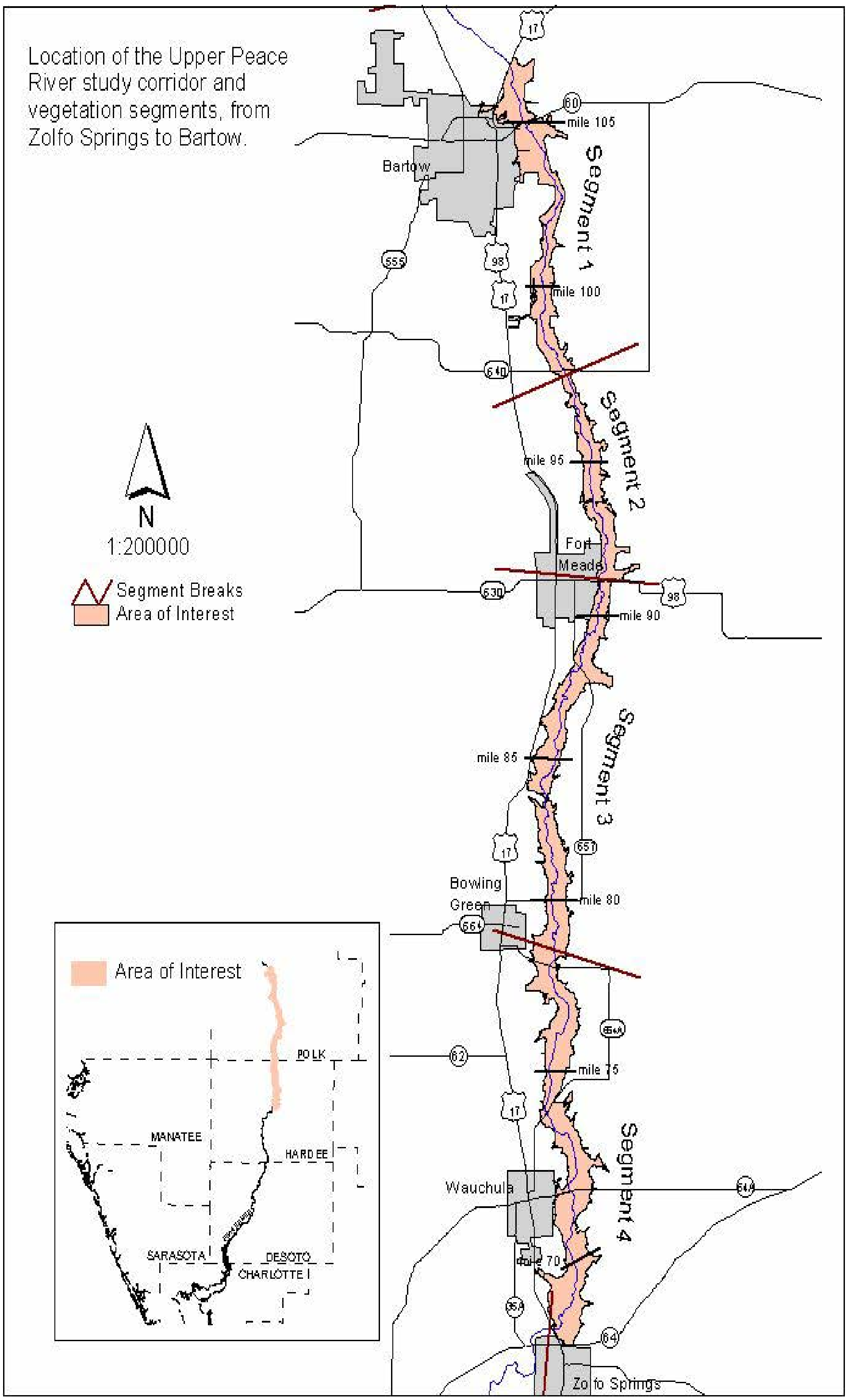



Figure 5-4. Map of Upper Peace River showing four physiographic segments used to stratify location of vegetation transects.

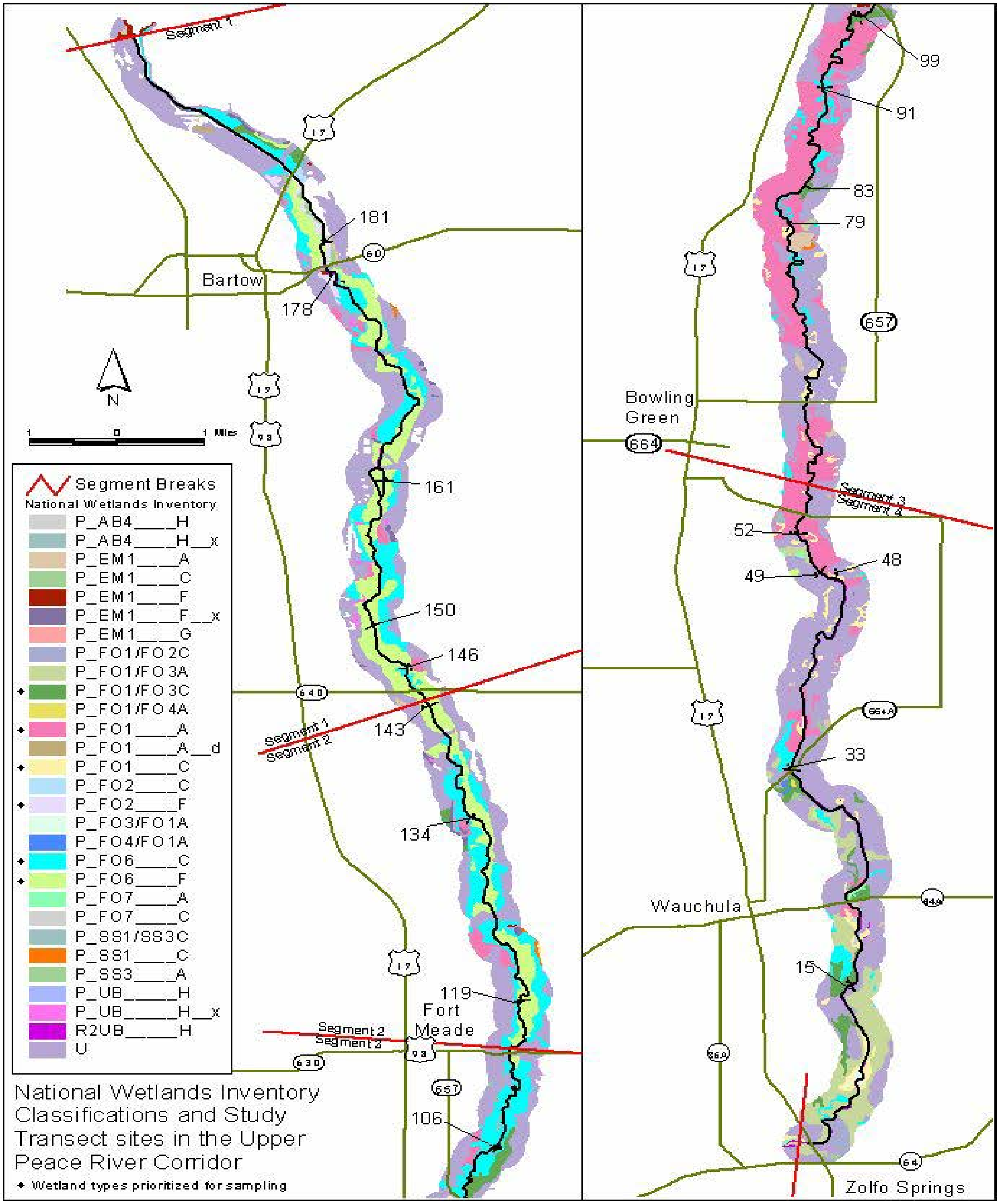



Figure 5-5. Map of National Wetlands Inventory classifications and study transect locations along the Upper Peace River.

A Geographic Information System (GIS ) was used to quantify the coverage of different NWI vegetation classifications in the four river segments. Three wetland types based on unique subclass/dominance/water regime classifications were found to be abundant in the upper river corridor and were prioritized for transect sampling. Three wetland types that are not widespread based on their areal coverage were considered to be hydrologically sensitive, because they are characterized by either seasonal or semi-permanent flooding. These communities were also prioritized for sampling. The six wetland types that were identified for transect sampling are listed in Table 5-3. Greater elaboration on the overall NWI classifications that occur in the river segments is presented in Chapter Six.

**Table 5-3. Six NWI wetland types selected for sampling in the Upper Peace River corridor**

| NWI Subclass | Water regime | Dominance Forest Type | Prevalence / Condition in the River |
|---|---|---|---|
| P_FO6_F | Semi-permanent flooding | Deciduous | Widespread & Sensitive |
| P_FO2_F | Semi-permanent flooding | Needle-leaved deciduous | Sensitive |
| P_FO6_C | Seasonal flooding | Deciduous | Widespread & Sensitive |
| P_FO1/ FO3_C | Seasonal flooding | Broad-leaved deciduous & Broad-leaved evergreen | Sensitive |
| P_FO1-C | Seasonal flooding | Broad-leaved deciduous | Sensitive |
| P_FO1_A | Temporary flooding | Broad-leaved deciduous | Widespread |

Sixteen sites and two alternates were identified for transect sampling. Two NWI wetland types (P_FO6_F and P_FO6_C) were considered to be both widespread and hydrologically sensitive. These two wetland types were allocated four study transects each. Four other wetland types were identified for sampling because they were either widespread or hydrologically sensitive, but not both. The driest of the wetland types that was prioritized for sampling was a widespread community that is characterized by temporary flooding (P_FO1_A).

To locate the study transects within each wetland type in a random manner, potential transect locations were identified along the channel of the river in 0.2 mile intervals using GIS. At these sites, transect belts 500 feet wide by 1500 feet long were delineated to quantify the area of different wetland types within each transect. Transects were grouped according to their dominant wetland types and a randomization technique was used to select study sites from each group. Sites were also stratified by river segment, so sites for a wetland type were distributed between segments. Potential sites that were disturbed by urban or agricultural development were discarded and the process continued until a suitable site for a community/segment combination was found.

Areal coverage of the NWI wetland types occurring at the sixteen transects (and two alternate sites) are listed in Table 5-4. Coverage values shown in bold denote the wetland type that transect was chosen to represent. Many of the transects crossed other wetland types as well. Two alternate sites (52 and 83) were added to the initial sixteen. The distribution of these 18 transects is shown along with the NWI coverages for the Upper River in Figure 5-5.

Table 5-4. Transects and percent NWI community composition at the eighteen transects based on 500' wide X 1500' long area. Bold-faced percentages indicate community for which transect was chosen. Transects are listed from upstream (181) to downstream (15).

| Site | River Mile | Upland | Palustrine, forested, deciduous (P_FO) | | | | | | Riverine |
|---|---|---|---|---|---|---|---|---|---|
| | | | Broad-leaved (1,3) | | | Broad- and needle-leaved (6) | | Needle-leave (2) | Uncon-solidated bottom |
| | | | Temporary Flooding (A) | Seasonal Flooding (C) | | | Semi-permanent Flooding (F) | | |
| | | U | P_FO1A | P_F01C | P_F01/3C | P_F06C | P_F06F | P_F02F | R2UBH |
| **181** | 105.7 | | | | | | 56% | **27%** | |
| **178** | 104.8 | | | | | 18% | 19% | **55%** | 9% |
| **161** | 101.2 | | | | | | **100%** | | |
| **150** | 98.9 | | | | | 5% | **94%** | | |
| **146** | 98.2 | | | | 33% | **38%** | 29% | | |
| **143** | 97.2 | | | | | | **100%** | | |
| **134** | 95.7 | | | | 7% | **32%** | 60% | | |
| **119** | 92.1 | 10% | | | | 19% | **71%** | | |
| **106** | 89.4 | | | | | **100%** | | | |
| **99** | 87.9 | 18% | 53% | | **30%** | | | | |
| **91** | 86.2 | | **56%** | | | 44% | | | |
| **79** | 83.8 | | 67% | **33%** | | | | | |
| **49** | 83.8 | 52% | **48%** | | | | | | |
| **48** | 76.9 | 48% | 36% | **15%** | | | | | 2% |
| **33** | 74.2 | 37% | 26% | | | **27%** | | | 10% |
| **15** | 70.3 | 40% | | | **42%** | | | | 18% |

Transect 181 also included temporarily flooded EM1 (17%)

### 5.6.2 Field Sampling: Floodplain Habitats

Initial field investigations indicated the waterward extent of uplands along the transects coincided with the approximate location of the 0.5% exceedance level (elevation at which flow is exceeded 0.5% of the time). Based on this observation, surveys were conducted along the transects extending from the 0.5% exceedance level on the west side of the river channel to the 0.5% exceedance level on the east side. Transect lengths ranged from 100 feet to over 3,000 feet on each side of the river. Elevations were surveyed along the length of all transects and marked with survey stakes. At each staked position, distance from the center of the river channel was recorded. Elevation data were entered into CADD software, and transect profiles were plotted.

Plant and soils scientists walked the length of each transect and identified changes and/or breaks in vegetation and corresponding distances from the river channel. Vegetation zones were identified in the field and generally followed a gradient of riverbank, swamp, lower floodplain, upper floodplain and upland. Zones were characterized by a conspicuous change in dominant tree species as well as changes in topography. For each wetland zone, a complete list of plant species was compiled for a six-meter wide belt transect for the length of each zone along the transect. Transects were also examined for inconsistencies in vegetation or soils that may indicate changes in historic inundation periods.

Data collected along the transects included a complete list of species for each community, and dominant species were noted (e.g. pop-ash, cypress, laurel oak, or any combination of species). Trees (woody plants with a diameter breast height (dbh) of greater than or equal to 2.54 cm), shrubs (woody plants greater than or equal to 50 cm in height with a dbh less than 2.54 cm and palmettos), and ground layer vegetation (herbaceous species and woody seedlings) were identified. Species listed as threatened or endangered by the U.S. Fish and Wildlife Service (USFWS) or the Florida Fish and Wildlife Conservation Commission (FFWCC) were also noted. A single state-protected species, *Matelea floridana* (Florida spiny pod) was observed in both Polk and Hardee counties, although it is not listed as occurring in Hardee County by the Florida Natural Areas Inventory (FNAI 1990). Florida spiny pod is not a wetland indicator species and occurs in pine-oak-hickory bluffs.

### 5.6.3 Soils Characterization

The U.S. Army Corps of Engineers' Wetlands Delineation Manual defines a hydric soil as one that is saturated, flooded or ponded long enough during the growing season to develop anaerobic conditions that favor the growth and regeneration of hydrophytic vegetation (USDA Soil Conservation Service (SCS) 1985, as amended by the National Technical Committee for Hydric Soils in December 1986). This definition was used in the soils evaluations.

Periodic flooding can leave physical evidence in the soil profile such as: thin strata of gravel, sand, silt, or clay deposited by flood waters; irregular decreases in organic matter content with increasing depth; and absence of distinctive horizons which are characteristic of soils that are not subject to flooding. The most common evidence is high silt content and very fine sand texture over sandy material; absence of distinct horizons shown as abrupt changes in texture and color; irregular changes in organic matter and thin strata layering. The source of silt is from stream flooding. Silt is somewhat characteristic of slow flow where smaller particle size takes longer to settle. However, in higher energy situations, sands can also be deposited and settle out away from the stream source. If movement is slow, there will be little or no sand in suspension. In addition, the shape of the local landform, such as well drained riverbanks, can greatly affect the movement of water through the landscape

A minimum of three soil cores were examined for each community type identified along each transect. The presence of hydric indicators, flooding indicators, and overall soil characteristics were recorded. The soil profile was examined to a minimum depth of 50 cm (20 inches), but was excavated as deep as necessary to make reliable interpretations. For example, examination to less than 50 cm (20 in.) sufficed in soils with surface horizons of organic material or mucky mineral material because these shallow organic accumulations only occur in hydric soils. Conversely, depth of excavation was often greater than 50 cm (20 in.) in mollisols because the upper horizons of these soils, due to the masking effect of organic material, often contained no visible redoximorphic features (Cowardin et al (1979).

Soils data were recorded as profiles in a field notebook. Hydric/nonhydric and flooded/ not flooded conditions were recorded and subsequently included with vegetation and elevation data for analysis. Other soils data (e.g. color, texture, depth) were not used in vegetation analyses.

### 5.6.4 Instream Habitats

Instream habitats were examined at the eighteen SWFWMD transect sites during February through April 2001. At each site, cross sections were surveyed along the transect line and at points 50 feet upstream and downstream of the transect line. The resulting three instream cross sections at each transect site were labeled as north, central and south, and were established to capture the local variation among instream habitats found in a particular stream segment. A total of 54 instream cross sections were sampled (18 cross-sections x 3 replicates).

All instream cross sections were oriented perpendicular to the direction of flow in the channel. Habitats bounded by the top of banks on either side of the channel were evaluated. For each cross section, a transect line was installed, and the upper and lower extent of each habitat intercepting the transect line was determined. Habitats were classified as:

- sand
- silt
- mud
- bedrock
- algal mats
- submersed aquatic vegetation
- floating leaved vegetation
- rooted emergent vegetation
- leaf packs
- exposed roots / root wads
- dead wood or snags
- wetland understory vegetation
- wetland trees

The total linear extent of each habitat type occurring along the north, central and south transect lines was recorded to the nearest tenth of a foot. In addition, the linear distance of a habitat along the horizontal axis was also recorded, especially if these habitats were situated along steep slopes. In situations where vegetative habitat zones were encountered, representative plant specimens were collected for identification and a species list for the habitat category was compiled.

Bedrock habitats consisted of areas of exposed limestone or sandstone. Sand, silt and mud were distinguished visually based on particle size. Algal mats included areas dominated by extensive growth of algae and filamentous cyanobacteria. Submersed aquatic vegetation habitats included areas dominated by *Hydrilla* sp. Habitats classified as floating -leaved vegetation were dominated by rooted taxa such as *Nuphar* sp. and *Nymphaea* sp. or free-floating taxa such as *Pistia* sp. Rooted emergent habitat included taxa adapted to growth in inundated or saturated soils. Common taxa included *Polygonum* sp. and *Panicum* sp. Wetland understory vegetation included herbaceous and woody sub-canopy taxa adapted to growth in inundated conditions but also tolerant of drier conditions. Common species included *Alternanthera philoxeroides*, *Parietaria floridana* or even *Colacasia esculenta*. This also includes seasonally occurring plants such as *Rumex verticillatus* and *Senecio glabellus.* Wetland trees habitat included canopy species such as *Fraxinus* caroliniana, *Acer rubrum*, and *Ulmus americana*. All vegetative species encountered within the boundary of the channel are listed in Appendix IH.

Physical stream features were also measured for each transect either from the field or derived from District survey drawings. Some of these features include stream channel width, stream depth, bank height, stream perimeter length, bank perimeter and bank slope angles. Bank height is the vertical distance between the lowest point of the bank to the top of the bank. This differed from bank perimeter in that the slope of the terrain was followed but was still the distance between the physical grade break at the base of the bank to the top of bank. Stream perimeter length, on the other hand, is the sum total of both bank perimeters plus the length of the river's bottom contour. Slope angles were measured from the horizontal axis at the base of the bank against the predominant slope of the bank.

Elevations of all marked habitat locations were subsequently surveyed by District Survey staff. Drawings and elevation measurements were rendered in accordance to surveying standards and protocols. Final statistical analyses of all measured instream habitat elevations were expressed in terms of mean elevations found for each of the 18 transect sites.

## 5.7 Inundation Characteristics of Instream and Floodplain Habitats

The HEC-RAS model was used with analyses of historical streamflow records to evaluate the inundation characteristics of the instream and floodplain habitats in the Upper Peace River. As described above, the locations and elevations of key habitats were surveyed at each of the eighteen study transects. Stage-discharge relationships for each transect were then produced with the HEC-RAS model using output from twenty-eight model runs (see page 5-2). A series of linear regression equations were developed from modeled output of stage and discharge at each site to estimate the flow needed to achieve a desired elevation (e.g., Figure 5-2a). Using these regressions, the flows necessary to inundate specified habitat elevations were determined at each of the study sites.

After the flow that inundated a habitat was determined, the next step was to relate that flow at the study site to the corresponding flow at the nearest long-term streamflow gaging station. Output from the twenty-eight model runs were used by the District to develop predictive regression equations between flows at each cross section site and the flows at the appropriate long-term gage (e.g., Figure 5-2b). Using these regressions, a particular flow at a cross section site could be used to predict the corresponding flow at long-term gage. Table 5-1 lists an example of flows and water levels at the Bartow gage and a nearby cross section study site for a series of flows as produced by the HEC-RAS model.

### 5.7.1 Historical Inundation Analysis

Using the steps described above, long-term streamflow records at a USGS gage were analyzed to see how often a corresponding flow at a study site occurred. That flow, in turn, corresponded to an elevation of a key instream or floodplain habitat at that site. Assuming the corresponding flows at the long-term gage and the study site occurred with the same frequency and duration, historic records of inundation for key habitats at the study sites were estimated. The procedure was repeated many times to create historical inundation records for different instream and floodplain habitats at the eighteen cross section study sites. Each inundation record was comprised of a binary variable that identified if that habitat was inundated for each day in the long-term streamflow record. These records were then used to calculate the total days of inundation per year and the longest consecutive number of days of inundation per year.

Time series plots and statistical summaries were generated from these records to examine how the yearly inundation characteristics of a given habitat have varied over time. The time series plots of these two parameters are presented in Appendix RH. As will be discussed in Chapter Six, many of the time series plots show a distinct pattern of decreasing inundation periods for instream and floodplain habitats over time. This is not surprising, since there have been a significant long-term decline in streamflow in the Upper Peace River. These declining trends have been caused by a combination of climatic and anthropogenic factors, with the relative effect of these factors differing between upstream and downstream locations.

### 5.7.2 Selection of Reference and Recent Periods for Inundation Comparisons

Declining flow trends on the Peace River raise the question - What would be the inundation characteristics of habitats in the Upper Peace River in the absence of deficit rainfall and reduced effects of human alterations? To address this question, we attempted to identify a suitable baseline period from which to evaluate the inundation characteristics of instream and floodplain habitats in the upper river. This baseline period can serve as a reference to evaluate the inundation characteristics of the river under fairly typical rainfall conditions and reduced effects of human influences. To identify such a reference period, rainfall and streamflow records were examined to identity multi-year periods during which there was near-average rainfall and streamflow did not exhibit an increasing or decreasing trend.

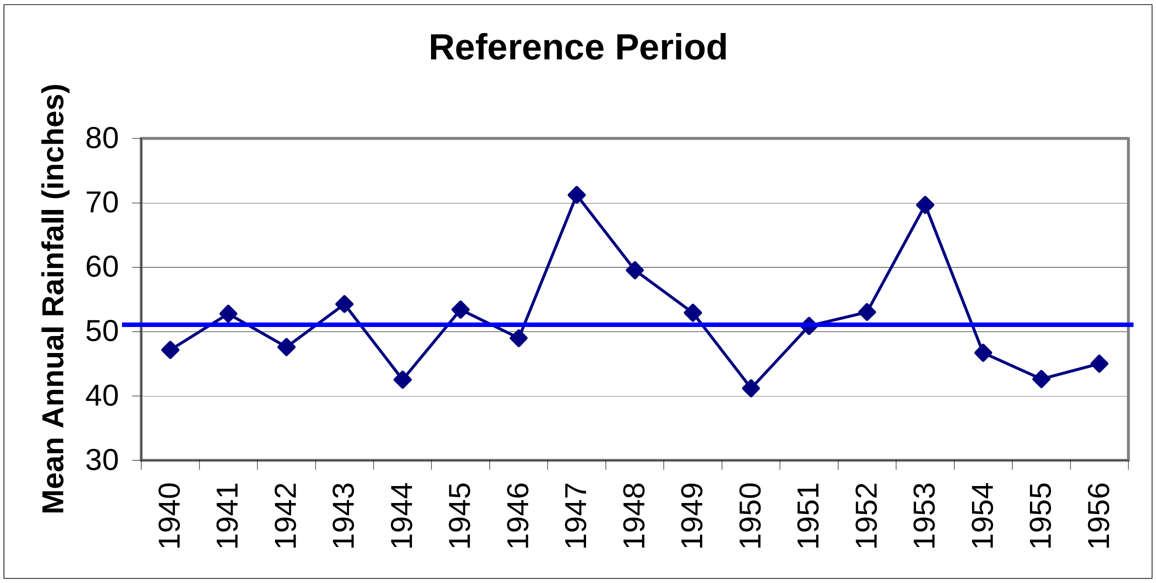
Based on this review, a seventeen-year period from 1940 to 1956 was selected as a reference period from which to evaluate the inundation characteristics of instream and floodplain habitats in the Upper Peace River. The average rainfall for this period at Bartow was 53.34 inches, which is very similar to the long-term average of 53.67 inches at this station. This reference period precludes the very wet period from 1957 through 1960, when four wet years occurred in succession. It also avoids the period after the early 1960s, which various investigators have identified as a period of transition for rainfall and streamflow trends in the Peace River. Streamflow over the 1940-1956 period exhibited no indication of trend, as evidenced by a flat and statistically insignficant slope ($p < 0.82$) based on a seasonal Kendall trend test.

After selection of the reference period, a comparable period after 1960 which had similar rainfall conditions was sought. Although the decades after 1960 have generally been somewhat drier than decades prior, there been multi-year periods during the last 41 years during which average or above average rainfall has occurred. By identifying a recent period with rainfall conditions similar to the reference period, information can be gained on how much the inundation characteristics of habitats in the Upper Peace River have changed under similar rainfall conditions.

A recent thirteen-year period from 1987 to 1999 was selected for comparison to the reference period. The average rainfall at the Bartow gage for the recent period was 52.32 inches, or about one inch lower than the average for the seventeen-year reference period. When average rainfall totals from four stations in the region are used (Bartow, Lakeland, Winter Haven and Wauchula), the yearly averages for the recent and reference periods are nearly the same (51.76 vs. 51.71 inches).

Hydrographs of yearly rainfall totals for the average of the four stations for the reference and recent periods are shown in Figure 5-6. The seventeen year reference period had three wet years (60 inches or greater), while the recent period had only one (1998). Similarly, the mean wet season rainfall (June through September) for the reference period was two inches greater than the wet season mean for the recent period (31.1 vs. 29.1 inches). However, the reference period also had dry periods that were as pronounced as the recent. The reference period had three dry years (< 44 inches) while the recent period had two. Also, the average dry season rainfall (October through May) for the reference period was 1.9 inches less than for the recent period.

Hydrographs and statistical summaries of yearly inundation durations for the recent and reference periods are discussed in the following sections. Although seasonal rainfall patterns during these two periods have some differences, useful comparisons can be made. Given the three wet years in the reference period, it would be expected that years with the longest inundation periods occurred during that period. However, both periods had dry years in their record, from which inundation characteristics during droughts can be evaluated.



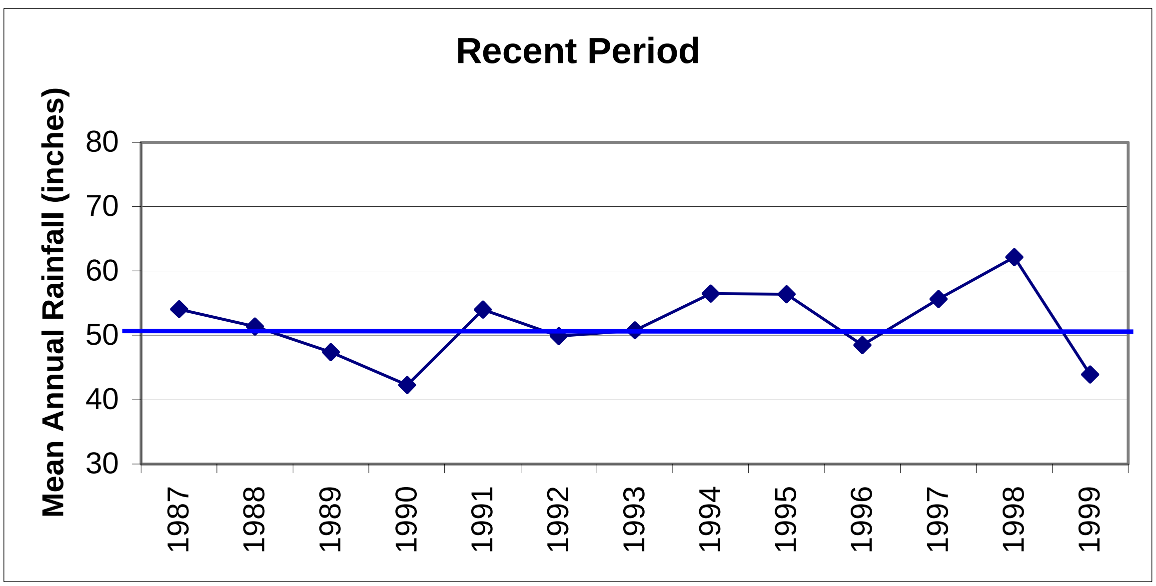




Figure 5-6. Hydrographs of yearly rainfall for the average of four rainfall stations (Lakeland, Bartow, Wauchula, Winter Haven).

### 5.7.3 Sources of Uncertainty in the Historical Inundation Analysis

An assessment of sources of uncertainty in the historical inundation analysis is needed to better understand the utility and limitations of those results. Inherent in the method is the accuracy of the rating curves to calculate discharge as a function of water level at each of the gaging sites. The ratings for all of the gages used in this analysis are rated as "good" by the USGS, meaning that about 95 percent of the daily dischrages are within 10 percent of their true values. A second level of uncertainty pertains to the HEC-RAS model, and the accuracy of its simulations of water levels at different points in the river channel. The model developed by the USGS was calibrated using data from the Bartow, Ft. Meade, and Zolfo Springs gages**.**

Another level of uncertainty pertains to use of the HEC-RAS model to calculate water levels over a long-term period that spans several decades. Changes in the morphology of river channel and floodplain could affect the relation between flows and water levels at the gages and the study sites. Also, as described in Section 5.7.1, in order to estimate habitat inundation records for a study site, the District related flows at that study site to flows at either the Bartow or Zolfo Springs gage. Long-term variations in daily flows at these gages were then extrapolated to flows and water levels at the study sites. Since the rate of streamflow decline has been most pronounced at the Bartow gage, it can be expected that estimated changes in yearly inundation periods at study sites that used the Bartow gage would be greater than changes estimated for study sites that used the Zolfo Springs gage. Sites above FT. Meade (181 to 119) were predicted using the Bartow gage, while sites below Ft. Meade (15 to 106) were calculated using the Zolfo Springs gage.

As described in Chapters Two and Three, portions of the Upper Peace River have switched from a gaining to a losing stream due to the effects of groundwater withdrawals. Secondly, at least some of the sinks in the upper river between Bartow and Ft. Meade are probably of recent origin, and capable of capturing large amounts of streamflow. The method to apportion flow at sites away from the boundary conditions in the HEC-RAS model was based on changes in drainage area, and did not account for changes in surface-water/ground-water relationships over time. Therefore, the use of long-term flow records at the Bartow gage probably underestimates reductions in flows (and water levels) at sites between Bartow and Ft. Meade, where flow losses have increased over time. In such cases, the inundation of habitats at these sites is overestimated for the recent period, and the differences in inundation between the reference and recent periods are probably greater than those presented in Chapter Six. Similarly, the flow record at the Zolfo Springs gage probably underestimates flow reductions at study sites just south of Ft. Meade where upstream flow losses continue to exert a significant hydrologic effect. In these cases, the differences between the recent and reference periods may also be greater than those represented in Chapter Six, with this source of error diminishing with closer proximity to the Zolfo Springs gage.

The interpretation of results for the longest consecutive days of inundation for instream and floodplain habitats is also subject to certain qualifiers. For instream habitats (roots and snags), the running tally of consecutive days of inundation ended on December 31 of each calendar year. During prolonged wet periods, the actual longest consecutive day periods could have extended between years. Therefore, repeated values of 365 days indicate multi-year periods when these habitats were inundated. For floodplain habitats, the tally of longest consecutive days was allowed to extend between years, but the tally was stopped when the count of days reached 400. Using this method, a value reported for a year could reflect a period that started in the previous year. For example, a 200-day period that ended on December 31 could be reported for year one, and a 231-day period that ended on January 31 could be reported for year two, although it reflects the same inundation period that extended from year one. In this regard, there may be some double counting of results presented in the plots and tables of longest consecutive day values for floodplain habitats. Conversely, the method for instream habitats did not involve any double counting between years, but inundation periods that extended past December 31 were not represented.

The relative effect of these calculation factors varies considerably between habitats and years. They will be most pronounced for instream habitats at low elevations that are inundated throughout much of the year, and much less of a factor for floodplain habitats that are seasonally or temporarily flooded. Flows and water levels in the Peace River are highest in July through October, then drop off to low values in November-December and April-May (see Figure 3-5). For a consecutive period to extend between years, inundation will typically have to persist from the peak summer wet season through the end of the calendar year. For many floodplain habitats, this will occur only during the wettest of years. It has not been determined how many years may be affected by this carry-over effect, but it is believed it affects a very small proportion of the results presented for the floodplain habitats.

Several lines of evidence were used to evaluate the effect of changes in flows and water levels on the inundation of instream and floodplain habitats in the Upper Peace River. Even with the qualifiers described above, these analyses overall present fairly consistent results that can be used to assess the hydrologic status of natural systems associated with the upper river and determine minimum flows and levels.

# Chapter 6

# Results of Minimum Flows and Levels Analysis

## 6.1. Overview

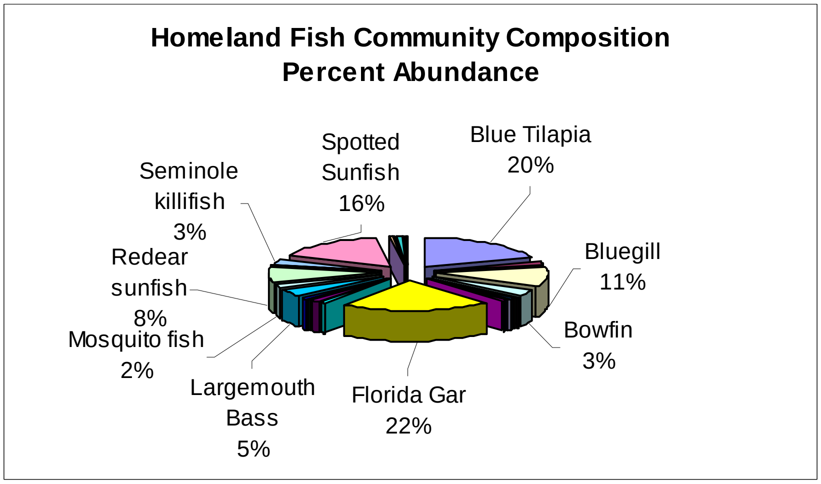
The results from modeling and field investigations at 18 transects on the Upper Peace River are assessed with the goal of developing minimum flow criteria/standards for insuring that ecological functions at various flow levels and elevations are protected. Minimum flows based on fish passage depth and wetted perimeter inflection point analysis are recommended. These flows primarily address low flow conditions, but as discussed in Section 3.3.5 may provide some benefit to medium and high flows as additional data and analyses are conducted to allow minimum flows to be set for medium and high flows at a later date. In the interim, standards are proposed to guide management approaches that ensure improved inundation of important instream habitat (exposed roots and snags) and riverine wetland systems where possible.

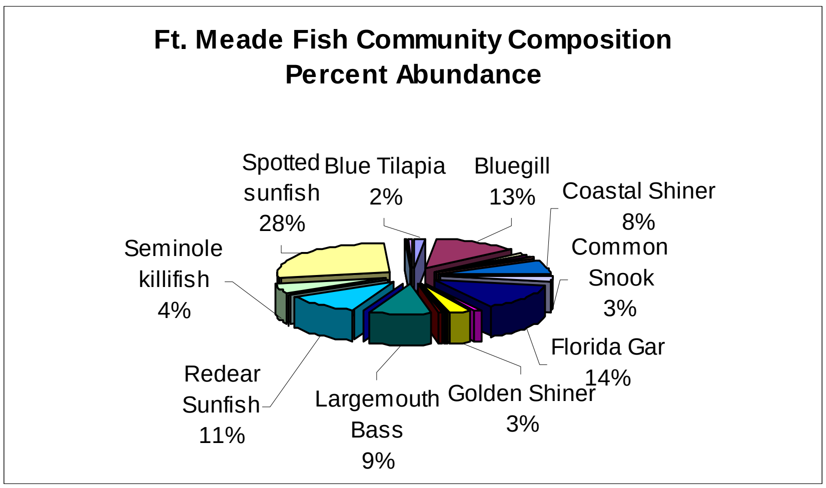
## 6.2 Fish Passage

The fish passage depth criteria is similar to that of the SJRWMD (Hupalo et al. 1994). As they noted, most work on this topic has been done on salmonid species, and the depth criterion used by them was based on body depth dimensions of large trout species (Hupalo et al. 1994 citing Thompson 1972). The SJRWMD proposed fish passage depth criterion of 0.6 foot for transects over bare substrate. The approach used by the SJRWMD is considered reasonable and would be appropriate for most fish that are frequently found on the Upper Peace River, although it is subject to criticism because salmonid fishes are not found in Florida waters.

### 6.2.1 The Adequacy of the 0.6 Foot Criterion

Actual fish body depth measurements are not currently available, but they are part of sampling planned during 2002-2003. However, to test the adequacy of a 0.6 foot minimum passage depth, a simple evaluation was done based on figures and drawings of fishes found in a number of published sources (FGFWFC no date, Lee et al. 1980, Hoyer and Canfield 1994, Harlan and Speaker 1956). First, the FFWCC database (FFWCC 2001) was used to determine which fish species have been taken in the Upper Peace River. Based on an analysis of this data for three sites (Homeland, Ft. Meade and Wauchula), it was determined that the dominant fish species in the Upper Peace River, in order of decreasing abundance at the Homeland site, are the Florida gar, blue tilapia, spotted sunfish, bluegill, redear sunfish, largemouth bass, bowfin, Seminole killifish, mosquito fish, and black crappie (Figure 6.1).



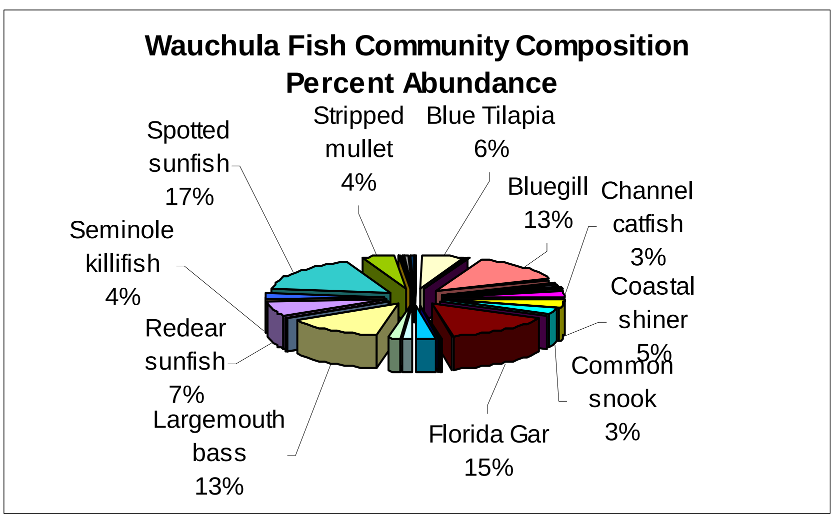




Figure 6-1. Diagrams depicting most abundant fish species at three FFWCC sampling sites on the Upper Peace River.

Although body depth measurements are generally not given in the literature, total length measurements are often reported. Using illustrations and photographs from four sources cited above, the maximum length to body depth ratio for the species listed above (Appendix FD-6) was obtained. Since the photographs and figures used were of adult fish, and assuming the ratio of length to depth is relatively constant in adult fish, the body depth based on the range of total length measurements given was computed for adult fish. Two sources were used for the total length data, the *Atlas of North American Freshwater Fishes* (Lee et al. 1980) and the *Handbook of Common Freshwater Fish in Florida Lakes* (Hoyer and Canfield 1994). When a range of total lengths was given for a typical adult fish by Lee et al. 1980, the maximum value given was used, and if a single maximum length was given it was also used. With respect to the Hoyer and Canfield handbook (1994), the maximum reported length was always used. The Seminole killifish and mosquito fish were not included in the subsequent analysis, since they are small fish, and any criterion used for the other eight species would be more than sufficient to allow for passage of these two species.

The Florida gar was the dominant fish at Homeland in terms of abundance, and was second in abundance at the Ft. Meade and Wachula sites. Based on our calculations, the largest fish may be expected to be 6.7 inches deep, but a more typical body depth was 4.5 inches. The exotic blue tilapia was the second most commonly encountered fish at the Homeland site and was among the top ten species found at the other two up-river sites. A large adult fish might have a body depth of 7.1 inches based on information in the *Atlas* (Lee et al. 1980). Data on tilapia were not included in the *Handbook* (Hoyer and Canfield 1994) because the fish is not native to Florida. A very large spotted sunfish, the most commonly captured fish at Wachula and Ft. Meade and third in abundance at Homeland, might attain a body depth of 3.1 inches. A large bluegill was projected to obtain a body depth of 6.7 inches based on information in the *Atlas*, while the largest bluegill captured by Hoyer and Canfield (1994) in their sampling of 60 north-central Florida lakes (which included lakes in the headwaters of the Upper Peace River) had a projected body depth of 5.3 inches. Florida is known for its large redear sunfish, and based on our calculations, the largest redear captured by Hoyer and Canfield (1994) would have had a body depth of 7.0 inches. The largemouth bass, an important game fish, was $4^{th}$, $5^{th}$ and $6^{th}$ in abundance at the three up-river sites, and based on body depth estimates is the "tallest" fish likely to be encountered with any frequency on the Upper Peace River. A bass weighing 12.4 pounds with a total length of 28.3 inches is projected to have a body depth of 7.9 inches; however, it is projected of the 7,692 bass measured by Hoyer and Canfield (1994), only 5 would have exceeded a body depth of 6.6 inches. Based on this simple analysis, the 0.6 foot criterion (equivalent to 7.2 inches) used by SJRWMD would permit passage by all but the very largest individuals of the fish species commonly encountered on the Upper Peace River.

### 6.2.2 Minimum Flows Needed to Permit Fish Passage

As previously described, the flow necessary to reach a maximum water depth of 0.6 foot was determined for each site represented in the HEC-RAS model. Once all site specific flows were determined, these data were plotted against distance (river miles from the mouth of the Peace River) and visually evaluated to determine the flows needed to allow fish passage along the reach. Inspection of the data points on Figure 6-2, suggests that with a flow of 16 cfs, a maximum fish passage depth of 0.6 foot can be maintained at upper transect sites and allow fish passage from the uppermost portion of the river near Bartow to a point just above Ft. Meade. Beginning in the vicinity of the Ft. Meade gage to the point of the confluence of Payne Creek with the Peace River, a 0.6 foot maximum fish passage depth can be met with four exceptions with a flow of 27 cfs. With a single exception the fish passage depth of 0.6 foot can be maintained with a flow of 45 cfs from the vicinity of the confluence of Payne Creek all the way to the Zolfo Springs gage.

At the five transects (all located downstream of Ft. Meade) where the proposed flows would not allow a 0.6 foot fish passage depth, fish passage would not be precluded for all fish, certain size fish will be able to pass; smaller species and smaller individuals of larger species. At the recommended fish passage flows (16 cfs at Bartow, 27 cfs at Ft. Meade, and 45 cfs at Zolfo Springs), the maximum fish passage depth at three of the five transects would be approximately 0.4 feet, and the depth at the other two sites would be approximately 0.2 feet. The proposed fish passage depths would be sufficient to maintain constant flow on the Upper Peace River and thus avoid the problems associated with extremely low to no flow conditions (e.g., reduced DO concentrations).

It is proposed that the flow necessary to provide for a fish passage depth of 0.6 foot (and the wetted perimeter flow to be discussed below) need not be met 100% of the time, rather it is recommended that the flows should remain above the proposed level at least 95% of the time each year. While it could be argued, particularly at Ft. Meade and Zolfo Springs, that the proposed flows would probably have been exceeded 100% of the time, a 95% exceedance value allows for periodic drought conditions without violating the minimum flow criteria. This is reasonable and would allow the flow to drop below the 0.6 ft criterion for no more than 18 days during severe drought conditions. Although unimpacted flow data for any site on the Peace River is not available, records during the 1940’s do show that a 16 cfs Low Minimum Flow (LMF) would have been violated at the Bartow site. Referring to plots of the 95% exceedance flows for each of the three gage sites (Figure 6-3), inspection indicates that as proposed in this document, the LMF at the Bartow Gage (16 cfs) was met only two years since 1985, that the LMF at the Ft. Meade Gage (27 cfs) has not been met for any year since 1985. In contrast, the proposed LMF of 45 cfs for the Zolfo Springs Gage was met on all but three occasions between 1985 and 2000, inclusive.

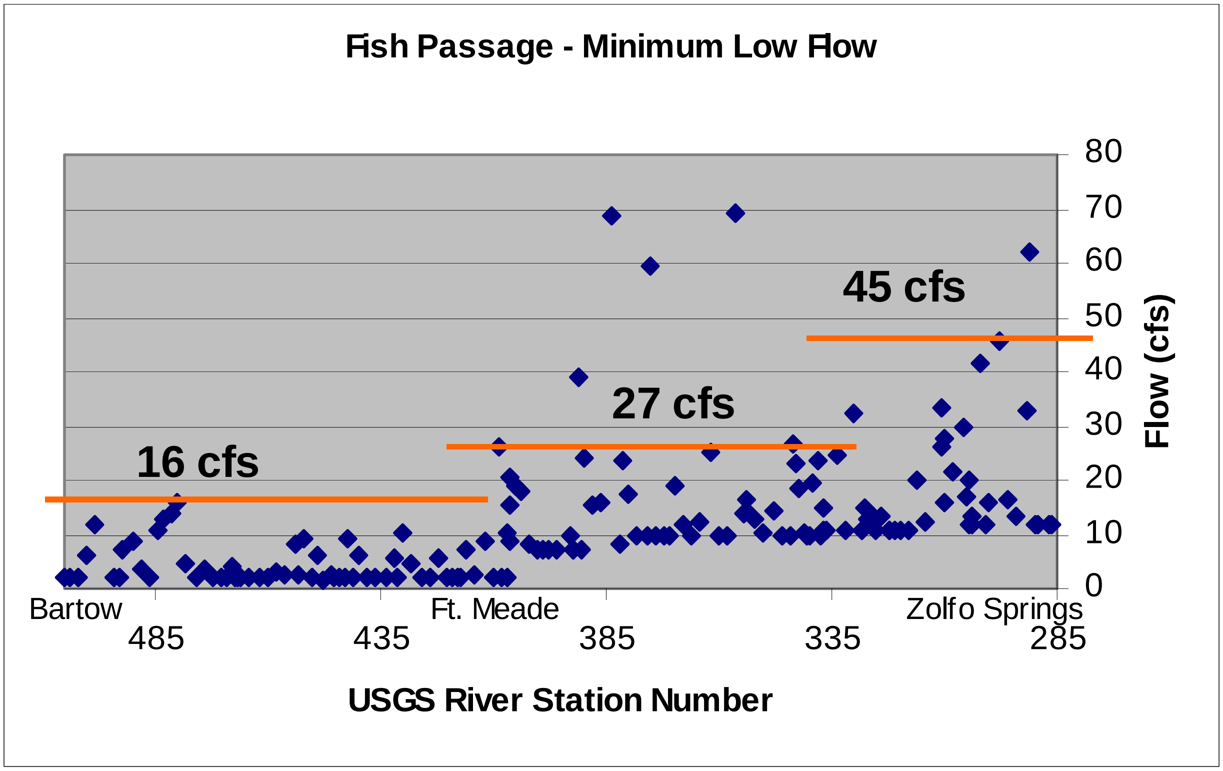
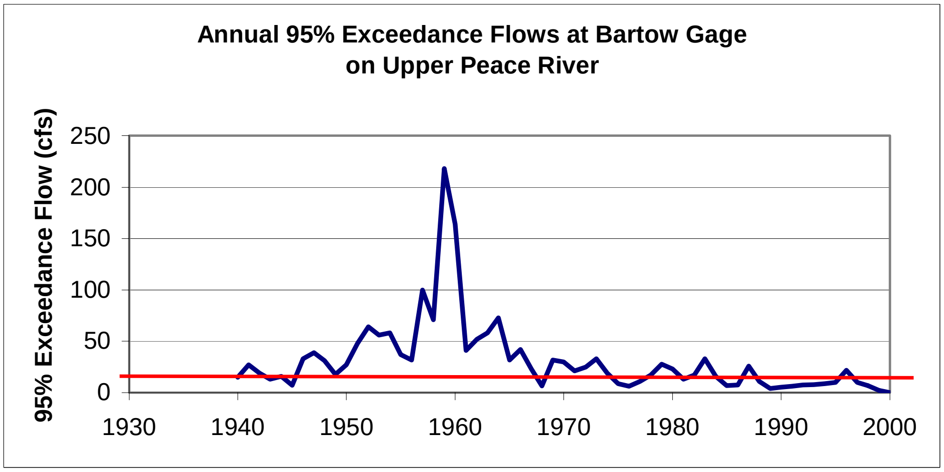
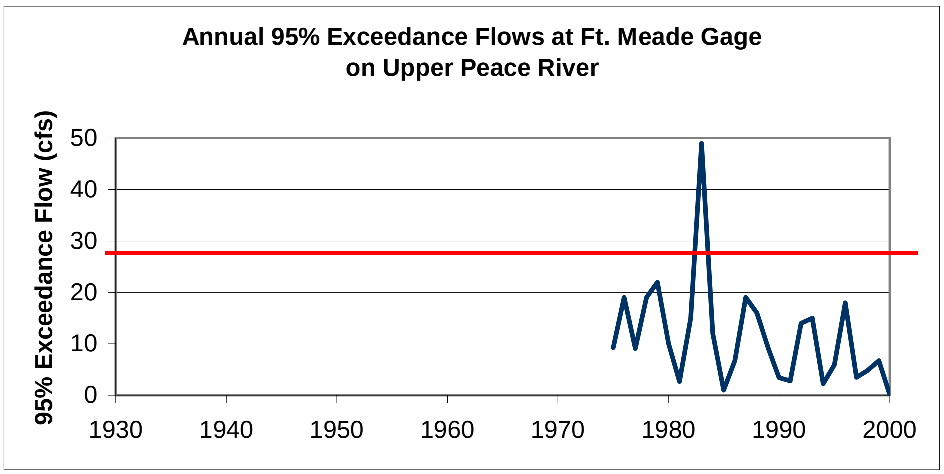



Figure 6-2. Flow needed at 160 transect sites on the Upper Peace River to allow a maximum depth of 0.6 foot for fish passage. Superimposed on this plot are recommended minimum fish passage flows for three river segments.



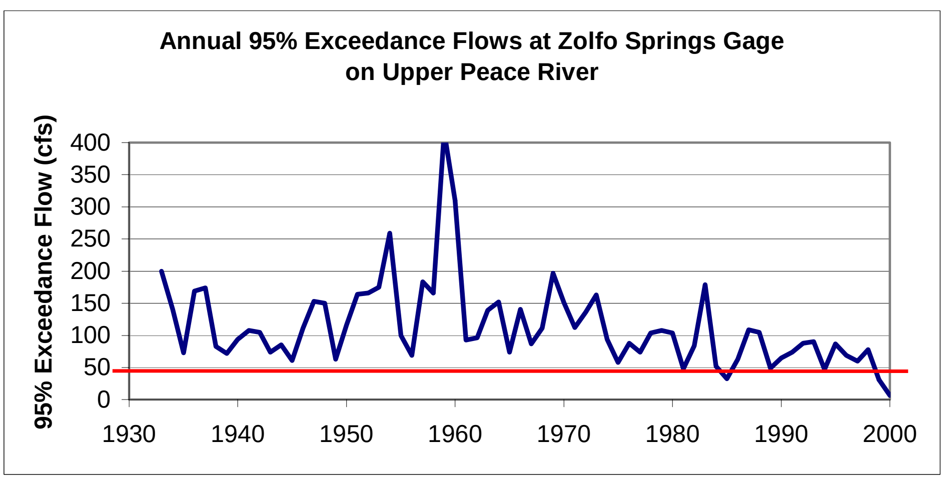




Figure 6-3. Annual 95% exceedance flows at the Bartow, Ft. Meade and Zolfo Springs gages for their respective periods of record. Red line drawn at proposed minimum low flow.

## 6.3 Wetted Perimeter

Wetted perimeter plots (wetted perimeter versus flow) were developed for the 160 SWFWMD-USGS transect sites using output from the HEC-RAS model runs (see Figure 5-3 for example wetted perimeter plot for SWFWMD Transect 150). Each plot was visually examined for "inflection" points. Although wetted perimeter plots were examined at the low flow end for the inflection point that would yield the LWPIP, other inflection points could be discerned and related to topographic breaks, such as top of bank, transition from swamp to lower flood plain, etc. Using Site 150 as an example, a clear inflection point occurs around 10 cfs when the wetted perimeter length is about 100 feet. By examining the model output for this site (refer toTable 5-4), at the modeled flow of 10.67 cfs, the calculated wetted perimeter is 98.64 feet. When the discharge is increased almost six fold (to 66 cfs), the calculated wetted perimeter for this discharge is only 128.51 feet. Stated differently, it would take a 600% increase in flow to increase the wetted perimeter by less than 30%. A flow of 10 cfs makes a relatively large area of habitat available for colonization by aquatic macroinvertebrates considering the flow provided. Since streams are a series of riffles (shoals), pools and runs, many of the wetted perimeter plots for the 160 transects on the Upper Peace River show no inflection points at flows below 100 cfs, this is because in pools and runs the LWPIP was already achieved at the lowest modeled flow. Appendix WP contains WP plots for all SWFWMD transects and for the USGS transects that showed an LWPIP above the lowest modeled flow.

Flows required to inundate the LWPIP at all transect sites are plotted in Figure 6-4. Since it is believed that the LWPIP at most sites was consistently exceeded historically due to the baseflow contribution from the Floridan and intermediate aquifers, it was reasoned that a decline in flows to a point below that which would not allow the LWPIP to be consistently met (>95% of the time), would result in significant harm to the resource by significantly decreasing the amount of habitat available for macroinvertebrate colonization.

Low minimum flow (LMF) values were developed based on the wetted perimeter approach using the LWPIP plot (Figure 6-4). Inspection of the plot of LWPIP flow versus site suggests that a flow equal to or greater than 17 cfs will allow the LWPIP to be met at all cross sections between Bartow and Ft. Meade. With only a single exception, a flow of 26 cfs will allow the LWPIP to be achieved at all cross-sections between Ft. Meade and Zolfo Springs. The single exception is transect 375 which is located near the Ft. Meade gage. The modeled flow required to meet the LWPIP at this site was 45 cfs. At the proposed 27 cfs for Ft. Meade based on fish passage, the wetted perimeter at USGS transect 375 would be approximately 32 feet, increasing the flow to the 45 cfs would inundate a wetted perimeter of around 36 feet, a 12% increase in the perimeter wetted by a 27 cfs discharge. For the most part, the proposed low minimum flows needed for a fish passage depth of 0.6 foot at each of the three gage sites is sufficient to meet the LWPIP at the vast majority of transect sites.

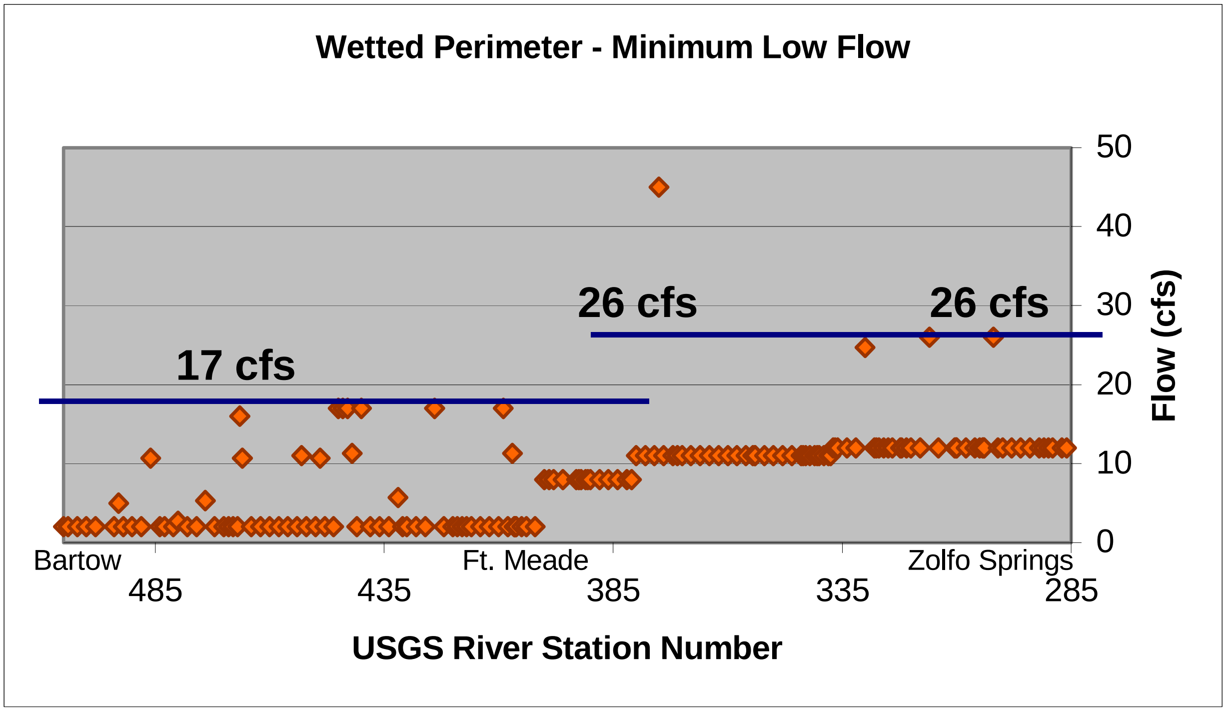



Figure 6-4. Flow needed at each transect site on the Upper Peace River to wet the Lowest Wetted Perimeter Inflection Point (LWPIP). Superimposed on this plot are recommended LWPIP minimum flows.

### 6.4 Proposed Low Minimum Flows based on Fish Passage and Wetted Perimeter

It was not assumed that fish passage needs will be met by the wetted perimeter approach, nor vice versa. Rather both approaches were used in tandem to evaluate the low minimum flow requirement, and have used the higher flow of the two as a conservative means for establishing the proposed Low Minimum Flow. As can be seen from a combination plot of wetted perimeter inflection point flows and minimum fish passage depth flows for the Upper Peace River, in the uppermost end of the study reach, wetted perimeter poses a slightly higher minimum standard, while fish passage depth establishes the standard for the middle and lower sections of the reach. It is felt that the proposed flows will also insure that recreational canoeing and aesthetics are maintained during low flow periods, since the proposed flows would ensure a minimum depth of not less that 0.6 feet at the highest points in the channel and ensure that flow is continuous over most of the river bottom.

In consideration of the wetted perimeter and fish passage plots produced (see Figure 6-5), the following low minimum flows are proposed for the upper Peace River:

An annual 95% Exceedance Flow of ***17 cfs*** as measured at the ***USGS Bartow Gage***

An annual 95% Exceedance Flow of ***27 cfs*** as measured at the ***USGS Ft. Meade Gage***

An annual 95% Exceedance Flow of ***45 cfs*** as measured at the ***USGS Zolfo Springs Gage***

As a frame of reference, the mean annual 95% exceedance flow at the Bartow Gage for the period of record, 1940 to 2000, averaged 31 cfs. It should be noted, however, that the mean of the annual 95% exceedance flows for the last 16 years (1985-2000) was 9 cfs, and only two times during this period (in 1987 and 1996) has the annual 95% exceedance flow been greater than 17 cfs (26 cfs in 1987 and 22 cfs in 1996).

The annual 95% exceedance flow at the Ft. Meade Gage, for the period of record, 1975 to 2000, averaged 16 cfs. The annual 95% exceedance flow at this site has only been greater than the proposed low minimum flow of 27 cfs once in its twenty-six year period of record (49 cfs in 1983). It is extremely telling that for the 26 years of record, the Ft. Meade annual 95% exceedance flow was below the Bartow annual 95% exceedance flow for 16 of those years; clearly indicative of the losing nature of the stream segment between Bartow and Ft. Meade.

The annual 95% exceedance flow at the Zolfo Springs Gage, for the period 1940 to 2000, averaged 112 cfs, and in general this site meets the proposed annual 95% exceedance flow, although flow at this site fell below 45 cfs in three years between 1985 and 2000 (33 cfs in 1985, 31 cfs in 1999, and 6.8 cfs in 2000).

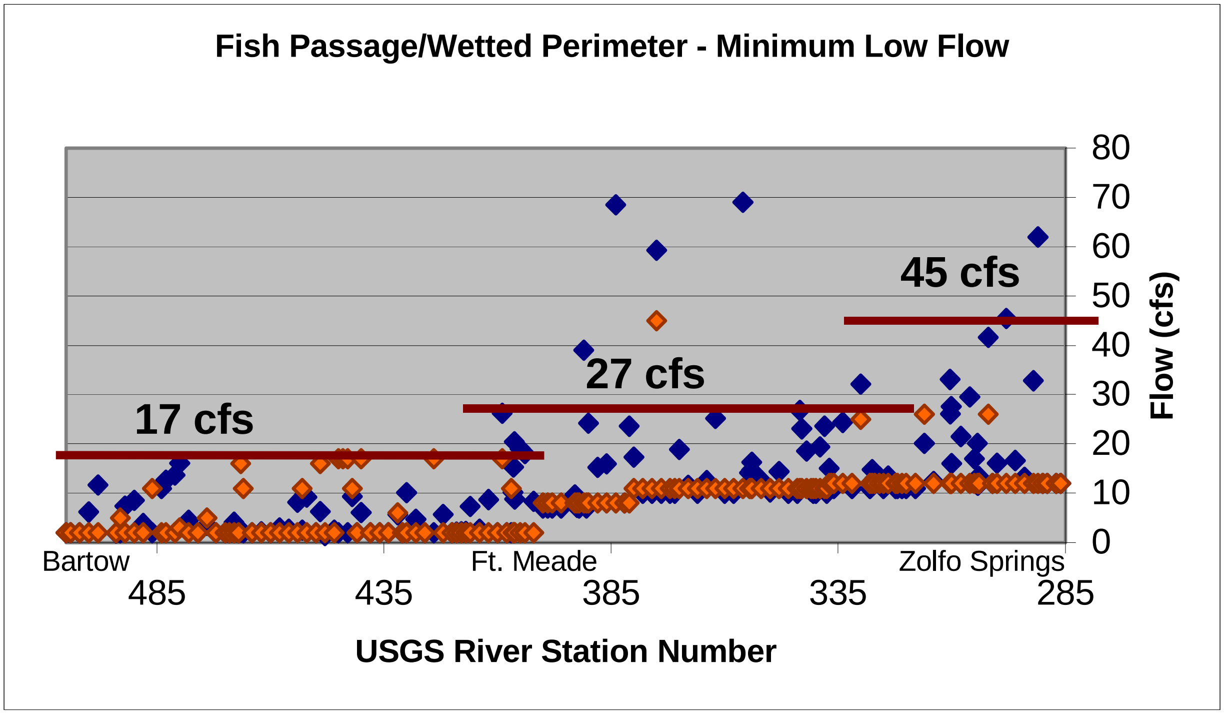



Figure 6-5. Combination plot of the Lowest Wetted Perimeter Inflection Point (LWPIP) and fish passage flow required at 160 transect sites with recommended Minimum Low Flows for Upper Peace River superimposed.

## 6.5 Instream Habitats of the Upper Peace River

In this section, the results from instream habitat investigations are presented for the purpose of developing a medium flow standard that can be used to protect these habitats and their associated biota. Discussion of results begins with a physical description of the instream habitats found in the Upper Peace River. Since previous studies recognize woody habitat as a critical habitat, the elevational distribution and inundation of these habitats was investigated in particular. As discussed in Section 3.3.5, we will continue to collect data and conduct analyses to better differentiate the effect of existing structural alterations and changes from those of withdrawals prior to establishing minimum flows for medium and higher flow conditions. The following information and analysis will help guide management approaches in the interim.

### 6.5.1 Channel Characteristics of the Upper Peace River

A general overview of the riparian corridor comprising the Upper Peace River is appropriate because it establishes the landscape setting that influences instream habitats. The channel of the Upper Peace River constitutes a minor fraction of the total floodplain coverage as determined from eighteen transects spanning the length of the riparian corridor up to the upland edge (see Figure 6-6). Beyond the river banks, cypress and hardwood swamps are abundant near Bartow. Seasonally inundated, lower floodplain forests are common to just below Ft. Meade (Transect 106), with more scattered abundance further downstream. Upper floodplain forests that experience temporary inundation are most abundant from just north of Ft. Meade southward.

Channel geomorphology varies considerably in the Upper Peace River corridor. Above Ft. Meade, bottom substrates of sand and/or silt predominate. Downstream bedrock becomes more prominent. From the confluence of Saddle Creek and Peace Creek Canal, the river has low bank heights (3-8 ft.) and shallow bank slope angles (15-60 degrees; measured from the horizontal axis at the base of the bank against the predominant slope of the bank). Mean channel widths approximate instream perimeter lengths with values ranging between 65-106 feet (Table 6-1). Downstream of Ft. Meade, the channel becomes more incised. This occurs as a result of increased bank heights (site means ranging between 7.3-16.3 ft.) with bank slope angles of 55-73 degrees. Channel widths are also greater, ranging from 108 to 150 feet. Consequently, these higher banks and wider channels increase instream perimeter length from 108 to150 feet. Mean bank perimeter ranged from 19-43 feet throughout the corridor, with no apparent longitudinal trend.

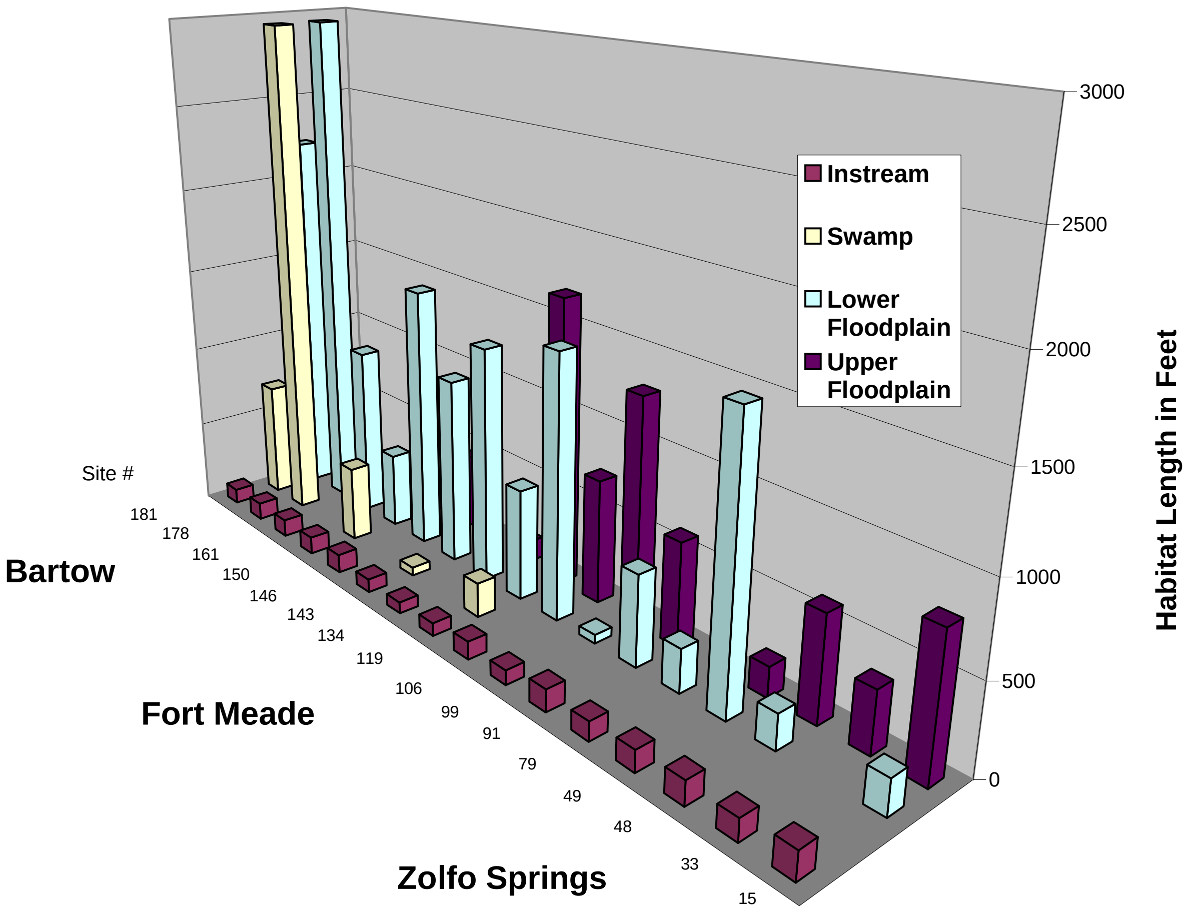



Figure 6-6. Floodplain habitats found in the Upper Peace River. Histobars represent habitat length (feet) measured from cross sections transects.

Table 6-1. Physical stream characteristics of sampled transects / sites on the Upper Peace River. Values are means from three replicate transects sampled per site.

| Site # | Channel Width (ft) | Perimeter Length (ft) | Bank Perimeter (ft) | Right Bank Slope Angle ( $^o$ ) | Left Bank Slope Angle ( $^o$ ) | Right Bank Height (ft) | Left Bank Height (ft) |
|---|---|---|---|---|---|---|---|
| **181** | 84.0 | 85.2 | 28.2 | 52.3 | 60.7 | 4.3 | 4.3 |
| **178** | 100.3 | 102.2 | 33.3 | 71.7 | 43.0 | 5.5 | 5.1 |
| **161** | 100.3 | 102.0 | 35.7 | 67.3 | 26.3 | 4.3 | 3.8 |
| **150** | 102.3 | 103.1 | 27.6 | 48.3 | 40.0 | 3.4 | 3.6 |
| **146** | 106.3 | 106.3 | 22.9 | 30.7 | 36.0 | 4.3 | 4.5 |
| **143** | 81.7 | 81.2 | 21.1 | 27.0 | 40.7 | 4.4 | 3.6 |
| **134** | 65.3 | 67.1 | 21.3 | 58.0 | 47.7 | 4.9 | 4.8 |
| **119** | 72.3 | 74.3 | 21.9 | 59.7 | 44.7 | 4.6 | 3.9 |
| **106** | 102.3 | 104.0 | 31.8 | 30.0 | 44.7 | 6.5 | 7.5 |
| **99** | 80.3 | 83.8 | 27.9 | 32.3 | 61.0 | 5.9 | 8.2 |
| **91** | 126.7 | 130.7 | 34.9 | 31.0 | 74.3 | 7.0 | 8.2 |
| **83** | 122.0 | 124.9 | 29.0 | 55.0 | 57.7 | 11.1 | 10.3 |
| **79** | 103.3 | 108.8 | 19.3 | 43.0 | 54.3 | 8.3 | 7.3 |
| **52** | 134.3 | 140.7 | 43.2 | 44.3 | 54.7 | 9.6 | 12.5 |
| **49** | 113.0 | 120.8 | 24.4 | 68.7 | 64.0 | 15.0 | 14.3 |
| **48** | 126.0 | 134.6 | 27.2 | 68.0 | 61.0 | 17.3 | 11.2 |
| **33** | 117.0 | 125.1 | 22.9 | 72.7 | 60.3 | 11.9 | 7.4 |
| **15** | 151.7 | 157.7 | 36.4 | 61.7 | 64.0 | 11.7 | 16.3 |

### 6.5.2 Instream Habitats - Lateral Distribution

Instream habitats were sampled at 18 transects. Bottom habitats were dominant, ranging from 20-65% of the total distance across each transect (see Figure 6-7). The relative importance of bottom habitat increases from upstream to downstream. This benthic habitat is composed of sand, silt or bedrock or a mix of any of these substrata. During spring and summer months, alga mats can cover these substrates, particularly during low flow periods.

Other instream habitats include wood (such as snags and exposed roots), aquatic plants, and riparian vegetation (such as wetland trees and understory plants). Aquatic plants included rooted emergent vegetation, floating-leaved vegetation and submersed aquatic vegetation. All other instream habitat types were less extensive than the bottom habitats. Although Lanquist (1953) reported that native submersed vegetation and water hyacinth were abundant in the Upper Peace River, floating leaved vegetation and submersed aquatic plant habitats were not common during this study. When present, however, most occurrences were below Ft. Meade. Relative abundance of wetland understory vegetation was highest upstream of Ft. Meade where bank height is low. At downstream sites with higher banks, riparian vegetative habitats were much narrower in lateral distribution. Wetland understory vegetation exhibited seasonality, and appeared to be influenced by shading of the tree canopy.

### 6.5.3 Instream Habitats - Vertical Distribution

Instream habitats exhibited a distinct pattern of vertical or elevational distribution at each site (Figure 6-8). Exposed roots typically occurred at higher elevations than river bottom, snags, aquatic plants (submersed, floating leaved, emergent), and wetland understory plants. When present, submersed aquatic or floating-leaved vegetation tended to occur along the edges of the waterline. Further up the bank, emergent aquatic vegetation was replaced by herbaceous wetland understory vegetation. Wetland trees were always found near the top of bank. On low banks, instream habitats were clustered vertically. Higher banks, typically located downstream of Ft. Meade, resulted in more dispersed instream habitats.

Figure 6-9 shows in more detail the elevational distribution of instream habitats at Site 161 (similar plots from other transects are compiled in Appendix IH). The occurrence of exposed roots at relatively high elevations is significant because inundation of this habitat results in inundation of numerous other instream habitats. Conceptually, in stream ecology, maintenance of a greater mosaic of habitats provides the greatest potential for stream productivity and ecosystem integrity (Pringle et al. 1988). Evaluation of inundation patterns of woody habitat on the Upper Peace River could, therefore, be used to develop a medium flow standard.

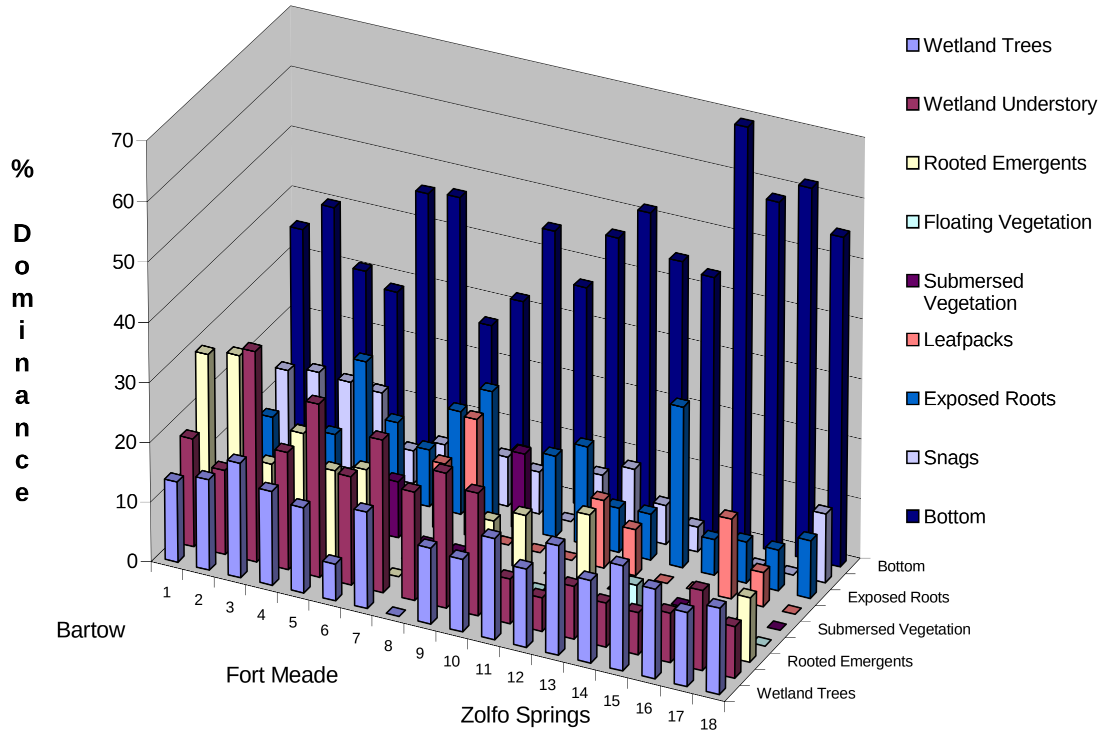



Figure 6-7. Instream habitats found in the Upper Peace River. Histobars represent percent dominance of various instream habitats.

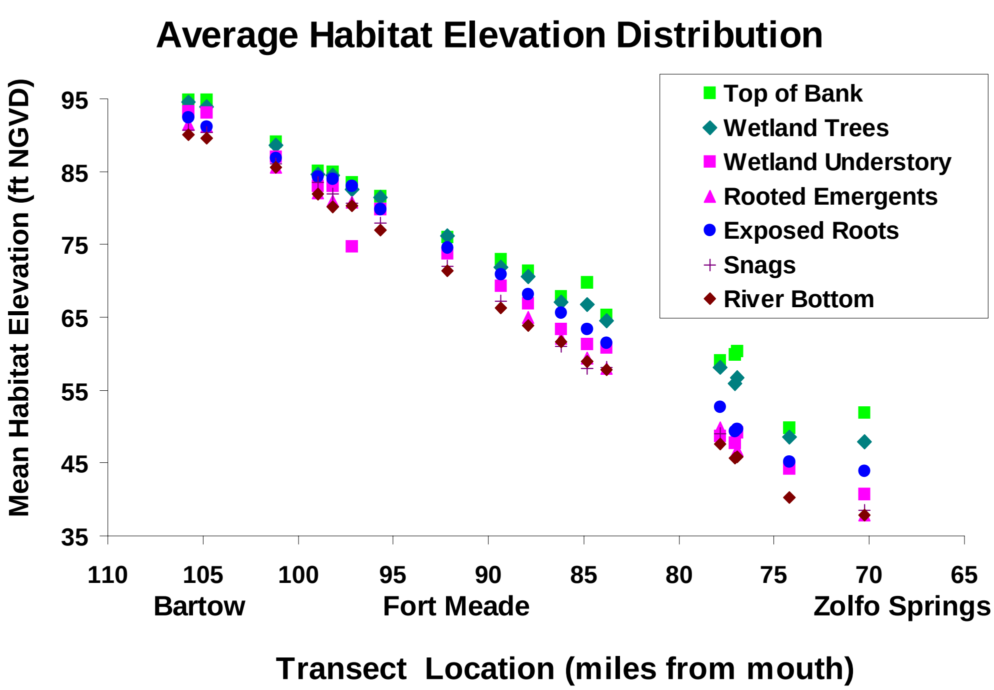



Figure 6-8. Distribution of mean instream habitat elevations at different study sites from the Upper Peace River.

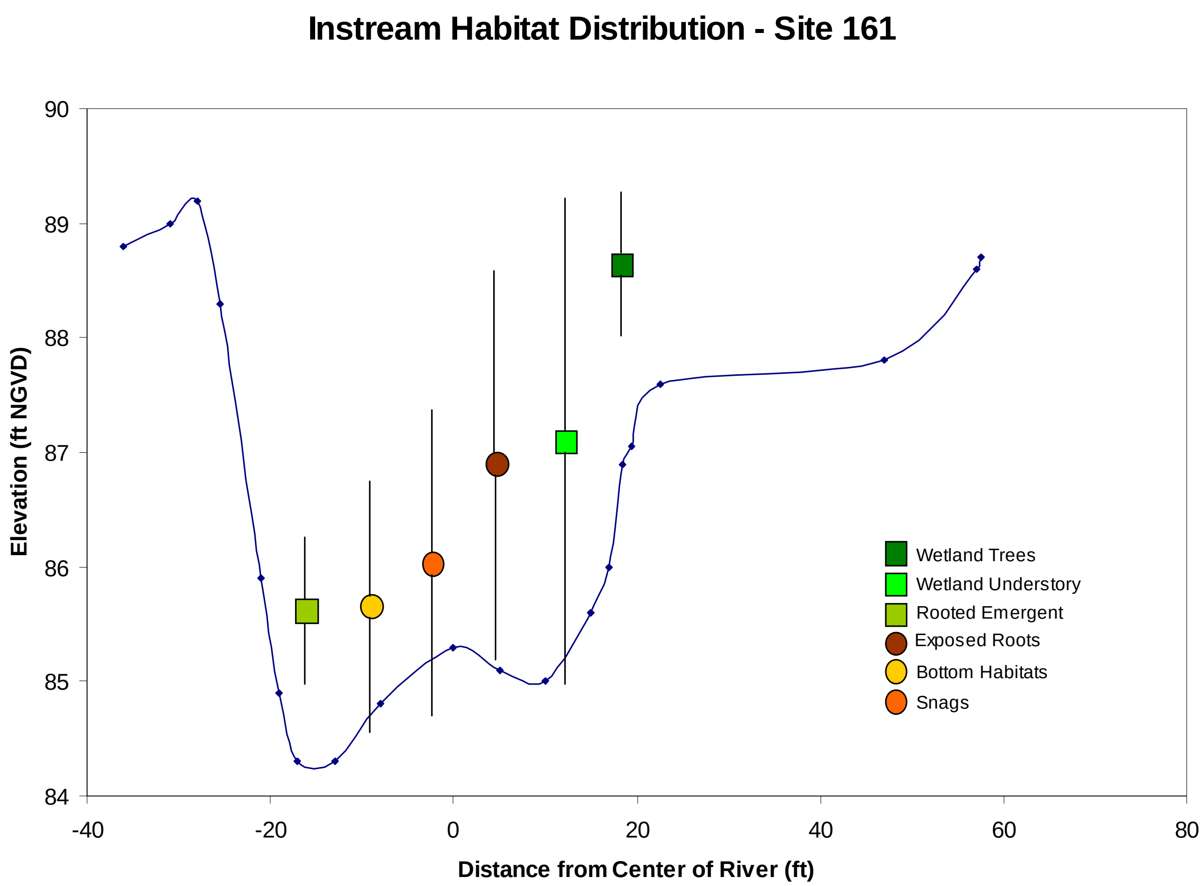


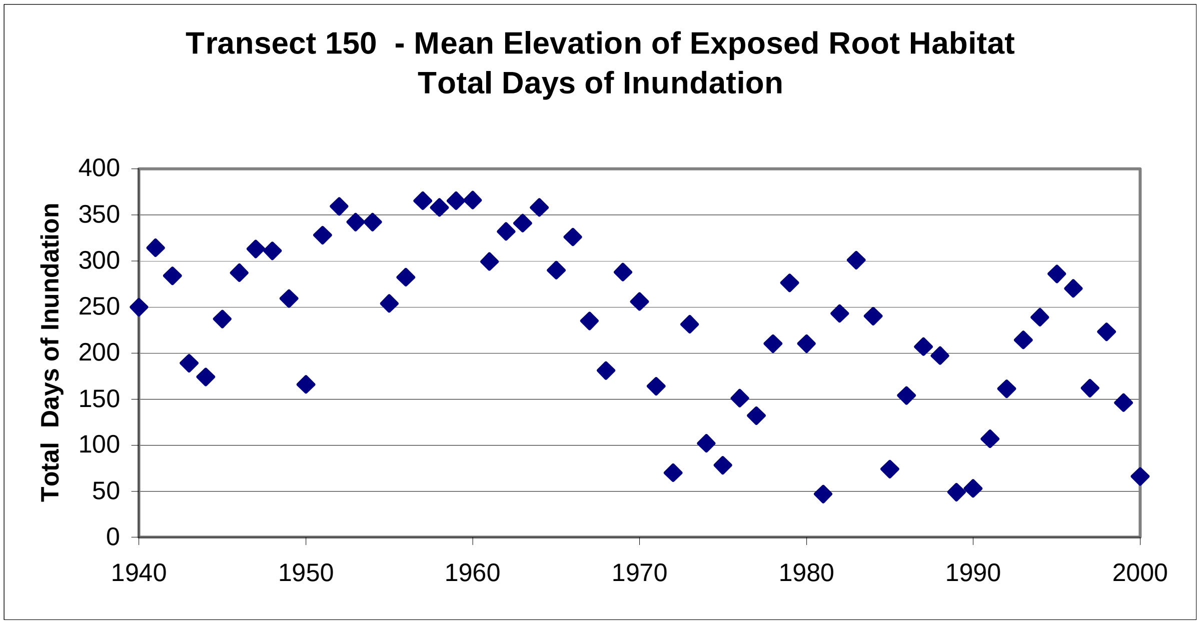

Figure 6-9. River channel elevation profile at Site 161 (near Bartow). Mean elevations (±SD) of various instream habitats were superimposed over this plot. Upper limit of the line graph represents top of bank.

### 6.5.4 Flow Relationships with Woody Instream Habitats

Based on the ecological importance of woody habitat, and its potential for use in the development of a medium flow standard, we examined historical inundation patterns for exposed root and snag habitats in the Upper Peace River. Using the modeled relationship of flow at a transect site to flow at one of the two long-term gage sites, an inundation history was reconstructed for a transect site as described in Section 5.7. Historic records of inundation were represented as total number of days of inundation per year and longest consecutive number of days of inundation that a particular stage (elevation) and its corresponding flow were reached or exceeded.

For example, Figure 6-10 shows the total number of days per year at Site 150 that river stage reached or exceeded the mean elevation of exposed root habitat for the period 1940 to 2000. This river stage is reached when site flow is 67 cfs, which is equivalent to a flow of 61 cfs at the Bartow gage. Sites 119 to 181 above Ft. Meade were related to the Bartow gage. Inundation histories at Sites 15 to 106 were extrapolated from the Zolfo Springs gage record.

Table 6-2 shows a summary of flows required to inundate woody habitats at all transect sites, and the equivalent percent exceedance flows for the period 1940-2000 at the corresponding reference gage. For this period, the percent exceedance flows averaged 53% for exposed roots and 90% for snag habitat. These results suggest exposed root habitat is inundated in the medium flow range, while snag habitat is typically inundated by lower flows.



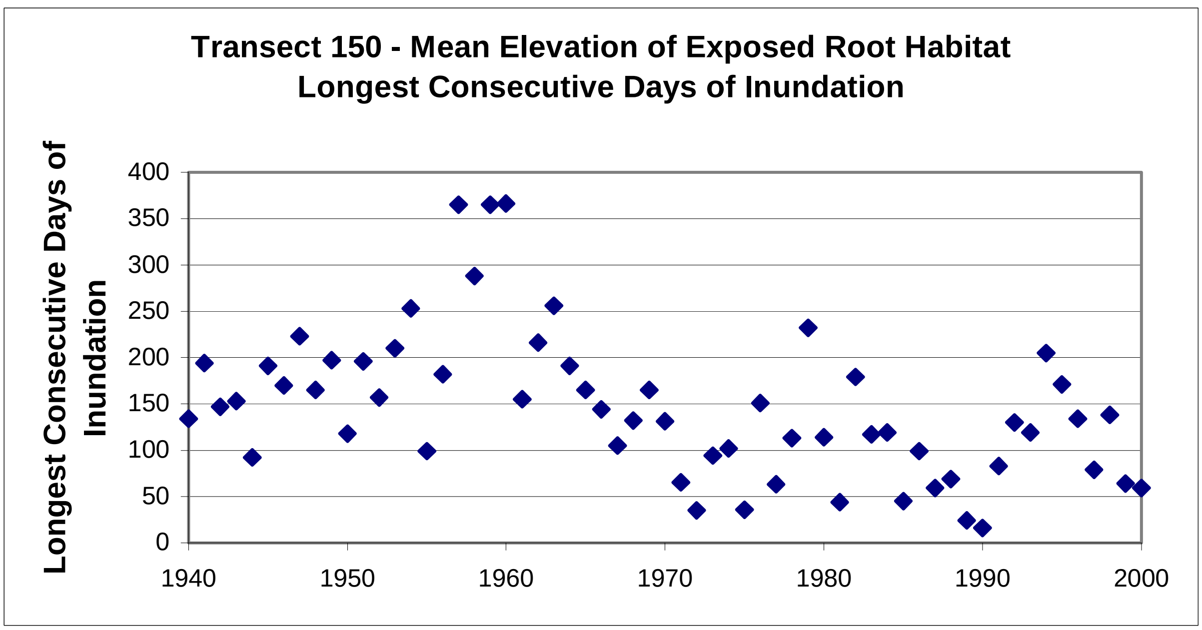




Figure 6-10. Total and longest consecutive number of days of inundation per year at the mean elevation (84.3 feet NGVD) of exposed root habitat at Site 150.

Table 6-2. Average elevation of instream woody habitats (exposed roots and snags) and corresponding flow requirements for inundation at site and reference gage with equivalent percent exceedance flows for the period of record (1940-2000).

| **Study Site** | **Exposed Root Mean Elevation (ft NGVD)** | **Corresponding Flow at Site (cfs)** | **Corresponding Flow at Gage (cfs)** | **Gage** | **% Exceedance Flow** |
|---|---|---|---|---|---|
| **181** | 92.4 | 61 | 61 | Bartow | 72 |
| **178** | 91.2 | 48 | 48 | Bartow | 84 |
| **161** | 86.9 | 44 | 40 | Bartow | 85 |
| **150** | 84.3 | 67 | 61 | Bartow | 72 |
| **146** | 84 | 104 | 94 | Bartow | 64 |
| **143** | 83 | 134 | 113 | Bartow | 56 |
| **134** | 79.8 | 64 | 54 | Bartow | 80 |
| **119** | 74.5 | 108 | 91 | Bartow | 65 |
| **106** | 70.9 | 283 | 430 | Zolfo Sp. | 43 |
| **99** | 68.2 | 318 | 484 | Zolfo Sp. | 39 |
| **91** | 65.6 | 1373 | 1946 | Zolfo Sp. | 5 |
| **83** | 63.5 | 1376 | 1557 | Zolfo Sp. | 8 |
| **79** | 61.5 | 817 | 925 | Zolfo Sp. | 20 |
| **52** | 52.7 | 541 | 612 | Zolfo Sp. | 32 |
| **49** | 49.3 | 287 | 300 | Zolfo Sp. | 57 |
| **48** | 49.7 | 314 | 329 | Zolfo Sp. | 54 |
| **33** | 45.2 | 67 | 72 | Zolfo Sp. | 100 |
| **15** | 43.9 | 945 | 945 | Zolfo Sp. | 19 |

| **Study Site** | **Mean Snag Elevation (ft NGVD)** | **Corresponding Flow at Site (cfs)** | **Corresponding Flow at Gage (cfs)** | **Gage** | **% Exceedance Flow** |
|---|---|---|---|---|---|
| **181** | 90.8 | 5 | 5 | Bartow | 100 |
| **178** | 90.3 | 10 | 10 | Bartow | 100 |
| **161** | 86 | 9 | 9 | Bartow | 100 |
| **150** | 83.5 | 35 | 31 | Bartow | 95 |
| **146** | 82 | 30 | 27 | Bartow | 97 |
| **143** | 80.6 | 27 | 23 | Bartow | 99 |
| **134** | 78 | 13 | 11 | Bartow | 10 |
| **119** | 72.1 | 15 | 13 | Bartow | 100 |
| **106** | 67.2 | 16 | 24 | Zolfo Sp. | 100 |
| **99** | none | none | none | Zolfo Sp. | none |
| **91** | 60.9 | 40 | 56 | Zolfo Sp. | 100 |
| **83** | 58 | 0 | 0 | Zolfo Sp. | 100 |
| **79** | 58.1 | 108 | 123 | Zolfo Sp. | 93 |
| **52** | 49.1 | 186 | 210 | Zolfo Sp. | 72 |
| **49** | none | none | none | Zolfo Sp. | none |
| **48** | none | none | none | Zolfo Sp. | none |
| **33** | none | none | none | Zolfo Sp. | none |
| **15** | 38.6 | 0 | 0 | Zolfo Sp. | 100 |

### 6.5.5 Woody Habitat Inundation Patterns between Bartow and Ft. Meade

All sites above Ft. Meade showed a temporal decline in the duration of inundation for exposed root habitat (Table 6-3; see Appendix IH for historic inundation plots). When the total number of days of inundation to the mean elevation of exposed root habitat at each site was compared between the reference (1940-1956) and recent (1987-1999) period as described in Section 5.7.2, results were statistically significant (Table 6-3) for all sites. For the reference period (1940 to 1956), root habitat (mean elevation) at sites upstream of Ft. Meade (Sites 119 to 181) averaged about 269 total days (74%) of inundation each year. The fewest total days of inundation in any one year was 118 days; several sites were inundated year-round in some years. In contrast, total days of inundation were considerably less at all sites during the recent period. On average root habitat at sites above Ft. Meade were only inundated for 185 days during the recent period; a decrease of 84 days or 31% from the reference period. More striking is the drop in yearly minimum values. Values at sites above Ft Meade ranged from 135 to 220 days for the reference period. The range of minimum values for the recent period was from 19 to 66 days. The duration of the minimum values had decreased by a factor of 5 to 6 at three sites. The inundation of root habitat has dropped dramatically in dry years. Similarly, comparisons were made between consecutive days of inundation, and results were statistically significant for all sites (Table 6-4). In the reference period consecutive days of inundation averaged 173, and ranged from 74 to 366; while the average was 96 days in the recent period, and ranged from 8 to 207. The difference in days of consecutive inundation between the two periods was 77 days for a decline of 45%. As with total days of inundation, the most dramatic drops were in the minimum days of consecutive days of inundation. The three lowest minimum values for the reference period ranged between 72 and 75 days, whereas the minimum values for these sites during the recent period were 8 days.

A similar trend or change in duration of inundation was also found for snag habitat. However, since snag habitat usually occurred at lower elevations than exposed root habitat, it was inundated longer. During the reference period the total number of days of inundation ranged from 243 days to 366 days with a mean of 353. During the recent period total days of inundation ranged from 92 to 366 and averaged 297 days. The difference in means between the two periods (reference and recent) was 56 days, representing a 19% reduction in number of continuous days of inundation. The declines were statistically significant at all sites in this reach of the river (Ft. Meade to Bartow) (Table 6-5). As with root habitat, greater reductions were observed in yearly minimum values. The difference between the means of the minimums for the two periods was 88 days (29%). Generally though, the reductions in minimum values were less pronounced for snags than roots, probably because snags occur lower in the river channel.

Although mean total rainfall during the reference and recent periods were similar, it should be noted that rainfall during the wet season was on average two inches greater in the reference period than in the recent period. Conversely, dry season rainfall was on average two inches greater in the recent period.

**Table 6-3. Total number of days per year of inundation to reach the mean elevation of exposed root habitats.**

| Site | Period 1940 to 1956 | | | | | Period 1987-1999 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Median | Mean | Min | Max | S.D. | Median | Mean | Min | Max | S.D. | P-value[a] |
| Zolfo Springs to Ft. Meade | | | | | | | | | | | |
| 15 | 63 | 77 | 15 | 181 | 50 | 51 | 51 | 2 | 133 | 43 | 0.1165 |
| 33 | 365 | 357 | 293 | 366 | 18 | 349 | 343 | 289 | 366 | 22 | 0.0346 |
| 48 | 208 | 203 | 105 | 301 | 67 | 159 | 149 | 54 | 260 | 62 | 0.0516 |
| 49 | 219 | 215 | 116 | 314 | 68 | 178 | 162 | 67 | 272 | 63 | 0.0597 |
| 52 | 115 | 119 | 39 | 251 | 59 | 86 | 86 | 3 | 165 | 51 | 0.2249 |
| 79 | 66 | 78 | 17 | 183 | 50 | 53 | 52 | 2 | 133 | 44 | 0.1319 |
| 83 | 30 | 43 | 5 | 124 | 38 | 16 | 28 | 0 | 112 | 35 | 0.1609 |
| 91 | 18 | 29 | 1 | 86 | 28 | 8 | 20 | 0 | 83 | 29 | 0.1165 |
| 99 | 147 | 145 | 59 | 280 | 63 | 109 | 108 | 30 | 195 | 53 | 0.1266 |
| 106 | 163 | 160 | 73 | 291 | 65 | 122 | 120 | 36 | 211 | 57 | 0.1738 |
| Ft. Meade to Bartow | | | | | | | | | | | |
| 119 | 255 | 241 | 135 | 316 | 66 | 157 | 151 | 24 | 263 | 74 | 0.0044 |
| 134 | 296 | 288 | 174 | 366 | 57 | 217 | 187 | 50 | 295 | 76 | 0.0008 |
| 143 | 235 | 221 | 118 | 302 | 66 | 138 | 135 | 19 | 230 | 71 | 0.0047 |
| 146 | 252 | 238 | 133 | 315 | 67 | 149 | 148 | 23 | 259 | 74 | 0.0047 |
| 150 | 284 | 276 | 166 | 359 | 59 | 197 | 178 | 49 | 286 | 75 | 0.0011 |
| 161 | 335 | 313 | 220 | 366 | 48 | 235 | 208 | 66 | 309 | 79 | 0.0005 |
| 178 | 316 | 298 | 198 | 366 | 55 | 221 | 195 | 55 | 303 | 77 | 0.0007 |
| 181 | 284 | 276 | 166 | 359 | 59 | 197 | 276 | 49 | 286 | 75 | 0.0011 |

[a] Mean values between recent (1987-1999) and reference (1940-1956) periods were compared statistically using Mann-Whitney-Wilcoxon Test. Alpha = 0.05.

**Table 6-4. Longest consecutive days per year of inundation to reach the mean elevation of exposed root habitats**

| Site | Period 1940 to 1956 | | | | | Period 1987-1999 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Median | Mean | Min | Max | S.D. | Median | Mean | Min | Max | S.D. | P-value[a] |
| Zolfo Springs to Ft. Meade | | | | | | | | | | | |
| 15 | 25 | 46 | 7 | 142 | 42 | 22 | 34 | 2 | 105 | 34 | 0.5579 |
| 33 | 365 | 309 | 188 | 366 | 79 | 204 | 222 | 149 | 366 | 67 | 0.0238 |
| 48 | 113 | 118 | 49 | 220 | 46 | 60 | 75 | 16 | 161 | 48 | 0.0202 |
| 49 | 123 | 131 | 50 | 220 | 48 | 80 | 81 | 17 | 199 | 54 | 0.0120 |
| 52 | 47 | 66 | 13 | 182 | 50 | 37 | 51 | 3 | 125 | 41 | 0.4768 |
| 79 | 25 | 46 | 7 | 143 | 42 | 22 | 34 | 2 | 105 | 33 | 0.5165 |
| 83 | 12 | 19 | 4 | 71 | 18 | 10 | 17 | 0 | 63 | 20 | 0.4768 |
| 91 | 7 | 12 | 1 | 37 | 10 | 6 | 12 | 0 | 61 | 18 | 0.2674 |
| 99 | 62 | 84 | 23 | 204 | 55 | 49 | 59 | 9 | 129 | 40 | 0.2249 |
| 106 | 96 | 97 | 29 | 219 | 54 | 55 | 66 | 10 | 160 | 46 | 0.1118 |
| Ft. Meade to Bartow | | | | | | | | | | | |
| 119 | 141 | 145 | 75 | 220 | 43 | 79 | 89 | 8 | 201 | 56 | 0.0069 |
| 134 | 183 | 189 | 95 | 366 | 65 | 85 | 102 | 19 | 205 | 57 | 0.0016 |
| 143 | 131 | 138 | 72 | 219 | 44 | 62 | 72 | 8 | 154 | 47 | 0.0016 |
| 146 | 141 | 144 | 74 | 220 | 43 | 70 | 85 | 8 | 201 | 56 | 0.0050 |
| 150 | 170 | 169 | 92 | 253 | 43 | 83 | 99 | 16 | 205 | 56 | 0.0021 |
| 161 | 203 | 227 | 119 | 366 | 76 | 105 | 116 | 25 | 207 | 50 | 0.0003 |
| 178 | 190 | 201 | 118 | 366 | 68 | 101 | 108 | 25 | 206 | 55 | 0.0006 |
| 181 | 170 | 169 | 92 | 253 | 43 | 83 | 99 | 16 | 205 | 56 | 0.0021 |

[a] Mean values between recent (1987-1999) and reference (1940-1956) periods were compared statistically using Mann-Whitney-Wilcoxon Test. Alpha = 0.05.

**Table 6-5. Total number of days per year of inundation to reach the mean elevation of snag habitats.**

| Site* | Period 1940 to 1956 | | | | | Period 1987-1999 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Median | Mean | Min | Max | S.D. | Median | Mean | Min | Max | S.D. | P-value [a] |
| Zolfo Springs to Bartow | | | | | | | | | | | |
| 15 | 366 | 366 | 366 | 366 | 0 | 366 | 366 | 366 | 366 | 0 | NA [b] |
| 52 | 251 | 262 | 157 | 364 | 64 | 247 | 217 | 141 | 310 | 58 | 0.0753 |
| 79 | 333 | 328 | 261 | 365 | 35 | 299 | 285 | 224 | 340 | 44 | 0.0144 |
| 83 | 366 | 366 | 366 | 366 | 0 | 366 | 366 | 366 | 366 | 0 | NA [b] |
| 91 | 365 | 364 | 351 | 366 | 4 | 362 | 354 | 311 | 366 | 17 | 0.0753 |
| 106 | 365 | 365 | 365 | 366 | 0 | 365 | 364 | 356 | 366 | 3 | 0.4388 |
| Ft. Meade to Bartow | | | | | | | | | | | |
| 119 | 365 | 360 | 306 | 366 | 15 | 335 | 310 | 241 | 366 | 46 | 0.0003 |
| 134 | 365 | 363 | 325 | 366 | 10 | 341 | 322 | 268 | 366 | 36 | 0.0002 |
| 143 | 361 | 343 | 271 | 366 | 31 | 284 | 260 | 122 | 352 | 75 | 0.0003 |
| 146 | 356 | 337 | 257 | 366 | 36 | 259 | 245 | 105 | 346 | 78 | 0.0003 |
| 150 | 348 | 330 | 243 | 366 | 40 | 247 | 230 | 92 | 325 | 80 | 0.0004 |
| 161 | 365 | 363 | 328 | 366 | 9 | 344 | 332 | 287 | 366 | 30 | 0.0003 |
| 178 | 365 | 363 | 326 | 366 | 10 | 343 | 326 | 276 | 366 | 34 | 0.0002 |
| 181 | 365 | 365 | 357 | 366 | 2 | 363 | 355 | 314 | 366 | 16 | 0.0039 |

***** Snags not present at Sites 33, 48, 49 and 99 during sampling period.

[a] Mean values between recent (1987-1999) and reference (1940-1956) periods were compared statistically using Mann-Whitney-Wilcoxon Test. Alpha = 0.05.

[b] Not Applicable. Zero variance between the two groups nullifies statistical test.

**Table 6-6. Longest consecutive days per year of inundation to reach the mean elevation of snag habitats**

| Site* | Period 1940 to 1956 | | | | | Period 1987-1999 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Median | Mean | Min | Max | S.D. | Median | Mean | Min | Max | S.D. | P-value [a] |
| Zolfo Springs to Ft. Meade | | | | | | | | | | | |
| 15 | 366 | 366 | 366 | 366 | 0 | 366 | 366 | 366 | 366 | 0 | NA [b] |
| 52 | 147 | 157 | 81 | 233 | 46 | 115 | 113 | 28 | 208 | 53 | 0.0120 |
| 79 | 198 | 217 | 145 | 365 | 65 | 147 | 151 | 97 | 210 | 35 | 0.0009 |
| 83 | 366 | 366 | 366 | 366 | 0 | 366 | 366 | 366 | 366 | 0 | NA [b] |
| 91 | 365 | 323 | 203 | 366 | 68 | 253 | 278 | 180 | 366 | 80 | 0.1547 |
| 106 | 365 | 365 | 365 | 366 | 0 | 365 | 345 | 216 | 366 | 50 | 0.4388 |
| Ft. Meade to Bartow | | | | | | | | | | | |
| 119 | 365 | 336 | 192 | 366 | 61 | 188 | 191 | 85 | 366 | 64 | 0.0002 |
| 134 | 365 | 348 | 192 | 366 | 51 | 193 | 200 | 115 | 366 | 59 | 0.0002 |
| 143 | 244 | 273 | 158 | 366 | 85 | 159 | 148 | 51 | 208 | 47 | 0.0002 |
| 146 | 233 | 270 | 155 | 366 | 88 | 141 | 138 | 27 | 207 | 52 | 0.0002 |
| 150 | 205 | 253 | 143 | 366 | 82 | 139 | 134 | 25 | 225 | 53 | 0.0003 |
| 161 | 365 | 348 | 192 | 366 | 51 | 194 | 205 | 133 | 366 | 53 | 0.0002 |
| 178 | 365 | 348 | 192 | 366 | 51 | 193 | 200 | 116 | 366 | 58 | 0.0002 |
| 181 | 365 | 356 | 210 | 366 | 38 | 215 | 244 | 188 | 366 | 71 | 0.0036 |

***** Snags not present at Sites 33, 48, 49 and 99 during sampling period.

[a] Mean values between recent (1987-1999) and reference (1940-1956) periods were compared statistically using Mann-Whitney-Wilcoxon Test. Alpha = 0.05.

[b] Not applicable. Zero variance between the two groups nullifies statistical test.

### 6.5.6 Woody Habitat Inundation Patterns between Ft. Meade and Zolfo Springs

Changes in inundation patterns of woody habitats downstream of Ft. Meade were not as dramatic as at upstream sites (see figures for Sites 15 to 106 in Appendix IH). The total number of days of inundation of exposed roots, with one exception (Site 33), were considerably less than at sites upstream of Ft. Meade. This is attributable to the distribution of exposed root habitat at relatively high elevations on the banks along this more incised segment of the river. The longer inundation pattern at Site 33 is attributed to its location in a depressional area. Nine of the ten sites below Ft. Meade showed no significant difference in total number of days of inundation of exposed root habitat between reference and recent periods (Table 6-3; alpha = 0.05). Although not significant at nine of ten sites using an alpha of 0.05, total days of inundation each year at sites downstream of Ft. Meade (Sites 15 to 106) averaged 143 days in the reference period contrasted to 112 days in the recent period; a difference of 31 days or a 22% decline. A similar percent decline in mean consecutive days of inundation was seen as well between the reference and recent period; the grand mean (the mean of the mean for all ten sites) declined from 93 to 65 days, or 30% (Table 6-4). There has been a greater percent decline in the inundation frequencies of exposed root habitat at sites above Ft. Meade than below.

The inundation duration of snag habitat were also examined at sites downstream of Ft. Meade. Unlike sites above Ft. Meade where snag habitat was always found, snags were not found at four of the ten sites between Ft. Meade and Zolfo. Of the remaining six sites, only two sites showed a statistically significant decline in total days (Table 6-5) and only one site showed a statistically significant decline in consecutive days (Table 6-6) of inundation. Of the six sites with snag habitat, two sites were always inundated 365 days/year); in the recent as well as the reference period. Consecutive days of inundation of snag habitat were also examined (Table 6-6). In the reference period sites were typically inundated for 299 days consecutive days, while in the recent period the mean was 270 days, a difference of approximately 10% between the two periods.

### 6.5.7 Development of a Medium Flow Standard

As repeatedly noted, streams require a range of flows to protect the many features and properties needed to maintain overall ecosystem integrity and function. We developed a low flow standard based on a consideration of fish passage and wetted perimeter. To support development of a medium flow criteria for the Upper Peace River, we have documented the importance of woody instream habitats such as exposed roots and snags, and examined the elevational distribution and inundation patterns of these habitats. To develop a criteria for duration of inundation of exposed root habitat, we considered microbial conditioning time and cohort production intervals (CPI) required by macroinvertebrates to complete their life histories.

Microbial colonization and conditioning of wood habitats (i.e., development of a biofilm) is necessary to promote optimal use of these habitats by macroinvertebrates, fish and other wildlife. This process is especially important in heterotrophic, blackwater systems such as the Peace River. Couch and Meyer (1992) examined bacterial dynamics within the biofilm of a blackwater river where sources of organic matter other than algae dominate. In such systems, bacteria assimilate abundant dissolved organic carbon, and wood can serve not only as a substratum for attachment but can also support microbial metabolism (Aumen et al. 1983). Couch and Meyer (1992) found that wood substrates from *Salix sp.* would provide substantial biofilm development within two weeks of inundation. For the purposes of developing a medium flow standard, we, therefore, suggest that a two week period of continuous inundation is needed for microbial colonization.

Once conditioned, woody habitat becomes more suitable for macroinvertebrate colonization. After conditioning and colonization, continued inundation is necessary to allow macroinvertebrates to complete their aquatic life stages (realizing that some macroinvertebrates are totally aquatic). Cohort production interval (CPI) is defined as the "time interval from hatching to final size class or emergence" (Benke 1979). Benke et al. (1984) reported the CPI for a number of dipterans found on snag habitats in the Satilla River, a blackwater river in southeastern Georgia, and we searched the literature for similar studies as well (especially in the southeast US) (see Table 6-7). Because many of the dipteran taxa (especially Chironomidae) for which CPI's have been developed occur in the Peace River (other invertebrate taxa reported for the Upper Peace River are listed in Appendix IH), we consider 30 days of continuous inundation of woody substrate as a reasonable period for completion of aquatic life cycles of many of the river's macroinvertebrate species (see Figure 6-11).

Table 6-7. Cohort production interval (CPI) in days for Diptera, the dominant invertebrate taxa found in the Upper Peace River.

| Invertebrate Taxa | CPI (in days) | Reference |
|---|---|---|
| Cricotopus group | 16 | Benke et al., 1984 |
| *Thienemannimyia* group/ *Ablabesmyia* | 18-20 | Benke et al., 1984 |
| *Polypedilum* sp. | 23 | Benke et al., 1984 |
| Tanytarsini | 30 | Benke et al., 1984 |
| *Corynoneura/Thienemanniella* | 46 | Benke et al., 1984 |
| *Chironomini* sp. A | 16 | Benke et al., 1984 |
| *Stenochironomus* | 13 | Benke et al., 1984 |
| *Tribelos/Xenochironomus* | 13 | Benke et al., 1984 |
| Miscellaneous Chironomidae | 16 | Benke et al., 1984 |
| Simuliidae | 18 | Benke et al., 1984 |
| Miscellaneous Diptera | 13 | Benke et al., 1984 |
| *Chironomus plumosus* | 10-12 | Syrjamake,1965 as cited by Stites and Benke, 1989 |
| *Cricotopus sylvestris* | <15 | Konstantinov, 1958 and Menzie,1981 |
| For various chironomids | 5-60 | Mackey, 1977 |
| *Orthocladius calvus* | 16 | Ladle, 1985 |
| Chironomini from January-February<br>Tanytarsini from January - February<br>Chironomini and Tanytarsini in September | 18<br>14<br>5-6 | Hauer and Benke, 1991 |
| Most Chironomids, assumed only | 60 | Smock et al. 1985 |
| *Simulium taxodium* | 60 | Smock et al., 1985 |
| Tanypodinae e.g. *Ablabesmyia parajanta, Clinotanypus pinquis* and *Procladius* sp. | 84 | Smock et al., 1985 |
| Orthocladinae and Chironominae | 60 | Smock et al., 1985 |
| *Stenochironomus* sp. | 150 | Smock et al., 1985 |

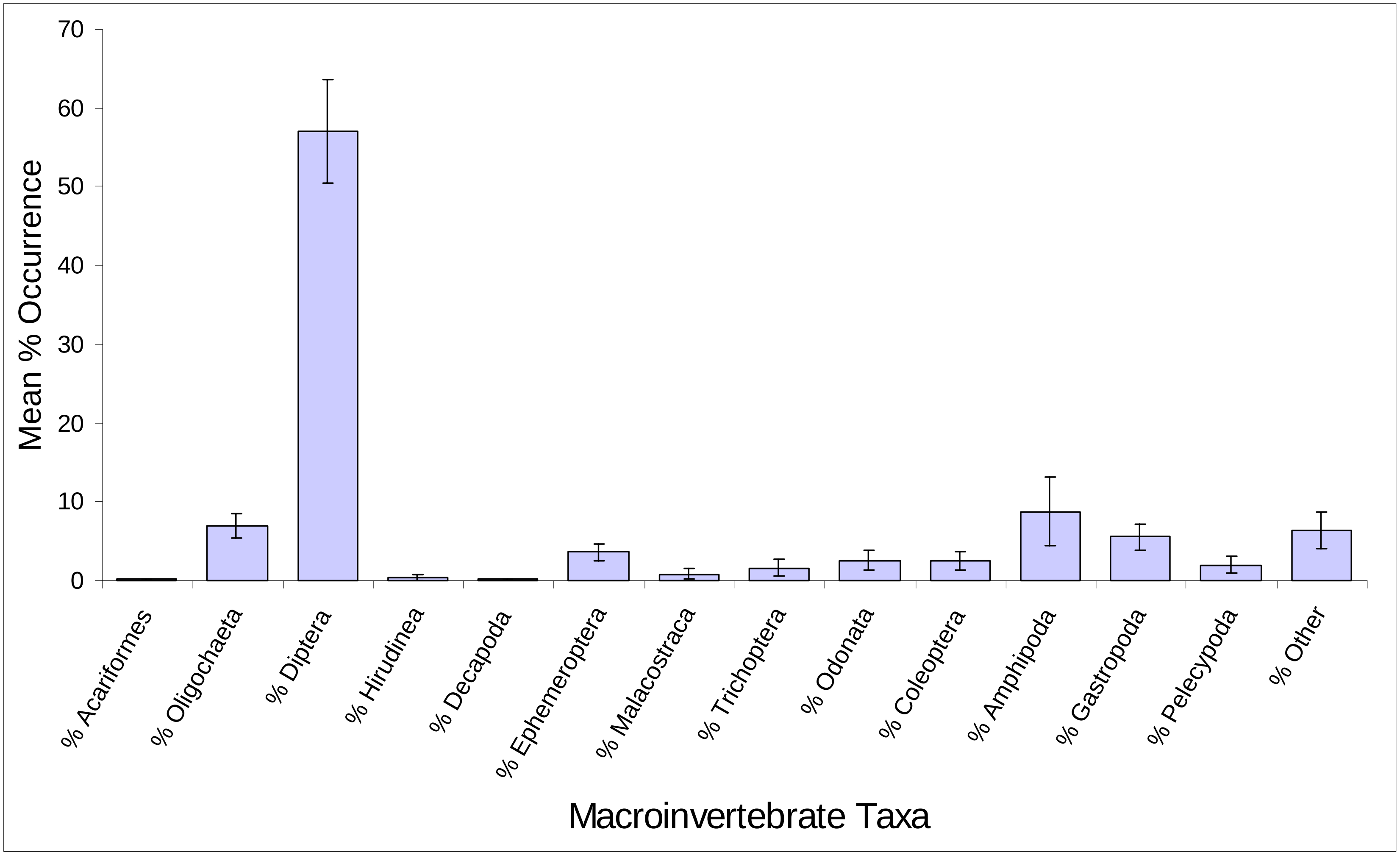



Figure 6-11. Percent occurrence of macroinvertebrate taxa at various sites in Peace River drainage by the Florida Department of Environmental Protection.

In consideration of a two week microbial conditioning period and a 30 day period for completion of aquatic phases of macroinvertebrate life cycles, it is recommended that exposed root habitat in the section of the Upper Peace River above Ft. Meade be inundated continuously for 45 days at a minimum each year. This would be considered a minimum, and annual variation in rainfall would ensure a range in consecutive days of inundation that would typically exceed 45 days. It should be noted that this standard is recommended for application on the segment of the river upstream of Ft. Meade, and is not applicable at sites between Ft. Meade and Zolfo Springs. In addition, a standard is not proposed for snags because this woody habitat would be inundated (to the mean elevation) for greater than 95% of the time (347 total days) at six of the nine most upstream sites (Sites 106 to 181) under the proposed Low Minimum Flows based on fish passage and wetted perimeter analyses discussed earlier.

The inundation histories of exposed root habitat at all sites above Ft. Meade were examined (Table 6-3; figures in Appendix IH). Although mean exposed root elevations at most sites could be inundated under fairly similar flow conditions, Site 143 required the greatest amount of flow to reach the mean elevation of root habitat. Stated differently, root habitat at this site would be inundated last under increasing flows and would be the first root habitat to dry under declining flow conditions. The flow required to meet the mean root elevation at Site 143 was equivalent to a flow of 113 cfs at the Bartow gage. Review of the flow history of Site 143 for the reference period (1940 to 1956) indicated that root habitat was typically continuously inundated for 92 days each year (mean for the period 1940 to 1956) and never dropped below 72 days of continuous inundation annually. Applying a medium flow standard of at least 45 days of continuous inundation to the mean elevation of root habitat at this site would ensure that all other sites between Bartow and Ft. Meade would be inundated continuously for greater than 45 days.

In contrast to the reference period, inspection of inundation histories of all sites above Ft. Meade over the last thirty years clearly shows that an annual 45 day continuous inundation period would frequently have been violated at all sites. For example, the mean elevation of exposed root habitat at Site 143 (which was never inundated for less than 72 consecutive days during the reference period) was below 45 days twelve times since 1971. Unlike sites above Ft. Meade, exposed root habitat occurs at such a relatively high elevation at a number of the transect sites that this standard would not be applicable to the river between Ft. Meade and Zolfo Springs.

A flow of 113 cfs for 45 consecutive days annually at the Bartow gage would ensure inundation to the mean elevation of exposed root habitat at all sites located upstream of the Ft. Meade gage for at least 45 consecutive days each year. This medium flow standard would never have been violated prior to 1960, and yet it represents a 37% reduction (from 72 to 45 days) in the number of days of continuous inundation that has occurred historically under low flow conditions. Compliance with the proposed standard would not, however, have occurred in recent years. During a recent period (1987-1999) of near normal rainfall (based on an analysis for four rainfall sites), a continuous flow of 113 cfs or greater occurred for only eight days during the lowest flow year (1990).

Because reductions in flows at the medium and high flow range in the Upper Peace River cannot be attributed solely to withdrawals due to the confounding effect of numerous structural alterations and changes (e.g., land development, drainage improvements, removal of waste water discharges, and long-term changes in rainfall patterns) that impact the flow regime (as discussed in some detail in Chapter Three), the 45 consecutive day 113 cfs medium flow standard is not recommended for adoption as a minimum flow statistic. Rather, it is suggested that this standard could be used as a management standard or target for establishing an ecologically more desirable flow regime for the Upper Peace River.

The proposed medium flow management standard includes two components: a flow (113 cfs) and a duration (45 consecutive days). Because it may be simpler to gauge standard compliance by defining a single parameter such as the annual percent exceedance flow, the feasibility of using the relationship between the number of consecutive days inundated annually and the total number of days inundated annually was examined to establish an annual percent exceedance flow.

Using the period of record data for the Bartow gage, it was determined that the total number of days and the number of consecutive days the medium flow standard of 113 cfs was achieved annually. A predictive regression line for these variables was developed (Figure 6-12). Data for years when the consecutive number of days inundated exceeded 120 were excluded from the analysis, because they tended to reduce the predictive power of the regression in the range of consecutive days of inundation values relevant to the medium flow standard (45 consecutive days).

Based on the regression equation shown in Figure 6-12, it was predicted that a total of 101 days of flow at 113 cfs at the Bartow gage would be associated with a 45 day period of continuous inundation at Site 143. Dividing the total number of days inundated annually (101 days) by the number of days in a year (365 days) yields an annual percent exceedance flow of 72%. While these results give an indication of the annual percent exceedance flow that may be needed to achieve 45 days of consecutive flow, this should not be strictly applied because inspection of the actual plot (Figure 6-12) suggests that the total number of days required may be anywhere within the range of 75 to 150 days. This means the actual annual percent exceedance flow may be in the range of 60 to 80%.

For illustrative purposes, a plot of the longest number of consecutive days that Site 143 was inundated to the mean elevation of exposed root habitat for the period of record is shown in Figure 6-13 with a line drawn at the suggested 45 day medium flow standard. The proposed standard would equate to a flow of 113 cfs at the Bartow gage for 45 consecutive days annually.

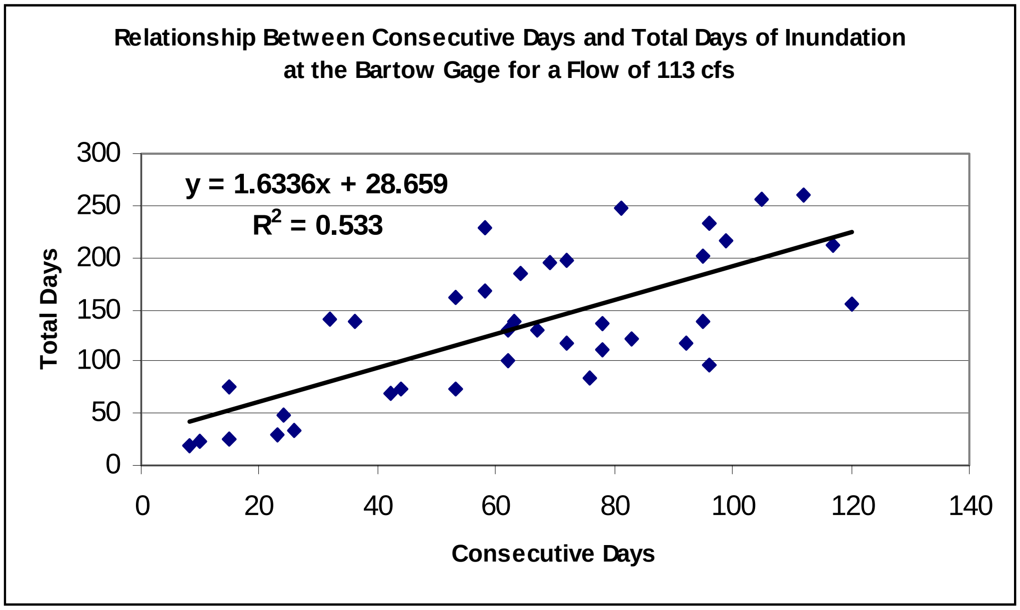



Figure 6-12. Simple linear regression equation derived to predict total number of days of inundation from longest consecutive number of days of inundation.

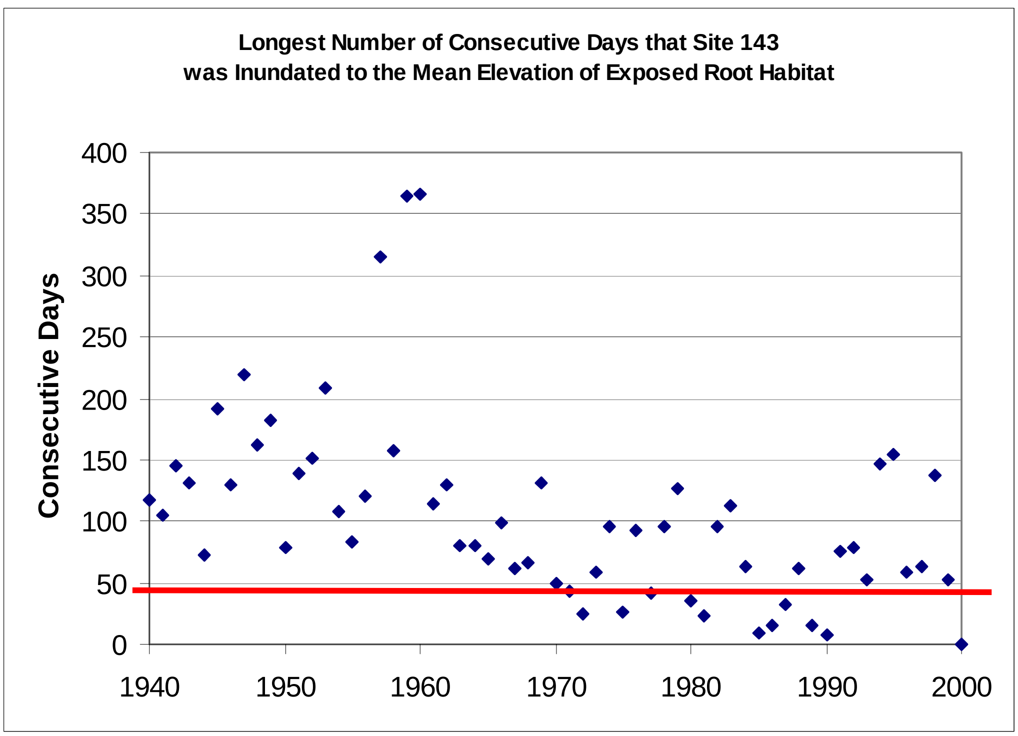



Figure 6-13. Longest number of consecutive days annually that Site 143 was inundated to the mean elevation of exposed root habitat. A reference line was added at 45 days, the recommended medium flow standard for protection of instream habitats.

## 6.6 Floodplain Wetlands

Field studies and hydrologic assessments were performed on wetlands at sixteen of the transects that were surveyed for the minimum flows and levels project. Prior to these studies, the geographic distribution of wetlands in the Upper Peace River floodplain was assessed using GIS with data from the National Wetlands Inventory (NWI) produced by the U.S. Fish and Wildlife Service. The distribution of NWI wetland classifications is described first below, followed by a discussion of site specific information for the sixteen study transect sites

### 6.6.1 Wetland Distributions from NWI maps

The NWI maps for the Upper Peace River system show distinct spatial patterns with regard to the physical setting and distribution of floodplain wetlands. The distribution of NWI classes in the Peace River corridor were presented in Figure 5.2. For greater resolution, Figure 6-14 displays this same information separately for four zones of the river. Table 6-8 lists percentage land covers of NWI wetland sub-classes in the four river segments that were used to stratify the wetland field sampling. The delineation of these segments is also shown in Figures 5.2 and 6-14. A key to the wetland classification terms corresponding to the NWI codes is provided in Appendix NWI.

The predominant NWI wetland sub-classes within the floodplain changes as the river extends downstream. Above Ft. Meade (segments 1 and 2), there are widespread wetlands that are characterized by semi-permanent flooding. These are low-lying floodplain swamps that are dominated by either deciduous hardwoods (P_FO6_F) or cypress (P_FO2_F). The hardwood swamps are more abundant, as cypress swamps are limited to regions near Bartow. Seasonally flooded deciduous forests (P_FO6_C) are common at slightly higher elevations in this reach of the river, comprising 16 and 25 percent of the land cover in segments 1 and 2, respectively.

The predominant wetland communities change below Ft. Meade, as the river channel becomes more incised and the floodplain slopes are steeper. Semi-permanently flooded wetlands are absent below Ft. Meade (segments 3 and 4 in Table 6-8). Seasonally flooded deciduous forests (P_FO6_C) extend as a contiguous band to near the confluence of Bowlegs Creek, located near the County Road 657 bridge about three miles south of Ft. Meade (Figure 6-14b). South of that location, four forested wetland NWI sub-classes characterized by seasonal flooding (P_FO1_C, P_FO1/FO3_C, P_FO1/FO2_C, P_FO6_C) are scattered throughout segments 3 and 4. All totaled, seasonally flooded wetlands comprise 19 and 16 percent of the land area in the corridor in segments 3 and 4, respectively (Table 6-8).

The NWI wetland classifications show a distinct change near Bowlegs Creek. Transect 106, just upstream of this location intercepts seasonally flooded wetlands, while transect 99 to the south intercepts temporarily flooded wetlands. Wetland communities that are particularly widespread in the floodplain below Bowlegs Creek are forests characterized by temporary flooding. Broad-leaved deciduous forests (P_FO1_A) are common in segment 3 (36% of land area), while this community plus two other communities with temporary flooding comprise 27% of land cover in segment 4. In many areas of segments 3 and 4, uplands come close to the river channel, with wetlands limited to areas near the river channel and bank (Figure 6-14 c, d). In sum, the NWI maps indicate that riparian wetlands are widespread within the Peace River corridor. However, semi-permanently and seasonally flooded wetlands are most common above Ft. Meade-Bowlegs Creek, while wetlands characterized by temporary flooding are most common below that location.

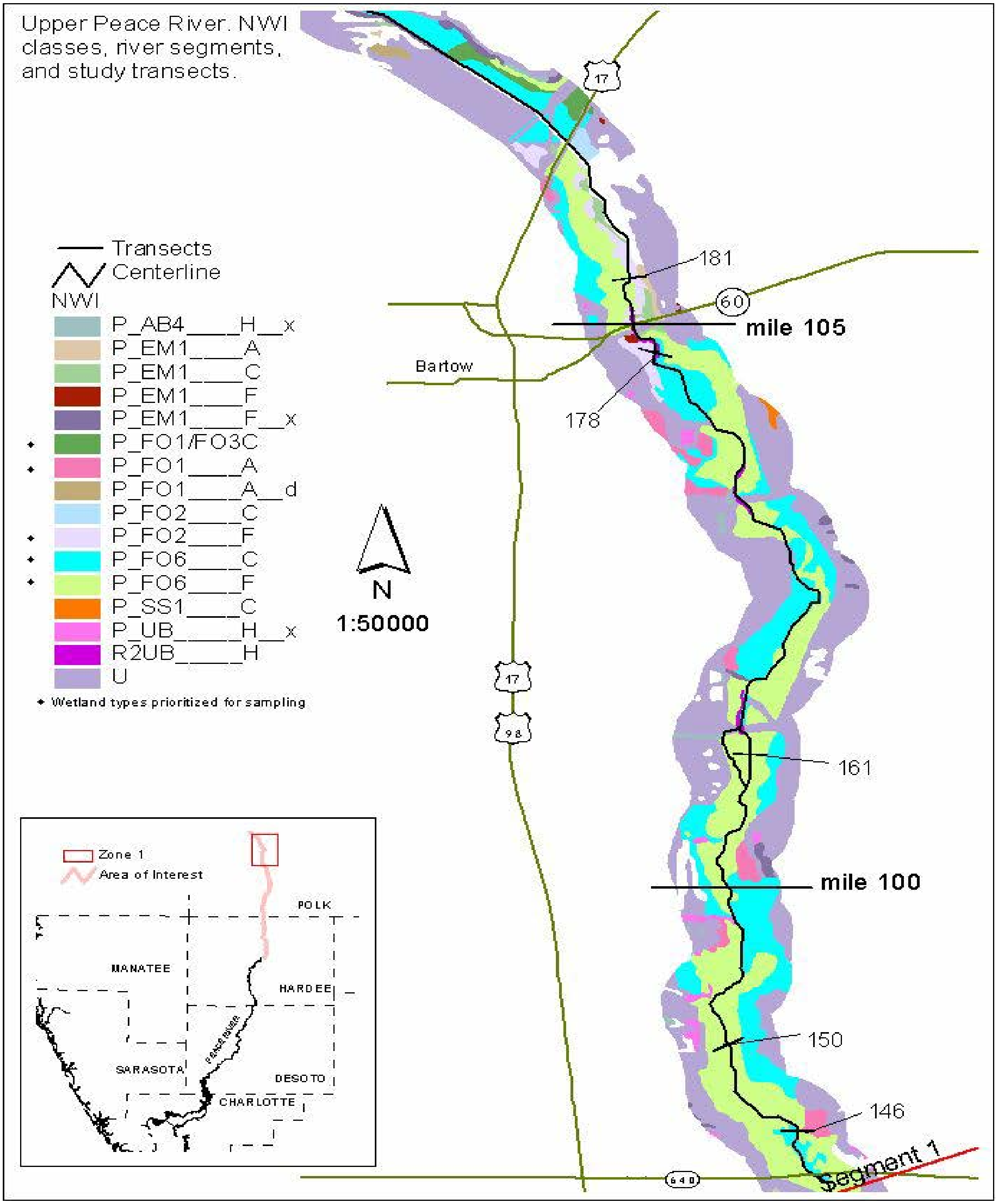



Figure 6-14a. Distribution of NWI wetlands in the Upper Peace River in Segment 1. River miles and locations of study transects are shown.

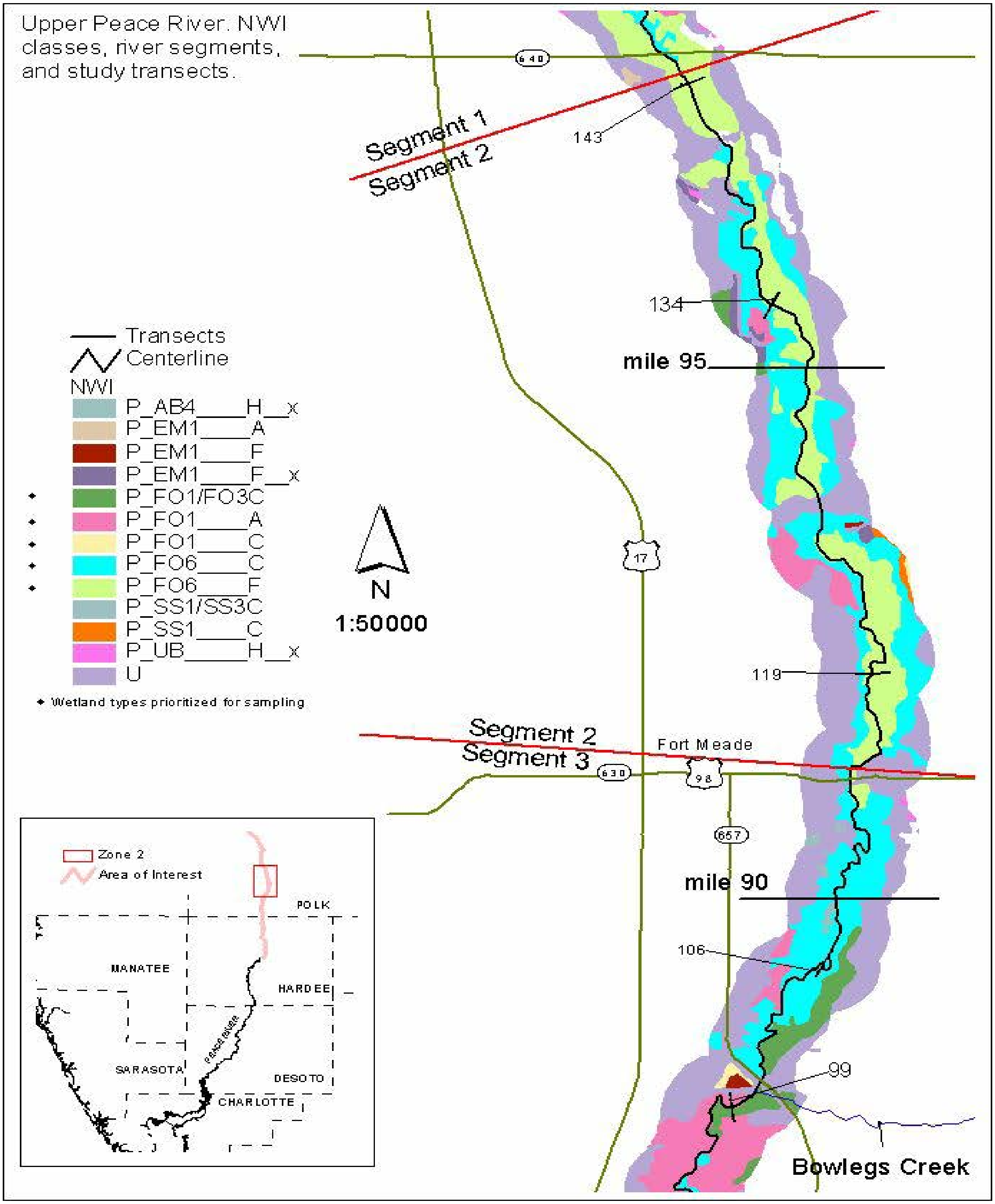



Figure 6-14b. Distribution of NWI wetlands in the Upper Peace River in Segments 2 and 3. River miles and locations of study transects are shown.

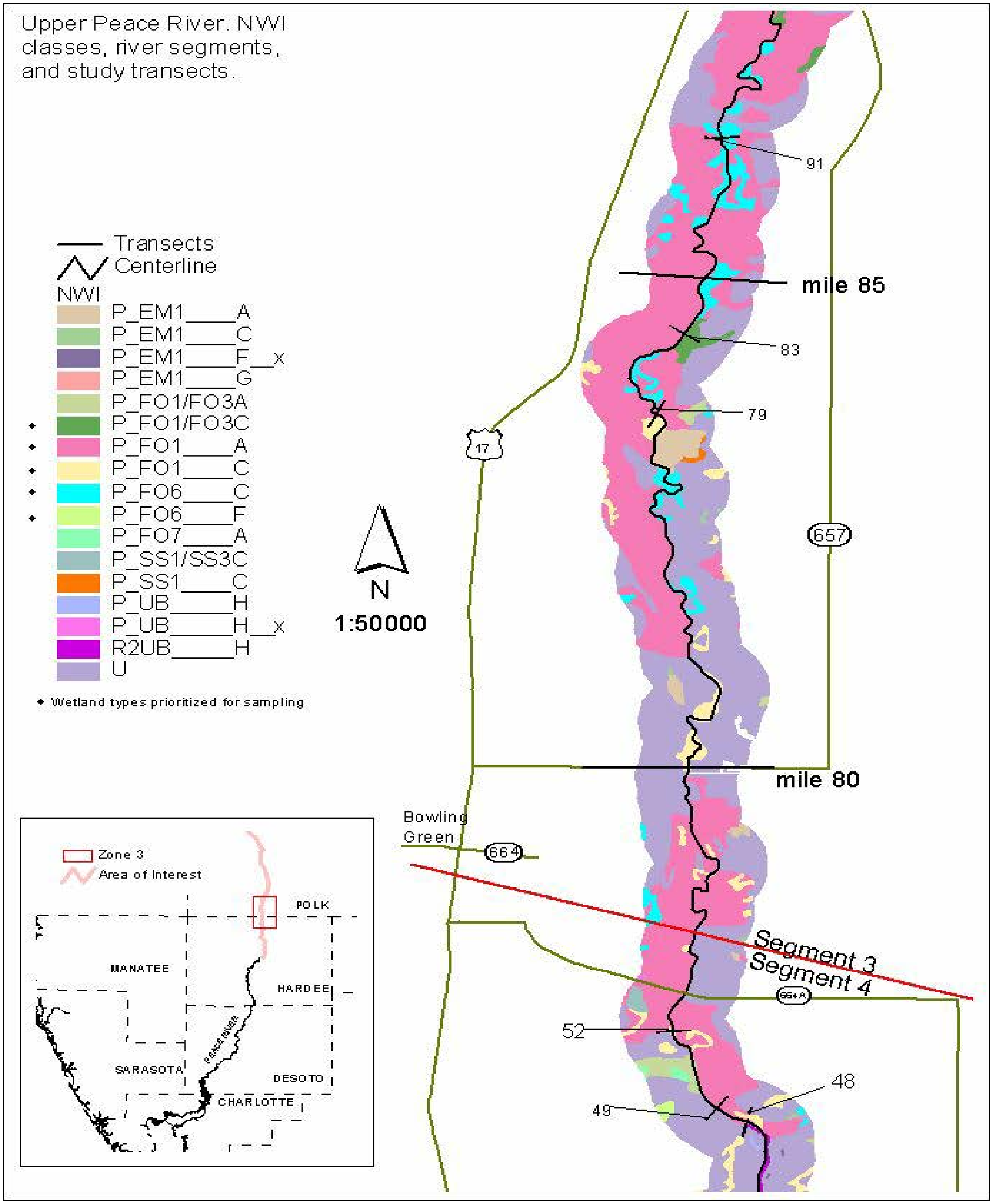



Figure 6-14c. Distribution of NWI wetlands in the Upper Peace River in Segments 3 and 4. River miles and locations of study transects are shown.

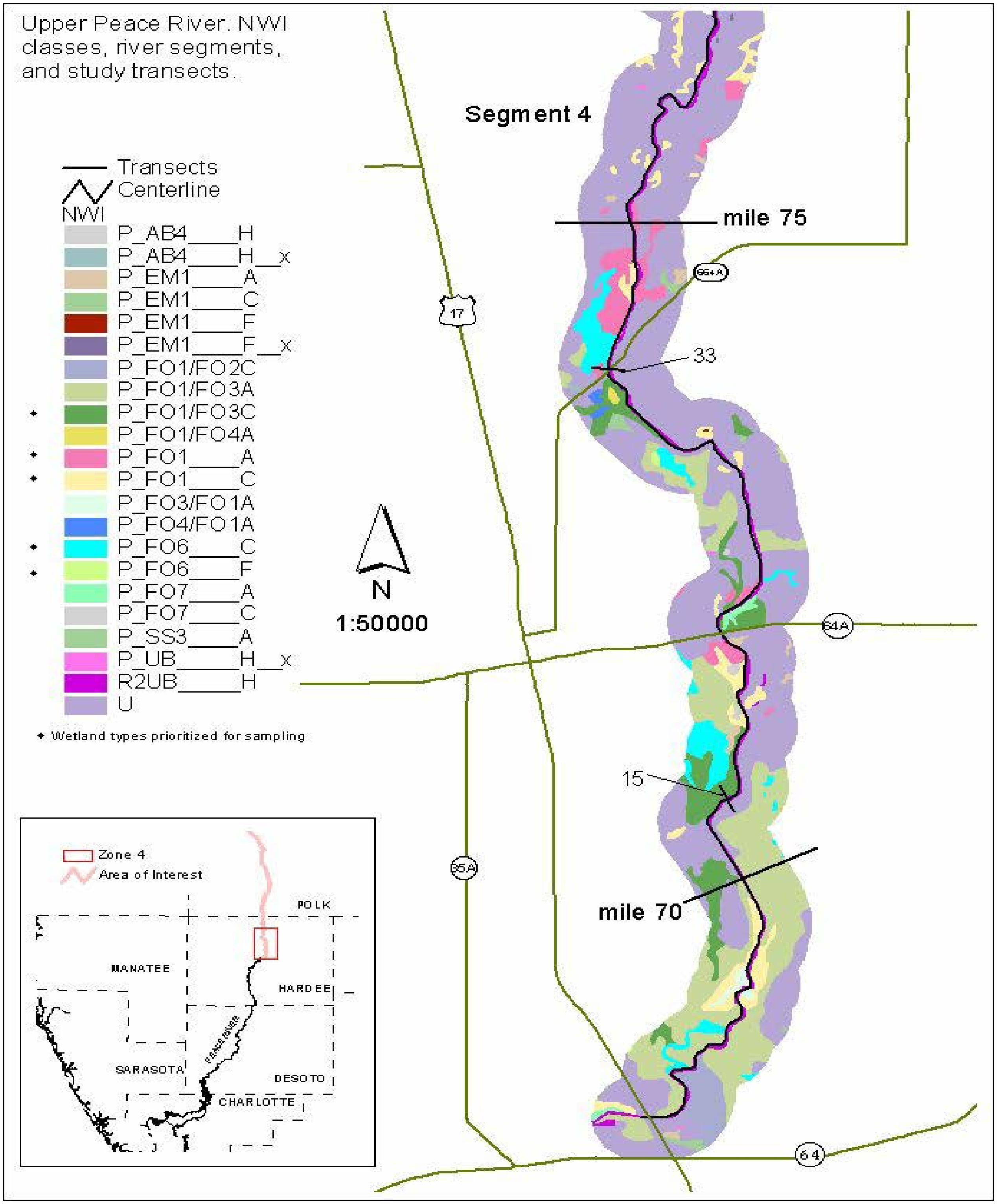



Figure 6-14d. Distribution of NWI wetlands in the Upper Peace River in Segment 4. River miles and locations of study transects are shown.

Table 6-8. Percent land coverages of major vegetationtypes along the Upper Peace River corridor from Bartow to Zolfo Springs as shown in Figure 6-14. Vegetation is classified as palustrine forest (P_FO), emergent (EM), riverine (R), or upland (U).

| NWI Class | Flood Regime | Vegetation Classification | Percent Land Coverage |
|---|---|---|---|
| Segment 1: Bartow to County Road 640 | | | |
| P_EM1_A_d | Temporary | Persistent/ditched | 2 |
| P_FO1_A | Temporary | Broad-leaved deciduous | 2 |
| P_F06_C | Seasonal | Broad-leaved deciduous | 16 |
| P_EM1_F | Semi-permanent | Persistent/ditched | 1 |
| P_FO2_F | Semi-permanent | Needle-leaved deciduous | 2 |
| P_FO6_F | Semi-permanent | Deciduous | 23 |
| Uplands | | | 40 |
| 30 other land cover types, each <1% of segment | | | 14 |
| | | Segment Total | 100 |
| Segment 2: County Road 640 to Ft. Meade | | | |
| P_F01_A | Temporary | Broad-leaved deciduous | 4 |
| P_FO6_C | Seasonal | Deciduous | 25 |
| P_FO6_F | Semi-permanent | Deciduous | 26 |
| L2UB_H_sx | Permanent | Unconsolidated bottom/excavated | 2 |
| Uplands | | | 38 |
| 11 other land cover types, each <1% of segment | | | 5 |
| | | Segment Total | 100 |
| Segment 3: Ft. Meade to Bowling Green | | | |
| P_FO1_A | Temporary | Broad-leaved deciduous | 36 |
| P_EM1_A | Temporary | Persistent | 1 |
| P_FO1_C | Seasonal | Broad-leaved deciduous | 2 |
| P_FO1/FO3_C | Seasonal | Broad-leaved deciduous/evergreen | 4 |
| P_FO6_C | Seasonal | Deciduous | 13 |
| Uplands | | | 42 |
| 11 other land cover types, each <1% of segment | | | 3 |
| | | Segment Total | 100 |
| Segment 4: Bowling Green to Zolfo Springs | | | |
| P_FO1_A | Temporary | Broad-leaved deciduous | 9 |
| P_FO1/FO3_A | Temporary | Broad-leaved deciduous/evergreen | 17 |
| P_EM1_A | Temporary | Persistent | 1 |
| P_FO6_C | Seasonal | Deciduous | 4 |
| P_FO1_C | Seasonal | Broad-leaved deciduous | 5 |
| P_FO1/FO2_C | Seasonal | Broad & needle-leaved deciduous | 2 |
| P_FO1/FO3_C | Seasonal | Broad-leaved deciduous/evergreen | 5 |
| R2UB_H | Permanent | Riverine/unconsolidated bottom | 3 |
| Uplands | | | 54 |
| 16 other cover types, each <1% of segment | | | 1 |
| | | Segment Total | 100 |

### 6.6.2 Vegetation Characterization from Field Studies

Vegetation communities were characterized on the ground along each of the sixteen study transects. Tree species were the most useful parameter for delineating plant communities. Herbaceous species composition did not vary significantly with elevation or soils. This was probably due to the extended drought that occurred during 1999-2001 and the invasion of herbaceous upland vegetation into wetland areas. Vegetation breaks based on woody plants generally followed a gradient of riverbank, swamp, lower floodplain, upper floodplain and upland, characterized by conspicuous changes in dominant tree species and topography. A general illustration of this transition in vegetation zones is shown in Figure 6-15.

Some species followed fairly consistent patterns in their distribution between these zones (Figure 6-16). For example, saw palmetto (*Serenoa repens*) and live oak *(Quercus virginiana*) occurred infrequently in lower floodplains. Cypress (*Taxodium ascendens*) never occurred above the lower floodplain, and ash never occurred above the upper floodplain. In contrast, persimmon (*Diospyrons virginiana*) and sugarberry (*Celtis laevigata)* occurred in the upper floodplains and uplands. While several species occurred in swamps, floodplains, and uplands, a few species typical of the habitat were always dominant.

Cypress and mixed swamps were dominated by cypress and/or ash (*Fraxinus americana)* and elm (*Ulmus Americana*), with very few other species. Lower floodplains were dominated by ash, elm, and diamond-leaf oak (*Q. laurifolia*), with <10% cypress, <5% bluestem palmettos (*Sabal minor*) and live oaks, and included several other species. Upper floodplain zones included many of the same species as the lower floodplain, but were often characterized by >50% bluestem palmettos and diamond-leaf oak and included several species more typical of uplands, such as live oak and buckeye.

Differences in species composition were conspicuous, but differences in frequency of occurrence (ranking within a zone) were significant only between swamps and all other zones (Table 6-9). Differences in frequency of overall species occurrence (ranking within zone) were not significant between lower and upper floodplains and uplands. This is most likely a result of the transition in species composition between zones that gradually progress from seasonally to temporarily flooded over an increase in elevations of five to ten feet.

Table 6-9. Results of comparisons of tree species frequencies between vegetation zones using Wilcoxon Signed Rank test ($P<0.05$; $n=31$). NS = not significant.

| Floodplain zones | Dominant tree species in waterward zone | Number of species waterward | W Statistic |
|---|---|---|---|
| Swamp (vs. lower floodplain) | Dominated by >75% cypress and/or ash, elm, little understory | 13 | -95 |
| Swamp(vs. upper floodplain) | | | -142 |
| Lower (vs. upper) floodplain | ash, elm, diamond-leaf oak, <10% cypress, <5% bluestem | 19 | 12 (NS) |
| Lower floodplain (vs. upland) | | | 16 (NS) |
| Upper floodplain (vs. upland) | maple, hickory, >50% bluestem | 24 (vs. 20) | 39 (NS) |

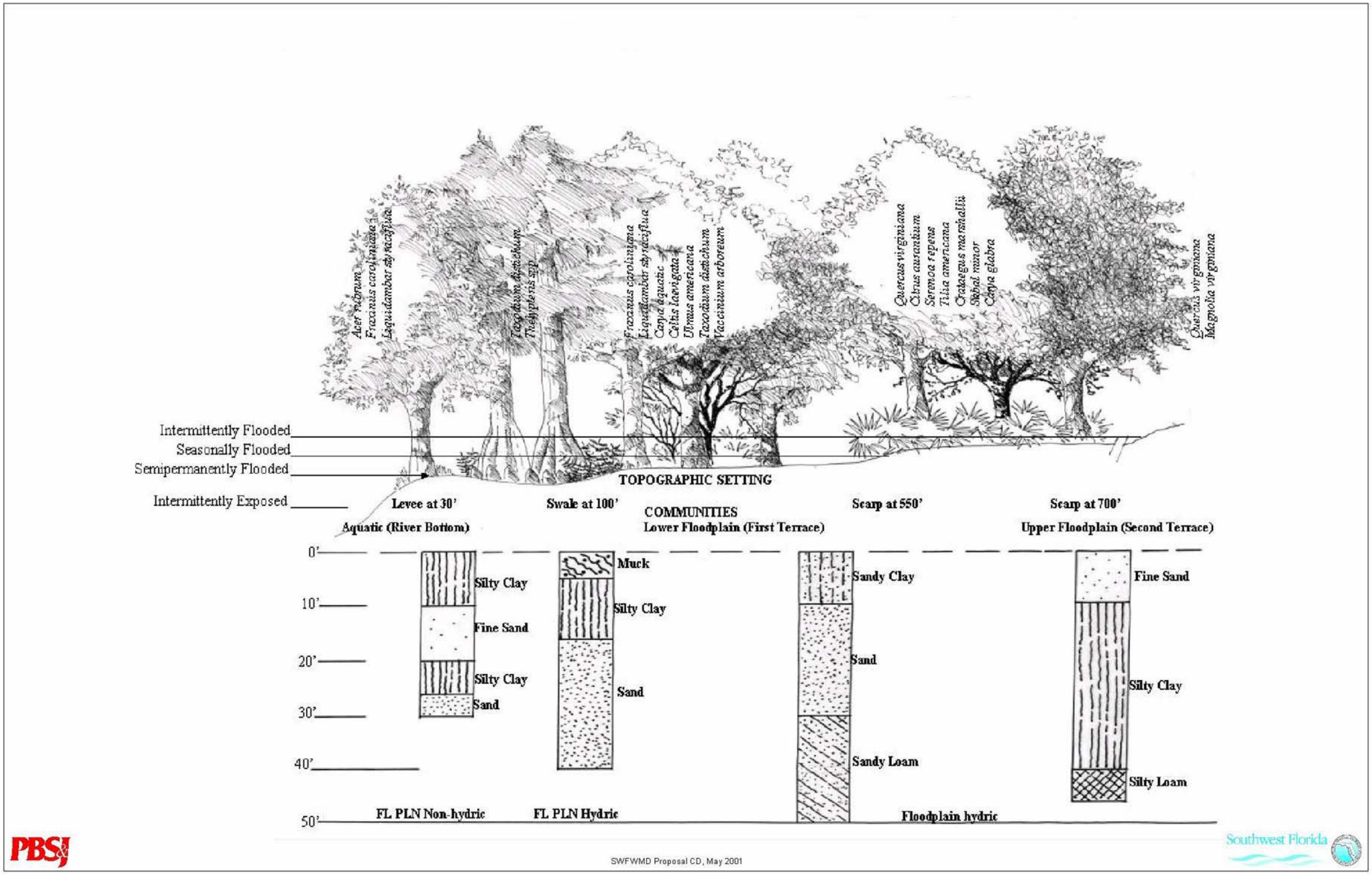



Figure 6-15. A typical profile of the vegetation, soils, topographic gradients, and hydrologic regimes of floodplain zones on the Upper Peace River (from PBSJ 2002).

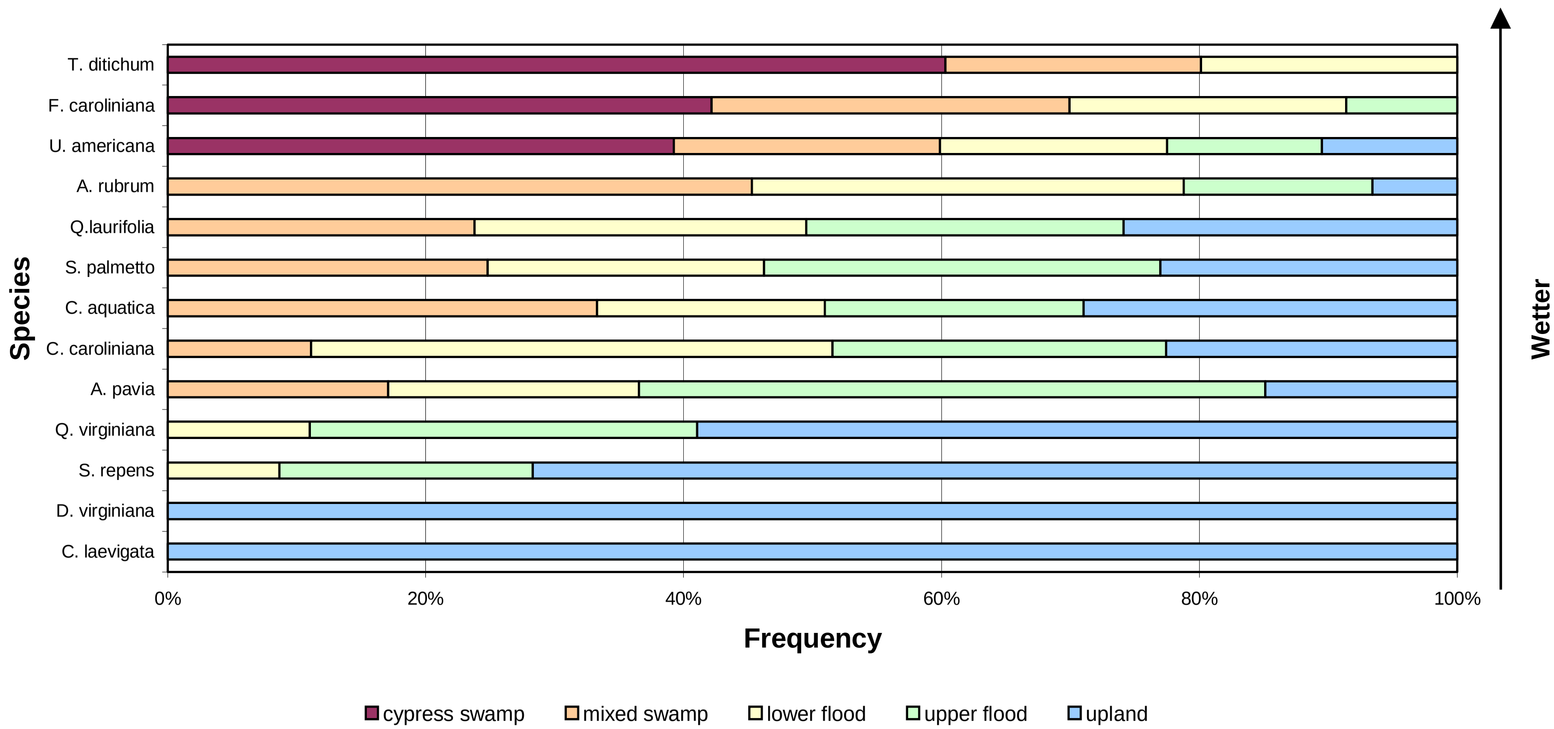



Figure 6-16. Cumulative frequency of common tree species in five floodplain zones in the Upper Peace River corridor.

Species found throughout the floodplain generally occurred on the levees as well, particularly cypress, hickory (*Carya aquatica)*, red maple (*Acer rubrum*), and often honey locust (*Robinia pseudoacacia*). This may be the result of differences in levees, as well as the mosaic of microenvironments that often occur on the levees (Radford *et al.* 1980). Swamps and lower floodplains occurred at lower elevations and were characterized by hydric soils. In contrast, upper floodplains had flooded but not always hydric soils, and included species less tolerant of saturated soils (e.g. holly, *Ilex vomitoria* and *I. decidua*).

Many impacts associated with alterations to natural flow regimes may not be readily apparent. For instance, a long-lived species with reduced reproduction due to altered flows, e.g. cypress, may persist in a community for many years. However, without floods to prevent the survival of upland species, wetland species are out-competed and precluded from these areas over time.

Community frequencies for dominant species are listed in Table 6-10. Species that occurred in five or more communities sampled are listed, i.e. bald cypress occurred in eight of the swamps and ten of the lower floodplains through which transects were placed. Wetland status of each species, i.e. its designation as a wetland indicator species, is also provided. Obligate wetland species under natural conditions are only found or achieve their greatest abundance in areas subject to inundation and/or saturation. Facultative wetland plants occur in areas subject to inundation and/or saturation, but can also be found in uplands, while facultative species have distributions that render them inappropriate for indicators of inundation or saturation.

Species frequencies among communities varies above and below Ft. Meade. For example, *F. caroliniana,* an obligate wetland species, occurred only in communities sampled below Ft. Meade, and *C. aquatica*, also an obligate wetland species, occurred in nearly twice as many floodplain communities below Ft. Meade. Species more prominent above Ft. Meade were *A. rubrum*, *C. laevigata*, and *S. minor*. In the upland communities above Ft. Meade, *F. americana* was co-dominant with *Q. virginiana*, while *S. repens* occurred as co-dominant with *Q. virginiana* below Ft. Meade.

Total community occurrences of obligate, facultative wetland, facultative, and upland species were similar above and below Ft. Meade, although some differences are apparent (Table 6-11). Swamp communities occurred only above Ft. Meade. Community occurrences of obligate and facultative wetland species in lower floodplain communities were greater below Ft. Meade. Upper floodplain communities above Ft. Meade had the greatest number of occurrences of facultative wetland species, while facultative wetland species were equally distributed between upper and lower floodplain below Ft. Meade.

It is an important point that wetland species occur in wetlands because they are tolerant of conditions that preclude species adapted to less stressful (i.e. upland) conditions. Invasive plant or animal species may have a competitive advantage under hydrologically altered conditions, and species more typical of drier conditions (e.g. live oak and saw palmetto) as well as exotic species (e.g., Brazilian pepper, *Schinus terebinthifolius*) may colonize the habitat under the new hydrologic regime. The canopy of dominant wetland trees is intact in areas along the Peace River examined during this study. These canopy trees will likely continue to shade out many invasive species and remain dominant until openings occur as the trees die, allowing invasive species to move into the lower floodplains and swamps under drier conditions.

Table 6-10. Frequency of species occurrences (presence/absence) in wetland zones in the Upper Peace River. Only listed species that had five or greater occurrences are listed.

| | | | Above Ft. Meade | | | | | Below Ft. Meade | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Genus / species | Common Name | Wetland Status | Swamp | Lower Floodplain | Upper Floodplain | Upland | Total | Lower Floodplain | Upper Floodplain | Upland | Total |
| *Carya aquatica* | Water hickory | OBL | 2 | 4 | 4 | 2 | 12 | 12 | 6 | 3 | 21 |
| *Fraxinus caroliniana* | Pop ash | OBL | | | | | | 4 | 1 | | 5 |
| *Taxodium distichum* | Bald cypress | OBL | 8 | 10 | 1 | | 19 | 12 | | | 12 |
| *Acer rubrum* | Red maple | FACW | 3 | 9 | 4 | 1 | 17 | 4 | 2 | 1 | 7 |
| *Carpinus* | Blue beech | FACW | 1 | | 7 | 5 | 13 | 5 | 5 | 2 | 12 |
| *Celtis laevigata* | Sugar berry | FACW | 3 | 2 | 8 | 5 | 18 | 5 | 1 | 3 | 9 |
| *Liquidambar styra* | Sweetgum | FACW | 3 | 3 | 8 | 6 | 20 | 9 | 11 | 8 | 28 |
| *Quercus nigra* | Water oak | FACW | 1 | | 1 | 4 | 6 | 1 | 1 | 3 | 5 |
| *Quercus laurifolia* | Laurel oak | FACW | 4 | 8 | 10 | 4 | 26 | 11 | 10 | 9 | 30 |
| *Sabal minor* | Bluestem palm | FACW | 3 | 4 | 9 | 3 | 19 | 3 | 4 | | 7 |
| *Ulmus americana* | Elm | FACW | 6 | 8 | 8 | 6 | 28 | 7 | 3 | 2 | 12 |
| *Robinia pseudoacacia* | Black locust | FAC | | | | | | 5 | 2 | | 7 |
| *Sabal palmetto* | Cabbage palm | FAC | 2 | 3 | 5 | 2 | 12 | 9 | 6 | 11 | 26 |
| *Fraxinus americana* | White ash | UPL | 5 | 9 | 3 | | 17 | 3 | 3 | | 6 |

OBL = obligate
FACW = facultative wetland
FAC = facultative
UPL = upland

Table 6-11. Occurrences of wetland species in Upper Peace River corridor by floodplain zone.

| Community | Obligate | Facultative wetland | Facultative | Upland | Total |
|---|---|---|---|---|---|
| | Above Ft. Meade | | | | |
| Swamp | 10 | 28 | 3 | 5 | 46 |
| Lower floodplain | 14 | 38 | 5 | 9 | 66 |
| Upper floodplain | 5 | 68 | 6 | 8 | 87 |
| Upland | 2 | 45 | 2 | 6 | 55 |
| Total | 31 | 179 | 16 | 28 | 257 |
| | Below Ft. Meade | | | | |
| Swamp | 0 | 0 | 0 | 0 | 0 |
| Lower floodplain | 24 | 62 | 9 | 6 | 101 |
| Upper floodplain | 6 | 60 | 6 | 6 | 78 |
| Upland | 3 | 45 | 11 | 17 | 76 |
| Total | 33 | 167 | 26 | 2 | |

### 6.6.3 Soils

Like other soils, those along the Peace River corridor are formed from varying combinations of climate, living organisms, topographic relief, parent material, and time. Surficial materials in the southwestern flatwoods physiographic district where the Peace River is located are predominantly sand, limestone, and organic deposits (Brown et al. 1990). Under saturated or flooded conditions that are anaerobic for part of the growing season, soil profiles usually acquire unique characteristics that can be relied upon as positive indicators of hydric soils. Most organic soils (histosols) are hydric, while mineral soils tend to develop one or more of the following characteristics when associated with a reducing environment:

- histic epipedon (organic surface horizon);
- hydrogen sulfide odor and other sulfidic material;
- aquic conditions (oxygen-deficient soil saturation);
- soil series on hydric soil lists; and
- redoximorphic features such as gleyed soil matrix color, low chroma matrix color with or without bright mottling and segregated iron and manganese concretions.

For example, the occurrence of histic epipedons is one of several hydric soil indicators. These peaty mucky soils represent extreme anaerobic conditions and are mineral soils that are saturated for at least 30 consecutive days in most years and have an organic layer 20-40 cm thick. This indicator was not an important soil component along the Upper Peace River. This soil type was, likewise, not found to be important along the Suwanee or

Apalachicola Rivers (Light *et al.* 2001). Flooding, river currents, and sediments are likely more important in soils formation along the Peace River rather than continuous inundation. Some soils along the Peace River transects were considered nonhydric, because the organic bodies were too small. For hydric soil indicators such as organic bodies, the organic material may be too sandy to meet the five percent organic matter requirement. This would be consistent with riverine systems where periodic flows remove and deposit sediments rather than pooling and creating anaerobic conditions. However, as will be discussed, hydroperiods in many wetlands in the Peace River floodplain have been markedly reduced, which may have increased the oxidation rate of soil organic matter.

Mean elevations of hydric soils along transects were significantly lower when compared with mean elevations of nonhydric soils (Table 6-12). Differences in mean elevations between hydric and nonhydric soils ranged from 1.6 (Transect 99) to 6.9 feet (Transect 143) and averaged about 3.5 feet. Interestingly, cypress trees grow on a range of soils, from sand to clay, and under various conditions ranging from acid to base, and occur on ultisols, histosols, entisols, and inceptisols in Florida (Coultas and Duever 1984). The only common factor is that they occur on poorly drained soils

Table 6-12. Summary of comparisons of mean elevations (feet) of hydric and nonhydric soils, by transect. All differences were significant (Wilcoxon Signed Rank test = 39, $p < 0.05$). Averages are provided by dominant community type.

| Transect | Nonhydric soils elevation (feet NGVD) | Hydric soils elevation (feet NGVD) | Landward extent of hydric soils |
|---|---|---|---|
| Above Ft. Meade | | | |
| 181 | No values | 95.5 | Upper floodplain |
| 178 | 95.3 | 92.9 | Lower floodplain |
| 161 | No values | 89.2 | Upper floodplain |
| 150 | 90.6 | 85.1 | Lower floodplain |
| 146 | 90.6 | 86 | Upper floodplain |
| 143 | 90.9 | 84 | Upper floodplain |
| 134 | 84.7 | 82.3 | Upper floodplain |
| 119 | 79.7 | 76.5 | Lower floodplain |
| Below Ft. Meade | | | |
| 106 | 74.2 | 71.9 | Lower floodplain |
| 99 | 71.6 | 70 | Lower floodplain |
| 91 | 71.7 | 68.4 | Lower floodplain |
| 79 | 66.3 | no hydric soils | na |
| 49 | 60.1 | 57 | Upper floodplain |
| 48 | 59.8 | 57.6 | Lower floodplain |
| 33 | 58.1 | no hydric soils | na |
| 15 | 49.7 | 46.6 | Lower floodplain |

Above Ft. Meade, the elevation change across wetland communities (including the upper floodplain) was approximately three to six feet. The gradient is more gradual in comparison with transects below Ft. Meade, and hydric soils extended into the upper floodplain at five of the eight transects. Transects 119 and 181 were the only transects along which hydric, but not flooded, conditions occurred. Nonhydric soils were not found at transects 181 and 161.

Below Ft. Meade, where elevation gradients were steeper, hydric soils were limited to lower floodplain communities in all but one case (Transect 49). In this reach of the river most floodplain soils are probably drained quickly following flooding due to incised channels and high banks. In some cases, the absence of historic flooding may result in a change to nonhydric conditions, although flooding is apparent. When drained, peat is subject to subsidence because of oxidation and settling (about 2.5 cm/yr) the soil classification changes (Brown *et al.* 1990 after Collins *et al.* 1986). Prior, relict, and/or drained wetlands may remain dominated by wetland plant species, although the hydrology necessary to maintain hydric soil conditions is absent, until upland species become established.

The Florida Department of Environmental Protection, under FAC Chapter 62-340.550 (Delineation of the Landward Extent of Wetlands and Surface Waters) identifies wetland hydrology needed to maintain hydric soils conditions. Under this section, inundation for at least seven consecutive days or saturation for at least twenty consecutive days annually constitutes long term hydrologic conditions necessary for the maintenance of hydric soils. The inundation characteristics of wetlands communities in the Upper Peace River are described in later sections.

### 6.6.4 Wetted Perimeter of Floodplain Habitats

The linear extent of floodplain habitats along transects in the Upper Peace River study corridor was calculated to provide an indication of potential changes in habitat that could result from changes in water level elevations. Graphs of elevation vs. linear extent of habitat (wetted perimeter) indicate that the change in wetted perimeter relative to the change in elevation was greatest for lower floodplains, followed by swamps and upper floodplains (Appendix WC). Two examples for these graphs are included as Figures 6-17 and 6-18. Transect 143, located above Ft. Meade, has a narrow band of mixed swamp adjacent to a broad, flat, lower floodplain. In contrast, Transect 15 in the southern end of the study area, has a much more incised floodplain with a narrower lower floodplain zone which gives rise to an upper floodplain zone.

The results of the Kruskal-Wallis test indicated a significant effect of floodplain zone on the ratio of linear feet of habitat /change in feet of elevation. These ratios indicate that changes in water level that occur in lower floodplain communities will impact the greatest amount of habitat when compared with cypress swamps, mixed swamps, and upper floodplains (Table 6-13).

Table 6-13. Statistical comparison of wetted perimeter (linear habitat/change in elevation) in dominanat vegetation zones along 16 transects in the Upper Peace River floodplain.

| Community | Mean Ratio (linear feet of habitat/ change in elevation) | Number of Transects | Kruskal Wallis Results |
|---|---|---|---|
| Cypress and mixed swamp | 319 | 3 | Chi-square = 8.61, DF=3, $p < 0.035$ |
| Lower floodplain | 520 | 10 | |
| Upper floodplain | 311 | 9 | |
| Upland | 133 | 9 | |

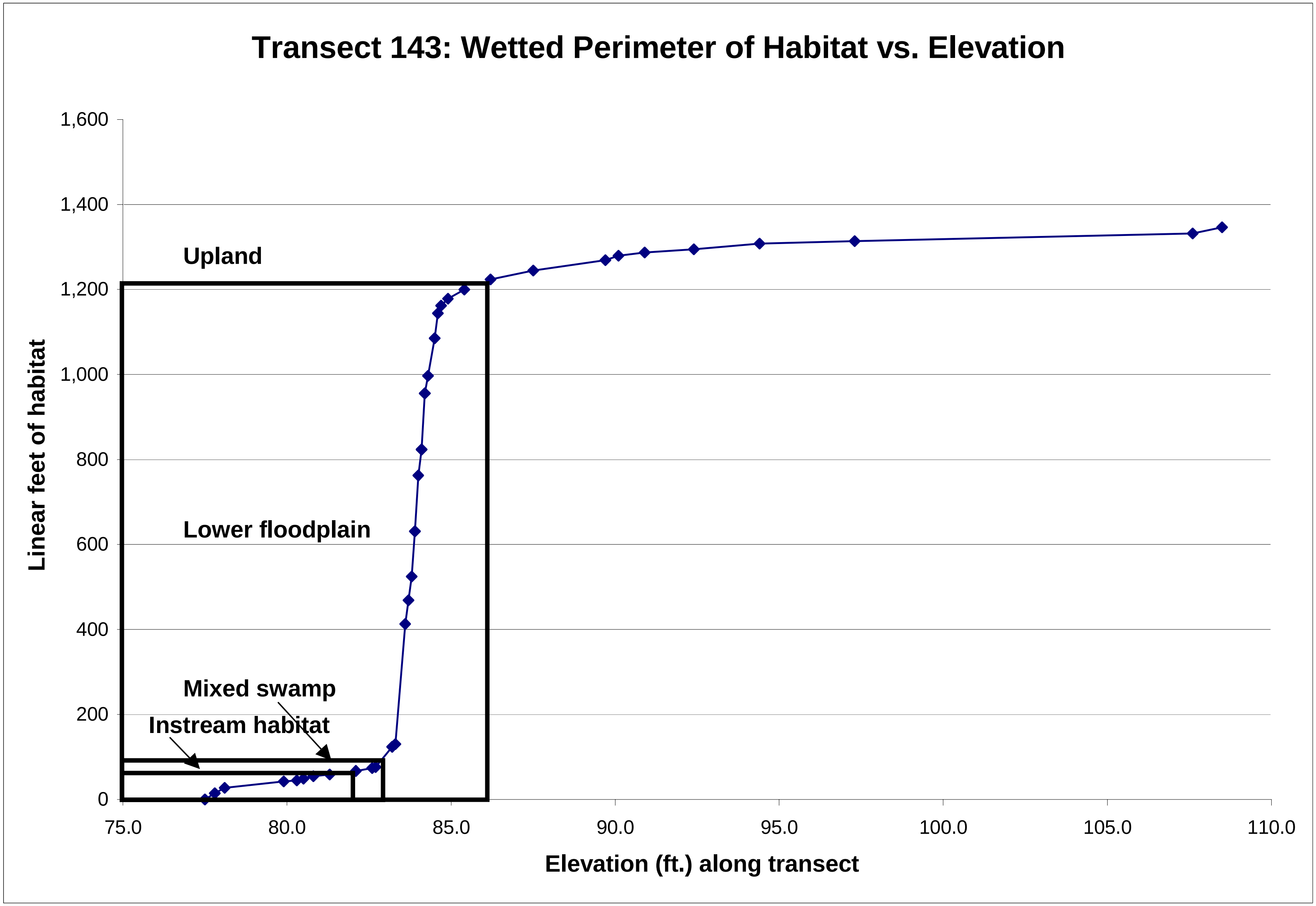



Figure 6-17. Wetted perimeter of major floodplain zones at Transect 143.

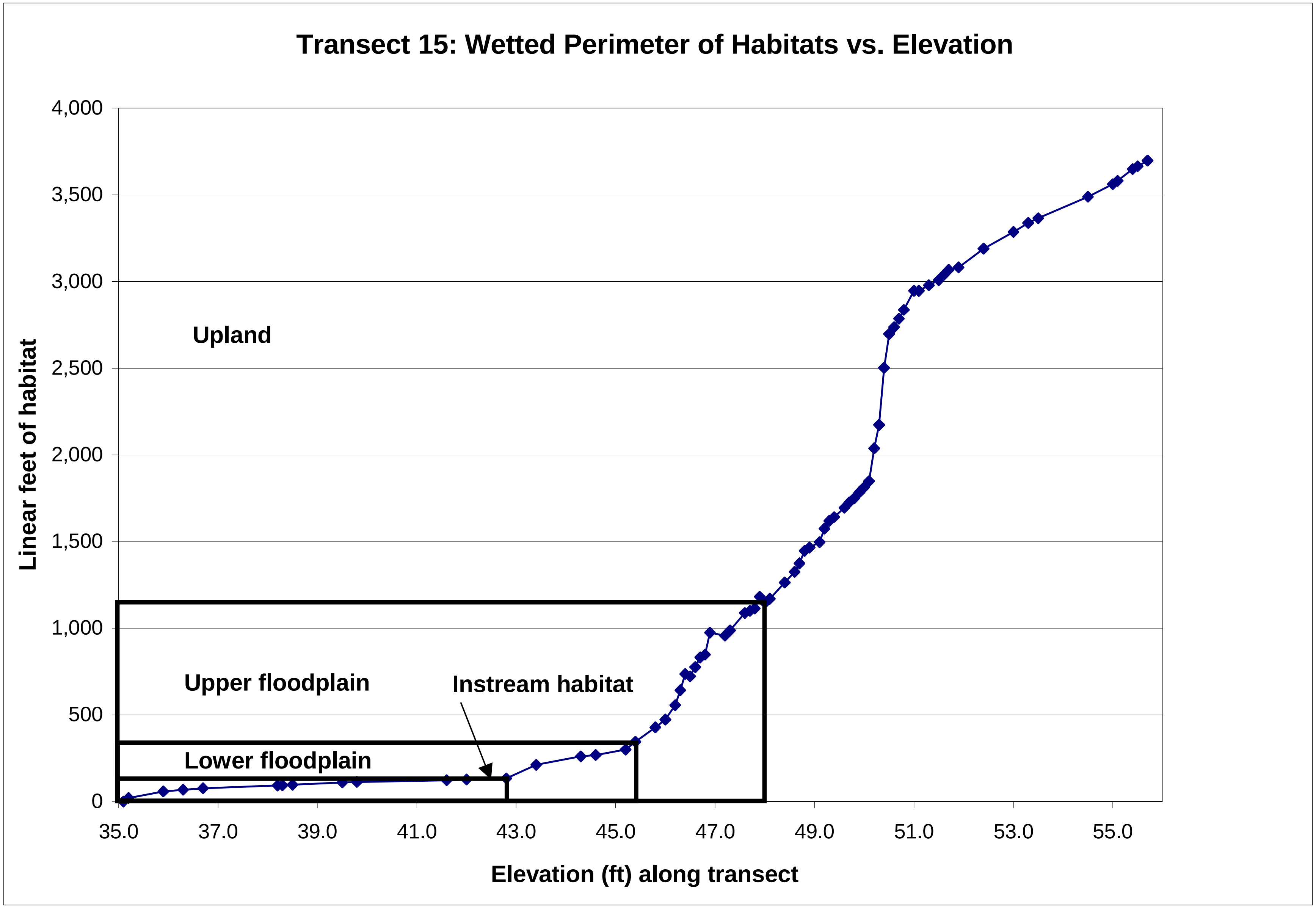



Figure 6-18. Wetted perimeter of major floodplain zones at Transect 15.

### 6.6.5 Inundation Characteristics of Floodplain Habitats in the Upper Peace River

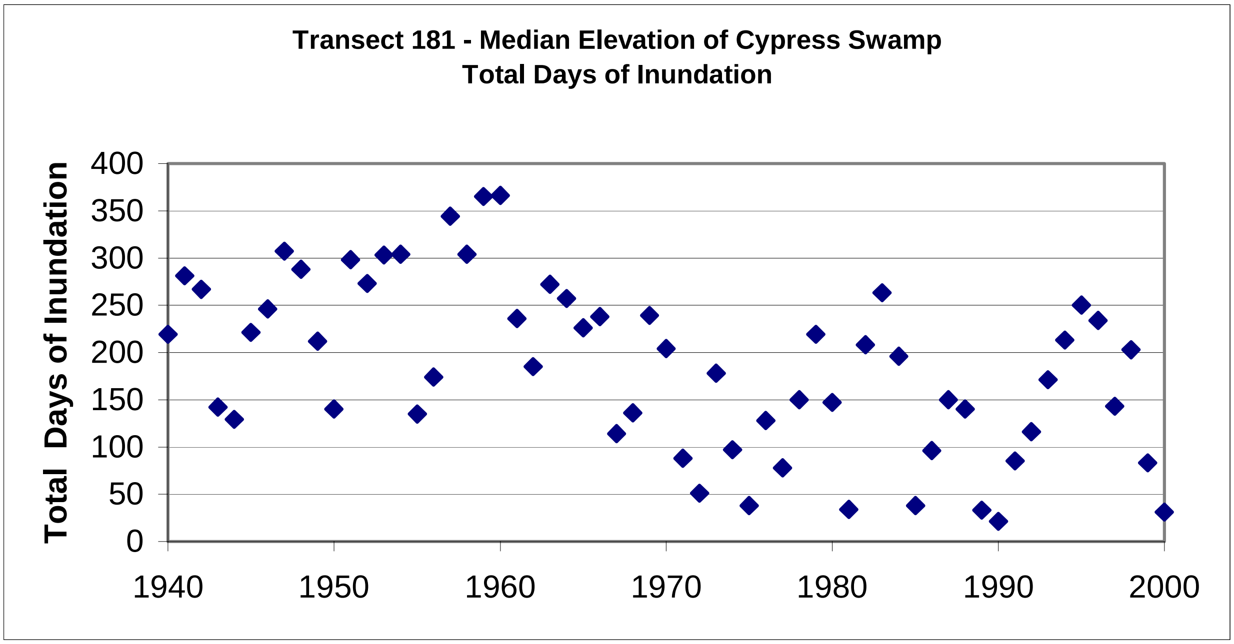
The inundation characteristics of the floodplain habitats along the upper Peace River were examined and compared to the hydrologic characteristics of floodplain wetlands from other locations in Florida. The inundation characteristics of floodplain wetland habitats in the Upper Peace River are examined on a long-term basis in order to determine if they have changed over time.

As was performed for instream habitats, the inundation of floodplain habitats along the Upper Peace River was simulated for the period from 1940 to 2000. For comparison purposes, this period was divided into reference (1940-1956 ) and recent (1987-1999) periods which had similar amounts of near-average rainfall. The documentation of long-term changes in the inundation characteristics of floodplain habitats allows for improved ecological characterization of these habitats, and is an important analytical tool for the determination of minimum flows and levels.

Hydrographs of simulated yearly inundation values for swamp, lower floodplain, upper floodplain, and upland habitats are included in Appendix RH**.** Yearly inundation plots are presented for the median elevation of swamps, lower and upper floodplain zones, and for the minimum elevation of swamps, lower floodplain and upland zones. Plots are provided for the total number of days of inundation per year and the longest number of consecutive days of inundation per year. The total number of days of inundation per year are referred to as yearly hydroperiods, while the longest number of consecutive days are referred to as yearly consecutive days of inundation.

The series of inundation plots in Appendix RH show that both of these yearly inundation parameters have declined over time in the Upper Peace River. This trend is not surprising, given the significant declines in streamflow that have occurred in the Upper Peace River. Also, two general points are apparent from comparison of the plots. First, the decline in inundation periods is most pronounced at upstream sites. Second, inundation periods are generally longer in the swamps and lower floodplain zones above Ft. Meade, and it is these inundation periods that have declined the most.

These trends are illustrated in yearly inundation plots presented for three transects in Figures 6-19 to 6-21. The yearly hydroperiods for the cypress swamp at Transect 181 have dropped dramatically (Figure 6-19). Prior to 1970, yearly hydroperiods were frequently above 200 days and never less than 125 days. Since 1970, however, there have been thirteen years with total days of inundation of less than 100 days per year. The yearly consecutive days of inundation has also dropped markedly. Since 1985, consecutive values of less than 50 days have occurred 12 times, and values less than 25 days have occurred five times. Prior to 1970, the lowest consecutive days of inundation was 75 days in 1944.



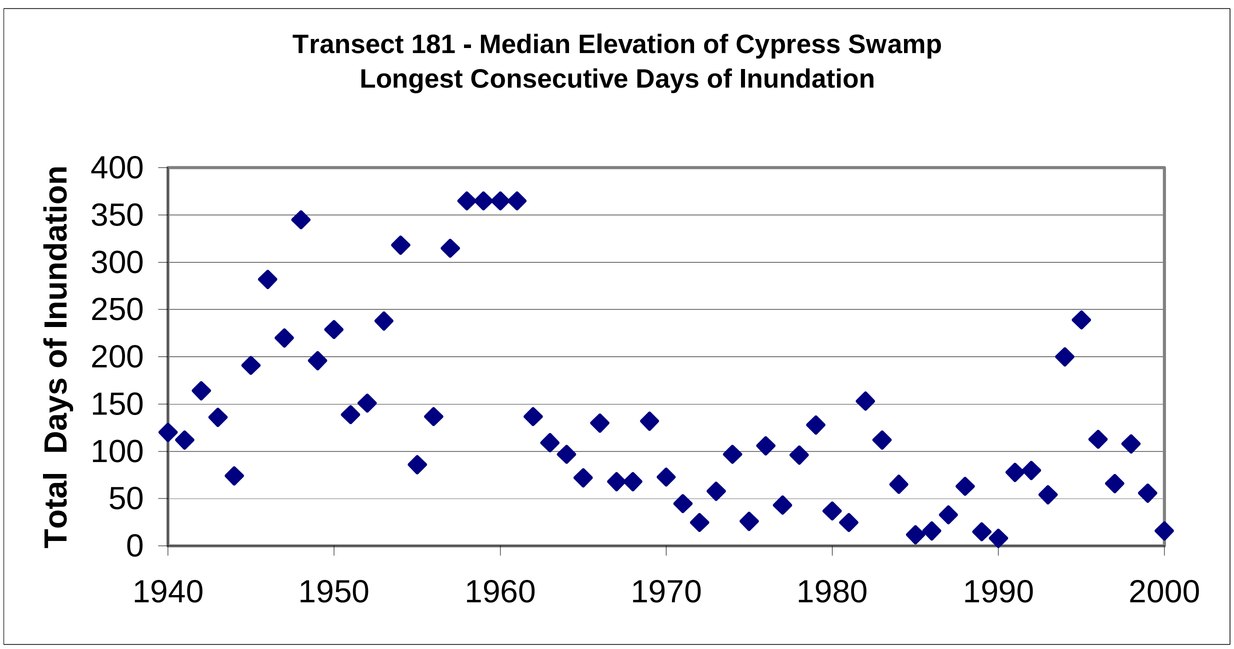
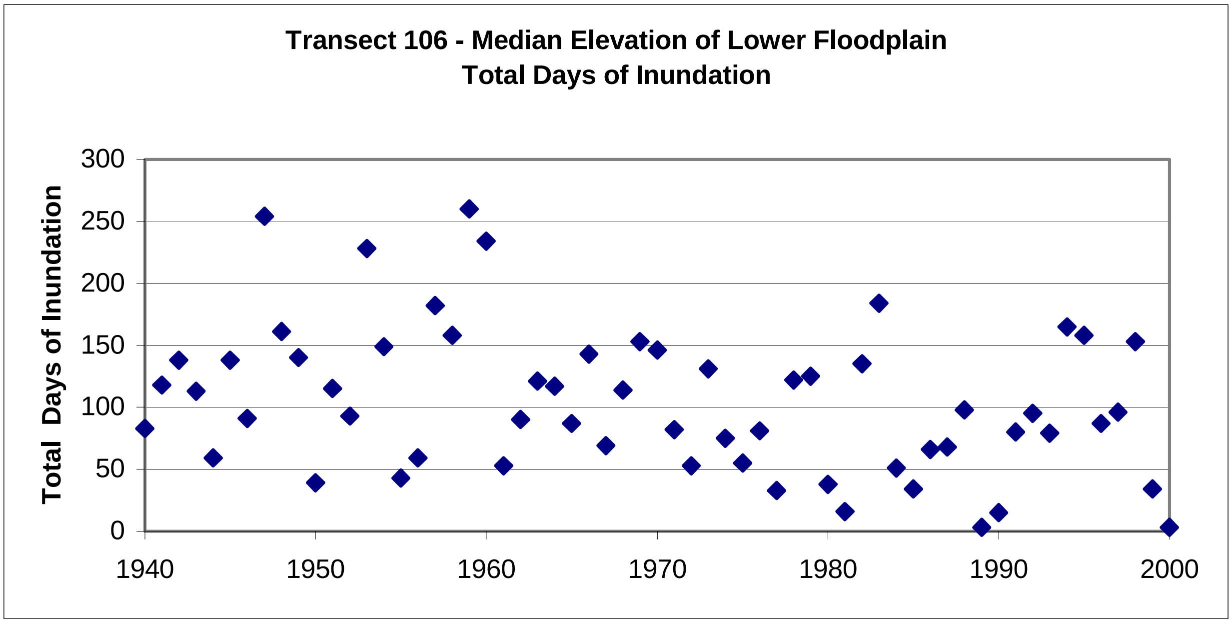




Figure 6-19. Time series plots of total and longest consecutive days of inundation per year for at Transect 181.



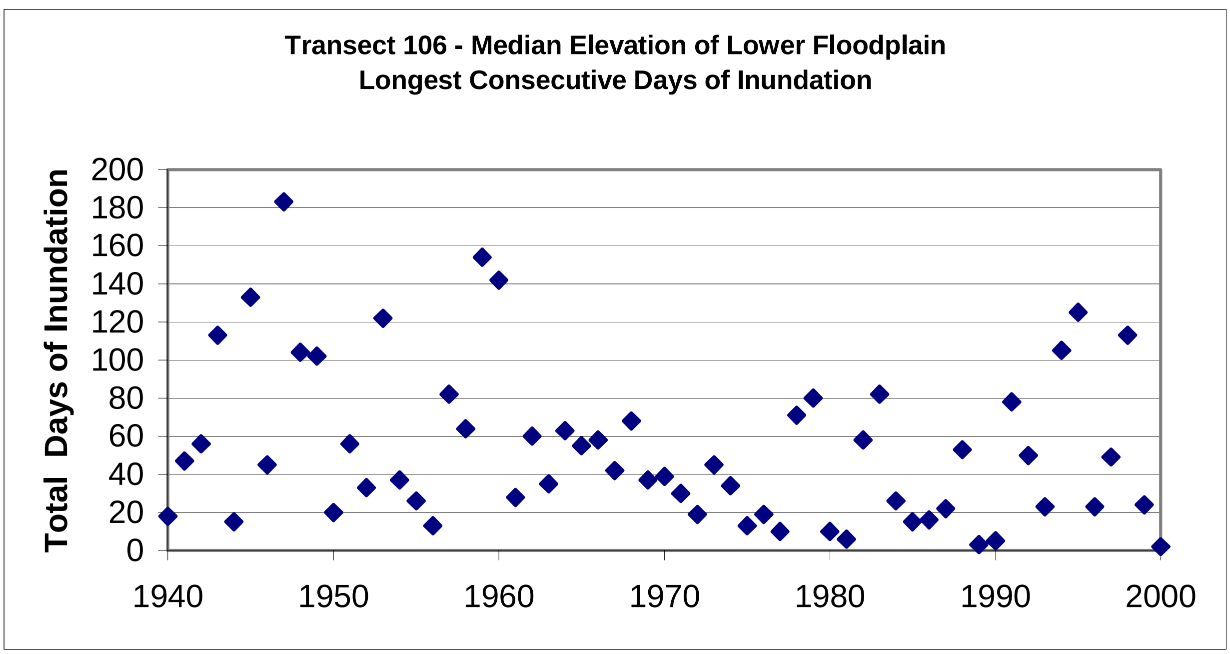
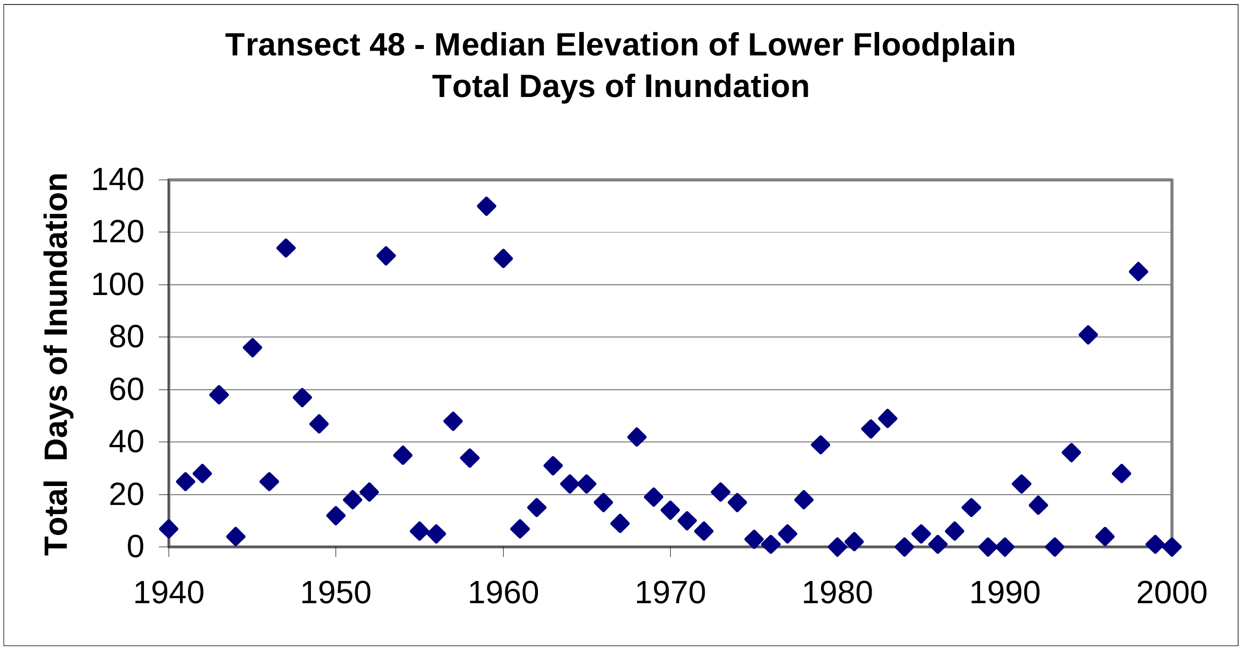




Figure 6-20. Time series plots of total and longest consecutive days of inundation per year at Transect 106.



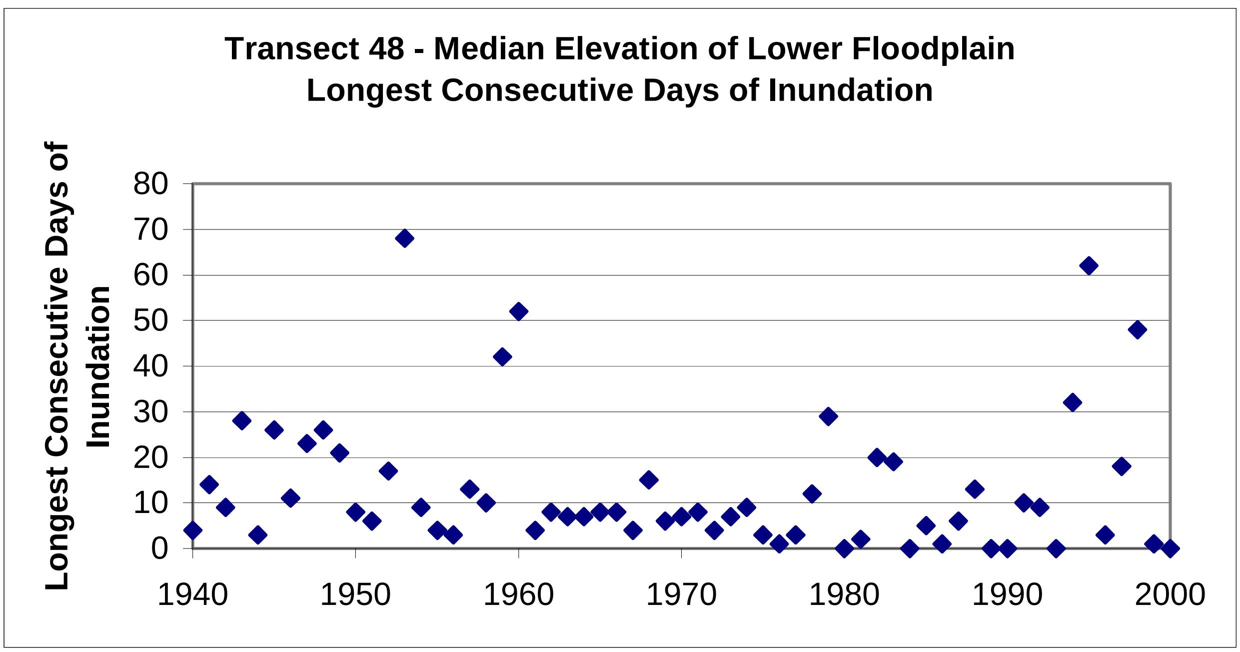




Figure 6-21. Time series plots of total and longest consecutive days of inundation per year at Transect 48.

Similar, but much less pronounced results, are seen at Transect 106, located in a zone of seasonally flooded wetlands just below the Ft. Meade gage. Plots for the lower floodplain zone (Figure 6-20) show a general decline in yearly hydroperiods, which are most apparent in dry years (1981, 1989, 1990, 2000). The yearly consecutive days of inundation have also had a general decline, but not nearly as dramatic as for the cypress zone at Transect 181. A similar trend is observed for the lower floodplain zone at Transect 48 (Figure 6-21) which occurs in a zone of temporarily flooded wetlands. Yearly hydroperiods are less at this site over the entire period of record due to the more incised morphology of the river. Reductions in inundation have occurred, but in contrast to Transects 106 and 181, the lowest yearly values after 1970 are not clearly different than low values that occurred prior. What has happened is the frequency of low values (e.g., 10 days) has increased.

#### 6.6.5.1 Statistical Comparison of Reference and Recent Periods

An assessment of the changes in inundation characteristics of floodplain habitats is aided by comparing inundation statistics from the reference and recent periods. Summary statistics were generated for three floodplain zones for both yearly hydroperiods and consecutive days of inundation (Tables 6-14 through 6-19). Comparison of these statistics allows an assessment of how the inundation characteristics of the river have changed under two periods that had roughly similar near-average rainfall conditions.

The median values of yearly hydroperiods were between 130 and 246 days during the reference periods for the cypress and mixed swamp communities with the exception of Site 178 (Table 6-14). The cypress swamp at Transect 178 is located in a depressional area separated by a small rise. The median elevation of cypress at this site is higher than that of the lower floodplain, which occurs primarily on the other bank of the river. Median values for yearly hydroperiods during the recent period were considerably lower, ranging between 75 and 143 days. However, the most dramatic declines are seen in the minimum values of total inundation. The minimum values of total days inundation in the reference period were between 32 and 129 days. The lowest values for the recent period were between 2 and 21 days. Also, as shown in the yearly plots for cypress and mixed swamps in Appendix RH, the frequency of low values just above the minimum at each transect has greatly increased.

Similar changes are seen for consecutive days of inundation for the cypress and mixed swamps (Table 6-15). As described in Chapter 5, mean and median values for consecutive days of inundation in floodplain zones that are frequently inundated should be viewed with caution, due to possible double counting of consecutive periods between high flow years. However, the changes in minimum values during dry years are accurate and are particularly striking between the recent and reference periods. With the exception of Site 178, the minimum days of consecutive inundation of cypress and mixed swamps during the reference period were between 26 and 74 days, while the minimum days of inundation during the recent period ranged between 2 and 8 days. This demonstrates that the inundation of swamps along the river has been dramatically reduced, particularly during dry years.

Table 6-14. Total number of days of inundation per year for the median elevations of cypress and mixed swamps for the reference and recent periods.

| Transect | Reference Period - 1940 to 1956 | | | | Recent Period - 1987 to 1999 | | | |
|---|---|---|---|---|---|---|---|---|
| | Median | Mean | Minimum | Maximum | Median | Mean | Minimum | Maximum |
| Cypress | | | | | | | | |
| 178 | 107 | 105 | 26 | 217 | 66 | 64 | 1 | 121 |
| 181 | 246 | 232 | 129 | 307 | 143 | 142 | 21 | 251 |
| Mixed Swamp | | | | | | | | |
| 119 | 245 | 230 | 128 | 308 | 142 | 140 | 21 | 246 |
| 143 | 167 | 172 | 72 | 287 | 96 | 105 | 6 | 193 |
| 150 | 130 | 131 | 32 | 257 | 75 | 82 | 2 | 154 |
| 181 | 153 | 147 | 44 | 268 | 89 | 92 | 4 | 170 |

Table 6-15. Longest consecutive number of days of inundation per year for the median elevations of cypress and mixed swamps for the reference and recent periods.

| Transect | Reference Period - 1940 to 1956 | | | | Recent Period - 1987 to 1999 | | | |
|---|---|---|---|---|---|---|---|---|
| | Median | Mean | Minimum | Maximum | Median | Mean | Minimum | Maximum |
| Cypress | | | | | | | | |
| 178 | 29 | 41 | 6 | 119 | 14 | 19 | 1 | 26 |
| 181 | 164 | 185 | 74 | 346 | 66 | 92 | 8 | 239 |
| Mixed Swamp | | | | | | | | |
| 119 | 164 | 184 | 73 | 344 | 65 | 91 | 8 | 228 |
| 143 | 117 | 128 | 38 | 319 | 49 | 65 | 3 | 174 |
| 150 | 93 | 96 | 26 | 225 | 37 | 51 | 2 | 142 |
| 181 | 97 | 107 | 27 | 299 | 45 | 57 | 3 | 142 |

Table 6-16. Total number of days of inundation per year for the median elevations of lower floodplain zones for the reference and recent periods.

| Transect | Reference Period - 1940 to 1956 | | | | Recent Period - 1987 to 1999 | | | |
|---|---|---|---|---|---|---|---|---|
| | Median | Mean | Minimum | Maximum | Median | Mean | Minimum | Maximum |
| 15 | 18 | 29 | 1 | 87 | 8 | 20 | 0 | 884 |
| 48 | 25 | 38 | 4 | 114 | 15 | 24 | 0 | 105 |
| 49 | 50 | 63 | 12 | 158 | 35 | 41 | 0 | 127 |
| 79 | 0 | 5 | 0 | 19 | 0 | 2 | 0 | 11 |
| 91 | 0 | 5 | 0 | 20 | 0 | 2 | 0 | 11 |
| 99 | 36 | 49 | 7 | 137 | 20 | 31 | 0 | 116 |
| 106 | 115 | 119 | 39 | 251 | 86 | 87 | 3 | 165 |
| 119 | 93 | 88 | 5 | 200 | 56 | 59 | 0 | 133 |
| 134 | 156 | 150 | 46 | 270 | 91 | 95 | 4 | 175 |
| 143 | 123 | 125 | 27 | 253 | 68 | 79 | 2 | 149 |
| 146 | 135 | 134 | 33 | 258 | 78 | 84 | 3 | 155 |
| 150 | 228 | 217 | 116 | 301 | 135 | 132 | 18 | 227 |
| 161 | 244 | 228 | 126 | 306 | 140 | 139 | 20 | 241 |
| 178 | 118 | 121 | 26 | 252 | 66 | 77 | 1 | 147 |
| 181 | 135 | 135 | 34 | 260 | 79 | 85 | 4 | 156 |

Table 6-17. Longest consecutive number of days of inundation per year for the median elevations of lower floodplain zones for the reference and recent periods.

| Transect | Reference Period - 1940 to 1956 | | | | Recent Period - 1987 to 1999 | | | |
|---|---|---|---|---|---|---|---|---|
| | Median | Mean | Minimum | Maximum | Median | Mean | Minimum | Maximum |
| 15 | 7 | 12 | 1 | 37 | 6 | 12 | 0 | 61 |
| 48 | 11 | 16 | 3 | 68 | 9 | 16 | 0 | 62 |
| 49 | 25 | 36 | 6 | 130 | 18 | 31 | 0 | 121 |
| 79 | 0 | 3 | 0 | 12 | 0 | 1 | 0 | 6 |
| 91 | 0 | 3 | 0 | 12 | 0 | 1 | 0 | 6 |
| 99 | 17 | 23 | 4 | 73 | 15 | 20 | 0 | 69 |
| 106 | 56 | 68 | 13 | 182 | 37 | 53 | 3 | 141 |
| 119 | 52 | 61 | 5 | 150 | 31 | 40 | 0 | 134 |
| 134 | 101 | 112 | 27 | 299 | 45 | 59 | 3 | 163 |
| 143 | 92 | 95 | 25 | 225 | 36 | 50 | 2 | 140 |
| 146 | 95 | 99 | 26 | 231 | 38 | 51 | 2 | 142 |
| 150 | 135 | 161 | 71 | 335 | 60 | 76 | 8 | 196 |
| 161 | 164 | 184 | 73 | 344 | 64 | 91 | 8 | 228 |
| 178 | 89 | 94 | 24 | 220 | 36 | 49 | 1 | 140 |
| 181 | 95 | 99 | 26 | 231 | 38 | 52 | 3 | 142 |

Summary statistics for the median elevation of the lower floodplain zones are listed in Tables 6-16 and 6-17. The yearly hydroperiods varied considerably among sites, even within the reference period for the lower floodplain zones. Upstream of Transect 106, located about two miles south of the Ft. Meade, median values for yearly hydroperiods for the lower floodplain zone range from 93 days at Transect 119 to 244 days at Transect 161. These differences are due to differences in the morphology of the river among these sites. Hydrologically, the wetter lower floodplain sites are functioning similar to swamp forests identified in this reach of the river. Below Transect 106, (Transect 99 southward) the median values of inundation are consistently less, ranging from 0 days at two sites to 50 days at Transect 49. These lower values reflect that the river is more incised below Bowlegs Creek. Given these results, it is clear that each lower floodplain zone must be viewed separately, or possibly within specific river reaches, and general conclusions about the hydrologic requirements of this category as a whole cannot be reached.

Although inundation durations vary between the lower floodplain sites, fairly consistent patterns are seen in reductions in total days of inundation between the reference and recent periods. With the exception of Transects 79 and 91 (which are infrequently inundated), yearly hydroperiods for the recent period ranged between 44 and 70 percent of the values for the reference period. There was grouping in the middle of the range as, median yearly hydroperiods for the recent period were between 55 and 60 percent of the medians for the reference period at ten of the thirteen transects where lower floodplain zones were identified.

Interesting results are observed in the minimum days of total inundation at the transects during the reference and recent periods. Below Bowlegs Creek (Transect 99 south), the lower floodplain zone was not inundated for long durations during dry years in the reference period, with minimum values ranging from zero to twelve days at Transects 15 through 99. Minimum values during the recent period for these sites were all zero. These changes in minimum yearly hydroperiods may not be important for sites that were not inundated during dry years in the reference period, but may be important at sites which experienced several days of minimum yearly inundation in the reference period (Transects 48, 49, 99). At sites upstream of Bowlegs Creek, reductions in minimum values of yearly hydroperiods are more pronounced. For example, the lowest total days of inundation at Transect 146 during the reference period was 46 days, but the lowest year during the recent period was only three days. Comparable reductions were observed at a number of other sites in the river above Bowlegs Creek. As discussed in subsequent sections, such declines in dry year inundation could have implications for wetland plant composition and soil characteristics in this part of the river.

As expected, the median elevations of upper floodplain zones show much less frequent inundation (Table 6-18 and 6-19). The minimum values for total days of inundation during dry years ranged from zero days at eight of twelve sites where upper floodplains occured to a high of seven days at Transect 33. Median values of total days of inundation were also low (< 7 days) for several sites, with the highest value of 49 days at Transect 146. As with lower floodplain zones, inferences about the upper floodplains cannot be made for the category as a whole. In general, however, most of these zones appear to be in the temporarily flooded category, with a few cases of seasonally flooded hydrology. Plots of the yearly hydroperiods and consecutive days of inundation for upper floodplain zones are presented in Appendix RH.

Summary statistics for the inundation of the minimum elevation of upland zones are presented in Table 6-20 and 6-21. These values represent the wetland/upland boundary. The median yearly hydroperiods for the reference period ranged from 0 days for five of the sites to 40 days at Transect 134. The values are highly variable above Ft. Meade. However, the upland/wetland boundary at many of the sites above Ft. Meade occurs on berms separating the floodplain from mined lands so this boundary does not represent a natural elevational gradient. Therefore, the remaining discussion of the upland/wetland transition zone pertains to transects south of Ft. Meade where mining has not occurred. The median values for yearly hydroperiods are fairly consistent, ranging from zero to eleven days per year, with five of the eight values between 3 and 6 days per year. Median yearly hydroperiods for the recent period are lower, ranging between 0 and 4 days. With the exception of Site 91, maximum yearly values are between 31 and 71 days, indicating these sites are clearly within the floodplain of the river and periodically receive prolonged inundation.

Table 6-18. Total number of days of inundation per year for the median elevations of upper floodplain zones for the reference and recent periods.

| Transect | Reference Period - 1940 to 1956 | | | | Recent Period - 1987 to 1999 | | | |
|---|---|---|---|---|---|---|---|---|
| | Median | Mean | Minimum | Maximum | Median | Mean | Minimum | Maximum |
| 15 | 17 | 27 | 1 | 83 | 6 | 18 | 0 | 75 |
| 33 | 39 | 53 | 7 | 143 | 22 | 33 | 0 | 120 |
| 49 | 6 | 16 | 0 | 57 | 2 | 12 | 0 | 53 |
| 91 | 0 | 2 | 0 | 10 | 0 | 0 | 0 | 4 |
| 99 | 18 | 28 | 1 | 83 | 6 | 18 | 0 | 76 |
| 106 | 31 | 44 | 5 | 124 | 17 | 29 | 0 | 112 |
| 119 | 7 | 16 | 0 | 81 | 3 | 11 | 0 | 69 |
| 134 | 57 | 63 | 0 | 163 | 43 | 41 | 0 | 130 |
| 146 | 61 | 67 | 0 | 167 | 44 | 42 | 0 | 130 |
| 150 | 14 | 24 | 0 | 98 | 7 | 18 | 0 | 92 |
| 161 | 40 | 47 | 0 | 134 | 28 | 33 | 0 | 122 |
| 181 | 0 | 5 | 0 | 25 | 0 | 2 | 0 | 26 |

Table 6-19. Longest consecutive number of days of inundation per year for the median elevations of upper floodplain zones for the reference and recent periods.

| Transect | Reference Period - 1940 to 1956 | | | | Recent Period - 1987 to 1999 | | | |
|---|---|---|---|---|---|---|---|---|
| | Median | Mean | Minimum | Maximum | Median | Mean | Minimum | Maximum |
| 15 | 7 | 11 | 1 | 36 | 4 | 10 | 0 | 38 |
| 33 | 19 | 26 | 4 | 73 | 17 | 23 | 0 | 90 |
| 49 | 5 | 7 | 0 | 20 | 2 | 7 | 0 | 30 |
| 91 | 0 | 2 | 0 | 10 | 0 | 0 | 0 | 4 |
| 99 | 7 | 11 | 1 | 36 | 4 | 10 | 0 | 38 |
| 106 | 13 | 20 | 4 | 71 | 14 | 18 | 0 | 63 |
| 119 | 6 | 11 | 0 | 56 | 3 | 7 | 0 | 30 |
| 134 | 37 | 40 | 0 | 90 | 21 | 33 | 0 | 125 |
| 146 | 37 | 45 | 0 | 145 | 22 | 34 | 0 | 125 |
| 150 | 12 | 17 | 0 | 61 | 6 | 14 | 0 | 53 |
| 161 | 23 | 32 | 0 | 77 | 18 | 26 | 0 | 118 |
| 181 | 0 | 4 | 0 | 17 | 0 | 1 | 0 | 15 |

Table 6-20. Total number of days of inundation per year to the minimum elevation of upland zones for the reference and recent periods.

| Transect | Reference Period - 1940 to 1956 | | | | Recent Period - 1987 to 1999 | | | |
|---|---|---|---|---|---|---|---|---|
| | Median | Mean | Minimum | Maximum | Median | Mean | Minimum | Maximum |
| 15 | 6 | 14 | 0 | 48 | 0 | 10 | 0 | 42 |
| 33 | 6 | 16 | 0 | 58 | 2 | 12 | 0 | 57 |
| 48 | 3 | 8 | 0 | 31 | 0 | 6 | 0 | 22 |
| 49 | 4 | 11 | 0 | 39 | 0 | 8 | 0 | 35 |
| 79 | 0 | 4 | 0 | 18 | 0 | 2 | 0 | 11 |
| 91 | 6 | 6 | 0 | 9 | 4 | 4 | 4 | 4 |
| 99 | 12 | 20 | 0 | 71 | 2 | 14 | 0 | 65 |
| 106 | 11 | 20 | 0 | 68 | 2 | 14 | 0 | 64 |
| 119 | 0 | 5 | 0 | 26 | 0 | 2 | 0 | 27 |
| 134 | 40 | 46 | 0 | 133 | 28 | 32 | 0 | 122 |
| 143 | 16 | 25 | 0 | 98 | 9 | 20 | 0 | 104 |
| 146 | 6 | 5 | 0 | 19 | 2 | 4 | 0 | 18 |
| 150 | 0 | 3 | 0 | 17 | 0 | 1 | 0 | 17 |
| 178 | 0 | 9 | 0 | 53 | 0 | 5 | 0 | 47 |
| 181 | 0 | 0 | 0 | 4 | 0 | 0 | 0 | 0 |

Table 6-21. Longest consecutive number of days of inundation per year to the minimum elevation of upland zones for the reference and recent periods.

| Transect | Reference Period - 1940 to 1956 | | | | Recent Period - 1987 to 1999 | | | |
|---|---|---|---|---|---|---|---|---|
| | Median | Mean | Minimum | Maximum | Median | Mean | Minimum | Maximum |
| 15 | 4 | 7 | 0 | 20 | 0 | 6 | 0 | 27 |
| 33 | 5 | 7 | 0 | 20 | 2 | 7 | 0 | 31 |
| 48 | 3 | 5 | 0 | 16 | 0 | 3 | 0 | 14 |
| 49 | 4 | 6 | 0 | 19 | 0 | 5 | 0 | 24 |
| 79 | 0 | 3 | 0 | 11 | 0 | 1 | 0 | 6 |
| 91 | 0 | 2 | 0 | 8 | 0 | 0 | 0 | 4 |
| 99 | 6 | 9 | 0 | 31 | 2 | 8 | 0 | 33 |
| 106 | 6 | 9 | 0 | 31 | 2 | 8 | 0 | 32 |
| 119 | 0 | 4 | 0 | 17 | 0 | 1 | 0 | 15 |
| 134 | 23 | 31 | 0 | 77 | 18 | 26 | 0 | 118 |
| 143 | 14 | 17 | 0 | 61 | 6 | 14 | 0 | 53 |
| 146 | 2 | 3 | 0 | 11 | 1 | 2 | 0 | 9 |
| 150 | 0 | 3 | 0 | 15 | 0 | 1 | 0 | 13 |
| 178 | 0 | 7 | 0 | 34 | 0 | 3 | 0 | 22 |
| 181 | 0 | 0 | 0 | 4 | 0 | 0 | 0 | 0 |

### 6.6.5.2 Comparisons with Other Systems

To evaluate the ecological condition of floodplain wetlands in the Upper Peace River, it is useful to compare their hydrologic characteristics to comparable wetlands from other locales. Hydrologic characteristics are presented in Table 6-22 for wetlands from several literature sources (Cowardin *et al.* 1979, Wharton *et al.* 1982), the Suwannee River floodplain (Light *et al.* 2001), South Florida (Duever et al 1984) and the Upper Peace River The reference period on the Upper Peace River was chosen for comparison as it may have been more representative of the natural hydrologic conditions of the river. General inundation periods from other sources are presented in more detail in Table 6-23 for the Suwannee River (Light et al. 2002) and Table 6-24 for South Florida wetlands (Duever et al. 1986, Brown and Starnes 1983, and ESE, 1993).

Table 6-22. Typical hydrology, soils, and species characteristics of floodplain communities including the Upper Peace River during the reference period (1940 to 1956).

| Community[1] | Hydrology | Hydrology[1] (Peace) | | Soils[1,2] | Dominant |
|---|---|---|---|---|---|
| | | Above Ft. Meade | Below Ft. Meade | | |
| Cypress/mixed swamp, semi-permanently flooded | Inundated average 7 months/year[2]; Flooded 4-7 months/year, saturated 9 months[3,4]; Minimum s14-day flood/2 year at 1 meter, range of 5-10 months inundation/year[5] | 4-8 months/year | not present | hydric clay, muck, loam | cypress dominant in lower swamp, mixed in higher swamp |
| Lower floodplain, seasonally flooded | Flooded average 2 months/year and saturated 3 months [2,3,4]; minimum 14-day flood/2 year | 3 to 8 months/year | 0 to 2.5 months/year | hydric? loam, sand, clay | cypress, hickory, ash, water oak, maple |
| Upper floodplain, temporarily flooded | Flooded up to 1 month of growing season [3,4]; minimum 14-day flood/5 year | 0 to 1.5 months/year | 0 to 1.3 months/year | hydric/ nonhydric | maple, elm, ash, gum, oak |

[1] from this study
[2] Light et al. 2001
[3] Wharton et al. 1982
[4] Cowardin et al. 1979
[5] Deuver et al. 1978

Inundation periods along the Peace River for the reference period are generally consistent with those from other studies. Cypress and mixed swamps identified north of Ft. Meade were inundated approximately 4 to 8 months per year. Median percent time of inundation of three riverine swamp zones along the non-tidal portion of the Suwannee River was from 30 to 60% (about 3½ to 7 months). Soil saturation for these swamps was higher, in the range of 70 to 80 %. Hydroperiods for floodplain swamps in south Florida were reported between 41 and 74 percent of the year (5 to 9 months).

More variable hydroperiods were observed for lower floodplain zones in the Upper Peace River, reflecting the variable geomorphology of the river. Median yearly hydroperiods of approximately eight months were estimated for two lower floodplain sties above Ft. Meade. These sites are hydrologicaly similar to mixed swamps and probably could be classified as such. The yearly hydroperiods for most other lower floodplain sites above Ft. Meade were in the range of 3 - 4 months per year, thus their classification of seasonally flooded wetlands.

The median values for yearly hydroperiods of lower floodplain zones below Bowlegs Creek ranged from zero days to almost two months per year. While many of these sites could be considered seasonally flooded, some others may be more properly termed temporarily flooded. All the sites classified as upper floodplains in this study could be characterized as temporarily flooded. In general terms, both the lower and upper floodplain forests in the Upper Peace River floodplain could be considered bottomland hardwood forests using the terminology of Wharton et al. (1982) or the Florida Natural Areas Inventory (FNAI 1984). However, within this broad category there are gradients in species composition between lower and upper floodplains zones. Similar findings were reported by Light et al. (2002) who identified lower and upper bottomland hardwood forests on the Suwannee River based on changes in trees species composition. Median yearly hydroperiods for lower bottomland hardwoods there were 15% (2 months) and less than 5% (1/2 month) duration in upper bottomland hardwood forests. However, there was considerable range in values for each zone around these medians.

Table 6-23. Duration and depth of inundation of floodplain communities along the Suwanee River (after Light et al. 2001)

| Community | Duration (%) Inundation | Saturation | Depth (meters) of flood 2-year 14 day | 5-year 14 day |
|---|---|---|---|---|
| Riverine swamp | 60 | 80 | 1.5 | 2.5 |
| Riverine swamp (mixed) | 30 | 70 | 1.25 | 2.25 |
| Lower bottomland hardwoods | 15 | 25 | 0.5 | 1.5 |
| Upper bottomwood hardwoods | <5 | 5 | -0.5 | 0.5 |

Table 6-24. Summary of floodplain hydroperiods in central and south Florida. (after Duever et al. 1978)

| Community | Depth (feet) | Days | % Flood duration |
|---|---|---|---|
| Mixed hardwood swamp[1] | 1.97 | 200 - 250 | 55-68 |
| Cypress dome[1] | 1.64 | 250 - 300 | 68-82 |
| Shallow cypress swamp | | 243 | 67 |
| Deep cypress swamp | 0.47 | 250 | 68 |
| Floodplain swamp | | 150-270 | 41-74 |
| Cypress swamp[2] | | 210 | 58 |
| Wetland forested mix[2] | | 150 | 41 |

[1] Brown and Starnes (1983)

[2] ESE (1993)

### 6.6.5.3 Changes in Hydrologic Indicators

Since the hydrologic characteristics of floodplain wetlands on the Peace River during the reference period are comparable to those from other Florida systems, changes in various hydrologic parameters were evaluated to determine if any associate ecological changes may have occurred. Light et al. (2001) suggested four hydrologic parameters are important for determining the distribution of floodplain wetlands on the Suwannee River. These are the duration of inundation, the duration of soil saturation, and the depths of the 2-year/14-day and 5-year/14-day floods. We do not have data to evaluate changes in soil saturation, but time series of time and duration and consecutive days of inundation have been presented and are discussed below.

Based on physiological tolerances and growth characteristics of wetland tree species, flood durations of 14 days with recurrence intervals between 2 and 5 years were considered important for determining tree species composition by Light et al. (2001). Waters of sufficient depth (e.g. 1 meter) at these intervals can drown the seedlings and young saplings of many species, with the depth of water varying between species. Wetland plants that germinate during intervening dry periods are more likely to grow to saplings of sufficient size to survive these periodic floods than upland vegetation, thus maintaining the characteristic species composition of the wetland community.

Using the longest consecutive day plots in Appendix RH, we evaluated the occurrence of 14-day inundation periods for different floodplain zones at the transect sites. We did not evaluate flood water depths, but instead examined the frequency of 14-day inundation periods at the median ground elevation for each zone. Water levels important for determining species composition in those zones using the flooding criteria suggested by Light et al (2001) would occur at greater water depths. However, the results for inundation are informative for identifying time periods where hydrologic changes in the wetlands occurred. Also, results for inundation periods at a given floodplain zone can be applied to flood water depths at lower elevations. For example, the time series plots for inundation of given zone would apply to a flood depth at an elevation some distance lower (e.g. 1m) on the same transect.

As previously described, marked reductions in yearly values of consecutive days of inundation have been observed for cypress and mixed swamps upstream of Ft. Meade. In the reference period, these zones either consistently exceeded fourteen days of continuous inundation or rarely not did meet that minimum value. In the recent period, however, several of these sites have gone below the fourteen-day value for a series of successive years (cypress at 178 and mixed swamps at sites 119, 143 and 150). Lower floodplain communities above Ft. Meade have similarly experienced frequent years not meeting 14-day criterion during the recent period, compared to isolated years of not meeting this criterion during the reference period. Again, these comparisons are for simple inundation and not flood depth, for which reductions in consecutive 14-day periods would have been more pronounced. Changes in the number of 14-day periods for the lower floodplain zones above Ft. Meade were also pronounced, showing similar patterns to the cypress and mixed swamps. In can be concluded that ecologically significant hydrologic changes have occurred in the semi-permanently and seasonally flooded wetlands above Ft. Meade.

Changes in the inundation of lower floodplain zones below Bowlegs Creek varied considerably, reflecting the more variable geomorphology of the river. At sites characterized by infrequent, temporary flooding (transects 79, 91), 14-day inundation periods were not achieved in the reference period, although consecutive inundation periods over ten days occurred. Inundation periods over six days were not observed in the recent period. Six sites below Bowlegs Creek have lower floodplains characterized by seasonal flooding. At these sites, the frequency of years with consecutive inundation periods of less than 14 days increased from the reference to the recent periods, but 14-day inundation intervals persist at what appears to be between a 2-year and 4-year intervals. Although the occurrence of 14-day inundation periods are less frequent, the results for the upper floodplains show a similar pattern. Although 14-day inundation periods continue to occur at a reduced frequency, the number of years when there were very low (< 4 days) consecutive inundation periods have noticeably increased.

Using soil inundation regardless of water depth, the St. Johns River Water Management District evaluated seven-day floods with five-year recurrence intervals to maintain the transition from wetland to upland communities along Blackwater Creek. Also, as described in the soil's discussion, the FDEP, under FAC Chapter 62-340.550 (Delineation of the Landward Extent of Wetlands and Surface Waters) identifies inundation for at least seven consecutive days or saturation for at least twenty consecutive days annually as hydrologic conditions necessary for the maintenance of hydric soils. Corresponding to these thresholds, we examined the occurrence of seven-day inundation periods for minimum elevation of the upland zones on the Upper Peace River. As previously discussed, this parameter did not seem important above Ft. Meade, where this transition often occurred on man-made berms.

Longest consecutive periods of inundation at the upland/wetland boundary showed variable patterns downstream of Ft. Meade. Most sites show a reduction in the number of years exceeding a seven-day inundation period, but exceedances of seven days still persist in the recent period within what appears to be a 1 in 5 year recurrence interval.

The results for 7- day and 14-day intervals show similar patterns. Periodic high flows have persisted during wet years in the recent period, such as 1988, 1995, and 1998. Thus, although the frequency of years exceeding 7-day and 14-day consecutive inundation periods has decreased, these floods still occur on a periodic basis, in many cases between what appears to be between a 2 and 5-year frequency. These frequencies may be sufficient to maintain the species composition of wetland plant communities. However, the durations of consecutive inundation have generally dropped, including the number of when there were very few (< 4 ) days of consecutive inundation.

As previously discussed, annual hydroperiods have decreased from the reference to the recent period, although some of this change may be due to some wetter years during the reference period. Above Ft. Meade these changes have been particularly pronounced, and as discussed in Section 5.7.3, our analyses may underestimate the change in inundation from the reference to the recent period in this reach of the river. However, from Transect 99 south (below Bowlegs Creek), it is unclear if these changes have been of a magnitude to affect wetland plant species composition. As discussed in the conclusions of this report, sites in the lower portion of the study area will be revisited for additional data collection as part of the determination of minimum flows for the Middle Peace River. This will allow for the closer examination of seasonally and temporarily flooded wetlands in this reach of the river.

## 6.7 Wildlife Use of Floodplain Habitats

The hydrologic characteristics of floodplain zones in the Upper Peace River described in the previous section are discussed below with regard to wildlife species that occur there. A large number of vertebrate and invertebrate species utilize floodplain habitats. However, it is not practical to assess the hydrologic requirements of all species or groups that utilize the floodplain. Instead, the hydrologic requirements of species or groups that are wetland dependent and for which life history relationships are well described can be used as ecological indicators to evaluate hydrologic relationships of floodplain habitats. In that regard, results are discussed for anuran species (frogs and toads) and fishes that occur in the floodplain of the Upper Peace River. Although the hydrologic requirements of these groups do not explicitly cover the requirements of other major groups (e.g. crayfish, wading birds), they can be used as an example of how the hydrologic characteristics of the floodplain habitats in the Upper Peace function with regard to two major wildlife groups.

### 6.7.1 Amphibians

A large number of amphibians, including frogs, toads and salamanders, require wetlands or permanent water bodies for reproduction activities. As part of their life cycle, many amphibians integrate components of both aquatic and terrestrial ecosystems and are influenced by environmental factors that occur at multiple spatial scales. The sensitivity of these animals to their environment makes them ideal indicators of changes in the health of aquatic ecosystems, particularly their hydrologic characteristics.

Beiswenger (1988) has suggested an approach for using frog and toad assemblages as indicators of wetland conditions. Information on general habitat requirements for amphibian species in Florida is summarized by Ashton and Ashton (1988). With the exception of two species of amphibians characterized by direct development, all south Florida amphibian species can be indicators of hydrologic change because of their dependence on wetland conditions. Recommendations concerning the hydrologic requirements of amphibian habitat have been made by staff of the Florida Fish and Wildlife Conservation Commission (Beever 2001, personal communication), who suggest that adequate floodplain inundation be provided for cover, forage, and nursery areas contiguous with, but not in, the deeper river channels.

A summary of the metamorphosing requirements for common frogs and toads expected to occur in south Florida wetlands (CH2MHill 1996) is presented in Table 6-25. Based on these metamorphosing requirements, there are several broad groups of species.

Group 1: 360 days or more (bullfrog, river frog, pig frog)
Group 2: 90 days or more (spring peeper, gopher frog, southern leopard frog)
Group 3: 60 to 90 days (Florida Cricket frog, green tree frog, Florida chorus frog, bronze frog)
Group 4: 45 to 90 days (squirrel tree frog, pinewoods tree frog, and southern toad
Group 5: 30 to 60 days (oak toad, eastern narrowmouth toad)

Group 6: 10 to 30 days (little grass frog, eastern spadefoot toad)
Group 7:   less than 10 days

A species can be expected to be adversely impacted and lost from an area, if the length of inundation does not meet its metamorphosing requirements. For example, a wetland with an inundation period greater than 360 days would support all the species listed above. In contrast, less than 60 days of inundation could preclude breeding by all but a few species.

The effects of changing hydroperiods on the metamorphosing times of the species listed above will be strongly affected by whether a wetland is an isolated system or is connected to a permanent water body such as a lake or a river. For example, if an isolated wetland fails to achieve a required hydroperiod, the immature aquatic stages (e.g. tadpoles) in that

Table 6-25. Summary of inundation requirements for frog and toad breeding habitats.
(adapted from CH2MHill 1996)

| Common Name | Days | Breeding habitat |
|---|---|---|
| | Greater than 360 day of inundation | |
| Bullfrog, pig frog | $\geq$360 days | lakes, marshes, ponds |
| River frog | $\geq$360 days | lakes |
| | Inundation period 90 to 360 days | |
| Southern leopard frog | $\geq$90 | |
| Gopher frog, spring peeper | $\geq$90 | |
| | Inundation period 60 - 90 days | |
| Green tree frog | 60 | lake, pond edges, forested wetlands |
| Florida chorus frog | 60 | roadside ditches, fields, cypress heads |
| Bronze frog | 60 | streams, cypress ponds, permanenet waterbodies |
| | Inundation period of 45 to 90 days | |
| Florida cricket frog | 45-90 | waterbodies with grassy edges |
| | Inundation period of 30 to 60 days | |
| Southern toad | 30-60 | any waterbody |
| Squirrel tree frog, pinewoods tree frog | 30-60 | roadside ditches, temporary waterbodies |
| | Inundation period of 10 to 30 days | |
| Oak toad | 30 | shallow ponds |
| Eastern narrowmouth toad | 30 | any waterbody |
| | Inundation period of 10 days or less | |
| Little grass frogs | 10 | flooded meadows, ponds, ditches |
| Eastern spadefoot toad | 10 | temporary ponds |

wetland will not reach maturity  However, if the wetland habitat is connected to a permanent water body, aquatic stages can migrate to areas that remain inundated providing these areas are connected by surface waters.  In river floodplains there are a wide variety of wetland habitats, including pools, sloughs and side channels. Some of these habitats will become hydraulicly isolated when floodwaters recede, whereas others may remain connected to the river.

In those wetlands that remain connected to the river, declining water levels can greatly reduce the available habitat for aquatic life stages. As flows continue to decline and water levels become confined to the river channel, aquatic stages that were able to migrate to the channel may be susceptible to higher losses due to predation and lack of suitable habitat. As described in Chapter Three, there are now reaches of the Peace River where both the river channel and floodplain dry completely during prolonged dry periods. This represents an extreme case of loss of habitat for wetland dependent species. In our analysis of habitat for wetland dependent wildlife, we examined the time that various floodplain habitats were inundated and how long the edges of these habitats were connected to the river.

Three frog species that can be considered valuable indicators of wetland conditions in the Upper Peace River are the southern leopard frog, the pig frog, and the bull frog (Beever 2001). The bull frog (*Rana castebeiana*) reproduces in permanent water bodies, with a complete larval period of up to two years. Generally, at least the first year is spent in shallow nursery habitats such a littoral zones on the river margin in pools or wetlands in the adjoining floodplain. Partly because of its long life cycle requirements, the bull frog is an indicator of healthy river hydoperiods and is becoming increasing rare in south Florida.

The pig frog, *Rana grylio*, reproduces in permanent water bodies, and is the most common frog in the Peace River in areas of permanent water. The complete larval period is one year, but the first four to six months should be spent in shallow nursery habitats. Adults often are found within river floodplains during inundation. The southern leopard frog, *Rana sphenocephala*, reproduces in all freshwater bodies and is not tied to permanent water bodies as are the bull frog and pig frog. The complete larval period is 90 days. Generally, this entire larval period should be spent in shallow nursery habitats. The southern leopard frog is the most common large river frog in the small tributary creeks of the Peace River basin. Of the large frogs, the southern leopard frog is the most able to tolerate hydroperiod disruptions if it can find adjacent freshwater wetlands.

These three species are representative of frogs and toads that utilize the Peace River but have different hydrologic requirements. Based on the species listed in Table 6-25, CH2MHill (1996) identified three hydroperiod categories corresponding to different groups of frogs and toads. Group 1 includes hydroperiods of greater than one year, which will meet the requirements of all seven groups listed above. The second category includes hydroperiods of between 90 and 360 days, The last category includes hydroperiods of less than 90 days. These authors concluded that 90 days represents somewhat of a breakpoint, as the number of amphibian groups that can survive in a wetland will be markedly be reduced if hydroperiods fall below that duration. Even when the 90-day threshold is met, longer hydroperiods are valuable as they increase the number of successful reproductions that can survive within a given year.

#### 6.7.1.1 Inundation of Amphibian Habitats in the Upper Peace River

The hydrologic requirements presented above can be used to examine the suitability of floodplain habitats in the Upper Peace River for different groups of frogs and toads. Table 6-26 shows median yearly hydroperiods for cypress and mixed swamp habitats ranged from four to eight months during the year, averaging six months. Although this does not meet the complete larval period of the bull frog and pig frog, it does provide excellent nursery habitat for these species for much of the year. Typical hydroperiods for the recent period were considerably lower, averaging 3 ½ months for the six sites where swamps were identified.

As discussed earlier, it is the decline in the minimum values that are recorded in drought years that are most problematic. The lowest yearly hydroperiod values recorded in cypress and mixed swamps during the reference period ranged between 32 and 129 days, averaging 79. Minimum yearly values for the recent period were much lower, ranging between 2 and 21 days and averaging 10. As discussed previously for wetlands, the frequency of very low values above minimum yearly values have increased substantially.

The longest consecutive days of inundation is important parameter if a species is to spend all of its larval stage in a particular wetland habitat. The lowest yearly values for longest consecutive days of inundation during the reference period ranged from 26 to 73 days, averaging 46. In contrast, the minimum yearly values recorded during the recent period were 8 days or less. Amphibian use of much of the swamp habitat on the upper river during very dry years is very limited, to being virtually non-existent.

As previously discussed, the inundation characteristics of the lower floodplain zones varied considerably due to changes in the river's geomorphology from upstream to downstream. At two of the transects (150 and 161), long hydroperiods were observed allowing these areas to function essentially as riverine swamps. Median hydroperiods between 93 and 156 days during the reference period were observed at the other seven transects above Bowlegs Creek (from Transect 106 upstream). During most years, these lower floodplains were suitable habitat for a large number of frog and toad species. Median hydroperiods during the recent period were less than 90 days at six of the nine transects above Bowlegs Creek. However, yearly hydroperiods at three of these sites were between 80 and 90 days. With the exception of Transects 150 and 151, minimum yearly hydroperiods were less than five days. During very dry years in the recent period, much of these lower floodplain zones (as indicated by their median elevation) lose their amphibian habitat function.

Downstream of Bowlegs Creek (Transect 99 and southward), the lower floodplain zones experience much less inundation. The functioning of these zones as productive habitats for frogs and toads has substantial year-to-year variability. Median hydroperiods were less than 90 days during the reference period at all transects. Hydroperiods at four of these transects nearly reached or exceeded 90 days during wet years, but minimum values of less than 12 days were recorded at all sites. Hydroperiods were generally less in the recent period, but hydroperiods in excess of 90 days still occurred in one or more wet years. In this reach of the river it is unclear if the functions of lower floodplain zones as amphibian habitat have experienced a persistent overall change or degradation. Instead, it appears that the frequency of years with good habitat functions have been reduced.

In contrast to the two zones described above, upper floodplain zones at most sites appear to have limited function as amphibian habitat during most years. Median hydroperiods in excess of 30 days during the reference period were observed at five sites. Hydroperiods in excess of 90 days were observed in wet years, but minimum values were near zero. As with lower floodplains, there is considerable inter-annual variability with regard to these being productive amphibian habitats. Since the inundation times of these habitats are relatively short, they may be sensitive to changes during high flow years when these habitats are inundated. The shorter inundation times that occur during wet years in the recent period may cause some lack of production in those habitats compared to reference conditions. However, in contrast to upstream areas, changes in habitats used during dry years are probably not important.

It is important to stress that the statistics presented above are for the median elevations of the floodplain zones. Approximately half of each zone would be available at lower water surface elevations, which could be important for providing amphibians with at least some amount of critical habitat. This relationship may be most critical for the floodplain habitats immediately adjacent to the river, as these would provide habitat for amphibians that otherwise would be restricted to the river channel. In that regard, hydrologic statistics are presented for cypress swamps and mixed swamps in Tabled 6-26 and 6-27 and for lower floodplains in Tables 6-28 and 6-29. These represent the most waterward wetland communities at each site.

With the exception of Transect 178, the median yearly hydroperiods for the minimum elevations of cypress or mixed swamps were above 250 days per year during the reference period, indicating that amphibians and other fauna in the river typically had access to these wetlands throughout much of the year. Minimum yearly values for the reference period ranged between 137 and 165 days, with an average of about five months. Minimum values for the recent period are considerably lower, ranging between 25 and 48 days, averaging slightly over one month. Clearly, access to swamp habitats by riverine fauna has declined from the reference to the recent period.

Table 6-26. Average total number of days of inundation per year to the minimum elevation of cypress/mixed swamp habitat for the reference and recent periods.

| Transect | Reference Period - 1940 to 1956 | | | | Recent Period - 1987 to 1999 | | | |
|---|---|---|---|---|---|---|---|---|
| | Median | Mean | Minimum | Maximum | Median | Mean | Minimum | Maximum |
| Cypress | | | | | | | | |
| 150 | 365 | 365 | 357 | 366 | 363 | 355 | 314 | 366 |
| 178 | 165 | 169 | 68 | 284 | 95 | 104 | 5 | 191 |
| 181 | 259 | 250 | 142 | 325 | 164 | 158 | 29 | 267 |
| Mixed Swamp | | | | | | | | |
| 143 | 261 | 256 | 152 | 329 | 171 | 163 | 36 | 273 |
| 150 | 277 | 272 | 165 | 356 | 190 | 174 | 48 | 282 |
| 181 | 256 | 243 | 137 | 318 | 160 | 152 | 25 | 265 |

Table 6-27. Average longest consecutive number of days of inundation per year to the minimum elevation of cypress/mixed swamp habitat for the reference and recent periods.

| Transect | Reference Period - 1940 to 1956 | | | | Recent Period - 1987 to 1999 | | | |
|---|---|---|---|---|---|---|---|---|
| | Median | Mean | Minimum | Maximum | Median | Mean | Minimum | Maximum |
| Cypress | | | | | | | | |
| 150 | 365 | 365 | 365 | 365 | 365 | 346 | 277 | 365 |
| 178 | 117 | 128 | 38 | 318 | 46 | 61 | 3 | 164 |
| 181 | 190 | 195 | 85 | 365 | 80 | 104 | 9 | 274 |
| Mixed Swamp | | | | | | | | |
| 143 | 192 | 210 | 88 | 365 | 81 | 109 | 15 | 275 |
| 150 | 219 | 232 | 91 | 365 | 82 | 111 | 16 | 278 |
| 181 | 190 | 192 | 76 | 347 | 79 | 103 | 8 | 274 |

Table 6-28. Total number of days of inundation per year to the minimum elevation of lower floodplain zones for the reference and recent periods.

| Transect | Reference Period - 1940 to 1956 | | | | Recent Period - 1987 to 1999 | | | |
|---|---|---|---|---|---|---|---|---|
| | Median | Mean | Minimum | Maximum | Median | Mean | Minimum | Maximum |
| 15 | 151 | 150 | 61 | 283 | 110 | 112 | 33 | 200 |
| 48 | 42 | 56 | 7 | 150 | 27 | 36 | 0 | 124 |
| 49 | 114 | 118 | 39 | 247 | 83 | 85 | 3 | 163 |
| 79 | 18 | 28 | 1 | 83 | 6 | 18 | 0 | 76 |
| 91 | 17 | 27 | 1 | 83 | 6 | 18 | 0 | 75 |
| 99 | 181 | 182 | 90 | 295 | 143 | 135 | 46 | 231 |
| 106 | 231 | 244 | 130 | 356 | 221 | 197 | 113 | 304 |
| 119 | 101 | 96 | 8 | 227 | 57 | 63 | 0 | 137 |
| 134 | 328 | 308 | 216 | 366 | 230 | 202 | 62 | 307 |
| 143 | 246 | 232 | 129 | 307 | 143 | 142 | 21 | 251 |
| 146 | 259 | 250 | 142 | 325 | 164 | 158 | 29 | 267 |
| 150 | 259 | 250 | 142 | 325 | 164 | 158 | 29 | 267 |
| 161 | 365 | 365 | 364 | 366 | 365 | 361 | 314 | 366 |
| 178 | 165 | 169 | 68 | 284 | 95 | 104 | 5 | 191 |
| 181 | 159 | 160 | 54 | 278 | 93 | 100 | 5 | 183 |

Table 6-29. Longest consecutive number of days of inundation per year to the minimum elevation of lower floodplain zones for the reference and recent periods.

| Transect | Reference Period - 1940 to 1956 | | | | Recent Period - 1987 to 1999 | | | |
|---|---|---|---|---|---|---|---|---|
| | Median | Mean | Minimum | Maximum | Median | Mean | Minimum | Maximum |
| 15 | 95 | 107 | 24 | 229 | 48 | 65 | 10 | 165 |
| 48 | 22 | 29 | 4 | 74 | 18 | 28 | 0 | 119 |
| 49 | 56 | 68 | 13 | 182 | 37 | 52 | 3 | 140 |
| 79 | 7 | 11 | 1 | 36 | 4 | 10 | 0 | 38 |
| 91 | 7 | 11 | 1 | 36 | 4 | 10 | 0 | 38 |
| 99 | 110 | 125 | 30 | 316 | 59 | 80 | 15 | 196 |
| 106 | 154 | 184 | 73 | 347 | 88 | 112 | 28 | 289 |
| 119 | 53 | 66 | 6 | 199 | 34 | 42 | 0 | 136 |
| 134 | 281 | 285 | 184 | 365 | 121 | 142 | 27 | 295 |
| 143 | 164 | 185 | 74 | 346 | 66 | 92 | 8 | 239 |
| 146 | 190 | 195 | 85 | 365 | 80 | 104 | 9 | 274 |
| 150 | 190 | 195 | 85 | 365 | 80 | 104 | 9 | 274 |
| 161 | 365 | 365 | 365 | 365 | 365 | 365 | 365 | 365 |
| 178 | 117 | 128 | 38 | 318 | 46 | 61 | 3 | 164 |

As expected, median yearly hydroperiods for the minimum elevations of lower floodplains are much greater north of Bowlegs Creek than further south. However, three sites (99, 49 and 15) south of Bowlegs Creek had median hydroperiods for the reference period between 114 and 181 days, allowing access to the floodplain between four and six months. Hydroperiods of three more incised sites (48,79 and 91), were considerably less (17 to 42 days), indicating that access to the floodplain is much less frequent occurrence in these river reaches. There are reductions in all values between the recent and the reference period. Possibly the most problematic are the reductions in minimum values in the region above Ft. Meade, where the access to the lower floodplain had been dramatically reduced during dry years.

### 6.7.1.2 Considerations for Using Amphibians for Developing Minimum Flow Criteria

Several lines of evidence indicate that declining trends in streamflow reductions have substantially reduced suitable habitat for amphibians in the Upper Peace River. The effect of these flow reductions has been most pronounced in the regions above Ft. Meade. Comparison of median inundation values between reference and recent periods indicates that large reductions in habitat have occurred during years of near average rainfall. Most striking, however, are the reductions in habitat inundation during dry years. During the reference period, many habitats retained some habitat function during dry years, but hydroperiods were so short during the recent period that habitat functions were lost.

Periodic loss of wetland functions in certain habitats (e.g. lower floodplain) might be acceptable if such loss occurred infrequently and there were other habitats the fauna could utilize. In this regard, an evaluation of significant harm and the establishment of minimum flows and levels should consider the frequency that unsuitable conditions have, or are predicted to, occur for specific habitats in the river/floodplain ecosystem.

A 90-day consecutive day hydroperiod could be used as one management criterion for establishing hydrologic targets for floodplain habitats. It has been suggested that if hydroperiods are reduced below 90 days, then the suitability for wetlands for certain groups of frogs and toads is diminished (CH2MHill 2002). Conversely, continuous inundation periods of 90 days are sufficient to allow many frog species to reach maturity; since it will accommodate all but the most long lived species (bull and pig frog). Maintaining 90 days of consecutive inundation in key floodplain habitats should therefore enhance the overall abundance and diversity of frogs and toads in the river system.

The hydroperiods of floodplain wetlands in the Upper Peace River exhibit considerable inter-annual variability due natural fluctuations in streamflow between wet and dry years. Through hydraulic modeling and use of long-term streamflow records, estimates were generated for how often 90-hydroperiods were met in floodplain zones in different reaches of the river. Using this information, it can be determined if a 90-day consecutive period of inundation is a reasonable threshold for different floodplain zones by examining how often this threshold was met in the past.

It is important to emphasize that a 90-day threshold does not meet all the requirements of the amphibian community. Some of the floodplain wetlands on the Upper Peace River had yearly hydroperiods of over 200 days during the reference period, providing high quality habitat for amphibians throughout much of the year. In these cases, a 90-day hydroperiod may not encompass the full hydrologic requirements of these habitats. Also, other hydrologic criteria could be applied to high flows for the maintenance of hydric soils or wetland plant communities, such as 14 days of continuous inundation as suggested by Light et al. (2001). Although other criteria could be applied for management purposes, the frequency of occurrence of 90 days of consecutive inundation can be used as an ecologically meaningful hydrologic threshold, and is the criterion that was evaluated for moderately high flows on the Upper Peace River.

The floodplain habitats in the Upper Peace River floodplain that frequently had greater than 90 days of consecutive days of inundation at their median elevation are listed in Table 6-29. Twelve floodplain zones were identified for which the median value of consecutive days of inundation was greater than 90 days during the reference period (one habitat with a value of 89 days was included). These included cypress, mixed swamp, and lower floodplain habitats at eight transects in the reach of the river above Ft Meade. Also listed is the percentage of years the longest consecutive days of inundation for each habitat exceeded 90 days during the reference period. Floodplain habitats at three of the transects (181, 161, and 119) had values of 88%, indicating they met the 90-day criterion during all but very dry years. These habitats represent the low-lying swamps in the upper river. Seven of the twelve habitats exceeded the 90-day criterion 47% or 53% of the years, or about half the time during the reference period. These habitats met the 90-day criterion with approximately a 2-year average recurrence interval during the reference period.

The percentages of years the 90-day threshold were met during the recent period were considerably lower. With one exception, all the values were either 23% or 31%, equal to 3 or 4 times during the 13-year recent period. This corresponds to an average frequency of slightly less frequently than once every three to four years. The values of 31% during the recent period were for the low-lying swamps that had values of 88% during the reference period, so their frequency of meeting the 90-day threshold is about one-third of what is used to be. The frequency of meeting the 90-day threshold for the other sites has been reduced by about half, from a two-year recurrence interval to a four-year recurrence interval.

It is clear the consecutive days of inundation at sites between Bartow and Ft. Meade have changed considerably, particularly when contrasted to sites downstream (between Ft. Meade and Zolfo Springs). In addition, the wetland systems potentially most suitable for amphibian production are all located in the most impacted reach of the river. While ground-water withdrawals are a major contributor to loss of baseflow, flow declines in the medium to high range are attributable to many confounding factors. Because of this minimum flows for medium and high flows are not being recommended for adoption. However, a standard for management purposes is proposed. Given that rainfall in the wet season of the reference period averaged approximately two inches more than in the recent period, and given that the concept of minimum flows standards implies that some amount of water is available before significant harm occurs, a standard midway between the reference and recent period is suggested.

The frequency and duration of inundation of wetlands that previously met the 90-day threshold on an approximate two-year recurrence interval can be used as a management standard for the river above Ft. Meade. As described above, the frequency of meeting the 90-day criterion has declined to about a four-year recurrence interval. Restoring the frequency of inundation to a three-year recurrence interval should provide meaningful improvement to the swamps and lower floodplain communities, but not take them back to the reference condition, which would be very difficult to achieve given the highly impacted, hydrologic status of the Upper Peace River. If flows were restored to achieve a 3-year recurrence interval in these wetlands, the recurrence intervals of 90-day inundation periods in the lower-lying swamps would be more frequent, as these wetlands are inundated at considerably lower flows.

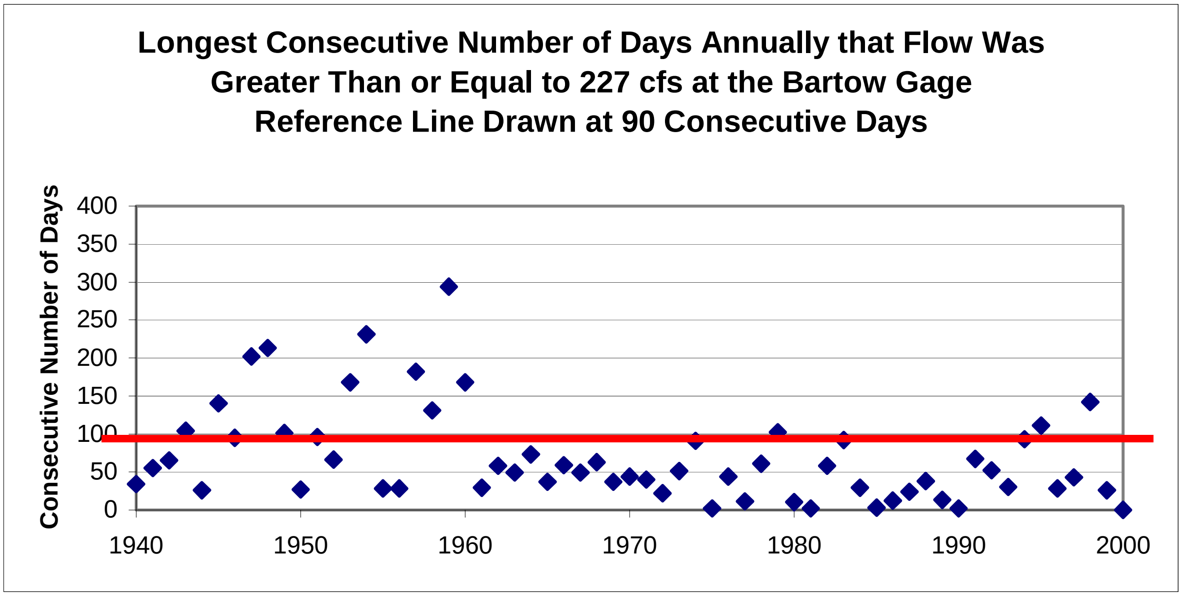
The flows that are required at Bartow to inundate the median elevation of the floodplain zones are listed in Table 6-29. The flows to inundate the seven wetlands that previously met the 90-day criterion with a 2-year recurrence interval range from 207 to 250 cfs, with a mean of 227 cfs. Using this mean flow value as a standard, flows at Bartow should exceed 227 cfs for 90 consecutive days with an approximate 3-year average recurrence interval. This does not mean that flows will not exceed 227cfs for at least 90 days every three years, but over longer periods of time the average recurrence interval will be approximately three years. For reference, a plot of the number of consecutive days that flows exceeded 227 cfs at Bartow is shown in Figure 6-21.

The 90-day flow with a 3-year recurrence interval at the Bartow is a management standard that affects the moderately high flow regime of the river. A flow of 227 cfs has been exceeded 26 percent of the time over the period of record at the Bartow gage (1940-2000). During the reference period, when the river was less impacted, 227 cfs was exceeded 34 percent of the time. Utilization of this standard with the minimum flows for fish passage and wetted perimeter and the management standards for woody habitat should provide hydrologic thresholds for most of the flow regime of the river. If management plans are proposed which could affect ecological features that are affected by flows greater than these standards, these will have to be evaluated with new analyses. For the time being, the river is below the standards that have been proposed and these should suffice as a set of criteria to guide hydrologic improvement in the upper river over the next several years.

There were no floodplain zones south of Ft. Meade for which the median values of longest consecutive days of inundation exceeded 90 days at the median elevation of those habitats. However, there were three transects where the minimum elevation of the lower floodplain zone was inundated fairly frequently, with median values for longest consecutive days of inundation between 56 and 154 days. Two of these lower floodplain habitats were at transects near the confluence of Bowlegs Creek (106 and 119), which has been described as a breakpoint in the river's morphology. Although the area of floodplain wetlands that are inundated at high flows are less in the southern reaches of the upper river than above Ft. Meade, access to these wetlands will be a criterion that will be evaluated as part of the determination of minimum flows for the middle Peace River.

Table 6-29. Floodplain wetlands for which the median values of consecutive days of inundation exceeded 90 days. The percentage of years that the consecutive number of days exceeded 90 days is listed for the recent and reference periods. The median elevation of each habitat and the flow at Bartow that inundates that elevation are also listed.

| Site | Community | Median consecutive days of inundation REFERENCE | Median Elevation of habitat (feet NGVD) | Flow at Bartow to inundate median elevation (cfs) | Percent of years exceeding 90-days REFERENCE | Percent of years exceeding 90 days RECENT |
|---|---|---|---|---|---|---|
| 181 | Cypress | 164 | 93 | 101 | 0.88 | 0.31 |
| 161 | Lower floodplain | 164 | 88.2 | 106 | 0.88 | 0.31 |
| 119 | Mixed swamp | 164 | 74.6 | 104 | 0.88 | 0.31 |
| 143 | Mixed swamp | 143 | 83.75 | 173 | 0.65 | 0.23 |
| 150 | Lower floodplain | 135 | 85.1 | 117 | 0.71 | 0.23 |
| 134 | Lower floodplain | 101 | 81.4 | 207 | 0.53 | 0.23 |
| 181 | Mixed swamp | 97 | 93.6 | 208 | 0.52 | 0.23 |
| 181 | Lower floodplain | 95 | 93.7 | 226 | 0.47 | 0.23 |
| 146 | Lower floodplain | 95 | 85.1 | 227 | 0.47 | 0.23 |
| 150 | Mixed swamp | 93 | 85.9 | 232 | 0.47 | 0.23 |
| 143 | Lower floodplain | 92 | 84.1 | 243 | 0.53 | 0.23 |
| 178 | Lower floodplain | 89 | 92.65 | 250 | 0.47 | 0.15 |
| | | | | | | |



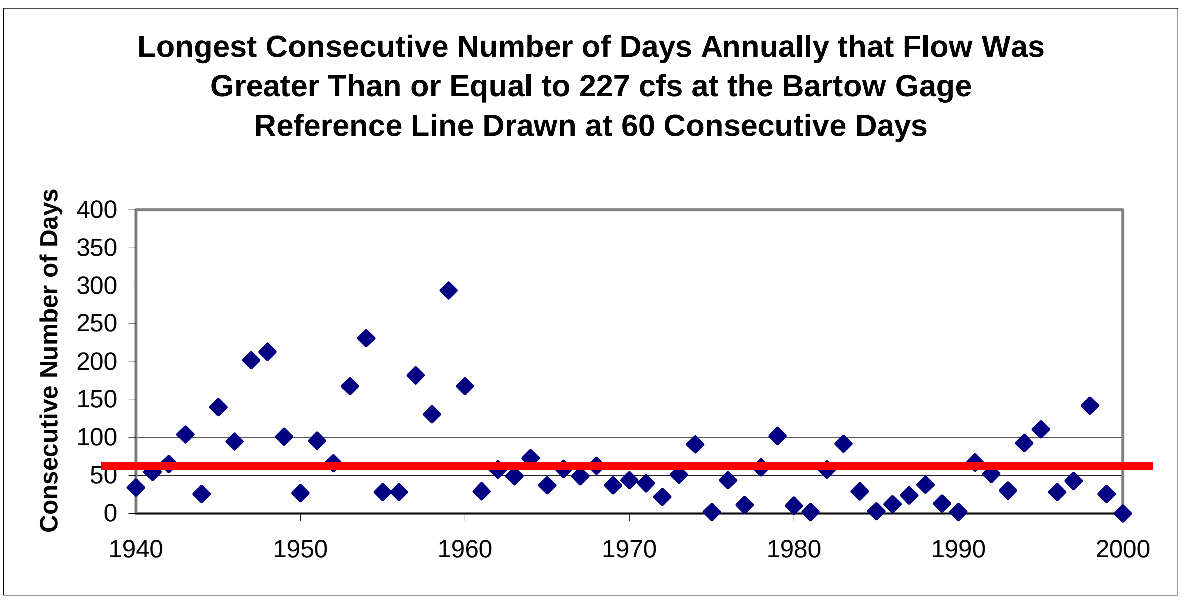




Figure 6-22. Time series plot showing the longest number of consecutive days per year that a flow of 227 cfs was maintained at the Bartow gage. Reference lines are drawn at 90 consecutive days (upper plot) and 60 consecutive days (lower plot) for comparison to proposed standard for anuran use of swamp systems in Upper Peace River.

### 6.7.2 Fishes

There is substantial documentation that fishes in river systems utilize floodplain habitats during periods of high river stage (Guillory 1979, Baker et al 1991, Baker and Kilgore 1994, Hoover and Kilgore 19958, Light et al. 1998, Hill and Cichra 2002). In the Ochlockonee River, Florida, Leitman et al. (1991) documented that three-quarters of the fish species known to occur in the main channel were collected in the floodplain during floods. Floodplains can greatly expand the food resources available for fish populations (Welcomme 1979, Wharton et al. 1982, Hill and Cichra 2002). Floodplains also serve as spawning areas for several species, and studies of larval fish on the floodplain or in sloughs in the floodplain suggest that immature stages of roughly one half of the species in the lower Mississippi River use the floodplain as a nursery (Gallagher 1979). Fish depend on seasonal and annual water level fluctuations to limit intra- and inter-specific competition for food, space, and spawning grounds. Fish distribution and abundance are thus keyed to these fluctuations (Bryan and Sabins 1979, Hern *et al.* 1980). For example, the time and extent of overflowing water can affect the size of the year classes of bass and sunfish (Wharton *et al.* 1982).

High river stages can make available to fishes the diverse physical habitats that occur in river floodplains (Light et al. 1998). Availability of relatively unaltered habitat patches with natural flow regimes, such as may occur in lower-order tributaries, can help sustain primary stream fish populations even when main channel habitats are periodically subjected to pollution or extreme hydrologic alteration (Gammon and Reidy 1981). During high flows, water is moving through most of the floodplain in a general downstream direction. Many main channel fishes migrate into flooded forests where greatly increased food sources and abundant vegetative structure are available to them. As the distance between wetlands containing fish becomes greater and/or hydrologic connections become severed by dehydration, species most dependent on floodplain habitats which do not disperse easily are most affected. The magnitude of the effect may depend on the size and intrinsic habitat heterogeneity of the wetlands that are being fragmented.

In Mississippi River floodplain ponds, "days flooded" was the most significant factor in explaining total community biomass and biomass of catastomids, clupeids, crappies, cyprinids, and ictalurids. Flooding in the sampled wetlands ranged from 24 to 115 days annually, with a mean of 81 (Cobb *et al.* 1984). Wetlands that normally contain surface waters that are then briefly dehydrated can, upon reflooding, support exceptionally high productivity and biomass of fish (Wegener *et al.* 1974, Welcomme 1979). However, this assumes fish have access into and out of the wetland as water levels change.

The most comprehensive evaluation of the fish fauna of the Peace River was presented by Champeau (1990), based on electrofishing data gathered at six sites on the main stem of the river between 1983 and 1998. Data were collected in the Upper Peace River near Homeland, Ft. Meade and Wachula. A total of 37 species were collected from the main river channel, including three non-indigenous species. Community characteristics such as species richness, diversity, abundance and biomass indicted the fish community of the Peace River has been significantly impacted by human activities. Degraded water quality due to discharge from Lake Hancock has resulted in fish populations in the upper reaches of the river that were dominated by pollution tolerant taxa (e.g. gar, bowfin, tilapia), although sport fish (e.g., largemouth bass, bluegill) were also present. Dilution from tributaries that have better water quality improved biotic conditions further downstream, as evidenced by higher species richness and diversity and more complex fish community structure. Champeau noted that 11 species that were collected from the river during previous studies were not collected during his project. However, several of these species were collected in tributaries that had improved water quality compared to the river (Champeau et al. 1988).

Champeau (1990) suggested that the flow reductions in the Peace River, particularly the loss of baseflow, has acted to exacerbate problems with poor water quality. In a follow-up study, Chapeau (no date) compared data up through 1992 with his previous study. He observed that higher river stages during 1991 and 1992 corresponded with increases in fish species richness and biomass. He suggested that increased access to the floodplain and recruitment from tributaries during high flows were factors contributing to improved fish population parameters.

As described in previous sections of this minimum flows and levels report, the Upper Peace River has experienced significant flow declines that have affected water levels in the river. In many reaches above Ft. Meade, the river can become a series of widely isolated pools during prolonged dry periods. Minimum standards for fish passage are frequently not being met over much of the upper river above Ft. Meade. The inundation of woody habitats in the stream channel, which can provide food sources and cover for fish, have also declined in many areas of the upper river. Similarly, the inundation of floodplain wetlands has been reduced dramatically. It can be concluded the effects of these flow reductions have negatively affected fish populations in the upper river, regardless of any impacts due to poor water quality.

The question becomes at what level have these flow reductions impacted fish populations and what level of restoration is needed to improve the status of fish populations in the upper river. Based on a recent review of water levels to fish populations dynamics, Hill and Cichra (2002) concluded that although it is clear that water level changes have profound implications on fish populations, there is a general lack of quantitative predictive ability concerning fish responses to water level changes in Florida. In previous sections of this report, minimum flow criteria were recommended to address fish passage depths and inflections in the extent of wetted perimeter of the stream bottom. Management proposals were also proposed to address macroinvertebrate production on instream woody habitats and amphibian life history requirements in floodplain habitats. Meeting these management proposals will not return the river to pre-impacted conditions, including the conditions simulated for the 1940-1956 reference period. It should not be concluded that these proposals will alleviate all the impacts the river has incurred. However, the flow reductions the Upper Peace River experienced has resulted from a variety of factors, and meaningful improvements in the river's hydrology and ecology should involve a combined management strategy that includes different management techniques.

Restoring flow in the river to meet the minimum flow criteria for low flows, and the management proposals for medium and moderately high flows, should result in meaningful improvement in the ecology of the river. Since they are oriented to macroinvertebrates and amphibians, the proposed management proposals should have a beneficial effect on food organisms that support fish populations. Also, improved inundation of woody instream habitats and floodplain zones should improve the physical habitats available for fishes. In this regard, management proposals specifically oriented to fish utilization of instream and floodplain habitats are not explicitly recommended. Instead, efforts should be made to restore flow in the river to the minimum flows and interim management proposals that have been recommended. During which time these objectives are addressed, continued efforts could be made through further research on developing quantitative tools for determining minimum flows based on fish populations.

## 6.8 Conclusions and Recommendations

In summary, low minimum flows based on fish passage and wetted perimeter criteria are proposed for adoption and are applicable to the Bartow, Ft. Meade and Zolfo Springs gages. It is recommended that the Low Minimum Flow as a 95% annual exceedance value not be allowed to go below 17 cfs at Bartow, 27 cfs at Ft. Meade and 45 cfs at Zolfo Springs. Two management standards have also been proposed that if met would provide some measure of improvement to the riverine ecosystem in the medium to medium-high flow range. It was documented that inundation of woody instream habitat is a particularly important habitat for development of macroinvertebrates, and for secondary production in general. As such the inundation patterns of snags and exposed root habitat were examined. To ensure that exposed root habitat in the uppermost reaches of the river (upstream of Ft. Meade) is inundated so that the habitat can be used long enough for dominant macroinvertebrates (dipterans, predominately chironomids) to colonize and reach maturity, it was recommended that the highest root indicator site measured in the upper river (Site 143) be inundated to its mean elevation for a minimum of 45 consecutive days annually. Finally, in order for the majority of anuran (frogs and toads) species expected to occur in association with the river and its floodplain to have access to and reproduce in riverine wetlands, it was proposed that periods of 90 consecutive days of inundation are needed in lower floodplain habitats at a three-year average recurrence interval.

While the flow regime of the Upper Peace River is such that medium and high flows are not adequate to protect ecological resources across the entire flow regime, the inability to achieve these flows in a quantitative way cannot, at this time, be adequately partitioned among the various controlling factors (rainfall, structural alterations and changes, withdrawals). For this reason, no medium and high minimum flow criteria are currently being proposed for adoption. However, the findings presented here for habitats requiring medium and high flows may be applicable to strategies to restore other components of the flow regime in the upper river by a combination of physical, regulatory, and other water management techniques. While it is desirable to quantify the various factors that affect flows regardless of whether desired minimum flows are being met or not, the inability to quantify this only becomes an issue on watercourses that are not meeting their minimum flows. If these factors cannot be quantified on a watercourse that would meet or exceed proposed minimum levels, the extent to which additional withdrawals (surface or ground water) can affect these levels can still be evaluated. Under this later condition a full range of minimum flows will need to be proposed for adoption.

Medium and high flow standards were proposed based on inundation of woody habitats, especially exposed roots, and swamps to ensure adequate periods of inundation for use by macroinvertebrates and frogs, respectively. Both of these standards are applicable to the reach of the river from Bartow to Ft. Meade, but are not necessarily applicable between Ft. Meade and Zolfo Springs. This is for two reasons. Because the flows between Ft. Meade and Zolfo Springs are not as demonstrably impacted as at upstream sites, quantities of water may be available for withdrawal at some point downstream of Ft. Meade, for this reason a full range of minimum flows will need to be developed for adoption. Also, since the river becomes more incised and wider downstream of Ft. Meade, it is capable of transporting large volumes of water (flows) within its banks. As a result, inundation of the floodplain does not result in the development of semi-permanently flooded swamps that were found between Bartow and Ft. Meade. Although not proposed in this document, minimum flow criteria will need to be developed for the entire flow regime at the Zolfo Springs gage. We propose to develop these criteria as minimum flows are developed for the Middle Peace River.

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